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Proprietary information contained in Attachment 1 and Attachment 3
Withhold from public disclosure under 10 CFR 2.390
When separated, this cover letter, Attachment 2, Attachment 4 and Attachment 5 are non-proprietary

RS-16-067

10 CFR 50.55a

March 22, 2016

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Braidwood Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Supplement to Response to Requests for Additional Information for Relief for Alternate Requirements for Repair of Reactor Vessel Head Penetrations with Nozzles Having Pressure-Retaining Partial-Penetration J-Groove Welds (RS-16-045)

References:

1) Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. Nuclear Regulatory Commission, "Requests for Relief for Alternate Requirements for Repair of Reactor Vessel Head Penetrations with Nozzles Having Pressure-Retaining Partial-Penetration J-Groove Welds," dated September 11, 2015

2) Email from J. Wiebe (NRC) to J. Krejcie (Exelon Generation Company, LLC), Preliminary Request for Additional Information Regarding the Braidwood and Byron Requests for Relief Regarding Repair of Reactor Vessel Head Penetration J-Groove Welds, dated January 6, 2016

3) Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. Nuclear Regulatory Commission, "Response to Requests for Additional Information for Relief for Alternate Requirements for Repair of Reactor Vessel Head Penetrations with Nozzles Having Pressure-Retaining Partial-Penetration J-Groove Welds," dated February 11, 2016

4) Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. Nuclear Regulatory Commission, "Supplement to Response to Requests for Additional Information for Relief for Alternate Requirements for Repair of Reactor Vessel Head Penetrations with Nozzles Having Pressure-Retaining Partial-Penetration J-Groove Welds," dated March 15, 2016

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In accordance with 10 CFR 50.55a, "Codes and standards," paragraph (z)(1), Exelon Generation Company, LLC (EGC), requested relief from the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PV Code) specifically related to the repair of the degraded reactor vessel closure head (RVCH) penetration nozzles and their associated partial penetration J-groove attachment welds. Specifically, the relief request proposed to perform an alternative repair technique using the Areva, Inc,(AREVA) Inside Diameter Temper Bead (IDTB) welding method to restore the pressure boundary of a degraded nozzle. EGC submitted this request to the NRC in Reference 1.

Subsequent to submittal of Reference 1, the NRC requested additional information to support the review of the subject relief request (Reference 2). EGC responded to the request in the Reference 3 transmittal.

The Reference 3 transmittal included supporting documents containing proprietary information as defined by 10 CFR 2.390, "Public inspection, exemption, requests for withholding." The Reference 3 transmittal indicated that non-proprietary versions of Attachments 2 through 5 would be transmitted at a later date. Reference 4 transmitted two of the four non-proprietary attachments. The purpose of this transmittal is to transmit the remaining non-proprietary versions of the evaluations included originally in Reference 3. The following non-proprietary evaluations included in this transmittal are:

1. AREVA Document #51-9252998-001, "Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary" (Corresponding to the Proprietary Evaluation included as Attachment 3 of Reference 3)

2. AREVA Document #51-9252742-001, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood units 1 and 2" (Corresponding to the Proprietary Evaluation included as Attachment 4 of Reference 3)

Note, this transmittal also includes revisions to the proprietary versions of the above documents as previously sent in the Reference 3 transmittal (i.e., revisions to Attachment 3 and Attachment 4 of Reference 3). Revisions to the proprietary documents were made for the purpose of annotating the proprietary information in brackets. Additionally, in updating the proprietary and non-proprietary versions of the evaluations as described above, AREVA identified that the remediation length discussed in Section 2.2 of Reference 3 Attachment 4 was changed. Specifically, Section 4.0 of the revised document (i.e., AREVA Document #51-9233902-002, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2") identifies a different required remediation length than that discussed in Reference 3 Attachment 4 Section 2.2. The reason for this change is that the previously identified value was a minimum value that AREVA has since refined for the Braidwood Station and Byron Station application.

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This revised remediation length change also impacts the statement made in the response to NRC RAI-3c in the Reference 3 letter. Specifically, this statement should identify that the dimension for the upper extent of the roll expanded surface is the dimension as described in Section 4.0 of Attachment 3.

In addition to the change to NRC RAI-3c as described above, AREVA has also identified a clarification to the response to NRC RAI-3b. Specifically, the response to NRC RAI-3b in Reference 3 read:

"The acceptance criteria that will be used for flaws detected by PT for weld metal, adjacent base materials and base materials are per ASME Section III, 2001 through summer of 2003 addenda, paragraph NB-2546."

The revised language should read:

"ASME Section III, 2001 Edition through 2003 Addenda acceptance criteria will be used for flaws detected by PT. Weld metal acceptance criteria is in accordance with paragraph NB-5352 and adjacent base materials acceptance criteria is in accordance with paragraph NB-2546."

The purpose of this clarification is to remain consistent with the AREVA design specification which required use of NB-2546 acceptance criteria for base material and NB-5232 acceptance criteria for weld metal.

AREVA as the owner of the proprietary information has executed the enclosed affidavit, which identifies that the enclosed proprietary information has been handled and classified as proprietary, is customarily held in confidence, and has been withheld from public disclosure. The proprietary information was provided to EGC by AREVA as referenced by the affidavit. The proprietary information has been faithfully reproduced in the attached information such that the affidavit remains applicable. AREVA hereby requests that the attached proprietary information be withheld, in its entirety, from public disclosure in accordance with the provisions of 10 CFR 2.390 and 10 CFR 9.17. The affidavit supporting the proprietary nature of the information is contained in Attachment 5. Note, the affidavit enclosed here is different from the Reference 3 Attachment 6 affidavit, updated to reflect the current revisions to the proprietary documents evaluations included in this transmittal.

