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January 18, 2006

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
ASME Section XI Relief Request to Use Weld Overlay and Associated Alternative Techniques

REFERENCES:

(a) Letter from Mr. G. Vanderheyden (CCNPP) to Document Control Desk (NRC), dated September 28, 2005, ASME Section XI Relief Request to Use Weld Overlay and Associated Alternative Techniques

(b) Letter from Ms. M. Gamberoni (NRC) to Mr. C. H. Cruse (BGE), dated April 5, 2000, Safety Evaluation of Proposed Alternate American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, 1998 Edition for the Third 10-Year Inspection Interval – Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 (TAC Nos. MA4647 and MA4648)

Calvert Cliffs Nuclear Power Plant (CCNPP) requested relief in a letter dated September 28, 2005 (Reference a), pursuant to 10 CFR 50.55a(a)(3)(i), and proposed alternatives to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) requirements concerning repair/replacement activities for pressure retaining welds subject to Article IWA-4000 in Section XI for the Third Ten-Year Inservice Inspection interval. Based upon discussion with the US Nuclear Regulatory Commission (NRC) staff on December 12, 2005, CCNPP withdraws the original relief request (Reference a) from consideration and submits the following request as a stand alone document without supplement. Paragraph 50.55a(a)(3)(i) allows the use of alternatives to the requirements of Paragraph 50.55a(g), which provides an acceptable level of quality and safety, when authorized by the Director of the Office of Nuclear Reactor Regulation.

The Third Ten-Year Inservice Inspection Program Plan for Calvert Cliffs Units 1 and 2 meets the requirements of the 1998 Edition, no Addenda, of Section XI of the ASME Code (except for Subsections IWE and IWL), as approved by NRC letter (Reference b).

A047

RELIEF REQUEST

Nuclear Regulatory Commission approved Code Cases N-504-2 and N-638-1 contain the requirements for structural weld overlay repair activities and temperbead welding technique. The ASME approved Code Cases N-504-2 and N-638-1 are listed as acceptable for use in NRC Regulatory Guide 1.147, Revision 14, with the following conditions. These conditions will be met for the purposes of this request, with the exception listed below for Code Case N-638-1:

N-638-1 – Ultrasonic testing examinations shall be demonstrated for the repaired volume using representative samples which contain construction type flaws. The acceptance criteria of NB-5330 of ASME Section III edition and addenda approved in 10 CFR 50.55a apply to all flaws identified within the required volume. The exception for the Code Case N-638-1 condition is to apply the acceptance criteria of Appendix Q as stipulated in the condition for Code Case N-504-2 (see below) for weld overlay in lieu of NB-5330 of ASME Section III.

N-504-2 – The provisions of Section XI, Nonmandatory Appendix Q, "Weld Overlay Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping Weldments," must also be met. (This appendix is now published in the 2005 Addenda of ASME Section XI.)

Appendix VIII, Supplement 11 of Section XI contains ultrasonic examination requirements for the completed structural weld overlay repair. In lieu of these ASME Code requirements, CCNPP proposes to use alternative techniques for full structural weld overlay repair, and the examination of dissimilar metal welds with unacceptable indications in existing Alloy 82/182 welds. Relief requests have been previously approved for Calvert Cliffs Unit 2 and other licensees, including AmerGen Energy Company for its Three Mile Island Nuclear Station, Unit 1 on July 21, 2004 and Indiana Michigan Power Company for its Donald C. Cook Nuclear Plant on December 1, 2005 for most of the alternative techniques proposed in this request. The detailed relief request and the justification are provided in Attachment (1).

SCHEDULE

The structural weld overlay is intended as a contingency repair for any flaws identified during examination of dissimilar metal welds in the upcoming Calvert Cliffs Unit 1 Spring 2006 refueling outage (scheduled to begin in late February 2006) and the remainder of the third ten-year inservice inspection interval for Units 1 and 2. We request that the NRC review and approve our proposed alternative for use during this outage and subsequent third interval outages.

Should you have questions regarding this matter, please contact Mr. L. S. Larragoite at (410) 495-4922.

Very truly yours,

J. E. Pollock
for
James A. Spina
Vice President - Calvert Cliffs Nuclear Power Plant

JAS/MJY/bjd

Attachment: (1) Relief Request To Use Alternative Techniques for Repair and Examination of Unacceptable Indications in Welded Nozzles

Enclosure (1) White Paper – Relaxation of the 100 square inch Size Limitation – Code Case N-638

cc: P. D. Milano, NRC
S. J. Collins, NRC
Resident Inspector, NRC
R. I. McLean, DNR

ATTACHMENT (1)

RELIEF REQUEST TO USE ALTERNATIVE TECHNIQUES FOR REPAIR AND EXAMINATION OF UNACCEPTABLE INDICATIONS IN WELDED NOZZLES

COMPONENT FOR WHICH RELIEF IS REQUESTED:

Class 1 dissimilar metal welds, with unacceptable indications attributed to primary water stress corrosion cracking (PWSCC) in existing Alloy 82/182 welds. These welds may include:

UNIT 1 DM WELD POPULATION					
Designator/ID	Weld Material	Nozzle Size	Location	Function	Base Material
102300/30-RC-11A-W7	182/82	30"	11A RCP Inlet	RCS Loop	A516-70/A351-CF8M
102450/30-RC-11A-W10	182/82	30"	11A RCP Outlet	RCS Loop	A516-70/A351-CF8M
104550/30-RC-11B-W7	182/82	30"	11B RCP Inlet	RCS Loop	A516-70/A351-CF8M
104700/30-RC-11B-W10	182/82	30"	11B RCP Outlet	RCS Loop	A516-70/A351-CF8M
107450/30-RC-12A-W7	182/82	30"	12A RCP Inlet	RCS Loop	A516-70/A351-CF8M
107600/30-RC-12A-W10	182/82	30"	12A RCP Outlet	RCS Loop	A516-70/A351-CF8M
109600/30-RC-12B-W7	182/82	30"	12B RCP Inlet	RCS Loop	A516-70/A351-CF8M
109750/30-RC-12B-W10	182/82	30"	12B RCP Outlet	RCS Loop	A516-70/A351-CF8M
110450/12-PSL-W1	182/82	12"	Bottom Head of PZR	PZR Surge	SA508-Cl2/ SA351-CF8M
111100/12-PSL-W13	182/82	12"	Top of 11 Hot Leg	PZR Surge	A105-GrII/ A351-CF8M
113150/12-SC-1004-W1	182/82	12"	Bottom of 12 Hot Leg	Shutdown Cooling	A105-GrII/ A351-CF8M
114350/12-SI-1009-W16	182/82	12"	Top of 11A Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
115200/12-SI-1010-W14	182/82	12"	Top of 11B Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
116000/12-SI-1011-W13	182/82	12"	Top of 12A Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
116750/12-SI-1012-W13	182/82	12"	Top of 12B Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
118500/4-PS-1003-W6	182/82	4"	Top Head of PZR	PZR Spray	SA508-Cl2/SA-182-F316
118550/3-PS-1001-W1	182/82	3"	Top of 11A Cold Leg	PZR Spray	A105-GrII/A-182-TP316
120350/3-PS-1002-W1	182/82	3"	Top of 11B Cold Leg	PZR Spray	A105-GrII/A-182-TP316
123100/4-SR-1005-W1	182/82	4"	Top of PZR	PZR Relief	SA508-Cl2/SA-182-F316
123450/4-SR-1006-W1	182/82	4"	Top of PZR	PZR Relief	SA508-Cl2/SA-182-F316
125050/2-LD-1004-W1	182/82	2"	Bottom of 12A Cold Leg	Letdown/Drain	A105-GrII/A-182-TP316
128900/2-CV-1004-W19	182/82	2"	12B Cold Leg	Charging Inlet	A105-GrII/A-182-TP316
130450/2-CV-1005-W29	182/82	2"	11A Cold Leg	Charging Inlet	A105-GrII/A-182-TP316
131200/2-DR-1003-W1	182/82	2"	Bottom of 11A Cold Leg	Loop Drain	A105-GrII/A-182-TP316
131500/2-DR-1004-W1	182/82	2"	Bottom of 11B Cold Leg	Loop Drain	A105-GrII/A-182-TP316
132150/2-DR-1006-W1	182/82	2"	Bottom of 12B Cold Leg	Loop Drain	A105-GrII/A-182-TP316

UNIT 1 DM WELD POPULATION					
Designator/ID	Weld Material	Nozzle Size	Location	Function	Base Material
132450/2-DR-1007-W1	182/82	2"	Bottom of 11 Hot Leg	Loop Drain	A105-GrII/A-182-TP316

