NMC
Committed to Nuclear Excellence

Palisades Nuclear Plant
Operated by Nuclear Management Company, LLC

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10 CFR 50.55(a)

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Palisades Nuclear Plant
Docket 50-255
License No. DPR-20

Request for Relief from ASME Section XI Code Requirements for Repair of Reactor Pressure Vessel Head Penetrations

By letter dated August 2, 2004, as supplemented by letters dated August 19, 2004, October 4, 2004, and October 28, 2004, Nuclear Management Company, LLC (NMC) requested relief from certain sections of the American Society of Mechanical Engineers (ASME) Code in the event a reactor vessel head penetration nozzle was in need of a repair at the Palisades Nuclear Plant (PNP). The NRC approved these relief requests by letter dated November 8, 2004.

NMC will implement a Framatome Advanced Nuclear Products (FANP) design repair, for the PNP, if a reactor vessel closure head (RVCH) penetration repair is necessary during the 2006 refueling outage. Framatome has revised the repair approach from that which was previously approved for PNP. The changes are described in the introduction section of each relief request. FANP performed the detailed analyses to justify this repair technique at PNP. NMC has reviewed and approved these analyses. Summaries of the analyses that support the relief requests are included as Enclosure 3.

NMC is performing ultrasonic examinations and visual examinations of the RVCH control rod drive (CRD), and incore instrumentation (ICI) nozzle penetrations, during the upcoming refueling outage at the PNP, in accordance with Order, EA-03-009, "Issuance of First Revised NRC Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors," dated February 20, 2004. NMC requires the enclosed relief requests in the event a RVCH penetration is in need of a repair at PNP. Therefore, NMC requests relief from certain sections of the ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, 1989 Edition, as described in the attached Enclosures.

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Enclosure 1 requests relief from the ASME Code, Section XI, IWA-4120, "Rules and Requirements." NMC proposes an alternative to the specified code requirements in accordance with 10 CFR 50.55a(a)(3)(i). The basis for the relief is provided, describing that the alternative provides an acceptable level of quality and safety.

Enclosure 2 requests relief from the ASME Code, Section XI, IWA-3300, "Flaw Characterization," IWB-3142.4, "Acceptance by Analytical Evaluation," IWB-3420, "Characterization," and IWB-3613, "Acceptance Criteria for Flanges and Shell Regions Near Structural Discontinuities." NMC proposes an alternative to the specified code requirements in accordance with 10 CFR 50.55a(a)(3)(i). The basis for the relief is provided, describing that the alternative provides an acceptable level of quality and safety.

Enclosure 3 contains AREVA document 51-5047343-03, "Palisades CRDM & ICI Nozzle IDTB Repair – Life Assessment Summary," dated June 2005. This is a non-proprietary report that contains summaries of the analyses that support the relief requests.

Relief is requested for the remainder of the current ten-year inspection interval, which will conclude on or before December 12, 2006.

NMC requests approval of the proposed relief requests by April 1, 2006, to support PNP's upcoming refueling outage.

Summary of Commitments

This letter contains no new commitments and no revisions to existing commitments.

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Nuclear Management Company, LLC

Enclosures (3)
Attachments (2)

CC Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

ENCLOSURE 1
RELIEF REQUEST #1: ALTERNATE REPAIR TECHNIQUE
REACTOR PRESSURE VESSEL PENETRATIONS

Introduction

During the 2004 refueling outage, repairs were performed on two control rod drive (CRD) nozzles using an alternate inner diameter temper bead (IDTB) weld repair. A part of this repair required the use of the abrasive water-jet machining (AWJM) conditioning technique. Nuclear Management Company, LLC (NMC) has evaluated the need to perform this AWJM conditioning during repairs that may be necessary during the 2006 refueling outage. This evaluation considered the CRD and incore instrumentation (ICI) nozzles in the as-repaired condition and encompassed initiation and crack growth due to primary water stress corrosion cracking (PWSCC). Framatome ANP (FANP) performed an analysis of a non-AWJM conditioned repair and determined that a crack will not grow to 75% through-wall in a time period of 5.04 effective full power years (EFPY) for a repaired CRD nozzle, and 5.13 EFPY for a repaired ICI nozzle. These time periods are beyond the duration for the relief request and therefore, AWJM conditioning has been determined to be unnecessary in the repair process. NMC has revised this relief request to reflect the removal of the AWJM conditioning technique.

ASME Code Component Affected

The affected components are the Palisades Nuclear Plant (PNP) reactor vessel closure head (RVCH), CRD, and ICI nozzle penetrations. The PNP has 45 CRD penetrations and eight ICI penetrations, which are American Society of Mechanical Engineers (ASME) Class 1 penetrations.

Applicable Code Edition and Addenda

The applicable code edition and addenda for the RVCH penetration repair is the ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, 1989 Edition with no addenda. Palisades is currently in the third ten-year inservice inspection interval.

Applicable Code Requirement

The applicable code requirement for the RVCH penetration repair is ASME Section XI, IWA-4120, "Rules and Requirements," as follows:

(a) Repairs shall be performed in accordance with the owner's design specification and the original construction code of the component or system. Later editions and addenda of the construction code or of Section III, either in their entirety or portions thereof, and code cases may be used. If repair welding cannot be performed in accordance with these requirements, the applicable alternative requirements of IWA-4500 and the following may be used:

(1) IWB-4000 for Class 1 components;
(2) IWC-4000 for Class 2 components;
(3) IWD-4000 for Class 3 components;
(4) IWE-4000 for Class MC components; or
(5) IWF-4000 for component supports.

(b) The edition and addenda of Section XI used for the repair program shall correspond with the edition and addenda identified in the inservice inspection program applicable to the inspection interval.

(c) Later editions and addenda of Section XI, either in their entirety or portions thereof, may be used for the repair program, provided these editions and addenda of Section XI at the time of the planned repair have been incorporated by reference in amended regulations of the regulatory authority having jurisdiction at the plant site.

The original construction code for the PNP RVCH is ASME Section III, 1965 Edition, including addenda through winter 1965.

The proposed repairs will be conducted in accordance with the 1989 Edition of ASME Section XI, no addenda, the 1989 Edition of ASME Section III, no addenda, and the alternative requirements discussed below. The general repair outline is shown in Attachment 2.

Reason for Request

NMC has determined that AWJM conditioning is not necessary in the repair process and the relief requests have been revised to reflect this change. NMC is requesting relief from ASME Section XI, 1989 Edition, IWA-4120, pursuant to 10 CFR 50.55a(a)(3)(i), because the alternative provides an acceptable level of quality and safety.

For the proposed repairs to the RVCH penetrations, paragraph N-528.2 of the 1965 Edition of Section III, including addenda through winter 1965, requires repairs be postweld heat treated (PWHT) in accordance with paragraph N-532. The PWHT requirements set forth therein are unreasonable to attain on a RVCH. In addition to possible distortion of the RVCH, significant personnel dose would be expended to set up and remove the PWHT equipment. Because of the risk of damage to the RVCH material properties or dimensions and the additional dose that would be required, it is not feasible to apply the PWHT requirements of paragraph NB-4622 of the 1989 ASME Section III Code to the RVCH or the elevated temperature preheat and post weld soak required by the alternative temper bead method offered by ASME Section XI, IWA-4500. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), NMC requests relief to use an ambient temperature temper bead welding method of repair as an alternative to the requirements of the 1989 Edition, no addenda, of ASME Section III, NB-4622.

Proposed Alternative and Basis for Use

NMC requests relief to use an ambient temperature temper bead method of repair as an alternative to the requirements of the 1989 Edition of ASME Section III, NB-4453, NB-4622, NB-5245, and NB-5330. Approval is requested to use filler material, Alloy 52 AWS Class ERNiCrFe-7/UNS No. 06052, which is endorsed by Code Case 2142-1, "F-Number Grouping for Ni-Cr-Fe, Classification UNC N06052 Filler Material," for the weld repair. Portions of Code Case N-638, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine [Gas Tungsten Arc Welding] GTAW Temper Bead Technique," which has been approved in Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability – ASME Section XI Division 1," Revision 13, have also been used as a template for this application. As an alternative to these code case requirements, the requirements of Attachment 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique," will be used.

Repairs to the RVCH, CRD, and ICI nozzle penetration J-groove attachment welds, which are required when ⅛-inch or less of non-ferritic weld deposit exists above the original fusion line, will be made in accordance with the requirements of IWA-4000, of the 1989 Edition of ASME Section XI. The requirements of paragraphs NB-4622, NB-3300, and NB-5245, of the 1989 Edition of ASME Section III, and QW-256 of the 1989 Edition of ASME Section XI are also applicable to the potential repairs. Applicable alternatives to these requirements will be used per the requirements of Attachment 1. Specifically, alternatives are being proposed for the following ASME Section III, Section IX, and Section XI requirements:

1. NB-4622.1 establishes the requirement for PWHT of welds including repair welds. In lieu of these requirements, NMC proposes to utilize a temper bead weld procedure, which would preclude the need for PWHT.

2. NB-4622.2 establishes requirements for time at temperature recording of the PWHT and their availability for review by the inspector. This does not apply because the proposed alternative does not involve PWHT.

3. NB-4622.3 addresses the definition of nominal thickness as it pertains to time at temperature for PWHT. This is not applicable because the proposed alternative involves no PWHT.

4. NB-4622.4 establishes the holding times at temperature for PWHT. This is not applicable because the proposed alternative involves no PWHT.

5. NB-4622.5 establishes PWHT requirements when different P-number materials are joined. This is not applicable because the proposed alternative involves no PWHT.

6. NB-4622.6 establishes PWHT requirements for nonpressure retaining parts. This is not applicable because the potential repairs in question will be to pressure retaining parts. Furthermore, the proposed alternative involves no PWHT.

7. NB-4622.7 establishes exemptions from mandatory PWHT requirements. NB- 4622.7 (a) through NB-4622.7 (f) are not applicable in this case because they pertain to conditions that do not exist for the proposed repairs. NB-4622.7 (g) addresses exemptions to weld repairs to dissimilar metal welds if the requirements of subparagraph NB-4622.11 are met. This does not apply because the ambient temperature temper bead repair is being proposed as an alternative to the requirements of NB-4622.11.

8. NB-4622.8 establishes exemptions from PWHT for nozzle to component welds and branch connections to run piping welds. NB- 4622.8(a) establishes criteria for exemption of PWHT for partial penetration welds. This is not applicable to the proposed repairs because the criteria involve buttering layers at least ¼- inch thick, which will not exist for the welds in question. NB- 4622.8(b) also does not apply because it addresses full penetration welds and the welds in question are partial penetration welds.

9. NB-4622.9 establishes requirements for temper bead repairs to P-No. 1 and P-No. 3 materials and A-Nos. 1, 2, 10, or 11 filler metals. This does not apply because the proposed repairs will involve F-No. 43 filler metals.

10. NB-4622.10 establishes requirements for repair welding to cladding after PWHT. This does not apply because the proposed repair alternative does not involve repairs to cladding.

11. NB-4622.11 addresses temper bead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs as follows:

    A. NB-4622.11 (a) requires surface examination prior to repair in accordance with NB-5000. The proposed alternative will include surface examination prior to repair consistent with NB-5000.

    B. NB-4622.11 (b) contains requirements for the maximum extent of repair including a requirement that the depth of excavation for defect removal not exceed ⅜-inch in the base metal. The proposed alternative will include the same limitations on the maximum extent of repair.

    C. NB-4622.11 (c) addresses the repair welding procedure and welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy these requirements, except for the stipulations of paragraph QW-256 of Section IX, as explained in the justification of relief section below. In addition, NB-4622.11 (c) requires that the welding procedure specification include the following requirements:

1) NB-4622.11 (c)(1) requires the area to be welded be suitably prepared for welding in accordance with the written procedure to be used for the repair. The proposed alternative will satisfy this requirement.

2) NB-4622.11 (c)(2) requires the use of the SMAW process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative uses GTAW with bare electrodes and bare filler metal meeting the F-No. 43 classification.

3) NB-4622.11 (c)(3) addresses requirements for covered electrodes pertaining to hermetically sealed containers or storage in heated ovens. These requirements do not apply because the proposed alternative uses bare electrodes and bare filler metal that do not require storage in heated ovens because neither bare electrodes nor bare filler metal will pick up moisture from the atmosphere as covered electrodes may.

4) NB-4622.11 (c)(4) addresses requirements for storage of covered electrodes during repair welding. These requirements do not apply because the proposed alternative utilizes bare electrodes and bare filler metal, which do not require any special storage conditions to prevent the pick up of moisture from the atmosphere.

5) NB-4622.11 (c)(5) requires preheat of the weld area and 1½ times the component thickness or five-inch band, whichever is less, to a minimum temperature of 350°F prior to and during repair welding, and a maximum interpass temperature of 450°F. Thermocouples and recording instruments shall be used to monitor the metal temperature during welding. The proposed ambient temperature temper bead alternative does not require an elevated temperature preheat. Interpass temperature measurements cannot be accomplished due to inaccessibility in the weld region.

6) NB-4622.11 (c)(6) establishes requirements for electrode diameters for the first, second, and subsequent layers of the repair weld and requires removal of the weld bead crown before deposition of the second layer. Because the proposed alternative uses machine GTAW, the requirement to remove the weld crown of the first layer is unnecessary and the proposed alternative does not include the requirement.

7) NB-4622.11 (c)(7) requires the preheated area to be heated from 450°F to 660°F for four hours after a minimum of 3/16-inch of weld metal has been deposited. The proposed alternative does not require this heat treatment because the use of the extremely low hydrogen GTAW temper bead procedure does not require the hydrogen bake out.

8) NB-4622.11 (c)(8) requires welding subsequent to the hydrogen bake out of NB-4622.11(c)(7) be done with a minimum preheat of 100°F and maximum interpass temperature of 350°F. The proposed alternative limits the interpass temperature to 350°F (maximum) and requires the area to be welded be at least 50°F prior to welding. This approach has been demonstrated to be adequate to produce sound welds.

12. NB-4622.11 (d)(1) requires a liquid penetrant examination after the hydrogen bake out described in NB-4622.11 (c)(7). The proposed alternative does not require the hydrogen bake out because it is unnecessary for the extremely low hydrogen GTAW temper bead process.

13. NB-4622.11 (d)(2) requires liquid penetrant and radiographic examinations of the repair welds and the preheated band after a minimum time of 48 hours at ambient temperature. Ultrasonic inspection is required if practical. The proposed alternative includes the requirement to inspect after a minimum of 48 hours at ambient temperature. Because the proposed repair welds are of a configuration that cannot be radiographed (due to limitations on access for source and film placement and the likelihood of unacceptable geometric unsharpness and film density), the proposed alternative final inspection will be by liquid penetrant and ultrasonic examination.

14. NB-4622.11 (d)(3) requires that all nondestructive examination be in accordance with NB-5000. The proposed alternative will comply with NB-5000, except that the progressive liquid penetrant examination required by NB-5245, will not be performed. In lieu of the progressive liquid penetrant examination, the proposed alternative will use liquid penetrant and ultrasonic examination of the final weld. The volumetric examination coupled with surface examination will provide a high level of confidence that the proposed welds are sound.

15. NB-4622.11 (e) establishes the requirements for documentation of the weld repairs in accordance with NB-4130. The proposed alternative will comply with the requirement.

16. NB-4622.11 (f) establishes requirements for the procedure qualification test plate relative to the P-Number and group number and the PWHT of the materials to be welded. The proposed alternative meets and exceeds those requirements except that the root width and included angle of the

cavity are stipulated to be no greater than the minimum specified for the repair. In addition, the location of the V-notch for the Charpy test specimen is more stringently controlled in the proposed alternative than in NB-4622.11(f).

17. NB-4622.11 (g) establishes requirements for welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs, which is pertinent to the SMAW manual welding process. The proposed alternative involves a machine GTAW process and requires welding operators be qualified in accordance with ASME Section IX. The use of a machine process eliminates any concern about obstructions, which might interfere with the welder's abilities, because all such obstructions will have to be eliminated to accommodate the welding machine.