There are no regulatory commitments contained within this letter.

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Should you have any questions concerning this letter, please contact Ms. Jessica Krejcie at (630) 657-2816.

Respectfully,

David M. Gullott
Manager – Licensing
Exelon Generation Company, LLC

Attachment 1: AREVA Document #51-9240805-003, "Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary" (PROPRIETARY)
Attachment 2: AREVA Document #51-9252998-001, "Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary" (NON-PROPRIETARY)
Attachment 3: AREVA Document #51-9233902-002, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2" (PROPRIETARY)
Attachment 4: AREVA Document #51-9252742-001, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2" (NON-PROPRIETARY)
Attachment 5: AREVA Inc., Affidavit for AREVA documents, March 11, 2016

ATTACHMENT 1

AREVA Document #51-9240805-003, "Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary"

PROPRIETARY

ATTACHMENT 2

AREVA Document #51-9252998-001, "Byron Units 1 & 2, and Braidwood Units 1 & 2
IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary"

NON-PROPRIETARY

AREVA Inc.

Engineering Information Record

Document No.: 51 - 9252998 - 001

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

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

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

Signature Block

Name and Title/Discipline	Signature	P/LP, R/LR, A-CRF, A	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
Greg Troyer Engineering II, Component Engineering		P	3/4/16	All
Ryan Hosler Supervisory Engineer, Materials Engineering		R	3/11/16	All
Brian Haibach Manager, Materials and RCS Structural Analysis Unit		A	3/11/16	All

Note: P/LP designates Preparer (P), Lead Preparer (LP)
R/LR designates Reviewer (R), Lead Reviewer (LR)
A-CRF designates Project Manager Approver of Customer Required Format (A-CRF)
A designates Approver/RTM – Verification of Reviewer Independence

Project Manager Approval of Customer References (N/A if not applicable)

Name (printed or typed)	Title (printed or typed)	Signature	Date
N/A			

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	This content of this document is identical to 51-9240805-002, except that proprietary information is redacted.
001	All	This content of this document is identical to 51-9240805-003, 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]. **[**

]

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. [

]

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 [

] .

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 initiate 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 initiate 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 32-9233803-000, "ASME Section III Analysis of Byron/Braidwood RVCH Nozzle and Penetration Modification."
2. AREVA Proprietary document 32-9236713-001, "Byron and Braidwood RVCH Nozzle As-Left J-Groove Analysis." (Non-proprietary version is AREVA document 32-9244434-000.)
3. AREVA Proprietary document 32-9237284-001, "Byron/Braidwood RVCH Nozzle IDTB Repair Weld Anomaly." (Non-proprietary version is AREVA document 32-9244389-000.)
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 08-9232121-000, "Byron Units 1 and 2, and Braidwood Units 1 and 2, RVCH Nozzle Penetration Modification."
7. AREVA Proprietary Drawing 02-9232823E-000, "Byron Units 1 and 2 / Braidwood Units 1 and 2 CRDM, Spare, & RVLIS Penetration Modification."
8. AREVA Proprietary Drawing 02-9232824E-000, "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."

ATTACHMENT 3

AREVA Document #51-9233902-002, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2"

PROPRIETARY

ATTACHMENT 4

AREVA Document #51-9252742-001, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2"

NON-PROPRIETARY

AREVA Inc.

Engineering Information Record

Document No.: 51 - 9252742 - 001

PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2

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

Signature Block

Name and Title/Discipline	Signature	P/LP, R/LR, A-CRF, A	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
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Sarah Davidsaver Principal Engineer Materials Engineering		R	3/11/16	All
Brian Haibach Manager Materials and RCS Structural Analysis Unit		A	3/11/16	All

Note: P/LP designates Preparer (P), Lead Preparer (LP)
R/LR designates Reviewer (R), Lead Reviewer (LR)
A-CRF designates Project Manager Approver of Customer Required Format (A-CRF)
A designates Approver/RTM – Verification of Reviewer Independence

Project Manager Approval of Customer References (N/A if not applicable)

Name (printed or typed)	Title (printed or typed)	Signature	Date
N/A	N/A		

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	This content of this document is identical to 51-9233902-001, except that proprietary information is redacted.
001	All	This content of this document is identical to 51-9233902-002, except that proprietary information is redacted.

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1.0 BACKGROUND AND PURPOSE

Routine inspection of control rod drive mechanism (CRDM) nozzles has revealed cracking in CRDM nozzles in United States (U. S.) commercial pressurized water reactors (PWRs). Some of the cracking has resulted in reactor coolant leaks at the pressure boundary. Evidence of such leaks was observed as boric acid crystal deposits via visual inspection of the reactor vessel closure head (RVCH). The cracking mechanism has generally been attributed to primary water stress corrosion cracking (PWSCC). Exelon Generation Company, LLC (hereafter Exelon) has requested that AREVA be prepared to repair RVCH penetration nozzles during a future outage at Byron Units 1 and 2 and Braidwood Units 1 and 2 [1].

