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Acting Director
Nuclear Safety & Licensing

CNRO-2005-00019

March 24, 2005

U. S. Nuclear Regulatory Commission
Attn.: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Response to Request for Additional Information Concerning ANO2-R&R-003-Proposed Alternative to ASME Requirements for Weld Repairs

Arkansas Nuclear One, Unit 2
Docket No. 50-368
License No. NPF-6

REFERENCES:

1. Entergy Operations, Inc. letter to the NRC, Request for Alternative ANO2-R&R-003 - Proposed Alternative to ASME Requirements for Weld Repairs, dated March 16, 2005
2. Entergy Operations, Inc. letter to the NRC, Supplemental Information for Request for Alternative ANO2-R&R-003 Proposed Alternative to ASME Requirement for Weld Repairs, dated March 18, 2005

Dear Sir or Madam:

Pursuant to 10 CFR 50.55a(a)(3)(i), Entergy Operations, Inc. (Entergy) proposed an alternative to the temper bead welding requirements of ASME Section XI IWA-4500 and IWA-4530. As documented in Request for Alternative ANO2-R&R-003 (see Reference 1), Entergy proposed to perform an ambient temperature temper bead welding repair on one pressurizer heater sleeve at Arkansas Nuclear One, Unit 2 (ANO-2). Entergy provided supporting technical bases for the request in Reference two.

On March 22, 2005 the NRC provided three questions. The enclosure contains the responses to those questions. Entergy has incorporated a change to the drawing discussed in question three of this RAI into ANO2-R&R-003.

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Entergy has requested NRC approval of ANO2-R&R-003 on an emergency schedule in order to support activities being performed during the ANO-2 refueling outage, 2R17, which commenced on March 9, 2005. This letter does not contain any new commitments. Should you have any questions regarding this submittal, please contact Bill Brice at (601) 368-5076.

Sincerely,

FGB/WBB/bal
Enclosures:
1. Response to Request For Additional Information
2. Request for Alternative ANO2-RR-003

Mr. W. A. Eaton (ECH)
Mr. J. S. Forbes (ANO)

Dr. Bruce S. Mallet
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U.S. Nuclear Regulatory Commission
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ENCLOSURE 1

CNRO-2005-00019

Response to Request For Additional Information

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING
REQUEST FOR ALTERNATIVE TO ASME SECTION XI
TEMPERBEAD WELDING
ARKANSAS NUCLEAR ONE, UNIT 2

1. On page 3 of the request under the first bulleted paragraph, Entergy states that they may use "052 modified" filler metal. Please provide the basis that Entergy has for assuming that the modified form of the 052 filler metal will be resistant to primary water stress corrosion cracking for the 1 cycle that the repairs will be in operation.

   Response: Chromium content has been shown to be the critical factor in assessing the resistance of nickel based alloys to primary water stress corrosion cracking (PWSCC). Section 2.2 of EPRI Technical Report MRP-115 states the following:

   > "The only well explored effect of the compositional differences among the weld alloys on PWSCC is the influence of chromium. Buisine, et al. evaluated the PWSCC resistance of nickel-based weld metals with various chromium contents ranging from about 15% to 30% chromium. Testing was performed in doped steam and primary water. Alloy 182, with about 14.5% chromium, was the most susceptible. Alloy 82 with 18-20% chromium took three or four times longer to crack. For chromium contents between 21 and 22%, no stress corrosion crack initiation was observed, as was also the case for Alloys 52 and 152 which have about 30% chromium. These results indicated that weld metals with 30% chromium were resistant to cracking, with a threshold for PWSCC resistance being between 22 and 30% chromium. This behavior is consistent with that of mill annealed wrought Ni-Cr-Fe base alloys. Tests by Yonezawa, et al. evaluated the effect of chromium on the PWSCC susceptibility of wrought Ni-Cr-Fe alloys and showed that the susceptibility decreased as the chromium content increased from about 1% to over 15%. Extensive testing has shown that Alloy 690, with about 30% chromium, is very resistant to PWSCC. MRP-111 summarizes additional laboratory data collected by AREVA that support these conclusions regarding the importance of chromium content."

   As shown in the table below, materials such as Alloy 600 and 082/182 weld metal which are generally considered non-resistant to PWSCC contain 14.0-22.0% chromium while resistant materials such as Alloy 690 and 052/152 weld metals contain 27.0-31.5% chromium.

Percentage of Chromium in Nickel Based Alloys

Non-Resistant Materials				Resistant Materials			
Alloy 600 Material	182 Filler Metal	082 Filler Metal		Alloy 690 Material	152 Filler Metal	052 Filler Metal	052 Modified
14.0-17.0	13.0-17.0	18.0-22.0		27.0-31.0	28.0-31.5	28.0-31.5	28.0-31.5

   "052" (UNS N06052) inconel filler metals have been used extensively in the performance of Alloy 600 repair activities and are considered resistant to PWSCC. However, these "052" weld filler metals have demonstrated a susceptibility to hot cracking. To resolve

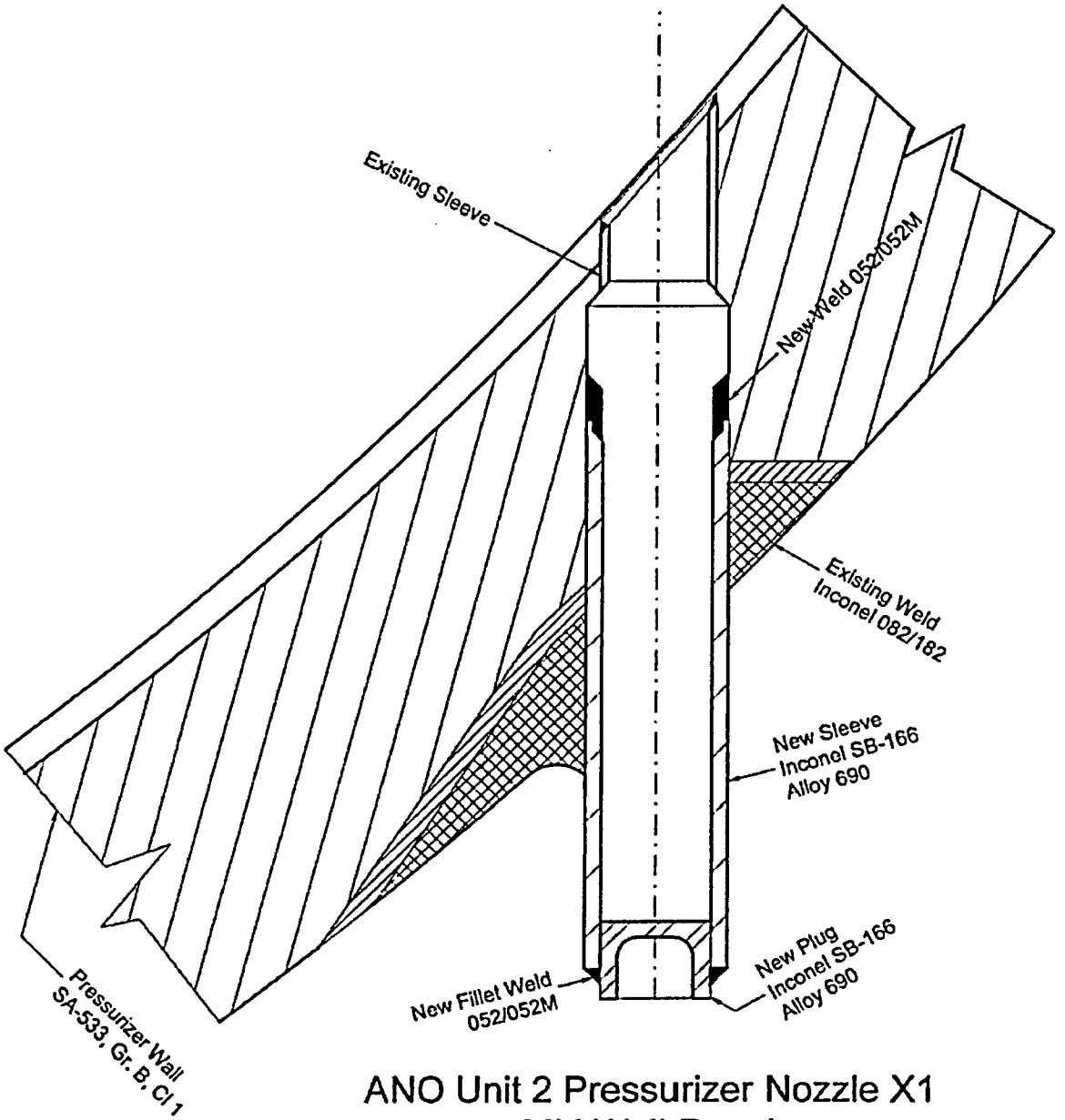
this hot cracking phenomenon, "052 Modified" (UNS N06054) inconel filler metal has been developed and approved by ASME in Section IX Code Case 2142-2. The chemical composition of the "052 Modified" filler metal is identical to that of "052" filler metal with one exception. The columbium content of the "052 Modified" filler metal has been increased from 0.1% (max) to 0.5-1.0% to improve the grain boundary strength of welds, thereby providing increased resistance to hot cracking. However, the chromium content (28.0-31.5%) of the "052 Modified" filler metal is identical to the "052" filler material making it equally resistant to PWSCC.

