HOLTEC
PALISADES

27780 Blue Star Highway, Covert, MI 49043

PNP 2025-058

10 CFR50.55a

August 20, 2025

ATTN: Document Control Desk
U.S. Nuclear Regulatory commission
Washington, DC 20555-0001

Palisades Nuclear Plant
NRC Docket 50-255
Renewed Facility Operating License No. DPR-20

Subject: Relief Request Number RR 5-11, *Proposed Alternative to ASME Section XI Code Requirements for Primary Coolant System Piping Branch Connection Modifications*

Pursuant to Title 10 of the Code of Federal Regulations (10 CFR) 50.55a, *Codes and standards*, paragraph (z)(1), Holtec[1] hereby requests Nuclear Regulatory Commission (NRC) approval of the attached relief request for the Palisades Nuclear Plant (PNP) Inservice Inspection (ISI) Program, fifth ten-year interval.

PNP ceased operation in Spring 2022. Holtec is performing modifications to PNP to support the restart of plant operations. The Palisades Primary Coolant System (PCS) piping branch connections contain full penetration unmitigated butt welds fabricated from materials that are susceptible to Primary Water Stress Corrosion Cracking (PWSCC). There exists the potential that flaws may develop in the unmitigated welds that may result in leakage.

Holtec is requesting relief under 10 CFR 50.55a (z)(1) from the defect removal requirements of ASME Code Section XI IWA-4000. The identified welds will be proactively mitigated utilizing a repair/replacement activity that meets the requirements of ASME Code Case N-853-1, PWR Class 1 Primary Piping Alloy 600 Full Penetration Branch Connection Weld Metal Buildup for Material Susceptible to Primary Water Stress Corrosion Cracking, Section XI, Division 1, Approval Date: November 20, 2020, with the alternatives discussed herein. This repair/ replacement activity provides an acceptable level of quality and safety.

The provisions of this relief are applicable to the fifth ten-year Inservice Inspection interval at PNP, which commenced on December 13, 2015, and is currently scheduled to end on December 12, 2025, as identified in the Fifth Interval Inservice Inspection Plan, submitted to the NRC on December 09, 2015, (Reference 2). While this relief request identifies some of the

[1] Holtec Palisades, LLC ("Holtec Palisades") is the licensed owner of PNP. Pursuant to the license transfer amendment received in connection with the PNP restart (Reference 1), licensed operating authority has transferred from Holtec Decommissioning International, LLC ("HDI") to Palisades Energy, LLC ("Palisades Energy").

same code cases as previous relief requests, updated versions of the applicable code cases, as approved by the NRC, may be used and are referenced in this submittal.

Attachments 1, 2 and 3 to this letter provide the supporting information for this relief request.

Holtec is requesting NRC approval by October 3, 2025.

This letter contains no new regulatory commitments.

Please refer any questions regarding this submittal to Frank Sienczak PNP Regulatory Assurance Manager, at (269) 764-2263.

Sincerely,

Jean A. Fleming

Digitally signed by Jean A. Fleming
DN: cn=Jean A. Fleming, o=Holtec Decommissioning International, LLC, ou=Regulatory and Environmental Affairs, email=J.Fleming@Holtec.com
Date: 2025.08.20 11:52:01 -04'00'

Jean A. Fleming
Vice President of Licensing and Regulatory Affairs
Holtec International

Attachment:

1. Relief Request RR-5-11,Primary Coolant System Piping Branch Connection Modifications, Inservice Inspection Program, Fifth Ten-Year Interval

2. Ambient Temperature Temper Bead Elimination of 48-Hour Hold Time from ASME Code Case N-888 When Using Austenitic Filler Material

3. Technical Basis for the Inclusion of 28% Chromium Nickel-Based Filler Metals in ASME Code Case N-770-X

References:

1. U.S. Nuclear Regulatory Commission (NRC) letter to Holtec, *Palisades Nuclear Plant –Order Approving Direct Transfer of Renewed Facility Operating License and Independent Spent Fuel Storage Installation General License and Issuance of Conforming Amendment 275 (EPID L-2023-LLM-0005),* dated July 24, 2025 (ADAMS Accession No. ML25167A243)

2. Entergy Nuclear Operations Inc. letter to NRC, “Inservice Inspection Master Program Fifth 10-year Interval”, dated December 09, 2015 (ADAMS Accession No. ML15343A090)

cc: NRC Senior Resident Inspector, PNP
NRC Project Manager, PNP
NRC Region III Administration

ATTACHMENT 1

Palisades Nuclear Plant

Relief Request RR 5-11

Proposed Alternative Requirements for the Modification of
Primary Coolant System Hot Leg and Cold Leg
Piping Branch Connection Dissimilar Metal Welds
In Accordance with 10 CFR 50.55a(z)(1)

1.0 ASME CODE COMPONENT AFFECTED

Component:	Primary Coolant System (PCS) Hot Leg / Cold Leg Piping
Description:	Alternative Requirements for the Modification of Primary Coolant System Hot Leg and Cold Leg Branch Connection Dissimilar Metal Welds
Code Class:	Class 1
Examination Category:	ASME Code Case N-770-7, Inspection Items A-2 and B-1
Identification:	• PCS-42-RCL-1H-3/2 NPS 2 Sch 160 Drain/Long Term Cooling Nozzle (Inspection Item A-2) • PCS-30-RCL-1A-11/2 NPS 2 Sch 160 Charging Inlet Nozzle (Inspection Item B-1) • PCS-30-RCL-2A-11/2 NPS 2 Sch 160 Charging Inlet Nozzle (Inspection Item B-1) • PCS-30-RCL-1B-10/3 NPS 3 Sch 160 Spray Outlet Nozzle (Inspection Item B-1) • PCS-30-RCL-2A-11/3 NPS 3 Sch 160 Spray Outlet Nozzle (Inspection Item B-1)
Reference Drawings:	• VEN-M1-D, Sheet 106, Rev. 10, Piping Assembly & Details (M0001D-0106, Rev. 10) • VEN-M1-D, Sheet 107, Rev. 76, Piping Assembly & Details (M0001D-0107, Rev. 76)
Materials:	• Primary Coolant System Piping – SA-516 Grade 70 (P-No. 1) • Alloy 600 Nozzles – SB-167 UNS N06600 (P-No. 43) • Alloy 182 Dissimilar Metal Welds (DMW) – ENiCrFe-3, SFA-5.11 (F-No. 43)

2.0 APPLICABLE CODE EDITION AND ADDENDA

The current edition for the Inservice Inspection (ISI) interval for Palisades Nuclear Plant (PNP) is the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC), Section XI, 2007 Edition with Addenda through 2008 (Reference 1). PNP is in the fifth inspection interval with a scheduled end date of December 12, 2025.

The Code of Construction for the PNP PCS piping is ASA B31.1, 1955 Edition and ASME B&PVC Section III, 1965 Edition including Addenda through Winter 1966.

ASME B&PVC Code Case N-770-7 (Reference 2) as conditioned by 10 CFR 50.55a.

ASME B&PVC Code Case N-853-1 (Reference 3).

ASME B&PVC Section III, Subsection NB, 2019 Edition.

3.0 APPLICABLE CODE REQUIREMENTS

Code Case N-770-7 (as conditioned by 10 CFR 50.55a) and Reference 5 (Alternative Inspection requirements for PCS branch connection DMWs) require that the hot leg and cold leg full penetration dissimilar metal butt welds susceptible to PWSCC be inspected in accordance with Table 1 of Code Case N-770-7 as part of the ISI program. Holtec International (Holtec) has decided to proactively mitigate selected branch connection nozzle butt welds in the primary coolant system (PCS) piping by installing a welded reinforcing pad and replacement nozzle. The ASME B&PVC requirements applicable to the mitigation are listed below.

A. ASME Code, Section XI (Reference 1), Article IWA-4000 provides requirements for repair/replacement activities:

- IWA-4421 states, in part:
  Defects shall be removed or mitigated in accordance with the following requirements...

- IWA-4422.1(a) states, in part:
  A defect is considered removed when it has been reduced to an acceptable size...

- IWA-4422.1(b) states, in part:
  Alternatively, the defect removal area and any remaining portion of the defect may be evaluated, and the component accepted in accordance with the appropriate flaw evaluation provisions of Section XI…

B. Paragraph 2(d) of Code Case N-853-1 requires that the weld between the replacement nozzle and the weld pad be a partial penetration weld.

C. Paragraph 3(d)(3) of Code Case N-853-1 requires volumetric examination of the weld pad deposit and the ferritic heat-affected zone beneath the weld deposit to be conducted no sooner than 48-hours following completion of the three tempering layers when ambient temperature temper bead welding is performed.

D. Paragraph 3(d)(3) of Code Case N-853-1 requires that the acceptance criteria of NB-5330 be applied to the volumetric examination of the weld pad deposit and the ferritic heat-affected zone beneath the weld deposit.

E. Paragraph 4 of Code Case N-853-1 requires the Preservice Examination to be a visual examination of the weld pad deposit, the partial penetration weld attaching the new branch connection nozzle, and ½-inch of the adjacent materials.

F. Paragraph 5 of Code Case N-853-1 requires the Inservice Examination to be a visual examination of the weld pad deposit, the partial penetration weld attaching the new branch connection nozzle, and ½-inch of the adjacent materials during the first or second refueling outage following implementation.

G. Paragraph -1210(b) of Code Case N-770-7 lists ERNiCrFe-7, ENiCrFe-7, and ERNiCrFe-7A as weld filler materials for mitigating piping nozzle butt welds fabricated with Alloy 82/182 material.

4.0 REASON FOR REQUEST

The welds identified in Section 1 are unmitigated full penetration butt welds fabricated from materials susceptible to PWSCC. There exists the potential that flaws may develop in these unmitigated welds that may result in leakage. In accordance with References 2 and 5, the hot leg DMW requires visual examination each refueling outage and volumetric examination every 5 years (Inspection Item A-2) and the cold leg DMWs require visual examination once per interval and volumetric examination every second inspection period not to exceed 7 years (Inspection Item B-1).

A. Holtec is applying a welded reinforcing pad on the outer surface of the PCS piping using PWSCC resistant nickel Alloy 52MSS (ERNiCrFe-13) filler material. The weld pad will be designed and installed in accordance with Code Case N-853-1, as modified herein.

B. ASME B&PVC, Section III (Reference 4), paragraph NB-3661.3 requires the branch connection to not be larger than NPS 2 when a partial penetration weld is used for the branch connection. Therefore, due to the Cold Leg Spray Outlet nozzles being larger than NPS 2, a full penetration nozzle corner weld will be used to attach the Cold Leg Spray Outlet replacement nozzles.

C. Surface and volumetric acceptance examinations of the weld pad will be performed sooner than 48-hours following completion of the three tempering layers.

D. Acceptance criteria for the fabrication volumetric acceptance examination will be in accordance with Section XI, IWB-3514. The reinforcement size of the weld pad determined per the structural design requirements of Code Case N-853-1 will be ultrasonically examined to detect laminar flaws in the weld pad material that might obstruct subsequent inservice examinations and will be examined for planar flaws. The weld pad material beyond the structural reinforcement material will be ultrasonically examined to detect laminar flaws in the weld pad material that might obstruct subsequent inservice examinations.

E. Preservice examination of the structural reinforcement material will be performed in accordance with Inspection Item C-1 of Code Case N-770-7. The PSI volumetric examination will be performed using the manual linear phased array ultrasonic examination technique.

F. Inservice examination of the structural reinforcement material will be performed in accordance with Inspection Item C-1 of Code Case N-770-7. The ISI volumetric examination will be performed using the manual linear phased array ultrasonic examination technique.