The purpose of this document is to evaluate PWSCC[1] of the remaining Alloy 600 nozzle material affected by the repair after performance of the contingency RVCH penetration nozzle inside diameter temperbead (IDTB) weld repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2 [1]. This evaluation includes the seventy-eight (78) CRDM-type nozzles within the scope of the repair drawing [2] [3], with exceptions noted in the drawings. The seventy-eight (78) CRDM-type nozzles include fifty-three (53) CRDM nozzles, five (5) thermocouple column nozzles, eighteen (18) spare nozzles, and two (2) reactor vessel level indication system (RVLIS) nozzles [1]. This evaluation considers the RVCH penetration nozzles in the as-repaired condition (no surface remediation), the optional as-repaired abrasive water jet machining (AWJM) remediated condition, and the optional as-repaired rotary peening remediated condition.

The areas adjacent to the IDTB weld and the roll and/or machined surface transition on the inner diameter (ID) are areas of the remaining Alloy 600 nozzle of concern. If a remediation technique is used, it is to be applied above the roll transition or machined ID surface, thereby helping to alleviate the concern for PWSCC at this transition region. Therefore, this evaluation is limited in scope to PWSCC concerns of the remaining Alloy 600 nozzle portion affected by the repair (i.e., adjacent to the IDTB weld and the roll and/or machined surface transition [2] [3]), as shown in Figure 1-2 and Figure 1-4. Figure 1-1 depicts a schematic of the overall repair configuration for the CRDM, spare, and RVLIS nozzles with the replacement thermal sleeve (not applicable to the spare nozzles) while Figure 1-2 shows an enlarged area depicted in Figure 1-1 as Detail E or Detail F. Figure 1-3 depicts a schematic of the overall repair configuration for the thermocouple nozzles while Figure 1-4 shows an enlarged area depicted in Figure 1-3 as Detail E or Detail F. The minimum remediation lengths in Figure 1-2 and Figure 1-4 include a portion of the IDTB weld, however the only area of interest for this document is the original Alloy 600 nozzle, as stated above.

[1] For Information Only: The corrosion evaluation for those corrosion mechanisms affecting pressure-boundary portions of this repair (excluding the remnant Alloy 600 nozzles) may be found in AREVA Documents 51-9234023 (Proprietary) and 51-9252740 (Non-Proprietary).

