Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

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ORIGINAL/ORIGINAL

CMD: 21-H111

Date signed/Signé le : OCTOBER 8, 2021

Approval to Restart

Authorization de redémarrage

CNSC staff assessment of information submitted by Ontario Power Generation Inc. to support Pickering NGS Unit 5 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 informations soumises par Ontario Power Generation Inc. à l'appui de la demande de redémarrage de la tranche 5 de la centrale de Pickering (conformément aux ordres délivrés en raison d'événements de découverte liés à la concentration d'hydrogène équivalent aux centrales de Bruce A et B)

Ontario Power Generation Inc.

Pickering Nuclear Generating Station Unit 5

Ontario Power Generation Inc.

Tranche 5 de la centrale nucléaire de Pickering

Hearing in writing based solely on written submissions

Audience fondée uniquement sur des mémoires

Scheduled for:

October 12 , 2021

Prévue pour :

12 octobre 2021

Submitted by:

CNSC Staff

Soumise par :

Le personnel de la CCSN

e-Doc 6652531 (WORD)
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Summary

Ontario Power Generation Inc. (OPG) was issued an Order requiring Commission approval to restart units in extended operation. OPG presented their restart request to the Commission on September 10, 2021. Subsequently, due to a forced outage strategy that may necessitate cooldown and depressurization of the Heat Transport System, OPG submitted an additional request for authorization to restart Pickering Unit 5.

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

- assessment of the submitted information, and
- conclusions and recommendations on Pickering Unit 5 restart.

CNSC staff conclude that Pickering NGS Unit 5 fitness for service analysis is in compliance with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission authorize Pickering NGS Unit 5 restart.

Résumé

Un ordre a été délivré à Ontario Power Generation Inc. (OPG) exigeant l'autorisation de la Commission avant le redémarrage des tranches en exploitation prolongée. OPG a présenté leur demande de redémarrage à la Commission le 10 septembre 2021. Subséquemment, dû à un arrêt imprévu nécessitant possiblement le refroidissement et la dépressurisation du circuit caloporteur, OPG a soumis une demande supplémentaire d'autorisation pour le redémarrage de la tranche 5 de la centrale de Pickering.

Ce CMD présente à la Commission :

- l'évaluation par le personnel de la CCSN de les informations soumises
- les conclusions et recommandations du personnel de la CCSN de la demande d'autorisation pour le redémarrage de la tranche 5 de la centrale de Pickering

Le personnel de la CCSN a conclut que l'analyse par OPG de l'aptitude fonctionnelle de la tranche 5 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 5.

Signed/signé le

October 8, 2021/8 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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EXECUTIVE SUMMARY

Ontario Power Generation Inc. was issued an Order requiring Commission approval to restart units in extended operation. Ontario Power Generation presented their restart request to the Commission on September 10, 2021. Subsequently, due to a forced outage strategy that may necessitate cooldown and depressurization of the heat transport system, OPG submitted an additional request for authorization to restart Pickering Unit 5.

The purpose of this CMD is to provide CNSC staff's conclusions and recommendations founded on their assessment of the information submitted by Ontario Power Generation, specifically to Pickering NGS Unit 5 restart.

CNSC staff conclude that Pickering Unit 5 fitness for service analysis complies with Option (b) of the Order. Therefore, CNSC staff recommend that the Commission authorize Unit 5 restart.

1. PREAMBLE

In early July, Bruce Power Inc (Bruce Power) reported to CNSC a discovery of elevated hydrogen equivalent (Heq) concentrations at Bruce NGS A and B, Units 3 and 6. On July 27, 2021, a Canadian Nuclear Safety Commission (CNSC) designated officer (DO) issued an order to Ontario Power Generation Inc. (OPG), for the Darlington NGS and the Pickering NGS, 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 concentrations exceeding the licensing limit for Bruce NGS, was considered by the DO to put into question the predictive capability of the model for the hydrogen equivalent concentration levels in all operating reactors with pressure tubes in extended operation.

