APPLYING OPERATING EXPERIENCE TO DESIGN THE CANDU 3 PROCESS

BY

D.S. HARRIS - E.M. HINCHLEY
J. PAUKSENS - V. SNELL - S.K.W. YU

ONTARIO - CANADA

APPLYING OPERATING EXPERIENCE TO DESIGN

THE CANDU 3 PROCESS

D.S. Harris
E.M. Hinchley
J. Pauksens
V. Snell
S.K.W. Yu

AECL CANDU

1. INTRODUCTION

The CANDU 3 is an advanced, smaller (450 MWe), standardized version of the CANDU now being designed for service later in the decade and beyond. The design of this evolutionary nuclear power plant has been carefully planned and organized to gain maximum benefits from new technologies and from world experience to date in designing, building, commissioning and operating nuclear power stations. The good performance record of existing CANDU reactors makes consideration of operating experience from these plants a particularly vital component of the design process.

Since the completion of the first four CANDU 6 stations in the early 1980's, and with the continuing evolution of the multi-unit CANDU station designs since then, AECL CANDU has devised several processes to ensure that such feedback is made available to designers.

An important step was made in 1986 when a task force was set up to review and process ideas arising from the commissioning and early operation of the CANDU 6 reactors which were, by that time, operating successfully in Argentina and Korea, as well as the Canadian provinces of Quebec and New Brunswick. The task force issued a comprehensive report which, although aimed at the design of an improved CANDU 6 station, was made available to the CANDU 3 team.

By that time also, the Institute of Power Operations (INPO) in the U.S., of which AECL is a Supplier Participant member, was starting to publish Good Practices and Guidelines related to the review and the use of operating experiences. In addition, details of significant events were being made available via the INPO SEE–IN (Significant Event Evaluation and Information Network) Program, and subsequently the CANNET network of the CANDU Owners' Group (COG). Systematic review was thus possible by designers of operations reports, significant event reports, and related documents in a continuing program of design improvement.

Another method of incorporating operations feedback is to involve experienced utility personnel in the early design stages of a project. This has been accomplished in a variety of ways for the CANDU 3 design, including visits to nuclear utilities, exchange of staff with utilities, and hiring of utility staff as consultants.

Input from equipment manufacturers is also a key item, particularly in the area of the technical specifications that are produced by designers. CANDU 3 approached this by requesting comments on technical specifications from traditional or established suppliers and by pre–selecting major equipment suppliers in advance – to permit early discussions on equipment details, and by giving consulting contracts to suppliers to establish major design parameters.

Design reviews have long been a traditional part of the design process. For the CANDU 3, participation of utility representatives has been actively solicited in order to incorporate their comments at an early stage. Some obvious benefits of this approach were in the areas of operational testing, maintainability, and that of the fuel channel design.

The application of a more formal human factors program to CANDU 3 design has led to the development of a functional design methodology which requires designers in key areas to evolve their designs from operating procedures, and thus produce designs which are easier for operators and maintainers. This is the reverse of the traditional approach where operating procedures produced after design completion have had to adapt to design features. The paper includes an outline of the application of the functional design methodology to the design of an advanced control centre for CANDU 3. It also shows how operating and maintainability considerations have been factored in at all design stages based on inputs from operating utilities.

2. KEY CANDU 3 REQUIREMENTS

The requirement for application of feedback of information to the CANDU 3 design can be traced through the hierarchy of project documentation to the Canadian Standards Association Standard CAN3–N286.2–86 "Design Quality Assurance for Nuclear Power Plants".

Article 4.11.1 states "Measures shall be established for obtaining, where possible, information from previous designs and the procurement, fabrication, construction, installation, commissioning, and operational phases; and for identifying and processing the information received." Article 4.11.2 follows with "These measures shall provide for assessing the need for and relevance of feedback information and for incorporating ensuing improvements in the design or quality assurance program, or both."

These requirements are reflected in the CANDU 3 Project Quality Assurance Manual which states that "Technical information received from operating stations is systematically reviewed and distributed to appropriate disciplines. Such information is reviewed for design safety and other aspects. Design input or the design process is modified as necessary. Review of feedback information is coordinated by a program–specific Committee on Information Feedback". The workings of this committee will be described later in this paper.