UNIT 2 DM WELD POPULATION					
Designator/ID	Weld Material	Nozzle Size	Location	Function	Base Material
109280/30-RC-21A-W7	182/82	30"	21A RCP Inlet	RCS Loop	A516-70/A351-CF8M
109310/30-RC-21A-W10	182/82	30"	21A RCP Outlet	RCS Loop	A516-70/A351-CF8M
110280/30-RC-21B-W7	182/82	30"	21B RCP Inlet	RCS Loop	A516-70/A351-CF8M
110310/30-RC-21B-W10	182/82	30"	21B RCP Outlet	RCS Loop	A516-70/A351-CF8M
111280/30-RC-22A-W7	182/82	30"	22A RCP Inlet	RCS Loop	A516-70/A351-CF8M
111310/30-RC-22A-W10	182/82	30"	22A RCP Outlet	RCS Loop	A516-70/A351-CF8M
112280/30-RC-22B-W7	182/82	30"	22B RCP Inlet	RCS Loop	A516-70/A351-CF8M
112310/30-RC-22B-W10	182/82	30"	22B RCP Outlet	RCS Loop	A516-70/A351-CF8M
113010/12-PSL-W1	182/82	12"	Bottom Head of PZR	PZR Surge	SA508-Cl2/ SA351-CF8M
113130/12-PSL-W13	182/82	12"	Top of 21 Hot Leg	PZR Surge	A105-GrII/ A351-CF8M
114900/12-SC-2004-W1	182/82	12"	Bottom of 22 Hot Leg	Shutdown Cooling	A105-GrII/ A351-CF8M
115140/12-SI-2009-W15	182/82	12"	Top of 21B Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
116190/12-SI-2010-W13	182/82	12"	Top of 21A Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
117120/12-SI-2011-W13	182/82	12"	Top of 22B Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
118120/12-SI-2012-W13	182/82	12"	Top of 22A Cold Leg	Safety Injection	A182-F-1/ A351-CF8M
136090/4-PS-2003-W8	182/82	4"	Top Head of PZR	PZR Spray	SA508-Cl2/SA-182-F316
137010/3-PS-2001-W1	182/82	3"	Top of 21A Cold Leg	PZR Spray	A105-GrII/A-182-TP316
138010/3-PS-2002-W1	182/82	3"	Top of 21B Cold Leg	PZR Spray	A105-GrII/A-182-TP316
141000/4-SR-2005-W1	182/82	4"	Top of PZR	PZR Relief	SA508-Cl2/SA-182-F316
142000/4-SR-2006-W1	182/82	4"	Top of PZR	PZR Relief	SA508-Cl2/SA-182-F316
152440/2-CV-2005-W30	182/82	2"	21A Cold Leg	Charging Inlet	A105-GrII/A-182-TP316
156530/2-CV-2021-W34	182/82	2"	22B Cold Leg	Charging Inlet	A105-GrII/A-182-TP316
157010/2-DR-2003-W1	182/82	2"	Bottom of 21A Cold Leg	Loop Drain	A105-GrII/A-182-TP316
158010/2-DR-2004-W1	182/82	2"	Bottom of 21B Cold Leg	Loop Drain	A105-GrII/A-182-TP316
160010/2-DR-2006-W1	182/82	2"	Bottom of 22B Cold Leg	Loop Drain	A105-GrII/A-182-TP316

CODE REQUIREMENTS FOR WHICH RELIEF IS REQUESTED:

The 1998 Edition, no Addenda, of American Society of Mechanical Engineers (ASME) Section XI, Article IWA-4000 and Appendix VIII, Supplement 11 and Nuclear Regulatory Commission (NRC) conditionally approved Code Cases N-504-2 and N-638-1, as approved in NRC Regulatory Guide 1.147, Revision 14. Tables 1-3 provide the specific requirements that are included in this relief request.

PROPOSED ALTERNATIVE AND SUPPORTING INFORMATION:

For dissimilar-metal welds with unacceptable indications in existing Alloy 82/182 welds attributed to PWSCC, a full structural weld overlay modification is proposed. The nozzle material is ferritic steel (either P1 or P3 depending on the nozzle). The pipe is austenitic stainless steel (P8). The existing weld filler material is Alloy 82/182 (F43 equivalent to P43). The overlay will be designed as a full structural overlay in accordance with ASME Section XI Code Case N-504-2. The temperbead welding technique will be implemented in accordance with ASME Section XI Code Case N-638-1 for that portion of the overlay over ferritic base material for which the Construction Code required post-weld heat treatment. This full structural overlay will satisfy all the structural design requirements of the pipe as if the pipe were not there. The structural weld overlay (weld reinforcement) will completely cover the existing Alloy 82/182 weld metal and extend onto the ferritic and austenitic stainless steel material on each end.

Tables 1, 2, and 3 provide the detailed requirements, the proposed alternatives, and the bases for the alternatives. The modification will be performed as a repair/replacement activity in compliance with Article IWA-4000 of the 1998 Edition, no Addenda, of ASME Section XI. Certain requirements of IWA-4000 will be accomplished using the methodology of Code Case N-504-2 (Alternative Rules for Repairs of Classes 1, 2, and 3 Austenitic Stainless Steel Piping) modified as shown in Table 1, and the methodology of Code Case N-638-1 [Similar and Dissimilar Metal Welding using Ambient Temperature Machine GTAW (Gas Tungsten Arc Welding) Temperbead Technique, Section XI, Division I] modified as shown in Table 2. Ultrasonic examination of the completed structural overlay will be accomplished in accordance with ASME Section XI, Appendix VIII, Supplement 11 modified to comply with the Performance Demonstration Initiative (PDI) program as shown in Table 3. Any applicable requirements not modified by Tables 1, 2, and 3 will be met as described in IWA-4000, Appendix VIII Supplement 11, and Code Cases N-504-2 and N-638-1, as stated in NRC Regulatory Guide 1.147, Revision 14.

Code Case N-504-2 was conditionally approved for generic use in Regulatory Guide 1.147, Revision 14, and was developed for austenitic stainless steel material. The provisions of ASME Section XI, Nonmandatory Appendix Q, Weld Overlay Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping Weldments, will be met except as noted in Table 1. An alternate application for nickel based and ferritic materials is proposed due to the specific configuration of the subject weldments. Therefore, Calvert Cliffs intends to follow the methodology of Code Case N-504-2, except for the differences identified in Table 1.

Code Case N-638-1 was conditionally approved for generic use in Regulatory Guide 1.147, Revision 14, and was developed for similar and dissimilar metal welding using ambient temperature machine GTAW temperbead technique. As stated in Regulatory Guide 1.147, Revision 14, ultrasonic testing examinations will be demonstrated for the repaired volume using representative samples which contain construction type flaws. Also, the acceptance criteria of NB-5330 of Section III edition and addenda approved in 10 CFR 50.55a will apply to all flaws identified within the repair volume. Calvert Cliffs intends to follow the methodology of Code Case N-638-1 for any welding on ferritic or ferritic/austenitic

interfaces where the Construction Code required post-weld heat treatment, except for the differences identified in Table 2.

CONCLUSION:

Calvert Cliffs believes the proposed alternatives to NRC conditionally approved Code Cases N-504-2 and N-638-1, as described in this request, provide an acceptable level of quality and safety.

Table 1

Modifications to Code Case N-504-2 and Corresponding ASME Code Section XI, Nonmandatory Appendix Q Requirements

Code Case N-504-2	Differences/Basis for Relief
Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4120 in Editions and Addenda up to and including the 1989 Edition with the 1990 Addenda, in IWA-4170(b) in the 1989 Edition with the 1991 Addenda up to and including the 1995 Edition, and in IWA-4410 in the 1995 Edition with the 1995 Addenda and later Editions and Addenda, defect in austenitic stainless steel piping may be reduced to a flaw of acceptable size in accordance with IWB-3640 from the 1983 Edition with the Winter 1985 Addenda, or later Editions and Addenda, by deposition of weld reinforcement (weld overlay) on the outside surface of the pipe, provided the following requirements are met: [Essentially same as Scope of Appendix Q]	**Relief.** We propose to apply Code Case N-504-2 for the weld overlay repairs to the ferritic (P1 or P3) and nickel alloy (F43/P43) base material as well as the austenitic stainless steel (P8) base material. Code Case N-504-2 is accepted for use, including the provisions of ASME Code Section XI, Nonmandatory Appendix Q, per NRC Regulatory Guide 1.147, Revision 14. The base material will be ferritic material (P1 or P3) with existing nickel alloy weld metal (F43/P43) to which an austenitic stainless steel (P8) pipe is welded. Industry operational experience has shown that PWSCC in Alloy 82/182 will blunt at the interface with stainless steel base metal, ferritic base metal, or Alloy 52/52M/152 weld metal. Calvert Cliffs Nuclear Power Plant plans to apply a 360°, full structural weld overlay to control growth in any PWSCC crack and maintain weld integrity. The weld overlay will put compressive stress around the weldment, thus impeding growth of any existing crack and will fulfill all structural requirements, independent of the existing weld. Furthermore, the overlay will be sized to meet all structural requirements independent of the existing weld.

