Dominion Nuclear Connecticut, Inc.
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Dominion

MAR 1 3 2002

Docket No. 50-336
B18601

RE: 10 CFR 50.55a(a)(3)(i)
10 CFR 50.55a(g)(5)(iii)
10 CFR 50.55a(g)(4)(iv)

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

Millstone Nuclear Power Station, Unit No. 2
ASME Section XI Request (RR-89-34, Revision 1), Use of Alternative to Weld Repair Requirements and Relief Request (RR-89-36), Characterization and Successive Examinations of Remaining Flaws in Reactor Vessel Head Penetrations
(TAC No. MB 4223)

On February 25, 2002,[1] Dominion Nuclear Connecticut, Inc. (DNC), submitted a request to use an alternative to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), in the event any flaws requiring repair in Reactor Vessel Head Penetrations (RVHPs) were discovered during inspections. Inspections have now been completed and U.S. Nuclear Regulatory Commission (NRC) approval of the repair technique and relief from ASME Code requirements will be necessary to affect repair to three RVHP nozzles for control rod drive mechanisms.

During a telephone conference call with the NRC staff on March 4, 2002, additional information was requested by the NRC to complete their review. Attachment 1 identifies the twelve items requested and our responses to each. As an outcome of the conference call, we are providing in Attachment 2, a revised request (RR-89-34) for the use of the ambient temper bead weld repair technique, and for use of an evaluation for embedded flaws. A new request (RR-89-36) is also made in Attachment 3 for relief from the flaw characterization requirements associated with Section XI on the remnant of the J-groove welds that may be left on the vessel head after repair, and relief from successive examinations.

(1) J. Alan Price letter to U.S. Nuclear Regulatory Commission, "Millstone Nuclear Power Station, Unit No. 2, Request to Use an Alternative to ASME Code Section XI Repair Welding Requirements by Employing Temper Bead Techniques," dated February 25, 2002, (B18590).

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Using the provisions of these requests will produce sound, permanent repair welds, with an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i) approval is requested for the alternatives proposed in RR-89-34. Pursuant to 10 CFR 50.55a(g)(4)(iv), approval is also requested for use of a later Edition in lieu of the current Code of Record for the inservice inspection program to support implementation of the RR-89-34 alternatives. Pursuant to 10 CFR 50.55a(g)(5)(iii), we also request relief be approved under 10 CFR 50.55a(g)(6)(i) from the specific ASME Code requirements identified in the attached RR-89-36.

Repair activities on Millstone Unit No. 2 are currently in progress. Therefore, DNC requests expedited concurrence of these requests.

There are no regulatory commitments contained within this letter.

Should there be any questions regarding this submittal, please contact Mr. Ravi G. Joshi at (860) 440-2080.

Very truly yours,

DOMINION NUCLEAR CONECTICUT, INC.

J. Alan Price
Site Vice President - Millstone

Attachments:
(1) Response to Request for Additional Information
(2) Request RR-89-34 (Revision 1), Use of Alternative Weld Repair Requirements for Reactor Vessel Head Penetration Nozzles
(3) Relief Request RR-89-36, Characterization of Remaining Flaws and Successive Examinations in Reactor Vessel Head Penetration Nozzles

cc: H. J. Miller, Region I Administrator
R. B. Ennis, NRC Senior Project Manager, Millstone Unit No. 2
NRC Senior Resident Inspector, Millstone Unit No. 2

Attachment 1

Millstone Nuclear Power Station, Unit No. 2

Response to Request For Additional Information

Response to Request For Additional Information

On March 4, 2002, a representatives of Dominion Nuclear Connecticut, Inc. (DNC), and members of the Nuclear Regulatory Commission (NRC) staff discussed twelve items related to DNC's submittal of February 25, 2002,[1] that requested an alternative repair technique for reactor vessel head (RVH) nozzles. The responses to each of the discussion items is provided below.

ITEM 1:

1989 Edition, IWA 4120(a) allows to use later editions of Section III. 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.

a) *Explain why a repair cannot be performed according to the criteria in Section III.*
b) *If an alternative to IWA-4000 was determined necessary, explain why the repair should not be performed according to Section III requirements and an alternative requested from Section III.*

ITEM 1 RESPONSE:

The alternative Request RR-89-34 has been revised to address the Section III requirements. See Attachment 2, CODE REQUIREMENTS.

ITEM 2:

1989 Edition, IWA-4120(b) and (c) applies to preservice inspection and inservice inspection that will be used after the repair. Explain when you plan on using Section XI examinations prior to, during and after performing the repair.

ITEM 2 RESPONSE:

See RR-89-34 in Attachment 2, Enclosure 1, Section 4.0, entitled Examination. Surface and volumetric examinations will be performed on the final welds in accordance with ASME Section III, NB-5000. ASME Section XI preservice or inservice examinations will not be performed on the repair welds prior to, during, or after performing the repair.

Per paragraph IWB-2200(a), no preservice examination is required for repairs to the partial penetration J-groove welds between the vessel head and its penetrations (Examination Category B-E). However, the non-destructive examination (NDE) performed after welding will serve as the preservice examination record if needed in the future. Furthermore, the inservice inspection requirements from Table IWB-2500-1, "Examination Category B-E...," is a VT-2 visual inspection of the external surface of 25

[1] J. Alan Price letter to U.S. Nuclear Regulatory Commission, "Millstone Nuclear Power Station, Unit No. 2, Request to Use an Alternative to ASME Code Section XI Repair Welding Requirements by Employing Temper Bead Techniques," dated February 25, 2002.

percent of the nozzles each interval with IWB-3522 as the acceptance standard. Currently, we perform visual examination, VT-2 of 100% of the nozzles each refueling outage.

ITEM 2a:

Each application is evaluated on its own merits. The request for relief must state the specific paragraphs/subparagraphs/sentences/etc. affected by the proposed alternative, state the proposed alternative for each paragraph/subparagraphs/sentences/etc., and provide a basis and justification for proposed alternative to the specific paragraphs/subparagraphs/sentences/etc.

ITEM 2a RESPONSE:

This requested format has been incorporated into the body of Alternative Request RR-89-34 and Relief Request RR-89-36, contained in Attachments 2 and 3, respectively.

ITEM 3:

Explain the differences between the inspection technique(s) used for detecting indications in the [Control Rod Drive Mechanisms] CRDMs and the [Ultrasonic Test] UT technique that will be used for repair and replacement. Discuss the limitations of the inspection techniques and any assumptions. Describe the capabilities of the repair inspection technique to locate and characterize defects in CRDMs and J-groove welds.

ITEM 3 RESPONSE:

The examination techniques implemented at Millstone for the initial Reactor Vessel Head Penetration (RVHP) examinations utilized an array of ultrasonic transducers contained within a rotating probe. For the Control Element Drive Mechanism (CEDM) and Incore Instrumentation (ICI) penetration examinations, 10 individual transducers are utilized. Many of these transducers provide redundant examination coverage and capabilities. These transducers provide detection capabilities for axial and circumferential oriented flaws as well as the detection of the leak path between the nozzle penetration and the vessel head through the interference fit region.

The techniques utilized for the examinations are intended for the detection and through-wall (depth) sizing of axial and circumferential ID and OD initiating flaws in the nozzle base metal only. Forward scatter, longitudinal wave and backward scatter shear wave techniques are used. The examinations were conducted from the ID of the bore of the head penetration in the J-groove weld region of the nozzle.

The inspections consisted of scanning for axial and circumferential reflectors within the nozzle. The tooling consisted of a transducer head that holds 10 individual search units. These search units were divided into two sets, one for the axial beam direction

and one for the circumferential beam direction. The axial beam direction set of search units consisted of 5.0 MHz, longitudinal wave forward scatter time of flight search units with angles of 30° and 45°; backward scatter pulse echo, 2.25 MHz 60° shear wave search units; and a 5.0 MHz 0° search unit. The circumferential beam direction set of search units consisted of 5.0 MHz, longitudinal wave forward scatter time of flight search units with angles of 45°, 55°, and 65°; backward scatter pulse echo, 2.25 MHz 60° shear wave search units; and a 5.0 MHz 0° search unit.

The detection of flaw indications is based upon the expected responses for each search unit and technique. The 0° transducer provides weld position information and also provides reflector positional information due to lack of backwall response in the region of the reflector. The forward scatter time of flight techniques provides reflector detection and sizing information. For the forward scatter transducers, reflector detection is identified by loss of signal response either from the lateral wave or backwall responses as well as crack tip diffracted responses. The 60° shear wave transducer provides detection by means of corner trap responses between the flaw and nozzle surface and sizing with tip diffracted signals.

The repair examination is based upon ASME Section III, NB-5000 and ASME Section V, Article 5 requirements. The examination techniques consist of dual element longitudinal wave transducers scanning in the axial and circumferential directions. The transducers angles consist of 45° and 70° longitudinal waves scanning in the axial beam direction and 45° longitudinal wave transducers scanning in the circumferential beam directions. A 0° transducer is also used for the examination. These techniques are intended to examine the weld plus ½" of base metal on each side of the weld to a depth of ¼" below the weld thickness.

There are no limitations with the weld repair inspection technique. The weld design allows full inspection of the examination volume. With respect to the capability of the inspection technique to locate and characterize the defects in the CEDMs and J-groove welds, the initial examination techniques used for the RVHPs have been demonstrated capable of detecting axial and circumferential Primary Water Stress Corrosion Cracking (PWSCC) indications in the nozzle material. The demonstrations have been performed and documented by the Materials Reliability Program (MRP) and Electric Power Research Institute (EPRI).

ITEM 4:

Identify the specific paragraphs/subparagraphs/sentences/etc. in the appropriate ASME Code that the welding repair and NDE examinations will not meet. State your proposed alternative for each paragraphs/subparagraphs/sentences/etc. and provide the supporting justification for each paragraphs/subparagraphs/ sentences/etc. In formulating the response to this question, the staff refers you to Surry's submittals of October 30, 2001 as supplemented December 3, 2001 (which is in the final stages of review) and Davis Besse's submittal of January 11, 2001 (unreviewed).

ITEM 4 RESPONSE:

Refer to section entitled CODE REQUIREMENTS in Attachment 2.

ITEM 5a:

In Section 4.0 "Examination" of the submittal, you discuss surface and ultrasonic examination methods for the machined surface prior to repair and after welding.

a. *Provide sketches showing the area that will be surface inspected prior to welding and after welding. Indicate any differences in the inspection areas (from Code requirements) for the instrument nozzles, header vents, and CRDM nozzles*

ITEM 5a RESPONSE:

See RR-89-34 in Attachment 2, Enclosure 1, Section 4.0, entitled Examination. The areas to be surface examined prior to welding consists of the machined bore of the vessel head penetration and the weld bevel plus ½" of the nozzle base material. (See figure 3 in Attachment 2.) The final weld surface examination will consist of the weld plus ½" of base material on each side of the weld.

ITEM 5b:

b. *Provide sketches showing the examination surface and volume required by CODE for each inspection method and show the actual surface and volume that will be inspected. Describe the percent of coverage that will be achieved for each transducer and the total coverage for each repair.*

ITEM 5b RESPONSE:

Refer to RR-89-34 in Attachment 2, Figure 4, and Figures 4a through 4e. The actual surface and volume that will be inspected is the same as that required by Code. The volume to be examined with UT consists of the full thickness of the weld plus ¼" of head base material below the weld. In addition, ½" of nozzle base material will be examined on each side of the weld. Based on the repair weld design, the examination volume expected for each transducer, 0° L-wave, 45° L-wave Up, 45° L-wave Down, 70° L-wave Up, 70° L-wave Down, 45° L-wave Clockwise, and 45° L-wave Counter Clockwise is as shown in Figures 4a through 4e. The PT examination area will consist of the weld surface and ½ inch on either side of the weld.

ITEM 5c:

c. *Will the UT examinations be performed according to the criteria in Appendix VIII of Section XI, Appendix III of Section XI, or Section V?*

ITEM 5c RESPONSE:

No, the UT examination will be performed in accordance with ASME Section III, NB-5000 and ASME Section V, Article 5.

ITEM 5d:

d. If UT will be used in lieu of a Section III RT, provide a comparison (advantages, disadvantages, detection sensitivity for different types of flaws, etc) of the different characteristic between the methods.

ITEM 5d RESPONSE:

UT will be performed in lieu of Radiography Testing (RT) due to the repair weld configuration. Meaningful RT cannot be performed due to the weld configuration and access limitations. The weld configuration and geometry of the penetration in the head provide an obstruction for the radiography 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.

Refer to RR-89-34, Attachment 2, BASIS FOR THE REQUESTED ALTERNATIVES, subsection 10 for additional description.