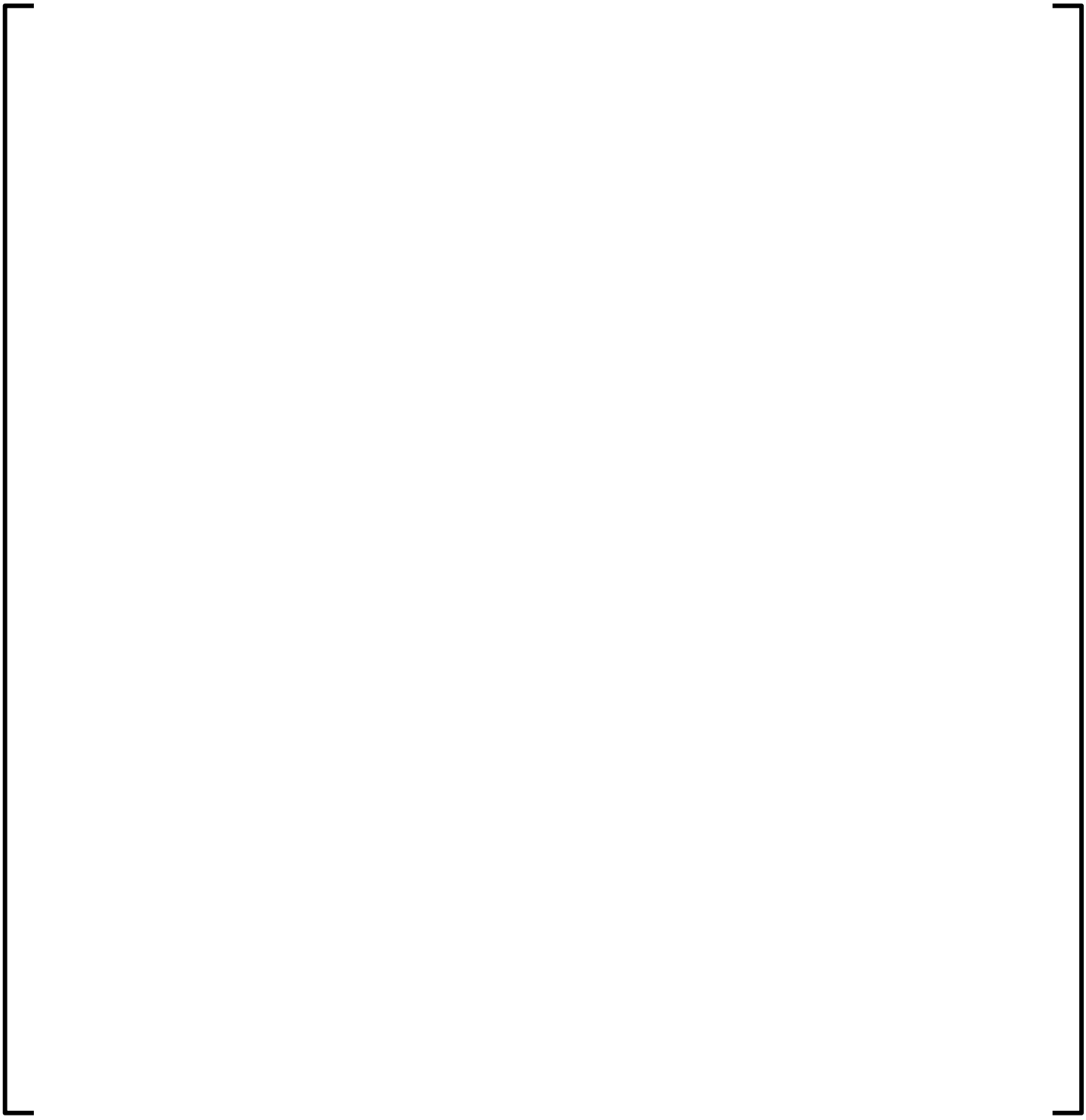

Figure 1-1: RVCH CRDM, Spare, and RVLIS Nozzles Repair Configuration (Replacement Thermal Sleeve Not Applicable for Spare Nozzles) [2]

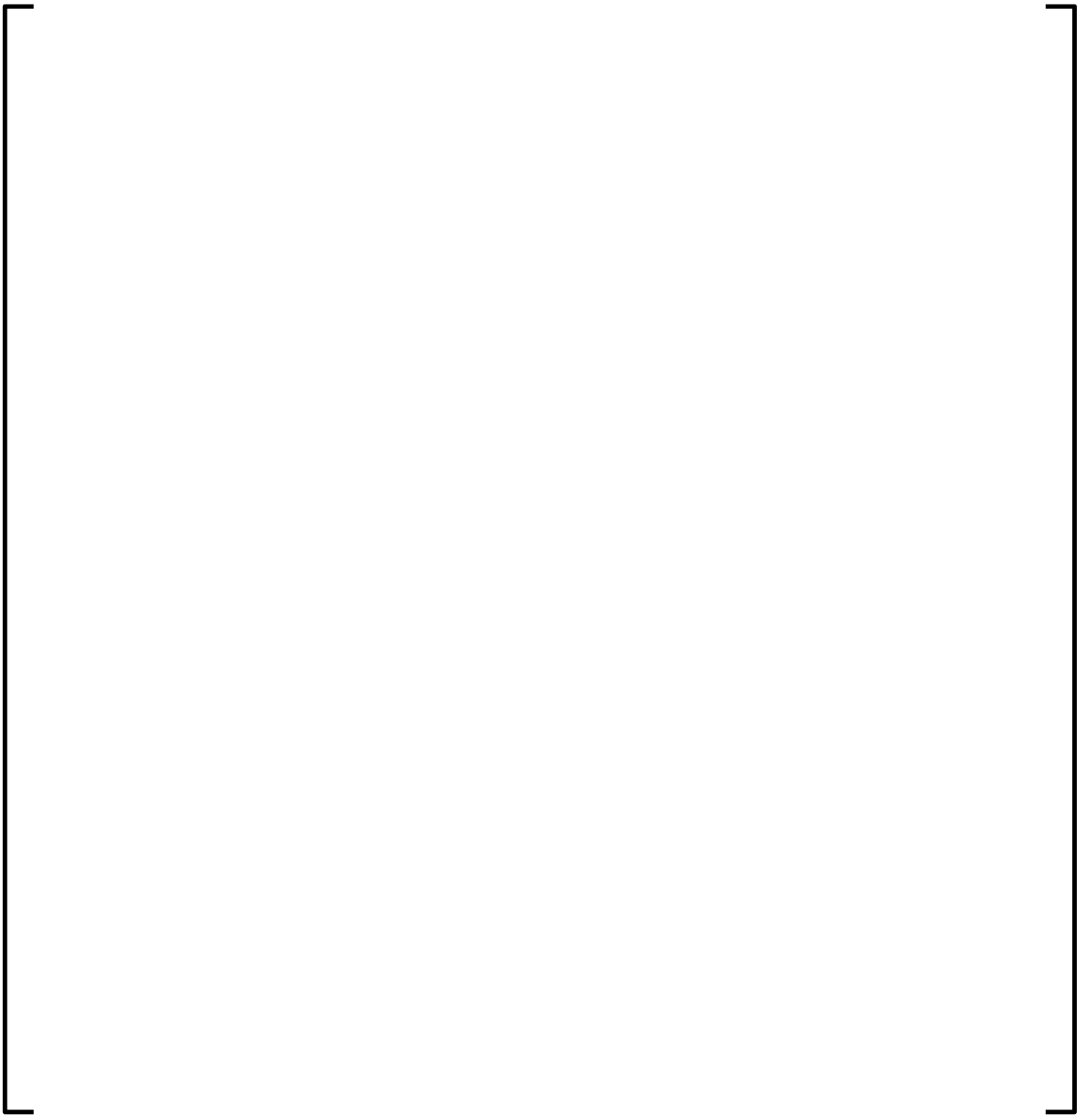

Figure 1-2: Detail E (top) and Detail F (bottom) of Figure 1-1 (Replacement Thermal Sleeve Not Shown) [2]

