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CNRO-2002-00017

March 29, 2002

U. S. Nuclear Regulatory Commission
Attn.: Document Control Desk
Mail Stop OP1-17
Washington, DC 20555-0001

Subject: Entergy Operations, Inc.
Proposed Alternative to ASME Code Requirements for Weld Repairs

Arkansas Nuclear One – Units 1 and 2
Docket Nos. 50-313 and 50-368
License Nos. DPR-51 and NPF-6

Waterford Steam Electric Station – Unit 3
Docket No. 50-382
License No. NPF-38

Reference: Letter No. CNRO-2002-00008, "Proposed Alternative to ASME Code Requirements for Weld Repairs," dated March 4, 2002

Dear Sir or Madam:

In the referenced letter, Entergy Operations, Inc., (Entergy) proposed to the NRC staff an alternative method to the temper bead welding requirements of ASME Section XI IWA-4300 and IWA-4500. This request, submitted as Relief Request PWR-R&R-001, Rev. 0, is applicable to Arkansas Nuclear One (ANO) – Units 1 and 2, and Waterford Steam Electric Station – Unit 3 (Waterford 3).

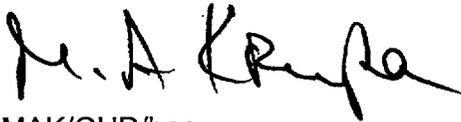
In a recent telephone conference call, the NRC staff requested that Entergy provide additional information supporting this request. A revised request PWR-R&R-001, Rev. 0, which provides the requested information, is attached. Revision bars in the margins of the request denote changes. This revised request replaces the previously submitted request in its entirety.

A047

This letter contains no new commitments beyond those made in the referenced letter.

Should you have any questions regarding this submittal, please contact Guy Davant at (601) 368-5756.

Very truly yours,



MAK/GHD/baa

Enclosure:

1. Request No. PWR-R&R-001, Rev. 0

cc: Mr. C. G. Anderson (ANO)
Mr. W. R. Campbell (ECH)
Mr. J. K. Thayer (ECH)
Mr. J. E. Venable (W3)

Mr. T. W. Alexion, NRR Project Manager (ANO-2)
Mr. R. L. Bywater, NRC Senior Resident Inspector (ANO)
Mr. N. Kalyanam, NRR Project Manager (W3)
Mr. E. W. Merschoff, NRC Region IV Regional Administrator
Mr. W. D. Reckley, NRR Project Manager (ANO-1)

CNRO-2002-00017

ENCLOSURE 1

REQUEST No. PWR-R&R-001, Rev. 0

**ENERGY OPERATIONS, INC.
ARKANSAS NUCLEAR ONE, UNITS 1 and 2
WATERFORD STEAM ELECTRIC STATION, UNIT 3
REQUEST NO. PWR-R&R-001, Revision 0**

I. COMPONENT/EXAMINATION

Component/Number: 1R-1, 2R-1, and RC MRCT0001

Description: Reactor Pressure Vessel (RPV) Head Penetration Nozzles

Code Class: 1

- References:
1. ASME Section XI, 1992 Edition with portions of the 1993 Addenda as listed in References 9 , 10, and 12
 2. ASME Section III, Subsection NB, 1965 Edition, Summer 1967 Addenda
 3. ASME Section III, Subsection NB, 1968 Edition, Summer 1970 Addenda
 4. ASME Section III, Subsection NB, 1971 Edition, Summer 1971 Addenda
 5. ASME Section III, Subsection NB, 1971 Edition, Summer 1972 Addenda
 6. ASME Section III, Subsection NB, 1989 Edition
 7. ASME Section XI Code Case N-638, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique"
 8. EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temper Bead Applications"
 9. CEP-ISI-001, "Waterford 3 Steam Electric Station Inservice Inspection Plan"
 10. CEP-ISI-004, "Arkansas Nuclear One Unit 2 Inservice Inspection Plan"
 11. Letter 1CAN090102, "30 Day Response to NRC Bulletin 2001-01 for ANO-1; Circumferential Cracking of VHP Nozzles," dated September 4, 2001
 12. CEP-ISI-002, "Arkansas Nuclear One Unit 1 Inservice Inspection Plan"

13. Letter 2CAN090102, "30 Day Response to NRC Bulletin 2001-01 for ANO-2; Circumferential Cracking of VHP Nozzles," dated September 4, 2001

14. Letter W3F1-2001-0081, "30 Day Response to NRC Bulletin 2001-01 for Waterford 3; Circumferential Cracking of VHP Nozzles," dated September 4, 2001

Unit / Inspection
Interval:

Arkansas Nuclear One Unit 1 (ANO-1) / Third (3rd) 10-Year
interval

Arkansas Nuclear One Unit 2 (ANO-2) / Third (3rd) 10-Year
interval

Waterford 3 Steam Electric Station (Waterford 3) / Second (2nd)
10-Year Interval

II. 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-Number 43 nickel alloy to P-Number 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" or less of nonferritic weld deposit exists above the original fusion line after defect removal."

Temper bead repairs to RPV head penetration nozzles and J-welds are performed in accordance with IWA-4500 and IWA-4530 whenever the repair cavity is within 1/8" of the ferritic base materials of the RPV head. When the Gas Tungsten Arc Welding (GTAW) process is used in accordance with IWA-4500 and IWA-4530, then 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 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 post weld soak or hydrogen bake-out at 450°F - 550°F for a minimum of 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

RPV penetration nozzles at ANO-2 and Waterford 3 are considered to have a moderate susceptibility to Primary Water Stress Corrosion Cracking (PWSCC) based upon a susceptibility ranking of greater than 5 effective full power years (EFPY) but less than 30 EFPY from the Oconee Nuclear Station 3 time-at-temperature condition. ANO-1 has already experienced cracking. Susceptibility rankings for ANO-1, ANO-2, and Waterford 3 have been reported to the NRC in response to NRC Bulletin 2001-01 (References 11, 13, and 14).