ITEM 5d.1:

1) *For (UT) examination, describe the differences between a Section III and Section XI UT examination. The description should compare paragraphs/figures/tables with a proposed reconciliation. Items that should be included in the description are examination volume, examination coverage (scanning directions and transducers characteristics) and acceptance criteria.*

ITEM 5d.1 RESPONSE:

The UT examination will be performed in accordance with ASME Section III, NB-5000. The acceptance criteria of NB-5330 apply to this examination. Section XI UT examination techniques do not apply to this repair weld. See previous responses for examination technique description, examination volume, and transducer characteristics.

ITEM 5d.2:

2) *Include in the discussions any demonstrations performed on mock-ups and the types of flaws in the mock-up which demonstrates that the effectiveness of the UT in detecting construction repair related flaws. Are the flaws representative examples of flaws common to fabrications.*

ITEM 5d.2 RESPONSE:

The effectiveness of the UT techniques to characterize the weld defects has been qualified by demonstration on a mockup of the repair temper bead weld involving the same materials used for repair. Notches were machined into the mockup at depths of 0.10", 0.15" and 0.25" in order to quantify the ability to characterize the depth of penetration into the nozzle. The depth characterization is done using tip diffraction UT techniques that have the ability to measure the depth of a reflector relative to the nozzle bore. Each of the notches in the mockup could be measured using the 45-degree transducer. During the examination, longitudinal wave angle beams of 45-degrees and 70-degrees are used. These beams are directed along the nozzle axis looking up and down. These transducers are effective at detecting defects near the root of the weld because of the impedance change at the triple point (intersection of weld material, penetration tube, and vessel head), as shown in figure 4 of Attachment 2. The 45-degree transducer is effective at depth characterization by measuring the time interval to the tip of the reflector relative to the transducer contact surface. The 70-degree longitudinal wave provides additional qualitative data to support information obtained with the 45-degree transducer. Together these transducers provide good characterization of possible defects in common fabrications. These techniques are routinely used for examination of austenitic weld in the nuclear industry for flaw detection and sizing.

In addition to the 45 and 70-degree beam angles described above, the weld is also examined in the circumferential direction using 45-degree longitudinal waves in both the clockwise and counterclockwise direction to look for transverse fabrication flaws. A 0-degree transducer is also used to look radially outward to examine the weld and adjacent material for laminar type flaws and evidence of under bead cracking.

ITEM 5e:

e. Discuss any inspection anomalies and assumptions associated with the UT technique.

ITEM 5e RESPONSE:

There are no inspection anomalies or assumptions with the associated UT techniques.

ITEM 6:

Section 6.0 in Relief Request RR-89-34 does not meet ASME Section IX, Paragraph QW-424. How will you comply with QW-424? ASME Section IX, Paragraph QW-424, requires that each P-No. material in a dissimilar metal weld be welded to each other in the procedure qualification process. Both of the base metals in a dissimilar weld shall be qualified by test in which the base metals have been welded to each other and tested in accordance with ASME Section IX.

ITEM 6 RESPONSE:

No Manual Shielded Metal Arc Welding (SMAW) temper bead weld repairs will be performed so Section 6.0 has been deleted. See Attachment 2 for revised request RR-89-34.

ITEM 7

On Page 3 of the relief request in the last paragraph in the CODE REQUIREMENTS Section, it states that paragraph IWA-4632 of Section XI has been modified by an alternative provided in the request. Please explain the nature of the relief requested for this Section IWA-4632 of ASME Section XI.

ITEM 7 RESPONSE:

No manual SMAW temper bead weld repairs will be performed so this reference has been deleted from request RR-89-34.

ITEM 8:

Clarify which components are to be repaired with the Shielded Metal Arc Welding (SMAW) process. Is it the control rod drive vessel head penetrations, instrument nozzle penetrations, head vent nozzle, etc.?

ITEM 8 RESPONSE:

No manual SMAW temper bead weld repairs will be performed so this reference has been deleted from request RR-89-34.

ITEM 9:

The relief request shall show details of each type of repair to be made for each weld process to be used.

ITEM 9 RESPONSE:

See RR-89-34 in Attachment 2, Figure 3 for an overview of the repair process.

ITEM 10:

Provide justification for granting of the relief from a welding process standpoint to show that quality temper bead welds can be made with an ambient temperature automatic or machine Gas Tungsten Arc Welding (GTAW) temper bead process. This should include procedure qualification and other test data that make it clear from these results that the machine GTAW temper bead process has the capability of producing acceptable repair welds. These data should show acceptability from notch toughness test results as well as tensile and bend test results.

ITEM 10 RESPONSE:

Refer to RR-89-34 in Attachment 2, section entitled, BASIS FOR THE REQUESTED ALTERNATIVES, subsection 6.

ITEM 11:

The Relief Request shall detail the methods to be used for monitoring maximum interpass temperature for the welding. If there is a justification for not using thermocouples for temperature measurement, then this justification shall be detailed in the Relief Request.

ITEM 11 RESPONSE:

Refer to RR-89-34 in Attachment 2, section entitled, BASIS FOR THE REQUESTED ALTERNATIVES, subsection 9.

ITEM 12:

The Relief Request shall detail the base metals, i.e., P-numbers, and filler metal classification to be used in these repairs. Both of the base metals in a dissimilar weld shall be qualified by test in which the base metals have been welded to each other and tested in accordance with ASME Section IX and the relief request.

ITEM 12 RESPONSE:

Refer to RR-89-34 in Attachment 2, Enclosure 1, Section 3.0(b) for description of the base metals used in these repairs. Refer to Attachment 2, Enclosure 1, Section 2.1(a), for qualification of these materials. The alternative repair methodology will be used to make welds of P-No. 3 RVH base material to P-No. 43 head penetration nozzle material using F-No. 43 classification ER NiCrFe-7 weld filler material.

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Attachment 2

Millstone Nuclear Power Station, Unit No. 2

Request RR-89-34 (Revision 1)
Use of Alternative to Weld Repair Requirements for
Reactor Vessel Head Penetration Nozzles

CONTENTS

Request RR-89-34 (Revision 1)
Use of Alternative to Weld Repair Requirements for
Reactor Vessel Head Penetration Nozzles

REQUEST: RR-89-34

COMPONENT IDENTIFICATION:

Component: Reactor Vessel Head (RVH) Penetrations for Control Element Drive Mechanisms (CEDMs)

There are 69 CEDM nozzle penetrations welded to the RVH. Three of the CEDM nozzles have presently been identified as requiring repair. Application of provisions of this alternative are applicable to the 69 CEDM penetrations.

Code Class: 1

System: Reactor Coolant System (RCS)

Code Category: B-E, Pressure Retaining Partial Penetration Welds In Nozzles

Code Item Nos: B4.11, Vessel Nozzles - Head Vent, (1)
B4.12, Control Rod Drive Nozzles - CED-C-01X through CED-C-69X, (69)
B4.13, Instrumentation Nozzles - IF-C-70Z through IF-C-77Z, (8)

References:

(1) 1968 Edition, ASME B&PV Code, Section III, Class A, with Addenda through Summer 1969, and for materials Code Cases 1359-1, 1336, and 1335-2.

(2) 1989 Edition, ASME B&PV Code, Section XI.

(3) 1992 Edition, ASME B&PV Code, Section III, and the 1992 Edition with the 1992 Addenda of Section II for materials.

(4) 1992 Edition, ASME B&PV Code, Section XI.

CODE REQUIREMENTS:

The Construction Code of record for the Millstone Unit No. 2 reactor vessel and head is the 1968 Edition of ASME Section III with Addenda through the Summer of 1969 reference (1). Millstone Unit No. 2 is currently in its third inspection interval using the 1989 Edition of ASME Section XI reference (2). ASME Section XI, paragraph IWA-4120(a), states the following:

> *"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;..."*

For the repairs to the reactor vessel head penetrations, paragraph N-528.2 of reference (1) requires repairs be postweld heat treated (PWHT) in accordance with paragraph N-532. The PWHT requirements set forth therein would be impossible to attain on a reactor vessel head in containment without distortion of the head. In addition, the existing penetration to head welds were not qualified with PWHT and cannot be so qualified at this time.

Consequently, the proposed repairs will be conducted in accordance with the 1989 Edition of ASME Section XI reference (2) as applicable, the 1992 Edition of Section III reference (3) as applicable, and alternative requirements discussed below.

CODE REQUIREMENTS FOR WHICH ALTERNATIVES ARE REQUESTED:

Millstone Unit No. 2 has performed inspections that have indicated the need to repair flaws identified in 3 reactor vessel head penetration (RVHP) control element drive mechanism (CEDM) nozzles. Per subarticle IWA-4120 of Section XI, repair welding must be done in accordance with the original Construction Code. Therefore, for any repair to the ferritic material of the vessel head, paragraph N-532 of ASME Section III reference (1) would require PWHT for the repair weld. As pointed out above, the PWHT parameters required by N-532 would be difficult to achieve on a reactor vessel head in containment and pose significant risk of distortion to the geometry of the head and vessel head penetrations, in addition to exposing the existing J-groove welds to PWHT for which they were not originally qualified.

Because of the inability to comply with the requirements of the original Construction Code, the rules of ASME Section III, 1992 Edition reference (3) will apply to the repairs. Therefore, for any RVHP flaws that resulted in a repair within 1/8-inch of the ferritic material of the vessel head, paragraph NB-4622 of Section III would require a postweld stress relief heat treatment for the repair weld using the temper bead weld technique. The temper bead procedure requirements, including preheat and postweld heat soaks contained in NB-4622, likewise would be difficult to achieve in containment, would result in a substantial increase in radiological dose, and are not necessary to produce a sound repair weld given the capabilities of the proposed alternative temper bead procedure below. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), Dominion Nuclear Connecticut, Inc. (DNC) requests relief to use an ambient temperature temper bead method of repair as an alternative to the requirements of the 1992 Edition of ASME Section III, NB-4622. In so doing, this request is also a request pursuant to 10 CFR 50.55a(g)(4)(iv), to use portions of the 1992 Edition in place of the 1989 Edition, Code of Record for Millstone Unit No. 2 Inservice Inspection Program.

The requirements of paragraphs NB-4622 and NB-5245,of the 1992 Edition of ASME Section III reference (3), and IWA-4700 and IWB-3600 of the 1989 Edition of ASME Section XI reference (2) are also applicable to the repairs. As an alternative to these requirements, the requirements of, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique," identified below will be used. Specifically, alternatives are being proposed for the following articles, subarticles, paragraphs, and subparagraphs of ASME Section III and Section XI:

NB-4622.1 establishes the requirement for postweld heat treatment of welds including repair welds. In lieu of the requirements of this subparagraph, DNC proposes to utilize a temper bead weld procedure obviating the need for preheat and postweld stress relief.

NB-4622.2 establishes requirements for time at temperature recording of the PWHT and their availability for review by the inspector. The requirement of this subparagraph will not apply because the proposed alternative does not involve PWHT.

NB-4622.3 discusses the definition of nominal thickness as it pertains to time at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.4 establishes the holding times at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

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

NB-4622.6 establishes PWHT requirements for non-pressure retaining parts. The subparagraph is not applicable in this case because the repairs in question will be to pressure retaining parts. Furthermore, the proposed alternative involves no PWHT.

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

NB-4622.8 establishes exemptions from PWHT for nozzle to component welds and branch connection to run piping welds. Sub-subparagraph 4622.8(a) establishes criteria for exemption of PWHT for partial penetration welds. This is not applicable to the proposed repairs because the criteria involves buttering layers at least 1/4 inch thick, which will not exist for the welds in question. Sub-subparagraph 4622.8(b) also does not apply because it discusses full penetration welds and the welds in question are partial penetration welds.

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. The subparagraph does not apply in this case because the proposed repairs will involve F-No. 43 filler metals using gas tungsten arc welding (GTAW) instead of shielded metal arc welding (SMAW).

NB-4622.10 establishes requirements for repair welding to cladding after PWHT. The subparagraph does not apply in this case because the proposed repair alternative does not involve repairs to cladding.

NB-4622.11 discusses temper bead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs.

- Sub-subparagraph 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.

- Sub-subparagraph 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 3/8 inch in the base metal. The proposed alternative includes the same limitations on the maximum extent of repair.

- Sub-subparagraph NB-4622.11(c) discusses the repair welding procedure and requires procedure and welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy this requirement. In addition, NB-4622.11(c) requires that the Welding Procedure Specification include the following requirements:

  - 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.

  - NB-4622.11(c)(2) requires the use of the shielded metal arc welding process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative utilizes GTAW with bare electrodes meeting F-No. 43 classifications.

  - NB-4622.11(c)(3) discusses 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 that do not require storage in heated ovens since bare electrodes will not pick up moisture from the atmosphere.

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

- NB-4622.11(c)(5) requires preheat to a minimum temperature of 350°F prior to repair welding. The proposed ambient temperature temper bead alternative does not require an elevated temperature preheat.

- 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 controls the tempering process by precise control of heat input and bead placement; the 3/32, 1/8, and 5/32 inch electrodes required by NB-4622.11(c)(6) and the requirement to remove the weld crown of the first layer, are unnecessary, and the proposed alternative does not include these requirements.

