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Proprietary information contained in Attachments 2, 3, 4 and 5
Withhold from public disclosure under 10 CFR 2.390
When separated, the cover letter and remaining attachments are Non-Proprietary

RS-17-039

10 CFR 50.55a

March 31, 2017

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

Braidwood Station, Unit 1
Renewed Facility Operating License No. NPF-72
NRC Docket No. STN 50-456

Subject: Request for Relief for Extension of Examination Interval for Reactor Pressure Vessel Head Penetration Nozzles with Mitigated Alloy 600/82/182 Peened Surfaces in Accordance with 10 CFR 50.55a(z)(1)

References:

1. Electric Power Research Institute (EPRI), Materials Reliability Program: Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement (MRP-335 Revision 3-A), EPRI Publication No. 3002009241, Final Report, dated November 2016

2. Letter from Kevin Hsueh, (U.S. NRC) to Matthew Sunseri, (EPRI), "Final Safety Evaluation of the Electric Power Research Institute MRP-335, Revision 3, 'Materials Reliability Program: Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement [Peening],'" dated August 24, 2016 (ML16208A485)

In accordance with 10 CFR 50.55a, "Codes and standards," paragraph (a)(z)(1), Exelon Generation Company, LLC (EGC), is requesting relief from the current examination requirements of Reactor Pressure Vessel Head Penetration Nozzles (RPVHPN) performed in accordance with 10 CFR 50.55a(g)(6)(ii)(D), which specifies the use of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," Code Case N-729-1 on the basis that the proposed alternative would provide an acceptable level of quality and safety.

EGC has implemented the Ultra High Pressure Cavitation Peening (UHPCP) process at Braidwood Station Unit 1 and is requesting a change to the examination interval of the follow-up inspections for peened RPVHPNs and associated welds in accordance with References 1 and 2; including relief from the Reference 2 Condition 5.4 (b) requirement for inspection in the first refueling outage after peening.

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Specifically, as discussed in the Attachment 1 Relief Request, Code Case N-729-1 (as conditioned by 10 CFR 50.55a(g)(6)(ii)(D)) requires volumetric and/or surface examination of the Braidwood Station Unit 1 RPVHPNs and associated welds of all nozzles every refueling outage or one fuel cycle, nominally every 18 months. However, the examination schedule of N-729-1 does not address the effects of Surface Stress Improvement (SSI) by peening or the associated inspection frequency for RPVHPNs in this mitigated state. Using analytical tools, EPRI developed a revised volumetric or surface inspection frequency interval for Alloy 600 RPVHPNs and Alloy 82/182 partial-penetration (J-groove) attachment welds that have received peening application (i.e., Reference 1). This technical basis demonstrates that for any peening SSI process meeting the performance criteria of section 4.3.8 of Reference 1, the inspection frequency interval can be changed. The examination schedule in Table 4-3 is supported by the Reference 2 Final Safety Evaluation. EGC proposes to follow the inspection interval specified in Reference 1 Table 4-3 with an additional request for relief from the Table 4-3 Note (11)(b) requirement for inspection in the first refueling outage after peening as described in Attachment 1.

The Attachment 1 Relief Request section 5.4.8 identifies conditions that occurred during implementation of the reactor head peening during the Fall 2016 Braidwood Station Refueling Outage (A1R19) that resulted in essential variables / critical parameters that were outside of qualified ranges but were later evaluated and satisfactorily dispositioned such that the peened nozzles remain within the scope of the Attachment 1 Relief Request.

The Attachment 2 "Summary Report, RVCH Peening Implementation, Braidwood Unit 1" section 2.5 identifies Condition Report (CR) CR-2017-1767 and CR-2017-1944 which discuss two peening process legacy issues identified during the Spring 2017 Byron Station Unit 1 outage (B1R21). These legacy issues resulted in the identification that certain Braidwood Station Unit 1 nozzles may not meet the essential variables/critical parameters in section 4.3.8 of MRP-335, R3-A. This will result in additional testing to verify if these nozzles met the MRP-335 requirements. If not, these nozzles will be re-peened during the next outage to meet the MRP-335 requirements. Once the requirements of MRP-335 are confirmed to be met through additional testing or repeening, these nozzles will be part of the Attachment 1 Relief Request ASME Code Component scope (see Attachment 1 section 1 "Identification" and associated note).

In accordance with 10 CFR 50.55a(z)(1), the proposed alternatives may be approved by the NRC provided an acceptable level of quality and safety are maintained. EGC concludes the proposed alternatives meet this requirement.

Attachments 2, 3, 4 and 5 contain proprietary information as defined by 10 CFR 2.390, "Public inspection, exemption, requests for withholding." AREVA, Inc, (AREVA) as the owner of proprietary information has executed the enclosed affidavits, 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 affidavits. The proprietary information has been faithfully reproduced in the attached information such that affidavits remain 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 affidavits supporting the proprietary nature of the information is contained in Attachments 7, 8, 9 and 10.

EGC requests approval of the proposed alternative by March 31, 2018, in support of the Spring Braidwood Station Unit 1 Refueling Outage (A1R20).

There are no regulatory commitments contained within this letter.

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:	10 CFR 50.55a Request Number I3R-22, Request for Relief for Extension of Examination Interval for Reactor Pressure Vessel Head Penetration Nozzles with Mitigated Alloy 600/82/182 Peened Surfaces in Accordance with 10 CFR 50.55a(z)(1)
Attachment 2:	AREVA Document # 51-8093944-001, "Summary Report, RVCH Peening Implementation, Braidwood Unit 1" (PROPRIETARY) (NOTE: This report is included through Appendix A. The remaining Appendices (i.e., B, C, and D) are not included)
Attachment 3:	AREVA Document # 150-8086004-001, "Special Process Qualification Record (SPQR)" (PROPRIETARY)
Attachment 4:	AREVA Document #32-9241722-001, "Byron and Braidwood Peening Residual Plus Operating Stress Analysis" (PROPRIETARY)
Attachment 5:	AREVA Document 51-9238120-002, "PWSCC Evaluation of UHP Cavitation Peening for Byron and Braidwood Reactor Vessel Head Penetrations" (PROPRIETARY)
Attachment 6:	AREVA Document 51-9263014-000, "PWSCC Evaluation of UHP Cavitation Peening for Byron and Braidwood Reactor Vessel Head Penetrations" (NON-PROPRIETARY)
Attachment 7:	AREVA Inc., Affidavit for 51-8093944-001, "Summary Report, RVCH Peening Implementation, Braidwood Unit 1" dated March 27, 2017
Attachment 8:	AREVA Inc., Affidavit for 150-8086004-001, "Special Process Qualification Record (SPQR)" dated December 7, 2016

Attachment 9: AREVA Inc., Affidavit for 32-9241722-001, "Byron & Braidwood Peening Residual plus Operating Stress Analysis" dated October 7, 2016

Attachment 10: AREVA Inc., Affidavit for 51-9238120-002, "PWSCC Evaluation of UHP Cavitation Peening for Byron and Braidwood Reactor Vessel Head Penetrations" dated October 7, 2016

Cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Braidwood Station
Illinois Emergency Management Agency

ATTACHMENT 1

10 CFR 50.55a Request Number I3R-22, Request for Relief for Extension of Examination Interval for Reactor Pressure Vessel Head Penetration Nozzles with Mitigated Alloy 600/82/182 Peened Surfaces in Accordance with 10 CFR 50.55a(z)(1)

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Request for Relief
Extension of Examination Interval for Reactor Pressure Vessel Head Penetration Nozzles with Mitigated Alloy 600/82/182 Peened Surfaces in Accordance with 10 CFR 50.55a(z)(1)

