

OPERATIONAL ASSESSMENT
OF
CRITICAL SAFETY PARAMETER MONITORING -
FINDINGS AND LESSONS LEARNED

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ABSTRACT

This paper summarizes the findings and recommendations from an operational assessment of the Critical Safety Parameter monitoring facilities and practices proposed for Pickering B. The Critical Safety Parameters consist of a small set of plant parameters that can be used to assess the degree of plant safety challenge in power control, fuel cooling and containment integrity.

The assessment was undertaken to:

- Confirm and improve the effectiveness of Critical Safety Parameter monitoring practice at Pickering B,
- Address regulatory concerns associated with the proposed operational introduction of a Critical Safety Parameter display at Pickering B, and
- Pilot test a proposed approach to integrating human factors in station design changes.

The paper begins by describing the role of Critical Safety Parameter monitoring and restoration practice in support of plant emergency response and the basis for the assessment. The balance of the paper outlines the assessment objectives and approaches applied, reviews the key assessment findings, and discusses the lessons learned.

BACKGROUND

For CANDU plants, the overall safety state can be represented in terms of a small set of plant parameters called the Critical Safety Parameters (CSPs). These parameters represent the status and degree of safety challenge to three primary safety goals, namely:

- Control of reactor power,
- Adequacy of reactor fuel cooling, and
- Integrity of containment barriers and containment of radioactivity.

For Pickering B, the Critical Safety Parameters are:

- Power control:
 - Reactor power.
- Fuel Cooling:
 - Reactor inlet header subcooling margin.
- Containment integrity:
 - Reactor building pressure,
 - Reactor building water level,
 - D₂O in H₂O in various liquid streams,
 - Condenser Cooling Water and Reactor Building Service Water radioactivity (i.e., Tritium, Gross β, Gamma), and
 - Main steam radioactivity (i.e., Tritium).

During plant upsets and emergencies, the control room crew is required to continuously monitor the status of CSPs in order to assess plant safety state. During normal operation, there is no need to continuously monitor these parameters since the continuous control of process conditions to established setpoints by automated systems provides assurance that safety goals remain unchallenged.

Initially, CSP monitoring involved repetitive touring of control room panels to acquire parameter updates, selection of conditions representative of greatest challenge to fuel cooling, calculation of subcooling challenge, manual tracking of parameter trends, and interpretation of results.

In 1992, Pickering and AECL staff undertook development of a specific CSP control room display under CANDU Owners Group (COG) sponsorship for the purpose of simplifying CSP monitoring practice (1). Based this on development initiative and the operational benefits identified in simulator evaluations, CSP displays have been engineered for Pickering control room use (see Figure 1).

The introduction of the CSP display automates the manual data acquisition, selection of conditions representative of greatest challenge to fuel cooling, subcooling margin