The QA Manual goes on to say that "Feedback of information obtained during design, fabrication, construction or commissioning of past projects is also disseminated to design groups for evaluation and incorporation into the design process, where necessary". The description of how such commissioning feedback was obtained from the first CANDU 6 projects follows in Section 3 of this paper.

3. COMMISSIONING FEEDBACK

The task force set up to review and process ideas arising from the commissioning and early operation of the CANDU 6 reactors had as its objectives the improvement of commissioning efficiency, a shortened commissioning schedule, and reduced capital cost, without compromising personnel safety or plant reliability.

It determined that these objectives could be met by:

- Redesign of some systems, taking into account problems encountered during commissioning and incorporating the latest technological advances
- Design changes to eliminate, as far as practicable, field modifications to systems during commissioning
- Coordinated turnover of systems from Construction to Commissioning
- Elimination of unnecessary commissioning tests/activities
- Introduction of a uniform commissioning program for all future CANDU projects

As a result of the task force review, a total of 311 items were identified on 63 Nuclear Steam Plant (NSP) systems as having the potential for a design change. These items were then categorized according to importance and need, with the final listing being as follows:

- Category 1
  Mandatory – to meet safety requirements/make system work per design – total 164
- Category 2
  Optional (major) – could result in significant cost/schedule reduction – total 20
- Category 3
  Optional (minor) – could result in some cost/schedule reduction – total 53
- Category 4
  Design enhancement – total 29
- Category 5
  Rejected – total 45

The changes which were chosen for implementation thus became part of the CANDU 6 design database used as a reference by the CANDU 3 designers.

4. THE OPERATIONAL FEEDBACK COMMITTEE

There are currently twenty operating CANDU reactors in Canada, two operating CANDU–6s overseas, and a number of PHWR's in India and Pakistan, representing over 250 reactor–years of operating experience. The experience can guide designers of future products, helping them reduce causes of downtime and improve plant safety.

Because most of the CANDU–3 designers have worked on previous CANDUs, and still communicate with the utility owners, they knew many of the problem areas, and have improved CANDU–3 accordingly. They are also well aware of "high–profile" events as they occur. However a way of systematically using the experience of minor events is desirable as well.

The CANDU Owners' Group (COG) maintains a number of databases on operating plants. Of particular interest to designers are the abnormal events, plant shutdowns, and impairments, since they represent a potential for improvement. These events are regularly reported on electronic bulletin boards run by COG, and all operating CANDU stations in Canada and overseas contribute to them. Events are usually on the boards the week that they occur.

Indeed, the difficulty is not in getting the information, but in screening it and assessing it. Simply circulating the ten to twenty event reports each week, to designers on new projects, produces information overload; sorting the wheat from the chaff is a major task for an individual (who may have experience related to only a few of the systems involved in the events) and is usually postponed.

To use operating experience systematically, an Operational Feedback Committee has been set up in AECL, whose purpose is to collect operating information, screen it, assess it, and ensure the incorporation of the appropriate lessons learned into new designs, particularly CANDU–3.

Figure 4.1 illustrates the process. A member of the committee is tasked with reviewing the COG event bulletin boards, usually weekly. He does an initial screening of events, which eliminates about two–thirds of them, and classifies the remainder by engineering discipline. These are then distributed to the Committee, whose members represent each major engineering discipline on CANDU–3. Copies are also distributed to each functional engineering manager in AECL–CANDU.

The committee meets about every six weeks, and reviews the event reports distributed since the last meeting. The committee discusses each event, and decides that either it is not relevant to new designs, or more detailed follow–up is required. In the latter case, it is assigned to the representative of the relevant engineering discipline. He does a further assessment, and reports the results at the next committee meeting. Again, with committee concurrence, he can reject the event as not relevant to new designs. If it is relevant, he produces a Review and Recommendation form, in which case the lessons learned are incorporated as requirements on the new project.

These requirements can affect the conceptual design, in which case they are effective immediately, or the detailed design, in which case they become part of the requirements for the detailed design phase.

In the 1990 calendar year, 24 events passed the initial screening and were the subject of detailed review. Of these, 11 were judged as potentially applicable to CANDU–3; the design was then assessed to show the same problem would not occur, or changes were made. Most of the changes were applicable to the detailed design phase, and were set as requirements to the detail designers.