2. Code Case N-638 requires that all of the other requirements of ASME Section XI IWA-4000 not taken exception to in the code case be met. Please supplement your original application to indicate that Entergy will meet all of the other requirements of IWA-4000 that are not taken exception to in the code case.

   Response: This information already exists within Section IV of the request. The last sentence of the third paragraph on Page 6 states: *"For clarification, Entergy will meet applicable requirements of IWA-4000 except as otherwise approved by the NRC in accordance with this request."*

3. Figure 3 on page 16 of the request is confusing. The horizontal lines in the mid-wall of the pressurizer make it appear that somehow a plug is being welded into the middle of the pressurizer wall. Please clarify this drawing.

   Response: The horizontal lines in Figure 3 between the existing sleeve and attachment weld of the new sleeve were not intended to show a plug. Rather, the top horizontal lines identify a machined chamfer from the boring operation while the lower horizontal lines identify the geometric profile of the top of the new attachment weld (new sleeve to pressurizer wall). Because the toe of this new attachment weld is located approximately 1.00" below the bottom of the existing or original sleeve, there is a gap (space) between the lower end of the existing sleeve and the toe of the new attachment weld. The horizontal lines in question are on the upper and lower ends of this gap. To clarify this information, a new drawing has been developed and is attached. The new drawing shows a machined chamfer at the upper end of the bore along the bottom of the existing sleeve. A revision to Request ANO2-R&R-003 to include this new drawing is provided in Enclosure 2.



ANO Unit 2 Pressurizer Nozzle X1
Mid Wall Repair

ENCLOSURE 2

CNRO-2005-00019

Request For Alternative

ANO2-R&R-003

ENTERGY OPERATIONS, INC.
ARKANSAS NUCLEAR ONE, UNIT 2
REQUEST FOR ALTERNATIVE
ANO2-R&R-003

I. COMPONENTS

Component/Number: Pressurizer 2T-1

Description: Pressurizer Heater Sleeve X-1

Code Class: 1

References:

1. ASME Section XI, 1992 Edition with portions of the 1993 Addenda as listed in Reference 6
2. ASME Section III, Subsection NB, 1968 Edition, Summer 1970 Addenda
3. ASME Section III, Subsection NB, 1989 Edition
4. ASME Section XI Code Case N-638, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique"
5. EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temper Bead Applications"
6. CEP-ISI-004, "Arkansas Nuclear One – Unit 2 Inservice Inspection Plan"
7. Welding Services, Inc. Bases Document, *Cooling Transients for Mid-Wall Weld Repair*

Unit / Inspection Interval: Arkansas Nuclear One – Unit 2 (ANO-2) / Third (3rd) 10-Year Interval

II. CODE REQUIREMENTS

Subarticle IWA-4170(b) of ASME Section XI, 1992 Edition states, "Repairs and installation of replacement items 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 requirements of IWA-4200, IWA-4400, or IWA-4500 may be used."

IWA-4500 of ASME Section XI establishes alternative repair welding methods for performing temper bead welding. According to IWA-4500(a), "Repairs to base materials and welds identified in IWA-4510, IWA-4520, and IWA-4530 may be made by welding without the specified postweld heat treatment requirements of the Construction Code or

Section III, provided the requirements of IWA-4500(a) through (e) and IWA-4510, IWA-4520, or IWA-4530, as applicable, are met."

IWA-4530 applies to dissimilar materials such as welds that join P-No. 43 nickel alloy to P-No. 3 low alloy steels. According to IWA-4530, "Repairs to welds that join P-No. 8 or P-No. 43 material to P-Nos. 1, 3, 12A, 12B, and 12C material may be made without the specified postweld heat treatment provided the requirements of IWA-4530 through IWA-4533 are met. Repairs made to this paragraph are limited to those along the fusion line of a nonferritic weld to ferritic base material where 1/8-inch or less of nonferritic weld deposit exists above the original fusion line after defect removal."

Temper bead repairs are performed in accordance with IWA-4500 and IWA-4530 whenever the repair cavity is within 1/8-inch of the ferritic base materials. When the gas tungsten arc welding (GTAW) process is used in accordance with IWA-4500 and IWA-4530, temper bead welding is performed as follows:

- Only the automatic or machine GTAW process using cold wire feed can be used. Manual GTAW cannot be used.
- A minimum preheat temperature of 300°F is established and maintained throughout the welding process. Interpass temperature cannot exceed 450°F.
- The weld cavity is buttered with at least six (6) layers of weld metal.
- Heat input of the initial six layers is controlled to within +/-10% of that used for the first six (6) layers during procedure qualification testing.
- After the first six weld layers, repair welding is completed with a heat input that is equal to or less than that used in the procedure qualification for weld layers seven and beyond.
- Upon completion of welding, a postweld soak or hydrogen bake-out at 450°F - 550°F for a minimum of four (4) hours is required.
- Preheat, interpass, and postweld soak temperatures are monitored using thermocouples and recording instruments.
- The repair weld and preheated band are examined in accordance with IWA-4533 after the completed weld has been at ambient temperature for 48 hours.

III. PROPOSED ALTERNATIVE

A. Background

The ANO-2 pressurizer lower head was manufactured from SA-533, Grade B, Class 1 low alloy steel (P-Number 3, Group 3 material). Ninety-six (96) heater sleeves are welded to the pressurizer lower head as shown in Figure 1. The heater sleeves were originally manufactured from Alloy 600 material which has a demonstrated sensitivity to primary water stress corrosion cracking (PWSCC).

During refuel outages in 1987 and 1988, heater sleeve "X1" was modified and plugged as shown in Figure 2 due to PWSCC. The modification to the X1 heater

sleeve included a weld repair of pressurizer base material in the immediate vicinity of the X1 sleeve. The modification was performed using Alloy 600 materials and 082/182 weld materials. This repair was performed to restore pressurizer base material that had experienced boric acid corrosion as a result of the PWSCC leak.

Refueling Outage 17 commenced at ANO-2 on March 9, 2005. While performing bare metal visual inspections, leakage from the heater sleeve X1 attachment weld (i.e. pressurizer to heater sleeve weld) was identified. The cause of leakage is believed to be PWSCC. As a repair, Entergy plans to perform the following:

- Replace the existing sleeve assembly with a modified sleeve design as shown in Figure 3. The new design will utilize Alloy 690 materials. Welding will be performed using 052 or 052 Modified (UNS N06054) filler metals. The 052 Modified filler metal has been approved by ASME in ASME Section IX Code Case 2142-2.

