Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 23-M3.1

Date: 2022-12-09
File / dossier : 6.02.04
Edocs pdf : 6951431

Written submission from Bruce Power

Mémoire de Bruce Power

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

December 9, 2022

BP-CORR-00531-03565

Mr. Denis Saumure
Commission Registrar
Legal and Commission Affairs Branch
Canadian Nuclear Safety Commission
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Dr. Alexandre Viktorov
Director General
Director of Power Reactor Regulation
Canadian Nuclear Safety Commission
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Dear Mr. Saumure & Dr. Viktorov:

Bruce A and B: Responses to the
External Advisory Committee Questions Detailed in CMD-22-M37.8

The purpose of this letter is to provide the Canadian Nuclear Safety Commission (the Commission) with Bruce Power's response to the questions and comments from the External Advisory Committee (EAC) as detailed in CMD-22-M37.8, Reference 1.

At the November 3, 2022, Commission meeting, CNSC staff updated the Commission on the discovery of elevated hydrogen equivalent concentrations ($[H]_{eq}$) in the pressure tubes of reactors in extended operation. The EAC had provided a submission for this agenda item that was received by licensees just days ahead of the Commission meeting. Given the short time between receiving the EAC CMD and the actual Commission meeting, Bruce Power committed to submit written responses to the questions and comments provided by the EAC by December 9, 2022. Bruce Power's written responses are contained in Attachment A of the letter.

Safety is paramount to Bruce Power and we remain committed to maintaining defence in depth for the safe operation of our units overall, including pressure tube integrity. Bruce Power continues to collaborate with industry and inform CNSC staff of our progress with research and development work described in Reference 2.

Bruce Power appreciates the time taken by the EAC to review and comment on the submissions to the Commission made by industry and CNSC staff. Should the EAC have further questions on the responses provided in Attachment A, Bruce Power is available to engage in a technical meeting.

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If you require further information or have any questions regarding this submission, please contact Mr. Maury Burton, Senior Director, Regulatory Affairs, at (519) 361-2673 extension 15291, or maury.burton@brucepower.com.

Yours truly,

Lisa Clarke Digitally signed by Lisa Clarke Date: 2022.12.09 10:37:47 -05'00'

Maury Burton
Senior Director, Regulatory Affairs
Bruce Power

cc: CNSC Bruce Site Office
Ms. Monica Hornof, CNSC – Ottawa

Attach.

References:

1. Email, Registrar to M. Burton, “November 3, 2022 Commission Meeting - CNSC staff and External Representatives”, November 1, 2022, BP-CORR-00531-03620.
2. Letter, M. Burton to Dr. A Viktorov and Mr. D. Samure, “Bruce A and B: Update to the Commission regarding Elevated Hydrogen Equivalent Concentrations – Action Item 2022-07-23135”, July 19, 2022, BP-CORR-00531-02909.

Attachment A

Bruce Power Responses to the External Advisory Committee Questions Detailed in CMD-22-M37.8

Attachment A: Bruce Power Responses to the
External Advisory Committee Questions Detailed in CMD-22-M37.8

Note: The following comments are directed at Ontario Power Generation (OPG) staff; however, Bruce Power (BP) has provided responses to the External Advisory Committee (EAC) comments as well, as all comments on the OPG CMD also apply to the Bruce Power CMD.

Item	Page and Location	EAC CMD 22-M37.1 OPG	Context	Bruce Power Response
1	p.2 of 18	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.	The region of interests (ROIs) have been conservatively identified based on all available surveillance results and scrape measurements to date. Additional surveillance and scrape results will be used to confirm the ROI definitions. OPG and BP is endeavouring to establish a common blip formation ROI going forward.
2	p.10 of 18	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? b) Is the Bearing Contact Point shifted at power, at shut down but at high temperature, or even at low temperature? c) What is the impact of this shift on units which are life-limited by bearing travel? 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). d) 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	a) Modeling work is ongoing to determine the formation of blip if a contact point between pressure tube (PT) and End Fitting (EF) exists and how the blip might evolve with time. This is covered in modeling work item 3B in the CMD. b) See the response to 2a above. c) The inboard bearing sleeve can provide support for the Fuel Channel (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. d) In the probabilistic pressure tube to calandria tube (PT/CT) contact and spacer load calculation, the following configuration/inputs are considered and applied as a distributed boundary condition of the PT which affects the PT/CT contact and the predicted spacers loads: • the range of EF tilt within the lattice tube (due to dimensions of the journal rings and bearing and the distance between the inboard and out bard

Item	Page and Location	EAC CMD 22-M37.1 OPG	Context	Bruce Power Response
				pairs); • the angle of 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 Tubes (CT's) on the opposite sides of the rectors.
3	p.9 of 18	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.		Based on thermal hydraulic modelling work on channels B3F16 and B6S13, the delta T is about 20 to 25º C cooler at the top of the tube vs. the bottom. The code used to perform these simulations (ASSERT-PV) has been validated against laboratory testing at Stern Lab (SL) which also demonstrated a temperature asymmetry between the top and bottom of the pressure tube.
4	Appendix 1, Starting on p.9 of 18	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?		• It is unclear which margins are referred to. However, work is ongoing to develop a new rolled joint (RJ) model and to validate the crack initiation models for high hydrogen equivalent ($[H]_{eq}$) concentration. Regular updates to the CNSC are scheduled. • For each of the items in the table presented by OPG, relevant detailed references were identified. - 2C: Preliminary modeling results from H3DMAP including predicted quantities of $[H]_{eq}$ with time, circumferential location and distance from PT end were presented to CNSC staff at the March 2022 workshop. Further documentation of the modeling is in progress. - 2G: CNSC submissions (Reference A1) provide the experimental results on the reductions to the K_{TH} at 60 ppm versus 240 ppm $[H]_{eq}$. Additional crack initiation tests are being completed to further investigate the cause.
5	Appendix 1,	3A: What is "low likelihood" 10E-2, 10E-3, 10E-4,	Consequential pressure	• 3A: There have been no detected flaws of