- NB-4622.11(c)(7) requires a hydrogen bake out be performed on the preheated area by heating to 450°F to 550°F for 4 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.

- 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 a maximum of 350°F and requires the area to be welded be at least 50°F prior to welding. These limitations have been demonstrated to be adequate for the production of sound welds with acceptable properties in both the weld and HAZ.

- 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 because it is unnecessary for the very low hydrogen GTAW temper bead welding process. Liquid penetrant examination will be performed per NB-4622.11(d)(2) below.

- NB-4622.11(d)(2) requires liquid penetrant and radiographic examinations of the repair welds 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, final inspection will be by liquid penetrant and ultrasonic inspection.

- 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 inspection required by NB-5245 will not be done. In lieu of the progressive liquid penetrant examination, the proposed alternative will use liquid penetrant and ultrasonic examination of the final weld.

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

- ➢ NB-4622.11(f) establishes requirements for the procedure qualification test plate relative to the P-No. and Group Number and the postweld heat treatment of the materials to be welded. The proposed alternative complies with those requirements, and with the additional requirements of this alternative 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 is more stringently controlled in the proposed alternative than in NB-4622.11(f).

- ➢ 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 particularly 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 concern about obstructions, which might interfere with the welder's abilities since these obstructions will have to be eliminated to accommodate the welding machine. Obstructions in close proximity but not blocking the movements of the machine will have no effect on the ability of the operator or the machine to make sound welds.

- Subparagraph 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 per 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 examination (PT or MT) at the lesser of 1/2 the maximum weld thickness or 1/2-inch as well a surface examination 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.

- Subarticle IWA-4700 of ASME Section XI 1989 Edition reference (2) requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure retaining boundary. As discussed in more detail in the section Basis for the Requested Alternative Requirements, item 8 below, the proposed alternative will utilize a system leakage test per IWA-5211(a) of ASME Section XI 1992 Edition reference (4).

BASIS FOR THE REQUESTED ALTERNATIVES

The alternative to 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 features of the alternative that make it applicable and acceptable for the contemplated repairs are enumerated 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 Enclosure 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." The alternative will be used to make welds of P-No. 3, RVH material to P-No. 43 nozzle head penetration using F-No. 43 weld filler material.

2) The use of a GTAW temper bead welding technique to avoid the need for postweld heat treatment is based on research that has been performed by EPRI and other organizations. (Reference, EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temper Bead 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 zones (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 heat affected zones in both cases. The temper bead process has been shown effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed. Many acceptable Procedure Qualifications Records (PQRs) and Welding Procedure Specifications (WPSs) presently exist and have been used to perform numerous successful repairs. These repairs have included all of the Construction Book Sections of the ASME Code, as well as the National Board Inspection Code (NBIC). The use of the automatic or machine GTAW process utilized for temper bead welding allows more precise control of heat input, bead placement, and bead size and contour than the manual SMAW process required by NB-4622. The very precise control over these factors afforded by the alternative provides more consistent and effective tempering and eliminates the need to grind or machine the first layer of the repair.

3) The NB-4622 temper bead procedure requires a 350°F preheat and a postweld soak at 450°-550°F for 4 hours for P-No. 3 materials. Typically, these kinds of restrictions are used to mitigate the effects of the solution of monatomic hydrogen in ferritic materials prone to hydrogen embrittlement cracking. The susceptibility of ferritic steels is directly related to three factors: 1) the propensity of the material to transform to a crack susceptible microstructure; 2) the level of monatomic hydrogen present; 3) the level of tensile stress. The P-No. 3 material of the reactor vessel head is able to produce martensite from the heating and cooling cycles associated with welding. However, the proposed alternative mitigates all three factors without the use of elevated preheat and postweld hydrogen bake out by closely controlling the welding heat input, bead placement and minimizing the introduction of hydrogen in the welding process.

The NB-4622 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, are a source of hydrogen even when very stringent electrode baking and storage procedures are followed. Even ultra low hydrogen (H4) SMAW electrodes can introduce up to 4 mL of monatomic hydrogen (H) per

100 grams of deposited weld metal. 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 the machine GTAW process which is essentially free of hydrogen. The GTAW process relies on bare welding electrodes with no flux to trap moisture. An inert gas blanket positively shields the weld and surrounding material from the atmosphere and moisture it may contain. It produces by far the lowest hydrogen levels of any of the commonly used arc welding processes. Typically, deposits are less than 1mL per 100 grams of deposited weld metal. To further reduce the likelihood of any hydrogen evolution or absorption, the alternative procedure requires particular care to ensure the weld region is free of all sources of hydrogen. The GTAW process will be shielded with welding grade argon (99.997% pure) which typically produces welds essentially free of H. A typical argon flow rate would be about 15 to 50 CFH and would be adjusted to assure adequate shielding of the weld without creating a venturi affect that might draw oxygen or water vapor from the ambient atmosphere into the weld.

4) The F-No. 43 (ERNiCrFe-7) filler metal that would be used for the repairs is not subject to hydrogen embrittlement cracking.

5) Final examination of the repair welds would be by surface examination (liquid penetrant) and ultrasonic examination and would be conducted at least 48 hours after the weld had returned to ambient temperature following the completion of welding. Given the 3/8-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 nonferritic weld material which has a higher solubility for hydrogen and is not susceptible to hydrogen embrittlement cracking. Thus, in the unlikely event that hydrogen induced cracking did occur, it would have to occur before the 48 hour delay, while hydrogen was still present, and would be detected by the 48-hour delay in examination.

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

As shown below, Procedure Qualification Record (FRA-ANP PQR 7164) using P-No. 3, Group No. 3 base material exhibited improved Charpy V-notch properties in the HAZ from all three measures. Absorbed energy, lateral expansion and %shear area were all improved, compared to the unaffected base material.

PQR 7164

	Unaffected Base Material	(avg)	HAZ	(avg)
50°F absorbed energy (ft-lbs.)	69, 55, 77	(67)	109, 98, 141	(116)
50°F lateral expansion (mils)	50, 39, 51	(47)	59, 50, 56	(55)
50°F shear fracture (%)	30, 25, 30	(28)	40, 40, 65	(48)
80°F absorbed energy (ft-lbs.)	78, 83, 89	(83)	189, 165, 127	(160)
80°F lateral expansion (mils)	55, 55, 63	(58)	75, 69, 60	(68)
80°F shear fracture (%)	35, 35, 55	(42)	100, 90, 80	(90)

The absorbed energy, lateral expansion, and percent shear fracture were significantly greater for the HAZ than the unaffected base material at both test temperatures.

Procedure Qualification Record (FRA-ANP PQR 7183) using P-No. 3, Group No. 3 to P-No. 43 base material with F-No. 43 filler metal exhibited improved Charpy V-notch properties in the HAZ absorbed energy, and %shear area perspectives, but had slightly lower average lateral expansion compared to the unaffected base material.

PQR 7183

	Unaffected Base Material	(avg)	HAZ	(avg)
30°F absorbed energy (ft-lbs.)	59,54,61	(58)	82,95,94	(90)
30°F lateral expansion (mils)	53, 51, 47	(50)	41,48,54	(48)
30°F shear fracture (%)	20, 30, 20	(23)	65, 70, 70	(68)
35°F absorbed energy (ft-lbs.)	n/a		95,84,95	(91)
35°F lateral expansion (mils)	n/a		49,52,50	(50)
35°F shear fracture (%)	n/a		45,35,55	(45)

The absorbed energy, and percent shear fracture were significantly greater for the HAZ than the unaffected base material. However, the mils lateral expansion averaged slightly less than that of the unaffected base material, (i.e., 48 mills vs. 50). This can be compensated for by making an adjustment in the nil ductility temperature of materials repaired with this procedure.

The difference between the results for the mills lateral expansion for these two qualification tests, which were welded with identical weld parameters, filler metal, and equipment, can only be attributed to the difference in the nil ductility temperature RT_{NDT} of the base material used. In PQR 7164 the nil ductility temperature was determined to be +30°F. In this case the Temper bead Welding Process resulted in a significant improvement in the impact properties. In PQR 7183 the base material had a nil ductility temperature of -30°F (60°F below that of the first PQR). In this case the effects on the impact properties were mixed, with HAZ absorbed energy and %shear area showing significant improvements while the mills lateral expansion averaged slightly lower than the unaffected base material. It appears from this that where the base material nil ductility temperature is higher (as it would be if it marginally met the vessel requirements) the temper bead welding process significantly improves the properties of the HAZ. Alternately where the nil ductility of the base material is very low (as it would be in cases where the material nil ductility temperature was well below the total vessel requirements) the affects of temper bead welding on the impact properties of the HAZ are mixed.

Generally speaking, it can be concluded that the temper bead welding process results in significant improvement of HAZ impact properties when the unaffected base material nil ductility temperature RT_{NDT} is relatively high and the margin between the actual RT_{NDT} and that of the vessel is small. Where a large margin exists the effects of temper bead welding on HAZ impact properties may be mixed but any possible degradation is insignificant because of the large margin to the total vessel RT_{NDT} requirement.

Temper bead welding improves the HAZ properties when the base material has marginal RT_{NDT} and any degradation could not be tolerated. Where the base material properties are better than required there may be some mixed results but any slight losses are insignificant because of the large margin to the total vessel RT_{NDT}.

From these results it is clear that the GTAW temper bead process has the capability of consistently producing acceptable repair welds with acceptable properties in both weld and HAZ.

7) Welding procedure qualifications fully support the welding procedure specifications. The Welding Procedure Qualifications supporting the applicable Welding Procedure Specifications (WPSs) to be used for the repair weld are for P-No. 3 Group No. 3 base material welded to P-No. 43 base material with F-No. 43 filler metal, and P-No. 43 to P-No. 43 base material welded with F-No. 43 filler metal. Using these WPSs, the proposed alternate (Enclosure 1)

provides a technique for repairing CEDM penetrations in the RVH that will produce sound, permanent repairs with an acceptable level of quality and safety.

8) IWA-4700 requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure retaining boundary. In lieu of a system hydrostatic test which must be conducted at pressures exceeding normal operating pressure, the proposed alternative relies on a system leak test at normal operating pressure coupled with nondestructive testing of the proposed weld that offers an equivalent or higher confidence of the soundness of the weld. As discussed previously, NB-5245 requires progressive surface examination of the proposed partial penetration welds while the alternative requires final surface examination (liquid penetrant inspection) and volumetric examination (ultrasonic inspection) which will provide added assurance of sound welds when done in conjunction with the planned system leak test. Since the proposed testing is similar to the provisions of approved ASME Code Case N-416-1[(2)] it is concluded that the proposed alternative provides an acceptable level of quality and safety.

9) The closure head preheat temperature will be essentially the same as the reactor building ambient temperature; therefore, closure head preheat temperature monitoring in the weld region and using thermocouples is unnecessary and would result in additional personnel dose associated with thermocouple placement and removal. Consequently, preheat temperature verification by use of contact pyrometer on accessible areas of the closure head is sufficient.

In lieu of using thermocouples for interpass temperature measurements; calculations, Welding Procedure Qualification tests, and previous experience all show that the 350°F maximum interpass temperature will never be exceeded.

The calculation is based on a typical inter-bead time interval of five minutes. The five minute inter-bead interval is based on: 1) the time required to explore the previous weld deposit with the two remote cameras housed in the weld head; 2) time to shift the starting location of the next weld bead circumferentially away from the end of the previous weld-bead; and 3), time to shift the starting location of the next bead axially to insure a 50 percent weld bead overlap required to properly execute the temper bead technique. The calculation shows that the interpass temperature at the start of a weld bead will return to within 1.23°F of the initial temperature prior to the start of the next weld pass.

A welding mockup was performed on the full size Midland reactor vessel closure head (RVCH). This is a different design but is close enough to Millstone Unit No. 2 to demonstrate the overall effect of this welding technique on interpass temperature. 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 closure head within a 5-inch band surrounding the CEDM nozzle. Three other thermocouples were placed on the closure head

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(2) Approval To Use Code Case N-416-1, NRC letter, "Evaluation of the Third 10-Year Interval Inservice Inspection Program Plan and Associated Requests for Relief for Millstone Nuclear Power Station, Unit No. 2, (TAC No. M96200)," dated July 22, 1998.

inside surface. One of the three thermocouples was placed 1-1/2 inches from the CEDM nozzle penetration, on the lower hillside. The other inside surface thermocouples were placed at the edge of the 5-inch band surrounding the CEDM 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. For the Midland RVCH mockup application, 300°F minimum preheat temperature was used and the interpass temperature never rose above 315°F.

Welding Procedure Qualification tests performed using the same parameters but on plates with much smaller Heat sink and without the 5 minute reset time between passes recorded maximum interpass temperatures of 142°F and 99°F from an initial ambient temperature of approximately 70°F.