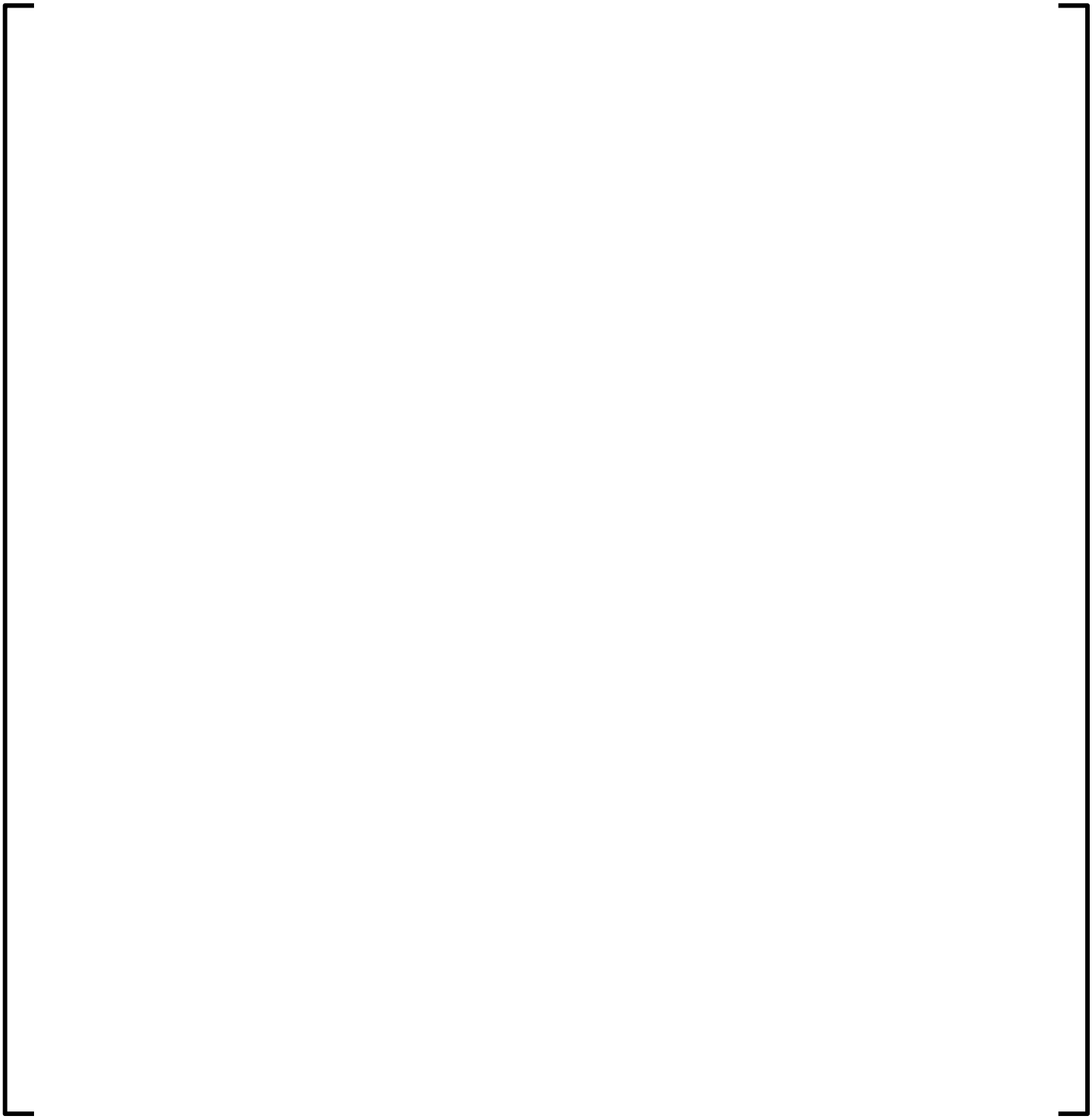

Figure 1-3. RVCH Thermocouple Nozzle Repair Configuration with Replacement Thermocouple Housing Extension [3]