- Surface-detected PWSCC cracks will be removed from the existing 082/182 weld metal. Other indications identified in the removal process will be evaluated in accordance with ASME Section III, NB-5350. The excavation (defect removal area) will be blended smoothly into the surrounding base material in accordance with ASME Section XI requirements. **Note**: Any remaining 082/182 weld metal will be located on the outside diameter of the pressurizer head and, therefore, isolated from reactor coolant. Because of this, it will no longer be susceptible to PWSCC.

- The reduced section of the excavated region will not be restored to its original design thickness by welding. Alternatively, Entergy will perform an analysis in accordance with NB-3000 to demonstrate that the as-left section thickness of the pressurizer head and the reinforcement surrounding heater sleeve X1 comply with applicable requirements of ASME Section III.

B. Proposed Alternative

Pursuant to 10 CFR 50.55a(a)(3)(i), Entergy proposes alternatives to the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530 of ASME Section XI. Specifically, Entergy proposes to perform ambient temperature temper bead welding in accordance with Attachment 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." Entergy will use this proposed alternative for performing a mid-wall repair of the pressurizer heater sleeve X1 as described in Section III.A above.

Entergy has reviewed the proposed ambient temperature temper bead welding techniques of Attachment 1 against the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530. This review was performed to identify differences between Attachment 1 and IWA-4500 and IWA-4530. Based upon this review, Entergy proposes alternatives to the following ASME Section XI requirements of IWA-4500 and IWA-4530:

1. **IWA-4500(a)** specifies that repairs to base materials and welds identified in IWA-4530 may be performed without the specified postweld heat treatment of the construction code or ASME Section III provided the requirements of IWA-4500 and IWA-4530 are met. IWA-4530 includes temper bead

requirements applicable to the shielded metal arc welding (SMAW) and the machine or automatic GTAW processes. As an alternative, Entergy proposes to perform temper bead weld repairs using the ambient temperature temper bead technique described in Attachment 1. Only the machine or automatic GTAW process can be used when performing ambient temperature temper bead welding in accordance with Attachment 1.

2. **IWA-4500(d)(2)** specifies that if repair welding is to be performed where physical obstructions impair the welder's ability to perform, the welder shall also demonstrate the ability to deposit sound weld metal in the positions, using the same parameters and simulated physical obstructions as are involved in the repair. This limited accessibility demonstration applies when manual temper bead welding is performed using the Shielded Metal Arc Welding (SMAW) process. It does not apply to "welding operators" who perform machine or automatic GTAW welding from a remote location. (This distinction is clearly made in IWA-4500 and IWA-4530.) Because the proposed ambient temperature temper bead technique described in Attachment 1 utilizes a machine GTAW welding process, limited access demonstrations of "welding operators" are not required. Therefore, the requirement of IWA-4500(d)(2) does not apply.

3. **IWA-4500(e)(2)** specifies that the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 300°F for the GTAW process during welding; maximum interpass temperature shall be 450°F. As an alternative, Entergy proposes that the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 50°F for the GTAW process during welding. The maximum interpass temperature shall be 350°F regardless of the interpass temperature during qualification.

4. **IWA-4500(e)(2)** specifies that thermocouples and recording instruments shall be used to monitor process temperatures. Entergy cannot use thermocouples and recording instruments to monitor process temperatures during the performance of the pressurizer heater sleeve mid-wall repair. Because the inside diameter of the new sleeve is only 1.30 inches and welding is being performed internally, there is insufficient space and accessibility along the inside diameter of the heater sleeve to use thermocouples. As an alternative, Entergy will verify the preheat temperature with a pyrometer or temperature indicating crayon prior to welding. With respect to interpass temperature, Entergy will implement a five (5) minute hold time between passes to ensure that the interpass temperature will not approach 350°F. Mock-up testing and supporting engineering analysis (Reference 7) have been performed to demonstrate that the 350°F interpass temperature limitation of the code case will not be exceeded.

5. **IWA-4500(e)(2)** specifies that thermocouple attachment and removal shall be performed in accordance with ASME Section III. Because Entergy will not use thermocouples, the thermocouple attachment and removal requirements of IWA-4500(e)(2) do not apply.

6. **IWA-4532.1** establishes procedure technique requirements that apply when using the SMAW process. Because the proposed ambient temperature temper bead technique of Attachment 1 utilizes the machine or automatic GTAW welding process, the SMAW temper bead technique requirements of paragraph IWA-4532.1 do not apply.

7. **IWA-4532.2(c)** specifies that the repair cavity shall be buttered with six layers of weld metal in which the heat input of each layer is controlled to within +/-10% of that used in the procedure qualification test, and heat input control for subsequent layers shall be deposited with a heat input equal to or less than that used for layers beyond the sixth in the procedure qualification. As an alternative, Entergy proposes to deposit the weld area with a minimum of three layers of weld metal to obtain a minimum thickness of 1/8-inch. The heat input of each weld layer in the 1/8-inch thick section shall be controlled to within +/- 10% of that used in the procedure qualification test. The heat input for subsequent weld layers shall not exceed the heat input used for layers beyond the 1/8-inch thick buttered section (first three weld layers) in the procedure qualification.

8. **IWA-4532.2(c)** specifies that the completed weld shall have at least one layer of weld reinforcement deposited. Once the weld is completed, this reinforcement shall be removed by mechanical means. As an alternative, Entergy's proposed ambient temperature temper bead technique does not include a reinforcement layer.

9. **IWA-4532.2(d)** specifies that, after at least 3/16-inch of weld metal has been deposited, the weld area shall be maintained at a temperature of 450°F - 550°F for a minimum of four (4) hours (for P-No. 3 materials). As an alternative, Entergy's proposed ambient temperature temper bead technique does not include a postweld soak.

10. **IWA-4532.2(e)** specifies that after depositing at least 3/16-inch of weld metal and performing a postweld soak 450°F - 550°F, the balance of welding may be performed at an interpass temperature of 350°F. As an alternative, Entergy proposes that an interpass temperature of 350°F may be used throughout the welding process without a postweld soak.

11. **IWA-4533** specifies the following examinations shall be performed after the completed repair weld has been at ambient temperature for at least 48 hours: (a) the repair weld and preheated band shall be examined by the liquid penetrant method; (b) the repaired region shall be volumetrically examined by the radiographic method, and if practical, by the ultrasonic method. As an alternative to the IWA-4533, Entergy proposes to perform the following examinations of the new mid-wall repair weld after the completed repair weld has been at ambient temperature for at least 48 hours:

    a. A liquid penetrant examination of the completed repair weld shall be performed in accordance with NB-5000 of ASME Section III, 1989 Edition. Acceptance criteria shall comply with NB-5350.

b. The completed repair weld shall be ultrasonically examined in accordance with NB-5000 of ASME Section III, 1989 Edition. Acceptance criteria shall comply with NB-5330.

IV. BASIS FOR PROPOSED ALTERNATIVE

The pressurizer lower head is P-No. 3, Group 3 low alloy steel. If the repair were to be performed in accordance with ASME Section III, Entergy would have two options:

1. Perform a weld repair that includes a postweld heat treatment at 1,100°F – 1,250°F in accordance with NB-4622.1; or

2. Perform a temper bead repair using the SMAW process in accordance with NB-4622.11.

Each option is discussed below.

1. Postweld Heat Treatment

   NB-4600 requires postweld heat treatment (PWHT) to be performed at 1,100°F – 1,250°F. PWHT of the pressurizer head is impractical. PWHT could cause ovalization and misalignment of heater sleeve, which would permanently damage the head including the heater support assembly.

2. Temper Bead Repair Using SMAW

   NB-4622.11 provides temper bead rules for repair welding dissimilar materials using the SMAW process. Because NB-4622.11 does not include temper bead rules for the machine or automatic GTAW process, a manual SMAW temper bead process must be used. However, a manual SMAW temper bead repair is not a desirable option due to radiological considerations. First, resistance heating blankets, thermocouples, and insulation must be installed. Secondly, the manual SMAW temper bead process is a time and dose intensive process. Each weld layer is manually deposited in a high dose and high temperature (350°F) environment. The manual SMAW process also requires the weld crown of the first weld layer to be mechanically removed by grinding. Upon completing repair welding, the resistance heating blankets, thermocouples, and insulation must be removed. Thermocouples and heating blanket-mounting pins must be removed by grinding. The ground areas must be subsequently examined by either magnetic particle or liquid penetrant examination techniques.