Some examples of changes implemented are:

- after the brakes on a Bruce–A fuelling machine released while the machine was still on the reactor, hardware interlocks were added to the CANDU–3 fuelling machine, so that the brakes cannot release if the machine is latched onto the channel;

OPERATIONS FEEDBACK LOGIC DIAGRAM

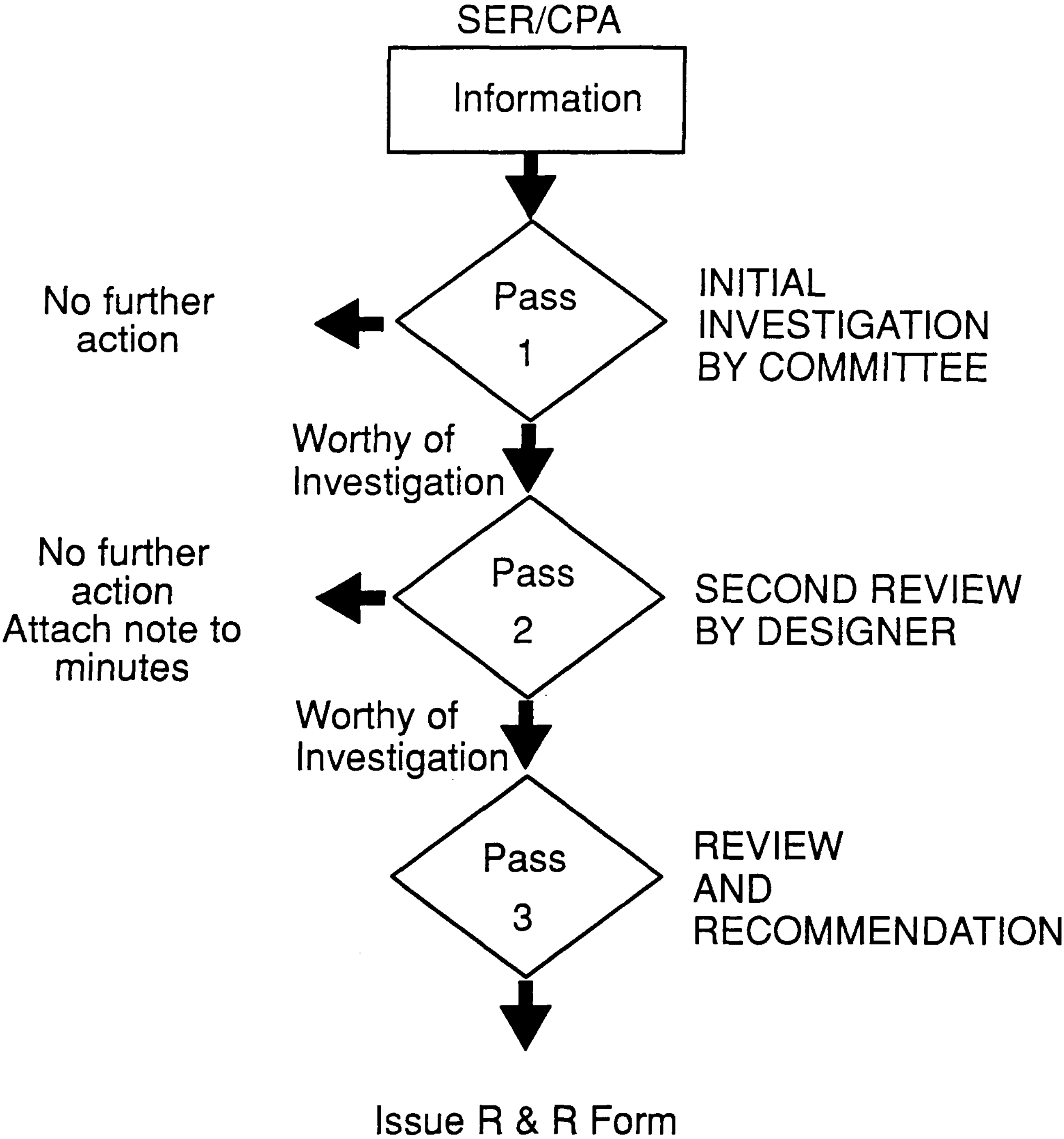

Figure 4.1

- the fuelling machine maintenance access control system on CANDU–3 was improved after an incident in which door interlocks were defeated; the interlocks must restrict simultaneously–open doors during operation but allow them during construction and maintenance;

- fuel handling alarms have been made much more specific on CANDU–3, identifying the end device to assist operator diagnosis.