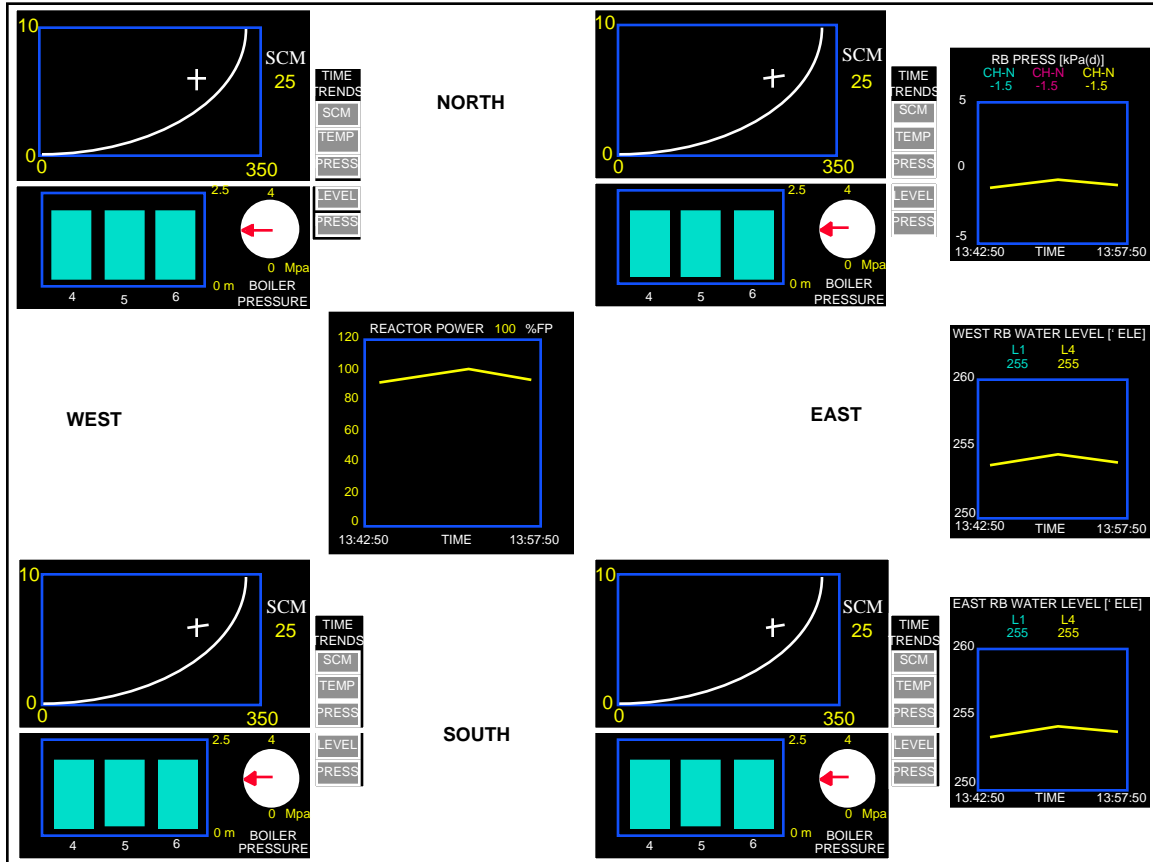


Figure 1: Pickering CSP Display.

calculation and tracking elements of the former CSP monitoring task, allowing control room staff undertaking CSP monitoring duties to focus on results interpretation in support of upset response. While the fundamental CSP monitoring task has been substantially simplified, the introduction of the new display medium posed some new operational challenges.

The CSP monitor display application is provided by the Data Extraction System control room computer and supporting display. This system also provides support for three other display applications at Pickering B:

- Heat Transport Leak Rate display,
- Neutron Flux display, and
- Vacuum Building Pressure and Filtered Activity Discharge display.

Only one display application is viewable at a time. Control room staff are free to choose which display application to use based on the monitoring needs of the operational situation.

In 1994 during preparation for introducing the CSP monitor into operational service, Atomic Energy Control Board (AECB) representatives raised concerns with the Pickering B Data Extraction System and Critical Safety Parameter monitor implementation and planned operational usage. In response, the station Engineering Services Manager committed to:

- Establish some basic human factor principles, criteria, and rules for guiding and assessing control room design changes, and
- Evaluate a candidate control room facility important to operator decision-making as a pilot demonstration of application of the human factors principles, criteria and rules developed.

The operational assessment of the CSP monitor discussed in this paper became the practical demonstration of the second part of this commitment.

ASSESSMENT OBJECTIVES AND SCOPE

At the beginning of the program, Pickering B and AECL project staff met with AECB representatives to discuss the basis for the AECB staff concerns with the introduction of the new CSP monitor into control room use. These discussions revealed that the assessment should primarily focus on the operational impacts of CSP monitor display introduction, for example:

- Changes in crew roles and responsibilities associated with monitoring and restoration practice,
- The performance of crews in detecting CSP challenges using the new display,
- Potential display use conflicts given the CSP monitor display is one of four monitoring applications sharing a common CRT display, and
- The operational integrity of CSP monitor display information given the unproven availability of the computing platform on which the CSP display application operates in comparison to the existing Digital Control Computers (DCC) and panel indications.

To develop a comprehensive set of operational issues to examine in the assessment program, several supporting analyses and observations of current CSP monitoring practice were undertaken, for example:

- Participation by assessment team members in CSP monitoring and restoration refresher training sessions,
- Analysis of the operational contexts (i.e., operational states, strategies, users and tasks supported) in which CSP and other Data Extraction System display applications were used helped identify potential instances of display use conflict,
- Examination of three alternative crew structures and supporting CSP monitoring practices were analyzed to clarify the potential advantages and disadvantages of each approach, and
- An assessment of Data Extraction System and CSP monitor display failure modes, and

- Simulator observations of CSP monitoring practice during crew training.

The resulting operational issues selected for examination are shown in Table 1.

ASSESSMENT APPROACH

The assessment program focused on demonstrating that the proposed new monitoring practice, based on usage of the CSP monitor display, facilitates effective CSP monitoring and restoration practice for representative operational situations. Demonstration of adequate monitoring performance was based on compliance with specific measures of monitoring performance, rather than demonstrating performance relative to the current manual CSP data collection practice.