Similar repair welding was performed by Framatome ANP during the fall 2001 outage at Crystal River - 3 using the same ambient machine GTAW temper bead technique. This weld repair did not include re-attachment of the lower portion of the CEDM nozzle, however the welding parameters and welding technique were essentially the same, (same weld procedure specification). Completion of this weld required 10 layers and totaled 110 weld passes. The weld was completed in 17 hours. During that time no significant breaks in welding were encountered. The weld head was removed not more than twice for routine cleaning and tungsten replacement. Thermocouples were attached directly to the head ID within 1-inch of the penetration opening and on the edge of the 5-inch band. An ambient temperature of 81°F was recorded prior to welding of the first bead. The maximum interpass temperature recorded during the entire weld was 123°F. This represents an increase of 42°F.

Based on the above it is evident that the 350°F maximum interpass temperature will never be exceeded.

10) UT will be performed in lieu of RT due to the repair weld configuration. Meaningful RT cannot be performed as can be seen in Figure 3. The weld configuration and geometry of the penetration in the head 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 conventional partial penetration weld configurations. In this case the weld is suitable for both UT and PT.

The effectiveness of the UT techniques to characterize the weld defects has been qualified by demonstration on a mockup of the repair temper bead weld involving the same materials used for repair. Notches were machined into the mockup at depths of 0.10-inch, 0.15-inch, and 0.25-inch in order to quantify the ability to characterize the depth of penetration into the nozzle. The depth characterization is done using tip diffraction UT techniques that have the ability

to measure the depth of a reflector relative to the nozzle bore. Each of the notches in the mockup could be measured using the 45-degree transducer. During the examination longitudinal wave angle beams of 45 degrees and 70 degrees are used. These beams are directed along the nozzle axis looking up and down. The downward looking beams are effective at detecting defects near the root of the weld because of the impedance change at the triple point (intersection of weld material, penetration tube, and vessel head), as shown in Figure 4. The 45-degree transducer is effective at depth characterization by measuring the time interval to the tip of the reflector relative to the transducer contact surface. The 70-degree longitudinal wave provides additional qualitative data to support information obtained with the 45-degree transducer. Together, these transducers provide good characterization of possible defects. These techniques are routinely used for examination of austenitic welds in the nuclear industry for flaw detection and sizing.

In addition to the 45 and 70-degree beam angles described above, the weld is also examined in the circumferential direction using 45-degree longitudinal waves in both the clockwise and counterclockwise directions to look for transverse fabrication flaws. A 0-degree transducer is also used to look radially outward to examine the weld and adjacent material for laminar type flaws and evidence of under bead cracking.

11) The repair weld UT examination of the triple point location described above is anticipated to result in a UT indication. This UT indication would be from this triple point weld anomaly and may appear to be a crack or incomplete penetration type of flaw that can only be characterized as unacceptable in accordance with NB-5330(b). In order to address this anticipated UT indication it will be evaluated in accordance with IWB-3600 of the 1992 Edition of ASME Section XI reference (4). DNC has determined that in order to perform an IWB-3600 evaluation of these anticipated flaws, it would be necessary to use the linear elastic fracture mechanics provisions of Appendix A of Section XI. Since Appendix A is *"In the course of preparation"* in the 1989 Edition of ASME Section XI, it will be necessary to use the 1992 Edition of ASME Section XI for this evaluation criteria. DNC considers this to be an acceptable part of this alternative based on the provisions of the 1989 Edition of Section XI, IWA-4120(c), which states the following:

> *"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 justification at the plant site."*

12) The welding head has video capability for torch positioning and monitoring during welding. The operator observes the welding operation as well as observing each bead deposited prior to welding the next bead. The video clarity and resolution is such that the welding operator can observe a ½ mil diameter color contrast wire.

13) The automated repair method described above leaves a band of ferritic low alloy steel exposed to the primary coolant. The effect of corrosion on the exposed area, both reduction of reactor vessel head thickness and primary coolant Iron (Fe) release rates, has been evaluated by Framatome-ANP (FRA-ANP). The results of this evaluation concluded that the total corrosion would be insignificant when compared to the thickness of the reactor vessel head. FRA-ANP has estimated that the total estimated Fe release from a total of 69 repaired CEDM nozzles would be significantly less than the total Fe release from all other primary sources. Since Millstone Unit No. 2 has 69 CEDM nozzles, this estimate is applicable.

ALTERNATIVE REQUIREMENTS

Repairs to RVHPs will be made in accordance with the requirements of paragraphs IWA-4110, 4120, 4130, 4140, 4210, 4330, 4340, 4400, 4600, and 4800 of the 1989 Edition of ASME Section XI with the alternative requirements identified below:

The requirements of paragraphs NB-4622 and NB-5245 of the 1992 Edition of ASME Section III reference (3), and IWA-4700 and IWB-3600 of the 1989 Edition of ASME Section XI reference (2) are also applicable to the contemplated repairs. As an alternative to these requirements, the requirements of, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique," (Enclosure 1) will be used. Specifically, alternatives are being proposed for the following articles, subarticles, paragraphs, and subparagraphs of ASME Section III and Section XI:

NB-4622.1 establishes the requirement for postweld heat treatment of welds including repair welds. In lieu of the requirements of this subparagraph, DNC proposes to utilize a temper bead weld procedure obviating the need for postweld stress relief.

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

NB-4622.3 discusses the definition of nominal thickness as it pertains to time at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.4 establishes the holding times at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

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

NB-4622.6 establishes PWHT requirements for non-pressure retaining parts. The subparagraph is not applicable in this case because the repairs in question will be to pressure retaining parts. Furthermore, the proposed alternative involves no PWHT.

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

NB-4622.8 establishes exemptions from PWHT for nozzle to component welds and branch connection to run piping welds. Sub-subparagraph 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 1/4 inch thick, which will not exist for the welds in question. Sub-subparagraph 4622.8(b) also does not apply because it discusses full penetration welds and the welds in question are partial penetration welds.

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. The subparagraph does not apply in this case because the proposed repairs will involve F-No. 43 filler metals.

NB-4622.10 establishes requirements for repair welding to cladding after PWHT. The subparagraph does not apply in this case because the proposed repair alternative does not involve repairs to cladding.

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

- Sub-subparagraph 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.

- Sub-subparagraph 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 3/8 inch in the base metal. The proposed alternative includes the same limitations on the maximum extent of repair.

- Sub-subparagraph NB-4622.11(c) discusses 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. In addition, NB-4622.11(c) requires the welding procedure specification include the following requirements:

  - 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.

- ➢ 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 utilizes GTAW with bare electrodes meeting the F-No. 43 classifications.

- ➢ NB-4622.11(c)(3) discusses 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 that do not require storage in heated ovens because bare electrodes will not pick up moisture from the atmosphere as covered electrodes may.

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

- ➢ NB-4622.11(c)(5) requires preheat to a minimum temperature of 350°F prior to repair welding. The proposed ambient temperature temper bead alternative does not require an elevated temperature preheat.

- ➢ 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 controls the tempering process by precisely controlling heat input and bead placement instead of the electrode diameter and removal of the weld crown, the 3/32, 1/8, and 5/32 inch electrodes required by NB-4622.11(c)(6), and the requirement to remove the weld crown of the first layer, are unnecessary. The proposed alternative does not include these requirements.

- ➢ NB-4622.11(c)(7) requires a hydrogen bake out be performed on the preheated area by heating to 450°F to 550°F for 4 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.

- ➢ 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 with acceptable properties in both the weld and ferritic HAZ.

- 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 very low hydrogen GTAW temper bead welding process. Liquid penetrant examination will be performed per NB-4622.11(d)(2) below.

- NB-4622.11(d)(2) requires liquid penetrant and radiographic examinations of the repair welds 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), final inspection will be by liquid penetrant and ultrasonic inspection.

- 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 inspection required by NB-5245 will not be done. In lieu of the progressive liquid penetrant examination, the proposed alternative will use liquid penetrant and ultrasonic examination of the final weld.

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

- NB-4622.11(f) establishes requirements for the procedure qualification test plate relative to the P-No. and Group Number and the postweld heat treatment of the materials to be welded. The proposed alternative complies with those requirements, and with the additional requirements of this alternative 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 is more stringently controlled in the proposed alternative than in NB-4622.11(f).

- 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. Obstructions in close proximity but not blocking the movements of the machine will have no effect on the ability of the operator or the machine to make sound welds.

- Subparagraph 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 per 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 (PT or MT) at the lesser of 1/2 the maximum weld thickness or 1/2-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 inspection coupled with surface examination

will provide a high level of confidence that the proposed welds are sound and defect free. Any flaws detected in the weld repair by ultrasonic examination will be evaluated in accordance with the requirements of IWB-3600 of the 1992 Edition of ASME Section XI reference (4).

- Subarticle IWA-4700 of ASME Section XI, 1989 Edition, reference (2), requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure-retaining boundary. As discussed in the Basis for Alternatives Section item 8, the proposed alternative will utilize a system leakage test per IWA-5211(a) of reference (4) in accordance with Code Case N-416-1 in lieu of the system hydrostatic test.

Per the 1989 Edition of ASME Section XI, paragraph IWB-2200(a), no preservice examination is required for repairs to the partial penetration J-groove welds between the vessel head and its penetrations (Examination Category B-E). However, the NDE performed after welding will serve as a preservice examination record if needed in the future. Furthermore, the inservice inspection requirement from Table IWB-2500-1, "Examination Category B-E...," is a VT-2 visual inspection of the external surfaces of 25% of the nozzles each interval with IWB-3522 as the acceptance standard. Currently, we perform visual examination, VT-2, of 100% of the nozzles each refueling outage without insulation removal. Ongoing vessel head penetration inspection activities undertaken as a result of NRC Bulletin 2001-01 and ongoing deliberations in Code committees will be monitored to determine the necessity of performing any additional or augmented inspections.

Based on the above information, it may be concluded that using the proposed alternative ambient temperature temper bead weld technique (Enclosure 1) is an acceptable alternative to Code requirements and will produce sound, permanent repair welds with an acceptable level of quality and safety, as required by 10 CFR 50.55a(a)(3)(i).

ENCLOSURE 1

Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique

Dominion Nuclear Connecticut, Inc. (DNC) plans to perform control element drive mechanism (CEDM) reactor vessel head penetration (RVHP) nozzle repairs by welding the reactor pressure vessel head (P-No. 3 base material) and CEDM tube (P-No. 43 base material) with weld filler material F-No. 43, in accordance with the following:

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 nonferritic weld to ferritic base material on which 1/8 inch or less of nonferritic 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 nonferritic weld filler material, may be performed provided the depth of repair in the base material does not exceed 3/8 inch.

(d) Prior to welding, the area to be welded and a band around the area of at least 1½ times the component thickness or 5 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, however, the final surface of the weld will be abrasive water jet conditioned.

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 base material shall be postweld heat treated to at least the time and temperature that was

applied to the materials being welded. This P-No. 3 Group No. 3 material shall be welded to P-No. 43 base material using F-No. 43 filler metal. An additional welding procedure qualification for welding P-No. 43 base material with F-No. 43 filler will also be used for welding the portion of the joint which is greater than 1/8" from the fusion line of the nonferritic weld to the ferritic base material.

(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 1 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 6 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. 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 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 will be equal to or greater than the average values of the three unaffected base metal tests, or meet 2.1(h) below.

(h) If the average Charpy V-notch lateral expansion for the heat affected zone of 2.1(g) above is less than that for the unaffected base material, and the qualification test meets the other criteria of acceptance, the Charpy V-notch test results may be recorded on the Welding Procedure Qualification Record. Data shall then be obtained as specified in 2.1(i) below to provide an additive temperature for any base material for which the welding procedure is being qualified, and shall be included. Alternatively, the welding procedure qualification may be rewelded and retested.

(i) The data for use in 2.1 (h) above shall be developed by performing additional Charpy V-notch tests on either the welding procedure qualification HAZ or the unaffected base material, or both, at temperatures which provide lateral expansion values equal to or greater than 35 mils. The average lateral expansion data for the HAZ and the unaffected base material may be plotted on a lateral expansion-temperature chart. The temperatures at which these two sets of data exhibit a common lateral expansion value equal to or greater than *35* mils shall be determined. The determined temperature for the unaffected base material shall be subtracted from the similarly determined temperature for the HAZ. This difference shall be used in 2.1 (h) above as the adjustment temperature. The adjustment temperature shall be added to the nil ductility temperature (RT_{NDT}) of each piece separately or collectively to the highest RT_{NDT} for all of the base material to be repair welded by this procedure. If the temperature difference is zero or is a negative number, no adjustment is required for the base material to be repair welded by this procedure.

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 GTAW process.

(b) Dissimilar metal welds shall be made using F-No. 43 ER NiCrFe-7weld filler metal 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 1/8 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 is 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. Because of the As Low As Reasonably Achievable (ALARA) concerns it is impractical and unnecessary to mount thermocouples near the weld. Therefore, thermocouples will not be used to monitor interpass temperature. Interpass temperature has been shown by calculation and demonstration to remain well below the 350°F maximum. Thus direct interpass temperature monitoring is not required. Preheat temperature will be monitored using contact pyrometers, on accessible areas of the closure head external surface(s).