1.0 ASME CODE COMPONENTS AFFECTED:

Component Numbers:	Unit 1, Reactor Vessel 1RC01R
Description:	Extension of Examination Interval for Reactor Pressure Vessel Head Penetration Nozzles (RPVHPNs) Having Pressure-Retaining Partial-Penetration J-groove Welds with Mitigated Alloy 600/82/182 Peened Surfaces
Code Class:	Class 1
Examination Category:	ASME Code Case N-729-1
Code Item:	B4.20
Identification:	RPVHPN Numbers 1 through 78 and vent, (P-1 through P-78 and vent) [1]
Reference Drawing:	Closure Head Assembly: 185313E
Size:	4 Inch Nominal Outside Diameter, 2.75 Inch Nominal Inside Diameter (Vent Nozzle NPS 1)
Material:	SB-167 UNS N06600 (Alloy 600), ENiCrFe-3 (Alloy 182), and ERNiCr-3 (Alloy 82)

2.0 APPLICABLE CODE EDITION AND ADDENDA:

Inservice Inspection (ISI) and Repair/Replacement Programs: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, 2001 Edition including Addenda through 2003 [1]. Examinations of the RPVHPNs are performed in accordance with 10 CFR 50.55a(g)(6)(ii)(D), which specifies the use of ASME Code Case N-729-1 with conditions.

Code of Construction [Reactor Pressure Vessel (RPV)]: ASME Section III, 1971 Edition through Summer 1973 Addenda.

[1] Applies to RPVHPNs mitigated in accordance with section 4.3.8 of MRP-335, R3-A [16]

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3.0 APPLICABLE CODE REQUIREMENT:

ASME Code Case N-729-1 contains requirements for the inspection of RPVHPNs, with or without flaws, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D). The specific Code requirements for which use of the proposed alternative is being requested are as follows:

Code of Federal Regulations (CFR) 10 CFR 50.55a(g)(6)(ii)(D)(1) requires (in part):

"All licensees of pressurized water reactors must augment their inservice inspection program with ASME Code Case N-729-1, subject to the conditions specified in paragraphs (g)(6)(ii)(D)(2) through (6) of this section. Licensees of existing operating reactors as of September 10, 2008 must implement their augmented inservice program by December 31, 2008."

10 CFR 50.55a(g)(6)(ii)(D)(3) conditions ASME Code Case N-729-1 by stating:

"Instead of the specified 'examination method' requirements for volumetric and surface examinations in Note 6 of Table 1 of Code Case N-729-1, the licensee must perform volumetric and/or surface examination of essentially 100 percent of the required volume or equivalent surfaces of the nozzle tube, as identified by Figure 2 of ASME Code Case N-729-1. A demonstrated volumetric or surface leak path assessment through all J-groove welds must be performed. If a surface examination is being substituted for a volumetric examination on a portion of a penetration nozzle that is below the toe of the J-groove weld (Point E on Figure 2 of ASME Code Case N-729-1), the surface examination must be of the inside and outside wetted surface of the penetration nozzle not examined volumetrically."

ASME 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 [2], Figure 2, "Examination Volume for Nozzle Base Metal and Examination Area for Weld and Nozzle Base Metal," is applicable to the RPVHPNs.

ASME Code Case N-729-1, Paragraph -2410 specifies that the reactor vessel upper head penetrations shall be examined on a frequency in accordance with Table 1 of the code case (Refer to Reference 2, hereafter known as N-729-1). However, 10 CFR 50.55a(g)(6)(ii)(D)(5) states "If flaws attributed to PWSCC have been identified, whether acceptable or not for continued service under Paragraphs –3130 or –3140 of ASME Code Case N–729–1, the re-inspection interval must be each refueling outage instead of the re-inspection intervals required by Table 1, Note (8), of ASME Code Case N-729-1." Since flaws attributed to PWSCC have been identified at Braidwood Station Unit 1, the RPVHPNs are examined every fuel cycle in accordance with 10 CFR 50.55a(g)(6)(ii)(D)(5).

As an alternative to the requirements above, required inspections will be conducted in accordance with the inspection requirements for Alloy 600 RPVHPNs mitigated by peening, based on Table 4-3 in MRP-335, Revision 3-A, "Materials Reliability Program: Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement," November 2016, (Reference 16); including relief from Final Safety Evaluation Condition 5.4 requirement for inspection in the first refueling outage post

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peening application (i.e., N+1 outage) which is reflected in Reference 16 Table 4-3 Note (11)(b).

4.0 REASON FOR REQUEST:

Exelon Generation Company, LLC (EGC) has implemented the Ultra High Pressure Cavitation Peening (UHPCP) process at Braidwood Station Unit 1 and is requesting a change to the reexamination interval of the follow-up inspections for peened RPVHPNs and associated welds in accordance with Reference 16 Table 4-3 with an additional request for relief from the Table 4-3 Note (11)(b) requirement for follow-up inspection in the first refueling outage after peening.

As discussed in section 3.0, N-729-1 as conditioned by 10 CFR 50.55a(g)(6)(ii)(D)(5) requires volumetric and/or surface examination of the Braidwood Station Unit 1 RPVHPNs and associated welds of all nozzles every refueling outage or one fuel cycle, nominally every 18 months. The examination schedule of N-729-1 does not address the effects of Surface Stress Improvement (SSI) by peening or the associated inspection frequency for RPVHPNs in this mitigated state. Electric Power Research Institute (EPRI) developed, using appropriate analytical tools, a volumetric or surface re-examination interval for Alloy 600 RPVHPNs and Alloy 82/182 partial-penetration (J-groove) attachment welds that have received peening application. This technical basis demonstrates that for any peening SSI process meeting the performance criteria of section 4.3.8 of Reference 16, the re-examination interval can be changed to the Table 4-3 inspection schedule.

As described in detail in section 5.0 of this relief, the UHPCP process implemented at Braidwood Station Unit 1 meets or exceeds the SSI residual plus operating stress, the coverage area and the depth of compression requirements specified in MRP-335. In addition, considering the deterministic analysis work described by EPRI [16] and by ASME in section 5.4.7 of this relief, EGC is requesting a change from the Final Safety Evaluation Condition 5.4 requirement for follow-up inspection in N+1, which is reflected in Reference 16 Table 4-3 Note (11)(b).

5.0 PROPOSED ALTERNATIVE AND BASIS FOR USE:

5.1. Introduction

The peening process was developed by the peening vendor (AREVA) as a Special Process in accordance with 10 CFR 50 Appendix B. Qualification of the AREVA UHPCP process on RPVHPNs for the purpose of PWSCC mitigation is documented in the Special Process Qualification Report [7].

Peening Mechanism for PWSCC Mitigation

When the applicable MRP-335 performance criteria are met, peening mitigation prevents initiation of PWSCC [16]. The possibility of pre-existing flaws that are not detected in the pre-peening Nondestructive Examination (NDE) is addressed through the required follow-up inspection that is performed during the second refueling outage (N+2) after application of peening. Peening also has the benefit of arresting PWSCC growth of shallow surface flaws that are located in regions at the surface where the residual plus

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normal operating stress is now compressive [16][15]. This secondary benefit is not credited in the main analyses of MRP-335 because these analyses conservatively assume that the bounding stress effect meeting the performance criteria is achieved.