18. NB-4453.4 of Section III requires examination of the repair weld in accordance with the requirements for the original weld. The welds being made in accordance with the proposed alternatives will be partial penetration welds as described by NB- 4244(d) and will meet the weld design requirements of NB-3352.4 (d). For these partial penetration welds, paragraph NB-5245 requires a progressive surface exam (liquid penetrate (PT) or magnetic particle (MT)) at the lesser of one-half the maximum weld thickness or ½-inch, as well as on the finished weld. For the proposed alternative, the repair weld will be examined by a liquid penetrant and ultrasonic examination no sooner than 48 hours after the weld has cooled to ambient temperature in lieu of the progressive surface exams required by NB-5245. The volumetric examination coupled with surface examination will provide a high level of confidence that the proposed welds are sound.

19. NB-5330 (b) does not allow any cracks or incomplete penetration regardless of length. As a result of the welding process, a linear indication often occurs at the intersection of the RVCH, the nozzle, and the first intersecting weld bead (triple point). The proposed alternative will allow this triple point indication to remain.

20. QW-256, of ASME Section IX, requires that the maximum interpass temperature during procedure qualification be no more than 100°F below that used for actual welding. Per Attachment 1, the maximum interpass temperature during welding is specified to be 350°F maximum. The maximum interpass temperature during the procedure qualification was less than 100°F.

The alternative to the NB-4622 requirements being proposed involves the use of an ambient temperature temper bead welding technique that avoids the necessity of traditional PWHT, preheat and postweld heat soaks. The welding technique described in Attachment 1 is similar to the requirements of Code Case N-638. The proposed welding technique differs from that described in sections 1.0 through 4.0 of Code Case N-638 as follows:

a) N-638 2.1 (b) requires consideration be given to the effects of welding in a pressurized environment. This requirement is not applicable because the welding will not occur in a pressurized environment.

b) N-638 2.1 (c) requires consideration be given to the effects of irradiation on the properties of materials in the core belt line region. This requirement is not applicable because the welding will be on the RVCH, not in the belt line region.

c) N-638 2.1 (h) specifies Charpy V notch requirements for ferritic weld material of the procedure qualification. The filler material is F-No. 43, which is not ferritic, therefore this requirement does not apply.

d) N-638 2.1 (j) requires the three heat affected zones (HAZ) impact tests be equal or greater than the unaffected base material tests. During the Charpy impact testing portion of the qualification process, the reference temperature (RT_{NDT}) was determined to be 30°F. At RT_{NDT} + 60°F temperature (+30°F), the average of the HAZ absorbed energy Charpy impact tests was greater than the average of the unaffected base material. However, the average of the mils lateral expansion for the HAZ was less than the average values for the unaffected base material. Additional Charpy V-notch tests were conducted on the HAZ material as permitted by NB-4335.2 to determine an additive temperature to the RT_{NDT} temperature. The average mils lateral expansion for the HAZ at +35°F was equivalent to the unaffected base material at +30°F. These test results require an adjustment temperature of +5°F to the RT_{NDT} temperature for base material on which welding is performed.

e) N-638 3.0 (c) requires a layer of weld reinforcement be applied and then machined to a flush surface. This requirement is not applicable because the welding will join dissimilar metals with non-ferritic weld filler metal.

f) N-638 3.0 (d) specifies the maximum interpass temperature for field applications shall be 350°F regardless of the interpass temperature during qualification. N-638 2.1 (e) specifies the maximum interpass temperature for the first three layers of the test assembly shall be 150°F. QW-256 specifies maximum interpass temperature as a supplementary essential variable that must be held within 100 °F above that used during procedure qualification. See part six below for variation to the requirements of QW-256.

g) N-638 3.0 (e) requires care be taken to ensure that the weld region is free of all potential sources of hydrogen. As described below, the proposed alternative temper bead procedure utilizes a welding process that is inherently free of hydrogen.

h) N-638 4.0(b) requires the final weld surface and band around the area defined in paragraph 1.0 (d) to be examined using surface and ultrasonic (UT) methods. The purpose for the examination of the band is to assure all flaws associated with the weld repair area have been removed or addressed. However, the band around the area defined in paragraph 1.0(d) cannot be examined due to the physical configuration of the partial penetration weld. The final examination of the new weld and immediate surrounding area within the bore will be sufficient to verify that defects have not been induced in the low alloy steel RVCH material due to the welding process. Figures 5 and 11 of Attachment 2 indicate the area for PT and UT for the CRD and ICI penetration repairs. UT will be performed by scanning from the inner diameter (ID) surface of the weld. The UT is qualified to detect flaws in the repair weld and base metal interface in the repair region, to the maximum practical extent. UT acceptance criteria will be in accordance with NB-5330. The extent of the examination is consistent with the construction code requirements.

The preheated band as specified in 4.0(b) of N-638 includes an annular area extending five inches around the penetration bore on the inside surface of the RVCH. The purpose for the examination of the band is to ensure all flaws associated with the weld repair area have been removed or addressed since these flaws may be associated with the original flaw and may have been overlooked. In this case, the repair welding is performed remote from the known flaw(s).

It is unreasonable to examine the band required by N-638, 4.0(b) due to the head configuration and interference from adjacent CRD/ICI nozzles, as well as the configuration of the partial penetration welds. The proposed alternative examination area includes the weld and adjacent base material to be examined by PT and UT methods in the regions shown in Figures 5 and 11 of Attachment 2.

Scanning is performed from the inside surface of the new weld, the adjacent portion of the original nozzle, and the top of the new lower nozzle. The volume of interest for UT extends from at least one-inch above and below the new weld into the RVCH low alloy steel base material to at least ¼-inch depth. The PT area includes the weld surface and extends upward on the original nozzle inside surface to include the rolled expansion area including the rolled transition area (approximately 2.7 inches on the CRD nozzles and approximately 3.1 inches on the ICI nozzles) and at least ½-inch below the new weld on the lower nozzle inside surface.

The final examination of the new weld and immediate surrounding area of the weld within the band will be sufficient to verify that defects have not been induced in the low alloy steel RVCH material due to the welding process, and will assure integrity of the nozzle and the new weld.

i) N-638 4.0 (c) requires areas which had weld-attached thermocouples to be ground and examined using a surface examination. This requirement will be met if thermocouples are used.

j) N-638 4.0 (e) requires UT acceptance criteria to be in accordance with IWB- 3000. However, for this configuration, there are no acceptance criteria in IWB-3000 that directly apply. Therefore, the proposed welding technique requires UT acceptance criteria in accordance with NB-5330, which is consistent with the original construction code requirements and generally more restrictive than Section XI standards because the NB-5330 standards do not permit many common welding flaws such as lack of fusion, incomplete penetration, or cracks, regardless of length. Section XI, IWB-3000 standards allow acceptance of these types of fabrication indications based on dimensioned flaw boundaries.

The features of the alternative repair technique that make it applicable and acceptable for the potential repairs are described below:

1) The proposed alternative will require the use of an automatic or machine GTAW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code. The proposed alternative will include the requirements of paragraphs 1.0 through 5.0 of Attachment 1. The alternative will be used to make welds of P-No. 43 (CRD and ICI nozzle material) to P-No. 3 (RVCH material) using F-No. 43 filler material.

2) The use of a GTAW ambient temperature temper bead welding technique to avoid the need for postweld heat treatment is based on research that has been performed by Electric Power Research Institute (EPRI) (EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temperbead Applications," dated November 1998). The research demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the heat affected zone (HAZ) of the base material and preceding weld passes. Data presented in Tables 4-1 and 4-2 of the report show the results of procedure qualifications performed with 300°F preheats and 500°F post-heats, as well as with no preheat and post-heat. From that data, it is clear that equivalent

toughness is achieved in base metal and HAZ in both cases. The ambient temperature temper bead process has been shown effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed.

3) The NB-4622.11 (c)(2) temper bead procedure requires the use of the SMAW welding process with covered electrodes. Even the low hydrogen electrodes, which are required by NB-4622, may be a source of hydrogen unless very stringent electrode baking and storage procedures are followed. The only shielding of the molten weld puddle and surrounding metal from moisture in the atmosphere (a source of hydrogen) is the evolution of gases from the flux and the slag that forms from the flux and covers the molten weld metal. As a consequence of the possibility for contamination of the weld with hydrogen, NB-4622 temper bead procedures require preheat and postweld hydrogen bake-out. However, the proposed alternative temper bead procedure utilizes a welding process that is inherently free of hydrogen.

4) Final examination of the repair welds would be by PT and UT and would not be conducted until at least 48 hours after the weld had returned to ambient temperature following the completion of welding. Given the ⅜-inch limit on repair depth in the ferritic material, the delay before final examination would provide ample time for any hydrogen that did inadvertently dissolve in the ferritic material to diffuse into the atmosphere or into the non-ferritic weld material, which has a higher solubility for hydrogen and is much less prone to hydrogen embrittlement cracking. Thus, in the unlikely event that hydrogen induced cracking did occur, it would be detected by the 48-hour delay in examination.

5) Results of procedure qualification work undertaken to date indicate that the ambient temper bead process produces sound and tough welds. Typical tensile test results have been ductile breaks in the weld metal.

6) The P-No. 43 to P-No. 3 welding procedure specifies a maximum interpass temperature of 350°F. The welding procedure was qualified with an interpass temperature less than 100°F. Per QW-256, of ASME Section IX, an increase greater than 100°F is a supplementary essential variable. The procedure qualification requirements recommended in Code Case N-638 impose an 150°F maximum interpass temperature during the welding of the procedure qualification. This requirement restricts base metal heating during qualification that could produce slower cooling rates that are not achievable during field applications. However, this requirement does not apply to field applications, as a 350°F maximum interpass temperature is a requirement in Section 3.0 of Code Case N-638. The higher interpass temperature is permitted because it would only result in slower cooling rates which could be helpful in producing more ductile transformation products in the HAZ.

FANP has qualified the machine GTAW of P-No. 3, low alloy steel base materials, to P-No. 43, nickel alloy base materials, with the ambient temperature temper bead weld technique in accordance with the rules of ASME Code Case N-638. The qualifications were performed on the same P-No. 3, Group No. 3 base material as proposed for the CRD and ICI penetration repairs, using the same filler material (i.e. Alloy 52 AWS Class ERNiCrFe-7) with similar low heat input controls as will be used in the repairs. Also, the qualifications did not include a post weld heat soak. Based on FANP prior welding procedure qualification test data using machine GTAW ambient temperature temper bead welding, quality temper bead welds can be achieved with 50°F minimum preheat and no post weld heat soak.

7) As discussed previously, NB-5245 requires progressive surface examination of the proposed partial penetration welds while the alternative requires final PT and UT, which will provide added assurance of sound welds. The original construction code required progressive PT in lieu of volumetric examination because volumetric examination is unreasonable for the conventional partial penetration weld configurations. In this case the weld is suitable for UT and a final PT can be performed. The final examination of the new weld repair and immediate surrounding area within the band will be sufficient to verify that defects have not been induced in the low alloy steel RVCH material due to the welding process. Figures 5 and 11 of Attachment 2 indicate the areas for PT and UT for the CRD and ICI nozzle penetration repairs. UT will be performed by scanning from the ID surface of the weld. The UT is qualified to detect flaws in the repair weld and base metal interface in the repair region, to the maximum practical extent. UT acceptance criteria will be in accordance with NB-5330 (with exception to NB-3330 (b) for the triple point anomaly). The extent of examination is consistent with the construction code requirements.

8) The RVCH preheat temperature will be essentially the same as the reactor building ambient temperature. Therefore, RVCH preheat temperature monitoring in the weld region and the use of thermocouples is unnecessary and would result in additional personnel dose associated with thermocouple placement and removal. Consequently, preheat temperature verification by use of a contact pyrometer on accessible areas of the RVCH is sufficient. In lieu of using thermocouples for interpass temperature measurements, calculations show that the maximum interpass temperature will never be exceeded based on a maximum allowable low welding heat input, weld bead placement, travel speed, and conservative preheat temperature assumptions. The calculation supports the conclusion that using the maximum heat input through the third layer of the weld, the interpass temperature returns to near ambient temperature. Heat input beyond the third layer will not have a metallurgical effect on the low alloy steel HAZ.

A welding mockup on the full size Midland RVCH, which is similar to the Palisades RVCH, was used to demonstrate the welding technique described herein. During the mockup, thermocouples were placed to monitor the temperature of the closure head during welding. Thermocouples were placed on the outside surface of the RVCH within a five-inch band surrounding the CRD nozzle. Three other thermocouples were placed on the RVCH inside surface. One of the three thermocouples was placed 1½ inches from the CRD nozzle penetration, on the lower hillside. The other inside surface thermocouples were placed at the edge of the five-inch band surrounding the CRD nozzle, one on the lower hillside, the second on the upper hillside. During the mockup, all thermocouples fluctuated less than 15°F throughout the welding cycle. Therefore, for ambient temperature conditions used for this repair, maintenance of the 350°F maximum interpass temperature will not be a concern.

9) UT will be performed in lieu of RT due to the repair weld configuration. Meaningful RT cannot be performed. The weld configuration and geometry of the penetration in the RVCH provide an obstruction for the x-ray path and interpretation would be very difficult. UT will be substituted for the RT and qualified to evaluate defects in the repair weld and at the base metal interface. This examination method is considered adequate and superior to RT for this geometry. The new structural weld is sized like a coaxial cylinder partial penetration weld. ASME Code Section III construction rules require progressive PT of partial penetration welds. The Section III original requirements for progressive PT were in lieu of volumetric examination. Volumetric examination is not practical for the conventional partial penetration weld configurations. In this case the weld is suitable for UT and a final surface PT will be performed.

10) The extent of PT examination is consistent with the construction code requirements. The final modification configuration and surrounding ferritic steel area affected by the welding is either inaccessible or extremely difficult to access. PT of the accessible ferritic steel bore will be performed after removal by boring of the lower end of the existing CRD nozzle prior to welding.

11) The J-groove weld has a high tensile stress state due to welding residual stresses that could promote PWSCC initiation. Removal of the nozzle will impart some additional cold work and tensile stress on the newly machined ID surface of the J-groove weld. The effect of the machining and cold work is not expected to adversely affect the susceptibility of the J-groove weld to PWSCC since it is already in a highly stressed state and has a high susceptibility. After the IDTB repair, the original J-groove weld no longer serves its original function and an ASME Section XI analysis was performed which justified an assumed radial planar flaw in the J-groove weld extending to the RVCH ferritic steel fusion zone.

12) An artifact of the temper bead weld repair is an anomaly in the weld at the triple point. Fracture mechanics analyses were performed by FANP to evaluate a 0.100-inch semi-circular flaw extending 360 degrees around the circumference at the triple point locations where the Alloy 600 original nozzle or Alloy 690 replacement nozzle, the Alloy 52 weld, and the low alloy steel head meet. This non-proprietary summary report, AREVA Document 51-5047343-03, "Palisades CRDM & ICI Nozzle IDTB Repair – Life Assessment Summary," dated June 2005, is provided as Enclosure 3. The flaw is assumed to propagate in each of the two directions on the uphill and downhill sides of the nozzle. Flaw acceptance is based on the 1989 ASME Code Section XI criteria for applied stress intensity (IWB-3612) and limit load (IWB-3642).

The results of the analyses for the CRD and ICI nozzles demonstrate that a 0.100-inch weld anomaly is acceptable for a 27-year design life of the ID temper bead weld repair for both the CRD and ICI nozzles.

13) The potential corrosion concerns of the RVCH low alloy steel include: general, galvanic, crevice, stress corrosion cracking (SCC), and hydrogen embrittlement. Galvanic corrosion, crevice corrosion, SCC, and hydrogen embrittlement of the RVCH low alloy steel are not significant concerns based on previous operational experience with low alloy steel exposed to primary coolant. The general corrosion rate for the RVCH low alloy steel, under the anticipated exposure conditions, is 0.0032 inches/year. This corrosion rate is based on an 18-month operating cycle followed by a two-month refueling cycle.

