Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

UNPROTECTED/NON PROTÉGÉ

ORIGINAL/ORIGINAL

CMD: 22-H100

Date signed/Signé le : JANUARY 31, 2022

Approval to Restart

Authorization de redémarrage

CNSC staff assessment of information submitted by Bruce Power to support Bruce A Unit 3 request for return to service following any outage (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 soumis par Bruce Power à l'appui de la demande de redémarrage de la tranche 3 de la centrale Bruce-A après touts arrêts (conformément aux ordres émis en raison d'événements de découverte liés à la concentration d'hydrogène équivalent aux 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:

February 22, 2022

Prévue pour :

22 février 2022

Submitted by:

CNSC Staff

Soumise par :

Le personnel de la CCSN

e-Doc 6721469 (WORD)
e-Doc 6722596 (PDF)

Summary

Bruce Power was issued an Order requiring Commission approval to restart units in extended operation. Bruce Power obtained Commission approval for Unit 3 restart following the 2021planned outage. Subsequently, Bruce Power submitted additional analyses to support Unit 3 return to service following any outage and requested closure of the Order.

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

- assessment of the information submitted by Bruce Power, and
- conclusions and recommendations on Bruce A Unit 3 restart following any outage and closure of the Order.

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 following any outage and close the Order for all Bruce Power units.

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 obtenu l'approbation de la Commission pour le redémarrage de l'unité 3 après l'arrêt planifié de 2021. Par la suite, Bruce Power a soumis des analyses supplémentaires pour appuyer la remise en service de la tranche 3 après touts arrêts et a demandé la clôture de l'ordre.

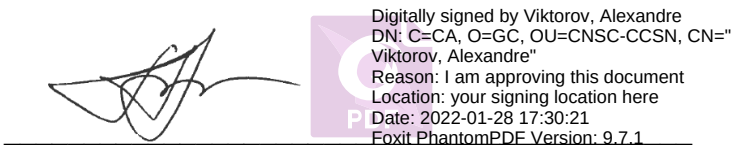
Ce CMD présente à la Commission :

- l'évaluation par le personnel de la CCSN de ces renseignements supplémentaires, et
- 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 après touts arrêts.

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 après touts arrêts et ferme l'ordre pour toutes les tranches de Bruce Power.

Signed/signé le

31 January 2022/31 janvier 2022



Alexandre Viktorov, PhD

Director General

Directorate of Power Reactor Regulation

Directeur général

Direction de la réglementation des centrales nucléaires

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EXECUTIVE SUMMARY

Bruce Power was issued an Order requiring Commission approval to restart units in extended operation in response to measurement of hydrogen equivalent concentration (Heq) near the outlet rolled joint burnish mark of pressure tubes from Bruce Unit 3 and Unit 6 exceeding the current licensing limit of 120 parts per million (ppm). Bruce Power obtained Commission approval for Unit 3 restart following the A2131 planned outage. Subsequently, Bruce Power submitted additional analyses to address the impact of these findings on the fitness for service of the Unit 3 pressure tubes to support the requested closure of the Order.

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 following any future outage.

CNSC staff conclude that the fitness for service of the Bruce Power's Unit 3 pressure tubes can continue to be demonstrated with Heq in excess of the 120 ppm in the defined Region of Interest (ROI) near the outlet rolled joint and that the licensee is in compliance with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission close the Order for Unit 3 and return the restart authorization process to CNSC staff.

1. PREAMBLE

In July 2021, Bruce Power Inc. (Bruce Power) reported to the CNSC a discovery of elevated hydrogen equivalent concentrations (Heq) exceeding the licensing limit of 120 parts per million (ppm) near the outlet rolled joint burnish mark in pressure tubes at Bruce NGS A and B, Units 3 and 6. On July 26, 2021, a 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 (Units 3, 4, 5, 7 and 8), 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.

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."

An overview of the recent actions taken in response to the discovery of elevated Heq at the outlet rolled joint of the pressure tubes is as follows:

1. Bruce Power requested restart of Units 3, 4, 5, 7 and 8.

2. The Commission authorized for Bruce NGS Units 4, 5, 7 and 8 (as well as OPG Darlington and Pickering units in extended operation) and returned the restart authorization process to CNSC staff.

3. The Orders have been closed for all units in extended operation with the exception of Bruce A Unit 3.

4. On September 17, 2021, Bruce Power provided qualitative and quantitative analyses to support Unit 3 return to service and requested authorization to restart Unit 3 [2-5]. The Commission authorized [6] restart of Unit 3 following the 2021 planned outage only.

5. The Commission did not grant Bruce Power full restart authorization of Unit 3 pending CNSC staff assessment of the additional information on initial crack initiation test results. The purpose of this CMD is to present to the Commission CNSC staff recommendations as elaborated below.

2. PURPOSE

The Commission decision [6] was limited to the return to service from the Unit 3 planned maintenance outage in 2021 (A2131), pending further information with respect to the validation of crack initiation models to confirm that scrape marks in locations of elevated hydrogen equivalent concentrations will not lead to crack initiation.

The purpose of this document is to provide the Commission with CNSC staff recommendations regarding Bruce Power's request for closure of the Order based on the additional information submitted by the licensee [7].

3. CNSC STAFF'S ASSESSMENT OF BRUCE POWER'S REQUEST FOR UNIT 3 RESTART

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 [8]. CNSC staff applied the restart criteria [9] 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" or ROI):

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 Review of previous submission related to Unit 3 restart from the A2131 outage

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 or ROI) 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 ROI. The impact of elevated Heq on the fracture toughness will not increase the risk of pressure tube failures.