In order to prevent the initiation of new PWSCC, the application of peening has to result in the peak tensile stresses at the wetted surface of material being less than the "threshold" stress for initiation of PWSCC. Based on laboratory testing, a tensile stress of +20 ksi is a conservative lower bound of the stress level below which PWSCC initiation will not occur over plant time scales per MRP-95 [5]. This applies to steady-state stresses during normal operation since stress corrosion cracking (SCC) initiation is a long-term process, and does not apply to transient stresses that occur only for relatively short periods of time. Additional conservatism is provided by the MRP-335 performance criterion limiting the surface stress to +10 ksi (tensile) for the case of RPVHPNs when normal operating stresses are considered [16].

The potential for growth of small flaws too shallow to be reliably detected in the pre-peening ultrasonic (UT) examination, or for flaws located in the J-groove weld metal, is addressed by the follow-up UT examination, and by the ongoing visual examinations for evidence of leakage performed at the same schedule as prior to peening. The N+2 and subsequent program of inspections addresses growth of any flaws via PWSCC that may not have been detected in the pre-peening examination. For the cold head operating conditions of the Braidwood Station RPVHPNs and 18 month refueling cycle, the bases described in Reference 16 section 5.2.3.2 supports the 36 month follow-up inspection time.

Stress Effect to Prevent Future PWSCC Initiations

The compressive residual stress depth required by the performance criteria ensures that the stress improvement effect extends a significant distance into the material. The Braidwood Station Unit 1 peening met or exceeded the MRP-335 depth of compression requirements. The deterministic and probabilistic analyses in MRP-335 that form the basis for the requested inspection relief show that it is not necessary for growth of shallow pre-existing flaws to be arrested by the post-peening stress field. Pre-existing flaws are effectively addressed by the combination of pre-peening and follow-up inspections. In cases when a shallow pre-existing flaw is located within a region of compressive residual plus operating stress, PWSCC growth of the pre-existing flaw would be arrested [16]. In the event of a pre-existing flaw that exists below the depth of peening application, probabilistic and deterministic evaluations show that the flaw growth and detection in N+1 is unlikely due to the Tcold head environment. The probability of flaw detection supports performing inspection in N+2 (Reference 16, section 5.1).

Effect of Pre-Existing Residual Stresses

High residual tensile stresses do not interfere with the ability of peening to develop the stress effect needed to be effective [6]. The peening effect is self-normalizing with regard to the level of pre-peening residual stresses [16][7]. A study was performed by AREVA (Item 9 of Attachment 1 of Reference 11) to verify that the unpeened residual stress state of the material does not have a significant effect on the final peened surface compressive stress and depth of compression. Testing supports that regardless of the initial stress state (i.e., high tension or high compression), the final compressive stresses ended up within a -63 ksi to -81 ksi range [16]. Theory and test data show that peening results in high compressive residual stresses regardless of the starting state of the residual stresses.

5.1.1 Proposed Alternative

EGC is requesting relief from the examination frequency requirements of 10 CFR 50.55a(g)(6)(ii)(D)(5), for performing volumetric and/or surface examinations of the Braidwood Station Unit 1 RPVHPNs each refueling outage. Specifically, relief is requested to allow an alternative inspection frequency consistent with requirements of MRP-335 Revision 3-A, Table 4-3 with an additional request for relief from the Table 4-3 Note (11)(b) requirement for follow-up inspection in the first refueling outage after peening.

The alternative inspection frequency requirements for Item B4.60 RPVHPNs mitigated by peening SSI per MRP-335 Table 4-3 [16] require a pre-peening baseline inspection, follow-up inspection, and subsequent in-service inspection, as summarized below.

Pre-Peening Baseline Inspection

Prior to performance of peening but during the same outage, examinations are to be performed in accordance with the requirements in Reference 16 Table 4-3, Note (13). Examinations include volumetric or surface examinations of essentially 100% of the required volume or equivalent surfaces of the nozzle tube as identified in Figure 2 of N-729-1, and a demonstrated volumetric or surface leak path assessment through all J-groove welds. The leak path examination detects through-wall cracking by checking for areas at the interface (annulus) between the nozzle tube and low-alloy steel head where leakage has caused a loss of interference fit. The analyses in Section 5 and Appendix B of MRP-335 conservatively do not take credit for the leak path examination.

Follow-Up Inspection

During the follow-up inspection, a volumetric examination of 100% of the required volume or equivalent surfaces of the nozzle tube is to be performed and a leak path examination is also to be performed. EGC proposes to follow the inspection interval specified in MRP-335 Table 4-3 [16] with an additional request for relief from the Table 4-3 Note (11)(b) requirement for follow-up inspection in the first refueling outage after peening. The follow-up inspection schedule is based on the value of the effective degradation year (EDY) parameter (defined in N-729-1) at the time of peening. EGC's proposed alternative is consistent with the Reference 4 Table 4-3 Note (11)(b) requirement, for plants where EDY < 8 at the time of peening and containing pre-existing flaws a follow-up inspection is to be performed in the second (N+2) refueling outage subsequent to peening (EDY=3.81 at the time of peening for Braidwood Station Unit 1). Furthermore, for the cold head operating conditions of the Braidwood Station RPVHPNs and 18 month refueling cycle, the bases described in Reference 16 section 5.2.3.2 supports the 36 month follow-up inspection time.

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Subsequent ISI Program

The ISI program interval examinations take effect after completion of the follow-up inspection per Item B4.60, Table 4-3 [16]. Examinations include volumetric or surface examinations of peened penetrations at an interval not to exceed one inspection interval (nominally 10 calendar years), and a demonstrated volumetric or surface leak path assessment through all J-groove welds each time the periodic volumetric or surface examination is performed.

5.2. Description of Application Specific Process

PWSCC is mitigated via surface remediation by inducing a compressive stress layer in the surface of each nozzle and J-groove weld at the Braidwood Station Unit 1 RPVHPNs through the application of water jet UHPCP as qualified in the Special Process Qualification Report (SPQR) [7] by AREVA. This compressive stress layer has been demonstrated to prevent PWSCC initiation [15].

5.2.1 Description of Peened Components and Selection of Peened Area

UHPCP was applied to the outer and inner surfaces of the Alloy 600/182/82 materials. Peening of the OD of the nozzle and outer weld surface was performed using an OD tool that rotates the water jet around the outer circumference of the nozzle and weld material (Figure 5.2.1-1). Note that a shoulder area of the Core Exit Thermocouple Column (CETC) funnel (upper collar), that when seated to the CETC nozzle penetration tube, physically blocked access to the required surface area to be peened. The portion of the funnel upper collar that was covering the +20 ksi area on the downhill side of the CETC nozzles was removed to permit peening of the +20 ksi area. Electrical Discharge Machining (EDM) was used to remove this piece of the funnel, which allowed the guide funnels to remain in place while the required high stress (+20 ksi) mitigation area was peened (Figure 5.2.1-2).

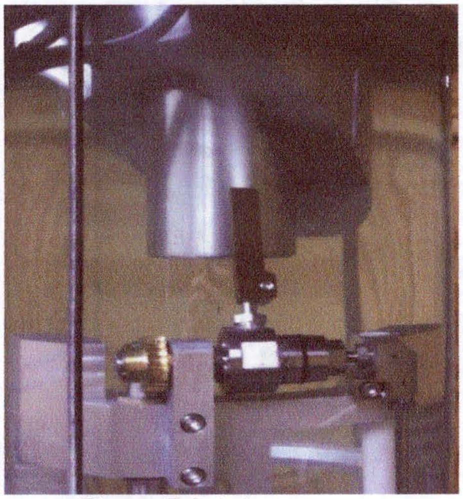
Figure 5.2.1-1

Figure 5.2.1-2

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Accessibility of the nozzle OD and J-groove weld surfaces is sufficient to permit UHPCP to meet and exceed the 0.04 inch minimum depth of compression for RPVHPNs. Peening the ID surface of the nozzle was performed using an ID tool that rotates the water jet around the inner circumference of the nozzle. For open penetrations and the vent line, the ID open penetration/vent line tool rotates the water jet around the inner circumference of the nozzle as the water jet is applied directly from inside the nozzle. For ID nozzles with thermal sleeves, the ID annulus tool moves the thermal sleeve to one side to allow the water jet access to fit into the annulus region between the OD of the thermal sleeve and ID of the nozzle. This allows the water jet to peen the inner circumference of the nozzle from inside the annulus region. The ID annulus tool has sufficient clearance to meet and exceed the 0.01 inch minimum depth of compression for RPVHPNs. See SPQR section 4.0 [7].

