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Written submission from Ontario Power Generation

Mémoire d' Ontario Power Generation

Follow up from November 3, 2022 Commission Meeting

Suivi découlant de la réunion de la Commission du 3 novembre 2022

Responses to the questions from the External Advisory Committee regarding the update on the discovery of elevated hydrogen equivalent concentrations in the pressure tubes of reactors in extended operation

Réponses aux questions du Comité consultatif externe au sujet de la mise à jour sur la découverte de concentrations élevées d'hydrogène équivalent dans les tubes de force des réacteurs en exploitation prolongée

Commission Meeting

Réunion de la Commission

January 25, 2023

Le 25 janvier 2023

Canada

ONTARIO POWER GENERATION

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OPG Proprietary

December 6, 2022

CD# N-CORR-00531-23498

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DR. A. VIKTOROV
Director General
Director of Power Reactor Regulation
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Dear Mr. Saumure and Mr. Viktorov:

OPG Response to Written Submission from the External Advisory Committee on Elevated Hydrogen Equivalent Concentration Discovery Events in Pressure Tubes in Extended Operation

The purpose of this correspondence is to provide responses to the written submission from the External Advisory Committee (EAC) on the elevated hydrogen equivalent concentration discovery events in pressure tubes of reactors in extended operation, submitted for the Commission Meeting on November 3, 2022 (Reference 1).

The EAC provided comments on Commission Member Documents (CMD) 22-M37.1, 22-M37.2, 22-M37.3 and 22-M37. OPG responses to the comments are provided, where applicable, in Attachment 1.

No new Regulatory Commitments or Regulatory Management Actions have been undertaken as a result of this submission, as indicated in Attachment 2.

If you have any questions, please contact Mr. Paul Fabian, Senior Manager, Major Components Engineering, at 289-314-8521, or by e-mail at paul.fabian@opg.com.

Sincerely,

Mark R. Knutson, P. Eng.
Senior Vice President, Enterprise Engineering
And Chief Nuclear Engineer
Ontario Power Generation Inc.

cc:

C. Chan	- CNSC Site Office (Pickering)
A. Mathai	- CNSC Site Office (Darlington)
N. Kline	- CNSC (Ottawa)
F. Lashgari	- CNSC (Ottawa)
V. Tavasoli	- CNSC (Ottawa)

References:

1. CNSC file for November 3, 2022 Commission Meeting, "Written submission from the External Advisory Committee, CNSC staff update on elevated hydrogen equivalent concentration discovery events in the pressure tubes of reactors in extended operation", October 31, 2022, File 6.02.04, Edocs pdf 6905238.

Attachment 1

OPG Responses to External Advisory Committee (EAC) Comments from November 3, 2022 Commission Meeting

(6 Pages)

Attachment 1

OPG Responses to External Advisory Committee (EAC) Comments from November 3, 2022 Commission Meeting

EAC Comment 1 (OPG Submission): *Why have two slightly different ROI circumferential extents (see items I and ii). This adds unnecessary complexity. Comment at a previous meeting, suggesting to standardize ROI's between OPG, Bruce Power and CNSC not acted upon.*

OPG Response to Comment 1:

- The Regions of Interest (ROIs) have been conservatively identified considering all available surveillance results and scrape measurements to date, based on the technical bases for outlet circumferential redistribution and blip formation. Additional surveillance and scrape results will be used to confirm the ROI definitions.
- For outlet circumferential redistribution, Ontario Power Generation (OPG) and Bruce Power (BP) ROIs are aligned as 75 mm axially inboard of the outlet Burnish Mark (BM) and 120 degrees circumferentially centered at PT Top Dead Center (TDC). For blip formation, OPG defines the ROI as 20 mm axially inboard of the BM spanning 90 degrees circumferentially with no dependence on where the peak orientation will be observed. OPG and BP will endeavor to establish a common blip formation ROI going forward.

EAC Comment 2a) (OPG Submission): *Modelling predicts that bearing contact will shift from Bottom Dead Center to Top Dead Center at end of life:*

a) Does every channel at Darlington and Pickering undergo this shift or is only a few at random?

