September 3, 2021

Bruce Power Presentation: CNSC Commission Meeting

Ensuring Pressure Tube Integrity

Bruce Power
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Introduction

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Context

- Bruce Power rigorously inspects all of its units during planned outages to ensure the integrity of pressure tubes while maintaining high levels of safety and compliance with the licensing basis
- At the time noted in the event report, Units 1, 2, 4, 5, 7 and 8 were safely operating and two other units were offline for planned activities:
  - **Unit 3 Planned Outage**: focused on reactor maintenance, Major Component Replacement (MCR) preparatory work and inspections
  - **Unit 6 MCR**: Full replacement of all major reactor components underway; two pressure tubes were removed for industry surveillance testing
- Results from these planned activities related to hydrogen concentration found some results inconsistent with previous inspections – higher concentration in a limited, localized (<0.5%) volume in the upper portion of the pressure tube

Bruce Power has maintained safety, pressure tube integrity, defence in depth and compliance with the licensing basis.

Licensing Basis

LICENCE CONDITION 15.3

Before hydrogen equivalent concentrations exceed 120 ppm, the licensee shall demonstrate that pressure tube fracture protection will be sufficient for safe operation beyond 120 ppm.

- Licence Condition Handbook - Compliance Verification Criteria:
- For continued operation of units containing pressure tubes with a [Heq] exceeding 120 ppm between the inlet and outlet burnish marks:
  - Bruce Power shall obtain approval from the Commission before operating any pressure tube with a measure [Heq] greater than 120 ppm, or beyond the time any pressure tube is predicted to have a [Heq] greater than 120 ppm

Bruce Power has maintained compliance with the licensing basis.
No operating unit has measured or predicted [Heq] greater than the Licensing Limit.

Response

- Proactively and transparently shared these developments with the CNSC staff and industry peers
- Carried-out an immediate evaluation to confirm operational safety was maintained – consistent with CNSC approved Management System and the licensing basis
- Sequentially expanded the scope of inspections during the Unit 3 planned outage for confirmation of hydrogen concentration being localized and limited to a targeted region and lack of flaws. Also, confirmed model predictability below licensing limits outside of the region of interest
- Reviewed a large population of bounding past inspections on all units confirming no flaws in the Region of Interest
- Openly communicated the facts with the Public - confirmed safety was maintained and described actions to be undertaken

Bruce Power was pro-active, transparent and open that safety and pressure tube integrity was maintained.

Operational Safety Overview

Chris Mudrick
Chief Nuclear Officer

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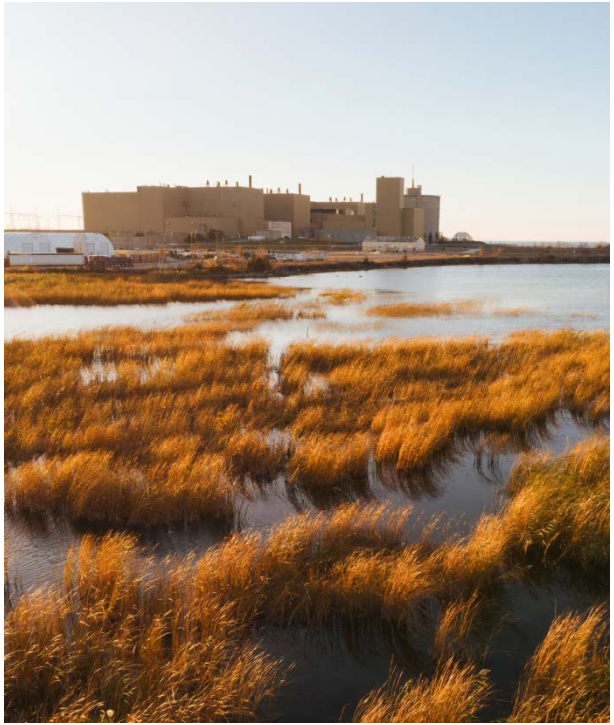
Safety First
Fuel Channel Integrity
Click to Play Video

Operational Safety

- Based on findings from Unit 3 and 6 a Technical Operability Evaluation (TOE) was initiated led by a cross-section of operational, engineering and technical leads
- The purpose of the process is to pro-actively review a potential change in condition or operability concern
  - The TOE process is part of the licensing basis [CSA N286-12 Sec.4.1.2(a)]
  - Includes a review of safety and licensing basis in the process
- Included an extensive review of all units, hundreds of results and confirmed the units are safe to operate



Safety and pressure tube integrity confirmed based on defence in depth, a large population of data confirming no flaws in the region of interest and hydrogen concentrations limited to this area.