4.0 EXAMINATION:

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

(b) 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.

(c) Ultrasonic testing (UT) will be performed 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. The examination extent is consistent with the Construction Code requirements.

(d) NDE personnel will be qualified in accordance with either NB-5000 of reference (3) or IWA-2300 of reference (2).

(e) Surface examination acceptance criteria will be in accordance with NB-5350. Ultrasonic examination acceptance criteria will be in accordance with NB-5330. Any flaws detected by ultrasonic examination will be evaluated in accordance with the requirements of the 1992 Edition of ASME Section XI reference (4), IWB-3600.

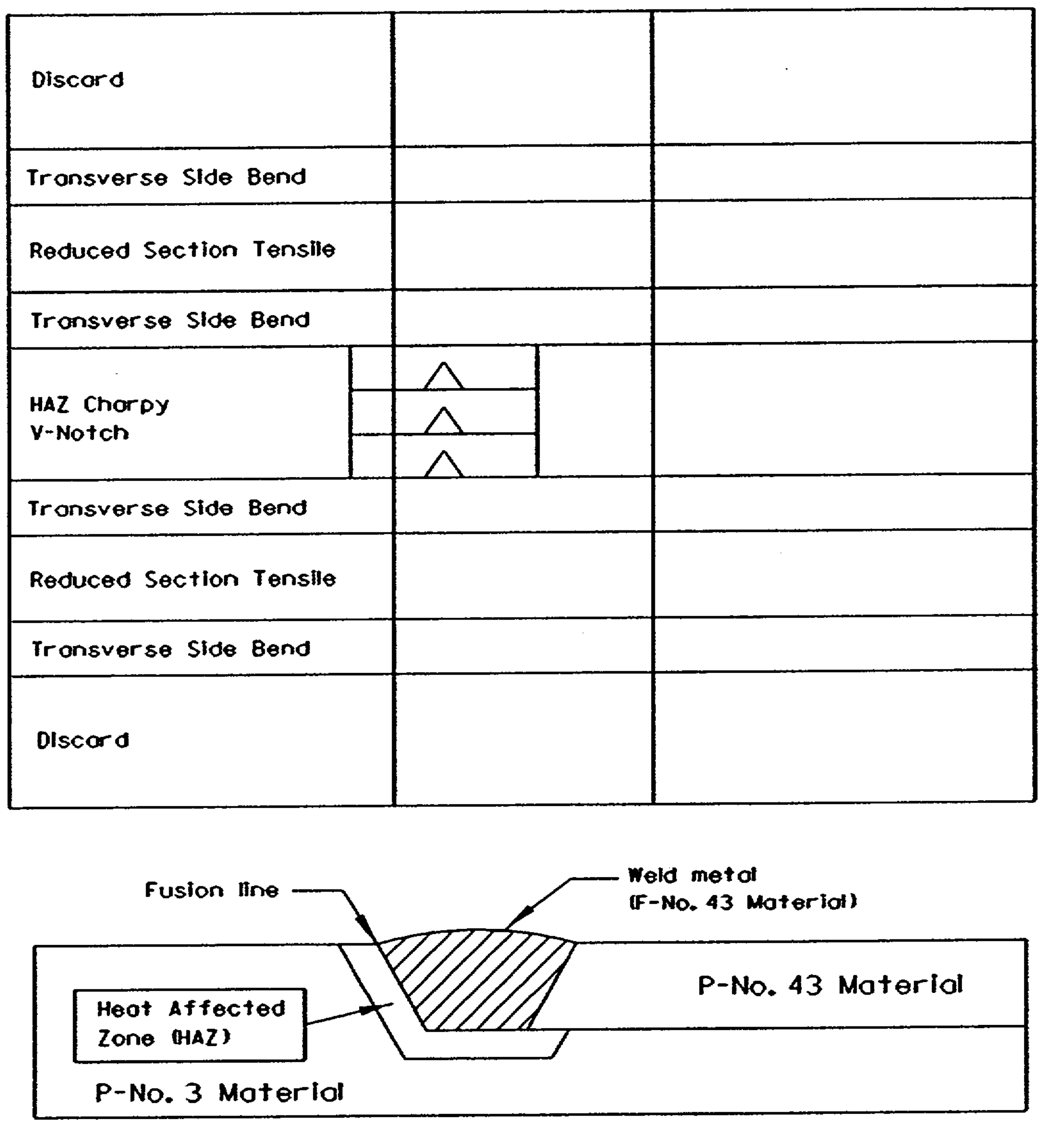
5.0 DOCUMENTATION:

Repairs will be documented on Form NIS-2.

6.0 Deleted:

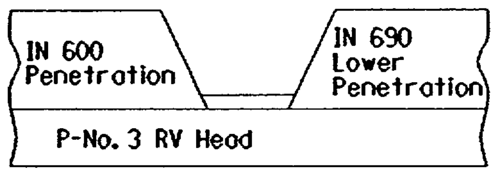
7.0 Deleted:

FIGURES: (Attached)

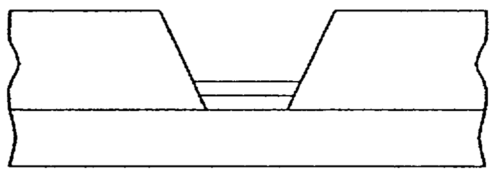


GENERAL NOTE: Base metalCharpy impact specimens are not shown.

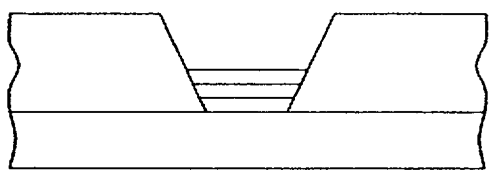
FIG 1. QUALIFICATION TEST PLATE



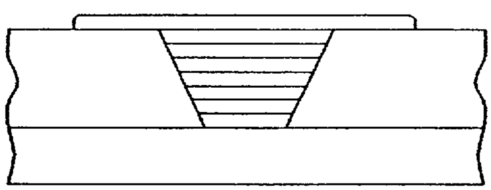
Step 1: Deposit layer one with first layer weld parameters used in qualification.



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 HAZ of the base metal is 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 HAZ of the base metal is tempered.



Step 4: Subsequent layers to be deposited as qualified, with heat input less than or equal to that qualified in the test assembly.

GENERAL NOTE:
For dissimilar-metal welding, only the ferritic base metal is required to be welded using steps 1 through 3 of the temperbead welding technique.

FIG 2. AUTOMATIC OR MACHINE (GTAW) TEMPER BEAD WELDING

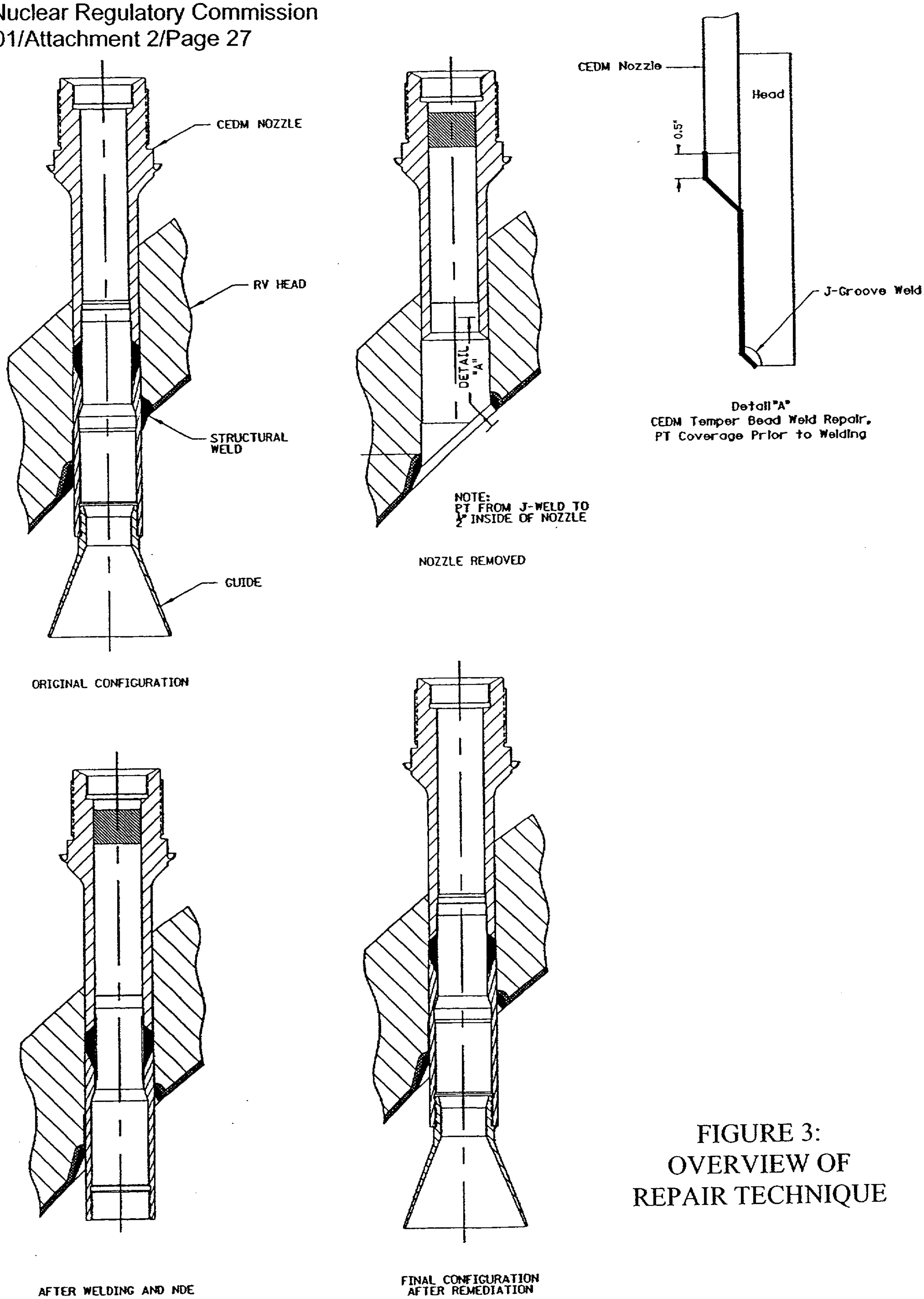
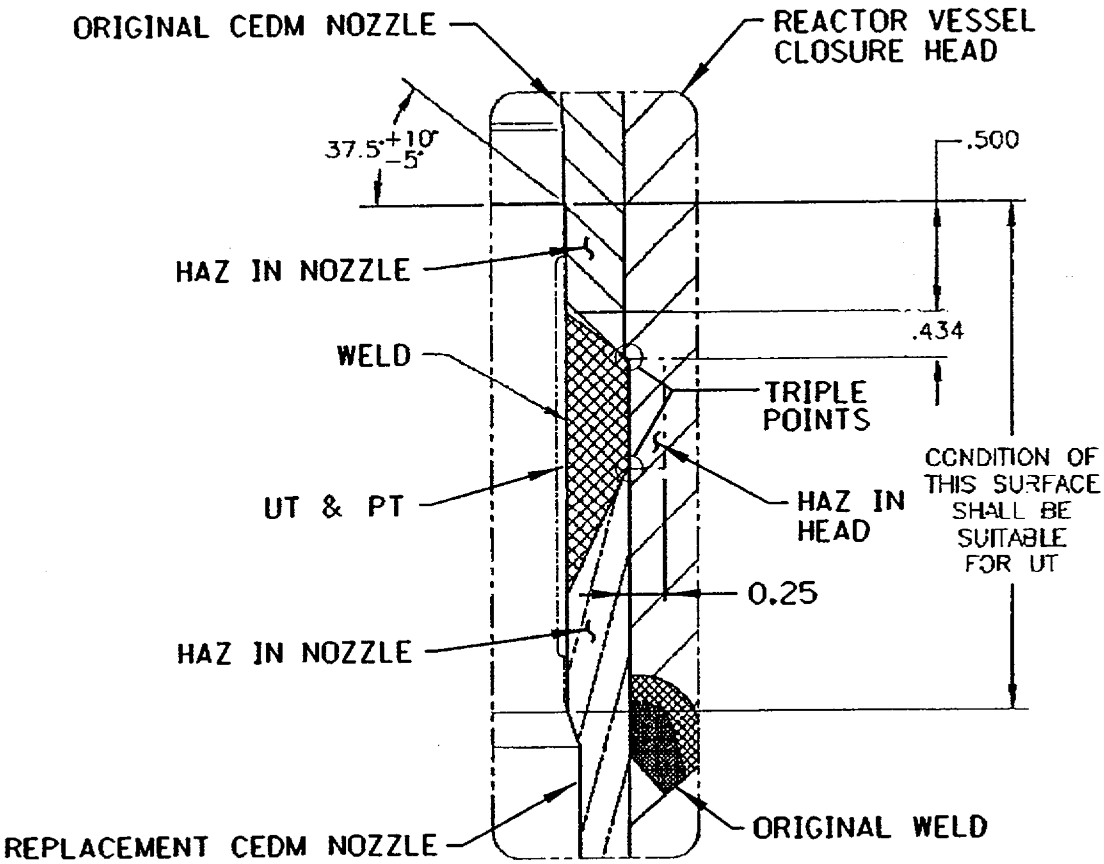


FIGURE 3:
OVERVIEW OF
REPAIR TECHNIQUE



NOTE: ALL UT TRANSDUCERS WILL PROVIDE 100% COVERAGE OF WELD AND HAZ IN NOZZLE, < 100% HAZ IN HEAD, SEE FIGURES 4A-4E.