14) Detailed stress and fatigue analyses of the ID temper bead (TB) CRD/ICI nozzle weld repair were performed. The analysis demonstrated that the IDTB CRD/ICI weld repair design meets the stress and fatigue requirements set by ASME Code, Section III, 1989 Edition without addenda. The conservative fatigue analyses conclude that the fatigue usage factor for 27 years of operation is 0.73 for the CRD weld repair and 0.682 for the ICI weld repair.

The life expectancy of the IDTB CRD/ICI weld repair was also evaluated with respect to the PWSCC concerns of the remaining Alloy 600 CRD nozzle portion affected by the IDTB weld repair. The Alloy 690 replacement lower nozzle and Alloy 52 IDTB weld are not considered susceptible to PWSCC. The life expectancy of the non-AWJM conditioned IDTB weld repair relative to PWSCC is conservatively estimated at 5.04 effective full power years (EFPY) for a CRD nozzle and 5.13 EFPY for an ICI nozzle. The PWSCC life was based on the EPRI MRP-55 PWSCC crack growth model. The PWSCC propagation path was conservatively assumed to follow the highest hoop tensile stress. The crack tip stress intensity factor was calculated for each increment of crack growth.

Transient	Cycles / 40 Years
Heatup and Cooldown	500
Normal Power Changes	2000
Fast Power Changes	2000
Plant Loading and Unloading	2000
Loss of Load	200
Loss of Flow	200
Safety Valve Operations	200
Leak Test	320

The results of the triple point flaw analyses demonstrate that a 0.100-inch weld anomaly is acceptable for 27 years of operation following the CRD/ICI nozzle IDTB weld repair, considering the transient frequencies listed in the above table.

Significant design margins have been demonstrated for all flaw propagation paths considered in the analysis. Flaw acceptance is based on the 1989 ASME Code Section XI criteria for applied stress intensity factor (IWB-3612) and limit load (IWB-3642). Fatigue crack growth is minimal along each flaw propagation path with the maximum final flaw size being only 0.166 inches for the CRD nozzle and 0.189 inches for the ICI nozzle. The minimum fracture toughness margin is 3.58 for the CRD nozzle and 4.41 for the ICI nozzle, compared to the required margin of $\sqrt{10}$ per IWB-3612. The margin on limit load is 7.96 for the CRD nozzle and 7.19 for the ICI nozzle, compared to the required margin of 3.0 per IWB-3642.

Based on the information presented, and pursuant to 10 CFR 50.55a(a)(3)(i), NMC requests approval for the proposed alternative on the basis that the alternative provides an acceptable level of quality and safety.

Duration of Proposed Alternative

NMC requests approval of the proposed alternative for the remainder of the third ten-year interval of the Inservice Inspection Program for Palisades Nuclear Plant, which will conclude on or before December 12, 2006.

Precedents

By letter dated February 23, 2004 (ADAMS Accession # ML040620671), as supplemented by letters dated March 4 (ADAMS Accession # ML040750278), April 8 (ADAMS Accession # ML041050668), April 12 (ADAMS Accession # ML041110821), May 3 (ADAMS Accession # ML041330262), May 4 (ADAMS Accession # ML041410519), June 1 (ADAMS Accession # ML041620398), and September 16, 2004 (ADAMS Accession # ML042660428), Entergy Operations, Inc. (Entergy) submitted two requests for relief from the requirements of the ASME Boiler and Pressure Vessel Code Sections III and XI as applied to reactor pressure vessel head penetration nozzles at Arkansas Nuclear One, Unit 1

(ANO-1). Entergy proposed using an alternative ambient temper bead welding method and alternatives to ASME Code nondestructive examinations and flaw evaluation requirements. Specifically, in ANO1-R&R-006, "Proposed Alternative to ASME Weld Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles," Entergy determined that water jet conditioning was not required. Entergy performed an analysis to determine the time for a postulated crack to grow 75% through wall in the Alloy 600 nozzle material above the repair weld without employing water jet conditioning. The analysis determined that a crack will not grow through-wall in a time period of four years. Entergy planned to replace the ANO-1 reactor pressure vessel head during an upcoming refueling outage which would be prior to the end of the four years, and therefore, the water jet conditioning was not necessary. The NRC issued the safety evaluation on this relief request by letter dated September 29, 2004 (ADAMS Accession # ML042730013).

NMC has also determined that AWJM is not required at PNP. An analysis was performed by FANP that determined a crack will not grow to 75% through-wall in a time period of approximately five years, which is beyond the duration of this relief request for PNP.

ATTACHMENT 1 to ENCLOSURE 1
RELIEF REQUEST #1: ALTERNATE REPAIR TECHNIQUE
DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

NMC plans to perform reactor vessel closure head (RVCH), control rod drive (CRD), and incore instrumentation (ICI) nozzle penetration repairs by welding the RVCH (P-No.3 base material) and the RVCH nozzle penetrations (P-No.43 base material) with filler material F-No.43, as shown herein. The general repair outline is shown in Attachment 2.

1.0 General Requirements

(a) The maximum area of an individual weld based on the finished surface will be less than 100 square inches, and the depth of the weld will not be greater than one-half of the ferritic base metal thickness.

(b) Repair/replacement activities on a dissimilar-metal weld are limited to those along the fusion line of a non-ferritic weld to ferritic base material on which ⅛-inch or less of non-ferritic weld deposit exists above the original fusion line.

(c) If a defect penetrates into the ferritic base material, repair of the base material, using a non-ferritic weld filler material, may be performed provided the depth of repair in the base material does not exceed ⅜ inches.

(d) Prior to welding, the area to be welded and a band around the area of at least 1½ times the component thickness (or five inches, whichever is less) will be at least 50°F.

(e) Welding materials will meet the owner's requirements and the construction code and cases specified in the repair/replacement plan. Welding materials will be controlled so that they are identified as acceptable until consumed.

(f) Peening will not be used.

2.0 Welding Qualifications

The welding procedures and the welding operators shall be qualified in accordance with Section IX and the requirements of paragraphs 2.1 and 2.2.

2.1 Procedure Qualification

(a) The ferritic steel base material for the welding procedure qualification is P-No. 3 Group No.3, which is the same P-No. and Group No. as the low alloy steel closure head base material to be welded. The ferritic base material shall be postweld heat treated to at least the time and temperature that was applied to the materials being welded. The other base material is P-No. 43. The filler metal is F-No. 43.

(b) The root width and included angle of the cavity in the test assembly will be no greater than the minimum specified for the repair.

(c) The maximum interpass temperature for the first three layers of the test assembly will be 150°F.

(d) The ferritic steel P-No. 3 Group No.3 base material test assembly cavity depth will be at least one-half the depth of the weld to be installed during the repair/replacement activity, and at least one-inch. The test assembly thickness will be at least twice the test assembly cavity depth. The test assembly will be large enough to permit removal of the required test specimens. The test assembly dimensions surrounding the cavity will be at least the test assembly thickness, and at least six inches. The qualification test plate will be prepared in accordance with Figure 1.

(e) Ferritic base material for the procedure qualification test will meet the impact test requirements of the construction code and owner's requirements. If such requirements are not in the construction code and owner's requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material, at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in subparagraph (f) below, but shall be in the base metal.

(f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) will be performed at the same temperature as the base metal test of subparagraph (e) above. Number, location, and orientation of test specimens will be as follows:

1. The specimens will be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The test coupons for heat affected zone (HAZ) impact specimens will be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimens will be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen will be inclined to allow the root of the notch to be aligned parallel to the fusion line.

2. If the test material is in the form of a plate or a forging, the axis of the weld will be oriented parallel to the principal direction of rolling or forging.

3. The Charpy V-notch test will be performed in accordance with SA-370. Specimens will be in accordance with SA-370, Figure 11, Type A. The test will consist of a set of three full-sized 10-mm x 10-mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens will be reported in the Procedure Qualification Record.

(g) The average values of the three HAZ impact tests shall be equal to or greater than the average values of the three unaffected base material tests.

2.2 Performance Qualification

Welding operators will be qualified in accordance with ASME Section IX.

3.0 Welding Procedure Requirements

The welding procedure shall include the following requirements:

(a) The weld metal will be deposited by machine gas tungsten arc welding (GTAW) process.

(b) Dissimilar metal welds shall be made using F-No. 43 weld metal (QW-432) for P-No. 43 to P-No. 3 weld joints.

(c) The ferritic steel area to be welded will be buttered with a deposit of at least three layers to achieve at least ⅛-inch overlay thickness as shown in Figure 2, steps 1 through 3, with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. Particular care will be taken in placement of the weld layers at the weld toe area of the ferritic material to ensure that the HAZ and ferritic weld metal are tempered. Subsequent layers will be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(d) The maximum interpass temperature for field applications will be 350°F regardless of the interpass temperature during qualification. The new weld is inaccessible for mounting thermocouples near the weld. Therefore, thermocouples will not be used to monitor interpass temperature. Preheat temperature will be monitored using contact pyrometer(s) and/or thermocouple(s), on accessible areas of the closure head external surface(s).

(e) Particular care shall be given to ensure that the weld region is free of all potential sources of hydrogen. The surface to be welded, filler metal, and shielding gas shall be suitably controlled as specified in the welding process control documents.

4.0 Examination

(a) Prior to welding, a surface examination will be performed on the area to be welded.

(b) Areas from which weld-attached thermocouples, if used, have been removed shall be ground and examined using a surface examination method.

(c) The final weld surface and adjacent HAZ shall be examined using surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours.

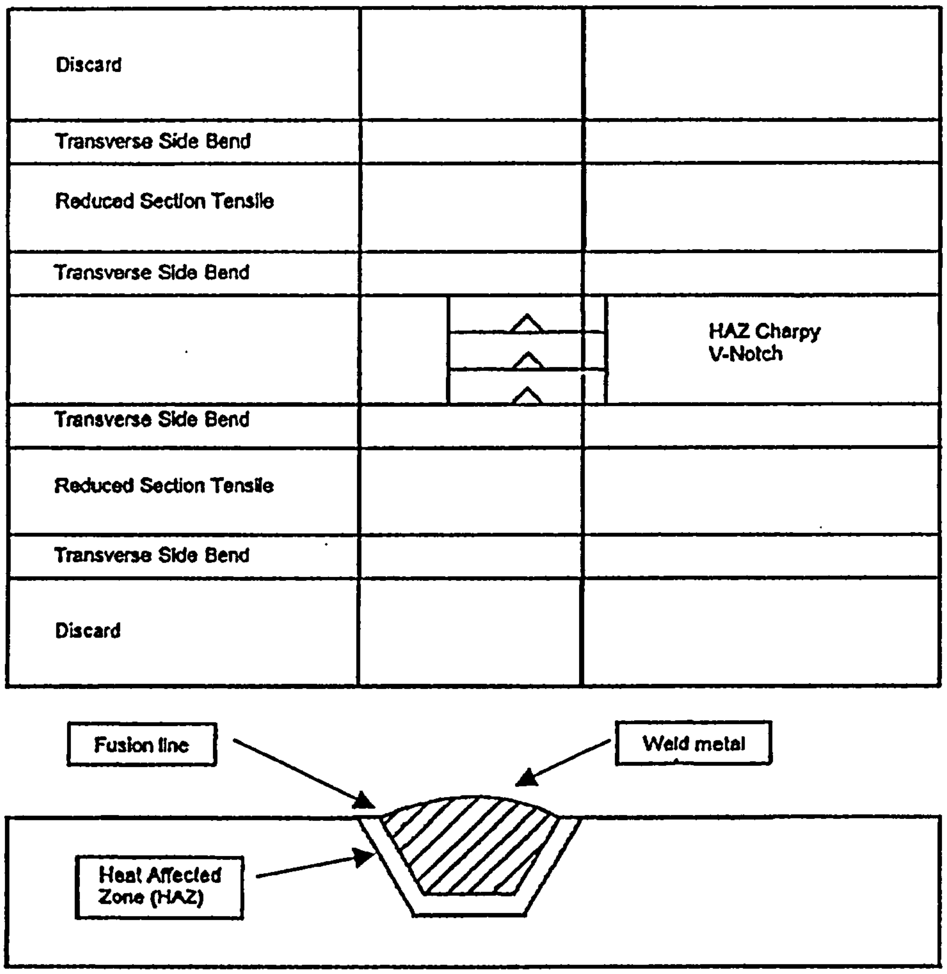
The purpose for the examination of the band is to assure all flaws associated with the weld repair area have been removed or addressed. However, the band around the area defined in paragraph 1.0(d) cannot be examined due to the physical configuration of the partial penetration weld. The final examination of the new weld repair and immediate surrounding area within the band will be sufficient to verify that defects have not been induced in the low alloy steel reactor vessel head material due to the welding process. Figures 5 and 11 of Attachment 2 indicate the area for PT and UT examination for the CRD and ICI nozzle penetration repairs. UT will be performed by scanning from the ID surface of the weld and adjacent portion of the CRD and ICI nozzle bore. The UT is qualified to detect flaws in the repair weld and base metal interface in the repair region, to the maximum practical extent. The examination extent is consistent with the construction code requirements.

(d) NDE personnel will be qualified in accordance with IWA-2300 or NB-5500 (1984 Edition of SNT-TC-1A).

(e) Surface examination acceptance criteria will be in accordance with NB-5350. Ultrasonic examination acceptance criteria will be in accordance with NB-5330.

5.0 Documentation

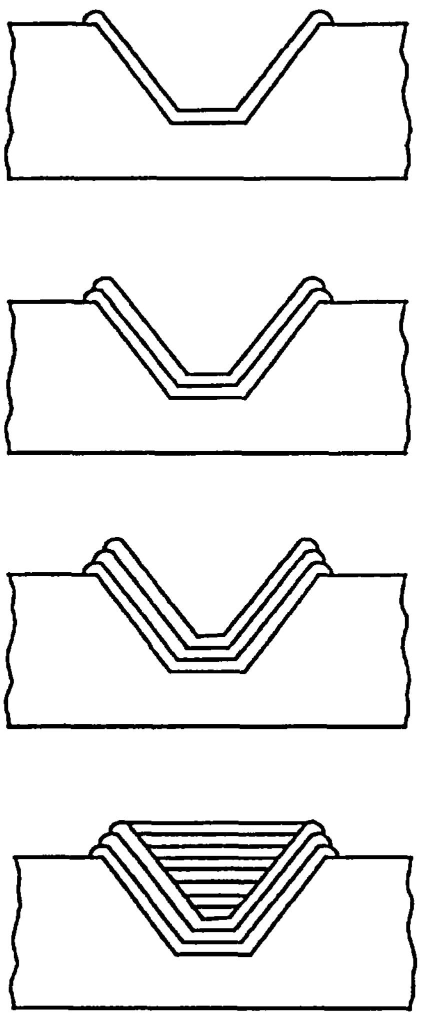
Repairs will be documented on Form NIS-2.



GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

QUALIFICATION TEST PLATE

Figure 1



Step 1: Deposit layer one with first layer weld parameters used in qualification.

Step 2: Deposit layer two with second layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the second layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.

Step 3: Deposit layer three with third layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the third layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.

Step 4: Subsequent layers to be deposited as qualified, with heat input less than or equal to that qualified in the test assembly. NOTE: Particular care shall be taken in application of the fill layers to preserve the temper of the weld metal and HAZ

GENERAL NOTE: The illustration above is for similar-metal welding using a ferritic filler material. For dissimilar-metal welding, only the ferritic base metal is required to be welded using steps 1 through 3 of the temperbead welding technique.

