Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 26-M22.A

Date: 2026-02-02

Supplementary Information

Written Submission from CNSC Staff

In the matter of the

Status Report on Power Reactors

CNSC Staff Update to the Commission on Elevated Heq R&D Activities

Commission Meeting

February 13, 2026

Renseignements supplémentaires

Mémoire du personnel de la CCSN

À l'égard du

Rapport d'étape sur les centrales nucléaires

Mise à jour du personnel de la CCSN à l'intention de la Commission sur les activités de R-D liées à l'Heq élevé

Réunion de la Commission

Le 13 février 2026

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MEMORANDUM

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Fully releasable ATIP :
Yes

To / A: Candace Salmon
Commission Registry

2025-12-22

From / De: X
Dr. Alexandre Viktorov
Director General, Directorate of Power Reacto...
Signed by: Viktorov, Alexandre

Subject: CNSC Staff Update to the Commission on Elevated Heq R&D Activities

Purpose

The purpose of this memorandum is to report to the Commission the results of CNSC staff's review of OPG and Bruce Power's research and development (R&D) program activities [1, 2]. This work was initiated following the discovery of elevated hydrogen equivalent concentration (Heq) in pressure tubes operating in extended operation beyond 210,000 equivalent full power hours (EFPH). This memorandum includes CNSC staff's conclusions regarding the outcomes of the R&D activities and whether the licensees can return to compliance with the fitness for service criteria for pressure tubes established under Licence Condition (LC) 6.1 (*The licensee shall implement and maintain a fitness for service program*) in the respective Nuclear Power Reactor Operating Licences (PROL), as well as outlining the revised compliance verification criteria for LC 6.2, which will remain in the respective PROLs until the Commission makes an amendment to the applicable licences.

Background

In 2021, Bruce Power identified elevated levels of hydrogen equivalent concentrations (Heq) in pressure tubes operating beyond 210,000 EFPH. Prior to that discovery, Licence Condition (LC) 15.3 had been included in the PROLs for both OPG and Bruce Power with compliance verification criteria (CVC) to confirm adequate fracture toughness prior to operation with Heq levels exceeding 120 parts per million (ppm)). Following Commission hearings in March 2023 and February 2024, the Commission determined that LC 15.3 no longer fulfilled its intended purpose. As a result, the Commission approved the removal of LC 15.3 and introduced a new LC 6.2 (see DEC 23-H103 and DEC 24-H5 [3, 4]):

> *The licensee shall implement and maintain an enhanced fitness for service program for fuel channels in extended operation*.

The CVC, outlined in Section 6.2 of the Bruce NGS A and B and Pickering NGS Licence Conditions Handbooks (LCH) [5, 6], specify CNSC staff expectations to implement and maintain an enhanced fitness-for-service program for the safe operation of pressure tubes in extended operation and to report on the progress of related research and development (R&D) activities. The interim approaches established in the CVC in Section 6.2 of the LCHs to assess the safety of operations of pressure tubes expire on December 31, 2025, with the intention for Bruce Power and OPG to return to the use of the CVC for pressure tube fitness for service evaluations established in Section 6.1 of the LCHs.

R&D Progress Update

CNSC staff have confirmed that all R&D activities scheduled for completion by the end of 2025 have been completed (see Table 1). The development of a comprehensive Heq predictive model is targeted for completion by Spring 2026, as originally planned [1,2]. This deliverable does not impact the licensees' ability to apply LC 6.1 CVC for pressure tube fitness for service evaluations, since bounding analyses show that regions of elevated Heq will not interact with flaws that could lead to crack initiation before end-of-life for Pickering and Bruce Power units.