G. Paragraph -1210(b) of Code Case N-770-7 does not list Alloy 52MSS as one of the mitigative weld filler materials for piping nozzle butt welds fabricated with Alloy 82/182 material.

Holtec is requesting relief under 10 CFR 50.55a(z)(1) from the defect removal requirements of ASME Code, Section XI, IWA-4000. The identified welds will be proactively mitigated by a repair/replacement activity that meets the requirements of Code Case N-853-1, with the alternatives discussed herein. The repair/replacement activity provides an acceptable level of quality and safety.

5.0 PROPOSED ALTERNATIVE AND BASIS FOR USE

Figure 8-1 provides a generic sketch of the existing configuration of the nozzles identified in Section 1.0. The Alloy 600 nozzle and Alloy 182 weld are materials with known susceptibility to PWSCC. The replacement of the PWSCC susceptible materials with material that is resistant to PWSCC provides for an acceptable level of quality and safety. The PWSCC susceptible material at the locations listed in Section 1.0 is currently unmitigated. Installation of the PWSCC resistant branch connection weld metal buildup will reduce the risk of a flaw propagating through the pressure boundary.

The PWSCC resistant branch connection weld metal buildup design will be in accordance with Code Case N-853-1. Implementation and examination of the BCWMB will be in accordance with Code Case N-853-1 as modified herein. The proposed alternatives and basis for use are discussed below.

A. Code Case N-853-1 has been unconditionally approved by the NRC as an alternative to the defect removal requirements of IWA-4000, and is listed as an acceptable Section XI Code Case in Table 1 of Regulatory Guide 1.147, Revision 21.

B. Paragraph 2(d) of Code Case N-853-1 requires that the weld between the replacement nozzle and the weld pad be a partial penetration weld as shown in Figure 8-2.

A full penetration nozzle corner weld will be used to join the two (2) PWSCC resistant Spray Outlet replacement nozzles to the weld pad using a non-temper bead manual welding technique with Alloy 52MSS filler material. The technical basis for Code Case N-853-1, Reference 6, includes discussion for the use of full penetration nozzle welds.

The full penetration nozzle corner weld configuration shown in Figure 8-3 complies with ASME Code Section III, Figure NB-4244(b)-1 detail (a) and will be examined in accordance with the requirements of ASME Code Section III, paragraph NB-5243. The reason for using a full penetration corner welded nozzle in lieu of a partial penetration weld is that paragraph 2(d)(1) of Code Case N-853-1 requires the replacement nozzle installation to be in accordance with the requirements of the Construction Code. The Construction Code applicable for this mitigation is ASME Code Section III, Reference 4. Paragraph NB-3661.3 requires the branch connection to be no larger than NPS 2 when a partial penetration weld is used for the branch connection. The Cold Leg Spray Outlet nozzles are NPS 3, therefore, a full penetration corner welded nozzle will be installed as part of the mitigation of the Spray Outlet nozzles.

Therefore, Holtec requests approval to install the cold leg Spray Outlet nozzles using full penetration nozzle corner welds in lieu of partial penetration welds as required by Code Case N-853-1.

C. When ambient temperature temper bead welding is performed, paragraph 3(d)(3) of Code Case N-853-1 requires volumetric examination of the weld pad deposit and the ferritic heat-affected zone beneath the weld deposit to be conducted no sooner than 48-hours following completion of the three tempering layers.

Surface and volumetric acceptance examinations of the weld pad will be performed sooner than 48-hours following completion of the three tempering layers. Technical justification for austenitic filler materials has been developed to allow NDE methods to be performed after completion of the weld modification, without waiting for the 48-hour hold time.

Elimination of the 48-hour hold is based on Attachment 2, which is a white paper based on PVP2023-107489, "Elimination of the 48-hour Hold for Ambient Temperature Temper Bead Welding with Austenitic Weld Metal." Removal of the 48-hour hold is supported by the white paper that was developed for the proposed change to ASME Code Case N-888-1. Although this ASME Code Case is not approved in Regulatory Guide 1.147, Revision 21, it has been approved by the ASME Section XI Standards Committee. Since Code Case N-888 is the culmination of temper bead code cases that have been produced over the years, combining requirements from Code Cases N-638, N-839, and ASME Section XI, Mandatory Appendix I in Code Cases such as N-740 and N-754, etc., the justification is also applicable to the planned use of Code Case N-853-1 at Palisades.

Therefore, Holtec requests approval to eliminate the 48-hour hold requirement specified in paragraph 3(d)(3) of Code Case N-853-1.

D. Paragraph 3(d)(3) of Code Case N-853-1 requires volumetric examination of the weld pad deposit and the ferritic heat-affected zone beneath the weld deposit with acceptance criteria in accordance with NB-5330. The UT volumetric examination is required to be demonstrated in accordance with Section V of the ASME Code.

In lieu of the NB-5330 acceptance criteria, acceptance criteria will be in accordance with ASME Code, Section XI, IWB-3514. In using the rules in IWB-3514 for evaluation of flaws in the weld pad, the thickness of only the weld pad will be used. The IWB-3514 rules have been previously used (Precedent 2) for UT volumetric examination of Alloy 52M branch connection weld metal buildups preemptively applied in accordance with Code Case N-853. The proposed inspection criteria will detect flaws in the weld pad such as inter-bead lack of fusion, inclusions, or cracks, and must meet the standards of IWB-3514 to be acceptable.

The weld pads to be installed at Palisades will be approximately 1.3-inch thick and approximately 18 inches square. Their deposition by welding produces a residual stress field that is used to evaluate the fatigue crack growth per Code Case N-853-1 requirements. Current rules in Section III would not allow for any crack-like defects, regardless of size, orientation, depth, cause, or significance to the overall structural integrity of the pad and its protection of the underlying pressure boundary material. Section III criteria would require removal of a portion of the pad, that would then have to be rewelded and re-inspected. The primary benefit to using the IWB-3514 acceptance criteria is that small, structurally insignificant defects, i.e., those that meet the IWB acceptance criteria, if found, would be allowed to remain without repair. The result would be a structurally acceptable, unrepaired weld pad producing an intact residual stress field that would protect the PCS pressure boundary components from PWSCC. The proposed alternative does not alter the required examination coverage, or the specific UT method used for the inspection. In addition, manual pad repairs are dose and time intensive processes; therefore, not repairing a weld pad enhances outage personnel safety by reducing potential injuries during grinder usage and the accumulation of less dose.

A Manual Linear Phased Array UT Procedure will be used that meets the demonstration requirements of ASME Code, Section V. This procedure will employ technical elements of the Performance Demonstration Initiative (PDI) qualified Supplement 11 procedures, which will be implemented by PDI-qualified Supplement 11 weld overlay examiners.

Prior to boring the hole and machining the joint preparation for the replacement nozzle, the volumetric examination will be performed using procedures, personnel and equipment qualified for flaw detection in accordance with Section V, Article 14 low rigor requirements, or Section XI Mandatory Appendix VIII, Supplement 11. The reinforcement size of the weld pad as determined per the structural design requirements of Code Case N-853-1 will be ultrasonically examined to detect laminar flaws in the weld pad material that might obstruct subsequent inservice examinations and will be examined for planar flaws. The weld pad and fusion zone between the Alloy 52MSS material and the carbon steel piping will be examined to ensure the presence of adequate bond between the weld pad and the carbon steel material. The weld pad material beyond the structural reinforcement material will be ultrasonically examined to detect laminar flaws in the weld pad material that might obstruct subsequent inservice examinations.

- The BCWMB volume A-B-G-H and D-C-F-E in Figure 8-4 will be ultrasonically examined to ensure adequate fusion (i.e., bond) with the base material and to detect laminar flaws in the weld pad material that might obstruct subsequent inservice examinations.
- The BCWMB volume B-C-F-M-J-G in Figure 8-4, that is determined from the design reinforcement size requirements of Code Case N-853-1, will be examined for laminar flaws and planar flaws. Planar flaws will meet the acceptance standards of Table IWB-3514-1. Laminar flaws will meet the acceptance standards of Table IWB-3514-3 and the following requirements:
  - The reduction in coverage of the examination volume in Figure 8-5 will be less than 10%. The dimensions of the uninspectable volume are dependent on the coverage achieved with the angle beam exam of the weld pad.
  - Any uninspectable volume will be assumed to contain the largest radial planar flaw that could exist within that volume. The assumed flaw will meet the acceptance standards of Table IWB-3414-1 or the requirements of IWB-3640. Both axial and circumferential flaws will be assumed.

- The base material beneath the BCWMB, examination volumes H-G-J-K-L and E-F-M-N-O in Figure 8-4, shall be examined for lamellar tearing. Lamellar tearing will be evaluated as a laminar type imperfection in accordance with NB-2500 and the applicable material product form.

Nonmandatory Appendix Q of ASME Section XI (2021 Edition) provides different acceptance criteria for structural reinforcement volume and the weld buildup volume deposited to permit ultrasonic examination of the structural volume. The NRC has approved the 2021 Edition of Nonmandatory Appendix Q in the latest issuance of 10 CFR 50.55a with no conditions on the examination requirements and one condition on subparagraph Q-3000(a) relating to the stress corrosion crack growth analysis.

Code Case N-894 (References 7 and 8) also provides different acceptance criteria for structural reinforcement volume and the weld buildup volume deposited to permit ultrasonic examination of the structural volume. Code Case N-894 is not listed in Regulatory Guide 1.147 Revision 21, however, the case has been approved by ASME.

Note that acceptance surface examination of the weld pad will meet the requirements of Code Case N-853-1.

Therefore, Holtec requests approval to apply IWB-3514 acceptance criteria to the ultrasonic examination results of the weld pad acceptance inspection.

E. Paragraph 4 of Code Case N-853-1 requires a preservice inspection visual examination of the weld pad deposit, the partial penetration weld attaching the new branch connection nozzle, and ½-inch of the adjacent materials.

Preservice examination of the structural reinforcement material will be performed in accordance with Inspection Item C-1 of Code Case N-770-7. The PSI volumetric examination will be performed using the manual phased array ultrasonic examination technique.

The examination volume A-B-C-D shown in Figure 8-5 will be ultrasonically examined. The angle beam will be directed perpendicular and parallel to the piping axis, with scanning performed in four directions, to identify flaws in the outer 25% of the underlying pipe base metal as a benchmark for subsequent examinations.

The examination acceptance standards of Table IWB-3514-1 will be met for flaws in the weld pad material. In applying the acceptance standards to planar indications, the thickness, t_1 or t_2 as defined in Figure 8-5, will be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., piping material) is not susceptible to PWSCC. For susceptible material, t_1 shall be used. Planar flaws in the outer 25% of the original weld or base material thickness will meet the design analysis requirements of -3132.3(d) of Code Case N-770-7.

The flaw evaluation requirements of IWB-3640 will not be applied to planar flaws in the weld pad material, identified during preservice examination, that exceed the examination acceptance standards of IWB-3514.

Therefore, Holtec requests approval to apply Code Case N-770-7 preservice acceptance examination in lieu of the Code Case N-853-1 PSI visual examination.

F. Paragraph 5 of Code Case N-853-1 requires an inservice inspection visual examination of the weld pad deposit, the weld attaching the new branch connection nozzle, and ½-inch of the adjacent materials during the first or second refueling outage following implementation.

The examination volume in Figure 8-5 will be ultrasonically examined to determine the acceptability of the mitigated branch connection. The angle beam will be directed perpendicular and parallel to the piping axis, with scanning performed in four directions.

The weld pad will meet the requirements of paragraph -3132 of Code Case N-770-7. In applying the acceptance standards to planar indications, the thickness t_1 or t_2 as defined in Figure 8-5, shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., piping material) is not susceptible to PWSCC. For susceptible material, t_1 shall be used.