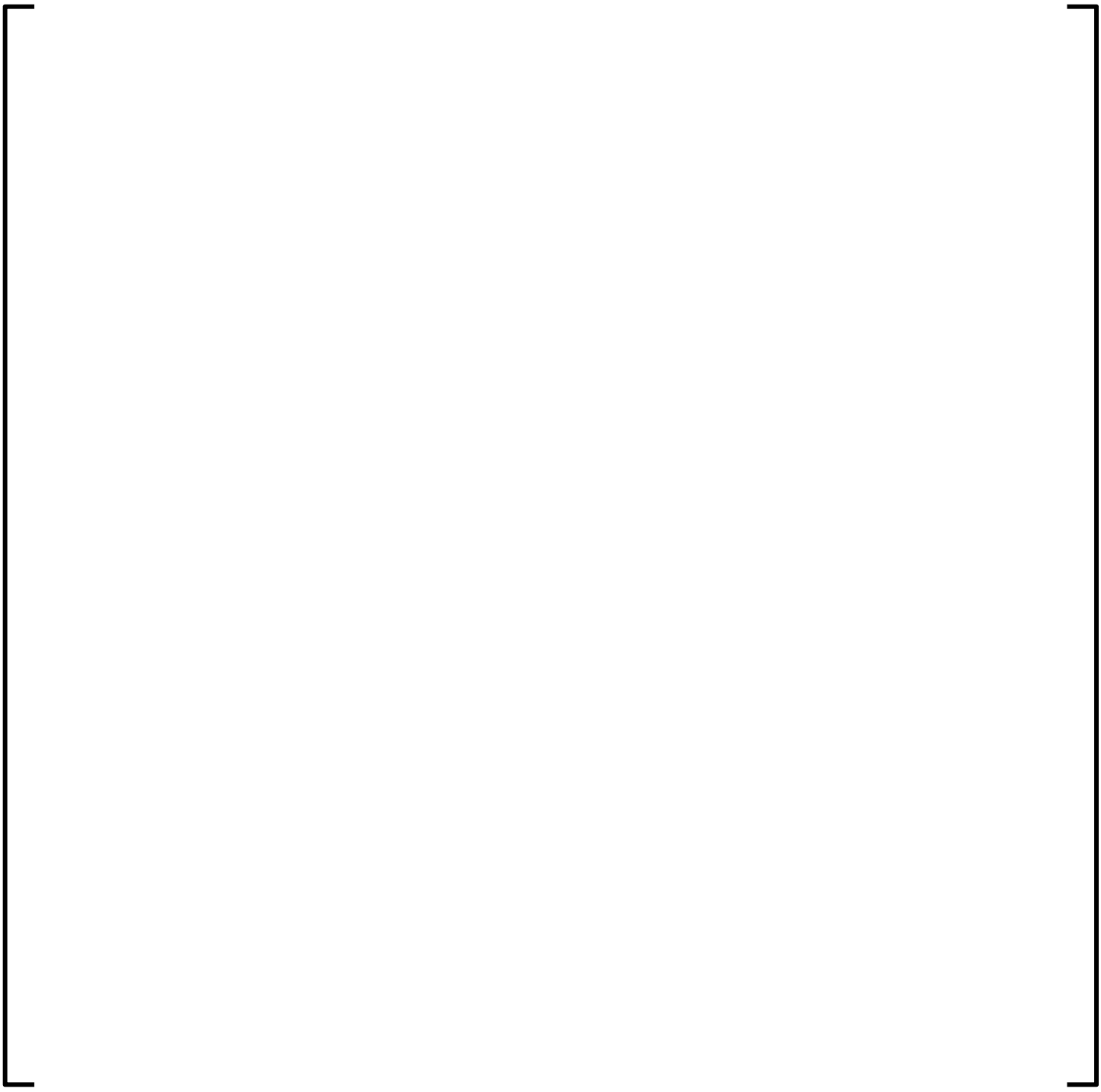

Figure 1-4. Detail E (top) and Detail F (bottom) of Figure 1-3 [3]

2.0 ASSUMPTIONS

2.1 Justified Assumptions

1. Upon completion of the repair, it is unlikely that PWSCC flaws will be present in the portion of the Alloy 600 nozzle affected by the repair. [ ] The assumption that it is unlikely that PWSCC flaws are present in the remaining Alloy 600 nozzle affected by the repair is justified for the following reasons [ ]

   a. [ ] factors that have historically caused PWSCC (elevated tensile stress (i) and/or off-chemistry conditions (ii)) [ ]

      i. For RVCH penetration nozzles, the primary cause of elevated tensile stress is residual stresses from the original J-groove welding process, which only affects the base metal directly adjacent to the weld. [ ]

      ii. Off-chemistry conditions have caused PWSCC flaws in CRDM nozzles in relatively low stress locations at one international site where resin ingress caused prolonged periods of high sulfate levels [4]. In response, the Nuclear Regulatory Commission (NRC) requested in Generic Letter (GL) 97-01 that all U.S. PWRs report whether any resin intrusions exceeded the EPRI PWR water chemistry guidelines [5]. Exelon responded to GL 97-01 stating that after review of primary coolant system chemistry and conductivity data from the beginning of plant life for Byron Units 1 and 2 and Braidwood Units 1 and 2, no evidence of resin intrusion was identified and no primary coolant system chemistry excursion observed was attributed to a resin intrusion [6]. The NRC was satisfied with Exelon's response [7].

   b. [ ] As part of the repair process, the whole length of the inner diameter of the remaining Alloy 600 nozzle affected by the repair is required to pass penetrant testing (PT) after machining [2] [3]. The lack of PT indications is commonly accepted as indicative of a flaw-free surface. While PT has missed reasonably deep cracks in CRDM nozzle welds, it is acknowledged that a higher quality inspection surface may help improve the reliability of the PT [8]. The surface of the CRDM nozzle weld in Reference [8] was decontaminated using pellet blasting and repeated application of replica material followed by repeated application of an etchant-gel wiped away with a cloth. [ ]

c. [ ] After performing the IDTB weld, the inner diameter of the Alloy 600 nozzle will be bored, [ ]

2. [ ]

3. [ ]

2.2 Assumptions Requiring Verification

There are no assumptions requiring verification.

3.0 EVALUATION

In November 2001, the NRC published flaw acceptance criteria for axial flaws in CRDM nozzle pressure boundary material [9]. In the repair configuration for Byron Units 1 and 2 and Braidwood Units 1 and 2 RVCH penetration nozzles, the final pressure boundary is comprised of the remaining Alloy 600 nozzle material and the Alloy 52/52M/52MSS [1] IDTB weld material. The maximum allowable flaw depth is 75% of the (original) nozzle wall thickness for pressure boundary material. Therefore, where surface remediation is performed, the life of the repair will be based on the estimated time for a PWSCC flaw to propagate through 75% of the thickness of the original Alloy 600 nozzle, considering no initiation time of the PWSCC flaw in the absence of a compressive stress layer. For the case where no surface remediation is performed, the life of the repair is conservatively estimated from initiation time operating experience at Byron Units 1 and 2 and Braidwood Units 1 and 2.

