UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 26, 2019

Vice President, Operations
Entergy Nuclear Operations, Inc.
Palisades Nuclear Plant
27780 Blue Star Memorial Highway
Covert, MI 49043-9530

SUBJECT: PALISADES NUCLEAR PLANT – APPROVAL OF ALTERNATIVE FOR REPAIR OF REACTOR PRESSURE VESSEL HEAD PENETRATIONS (EPID L-2018-LLR-0139)

Dear Sir or Madam:

By letter dated November 26, 2018, as supplemented by letter December 3, 2018, Entergy Nuclear Operations, Inc. (ENO, the licensee) submitted a request in accordance with paragraph 50.55a(z)(1) of Title 10 of the *Code of Federal Regulations* (10 CFR) for a proposed alternative to the requirements of Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) for the Palisades Nuclear Plant (PNP).

Specifically, pursuant to 10 CFR 50.55a(z)(1), ENO requested to use the proposed alternative on the basis that the alternative provides an acceptable level of quality and safety. The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the subject request and concludes, as set forth in the enclosed safety evaluation, that the licensee has adequately addressed the regulatory requirements set forth in 10 CFR 50.55a(z)(1).

The NRC authorizes the use of Relief Request No. RR 5-7 at PNP for the remaining period of the fifth 10-year inservice inspection interval, which is scheduled to end on December 20, 2025. The repairs performed under RR 5-7 are acceptable for a design life of 27 years.

All other requirements of ASME Code, Section XI, for which relief was not specifically requested and authorized by the NRC staff remain applicable, including the third-party review by the Authorized Nuclear In-service Inspector.

If you have any questions, please contact Kimberly Green at (301) 415-1627 or via email at Kimberly.Green@nrc.gov.

Sincerely,

David J. Wrona, Chief
Plant Licensing Branch III
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-255

Enclosure:
Safety Evaluation

cc: Listserv

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO RELIEF REQUEST NO. 5-7

ALTERNATIVE REPAIR OF REACTOR VESSEL CLOSURE HEAD PENETRATIONS

ENTERGY NUCLEAR OPERATIONS, INC.

PALISADES NUCLEAR PLANT

DOCKET NO. 50-255

1.0 INTRODUCTION

By letter dated November 26, 2018 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML18330A141), as supplemented by letter dated December 3, 2018 (ADAMS Accession No. ML18337A053), Entergy Nuclear Operations, Inc. (ENO, the licensee), submitted proposed alternative Relief Request (RR) No. RR 5-7 for the repair of degraded VCH penetration nozzle Nos. 25, 33, and 36, that requests relief from certain requirements of American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," for the repair of three degraded reactor vessel closure head (RVCH) penetration nozzles at the Palisades Nuclear Plant (PNP). The licensee proposed to use the inside diameter temper bead (IDTB) welding method to repair the subject RVCH penetration nozzles.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a(z)(1), the licensee requested to use the proposed alternative on the basis that the alternative provides an acceptable level of quality and safety.

On December 4, 2018, the U.S. Nuclear Regulatory Commission (NRC) verbally authorized the use of RR 5-7 for RVCH penetration nozzle Nos. 25, 33, and 36 at PNP for the remaining period of the fifth 10-year inservice inspection (ISI) interval, which is scheduled to end on December 12, 2025. The NRC staff determined that the proposed alternative is technically justified and provides an acceptable level of quality and safety. Details of the verbal authorization are documented in a letter dated December 6, 2018 (ADAMS Accession No. ML18340A007). This safety evaluation (SE) documents the technical basis for the NRC's verbal authorization.

2.0 REGULATORY EVALUATION

Adherence to Section XI of the ASME Code is mandated by 10 CFR 50.55a(g)(4), which states, in part, that ASME Code Class 1, 2, and 3 components must meet the requirements, except design and access provisions and the pre-service examination requirements, set forth in the ASME Code, Section XI.

Pursuant to 10 CFR 50.55a(g)(6)(ii), the NRC may require the licensee to follow an augmented ISI program for systems and components for which the NRC deems that added assurance of structural reliability is necessary.

As stated in 10 CFR 50.55a(g)(6)(ii)(D), "Augmented ISI requirements: Reactor vessel head inspections—(1) Implementation," holders of operating licenses or combined licenses for pressurized-water reactors [PWRs] as of or after August 17, 2017, shall implement the requirements of ASME BPV Code Case N-729-4 ["Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds Section XI, Division 1"] instead of ASME BPV Code Case N–729–1, subject to the conditions specified in paragraphs (g)(6)(ii)(D)(2) through (4) of this section, by the first refueling outage starting after August 17, 2017.