CEDM TEMPERBEAD WELD REPAIR
AREAS TO BE EXAMINED

FIGURE 4

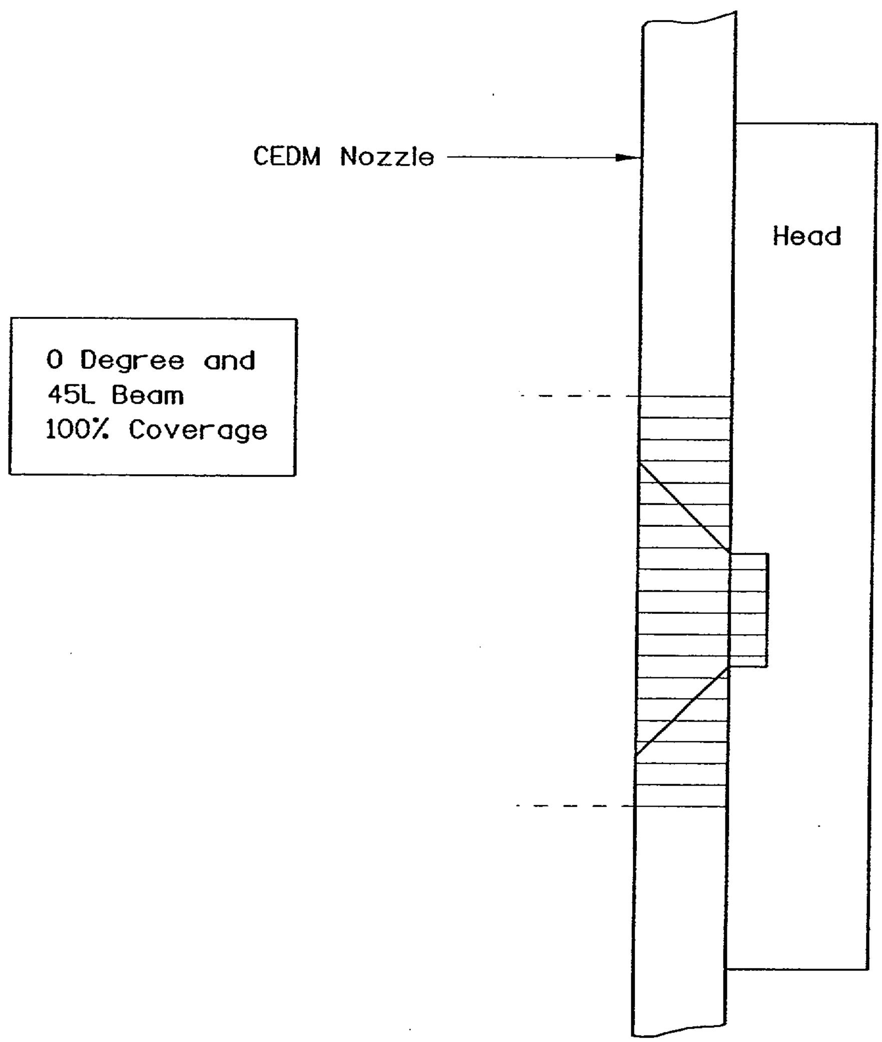


Figure 4a
CEDM Temper Bead Weld Repair,
UT 0 degree and 45L Beam Coverage
Looking Clockwise and Counter-Clockwise