Table 1

Modifications to Code Case N-504-2 and Corresponding ASME Code Section XI, Nonmandatory Appendix Q Requirements

Code Case N-504-2	Differences/Basis for Relief
(b) Reinforcement weld metal shall be low carbon (0.035% max.) austenitic stainless steel applied 360° around the circumference of the pipe, and shall be deposited in accordance with a qualified welding procedure specification identified in the Repair Program. [Same as Q-2000(a)]	**Relief.** In lieu of austenitic stainless steel filler material, the reinforcement weld metal will be a nickel alloy. The weld metal will be either ERNiCrFe-7 (Alloy 52, UNS N06052) or ERNiCrFe-7A (Alloy 52M, UNS N06054). ENiCrFe-7 may be used to shielded metal arc weld seal weld the initial base metal surfaces or to perform repair on the weld reinforcement. These weld metals are assigned F43 by ASME per Code Case 2142-2. The requirements of ASME Section III, NB-2400 will be applied to all filler material. The chromium content of Alloy 52M is 28-31.5%, identical to that of Alloy 52. The main difference in Alloy 52 is a higher Niobium content (0.5-1%). The difference in chemical composition between Alloy 52 and Alloy 52M improves weldability of the material, pinning the grain boundaries preventing separation between grains, and hot tearing during weld puddle solidification. This filler material was selected for its improved resistance to PWSCC. Alloys 52, 52M, and 152 all contain about 30% chromium that imparts excellent corrosion resistance. The existing Alloy 82/182 weld and the Alloy 52/52M overlay are austenitic and have ductile properties and toughness similar to austenitic stainless steel piping welds at pressurized water reactor operating temperature. These filler materials are suitable for welding over the ferritic nozzle, Alloy 82/182 weld and the austenitic stainless steel piping. (**NOTE:** ERNiCrFe-7 and ENiCrFe-7 are assigned F number 43 by the 2004 Edition of ASME Section IX. ERNiCrFe-7A (UNS N06054) is assigned F number 43 by Boiler and Pressure Vessel Code Case 2142-2.)
(e) The weld reinforcement shall consist of a minimum of two weld layers having as-deposited delta ferrite content of at least 7.5 FN. The first layer of weld metal with delta ferrite content of least 7.5 FN shall constitute the first layer of the weld reinforcement design thickness. Alternatively, first layers of at least 5 FN may be acceptable based on evaluation. [Same as Q-2000(d)]	**Relief.** Delta ferrite (FN) measurements will not be performed for this overlay because welds of Alloy 52/52M/152 are 100% austenitic and contain no delta ferrite due to the high nickel composition (approximately 60% nickel).

Table 2

Modifications to Code Case N-638-1

Code Case N-638-1	Differences/Basis for Relief
1.0(a) The maximum area of an individual weld based on the finished surface shall be 100 in^2, and the depth of the weld shall not be greater than one-half of the ferritic base metal thickness.	**Relief.** We propose to exceed the 100 in^2 limitation when necessary. Application of Code Case N-638-1 will be on the ferritic portion of the base material extending onto the existing F43 buttering a minimum of 1/8 inch [to satisfy 1.0(b)]. Depending on the diameter of the nozzle to be overlaid and the axial extent of the overlay onto the ferritic material, the 100 in^2 limit may be exceeded. Additional axial extent onto the ferritic material may be necessary to facilitate ultrasonic examination and/or to ensure a smooth final nozzle contour. A White Paper to Revise Code Case N-638-2 to Address Limitations on Size of Repairs, by Structural Integrity Associates, Inc. (SI), (Enclosure 1) indicates the 100 in^2 limitation is arbitrary and repair areas to at least 500 in^2 have no adverse effect.
(l) Regulatory Guide 1.147 condition for Code Case N-638-1.	**Relief.** In lieu of the ultrasonic examination acceptance criteria of the Construction Code in the conditions for use of Code Case N-638-1, the acceptance criteria of ASME Section XI Nonmandatory Appendix Q, as stipulated in the conditions of Regulatory Guide 1.147, Revision 14 for Code Case N-504-2 will be applied for the entire structural weld overlay.

Appendix VIII of Section XI cannot be used for the structural weld overlay required nondestructive examination. Relief is requested to use the PDI program implementation of Appendix VIII. A detailed comparison of Appendix VIII and PDI requirements is summarized in Table 3 below.

Relief is requested to allow closer spacing of flaws provided they do not interfere with detection or discrimination. The specimens used to date for qualification to the Tri-party (NRC/BWROG/EPRI) agreement have a flaw population density greater than allowed by current Code requirements. These samples have been used successfully for all previous qualifications under the Tri-party agreement program. To facilitate their use and provide continuity from the Tri-party agreement program to Supplement 11, the PDI program has merged the Tri-party test specimens into their weld overlay program.

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements
1.0 SPECIMEN REQUIREMENTS	
1.1 General. The specimen set shall conform to the following requirements.	
(b) The specimen set shall consist of at least three specimens having different nominal pipe diameters and overlay thicknesses. They shall include the minimum and maximum nominal pipe diameters for which the examination procedure is applicable. Pipe diameters within a range of 0.9 to 1.5 times a nominal diameter shall be considered equivalent. If the procedure is applicable to pipe diameters of 24 in. or larger, the specimen set must include at least one specimen 24 in. or larger but need not include the maximum diameter. The specimen set must include at least one specimen with overlay thickness within -0.1 in. to +0.25 in. of the maximum nominal overlay thickness for which the procedure is applicable.	*(b)* ...The specimen set shall include specimens with overlays not thicker than 0.1 in. more than the minimum thickness, nor thinner than 0.25 in. of the maximum nominal overlay thickness for which the examination procedure is applicable. *To avoid confusion, the overlay thickness tolerance contained in the last sentence was reworded and the phrase "and the remainder shall be alternative flaws" was added to the next to last sentence in paragraph 1.1(d)(1).*

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	**PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements**
(d) Flaw Conditions	
(1) Base metal flaws. All flaws must be cracks in or near the butt weld heat-affected zone, open to the inside surface, and extending at least 75% through the base metal wall. Flaws may extend 100% through the base metal and into the overlay material; in this case, intentional overlay fabrication flaws shall not interfere with ultrasonic detection or characterization of the cracking. Specimens containing intergranular stress corrosion cracking shall be used when available.	(1) ...must be in or... intentional overlay fabrication flaws shall not interfere with ultrasonic detection or characterization of the base metal flaws. Specimens containing intergranular stress corrosion cracking shall be used when available. At least 70% of the flaws in the detection and sizing tests shall be cracks and the remainder shall be alternative flaws. Alternative flaw mechanisms, if used, shall provide crack-like reflective characteristics and shall be limited by the following: (a) The use of alternative flaws shall be limited to when the implantation of cracks produces spurious reflectors that are uncharacteristic of actual flaws. (b) Flaws shall be semi elliptical with a tip width of less than or equal to 0.002 inches. *This paragraph requires that all base metal flaws be cracks. Implanting a crack requires excavation of the base material on at least one side of the flaw. While this may be satisfactory for ferritic materials, it does not produce a useable axial flaw in austenitic materials because the sound beam, which normally passes only through base material, must now travel through weld material on at least one side, producing an unrealistic flaw response. To resolve this issue, the PDI program revised this paragraph to allow use of alternative flaw mechanisms under controlled conditions. For example, alternative flaws shall be limited to when implantation of cracks precludes obtaining an effective ultrasonic response, flaws shall be semi elliptical with a tip width of less than or equal to 0.002 inches, and at least 70% of the flaws in the detection and sizing test shall be cracks and the remainder shall be alternative flaws.* *To avoid confusion, the overlay thickness tolerance contained in paragraph 1.1(b) last sentence, was reworded and the phrase "and the remainder shall be alternative flaws" was added to the next to last sentence.* *Paragraph 1.1(d)(1) includes the statement that intentional overlay fabrication flaws shall not interfere with ultrasonic detection or characterization of the base metal flaws.*

