Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 21-H11.1A

File / dossier : 6.01.07
Date: 2021-09-02
Edocs: 6633410

Presentation from
Ontario Power Generation

Présentation d'
Ontario Power Generation

In the Matter of the

À l'égard de la

Opportunity to be heard on the orders issued by a Designated Officer to Bruce Power and Ontario Power Generation

Possibilité d'être entendu au sujet des ordres délivrés par un fonctionnaire désigné à Bruce Power et Ontario Power Generation

Commission Public Hearing

Audience publique de la Commission

September 10, 2021

10 septembre 2021

Canada

OPG Response to Designated Officer Orders

Opportunity to be Heard Commission Hearing

September 10, 2021

ONTARIO POWER GENERATION

Where a brighter tomorrow begins.

Outline

1 | Introduction & Background

2 | Pickering 1 & 4 Pressure Tube Fitness for Service Assessment

3 | Pickering 5-8 Pressure Tube Fitness for Service Assessment

4 | Darlington 1 & 4 Pressure Tube Fitness for Service Assessment

5 | Pressure Tube Inspection and [Heq] Modeling Enhancements

6 | Operational Safety & Defense in Depth

7 | Closing Remarks

Context

- Two Orders issued to OPG:
  - Pickering Units 1 and 4, and 5-8
  - Darlington Units 1 and 4
- Require authorization from the Commission prior to the restart of units following any outage that results in the cooldown of the heat transport system

Context (cont'd)

- Prior to seeking 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*

OPG Perspective and Response to the Orders

- OPG understands and is complying with the Orders
- OPG has carefully considered the Bruce Power information on [Heq] and maintains there is no undue risk from the safe restart of Pickering/Darlington units following any outage
- In advance of any unplanned or planned outage, OPG proactively addressed the Orders (both options therein) and substantiated that OPG unconditionally meets the requirements of the Orders for the Pickering/Darlington units
- **OPG requests an expedited decision on pre-authorization to restart the specified Pickering and Darlington Units following any planned or unplanned outage, and to close the Orders**

Pickering NGS: Pressure Tube Fitness for Service

Pickering Units 1 and 4: Pressure Tube Fitness for Service Overview

Pickering Units 1 and 4:

- Pressure tubes were replaced in 1987 and 1993, respectively
- Pickering Units 1 and 4 are not in extended operation and will not exceed 210,000 Equivalent Full Power Hours (EFPH)
- These units will continue to have low [Heq] until the end of commercial operation

High degree of confidence that Pickering Units 1 and 4 pressure tube [Heq] will remain well within OPG's licensing basis

Pickering Units 5-8: Pressure Tube Fitness for Service Overview

Pickering Units 5-8:

- There are 2 flaws in Pickering Unit 5 in the region of interest, i.e., same region where high [Heq] was observed at Bruce Power, the cause of these flaws is well understood (not random flaws)
- Corrective actions have been in place since 2015 and have proven to be effective in preventing reoccurrence of flaw formation
- High confidence that no new flaws will be created in the region of interest
- Sensitivity analyses have been conducted for these flaws to show that they are fit for service even at postulated higher [Heq] up to / beyond 120 ppm

High degree of confidence that Pickering Units 5-8 pressure tube [Heq] is within OPG's licensing basis and that no new flaws will occur in the region of interest

Pickering Units 1 & 4: Technical Details

ONTARIO POWER GENERATION

Where a brighter tomorrow begins.

