Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 23-M3.A

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Supplementary Information

Written submission from CNSC Staff

Follow up from November 3, 2022 Commission Meeting

Responses to the questions from the External Advisory Committee regarding the update on the discovery of elevated hydrogen equivalent concentrations in the pressure tubes of reactors in extended operation

Commission Meeting

January 25, 2023

Renseignements supplémentaires

Mémoire du personnel de la CCSN

Suivi découlant de la réunion de la Commission du 3 novembre 2022

Réponses aux questions du Comité consultatif externe au sujet de la mise à jour sur la découverte de concentrations élevées d'hydrogène équivalent dans les tubes de force des réacteurs en exploitation prolongée

Réunion de la Commission

Le 25 janvier 2023

Canada

Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

MEMORANDUM NOTE DE SERVICE

To
À

Denis Soumure
Commission Registry

c.c.: R. Jammal, P. Elder, M. Rickard, M. Hornof, A. Mathai, R. Richardson, V. Tavasoli, T. Nitheanandan, R. Rulko, B. Carroll, S. Yalaoui, A. Robert, W. Grant, D. Carrière, N. Kline

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January 19, 2023	N/A

From
De

Alex Viktorov
Director General, Directorate of Power Reactor Regulation

Subject
Objet

CNSC Staff's Supplementary Information Regarding EAC Questions

Purpose

In CMD 23-M3, CNSC staff responded to a question raised by the External Advisory Committee (EAC) in CMD 22-M37.8 regarding the risk significance of elevated hydrogen equivalent concentration (Heq) findings near the rolled joints of pressure tubes. The purpose of this memorandum, CMD 23-M3.A, is to provide to the Commission a clarification on the complex assessment performed by CNSC staff. The assessment considered the impact of the elevated Heq findings near the rolled joints of the Bruce Power pressure tubes in Units 3 and Unit 6 in 2021 on the protection of health, safety, security and the environment. CNSC staff have determined that there is no adverse impact on nuclear safety arising from these findings and appropriate corrective actions have been implemented to return the risk from tolerable to acceptable levels within an appropriate period of time.

Illustration of CNSC staff's assessment of the impact of pressure tube aging on safe operation

Figure 1 schematically illustrates CNSC staff's assessment of the events and the actions taken by the licensees in relation to the potential impact on safe operation of units with pressure tubes in extended operation beyond 210,000 equivalent full power hours (EFPH).

The Licence Conditions Handbook (LCH) establishes compliance verification criteria (CVC)[1] that CNSC staff uses to assess licensee performance. When the CVC are met, the risk to health,

[1] CVC can be in the form of specific requirements stated in the LCH or in the form of references to regulatory documents or industry standards.

safety, security, and the environment from nuclear plant operation fall within established norms and is assessed as acceptable. The relevant CVC for pressure tube operation are primarily addressed under the Safety Analysis, Physical Design and Fitness for Service Safety and Control Areas (SCAs) in the LCH.

If a finding leads to a scenario in which compliance with specific CVC cannot be verified, CNSC staff can evaluate the overall impact of the finding on safe operation. Findings with a significant risk impact are reported to the Commission for their review. Typical approaches for doing so include regulatory status updates on power reactor operation, the annual Regulatory Oversight Report or subject-specific Commission proceedings. If a finding potentially violates the requirements of a Licence Condition the Commission is notified promptly.

The coloured regions of Figure 1 represent the impact of pressure tubes aging on safe operation for four operating scenarios.

- The green rectangle is the risk region in which all relevant CVC addressing safe operation of pressure tubes in the LCH can be satisfied.
- The gray rectangle bounds the risk region in which a finding raises uncertainty about the ability to satisfy some of the CVC, but operation remains overall in accordance with the licensing basis. A risk assessment can be performed to assess the overall impact of the finding on the safe operation of a nuclear power plant. The outcome of the risk assessment can form the basis for a risk-informed decision to allow continued operation of reactors for a limited time until the necessary work is completed to return to compliance with the CVC.
- The yellow rectangle bounds the region in which CVC cannot be confirmed and CNSC staff has determined that the risk is unacceptable and immediate actions would be required.
- The red rectangle bounds risk scenarios which are considered improbable.

CNSC staff's assessment of the impact of the elevated Heq events

The following discussion explains how CNSC staff assessed the safety impact of elevated Heq findings in the Bruce Power pressure tubes (see Figure 1).

Typical Operation Below 210,000 EFPH (Acceptable):

Industry has significant experience operating pressure tubes below 210,000 EFPH. Effective programs have been established to confirm physical design, safety analysis and fitness for service CVC are met with significant margins. Regulatory oversight by CNSC staff would be considered routine for this operating scenario.

Operation Above 210,000 EFPH prior to the Bruce Power Findings (Acceptable):

All compliance verification criteria were met with adequate margins but given the lack of experience with pressure tube operation beyond 210,000 EFPH, the possibility existed that a new finding could impact the ability to confirm the existing CVC are met. Regulatory oversight by CNSC staff was enhanced.

