Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

UNPROTECTED/NON PROTÉGÉ

ORIGINAL/ORIGINAL

CMD: 21-H113

Date signed/Signé le : NOVEMBER 3, 2021

Approval to Restart

Authorization de redémarrage

CNSC staff assessment of supplemental information submitted by Bruce Power to support Bruce A and B Units 4, 5, 7 and 8 request for return to service from an unplanned 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 supplémentaires soumis par Bruce Power à l'appui de la demande de redémarrage des tranches 4, 5, 7 et 8 des centrales de Bruce A et B après un arrêt imprévu (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 Stations A and B

Bruce Power Inc.

Centrales nucléaires de Bruce A et B

Hearing in writing

Audience fondée

Scheduled for:

November 12, 2021

Prévue pour :

12 novembre 2021

Submitted by:

CNSC Staff

Soumise par :

Le personnel de la CCSN

e-Doc 6661796 (WORD)
e-Doc 6669250 (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 Units 4, 5, 7 and 8 return to service and re-requested authorization to restart Unit 4, 5, 7 and 8 from an unplanned outage.

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

- assessment of the supplemental information, and
- conclusions and recommendations on Bruce Units 4, 5, 7 and 8 restart.

CNSC staff conclude that Bruce Power's Units 4, 5, 7 and 8 fitness for service analyses are in compliance with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission authorize Units 4, 5, 7 and 8 restart following any planned or unplanned outage.

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 des tranches 4, 5, 7 et 8 et a soumis une nouvelle demande d'autorisation pour le redémarrage des tranches 4, 5, 7 et 8 après un arrêt imprévu.

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 des tranches 4, 5, 7 et 8 des centrales de Bruce A et B.

Le personnel de la CCSN a conclut que les analyses par Bruce Power de l'aptitude fonctionnelle des tranches 4, 5, 7 et 8 est conforme à l'option (b) de l'ordre. Par conséquent, le personnel de la CCSN recommande que la Commission autorise le redémarrage des tranches 4, 5, 7 et 8 après tout arrêt prévu ou imprévu.

Signed/signé le

3 November 2021/3 novembre 2021

Digitally signed by Viktorov, Alexandre
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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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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 Units 4, 5, 7 and 8 return to service and re-requested authorization to restart these Units following any unplanned outage.

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 for restart of Bruce A and B Units 4, 5, 7 and 8 (Bruce Unit 3 was assessed by CNSC staff in CMD 21-H110).

Having reviewed the Bruce Power submission, CNSC staff conclude that Bruce Power's Units 4, 5, 7 and 8 fitness for service analyses are in compliance with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission authorize Units 4, 5, 7 and 8 restart following any planned or unplanned outage.

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."

Bruce Power requested authorization to restart Bruce Unit 3 following the planned A2131 outage, which was reviewed by the Commission on October 5, 2021. The Commission has issued a Summary Decision (via e-mail to Bruce Power) [2], which states that, *"The Commission has approved the restart of Bruce Power Unit 3, effective immediately."*. Therefore, Bruce Unit 3 will be excluded from this CMD. At the time of writing this CMD the Unit 3 Record of Decision is still in progress.

On October 6, 2021, Bruce Power provided qualitative and quantitative analyses to support Units 4, 5, 7 and 8 return to service and re-requested authorization to restart Units 4, 5, 7 and 8 from any unplanned outage [3].

2. PURPOSE

The purpose of this document is to provide the Commission with CNSC staff recommendations regarding Bruce Power's request for Units 4, 5, 7 and 8 restart after any outage based on the information submitted by the licensee [3].

3. CNSC STAFF'S ASSESSMENT OF SUPPLEMENTAL SUBMISSIONS TO SUPPORT BRUCE POWER'S UNITS 4, 5, 7 and 8 RESTART REQUEST

In order for CNSC staff to recommend restart of a unit, given the potential for elevated Heq above 120 ppm near the outlet burnish mark, Bruce Power must demonstrate compliance with the Order issued on July 26, 2021 [4]. CNSC staff applied the restart criteria [5] communicated to Bruce Power on August 12, 2021, to assess the request for restart of Units 4, 5, 7 and 8 from unplanned outages. 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 360º 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 [4] and the associated restart criteria [5], Bruce Power 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.

Otherwise, predictions of Heq in the region of interest near the outlet burnish mark will be subject to uncertainty and thereby invalidate the Heq models. The long term actions noted above are in progress and are being trackeded through CNSC's license and compliance program [6]. Bruce Power will provide the first update on their progress towards completing the long term actions in January 2022.

CNSC staff conclude that Bruce Power does not comply with Option (a) since there is insufficient information to confirm the Units 4, 5, 7 and 8 pressure tubes satisfy the associated restart criteria.

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

The following criteria would permit a licensee to demonstrate that pressure tubes are safe to operate even if the region of interest contains Heq in excess of 120 ppm near the outlet burnish mark, and would satisfy option (b) restart criteria.

Namely, through an evaluation of the inspection history data and knowledge of the potential flaw formation mechanisms, Bruce Power should be able to demonstrate that in the region of interest:

- flaws deeper than 0.15 mm are unlikely to exist in the population of pressure tubes that have not been inspected in a reactor; and
- appropriate compensatory measures have been implemented for detected flaws deeper than 0.15 mm.