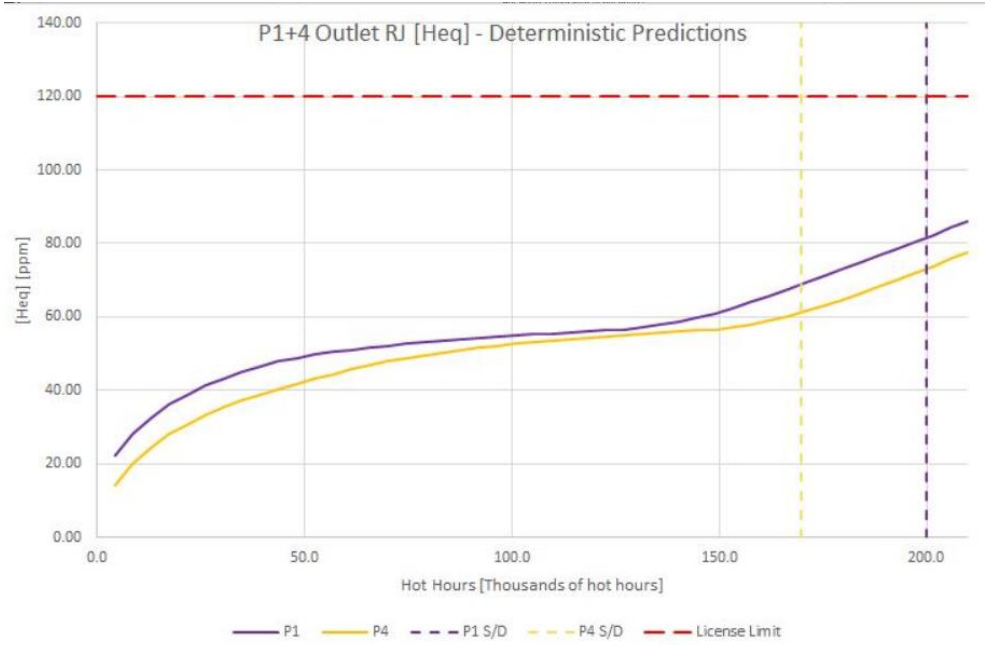
Pickering 1 & 4: Pressure Tubes

- Pickering Units 1 and 4 predicted Hot Hours at end of life will be significantly lower than Bruce Power Units 3 and 6
- Hot Hours is a measure of time spent with heat transport system hot and influences deuterium ingress into the pressure tubes
- Pickering Units 1 and 4 will be approximately 70,000 Hot Hours younger (equivalent to 8-9 years) at the target end of life when compared to Hot Hours for Bruce Power Units 3 and 6
- Pickering Units 1 and 4 operate at lower flux and temperature in comparison to Bruce Power Units 3 and 6

Pickering 1 & 4 [Heq] Results

- OPG has performed scrapes on Pickering Units 1 and 4 in the Outlet Rolled Joint and body of tube which exceeds CSA N285.4 requirements
- Results are within the licensing basis and adhere to model predictions

Unit	Current ORJ Heq (Deterministic)	ORJ Heq at EoL (Deterministic)
P1	73 ppm	86 ppm
P4	57 ppm	65 ppm



Pickering Units 5-8: Technical Details

ONTARIO POWER GENERATION

Where a brighter tomorrow begins.

Pickering 5-8: Pressure Tubes

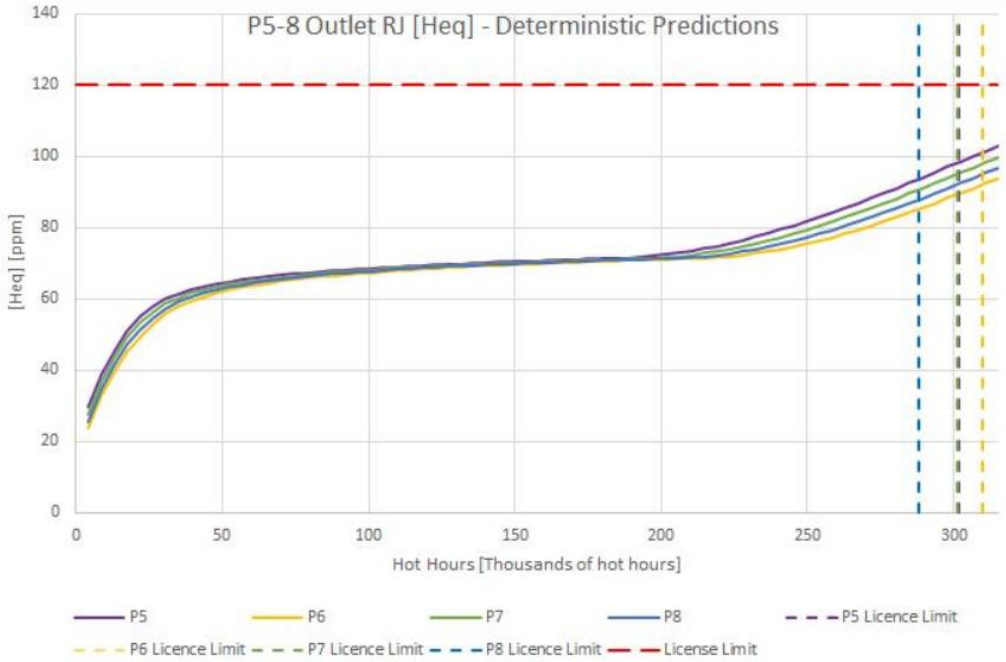
- Pickering Units 5 to 8 pressure tubes operate at lower flux and temperature in comparison to Bruce Power Units 3 and 6
- Pickering Units 5-8 [Heq] inspection program includes both scrape and punch samples exceeding CSA N285.4 requirements
  - Since 2017, OPG has programmatically performed hundreds of punch samples from ex-service pressure tubes to understand variability of [Heq] both axially and circumferentially in the pressure tubes
  - Punch samples are obtained from the Body of the Tube (BOT) as well as both the Inlet Rolled Joint (IRJ) and Outlet Rolled Joint (ORJ)

