Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 23-M27.11A

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Supplementary Information

Renseignements supplémentaires

Presentation from
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Présentation de
Paul Sedran, RESD Inc.

Bruce Power

Bruce Power Mid-Term Update of Licensed Activities

Bruce Power

Rapport de mi-parcours au sujet des activités autorisées de Bruce Power

Commission Meeting

Réunion de la Commission

September 20 and 21, 2023

Le 20 et 21 septembre 2023

Canada

Review of CNSC and Bruce Power Submissions on Elevated Heq in B6S13 for the Bruce Power Mid-term Review

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Presentation Contents

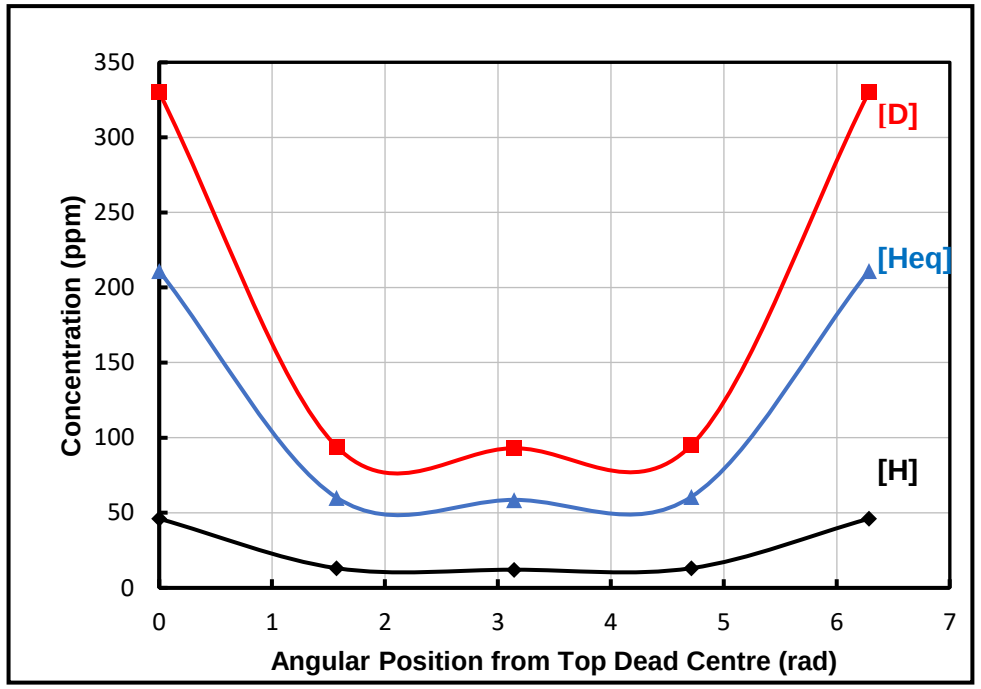
1. Introduction
2. Revised Circumferential Diffusion Analysis for the Outlet BM of B6S13
3. Comments from the Review of CMD 23-M27 and CMD 23-M27-1
4. Conclusions

1. Introduction

- In the public meeting of Nov 3rd, 2022, Bruce Power's thermal diffusion theory was disputed, noting that the opposing analysis was highly simplified & not Qaed
- Bruce Power responded that the simplified analysis excluded hydride ratchetting
- Bruce Power's FE analysis included hydride precipitation and dissolution, and demonstrated that the Heq measurements were attributable to thermal diffusion
- For this intervention, the diffusion analysis for B6S13 was revised to include hydride precipitation and dissolution to confirm BP's thermal diffusion theory
- Comments were also provided for CMD 23-M27 and CMD 23-M27-1