Should repair welding of RPV head penetration nozzle base materials or J-welds encroach (within 1/8") on the ferritic base material of the RPV head, temper bead weld repairs would be required. See the following figures for additional details.

- Figure 1: Typical RPV Penetration Nozzle
- Figure 2: Example Repair of an RPV Penetration Nozzle J-Weld
- Figure 3: Example Repair of an RPV Penetration Nozzle

B. Proposed Alternative

Pursuant to 10CFR50.55a(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 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 "welders" 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 1-1/2 times the component thickness or 5", 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 1-1/2 times the component thickness or 5", whichever is less, shall be preheated and maintained at a minimum temperature of 50°F for the GTAW process during welding; maximum

interpass temperature shall be 150°F for the 1/8" butter thickness (first three weld layers as a minimum) and 350°F for the balance of welding.

4. **IWA-4500(e)(2)** specifies that thermocouples and recording instruments shall be used to monitor process temperatures. As an alternative, Entergy proposes to monitor preheat and interpass temperatures using an infrared thermometer.
5. **IWA-4500(e)(2)** specifies that thermocouple attachment and removal shall be performed in accordance with ASME Section III. Because Entergy will use an infrared thermometer to monitor preheat and interpass temperatures, thermocouples will not be used. Therefore, 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** establishes procedure technique requirements that apply when using the GTAW process but do not address joint design qualification of the repair cavity. As an alternative, Entergy proposes to qualify the joint design of the proposed repair cavity by requiring that the root width and included angle of the repair cavity in the test assembly be no greater than the minimum specified for the repair.
8. **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 butter the weld area with a minimum of three layers of weld metal to obtain a minimum butter thickness of 1/8". The heat input of each weld layer in the 1/8" 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" thick buttered section (first three weld layers) in the procedure qualification.
9. **IWA-4532.2(c)** specifies that the completed weld shall have at least one layer of weld reinforcement deposited and then 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.
10. **IWA-4532.2(d)** specifies that, after at least 3/16" of weld metal has been deposited, 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). As an alternative, Entergy's proposed ambient temperature temper bead technique does not include a postweld soak.

11. **IWA-4532.2(e)** specifies that after depositing at least 3/16" of weld metal and performing a postweld soak at 450°F - 550°F, the balance of welding may be performed at an interpass temperature of 350°F. As an alternative, Entergy's proposes that an interpass temperature of 350°F may be used after depositing at least 1/8" of weld metal without a postweld soak.
12. **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. Entergy will perform the liquid penetrant examination of the completed repair weld and preheated band as required by IWA-4533. As an alternative to the volumetric examination of IWA-4533, Entergy proposes the following examinations.
 - A. Repair Welds in RPV Penetration Nozzle Base Materials
 - Repair welds will be ultrasonically examined in accordance with NB-5000 of ASME Section III after the completed repair weld has been at ambient temperature for at least 48 hours. Acceptance criteria shall be in accordance with NB-5330.
 - Repair welds will also be examined by the eddy current method after the completed repair weld has been at ambient temperature for at least 48 hours. The eddy current inspection will complement the ultrasonic examination by providing sensitivity to surface and subsurface flaws along the inspection surface.
 - B. Repair Welds in RPV Penetration Nozzle J-Welds
 - Repair welds will be progressively examined by the liquid penetrant method in accordance with NB-5245 of ASME Section III. The liquid penetrant examinations will be performed in accordance with NB-5000 of ASME Section III. Acceptance criteria shall be in accordance with NB-5350.

This request for alternative is specific to the repairs described below.

- Localized weld repair of RPV head penetration nozzle base materials along the inside diameter of the nozzle and above the J-weld where 1/8" or less of Alloy 600 base material exists between the repair cavity of the nozzle and the ferritic base material of the RPV head. See Figures 1 and 3.
- Localized weld repair of RPV head penetration nozzle J-welds where 1/8" or less of Inconel weld metal exists between the J-weld repair cavity and the ferritic base material of the RPV head. See Figures 1 and 2.

IV. BASIS FOR PROPOSED ALTERNATIVE

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. Resistant heating blankets are attached to the RPV head; typically a capacitor discharge stud welding process is used. Thermocouples must also be attached to the RPV head using a capacitor discharge welding process to monitor preheat, interpass, and postweld soak temperatures. Prior to heat-up, 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 RPV head. 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. Because the ASME Code does not presently include rules for ambient temperature temper bead welding, Entergy proposes the alternative described in Section III.B.

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 affects 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 principle 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, "the 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 to 550°F for 4 hours (P-Number 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 to 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. Simulating base materials, filler metals, restraint, impact properties, and 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. It should also be noted that the qualification requirements of Section 2.1 of Attachment 1 are identical to those in IWA-4530. Ambient temperature temper bead WPS 3-43/52-TB MC-GTAW-N638 was qualified in accordance with Attachment 1. Based upon the procedure qualification test results, the impact properties of the base material heat affected zone were superior to those of the unaffected base material. The mechanical testing results for the procedure qualification are summarized in Section IV.C.

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 manifest 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 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 are susceptible to moisture absorption from the environment. Conversely, the GTAW process utilizes dry inert shielding gases that covers 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.