OPG has a good understanding of [Heq] behavior in Pickering Pressure Tubes

Pickering 5-8 [Heq] Results

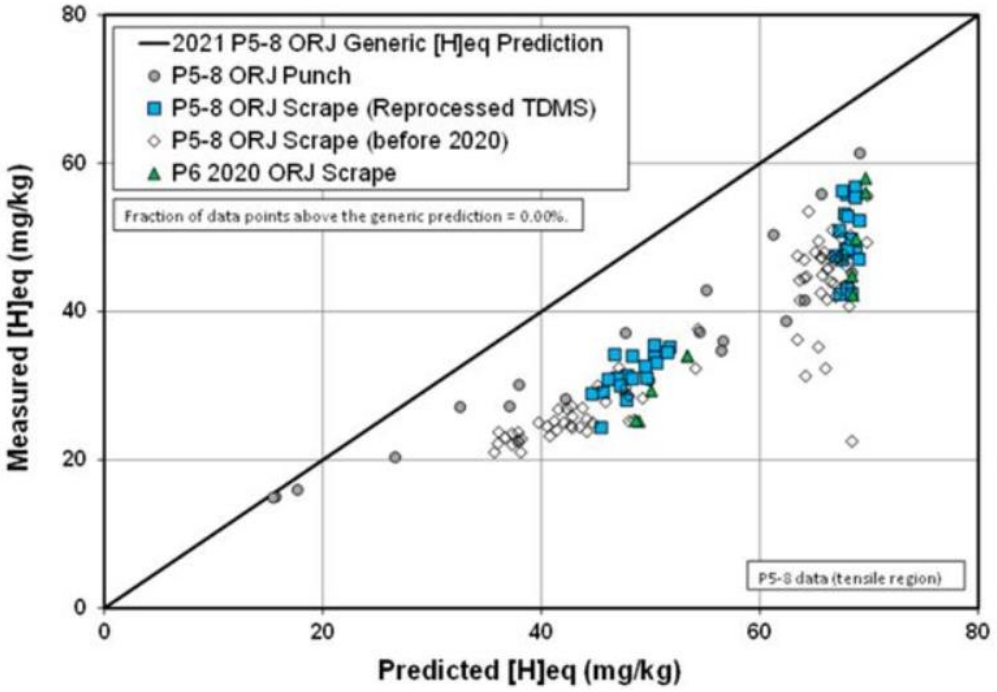
- For Pickering Units 5-8, OPG has been performing scrapes in the Outlet Rolled Joint and body of tube (exceeding CSA N285.4 requirements)
- Results have shown to be within licensing basis and adhere to model predictions

Unit	Current ORJ Heq (Deterministic)	ORJ Heq at EoL (Deterministic)
P5	88 ppm	98 ppm
P6	82 ppm	93 ppm
P7	85 ppm	95 ppm
P8	78 ppm	88 ppm



Pickering 5-8: Ex-Service Material Surveillance

Measured [Heq] vs. predicted [Heq] from punch samples removed from ex-service material and outlet rolled joint scrape samples performed (this includes measurements at 12 o'clock top dead centre near the burnish mark)



Pickering 5-8: Flaw Inspections

- 226 unique full-length pressure tube inspections across Pickering Units 5-8
- 2 flaws in the region of interest at Pickering Unit 5
- Flaws have been dispositioned and are fit for service, and sensitivity assessments have been performed to show these flaws continue to be fit for service at postulated higher [Heq] values (140 ppm)
- The root cause of these flaws is well understood and corrective actions are in place to prevent formation of new flaws

Darlington 1 & 4: Pressure Tube Fitness for Service

Darlington Units 1&4: Pressure Tube Fitness for Service Overview

- Darlington Units 1 and 4 inspection program includes both scrape and punch samples to confirm that [Heq] is within the licensing basis
  - No unit has measured or predicted [Heq] similar to Bruce Units 3 and 6
- A large population of inspection results confirms that there are no flaws in the region of interest
  - High confidence no flaws will be created therein

High degree of confidence that Darlington Units 1 & 4 pressure tube [Heq] is within OPG's licensing basis and that no flaws are present in the region of interest

Darlington Units 1 & 4: Technical Details

ONTARIO POWER GENERATION

Where a brighter tomorrow begins.