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements
(e) Detection Specimens	
(1) At least 20% but less than 40% of the flaws shall be oriented within ±20° of the pipe axial direction. The remainder shall be oriented circumferentially. Flaws shall not be open to any surface to which the candidate has physical or visual access. The rules of IWA-3300 shall be used to determine whether closely spaced flaws should be treated as single or multiple flaws`.	(1) At least 20% but less than 40% of the base metal flaws shall be oriented within ±20° of the pipe axial direction. The remainder shall be oriented circumferentially. Flaws shall not be open to any surface to which the candidate has physical or visual access. *The requirement for axially oriented overlay fabrication flaws was excluded from the PDI Program as an improbable scenario. Weld overlays are typically applied using automated GTAW techniques with the filler metal applied in a circumferential direction. Because resultant fabrication induced discontinuities would also be expected to have major dimensions oriented in the circumferential direction axial overlay fabrication flaws are unrealistic.* *The requirement for using IWA-3300 for proximity flaw evaluation was excluded. Instead, indications will be sized based on their individual merits.*
(2) Specimens shall be divided into base and over-lay grading units. Each specimen shall contain one or both types of grading units.	(2) Specimens shall be divided into base metal and overlay fabrication grading units. Each specimen shall contain one or both types of grading units. Flaws shall not interfere with ultrasonic detection or characterization of other flaws.
(a)(1) A base grading unit shall include at least 3 in. of the length of the overlaid weld. The base grading unit includes the outer 25% of the overlaid weld and base metal on both sides. The base grading unit shall not include the inner 75% of the overlaid weld and base metal overlay material, or base metal-to-overlay interface.	*(a)(1)* A base metal grading unit includes the overlay material and the outer 25% of the original overlaid weld. The base metal grading unit shall extend circumferentially for at least 1 in. and shall start at the weld centerline and be wide enough in the axial direction to encompass one half of the original weld crown and a minimum of 0.50" of the adjacent base material. *The phrase* "and base metal on both sides," *was inadvertently included in the description of a base metal grading unit. The PDI program intentionally excludes this requirement because some of the qualification samples include flaws on both sides of the weld. To avoid confusion several instances of the term "cracks" or "cracking" were changed to the term "flaws" because of the use of alternative flaw mechanisms.* *Modified to require that a base metal grading unit include at least 1 in. of the length of the overlaid weld, rather than 3 inches.*

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements
(a)(2) When base metal cracking penetrates into the overlay material, the base grading unit shall include the overlay metal within 1 in. of the crack location. This portion of the overlay material shall not be used as part of any overlay grading unit.	(a)(2) When base metal flaws penetrate into the overlay material, the base metal grading unit shall not be used as part of any overlay fabrication grading unit.
(a)(3) When a base grading unit is designed to be unflawed, at least 1 in. of unflawed overlaid weld and base metal shall exist on either side of the base grading unit. The segment of weld length used in one base grading unit shall not be used in another base grading unit. Base grading units need not be uniformly spaced around the specimen.	(a)(3) Sufficient unflawed overlaid weld and base metal shall exist on all sides of the grading unit to preclude interfering reflections from adjacent flaws. *Modified to require sufficient unflawed overlaid weld and base metal to exist on all sides of the grading unit to preclude interfering reflections from adjacent flaws, rather than the 1 inch requirement.*
(b)(l) An overlay grading unit shall include the overlay material and the base metal-to-overlay interface of at least 6 in^2. The overlay grading unit shall be rectangular, with minimum dimensions of 2 in.	*(b)*(l) An overlay fabrication grading unit shall include the overlay material and the base metal-to-overlay interface for a length of at least 1 in. *Modified to define an overlay fabrication grading unit as including the overlay material and the base metal-to-overlay interface for a length of at least 1 in, rather than the 6 in^2 requirement*
(b)(2) An overlay grading unit designed to be unflawed shall be surrounded by unflawed overlay material and unflawed base metal-to-overlay interface for at least 1 in. around its entire perimeter. The specific area used in one overlay grading unit shall not be used in another overlay grading unit. Overlay grading units need not be spaced uniformly about the specimen.	(b)(2) Overlay fabrication grading units designed to be unflawed shall be separated by unflawed overlay material and unflawed base metal-to-overlay interface for at least 1 in. at both ends. Sufficient unflawed overlaid weld and base metal shall exist on both sides of the overlay fabrication grading unit to preclude interfering reflections from adjacent flaws. The specific area used in one overlay fabrication grading unit shall not be used in another overlay fabrication grading unit. Overlay fabrication grading units need not be spaced uniformly about the specimen. *Paragraph 1.1(e)(2)(b)(2) states that overlay fabrication grading units designed to be unflawed shall be separated by unflawed overlay material and unflawed base metal-to-overlay interface for at least 1 in. at both ends, rather than around its entire perimeter.*

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements
(b)(3) Detection sets shall be selected from Table VIII-S2-1. The minimum detection sample set is five flawed base grading units, ten unflawed base grading units, five flawed overlay grading units, and ten unflawed overlay grading units. For each type of grading unit, the set shall contain at least twice as many unflawed as flawed grading units.	...base metal grading units, ten unflawed base metal grading units, five flawed overlay fabrication grading units, and ten unflawed overlay fabrication grading units. For each type of grading unit, the set shall contain at least twice as many unflawed as flawed grading units. For initial procedure qualification, detection sets shall include the equivalent of three personnel qualification sets. To qualify new values of essential variables, at least one personnel qualification set is required.
(f) Sizing Specimen	
(1) The minimum number of flaws shall be ten. At least 30% of the flaws shall be overlay fabrication flaws. At least 40% of the flaws shall be cracks open to the inside surface.	(1) The .... least 40% of the flaws shall be open to the inside surface. Sizing sets shall contain a distribution of flaw dimensions to assess sizing capabilities. For initial procedure qualification, sizing sets shall include the equivalent of three personnel qualification sets. To qualify new values of essential variables, at least one personnel qualification set is required.
(3) Base metal cracking used for length sizing demonstrations shall be oriented circumferentially.	(3) Base metal flaws used ... circumferentially.
(4) Depth sizing specimen sets shall include at least two distinct locations where cracking in the base metal extends into the overlay material by at least 0.1 in. in the through-wall direction.	(4) Depth sizing specimen sets shall include at least two distinct locations where a base metal flaw extends into the overlay material by at least 0.1 in. in the through-wall direction.
2.0 CONDUCT OF PERFORMANCE DEMONSTRATION	
The specimen inside surface and identification shall be concealed from the candidate. All examinations shall be completed prior to grading the results and presenting the results to the candidate. Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited.	The specimen.....prohibited. The overlay fabrication flaw test and the base metal flaw test may be performed separately.
2.1 Detection Test.	
Flawed and unflawed grading units shall be randomly mixed. Although the boundaries of specific grading units shall not be revealed to the candidate, the candidate shall be made aware of the type or types of grading units (base or overlay) that are present for each specimen.	Flawed.... (base metal or overlay fabrication) ... each specimen.

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements
2.2 Length Sizing Test	
(d) For flaws in base grading units, the candidate shall estimate the length of that part of the flaw that is in the outer 25% of the base wall thickness.	*(d)* For ... base metal grading ... base metal wall thickness.
2.3 Depth Sizing Test.	
For the depth sizing test, 80% of the flaws shall be sized at a specific location on the surface of the specimen identified to the candidate. For the remaining flaws, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.	(a) The depth sizing test may be conducted separately or in conjunction with the detection test. (b) When the depth sizing test is conducted in conjunction with the detection test and the detected flaws do not satisfy the requirements of 1.1(f), additional specimens shall be provided to the candidate. The regions containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region. (c) For a separate depth sizing test, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.
3.0 ACCEPTANCE CRITERIA	
3.1 Detection Acceptance Criteria	
Examination procedures, equipment, and personnel are qualified for detection when the results of the performance demonstration satisfy the acceptance criteria of Table VIII-S2-1 for both detection and false calls. The criteria shall be satisfied separately by the demonstration results for base grading units and for overlay grading units.	Examination procedures are qualified for detection when: a. All flaws within the scope of the procedure are detected and the results of the performance demonstration satisfy the acceptance criteria of Table VIII-S2-1 for false calls. b. At least one successful personnel demonstration has been performed meeting the acceptance criteria defined in (c). c. Examination equipment and personnel are qualified for detection when the results of the performance demonstration satisfy the acceptance criteria of Table VIII-S2-1 for both detection and false calls. d. The criteria in (b) and (c) shall be satisfied separately by the demonstration results for base metal grading units and for overlay fabrication grading units.

Table 3

Modifications to ASME Section XI, Appendix VIII, Supplement 11

SUPPLEMENT 11 – QUALIFICATION REQUIREMENTS FOR FULL STRUCTURAL OVERLAID WROUGHT AUSTENITIC PIPING WELDS	PDI PROGRAM: The Proposed Alternative to Supplement 11 Requirements
3.2 Sizing Acceptance Criteria	
(a) The RMS [root mean squared] error of the flaw length measurements, as compared to the true flaw lengths, is less than or equal to 0.75 inch. The length of base metal cracking is measured at the 75% through-base-metal position.	*(a)* The ... base metal flaws is ... position.
(b) All extensions of base metal cracking into the overlay material by at least 0.1 in. are reported as being intrusions into the overlay material.	This requirement is omitted. *The requirement for reporting all extensions of cracking into the overlay is omitted from the PDI Program because it is redundant to the RMS calculations performed in paragraph 3.2(c) and its presence adds confusion and ambiguity to depth sizing as required by paragraph 3.2(c). This also makes the weld overlay program consistent with the Supplement 2 depth sizing criteria.*

ENCLOSURE (1)

WHITE PAPER – RELAXATION OF THE 100 SQUARE INCH SIZE LIMITATION – CODE CASE N-638

Calvert Cliffs Nuclear Power Plant, Inc.
January 18, 2006

RRA 00-04, BC 04-1000, Revise Code Case N-638-2 to Address Limitations on Size of Repairs