Operational Safety Margin

Technical Operability Evaluation – Full Power Hot Operation	Safety Margin Enhancements – Beyond Steady State Operation	Pressure Tube Integrity Lack of Flaws
Confirmed the ability of all operating pressure tubes to perform their safety-related functions at full power hot	Defined mitigating actions that could be taken if a unit is removed from service in an unplanned manner before its planned maintenance outage	Inspections demonstrate (data from large population of pressure tubes), that there is no evidence of flaws in the region of interest

All units are safe to operate in any mode as changing conditions (start-up, shut-down and power operation) will not impact pressure tube integrity as demonstrated through fitness for service assessments.

Operational Safety Summary

Based on hundreds of measurements, additional inspections, a defence in depth and various reviews our operational safety reviews have concluded:

1. Units safe to operate in any mode
2. Units 1 and 2 refurbished. Unit 6 is having its pressure tubes replaced
3. Unit 3 safe to return to service with a small region of interest for increased hydrogen concentrations (<0.5% volume) and no flaws in region of interest based on a large population of evidence from past inspections and verification
4. Based on hydrogen concentration inspection results (both historic and recent), Units 4, 5, 7, and 8, have not had high measured concentrations or flaws in region of interest. This is part of routine outage inspection scope
5. A very large body of inspections for flaws on all units – no flaws identified in the region of interest
6. Hydrogen concentrations outside of region of interest confirmed to conservatively predict below licensing limits

Further inspections are planned over the next 18-months in Units 4, 5, 7 and 8 outages for additional confirmation of pressure tube integrity and fitness for service.

Pressure Tube Integrity

Gary Newman
Chief Nuclear Engineer

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Pressure Tube Integrity

- High hydrogen concentrations in isolation will not initiate a challenge to the integrity of a pressure tube
  - Based on empirical evidence, it has been demonstrated that **both** high hydrogen concentrations and a flaw with certain characteristics is needed to challenge pressure tube integrity
- Bruce Power inspects for both Hydrogen Concentrations and Flaws in the pressure tube to maintain pressure tube integrity
- In addition to requiring both a flaw and high concentrations, this risk is limited to a certain temperature/operational envelope including heat-up and cool down which is limited to <3% of full operating conditions. Defence in depth is also maintained

Pressure tube integrity in all units maintained through defence in depth.

Inspections for Flaws

Bruce Power has performed 448 unique pressure tube inspections (or 728 total inspections including revisits) in Units 3, 4, 5, 6, 7 and 8 – equivalent to nearly one full reactor core (480 channels). This is done on a routine, planned basis as normal practice for planned outages

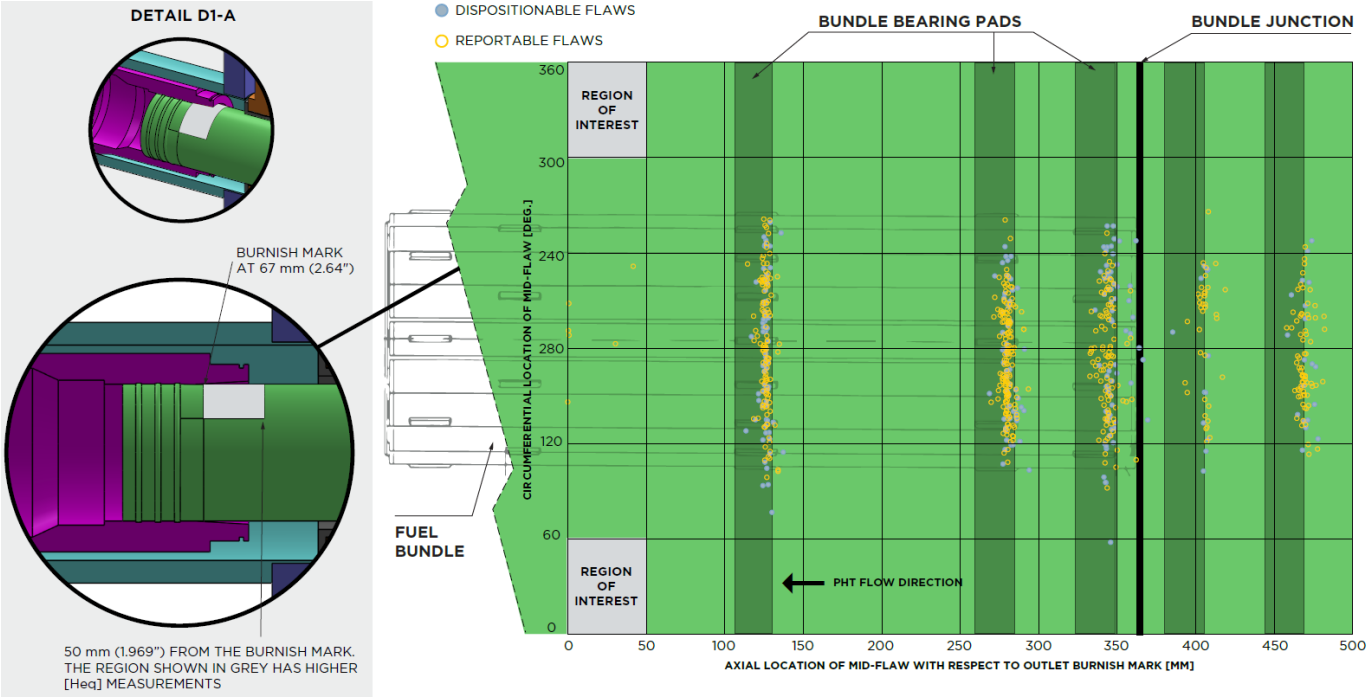
Based on this evidence and a large population of Bruce channels, **no flaws** have ever been detected in the region of interest at the top of the tube in any Bruce Power unit. This provides a high degree of confidence in both safety and pressure tube integrity for all units and will continue to be verified during planned outages