Darlington 1 & 4: Pressure Tubes

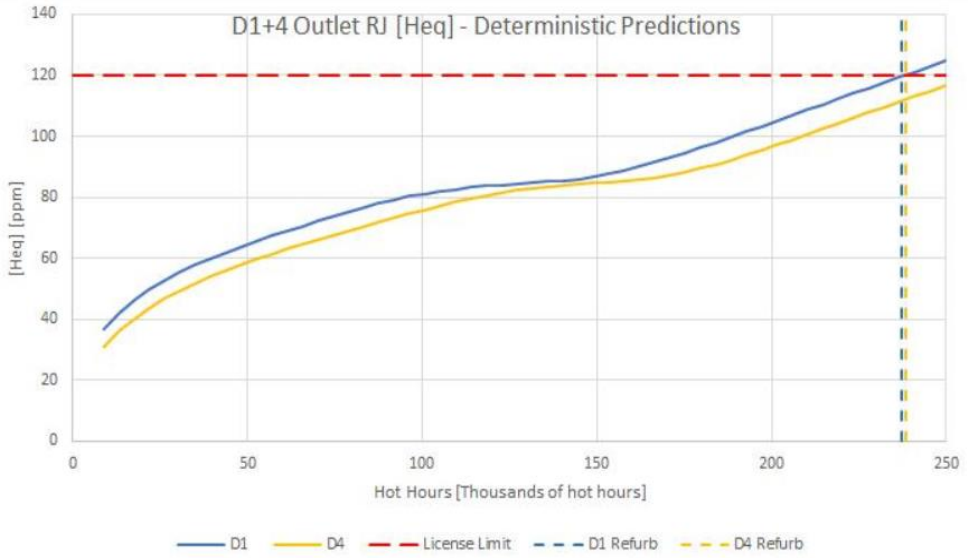
- Darlington Units 1 and 4 predicted Hot Hours at end of life will be approximately 30,000 Hot Hours lower (equivalent to 4-5 years) when compared to Hot Hours for Bruce Power Units 3 and 6
- Darlington has been performing material scrape and punch sampling in both inlet and outlet RJs and body of tube
- Hundreds of punch samples have been taken from ex-service pressure tubes to understand variability of [Heq] both axially and circumferentially.

OPG has a good understanding of [Heq] behavior in Darlington Pressure Tubes

Darlington 1 & 4: [Heq] Results

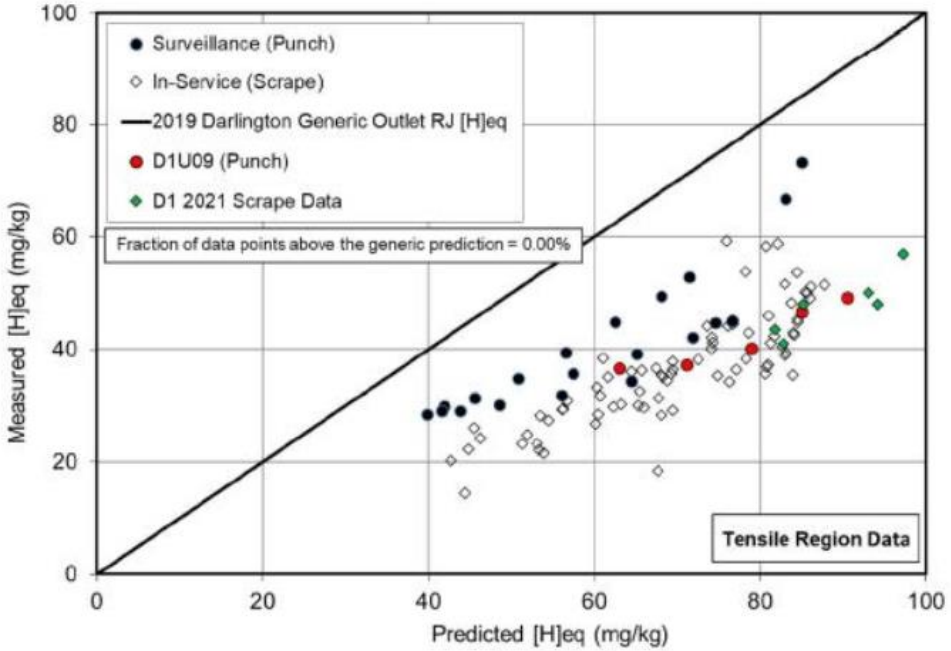
- For Darlington 1 & 4, OPG has been performing scrapes in the Outlet Rolled Joint and body of tube (exceeding CSA N285.4 requirements)
- Results have shown to adhere to model predictions