The outer surface (nozzle OD and weld) and nozzle ID peening mitigation coverage was based on Figure 2 of N-729-1, which is also the extent of the ISI inspection area. The extent of peening coverage on the nozzle and weld outer surface is zone G-F-E-C. The extent of peening coverage on the nozzle ID surface is zone A-D. Note: the surfaces required to be peened are defined in Figures 4-1, 4-2 and 4-3 of MRP-335, which is less OD surface area than that identified in Figure 2 of N-729-1. Thus, the Braidwood Station Unit 1 nozzle OD peened surface area exceeded the MRP-335 peening area mitigation requirement. This margin is discussed in section 5.4 of this relief with additional detail provided in the post peening Summary Report [14].

<u>Peening of Previously Repaired RPVHPNs</u>

Exceptions to the above RPVHPNs are nozzles that have been previously repaired e.g., nozzles that were repaired by weld overlay. This type of repair is known as an embedded flaw repair. Braidwood Station Unit 1 penetration 69 was previously repaired by weld overlay. For this penetration, peening of the weld repair area is not required since this weld material is PWSCC resistant (J-groove weld area and portions of the nozzle tube OD that are covered by the repair weld). However, peening of the ID and the portion of the nozzle tube OD surfaces not having weld repair material is required from the weld overlay to the top of the threads.

The Braidwood Station Unit 1 nozzle 69 J-groove weld and top portion of the nozzle OD has been mitigated with a weld overlay. The OD of the nozzle below the weld overlay to the top of the threads was peened and the required nozzle ID area was peened.

The exposed areas of Alloy 52 weld metal (overlay) are not required to be peened since Alloy 52 is PWSCC resistant per MRP-375 [8] and section 4.3.7 of MRP-335 [16]. Therefore, from the perspective of susceptibility to PWSCC degradation, a penetration repaired using the embedded flaw repair technique (i.e., with an Alloy 52 repair weld applied to the J-groove weld area and portion of the nozzle tube OD) is mitigated. Subsequent to peening the unrepaired OD and ID, the nozzle areas with Alloy 600 material in contact with reactor coolant, will have a residual plus operating surface stress well below that necessary to initiate PWSCC per the residual plus operating stress analysis [13].

If the requirements of section 4.3 of MRP-335 are satisfied, a RPVHPN with flaws that has been corrected and subsequently peened using a process meeting the performance criteria of section 4.3.8 of MRP-335 may be identified as Item B4.60 in Table 4-3 (Note 12) of MRP-335. Thus, follow-up and ISI program examinations for weld overlay repaired nozzles subsequent to peening are equivalent to the follow-up and ISI program examinations for unrepaired nozzles subsequent to peening i.e., may be identified as Item B4.60.

5.2.2 Process Description

Performance demonstration is the method used to ensure that peening fully covers all of the areas that require peening, and achieves the desired magnitude and depth of residual compressive stresses. The critical parameters to be controlled ensure that peening develops the intended levels of compressive residual stresses in each peened area [7][14]. The SPQR is the Qualification Report that demonstrates desired results are achieved per MRP-335 with a bounded set of parameters. The UHPCP procedure implements the process per the requirements defined in the SPQR. During the implementation process, essential variables are recorded for each nozzle. Completed procedural enclosures and data output files are provided in the Summary Report [14] to document and log the performance results of the UHPCP process. The post peening Summary Report [14] confirms performance demonstration of peening at each nozzle and summarizes the essential variables/critical parameters.

Surface Condition Considerations

There are no limitations imposed by surface conditions on UHPCP. No preparations of the surfaces to be peened are required before peening is performed. In addition, there are no limitations on the peening caused by irregularities or undulations of the surface, such as those associated with weld beads, local grinding, or from initial forging [7].

Pre-Peening NDE

The pre-peening base line RPVHPN inspection was performed in accordance with N-729-1 as conditioned by 10 CFR 50.55a and found no conditions requiring repair in areas to be peened.

Contingencies

If critical parameters go outside of the specified range during the peening process, the issue is displayed on the peening controls system and evaluated or the process is shut down automatically. If peening is stopped for any reason the process is restarted in accordance with the approved peening process procedures to ensure adequate peening coverage. A Condition Report (CR) is issued if corrective action is required that is outside of the approved peening process procedures and appropriately evaluated by AREVA and EGC.

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5.3. Performance Criteria

The following is an overview of MRP-335 [16] performance criteria requirements for RPVHPN peening. The Braidwood Station Unit 1 UHPCP implementation demonstrated meeting or exceeding these criteria is addressed in detail in section 5.4 of this relief.

Stress Magnitude

The stress prior to consideration of operating stresses must be compressive on all peened surfaces. The residual stress plus operating stress on peened surfaces must not exceed +10 ksi (tensile).

Peening Coverage

The required coverage is the full wetted area of the susceptible material with surface stress (residual plus operating stress) of at least +20 ksi (tensile), which is a conservative measure of the threshold for PWSCC initiation [16][5]. The susceptible material locations to be considered are the wetted surface of the Alloy 82/182 J-groove weld and butter material and the surfaces of the Alloy 600 nozzle tube material in the region of the J-groove weld as defined in Figures 4-1, 4-2 and 4-3 of Reference 16.

Depth of Effect

The compressive residual stress field extends a nominal minimum depth of:
- 0.04 inch on the susceptible area of the outer nozzle and weld surfaces
- 0.01 inch on the susceptible area of the inner nozzle surface

Sustainability of Effect

The mitigation process is effective for at least the remaining service life of the component i.e., the residual plus operating surface stress state after considering the effects of thermal relaxation and load cycling (i.e., shakedown) must remain no greater than +10 ksi (tensile).

Inspectability

The capability to perform Ultrasonic Testing (UT) examinations of the relevant volume of the Alloy 600 nozzle tube material is not adversely affected, and the relevant volume or surface of the J-groove weld and Alloy 600 nozzle tube material is inspectable using a qualified process.

Lack of Adverse Effects

As verified by analysis or testing, the mitigation process is not to have degraded the component, caused detrimental surface conditions, or adversely affected other components in the system.

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5.4. Reactor Vessel CRDM UHPCP Implementation Results and Margins

This section provides detail on the AREVA Qualification Program, summarizes the Braidwood Station Unit 1 peening performance margin achieved in meeting or exceeding MRP-335 performance criteria, and highlights additional technical rigor performed to validate the peening process.

5.4.1 Qualification as a Special Process

Surface stress improvement by peening affects the performance of nuclear safety-related systems and components, thus, it shall be performed in accordance with a quality assurance program meeting the requirements of 10 CFR 50 Appendix B. Further, since peening is a special process, it is required to be controlled in a manner consistent with Appendix B Criterion IX, "Control of Special Processes."

