



Record of Decision

DEC 21-H114

In the Matter of

Applicant Ontario Power Generation Inc.

Subject Request for Authorization to Restart Darlington Nuclear Generating Station Units 1 and 4 following future outages

Date of Decision November 5, 2021

Record of Decision Date February 4, 2022

RECORD OF DECISION – DEC 21-H114

Applicant: Ontario Power Generation Inc.

Address/Location: 700 University Avenue, Toronto ON, M5G 1X6

Purpose: Request for Authorization to Restart Darlington Nuclear Generating Station Units 1 and 4 following future outages

Application received: September 29, 2021

Hearing: Public Hearing in Writing – Notice of Hearing in Writing published on September 28, 2021

Date of decision: November 5, 2021

Panel of Commission: Ms. R. Velshi, Chair
Dr. M. Lacroix
Ms. I. Maharaj

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External Advisory Committee on Pressure Tubes		Document Number
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Dr. M. Daymond	External Advisory Committee member	
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Decision: Authorization granted to restart Darlington NGS Units 1 and 4 following any outage

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1.0 INTRODUCTION

1. Ontario Power Generation Inc. (OPG) has applied to the Canadian Nuclear Safety Commission¹ (CNSC) for authorization to return Darlington Nuclear Generating Station (NGS) Units 1 and 4 to service following any unplanned outage that results in the cooldown of the heat transport system, as well as for authorization to return Unit 4 to service following its current planned outage. Darlington Units 1 and 4 are [subject to a CNSC order](#)² (the order) that requires the licensee to obtain authorization from the Commission prior to restart following any outage that results in the cooldown of the heat transport system. The Darlington NGS is located in the Municipality of Clarington, Ontario, and is comprised of four Canada Deuterium Uranium (CANDU) pressurized heavy water reactors and their associated equipment.
2. The discovery of elevated hydrogen equivalent concentrations ([Heq]) at Bruce Power Inc.'s Bruce NGS A and B, Units 3 and 6 respectively, was considered by a CNSC designated officer to put into question the predictive capability of the model for [Heq] levels in all operating reactors in Canada with pressure tubes in extended operation³. The CNSC designated officer issued the order to OPG in July 2021, and the Commission amended the order following a proceeding on [September 10, 2021](#).

Hearing in writing

3. Pursuant to section 22 of the NSCA, the President of the Commission established a Panel of the Commission over which she would preside, including Commission Members Dr. Marcel Lacroix and Ms. Indra Maharaj, to decide on the request. A [notice of hearing in writing](#) was published on November 4, 2021. The hearing in writing was conducted in accordance with the [Canadian Nuclear Safety Commission Rules of Procedure](#). The Commission considered written submissions from OPG ([CMD 21-H114.1](#) and [CMD 21-H114.1A](#)) and CNSC staff ([CMD 21-H114](#) and [CMD 21-H114.A](#)). The Commission also received a written submission from the Commission's [External Advisory Committee on Pressure Tubes](#)⁴ ([CMD 21-H114.2](#)).

¹ The *Canadian Nuclear Safety Commission* is referred to as the "CNSC" when referring to the organization and its staff in general, and as the "Commission" when referring to the tribunal component.

² The Commission confirmed this order on September 22, 2021; refer to the Detailed Record of Decision DEC 21-H11, *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*, November 10, 2021.

³ Extended operation of pressure tubes refers to operation beyond 210,000 equivalent full power hours (EFPH).

⁴ Established on July 30, 2021, the External Advisory Committee on Pressure Tubes was created by the Commission, under its statutory authority to establish advisory committees, to complement the expertise of Commission Members, and to provide an external perspective for the benefit of Commission members in their role as decision-makers.

4. The Commission Secretary communicated the Commission's decision on this matter to OPG on [November 5, 2021](#).⁵ This *Record of Decision* provides the detailed reasons for that decision.

Issues

5. The Commission considered whether OPG satisfied the conditions of the order, which provides that:

Prior to the restart of any of Units 1 or 4 following any outage that results in the cooldown of the heat transport system, OPG shall obtain authorization from the Commission to restart.