ASME Code Case N-638-6, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW [Gas Tungsten Arc Welding] Temper Bead Technique, Section XI, Division 1," provides requirements for automatic or machine GTAW of Class 1 components without the use of preheat or post-weld heat treatment. Code Case N-638-6 is listed in Regulatory Guide (RG) 1.147, Revision 18, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1," March 2017 (ADAMS Accession No. ML16321A336), as acceptable for use with one condition which will be discussed further in the SE.

As stated, in part, in 10 CFR 50.55a(z), alternatives to the requirements of paragraph (g) of 10 CFR 50.55a may be used, when authorized by the NRC, if the licensee demonstrates that: (1) the proposed alternative provides an acceptable level of quality and safety, or (2) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Based on the above, and subject to the following technical evaluation, the NRC staff finds that regulatory authority exists for the licensee to request and the NRC to authorize the alternative requested by the licensee.

3.0 TECHNICAL EVALUATION

3.1 Relief Request No. RR 5-7

3.1.1 ASME Code Components Affected

The affected components are ASME Class 1, RVCH penetration nozzle Nos. 25, 33, and 36, which are made of nickel-based alloy Inconel™ Alloy 600 (SB-167) UNS N06600.

3.1.2 Applicable Code Edition and Addenda

The Code of Record for the fifth 10-year ISI interval is the ASME Code, Section XI, 2007 Edition through 2008 Addenda. The Code of Construction for the RVCH is the 1965 Edition through winter 1965 Addenda of the ASME Code, Section III.

3.1.3 Applicable Code Requirements

ASME Code Section XI, 2007 Edition through 2008 Addenda

Subparagraph IWA-4221(b) states, in part, "An item to be used for repair/replacement activities shall meet the Construction Code . . . "

Subparagraph IWA-4221(c) states, in part, "As an alternative to (b) [IWA-4221] above, the item may meet all or portions of the requirements of different Editions and Addenda of the Construction Code, or Section III . . . provided the requirements of IWA-4222 through IWA-4226, as applicable, are met . . ."

Subparagraph IWA-4224.1, Identical Material Procured to a Later Edition or Addenda of the Construction Code, Section III or Material Specification.

(a) Materials, including welding materials may meet the requirements of later dates . . .
(b) Differences in the specified material tensile stress . . . .

Subarticle IWA-4400 provides welding, brazing, metal removal, fabrication, and installation requirements related to repair/replacement activities.

Paragraph IWA-4411 states, in part, "Welding, brazing, and installation shall be performed in accordance with the Owner's Requirements and, except as modified below, in accordance with the Construction Code of the item."

Subparagraph IWA-4411(a) states, in part, "Later editions and addenda of the Construction Code, or a later different Construction Code, either in its entirety or portions thereof, and Code Cases may be used, provided the substitution is as listed in IWA-4221(c). Filler metal requirements shall be reconciled, as required, in accordance with IWA-4224."

Subparagraph IWA-4611.1(a) states, "Defects shall be removed in accordance with IWA-4422.1. A defect is considered removed when it has been reduced to an acceptable size."

Subarticle IWA-3300 specifies requirements for characterization of flaws detected by inservice examination.

Paragraph IWB-3420 states, "Each detected flaw or group of flaws shall be characterized by the rules of IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of IWB-3500."

Subparagraph IWB-3132.3 states, "A component whose volumetric or surface examination detects flaws that exceed the acceptance standards of Table IWB-3410-1 is acceptable for continued service without a repair/replacement activity if an analytical evaluation, as described in IWB-3600, meets the acceptance criteria of IWB-3600. The area containing the flaw shall be subsequently reexamined in accordance with IWB-2420 (b) and (c)."

ASME Code, Section III, 2001 Edition through 2003 Addenda

The ASME Code Section III, "Rules for Construction of Nuclear Facility Components," paragraph NB-5245, requires progressive surface examination of partial penetration welds. Subparagraph NB-5331(b) states "indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length."

ASME Code Case N-638-6

ASME Code Case N-638-6 provides requirements for automatic or machine GTAW of Class 1 components without the use of preheat or post weld heat treatment.

Paragraph 1(a) states, in part, "This Case shall not be used to repair SA-302, Grade B material, unless the material has been modified to include 0.4% to 1.0% nickel, quenching and tempering, and application of a fine gain practice."