As explained above, the potential for hydrogen induced cracking is greatly reduced by using machine GTAW process. However, should it occur, cracks would be detected by the final nondestructive examinations (NDE) performed after the completed repair weld has been at ambient temperature for at least 48 hours as required in Section 4.0 of Attachment 1. Regarding this issue, EPRI Report GC-111050, Section 6.0 concluded the following:

“No preheat temperature or postweld bake above ambient temperature is required to achieve sound machine GTAW temper bead repairs that have high toughness and ductility. This conclusion is based on the fact that the GTAW process is an inherently low hydrogen process regardless of the welding environment. Insufficient hydrogen is available to be entrapped in solidifying weld material to support hydrogen delayed cracking. Therefore, no preheat nor postweld bake steps are necessary to remove hydrogen because the hydrogen is not present with the machine GTAW process.”

3. COLD RESTRAINT CRACKING

Cold 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. Additionally, even if cold cracking were to occur, it would be detected by the final NDE which is performed after the completed repair weld has been at ambient temperature for at least 48 hours as required in Section 4.0 of Attachment 1.

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. EPRI Report GC-111050, Section 6.0 concluded the following:

“Repair of RPV components utilizing machine GTAW temper bead welding at ambient temperature produces mechanical properties that are commonly superior to those of the service-exposed substrate. The risk of hydrogen delayed cracking is minimal using the GTAW process. Cold stress cracking is resisted by the excellent toughness and ductility developed in the weld HAZ (heat affected zone). Process design and geometry largely control restraint considerations, and these factors are demonstrated during weld procedure qualification.”

B. Evaluation of Proposed Alternatives to ASME Section XI, 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 which 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 1-1/2 times the component thickness or 5", 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 1-1/2 times the component thickness or 5", whichever is less. However, the ambient temperature temper bead technique requires a minimum preheat temperature of 50°F, a maximum interpass temperature of 150°F for the first three layers, and a maximum interpass temperature of 350°F for the balance of welding. 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 an alternative to IWA-4500(e)(2), Entergy proposes to monitor preheat and interpass temperatures using an infrared thermometer. Infrared thermometers are hand-held devices that can be used to monitor process temperature from a remote location. To determine the preheat and interpass temperatures during the welding operation, the infrared thermometer is pointed at a target location adjacent to the repair weld. The target location is identified by a circle consisting of eight laser spots. A single laser spot in the center of the circle identifies the center of the measurement area. As the distance (D) from the object being measured increases, the diameter of the target location or "spot size" (S) also increases. The optics of the infrared thermometer sense emitted, reflected, and transmitted energy from the target location that is collected and focused onto a detector. The infrared thermometer's electronics translate the information into a temperature reading that is displayed on the unit. The infrared thermometer measures the maximum, minimum, differential, and average temperatures across the target location. This data can be stored and recalled until a new measurement is taken. Entergy plans to use a Raytek Raynger ST80 (or equivalent) infrared thermometer. The Raytek Raynger ST80 infrared thermometer measures temperatures from -25°F to 1400°F over the target location with the following accuracy: +/-3°F over the 0°F - 73°F temperature range and +/-1% of reading or 2°F, whichever is greater, above 73°F. Display resolution is 0.1°F. The distance (D) to "spot size" (S) is 50:1 for the Raytek Raynger ST80 infrared thermometer. Since the "distance" (D) to the target location on the RPV penetration nozzle or J-weld is estimated to range from 3'-0 to 6'-0, the "spot size" (S) will also range from 0.72" to 2.22". The infrared thermometer will be appropriately calibrated prior to use.

4. **IWA-4532.2** establishes procedure technique requirements but do not address joint design qualification of the repair cavity. As an alternative to IWA-4532.2, Entergy proposes to qualify the joint design of the proposed repair cavity. Paragraph 2.1(c) of Attachment 1 requires that the root width and included angle of the repair cavity in the test assembly be no greater than the minimum specified for the repair. This requirement ensures that the

welding procedure is only used in repair cavity configurations where it has demonstrated capability (i.e. sufficient access to deposit root passes, tie-in to the beveled or tapered walls of the repair cavity, provide appropriate tempering, and ensure complete weld fusion).

5. 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 repair cavity or weld area with at least three layers of weld metal to obtain a minimum butter thickness of 1/8". The heat input of each layer in the 1/8" 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" 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 buttering the ferritic base material with at least 1/8" 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" thick buttered section. It should also be noted that IWA-4530 does not require temper bead welding except "where 1/8" or less of nonferritic weld deposit exists above the original fusion line after defect removal". The proposed heat input techniques of Attachment 1 were utilized in the qualification of Welding Procedure Specification (WPS) 3-43/52-TB MC-GTAW-N638. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat affected zone were superior to those of the unaffected base material. Therefore, the proposed heat input controls of Attachment 1 provide an appropriate level of tempering. Test results of the WPS qualification are provided in Section IV.C.

6. 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" thick butter 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 this reinforcement layer is necessary. This position is supported by the fact that ASME Code Case N-638 only requires the deposition and removal of a reinforcement layer when performing repair welds on similar (ferritic) materials. Repair welds on dissimilar materials are exempt from this requirement.

7. 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" 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.
8. According to **IWA-4532.2(e)**, after depositing at least 3/16" of weld metal and performing a postweld soak at 450°F-550°F, the balance of welding may be performed at an interpass temperature of 350°F. As an alternative, Entergy's proposes that an interpass temperature of 350°F may be used after depositing at least 1/8" of weld metal 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 by the qualification of WPS 3-43/52-TB MC-GTAW-N638. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat affected zone were superior to those of the unaffected base material. Test results of the WPS qualification are provided in Section IV.C. The suitability of an ambient temperature temper bead technique without a postweld soak is addressed in Section IV.A.
9. **IWA-4533** specifies that the repair weld shall be volumetrically examined by the radiographic method, and if practical, by the ultrasonic method after the completed repair weld has been at ambient temperature for at least 48 hours. As an alternative to the volumetric examinations of IWA-4533, Entergy proposes the examinations described below. The suitability of the alternative examinations is addressed in Section IV.D.