AUTOMATIC OR MACHINE (GTAW) TEMPERBEAD WELDING

Figure 2

ATTACHMENT 2 to ENCLOSURE 1
RELIEF REQUEST #1: ALTERNATE REPAIR TECHNIQUE
DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

NMC plans to perform reactor vessel closure head (RVCH), control rod drive (CRD), and incore instrumentation (ICI) nozzle penetration repairs by welding the RVCH (P-No.3 base material) and the RVCH nozzle penetrations (P-No.43 base material) with filler material F-No.43, as shown herein. Figures 1 through 6 for the CRD repair and Figures 7 through 12 for the ICI repair show the general nozzle configurations during the process. A general process outline is shown below. The process outline is generally the same for the CRD and ICI nozzles except as noted.

a. Ultrasonic examine (UT) the weld repair area
b. Cut tube grid structure adjoining the target nozzle and surrounding CRDs. (CRD nozzle only) NOTE: Thermal sleeve removal was completed as part of the RVCH inspection procedure during the 2004 refueling outage.
c. Cut the nozzle and remove the nozzle extension close to the underside of the head.
d. Roll expand nozzle body.
e. Clean the bore.
f. Bore the lower nozzle OD slightly oversize up to the location of the repair weld. The lower portion of the remaining nozzle is beveled suitable for welding.
g. Machine the replacement lower nozzle (diameter and length).
h. Chamfer grind the original J-groove weld (ICI Only)
i. Clean the weld prep area.
j. PT the weld prep and exposed low alloy steel base material.
k. Clean PT consumables from weld prep and dry nozzle and crevice using heating element.
l. Insert new replacement lower nozzle and weld using the ambient temperature temper bead machine gas tungsten arc welding (GTAW) process.
m. Weld cool down then 48-hour hold.
n. Machine new weld ID. This may be performed during the 48-hour hold.
o. UT the weld after 48-hour hold.
p. PT weld and roll expanded portion of nozzle, including the roll transition region.
q. Install the new extension assembly (and tube grid structure for CRD locations).
r. Position and weld the new tube grid structure and the fillet weld new extension assembly to lower nozzle and grid structure(CRD nozzle only) and intermittent fillet weld extension to lower nozzle (ICI nozzle only).
s. Visually inspect the new welds.

t. Dimensional inspect the location of the new nozzle extension assembly. The positioning tool shall perform a free path check for nozzles (CRD only).
u. Perform final cleaning and visual inspection of each nozzle.