White Paper-Relaxation of the 100 square inch Size Limitation-Code Case N-638

EXECUTIVE SUMMARY

The restriction on surface area size of 100 square inches for ambient temperature temper bead welding using the machine GTAW welding was arbitrarily established. The restriction was imposed to facilitate acceptance of the original code case. Dissimilar weld overlays have been approved by the NRC and in service on BWR piping since 1985. Many BWR dissimilar metal weld overlay applications have exceeded 100 square inches. In addition a dissimilar metal weld overlay over 100 square inches was installed, approved by the NRC and put in service at Three Mile Island Unit 1 (TMI-1) on a surge line to hot leg nozzle. In addition weld buttering for the reactor coolant pipe to the reactor vessel outlet nozzle weld repair at the VC Summer plant was performed using ambient temperature temper bead welding in accordance with N-638. The surface area that was buttered was about 140 square inches. Further ambient temperature temper bead welding per the case has been used for weld pads on pressurizers to replace heater sleeves. About 120 such pads were welded to the pressurizer lower heads to replace the heater sleeves at Calvert Cliffs with no adverse effects. The pads had a combined surface area greater than 1800 square inches

The results from both analytical and experimental programs discussed in the report show that the residual stress distributions for both cavity repairs and weld overlay repairs of 100 square inches and repairs up to 500 square inches are comparable. This includes comparison of the tensile stresses that result beyond the edges of the cavity type repairs in the base material and at the ends of weld overlay repairs. Thus up to 500 square in welds made in accordance with the requirements of Case N-638 have similar or better residual stress distributions to 100 square in welds and all welds meet the stress allowable requirements of Section III, the Construction Code or Owner's requirements as applicable. Further results from metallurgical evaluations and mechanical testing show that cooling of the heat affected zone is rapid enough to form a martensitic structure that is adequately tempered by the subsequent weld deposited layers.

Performance of the repairs over 100 square inches in service as well as the results of analyses and experimental results for repairs up to 500 square inches demonstrate that the repairs are acceptable and safe.

1) Background

The purpose of this action is to relax an arbitrary limitation that was included in N-638 to restrict the use of the ambient temperature bead welding to a surface area of less then 100 square inches and a depth of less then 50% through wall. Code Case N-432-1, which requires a preheat temperature of 300 F and a post weld soak in the 450 – 550 F for 2 hours. The same rules for temper bead welding by GTAW in IWA – 4630 require the same preheat and post weld soak requirement for temperature but a 2 hour hold is required for P-1 materials and a 4 hour hold for P-3 materials except restrictions on size and depth similar to those in N-638 are required.

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It is not clear what the restriction on surface area for ambient temperature temper bead process was intended to address. The welding in N-638 is done using bare filler wire and welding grade shielding gases. The process is by its nature a low hydrogen process. Further diffusion of hydrogen is very rapid for low alloy steels. Nonetheless the post weld soaks in the Code and Code Case are intended as post hydrogen bake outs permitting NDE after the repair has returned to ambient temperature. N-638, since it does not impose the post bake, requires that a 48 - hour hold time prior to NDE be imposed to verify that the unlikely event of hydrogen induced cold cracking has not occurred. Further it should be pointed out that the post weld soak temperatures are too low to either temper the heat affected zone (HAZ) in the ferritic material or be an effective stress relief.

2) Technical Discussion

The temper bead weld process for excavated cavity and overlay repairs of ferritic and dissimilar metal welds using the automatic GTAW process have been performed at operating nuclear power plants for the past 20 years or longer. They have been performed by both welding at ambient temperature and with a pre-heat and post weld soak as discussed above. In no instance has hydrogen induced cracking occurred. Further qualification tests have demonstrated that fracture toughness of the heat affected zones are as high or higher than repairs using conventional welding and post weld stress relief heat treatments in accordandce with ASME code rules. Further all repairs meet the stress allowables of Section III, the Construction Code or Owner's requirements as applicable. Results from metallurgical evaluations and mechanical testing show that cooling of the HAZ is rapid enough to form a martensitic structure that is adequately tempered by the subsequent weld deposited layers.

a) *Older Qualification Programs*

EPRI conducted a program to evaluate weld overlay repairs of 12" BWR N-2 inlet nozzle to safe end weld joints (1) that was published in January 1991. As a part of the program a mockup of a nozzle to safe end weld was fabricated and destructive tested. The destructive testing included mechanical, hardness and Metallographic testing. The metallography and hardness demonstrated that the temper bead welding resulted in adequate tempering of the P-3 nozzle in the HAZ and reduced hardness in the HAZ to about 300 to 350 Knoop (about R_c 34 - 37) after three layers of weld had been deposited. In addition FEA analysis was performed to demonstrate that the residual stresses after the overlay were compressive on the ID in the region of the weld with the material susceptible to IGSCC. An overlay following the EPRI program was implemented at Vermont Yankee. Results of the qualification program and inspections are included in the report as well. The overlay has been in-service since the 1990's, been inspected several times and showed no evidence of degradation.

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EPRI conducted a program to provide a justification for extended overlay design life (2). While most of the program was intended to address overlay repairs for susceptible SS welds, the results of several test programs are included that show experimental results for ID residual stresses before and after application of a weld overlay. Further these programs were conducted on large diameter piping where the overlays would be far in excess of the 100 square inch limitation.

In one test (GPC/SI/WSI) two sections of 28" diameter pipe were welded together in a manner similar to that for the BWR main reactor coolant piping. A baffle was welded axially to divide the pipe segment into 2 halves. Axial and circumferential notches were ground in to the pipe near the girth weld. One half of the pipe ID was exposed to boiling $MgCl_2$ prior to applying the weld overlay. Extensive cracking was seen at the tip of each notch showing the presence of high residual tensile stresses at the notch tip. After weld overlay the other half of the pipe was exposed to boiling $MgCl_2$. No cracking occurred at the similar notch locations in the second half of the pipe showing the residual tensile stress at the notch tips changed from tensile to compressive following application of the overlay. This test confirmed the efficacy of the FEA.

In a second test (EPRI/J.A. Jones 24" mockup) a weld overlay was applied to the pipe and the residual stresses were determined experimentally and by FEA. The results of this residual stress and measurement project have shown that both axial and circumferential residual stresses are compressive at the pipe ID surface following a weld overlay of the thickness applied to the pipe. This also represents an experimental verification of FEA results for a large diameter reasonably thick wall pipe where the overlay would well exceed 100 square inches.

It should be noted that much of the weld shrinkage numerical methods as well the experimental verifications and failure analysis have been performed at government and not-for- profit laboratories (ANL, PNL and Battelle Columbus). Further details on the specific programs are found in the Reference Section in (1) and (2).

b) *More Recent Qualification Programs*

During the development of the code case to relax the limitation on the surface area for ambient temperature Working Group on Welding, after receiving comments from other Code Committees and the NRC, requested that supporting analyses be performed to determine if any significant changes in residual stresses occur if the repair exceeded 100 square inches. It is assumed that the focus on residual stresses was made because past programs have demonstrated that temper bead welding using automatic GTAW provides adequate tempering of the HAZ in P-1 and P-3 materials and does not degrade strength or fracture toughness. Further associated inspections have shown that hydrogen induced cracking has not been a problem with repairs produced by the automatic GTAW temper bead process. The metallurgical aspects discussed appear to be independent of the surface area of the repair but related to input qualified for the welding.

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EPRI sponsored analytical work (3) to evaluate the effects from increases in surface area beyond 100 square inches for both cavity and weld overlay repairs. Three cases were evaluated as a part of the program: a 100 square inch overlay on a nozzle was increased modestly and analyzed, a 500 square inch cavity repair was analyzed and three adjacent 100 square inch cavity repairs were analyzed.

In the first case a weld overlay that was applied to one of the 12 in. diameter Feedwater Nozzles of an operating BWR. The weld overlay was applied in order to restore the structural integrity of the flawed location assuming no credit for any remaining uncracked material in the original safe end. Due to the availability of the information from the utility and a finite element model, this geometry was selected for this initial phase of this work. These residual stress predictions were performed using the ANSYS Rev. 5.3 finite element program. The analysis consists of two parts: a thermal analysis and a stress analysis, to model the welding process in both thermal and mechanical respects. Two axisymmetric finite element models were created, one with a weld overlay of 100 in^2 (Figure 1), the other with the weld overlay extended on the nozzle side until it blends into the nozzle taper surface (Figure 2) (approximately 126 in^2). Figure 3 shows the residual stress on the pipe inside surface. These two figures show that the residual hoop stress is very similar, and in fact the hoop stress for the extended case is even more compressive. The axial stress is less compressive for the extended model, but still with significant compressive stress. This figure also shows that the main area of concern, on the edges of the repair, that stress caused by the 100 sq. in. repair and the larger repair are similar.