CNSC staff previously reviewed Bruce Power's submission [3] provided to the Commission in support of the request to close the Order for Unit 3. Staff have determined that:

- There have been no flaws greater than 0.15 mm deep in the ROI 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 ROI 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 concluded that Bruce Power has successfully demonstrated that the Unit 3 pressure tubes satisfy the restart criteria for Option (b) of the Order [8]. Pressure tube fitness for service can be demonstrated considering the low likelihood of service induced pressure tube flaws that could lead to crack initiation.

CNSC staff noted that the licensee has introduced scrape marks deeper than 0.15 mm in regions of elevated Heq near the outlet rolled joint burnish mark of some pressure tubes when obtaining samples for Heq measurement. Scrape marks are of a known (blunt) geometry and are therefore not considered to be susceptible to crack initiation at the end-of-life Heq levels that were estimated at the time regulatory approvals for extended operation were granted for the Bruce Power reactors. During the A2131 outage, Bruce Power introduced several scrape marks in the ROI with elevated Heq. There was no impact on safe operation associated with restart from the A2131 outage or subsequent full power operation since cracks could not form under these operating conditions.

With the A2131 restart request, Bruce Power provided the results of stress analyses for the scrape marks resulting from the Heq measurement samples collected during the outage, which indicate that the stresses associated with these scrape marks are low and insufficient to initiate cracks in-service. CNSC staff note that this assessment assumed that the crack initiation behaviour of pressure tubes does not change with elevated Heq levels. Current theory suggests that crack initiation behaviour is only affected by

hydrogen isotopes in solution in the material that is free to diffuse to a higher stress region near a flaw. The elevated Heq levels at the scrape locations are well above the solubility limits for hydrogen at normal operating temperatures so the majority of the hydrogen isotope would be in locked in place in the form of zirconium hydrides and not free to diffuse to a flaw. While CNSC staff acknowledge the basis for this theory, it was not proven with physical testing of pressure tube material at the elevated Heq levels observed at some of the Unit 3 scrape locations. Nevertheless, CNSC staff are of the opinion that this theory does not impede staff's recommendations for restart of Unit 3 following any outage.

Bruce Power committed [3] to carrying out additional activities to confirm the assumption that the crack initiation model remains valid for scrape marks and application to pressure tubes with elevated Heq during future shutdown and restart cycles to evaluate pressure tube fitness for service prior to restart from future outages.

3.2 Review of submission crack initiation model validity for scrape marks

The first update for the crack initiation program was submitted in December 2021 [7]. Bruce Power provided a technical evaluation [7] that demonstrated the geometry of the scrape marks could tolerate a reduction of more than 40% for the limits set for key input parameters before crack initiation would occur. Staff also note that this analysis incorporated conservative assumptions regarding the geometry of the scrape flaws, which is expected to increase this margin further.

Initial crack initiation tests were completed on unirradiated pressure tube material samples with Heq = 240 ppm for comparison with past test results for material from the same sample pressure tube with Heq = 60 ppm. The 240 ppm tests demonstrated a reduction in the crack initiation threshold of about 20% compared to the 60 ppm tests. The findings do not pose a concern for the fitness for service of Bruce Unit 3 pressure tubes with scrape marks in the ROI since the reduction in the initiation threshold is not sufficient to consume the margins established in the previous technical evaluation. In summary, CNSC staff review of Bruce Power's initial crack initiation test results [7] does not change the conclusion that the scrape marks in the ROI of the Unit 3 pressure tubes are benign features that are not at risk of initiating cracks. Notwithstanding this conclusion, the findings highlight the importance of further testing to better characterize the effects of elevated Heq on the crack initiation behaviour of pressure tube material.

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 [7], 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 flaws greater than 0.15 mm are present in the region of interest"* [9].
- Bruce Power has demonstrated that scrape marks in the region of interest are not at risk of initiating cracks.
- 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"*.
- For fitness for service evaluations, the region of interest near the outlet rolled joint burnish mark should remain defined as 75 mm axially inboard of the burnish mark and the full circumference of the pressure tube until such time as Bruce Power has provided a technical evaluation to confirm the region will not expand axially or circumferentially beyond 60° either side of top dead center of a pressure tube.

5. RECOMMENDATIONS

CNSC staff recommend that the Commission close the Order for Bruce Power Unit 3 and and return the authority to approve restart Unit 3 from planned and unplanned outages to CNSC staff.

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-Doc 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 Letter, Secretariat to M. Burton, "Record of Decision DEC 21-H110 Request for Authorization to Restart Bruce Nuclear Generating Station A Unit 3 following its current planned outage", November 10, 2021, BP-CORR-00531-02250, e-Doc 6672394.
7. Bruce Power Letter, M. Burton to M. Leblanc, "Bruce A Unit 3: Designated Officer Order Issued to Bruce Power: Elevated Hydrogen Equivalent Concentrations and Delayed Hydride Cracking Initiation", December 17, 2021, BP-CORR-00531-02326, e-Doc 6707609.
8. 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.
9. 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.
10. CNSC Letter, A. Viktorov to M. Burton, "Bruce A and B: Request pursuant to Subsection 12(2) of the General Nuclear Safety and Control Regulations: Issues Relating to Measurement of Hydrogen Equivalent Concentration in Pressure Tubes", July 13, 2021, BP-CORR-00531-01868, e-Doc 6603948.