The committee has been successful in implementing minor lessons learned – the major ones would of course be implemented regardless. Moreover, because of the successive screening before an event is evaluated in detail, the committee works without major demands on design manpower.

5. UTILITY INVOLVEMENT IN DESIGN

AECL undertook at the beginning of the CANDU 3 design to find ways to ensure that the design would benefit from the knowledge and experience of nuclear utilities. Much information useful to designers is available in a variety of utility reports, but a utility voice is more clearly heard by designers when spoken personally and with conviction. The requirement was that experienced utility staff be part of the design team.

The CANDU 3 designers looked for utility requirements worldwide through organizations like INPO and EPRI. Visits were made to utilities in other countries (e.g. EdF in France) where there was some visible parallel experience in areas such as standardization that the CANDU 3 could benefit from. For obvious reasons the major effort was to involve CANDU utilities and for logistical reasons this was largely restricted to Canadian CANDU utilities.

When utility staff were approached about temporary assignments to design teams there was usually initial enthusiasm over the prospect of showing designers how it should be done. Once reality set in, it was realized that very few key staff could easily be spared from their utility assignments. In addition other staff would be needed to fill these vacant positions. While the utilities were anxious to be heard, they could not be expected to incur large direct costs associated with helping a new design. Agreements were sought to help deal with these realities. The program logistics worked as follows:

NB Power became a lead supporting utility with additional help from Ontario Hydro and Hydro Quebec. NB Power agreed to free staff from various technical areas at Point Lepreau Nuclear Generating Station to visit AECL design offices on a series of rotating assignments lasting an average of two weeks each. The visits were timed both to allow design input at an appropriate stage and to be acceptable to the Point Lepreau work schedule. In exchange, AECL sent an engineer to work at Point Lepreau while the assignment program was underway. This had the added advantage for the design team of giving first hand nuclear plant experience at Point Lepreau to an AECL designer.

The staff exchange was the centrepiece of a program in which NB Power staff reviewed preliminary CANDU 3 documents and sent questions and comments in writing to AECL. AECL designers visited the Point Lepreau station for presentations to staff and to clarify concerns raised in the questions. Written answers were provided and where the utility staff were still not satisfied by the design approach, the issues were left for resolution during the staff exchange program. Ultimately all written concerns were resolved.

NB Power, Hydro Quebec, and Ontario Hydro were all very open in receiving AECL designers and providing them with information. Traditionally AECL has not been closely involved in cost and staffing issues associated with Operations, Maintenance and Administration. For CANDU 3 we were anxious to see if there were ways that designers could reduce these costs through design improvements. All three utilities cooperated in discussing staffing issues and plans, areas of cost concern, and places to look for design driven savings.

Since Ontario Hydro offices and stations were close to AECL design offices, designers relied on many Ontario Hydro staff to answer questions and comment on key CANDU 3 issues. In addition, contracts for consulting help were given to Ontario Hydro in areas where more extensive assistance was required. Ontario Hydro staff experienced in pressure tube replacements assessed the planned CANDU 3 pressure tube replacement methods and recommended improvements. Other Ontario Hydro staff worked under contract to help establish turbine–generator requirements and work with potential suppliers. Private consultants with experience from Ontario Hydro stations also brought that experience to the CANDU 3 design – especially in the fuel handling design.

The utility inputs resulted in many changes to the CANDU 3 design. Examples included better provisions for recovery in the event of a stuck fuelling machine, a revised deuteration de–deuteration system design, improved airlock/hatch design, and numerous layout changes to improve maintenance access.

The AECL CANDU 3 team has also benefited significantly from Ontario Hydro's recent experience in licensing Darlington. As a result of the licensing problems associated with safety system software, AECL and Ontario Hydro have established a joint team to establish software standards and methodologies which will be common to both organizations and acceptable to the licensing authorities. A similar joint committee is establishing common approaches in the areas of human factors and control centre designs.

CANDU 3 designers must make trade–offs in establishing a safe, cost–effective, reliable plant that is easy to operate and maintain. There hasn't been 100% agreement between designers and utility advisers on every trade–off. But overall the design has benefited enormously by making this deliberate effort to seek out and pay close attention to utility advice.