Per Criterion IX, the personnel and procedures involved are required to be appropriately qualified. Since there are no industry standards that apply to peening, these qualifications shall be done to peening vendor requirements developed and documented per the vendor's 10 CFR 50 Appendix B quality assurance program.

The Qualification Program for the UHPCP process covered in this relief request was developed by AREVA and is documented in the Special Process Qualification Report [7]. The qualification program addresses both the generic process and, by use of representative test coupons, the effectiveness of the peening process when applied to the specific geometries of the components covered by this relief request.

Technical justification is included in the SPQR based on MRP-335 section 6.3. The specific process used has been demonstrated to be effective, including surface stress magnitude, compressive residual stress depth, and sustainability of the stress effect. Included is a description of the demonstration testing of peening of coupons representative of the geometry, material, accessibility, and surface condition of the component to be peened (see section 5.4.2 of this relief). The specific process has been demonstrated to result in no adverse effects (see section 5.4.6 of this relief). Essential variables with associated ranges of acceptable values are determined for the specific application, plus a description of the process controls is included which ensure essential variables remain within acceptable ranges (see sections 5.2.2 and 5.4.2 of this relief). Specific process controls were provided ensuring coverage requirements are met with a high degree of confidence, including what overlap of peening beyond the susceptible material is required (see section 5.2.2 and 5.4.2 of this relief). Disposition of non-conforming issues encountered are included (see section 5.2.2 of this relief).

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Critical Process Parameters and Acceptable Values

MRP-335 Performance Criterion 4.3.8.1 requires testing be performed "to demonstrate the critical process parameters and [to] define acceptable ranges of the parameters needed to ensure that the required residual stress field (exclusive of normal operating stresses) has been produced on the mitigated surface."

Demonstration that the stress improvement parameters are met is provided, in part, by verification that all of the control process parameters (essential variables) were maintained within the specified ranges during the application of UHPCP. The peening process parameters were maintained and verified within acceptable ranges [14]. The critical process parameters were monitored and recorded as described in the SPQR [7]. The data is reviewed and verified by AREVA's quality control. The essential variables/critical parameters and acceptable ranges for UHPCP implementation for Braidwood Station Unit 1 RVCH nozzle penetrations are provided in section 3.0 of the Summary Report [14].

5.4.2 Demonstration that Required Stress Effect is Achieved

In accordance with the performance criteria, testing and analysis demonstrate that the required stress improvement effect exceeded over 100% of the required area and that the required effect will be sustained for at least the remaining service life of the peened components. The stress effect is quantified to be conservative relative to that required in MRP-335 in terms of the residual plus operating stress at the peened surface and the depth of the compressive residual stress. The requested testing and analysis are documented in the Special Process Qualification Report [7] and summarized below.

Residual Stress Measurements Using Representative Test Coupons

Per the Special Process Qualification Report, demonstration testing has been performed in accordance with MRP-335 Performance Criterion 4.3.8.1 to determine the residual stress state at peened surfaces. Residual stress measurements were made for full scale peened test coupons representative of the geometry, material, accessibility, and surface condition of the components to be peened (see Figure 5.4.2-1 and Figure 5.4.2-2).

Figure 5.4.2-1, Representative Full Scale Coupon

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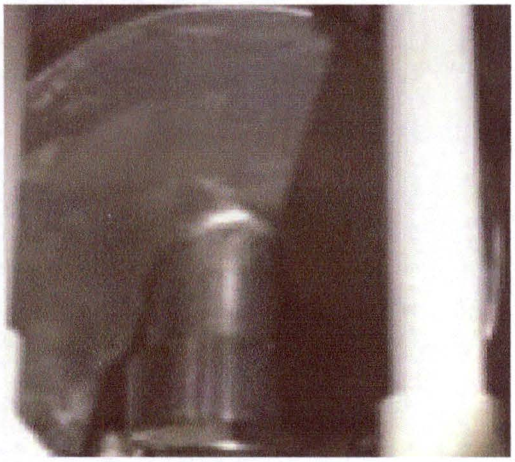

Figure 5.4.2-2, Representative Full Scale Coupon

The residual stress measurements satisfied the nominal depth requirement for the compressive residual stress of MRP-335 Performance Criterion 4.3.8.1.2. The magnitude of the residual stress at the surface was combined with the operating stress at the surface to demonstrate compliance with MRP-335 Performance Criterion 4.3.8.1.1. Key aspects of demonstration testing are provided below.

Site specific geometry is identified and validated through mockup testing. A total of 18 mockup coupons were peened as part of the qualification testing activity that included various RVCH penetration tiers and the head vent. A summary matrix of the qualification coupon peened surfaces is provided in the Special Process Qualification Report, Table 3-1 [7]. The test coupons were peened within control parameters that were recorded. As discussed in section 5.4.1 of this relief "Critical Process Parameters and Acceptable Values," this testing was used to determine the ranges of acceptable values for the critical process parameters for application in the plant. As simulated in the Qualification testing, UHPCP achieved the performance requirements despite the geometric limitations associated with the application of peening to RVCH penetrations, such as limited access associated with ID annulus peening or CETC downhill nozzle to RVCH head clearance.

The residual stress measurements ensure that the required stress effect was achieved in each portion of the component area required to be peened, including areas with different materials, curvature or accessibility. For RPVHPNs, the nozzle tube ID, nozzle tube OD, and weld surfaces are addressed. The actual peening coverage was checked during examination of the test coupons using X-ray Diffraction (XRD) of the peened surface. XRD testing confirmed that the compressive residual stress depth measurements met the requirement of the performance criteria. For each of the peened areas, the magnitude and depth of the compressive residual stresses that would be developed by lower bound allowable values of the critical peening parameters were identified. As analyzed, the post peening surface stress is not adversely affected by the effects due to operating stresses, load cycling (shakedown) and thermal stress relaxation [13].

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Verification and validation of the residual stress measurements on Alloy 600 and Alloy 182 materials used for the qualification mockups was demonstrated. As reported in the SPQR [7], the accuracy of each XRD measurement is recorded on the applicable laboratory data sheet. Typically, the highest accuracy is on the surface of the Alloy 600 base material with reduced accuracy at full depth (0.04 inch and deeper) in the Alloy 182 weld material. Using AREVA provided representative Braidwood RVCH test coupons (Inconel 600 nozzle / J-groove weld filler metals 82/182), the XRD vendor (PROTO) performed validation testing based on criteria from the ASM handbook publication (section G.2 of Reference 7). A report was generated by PROTO to document their results, as well as the independent verification of results as performed by the University of Manchester (independent laboratory), which confirmed repeatability and reproducibility. AREVA peened six identical flat plates (same lot). Three were sent to PROTO for XRD and three were sent to Manchester for XRD, to provide data from two different independent labs for comparison. Both labs followed the XRD validation process procedure and are ISO/IEC 17025:2005 accredited laboratories. The test report addresses uncertainty in XRD residual stress measurements, documents compliance with accepted international standards and meets MRP 335, section 2.3.6 requirements [16].

Mock-up testing demonstrated the effects that cavitation peening has to the ID of the nozzle penetration surfaces at thermal sleeve centering tab locations. The thermal sleeve centering tabs produce cold working during cavitation peening that reduces tensile stresses at the thermal sleeve centering tab wear groove locations. Thus, peening at wear groove locations produces higher conservative compressive stresses at these locations and is bounding for nozzle surfaces without wear grooves. Site specific wear groove geometry due to centering tabs is not required since deeper wear grooves would produce conservative compressive stress results. XRD results further confirmed that cavitation peening near the thermal sleeve centering tabs creates a compressive stress that is greater in the localized area than the results produced by the cavitation peening process per the SPQR, section 7.7.4.1 and A.6.