OPG requested an Opportunity to be Heard on the DO Orders, which was reviewed by the Commission on September 10, 2021. On September 22, 2021, the Commission issued a Summary Record of Decision [1], which confirmed the DO order issued to OPG. 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."

On October 1st, 2021, OPG requested authorization to restart Pickering Unit 5 following the potential forced outage where cooling down the primary heat transport system (PHTS) is necessary [2]. This request was supported by qualitative and quantitative analyses included in the OPG September 29th request for authorization to restart Pickering Units 5-8 [3] following any forced outages, as well as the information that was submitted in early September [4]. At the time of preparing this CMD, the Pickering Unit 5 PHTS was still in a hot and pressurized state. Therefore, the Commission approval for restart will only be needed if OPG cools down Pickering Unit 5 PHTS.

2. PURPOSE

The purpose of this document is to provide the Commission with CNSC staff recommendations regarding OPG's request for Pickering Unit 5 restart following a potential forced outage. These recommendations are being provided in anticipation of OPG needing to cool down the Pickering Unit 5 PHTS to implement repairs and subsequently restart the reactor. Staff recommendations are based on the information submitted by the licensee [3, 4, 7-8].

The separate request [3] for authorization to restart following the Pickering Unit 7 fall outage and pre-authorization for a blanket restart following any Pickering Units 5-8 forced outage will be considered in a separate CMD at a later date.

3. CNSC STAFF'S ASSESSMENT OF SUBMITTED INFORMATION TO SUPPORT PICKERING NGS UNIT 5 RESTART REQUEST

In order for CNSC staff to recommend restart of a unit, given the potential for elevated Heq concentration near the outlet burnish mark, OPG must demonstrate compliance with the Order issued on July 26, 2021 [5]. CNSC staff applied the restart criteria [6] communicated to OPG on August 12, 2021, to assess the request for restart. OPG was required to satisfy either Option (a) or (b) of the criteria for restart:

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 OPG's Compliance with Option (a) of the Order

To comply with Option (a) of the Order [5] and the associated restart criteria [6], a licensee must demonstrate a thorough understanding of the mechanism that resulted in elevated Heq concentrations in the Bruce Unit 3 and Bruce Unit 6 pressure tubes, and be able to predict Heq concentrations in the region of interest near the outlet burnish mark to confirm the Heq concentration remains below the current licensing limit of 120 ppm.

CNSC staff conclude that OPG does not comply with Option (a) since there is insufficient information to confirm that Pickering Unit 5 pressure tubes satisfy the associated restart criteria.

3.2 OPG'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 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 have not been inspected; and
- appropriate compensatory measures have been implemented for detected flaws deeper than 0.15 mm.

These criteria permit a licensee to demonstrate that pressure tubes are safe to operate if the region of interest contains Heq concentration in excess of 120 ppm near the outlet burnish mark.

CNSC staff conclude that OPG has demonstrated compliance with Option (b) of the Order and Pickering Unit 5 is safe to restart from an unplanned outage. The basis for this conclusion is discussed below.

Reduction in Size of Region of Interest for Pickering Pressure Tubes

For Pickering Units 5-8, CNSC staff recommend a reduction of the axial length of the region of interest from 75 mm to 60 mm from the outlet burnish mark.

The 75 mm axial length defined by CNSC staff as the region of interest, for the restart criteria [6], was based on information obtained from past Bruce Power scrape campaigns in response to the Bruce Power Unit 3 and Unit 6 events. The axial dimension was selected to ensure the region of interest encapsulated the region of pressure tubes where Heq concentration was not directly measured from in-service scrapes and where there was uncertainty about the concentration. The region of interest was defined by CNSC staff solely on information from the Bruce Power units and Bruce Power's approach to scrape sampling.

CNSC staff have since completed a comparison of the Pickering and Bruce Power Heq concentration scrape programs. For the Pickering units, OPG has consistently obtained the first Heq concentration scrape from an axial location of approximately 50 to 55 mm inboard of the burnish mark. For comparison, prior to the most recent Bruce Unit 3 outage, the first inboard scrape was often obtained from axial locations of approximately typically 65 to 70 mm from the burnish mark in the Bruce Power pressure tubes.