CNSC staff reviewed Bruce Power's supplemental submission [3] provided to the Commission in support of the request to restart Units 4, 5, 7 and 8 and have determined that:

- There have been no flaws greater than 0.15 mm deep (dispositionable flaws) in the region of interest of the pressure tubes that have been volumetrically inspected in Units 4, 5, 7 and 8, as summarized in Table 1.
- Statistical analyses 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 Units 4, 5, 7 and 8 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 Units 4, 5, 7 and 8 remain within the safety case as approved by the Commission. The Deterministic Safety Analysis 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 not significant. 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.
- Units 4, 5, 7 and 8, like all other units of Bruce NGS, are equipped with a fuel carrier, which prevents the formation of flaws due to cross flow conditions during fueling operations.

Table 1: Estimates of the Number of Dispositionable Flaws within the Region of Interest in the Uninspected Populations of Pressure Tubes in Bruce Units 4, 5, 7 and 8 [3]

Unit	No. of Inspected Tubes in each Unit (480 tubes per reactor)	Number of Dispositionable Flaws in Inspected Tubes	Expected No. of Flaws in Uninspected Tube
4	82	0	0.6
5	77	0	0.6
7	70	0	0.6
8	79	0	0.6

Given these observations, CNSC staff conclude that Bruce Power has successfully demonstrated that the Units 4, 5, 7 and 8 pressure tubes satisfy the restart criteria for Option (b) of the Order [4] and can be safely returned to service following any (unplanned or planned) outage.

The risks associated with restarting any unit from a planned compared to an unplanned outage with pressure tubes that potentially have elevated Heq above 120 ppm near the outlet burnish mark is essentially the same. From a pressure tube fitness for service perspective, the primary concern is the fracture toughness of pressure tubes in the event that a crack exists in a region of elevated Heq during heat-up.

The information provided by Bruce Power to CNSC staff at the time of writing this CMD was considered by staff in support of their conclusions and recommendations. Inspection findings from future outages and the results of planned crack initiation tests on material with elevated Heq [7] will be provided to the CNSC and reviewed by staff to confirm that new findings do not invalidate the inputs to the analysis that was completed by Bruce Power with respect to the likelihood of flaws in the region of interest of pressure tubes.

Furthermore, this conclusion does not excuse Bruce Power from satisfying all other compliance verification criteria established in the licensing basis for each unit related to pressure tube fitness for service.

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 reviewing 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.

On September 30, 2021, Bruce Power provided a notification of the implementation of the Cold Overpressure Transient (COPT) mitigation enhancement. As a result of CNSC's staff's review of this notification, Bruce Power has been requested [8] to provide an assessment that analyzes the safety limit and trip parameter changes resulting from this operational change. This request is being tracked through the licensing and compliance program. CNSC staff does not expect the requested analysis to challenge the conclusion of the current safety analysis of record (or safety report).

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 [3], CNSC staff conclude that:

- There were no flaws deeper than 0.15 mm (within the region of interest) in the 308* Bruce pressure tubes that were inspected in Units 4, 5, 7 and 8. (*Note: Bruce Power's submission included Units 3 and 6. Based on Table 1, the total number of inspected tubes in Units 4, 5, 7 and 8 is 308.)
- There are no known mechanisms that can result in deep flaws in the region of interest during normal operation.
- 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"* [5], 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"*.

From the perspective of the Order [4], the same conclusions are applicable to planned or unplanned outages. Pressure tubes are most at risk of crack initiation and failure during heatup or cooldown of the reactor; it is irrelevant whether the heatup or cooldown cycle occurs as a result of a planned or unplanned outage.

5. RECOMMENDATIONS

The restart criteria for Option (b), as stated in the Order, has been met. Therefore, CNSC staff recommend that the Commission authorize the restart of Bruce Units 4, 5, 7 and 8 following any planned or unplanned outages when all other pressure tube fitness for service requirements in the licensing basis are satisfied. Although the Bruce Power request was specific to unplanned outages, the conclusions are applicable to any outage provided future inspection findings continue to verify the results of Bruce Power's evaluations that were submitted to address Option (b) of the Orders.

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. CNSC E-Mail, M. Leblanc to M. Burton, "Bruce Unit 3 restart request - Commission decision", October 5, 2021, e-Doc 6654572.

3. Bruce Power Letter, M. Burton to M. Leblanc, "Designated Officer Order to Bruce Power: Unplanned Outage Restart Request – Supplemental Information", October 6, 2021, BP-CORR-00531-02059, e-Doc 6656461.

4. 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.

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

6. CNSC Letter, L. Sigouin to M. Burton, "Bruce A and B: CNSC Request for Additional Information to Address the Long Term Actions regarding Elevated Hydrogen Equivalent Concentration Measurements in Pressure Tubes – New Action Item 2021-07-23988", October 4, 2021, e-Doc 6643726.

7. Bruce Power Letter, M. Burton to M. Leblanc, "Bruce A Unit 3: Return to Service Additional Information", September 17, 2021, BP-CORR-00531-02033, 6643891.

8. CNSC E-Mail, K. Lun to C. Sauveur, "RE: Notification of the Implementation of Cold Overpressure Transient Mitigation Enhancement", October 27, 2021, e-Doc 6671361.