Entergy is not requesting an alternative to NB-4600; rather this request proposes an alternative to IWA-4500 and IWA-4530. Owners are allowed by ASME Section XI IWA-4170(b) and IWA-4500(a) to perform temper bead repairs of dissimilar materials. IWA-4170(b) and IWA-4500(a) provide requirements and controls for performing such repairs. For clarification, Entergy will meet applicable requirements of IWA-4000 except as otherwise approved by the NRC in accordance with this request.

IWA-4500 and IWA-4530 of ASME Section XI establish requirements for performing temper bead welding of "dissimilar materials". According to IWA-4530, either the automatic or machine GTAW process or SMAW process may be used. When using the machine GTAW process, a minimum preheat temperature of 300°F must be established

and maintained throughout the welding process while the interpass temperature is limited to 450°F. Upon completion of welding, a postweld soak is performed at 450°F - 550°F for a minimum of 4 hours.

The IWA-4500 and IWA-4530 temper bead welding process is a time and dose intensive process. Resistance heating blankets are attached to the pressurizer base material; typically a capacitor discharge stud welding process is used. Thermocouples must also be attached to the pressurizer base material using a capacitor discharge welding process to monitor preheat, interpass, and postweld soak temperatures. Prior to heatup, thermal insulation is also installed. Upon completion of repair welding (including the postweld soak), the insulation, heating blankets, studs, and thermocouples must be removed from the pressurizer base material. Thermocouples and stud welds are removed by grinding. Ground removal areas are subsequently examined by the liquid penetrant or magnetic particle method. A significant reduction in dose could be realized by utilizing an ambient temperature temper bead process. Therefore, Entergy proposes an alternative welding technique based on the methodology of ASME Code Case N-638.

Suitability of Proposed Ambient Temperature Temper Bead Technique

A. Evaluation of the Ambient Temperature Temper Bead Technique

Research by the Electric Power Research Institute (EPRI) and other organizations on the use of an ambient temperature temper bead operation using the machine GTAW process is documented in EPRI Report GC-111050. According to the EPRI report, repair welds performed with an ambient temperature temper bead procedure utilizing the machine GTAW welding process exhibit mechanical properties equivalent or better than those of the surrounding base material. Laboratory testing, analysis, successful procedure qualifications, and successful repairs have all demonstrated the effectiveness of this process.

The effects of the ambient temperature temper bead welding process of Attachment 1 on mechanical properties of repair welds, hydrogen cracking, and restraint cracking are addressed below.

1. Mechanical Properties

The principal reasons to preheat a component prior to repair welding is to minimize the potential for cold cracking. The two cold cracking mechanisms are hydrogen cracking and restraint cracking. Both of these mechanisms occur at ambient temperature. Preheating slows down the cooling rate resulting in a ductile, less brittle microstructure thereby lowering susceptibility to cold cracking. Preheat also increases the diffusion rate of monatomic hydrogen that may have been trapped in the weld during solidification. As an alternative to preheat, the ambient temperature temper bead welding process utilizes the tempering action of the welding procedure to produce tough and ductile microstructures. Because precision bead placement and heat input control is characteristic of the machine GTAW process, effective tempering of weld heat affected zones is possible without the application of preheat. According to Section 2-1 of EPRI Report GC-111050, "[T]he temper bead process is carefully designed and controlled such that successive weld beads supply the appropriate quantity of heat to the untempered heat affected zone

such that the desired degree of carbide precipitation (tempering) is achieved. The resulting microstructure is very tough and ductile."

The IWA-4530 temper bead process also includes a postweld soak requirement. Performed at 450°F - 550°F for 4 hours (P-No. 3 base materials), this postweld soak assists diffusion of any remaining hydrogen from the repair weld. As such, the postweld soak is a hydrogen bake-out and not a postweld heat treatment as defined by the ASME Code. At 450°F - 550°F, the postweld soak does not stress relieve, temper, or alter the mechanical properties of the weldment in any manner.

Section 2.1 of Attachment 1 establishes detailed welding procedure qualification requirements for base materials, filler metals, restrain, impact properties, and other procedure variables. The qualification requirements of Section 2.1 provide assurance that the mechanical properties of repair welds will be equivalent or superior to those of the surrounding base material.

2. Hydrogen Cracking

Hydrogen cracking is a form of cold cracking. It is produced by the action of internal tensile stresses acting on low toughness heat affected zones. The internal stresses are produced from localized build-ups of monatomic hydrogen. Monatomic hydrogen forms when moisture or hydrocarbons interact with the welding arc and molten weld pool. The monatomic hydrogen can be entrapped during weld solidification and tends to migrate to transformation boundaries or other microstructure defect locations. As concentrations build, the monatomic hydrogen will recombine to form molecular hydrogen – thus generating localized internal stresses at these internal defect locations. If these stresses exceed the fracture toughness of the material, hydrogen induced cracking will occur. This form of cracking requires the presence of hydrogen and low toughness materials. It is manifested by intergranular cracking of susceptible materials and normally occurs within 48 hours of welding.

IWA-4500 establishes elevated preheat and postweld soak requirements. The elevated preheat temperature of 300°F increases the diffusion rate of hydrogen from the weld. The postweld soak at 450°F - 550°F was also established to bake-out or facilitate diffusion of any remaining hydrogen from the weldment. However, while hydrogen cracking is a concern for SMAW, which uses flux covered electrodes, the potential for hydrogen cracking is significantly reduced when using the machine GTAW welding.

The machine GTAW welding process is inherently free of hydrogen. Unlike the SMAW process, GTAW welding filler metals do not rely on flux coverings that may be susceptible to moisture absorption from the environment. Conversely, the GTAW process utilizes dry inert shielding gases that cover the molten weld pool from oxidizing atmospheres. Any moisture on the surface of the component being welded will be vaporized ahead of the welding torch. The vapor is prevented from being mixed with the molten weld pool by the inert shielding gas that blows the vapor away before it can be mixed. Furthermore, modern filler metal manufacturers produce wires having very low residual

hydrogen. This is important because filler metals and base materials are the most realistic sources of hydrogen for automatic or machine GTAW temper bead welding. Therefore, the potential for hydrogen-induced cracking is greatly reduced by using the machine GTAW process.

3. Cold Restraint Cracking

Cold restraint cracking generally occurs during cooling at temperatures approaching ambient temperature. As stresses build under a high degree of restraint, cracking may occur at defect locations. Brittle microstructures with low ductility are subject to cold restraint cracking. However, the ambient temperature temper bead process is designed to provide a sufficient heat inventory so as to produce the desired tempering for high toughness. Because the machine GTAW temper bead process provides precision bead placement and control of heat, the toughness and ductility of the heat affected zone will typically be superior to the base material. Therefore, the resulting structure will be appropriately tempered to exhibit toughness sufficient to resist cold cracking.

In conclusion, no elevated preheat or postweld soak above ambient temperature is required to achieve sound and tough repair welds when performing ambient temperature temper bead welding using the machine GTAW process. This conclusion is based upon strong evidence that hydrogen cracking will not occur with the GTAW process. In addition, automatic or machine temper bead welding procedures without preheat will produce satisfactory toughness and ductility properties both in the weld and weld heat affected zones. The results of previous industry qualifications and repairs further support this conclusion. The use of an ambient temperature temper bead welding procedure will improve the feasibility of performing localized weld repairs with a significant reduction in radiological exposure.