FIGURE 1
CRD THERMAL SLEEVE REMOVAL,
TUBE SUPPORT PLATE REMOVAL,
AND NOZZLE CUT

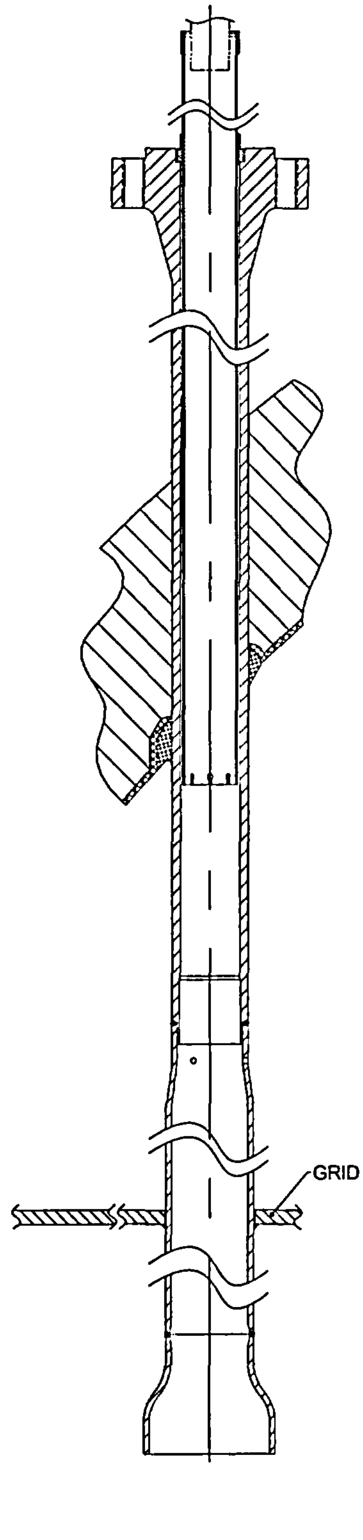


FIGURE 2
CRD ROLL EXPANSION

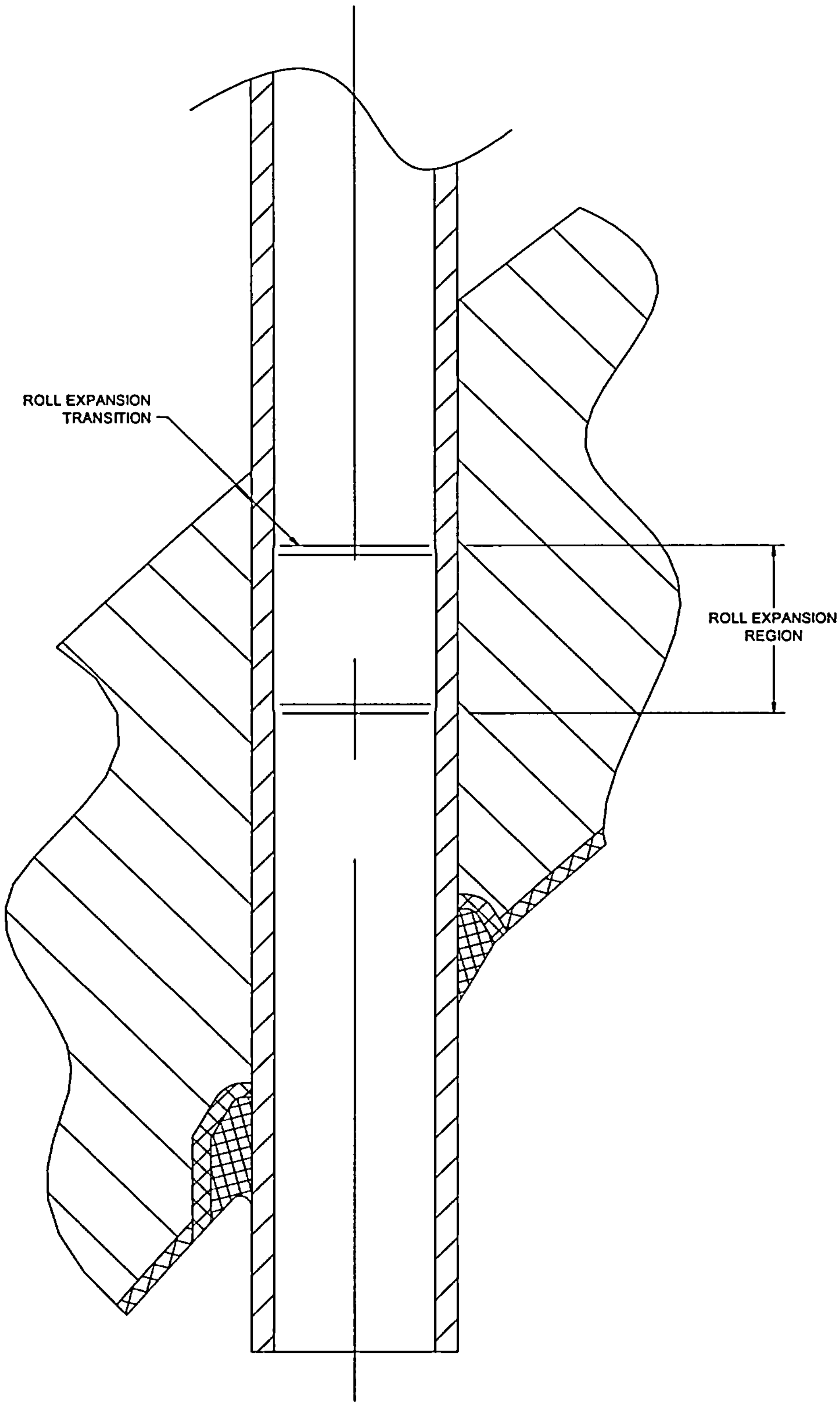


FIGURE 3
CRD NOZZLE BORING AND
WELD PREP MACHINING

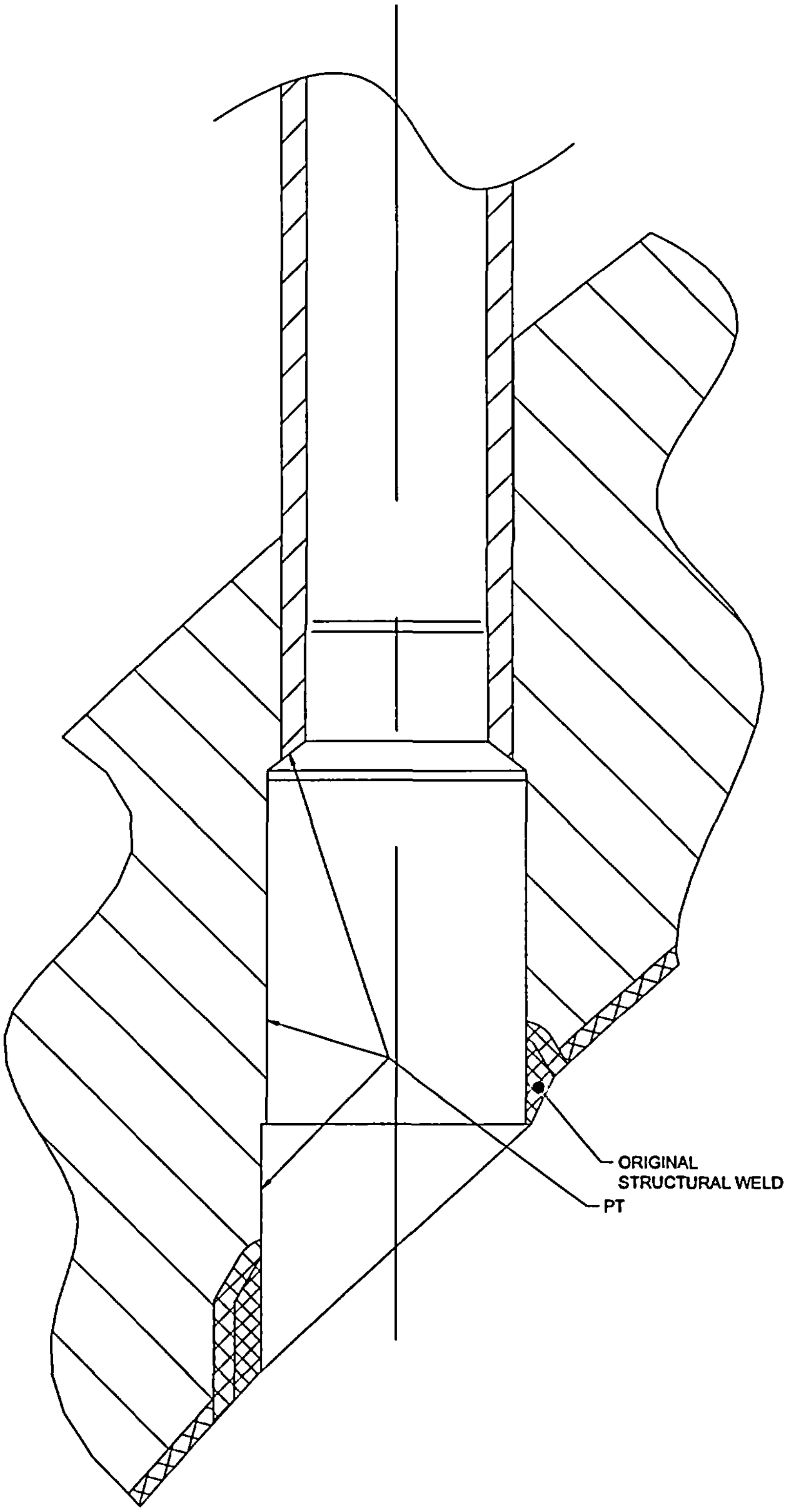


FIGURE 4
CRD
WELDING

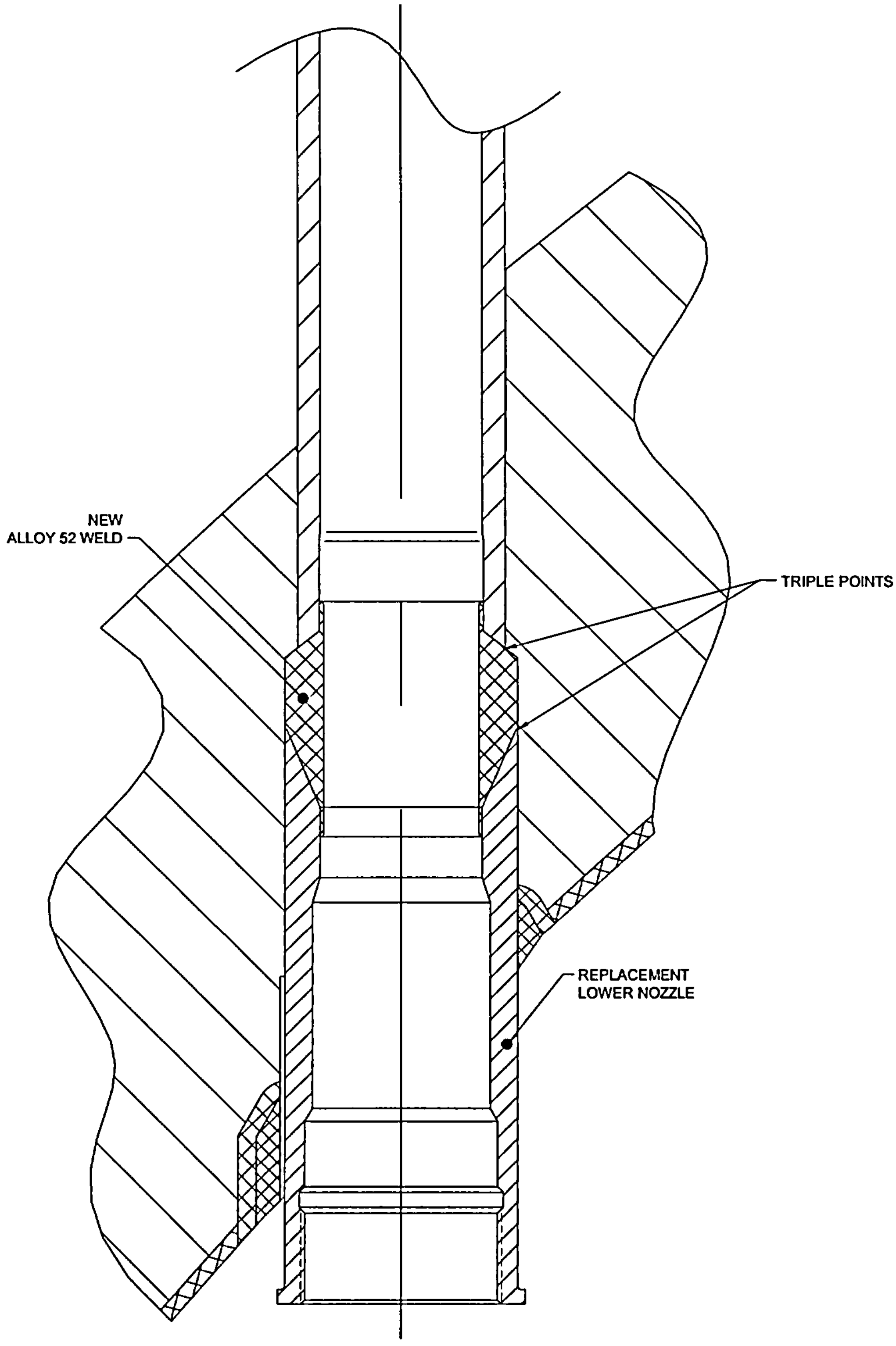


FIGURE 5
CRD MACHINING AND NDE

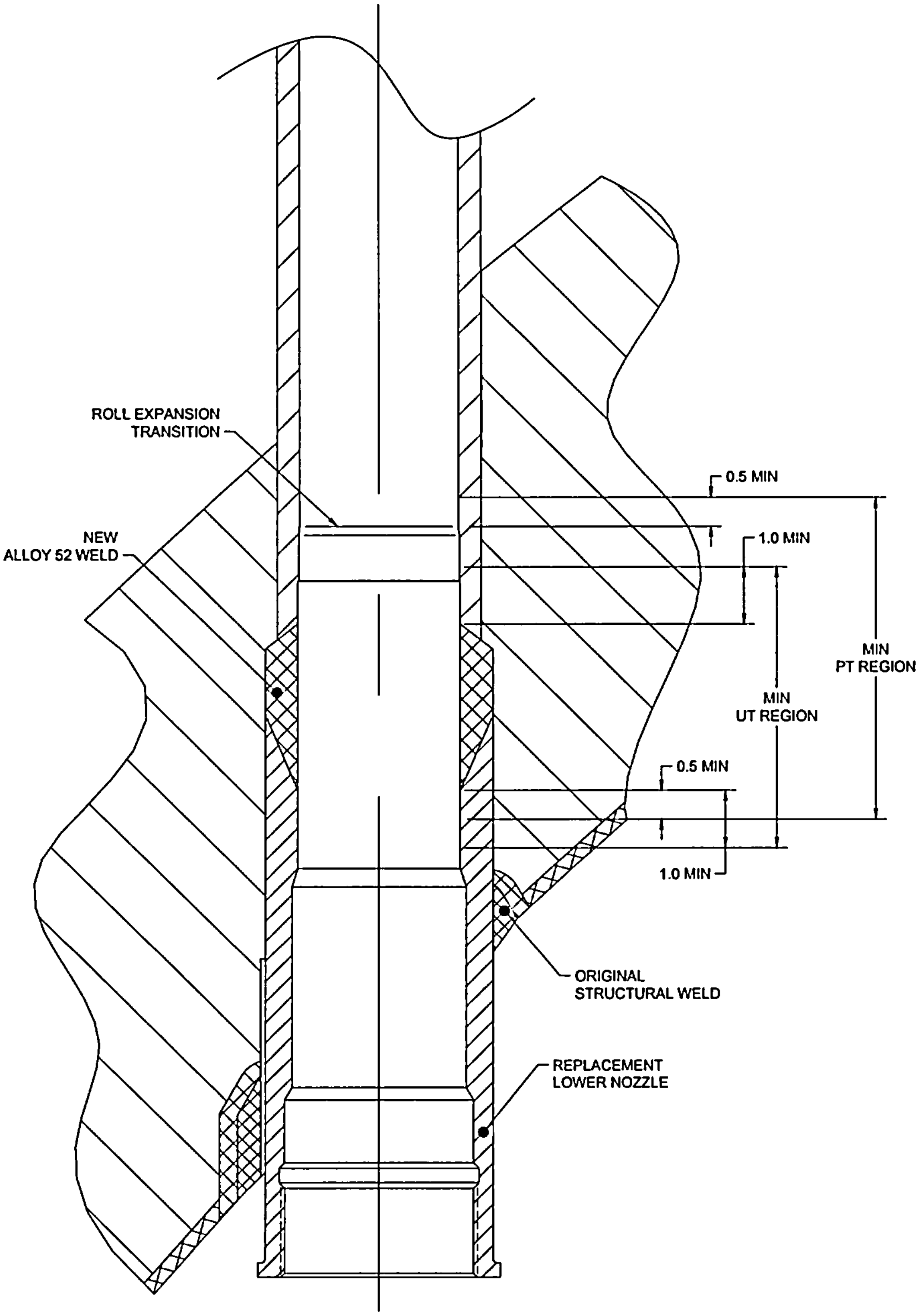


FIGURE 6
CRD EXTENSION ASSEMBLY AND
TUBE SUPPORT PLATE INSTALLATION

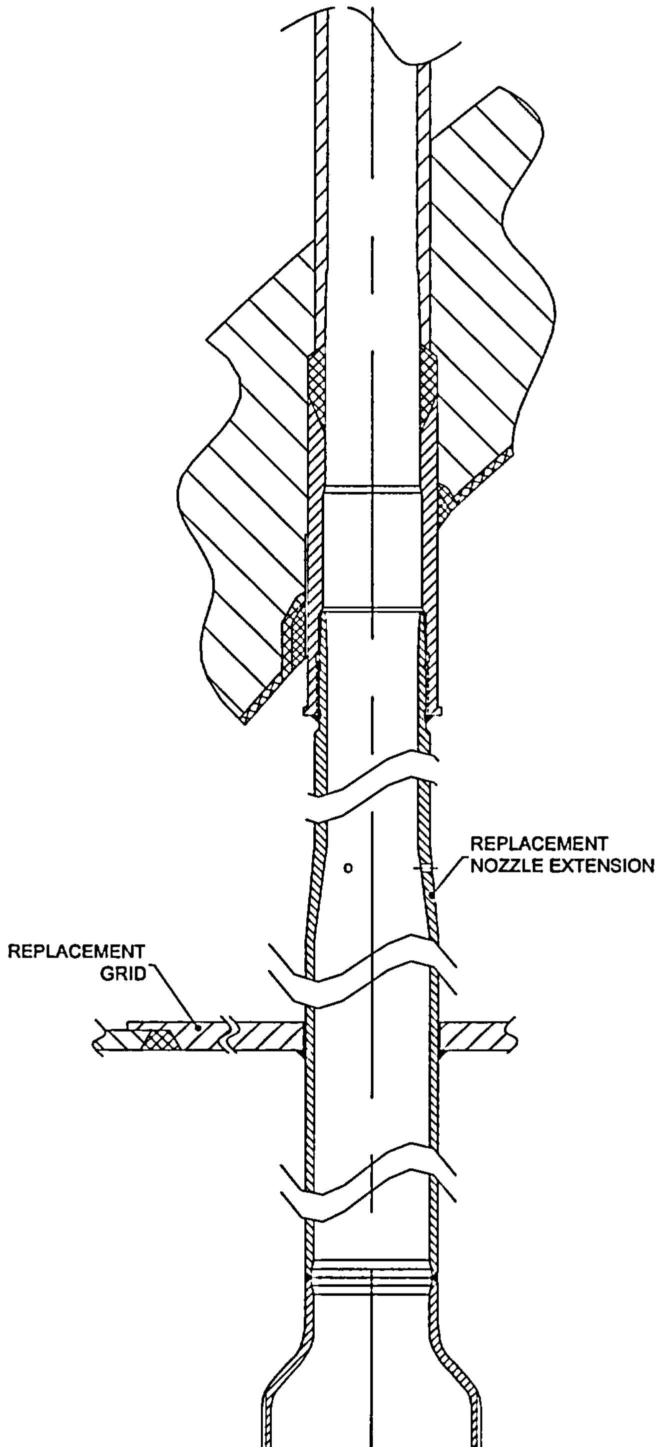


FIGURE 7
ICI INITIAL NOZZLE CUT

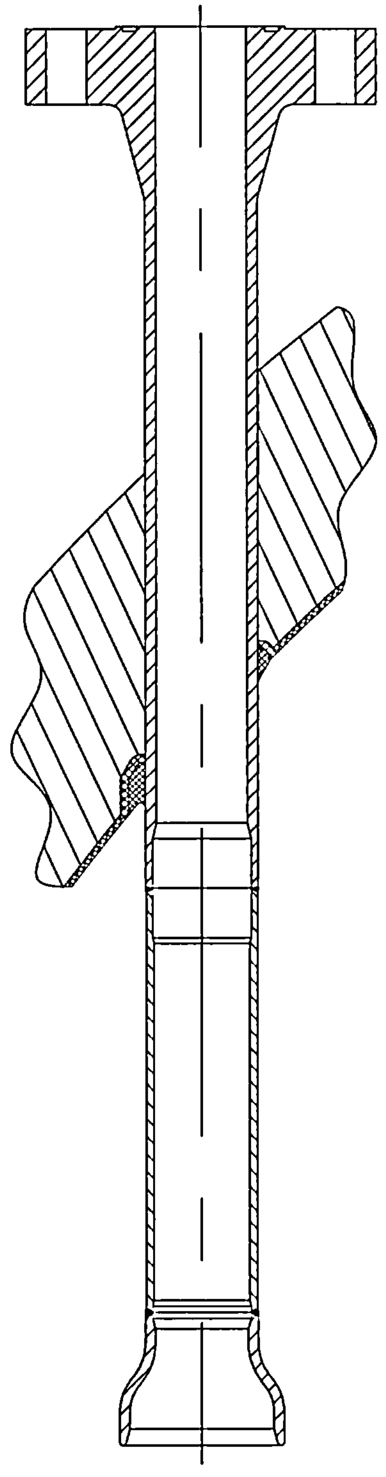


FIGURE 8
ICI ROLL EXPANSION

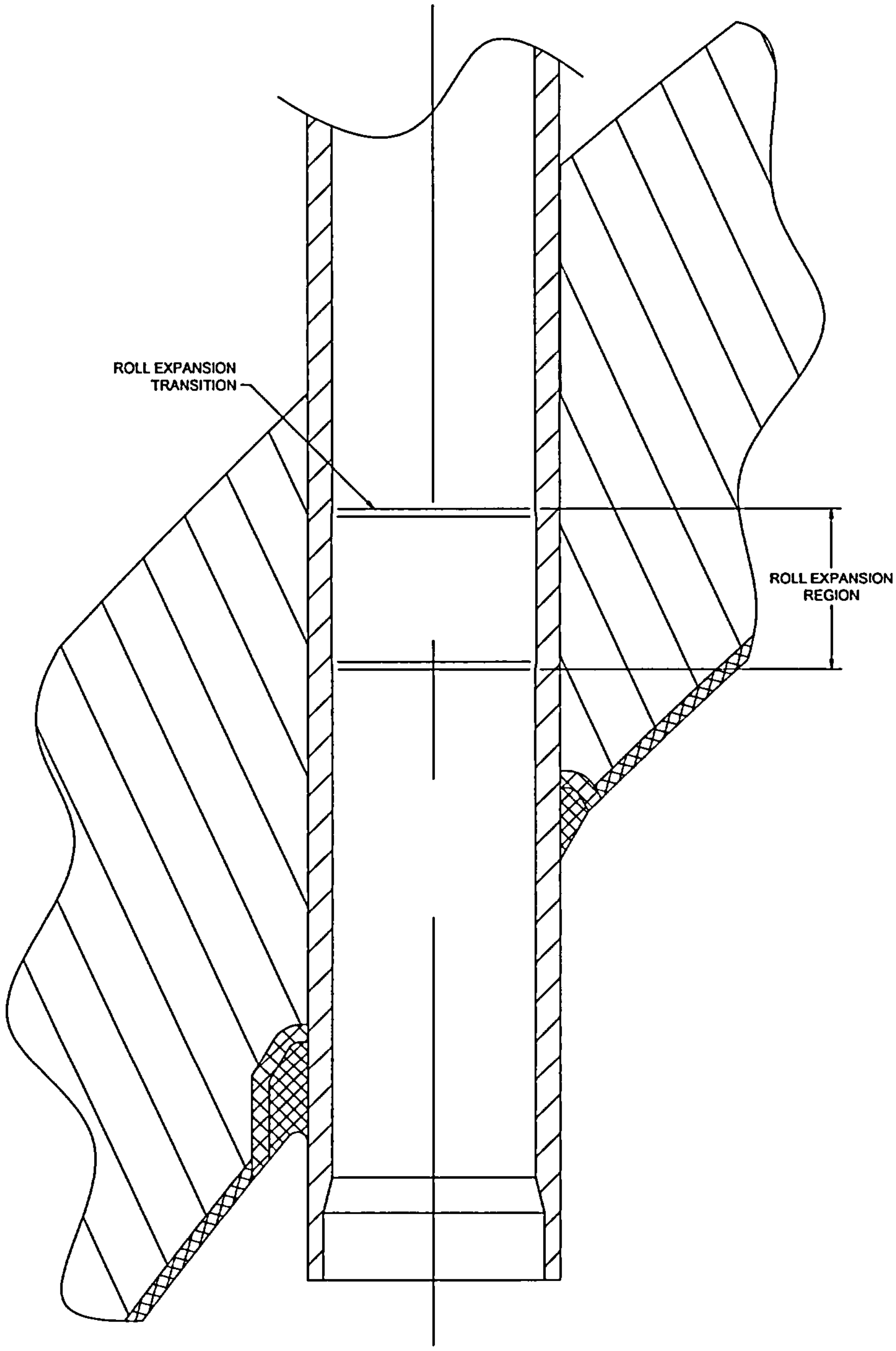


FIGURE 9
ICI NOZZLE BORING, WELD PREP MACHING, AND ORIGINAL WELD GRINDING

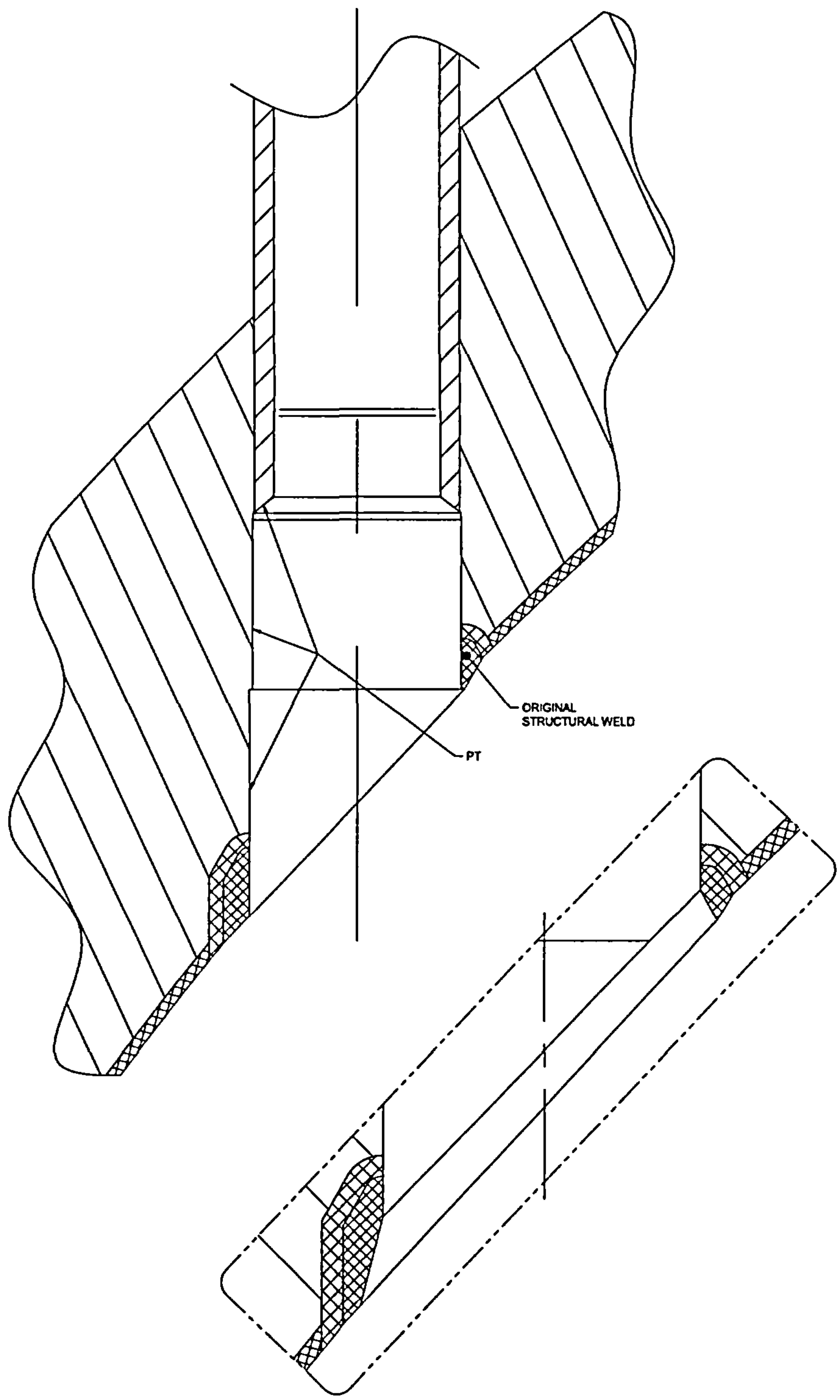


FIGURE 10
ICI WELDING

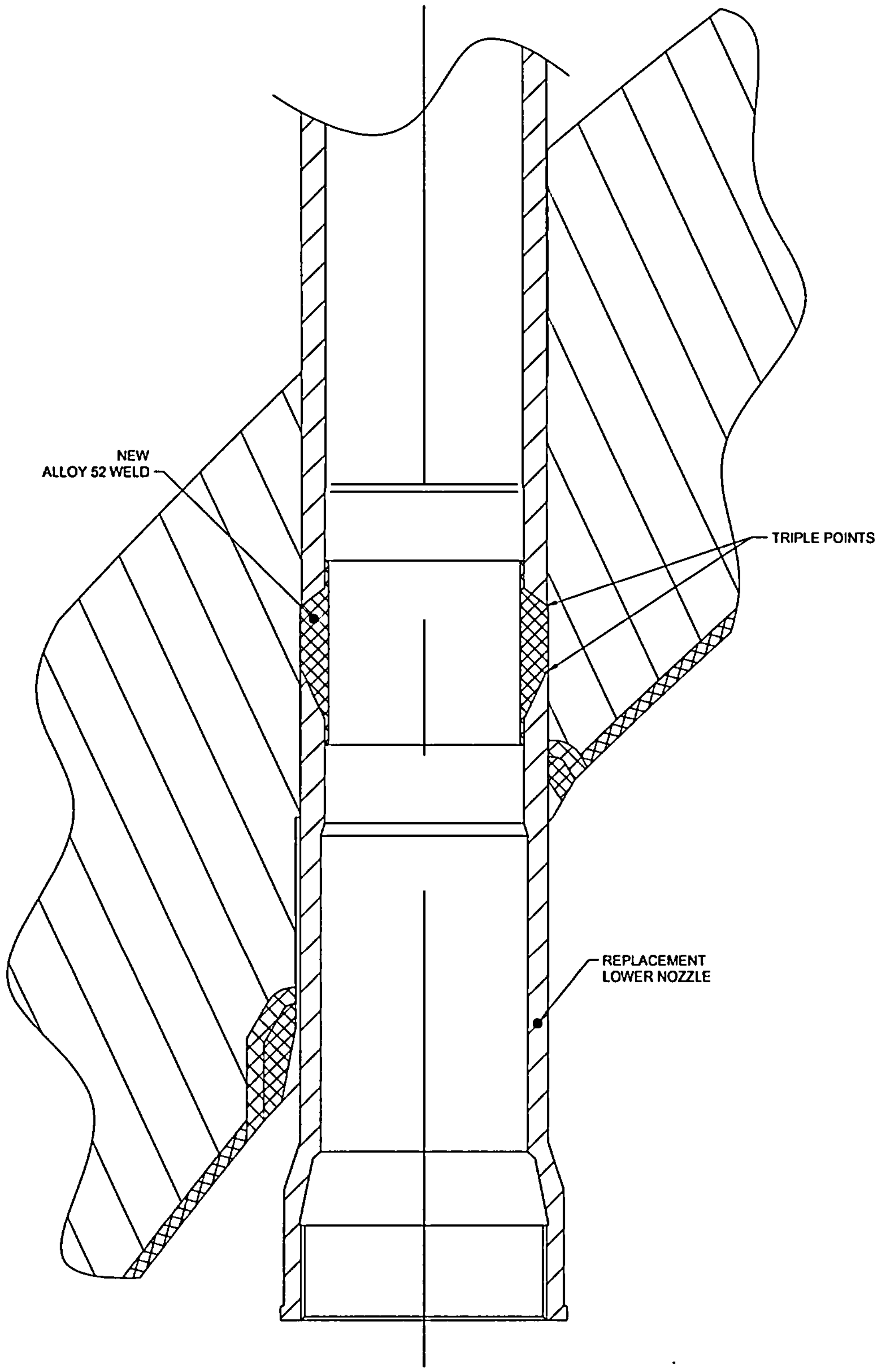


FIGURE 11
ICI MACHINING AND NDE

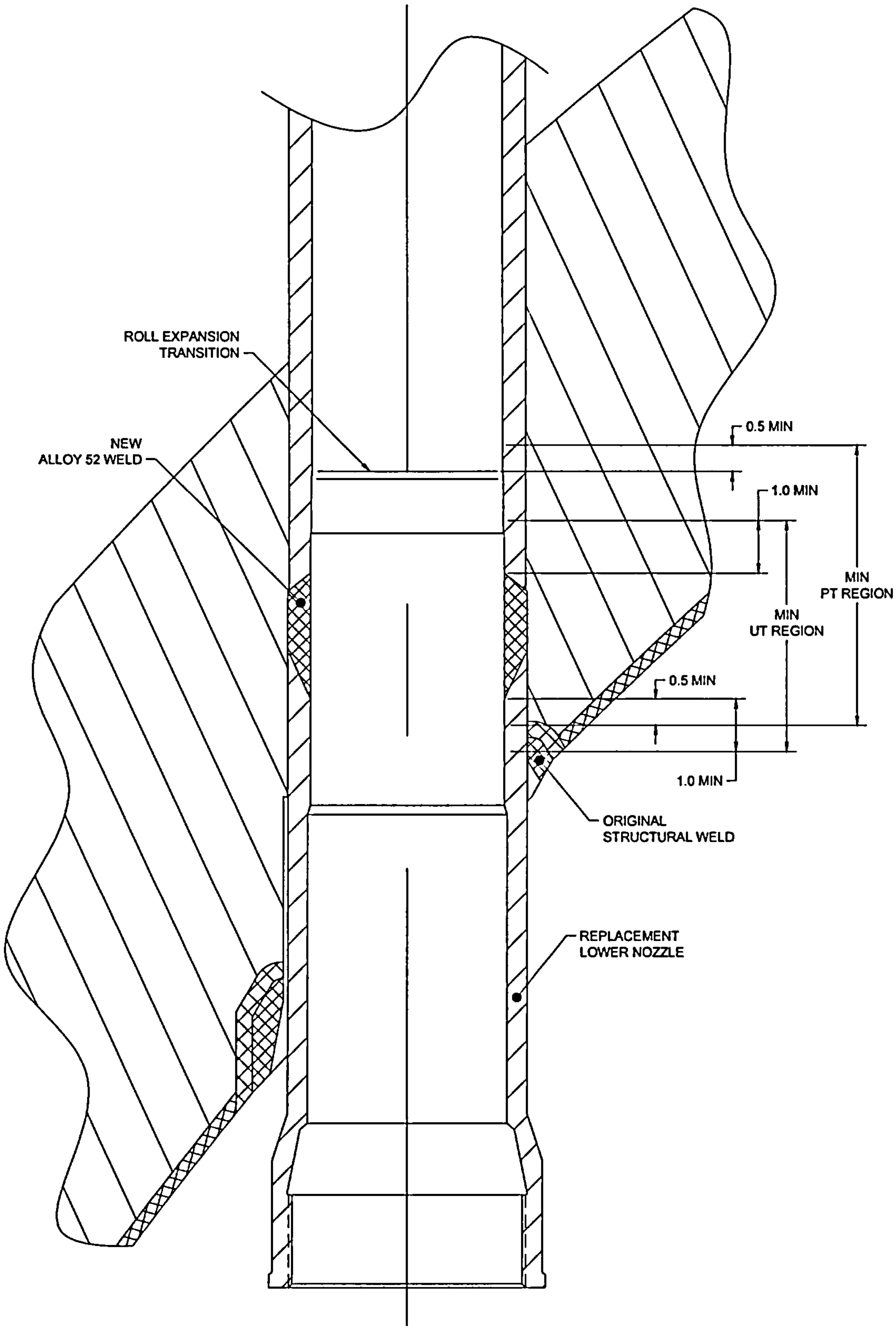
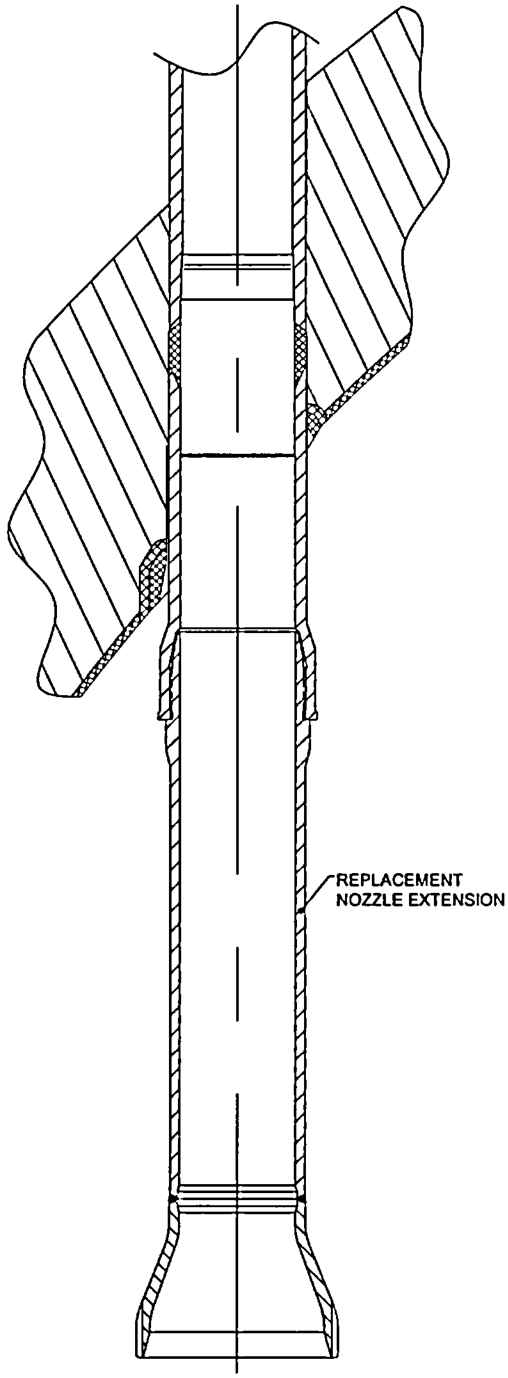


FIGURE 12
ICI EXTENSION AND REDUCER INSTALLATION



ENCLOSURE 2
RELIEF REQUEST #2: ALTERNATE REPAIR TECHNIQUE
REACTOR PRESSURE VESSEL PENETRATIONS

Introduction

During the 2004 refueling outage, repairs were performed on two control rod drive (CRD) nozzles using chamfer grinding to remove potential cracks in the remnant of the CRD J-groove weld. Extensive dose was received during these repairs due to the chamfering process. With the installation of the new pressure boundary welds, the original function of the CRD J-groove weld is no longer required. Using an assumed worst case crack size, analyses ensure that unacceptable crack growth into the reactor pressure vessel head does not occur within the next 27 years. Therefore, chamfer grinding has been determined to be unnecessary in the repair process for CRD nozzles. NMC has revised this relief request to reflect the removal of the chamfer grinding for the CRD nozzles.

ASME Code Component Affected

The affected components are the Palisades Nuclear Plant reactor vessel closure head (RVCH), control rod drive (CRD), and incore instrumentation (ICI) nozzle penetrations. The Palisades Nuclear Plant has 45 CRD penetrations and 8 ICI penetrations, which are American Society of Mechanical Engineers (ASME) Class 1 penetrations.

Applicable Code Edition and Addenda

The applicable code edition and addenda for the RVCH penetration repair is the (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, 1989 Edition with no addenda. Palisades is currently in the third ten-year inspection interval.

Applicable Code Requirement

The applicable code requirement for the RVCH penetration repair is ASME Section XI. IWB-2500, examination category B-E, "Pressure Retaining Partial Penetration Welds in Vessels," Item B4.12 and B4.13, are applicable to the inservice examination of the CRD and ICI nozzle to RVCH welds. IWA-3300, IWB-3142.4, and IWB-3420 are applicable to any flaws discovered during inservice inspection. IWB-3612 and IWB-3613 provide acceptance criteria for the analytical evaluation of flaws that, in this case, are assumed to exist in the remnant of the J-groove weld material. Specifically:

1. IWA-3300(b) contains a requirement for flaw characterization.

2. IWB-3142.4 allows for analytical evaluation to demonstrate that a component is acceptable for continued service. It also requires that components found acceptable for continued service by analytical evaluation be subsequently examined in accordance with IWB-2420(b) and (c).

3. IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300.

4. IWB-3613 provides acceptance criteria for flaws in flanges and shell regions near structural discontinuities.