Motion profiles were created within parameters for controlling the water jet application for the various RPVHPN geometries. The specific motion profile parameters required to peen each nozzle for Braidwood Station Unit 1 were defined by the special process to achieve the required peening stresses and depth of compression per the SPQR, section 4.0.

<u>Post Peening Residual Plus Operating Stress</u>

Stress analyses document the levels of operating stress that occur in the peened RPVHPNs [12][13]. The analysis approach included Finite Element Analysis (FEA) modeling with operating pressure and temperature applied to the model. The residual plus operating stress at the peened surface exceeds the surface stress MRP-335 Performance Criterion 4.3.8.1.1.

In accordance with MRP-335 Performance Criterion 4.3.8.2, sustainability of the stress effect induced by the application specific water jet UHPCP process used is demonstrated to last the life of the plant by the testing included in the Special

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Process Qualification Report [7] and analyzed in the peening residual plus operating stress analysis [13]. The effects of both thermally induced stress relaxation and load cycling (shakedown) induced stress relaxation are evaluated in the stress analysis.

The post peening residual plus operating surface stress levels achieved are below the MRP-335 requirement of +10 ksi tensile. The nozzle (Alloy 600) OD stress range is -42.7 to -47.3 ksi for a margin of 52.7 to 57.3 ksi. The J-groove weld (Alloy 182) OD stress range is -11.1 to -41.6 ksi for a margin of 21.1 to 51.6 ksi. The nozzle (Alloy 600) ID stress range is 0 to -34 ksi for a margin of 10 to 44 ksi. The post peening residual plus operating stress levels and demonstrated margin for UHPCP implementation for Braidwood Station Unit 1 RVCH nozzle penetrations is provided in section 5.0 of the Summary Report [14].

The increased margin to the residual plus operating stress to the +10 ksi requirement places the nozzles in an increased compressive state that reduces the susceptibility to initiation and increases the duration before a small pre-existing flaw may be detectable. Therefore, supporting the conclusion that a follow-up inspection in the N+1 outage is not necessary.

5.4.3 Peening Coverage Area

The peening coverage area was determined in accordance with MRP-335 Performance Criterion 4.3.8.1. The required stress improvement effect was obtained over the area required to be peened. As stated in section 5.2.1 of this relief, UHPCP was applied to the standard RPVHPN inspection area per N-729-1 Figure 2, which exceeded the MRP-335 coverage requirements.

MRP-335 Performance Criterion 4.3.8.1 does not require RPVHPN threaded areas to be peened. Therefore, threaded areas near the end of the RPVHPNs that are within the area normally required to be peened, but which are impractical to peen using the method being applied, were not peened. These nozzles include the CETCs where portions of the threaded area were covered by the CETC funnel.

Controls used to ensure the required coverage area is peened to achieve the required stress improvement effect are described in section 5.2.2 of this relief. Measures that ensured complete coverage of the required area include the following:

- Complete coverage of the area designated for peening is assured by use of overlapping passes and by extending the peening out beyond the edge of the designated area.
- Critical parameters with acceptable ranges were established to ensure full peening coverage and depth of compression is achieved when all parameters are at both the maximum or minimum limits.
- Process controls are used to ensure the required surface areas are peened for the required length of time. Peening coverage area is programmed into the peening process via motion profiling.
- Process control document records are reviewed by independent reviewer(s) and Quality Assurance to assure accuracy.

The Summary Report documents where the post peening coverage area for the nozzle OD, nozzle ID and J-groove weld surfaces contained margin (e.g., exceeded MRP-335 requirements) due to the peening process and site specific FEA model. The FEA model determined that the actual +20 ksi stress region on the OD and ID nozzle surfaces did not extend down below the J-groove weld as far as the coverage region shown in Figures 4-1 and 4-2 of MRP-335. Five cases were run which bound the CRDM penetration angles for the Braidwood RVCH. The FEA model determined the actual nozzle OD downhill side +20 ksi stress region extends 0.44 to 0.48 inch below the toe of the weld. The FEA model determined the actual nozzle OD uphill side +20 ksi stress region extends 0.46 to 0.61 inch below the toe of the weld. The FEA model determined the actual nozzle ID downhill side +20 ksi stress region extends 0.47 to 1.26 inch below the toe of the weld. The FEA model determined the actual nozzle ID uphill side +20 ksi stress region extends 0.93 to 1.22 inch above the J-groove weld.

The nozzle OD downhill side peening process margin is 0.06 to 0.64 inch below the MRP-335 identified +20 ksi region. The nozzle OD uphill side peening process margin is 0.24 to 4.25 inch below the MRP-335 identified +20 ksi region. The nozzle ID, below the weld toe, downhill side peening process margin is 0.26 to 1.25 inch below the MRP-335 identified +20 ksi region. The nozzle ID, above the weld toe, uphill side peening process margin is 0.51 to 5.56 inch above the MRP-335 identified +20 ksi region. The J-groove weld was peened to a minimum of 0.25 inch beyond the cladding/buttering interface.

The OD area of the CETC nozzle with +20 ksi and greater weld residual stress is conservatively peened with margin. A portion of the CETC guide funnel was removed to expose the required SSI area in accordance with MRP-335 with a minimum clearance of 0.5 inch [14]. The ID surface of the CETC nozzle was peened in accordance with MRP-335 with conservative margin. UHPCP implementation coverage data for Braidwood Station Unit 1 is provided in section 4.0 of the Summary Report applicable for RPVHPN Tiers 1-15 [14].

Peening the full inspection area beyond the +20 ksi region area in combination with the plant specific actual FEA +20 ksi region being smaller than that specified in the MRP-355 and the peening process margin places a larger area of the nozzles in an increased compressive state giving further assurance of a low probability that a flaw would initiate. Therefore, supporting the conclusion that a follow-up inspection in the N+1 outage is not necessary.

5.4.4 Depth of Compression

The minimum OD and ID depth of compression per MRP-335 is 0.04 inch and 0.01 inch respectively. UHPCP consistently achieved a demonstrated depth of compression that met or exceeded MRP-335 requirements per section 6.0 of the Summary Report [14]. The depth of OD compression was from 0.04 to 0.06 inch for RPVHPNs. The depth of ID compression was from 0.01 to 0.05 inch for open penetrations. The depth of ID compression was from 0.01 to 0.02 inch for annulus penetrations (containing thermal sleeves) and the vent penetration.

The depth of compression results meet and exceed the requirements specified in the MRP-335 and therefore provide compressive stresses to a deeper level of the nozzles. This increased compressive state reduces the potential that a small pre-existing flaw would grow to a detectable size in one cycle. Therefore, supporting the conclusion that a follow-up inspection in the N+1 outage is not necessary.

5.4.5 XRD Accuracy and Effect on Cavitation Peening

The post peening stress accuracy is documented in the Special Process Qualification Report and typically within ±1 to ±3 ksi for the nozzle (Alloy 600) and ± 5 ksi to ± 13 ksi for the J-groove weld (Alloy 182). The internationally recognized best practices for instrument calibration and validation of results as defined in the ASM Handbook was used for XRD measurements per the Summary Report, section 7.0 [14]. The stress results were repeatable for nozzle material (Alloy 600) with a standard deviation of ±0.9 ksi and repeatable with a standard deviation of ±0.7 for J-groove weld material (Alloy 182). Likewise, the stress results were reproducible for nozzle material (Alloy 600) with a standard deviation of ±0.3 ksi and reproducible with a standard deviation of ±0.3 ksi for J-groove weld material (Alloy 182).