2. Revised Diffusion Analysis for the Outlet BM of B6S13

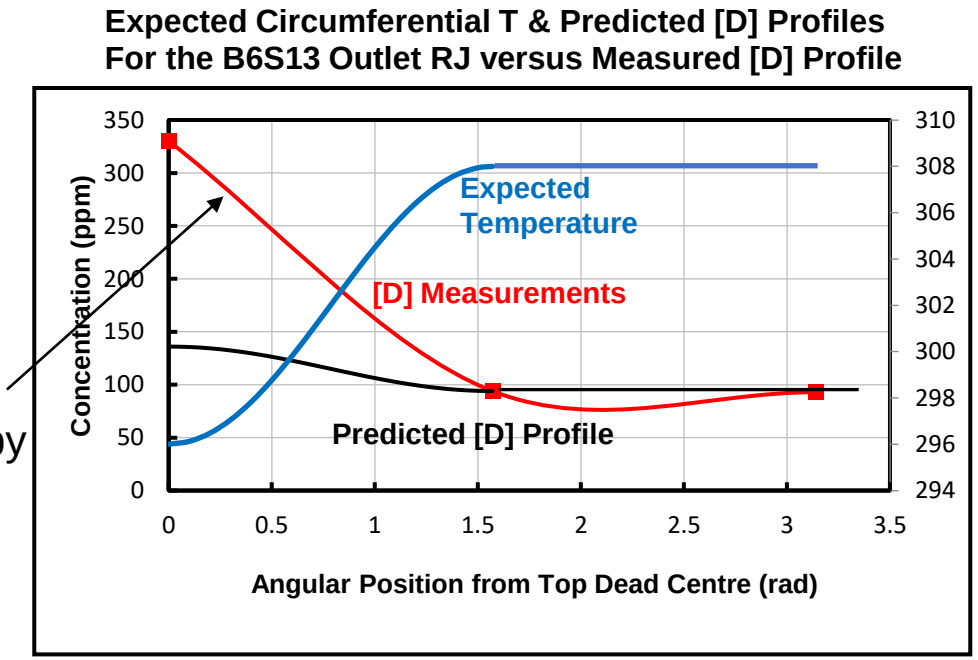
Circumferential Distribution of [H], [D], and [Heq] at the Outlet
PT RJ of B6S13 at 271,729 HH



2. Revised Diffusion Analysis for the Outlet BM of B6S13

Previous Assessment

Measured [D] gradient is too steep to have been caused by the expected temperature profile



2. Revised Diffusion Analysis for the Outlet BM of B6S13

Part 1- Use Equation 5 to predict the instantaneous D mass flux at 271279 HH

Part 2 - Use Equation 5 to predict the average D mass flux from 0 to 271279 HH

Part 3 - Use the average D mass Flux to predict the mass of D diffused into an elemental volume at the top of the PT over 271279 HH ❶

Part 4 - Check the actual mass of D that diffused into the elemental volume from the D concentration measurements ❷

If ❶ = ❷, then the observed circumferential D distribution for the B6S13 Outlet BM at 271279 HH was caused by thermal diffusion based on Equation 5

$$\textbf{D mass flux - J} = -\mathbf{D}_{\boldsymbol{D}} \frac{\mathbf{d}\boldsymbol{C}_{\boldsymbol{D}}}{\mathbf{dy}} - \frac{\mathbf{DQ}\boldsymbol{C}_{\boldsymbol{D}}}{\mathbf{RT^2}} \frac{\mathbf{dT}}{\mathbf{dy}} \quad \ldots\ldots\ldots 5$$

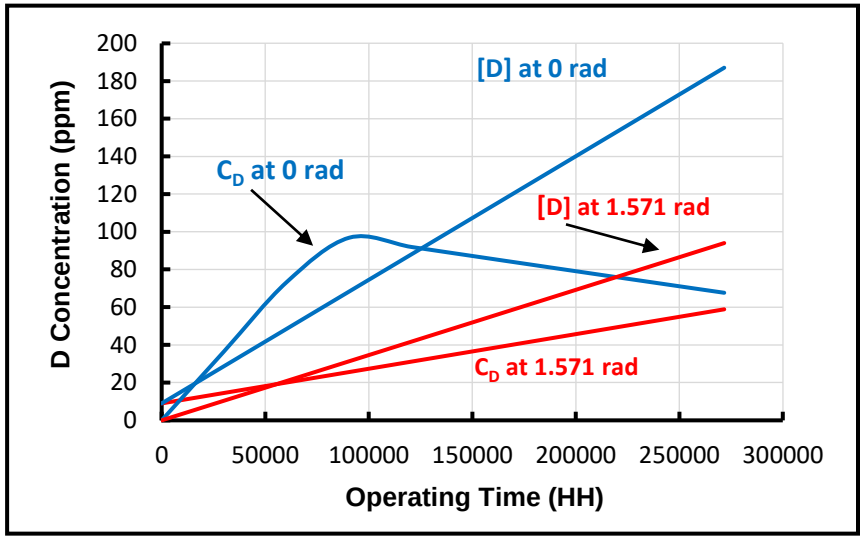
y is the circumferential coordinate, T is Temperature, $\boldsymbol{C}_{\boldsymbol{D}}$ is the D concentration in solution