Paragraph 2.1(a) states: "The materials that are used for procedure qualification testing shall receive a heat treatment that is at least equivalent to the time and temperature already applied to the materials being welded."

Paragraph 1(g) states: "Peening may be used, except on the initial and final layers."

ASME Code Case N-729-4

ASME Code Case N-729-4, Figure 2, "Examination Volume for Nozzle Base Metal and Examination Area for Weld and Nozzle Base Metal," is applicable to the subject RVCH penetration nozzles.

3.1.4 Reason for Request

During the 2018 refueling outage (RO26), the licensee detected unacceptable flaws on RVCH penetration nozzle Nos. 25, 33, and 36. The licensee stated that the flaws are axially oriented, in the tube wall, near the low hill side, and approximately adjacent to the root of the J-groove weld. All three nozzles (Nos. 25, 33, and 36) will be repaired under the proposed alternative.

The licensee stated that the repair technique, sometimes referred to as the half-nozzle repair, is intended to be the same as was used previously for RVCH penetration nozzle Nos. 29 and 30 in 2004 with the exception that surface stress improvement will be performed using rotary peening on the repaired nozzles (Nos. 25, 33, and 36) in place of abrasive water jet machining. The half-nozzle repair involves machining away the lower section of the nozzle containing the flaws, then welding the remaining portion of the nozzle to the RVCH to form the new pressure boundary. A replacement lower nozzle will also be welded to the RVCH that provides a means for reattaching the control element drive mechanism extension and grid structure.

The licensee stated that because of the risk of damage to the RVCH material properties or dimensions, it is not feasible to apply the post-weld heat treatment (PWHT) requirements of the original Construction Code to the RVCH. As an alternative to the requirements of the RVCH Construction Code, the licensee proposed to repair the RVCH penetration nozzles using the IDTB welding method to restore the pressure boundary of the degraded nozzles. The IDTB welding method is performed with a remotely operated welding tool, using the machine GTAW process and the ambient temperature temper bead method with 50 °F minimum preheat temperature and no PWHT.

3.1.5 Proposed Alternative

The licensee proposed to perform the repair in accordance with the requirements of the ASME Code, Sections III and XI, Code Case N-638-6 and Code Case N-729-4, with alternatives discussed below. The license summarized the repair as follows:

1. Cut grid structure adjoining the target nozzle and surrounding extensions.
2. Cut the nozzle close to the underside of the head and remove the nozzle extension.
3. Roll expansion of the nozzle above the area to be modified to stabilize the nozzle and prevent any movement when the nozzle is separated from the nozzle-to-RVCH J-groove weld.
4. Machining to remove the lower nozzle to above the J-groove weld eliminating the portions of the nozzle containing the unacceptable indication(s). This machining operation also establishes the weld preparation area (Figure 1 of the RR).
5. Liquid penetrant (PT) examination of the machined area (Figure 3 of the RR).
6. Welding the remaining portion of the nozzle and the new replacement lower nozzle using Alloy 52M weld material (Figure 2 of the RR).
7. Machining the weld and nozzle to provide a surface suitable for nondestructive examination).
8. PT and ultrasonic (UT) examination of the weld and adjacent region (Figure 3 of the RR).
9. Rotary peening of the repair region most susceptible to primary water stress corrosion cracking (PWSCC)

3.1.6 Basis for Use

Repair

<u>Welding</u>

The licensee's alternative implements Code Case N-638-6, as conditioned in RG 1.147, Revision 18, with deviations. The UT examination procedure used at PNP was qualified using an IDTB weld half-nozzle repair mock-up containing reflectors to simulate construction type flaws applicable to the weld process used. The licensee proposed three deviations from the Code Case as described below.

Paragraph 1(a) of Code Case N-638-6 prohibits the use of the Code Case to repair SA-302, Grade B material, unless the material has been modified to include 0.4 percent to 1.0 percent nickel, quenching and tempering, and application of fine grain practice. [Note: ASME Code Case N-638-6 erroneously uses the term "fine gain practice." The error has been corrected in later editions of the Code Case.] The licensee stated that the RVCH material at PNP is SA-302, Grade B modified, quenched and tempered plate. The licensee stated that RVCH certified material test reports (CMTRs) support that the material used at PNP is modified to include 0.4 percent to 1.0 percent nickel and was quenched and tempered, however, the application of fine grain practice cannot be verified from the information provided in the CMTRs. Therefore, it is unknown if the material meets paragraph 1(a) of Code Case N-638-6. The licensee stated that prior to 1987, the prescriptive quench and temper was the primary difference between SA-302, Grade B, plate and SA-533, Grade B Class 1, plate specifications. Prior to 1987, fine grain practice was not required for SA-533, Grade B Class 1, plate. Code Case N-638-6 does not prohibit its use on SA-533, Grade B Class 1, plate manufactured prior to 1987. The licensee stated that the GTAW ambient temperature temper bead welding process is designed to develop a tough, ductile microstructure in the weld heat affected zone (HAZ) that is equivalent or superior to the surrounding base material. Adequate notch toughness of the weld HAZ is assured by impact testing as part of the weld procedure qualification in accordance with N-638-6, paragraph 2.1(e)(4).