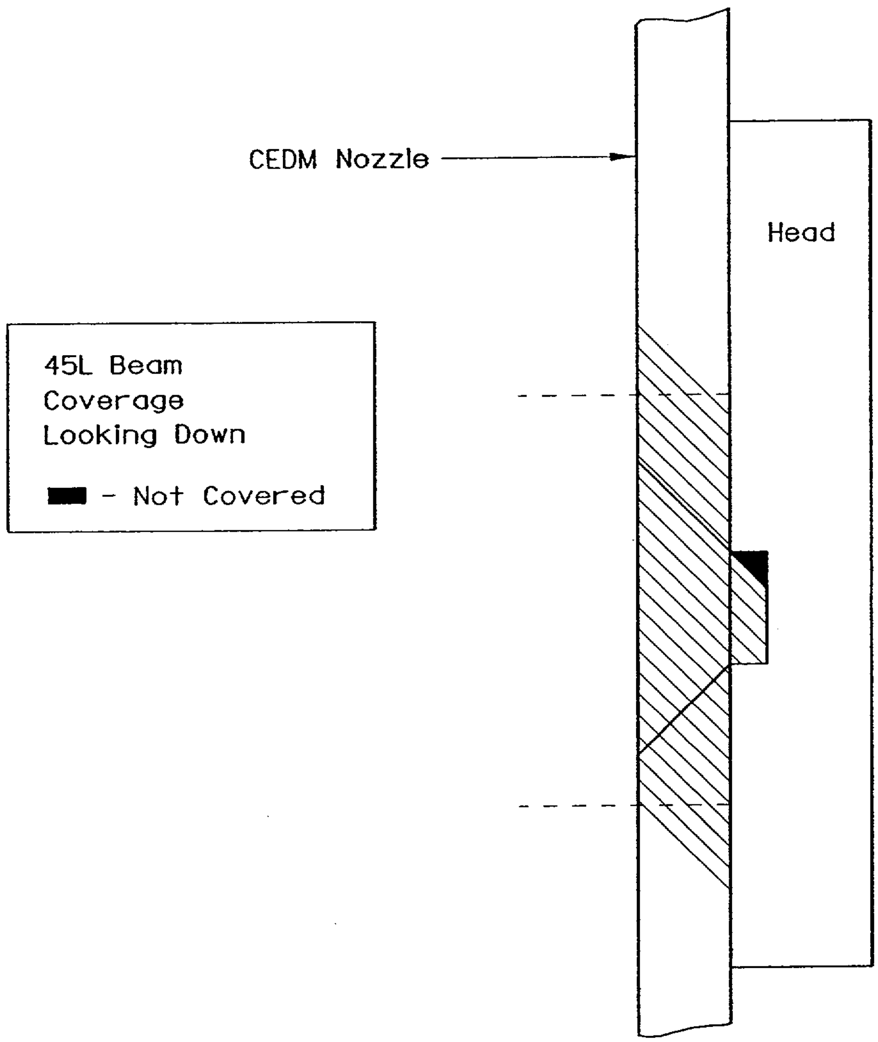


Figure 4b
CEDM Temper Bead Weld Repair,
45L UT Beam Coverage Looking Down

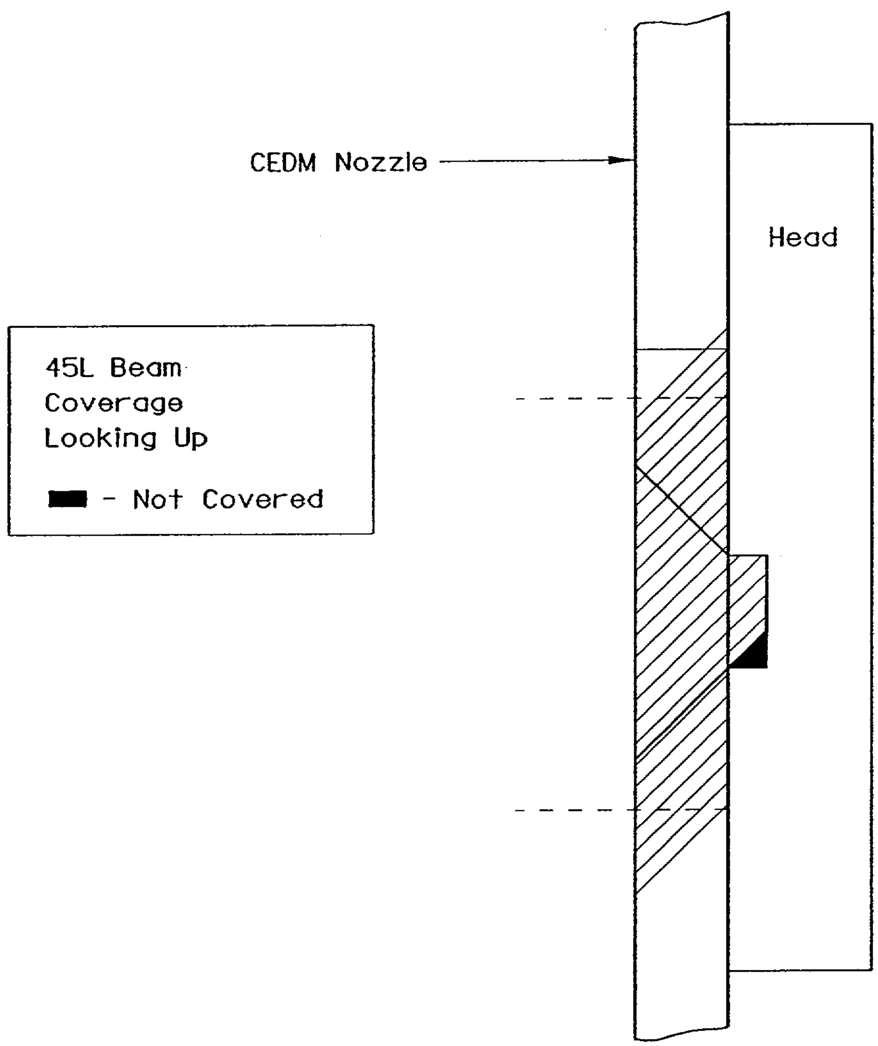


Figure 4c
CEDM Temper Bead Weld Repair,
45L UT Beam Coverage Looking Up

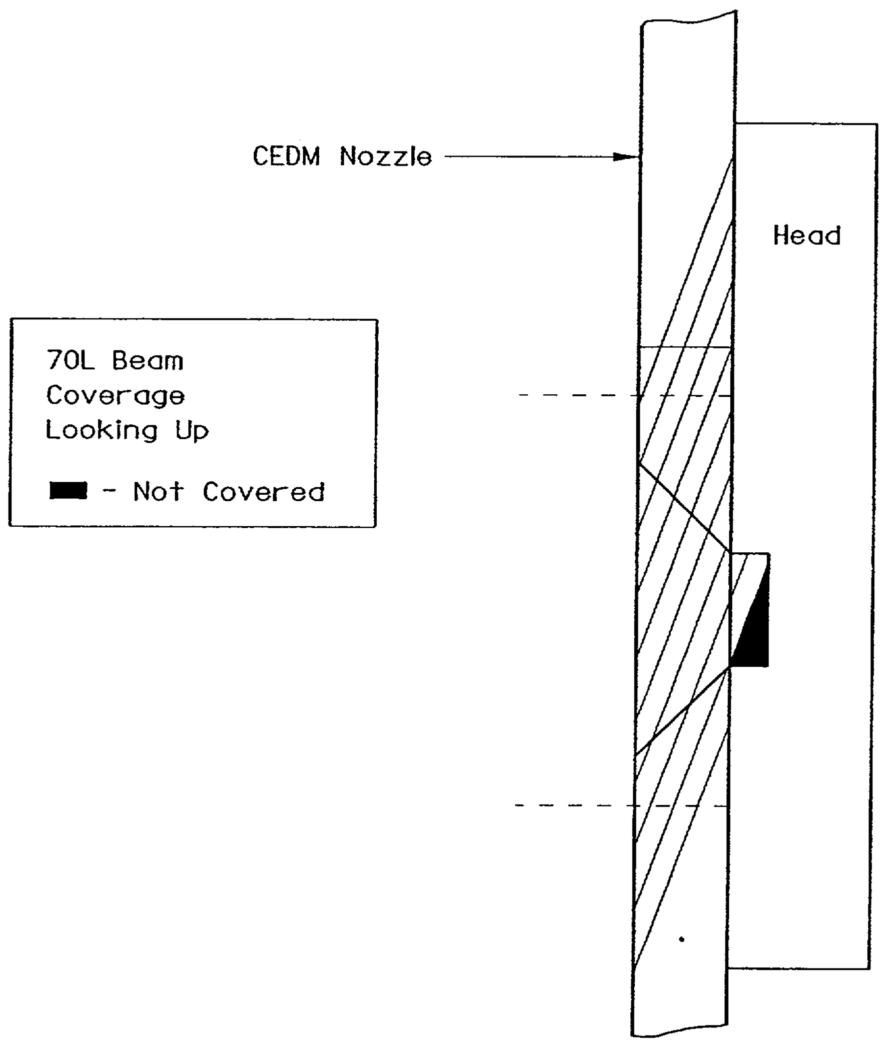


Figure 4d
CEDM Temper Bead Weld Repair,
70L UT Beam Coverage Looking Up

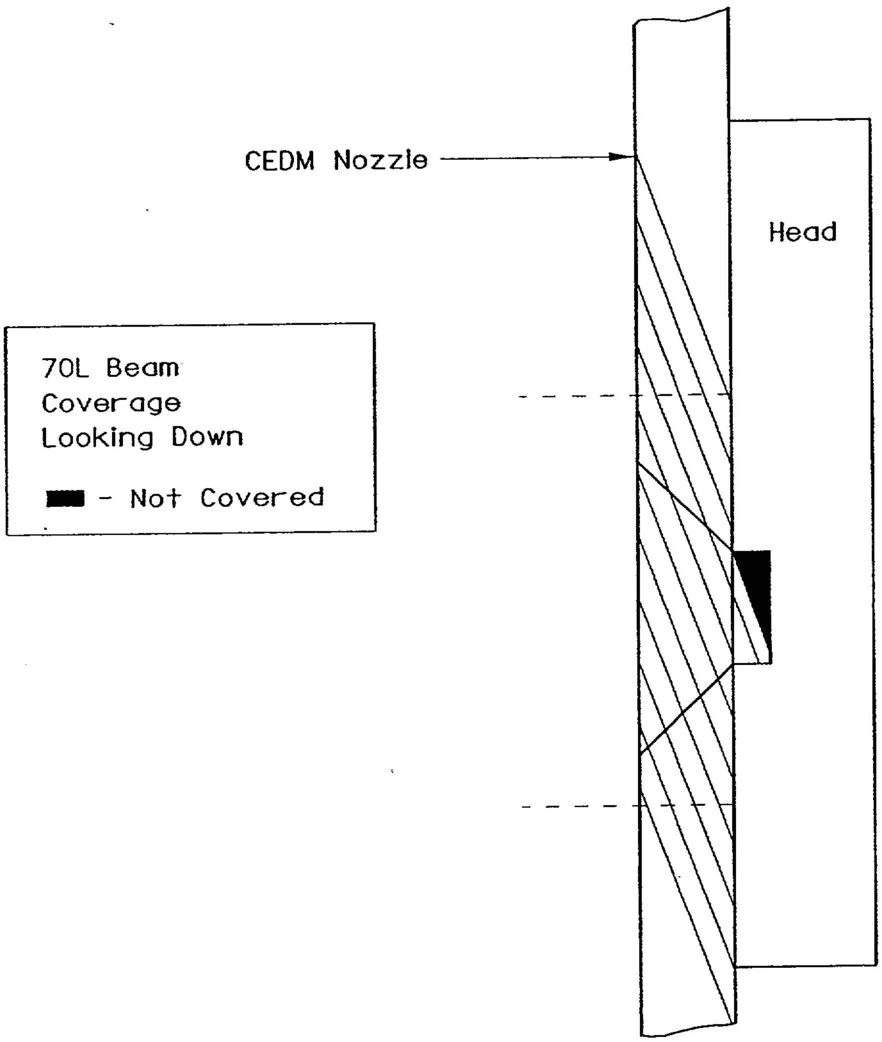


Figure 4e
CEDM Temper Bead Weld Repair,
70L UT Beam Coverage Looking Down

Attachment 3

Millstone Nuclear Power Station, Unit No. 2

Relief Request RR-89-36, Characterization and Successive Examinations of Remaining Flaws in Reactor Vessel Head Penetration Nozzles

Relief Request RR-89-36, Characterization and Successive Examinations of Remaining Flaws in Reactor Vessel Head Penetration Nozzles

System/Component(s) for Which Relief is Requested:

Millstone Power Station, Unit No. 2 Reactor Vessel Head (RVH) Control Element Drive Mechanism (CEDM) nozzle penetrations:

> There are 69 CEDM nozzle penetrations welded to the RVH, shown on Millstone Station drawing 25203-29139-00020. The ASME Boiler and Pressure Vessel (B&PV) Code Class for the RVH and CEDM nozzles is Class 1. Three of the CEDM nozzles have presently been identified as requiring repair. (No relief is necessary at this time for instrument nozzles (ICI's) or the head vent nozzle.)

Code Requirements:

The Construction Code of record for Millstone Unit 2 vessel head and nozzle penetrations is the 1968 Edition of ASME Section III with Addenda through Summer 1969. The repair of identified flaws in the CEDM nozzles is in accordance with the requirements of both the 1992 Edition of ASME Section III and the 1989 Edition of Section XI, with alternatives (which include evaluation of Ultrasonic Testing (UT) flaws in accordance with the requirements of IWB-3600, 1992 Edition) as requested in Attachment 2 of this submittal. The ASME Section XI ISI Program for Millstone Unit No. 2 is currently in the third inspection interval, and is implemented under the 1989 Edition of Section XI. The Code Requirements discussed below are with reference to the 1989 Edition except as noted. The following Code Requirements are addressed in this Relief Request:

- IWA-3300 requires characterization of flaws detected by inservice examination.
- IWB-3420 requires each detected flaw or group of flaws be characterized by the rules of IWA-3300 to establish the dimensions of the flaws, which are required for comparison with acceptance standards or for evaluation.
- IWB-3142.4 requires that a component accepted for continued service based on analytical evaluation be subsequently examined in accordance with IWB-2420(b).

Code Requirements from Which Relief Is Requested:

Dominion Nuclear Connecticut, Inc. (DNC), pursuant to 10 CFR 50.55a(g)(5)(iii), requests the NRC grant relief under 10 CFR 50.55a(g)(6)(i), from performing flaw characterization for flaws originating in the remnant J-groove weld, as required by IWA-3300 and IWB-3420. Following the repair of the CEDM nozzles, it is assumed that flaws will remain in the original CEDM nozzle to RVH J-groove weld. During the repair process, DNC will remove portions of the original J-groove weld to limit the size of the flaws that remain. As an alternative and in lieu of fully characterizing the existing flaws,

DNC proposes to utilize worst-case assumptions to conservatively bound the flaw extent and orientation. A flaw growth and fracture mechanics evaluation of the assumed flaw configuration provides a reasonable assurance of maintaining the RVH structural integrity.

DNC requests the NRC grant relief in accordance with 10 CFR 50.55a(g)(6)(i) from IWB-3142.4. IWB-3142.4 requires that components found acceptable for continued service by analytical evaluation be subject to successive examination. As justified below, a successive examination able to fully characterize any remaining flaw of the J-groove weld remnant will be impractical and will not be performed. As already noted, an analytical evaluation of the worst case flaw originating in the J-groove weld has been performed to demonstrate its acceptability for continued operation.

The relief requested under IWB-3142.4, regarding a successive examination requirement, is also requested for the new repair weld. The new pressure boundary weld that will connect the remaining portion of the CEDM nozzle to the low alloy RVH may contain a weld "triple point". The triple point is at the root of the weld where the existing Alloy 600 CEDM nozzle will be welded to the SA-533 Grade B, Class 1 Mn-Mo-Ni low alloy RVH with Alloy 690 (52) filler metal. Another triple point is formed at the lower end of the weld to the replacement A-690 material nozzle (See Figure 1). Experience has shown that during solidification of the Alloy 690 weld filler material, a welding solidification anomaly area may occur at the root of the partial penetration welds. The presence of the weld anomaly is evaluated under Section XI (1992 Edition) rules for acceptance by evaluation, however the associated IWB-3142.4 requirement for successive examination of such flaws will not be performed. Instead, an analytic evaluation of the worst case flaw originating from the triple point, including projected service related growth, has been performed to demonstrate its acceptability for continued operation. The UT examination of the weld after repair will be used to validate that any triple point flaws do not exceed the assumption of the evaluation.

Basis for Relief:

The basis for relief of each Code requirement is outlined below with reference to more detailed discussions of flaw characterization, flaw growth, and flaw analytical evaluation.

- IWA-3300/IWA-3420/IWA-3142.4 - Flaw Characterization of J-Groove Weld:

  The nozzles to be repaired have UT indications within the nozzle, identified by the initial nozzle inspection results, that are assumed to extend into the weld. The inspection methodology utilized can identify flaws in the nozzle but is not capable of characterizing flaws in the weld. Liquid penetrant exams have been used to identify surface indications on the bottom surface of the weld which correspond to indications from the UT exam, but do not determine the extent of the flaw in the weld.

  Additional characterization of the flaws in the weld is impractical because manual examination techniques entailing large personnel dose would be required. Further, detailed characterization by examination is not necessary for

J-groove weld flaw evaluation purposes because an adequate bounding characterization can be developed by alternative means considering weld geometry, calculable stress fields, and known flaw growth relations for Primary Water Stress Corrosion Cracking (PWSCC) and fatigue. Finally, after the temper bead weld repair the J-groove weld no longer functions as a primary pressure boundary. More details of this rationale is are provided in separate discussions below.

- IWB-3142.4 - Successive Examinations for J-Groove Weld and Triple Point Anomaly

  IWB-3124.4 requires successive examinations of flaws accepted by evaluation for continued service. Such examinations are a measure to assure that the evaluated flaw does not grow beyond its analyzed bounding extent. Relief is requested from the successive examination requirement for both the J-groove weld flaw and new weld triple point anomaly because it is impractical with existing examination technology and from dose burden viewpoint.

  The successive examination for the remnant J-groove weld is impractical for the same reasons as stated above in the discussion of flaw characterization. It is impractical for the triple point anomaly because of the personnel dose impact of available techniques. Not performing successive examinations is acceptable for both the J-groove and triple point anomaly because an evaluation of future growth of the assumed flaws shows they would remain acceptable for the intended service life with an adequate degree of conservatism. More details of the examination impracticality and flaw evaluation are provided in separate discussions below.

It is concluded that the alternatives to flaw characterization of the J-groove weld and successive examinations for the J-groove weld and triple point anomaly, that are discussed above and used in lieu of existing Code requirements, will provide an acceptable level of quality and safety.

Implementation Schedule:

The above relief is requested for the current Third 10-Year Inservice Inspection Interval. The evaluations referenced as the basis for the relief will be completed before returning to operations from the current cycle 14 refueling outage.

Additional Details of Basis for Relief:

The following topics provide additional discussion on the basis for relief of the Code requirements. The analyses and evaluations referred to below are in the final stages of completion and will be made available for review by the staff if requested.

- Impracticality of J-Groove Flaw Characterization By Examination:

  The original CEDM nozzle to closure head J-groove weld configuration is extremely difficult to UT due to the compound curvature and fillet radius as can

be seen in Figure 1. The chamfer modification presents another impediment. 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 it is impractical, and presently the technology does not exist, to characterize flaw geometries that may exist within the J-groove weld. Not only is the configuration not conducive to UT, but the dissimilar metal interface between the NiCrFe weld and the low alloy steel closure head increases the UT difficulty. Furthermore, due to limited accessibility from the closure head outer surface and the proximity of adjacent nozzle penetrations, it is impractical to scan from this surface on the closure head base material to detect flaws in the vicinity of the original weld.

- Impracticality of Successive Examinations of the Triple Point Anomaly:

  Successive examinations to inspect the assumed triple point weld anomaly are impractical because they would impose a large personnel dose burden for little benefit gained. The under-head dose rate observed during the cycle 14 refueling outage was approximately 8 R, reducible somewhat by decontamination procedures. Assuming the existing partly automated UT exam utilized for the Section III NB-5000 inspection of the weld could be adapted to a qualified Section XI exam, the inspection would nonetheless incur a large dose simply to set up the head for under-head inspection, then place and adjust the equipment to obtain the UT scan data, and then remove the equipment.

- Characterization of J-groove Weld for Evaluation Purposes:

  To account for the uncertainty in flaw characterization, DNC proposes to bound the assumed flaw by the geometry of the J-groove weld material. Although a flaw propagating through the J-groove weld by PWSCC would eventually grow to the low alloy steel reactor vessel head, continued growth by PWSCC into the low alloy steel is not expected to occur. Stress Corrosion Cracking (SCC) of carbon and low alloy steels is not a problem under boiling water reactor or pressurized water reactor conditions. SCC of steels containing up to 5% chromium is most frequently observed in caustic and nitrate solutions and in media containing hydrogen sulfide. Based on this information, SCC is not expected to be a concern for low alloy steel exposed to primary water. Instead, an interdendritic flaw propagating from the J-groove weld area is expected to blunt and cease propagation. This has been shown to be the case for interdendritic SCC of stainless steel cladding flaws in charging pumps and by recent events with PWSCC of Alloy 600 weld materials at Oconee Nuclear (ONS-1) and V.C. Summer stations. Based on extensive industry experience and Framatome ANP direct experience, there are no known cases where flaws initiating in an Alloy 82/182 weld have propagated into the ferritic base material. It has therefore been assumed for evaluation purposes that an initiating flaw may exist within the bounds of the geometry of the J-groove weld. The bounding flaw is therefore at its maximum extent of growth due to PWSCC.