Stress corrosion cracking requires three synergistic components to occur: 1) susceptible material, 2) aggressive environment, and 3) a sustained tensile stress. Based on laboratory testing and operating experience, Alloy 600 is susceptible to PWSCC in PWR primary water when sufficient tensile stresses are present (typically due to weld residual stresses) [10]. [ ]

This evaluation will estimate the service life (regarding PWSCC) of the remaining Alloy 600 nozzle material affected by the repair for the following three scenarios: 1) no surface remediation, 2) optional AWJM, and 3) optional rotary peening.

3.1 Scenario #1: Weld Repair without Surface Remediation

By not performing any surface remediation process, the remaining Alloy 600 nozzle affected by the repair will be susceptible to PWSCC. Initiation of a PWSCC crack can sometimes take decades, but laboratory testing [10] and operating experience [11] also indicates that initiation can occur almost immediately in some cases. For the over 300 Alloy 600 nozzles in service at Byron and Braidwood, PWSCC initiation at the IDTB weld was first identified in 1 nozzle approximately 20 years after plant startup and later in 6 additional nozzles approximately 25 years after plant startup [12,13]. Therefore, it is unlikely that PWSCC initiation will occur in these same Alloy

600 nozzles within one fuel cycle following a weld repair without surface remediation. Thus, a 2 EFPY estimated life (based on initiation time alone, conservatively neglecting crack growth) is reasonable and conservative. Since this estimated life is based on initiation time and not crack growth, additional analysis would be required to support more than 2 EFPY of operation, even if subsequent in service inspection results show no relevant indications.

3.2 Scenario #2: Weld Repair with AWJM

The AWJM process removes material from the ID surface of the Alloy 600 remnant nozzle and creates a shallow compressive stress layer. [

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The Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) has conducted a test program of various Alloy 600 RVCH penetration PWSCC mitigation techniques including AREVA's AWJM process. Other mitigation techniques tested in the program include: excavation weld repair, laser cladding, laser weld repair, EDM, flapper wheel, shot peening, brush Ni plating, and electroless Ni plating. Alloy 600 samples mitigated by each technique were autoclave tested under accelerated SCC conditions at 750°F in doped steam with hydrogen. Many of the mitigation techniques showed SCC in 100 to 1996 hours of testing, but AWJM samples showed no evidence of SCC after 2000 hours of testing [14]. These results support that AWJM mitigates PWSCC initiation.

[

] A minimum compressive stress layer of 0.003 inches deep was observed. [

] of 0.002 inches, the remaining minimum compressive stress layer would be 0.001 inches.

Since PWSCC initiation is not expected in the compressive stress region induced by the AWJM process, the dominant degradation mechanism is considered to be general corrosion. The AWJM remediated Alloy 600 surfaces will be effectively mitigated relative to PWSCC provided that the layer of surface compressive stresses is intact. Laboratory testing of Alloy 600 in an environment consistent with CRDM nozzles resulted in an average general corrosion rate [

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3.3 Scenario #3: Weld Repair with Rotary Peening

Rotary peening is a captive shot technology that was originally developed by 3M Corporation for small and/or hard-to-reach surfaces. This process creates compressive residual stresses on the surface much like traditional shot peening, except that the rotary peening process is more controlled and thus results in a more consistent and uniform compressive stress layer. Surface remediation using rotary peening should inhibit PWSCC initiation based on the principle that PWSCC requires a sustained tensile stress and the peening process will create a uniform compressive stress layer.

As mentioned in the previous section, the EPRI MRP conducted a test program of various Alloy 600 RVCH penetration PWSCC mitigation techniques, which included flapper wheel and shot peening [14]. The flapper wheel technique discussed in Reference [14] is a grinding process and is not similar to rotary peening. Rotary peening is a captive shot technology, which is expected to perform very similarly to shot peening regarding inhibiting PWSCC initiation. The conclusions of the EPRI report indicate that shot peening was among the best techniques tested with no PWSCC observed in sample regions applicable to remediation performed at an operating plant. The sample region that was considered not applicable was at the cut edge of the sample where the compressive stress field was compromised.

[

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As discussed in the previous section, PWSCC initiation is not expected in the compressive stress region induced by the rotary peening process; thus general corrosion is considered to be the dominant degradation mechanism for the remnant Alloy 600 nozzle. [ ] it is estimated to take 100 EFPY for the compressive stress layer to be removed. [

]

[2] For conservatism, intermediate calculation values are truncated instead of rounded.

4.0 REQUIRED REMEDIATION LENGTH

The purpose of this section is to establish the remediation length [ ] needed to ensure all regions with stress > 20 ksi (per Code Case N-729-1]) are remediated. [19]

[

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[

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Figure 4-1: Distinction between Top of Rolled Transition and Effective Length of Roll Expansion

5.0 CONCLUSION

An evaluation of PWSCC initiation and growth was performed for the proposed RVCH penetration IDTB weld repair process with consideration of 1) no surface remediation, 2) AWJM remediation, and 3) rotary peening remediation for Byron Units 1 and 2 and Braidwood Units 1 and 2. Conservative assumptions were used for the flaw initiation time and CGR. The industry adopted 75% though-wall flaw acceptance criterion was used.