The licensee stated that the acceptable UT examination results for previously repaired penetration Nos. 29 and 30, reported at each refueling outage since installation in 2004, provide evidence that the plate material was not adversely affected by the temper bead weld process.

The licensee stated that the PNP RVCH has received a total of 40 hours of PWHT but the weld procedure qualification test plate received a total of 37.5 hours. Therefore, the licensee proposed an alternative to paragraph 2.1(a) of Code Case N-638-6. The licensee contends that it is not conservative to perform a simulated PWHT of welding qualification test plate material that will be compared to the temper bead HAZ for acceptance because PWHT can slightly degrade the fracture (notch) toughness of low alloy steels.

The licensee's proposed alternative implements rotary peening of the final layer of the new attachment weld. Paragraph 1(g) of Code Case N-638-6 prohibits peening of the initial and final weld layers. The licensee believes that the prohibition to peening in the Code Case is intended to be applied to high cold work peening for distortion control and not rotary peening which is highly controlled, uniform, and only influences a shallow surface layer. The rotary peening will be applied to produce a residual compressive layer at the new attachment weld and surrounding material to reduce the potential for PWSCC initiation.

Acceptance Examination

The ASME Code, Section III, paragraph NB-5245, specifies progressive surface examination of partial penetration welds. In lieu of the requirement, the licensee will perform UT and PT of the new attachment weld and immediate surrounding area within the RVCH bore as shown in Figure 3 of Attachment 1 to the licensee's relief request. A PT examination will be performed before welding and after the weld is completed. The licensee stated that the UT examination will be performed in accordance Code Case N-638-6, paragraphs 4(a)(2) and 4(a)(4).

The licensee will perform UT examination by scanning from the inner diameter surface of the nozzle. The UT examination is qualified to detect flaws in the new weld and base metal interface in the repair region. The licensee clarified that UT examination acceptance criteria will follow paragraph NB-5330 of the ASME Code, Section III, for all flaws identified within the repaired volume. The final examination of the new weld and immediate surrounding region will be sufficient to verify that defects have not been induced in the ferritic low alloy steel RVCH base material, due to welding, to the extent practical.

Preserve and ISIs

The licensee stated that the preservice inspection following the repair and future ISI inspections will comply with ASME Code Case N-729-4, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D) and as depicted in Figure 9 of Attachment 1 to the RR.

Analyses

Triple Point Anomaly

The ASME Code, Section III, subparagraph NB-5331(b), states, in part, "Indications characterized as cracks, lack of fusion, or incomplete penetrations are unacceptable regardless of length." The licensee stated that an artifact of ambient temperature temper bead welding is an anomaly at the triple point. The triple point is the junction where the low alloy steel of RVCH, Alloy 52 weld metal, and Alloy 600 remnant nozzle/Alloy 690 new nozzle meet. There are two triple points—upper and lower—in the licensee's proposed modification. The locations of the upper and lower triple points are provided in Figure 2 of Attachment 1 to the RR. The licensee characterized the anomaly as an irregularly shaped, very small void. According to the licensee, mock-up testing has verified that the anomalies are common and do not exceed 0.10-inch in through wall extent.

The licensee's proposed alternative would permit anomalies at the triple point to remain in service based on a fracture mechanics analysis performed in accordance with the ASME Code, Section XI. The licensee modeled the anomaly as a 0.10-inch, circular crack-like defect, extending 360 degrees around the circumference of the nozzle at the triple point location. The licensee postulated two flaw propagation paths for the triple point anomaly. The licensee demonstrated that the fatigue crack growth of the anomaly is acceptable, and the anomaly will remain stable in service for 27 years.