Hence for evaluation purposes the flaw is evaluated for future fatigue crack growth into the ferritic base material.

Since the hoop stresses in the J-groove weld are generally about two times the axial stress at the same location (as determined by the analysis described below), the preferential direction for flaw growth is axial, or radial relative to the nozzle. It was postulated that a radial flaw in the Alloy 182 weld metal would propagate by PWSCC through the weld and butter, to the interface with the low alloy steel head. It is fully expected that such a flaw would then blunt and arrest at the butter-to-head interface. On the uphill side of the nozzle, where the hoop stresses are highest and the area of the J-groove weld is largest, a radial flaw depth extending from the corner of the weld to the low alloy steel head would be very deep, up to and about 1 ¾ inch at the outermost row of nozzles.

The above characterization of the J-groove weld flaw is adequate and sufficient for use in the flaw evaluation described in this section.

- Stress Analysis of Vessel Head and CEDM Nozzles:

An analysis of the new pressure boundary welds was performed using a three-dimensional finite element model of a CEDM nozzle located at the most severe hillside orientation. The analytical model included the vessel head, the CEDM nozzle, repair weld, and remnant portions of the original Alloy 600 welds. The model was analyzed for pressure and thermal operating conditions consolidated to envelop the original design specification. The resulting maximum thermal gradients were applied to the model along with the coincident internal pressure values. The weld region is isolated from seismic lateral and bending loads and seismic axial loads are negligible relative to pressure. The model was then analyzed for these loads to calculate the stresses throughout the model (including the repair weld). The stresses were post-processed to categorize stresses for comparison to the criteria of the ASME Code Section III, NB-3200 criteria for structural integrity and fatigue usage.

In the fatigue evaluation, a very conservative Stress Concentration Factor (SCF) of 4.0 was assumed for the new partial penetration pressure boundary weld. The maximum cumulative fatigue usage factor was calculated at the interfaces between the vessel head, weld, and nozzle material. It was within the Code limitation of 1.0 for the assumed 35 years of future plant life.

As an adjunct of the stress analysis described above the applicable stresses required for the fracture mechanics evaluation were calculated along pathways of expected flaw propagation.

- Flaw Growth and Evaluation of J-Groove Weld Flaw:

  Given the bounding flaw characterization described above, the evaluation of present and future flaw acceptability may be performed. A fracture mechanics evaluation was performed to determine if degraded J-groove weld material could be left in the RVH. In the alternative being proposed, the acceptance of the postulated flaw is calculated based on the two inputs of expected flaw orientation and the geometry of the weld. Typically, an expected flaw orientation is evaluated based on prevalent stresses at the location of interest. In these welds, operating stresses were obtained from the stress analysis described above. Since hoop stresses were calculated to be the dominant stress, it is expected that radial type flaws (with respect to the penetration) will occur. Using worst case (maximum) assumptions with the geometry of the as-left weld, the postulated flaw was assumed to begin at the intersection of the RVH inner diameter surface and the CEDM nozzle bore and propagate slightly into the RVH low alloy steel. The depth and orientation are worst-case assumptions for flaws that may occur in the remaining J-groove partial penetration weld configuration.

  Based on industry experience and operating stress levels, there is no reason for service related flaws to exist in the ferritic material. However, even though residual stresses in the head material are low, it was assumed that a small flaw could initiate in the low alloy steel material and grow by fatigue. Flaw growth through the Alloy 182 material will tend to relieve the residual stresses in the weld as the flaw grows to its final size. It was therefore postulated that a small flaw in the head would combine with a large stress corrosion flaw in the weld to form a radial corner flaw that would propagate into the low alloy steel head by fatigue crack growth under cyclic loadings associated operating conditions.

  Residual stresses were not included in the flaw evaluations since it has been demonstrated by analysis that these stresses are compressive in the low alloy steel base material. Any residual stresses that remained in the area of the weld following the boring operation would be partially relieved by such a deep flaw, and therefore need not be considered.

  Flaw evaluations were performed for a postulated radial corner flaw on the uphill side of the head penetration, where stresses are the highest and the radial distance from the inside corner to the low alloy steel base metal (flaw depth) is the greatest. Hoop stresses were used since they are perpendicular to the plane of the flaw. Among the significant contributors to fatigue crack growth of the base material are heat-up/cool-down cycles (12.5 cycles assumed per year) and plant loading/unloading (75 cycles assumed per year). Fatigue crack growth, calculated for 35 years of operation, was small (about 0.664 inch), and the final flaw size met the fracture toughness requirements of the ASME Code using an upper shelf value limited to of 200 ksi-in^.5 for ferritic materials.

Based on the analysis performed, it is acceptable to leave the postulated flaws in the attachment (J-groove) and buttering. The calculations performed show the remaining flaws within the weld and base material are acceptable for 35 years.

- Flaw Growth and Evaluation of Temper Bead Weld Triple Point Anomaly:

An artifact of the ambient temperature temper bead weld repair is an anomaly in the weld at the triple point. The triple point is the point in the repair weld where the low alloy head, the Alloy 600 nozzle and the first Alloy 52 weld bead intersect. Welding solidification is an inherent problem when using high NiCr alloys in the presence of a notch located at the triple point. NB-5330(b) of the 1992 Edition of ASME Section III stipulates that no lack of fusion area be present in the weld. A fracture mechanics analysis was performed to provide justification, in accordance with ASME Section XI, for operating with the postulated weld anomaly described above. The anomaly was modeled as a 0.1 inch semi-circular 'crack-like' defect 360 degrees around the circumference at the triple point location. Postulated flaws could be oriented within the anomaly such that there are two possible flaw propagation paths, as discussed below.

Radial Propagation Path: The radial flaw propagation paths traverse the CEDM tube wall thickness from the OD of the tube towards the ID of the tube. This is the shortest path through the component wall, passing through the new Alloy 690 weld material. However, Alloy 600 tube material properties or equivalent were used to ensure that another potential path through the Heat Affected Zone (HAZ) between the new repair weld and the existing Alloy 600 tube material is bounded. A total of four radial paths were considered, to include both the upper and lower triple points at both the upper and lower hillside locations.

For completeness of evaluation of radial paths, two flaw orientations were postulated at the outside surface of the tube. A 360 degree continuous circumferential flaw, lying in a horizontal plane, was considered to be a conservative representation of crack-like defects that may exist in the weld anomaly. This flaw was subjected to axial stresses in the tube. An axially oriented semi-circular outside surface flaw was also considered since it would lie in a plane normal to the higher circumferential stresses. Both of these flaws would propagate toward the inside surface of the tube.

Axial Propagation Path: The axial flaw propagation runs down the outside surface of the repair weld between the weld and the RVH. A semi-circular cylindrically oriented flaw was postulated to lie along this interface, subjected to radial stresses with respect to the tube. This flaw may propagate through either the new Alloy 690 material or the low alloy steel RVH material. Two axial paths were considered, at the upper and lower hillside locations.

Flaw propagation growth rates due to fatigue, appropriate for air and pressurized water reactor environments, were selected for the upper and lower triple points respectively. Growth rates in the vessel head material were taken from Section XI, Appendix A. Flaw growth rates in air for A600/A690/A52 were taken from Section XI, Appendix C. Corresponding growth rates in the PWR environment were taken as twice the Appendix C rates in air, as suggested in the basis white paper for Appendix C.

The results of the analysis for both radial and axial propagation paths demonstrated that a 0.10 inch weld anomaly is acceptable for a 35 year design life of the CEDM ambient temperature temper bead weld repair. Significant fracture toughness margins were obtained for both of the flaw propagation paths considered in this analysis. The minimum margin of fracture toughness, calculated as a ratio relative to the Code allowable K_{Ia}, was 12.5 for the radial paths and 32.7 for axial paths, and are significantly greater than the required minimum margin of $\sqrt{10} = 3.16$ per paragraph IWB-3612 of Section XI. Fatigue crack growth is minimal. Starting from the assumed 0.100 inch initial flaw, the maximum final flaw size is 0.130 inch for radial propagation paths and 0.101 for axial paths. A limit load analysis was also performed considering the ductile Alloy 600/Alloy 690 materials along the radial flaw propagation. The analysis showed a limit load margin of 4.77 for all conditions. This is significantly greater than the required margin of 3.0 for normal/upset conditions per paragraph IWB-3642 of ASME Section XI. In conclusion, the structural integrity of the vessel head and CEDM nozzles is maintained even considering the presence of the triple point anomaly.

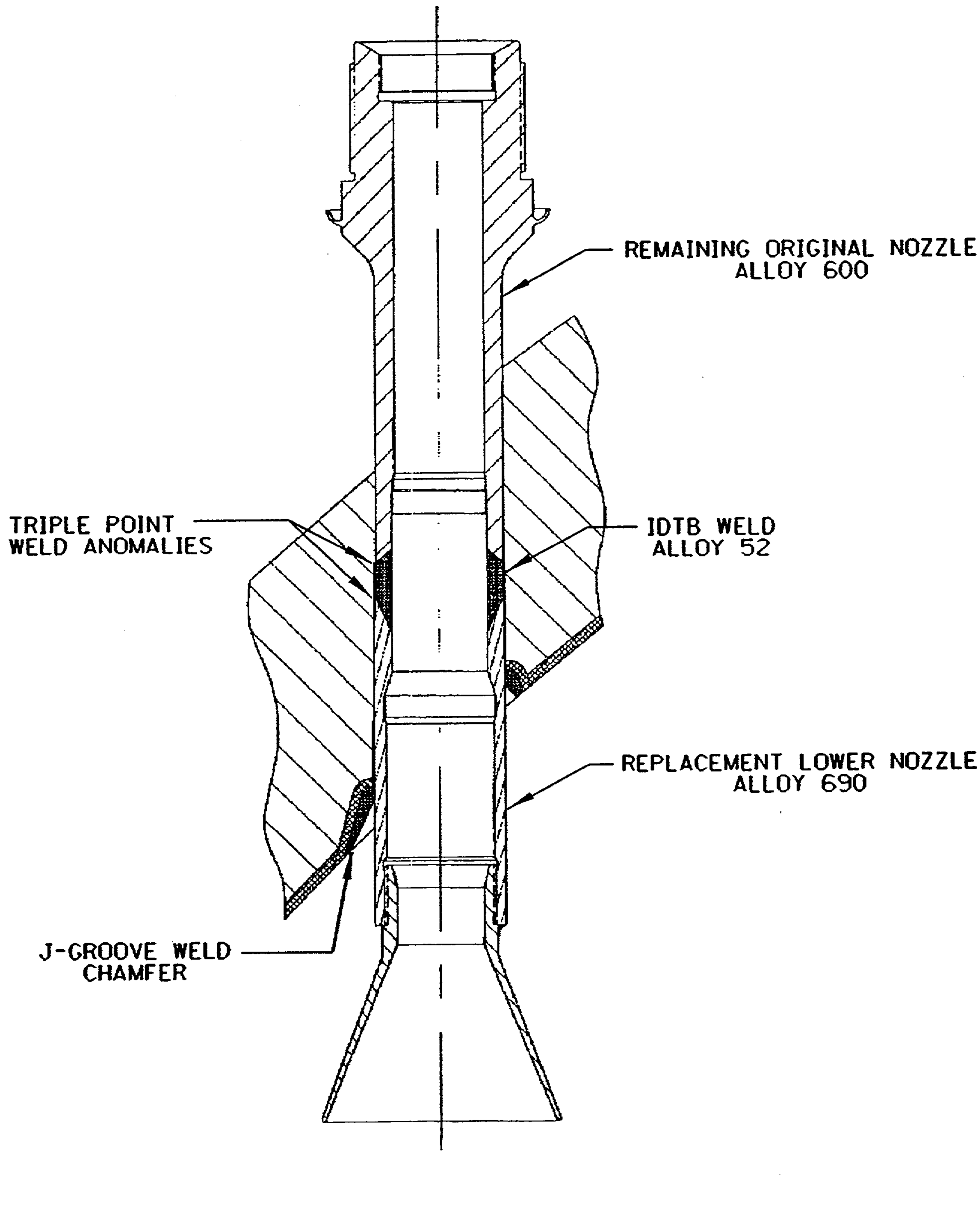

REMAINING ORIGINAL NOZZLE
ALLOY 600
TRIPLE POINT
WELD ANOMALIES
IDTB WELD
ALLOY 52
REPLACEMENT LOWER NOZZLE
ALLOY 690
J-GROOVE WELD
CHAMFER

FIGURE 1