6. DESIGN USE OF OPERATING EXPERIENCE FROM CANDU VENDORS AND SUPPLIERS

Just as designers cannot understand all the operating and maintenance issues as well as utilities, they are also limited in their access to information about manufacturing problems and equipment performance records.

Past experience has shown that vendors and manufacturers frequently suggest improvements in the technical specifications produced by designers. In many of these past situations the suggestions came too late to be easily used.

The CANDU 3 designers approached this problem in three ways:

a. Traditional or established suppliers have been requested to comment on technical specifications while they are at the development stage.

b. For a significant number of major equipment contracts, suppliers are being pre–selected in advance of the actual commitment to construct the first CANDU 3 units. These pre–selection contracts allow early discussions between designers and suppliers, and give the designers detailed advance knowledge of equipment characteristics.

c. In a few cases (for example steam generators) suppliers have been given consulting contracts to help establish major design parameters and help write an optimum specification.

Obtaining assistance from suppliers is really another way of basing the design on operating experience. The pre–selection program ensures that the chosen suppliers have the right qualifications and experience. This experience makes them familiar with previous failure modes of both their own equipment, and equipment supplied by competitors. They are also generally aware of the most recent thinking on optimizing designs and preventing failures. The designers are taking advantage of this experience by having the suppliers comment on technical specifications before they are completed and through discussions. The suppliers in return have contractual assurance of their favoured position in supplying equipment for future CANDU stations (subject to a number of conditions). They are also assured of a close understanding between themselves and the AECL designers.

An additional advantage of the pre–selection program is the greater standardization it promises for a series of CANDU 3 stations. By using identical suppliers for such a series of stations, there will be very few design changes in proceeding to each successive station. Sharing of experience and spare parts will also be easier.

At this stage of the CANDU 3 design there are only two signed pre–selection agreements in place (steam generators, reactivity mechanisms). There is an additional agreement with General Electric Canada for fuel handling design services. A number of other suppliers have been closely involved in the design in anticipation of pre–selection agreements shortly. Additional CANDU 3 pre–selection agreements are expected to follow awarding of upcoming contracts for the next CANDU 6 – Wolsong 2. Overall the CANDU 3 program of pre–selecting suppliers has been something of a pilot program. It appears to be working well in allowing designs to benefit from operating experience.

7. THE DESIGN REVIEW PROCESS AND PARTICIPATION BY UTILITIES AND VENDORS

Design reviews are an important and recognized part of quality–assured design. They are one of the methods of design verification named by the Canadian Standards Association Standard CAN3–N286.2–86, "Design Quality Assurance for Nuclear Power Plants". They are a routine part of AECL–CANDU's design process. Their thoroughness and frankness are well–known in the Canadian nuclear industry.

The purpose of a design review is to independently assess the adequacy of conceptual or final design by:

- verifying the completeness and accuracy of design requirements;
- verifying that the conceptual or detailed design meets design requirements;
- verifying that the design is documented and that the documentation is clear, complete, and correct.

There are two types of design reviews. A conceptual design review is performed at an early stage in the design process; a final design review is performed when the design is complete. Of the two, the conceptual design review is by far the more important, as there is an opportunity to identify and implement fundamental changes; later design reviews focus more on implementation details.

The process of a design review begins with issuing of a review package to the selected reviewers; it consists of the review scope and objectives, and copies of the design documents to be reviewed. For a conceptual design review, the documentation includes system performance specifications, design concept decisions (reasons for the choice of the design concept over alternatives), and the design description. Final design reviews are based on design requirements, design guides, design descriptions, flow sheets, drawings, etc.

Selection of the appropriate review group is a major ingredient in the usefulness of the design review. Normally review group members have expertise (either specialized or general) in the area under review, and have not been associated with the day–to–day development of the specific design. They include staff outside AECL–CANDU.

The CANDU–3 project requirements include ambitious targets for operating costs. This meant that input to the design from utilities operating CANDUs was essential, if these targets were to be credible and achievable. The project, therefore, actively solicited utility participation in the design reviews, including those utilities who were potential customers. The utility view could then be incorporated into the design at an early stage.

We summarize the results of two such reviews.