Flaw Characterization and Successive Examinations

The ASME Code, Section XI, Subarticle IWB-3600, requires that cracks be fully characterized in order to compare the calculated parameters to the acceptable parameters addressed in Subarticle IWB-3500. The licensee requested relief from flaw characterization and subsequent examinations of the J-groove weld because it is impractical to characterize the flaw geometry that may exist in the J-groove welds. In lieu of flaw characterization and subsequent examinations, the licensee evaluated a postulated flaw occurring in the remaining J-groove weld extending through the entire J-groove weld and butter material to the interface with the RVCH material. Any growth of the postulated flaw into the RVCH would be caused by fatigue under cyclic loading conditions.

Based on a combination of linear elastic fracture mechanics analysis and an elastic-plastic fracture mechanics analysis, the licensee showed that the RVCH is acceptable for a minimum of 27 years of operation with the postulated flaw that is propagated from the J-groove weld into the RVCH. Following the detailed fracture mechanics analyses, the licensee also performed an analysis in accordance with the ASME Code, Section XI, subparagraph IWB-3610(d)(2), to satisfy the primary stress limits of ASME Code, Section III, Article NB-3000. Based on various analyses, the licensee demonstrated the service life of 27 years for the repaired nozzles.

The licensee stated that it will not perform successive examinations in the future of the J-groove weld as required by the ASME Code, Section XI, subparagraph IWB-3132.3, because its analytical evaluation of the worst-case postulated flaw has demonstrated the acceptability of continued operation of the repaired RVCH nozzles.

General Corrosion of Exposed Low Alloy Steel

As a result of the proposed repair, a small portion of low-alloy steel base metal in the RVCH penetration will be exposed to primary system coolant.

The licensee evaluated the potential corrosion of the wetted surface of the RVCH. The licensee noted that galvanic corrosion, hydrogen embrittlement, stress-corrosion cracking, and crevice corrosion are not expected to be a concern for the exposed RVCH low alloy steel. General corrosion of the exposed low alloy steel will occur in the area between the new IDTB weld and the original J-groove weld in the annulus region between the lower replacement nozzle and the RVCH. The licensee stated that the long-term corrosion rate and overall release of iron into the primary coolant system is expected to be negligible.

Alloy 600 PWSCC Evaluation

The licensee performed a PWSCC evaluation and determined that the rotary peening process that it will apply appropriately mitigates residual surface stress in the Alloy 600 remaining nozzle inside diameter affected by the repair, which includes the IDTB weld HAZ and the roll expansion area. The licensee stated that PWSCC initiation is not expected during the 27-year design life of the repair.

Loose Parts Evaluation

The licensee evaluated the potential for debris as a result of PWSCC from a degraded remnant J-groove weld. The licensee postulated radial cracks to occur in the remnant J-groove weld due to the dominance of hoop stresses at this location. The licensee stated that the occurrence of transverse cracks that could intersect the radial cracks is considered remote because there are no forces that would drive a transverse crack. The radial cracks would relieve the potential transverse crack driving forces. The licensee concluded that there are no known service conditions that could drive radial cracks and transverse cracks to intersect to produce a loose part.

3.1.7 Duration of Proposed Alternative

The licensee requested the proposed RR for the fifth 10-year ISI interval, which began on December 13, 2015, and is currently scheduled to end on December 12, 2025. The licensee stated that PNP is currently scheduled to permanently shutdown in the spring of 2022.

3.2 NRC Staff Evaluation

The NRC staff evaluated the licensee's proposed alternative, including the weld design, flaw evaluations, welding, and examinations in accordance with ASME Code, Sections III and XI, Code Case N-638-6, and Code Case N-729-4. The NRC staff also evaluated the proposed deviations from the applicable ASME Code requirements included in the proposed alternative.

3.2.1 ASME Code Case N-638

ASME Code Case N-638-6 is listed in RG 1.147, Revision 18, as acceptable for use with one condition. The condition states: "Demonstration for ultrasonic examination of the repaired volume is required using representative samples which contain construction type flaws."

Paragraph 1(a) of Code Case N-638-6 prohibits the use of the Code Case to repair SA-302, Grade B material, unless the material has been modified to include 0.4 percent to 1.0 percent nickel, quenching and tempering, and application of fine grain practice. The use of SA-302, Grade B material, modified to include 0.4 percent to 1.0 percent nickel, was originally permitted by the ASME Code via ASME Code Case 1339. However, quenching and tempering, and fine grain practice was not a requirement of this Code Case. SA-302, Grade B material, specification called for a heat treatment of normalized with or without accelerated cooling. The RVCH at PNP is SA-302, Grade B modified, and the licensee stated that the CMTRs show that the materials used have been modified to include 0.4 percent to 1.0 percent nickel and have been quenched and tempered. However, there is no conclusive evidence that fine grain practice was used.