The estimated minimum time for a PWSCC flaw to reach through 75% of the original wall thickness is 2 EFPY for no surface remediation, [ ] over 100 EFPY for rotary peening surface remediation.

[

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6.0 REFERENCES

1. AREVA Document 08-9232121-000, "Byron Units 1 and 2 and Braidwood Units 1 and 2, RVCH Nozzle Penetration Modification."
2. AREVA Drawing 02-9232823E-000, "Byron Units 1 and 2 / Braidwood Units 1 and 2 CRDM, Spare, & RVLIS Penetration Modification."
3. AREVA Drawing 02-9232824E-000, "Byron Units 1 and 2 / Braidwood Units 1 and 2 Thermocouple Column Penetration Modification."
4. NRC Information Notice 96-11, "Ingress of Demineralizer Resins Increases Potential for Stress Corrosion Cracking of Control Rod Drive Mechanism Penetrations," February 14, 1996.
5. NRC Generic Letter 97-01, "Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations," April 1, 1997.
6. Letter from John B. Hosmer, Commonwealth Edison Company (ComEd) to Nuclear Regulatory Commission, "Commonwealth Edison Company (ComEd) Response to NRC Generic Letter 97-01, "Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations," Dated April 1, 1997, July 30, 1997, NRC Accession Number 9708040212.
7. Letter from George F. Dick, NRC, to Oliver D. Kingsley, Commonwealth Edison Group, "Generic Letter 97-01, 'Degradation of CRDM/CEDM Nozzle and Other Vessel Closure Head Penetrations' – Byron Station, Units 1 and 2 and Braidwood Station, Units 1 and 2 (TAC Nos. M98549, M98550, M98547, and M98548), December 8, 1999, NRC Accession Number ML993490331.
8. NRC Report NUREG/CR-6996 (PNNL-18372), "Nondestructive and Destructive Examination Studies on Removed-from-Service Control Rod Drive Mechanism Penetrations," July 2009, NRC Accession Number ML092170313 and ML092170314.
9. Letter from J. Strosnider, NRC, to A. Marion, NEI, "Flaw Evaluation Guidelines," NRC Accession Number ML013250451.
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12. "Exelon Presentation Slides for December 10, 2014 Meeting on Alloy 600 PWSCC Mitigation for RVH Nozzles", NRC Accession Number ML14342A812.
13. NUREG-1350, Volume 27, "Information Digest, 2015-2016", NRC Accession Number ML15254A321.
14. Materials Reliability Program: An Assessment of the Control Rod Drive Mechanism (CRDM) Alloy 600 Reactor Vessel Head Penetration PWSCC Remedial Techniques (MRP-61), EPRI, Palo Alto, CA: 2003. 1008901.
15. AREVA Document 51-5002387-03, "AWJ Remediation of Alloy 600 CRDM Nozzle-Material Test Results."
16. AREVA Document 51-1236573-02, "Corrosion Rate of Control Rod Drive Materials."

17. Materials Reliability Program Crack Growth Rates for Evaluation Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Materials (MRP-55) Revision 1, EPRI, Palo Alto, CA: 2002. 1006695.

18. AREVA Document 51-9218367-001, "Compressive Stress Depth Profile Produced by Rotary Peening on Alloy 600 [3M® TC330 Roto Peen]."

19. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel (B&PV) Code, Code Case N-729-1, "Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds, Section XI, Division 1," March 28, 2006.

20. AREVA Document 32-9247532-002, "Byron & Braidwood Units 1 & 2 CRDM Nozzle Repair Analysis for Roll Expansion and Operating Conditions."

ATTACHMENT 5

AREVA Inc., Affidavit for AREVA documents, March 11, 2016

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Morris Byram. I am Manager, Product Licensing, for AREVA Inc. (AREVA) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA to determine whether certain AREVA information is proprietary. I am familiar with the policies established by AREVA to ensure the proper application of these criteria.

3. I am familiar with the AREVA information contained in the following AREVA Engineering Information Records: 51-9233902-002, "PWSCC Evaluation for Contingency RVCH Nozzle Repairs at Byron Units 1 and 2 and Braidwood Units 1 and 2," dated March 11, 2016; and 51-9240805-003, "Byron Units 1 & 2, and Braidwood Units 1 & 2 IDTB Reactor Vessel Head Penetration Nozzle Weld Repair-Life Assessment Summary ," dated March 11, 2016, and referred to herein as "Documents." Information contained in these Documents has been classified by AREVA as proprietary in accordance with the policies established by AREVA Inc. for the control and protection of proprietary and confidential information.

4. These Documents contain information of a proprietary and confidential nature and are of the type customarily held in confidence by AREVA and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in these Documents as proprietary and confidential.

5. These Documents have been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in these Documents

be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA, would be helpful to competitors to AREVA, and would likely cause substantial harm to the competitive position of AREVA.

The information in these Documents is considered proprietary for the reasons set forth in paragraphs 6(b), 6(c), and 6(d) above.

7. In accordance with AREVA's policies governing the protection and control of information, proprietary information contained in these Documents has been made available, on a limited basis, to others outside AREVA only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Marvin E. Beyer

SUBSCRIBED before me this 11th
day of March, 2016.

Sherry L. McFaden
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 10/31/18
Reg. # 7079129

SHERRY L. MCFADEN
Notary Public
Commonwealth of Virginia
7079129
My Commission Expires Oct 31, 2018