$\mathbf{D}_{\boldsymbol{D}}$ is diffusion coefficient for D

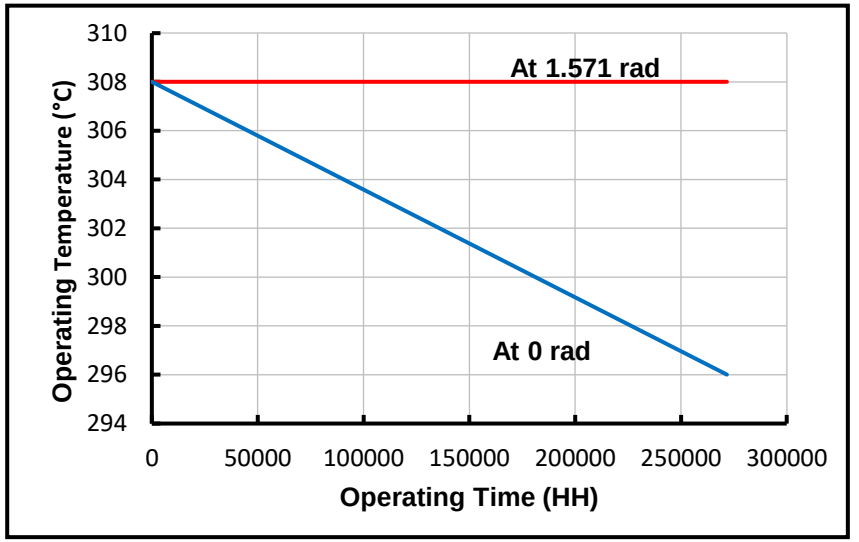
2. Revised Diffusion Analysis for the Outlet BM of B6S13

Inputs into Diffusion Analyses

Bulk and Dissolved D Concentrations vs HH



Operating Temperature vs HH



2. Revised Diffusion Analysis for the Outlet BM of B6S13

Results

Part 1 – Instantaneous D mass flux at 271279 HH = 2.4×10^{-10} kg m^{-2} s^{-1}

Part 2 – Average D mass flux from 0 to 271279 HH = 1.044×10^{-11} kg m^{-2} s^{-1}

2. Revised Diffusion Analysis for the Outlet BM of B6S13

Results

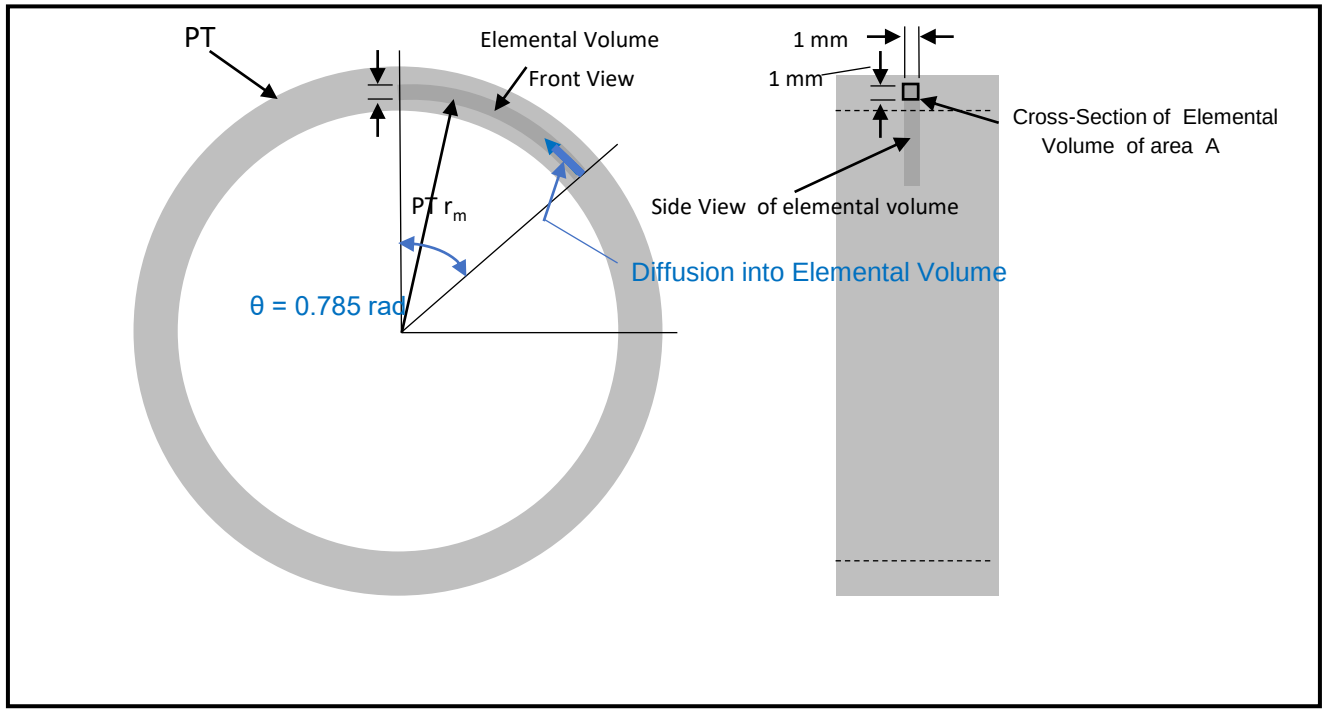
Part 3 – Predicted mass of D diffused into the elemental volume over 271279 HH
= 2.043×10^{-8} kg ❶