Electric Power Research Institute (EPRI) Technical Update 1014351, "Repair and Replacement Applications Center: Topical Report Supporting Expedited NRC Review of Code Cases for Dissimilar Metal Weld Overlay Repairs," states that original equipment manufacturers (OEMs) were contacted to discuss their use of SA-302, Grade B modified, materials to manufacture nuclear pressure vessels. The EPRI document further states that according to OEMs, purchase orders for SA-302, Grade B modified, supplemented the requirements to include quenching and tempering and the application of fine grain practice. The document further states that random spot checking seemed to confirm this information. Although not documented on the CMTRs, it is possible that the PNP RVCH plate material was manufactured using fine grain practice. The ambient temperature temper bead welding method involves the formation of martensite in the HAZ, which is tempered by subsequent weld layers. Qualification of the welding procedure in accordance with Code Case N-638-6 ensures that the welding variables used during field weld repairs produce martensite in the HAZ, which is later transformed to tempered martensite by subsequent weld passes. A tempered martensite HAZ structure exhibits exceptional toughness. There is no technical reason that would prevent the successful application of temper bead welding on SA-302, Grade B modified, material that was not manufactured with the application of fine grain practice. In addition, previously repaired nozzles at PNP have received a UT examination every refueling outage, since their installation in 2004, without the detection of any RVCH base material flaws. Based on the foregoing, the NRC staff finds that proposed alternative to paragraph 1(a) is acceptable.

Paragraph 2.1(a) of Code Case N-638-6 requires that materials that are used for procedure qualification testing shall receive a heat treatment that is at least equivalent to the time and temperature already applied to the materials being welded. The PNP RVCH has received a total of 40 hours of PWHT; however, the weld procedure qualification test plate received a total of 37.5 hours. Code Cases N-638-6 requires that the weld HAZ Charpy V-notch (CVN) average mils lateral expansion (MLE) value must be equal to or greater than the test plate material. Simulated PWHT can degrade the mechanical properties of the test plate material, thus, meeting the MLE requirement becomes easier when a simulated PWHT is performed. The portion of the HAZ that is heated into the austenite region during welding transforms to predominantly martensite when rapidly cooled. Martensite that is formed in the HAZ is tempered by subsequent welding passes and results in improved notch toughness. Therefore, performing a simulated PWHT of test materials have little or no impact on the HAZ CVN values but can decrease the MLE values of the test plate material. The NRC staff finds that the licensee's use of a welding procedure qualification with simulated PWHT less than the PWHT time that has been applied to the PNP RVCH is more conservative than the requirement in paragraph 2.1(a), and is, therefore, acceptable.

Paragraph 1(g) of Code Case N-638-6 prohibits peening of the initial and final weld layers. The licensee has proposed to apply rotary peening of the roll expanded transition area, the HAZ between the Alloy 52M IDTB weld and the Alloy 600 control element drive mechanism nozzle following the repair of RVCH penetration nozzles. This form of peening is considered surface stress improvement and is not similar to the type of peening that is prohibited by paragraph 1(g). The prohibition in 1(g) would only be applicable to a peening practice that involves the application of a large amount of localized and non-uniform compressive stresses on the weld joint, normally applied manually and not well controlled, to control configurational distortion. The NRC staff is not aware of any field applications of N-638 that have used peening to control configurational distortion.

Surface stress improvement is a process that introduces uniform compressive stresses on the surface of the weld joint and adjacent base material and is known to be beneficial in delaying or even eliminating crack initiation and growth due to fatigue or stress corrosion cracking (SCC). Paragraph W-2140 of Appendix W to ASME Code, Section III, describes the benefit of surface stress improvement or peening. Furthermore, rotary peening has been used by other industries, such as aerospace, for mitigating or delaying fatigue cracking and SCC. Therefore, the NRC staff finds that peening of the repair weld is acceptable because the proposed peening provides similar stress improvement to that described in paragraph W-2140 of Appendix W to Section III. The NRC staff also finds that the proposed peening will add additional assurance of the structural integrity of the repaired RVCH penetration nozzles.

3.2.2 Flaw Evaluations

The NRC staff evaluated the licensee's analyses of the triple point anomaly, postulated flaw growth from the existing J-groove weld into the RVCH, corrosion evaluation, and loose parts evaluation.

