Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

UNPROTECTED/NON PROTÉGÉ

ORIGINAL/ORIGINAL

CMD: 21-H110

Date signed/Signé le : OCTOBER 1, 2021

Approval to Restart

Authorization de redémarrage

CNSC staff assessment of supplemental information submitted by Bruce Power to support Bruce A Unit 3 request for return to service (pursuant to Orders issued due to hydrogen equivalent concentration discovery events at Bruce NGS A and B)

Évaluation par le personnel de la CCSN des renseignements supplémentaires soumis par Bruce Power à l'appui de la demande de redémarrage de la tranche 3 de la centrale Bruce-A (conformément aux ordres délivrés en raison d'événements de découverte liés à la concentration d'hydrogène équivalent au centrales de Bruce A et B)

Bruce Power Inc.

Bruce Nuclear Generating Station A

Bruce Power Inc.

Centrale nucléaire de Bruce A

Hearing in writing based solely on written submissions

Audience fondée uniquement sur des mémoires

Scheduled for:

October 1, 2021

Prévue pour :

1 octobre 2021

Submitted by:

CNSC Staff

Soumise par :

Le personnel de la CCSN

e-Doc 6640625 (WORD)
e-Doc 6648168 (PDF)

Summary

Bruce Power was issued an Order requiring Commission approval to restart units in extended operation. Bruce Power presented their restart request to the Commission on September 10, 2021. Subsequently, Bruce Power submitted additional qualitative and quantitative analyses to support Unit 3 return to service and re-requested authorization to restart Unit 3.

The purpose of this CMD is to provide CNSC staff's:

- assessment of the supplemental information, and
- conclusions and recommendations on Bruce A Unit 3 restart.

CNSC staff conclude that Bruce Power's Unit 3 fitness for service analysis is in compliance with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission authorize Unit 3 restart.

Résumé

Un ordre a été délivré à Bruce Power exigeant l'autorisation de la Commission avant le redémarrage des tranches en exploitation prolongée. Bruce Power a présenté leur demande de redémarrage à la Commission le 10 septembre 2021. Subséquemment, Bruce Power a soumis des analyses qualitatives et quantitatives supplémentaires à l'appui de la remise en service de la tranche 3 et a soumis une nouvelle demande d'autorisation pour le redémarrage de la tranche 3.

Ce CMD présente à la Commission :

- l'évaluation par le personnel de la CCSN de ces renseignements supplémentaires
- les conclusions et recommandations du personnel de la CCSN de la demande d'autorisation pour le redémarrage de la tranche 3 de la centrale de Bruce-A

Le personnel de la CCSN a conclut que l'analyse par Bruce Power de l'aptitude fonctionnelle de la tranche 3 est conforme à l'option (b) de l'ordre. Par conséquent, le personnel de la CCSN recommande que la Commission autorise le redémarrage de la tranche 3.

Signed/signé le

1 October 2021/1 octobre 2021

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Alexandre Viktorov, PhD

Director General

Directorate of Power Reactor Regulation

Directeur général

Direction de la réglementation des centrales nucléaires

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Table of Content

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EXECUTIVE SUMMARY

Bruce Power was issued an Order requiring Commission approval to restart units in extended operation. Bruce Power presented their restart request to the Commission on September 10, 2021. Subsequently, Bruce Power submitted additional qualitative and quantitative analyses to support Unit 3 return to service and re-requested authorization to restart Unit 3.

The purpose of this CMD is to provide CNSC staff's conclusions and recommendations founded on their assessment of the supplemental information submitted by Bruce Power specifically to Bruce A Unit 3 restart.

CNSC staff conclude that Bruce Power's Unit 3 fitness for service analysis is in compliance with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission authorize Unit 3 restart.

1. PREAMBLE

In early July, Bruce Power Inc (Bruce Power) reported to CNSC a discovery of elevated hydrogen equivalent concentrations (Heq) at Bruce NGS A and B, Units 3 and 6. On July 26, 2021, a Canadian Nuclear Safety Commission (CNSC) designated officer (DO) issued an order to Bruce Power, requiring that the licensee obtain an authorization from the Commission prior to the restart of any operating unit with pressure tubes in extended operation, following any outage that results in the cooldown of the heat transport system. The discovery of Heq exceeding the licensing limit, was considered by the DO to put into question the predictive capability of the model for the hydrogen equivalent concentration levels in operating reactors with pressure tubes in extended operation. The DO subsequently issued orders to Ontario Power Generation Inc. (OPG) for the Darlington NGS and the Pickering NGS on July 27, 2021.