7.1 MAINTENANCE ASSESSMENT

The CANDU–3 project requirements include the capability to run for two years between planned shutdowns, with most components (except for the concrete structures and reactor assembly) replaceable within an outage of 90 days or less. Thus a maintenance assessment review was called in January 1987, during the conceptual design. There were five reviewers, including one from New Brunswick Electric Power Commission, which operates the Point Lepreau Nuclear Generating Station, and one from Ontario Hydro.

The initial review of the design package generated 157 comments. These were addressed by the designers and their responses given to reviewers prior to the review meeting; thus the meeting could concentrate on those responses where there was disagreement. In the end, each review comment was either accepted by the designer; answered to the satisfaction of the reviewer; or further action was assigned.

Some review comments could be addressed as part of the conceptual design; others would have to be resolved as part of the detailed design. An action list for each type was generated for follow-up. There were 165 actions assigned altogether. These actions are tracked periodically until completion.

A maintenance review is novel. A challenge to the reviewers was the lack of well-established review criteria and the heavy reliance on experience and judgement—this made the utility presence even more important.

Examples of the concept phase comments from the review follow:

1. Use of anything less than a full steel liner for the containment building would require provisions for extensive external and internal inspection. [In the end, a full steel liner was chosen].
2. The proposal to substitute an equipment hatch for an equipment airlock could degrade maintainability. [The role was clarified: the main airlock was sized to accommodate all equipment and components required during operation; the hatch was for a long shutdown only.]
3. The sizing of service maintenance shops, fuel handling shops, and waste handling was felt to be inadequate. [Revised].
4. If the boilers need replacing, it should be done by cutting holes in the steel-lined reinforced concrete dome. [Agreed].

7.2 FUEL CHANNEL

The CANDU–3 fuel channel introduces several novel concepts and extends existing ones. Fuelling is done at one end only, assisted by the flow, unlike all operating CANDUs which use two fuelling machines, one at each end. The fuel channel itself is designed for rapid replaceability: the initial requirement was that the entire reactor could be re–tubed within a 90–day outage. Finally a channel design life of 40 years was proposed.

The design review was held in June 1987. The review panel of fourteen members included members from AECL–Research, two utility members (from Ontario Hydro), a member from the CANDU Owners' Group (COG), and a member from Canadian General Electric (manufacturers of some of the CANDU fuel and fuelling machines).

The action item status summary contains 305 items. Typical comments included:

1. It is preferable to design for fast channel replacement than to design for, and prove, that the channel will last for 40 years. [Agreed, although creep allowances for long channel life will also be made].
2. A black oxide coating on the calandria tube was proposed, to reduce the estimated temperature of the pressure tube under severe accident conditions. [Later adopted].
3. Mockup testing should be done to demonstrate that rapid channel replacement was feasible in the time–scale claimed. [Some laboratory testing was done].

Clearly these reviews were thorough, and used utility input to advantage in identifying issues which would impact future operation.

8. THE USE OF OPERATING PROCEDURES IN CONTROL CENTRE DESIGN

A new development in the CANDU 3 is the introduction of a function–oriented control room design methodology based on early consideration of operating procedures, and operator information needs and capabilities. This approach, outlined below, represents an evolution of traditional CANDU design methods, along the directions of an internationally evolving trend towards more formal application of Human Factors methods and knowledge in Nuclear Power plant design. It is derived in part from IEC 964, a recently published IEC standard on Nuclear Power Plant design [1]. It ensures that operating requirements are assessed and considered at the design stage.

8.1 TRADITIONAL APPROACH TO CANDU CONTROL CENTRE DESIGN

Under the traditional CANDU design approach, plant design began with the definition of the major process functions, and proceeded to process system design, followed by instrumentation and control design, which included design of both automatic and manual control loops. The design of the plant process systems and of the corresponding control systems and control interface panels was subdivided on a by–system basis, with individual process control system designers having prime responsibility for specifying control algorithms and manual control requirements. This included consideration of both normal and abnormal operating conditions, and of special requirements for commissioning, all briefly documented in the system design manuals.

Various design guide documents, centralization of panel design and computer system design authority, and control room mockups, helped to ensure a reasonably consistent style of interface. System design reviews, (which included participation from multiple design disciplines and operations experts), and accident event sequence analyses, helped to ensure the completeness and basic soundness of the design. After the design was complete, operating procedures were developed and the plant was commissioned by commissioning personnel, based on the design documentation and consultations with the designers. Verification of the integrated plant/personnel/procedure system consisted principally of walkthroughs and reviews at the plant itself in the later stages of commissioning.