Prior to seeking such authorization, OPG shall either:

- a. carry out inspection and maintenance activities that demonstrate with a high degree of confidence that pressure tube [Heq] is within OPG's licensing basis, per licence condition G.1, and submit results of such activities to CNSC staff;

or

- b. carry out inspection and maintenance activities that demonstrate with a high degree of confidence that no flaws are present in the region of pressure tubes where the models failed to conservatively predict the elevated [Heq], and submit results of such activities to CNSC staff.

6. The Commission has also considered the application of licence condition 15.3 of OPG's CNSC licence, PROL 13.03/2025, to this request for restart. That condition provides:

Before hydrogen equivalent concentrations exceed 120 ppm (parts per million), the licensee shall demonstrate that pressure tube fracture toughness will be sufficient for safe operation beyond 120 ppm.

2.0 DECISION

7. Based on its consideration of the matter, with respect to the restart of Darlington NGS Units 1 and 4 following any unplanned outage that results in the cooldown of the heat transport system, the Commission concludes that OPG has:

⁵ Email from M. Leblanc (CNSC) to S. Irvine, M. Knutson, J. Vecchiarelli and J. Franke (OPG), *OPG Pickering and Darlington Requests for restart - Summary decision*, November 5, 2021.

- demonstrated a low likelihood of flaws deeper than 0.15 mm in the region of interest of the uninspected pressure tubes of Darlington Units 1 and 4 that could lead to crack initiation; and
- demonstrated with a high degree of confidence that no flaws that could call into question the fitness for service of Unit 1 and 4 pressure tubes are present in the region of pressure tubes where the models failed to conservatively predict the elevated [Heq], satisfying Option (b) of the conditions set in the order.

The Commission authorizes OPG to restart Darlington Nuclear Generation Station Units 1 and 4 from any outage where cooling down the primary heat transport system is necessary, subject to all other pressure tube fitness for service requirements in the licensing basis being satisfied. As a result of this decision, OPG will no longer be required to request authorization to restart Units 1 and 4 pursuant to the order. The Commission considers the order to have been satisfied.

3.0 ISSUES AND COMMISSION FINDINGS

8. In conducting this hearing in writing, the Commission invited the EAC to comment on the submissions from OPG, and the analysis and recommendations of CNSC staff, who were in turn provided an opportunity to respond. In order to obtain additional information in a fair and expeditious manner, the Commission held a virtual question and answer session via [transcribed](#) videoconference on November 5, 2021, with representatives from OPG, CNSC staff and EAC members in attendance. The responses provided during the question and answer session addressed the Commission's questions.

Conditions of the Order

9. The Commission assessed whether OPG had satisfied the conditions of the order. Prior to seeking authorization to restart Units 1 and 4, OPG was required to satisfy either option (a) or (b) of the order. CNSC staff had previously established the following restart criteria for each option:

Criteria for option (a):

1. Licensee shall demonstrate an understanding of the mechanism leading to high Hydrogen equivalent (Heq) concentration in the region of interest⁶, and are able to conservatively model Heq concentration in this region.

Criteria for 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; and

⁶ For the Darlington NGS, the "region of interest" is the region of the pressure tubes defined as 60 mm inboard from the outlet burnish mark and 360° of the pressure tube circumference.

2. Corrective actions shall be implemented for tubes containing flaws greater than the specified depth.

10. With respect to defining the region of interest to assess the request for authorization to restart Darlington Units 1 and 4, CNSC staff recommended that an axial length of 60 millimetres (mm) from the outlet burnish mark is appropriate. CNSC staff had previously used a 75 mm length, however, CNSC staff stated that there is high confidence that [Heq] levels do not exceed 120 ppm beyond the 60 mm region of interest, and that there is adequate conservatism for the evaluation of flaws in this region of interest. CNSC staff explained that OPG has consistently obtained [Heq] scrapes from an axial location of approximately 50 to 55 mm inboard of the burnish mark, and that none of these samples had measured [Heq] values that exceeded 120 ppm. CNSC staff further reported that the [Heq] measurements in this region were consistent with model predictions.