- a. Examination of Repair Welds in RPV Penetration Nozzle Base Materials
 - Repair welds will be ultrasonically examined in accordance with NB-5000 of ASME Section III after the completed repair weld has been at ambient temperature for at least 48 hours. Acceptance criteria shall be in accordance with NB-5330.
 - Repair welds will also be examined by the eddy current method after the completed repair weld has been at ambient temperature for at least 48 hours. The eddy current inspection will complement the ultrasonic examination by providing sensitivity to surface and subsurface flaws along the inspection surface.
- b. Examination of Repair Welds in RPV Penetration Nozzle J-Welds
 - Repair welds will be progressively examined by the liquid penetrant method in accordance with NB-5245 of ASME Section III. The liquid penetrant examinations will be performed in accordance with NB-5000 of ASME Section III. Acceptance criteria shall be in accordance with NB-5350.

C. Mechanical Properties of WPS 3-43/52-TB MC-GTAW-N638

WPS 3-43/52-TB MC-GTAW-N638 was qualified in accordance with Attachment 1. The welding procedure qualification test assembly was 3" thick and consisted of SA-533, Grade B, Class 1 (P-No. 3, Group 3) and SB-166, N06690 (P-No. 43) base materials. Prior to welding, the SA-533, Grade B, Class 1 portion of the test assembly was heat treated for 40 hours at 1,200°F. The repair cavity in the test assembly was 1.5" deep. The test assembly cavity was welded in the 3G (vertical) position using ERNiCrF3-7 (F-No. 43) filler metal. Results of the welding procedure qualification were documented on procedure qualification record PQR 707. Results of mechanical testing – tensile testing, bend testing, Charpy V-notch testing, and drop weight testing – are summarized below. WPS 3-43/52-TB MC-GTAW-N638 will be used to perform the repair welding activities described in Section III.B.

- Tensile test specimens exhibited a tensile strength that exceeded 80,000 PSI and were acceptable per ASME Section IX. The bend testing was also acceptable. Test results are as follows:

Tensile Test Results

Specimen No.	Tensile Specimen	Actual Tensile Strength	Failure
Test 1-1	0.505" Turned Specimen	86,600 psi	Ductile/Base
Test 1-2	0.505" Turned Specimen	84,500 psi	Ductile/Base
Test 2-3	0.505" Turned Specimen	82,400 psi	Ductile/Base
Test 2-4	0.505" Turned Specimen	86,600 psi	Ductile/Base

Bend Test Results

Specimen Type and Figure No.	Result
Side Bend 1 QW-462.2	Acceptable
Side Bend 2 QW-462.2	Acceptable
Side Bend 3 QW-462.2	Acceptable
Side Bend 4 QW-462.2	Acceptable

- Drop weight and Charpy V-notch testing of the SA-533, Grade B, Class 1 "unaffected" base material was performed. Based upon drop weight testing of the SA-533, Grade B, Class 1 "unaffected" base material, a nil ductility transition temperature (T_{NDT}) of -50°F was established. Charpy V-notch testing was also performed at $+10^{\circ}\text{F}$. All three Charpy V-notch specimens exhibited at least 35 mils and 50 ft-lbs. Based upon the above testing, an RT_{NDT} of -50°F was established for the SA-533, Grade B, Class 1 base material. Test results are as follows:

Drop Weight Test: Unaffected Base Material				
Specimen ID	Specimen Type	Test Temperature	Drop Weight Break	T_{NDT}
DW1	P-3	-40°F	No	-50°F
DW2	P-3	-40°F	No	-50°F

Charpy V-Notch Tests: Unaffected Base Material				
Specimen ID	Test Temperature	Absorbed Energy (ft-lbs)	Lateral Expansion(mils)	% Shear Fracture
1	$+10^{\circ}\text{F}$	59.0	50.0	60.0
2	$+10^{\circ}\text{F}$	51.0	43.0	50.0
3	$+10^{\circ}\text{F}$	50.0	45.0	50.0
Average	$+10^{\circ}\text{F}$	53.3	46.0	53.3

- Charpy V-notch testing of the SA-533, Grade B, Class 1 heat affected zone was also performed at $+10^{\circ}\text{F}$. The absorbed energy, lateral expansion, and percent shear fracture of the heat affected zone test specimens were compared to the test values of the unaffected base material specimens. The average values of the three heat affected zone specimens were greater than those of the unaffected base material specimens. Based upon these results, it is clear that the proposed ambient temperature temper bead process improved the heat affected zone properties. Test results are as follows:

Charpy V-Notch Tests: Heat Affected Zone				
Specimen ID	Test Temperature	Absorbed Energy (ft-lbs)	Lateral Expansion(mils)	% Shear Fracture
1	+10°F	85.0	65.0	90.0
2	+10°F	136.0	64.0	75.0
3	+10°F	124.0	49.0	30.0
Average	+10°F	115.0	59.3.0	65.0

D. Suitability of Alternative Nondestructive Examinations (NDE)

IWA-4533 specifies that the repaired region shall be examined by the radiographic method, and if practical, by the ultrasonic method. The NDE requirements of IWA-4533 were established based upon a temper bead weld repair to butt welds. Figures IWA-4532.1-1 and IWA-4532.2-1 clearly indicate this. While the requirement to perform a radiographic examination, and if practical, an ultrasonic examination of a butt weld between a nozzle and pipe is appropriate, these examinations are not appropriate for weld repairs of RPV penetration nozzle base materials or J-welds. See Figures 1, 2, and 3. Each type of repair is discussed below.