8.2 FUNCTION–ORIENTED CONTROL CENTRE DESIGN PROCESS

The above process served CANDU quite well, as demonstrated by the good overall performance records of the operating stations. However, it had the undesirable characteristics of placing a substantial integrating and verification burden on the commissioning staff, and of shifting a large part of the burden for dealing with human/machine system design limitations to the personnel training and procedures domain.

The recent International Electrotechnical Commission Standard, IEC 964, [1], promotes a "function–analysis" approach to control room design which addresses these concerns. The IEC 964 approach calls for a systematic analysis of control functions, human/machine function allocation, and control room system integration and design concept validation all done in the early stages of system design, followed by detailed design, verification, and validation work in later stages.

The CANDU 3 approach to control room design can be viewed as a streamlined and tailored version of the approach proposed in IEC 964, adjusted to take advantage of other elements of CANDU design and Safety analysis, and to fit the overall CANDU 3 plant design process and schedules. It consists of the following main elements:

i. Function Analysis.

A comprehensive description of the functions to be performed from the control room.

ii. Function Information Analysis.

A definition of the essential information (goals, entry conditions, input and output variables, etc.) associated with each function.

iii. Function Allocation.

A review of the man/machine function allocations.

iv. Peer Review.

Review of the preceding steps by related design disciplines and plant operations experts.

v. Preliminary Man/Machine Interface design.

Control room layout definition, selection of interface device types, allocation of functions to device types and locations, control room mockup development.

vi. Preliminary Job Analysis.

Preliminary definition of operator tasks and procedures, and preliminary assessment of operator workloads.

vii. Formal Design Review.

Formal review of the integrated control room design concept.

viii. Requirements Handover and Detailed Design.

Handover of requirements to detailed hardware and software designers, and procedure development personnel; continuing support and review of detailed design.

The approach to be followed for different classes of functions varies in degree of formality and depth of analysis. Some details remain to be settled. In general,the approach is to treat power production functions less formally and at higher levels of abstraction in the conceptual design stage, and to leave more detailed decisions about these functions to the discretion of the process control system designers. Accident mitigation functions are treated more formally, and analyzed to greater depth, in the conceptual stages of control centre design.

8.3 ROLE OF OPERATING PROCEDURES AND INVOLVEMENT OF OPERATIONS PERSONNEL

An important aspect of the function–oriented design methodology is the use of preliminary versions of emergency operating procedures during the conceptual design stage. The preliminary emergency operating procedures, which are to be developed over the next two years, will be based on preliminary CANDU 3 probabilistic safety analyses, and on analogous procedures from existing CANDU plants, with adjustments to cater to CANDU 3 specific plant design differences. They will be used as inputs into the function analysis, allocation, and preliminary design stages outlined above, and will be key elements in the workload analyses which we are planning to conduct with the help of a control room mockup. In this process, extensive consultations with operations personnel and involvement of qualified CANDU operators in the mockup tests are planned.

The function–oriented control room design methodology is expected to bring several benefits to the CANDU 3 design. The most obvious is the benefit of concentrated operations feedback at a stage where control room provisions can still be easily modified. In addition the methodology will help to satisfy regulatory demand for more formal and more auditable treatment of human factors aspects of the design, will help to facilitate up–front licensing, and should lighten the burden of producing detailed operating procedures at the tail end of the detailed design process.

Reference:

1. "Design for Control Rooms of Nuclear Power Plants", International Electrotechnical Commission Standard, IEC964, March 1989

9. CONCLUSIONS

There are a variety of processes by which operating experience can be applied to design, and the CANDU 3 project is actively using many of them to ensure that lessons learned in the field on earlier projects do not have to be relearned on the CANDU 3.

The incorporation of the expertise of utility staff, and the experience of equipment manufacturers, has provided AECL's design team for the CANDU 3 with valuable insight into potential design improvements. Basing the design of the control room on the operating procedures, instead of vice versa, is another innovation in keeping with the 1990's image of this new reactor model. Combining these approaches with the more traditional design reviews and the continuing operational feedback process by means of review of significant events and design changes has given AECL the confidence that the new CANDU 3 nuclear power plant will be an operational success from first startup.