OPG Response to Comment 2a):

- Noting that work remains ongoing to simulate additional Fuel Channels (FCs) and validate top-out time predictions, results to date indicate that both Pickering-B and Darlington FCs are expected to operate in the top-out condition late in life. Note that vertical feeder loads are expected to influence top-out timing, but further work is required to quantify this impact.
- Neglecting feeder loads applied to the End Fitting (EF) (which are generally small relative to fuel channel loads) top-out evolution is typically predicted at both the inlet and the outlet inboard bearing assemblies for operation beyond 210,000 EFPH.

EAC Comment 2b) (OPG Submission):

b) Is the Bearing Contact Point shifted at power, at shut down but at high temperature, or even at low temperature?

OPG Response to Comment 2b):

- For a late life channel, the bearing contact point is expected to be shifted (topped-out) at power, when shut down at high temperature, and when shut down at low temperature.
- For an example Pickering 5-8 channel (simulated at ~240 kEFPH), the EF position within the bearings is predicted to be insensitive to operating/thermal conditions. This is the expected behaviour once top-out condition has been fully established.

EAC Comment 2c) (OPG Submission):

c) What is the impact of this shift on units which are life-limited by bearing travel?

OPG Response to Comment 2c):

- The inboard bearing sleeve can provide support for the FC at any contact orientation. Accordingly, fuel channel inspections to determine remaining available bearing travel are not affected by a change in bearing contact orientation. Existing available bearing travel calculations remain applicable in the top-out condition.

EAC Comment 2d) (OPG Submission):

d) How does this shifted Bearing Contact Point affect the loading on the garter springs? If a and b are predictable and cover all the lead channels, this could provide a new strategy for extending units in c). Is bad if it imposes loads on X750 garter springs, or if it reduces loads on P5-8 garter springs and causes them to shift to unfavourable places. May cause extra Pressure tube/Calandria tube contacts or at least extra SLAR needs

OPG Response to Comment 2d):

- The most limiting configuration with respect to magnitude of applied garter spring loads (outboard bearing contact at 12 o'clock and inboard bearing contact at 6 o'clock) is already addressed via fuelling machine interaction assessments previously provided to the Canadian Nuclear Safety Commission (CNSC).
- In current probabilistic blister susceptibility assessments evaluating PT to Calandria Tube (PT-CT) contact (with consideration for spacer movement), the following configuration/inputs are considered via a distributed boundary condition of the model:
    - The range of EF tilt within the lattice tube (based on dimensions of the journal rings/bearings and the distance between the inboard and outboard pairs)
    - The angle of the lattice tube (caused by possible misalignment of the two bores on the same face of the reactor)
    - The misalignment of the FC assembly (due to the misalignment of the two bores on the calandria tube sheets from opposite sides of the reactor).

EAC Comment 3 (OPG Submission): *What difference in temperature between the top of the pressure tube and the bottom (i.e., "delta T") do your models predict (or assume)? Some intervenors have found that the required delta T to cause the observed levels of hydrogen migration is unrealistic. Without access to the quantitative results, we cannot determine why there is a difference in the modelled delta T's.*

OPG Response to Comment 3:

- Noting that channel to channel variation can be expected depending on specific lattice location, ASSERT-PV simulations predict delta Ts as follows:
    - Darlington PT D1U09 delta T at the outlet at removal (191,100 EFPH): 14 degrees C
        - Delta T predicted to increase to 15 degrees C by 285,000 EFPH
    - Pickering 5-8 PT P6M14 delta T at the outlet at removal (162,230 EFPH): 20 degrees C
        - Delta T predicted to increase to 23 degrees C by 300,000 EFPH

- Preliminary simulations of outlet circumferential redistribution applied a 20 degree C delta T as a starting point with refined inputs from ASSERT calculations considered in subsequent modelling efforts:
    - H3DMAP simulations predict that delta T values in this range are sufficient to manifest observed redistribution at the outlet rolled joint because Terminal Solid Solubility of Dissolution (TSSD) has been exceeded locally (in the cold top of PT region) and ratcheting of [Heq] to the cold region occurs with each heatup/cooldown cycle.
- ASSERT predictions of circumferential temperature variation have been validated via mock-up assembly and testing performed at Stern Laboratories which also demonstrated a temperature asymmetry between the top and bottom of the pressure tube.