In accordance with MRP-335 Performance Criterion 2.3.6, residual stress measurement uncertainty has been considered when assessing the surface stress after peening and presented in the Special Process Qualification Report [7]. XRD was performed using the multiple exposure technique with a minimum of 22 Ψ (psi) angles to increase accuracy of results per SAE HS784 with the best accuracy on the surface of the nozzle (Alloy 600). In addition, an independent third party laboratory confirmed the XRD methodology used by AREVA and validated process repeatability and reproducibility. Since the Special Process Qualification Report used median surface stress XRD values, the reported measurement error (i.e., ±3 ksi for Alloy 600 and ±13 ksi for Alloy 182) is bounded. Thus, XRD uncertainty associated with AREVA UHPCP does not impact the residual plus operating stresses on peened nozzles as qualified in the SPQR [7]. This is attributed to the highly accurate XRD process that was selected.

The highly accurate and reproducible XRD results increase the confidence that the residual stresses and depth of compression are representative of actual stress conditions of the nozzles and weld materials. Therefore, supporting the increased compressive state that reduces the potential that a small pre-existing flaw would grow to a detectable size in one cycle and that a follow-up inspection in the N+1 outage is not necessary.

5.4.6 Technical Rigor

Additional technical rigor was applied to the peening process beyond the requirements of MRP-335 through additional testing to ensure peening does not adversely affect the RVCH nozzles.

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Demonstration of No Adverse Effects

Qualification testing and analysis verifying the lack of adverse effects including the items covered by MRP-335 Performance Criterion 4.3.8.4 are documented in the Special Process Qualification Report and MRP-335. A summary of the specific testing and analysis is documented in Reference 7 and is provided below:

The effect of peening on surface roughness and inspectability was evaluated. Surface roughness measurements were compared before and after peening on representative mock-up test coupons, using bounding values of peening parameters. The testing confirmed that the surface roughness was not significantly increased by the bounding values of peening parameters, and that the maximum surface roughness does not affect the capability to perform qualified NDE methods i.e., UT Time of Flight Diffraction, Penetrant Testing (PT) and Eddy Current Testing. Refer to the Special Process Qualification Report, Appendix A and section 11.10.

The effect of peening to induce surface cracking is evaluated. The absence of peening-induced cracks in the surface, after exposure to bounding values of peening parameters is confirmed. Refer to the Special Process Qualification Report, Appendix A.

The effect of transitions from peened to unpeened conditions on the magnitude of surface tensile stresses and on the likelihood of developing SCC cracks is evaluated. Testing verifies that the tensile stresses on the surfaces in transition regions from peened to unpeened conditions are not high enough to raise the risk of inducing PWSCC initiation. Refer to the Special Process Qualification Report, Appendix A.

The effect of flow induced vibration (FIV) on peened components or nearby components is evaluated. For water jet UHPCP of RPVHPNs with thermal sleeves, the integrity of the thermal sleeve and its connection to the nozzle will not be adversely affected by FIV. Likewise, there is no adverse impact to nearby components due to FIV. Refer to the Special Process Qualification Report section 11.4 and Appendix B.

The effect of over peening is evaluated. Erosion Testing demonstrates the margin, beyond the maximum allowed peening conditions required to result in adverse effects such as erosion, roughening, or development of cracks. By demonstrating a large margin factor prior to unacceptable damage, there is confidence that unacceptable damage will not occur. Results showed that continuous peening of a location would be required for over eight times (8X) exposure time prior to experiencing any detectable detrimental surface conditions. The peening process is controlled to ensure that such over peening does not occur. Refer to the Special Process Qualification Report, Appendix A.

The potential for adverse effects due to UHPCP has also been addressed. The engineering evaluation determined that peening the wetted RPVHPN surfaces has no adverse effects on maintaining leak tight integrity. Peening was concluded to increase the resistance to PWSCC on these surfaces.

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Performance of the erosion testing confirmed that peening will not adversely affect the RVCH. This additional rigor was completed to increase the understanding of the enterprise risk impact related to implementation of the peening process.

Corrosion Testing to Confirm PWSCC Mitigated Effectiveness

Corrosion testing for crack initiation and growth performed for the peening process is described in the SPQR [7]. Alloy 600 specimens were exposed to simulated nominal PWR primary environment to determine the extent of SCC of peened vs non-peened samples. The peened samples were peened to a compressive depth of 0.01 inch, which meets the minimum nozzle ID depth requirements. After the test period, all of the non-peened specimens were heavily cracked (crack indications and through wall cracks). The peened specimens were visually examined, PT examined, cross sectioned and examined by scanning electron microscopy. None of the peened specimens revealed any evidence of PWSCC indications or significant change in grain boundary [7]. Based on the above corrosion testing, the samples that were peened to the required nozzle ID depth of 0.01 inch did not exhibit any PWSCC; which is a depth of only one fourth (1/4) of the outer surface peened depth requirement of 0.04 inch.

5.4.7 Deterministic Technical Basis

A fully deterministic technical basis paper [17] has been published supplementing MRP-395 [9] with additional deterministic crack growth analyses, demonstrating the acceptability of a 36-month UT interval for heads with previously detected PWSCC that operate at Tcold. This new analysis extends the deterministic analysis in MRP-395 by applying the 95th percentile factor, rather than the standard 75th percentile per ASME Section XI. This new analysis exceeds the ASME approach and supports the 36-month inspection interval without crediting peening. On the basis of this technical analysis, a 36-month interval would continue to ensure that the nuclear safety and leakage (for defense in depth) concerns are conservatively addressed to support the additional request for relief from the Reference 16 Table 4-3 Note (11)(b) requirement for inspection in the first refueling outage after peening.

5.4.8 Implementation Issues (AREVA CRs)

The following issues were identified during implementation of the Reactor Head Peening during A1R19. These issues were evaluated per AREVA's 10 CFR Appendix B program via the Condition Report (CR) Process. All CRs were satisfactorily dispositioned per the required process and determined to not impact UHP cavitation peening results. Although there is a Condition Report Section contained in the post peening Summary Report [14], these five CRs are further discussed here since the CRs pertain to essential variables / critical parameters that were outside of qualified ranges.

CR-2016-6613 - Nozzle 1 ID back pressure greater than 45 psi:

While cavitation peening the ID of nozzle 1, back pressure was at times greater than 45 psi. Back pressure per the SPQR [7] is required to be maintained

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between 35 and 45 psi. Thus, the upper bound of the essential variable i.e., back pressure was exceeded in some instances (see CR in Appendix D of Summary Report). However, the upper pressure bound of 45 psi was established to prevent peening tool cladding seal damage and is not critical to the process for maintaining performance criteria per section 5.3 e.g., stress magnitude or depth of compression. Therefore, exceeding the 45 psi back pressure upper bound is acceptable and does not impact the UHP cavitation peening process.

CR-2016-6615 and CR-2016-6617 - Excess flow during ID peening:

During ID cavitation peening, excess UHP flow rate was experienced. Flow rate through the high pressure nozzle, per the SPQR, is a secondary variable and not an essential variable / critical parameter [7]. The UHP water flow rate through the system most likely increased due to leaks within the nozzle orifice. However, provided the pressure is maintained (which is an essential variable measured at the high pressure transducer), flow rate through the orifice is also maintained even if there are leaks (see CR in Appendix D of Summary Report). Therefore, excess flow during ID peening is acceptable since pressure was maintained as the flow rate increased; and as such there is no impact to the peening results as a result of the increased flow rate.