None of the first inboard scrape samples from Pickering pressure tubes had measured Heq concentration values that exceeded 120 ppm. The Heq concentration measurements were also consistent with model predictions. Hence, for Pickering Units 5-8, CNSC staff recommend a reduction of the axial length of the region of interest from 75 mm to 60 mm from the outlet burnish mark. There is high confidence that Heq concentration does not exceeding 120 ppm beyond the 60 mm region of interest and provides adequate conservativism for the evaluation of flaws in the region of interest.

Therefore, CNSC staff have used a 60 mm long region of interest to assess the Pickering Unit 5 request for authorization to restart.

Flaws at Risk of Cracking in the Region of Interest in Uninspected Population of Pickering Unit 5 Pressure Tubes

CNSC staff conclude that OPG has demonstrated a low likelihood of flaws deeper than 0.15 mm in the region of interest of the uninspected pressure tubes of Pickering Unit 5 that could lead to crack initiation. This was achieved through a statistical evaluation using the historical flaw population in the 299 inspected Pickering pressure tubes and through a review of the flaw formation mechanisms.

In order to perform the statistical evaluation, OPG first evaluated the population of flaws in the region of interest on inspected pressure tubes at Pickering and Darlington units [3]. CNSC staff's review for Pickering Unit 5 focuses solely on the information obtained from inspections from Pickering pressure tubes. The reason being is that the fuel bundle configurations are different for the Pickering and Darlington units. The information obtained from the inspected population of tubes was then used to infer the likelihood of the existence of flaws in the pressure tubes that have not been inspected at Pickering Unit 5.

OPG has inspected 299 pressure tubes in total for flaws in Pickering Units 1, 4, 5-8. Six flaws with a depth greater than 0.15 mm were observed in the region of interest in this population of pressure tubes. These flaws had all been evaluated in the past by OPG and it was determined that they had no impact on safe operation of pressure tubes because they would not lead to crack initiation. CNSC staff agreed with this determination. However, the discovery of region of Heq concentration in excess of 120 ppm in several Bruce Unit 3 and Unit 6 pressure tubes has raised concerns over the ability to adequately predict Heq concentration near the outlet burnish mark, which put into question the predictive capability of the Heq model for the previous flaw evaluations.

CNSC staff's analysis of flaws, is as follows:

- Five of these flaws are attributed to bearing pad frets due to cross flow during fueling activities. Analysis of these flaws demonstrated they are not susceptible to crack initiation even if they are deeper than 0.15 mm and Heq concentration is higher than 120 ppm [9]. In 2015, OPG implemented procedures to limit the formation of these flaws during the remainder of the operating lives of the Pickering units. No flaws of this type have been observed since the change in procedure. Hence, it is concluded that it is not necessary to consider them in the statistical analysis to estimate the expected number of flaws in the uninspected population of Pickering Unit 5 pressure tubes.

- The sixth flaw, identified as P5O05-IND1, was located in the region of interest in a Pickering Unit 5 pressure tube. It was attributed to debris fretting and is very small, measuring only 0.17 mm deep, 4.6 mm in length and 1.2 degrees in width. In Pickering B reactors, a shield plug extends approximately 85 mm past the outlet burnish mark and supports the last fuel bundle (see Figure A.1 in Attachment A). Therefore, pressure tube flaw formation mechanisms associated with contact between the fuel bundle and pressure tube wall are not active during normal operation in the region of interest. The shield plug configuration is not conducive to trapping debris against the pressure tube wall during normal operation. This limits the potential for the formation of deeper flaws that would be at risk for crack initiation in the region of interest. The location of flaw P5O05-IND1 is covered by the shield plug during normal operation. The flaw was detected and reported to the CNSC in 1999 and no other similar flaws have been detected in any of the other 299 Pickering pressure tubes inspected in Units 1, 4, 5-8. Based on this evidence, it was concluded that this flaw was not due to a mechanism that was likely to be repeated in other pressure tubes Thus, it was also concluded that this flaw could be excluded from the statistical evaluation.