1. Base Material Repairs in RPV Penetration Nozzles

Impracticality of Radiographic Examinations

Radiography is not appropriate for base material weld repairs of RPV penetration nozzles. Radiographic techniques require that the source of radiation be placed as near normal to the item being examined as possible, with the film in intimate contact with the item on the opposite surface. An attempt to radiograph repair welds in the RPV penetration nozzles would have the radiation source being placed at various angles other than normal, penetrating from fractions of an inch of material thickness up to multiple inches of material thickness. Image quality indicators (penetrameters) would have to be placed on the inside bores of the RPV penetration nozzles. Multiple exposures would be required, and the image distortion would increase as the repair weld moved up the nozzle bore. The required radiographic sensitivity and geometric unsharpness would not be obtainable with generally used radiographic techniques. Depending on the location of the repair weld, access to both surfaces of the RPV nozzle may not be available to allow radiographic examinations. In other cases, clearances between the RPV nozzles and the RPV head would make radiography of a repair weld impossible. Multiple exposures, complex geometry and thickness, and the adverse radiological environment make radiographic examination of RPV penetration nozzle repair welds impractical.

Suitability of Proposed Alternative

Meaningful radiographic examination of repair welds in RPV penetration nozzle base materials cannot be performed. As an alternative, Entergy proposes to utilize the ultrasonic and eddy current examination methods. The ultrasonic examination method will use a combination of Time of Flight Diffraction (TOFD) and standard 0° pulse-echo techniques.

The TOFD approach utilizes two pairs of 0.250" diameter, 55° refracted-longitudinal wave transducers pointed at each other. One of the transducers sends sound into the inspection volume, while the other transducer receives the reflected and diffracted signals, as they interact with the material. There will be one TOFD pair looking in the axial direction of the penetration tube, and one TOFD pair will be looking in the circumferential direction of the penetration tube. The TOFD technique is primarily responsible for detecting and characterizing planer-type defects within the full volume of the penetration tube. This TOFD ultrasonic technique will be used in the pre-inspections of the RPV penetration nozzles as well as in the post-repair inspections.

The standard 0° pulse-echo ultrasonic approach utilizes two 0.250" diameter straight beam transducers. One transducer uses a center frequency of 2.25 MHz while the other uses a frequency of 5.0 MHz. The 0° technique is primarily responsible for plotting the penetration tube outside diameter location and the J-groove attachment weld location, which will aid in defect orientation and sizing information. Additionally, the 0° technique will be capable of locating and sizing any laminar-type defects that may be encountered. These transducers will interrogate the weld repair area for lack of fusion and other laminar-type defects. This ultrasonic technique will be used in the pre-inspections of the RPV penetration nozzles as well as in the post-repair inspections.

The eddy current examination approach utilizes a 5 mm diameter, "cross wound" probe design, which is capable of operating frequencies between 75 and 500 kHz. This technique is primarily responsible for detection and length sizing of defects, which are open to the inside diameter surface of the penetration tube. Since this particular probe design produces eddy currents that penetrate to approximately 0.030" into the inside diameter surface, it will also aid in the evaluation of very shallow surface defects. For post-repair inspection purposes, this eddy current examination technique will provide the necessary surface examination of the weld repair area. This eddy current technique will be used in the pre-inspections of the RPV penetration nozzles as well as in the post-repair inspections.

The above ultrasonic and eddy current examination techniques have been demonstrated capable of detecting axial and circumferential PWSCC indications in the nozzle material, utilizing cracked nozzle samples which were taken from the Oconee-3 cracked RPV penetration nozzles. Additionally, a mock-up of a typical RPV penetration nozzle was built by the

EPRI Center on behalf of Entergy and the EPRI Materials Reliability Program (MRP). The mock-up was built to aid in the development of these NDE processes. This mock-up contains axial and circumferential crack-like defects in the volume of the tube, both above and below the J-groove attachment weld. Mock-up defects were fabricated by cutting narrow notches of specified lengths and depths using electrical discharge machining (EDM). The notches were then squeezed using the Cold Isostatic Process (CIP). This process produces flaws that exhibit characteristics similar to PWSCC. (The CIP process has also been used by the Performance Demonstration Initiative Program.) The described demonstrations have been performed and documented by the MRP and EPRI. The proposed ultrasonic and eddy current examinations meet or exceed the requirements of NB-5000 of ASME Section III.

Examination Requirements in Later Editions/Addenda of ASME Section XI

IWA-4533 of the 1992 Edition of ASME Section XI requires a radiographic examination, and if practical an ultrasonic examination. However, according to IWA-4170, "later Editions and Addenda of Section XI, either in their entirety or portions thereof, may be used for the Repair/Replacement Program, provided these Editions and Addenda of Section XI at the time of the planned repair or replacement are acceptable to the enforcement and regulatory authorities having jurisdiction at the plant site." According to 10CFR50.55a(b)(2), the NRC has approved Editions and Addenda of ASME Section XI through the 1995 Edition and Addenda through the 1996 Addenda. Therefore, based upon IWA-4170 and 10CFR50.55a(b)(2), portions of later editions and addenda of ASME Section XI through the 1996 Addenda of the 1995 Edition may be used for repair and replacement activities.

The 1996 Addenda of the 1995 Edition revised the examination requirements of IWA-4530 for temper bead welding of dissimilar materials. Instead of a radiographic examination, and if practical, an ultrasonic examination of the repair weld, IWA-4534 of the 1996 Addenda requires the following: "the weld shall be volumetrically examined." Note that the examination requirements for temper bead repair welds in dissimilar materials are addressed in IWA-4634 of the 1996 Addenda.