From $\Delta m_D = J_{total} \bullet A \bullet \Delta t$ …… 9

Diffused Mass = Mass flux ● Area ● Duration

2. Revised Diffusion Analysis for the Outlet BM of B6S13

Illustration of the Elemental Volume for the Diffused Mass Calculation of Part 3

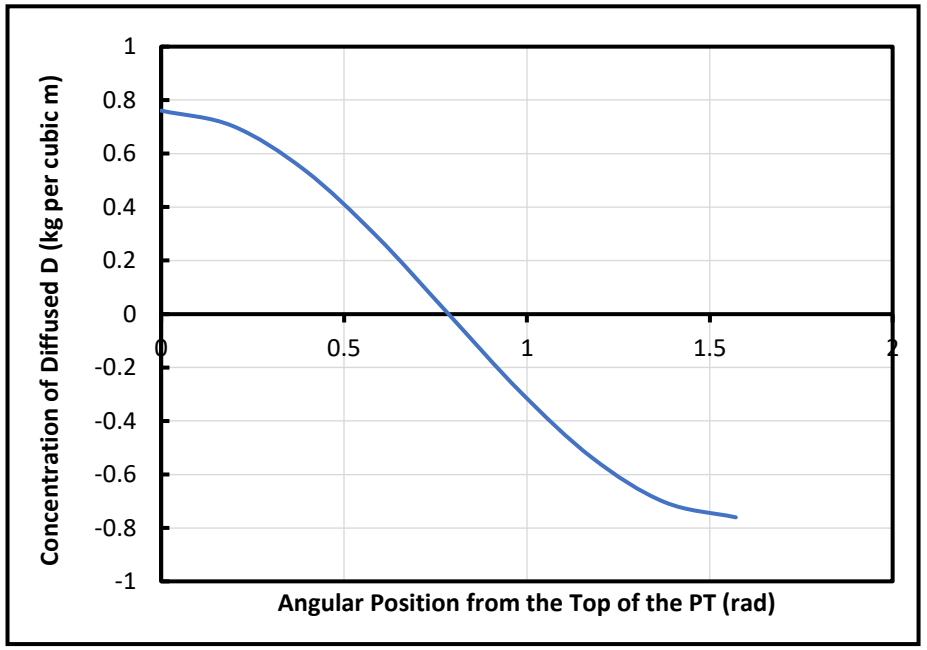


2. Revised Diffusion Analysis for the Outlet BM of B6S13

Results

Part 4 – Actual mass of D diffused into the elemental volume = 2.054×10^{-8} kg ❷

Concentration of Diffused D in the Elemental Volume vs θ



Since ❶ (2.043×10^{-8} kg) ≈ ❷ (2.054×10^{-8} kg) , then the circumferential D distribution for the B6S13 Outlet BM at 271279 HH is attributable to thermal diffusion based on Equation 5

3. Comments from the Review of CMD 23-M27 and CMD 23-M27-1

1. The CNSC expressed a concern about the validity of RJ D ingress model and whether additional theoretical model development would be required. Work by BP and this assessment show that the theoretical basis of the model is sound and the issue could be closed through documentation by the CNSC.
2. BP could benefit by renaming the *elevated Heq concentrations* in the PTs as the *circumferential redistribution of Heq concentrations.* Essentially H/D is diffusing away from potential flaws at the bottom of the PT to regions that are free of flaws. The 120 ppm limit on Heq was intended for the entire circumference of the PT, with flaws in mind. It may be possible to derive a higher Heq limit for the flaw-free regions of the PT.

5. Conclusions from the Revised Diffusion Analysis

1. For the operating temperature distribution assumed, the measured circumferential [D] gradient at the outlet BM of B6S13 is entirely attributable to thermal diffusion over a period of 217279 HH, in agreement with the Bruce Power hypothesis.
2. From Conclusion 1, there is no longer a rationale for postulating the existence of a novel point source of D at the top of the RJ in B6S13 as thermal diffusion is a sufficient explanation.