EAC Comment 4 (OPG Submission): *2C, 2G: Findings and conclusions are presented in vague, qualitative terms. How can the CNSC get a sense of the remaining margins is there are no quantitative data?*

OPG Response to Comment 4:

- For each of the items in the table, relevant detailed references were identified.
- 2C: Preliminary modeling results from H3DMAP including predicted quantities of [Heq] with time, circumferential location, and distance from PT end were presented to CNSC staff at the March 2022 [Heq] workshop. Further documentation of the modeling is in progress.
- 2G: OPG submissions to the CNSC provided experimental results including the observed reduction in K_{TH} with increase in [Heq] from 60 ppm vs 240 ppm. Additional crack initiation tests are being completed to further investigate.

EAC Comment 5 (OPG Submission): *3A: What is "low likelihood" 10E-2, 10E-3, 10E-4, 10E-5, 10E-6? 3F: Two independent pressure tube failures are "very unlikely". But has the possibility of the pressure surge accompanying a catastrophic pressure tube failure causing another weakened pressure tube to fail been considered. Consequential pressure failures are outside the design basis and are not allowed.*

OPG Response to Comment 5:

- 3A: OPG performed a statistical analysis of the estimated number of flaws in the uninspected PT population based on available data. A conservative estimate of the probability of finding a dispositionable flaw in the ROI in an uninspected channel in OPG reactors was found to be between 10E-2 to 10E-3. A sensitivity case crediting the shield plug configuration and rolled joint scrape sampling results demonstrated that the probability could be as low as ~10E-3.
- 3F: Based on multiple full-scale FC rupture tests performed at Stern Labs, it is expected that a single PT failure would not result in the failure of the surrounding PTs.

EAC Comment 6 (OPG Submission): *4D: It is difficult to understand why a feasibility study would take up to 8 months, i.e., end of Q2, 2023. Work which relies on reactor data takes time because the time between outages is long. But an assessment of whether a non-active laboratory experiment is feasible should not take 8 months.*

OPG Response to Comment 6:

- Construction of an unirradiated mock-up that adequately reflects late life FC conditions for the purpose of defining model inputs is not trivial due to differences in geometry between new and aged FCs. To ensure that test results can be reliably used for further decision making and modelling purposes, it is critical that mock-up test plans are scrutinized, and that test execution is methodical. Industry will endeavor to improve this schedule, if possible.

EAC Comment 7 (OPG Submission): *5: 4 years is a long time for a model to be completed, especially when the earlier sections in this CMD seem to say that the current models can reproduce the observed field observation - does that meant it is still worthwhile? All Darlington units and most Bruce units will be through or in their MCR campaign. Even if a one-year extension of Pickering B were feasible, it would also be over by 2026.*

OPG Response to Comment 7:

- As per the industry [Heq] roadmap plan, an interim model addressing elevated [Heq] observations is expected to be issued for use by end of year 2023, with recurring interim model validity confirmations planned yearly. The current schedule to issue the comprehensive model has been defined to allow for near term experimental work to be completed and for Canadian Standards Association (CSA) N286.7 software qualification to be documented. Industry will endeavor to improve this schedule, if possible. This interim model will provide improved capability to predict hydrogen redistribution and additional insight supporting development of the final model.

EAC Comment 8 (BP Submission): *General Question: You have postulated that there are different mechanisms of hydrogen behaviour at the inlet and the outlet ends of the pressure tube. Is it possible that the process which produces the 'blip' (postulated for inlet) in fact operates at both ends of the vulnerable pressure tubes, but that the blip is hidden at the outlet end due to the large amount of hydrogen movement/redistribution that is occurring due to the delta T?*

OPG Response to Comment 8:

- The current understanding is that blip formation can occur at both ends of the PT. OPG's current approach to Fitness for Service (FFS) assessment considers outlet circumferential redistribution and blip formation as distinct mechanisms at the outlet. For PT B6S13, elevated [Heq] due to outlet blip formation appears to have been bounded by the circumferential redistribution.