B. Evaluation of Proposed Alternatives to IWA-4500 and IWA-4530

1. According to **IWA-4500(a)**, repairs may be performed to dissimilar base materials and welds without the specified postweld heat treatment of ASME Section III provided the requirements of IWA-4500 and IWA-4530 are met. The temper bead rules of IWA-4500 and IWA-4530 apply to dissimilar materials such as P-No. 43 to P-No. 3 base materials welded with F-No. 43 filler metals. When using the GTAW-machine process, the IWA-4500 and IWA-4530 temper bead process is based fundamentally on an elevated preheat temperature of 300°F, a maximum interpass temperature of 450°F, and a postweld soak of 450°F - 550°F. The proposed alternative of Attachment 1 also establishes requirements to perform temper bead welding on dissimilar material welds that join P-No. 43 to P-No. 3 base materials using F-No. 43 filler metals. However, the temper bead process of Attachment 1 is an ambient temperature technique that only utilizes the GTAW-machine or GTAW-automatic process. The suitability of the proposed ambient temperature temper bead technique is evaluated in this section. The results of this evaluation demonstrate that the proposed ambient temperature temper bead technique provides an acceptable level of quality and safety.

2. According to **IWA-4500(e)(2)**, the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 300°F for the GTAW process during welding while the maximum interpass temperature is limited to 450°F. The ambient temperature temper bead technique of Attachment 1 also establishes a preheat band of at least 1½ times the component thickness or 5 inches, whichever is less. However, the ambient temperature temper bead technique requires a minimum preheat temperature of 50°F and a maximum interpass temperature of 350°F. The suitability of an ambient temperature temper bead technique with reduced preheat and interpass temperatures is addressed in Section IV.A.

3. According to **IWA-4500(e)(2)**, thermocouples and recording instruments shall be used to monitor process temperatures. As explained in Section III.B., Entergy cannot use thermocouples and recording instruments to monitor process temperatures during the performance of the heater sleeve mid-wall repair. Because the inside diameter of the new sleeve is only 1.30 inches and welding is being performed internally, there is insufficient space and accessibility along the inside diameter of the heater sleeve to use thermocouples. As an alternative, Entergy will verify the preheat temperature with a pyrometer or temperature indicating crayon prior to welding. This method will provide an accurate measure of preheat temperature and is extensively used in non-temper bead welding applications. With respect to interpass temperature, Entergy will implement a five (5) minute hold time between passes to ensure that the interpass temperature will not approach 350°F. Because of the large heat sink of the pressurizer and the five minute hold time between passes, the 350°F interpass limitation of the welding procedure will not be exceeded. Mock-up testing and supporting engineering analysis (Reference 7) have been performed by Welding Services, Inc. and Structural Integrity Associates to support this position. This alternative approach for controlling interpass temperature has been approved by the NRC for performing mid-wall repairs of reactor pressure vessel head nozzles at Arkansas Nuclear One - Unit 1, Calvert Cliff Units 1 and 2, Millstone Unit 2, Oconee Units 1 and 2, Palisades, and Point Beach Units 1 and 2.

4. According to **IWA-4532.2(c)**, the repair cavity shall be buttered with six layers of weld metal in which the heat input of each layer is controlled to within +/-10% of that used in the procedure qualification test, and heat input control for subsequent layers shall be deposited with a heat input equal to or less than that used for layers beyond the sixth in the procedure qualification. As an alternative to IWA-4532.2, Entergy proposes to butter the ferritic base material with at least three layers of weld metal to obtain a minimum butter thickness of 1/8-inch. The heat input of each layer in the 1/8-inch thick buttered section shall be controlled to within +/-10% of that used in the procedure qualification test. The heat input for subsequent weld layers shall not exceed the heat input used for layers beyond the 1/8-inch thick buttered section (first three weld layers) in the procedure qualification. When using the ambient temperature temper bead technique of Attachment 1, the machine GTAW process is used. Machine GTAW is a low heat input process that produces consistent small volume heat affected zones. Subsequent GTAW weld layers introduce heat into the heat affected zone produced by the initial weld layer. The heat

penetration of subsequent weld layers is carefully applied to produce overlapping thermal profiles that develop a correct degree of tempering in the underlying heat affected zone. When welding dissimilar materials with nonferritic weld metal, the area requiring tempering is limited to the weld heat affected zone of the ferritic base material along the ferritic fusion line.

After welding the ferritic base material to Alloy 690 with at least 1/8-inch of weld metal (first 3 weld layers), subsequent weld layers should not provide any additional tempering to the weld heat affected zone in the ferritic base material. Therefore, less restrictive heat input controls are adequate after depositing the 1/8-inch thick weld section.

5. According to **IWA-4532.2(c)**, at least one layer of weld reinforcement shall be deposited on the completed weld and with this reinforcement being subsequently removed by mechanical means. In the proposed alternative of Attachment 1, the deposition and removal of a reinforcement layer is not required. A reinforcement layer is required when a weld repair is performed to a ferritic base material or ferritic weld using a ferritic weld metal. On ferritic materials, the weld reinforcement layer is deposited to temper the last layer of untempered weld metal of the completed repair weld. Because the weld reinforcement layer is untempered (and unnecessary), it is removed. However, when repairs are performed to dissimilar materials using nonferritic weld metal, a weld reinforcement layer is not required because nonferritic weld metal does not require tempering. When performing a dissimilar material weld with a nonferritic filler metal, the only location requiring tempering is the weld heat affected zone in the ferritic base material along the weld fusion line. However, the three weld layers of the 1/8-inch thick weld section are designed to provide the required tempering to the weld heat affected zone in the ferritic base material. Therefore, a weld reinforcement layer is not required.

   While Entergy recognizes that IWA-4532.2(c) does require the deposition and removal of a reinforcement layer on repair welds in dissimilar materials, Entergy does not believe that it is necessary for repair using a nonferritic filler material. This position is supported by the fact that ASME Code Case N-638 only requires the deposition and removal of a reinforcement layer of a similar filler material (ferritic) when performing repair welds on similar (ferritic) materials. Repair welds on dissimilar materials using nonferritic filler materials are exempt from this requirement in Code Case N-638.

6. According to **IWA-4532.2(d)**, the weld area shall be maintained at a temperature of 450°F - 550°F for a minimum of 4 hours (for P-No. 3 materials) after at least 3/16-inch of weld metal has been deposited. In the proposed alternative of Attachment 1, a postweld soak is not required. The suitability of an ambient temperature temper bead technique without a postweld soak is addressed in Section IV.A.

7. According to **IWA-4532.2(e)**, after depositing at least 3/16-inch of weld metal and performing a postweld soak at 300°F, the balance of welding may be performed at an interpass temperature of 350°F. As an alternative, Entergy proposes that an interpass temperature of 350°F may be used throughout the welding process without a postweld soak. The proposed ambient temperature

temper bead process of Attachment 1 is carefully designed and controlled such that successive weld beads supply the appropriate quantity of heat to the untempered heat affected zone such that the desired degree of carbide precipitation (tempering) is achieved. The resulting microstructure is very tough and ductile. This point is validated during weld procedure qualification. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat affected zone will be demonstrated to be equal to or better than those of the unaffected base material. The suitability of an ambient temperature temper bead technique without a postweld soak is addressed in Section IV.A.

8. **IWA-4533** specifies that (a) the repair weld and preheated band shall be examined by the liquid penetrant method; (b) the repaired region shall be volumetrically examined by the radiographic method, and if practical, by the ultrasonic method. As an alternative to IWA-4533, Entergy proposes to perform the following examinations after the completed repair weld has been at ambient temperature for at least 48 hours:

   a. Liquid penetrant examination shall be performed in accordance with NB-5000 of ASME Section III, 1989 Edition. Acceptance criteria shall comply with NB-5350.

      Suitability: When using an ambient temperature temper bead technique, an elevated preheat temperature is not used. As a result, there is no preheated band. Therefore, the proposed alternative to only examine the new mid-wall repair weld (including weld heat affected zones) is acceptable.

   b. The completed repair weld shall be ultrasonically examined in accordance with NB-5000 of ASME Section III, 1989 Edition. Acceptance criteria shall comply with NB-5330.