In summary results of this evaluation indicate that the combination of the extended overlay and geometric discontinuity of caused by the increased nozzle diameter on the outside surface modify the residual stress. This modified behavior is local to the end where the extension of the overlay was made and the presence of the geometric discontinuity. All other stresses remain essentially the same and the effectiveness of the overlay to provide structural reinforcement at the nozzle-to-safe end weld remains assured. Results of this evaluation indicate that the alternate extended overlay would have been an acceptable overlay from a structural integrity perspective.

In the second case the weld repair configuration selected for evaluation is a cavity of rectangular trough shape, along the longitudinal axis of the reactor vessel, with a depth equal to half of the vessel wall thickness. Two repair sizes, 100 in^2 and 500 in^2 are used. These are the projected areas on the inside surface of the vessel. The actual surface areas in the cavity are much larger, at 328 in^2 and 1894 in^2.

Comparison was made on different paths for the residual stress distribution between the two repair sizes. The stress contours for the two repairs are shown in Figures 4 through 9. In general, the residual stress distributions in the axial and hoop directions are very similar to each other for the two repair sizes. Within the weld repair area, the axial surface residual stress (S_z) for the smaller repair area is lower than the larger repair area. The hoop surface residual stress (S_y) for the smaller repair area is higher than the larger repair cavity. Outside the weld repair cavity, the residual stress for the larger repair area

has lower residual stresses on the selected paths, both on the inside surface and through the wall of the reactor vessel.

It is shown that a larger weld repair area does not have a significant adverse effect on the weld residual stress. In some cases, the larger repair area is much more beneficial because of the lower tensile residual stress or higher compressive residual stress. Especially for the case of axial weld repair where an axial crack could exist, the hoop stress is more compressive or less tensile within the weld repair area and outside the repair area. The larger repair area could be less susceptible to the crack growth, due to either stress corrosion or fatigue.

The third case addresses the implementation of a 300 in^2 weld repair on a Reactor Pressure Vessel (RPV) vertical shell weld. The repair is implemented in 3 separate 100 in^2 repair, i.e., a 100 in^2 repair is simulated, then another 100 in^2 repair is simulated immediately adjacent to the first repair, followed by a third 100 in^2 repair immediately adjacent to the second repair. This case was selected to evaluate to ascertain the ramifications of repairs being performed sequentially to stay within the 100 in^2 limitations.

The final weld repair configuration selected for evaluation is a rectangular trough shape, with a depth equal to half of the vessel wall thickness. The final weld repair consists of three temperbead layers, and a weld out of the remaining cavity. Due to the complexity in the modeling, the temperbead layers are present only on the final weld repair volume outside surfaces, or boundaries, that are in contact with the base metal. The temperbead was not modeled in between the two adjacent weld repairs. Also, a half model of the weld repair is used in order to account for the effect of sequence in the weld repairs.

Due to the large volume of the repair cavity and the large number of bead passes, simplifying assumptions, as identified earlier, were used in the weld residual stress analyses. These assumptions should not have a significant impact on the conclusion since the evaluation is made on the comparison of residual stresses among the three individual weld repair areas using similar assumptions and parameters.

The stress contours for the single and three sequential repairs are shown in Figures 10 and 11. Comparison was made for the residual stress distribution on different paths after the completion of each 100 in^2 repair area. In general, each weld repair area induces a similar residual stress distribution within its repair area. In addition, the residual stress in the previously repaired area is reduced due to the subsequent adjacent repairs. This is due to the excavation of base metal in the subsequent weld repair volume that has a relaxation effect of residual stress in the previously repaired area. Also, the welding in the subsequent repair area has an effect similar to PWHT on the previously repair area.

Based on the comparison of the residual stress distributions for the sequential weld repairs, it can be concluded that a subsequent adjacent repair has an overall effect on reducing the residual stress distribution in the previously repair areas. Also, the residual stress in the last repaired area has a very similar residual stress magnitudes compared to an individual repair of 100 in^2.

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The current evaluation uses three 100 in^2 repair areas. But the discussions on these results and the conclusions could be applied to any number of weld repair areas in each with an area of 100 in^2.

As a part of a program to evaluate weld overlays as a measure to mitigate PWSCC (4), SI conducted an analysis to determine the residual stress profiles of a 33 in. OD PWR reactor coolant nozzle to a stainless steel pipe. A summary of the dimensions for the finite element mode is shown in Figure 12. The reduced thickness overlay modeled is 0.48 in. thick which is about ½ the thickness of a full structural overlay. The surface area of the overlay on the low alloy steel nozzle was 332 square in. The stress contours before and after the overlaying is shown in Figures 13 and 14. Please note that the overlay is shown in Figure 13 but is not active for analysis purposes since it does not exist at that time. Again it is quite apparent that tensile residual stresses at the ID in the weld location before overlaying become compressive after the overlay is applied. The inside surface axial and hoop stresses are shown in Figure 15. Note that the condition for the pre-WOL at 120 F shown in black curve with diamonds shows the high residual tensile stresses and the post-WOL leakage test curve at 120 F shown in the blue curve with diamonds show that all residual stresses in the weld are compressive where there is any PWSCC susceptible material. Other conditions for residual stresses for the hoop and axial directions are also shown. This evaluation as well as those shown above again demonstrates that acceptable residual stresses to mitigate PWSCC are induced by the shrinkage of the weld overlay. Also it demonstrates that these residual stresses are independent of the surface area of the repair and related to other parameters. The overlay could well have been extended an additional 2 in. up the nozzle to increase the surface area over 500 square in. with similar results for the 332 square in. case analyzed.

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c) Service History

Dissimilar metal overlays have been performed at some BWR units as long as 15 to 20 years ago. Several BWR units recently applied weld overlays to nozzle/safe-end locations and one PWR unit, Three Mile Island Unit 1 applied an overlay on a hot leg-to-surge line nozzle using temperbead welding procedures. Machine GTAW temperbead procedures were used to perform the repairs with the RPVs filled with water to avoid excessive radiation exposure to repair personnel. These BWR plants were Perry, Duane Arnold, Hope Creek, Nine Mile Point Unit 2 (NMP-2), Pilgrim, Susquehanna and two at Hope Creek. The Perry and Nine Mile Point Unit 2 overlays were applied to feedwater nozzles. Duane Arnold applied overlays to two recirculation inlet nozzles, and Hope Creek applied an overlay to a core spray nozzle and a recirculation inlet nozzle. All of these repairs were performed at ambient preheat temperatures except for the Hope Creek core spray nozzle overlay. Further several utilities have planned contingent repairs for nozzle welds that have Alloy 182 butter and Alloy182 filler. The code requirement limiting the application of temperbead procedures to 100 in^2 significantly influenced the design of some of the weld overlays. Further relief from the surface area limitation has been requested and approved by the NRC on a case basis for several of these repairs.

In addition weld buttering for the reactor recirculation pipe to the reactor vessel outlet nozzle weld repair at the VC Summer plant was performed using ambient temperature temper bead welding in accordance with N-638. The surface area that was buttered was about 140 square inches. Further ambient temperature temper bead welding per the case has been used for weld pads on pressurizers to replace heater sleeves. About 120 such pads were welded to the pressurizer lower heads to replace the heater sleeves at Calvert Cliffs with no adverse effects.

Service history with these overlays at dissimilar metal weldments has been excellent. Inspection methods that are qualified in accordance with PDI are available and have been used to conduct the examinations.

Further all repairs meet the stress allowables from Section III, the Construction Code or Owner's requirements as applicable. Further results from metallurgical evaluations and mechanical testing show that cooling of the heat affected zone is rapid enough to form a martensitic structure that is adequately tempered by the subsequent weld deposited layers.

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3) Conclusions

The restriction on surface area for temper bead welding was arbitrary, is overly restrictive, leads to increased cost and dose for repairs and does not contribute to safety. There is no direct correlation of residual stresses either for cavity or overlay repairs done using temper bead welding. Cases have been analyzed up to 500 square in. that verify that residual stresses for cavity repairs are at an acceptable level and that residual stresses associated with weld overlay repairs remain compressive in the weld region for larger area repairs as well a for smaller area repairs. The implementing ASME Code and Code Case requirements assure that code stress limits and safety factors are maintained for overlay repairs regardless of size. Metallurgical, mechanical, and hardness testing results show that adequate tempering is achieved and that adequate fracture toughness and strength is maintained in the weld and heat affected zone. The restriction on surface area of repairs should be increased to 500 square in. based on the results of analyses and testing performed to date. The Code should provide an option to users to justify repairs beyond 500 square in. by additional analysis and evaluation.