Twenty-nine performance hypotheses were defined for examination in the assessment program based on the operational issues selected for examination. To assess the degree to which each performance hypothesis was satisfied by the proposed new CSP monitoring practice:

- Specific measures of monitoring performance were identified for each performance hypothesis, and
- Standards that demonstrate adequate performance for each measure were established.

The performance standards were developed based on known CSP monitoring objectives, observations of representative monitoring practice and former COG program work which characterized aspects of the approved manual CSP monitoring practice.

Two assessment methods were used in examining the validity of the 29 performance hypotheses:

- Analytical techniques, and
- Simulator evaluation.

Analytical techniques rely on operations, function and/or task analyses or design reviews to develop a rationale for justifying the acceptance or rejection of a selected performance hypothesis. Analytical techniques are appropriate where it is unnecessary or unfeasible to prove or disprove an hypothesis by an experimental test.

Simulator evaluation is one of a number of means that can be used for conducting an experimental test of the validity of a performance hypothesis. With simulator evaluation, acceptance or rejection of the performance hypothesis is based on collected experimental data for specific performance measures that is compared with performance standards according to a formal experimental design.

Table 1: Operational Issues Selected for Examination.

- Crew Roles and Responsibilities:
 - Increased crew communication to support CSP monitoring and restoration,
 - Potential for disruptions in individual performance due to multiple/conflicting responsibilities or distractions, and
 - Preferred practice for transfer of responsibilities to replacement staff.
- Information Monitoring/Interpretation Challenges:
 - Timeliness of detection of parameter challenges,
 - Detection of safety decision thresholds,
 - Detection of changes in CSP values,
 - Detection of changes in SP values, and
 - Understanding of safety state and trends.
- Decision-making Challenges:
 - Challenges to multiple CSPs or SPs,
 - Changes in CSP or SP values,
 - Changes in heat sink state, and
 - Timeliness of restoration actions.
- Variations in Situations:
 - Upsets from full power steady state,
 - Upsets from outage conditions,
 - Single parameter and multiple parameter challenges, and
 - Multiple unit upsets.
- Display Use Conflicts:
 - Conflicts in multiple users of the CSP display, and
 - Conflicts between different users of DES applications.
- Information Integrity, Failure Detection and Backup:
 - Preferred priority of CSP and SP source use,
 - Availability of confirmatory sources for all parameters,
 - Conflicts in parameter values indicated by different sources,
 - Unavailability of specific CSP or SP indications,
 - DES and CSP application failure modes, and
 - Transition to backup information sources.

Three experimental factors (i.e., independent variables) were selected to create experimental variations to address the performance hypotheses to be examined. The factors and levels selected were:

- Scenario - number of CSPs challenged (2):
 - Single CSP challenge - subcooling margin, and
 - Multiple CSP challenge - containment pressure and subcooling margin.

- Data confirmation approach (2):
 - Confirm CSP monitor indications with panel indications only when CSP monitor indications are in question, and
 - Confirm CSP monitor indications with panel indications periodically.
- DES/CSP failure mode (4):
 - Loss of a single parameter (e.g., sensor failure/corruption),
 - Display lock-up/freeze,
 - Loss of data feed (e.g., communication failure), and
 - Loss of CSP monitor application.

The assessment of CSP monitoring practice and the validity of the performance hypotheses was conducted in 1996. Three simulator sessions of a day each were used to conduct sixteen scenario trials with eight operating teams.

FINDINGS AND RESULTS INTERPRETATION

Key findings from the assessment program include:

- **CSP Monitoring Practice Confirmed Effective** - The assessment findings demonstrated that the proposed CSP monitoring practice using the CSP monitor display meets the performance standards established. The use of the CSP monitor display is expected to simplify and improve CSP monitoring in comparison with the current manual data collection and tracking practice.
- **CSP Monitoring Training Needed for SCPOs** - Current station practice delivers formal CSP monitor training to Shift Supervisors, Shift Operating Supervisors (SOS) and Authorized Nuclear Operators (ANO). In contrast, participants indicated that delivery of CSP monitor training to Supervised Control Panel Operators (SCPO) has been less emphasized. Consequently, several SCPO participants were less familiar with CSP monitoring practice than they were comfortable with.
- **Unit 5 Display Use Conflict** - During upsets and emergencies on Unit 5 involving the use of the vacuum building, a potential conflict in display application use may occur. In such situations, both the CSP monitor and the Vacuum Building Pressure and Filtered Air Discharge Rate applications may need to be used simultaneously.
- **Periodic Data Confirmation Strategy** - Adoption of a periodic confirmation of CSP monitor display indications with parameter values from panel indications was found to improve detection of CSP monitor failures, ensure monitoring staff are practiced in manual CSP data collection, and smooth transition to the use of panel indications when CSP monitor failures are encountered.
- **Detection of CSP Monitor Failure Modes** - Some CSP monitor failure modes do not provide direct indication of CSP monitor failure. Thus, the potential exists for crew members to not detect CSP monitor failures in a timely fashion.