Licence Condition 15.3 (Transition from Acceptable to Tolerable):

Licence Condition 15.3 was established to ensure that the Commission would be notified if the measured or predicted Heq levels in the pressure tubes exceeded the validity limits for the fracture toughness model used for fitness for service CVC. Exceeding the Heq limit specified in Licence Condition 15.3 was not an indication that pressure tubes were at imminent risk of failure. Instead, it was an indication that pressure tube fitness for service could no longer be confirmed using the established CVC in the LCH and enhanced regulatory oversight would be required.

Licensees were engaged in activities that would extend the CVC to higher Heq levels, but the work was not completed prior to the Bruce Power elevated Heq findings.

Operation above 210,000 EFPH after Outlet Finding (Tolerable):

After the elevated Heq findings in the outlet region of the Bruce Power pressure tubes, CNSC staff could no longer confirm that the fitness for service CVC could be met using the established approach in the industry standards referenced in the LCH, but an alternate approach was implemented on a short-term basis to verify safe operation and establish the timeframe for industry to undertake the necessary research and development to return to the acceptable (green) risk regime. The alternate approach provided CNSC staff with a quantifiable means to demonstrate that the risk of a pressure tube failure remained low. Regulatory oversight by CNSC staff was further enhanced.

Operation above 210,000 EFPH after Inlet Finding (Tolerable):

After the elevated Heq finding in the inlet region of the Bruce Power pressure tube, CNSC staff could no longer confirm that fitness for service CVC could be met using the established approach in the industry standards or the alternate approach established for the outlet region of the pressure tubes. CNSC staff carried out a RIDM evaluation to demonstrate that, in the event of pressure tube failures, the special safety systems will effectively complete their safety functions of Control, Cool and Contain. It was concluded that there would be no increase in risk to the public or the environment if operation continued for a period of at least three years, which provides sufficient time for the industry to conduct the proposed research and development to return to a risk level associated with the acceptable region. There are physical reasons why the risk of pressure tube failure is expected to remain low in the near term when considering the locations of flaws in relation to the regions of elevated Heq, but the risk cannot be quantified at this time.

Risk of Continued Operation Unacceptable (Transition from Tolerable to Unacceptable):

This represents a hypothetical scenario where CNSC staff would determine that the risk of a pressure tube failure becomes unacceptable, even though no pressure tubes have yet failed. At this point CNSC staff would, at the very least, make recommendations to the Commission concerning operation with restrictions and potentially recommend shutdown of affected units. CNSC staff's assessment indicates that the licensees will not reach this level of risk for at least three years.

- The Orders that were issued to the licensees following outlet region elevated Heq event are examples of the type of recommendations that would be made as operation approached this level of risk. At the time the Orders were issued, CNSC staff did not have sufficient information to perform a thorough risk evaluation for potential pressure tube failures when restarting reactors in extended operation from planned or unplanned outages. When further information became available, CNSC staff was able to reduce the level of risk associated with the finding.

Single Pressure Tube Failure Likely (Unacceptable):

This represents the point where the scenario assessed in the RIDM evaluation could occur. The affected reactor would be forced to shut down to deal with a failure, but releases of radioactivity from the primary heat transport system would be contained and there would be no adverse impact on the public or the environment. This scenario has occurred in Canadian reactors in 1983 [1] and 1986 [2] and more recently in an Indian pressurized heavy water reactor [3] as discussed in CMD 21-M4. In all cases, the outcome of the events were bounded by the safety analysis evaluations described in the RIDM report.

Failure of Multiple Pressure Tubes (Improbable):

This represents hypothetical scenarios raised by some external stakeholders where multiple pressure tubes might fail simultaneously. There are several reasons why CNSC staff has considered this an improbable scenario. For example:

- After failure of a single pressure tube, the internal pressure in the primary heat transport system would drop, reducing the driving force required to fail other pressure tubes.
- The CANDU safety analysis considers the potential for a failed pressure tube to interact with surrounding fuel channels and determined that it could not damage the adjacent fuel channels. A pressure tube failure could adversely impact nearby shutoff rods, and the safety analysis accounts for the impaired shutoff rods in the scenario following a pressure tube failure.
- The scenario for multiple fuel channel failures is implicitly covered by analysis of larger breaks in the primary heat transport system. For breaks larger than one pressure tube failure, the special safety systems effectively perform their Control, Cool and Contain safety functions.
- There are several examples of Canadian and Indian pressurized heavy water reactor pressure tube failure events during which the failed pressure tube had no impact on surrounding pressure tubes.

Abbreviations used in this Document

CNSC	Canadian Nuclear Safety Commission
CVC	compliance verification criteria
EAC	External Advisory Committee
EFPH	equivalent full power hours
Heq	hydrogen equivalent concentration
LCH	Licence Conditions Handbook
PHWR	pressurized heavy water reactor
RIDM	risk-informed decision-making

References

1. Ontario Hydro Report, “Pressure Tube Failure – Pickering NGS Unit 2”, CNS-75, July 1984.
2. Ontario Hydro Report, “Ontario Hydro CANDU Operating Eperience”, NGD-9, 1987.
3. “Leak from primary coolant system at Kakrapar Atomic Station-1”, IAEA News, November 19, 2018, IAEA NUCLEUS.

Figure 1: CNSC Staff's Assessment of the Elevated Heq Events in Relation to the Potential Impact on Safe Operation of Reactors with Pressure Tubes in Extended Operation Beyond 210,000 EFPH