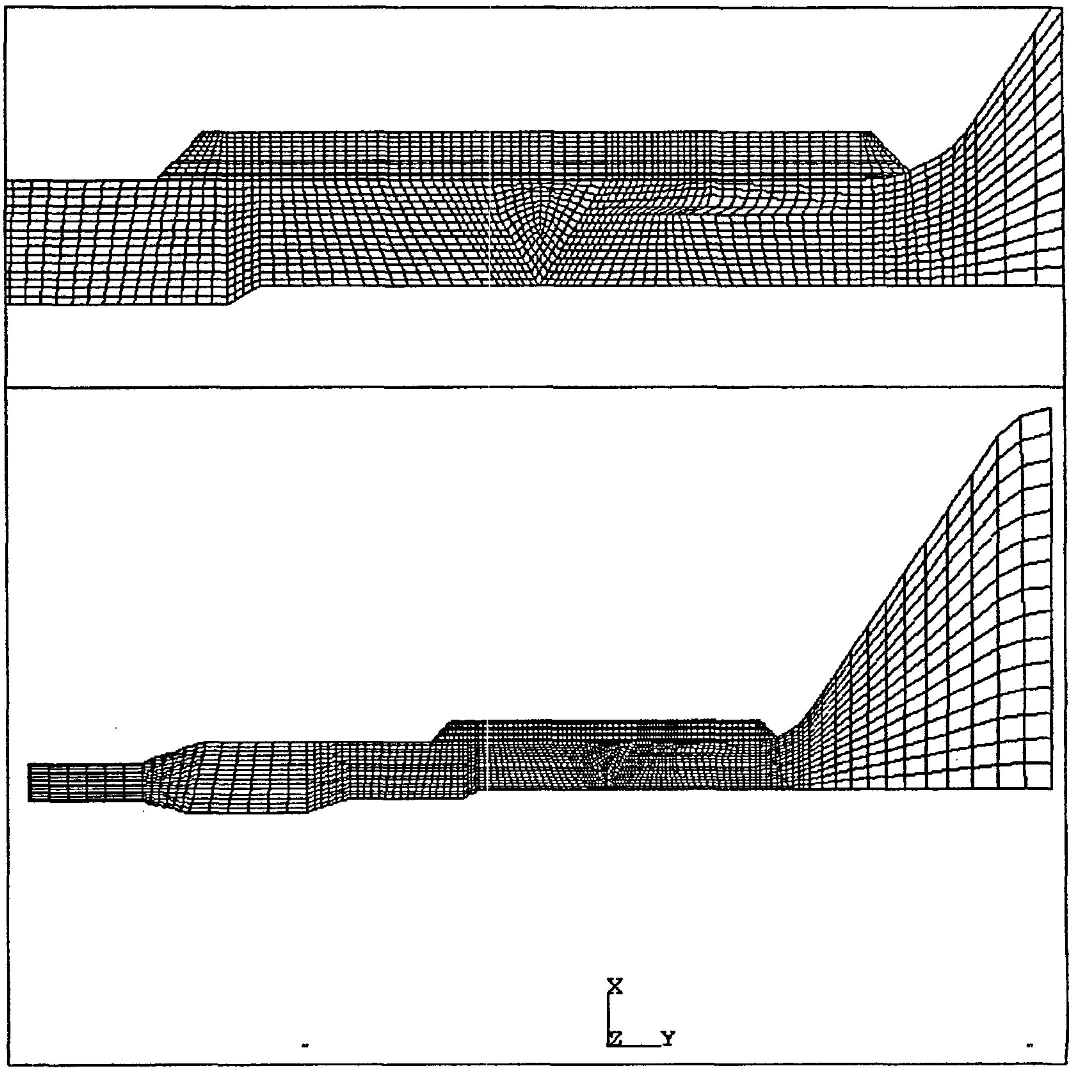


Figure 1. 100 in^2 Finite Element Model

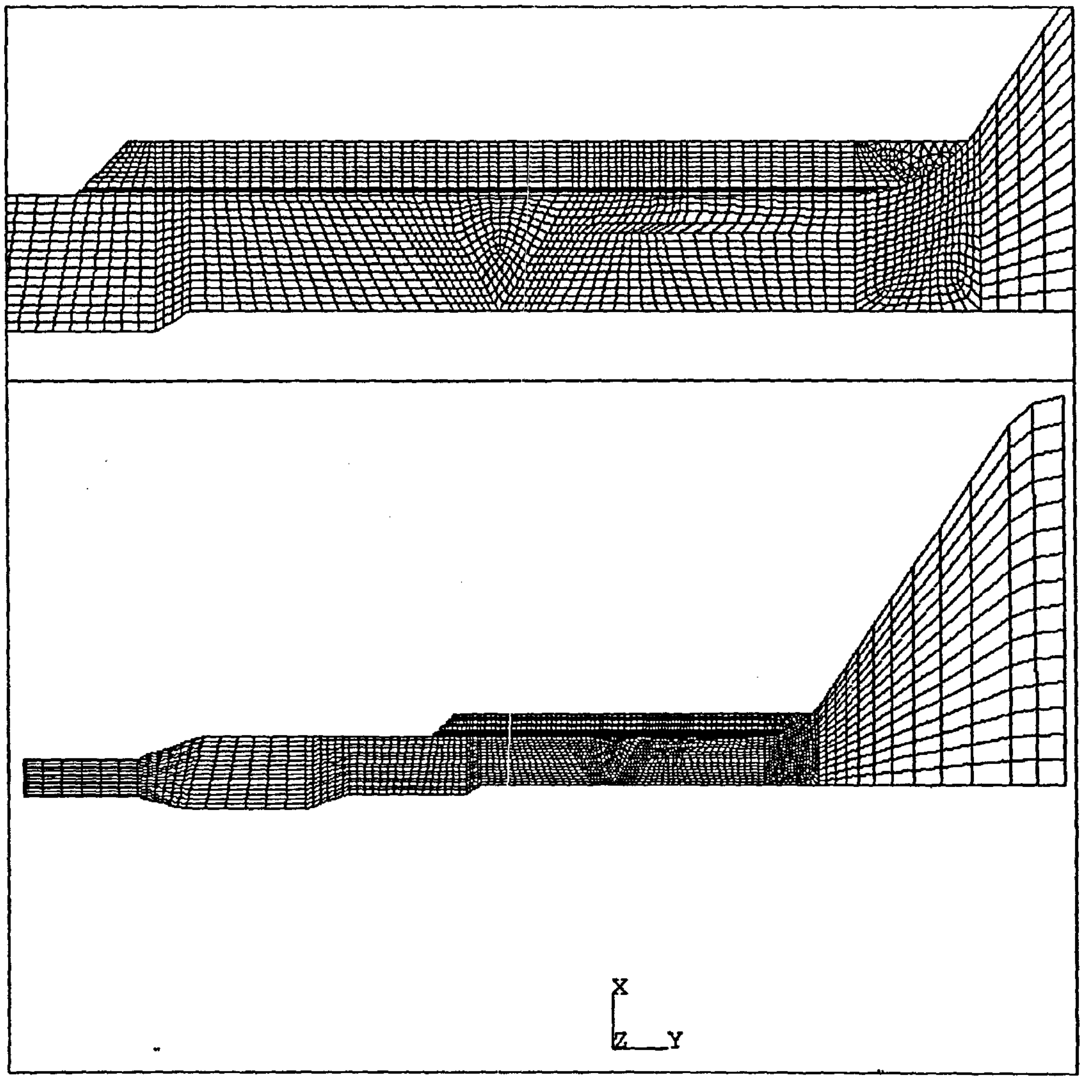
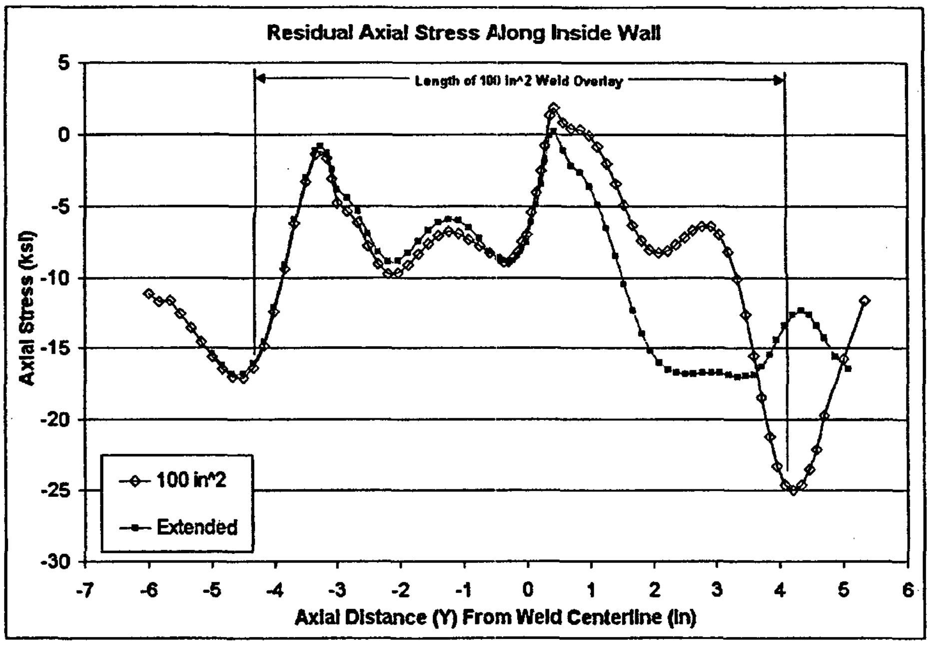