On September 22, 2021, the Commission issued a Summary Record of Decision [1] which confirmed the DO order issued to Bruce Power. The Summary Record of Decision stated that: "The Commission does not, at this time, pre-authorize the restart of any designated reactor unit pursuant to the terms of the orders. The Commission will consider requests to restart a designated reactor unit, or group of units with similar characteristics, on a case-by-case basis, upon the submission of a specific request by a licensee. Any request shall contain qualitative and quantitative analyses to satisfy the conditions of the order."

In mid to late September 2021, Bruce Power provided qualitative and quantitative analyses to support Unit 3 return to service and re-requested authorization to restart Unit 3 [2-5]. CNSC staff consider the supplemental information submitted on September 17, 2021 [2, 3] to be a new request for Unit 3 restart.

2. PURPOSE

The purpose of this document is to provide the Commission with CNSC staff recommendations regarding Bruce Power's request for Unit 3 restart post-A2131 planned outage based on the additional information submitted by the licensee [2-5].

Bruce NGS Units 4, 5, 7 and 8 as well as OPG Darlington and Pickering units in extended operation will be considered in separate CMDs, upon the submission of the requests from the licensees.

3. CNSC STAFF'S ASSESSMENT OF SUPPLEMENTAL SUBMISSIONS TO SUPPORT BRUCE POWER'S UNIT 3 RESTART REQUEST

In order for CNSC staff to recommend restart of a unit, given the potential for elevated Heq near the outlet burnish mark, Bruce Power must demonstrate compliance with the Order issued on July 26, 2021 [6]. CNSC staff applied the restart criteria [7] communicated to Bruce Power on August 12, 2021, to assess the request for restart. Bruce Power was required to satisfy either Option (a) or (b) of the criteria for the region of the pressure tubes defined as 75 mm inboard from the outlet burnish mark and 360^{o} of the pressure tube circumference ("region of interest"):

Option (a):

1. *Licensee shall demonstrate an understanding of the mechanism leading to high Hydrogen equivalent (Heq) concentration in the region of interest, and are able to conservatively model Heq concentration in this region.*

Option (b)

1. *Sufficient inspection data shall be available for the reactor unit to justify, with a high degree of certainty, that no flaws are present in the region of interest greater than 0.15 mm in depth.*
2. *Corrective actions shall be implemented for tubes containing flaws greater than the specified depth*.

3.1 Bruce Power's Compliance with Option (a) of the Order

To comply with Option (a) of the Order [6] and the associated restart criteria [7], a licensee must demonstrate a thorough understanding of the mechanism that resulted in elevated Heq in the Bruce Unit 3 and Bruce Unit 6 pressure tubes, and be able to predict Heq in the region of interest near the outlet burnish mark to confirm the Heq remains below the current licensing limit of 120 ppm. The measured Heq concentration for some tubes in Unit 3 have exceeded the current licensing basis approved by the Commission.

3.2 Bruce Power's Compliance with Option (b) of the Order

To satisfy Option (b), the licensee must demonstrate through an evaluation of the inspection history data and knowledge of the potential flaw formation mechanisms, that flaws deeper than 0.15 mm do not exist in regions where Heq may be above 120 ppm (region of interest) in tubes that have been inspected and are unlikely to exist in tubes that have not been inspected. If no such flaws exist, then there is no potential for crack initiation in the region of interest. The impact of elevated Heq on the fracture toughness will not increase the risk of pressure tube failures.

CNSC staff reviewed Bruce Power's supplemental submissions [2-5] provided to the Commission in support of the request to restart Unit 3 and have determined that:

- There have been no flaws greater than 0.15 mm deep in the region of interest of the 111 pressure tubes that have been volumetrically inspected in Unit 3.
- A statistical analysis based on inspection data gathered from Bruce NGS Units 3 to 8 demonstrated that the expected number of flaws deeper than 0.15 mm in the population of Unit 3 pressure tubes that have not been inspected is less than 1.0. Less than one flaw (which could lead to a pressure tube failure if a crack were to initiate and propagate through wall) means that Unit 3 remains within the safety case as approved by the Commission. The safety case demonstrates that failure of a single pressure tube can be mitigated by safety systems (as further described in section 3.4).
- Based on the positioning of the fuel bundles at the outlet end of the pressure tubes, the potential drivers for the formation of pressure tube flaws deeper than 0.15 mm are limited. Deeper pressure tube flaws are typically associated with locations where fuel bundle bearing pads contact the surface of the pressure tubes. There are no bearing pad contact locations in the region of interest during normal operation of Bruce NGS reactors.
- Unit 3, as all other units of Bruce NGS, is equipped with a fuel carrier, which prevents the formation of flaws due to cross flow conditions during fueling operations.