If inservice examinations reveal crack growth, or new cracking in the weld pad or outer 25% of original weld/base material meeting the acceptance standards, the weld pad examination volume will be reexamined during the first or second refueling outage following detection of the crack growth or new cracking. The weld pad examination volume will be subsequently examined two additional times at the period of one or two refueling outages, i.e., a total of three examinations within six refueling outages of detection of the crack growth or new cracking.

If the follow-up examinations required after detection of crack growth or new cracking reveal that the flaws remain essentially unchanged for three successive examinations, the weld examination schedule will revert to the sample and schedule of examinations identified in Table 1 of Code Case N-770-7 and the weld will be included in the 25% sample.

Therefore, Holtec requests approval to apply Code Case N-770-7 inservice acceptance examination in lieu of the Code Case N-853-1 ISI visual examination.

G. Paragraph -1210(b) of Code Case N-770-7 does not include Alloy 52MSS as one of the mitigative weld filler materials for piping nozzle butt welds fabricated with Alloy 82/182 material.

Many years of operating experience show the exceptional performance of all Alloy 52 type filler materials that utilize a chemistry consisting of greater than 28% Chromium for resisting Stress Corrosion Cracking. Therefore, it is appropriate to include other 28% Chromium bearing nickel-based filler materials in the list of Alloy 52 materials in Code Case N-770-X. Attachment 3 provides a technical basis for including other Alloy 52 variants that contain at least 28% Chromium as an acceptable filler material in N-770-7.

Therefore, Holtec requests approval for using Code Case N-770-7 examinations on weld pads consisting of Alloy 52MSS weld metal.

In summary, Holtec is requesting relief under 10 CFR 50.55a(z)(1) from the ASME Code, Section XI Code Case N-853-1 requirements listed in Section 3.0. The repair/replacement activity will follow the requirements stated in Code Case N-853-1 as modified herein. The requested relief is based on the use of Code Case N-853-1 (with the noted deviations/exceptions) that will provide an alternative with an acceptable level of quality and safety. The subject welds will be preemptively mitigated or repaired by application of a PWSCC resistant reinforcing weld pad and attachment of a PWSCC resistant nozzle.

6.0 DURATION OF PROPOSED ALTERNATIVE

The results of the analyses performed to establish the overall acceptable life of the modification design, as summarized in the Life Assessment Summary (Reference 9), demonstrate that the design of the BCWMB modifications is acceptable for continued operation, at a minimum, for the remainder of the 60-year licensed operational life (until 2031) plus an additional 20-year operational life extension.

The provisions of this relief are applicable to the fifth ten-year inservice inspection interval for PNP which began on December 13, 2015, and is currently scheduled to end on December 12, 2025.

The modifications installed in accordance with the provisions of this relief request shall remain in place for the remaining operational life of the plant/modification.

7.0 PRECEDENTS

1. Oconee Nuclear Station, Units 1, 2, And 3 – Proposed Alternative Request 19-ON-001 To Use Modified American Society of Mechanical Engineer's Boiler and Pressure Vessel Code Case N-853 (EPID No. L-2019-LLR-0028) (ADAMS Accession No. ML20055F571) [Safety Evaluation of Relief Request 19ON-001]

2. Oconee Nuclear Station, Units 1, 2, And 3 Authorization and Safety Evaluation For Relief Request RA-20-0334 For Use of Alternative Acceptance Criteria in Code Case N-853 (EPID L-2021-LLR-0032) (ADAMS Accession No. ML22028A365)

3. Oconee Nuclear Station, Units 1, 2, And 3 – Relief Request (RA-23-0018) to Utilize Code Case N-853, With Deviations (EPID L-2023-LLR-0024) (ADAMS Accession No.: ML23285A074) [*Safety Evaluation of Relief Request RA-23-0018*]

4. Palo Verde Nuclear Generating Station Unit 1 Re: Relief Request 70 – Proposed Alternatives for Pressurizer Lower Shell Temperature Nozzle (EPID L-2023-LLR-0057) (ADAMS Accession No.: ML24197A199) [Safety Evaluation of Relief Request 70]

8.0 REFERENCES

1. American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, 2007 Edition with the 2008 Addenda

2. ASME Code Case N-770-7, Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities, Section XI, Division 1, Approval Date: December 4, 2020

3. ASME Code Case N-853-1, PWR Class 1 Primary Piping Alloy 600 Full Penetration Branch Connection Weld Metal Buildup for Material Susceptible to Primary Water Stress Corrosion Cracking, Section XI, Division 1, Approval Date: November 20, 2020

4. ASME Code Section III, 2019 Edition

5. Palisades Nuclear Plant- Proposed Alternative, Use of Alternate ASME Code Case N-770-1 Baseline Examination (TAC NO. MF3508) [Safety Evaluation of RR-4-18 ML14056A533] (ADAMS Accession No. ML14223B226)

6. Waskey, D., McCracken, S., (2016); Technical Basis for Code Case N-853 – A600 Branch Connection Weld Repair for SCC Mitigation; Proceedings of the ASME 2016 Pressure Vessels and Piping Conference; PVP2016; July 17-21, 2016, Vancouver, British Columbia, Canada; PVP2016-63902

7. ASME Code Case N-894, Repair of Class 1, 2, and 3 Austenitic Stainless Steel with Thermal Fatigue Cracking, Section XI, Division 1, Approval Date: September 22, 2023

8. Marlette, S., McCracken, S., Lohse, C., (2020): Technical Basis for Code Case N-894 Alternative Rules for Repair of Classes 1, 2, and 3 Austenitic Stainless Steel Piping with Thermal Fatigue Cracking; Proceedings of the ASME 2020 Pressure Vessels and Piping Conference; PVP2020: July 19-24, 2020, Minneapolis, MN, USA; PVP2020-21544

9. Framatome Evaluation 51-9392837-000, Life Assessment Summary for Palisades Hot Leg and Cold Leg Branch Connection Modifications (Proprietary)

