ATTACHMENT 8

AREVA Document #51-9252998-002, "Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary"

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AREVA

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Engineering Information Record

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Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary

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Safety Related? ☒ YES ☐ NO

Does this document establish design or technical requirements? ☐ YES ☒ NO

Does this document contain assumptions requiring verification? ☐ YES ☒ NO

Does this document contain Customer Required Format? ☐ YES ☒ NO

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000	All	The content of this document is identical to 51-9240805-002, except that proprietary information is redacted.
001	All	The content of this document is identical to 51-9240805-003, except that proprietary information is redacted.
002	All	The content of this document is identical to 51-9240805-004, except that proprietary information is redacted.

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1.0 PURPOSE

The purpose of this Engineering Information Record is to provide a summary of the calculations and evaluations performed to establish the life expectancy of the inner diameter temper bead (IDTB) weld repair on select reactor vessel closure head (RVCH) penetrations for Units 1 and 2 of both Byron and Braidwood Nuclear Stations (Byron/Braidwood).

2.0 BACKGROUND

Due to concerns that the Control Rod Drive Mechanism (CRDM), spare nozzles, core exit thermocouple (CETC), and reactor vessel level indication system (RVLIS) nozzle penetration degradation may have occurred in the RVCHs at Units 1 and 2 of both Byron and Braidwood Nuclear Stations, Exelon Generation Company, LLC contracted AREVA to create a modification to repair these nozzles as a contingency.

In the event that a nozzle repair is necessary, an IDTB weld repair procedure has been developed wherein the lower portion of the nozzle is removed by a boring procedure and the remaining portion of the nozzle is welded to the low alloy steel reactor vessel head above the original Alloy 82/182 J-Groove attachment weld [Reference 6], as shown in Figure 1 [References 5, 7, 8].

Analyses and evaluations have been performed in order to determine the minimum life expectancy of the postulated IDTB repairs. They include an ASME Section III code evaluation (which considered general corrosion), a J-groove flaw evaluation, a weld anomaly flaw evaluation, and a Primary Water Stress Corrosion Cracking (PWSCC) life evaluation. The general description of each analysis/evaluation and their respective conclusions are summarized below.

Figure 1: RV Head Penetration IDTB Repair Configuration CRDM/RVLIS/Spare (left) and CETC (right)

3.0 ASSUMPTIONS

No assumptions are made in this document.

4.0 CALCULATIONS AND EVALUATIONS RESULTS

The following sections outline and summarize the results of the various calculations and evaluations performed to quantify the expected life of the postulated IDTB repair of the CRDM, Spare, CETC, and RVLIS nozzles at the Byron/Braidwood Nuclear Stations.

4.1 ASME Section III Evaluation

An ASME Section III analysis [Reference 1] was performed to qualify the Exelon Byron/Braidwood RVCH Nozzle and Penetration Modification to the applicable requirements of the Design Specification [Reference 6] and the ASME Code Section III Subsection NB Class 1 Components, 2001 Edition, Through 2003 Addenda. This analysis considered material loss due to general corrosion of the exposed low alloy steel [Reference 5].

The corrosion evaluation included within this analysis determined that the total surface (radial) corrosion in the penetration bore for 40 years would be 0.144 inches. This small amount of corrosion volume lost would not have a significant impact on the analysis and was bounded by other considerations within the analysis [Reference 1].

This analysis demonstrated that the Byron/Braidwood RVCH Nozzle Penetration Modification satisfies the ASME code primary stress and primary plus secondary stress requirements, as well as the criteria to protect against fatigue failure. The cumulative usage factors at the critical locations are less than 1.0 for the number of design cycles specified for 40 years of plant life (after the repair) [Reference 1, Table 4-6, Note 2]. [

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4.2 Weld Residual Stress Analysis

The Weld Residual Stress analysis [Reference 9] considered the welding of the existing J-Groove Butter, the J-Groove weld attaching the CRDM/CETC nozzle to the RVCH and the new IDTB repair weld. The state of stress after welding and operating (heatup/cooldown) cycles was determined to support flaw evaluations of the RVCH and the IDTB repair weld.

This analysis did not determine a repair life, but provides input to the As-Left J-Groove Evaluation [Reference 2], and the RVCH Nozzle IDTB Repair Weld Anomaly Flaw Evaluation [Reference 3].

4.3 As-Left J-Groove Flaw Evaluation

A fracture mechanics analysis [Reference 2] was performed on the IDTB nozzle repair to justify postulated worst-case flaw(s) remaining in the original nozzle-to-RVCH weld (as-left J-groove weld) at the postulated worst-case penetration location(s). This analysis considered the worst-case nozzle location and utilized material properties which bound the properties of all four units. The applicable code is ASME Section XI, 2001 Edition with Addenda through 2003. If the service life of the component was shown to be limited, ASME Section XI Code Case N-749 (as modified by the Nuclear Regulatory Commission) was considered in the evaluation.

A 20 year license extension for each unit was assumed in the analysis, and the results are applicable for 33 years of remaining operation (60 year plant licensed life) [Reference 2, Section 3.2, Item 2].