LESSONS LEARNED

Key lessons learned from this assessment included:

- **Operational Context and Principles** - To adequately identify the needs to be addressed with a system design, we found it important to first understand the operational context and system performance objectives. We found that examining the operational context of use of the proposed system (i.e., operating states the system must perform in, operating strategies the system must support) was an excellent way to uncover the full performance expectations for the system.
- **User Task versus Technology Driven Principles and Constraints** - Design principles can provide a useful supplement to assist designers in interpreting and evaluating design requirements. While principles established from a technology perspective can prove useful in guiding design choices, we have found it essential to ensure that principles established from an operational or user task perspective be established on projects to additionally guide design choices and assessment needs.
- **Multiple Sources of Information** - To acquire a sound understanding of operational needs and issues associated with a specific system design, the experience on this project has shown that it is useful to employ a diversity of information gathering approaches. We found that all of the important issues that the assessment eventually addressed, in hindsight would not have been identifiable from one or two sources alone.
- **Effectiveness of Simulator Assessments** - The simulator assessments involving qualified Operations staff participants proved valuable from several perspectives. By studying overall performance in an integrated operational setting, we were able to:
 - Confirm overall performance expectations for the system in representative operational settings,
 - Directly relate operational requirements and performance objectives to actual performance, thus identifying areas for improvement and clarity in specifications and requirements, operating procedures, and training practice,
 - Observe the range of diversity in crew operational practice that the technical system being examined must support, thus identifying improvement options that would offer a more supportive and robust technical system design, and
 - Practically demonstrate the degree and limitations of proposed technical system support to representative Operations staff, thus providing opportunities to identify mismatches in expectations and solicit improvement suggestions prior to finalizing the design and implementation.

- **Simulator and Participant Availability** - Simulator and Operations staff availability is always an issue where the scope of a design change requires assessment of system use in an operational environment. Both resources tend to be in high demand thus, affording few opportunities for and flexibility in evaluation planning. We have found that assessment programs can be conducted with minimal disruption in simulator use and Operations staff dislocation from regular duties by:
 - Conducting assessment exercises within:
 - the non-scheduled simulator times (i.e., late evenings and weekends), or
 - scheduled refresher training, and
 - Employing trainers, former Operations staff and trainees as appropriate to acquire sufficient operating teams for test scenarios.
- **Cost-effective Simulator Use** - Realistic performance assessments of the usage of new control room systems can be undertaken with modest cost and disruption to the normal training use of simulator facilities and support maintenance activities. Good preparation, a sound experimental design and trained evaluators permit assessment sessions to be executed with minimal wasted time.
- **Simulator Limitations** - The current PND B simulator model is limited in undertaking some classes of scenarios (e.g., certain upsets where station are challenged. Considerable effort by Simulator support and Training staff was required to 'tune' simulator response for the test scenarios applied.
- **Communication with Regulatory Representatives** - Regular communication with regulatory representatives ensures that there are timely opportunities for concerns to be discussed, and promotes timely resolution of issues. Frequent communication also allows regulatory representatives time to build confidence in the overall design prior to making acceptance judgments.
- **Emphasis of Human Factors Application** - The purpose of applying human factors criteria and methods in design is to ensure that the overall performance objectives can be achieved where performance is dependent on human involvement with a technical system in some way. Thus, we found it important to use an 'plant operations' perspective to guide the selection and application tailoring of supporting human factors design and assessment activities. While this approach, and supporting principles and methods are not new, it places greater emphasis on operational analysis and practical measurement of proposed human and system performance to ensure overall performance objectives are achieved.

The belief that such a strong 'plant operations' and 'performance confirmation' emphasis should guide the selection, tailoring and application of project human factors activities, is not universally shared among industry human factors practitioners. For this reason and others, a diversity of methods and approaches are being applied in support of industry projects. There should be a rationalization and standardization of

the best of these methods and approaches into a common practice to simplify application and communication of human factors results within the industry.

CONCLUSIONS

This assessment program has confirmed and demonstrated the benefits of the new CSP display in supporting upset management, and demonstrated the practicality and value of undertaking operational assessments in support of control room changes.

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