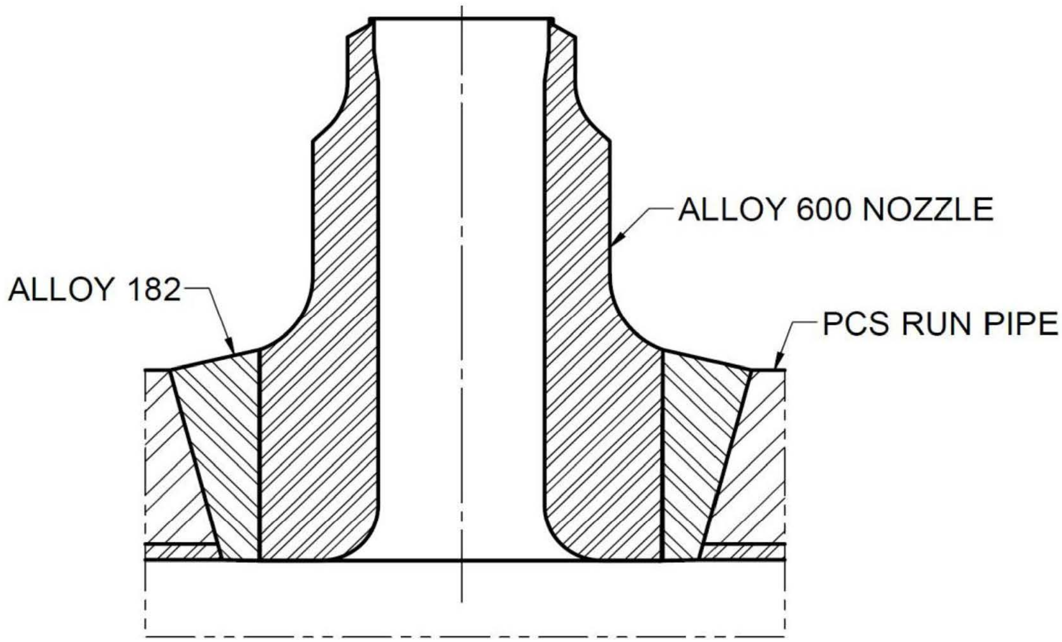

Figure 8-1 Example of Typical Existing Nozzle Configuration

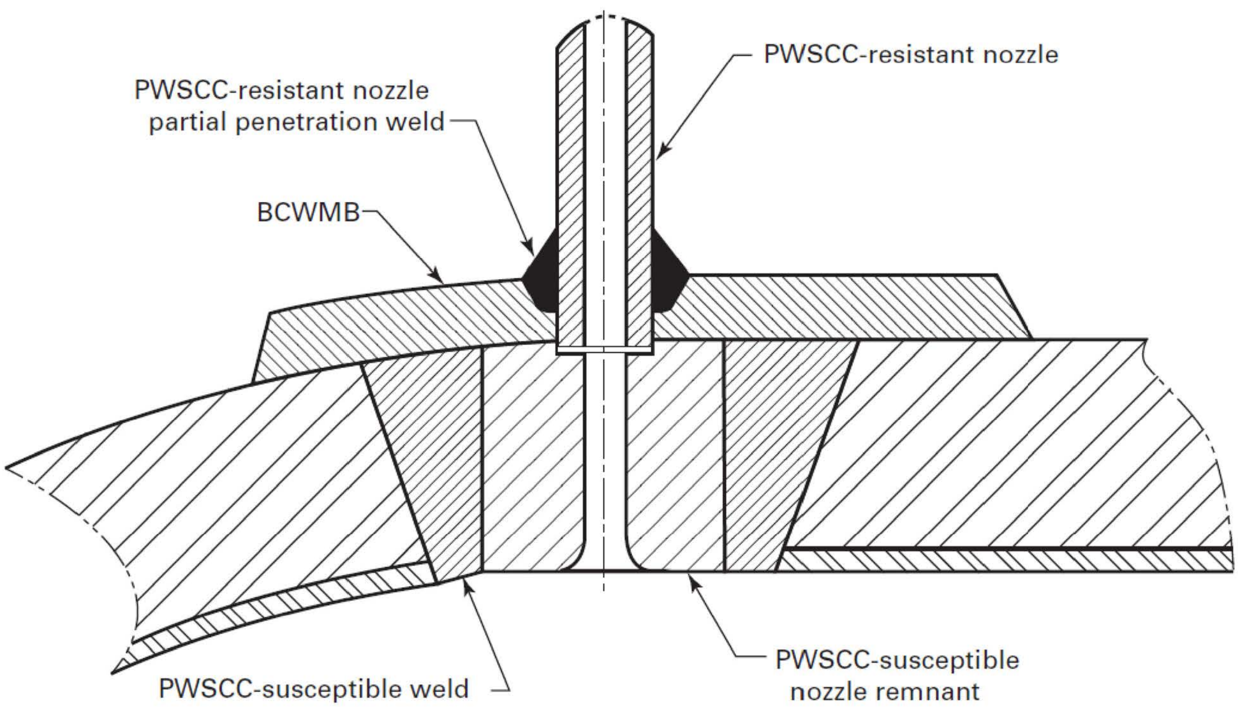

Figure 8-2 Typical Representative Branch Connection Mitigation

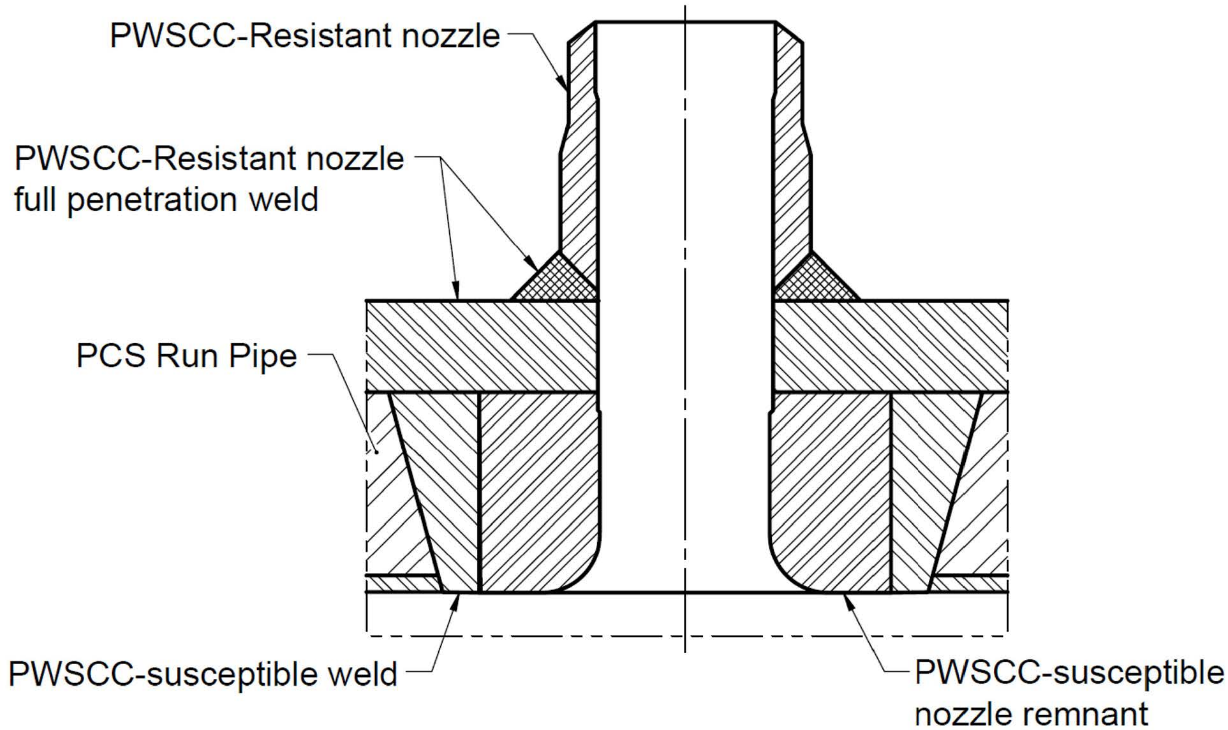

Figure 8-3 Spray Outlet Nozzle Full Penetration Corner Weld

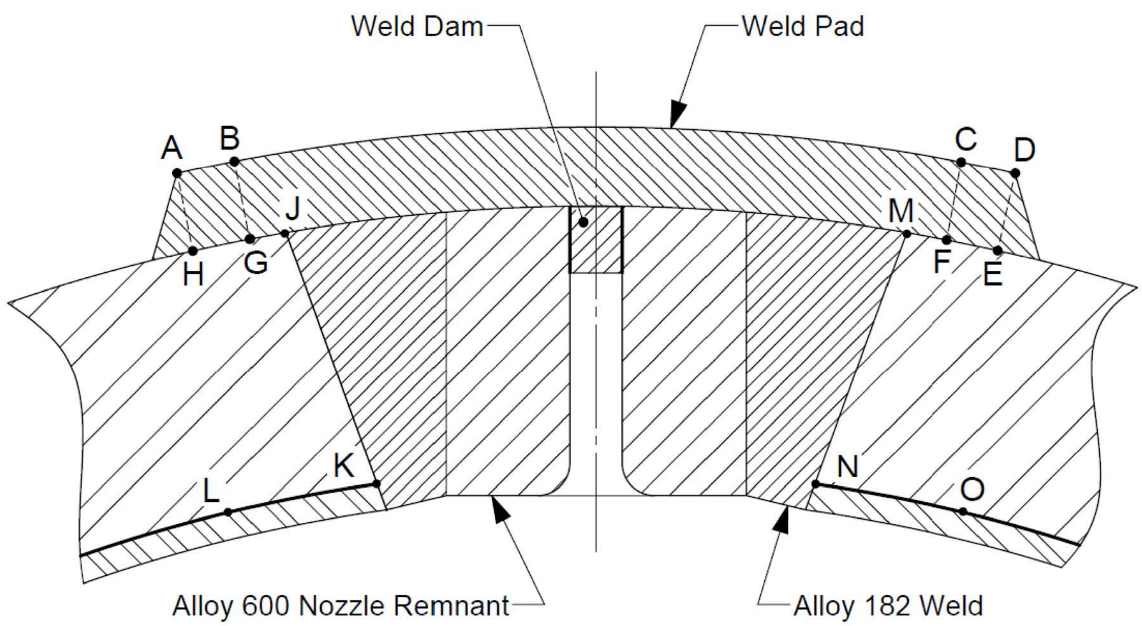

Figure 8-4 Volumetric Acceptance Examination of Weld Pad

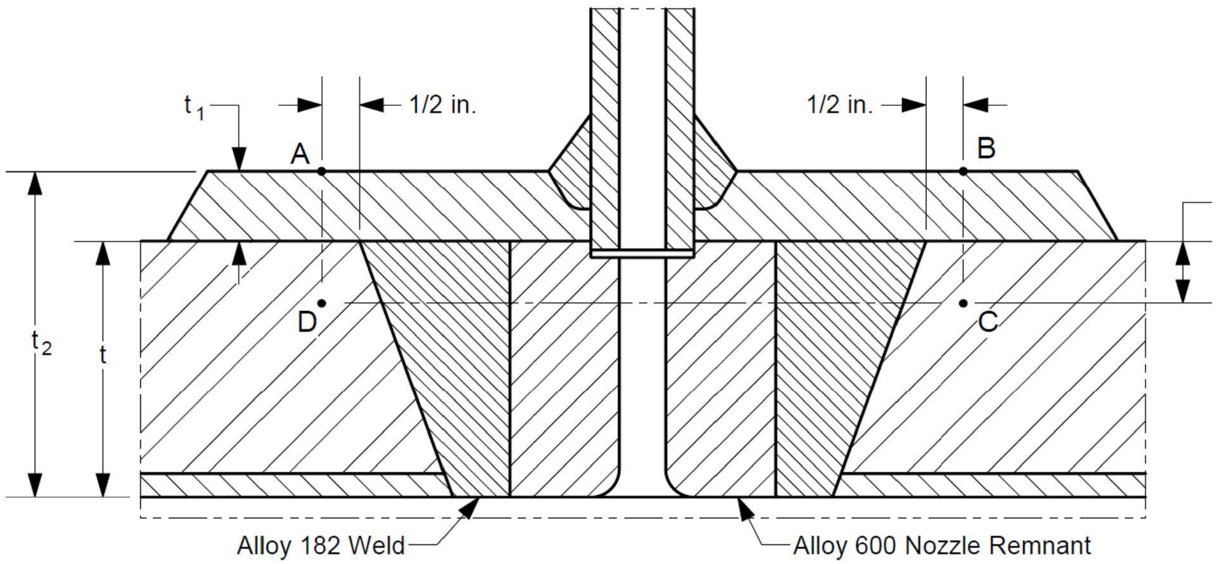

Figure 8-5 Preservice and Inservice Examination Volume

ATTACHMENT 2

Ambient Temperature Temper Bead-

Elimination of 48-Hour Hold Time from N-888 When using Austenitic Filler Material

White Paper

1. **Introduction and Background**

In welding, the presence of hydrogen in the weld metal or heat affected zone (HAZ) can cause hydrogen-induced cracking (HIC) occurring phenomena that occurs after the weldment has cooled to at or near room temperature. HIC is largely dependent upon three main factors, diffusible hydrogen, residual stress and susceptible microstructure. There are many theories on the mechanism for HIC, however, it is well understood that HIC requires simultaneous presence of a threshold level of hydrogen, a susceptible brittle microstructure and tensile stress. Additionally, the temperature must be in the range of 32 to 212°F (0 to 100°C). Elimination of just one of these four contributing factors will prevent HIC. (Reference 1).

Two early overlay (WOL) repairs involving temper bead welding were applied to two core spray nozzle-to-safe end joints at the Vermont Yankee boiling water reactor (BWR) in 1986 to mitigate intergranular stress corrosion cracking (Reference 2). To avoid post weld heat treatment, temper bead was deployed when installing the repair overlay on the low alloy steel SA-508 Class 2 (P- No. 3 Group 3) reactor pressure vessel nozzle. This early application of temper bead welding required elevated preheat and a post weld hydrogen bake.

As the industry experienced an increased need for temper bead welding the requirement for preheating and post weld bake made temper bead welding complicated. EPRI responded to the industry concern and conducted studies that demonstrated that repair to low alloy steel pressure vessel components could be made without the need for preheat or post weld bake (References 3 and 4). As a result of these studies the preheat and post weld bake requirements were not included in Case N-638 for ambient temperature temper bead welding with machine GTAW.

Deployment of the ambient temperature temper bead technique has been highly successful for many years with no evidence of HIC detected by nondestructive examination (NDE). During the past twenty years, many temper bead weld overlay repairs were successfully performed on BWRs and PWRs using ambient temperature temper bead technique, as illustrated in Table 1. The operating experience shows that with hundreds of ambient temperature temper bead applications, there has not been a single reported occurrence of hydrogen induced cracking.

Case N-888 is the culmination of temper bead code cases that have been produced over the years, combining requirements from N-638, N-839, and Appendix I in cases such as N-740 and N-754, etc. Case N-888 applies to temper bead of P-No. 1 or P-No. 3 materials and their associated welds or welds joining P-No. 8 or P-No. 43 materials to P- No. 1 or P- No. 3 materials. Additionally, Case N-888 provides provisions to allow for ambient temperature preheat with no post weld bake. However, the post weld 48-hour hold at ambient temperature has remained as a requirement in N-888. This 48-hour delay between welding completion and cooling to ambient temperature and the final nondestructive examination (NDE) of the fully welded component is intended to assure detection of delayed hydrogen cracking that is known to occur up to 48-hours after the weldment is at ambient temperature.

The post weld 48-hour delay following cooling to ambient temperature has resulted in a considerable cost burden to utilities. As there are significant economic advantages associated with eliminating the 48-hour hold time and immediately performing NDE following the completed weld, it is important to determine the technical advantages and disadvantages of making such a change.