OPG completed a statistical evaluation to estimate the likelihood of flaws in the region of interest of the uninspected population of Pickering Unit 5 pressure tubes (Unit 5 has 380 pressure tubes in total and 62 have been inspected) based on zero observations of flaws in the 299 Pickering pressure tubes that were inspected [8]. The evaluation provided a hypothetical, expected number of 0.8 flaws in the uninspected tube population. This satisfies the safety case established for Canadian CANDU plants, which requires the plant design to incorporate safety systems to mitigate the consequences of a single pressure tube failure.

While CNSC staff consider the exclusion of the P5O05-IND1 as a reasonable assumption, for comparison purposes, staff used the OPG assessment methodology [3] assuming 1 flaw in the region of interest of 299 inspected pressure tubes. This resulted in a best estimate value of 1.8 flaws for the expected number of flaws in the uninspected pressure tube population. This illustrates that the risk of a flaw in the region of interest in the uninspected population or pressure tubes does not increase significantly if P5O05-IND1 is not removed from the flaw population.

OPG's original statistical evaluation also provided a conservative, upper bound estimate of 7 flaws in the region of interest [3]. To provide assurance to the Commission that CNSC staff have not overlooked this evaluation result. CNSC staff would like to provide the Commission with the following observations, which have led to staff's conclusion that this estimate contained excessive conservatism and was not an accurate reflection of the likelihood of flaws in the uninspected tube population.

- The original assessment [3] assumed a 75 mm long region of interest, which resulted in the inclusion of 2 flaws in the region of interest (Unit 5 flaw P5O05-IND1 and Unit 6 flaw P6N04-IND9) in the population of 299 inspected pressure tubes.
- P6N04-IND9 resides outside of the redefined 60 mm long region of interest. OPG has sufficient scrape measurements from Pickering pressure tubes that demonstrate the Heq concentration models are acceptable for the location of this flaw and that Heq concentration will be below 120 ppm.
- There was only one flaw deeper than 0.15 mm in the region of interest in the population of 299 inspected pressure tubes. The prediction of seven flaws in the 318 Pickering Unit 5 pressure tubes would represent a 600% increase in the number of flaws for a 6% increase in the sample size of pressure tubes. This demonstrates that the original statistical evaluation by OPG was very conservative.

Compensatory Measures for Known Flaws Deeper than 0.15 mm in the Region of Interest

No compensatory measures are necessary for the pressure tube containing flaw P5O05-IND1 to address the Option (b) restart criteria [6].

Even though flaw P5O05-IND1 is deeper than 0.15 mm, it is a very small flaw. An evaluation completed by OPG for this flaw indicated that, even if it was located in a region of elevated Heq concentration, this flaw would not challenge safe operation of the pressure tube [9].

Also, to reiterate, the bearing pad fretting flaws in the region of interest of the Pickering Unit 5 pressure tubes will not impact safe operation of the pressure tubes. These flaws are only slightly

deeper than 0.15 mm and the geometry of the flaws will not lead to significant stress concentrations.

3.3 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), in order to predict failures of barriers to radioactivity releases. This is performed by determining the bounding initiating events/failures, mapping out the accident sequence, modeling 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 licensees. These analyses demonstrate that the plant is able to perform the fundamental safety functions of control, cool and contain. This includes being able to shutdown the reactor with one shutdown system alone, adequately cool the reactor core, prevent further failures of other pressure tubes and limit radiological releases to below regulatory limits.

CNSC staffs assessment has determined that the Heq concentration findings at Bruce NGS Unit 3 and 6 do not impact the accident sequence, the key analysis parameters (sub-criticality margin and fuel temperatures), the ability of the NPPs to perform its fundamental safety functions or the accident consequences (dose).

3.4 Considerations of the Probabilistic Safety Analysis

Probabilistic Safety Analysis (PSA) is a comprehensive and integrated assessment of the safety of a reactor facility. The safety assessment considers the probability, progression and consequences of equipment failures or transient conditions to derive numerical estimates of frequencies of severe core damage (SCD) and large radioactive release (LF). PSA is used to complement Deterministic Safety Analysis (DSA) to demonstrate the safety of the nuclear power plant.