Unit	Current ORJ Heq (Deterministic)	ORJ Heq at EoL (Deterministic)
D1	119 ppm	120 ppm
D4	108 ppm	113 ppm



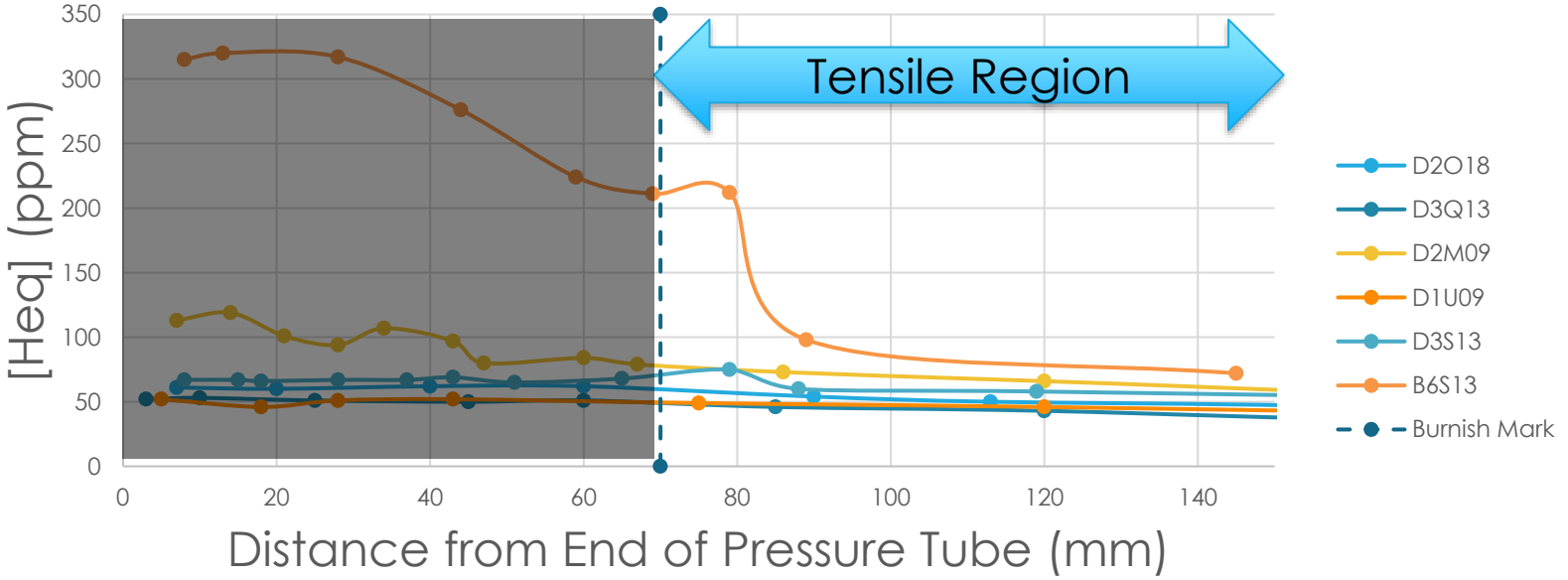
Darlington 1 & 4: [Heq] Results

- Measured [Heq] vs. predicted [Heq] from punch samples removed from ex-service material and ORJ scrape samples performed (this includes measurements at 12 o'clock top dead centre near the Burnish Mark)



Darlington 1 & 4: Ex-Service Material Surveillance

- Figure shows a comparison of D2O18, D3Q13, D2M09, D1U09, and D3S13 outlet RJ measurement against B6S13 at 12 o'clock position
- Results from D2O18, D3Q13, D2M09, D1U09 and D3S13 material surveillance are significantly lower than Bruce Unit 6 and within [Heq] licensing basis