Table 1: Successfully Implemented Repairs Completed Using Temper Bead Technique from 2002-2021

Date	Plant	Component (Qty.)
2002	Oconee[1]	Mid-Wall RVH Repair (15)
2002	ANO[1]	Mid-Wall RVH Repair (6)
2002	Oyster Creek[2]	Recirculation outlet nozzle (1)
2002	Peach Bottom Units 2 & 3[2]	Core spray, recirculation outlet, and CRD return nozzles
2002	Calvert Cliff[2]	Heater Sleeve Repairs (Pads) (~50)
2002	Oconee[1]	Mid-Wall RVH Repair (2)
2002	Davis-Besse[1]	Mid-Wall RVH Repair (5)
2002	Millstone[1]	Mid-Wall RVH Repair (3)
2003	Palo Verde 1[2]	Heater Sleeve Repairs -Pads (36)
2003	Pilgrim[2]	Core spray nozzle and CRD return nozzle
2003	TMI Unit 1[2]	Hot leg and Surge line nozzle
2003	Ringhals[1]	1/2 Nozzle with Structural Pad (2)
2003	Crystal River[1]	1/2 Nozzle with Structural Pad (3)
2003	South Texas[1]	1/2 Nozzle with Structural Pad (2)
2003	Millstone[1]	Mid-Wall RVH Repair (8)
2003	St. Lucie[1]	Mid-Wall RVH Repair (2)
2004	Palo Verde 2[2]	Heater Sleeve Repairs -Pads (34)
2004	Susquehanna Unit 1[2]	Recirculation inlet and outlet nozzles
2004	Hope Creek[1]	SWOL (1)
2004	Palisades[1]	Mid-Wall RVH Repair (2)
2004	Point Beach[1]	Mid-Wall RVH Repair (1)
2004	ANO[1]	Mid-Wall RVH Repair (1)
2005	Palo Verde 3[2]	36 Heater Sleeve Repairs – Pads (36)
2005	ANO[2]	Mid Wall heater sleeve repair
2005	Waterford[2]	Mid Wall heater sleeve repair
2005	Calvert Cliffs Unit 2[2]	Hot Leg Drain and Cold Leg Letdown Nozzles
2005	DC Cook Unit 1[2]	Pressurizer Safety Nozzle
2005	TPC Kuosheng[2]	N1 Nozzle
2005	SONGS 3[2]	Heater Sleeve Repairs -Pads (~29)
2005	Three Mile Island[1]	SWOL (1)
2005	St. Lucie[1]	Mid-Wall RVH Repair (3)
2006	SONGS 2[2]	Heater Sleeve Repairs -Pads (~30)
2006	Davis Besse[2]	Hot and Cold Leg
2006	SONGS 2[2]	Pressurizer Nozzles (6)
2006	Millstone 3[2]	Pressurizer Nozzles (6)
2006	SONGS 3[2]	Pressurizer Nozzles (6)
2006	Oconee 1[2]	Pressurizer Nozzles (6)
2006	Beaver Valley 2[2]	Pressurizer Nozzles (6)
2006	Byron 2[3]	Pressurizer Nozzles (6)
2006	Wolf Creek[3]	Pressurizer Nozzles (6)
2006	McGuire[2]	Pressurizer Nozzles (6)
2006	DC Cook[1]	SWOL (4)
2007	Callaway[3]	Pressurizer Nozzles (6)
2007	St. Lucie[1]	SWOL (4)
2007	Crystal River[1]	SWOL (4)
2007	Three Mile Island[1]	SWOL (4)
2007	North Anna[1]	SWOL (4)
2008	Prairie Island[1]	SWOL (1)
2008	Diablo Canyon[1]	SWOL (6)
2008	Diablo Canyon[1]	SWOL (4)
2008	Seabrook[1]	SWOL (4)
2009	Three Mile Island[1]	SWOL (1)
2009	Three Mile Island[1]	Full Nozzle with Structural Pad (1)

Date	Plant	Component (Qty.)
2009	Crystal River[1]	SWOL (1)
2009	Palisades[1]	Mid-Wall RVH Repair (2)
2010	Oconee[4]	U3 Letdown WOL (1)
2010	Krsko[1]	SWOL (5)
2010	Tihange[1]	SWOL (1)
2010	Davis-Besse[1]	Mid-Wall RVH Repair (24)
2011	Hatch[4]	Nozzle WOL (1)
2011	Talen Energy Corporation[4]	N5 core spray nozzles
2011	Monticello[4]	Emergent WOL (1)
2011	Three Mile Island[4]	TMI PZR Spray Nozzle (1)
2011	Doel[1]	SWOL (1)
2011	Tihange[1]	SWOL (1)
2011	St. Lucie[1]	1/2 Nozzle with Structural Pad (30)
2012	North Anna[4]	SG Nozzle WOLS (3)
2012	Palo Verde[4]	Small Bore CL Nozzles WOL
2012	Grand Gulf[4]	Reactor Vessel Nozzle Contouring and N6 Weld Overlay
2012	Doel[1]	SWOL (1)
2012	Calvert Cliffs[1]	Mid-Wall Przr Heater Repair (119)
2012	Quad Cities[1]	1/2 Nozzle with Structural Pad (1)
2012	Harris Nuclear Plant[1]	Mid-Wall RVH Repair (4)
2013	Farley[4]	Unit 2 FAC Pipe Replacement and WOL
2013	Oconee[4]	Hot/Cold Leg Small Bore Alloy 600
2013	Hope Creek[4]	Emergent N5A WOL
2013	Three Mile Island[1]	SWOL (1)
2013	Palo Verde[1]	1/2 Nozzle with Structural Pad (1)
2013	Harris Nuclear Plant[1]	Mid-Wall RVH Repair (2)
2015	Harris Nuclear Plant[1]	Mid-Wall RVH Repair (3)
2015	Hatch[4]	N4A WOL
2015	Millstone[4]	2" Drain WOL
2015	Hatch[4]	Recirc (N2) WOL
2016	Harris Nuclear Plant[1]	Mid-Wall RVH Repair (4)
2017	Fitzpatrick[4]	RHR WOL
2017	Limerick[1]	1/2 Nozzle with Structural Pad (1)
2018	Waterford[4]	Emergent Drain Nozzle WOLs (2)
2018	Palisades[1]	Mid-Wall RVH Repair (3)
2018	Doel[1]	Mid-Wall RVH Repair (16)
2018	Harris Nuclear Plant[1]	Mid-Wall RVH Repair (1)
2018	Brunswick[1]	SWOL (2)
2020	Peach Bottom[1]	1/2 Nozzle with Structural Pad (1)
2020	Palisades[1]	Mid-Wall RVH Repair (2)
2021	Oconee[4]	Complex nozzle pads on RCS piping
2021	ANO-2[1]	Mid-Wall RVH Repair (1)

Notes: Operating experience provided by Steve McCracken (EPRI), Darren Barborak (EPRI, formerly with AZZ), and Travis Olson (Framatome)

(1) Framatome
(2) Unknown
(3) PCI
(4) AZZ Specialty Welding

2. Objective

The objective of this white paper is to provide technical justification to eliminate the 48-hour delay when using austenitic filler materials in the temper bead welding process for P-No. 1 and P-No. 3 ferritic materials. The industry and regulatory technical concerns related to this change are examined and the technical bases for changing the requirements for the 48-hour delay are presented. Discussion from white paper for *Ambient Temperature Temper Bead Weld Overlay Gas Tungsten Arc Welding* by Hermann and Associates (Reference 9) are included in this white paper.

If adopted, it is expected that the change in the 48-hour delay requirement will become part of a revision to the current ASME Section XI Case N-888 that currently allows for ambient temperature temper bead repairs but requires 48-hour delay after the initial three temper bead layers prior to final NDE.

3. Technical Issues Related to the 48-Hour Delay

The reasons for performing the final NDE after the 48-hour delay is the recognition that alloy steels can become susceptible to HIC. There are two primary weld cracking mechanisms of concern for low alloy steels during cooling or after reaching ambient temperature. These are cold cracking of high restraint geometries (weld shrinkage-induced) and hydrogen induced cracking (HIC), often referred to as hydrogen delayed cracking. Cold cracking occurs immediately as the weldment cools to ambient temperature. In contrast, HIC can occur immediately during cooling to ambient temperature or up to 48-hours after reaching ambient temperature. Cold cracking that occurs with high restraint weldments would therefore be detected by NDE performed immediately after the weldment is complete.

EPRI studies [4] have indicated that cold cracking occurs under conditions of high geometrical restraint especially where low toughness HAZs are potentially present.

Restraint mechanisms can occur either hot (resulting in intergranular or interdendritic cracking), or cold (resulting in transgranular cracking of material having marginal toughness). Cold cracking occurs immediately as the weld deposit cools to ambient temperature. Proper joint design, appropriate welding procedures and bead sequences, are practical solutions that avoid critical cold cracking conditions. This form of cracking is addressed effectively by the ASME code guidance including welding procedure qualification testing and by in-process and or post-weld inspections.

The other form of cracking at ambient temperature, which is the focus of this white paper, is HIC. This cracking mechanism manifests itself as intergranular cracking of prior austenite grain boundaries and in contrast to cold cracking generally occurs during welding, but also up to 48-hours after cooling to ambient temperature. It is produced by the action of internal tensile stresses acting on low toughness HAZs (generally characterized by inadequate tempering of weld related transformation products). The most widely accepted theory suggests that the internal stresses will be produced from localized buildup of monatomic hydrogen. Monatomic hydrogen can be entrapped during weld solidification, and will tend to migrate, over time, to prior austenite grain boundaries or other microstructure defect locations. As concentrations build, the monatomic hydrogen will recombine to form molecular hydrogen, thus generating highly localized internal stresses at these internal defect locations. Monatomic hydrogen is produced when moisture or hydrocarbons interact with the welding arc and molten weld pool.

The concerns with and driving factors that cause hydrogen induced cracking have been identified. These issues are fundamental welding and heat treatment issues related to temper bead welding, requiring a technical resolution prior to modification of the current ASME Code Cases N-888 by the ASME Code and the technical community. Specific concerns relate to the following issues:

-Microstructure

-Sources for Hydrogen Introduction

-Diffusivity and Solubility of Hydrogen

In the following discussion of this white paper each of these factors is briefly described to provide insight into the impact and proper management of these factors that cause HIC.

4. Discussion of Technical Issues Related to the 48-Hour Delay

Microstructure:

C-Mn and low alloy steels can have a range of weld microstructures which is dependent upon both specific composition of the steel and the welding process/parameters used. Generally, untempered martensitic and untempered bainitic microstructures are the most susceptible to hydrogen cracking. These microstructures are produced when rapid cooling occurs from the dynamic upper critical (A_{c3}) transformation temperature (Reference 1). Generally, a critical hardness level necessary to promote hydrogen cracking is on the order of Rc 35 for materials with high hydrogen and Rc 45 for low level of hydrogen. Maintaining hardness levels below these thresholds generally avoids hydrogen cracking (Reference 1).

EPRI has examined in detail the effects of welding on the hardening of low alloy steels. The microstructure evaluations and hardness measurements discussed in EPRI reports References 4, 5 and 6) have described the effects of temper bead welding on the toughness and hardness of P-No. 3 materials. The research results have illustrated that the microstructure in the low alloy steel (P-No. 3) beneath the temper bead WOL in the weld HAZ consists of a structure that is tempered martensite or tempered bainite and has maximum hardness at a distance of 2 to 3 mm (80 to 120 mils) beneath the surface of the order of 280 to 300 KHN (28 to 30Rc) or lower. The research outlines that the microstructure resulting from temper bead welding is highly resistant to HIC. Additionally, hardness would not be a concern provided there are adequate hydrogen controls are in place.

Furthermore, materials having face-centered-cubic (FCC) crystal structures such as austenitic stainless steels (300 series) and nickel base alloys such as Inconel are not susceptible to hydrogen induced cracking. The reason is that FCC atomic structures have ample unit cell volume space to accommodate atomic (diffusible) hydrogen. It is noted that the diffusion of hydrogen at a given temperature is slightly higher in body-centered- cubic (BCC) materials, ferritic steels, than it is in FCC austenitic materials. The FCC crystal structure has increased capacity to strain significantly without cracking (ductility) providing acceptable levels of toughness capable of resisting HIC. The inherent ability to deform and accommodate diffusible hydrogen are the reasons austenitic stainless steel and nickel base coated electrodes do not have low hydrogen designators that are found for ferritic weld materials (Reference 6). Since the ferritic HAZ is in a tempered condition and an FCC filler material is used, a susceptible microstructure susceptible to HIC is highly unlikely.

<u>Presence/sources of Hydrogen:</u>

Hydrogen can be introduced into the weld from several sources. These include 1) hydrogen in the original base material, 2) moisture in electrode coatings and fluxes, 3) organic contaminants (grease or oils), 4) hydrogen in the shielding gas and 5) humidity in the atmosphere.