Item	Page and Location	EAC CMD 22-M37.1 OPG	Context	Bruce Power Response
	Starting on p.9 of 18	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.	failures are outside the design basis and are not allowed.	significance within any outer region of interest (OROI). This is based on volumetric inspections of 564 unique tubes. The results of the probabilistic evaluation (performed as a defense in depth) is that the probability for having at least one dispositionable flaw in the OROI is < 0.5% for Unit 3 (and all Bruce Power units) and therefore, the risk of having a significant flaw in the OROI, which could challenge pressure tubes fitness for service, is also low. • 3F: Yes, this was considered and based on full-scale fuel channel rupture tests performed through STERN Laboratories, it is expected that a single pressure tube failure would not result in the failure of the surrounding pressure tubes.
6	Appendix 1, Starting on p.9 of 18	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.	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. The Industry is endeavouring to improve this schedule, if possible.
7	Appendix 1, Starting on p.9 of 18	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.	As per the industry $[H]_{eq}$ roadmap plan, an interim model (for inlet and outlet) addressing elevated $[H]_{eq}$ 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 CSA N286.7 software qualification to be fully documented. The Industry is endeavouring to improve this schedule, if possible. This interim model would give the industry a better capability to predict hydrogen redistribution and more insights into the development of the final model.

Note: The following comments are directed to Bruce Power, responses are provided accordingly

Item	Page and Location	EAC CMD 22-M37.3 Bruce Power	Context	Bruce Power Response
8	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?		Blips have been observed in both IRJ and ORJ based on surveillance results from B6S13 so it is believed that the mechanisms are similar at both ends of the tube. As seen on B6S13, the outlet blip was bounded by the redistribution.
9	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?		• As part of the $[H]_{eq}$ roadmap work packages, industry is investigating hydrogen and deuterium concentrations in RJ material from ex-service PTs. As part of this review, ratios between H and D are being considered. • Measurements to date indicate that the protium profile mimics the RJ 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.

Note: The following comments are directed at CNSC staff; however, Bruce Power has added relevant information for consideration, where applicable.

Item	Page and Location	EAC CMD 22-M37 CNSC Staff	Context	Bruce Power Response
10	p.20 last para	"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.	Bruce Power has performed a risk informed deterministic fracture protection assessments to evaluate the potential impact of elevated $[H]_{eq}$ on pressure tube fitness for service, and the results of these assessments have demonstrated the pressure tubes remain fit for service to allow for the necessary time to complete R&D activities.
11	p.22	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.	Bruce Power conducted an internal Risk Informed Decision Making (RIDM) process following the same NRC guidance that is based on probabilistic safety analysis. The calculation results (Bruce A ~4 year and Bruce B ~9 years) have been provided to CNSC informally for information in Reference A2.
12	p.23 Point 2	"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.	Bruce Power is currently exploring the possibility of removing multiple tubes from each upcoming MCR. Note, however, that sampling in a large number of removed PTs is not necessarily required to confirm the mechanism of blip formation. Justification of continued PT fitness for service (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. Scraping different circumferential location at the outlet should also be sufficient to demonstrate the redistribution theory.
13	p.23 Section 3	When is the RIDM report going to be issued?		n/a
14	p.23 Section 4	"...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.	Bruce Power can confirm the following: • An interim model (inlet and outlet) is targeted for end of 2023 which would give the industry a better capability to predict hydrogen redistribution and more insights into the development of the final model. Industry will perform recurring interim model validity confirmations while the comprehensive model is developed/finalized. • Work packages in the $[H]_{eq}$ roadmap are

Item	Page and Location	EAC CMD 22-M37 CNSC Staff	Context	Bruce Power Response
				scheduled according to their dependencies and priority.
15	p.25	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.		Bruce Power can confirm the following: • The current revision 2 cohesive zone fracture toughness model validity limits applicable to Bruce Power reactors are 100 ppm for inlet material and 140 ppm for outlet material. • The results from the latest burst tests performed on the front end material show that the model is valid up to much higher $[H]_{eq}$, i.e. > 300 ppm. Work is ongoing to extend the validity limits of the Rev. 2 Fracture Toughness (FT) model to higher $[H]_{eq}$.

References:

A1. Letter, M. Burton to L. Sigouin, “Bruce A and B: Defense-in-Depth Approach for Addressing Elevated Hydrogen Equivalent Concentration ([H]eq) in the Inlet Rolled Joint”, March 11, 2022, BP-CORR-00531-02589.

A2. Email, J. Goldberg to A. Robert, “RE: CMD 22-M37, CNSC staff update on elevated hydrogen equivalent concentration discovery events in the pressure tubes of reactors in extended operation”, November 15, 2022, BP-CORR-00531-03629.