Given these observations, CNSC staff conclude that Bruce Power has successfully demonstrated that the Unit 3 pressure tubes satisfy the restart criteria for Option (b) of the Order [6] and can be safely returned to service following the current A2131 planned outage.

Bruce Power has also provided the results of stress analyses for the scrape marks resulting from the Heq measurement samples collected during the A2131 outage, which indicate that the stresses associated with these scrape marks are low and insufficient to initiate cracks in-service. Scrape marks are low risk “flaws” introduced through scrape testing; they are not service induced flaws or operational flaws. Scrape marks are of a known (blunt) geometry and are therefore not considered to be susceptible to crack initiation. However, during the A2131 outage, Bruce Power introduced several scrape marks in the region of interest with elevated Heq; therefore, Bruce Power has been requested to conduct confirmatory tests to validate the assumption that the crack initiation model remains valid for pressure tubes with elevated Heq. Nevertheless there is no impact on safe operation associated with restart from the A2131 outage or subsequent full power operation.

CNSC staff request that Bruce Power commits to carrying out additional activities for the longer term to enhance fitness for service analysis capabilities for all units with pressure tubes in extended operation, including:

- A proposed testing program to enhance the validation of crack initiation models for materials with elevated Heq. This testing program will be conducted between Q4 2021 and Q4 2024. While CNSC staff consider the scope of the program to be

adequate, the duration of the testing program extends over a period of three years. CNSC staff is working with Bruce Power and their industry partners to accelerate this test program to the extent practicable.

- Continued activities aimed at understanding the root cause of the elevated Heq measured in the Unit 3 and Unit 6 pressure tubes and enhance Heq model predictive capabilities.

- Expanded pressure tube fracture toughness testing program for material with elevated Heq.

CNSC staff will monitor these activities and provide regular updates to the Commission.

3.3 Impact of Operational Changes to reduce the risk of a Cold Over-Pressurization Transient (COPT)

In CMD 21-M37.1, Bruce Power proposed to update their Heat Transport (HT) system operating conditions in order to reduce the possibility of over-pressurizing the pressure tubes when they are relatively cold and consequently less ductile. To implement these changes, Bruce Power is updating the software for the digital control computer (DCCs) to automatically shut off the HT feed pumps under certain conditions when the reactor power and the HT system temperature is low.

Currently, CNSC staff are waiting for additional information from the licensee to verify that the proposed updates to the DCC software follows the applicable regulatory requirements, relevant industry standards, and industry best practices. In addition, CNSC staff plan to include the DCCs in a software maintenance inspection at Bruce Power scheduled later this year.

From the perspective of pressure tube integrity, CNSC staff are of the opinion that Bruce Power's proposed operational changes would promote safe operation.
From a safety analysis perspective, CNSC staff verified that Bruce Power has assessed the safety analysis implications of the proposed changes to the HT feed pump trip logic. CNSC staff noted that the current safety report conclusions regarding the unlikely failure of a pressure tube (with and without a failure of the corresponding calandria tube) would not be changed by the proposed HT feed pump trip logic changes. CNSC staff also verified that the HT system and the emergency coolant injection system would not be adversely affected by the new trip logic.

3.4 Impact on Deterministic Safety Analysis

Deterministic safety analysis (DSA) is used to analyze the behaviour of a nuclear power plant (NPP) following a postulated event. For the analyzed event, the DSA allows prediction and quantification of challenges to the plant's physical barriers, and the performance of plant structures, systems and components (particularly safety systems). This is performed by determining the bounding initiating events/failures, mapping out the accident sequence, modelling the plant and safety system responses, analyzing the consequences and then comparing against regulatory limits.