The reduction of diffusible hydrogen in temper bead and non-temper bead weldments begins with implementing low hydrogen weld practices. These practices originate with Federal requirements that nuclear utilities control special processes such as welding and design and fabricate components to various codes and standards. These requirements, when followed, will effectively eliminate the contamination, and minimize the environment pathways.

Cleanliness of surfaces to be welded are mandated by Code and subsequently implemented via adherence to sound welding programs. The controls and requirements for cleanliness of the welded surface at nuclear utilities significantly reduce the likelihood of hydrogen entering the weld from surface contamination. Furthermore, repair and replacement applications typically deal with components that have been at operating temperatures above 390ºF (200ºC) for many years and any hydrogen present in the base material would have diffused from the steel and escaped to the atmosphere. Thus, surface contaminants and the base materials are not expected to be a significant source of diffusible hydrogen.

For SMAW, main pathway for diffusible hydrogen to enter the weldment will be the electrode coating. Welding programs primarily maintain low moisture in electrode coatings through procurement via an approved supplier, controlled storage conditions, and conservative exposure durations. The conservative exposure duration and coatings that resist moisture uptake minimize the amount of additional moisture in the coated electrode taking into consideration that moisture uptake is a function of time, temperature, and relative humidity. Extensive testing by the EPRI Welding and Repair Technology Center shows there is an extremely low probability of HIC with H4 and H4R electrodes. EPRI performed diffusible hydrogen analysis per AWS A4.3 via gas chromatography on thirteen commercially available electrodes. Electrodes with AWS E7018, E8018 and E9018 from multiple vendors exposed at 27°C at 80% relative humidity (HR) for exposure times from 0 to 72 hours. Many of the electrodes did not have "R" moisture resistant coating.

Figure 1 shows EPRI diffusible hydrogen test results for the thirteen lots of low hydrogen electrodes. All H4R electrodes exhibited < 16ml/100g of diffusible hydrogen at 72 hours of exposure. Figure 3 shows that new electrodes without exposure have < 2ml/100g diffusible hydrogen. Only one of the electrodes tested at the extremely aggressive 27°C and 80% Relative Humidity (HR) 72-hour exposure had diffusible hydrogen > 4 ml/100g. This demonstrates that exposure limits in the field of 24 hours or less is adequate to assure electrodes maintain the H4R limit. Ferritic electrodes were verified to have less than 4ml/100g diffusible hydrogen (Reference 6). Testing verifies that ambient temperature is acceptable, post weld hydrogen bakeout is not needed, and a 48 hour hold at ambient temperature prior to performing final NDE is unnecessary and diffusible hydrogen levels will be below any susceptibility threshold that supports HIC.

For GTAW, EPRI performed studies investigating the diffusion of hydrogen into low alloy pressure vessel steels (Reference 4). Due to the little information published at the time, EPRI decided to generate experimental data that would provide information on the levels of diffusible hydrogen associated with GTAW welding. The experimentation included individual sets of diffusible hydrogen tests as follows:

1. determination of diffusible hydrogen levels for the GTAW process under severe welding and environmental conditions simulating (or exceeding) repair welding conditions which may be expected in a nuclear plant.
2. measurement of diffusible hydrogen levels for various shieling gas dew point temperatures
3. examination of diffusible hydrogen levels for modern off-the-shelf filler wires,

Discussion of these items can be found in the EPRI documents and will not be reiterated in this report. The results demonstrate that introducing hydrogen is unlikely with the GTAW process. The typical hydrogen content for the GTAW process is less than 1.0mL/100g. Therefore, hydrogen cracking is extremely unlikely.

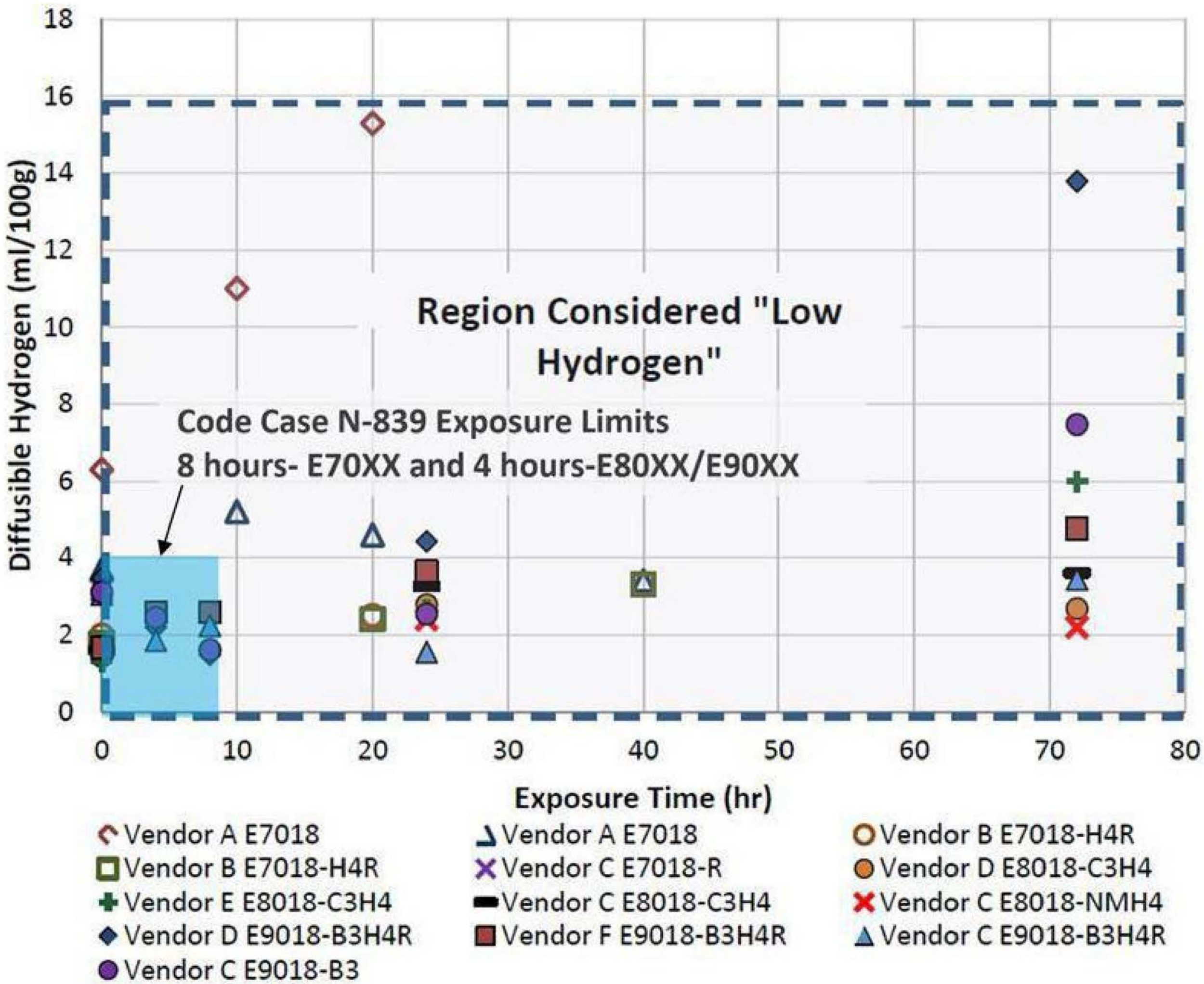

Figure 1. Results of EPRI diffusible hydrogen testing at 27° C 80% Relative Humidity (HR) for zero to 72 hours of exposure (Reference 6)

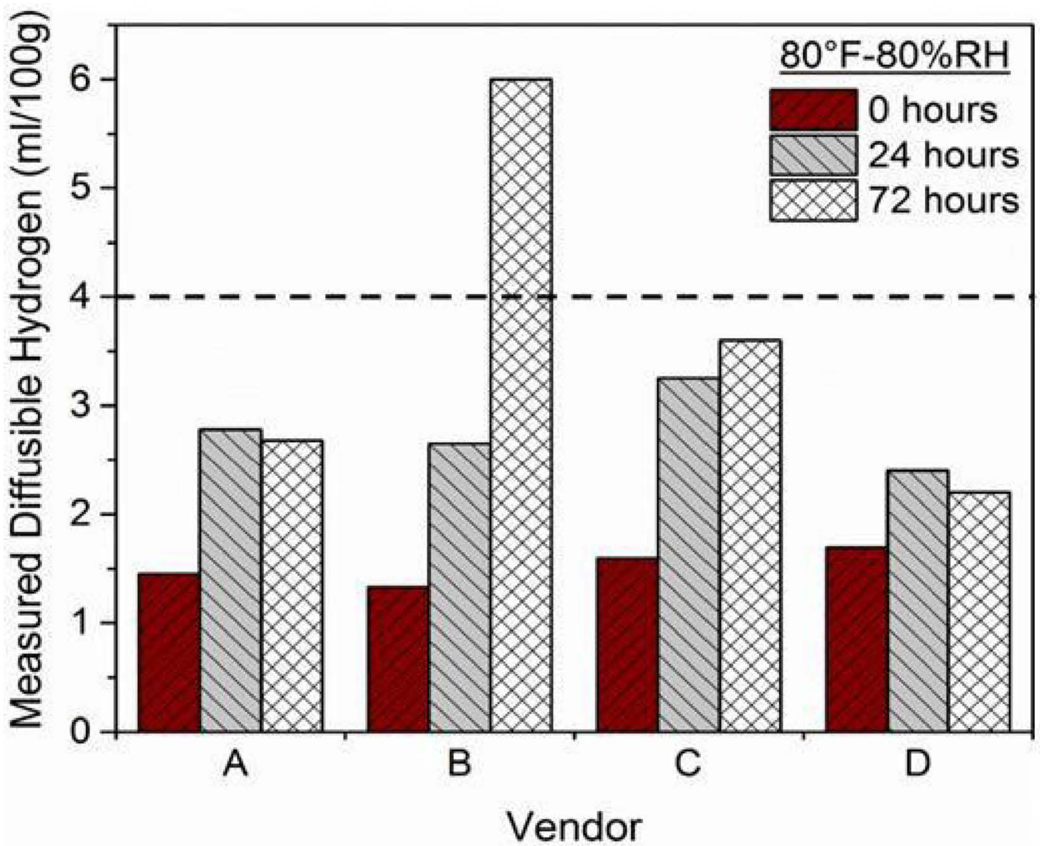

Figure 2. Graph showing slight increase of diffusible hydrogen after exposure of 24 and 72 hours. (Reference 6)

<u>Diffusivity and Solubility of Hydrogen</u>

Diffusivity and solubility of hydrogen in ferritic, martensitic, and austenitic steels is an important factor to consider. Materials having face-centered-cubic (FCC) crystal structures such as austenitic stainless steels (300 series) and nickel base Inconels generally are not considered to be susceptible to hydrogen delayed cracking as discussed in the microstructure section, above. Additionally, due to the temperatures expected during the welding of the temper bead layers, and during the welding of any non-temper bead layers, the temperature should be sufficient for the hydrogen to diffuse out of the HAZ, either escaping the structure or diffusing into the austenite, where it can be held in much greater quantities. The diffusion rate is clearly from the ferrite to the austenite and whatever hydrogen remains will reside in the austenite, which has little to no propensity to hydrogen related cracking.