The original construction code for the Palisades RVCH is ASME Section III, 1965 Edition, including addenda through winter 1965.

Reason for Request

NMC has determined that chamfer grinding is not necessary in the repair process for the CRD nozzle penetration locations and the relief request has been revised to reflect this change. The above sections would require characterization of a flaw existing in the remnant of the J-groove weld that will be left on the RVCH if a CRD or ICI nozzle must be partially removed.

If inspection of the RVCH CRD and ICI nozzle penetrations reveals flaws affecting the J-groove attachment welds, it may be unreasonable to characterize these flaws by nondestructive examination (NDE) and it may be unreasonable to perform any successive examinations of these flaws. The original CRD and ICI nozzle to RVCH weld configuration is difficult to ultrasonically (UT) examine due to the compound curvature and fillet radius. The configuration is not conducive to UT due to the configuration and dissimilar metal interface between the NiCrFe weld and the low alloy steel RVCH. Furthermore, due to limited accessibility from the RVCH outer surface and the proximity of adjacent nozzle penetrations, it is unreasonable to scan from this surface on the RVCH base material to detect flaws in the vicinity of the original weld. These conditions preclude ultrasonic coupling and control of the sound beam in order to perform flaw sizing with reasonable confidence in the measured flaw dimension. Therefore, NMC is requesting relief from ASME Section XI, IWA-3300(b), IWB-3142.4, IWB-3420, and IWB-3613 pursuant to 10 CFR 50.55a(a)(3)(i), because the alternative proposed below provides an acceptable level of quality and safety.

Proposed Alternative and Basis for Use

The alternative requirements are:

1. IWA-3300(b) contains a requirement for flaw characterization. In lieu of this requirement, a conservative worst-case flaw shall be assumed to exist in this weld that extends from the weld surface to the RVCH low alloy steel base material interface. Appropriate fatigue analyses have been performed based on that flaw to establish the minimum remaining service life of the RVCH.

2. IWB-3142.4 allows for analytical evaluation to demonstrate that a component is acceptable for continued service. It also requires that components found acceptable for continued service by analytical evaluation be subject to successive examination. Analytical evaluation of

the worst-case flaw referred to above has been performed to demonstrate the acceptability of continued operation. However, because of the impracticality of performing any subsequent inspection that would be able to characterize any remaining flaw, successive examination will not be performed.

3. Paragraph IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300. As previously stated, a conservative worst-case flaw shall be assumed to exist and appropriate fatigue analyses have been performed based on that flaw.

4. Paragraph IWB-3613(a) requires that, for conditions <20% of design pressure, the ratio of the maximum applied stress intensity factor and the available fracture toughness based on crack arrest (K_{Ia}) for the corresponding crack tip temperature be $< \sqrt{2}$ at a temperature of RT_{NDT} + 60°F. NMC proposes to use the 2005 Addenda of ASME Section XI, 2004 Edition where the code rules allow the ratio of the maximum applied stress intensity factor and the available fracture toughness based on crack initiation (K_{Ic}) for the corresponding crack tip temperature be $< \sqrt{2}$ at a temperature of RT_{NDT}. This applies only to the CRD J-groove fracture mechanics evaluation.