Bruce Power does not anticipate flaws to ever occur in the region of interest as fuel bundles do not come in contact with this area of the pressure tube based on the design of the bundles and channels. Integrity is assured and verified during planned outage inspections

The existing flaw dispositions remain valid and are not impacted by elevated [Heq] observed in the region of interest; there are no flaws detected in the region of interest.

Surveillance Evidence Demonstrates –

No Flaws in Region of Interest



NO FLAWS in the limited region of interest where hydrogen concentration is above model predictions (<0.5% of tube)

+

HIGH CONFIDENCE hydrogen concentrations conservatively below the licensing limit in the balance of the tube (>99.5%)

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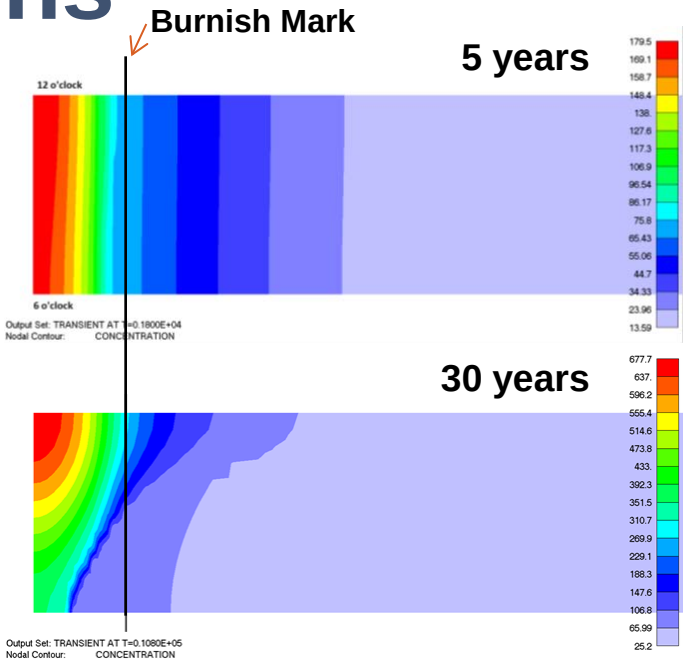
Pressure Tube INTEGRITY