A fatigue crack growth and fracture mechanics evaluation of the worst-case flaw in the as-left J-groove weld and buttering at the worst-case penetration location was performed. Based on a combination of linear elastic and elastic-plastic fracture mechanics, the postulated flaws are shown to be acceptable for the remaining life of the

plant utilizing the appropriate safety factors for the operating condition and analysis method, and the lower bound J-R curve from Regulatory Guide 1.161. [

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4.4 Weld Anomaly Flaw Evaluation

A fracture mechanics evaluation [Reference 3] of a postulated weld anomaly in the potential repair locations within any of the Byron/Braidwood RVCHs was performed. The weld anomaly was postulated to be a 0.10 inch flaw extending 360 degrees around the circumference at the "triple point" locations where there is a confluence of three materials; the RVCH low alloy steel base material, the SB-167 Alloy 600 existing nozzle or SB-166 Alloy 690 replacement nozzle, and the Alloy 52/52M/52MSS weld material. Several potential flaw propagation paths were considered in the flaw evaluations. Flaw acceptance is based on the ASME B&PV Code 2001, with 2002 & 2003 Addenda, Section XI criterial for applied stress intensity factors (IWB-3612) and limit load (IWB-3642).

The results of the analyses demonstrate that a 0.10 inch weld anomaly is acceptable for a 40 year design life of the Byron/Braidwood potential nozzle repair locations (after the repair) [Reference 3, Section 4.4.1]. The minimum fracture toughness margins for flaw propagation have been shown to be acceptable as compared to the required margins of $\sqrt{10}$ for normal/upset conditions and $\sqrt{2}$ for emergency/faulted conditions per Section XI, IWB-3612.

A limit load analysis was performed considering the ductile weld repair material along the flaw propagation path. This analysis showed that the minimum margin on the allowable stress is [

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Fracture toughness margins have been demonstrated to be acceptable for the postulated cylindrical flaws. For the cylindrical flaws, it has also been shown that the applied shear stress at the remaining ligament is less than the allowable shear stress per NB-3227.2.

4.5 Primary Water Stress Corrosion Cracking Evaluation

A PWSCC evaluation [Reference 4] was performed on the remaining Alloy 600 nozzle material after a postulated RVCH IDTB nozzle repair. This evaluation considered the RVCH penetration nozzles in the as-repaired condition (no surface remediation), the as-repaired condition with abrasive water jet machining (AWJM) remediation, and the as-repaired condition with rotary peening remediation.

The areas of interest for this evaluation were 1) Alloy 600 nozzle adjacent to the IDTB weld and 2) Alloy 600 nozzle at the roll (and/or machined surface) transition region. If a remediation technique is used, it will be applied to the full length of the remaining Alloy 600 nozzle affected by the repair (i.e., covering both areas of interest).

Conservative assumptions were used for the flaw initiation time and the crack growth rate. The industry adopted 75% through-wall flaw acceptance criterion was used.

Based on operating experience at Byron Units 1 and 2 and Braidwood Units 1 and 2, the estimated minimum time for a PWSCC flaw to reach 75% through wall is 2 EFPY for the as-repaired condition (no surface remediation). The estimated minimum time for a PWSCC flaw to reach through 75% of the original wall thickness is [

] and over 100 EFPY for rotary peening surface remediation.

5.0 CONCLUSION

Based on the calculations and evaluations documented above,

- The RVCH penetration nozzle repairs meet the requirements of ASME Section III, and the cumulative usage factors at the critical locations are less than 1.0 for the number of design cycles specified for 40 years of plant life after the repair.
- The J-groove flaw evaluation is acceptable for the remaining life of a 60 year plant license.
- A triple point weld flaw of up to 0.10" is acceptable for a 40 year design life after the repair.
- The estimated minimum time for a PWSCC flaw to reach 75% through wall is 2 EFPY for the as-repaired configuration (no surface remediation). The estimated minimum time for a PWSCC flaw to propagate through 75% of the original wall thickness is [ ] over 100 EFPY utilizing rotary peening surface remediation.

6.0 REFERENCES

1. AREVA Proprietary document 32-9233803-001, "ASME Section III Analysis of Byron/Braidwood RVCH Nozzle and Penetration Modification."
2. AREVA Proprietary document 32-9236713-002, "Byron and Braidwood RVCH Nozzle As-Left J-Groove Analysis." (Non-proprietary version is AREVA document 32-9244434-001.)
3. AREVA Proprietary document 32-9237284-002, "Byron/Braidwood RVCH Nozzle IDTB Repair Weld Anomaly." (Non-proprietary version is AREVA document 32-9244389-001.)
4. AREVA Proprietary document 51-9233902-002, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2." (Non-proprietary version is AREVA document 51-9252742-001.)
5. AREVA Proprietary document 51-9234023-002, "Corrosion Evaluation of Byron Units 1 and 2 and Braidwood Units 1 and 2 IDTB Weld Repairs." (Non-proprietary version is AREVA document 51-9252740-001.)
6. AREVA Proprietary document 08-9232121-001, "Byron Units 1 and 2, and Braidwood Units 1 and 2, RVCH Nozzle Penetration Modification."
7. AREVA Proprietary Drawing 02-9232823E-001, "Byron Units 1 and 2 / Braidwood Units 1 and 2 CRDM, Spare, & RVLIS Penetration Modification."
8. AREVA Proprietary Drawing 02-9232824E-001, "Byron Units 1 and 2 / Braidwood Units 1 and 2 Thermocouple Column Penetration Modification."
9. AREVA Proprietary document 32-9233779-000, "Weld Residual Stress Analysis of Byron 1 & 2, and Braidwood 1 & 2 RVCH Nozzle/Penetration Repair."