5. Paragraph IWB-3613(b) requires that, for normal conditions, the ratio of the maximum applied stress intensity factor and the available fracture toughness based on crack arrest (K_{Ia}) for the corresponding crack tip temperature be $< \sqrt{10}$. Rather than using this criterion, NMC proposes to use elastic plastic fracture mechanics (EPFM) acceptance criteria evaluate flaw stability with safety factors of 3 on primary (pressure) stresses and 1.5 secondary (residual plus thermal) stresses as described below. This applies only to the CRD J-groove fracture mechanics evaluation.

Refer to Attachment 2 of Enclosure 1 for additional information regarding the proposed alternative repair.

Fracture mechanics evaluations were performed by FANP, AREVA Document 51-5047343-03, "Palisades CRDM & ICI Nozzle IDTB Repair – Life Assessment Summary," dated June 2005, to determine if degraded J-groove weld material could remain in the reactor vessel closure head, with no examination to size any flaws that might remain following the repair. This non-proprietary summary report is provided as Enclosure 3.

The remaining non-chamfered J-groove weld in the CRD nozzles, after the IDTB repair, was analyzed by postulating a radial crack in the Alloy 182 J-groove weld and butter and evaluating fatigue crack growth into the low alloy steel head. Since a potential flaw in the J-groove weld can not be sized by currently available nondestructive examination techniques, it was assumed that the "as-left" condition of the remaining J-groove weld includes degraded or cracked weld material extending through the entire J-groove weld and Alloy 182 butter material. It was further postulated that a small fatigue initiated flaw forms in the low alloy steel head and combines with the primary water stress corrosion crack in the weld to form a large radial corner flaw that propagates into the head by fatigue crack growth under cyclic loading conditions. A flaw evaluation of any partial penetration nozzle J-groove weld is inherently difficult due to the presence of large residual stresses created during the welding process. An analysis of the Palisades head is particularly challenging because of a high RT_{NDT} (72°F) for the low alloy steel base metal.

Fatigue crack growth analysis was performed to determine final flaw sizes on the uphill and downhill sides of the J-groove weld after 27 years of operation. Stress intensity factors were first determined using three-dimensional finite element analysis for cracks extending to the butter/head interface and applying both residual and operating stresses for each of eight analyzed transients. For each increment of crack growth, stress intensity factors were increased by the square root of the ratio of flaw sizes. This is a conservative approximation since both the residual stresses and the thermal gradient stresses decrease in the direction of crack propagation. Flaw growth into the head was calculated to be 0.610 inch on the uphill side and 0.324 inch on the downhill side.

A combination of linear elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM) was utilized to evaluate the final uphill and downhill flaw sizes after 27 years of crack growth. At operating temperatures when EPFM is the appropriate analysis method, a J-integral/tearing modulus (J-T) diagram was used to evaluate flaw stability with safety factors of 3 on primary (pressure) stresses and 1.5 secondary (residual plus thermal) stresses. The crack driving force was also checked against the J-R curve at a crack extension of 0.1 inch using safety factors of 1.5 and 1.0 for primary and secondary stresses, respectively. Near room temperature, when the material is less ductile and LEFM is the more appropriate analysis method, stress intensity factors were compared to the crack initiation fracture toughness (K_{Ic}) using a safety factor of $\sqrt{2}$.

The highest crack tip stress intensity factors occur during cooldown when the pressure is still 2085 psig and the temperature decreases to 400 °F. At these conditions, the applied J-integral at the uphill crack front is 1.470 kips/in, with safety factors of 3 on pressure stresses and 1.5 on residual and thermal stresses, which is less than the J-integral for the material, 3.259 kips/in, at the point of instability. Flaw stability is also demonstrated by an applied tearing modulus of 9.323 kips/in, which is well below a tearing modulus of 62.04 kips/in for the material. For a flaw on the downhill side, the applied J-integral is 2.414 kips/in, compared to a J-integral at the point of instability of 3.270 kips/in. The applied tearing modulus is 15.18 kips/in and the corresponding tearing modulus for the material is 31.28 kips/in, again demonstrating flaw stability. As a final check on the EPFM analysis, the applied J-integrals for safety factors of 1.5 on pressure and 1.0 on residual and thermal loads are compared to the J-integral for the material at a crack extension of 0.1 inch. It was determined that the applied J-integrals of 0.361 kips/in on the uphill side and 0.597 kips/in on the downhill side are both less than the required value of 1.711 kips/in for the material.

At low temperature conditions near the end of cooldown, where linear elastic fracture mechanics (LEFM) is the appropriate method for flaw evaluation, it is widely recognized that J-groove weld residual stresses make it improbable that the Code required fracture toughness margin can be satisfied, as was the case for the Palisades CRD J-groove weld flaws. Although these residual stresses would tend to be relieved as a crack propagated farther into the head, additional analysis was performed for larger flaw sizes to demonstrate that the required fracture toughness margin could be met while still considering residual stress. New crack sizes were determined by reviewing stress contour plots and selecting crack extensions that would locate the uphill and downhill crack fronts in regions of compressive residual stress. On the uphill side, the crack was extended 1.25 inches beyond the butter. A larger crack extension of 2.5 inches was required on the downhill side to extend the crack into the compressive residual stress field. The controlling low temperature condition occurs at the end of cooldown when the temperature is about 70°F with a pressure of 295 psig. The K_{Ic} fracture toughness at this temperature is only 53.1 ksi$\sqrt{in}$. Nevertheless, at these larger crack sizes, the applied stress intensity factors were calculated to be 29.5 ksi$\sqrt{in}$ on the uphill side and 28.5 ksi$\sqrt{in}$ on the downhill side, both of which satisfy a $K_{Ic}/\sqrt{2}$ acceptance criterion of 37.5 ksi$\sqrt{in}$. In summary, a combination of linear elastic and elastic-plastic fracture mechanics has been used to show that postulated flaws in the CRD J-groove weld and butter are acceptable for 27 years of operation.

Fracture mechanics evaluation was also performed by FANP to determine if degraded ICI J-groove weld material could be left in the reactor vessel head, with no examination to size any flaws that might remain following the repair. Since the hoop stresses in the J-groove weld are higher than the axial stress at the same location, the preferential direction for cracking is axial, or radial relative to the nozzle. It was postulated that a radial flaw in the Alloy 182 weld metal would propagate by primary water stress corrosion cracking through the weld and butter to the interface with the low alloy steel head, where the flaw would blunt and arrest. To reduce the size of the postulated flaw, the repair design specifies that the inside corner of the ICI J-groove weld be chamfered (See Figure 9 in Attachment 2 of Enclosure 1).

Crack growth through the Alloy 182 material would tend to relieve the residual stresses in the weld as the crack grew to its final size and blunted. Although residual stresses in the head material are low, the size of the postulated flaw was increased to include the region where the residual stresses are tensile. It was then not necessary to further consider residual stresses for crack growth into a compressive residual stress field. It was further postulated that a small flaw could initiate in the low alloy steel head material and combine with the large stress corrosion crack in the weld to form a radial corner flaw that would propagate further into the low alloy steel head by fatigue crack growth under cyclic loading associated with heat up, cool down, and other applicable transients.

The results of the analysis for the ICI nozzle demonstrate that a postulated radial crack in the remnants of the original J-groove weld and butter would satisfy the

1989 ASME Code Section XI criteria (IWB-3612) for 5 years of operation, when the ratio of material fracture toughness to applied stress intensity factor would be 3.16 (or $\sqrt{10}$), which is the maximum permitted by IWB-3612.

The evaluations discussed above provide an acceptable level of quality and safety without performing flaw characterization as required in ASME Section XI 1989, IWA-3300 (b), IWB-3142.4, IWB-3420, and IWB-3613.

Based on the information presented, and pursuant to 10 CFR 50.55a(a)(3)(i), NMC requests approval for the proposed alternative on the basis that the alternative provides an acceptable level of quality and safety.

Duration of Proposed Alternative

NMC requests approval of the proposed alternative for the remainder of the third ten-year interval of the Inservice Inspection Program for Palisades, which will conclude on or before December 12, 2006.

Precedents

By letter dated February 23, 2004 (ADAMS Accession # ML040620671), as supplemented by letters dated March 4 (ADAMS Accession # ML040750278), April 8 (ADAMS Accession # ML ML041050668), April 12 (ADAMS Accession # ML041110821), May 3 (ADAMS Accession # ML041330262), May 4 (ADAMS Accession # ML), June 1 (ADAMS Accession # ML041620398), and September 16, 2004 (ADAMS Accession # ML042660428), Entergy Operations, Inc. (Entergy) submitted two requests for relief from the requirements of the ASME Boiler and Pressure Vessel Code Sections III and XI as applied to reactor pressure vessel head penetration nozzles at Arkansas Nuclear One, Unit 1 (ANO-1). Entergy proposed using an alternative ambient temper bead welding method and alternatives to ASME Code nondestructive examinations and flaw evaluation requirements. Specifically, in ANO1-R&R-006, "Proposed Alternative to ASME Weld Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles," Entergy proposed to utilize worst-case assumptions to conservatively evaluate the acceptance of a postulated flaw. Entergy proposed an alternative to the use of a safety factor of $\sqrt{10}$, as required per IWB-3613(b), to determine the stress intensity factor of a flaw during normal operating conditions. The NRC issued the safety evaluation on this relief request by letter dated September 29, 2004 (ADAMS Accession # ML042730013).

NMC used the same analytical methods as Entergy to determine that the CRD nozzle repair is acceptable when applying the alternate repair technique.

ENCLOSURE 3

AREVA Document 51-5047343-03, "Palisades CRDM & ICI Nozzle IDTB Repair – Life Assessment Summary," dated June 2005

10 Pages Follow

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ENGINEERING INFORMATION RECORD

Document Identifier 51 - 5047343-03

Title PALISADES CRDM & ICI NOZZLE IDTB REPAIR – LIFE ASSESSMENT SUMMARY

PREPARED BY:		REVIEWED BY:	
Name J. B. Hall		Name B.R. Grambau	
Signature J B Hall	Date 6-23-05	Signature	Date 6/23/05

Technical Manager Statement: Initials ADM

Reviewer is Independent.

Remarks:

Summary
Based on the analyses and evaluations summarized above, the minimum life expectancy for the non-abrasive water-jet machine (AWJM) conditioned repair is conservatively estimated at 5 effective full power years (EFPY) for a control rod drive mechanism (CRDM) nozzle and 5 EFPY for an in-core instrument (ICI) nozzle.

Record of Revisions
Rev. 00, July 2004: Original release.
Rev. 01, September 2004: Update References 2 to 11. The conclusion remains unchanged.
Rev. 02, May 2005: Update References 2 to 11. The conclusion has been updated from Rev. 01.
Rev. 03, June 2005: Acronyms have been defined throughout. Minor wording changes have been made.

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DESIGN VERIFICATION CHECKLIST

Document Identifier 51 - 5047343 - 03

Title PALISADES CRDM & ICI NOZZLE IDTB REPAIR LIFE ASSESSMENT SUMMARY

1.	Were the inputs correctly selected and incorporated into design or analysis?	☐ Y	☐ N	☑ N/A
2.	Are assumptions necessary to perform the design or analysis activity adequately described and reasonable? Where necessary, are the assumptions identified for subsequent re-verifications when the detailed design activities are completed?	☐ Y	☐ N	☑ N/A
3.	Are the appropriate quality and quality assurance requirements specified? Or, for documents prepared per FANP procedures, have the procedural requirements been met?	☑ Y	☐ N	☐ N/A
4.	If the design or analysis cites or is required to cite requirements or criteria based upon applicable codes, standards, specific regulatory requirements, including issue and addenda, are these properly identified, and are the requirements/criteria for design or analysis met?	☐ Y	☐ N	☑ N/A
5.	Have applicable construction and operating experience been considered?	☐ Y	☐ N	☑ N/A
6.	Have the design interface requirements been satisfied?	☐ Y	☐ N	☑ N/A
7.	Was an appropriate design or analytical method used?	☐ Y	☐ N	☑ N/A
8.	Is the output reasonable compared to inputs?	☐ Y	☐ N	☑ N/A
9.	Are the specified parts, equipment and processes suitable for the required application?	☐ Y	☐ N	☑ N/A
10.	Are the specified materials compatible with each other and the design environmental conditions to which the material will be exposed?	☐ Y	☐ N	☑ N/A
11.	Have adequate maintenance features and requirements been specified?	☐ Y	☐ N	☑ N/A
12.	Are accessibility and other design provisions adequate for performance of needed maintenance and repair?	☐ Y	☐ N	☑ N/A
13.	Has adequate accessibility been provided to perform the in-service inspection expected to be required during the plant life?	☐ Y	☐ N	☑ N/A
14.	Has the design properly considered radiation exposure to the public and plant personnel?	☐ Y	☐ N	☑ N/A
15.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification that design requirements have been satisfactorily accomplished?	☐ Y	☐ N	☑ N/A
16.	Have adequate pre-operational and subsequent periodic test requirements been appropriately specified?	☐ Y	☐ N	☑ N/A
17.	Are adequate handling, storage, cleaning and shipping requirements specified?	☐ Y	☐ N	☑ N/A
18.	Are adequate identification requirements specified?	☐ Y	☐ N	☑ N/A
19.	Is the document prepared and being released under the FANP Quality Assurance Program? If not, are requirements for record preparation review, approval, retention, etc., adequately specified?	☑ Y	☐ N	☐ N/A

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DESIGN VERIFICATION CHECKLIST

Document Identifier 51 - 5047343 - 03

Comments:

This document performs no analysis or design function – summary only.

Verified By:	B. R. Grambau		6/23/05
(First, MI, Last)	Printed / Typed Name	Signature	Date

1 Introduction

Alloy 600 control rod drive mechanism/control element drive mechanism (CRDM/CEDM) nozzles and thermocouple (TC) nozzles at domestic pressurized water reactors (PWRs) have leaked via cracking attributed to primary water stress corrosion cracking (PWSCC).[1] As a result of these discoveries and the NRC 03-009 inspection order, the Nuclear Management Company (NMC) is performing inspections of the Palisades Unit 1 reactor vessel (RV) head penetrations for leakage during an upcoming outage, and making preparations for possible repairs. Based on recent RV head penetration repair experiences, AREVA has prepared repair configurations. If required, the inner diameter temper bead (IDTB) CRDM/in-core instrumentation (ICI) nozzle repair method shown in Figure 1 and Figure 2 will be used.[2,3] The proposed repair configuration will leave portions of the low alloy steel inside the RV head penetrations exposed to the primary reactor coolant.