Use of fully austenitic weld metal on ferritic base material is a technique that has been used for decades to install welds on ferritic base materials with high potential of HIC. Austenitic filler materials are used in applications where preheat or post weld bake out is not possible because hydrogen (H^+) has high solubility, Figure 3, and low diffusivity, Figure 4, in austenite relative to other phases and acts as a trap for hydrogen to prevent HIC. Figure 3 show the solubility of hydrogen in α-Fe and γ-Fe. Note that α-Fe is at the saturation limit at ~4ml/100g of hydrogen. At temperatures above ~1700° C the solubility of hydrogen in austenite (γ-Fe) is nearly five times that of ferrite (α-Fe). The benefit regarding HIC is the hydrogen stays in the austenite and is not available to promote HIC. Figure 4 shows the overall difference in hydrogen diffusion between ferritic and austenitic materials. The diffusion of hydrogen in ferritic material is orders of magnitude greater compared to austenite. Again, the obvious advantage regarding HIC prevention is the hydrogen is slow to diffuse out of the austenitic material. When comparing how hydrogen behaves in ferritic versus austenitic weldments the hydrogen stays within the austenitic material whereas in ferritic welds, it tends to diffuse into the base material. For a weld made with ferritic electrodes, the H^+ is absorbed in the molten weld puddle and as the weld solidifies, it transforms from austenite to ferrite and the H^+ is rejected and diffuses into the HAZ of the base material. When the HAZ transforms from austenite to martensite, the H^+ becomes trapped in the brittle microstructure and causes cracking, Figure 5. However, with an austenitic electrode, H^+ is absorbed in the molten weld puddle and there is no solid state transformation in the solidified weld metal so the H^+ stays in the austenitic weld material. No diffusion of the H^+ into the brittle martensite, thus avoiding the possibility of HIC, Figure 6. Schematics in Figure 5 and Figure 6 are adapted from Lippold and Granjon as shown in draft chapters 2 & 4 for Temper Bead Welding Process in Operating NPP's, International Atomic Energy Agency, (References 1 and 8).

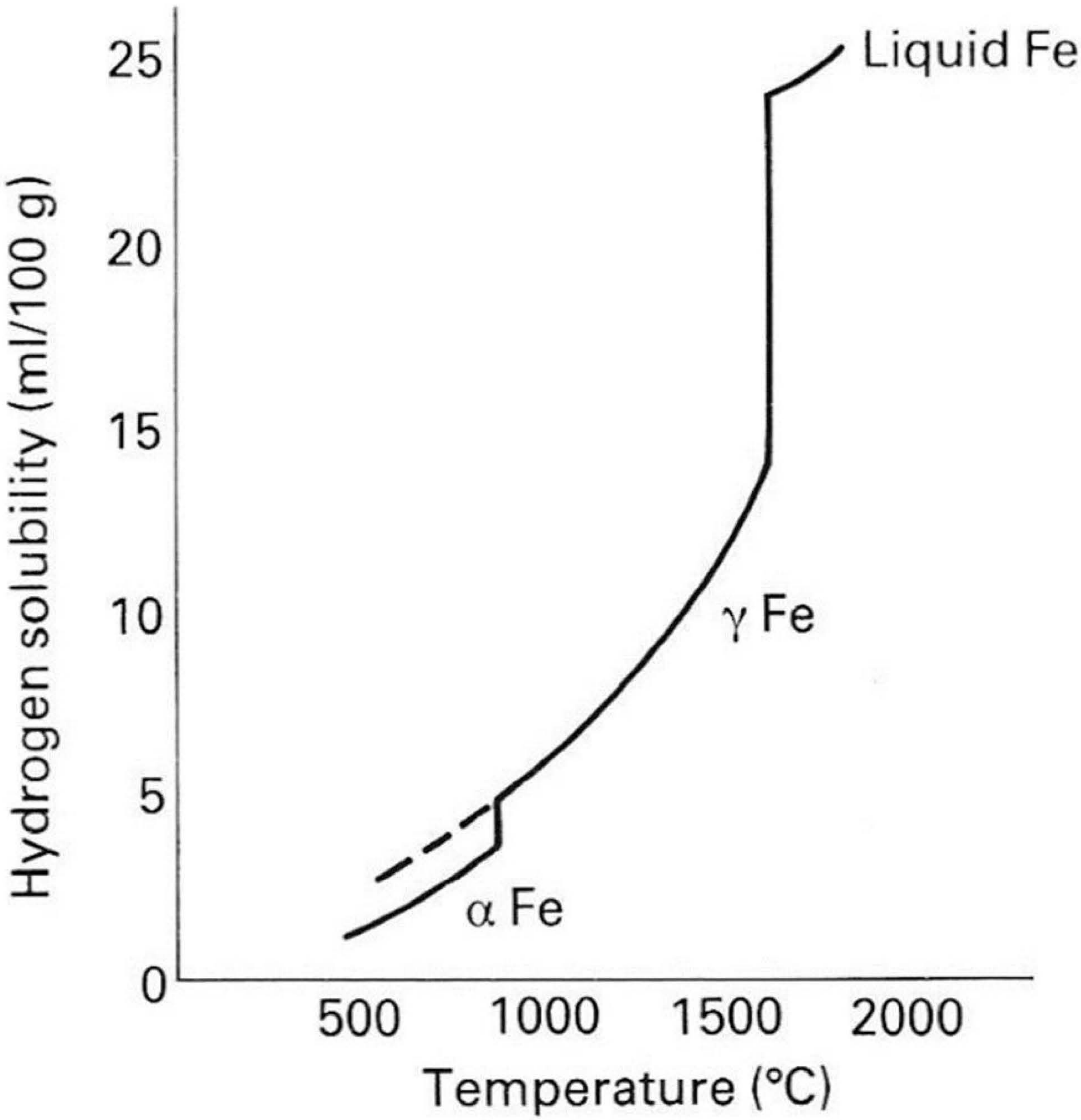

Figure 3. – Hydrogen solubility in ferritic and austenitic materials as a function of temperature.

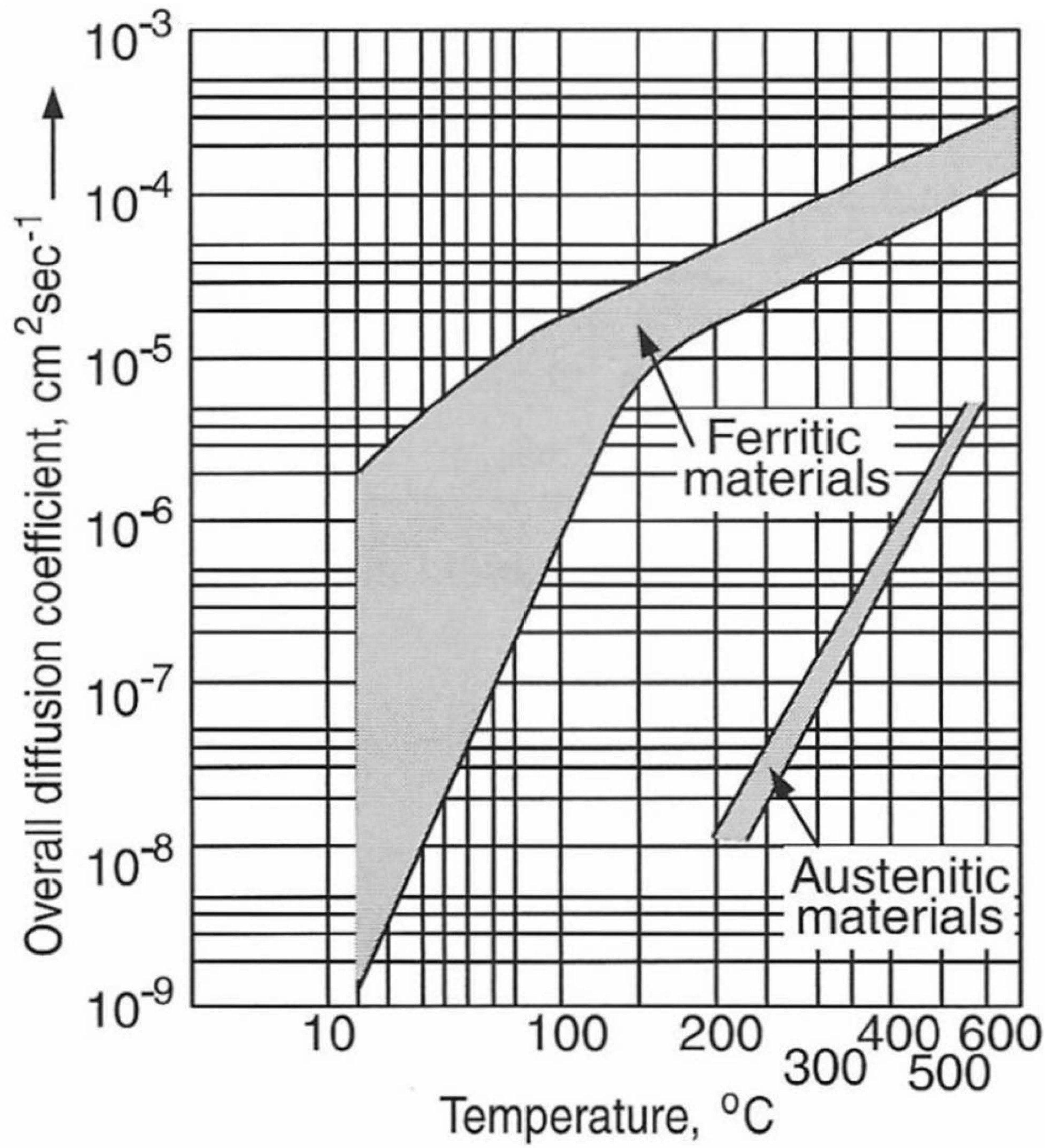

Figure 4 – Diffusion Coefficient of hydrogen in ferritic and austenitic materials as a function of temperature.

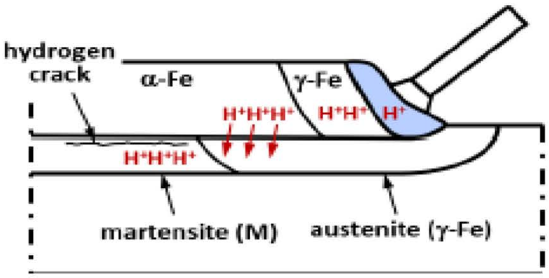

Figure 5 – Hydrogen movement with ferritic electrodes (Reference 8)

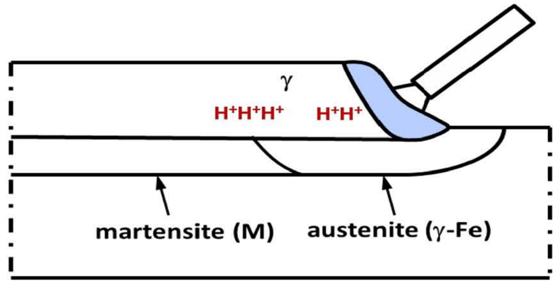

Figure 6 – Hydrogen movement with austenitic electrodes (Reference 8)

5. Conclusion

The temper bead technique has become an increasingly effective tool for performing repairs on carbon and low alloy steel (P-No. 1 and P-No. 3) materials. Case N-888 provisions allow for ambient temperature temper bead welding with no post weld bake. However, the 48-hour hold at ambient temperature prior to performing the final weld acceptance NDE has remained a requirement. This white paper summarizes the technical basis to eliminate the 48-hour delay for temper bead welding when using austenitic filler materials. The data and testing by EPRI and other researchers show that when austenitic weld metal is used the level of diffusible hydrogen content in the ferritic base metal HAZ is too low to promote HIC. The 48-hour hold requirement in Case N-888 can therefore be removed.

Lastly, field experience applying austenitic filler materials to hundreds of dissimilar metal weld overlays using the ambient temperature temper bead procedures has never experienced hydrogen delayed cracking nor would it be expected. The reason is simply that the final diffusible hydrogen content is low –well below any threshold level that would be required for hydrogen induced cracking. Table 1 outlines the last 20 years of temper bead weld repairs in the nuclear industry with no reported occurrence of HIC when using austenitic weld metal.