A simultaneous pressure tube and calandria tube rupture is explicitly analyzed as a design basis accident in the safety analysis for all NPP licensees. These analyses demonstrate that the plant is capable of performing the fundamental safety functions of control, cool and contain. This includes being able to shutdown the reactor with one shutdown system acting alone, adequately cool the reactor core, prevent further failures of other pressure tubes and limit radiological releases to below regulatory limits.

CNSC staff's assessment has determined that the Heq findings do not impact the accident sequence, the key analysis parameters, the ability of the NPP to perform its fundamental safety functions or the accident consequences (radiological dose to the public).

4. CONCLUSIONS

Licence condition 15.3 for PROL 18.01/2028 requires that "*Before hydrogen equivalent concentrations exceed 120 ppm, the licensee shall demonstrate that pressure tube fracture toughness will be sufficient for safe operation beyond 120 ppm*". The compliance verification criteria for this licence condition, as outlined in Section 15.3 of LCH-18.01/2028-R002, establish that "*Bruce Power shall obtain approval from the Commission before operating any pressure tube with a measured [Heq] greater than 120 ppm, or beyond the time any pressure tube is predicted to have a [Heq] greater than 120 ppm…*"

Based on the information provided by Bruce Power [2-5], CNSC staff conclude that:

- Bruce Power has met the restart criteria for Option (b) of the Order since they have demonstrated "*with a high degree of certainty, that no [service-induced] flaws greater than 0.15 mm are present in the region of interest"* [7], and
- Bruce Power complies with the intent of Licence Condition 15.3 to provide assurance of pressure tube fitness for service, since they have demonstrated that "*pressure tube fracture toughness will be sufficient for safe operation beyond 120 ppm"*.

5. RECOMMENDATIONS

CNSC staff recommend that the Commission authorize Unit 3 restart.

6. REFERENCES

1. CNSC Summary Record of Decision DEC 21-H11, R. Velshi to Bruce Power Inc., "Review by the Commission of the Designated Officer Orders Issued to Bruce Power and Ontario Power Generation Inc. on July 26-27, 2021; and Requests to Restart Reactors subject to the Orders", September 22, 2021, e-Doc 6644319.

2. Bruce Power Letter, M. Burton to M. Leblanc, "Bruce A Unit 3: Return to Service Additional Information", September 17, 2021, e-Doc 6643891.

3. Bruce Power Enclosures to Reference [2], M. Burton to M. Leblanc, "Bruce A Unit 3: Return to Service Additional Information", September 17, 2021, e-Doc 6644130.
   Enclosure 1, B-31100 LOF NSAS Rev. 00, *Justification for Application of Crack Initiation Models to High Hydrogen Equivalent Concentration Regions in Pressure Tubes*

   Enclosure 2, B-REP-31110-00004 Rev. 000, *Estimation of Encountering Reportable & Dispositionable Pressure Tube Flaws in Various Regions of Interest in Bruce Power Units 3-8*

   Enclosure 3, NK21-REP-31100-00129 Rev. 000, *Risk-Informed Deterministic Evaluation of Fracture Protection for the Region of Interest in Outlet Rolled Joints in Bruce Unit 3*

   Enclosure 4, B-03644.4 LOF NSAS Rev. 000, *Concentrating Hydrogen Isotopes at the Top of Tube at the Outlet End Rolled Joint Region*

   Enclosure 5, NK21-03644.4 LOF NSAS Rev. 000, *Re: Hydrogen Equivalent Concentration Measurements Taken Near the Outlet Burnish Mark in the Bruce Unit 3 2021 Outage (A2131)*

4. Bruce Power Letter, M. Burton to M. Leblanc, "Bruce A Unit 3: Response to CNSC Review of Return to Service Additional Information", September 24, 2021, E-Docs 6648875.

5. Bruce Power Letter, M. Burton to M. Leblanc, "Bruce A and Bruce B: Supplementary Information with Respect to Flaw Probability", September 29, 2021, BP-CORR-00531-02090, e-Doc 6651887.

6. CNSC Designated Officer Order, R. Jammal to Bruce Power, "Order by a Designated Officer Under Paragraph 37(2)(f) and Subsection 35(1) of the *Nuclear Safety and Control Act*", July 26, 2021, e-Doc 6612405.

7. CNSC Letter, A. Viktorov to M. Burton, "Bruce A and B: CNSC Staff Assessment Criteria for Restart Requirements", August 12, 2021, CNSC File 4.01.03, e-Doc 6621711.