The low alloy steel will be subject to general corrosion during operating and shutdown conditions. A materials evaluation has been performed to determine the maximum corrosion rate of the exposed reactor pressure vessel (RPV) head low alloy steel and to evaluate any other potential corrosion concerns involving the IDTB weld repair.[4] Detailed stress and fatigue analyses were performed to establish the minimum life expectancy.[5, 6] The proposed repair involves leaving a portion of the original nozzle in place. A roll expansion is used to hold the nozzle in place during the welding process. A life assessment was performed to evaluate the PWSCC susceptibility of the remaining Alloy 600 CRDM/ICI nozzle portion affected by the IDTB weld repair.[7]

In addition, two fracture mechanics flaw evaluations were performed to evaluate the life expectancy of the repair with assumed flaw sizes and locations. The first analysis considered sub-critical growth of presumed pre-existing PWSCC cracks in the original Alloy 182 J-groove weld.[8, 9] The second analysis evaluated a postulated weld anomaly in the CRDM/ICI nozzle temperbead weld. The postulated anomaly was assumed to be a 0.1 inch semi-circular flaw that is 360 degrees around the circumference at the "triple point" location where there is a confluence of three different materials; the Alloy 600 CRDM/ICI nozzle, the Alloy 52 temperbead weld, and the low alloy steel head.[10, 11]

2 Results

The materials evaluation addressed the potential corrosion concerns associated with the weld repairs planned for the CRDM nozzles. The PWSCC and general corrosion properties of Alloy 690 and Alloy 52/152 (Alloy 690 type) weld metals were addressed. It was concluded that Alloy 690 and its weld metals are the best commercially available material for this application.[4]

The potential corrosion concerns of the RPV closure head low alloy steel include: general, galvanic, crevice, stress corrosion cracking (SCC), and hydrogen embrittlement. Galvanic corrosion, crevice corrosion, SCC, and hydrogen embrittlement of the RPV head low alloy steel are not significant concerns based on previous operational experience with low alloy steel exposed to primary coolant. The general corrosion rate for the RPV head low alloy steel, under the anticipated exposure conditions, is 0.0032 in./year. This corrosion rate is based on an 18-month operating cycle followed by a 2-month refueling cycle.[4]

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Detailed stress and fatigue analyses of the IDTB CRDM/ICI nozzle weld repair were performed. The analyses demonstrated that the IDTB CRDM/ICI weld repair design meets the stress and fatigue requirements set by ASME Code, Section III, 1989 edition without addendum. The conservative fatigue analyses conclude that the fatigue usage factor for 27 years of operation is 0.73 for the CRDM weld repair and 0.682 for the ICI weld repair.[5, 6]

The life expectancy of the non-abrasive water-jet machine (AWJM) conditioned IDTB CRDM/ICI weld repair was evaluated with respect to the PWSCC concerns of the remaining Alloy 600 CRDM nozzle portion affected by the IDTB weld repair. The evaluation conservatively assumed that there are small existing axial flaws undetected by non-destructive examination (NDE) on the remaining Alloy 600 nozzle ID surface and these flaws will propagate after plant restart without incubation. The PWSCC life was based on the EPRI MRP-55 PWSCC crack growth model. The PWSCC propagation path was conservatively assumed to follow the highest hoop tensile stress. The crack tip stress intensity factor was calculated for each increment of crack growth. The results of this evaluation show that the minimum PWSCC life for the non-AWJM conditioned IDTB weld repair is 5.04 effective full power years (EFPY) for a CRDM nozzle and 5.13 EFPY for an ICI nozzle.[7]

The remaining J-groove weld in the CRDM nozzles, after the IDTB repair, was analyzed by postulating a radial crack in the Alloy 182 J-groove weld and butter and evaluating fatigue crack growth into the low alloy steel head.[8] Since a potential flaw in the J-groove weld can not be sized by currently available non-destructive examination techniques, it was assumed that the "as-left" condition of the remaining J-groove weld includes degraded or cracked weld material extending through the entire J-groove weld and Alloy 182 butter material. It was further postulated that a small fatigue initiated flaw forms in the low alloy steel head and combines with the primary water stress corrosion crack in the weld to form a large radial corner flaw that propagates into the head by fatigue crack growth under cyclic loading conditions. A flaw evaluation of any partial penetration nozzle J-groove weld is inherently difficult due to the presence of large residual stresses created during the welding process. An analysis of the Palisades head is particularly challenging because of a high reference nil ductility transition temperature (RT_{NDT}) (72 °F) for the low alloy steel base metal.

A fatigue crack growth analysis was performed to determine final flaw sizes on the uphill and downhill sides of the J-groove weld after 27 years of operation. Stress intensity factors were first determined using a three-dimensional finite element analysis for cracks extending to the butter/head interface and applying both residual and operating stresses for each of eight analyzed transients. For each increment of crack growth, stress intensity factors were increased by the square root of the ratio of flaw sizes. This is a conservative approximation since both the residual stresses and the thermal gradient stresses decrease in the direction of crack propagation. Flaw growth into the head was calculated to be 0.610 inch on the uphill side and 0.324 inch on the downhill side.[8]

A combination of linear elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM) was utilized to evaluate the final uphill and downhill flaw sizes after 27 years of crack growth. At operating temperatures when EPFM is the appropriate analysis method, a J-integral/tearing modulus (J-T) diagram was used to evaluate flaw stability with safety factors of 3 on primary (pressure) stresses and 1.5 secondary (residual plus thermal) stresses. The crack driving force was also checked against the J-integral resistance (J-R) curve at a crack extension of 0.1 inch using safety factors of 1.5 and 1.0 for primary and secondary stresses, respectively. Near room temperature, when the material is less ductile and LEFM is the more appropriate analysis method, stress intensity factors were compared to the crack initiation fracture toughness (K_{Ic}) using a safety factor of $\sqrt{2}$.[8]

The highest crack tip stress intensity factors occur during cooldown when the pressure is still 2085 psig and the temperature decreases to 400 °F. At these conditions, the applied J-integral at the uphill crack front is 1.470 kips/in, with safety factors of 3 on pressure stresses and 1.5 on residual and thermal stresses, which is less than the J-integral for the material, 3.259 kips/in, at the point of instability. Flaw stability is also demonstrated by an applied tearing modulus of 9.323 kips/in, which is well below a tearing modulus of 62.04 kips/in for the material. For a flaw on the downhill side, the applied J-integral is 2.414 kips/in, compared to a J-integral at the point of instability of 3.270 kips/in. The applied tearing modulus is 15.18 kips/in and the corresponding tearing modulus for the material is 31.28 kips/in, again demonstrating flaw stability. As a final check on the EPFM analysis, the applied J-integrals for safety factors of 1.5 on pressure and 1.0 on residual and thermal loads are compared to the J-integral for the material at a crack extension of 0.1 inch. It was determined that the applied J-integrals of 0.361 kips/in on the uphill side and 0.597 kips/in on the downhill side are both less than the required value of 1.711 kips/in for the material.[8]

At low temperature conditions near the end of cooldown, where LEFM is the appropriate method for flaw evaluation, it is widely recognized that J-groove weld residual stresses make it improbable that the Code required fracture toughness margin can be satisfied, as was the case for the Palisades CRDM J-groove weld flaws. Although these residual stresses would tend to be relieved as a crack propagated farther into the head, additional analysis was performed for larger flaw sizes to demonstrate that the required fracture toughness margin could be met while still considering residual stress. New crack sizes were determined by reviewing stress contour plots and selecting crack extensions that would locate the uphill and downhill crack fronts in regions of compressive residual stress. On the uphill side, the crack was extended 1.25 inches beyond the butter. A larger crack extension of 2.5 inches was required on the downhill side to extend the crack into the compressive residual stress field. The controlling low temperature condition occurs at the end of cooldown when the temperature is about 70 °F with a pressure of 295 psig. The K_{Ic} fracture toughness at this temperature is only 53.1 ksi$\sqrt{in}$. At these larger crack sizes, the applied stress intensity factors were calculated to 29.5 ksi$\sqrt{in}$ on the uphill side and 28.5 ksi$\sqrt{in}$ on the downhill side, both of which satisfy a $K_{Ic}/\sqrt{2}$ acceptance criterion of 37.5 ksi$\sqrt{in}$. In summary, a combination of LEFM and EPFM was used to show that postulated flaws in the CRDM J-groove weld and butter are acceptable for 27 years of operation.[8]

The remaining J-groove weld in the ICI nozzles after the IDTB repair was analyzed for fatigue crack growth into the low alloy steel head using ASME Section XI flaw acceptance standards for preventing non-ductile failure with a postulated radial crack in the Alloy 182 J-groove weld and butter.[8] The results showed that the postulated radial crack in the Alloy 182 J-groove weld and butter would be acceptable for 5 years of operation for an ICI nozzle.[9]

The results of the triple point flaw analyses demonstrate that a 0.100 inch weld anomaly is acceptable for 27 years of operation following the CRDM/ICI nozzle ID temper bead weld repair, considering the transient frequencies of the applicable transients. Significant design margins have been demonstrated for all flaw propagation paths considered in the analysis. Flaw acceptance is based on the 1989 ASME Code Section XI criteria for applied stress intensity factor (IWB-3612) and limit load (IWB-3642). Fatigue crack growth is minimal along each flaw propagation path with the maximum final flaw size being only 0.166 inch for the CRDM nozzle repair and 0.189 inch for the ICI nozzle repair. The minimum fracture toughness margin is 3.58

for the CRDM and 4.41 for the ICI, compared to the required margin of $\sqrt{10}$ per IWB-3612. The margin on limit load is 7.96 for a CRDM nozzle and 7.19 for an ICI nozzle, compared to the required margin of 3.0 per IWB-3642.[10, 11]

3 Conclusion

Based on the analyses and evaluations summarized above, the minimum life expectancy for the non-AWJM conditioned repair is conservatively estimated at 5 EFPY for a CRDM nozzle and 5 EFPY for an ICI nozzle.

Figure 1 IDTB CRDM Nozzle Repair Configuration [2]

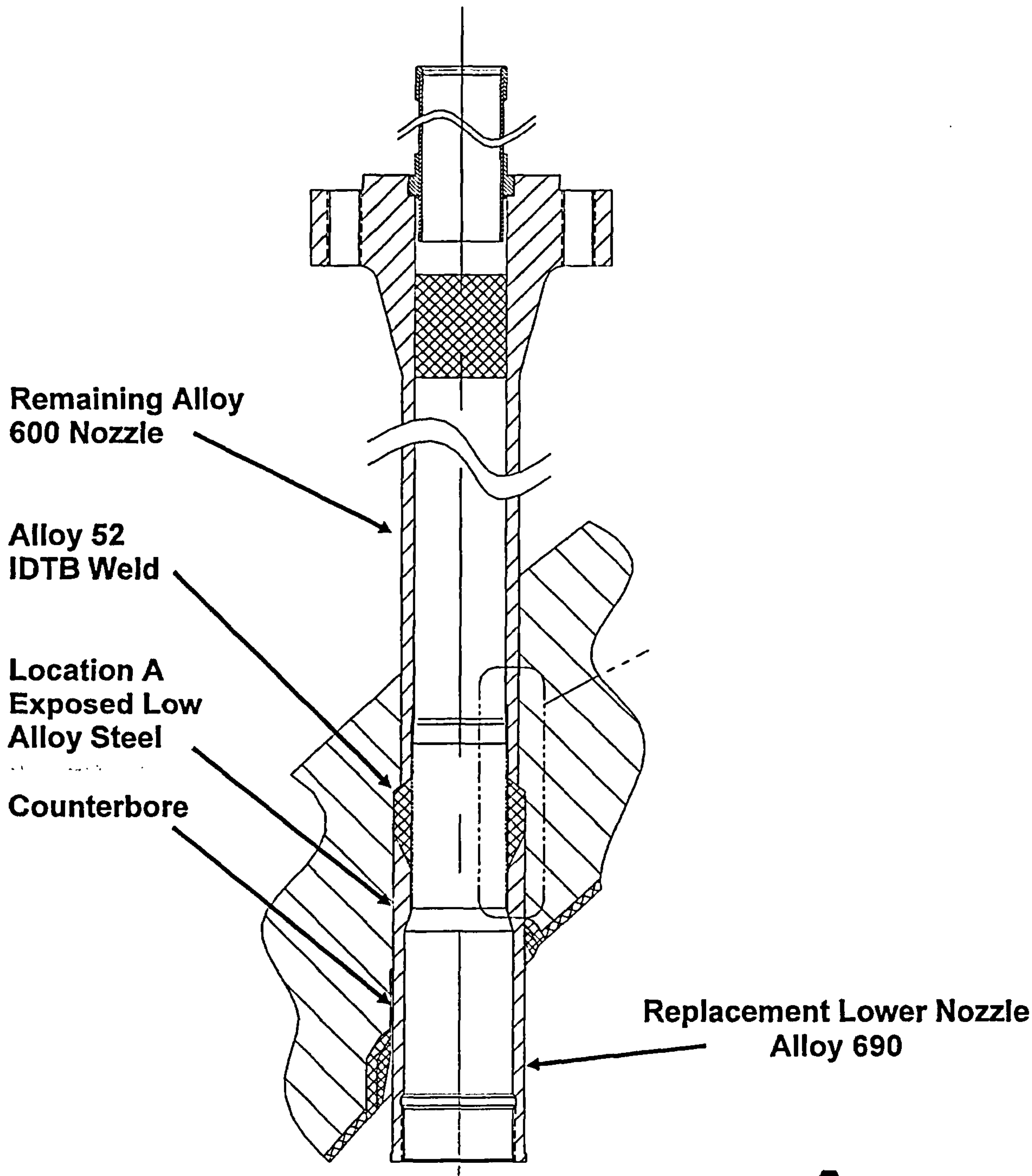

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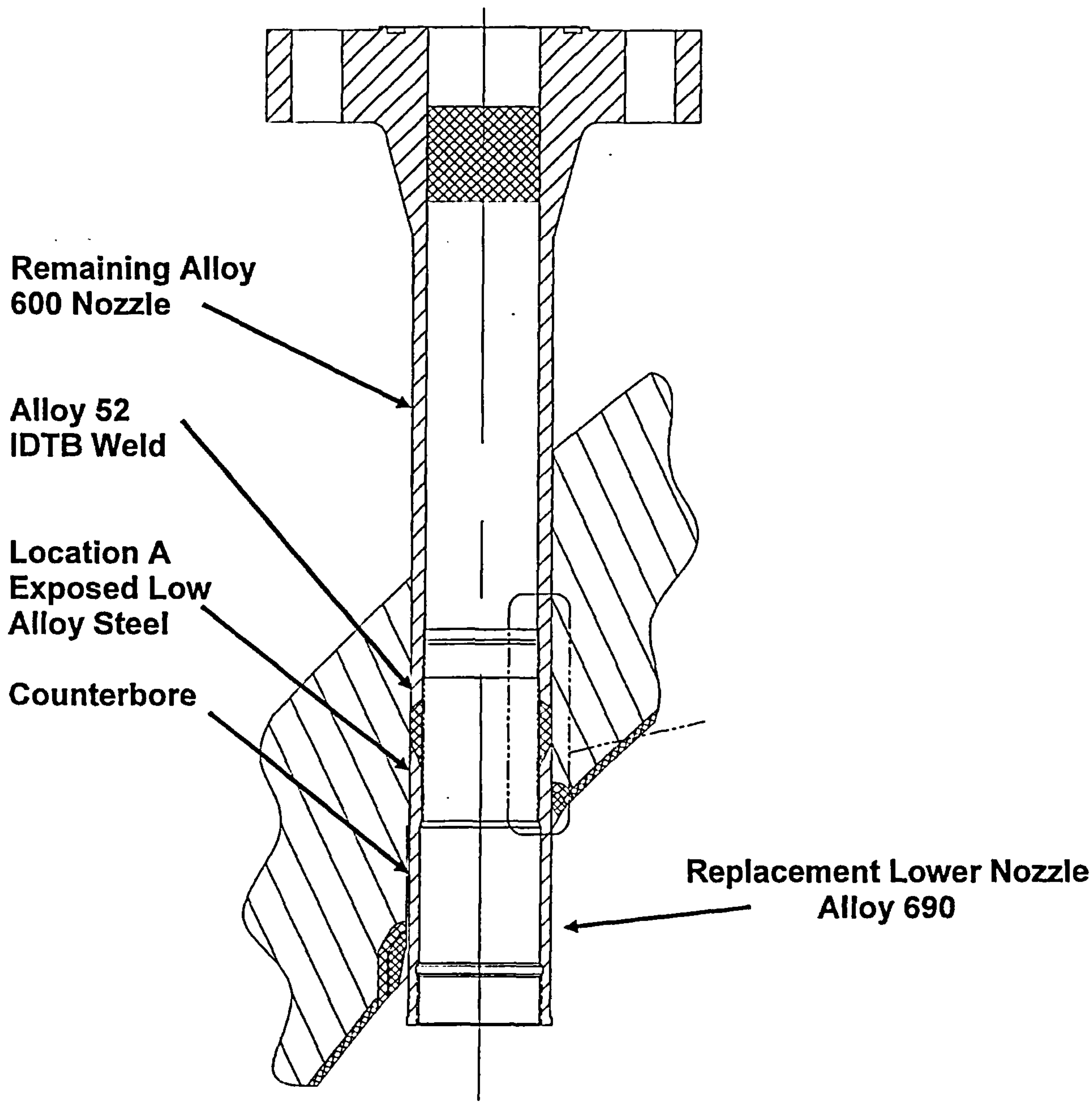
Figure 2 IDTB ICI Nozzle Repair Configuration[3]



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