The 1992 Edition of ASME Section XI allows the use of later editions and addenda of Section XI, in whole or in part. The 1992 Edition does not specifically require that the related requirements of the later editions or addenda be met. However, to meet the intent of ASME Section XI in later editions and addenda with regard to related requirements, Entergy has performed a review of the temper bead requirements in the 1996 Addenda. The results of this review demonstrate that the provisions of IWA-4634 are stand-alone and are not based upon provisions of other related requirements. The ASME Section XI requirements in IWA-4533 of the 1992 Edition and IWA-4634 of the 1996 Addenda are specific to examination of repair welds. To more adequately address the volumetric examination requirements applicable to various repair scenarios, the change incorporated into the 1996

Addenda generalizes the examination criteria and removes specificity (i.e., repair weld examination requirement changed from radiography and, if practical, ultrasonic examination, to volumetric examination). Therefore, based upon the 1996 Addenda of ASME Section XI, the ultrasonic examination being proposed by Entergy is acceptable as endorsed by 10CFR50.55a.

2. Weld Repairs in RPV Penetration Nozzle J-Welds

Impracticality of Volumetric Examinations

Radiographic examination of weld repairs of RPV penetration nozzle J-welds is not practical. Meaningful radiographic examination 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. Ultrasonic examination of the J-weld would also be impractical.

Suitability of Proposed Alternative

As an alternative to radiographic and ultrasonic examinations, Entergy proposes to perform a progressive liquid penetrant of the J-weld repair weld in accordance with NB-5245 of ASME Section III. It should be noted that ASME Section III does not require volumetric examination of J-welds. According to NB-3352.4(d)(1), "partial penetration welds used to connect nozzles as permitted in NB-3337.3 shall meet the fabrication requirements of NB-4244(d) and shall be capable of being examined in accordance with NB-5245." NB-4244(d) establishes fabrication details for nozzles welded with partial penetration welds as shown in Figures NB-4244(d)-1 and NB-4244(d)-2.

According to NB-5245, "Partial penetration welds, as permitted in NB-3352.4(d), and as shown in Figures NB-4244(d)-1 and NB-4244(d)-2, shall be examined progressively using either the magnetic particle or liquid penetrant method. The increments of examination shall be the lesser of one-half of the maximum weld dimension measured parallel to the centerline of the connection or 1/2". The surface of the finished weld shall also be examined by either method."

The partial penetration J-welds of the RPV penetration nozzles were designed and fabricated in accordance with NB-3352.4(d) and NB-4244(d). Therefore, according to NB-3352.4(d), the code required examination for these partial penetration J-welds is a progressive liquid penetrant examination performed in accordance with NB-5245. A volumetric examination is not required.

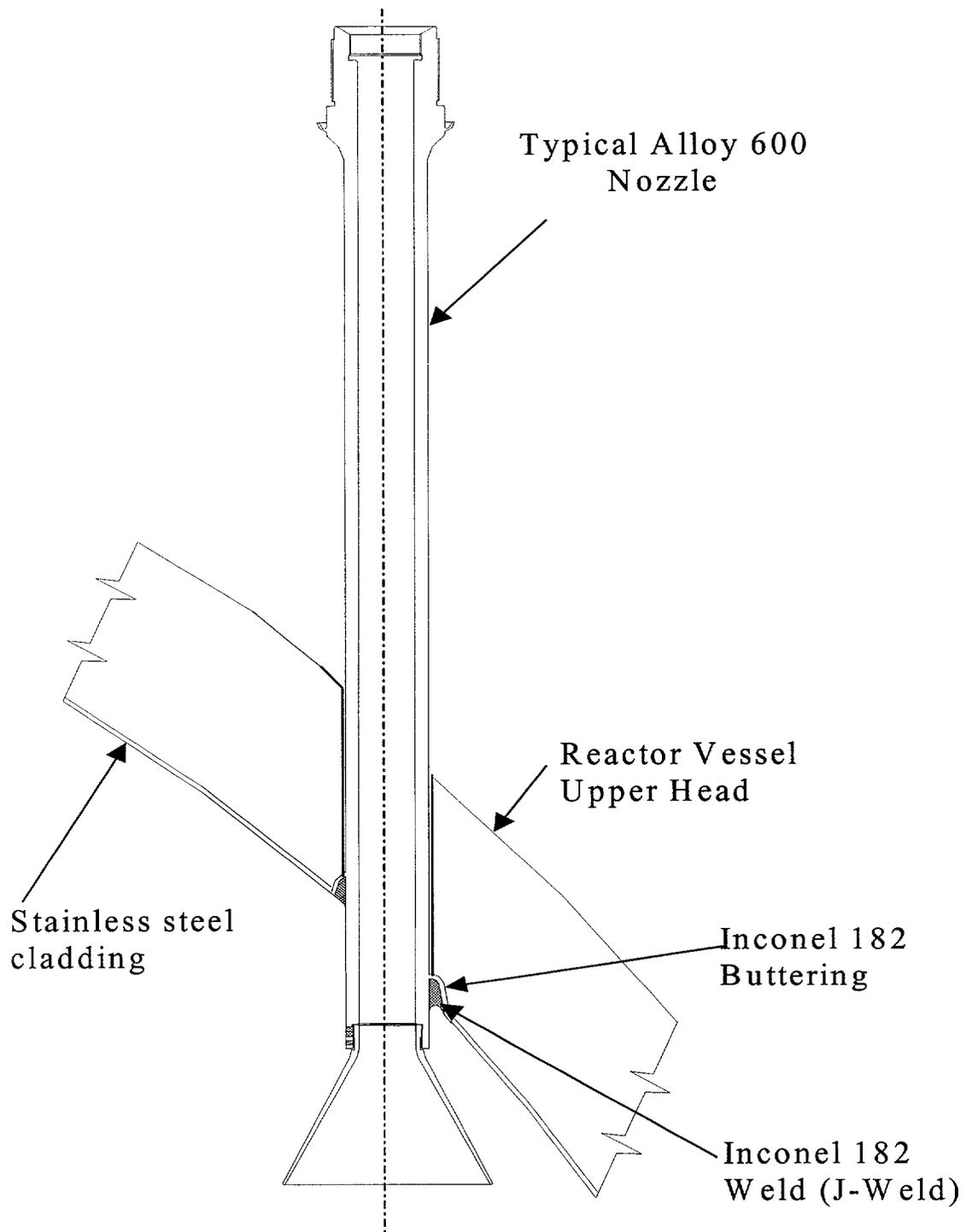
V. CONCLUSION

10CFR50.55a(a)(3)(i) 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:

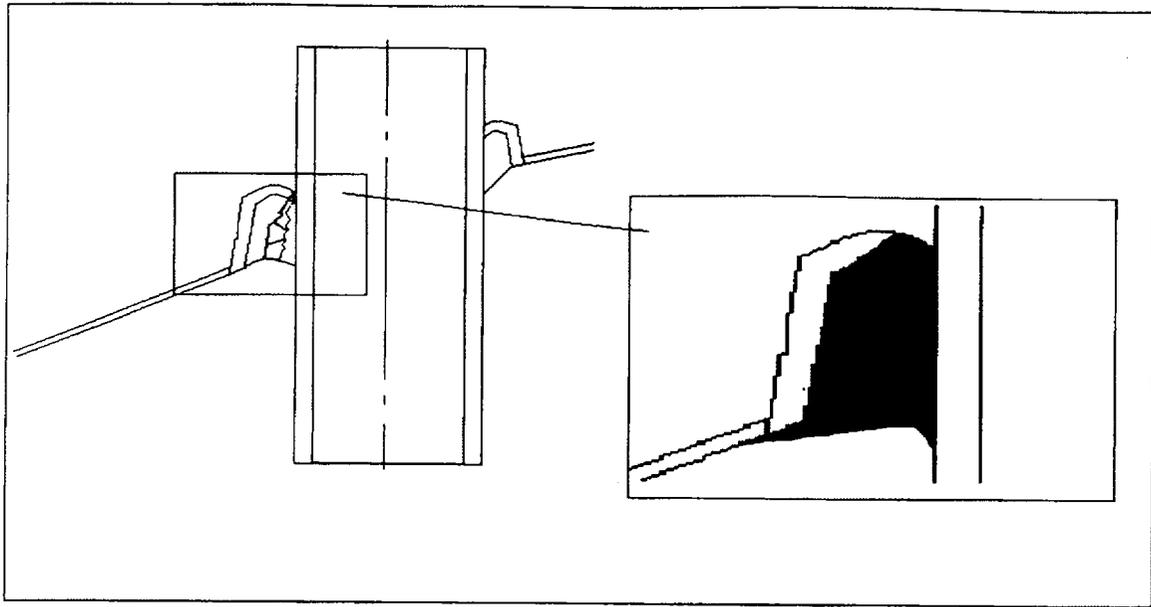
- (i) The proposed alternatives would provide an acceptable level of quality and safety, or
- (ii) Compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.”

Entergy believes that compliance with the repair rules as stated in Reference 1 and as described in Section II of this request would result in unwarranted radiological exposure. The proposed alternative would provide an acceptable level of quality and safety. The proposed alternative would also result in a reduction of radiological exposure to personnel. Therefore, we request that the proposed alternative be authorized pursuant to 10CFR50.55a(a)(3)(i).



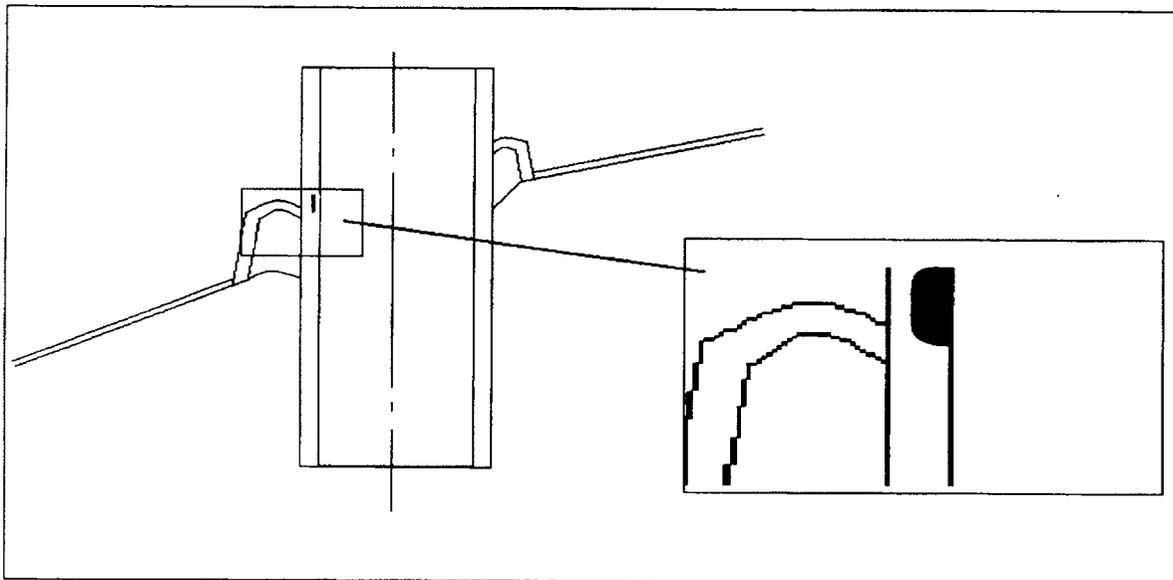
Typical RPV Penetration Nozzle

FIGURE 1



Example Repair of an RPV Penetration Nozzle J-Weld

FIGURE 2



Example Repair of an RPV Penetration Nozzle

FIGURE 3

RELIEF REQUEST NO. PWR-R&R-001

ATTACHMENT 1

**DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE
MACHINE GTAW TEMPER BEAD TECHNIQUE**

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" 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" 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".
- (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", 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.

DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

- (d) The maximum interpass temperature for the first three layers or as required to achieve the 1/8" 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". 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". 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 (i) 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 (g) above.
- (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 (g) 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.

DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

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" butter thickness as shown in Figure 2, steps 1 through 3, with the heat input for each layer controlled to within $\pm 10\%$ 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" 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 on the area to be welded.
- (b) Repair welds in RPV penetration nozzle base materials shall be examined as follows:

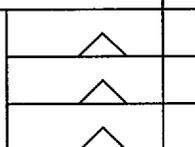
DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

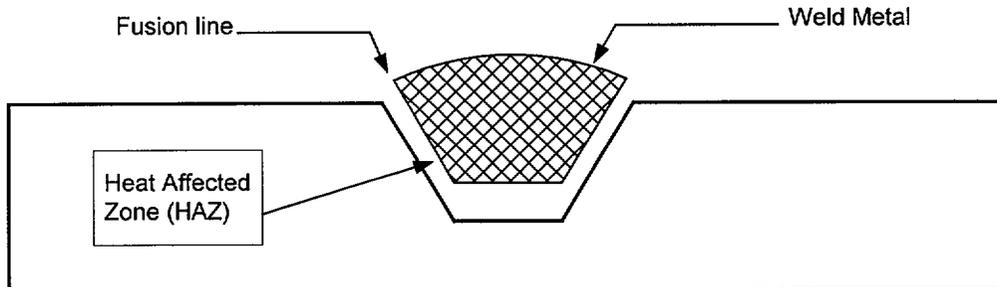
- Repair welds including the preheat band (1.5 times the component thickness or 5", whichever is less) around the repair weld shall be examined by the liquid penetrant method after the completed repair weld has been at ambient temperature for at least 48 hours. The liquid penetrant examinations will be performed in accordance with ASME Section III, NB-5000. Acceptance criteria shall be in accordance with NB-5350.
 - Repair welds will be ultrasonically examined in accordance with ASME Section III, NB-5000 after the completed repair weld has been at ambient temperature for at least 48 hours. Acceptance criteria shall be in accordance with NB-5330.
 - Repair welds will also be examined by eddy current method. The eddy current inspection will complement the ultrasonic examination by providing sensitivity to surface and subsurface flaws near the inspection surface.
- (c) Repair welds in RPV penetration nozzle J-welds shall be examined as follows:
- Repair welds will be progressively examined by the liquid penetrant method in accordance with NB-5245 of ASME Section III. After the completed repair weld has been at ambient temperature for at least 48 hours, repair welds including the preheat band (1.5 times the component thickness or 5", whichever is less) around the repair weld shall be examined by the liquid penetrant method. The liquid penetrant examinations will be performed in accordance with ASME Section III, NB-5000. Acceptance criteria shall be in accordance with NB-5350.
- (d) NDE personnel performing ultrasonic and liquid penetrant examination will be qualified and certified in accordance with IWA-2300 or NB-5500. NDE personnel performing eddy current examinations will be qualified and certified using a written practice prepared in accordance with SNT-TC-1A.

5.0 DOCUMENTATION

Use of Request No. PWR-R&R-001, Rev. 0 shall be documented on NIS-2. Alternatively, repairs may be documented on Form NIS-2A as described in Code Case N-532 if prior approval is obtained from the NRC.

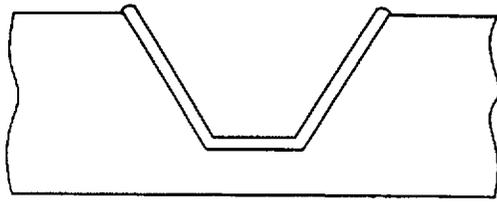
**DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE
MACHINE GTAW TEMPER BEAD TECHNIQUE**

Discard		
Transverse Side Bend		
Reduced Section Tensile		
Transverse Side Bend		
		HAZ Charpy V-Notch
Transverse Side Bend		
Reduced Section Tensile		
Transverse Side Bend		
Discard		

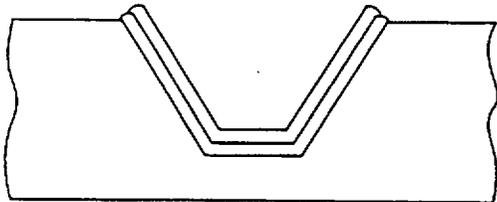


GENERAL NOTE: Base Metal Charpy impact specimens are not shown.

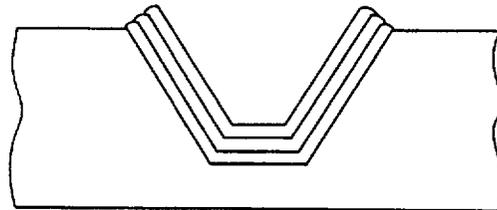
Figure 1 - QUALIFICATION TEST PLATE



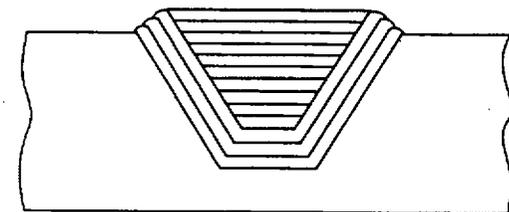
Step 1: Deposit layer one with first layer weld parameters used in qualification.



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 temperbead welding technique.

Figure 2 - AUTOMATIC OR MACHINE GTAW TEMPER BEAD WELDING