6. References

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9. Repair and Replacement Applications Center: Temperbead Welding Applications 48-Hour Hold Requirements for Ambient Temperature Temperbead Welding, EPRI, Palo Alto, CA: 2006.1013558

ATTACHMENT 3

TECHNICAL BASIS FOR THE INCLUSION OF 28% CHROMIUM NICKEL-BASED FILLER METALS IN ASME CODE CASE N-770-X

1.0 Purpose

Provide a technical basis to the inclusion of ERNiCrFe-13 filler material to the list of acceptable filler materials in N-770-X.

2.0 Executive Summary

Code Case N-770-8 provides for alternative examination requirements for Alloy 82/182 welds with or without mitigation activities. These requirements affect the method (volumetric, visual, and/or surface), extent and frequency of inservice examinations as well as the preservice baseline examination. Per 1210 (b), these examination requirements only apply to mitigation activities involving welding (full structural overlay, onlay, etc.) that utilize Alloy 52 (UNS 06052, SFA-5.14, ERNiCrFe-7), Alloy 152 (UNS W86152, SFA 5.11, ENiCrFe-7) and Alloy 52M (UNS N06054, SFA-5.14, ERNiCrFe-7A) filler materials. Exceptional corrosion-resistance performance has been reported for all Alloy 52 type filler materials that utilize alloy content greater than 28% Chromium. Given this proof of performance and established standard of 28% Chromium for resistance to Stress Corrosion Cracking, it is appropriate to include other 28% Chromium bearing nickel-based filler materials in the list of Alloy 52 materials in code case N-770-X.

3.0 Introduction

This white paper has the objective of establishing the technical basis for inclusion of all Alloy 52 variants (28% Chromium nickel-based filler wire) into Code Case N-770, which modifies the Section XI inspection requirements for Class 1 PWR piping and vessel nozzle butt welds fabricated with Alloy 82/182 material.

4.0 Scope of N-770-8

Code Case N-770-8, “Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities Section XI, Division 1,” provides alternative examination requirements and acceptance standards for volumetric examination, surface examination and visual examination of pressure containing Class 1 PWR piping and nozzle butt welds fabricated with Alloy 82/182 (UNS N06082/W86182) materials, with or without application of mitigation activities.

5.0 Brief Technical Background on SCC in Alloy 600/690 and Associated Weld Fillers

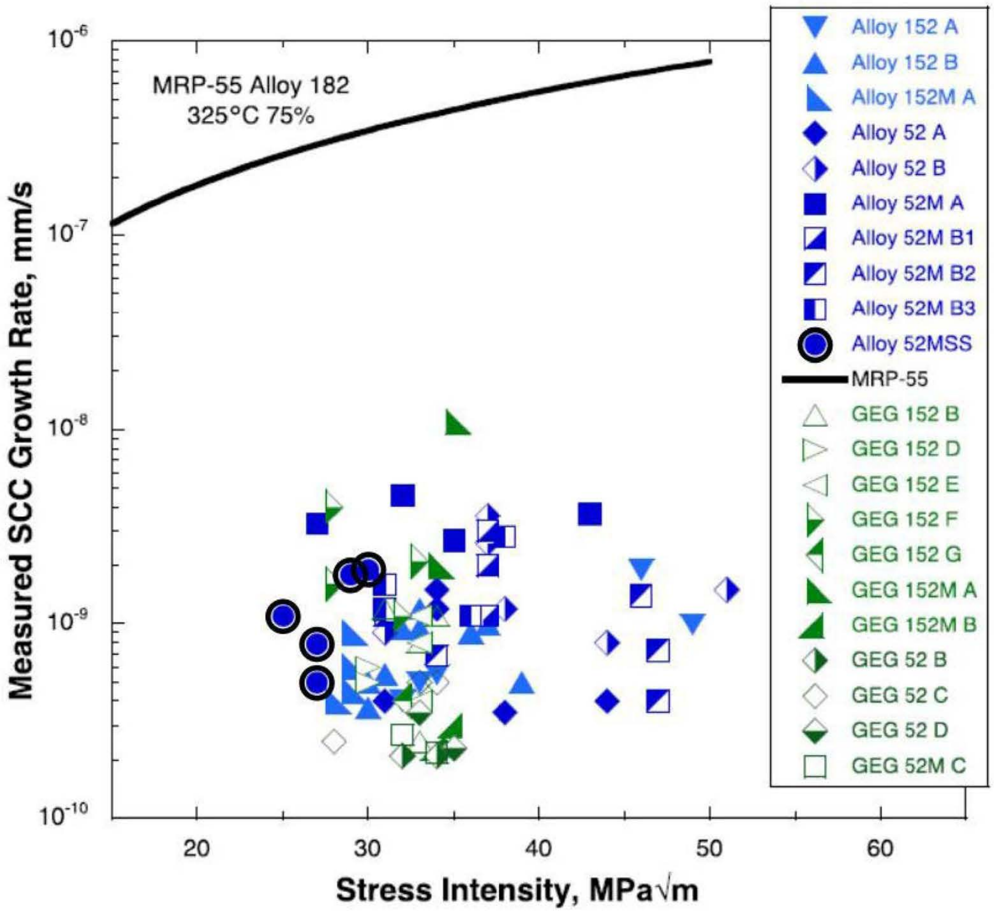
Stress corrosion cracking (SCC) has been a significant degradation mechanism for Alloy 600 and its associated weld metals (Alloy 82/182) in primary water environments of pressurized water reactors (PWRs). The low chromium content (~15–20 wt%) in Alloy 600 and its weld metals has been identified as a key contributor to susceptibility to SCC, especially in high-temperature, high-pressure, hydrogenated water environments where aggressive oxidation can occur along grain boundaries. In contrast, Alloy 690, with a chromium content of approximately 30 wt%, has demonstrated excellent resistance to SCC, attributed to the formation of a stable, protective Cr_2O_3 passive film on the alloy surface. This performance has prompted a shift toward the use of high-chromium nickel-base filler metals, such as Alloy 52 and its variants, for structural overlays and new welds on components originally fabricated with Alloy 600 or 82/182. The associated filler metals Alloy 52 (ERNiFeCr-7), 52M (ERNiFeCr-7A), and 52MSS (ERNiFeCr-13) were developed to match the corrosion performance of Alloy 690. Alloy 52 variants typically contain greater than 28 wt% chromium, significantly improving their resistance to SCC and corrosion fatigue in PWR primary water.

6.0 Background on the Development of New Alloy 52 Variants

Alloy 52 and its derivatives have evolved over the past two decades in response to performance needs related to fabrication and in-service conditions. While Alloy 52 has always provided strong resistance to SCC, weldability issues such as solidification cracking and ductility dip cracking (DDC) prompted further development. Alloy 52M was introduced with optimized trace element controls and minor composition shifts to reduce susceptibility to DDC, especially in multi-pass welding over stainless steel base materials. Subsequent developments, including 52MSS and 52MSS-Ta, have further improved weldability by adjusting elements such as niobium, tantalum and molybdenum. The core design principle across all these variants remains the retention of high chromium content (≥28%) to ensure PWR-relevant SCC resistance.

7.0 Technical Justification For The Inclusion Of ERNiCrFe-13 (Alloy 52mss) Into N-770-X Based On Chemistry

The principal justification for inclusion of additional Alloy 52 variants lies in the chromium threshold for SCC resistance. Extensive research, including NUREG/CR-7103 and EPRI test data, demonstrates that a minimum bulk chromium content of 28 wt% in nickel-based weld metal is critical for suppressing intergranular SCC in simulated PWR primary water. From NUREG/CR-7103: *"The main conclusion from these experiments on alloy 152, 152M, 52, 52M and 52MSS weld metals with typical Cr bulk concentrations (28-30 wt%) is that they are resistant to SCC crack growth."* From the NUREG/CR-7103 report, the following plot is given which demonstrates the performance of Alloy 52 MSS (ERNiCrFe-13) alongside other Alloy 52 variants.



Additional work performed by EPRI's Welding and Repair Technology Center provides additional data points for SCC crack growth rates in recent heats of ERNiCrFe-13:

Summary of SCC Crack Growth Rates; 52M, 52MSS-0Fe, 52XL, 52MSS-Ta

Weld Metal	CGR (mm/s)
52M, Special Metals NX7206TK	$4.0 \times 10^{-10} \rightarrow 1.0 \times 10^{-8}$
52MSS-0Fe, Special Metals HV1500	$3.5 \times 10^{-9} \rightarrow 1.3 \times 10^{-9}$
EPRI 52XL, Kobelco S2768	$7.8 \times 10^{-10} \rightarrow$ ~0
52MSS-Ta, Special Metals NV1673	$2.0 \times 10^{-10} \rightarrow 1.5 \times 10^{-8}$
52MSS-Ta, Special Metals VX131WXW	$4.0 \times 10^{-10} \rightarrow 1.6 \times 10^{-9}$
52MSS-Ta, Special Metals VX135WXW	$5.0 \times 10^{-10} \rightarrow 1.7 \times 10^{-9}$

Chromium enhances the formation of a stable, adherent oxide film that impedes localized oxidation and crack initiation along grain boundaries. All known Alloy 52 variants—including 52M, 52MSS, and 52MSS-Ta—meet or exceed this threshold and share comparable electrochemical and SCC resistance characteristics in autoclave and corrosion-fatigue tests. Alloy developments intended to resist weldability issues have not been shown to decrease their corrosion performance.

Additionally, the Materials Reliability Program (MRP) MRP-169, Technical Basis for Preemptive Weld Overlays for Ally 82/182 Butt Welds in PWRs, provides additional basis for the performance of a number of 28% chromium bearing nickel based alloys.

As Code Case N-770-8 currently restricts the list of acceptable mitigation fillers to only three named designations, the exclusion of ERNiCrFe-13 which meets the same metallurgical performance targets constitutes an unnecessary limitation.

8.0 Conclusion

Stress corrosion cracking mitigation in Alloy 82/182 welds is a critical issue for the long- term reliability of Class 1 pressure boundary components in PWRs. The effectiveness of mitigation depends largely on the corrosion resistance of the deposited weld metal. As demonstrated by the body of research cited, ERNiCrFe-13 which contains ≥28 wt% Chromium provides superior resistance to SCC due to its enhanced passivity and resistance to grain boundary oxidation in PWR primary environments. Inclusion of this material classification into Code Case N-770-X will ensure the reliable corrosion performance expected out of Alloy 52, with the added benefit of modern weldability improvements which will serve to decrease outage lengths by increasing the frequency of first-time quality for welds and weld overlays in the field.

Reference Documents

1. ASME Code Case N-770-8

2. NUREG/CR-7103 Vol. 4, Pacific Northwest National Laboratory, 2019

3. EPRI WRTC TAC Meeting, June 2024, RFA-1 Material Weldability and Welding Alloy Development

4. Liang, H. C., Wang, C. J., & Wu, Z. W. (2021). Corrosion behavior of alloy 52M and 52MSS weld surfacing. International Journal of Pressure Vessels and Piping, 191, 104356.

5. Andresen, P. L., Morra, M. M., & Ahluwalia, K. (2016). SCC of Alloy 690 and its Weld Metals. In Proceedings of the 15th International Conference on Environmental Degradation of Materials in Nuclear Power Systems—Water Reactors (pp. 161-178).

6. Materials Reliability Program (MRP) MRP-169, Technical Basis for Preemptive Weld Overlays for Ally 82/182 Butt Welds in PWRs