11. The Commission notes that the 0.15 mm depth specified in the criteria for option (b) is based on CSA standard N285.8, *Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors*⁷, and represents the threshold at which a flaw is considered to be unconditionally acceptable. The Commission understands that the primary mechanisms and characteristics of flaws that would pose a risk to pressure tube integrity are [Heq], flaw depth, and flaw sharpness.

12. The Commission is satisfied that the restart criteria established by CNSC staff are appropriate and provide reasonable bases on which to demonstrate that the conditions of the order have been met. The Commission is of the view that compliance with these criteria would demonstrate that the risk associated with elevated [Heq] in the region of interest is low. The Commission is satisfied that the 60 mm region of interest for Darlington Units 1 and 4 is appropriate, as measured [Heq] levels in this region are below 120 ppm and consistent with model predictions.

13. This decision will focus on the criteria for option (b). Satisfying option (a) would require strengthening the predictive capability of the model that has been called into question. OPG has indicated that it is working with Bruce Power and others in the nuclear industry to better understand the cause of the elevated [Heq]. While the Commission acknowledges OPG's progress in its analysis to satisfy this criterion, there is insufficient information to support option (a) at this time.

Option (b), Criterion 1

14. In its CMD, CNSC staff specified that, to satisfy criterion 1 of option (b), the licensee must demonstrate, through an evaluation of the inspection history data and knowledge of the potential flaw formation mechanisms, that in the region of interest, flaws deeper than 0.15 mm are unlikely to exist in the population of pressure tubes in a reactor that

⁷ CSA N285.8, *Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors*, CSA Group, 2020.

has not been inspected. CNSC staff's assessment is that OPG's inspection data and statistical analysis satisfy restart criterion 1 for option (b) of the order.

15. OPG submitted that, over time through its ongoing pressure tube inspection program, OPG has inspected 232 pressure tubes for flaws in Darlington Units 1 to 4. OPG reported that it has observed 0 flaws with a depth greater than 0.15 mm in the defined region of interest in this population of pressure tubes. CNSC staff submitted that pressure tube flaws deeper than 0.15 mm are not likely to develop in the region of interest in Darlington NGS pressure tubes, as the potential drivers for the formation of such flaws are limited.
16. OPG also submitted statistical analysis in order to demonstrate that the probability of a flaw in the region of interest for uninspected Unit 1 and 4 pressure tubes is low. OPG's statistical analysis, based on inspection data gathered from Darlington NGS units, demonstrates that the expected number of flaws deeper than 0.15 mm in the population of Unit 1 and 4 pressure tubes that have not been inspected is 1.2 and 1.3, respectively. CNSC staff noted that this is a higher expected number of flaws compared to OPG's Pickering NGS, which is less than 1.0, as well as above the safety case for the Darlington NGS, as approved by the Commission, which is also 1.0.
17. To supplement its analysis, OPG submitted sensitivity analyses incorporating data from other Canadian CANDU reactor units, including from the Pickering and Bruce NGSs. OPG noted that the Darlington and Bruce Power reactors have similar fuel bundle configurations and have similar fuelling machine designs with the use of fuel carriers. Using this information, OPG submitted that the expected number of flaws in each of the uninspected tube populations in the region of interest for Darlington units 1 and 4 is approximately 0.4.
18. Asked for more information concerning the statistical analysis, CNSC staff explained that it performed different sensitivity analyses, which provided consistent results. CNSC staff noted that its recommendations concerning Darlington Units 1 and 4 were based on the data available for those units, and that the sensitivity analyses supported that assessment. CNSC staff's position is that the approach of combining data with Bruce Power NGS inspection results was acceptable for the purpose of the sensitivity analyses, given the design similarities. The Commission is satisfied that CNSC staff performed sufficient analyses to verify OPG's results. The Commission also notes that the EAC indicated its satisfaction with how OPG and CNSC staff had addressed its comments.
19. With respect to Darlington Units 1 and 4, the Commission concludes that OPG has satisfied criterion 1 for Option (b) of the order. The Commission finds that:
 - no flaws have been identified in the region of interest in inspected Darlington Unit 1 and 4 pressure tubes;
 - OPG has demonstrated, with a high degree of confidence, that flaws deeper than 0.15 mm are unlikely to exist in the region of interest in the population of pressure tubes that have not been inspected; and that

- pressure tube flaws deeper than 0.15 mm are not likely to develop in the region of interest.