EAC Comment 9 (BP Submission): *General Question: some of the intervenors have asked questions about the ratio of H to D in the samples. There may be another mechanism at work to increase the H concentration, in addition to the redistribution that is occurring due to the delta T. Do you have any comments on this possibility and do you intend to review the ratio of H/D question?*

OPG Response to Comment 9:

- As part of the [Heq] roadmap, industry is investigating both Hydrogen (H) and Deuterium (D) concentrations in rolled joint material. As part of this review, ratios between H and D are being considered.
- Measurements to date indicate that the rolled joint protium profile mimics the rolled joint deuterium profile spatially. To account for this, industry has implemented a H-D tracking model that postulates increased [H] as a function of measured [D] (linear relationship). This model is currently being applied as a sensitivity case in applicable assessments.

EAC Comment 10 (CNSC Submission): *"probabilistic evaluations.(of fracture protection and leak-before-break) …lack of evidence that…appropriate for all PTs". Is the use of probabilistic assessments by the licensees in their current CMDs consistent with the Staff concern on applicability? See for example OPG p. 12 item 3E.*

OPG Response to Comment 10:

- CNSC to provide a response.

EAC Comment 11 (CNSC Submission): *When the Risk Significance level is judged to be tolerable for 2-3 years, is that based on the projected rates of flaw and [Heq] progression, or is it a "time at risk" argument? "Time at risk" arguments are fraught with problems.*

OPG Response to Comment 11:

- CNSC to provide a response.

EAC Comment 12 (CNSC Submission): *"Material surveillance ….by removing…pressure to provide a statistically significant sample size". What is the statistical level that must be met, and how many pressure tubes would be needed to satisfy this level? Representing a population of several hundred pressure tubes in a unit requires a large number of samples, a major impact on the MCR or refurb.*

OPG Response to Comment 12:

- OPG is reviewing opportunities to obtain additional PT material during refurbishment that can be diverted for elevated [Heq] monitoring. Note however that justification of continued PT FFS is achieved through a combination of condition monitoring (in-service and ex-service sampling), and application of conservative assumptions consistent with the technical basis understanding.

EAC Comment 13 (CNSC Submission): *When is the RIDM report going to be issued?*

OPG Response to Comment 13:

- CNSC to provide a response.

EAC Comment 14 (CNSC Submission): *"...industry's R&D plans are in the right direction…". But are the expected completion dates acceptable? Completion dates are after most units have reached end of life.*

OPG Response to Comment 14:

- As noted in response to Comment 7, industry plans to issue an interim model addressing elevated [Heq] observations by the end of 2023. Industry will perform recurring interim model validity confirmations while the comprehensive model is developed/finalized.
- Note that in general, work packages in the [Heq] roadmap are scheduled according to their dependencies and priority.

EAC Comment 15 (CNSC Submission): *The restriction on "front end" of tubes is 100 ppm if at the outlet and 80 ppm if at the inlet. The licensee CMDs quote the 120 ppm limit, but not the more restrictive "front end" limits. What is the number (estimated or measured) of tubes which fail to meet these tighter limits.*

OPG Response to Comment 15:

- The revision 2 cohesive zone fracture toughness model validity limits applicable to currently operating late life OPG reactors (D4, P5, P6, P7, P8) are 100 ppm for inlet material and 140 ppm for outlet material:
    - No OPG PTs installed in late life reactors are oriented with the front-end at the outlet (all back-end outlet PTs).

Attachment 2 to OPG Letter, M.R. Knutson to D. Saumure and A. Viktorov, "OPG Response to Written Submission from the External Advisory Committee on Elevated Hydrogen Equivalent Concentration Discovery Events in Pressure Tubes in Extended Operation ", CD# N-CORR-00531-23498.

Summary of Regulatory Commitments, Regulatory Obligations and Regulatory Management Actions Made/Concurrence Requested

CD# N-CORR-00531-23498

Submission Title: **OPG – Response to Written Submission from the External Advisory Committee on Elevated Hydrogen Equivalent Concentration Discovery Events in Pressure Tubes in Extended Operation**

Regulatory Commitments (REGC):

No.	Description	Date to be Completed
	None	

Regulatory Management Action (REGM):

No.	Description	Date to be Completed
	None	

Regulatory Obligation Action (REGO):

No.	Description	Date to be Completed
	None	

Concurrence Requested: None.