Hydrogen Concentrations

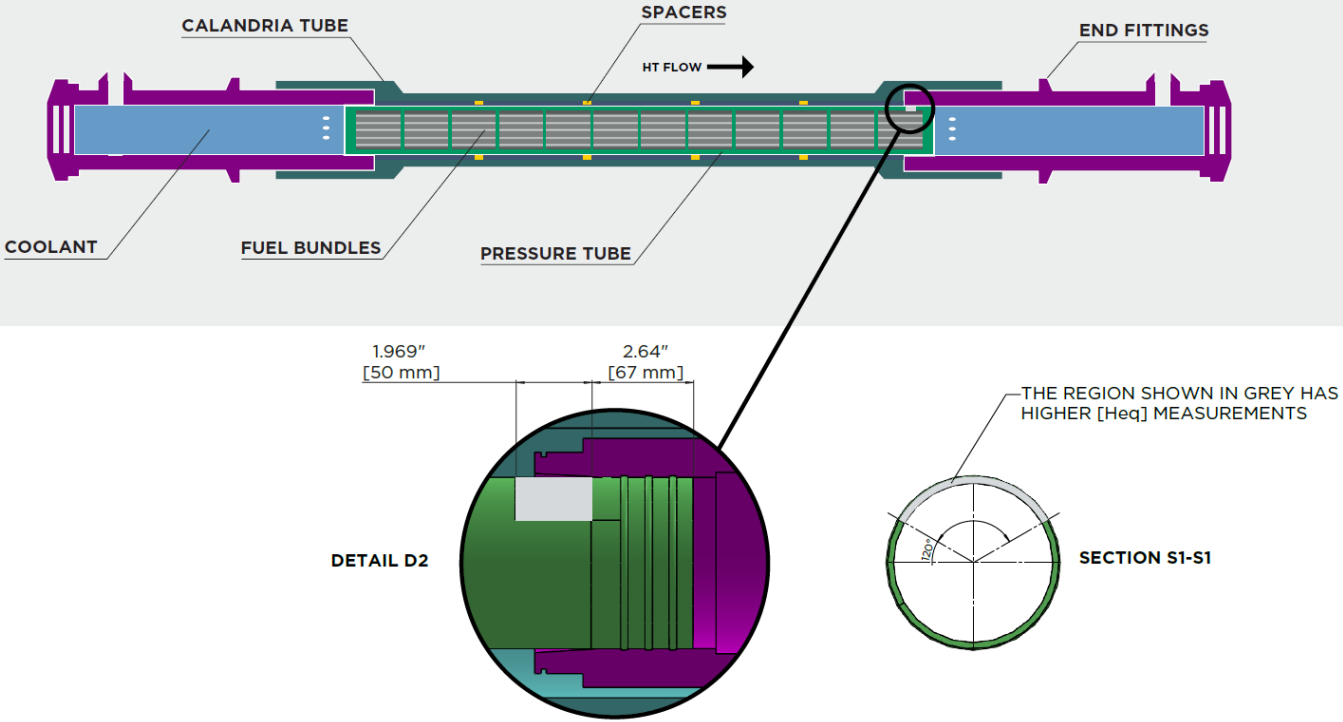
- Based on a large population of historic inspections and recent results, Bruce Power has demonstrated the existing predictive model for hydrogen concentration continues to provide bounding predictions for all pressure tubes outside this targeted region of interest
  - The elevated hydrogen concentrations are limited to this region of interest
- The results continue to demonstrate hydrogen concentrations are below the licensing limit in the lower 240 degrees of the pressure tube



Higher than predicted hydrogen concentrations are limited to a localized (<0.5%) volume in the upper portion of the pressure tube.

Surveillance Evidence Demonstrates –

Heq limited to <0.5% region of interest



Summary

- Both a flaw of significant dimensions and high hydrogen concentrations are needed to challenge pressure tube integrity
  - Based on evidence from a large population of measured results, no flaws are present in the region of interest
  - Bruce Power does not anticipate flaws to ever occur in the region of interest as fuel bundles do not come in contact with this area of the pressure tube based on the design of the bundles and channels
- Elevated hydrogen concentrations are localized to a targeted region of interest (<0.5% volume of the pressure tube)
- Operational measures to build and maintain safety margin are in place during certain conditions such as plant start up and cool down

Safety, pressure tube integrity, defence in depth demonstrated in all Bruce Power units.

Conclusions

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Conclusions

- Bruce Power has been open and transparent with the public, CNSC and the industry on these developments
  - **Safety and pressure tube integrity have not been compromised**
- The operating units at Bruce Power have all undergone recent inspections since 2019 confirming safety, pressure tube integrity (hydrogen concentration/lack of flaws) and compliance with the licensing basis. This builds on a large population of inspections in prior campaigns and industry testing
  - **Planned inspections over the next 18-months will be conducted to further verify**
- Unit 3 has undergone an expanded scope of inspections confirming a limited region of interest for hydrogen concentration and no flaws in this area
  - **Unit 3 meets the requirements set out to safely operate to its MCR commencing in 18-months**

High Levels Safety and Pressure Tube Integrity Maintained in the Operation of all Bruce Power Units.