      Suitability: Radiographic examination is impractical since the pressurizer vessel inside diameter is inaccessible for positioning the gamma source. As an alternative to radiographic examination, an ultrasonic examination of the new mid-wall repair weld will be performed. Ultrasonic examination of temper bead repair welds is an acceptable option according to ASME Section XI, IWA-4630 in the 1995 Edition, 1996 Addenda and later (approved by NRC through the 2001 Edition, 2003 Addenda). Ultrasonic examination of repair welds is also required in Code Case N-638. The proposed ultrasonic examination will be performed in accordance with ASME Section III, NB-5000 which includes acceptance criteria that is appropriate for fabrication type flaws.

V. CONCLUSION

10 CFR 50.55a(a)(3) states:

"Proposed alternatives to the requirements of (c), (d), (e), (f), (g), and (h) of this section or portions thereof may be used when authorized by the Director of the Office of Nuclear Reactor Regulation. The applicant shall demonstrate that:

(i) The proposed alternatives would provide an acceptable level of quality and safety, or

(ii) Compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety."

Entergy believes that compliance with the repair rules as stated in ASME Section XI (Reference 1) and as described in Section II of this request would result in unwarranted damage to the pressurizer head assembly. Additionally, the work required to meet the current Code repair method, automatic or machine GTAW temper bead with 300°F minimum preheat and 450°F - 550°F postweld hydrogen bake-out, would be extremely difficult and personnel radiation exposure resulting from set-up, monitoring, and removing the required equipment is not justified.

Entergy also believes that the proposed alternative provides an acceptable level of quality and safety without exposing the pressurizer to potential distortion of the sleeves and heater support structure, as discussed in Section IV. Therefore, Entergy requests that the NRC staff authorize the proposed alternative in accordance with 10 CFR 50.55a(a)(3)(i).