Darlington 1 & 4: Flaw Inspections

- 131 unique full-length pressure tube inspections between Darlington Units 1 & 4
- No flaws located within the region of interest
- High confidence no flaws will be created in the region of interest

Summary of Supporting Case for Pickering and Darlington

Extensive inspections and measurements and detailed review of safety and fitness for service assessments have concluded:

1. High [Heq] values as reported for Bruce Power Units 3 and 6 have not been observed throughout hundreds of scrape and punch samples performed at Pickering Units 1 &4, 5-8 and Darlington Units 1 &4 →**High confidence the OPG units are within [Heq] licensing basis**

2. Pickering Units 1 and 4 are not in extended operation - low [Heq] until end of commercial operation

3. **High confidence that no flaws of significance will occur in the region of interest**

   a. At Pickering, flaws in the region of interest are of known causes. The flaws are well understood, dispositioned and shown to be safe even at postulated high [Heq]. Corrective actions in place since 2015.

   b. No flaws in the region of interest at Darlington Units 1 and 4

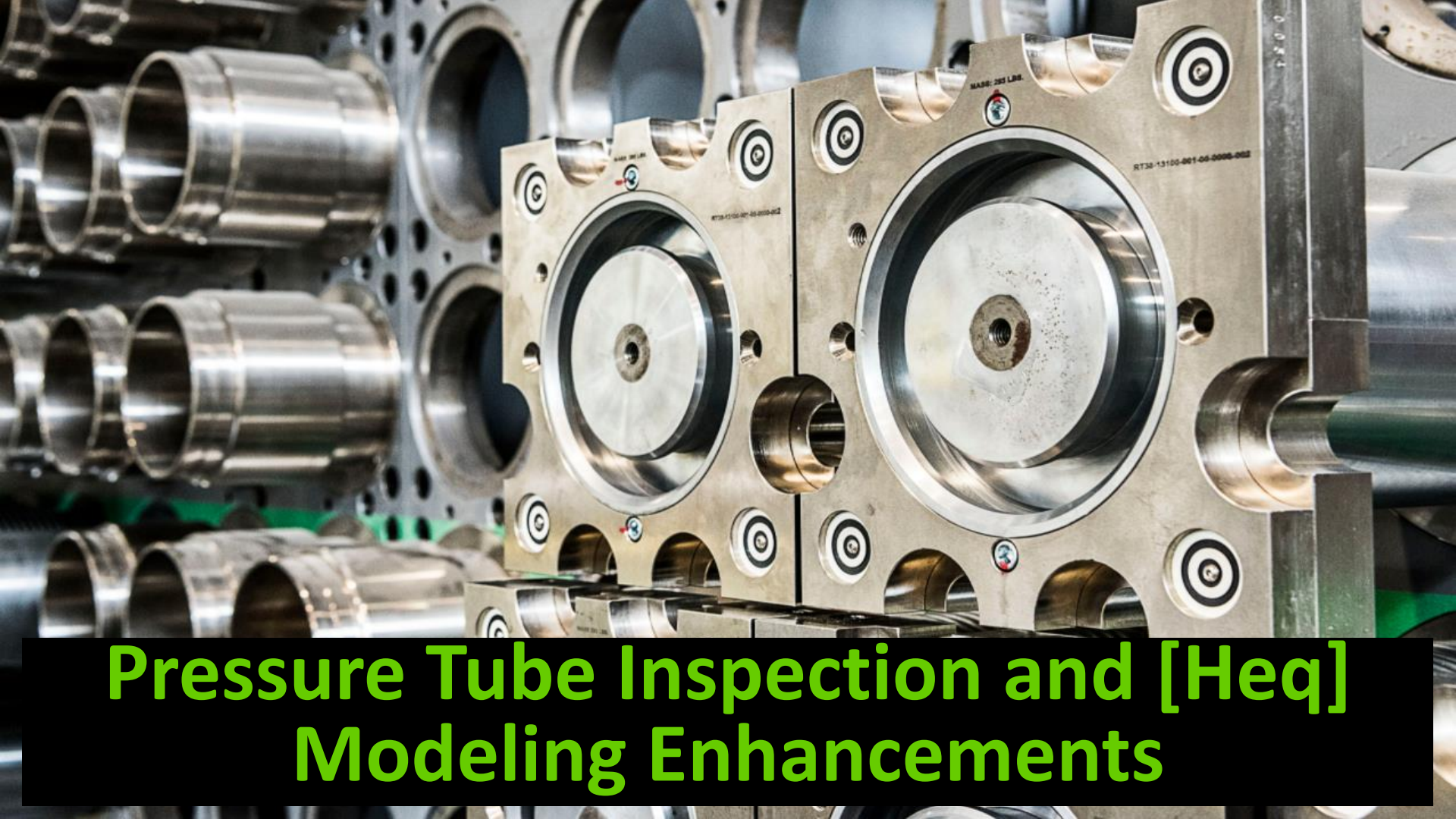
Causes of OPG flaws in the region of Bruce Power High [Heq] OPEX