Option (b), Criterion 2

20. The second criterion that CNSC staff set out for satisfying option (b) of the order requires that corrective actions be implemented for pressure tubes containing flaws greater than the specified depth (0.15 mm). There are no flaws in Units 1 and 4 that would necessitate invoking criterion 2. The Commission therefore concludes that corrective measures are not required, and that OPG has satisfied both criteria for option (b) of the order.

Compliance with Licence Condition 15.3

21. Licence condition 15.3 of OPG's licence for the Darlington NGS, PROL 13.03/2025, 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”.

CNSC staff submitted that, in satisfying option (b) of the order, OPG has demonstrated that pressure tube fracture toughness will be sufficient for safe operation beyond 120 ppm.

22. Acknowledging the limitations of the model that has been called into question, the Commission understands that OPG has not had a pressure tube with a measured [Heq] in excess of the licence limit. The Commission is satisfied that OPG has demonstrated, for the purposes of licence condition 15.3 in relation to the restart request, that pressure tube fracture toughness is sufficient for safe operation.

Scope of Restart Request

23. OPG is seeking authorization to return:
- Darlington Units 1 and 4 to service following any unplanned outage that results in the cooldown of the heat transport system; and
 - Darlington Unit 4 to service following its current planned outage.

CNSC staff stated that its recommendations would be applicable to any outage – planned or unplanned – provided that future inspection findings continue to verify the results of OPG's evaluations that were submitted to address option (b) of the order.

CNSC staff noted that the Commission would be informed if any unexpected results are identified in future pressure tube inspections.

24. The Commission considered whether the restart authorization should be applicable to any future outage for Units 1 and 4. In response to questions from the Commission, CNSC staff explained that regardless of the type of outage, it is the warm-up process during the restart of a reactor with a cooled-down heat transport system that necessitates the restrictions to prevent crack initiation. In the event that a reactor is rapidly cooled during an unplanned outage, additional assessments are required to ensure that the reactor is safe to restart. CNSC staff noted that such assessments are a normal part of operational procedures.
25. The Commission sought OPG's perspective with respect to the scope of the restart request. A representative from OPG stated that OPG limited the scope of its request to focus on more time-sensitive restart scenarios. OPG's view is that the information it submitted supports restart following unplanned and planned outages for all units.
26. The Commission finds that, in satisfying option (b) of the order for Units 1 and 4, OPG has:
 - demonstrated a low likelihood of flaws deeper than 0.15 mm in the region of interest of the uninspected pressure tubes of Darlington Units 1 and 4 that could lead to crack initiation; and
 - demonstrated with a high degree of confidence that no flaws that could call into question the fitness for service of Unit 1 and 4 pressure tubes are present in the region of pressure tubes where the models failed to conservatively predict the elevated [Heq].
27. The Commission's view is that, barring unforeseen future pressure tube inspection results outside the licensing basis, it is reasonable to expect that the conditions in the Darlington Unit 1 and 4 pressure tubes will not significantly change for the remainder of their operating lives. That is, the Commission is satisfied that the pressure tubes in Darlington Units 1 and 4 are likely to remain fit for service, within the licensing basis. The Commission therefore authorizes OPG to restart Darlington NGS Units 1 and 4 from any outage where cooling down the primary heat transport system is necessary, subject to all other pressure tube fitness for service requirements in the licensing basis being satisfied. The Commission expects to be informed of any unexpected pressure tube inspection results.

28. As a result of this decision, OPG will no longer be required to request authorization to restart Darlington Units 1 and 4 pursuant to the order. The Commission considers the order to have been satisfied.

Velshi, Rumina  My signed by Velshi, Rumina
CA, O=GC, OU=ENSC-OCSN, CN=Velshi,
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February 4, 2022

Rumina Velshi
President,
Canadian Nuclear Safety Commission

Date