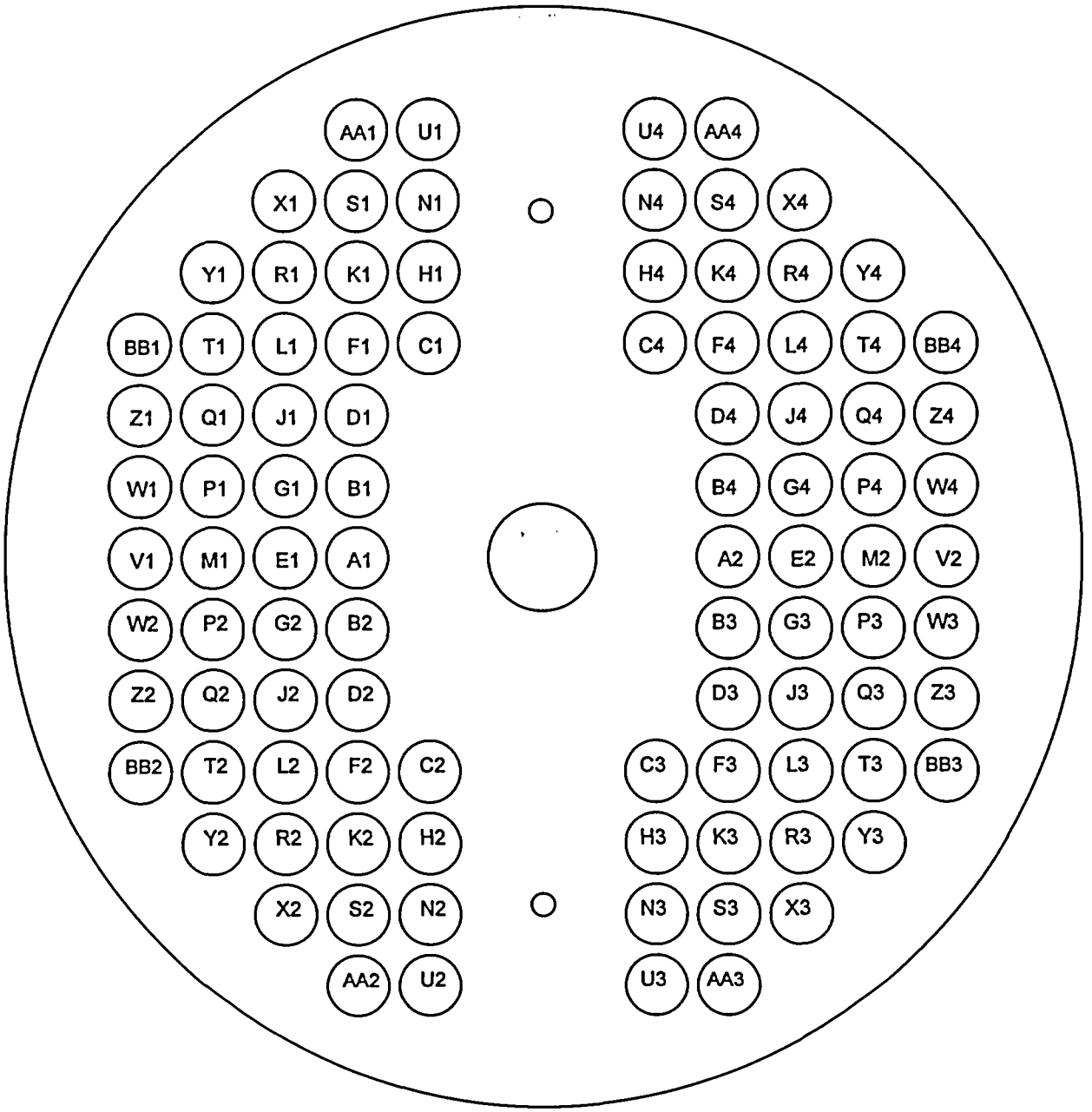


Figure 1

Pressurizer Lower Head Showing Heater Sleeves

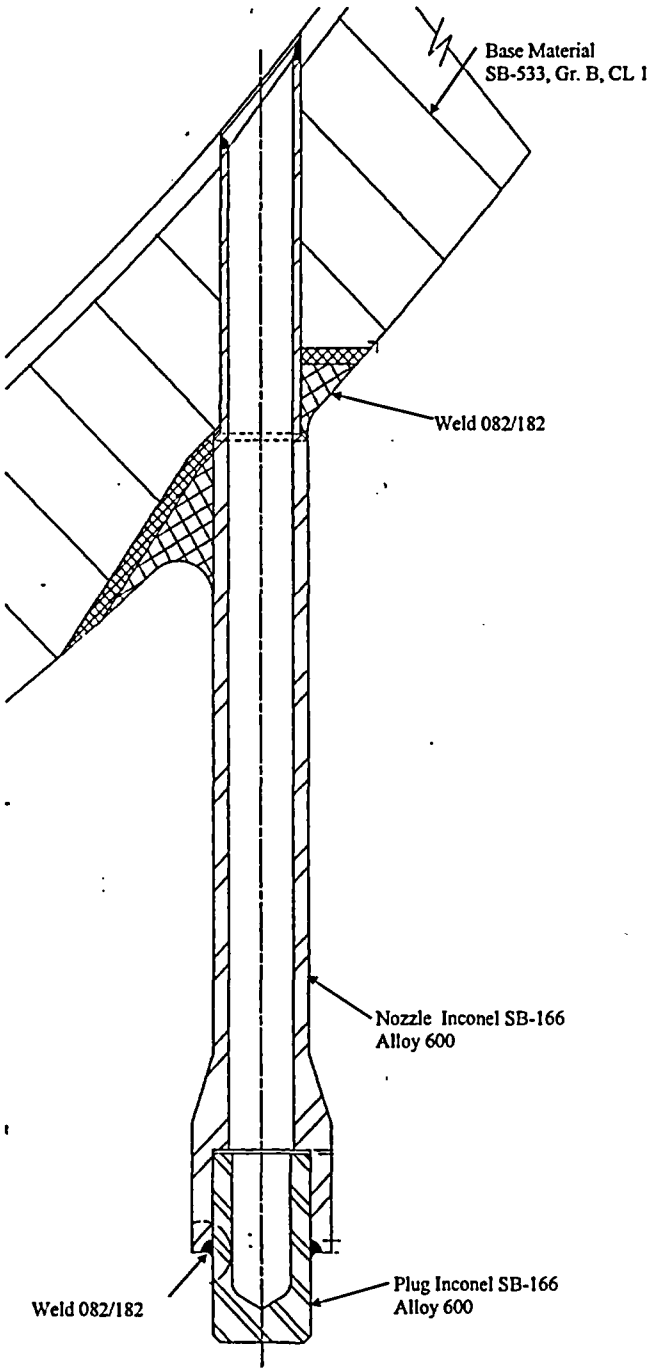
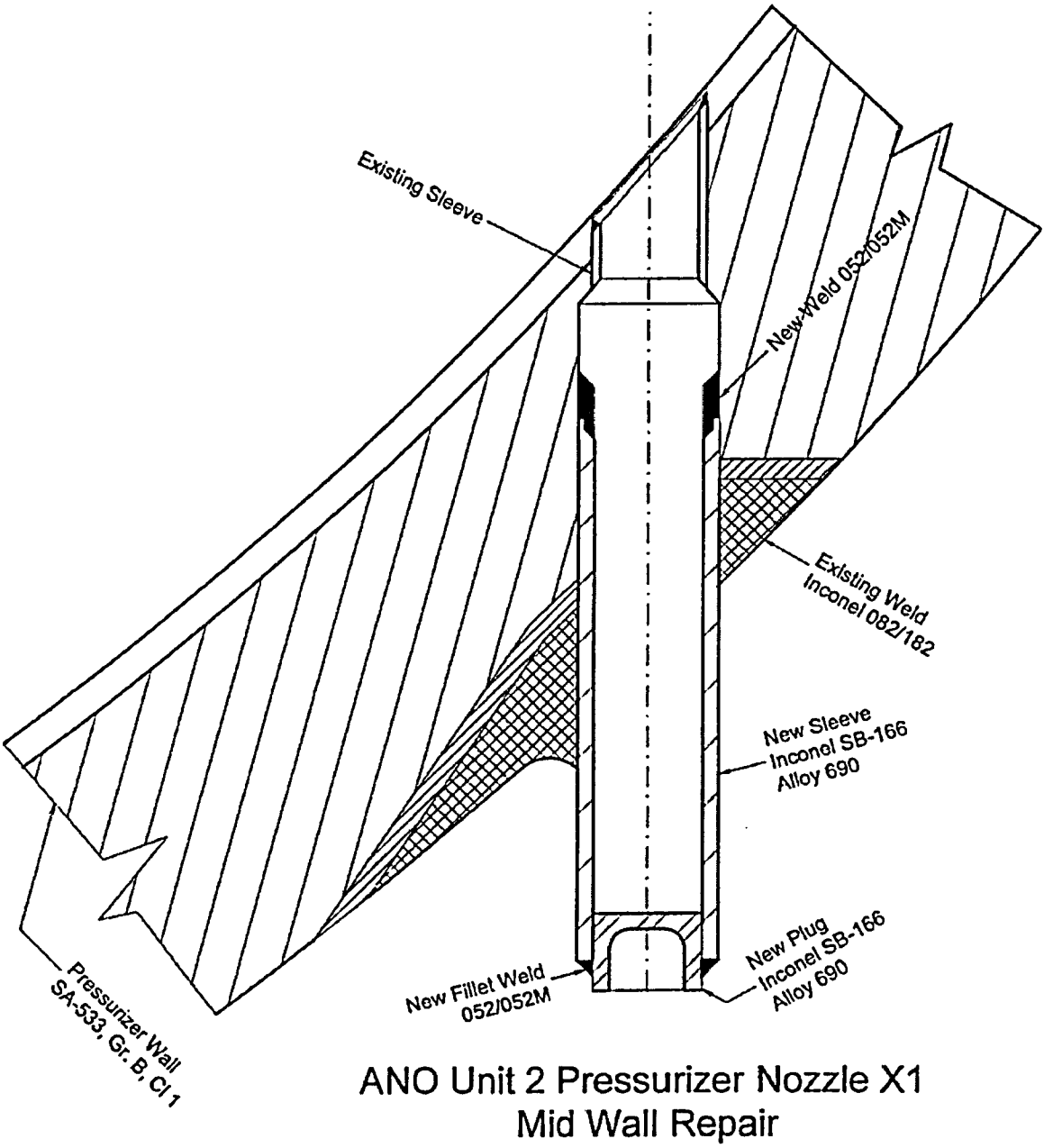


Figure 2

Existing X-1 Heater Sleeve Configuration



ANO Unit 2 Pressurizer Nozzle X1
Mid Wall Repair

Figure 3

REQUEST NO. ANO2-R&R-003

ATTACHMENT 1

DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

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. Repair/replacement activities on nonferritic base materials where the repair cavity is within 1/8-inch of a ferritic base material may also be performed.

(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 temperature of 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) The area prepared for welding shall be suitably prepared for welding in accordance with a written procedure.

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 base materials for the welding procedure qualification will be the same P-Number and Group Number as the materials to be welded. The materials shall be post weld heat treated to at least the time and temperature that was applied to the material being welded.

(b) Consideration will be given to the effects of irradiation on the properties of material, including weld material for applications in the core belt line region of the reactor vessel. Special material requirements in the Design Specification will also apply to the test assembly materials for these applications.

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

(d) The maximum interpass temperature for the first three layers or as required to achieve the 1/8-inch butter thickness in the test assembly will be 150°F. For the balance of the welding, the maximum interpass temperature shall be 350°F.

(e) The 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.

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

(g) Charpy V-notch tests of the ferritic weld metal of the procedure qualification shall meet the requirements as determined in subparagraph (f) above. This test is not required when non-ferritic weld metal is used.

(h) 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 (f) 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-size 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.

(i) 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.

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 shall be deposited by the automatic or machine GTAW process using cold wire feed.

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

(c) The area to be welded will be buttered with a deposit of at least three layers to achieve at least 1/8-inch butter 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 base 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 (or as required to achieve the 1/8-inch butter thickness) in the procedure qualification.

(d) The maximum interpass temperature field applications will be 350°F regardless of the interpass temperature during qualification.

(e) Particular care will be given to ensure that the weld region is free of all potential sources of hydrogen. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

4.0 EXAMINATION:

(a) Prior to welding, a surface examination will be performed in accordance with ASME Section III on the area to be welded.