Table 1: Status of Heq R&D program activity commitments by Bruce Power and OPG

R&D Activity	Planned Completion Date (from CMD 22-M37.1 and 22-M37.3)	Updated Status of R&D Activities
Update finite element software to simulate outlet rolled joint Heq evolution	Fall 2023	Work has been completed
Develop finite element software to simulate inlet rolled joint Heq evolution	Fall 2023	Work has been completed
Perform evaluation to assess the potential impact of the high levels of Heq on flaws at the inside surface of pressure tubes near the inlet region of interest	Fall 2023	Work has been completed
Improve characterization of 'blip' and expected evolution of the inlet region of elevated Heq with continued operation	Spring 2024	Work has been completed
Confirm the potential roles of hydrogen isotope ingress and redistribution on the development of the inlet regions of elevated Heq	Summer 2023	Work has been completed
Improve characterization of solubility behaviour of hydrogen isotopes in tubes with elevated Heq	Winter 2024	Work has been completed
Enhance modeling of temperature distributions near the outlet rolled joint region of pressure tubes	Summer 2023	Work has been completed
Define input parameters required for interim updates to the Heq model	Summer 2023	Work has been completed
Develop interim Heq model	Fall 2024	Work has been completed
Validation activities for the interim Heq model to support development of final comprehensive model	Fall 2025	Work has been completed
Define input parameters required for the final comprehensive Heq model	Summer 2025	Work has been completed

Define the relative importance of variables influential to Heq evolution	Fall 2025	Work has been completed
Develop the final comprehensive Heq model	Spring 2026	Progressing as planned
Complete hydride related crack initiation experiments for unirradiated material at Heq of 220 ppm or higher	Fall 2024	Work has been completed
Complete fatigue crack initiation experiments for unirradiated material at Heq of 220 ppm or higher	Fall 2024	Work has been completed
Complete crack initiation experiments for irradiated material with elevated Heq without flaws present	Fall 2024	Work has been completed
Complete crack initiation and crack growth experiments for irradiated material with elevated Heq with flaws present	Fall 2024	Work has been completed

R&D Results

Based on the review of the licensees' R&D program to date, CNSC staff can confirm the following:

- The licensees have demonstrated that the regions of elevated Heq can be reproduced through modelling the following phenomena, without requiring additional sources of hydrogen isotope ingress:
    - For the outlet region: circumferential redistribution to the top half of a pressure tube due to a circumferential temperature gradient arising from coolant flow bypass above the top of fuel bundles.
    - For the inlet region: a localized cool spot on the outer diameter (OD) surface of a pressure tube arising from a thermal contact path from the pressure tube, through the end fitting, journal bearing and bearing sleeve to the calandria end shield lattice tube.
- Modelling has demonstrated that the regions of interest for elevated Heq will not exceed the bounding definitions that were adopted for LC 6.2 prior to the planned refurbishment dates for the Bruce B and Pickering B reactors.
- The licensees have provided a process to permit the evaluation of pressure tube fitness for service based on the CVC in LC 6.1:
    - A modification to the delayed hydride cracking (DHC) initiation model was implemented for Heq levels above 120 ppm based on material test results, but testing indicated that no modifications were required for the evaluation of hydride region overload (HROL) crack initiation or fatigue crack initiation.
    - A modification is being implemented for the pressure tube fracture toughness model for front-end material with Heq levels above 100 ppm based on material testing. The model currently assumes that all material will reach upper-shelf (maximum) toughness at an operating temperature of 250^{o}C, but testing indicates that front-end material with higher Heq levels does not reach upper-shelf behaviour at 250^{o}C. The impact of an upper-shelf transition temperature shift can be addressed in the required evaluations per LC 6.1.

Therefore, CNSC staff conclude that the licensees have demonstrated that an appropriate analytical toolset is available to perform the required evaluations per LC 6.1. CNSC staff will continue to review OPG and Bruce Power pressure tube fitness for service submissions, per the licensees' established periodic inspection programs, and in accordance with established practices.

Continued R&D and CNSC Staff Oversight

Further R&D will continue, including further refinements of Heq models, high Heq crack initiation testing and fracture toughness testing. It is expected that many of these activities will focus on addressing excess conservatism in the analytical toolset developed under the current R&D program. CNSC staff will actively monitor the results of these activities, and the licensees are required to submit event reports should any findings ever present challenges to the analytical toolset required to demonstrate pressure tube fitness for service.