OPG has completed PSAs for Pickering Units 5-8 (Enclosures 2-4 of [2]), which have demonstrated that the plant risk is low and that the safety goals are met with sufficient safety margin. Pressure Tube Leak (PTL, leak rate is less than 1 kg/sec) and Pressure Tube Failure (PTF, leak rate is above 1 kg/sec) are two initiating events modelled in a PSA. Pickering Units 5-8 PSA has modelled both PTL and PTF initiating events. CNSC staff have verified OPG's estimation and calculation and confirmed that all information provided in Enclosures 2-4 [2] are valid.

CNSC staff concur that OPG has demonstrated that the Heq concentration findings at Bruce NGS Unit 3 and 6 do not impact the likelihood of a pressure tube failure or pressure tube leak do not change the PSA estimations. Therefore, the plant risk does not change and all the conclusions from the PSA are still valid.

4. CONCLUSIONS

Licence condition 15.3 for PROL 48.01/2028 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*".

Based on the information provided by OPG [3, 4, 7-8], CNSC staff conclude that:

- OPG 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".
- Pickering models have reliably predicted Heq concentration measurements taken at locations greater than approximately 50 to 55 mm from the outlet burnish mark. Therefore, the axial length of the region of interest for the restart evaluation for the Pickering Unit 5 pressure tubes can be reduced to 60 mm.
- The evaluation completed for the Pickering Unit 5 indication (P5O05-IND1) generated significant safety margins against pressure tube failure. As a result, no compensatory measures are necessary for this pressure tube.
- There are no known mechanisms that can result in deep flaws in the region of interest during normal operation.
- OPG 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 in depth are expected in the region of interest in the population of uninspected pressure tubes in Pickering Unit 5.

5. RECOMMENDATIONS

CNSC staff recommend that the Commission authorize Pickering Unit 5 restart.

6. REFERENCES

1. CNSC Summary Record of Decision DEC 21-H11, R. Velshi to Ontario Power Generation 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. OPG Letter, J. Franke to M. Leblanc and Dr. Viktorov, "Pickering NGS: Request for expedited authorization to restart following the Pickering Unit 5 2021 fall forced outage", October 1, 2021, CD# NK30-CORR-00531-08332, e-Doc 6653074.

3. OPG Letter, J. Franke to M. Leblanc and Dr. Viktorov, "Pickering NGS: Request for Authorization to restart following the Pickering Unit 7 fall outage 2021 and pre-authorization to restart following any Pickering Units 5-8 Forced Outage with Heat Transport System Cooldown", September 29, 2021, CD# NK30-CORR-00531-08328, e-Doc 6652773.

4. OPG Letter, J. Franke to M. Leblanc, "Pickering and Darlington NGS: Submission of Supplemental Information in Response to Designated Officer Orders and to Support Opportunity to be Heard Public Hearing", September 8, 2021, CD# N-CORR-00531-22866, e-Doc 6636778.
5. 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.
6. CNSC Letter, A. Viktorov to J. Franke, "Pickering NGS – CNSC Staff Assessment for Restart Requirements", August 12, 2021, e-Doc 6621914.
7. OPG Letter, J. Franke to M. Leblanc and A. Viktorov, "Pickering NGS: OPG responses to CNSC staff inquiries related to OPG's request for expedited authorization to restart following the Pickering Unit 5 2021 fall forced outage", October 6, 2021, CD# NK30-CORR-00531-08334, e-Doc 6655147.
8. OPG Letter, M. Knutson to M. Leblanc and A. Viktorov, "Darlington and Pickering NGS: Sensitivity Analysis to Supplement NK30-CORR-00531-08328 and NK38-CORR-00531-22869", October 8, 2021, CD# N-CORR-00531-22916, e-Doc 6656745.
9. CMD 21-H11.1B, "Supplementary written submission from Ontario Power Generation", September 8, 2021, e-Docs 6636778

Attachment A

Figure A.1: Diagram showing the location of the fuel bundle in relation to the burnish mark