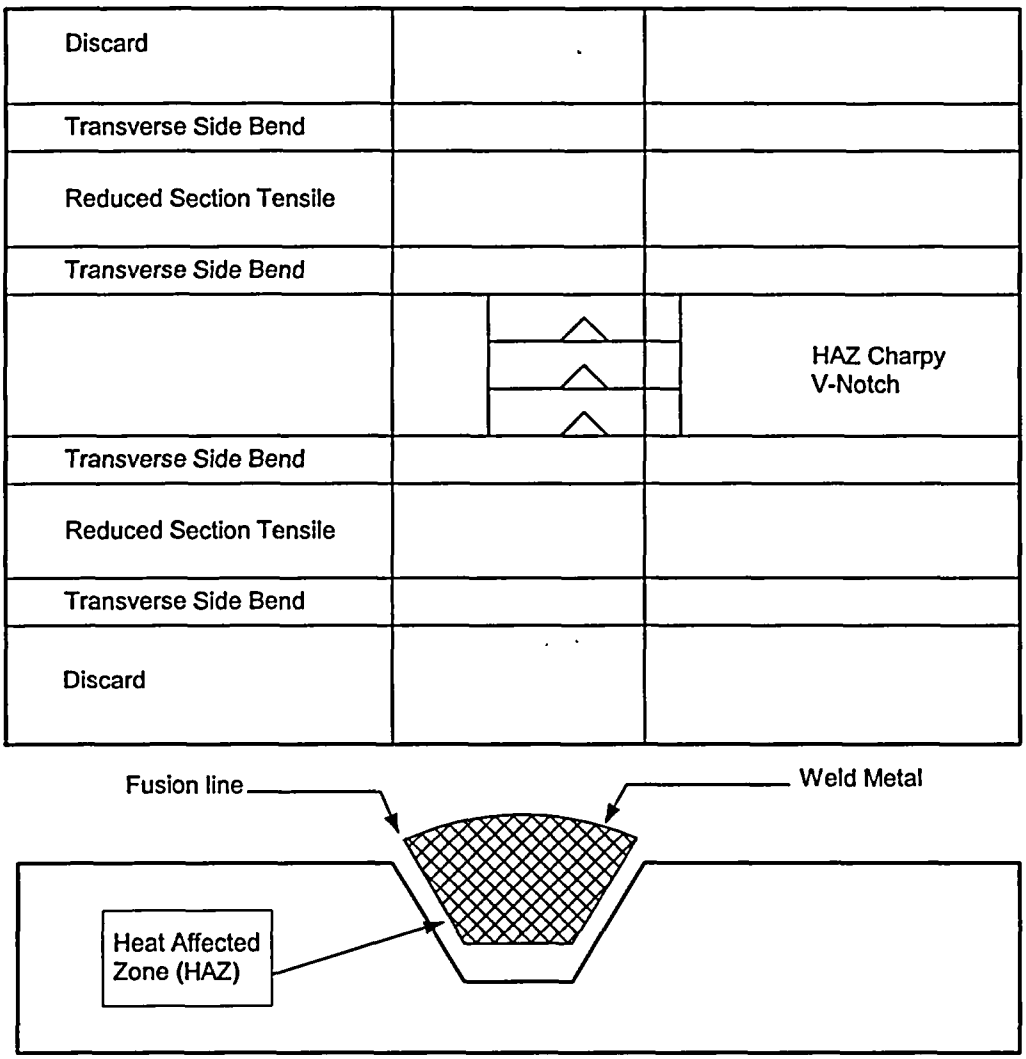
(b) A liquid penetrant examination of the completed repair weld shall be performed in accordance with NB-5000 of ASME Section III after the competed weld has been at ambient temperature for at least 48 hours.

(c) An ultrasonic examination of the completed repair weld shall be performed in accordance with NB-5000 of ASME Section III after the competed weld has been at ambient temperature for at least 48 hours.

(d) NDE personnel performing liquid penetrant and ultrasonic examinations will be qualified and certified in accordance with NB-5500.

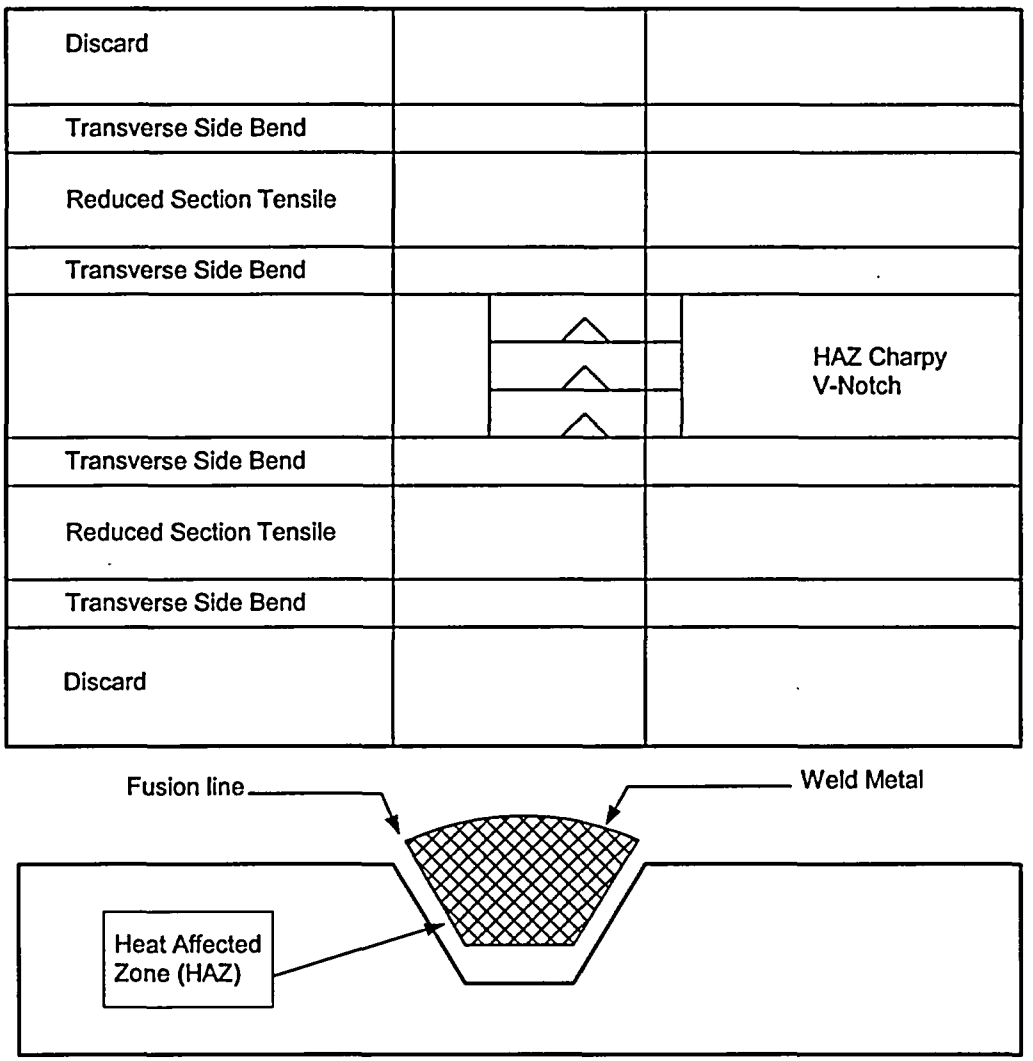
5.0 DOCUMENTATION

Use of Request No. ANO2-R&R-003 shall be documented on NIS-2. Alternatively, repairs may be documented on Form NIS-2A as described in Code Case N-532-1 based on appropriate NRC approval.



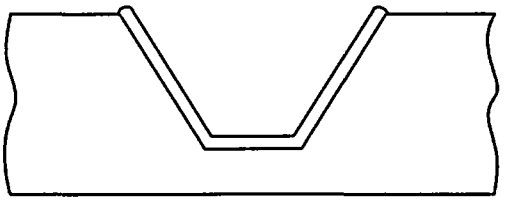
GENERAL NOTE: Base Metal Charpy impact specimens are not shown.

Figure 1 - QUALIFICATION TEST PLATE

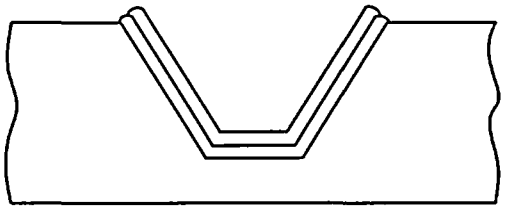


GENERAL NOTE: Base Metal Charpy impact specimens are not shown.

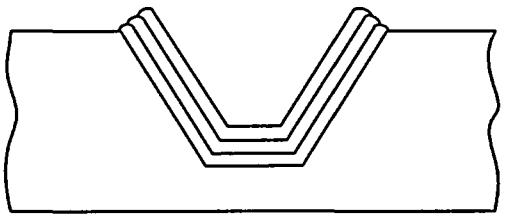
Figure 1 - QUALIFICATION TEST PLATE



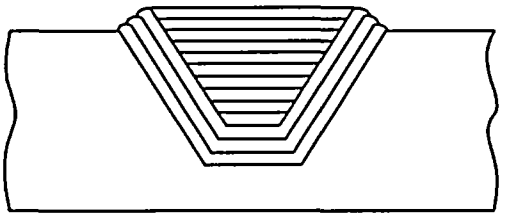
Step 1: Deposit layer one with first layer weld parameters used in qualification.



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 weld metal and HAZ of the base metal are tempered.



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



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

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

Figure 2 - AUTOMATIC OR MACHINE GTAW TEMPER BEAD WELDING