It is CNSC staff's conclusion that OPG and Bruce Power no longer require the interim approaches outlined in the current CVC for LC 6.2 to assess the safe operability of pressure tubes in extended operation; however, the minimum Heq measurement requirements of CSA standard N285.4 are not sufficiently detailed to capture and characterize regions of elevated Heq near the burnish marks. Therefore, the CVC for LC 6.2 will be modified to complement the CVC for LC 6.1 in order to:

- Provide clarifications to the requirements in CSA Standard N285.8 for flaw evaluations near the burnish marks until such time that the Standard is updated to reflect the findings of the elevated R&D program.
- Elaborate on the minimum Heq measurement requirements of CSA standard N285.4 to characterize regions of elevated Heq near the burnish marks.
    - For reactors with pressure tubes operating beyond 210,000 EFPH, the licensees should establish an enhanced Heq monitoring program for in-service Heq scrape sampling and ex-service surveillance tube Heq sampling that is sufficient to characterize the axial, circumferential and radial extents of inlet and outlet rolled joint regions of elevated Heq that may arise due to circumferential and/or localized temperature gradients. In doing so, it is expected that:
        - Licensees work with industry partners to obtain a larger sample of data obtained from ex-service pressure tube, as this could lead to further refinement of the modelling process.
        - Licensees continue with material surveillance activities through both planned inspection program surveillance tubes as well as opportunities for additional material removal during refurbishment outages.

LC 6.2 will remain in the respective PROLs until the licensees submit an application to the Commission requesting amendments to the applicable licences. If a licensee chooses to request an amendment to their licence, CNSC staff will review the application and provide their recommendation to the Commission.

After December 31st, 2025, CNSC staff will update Section 6.2 of the Pickering NGS and Bruce NGS A and B LCHs accordingly with CVC for continued implementation of an enhanced fitness for service program for fuel channels in extended operation.

Summary

- CNSC staff confirm that all R&D activities scheduled for completion by the end of 2025 have been completed.
- CNSC staff conclude that the licensees have developed the necessary understanding of the factors that lead to the formation of the regions of elevated Heq and have sufficiently expanded the analytical toolset to complete fitness for service evaluations in accordance with Licence Condition 6.1.
- Licensees will continue with R&D on a variety of subjects, including further refinements of Heq models, high Heq crack initiation testing and fracture toughness testing.

- LC 6.2 to remain in the Bruce NGS A and B and Pickering NGS PROLs and CNSC staff will update Section 6.2 of the LCHs accordingly.

CNSC staff, along with OPG and Bruce Power, will be providing a detailed update on the current status of the Heq R&D program to the Commission in an upcoming public Commission Meeting in Spring 2026.

Acknowledgement of concurrence with Director General:

I approve

2025-12-22

X

Ramzi Jammal
Executive Vice-President and CROO
Signed by: Jammal, Ramzi

I do not approve

X

Ramzi Jammal
Executive Vice-President and CROO

Attachment: Approvals Routing Slip - Memo CNSC Staff Update to the Commission on Elevated Heq R&D Activities - December 2025, via Approvals process

c.c.: R. Jammal, D. Haslip, M. Rickard, A. Bulkan, R. Richardson, V. Tavasoli, B. Carroll, P. Szymanski, D. Carrière

References:

1. Commission Member Document, "OPG Response – Darlington and Pickering NGS – Request for an Update to the Commission on Activities Related to the Discovery of Elevated Hydrogen Equivalent Concentration (Heq) – New Action Item 2022-OPG-23135", July 19, 2022, CMD 22-M37.1, e-Doc 6858724.
2. Commission Member Document, "Bruce A and B: Update to the Commission regarding Elevated Hydrogen Equivalent Concentrations -Action Item 2022-07-23135", July 19, 2022, CMD 22-M37.3, e-Doc 6858728.
3. Record of Decision, "In the Matter of Bruce Power Inc. - Application to Amend the Power Reactor Operating Licence for the Bruce Nuclear Generating Stations A and B with Respect to Fitness for Service Requirements", April, 2023, DEC 23-H103, e-Doc 7144134.
4. Record of Decision, "In the Matter of Ontario Power Generation Inc. – Application to Extend the Operation of the Pickering Nuclear Generating Station Units 5 to 8 until December 31, 2026", October, 2024, DEC 24-H5, e-Doc 7426653.
5. Bruce NGS A and B Licence Conditions Handbook, LCH-PR-18.04/2028-R005, March 4, 2025, e-Doc 7474949.
6. Pickering NGS Licence Conditions Handbook, LCH-PR-48.00/2028-R008, June 24, 2025, e-Doc 7525633.