<u>Triple Point Anomaly</u>

The licensee requested relief from the ASME Code, Section III, Article NB-5000, so that potential anomalies at the triple point location may remain in service. The NRC staff notes that ASME Code, Section III, paragraph NB-5331(b), prohibits the existence of indications that are characterized as cracks, lack of fusion, or incomplete penetration regardless of length. As an alternative to paragraph NB-5331(b), the licensee analyzed a postulated crack-like anomaly at the triple point in accordance with ASME Code, Section XI, Subarticle IWB-3600, to justify operating with the anomaly left in service. The results of the licensee's analysis demonstrate that a postulated 0.10-inch weld anomaly is acceptable for 27 years. The NRC staff finds that the licensee has adequately demonstrated by analysis and by mockup testing that the triple point weld anomaly is acceptable to remain in service without affecting structural integrity of the repaired nozzle for 27 years.

Flaw Evaluation for the J-groove Weld

The ASME Code, Section XI, paragraph IWB-3132.3 requires that successive examinations be performed on a weld that contains an unacceptable flaw. The licensee proposed not to re-examine the remnant J-groove weld in the future because it is difficult to examine the remnant J-groove weld with reasonable confidence. As an alternative, the licensee analyzed a postulated flaw in the remnant J-groove weld based on the linear-elastic and elastic-plastic fracture mechanics methods. The licensee performed its linear-elastic fracture mechanics analysis in accordance with the ASME Code, Section XI, Subarticle IWB-3600. The licensee performed the elastic-plastic fracture mechanics analysis based on the generally accepted J-integral/tearing modulus method. The postulated flaw is the worst-case flaw in the J-groove weld in which the flaw extends the entire length of the weld and the flaw tip has reached the interface between the butter and the RVCH base metal. The flaw is postulated to propagate into the RVCH base metal by fatigue. The licensee's flaw evaluation result shows that the repaired RVCH nozzle is acceptable for a minimum of 27 years of operation after the repair per the ASME Code, Section XI, IWB-3610(d)(2).

The NRC staff finds the licensee's flaw evaluation acceptable because the licensee postulated and analyzed a worst-case flaw in the J-groove weld propagating into the RVCH based on the acceptable linear-elastic and elastic-plastic fracture mechanics methods as specified in the ASME Code, Section XI. The NRC staff further finds that the final postulated flaw will be stable in the RVCH and will not affect structural integrity of the repaired nozzles for the design life of 27 years.

Corrosion Evaluation

As a result of the nozzle repair, the annulus region between the RVCH bore and the lower replacement is exposed to primary coolant. The NRC staff finds that the licensee appropriately considered various corrosion mechanisms and that general corrosion of the annulus region between the RVCH bore and the lower replacement nozzle will be negligible. Based on the licensee's analysis, the NRC staff finds that the bore of the RVCH penetration will be acceptable for the design life of the repair and the overall release of iron into the primary coolant system will most likely be negligible.

Alloy 600 PWSCC Evaluation

The cold work imparted by the roll expansion process (although controlled) and residual stress imparted on the Alloy 600 nozzle from welding increases the probability of the initiation of PWSCC. To mitigate the potential of PWSCC in the most susceptible regions of the repair, the licensee will implement rotary peening to impart a surface compressive stress on the affected surface of the repaired nozzles. Tensile stresses are necessary to initiate stress corrosion cracks as well as act as a driver for crack propagation. By imparting a compressive stress on the surface of a material, or reducing tensile stresses, the potential for PWSCC can be mitigated. The licensee stated that rotary peening will be performed on all portions of the Alloy 600 remaining nozzle inside diameter (ID) affected by the repair that are expected to have tensile stresses greater than 20,000 pounds per square inch (20 ksi). The NRC staff notes that Alloy 600 in a reactor coolant environment is less likely to initiate flaws as a result of PWSCC when the residual tensile stress is less than 20 ksi. Therefore, the NRC staff finds that the licensee's application of rotary peening provides reasonable assurance that PWSCC flaws will not initiate in the repaired area of the nozzles. In addition, the staff notes that the nozzle material will be examined in accordance with Code Case N-729-4 each refueling outage which should be sufficient to detect any cracks before they can reach through-wall.

Loose Parts Evaluation

The licensee postulated radial cracks to occur in the remnant J-groove weld due to the dominance of hoop stresses and transverse cracks. The NRC staff determines that there are no driving forces that could cause transverse cracks to link with radial cracks to results in a portion of the J-groove weld to break off. The NRC staff finds that the licensee has adequately demonstrated that the fragments from the remnant J-groove weld are not likely to fall into the reactor vessel to become loose parts.