- At PNGS, causes of flaws in region of interest are understood and are tied to specific operational events and are not random in nature
  - Crossflow flaws occur when a fuel bundle is transitioned through the reactor for fueling and passes over the flow holes in the liner tube. Damage to the fuel bundle and/or pressure tube can occur when it remains in this position for an extended period of time
  - Corrective actions have been put in place to mitigate risk and have been shown to be effective with eliminating flaw formation
  - All flaws detected have been dispositioned to be fit for service to Unit EOL, and have shown to be fit for service for elevated [Heq] levels

- At DNGS, there are no flaws in this region as the Fuel Handling system contains a fuel carrier which is designed to support the fuel bundles preventing damage to the pressure tube due to crossflow

Summary of technical submissions

- July 27, 2021 – Interim Assessment of High Hydrogen Concentration Discovery Issue at Bruce Power (N-CORR-00531-22809)
  - Risk assessment of BP's OPEX showing minimal risk to continued PT fitness for service (FFS) at OPG
- July 30, 2021 – OPG Response to 12(2) Letter (N-CORR-00531-22081)
  - OPG responded to CNSC items 1-4, provided two FFS impact assessments
    - Risk assessment of BP's OPEX showing no impact to continued PT fitness for service (FFS) at OPG
    - Sensitivity assessment at Higher [Heq] confirms Fracture protection and flaws remain acceptable (P1&4: 80/100ppm, P5-8: 120/140 ppm, DNGS: 120/140ppm)
- August 6, 2021 – OPG Response to Designated Officer Order (N-CORR-00531-22817)
  - OPG submitted station restart letters which indicate that:
    - Models provide conservative upper bound [Heq] predictions
    - Limited flaw population in area of BP OPEX
    - Conservative sensitivity assessment (PCA and LBB) postulating higher than measured [Heq] have been performed and demonstrate that the stations remain within the licensing basis and FFS



Pressure Tube Inspection and [Heq] Modeling Enhancements

Pressure Tube Inspection and [Heq] Modeling Enhancements

In addition to extensive material surveillance the following enhancements are planned:

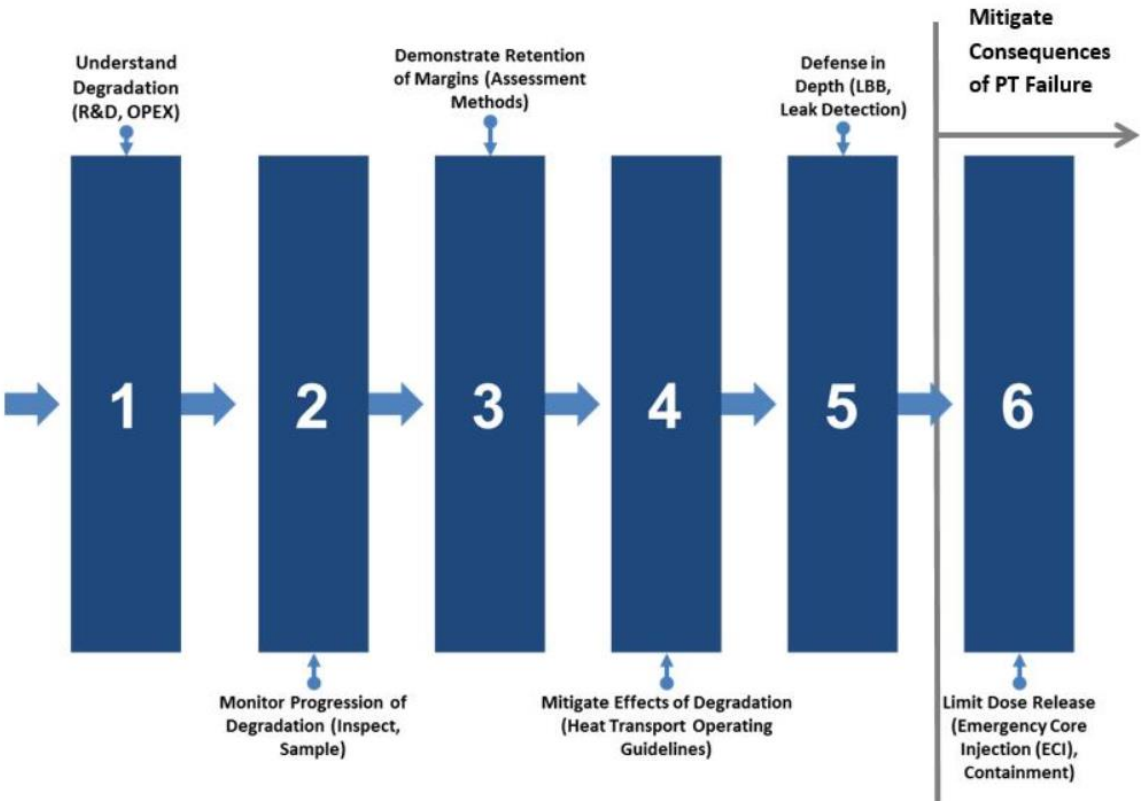
1. Future scrapes at pressure tube top dead centre or 12 o'clock orientation
2. Accelerating analysis of scrape samples after inspection campaigns to acquire interim results as soon as practicable
3. Additional punch sampling for ex-service material to continue with our extensive material surveillance program:
   - Four RJ sections scheduled for removal during Darlington Unit 3 refurbishment
   - Ex-service channel removed from Pickering Unit 8 during P2181
   - Single Fuel Channel Replacement from Pickering Unit 5 outage P2251
4. Modelling enhancements including use of 3D Finite Element Analysis considering fuel channel geometries, local temperatures, location-specific [Heq], and material stress states

Operational Safety and Defense in Depth

Operational Safety

- Heat transport system pressure and temperature are strictly controlled during Unit heat-up and cooldown
- In 2014, Pickering and Darlington proactively modified operating procedures and implemented design changes to reduce pressure limits during Unit heat-up and cooldown to minimize stress on pressure tubes
- Impact of pressure tube fitness-for-service is assessed following each cooldown
- Flaw fitness for service is confirmed prior to warm up of the unit

Defense in Depth Provisions for Reactor Safety



Low Risk of Pressure Tube Failure

Closing Remarks

Closing Remarks

1. OPG has a good understanding of [Heq] behavior in pressure tubes and we have confidence in our inputs and model predictions
2. High confidence no flaws of significance in the region of interest
3. Continued safe operation of OPG units is assured – low risk of pressure tube failure
4. OPG requests pre-authorization to restart Pickering Units 1 & 4, 5-8 and Darlington Units 1 & 4 should they enter an outage with heat transport system cooldown
5. OPG requests closure of Designated Officer Orders

ONTARIO POWER GENERATION

Where a brighter tomorrow begins.

EXTRA SLIDES

ONTARIO POWER GENERATION

Licensing Basis – Pickering NGS

- Licence Condition 15.3:

  Before Hydrogen equivalent concentration exceeds 120 ppm, the licensee shall demonstrate that pressure tube fracture toughness will be sufficient for safe operation beyond 120 ppm

- Licence Condition Handbook – Compliance Verification Criteria include that:

  OPG shall provide prior written notification and seek CNSC staff concurrence before operating any pressure tube with a predicted [Heq] concentration greater than 120 ppm between the inlet and outlet burnish marks

Licensing Basis – Darlington NGS

- Licence Condition 6.1:

The licensee shall implement and maintain a fitness for service program.

OPG: Key Submissions

- N-CORR-00531-22809: OPG Interim Assessment of High Hydrogen Equivalent Concentration ([Heq]) Discovery Issue at Bruce Power's Units 3 and 6 on Pickering and Darlington Nuclear Generating Stations Pressure Tube Fitness For Service - Submitted on July 27, 2021
- N-CORR-00531-22801: OPG Response to Request pursuant to Subsection 12(2) of the General Nuclear Safety and Control Regulations: Responses to Items 1-4 Related to Measurement of Hydrogen Concentration in Pressure Tubes - Submitted on July 30, 2021
- N-CORR-00531-22817: Pickering and Darlington: OPG Response to Designated Officer Orders and Opportunity to be Heard on Designated Officer Orders - Submitted on August 8, 2021