CR 2016-6629 - A1R19 Nozzle 42 OD:

While cavitation peening the OD of nozzle 42, the low pressure transducer failed. However, acceptable tool pressure was maintained by monitoring three other instrument gages as documented in the CR. The low pressure transducer is a calibrated instrument whereas the instrument gages are not. Since the readings of the instrument gages were continuously monitored and did not fluctuate before and after failure of the low pressure transducer, it is concluded that the essential backpressure variable did not fluctuate and remained constant (see CR in Appendix D of Summary Report). Thus, the OD of nozzle 42 was peened within essential variable limits.

CR 2016-6869 - A1R19 Nozzle 75 OD:

While cavitation peening the remainder profile on the OD of nozzle 75, the back pressure dropped below the lower limit of the essential variable acceptable range (35 psi) due to a seal leak. Per the CR, the back pressure ranged between 33 to 34 psi for the final 10 minutes. The reduction in back pressure to 33-34 PSIG was less than 6% below the minimum specified pressure of 35 PSIG. However a back pressure as low as 20 PSIG produces the required surface compressive stress magnitude and depth of compression as documented in the SPQR. Therefore a loss of only 6% back pressure was determined to have no impact on the peening results.

5.5. Conclusions

On the basis of the above, the applicable peening performance criteria of MRP-335 section 4.3.8 are satisfied and exceeded with significant margin considering coverage area and post peened residual plus operating stresses. The detailed qualification work shows that the required SSI is achieved, and that the required operating stress effect and depth of compression is sustained with sufficient margin for the remaining service life of the peened component. The N-729-1 inspection area was peened compared to the MRP-335 required +20 ksi region, thus demonstrating margin. A highly accurate XRD methodology was used that provided repeatable and reproducible results, supporting the stress measurements in the Special Process Qualification Report.

A 36-month inspection interval is demonstrated as acceptable by ASME deterministic crack-growth rate analysis confirming inspection during N+1 is not required, which is consistent with industry approved inspection requirements per Code Case N-729-5. Code Case N-729-5 has been approved by ASME to credit peening RPVHPNs consistent with MRP-335 [4]. In addition, the increased margins demonstrated in the Braidwood Station Unit 1 peening application support the conclusion that a follow-up inspection in the N+1 outage is not necessary.

On the basis that the MRP-335 section 4.3.8 performance criteria were met or exceeded in accordance with MRP-335 requirements, demonstrates that inspection of the peened RPVHPNs at the alternative schedule requested will provide an acceptable level of quality and safety. Pending follow-up examination (i.e., N+2 inspection) confirming no previous PWSCC present, the life of the peened RVCH penetrations is acceptable for a 60-year plant license [15]. Thus, in accordance with 10 CFR 50.55a(z)(1), it is requested that NRC authorize this proposed alternative.

6.0 DURATION OF PROPOSED ALTERNATIVE:

The proposed Alternative is requested for the remainder of the 3rd Inservice Inspection Interval for Braidwood Station Unit 1, currently scheduled to end on July 28, 2018.

7.0 PRECEDENT:

None

8.0 ACRONYMS:

ALARA	As Low As Reasonably Achievable
ASM	American Society of Metals
ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel
CFR	Code of Federal Regulations
CETC	Core Exit Thermocouple Column
CR	Condition Report
CRDM	Control Rod Drive Mechanism
EDM	Electrical Discharge Machining
EDY	Effective Degradation Year
EPRI	Electric Power Research Institute
FEA	Finite Element Analysis
FIV	Flow Induced Vibration
ID	Inner Diameter
ISI	Inservice Inspection

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MRP	[EPRI] Materials Reliability Program
NDE	Nondestructive Examination
OD	Outer Diameter
PT	[Liquid] Penetrant Testing
PWR	Pressurized Water Reactor
PWSCC	Primary Water Stress Corrosion Cracking
RPV	Reactor Pressure Vessel
RPVHPN	Reactor pressure vessel [upper] head penetration nozzle
RVCH	Reactor Vessel Closure Head
SCC	Stress Corrosion Cracking
SPQR	Special Process Qualification Report
SSI	Surface Stress Improvement
UHP	Ultra High Pressure
UHPCP	Ultra High Pressure Cavitation Peening
UT	Ultrasonic Testing
XRD	X-ray Diffraction

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9.0 REFERENCES:

1. *ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components", 2001 Edition including Addenda through 2003*
2. *ASME 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", Approved March 28, 2006.*
3. *Final Safety Evaluation of The Electric Power Research Institute MRP-335, Revision 3, "Materials Reliability Program: Topical Report For Primary Water Stress Corrosion Cracking Mitigation By Surface Stress Improvement [Peening]", (TAC NO. MF2429)*
4. *Materials Reliability Program: Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement (MRP-335 Revision 3)*, EPRI, Palo Alto, CA: 2016. 3002007392. [available at www.epri.com]
5. *Materials Reliability Program Generic Evaluation of Examination Coverage Requirements for Reactor Pressure Vessel Head Penetration Nozzles, Revision 1 (MRP-95R1), EPRI, Palo Alto, CA: 2004. 1011225. [Non-proprietary version: NRC ADAMS Accession No. ML043200602]*
6. *Materials Reliability Program: Technical Basis for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement (MRP-267, Revision 1), EPRI, Palo Alto, CA: 2012. 1025839.* [available at www.epri.com]
7. *AREVA Document No. 150-8086004-001, Special Process Qualification Record (SPQR), "SPQR, Qualification of the Cavitation Peening Process for RVCH Nozzles," (EC 401061)*
8. *Materials Reliability Program: Technical Basis for Reexamination Interval Extension for Alloy 690 PWR Reactor Vessel Top Head Penetration Nozzles (MRP-375), EPRI, Palo Alto, CA: 2014. 3002002441.* [available at www.epri.com]
9. *Materials Reliability Program: Reevaluation of Technical Basis for Inspection of Alloy 600 PWR Reactor Vessel Top Head Nozzles (MRP-395), EPRI, Palo Alto, CA: 2014. 3002003099.*
10. *Section titled "Shot Peening", page 131, ASM Handbook, Volume 5, "Surface Engineering", ASM, 1994.*
11. *MRP Letter 2014-027, "Response to the NRC Request for Additional Information (RAI) related to Electric Power Research Institute (EPRI) MRP-335, Revision 1, 'Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement [Peening]' (TAC No. MF2429)," dated October 10, 2014. [NRC ADAMS Accession No. ML14288A370]*
12. *AREVA Analysis No. 32-9238505-001, "Byron/Braidwood RVCH Nozzle and Penetration Original Configuration Stresses", (Calculation BRW-15-0057-M)*
13. *AREVA Analysis No. 32-9241722-001, "Byron & Braidwood Peening Residual Plus Operating Stress Analysis", (Calculation BRW-15-0059-M)*

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14. *AREVA Document No. 51-8093944-001, Engineering Information Record, "Summary Report, RVCH Peening Implementation, Braidwood Unit 1" (EC 401061)*

15. *AREVA Evaluation No. 51-9238120-002, "PWSCC Evaluation of UHP Cavitation Peening for Byron and Braidwood Reactor Vessel Head Penetrations", (Calculation BRW-15-0060-M)*

16. *Materials Reliability Program: Topical Report for Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement (MRP-335 Revision 3-A)*, EPRI, Palo Alto, CA: 2016. 3002009241. [available at www.epri.com]

17. *Deterministic Technical Basis for Re-Examination Interval of Every Second Refueling Outage for PWR Reactor Vessel Heads Operating at T_{cold} with Previously Detected PWSCC, No. PVP2016-64032, Copyright 2016 by ASME.*

18. *ASME Code Case N-729-5, "Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds, Section XI, Division 1", Approved October 7, 2015.*