3.2.3 Examinations

The NRC staff determined that the examinations provide reasonable assurance that structural integrity of the repaired nozzle will be maintained. As such, the NRC evaluated the requirements of the pre-welding examination, acceptance examinations, preservice, and ISIs as discussed below.

Pre-Welding Examination

The NRC staff notes that prior to making the new weld, the licensee will perform PT of the RVCH penetration bore and the ID of the nozzle as shown in Figure 3 of Attachment 1 to the RR. The examination coverage will be from the top of the remnant J-groove weld to 1/2 inch above the upper portion of the weld preparation on the bottom of the Alloy 600 nozzle. The NRC staff finds that the examination coverage is adequate to ensure that the welded surface and machined surface are free of defects prior to welding.

Acceptance Examination

The licensee requested to deviate from the requirement of ASME Code, Section III, paragraph NB-5245, related to incremental surface examinations of the new welds. As an alternative, the licensee proposed to perform PT and UT examinations of the final weld to the extent possible. The NRC staff finds that as long as the licensee performs a PT and UT examination of the completed weld, the incremental surface examinations are not needed because the UT examination and the final PT examination will be able to detect fabrication defects that have been verified by mock-up testing performed by the licensee.

The proposed acceptance examination of the completed weld consists of UT and PT. The proposed examination coverage for UT and PT is shown in Figure 3 of Attachment 1 to the RR. The proposed UT examination will extend from 1 inch below the new weld in the Alloy 690 replacement nozzle material up to 1 inch above the new weld into the Alloy 600 nozzle. The inspected volume will also include at least 1/4-inch depth into the RVCH base metal underneath the new weld. The post weld PT will extend from 1 inch below the weld joining the Alloy 690 replacement nozzle to the RCVH to 3 inches above the top of the weld on the Alloy 600 nozzle material to the RVCH. The area above the weld includes the entire region of the Alloy 600 nozzle that was roll expanded.

The NRC staff finds that the proposed acceptance examinations are acceptable because PT and UT will cover sufficient examination areas of the new weld and the surrounding regions to provide reasonable assurance of structural integrity of the new weld and associated nozzle penetration region.

Preservice and ISIs

The post-weld PT examination discussed above meets the requirements of Code Case N-729-4, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D), for preservice examinations required by paragraph 2200 of N-729-4 and are, therefore, acceptable.

The NRC staff finds that the UT ISI volume, identified in Figure 9 of Attachment 1 to the RR, that the licensee will use to perform ISIs in accordance with Code Case N-729-4, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D), is acceptable because the inspection volume is greater than that required by Figure 2 in Code Case N-729-4.

Based on the above, the NRC staff finds that the preservice and future ISIs are acceptable because they meet the requirements 10 CFR 50.55a(g)(6)(ii)(D).

In summary, the NRC staff determines that the proposed alternative provides reasonable assurance of structural integrity of the repaired RVCH penetration nozzles because: (a) the weld design and the proposed repair are performed in accordance with the ASME Code, Sections III and XI, Code of Construction, and Code Case N-638-6, with deviations, to which the licensee has satisfactorily addressed; (b) the licensee has performed necessary analyses to demonstrate the acceptability of the RVCH and repaired nozzles containing postulated flaws to remain in service; and (c) the licensee will examine the repaired RVCH nozzles every refueling outage in the future in accordance with ASME Code Case N-729-4, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D).

4.0 CONCLUSION

The NRC staff concludes that RR No. RR 5-7 will provide an acceptable level of quality and safety for the repaired RVCH nozzle Nos. 25, 33, and 36. Accordingly, the NRC staff concludes that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(z)(1), and is in compliance with the requirements of the ASME Code, Section XI, ASME Code Case N-638-6, as conditioned in RG 1.147, and ASME Code Case N-729-4, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D). Therefore, the NRC authorizes the use of RR No. RR 5-7 at PNP for the remaining period of the fifth 10-year ISI interval, which is scheduled to end on December 20, 2025. The repairs performed under RR No. RR 5-7 are acceptable for a design life of 27 years.

All other requirements of ASME Code, Section XI, and 10 CFR 50.55a(g)(6)(ii)(D) for which relief was not specifically requested and authorized by the NRC staff remain applicable, including third-party review by the Authorized Nuclear Inservice Inspector.

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Date of issuance: April 26, 2019

SUBJECT: PALISADES NUCLEAR PLANT – APPROVAL OF ALTERNATIVE FOR REPAIR OF REACTOR PRESSURE VESSEL HEAD PENETRATIONS (EPID L-2018-LLR-0139) DATED APRIL 26, 2019

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