Figure 2. Extended (126 in^2) Overlay Finite Element Model



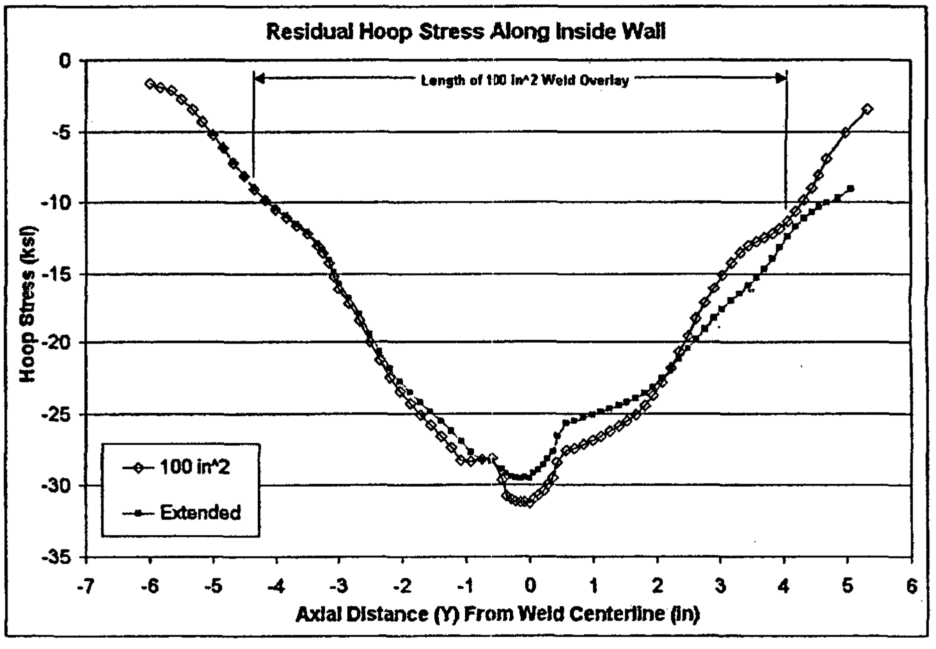


Figure 3. Residual Stresses Along Inside Wall of Pipe

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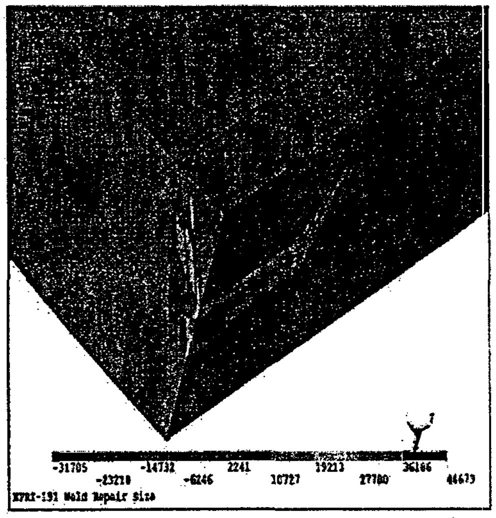


Figure 4 Stress Contour, Sx, at 50 °F After 100 in^2 Repair

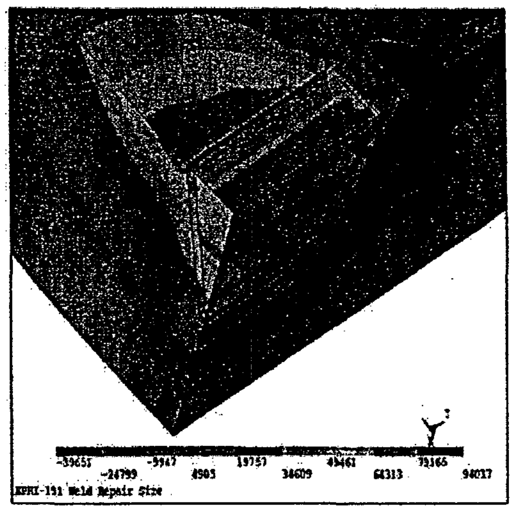


Figure 5 Stress Contour, Sy, at 50 °F After 100 in^2 Repair

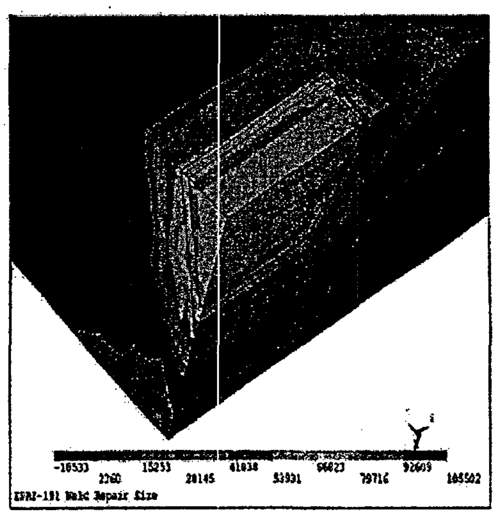


Figure 6 Stress Contour, Sz, at 50 °F After 100 in^2 Repair

43.16

RRA 00-04, BC 04-1000, Revise Code Case N-638-2 to Address Limitations on Size of Repairs

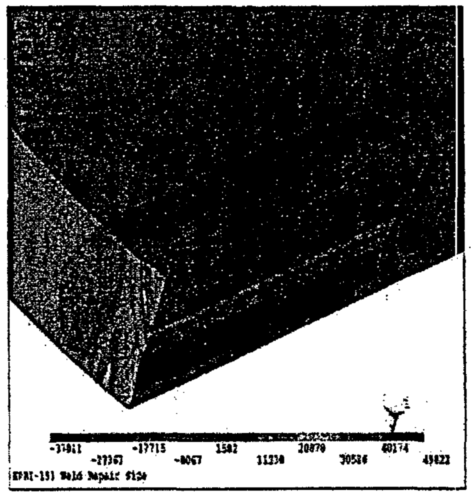


Figure 7 Stress Contour, Sx, at 50 °F After 500 in^2 Repair

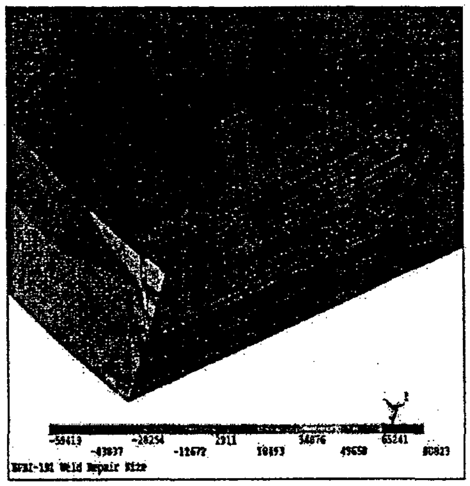


Figure 8 Stress Contour, Sy, at 50 °F After 500 in^2 Repair

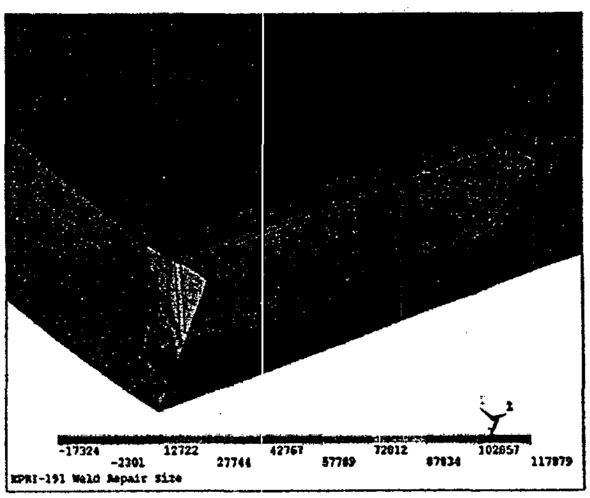
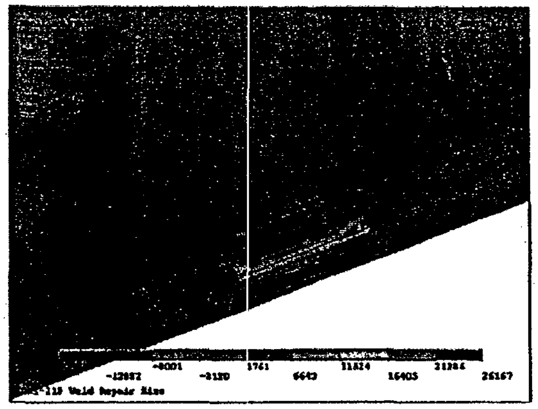
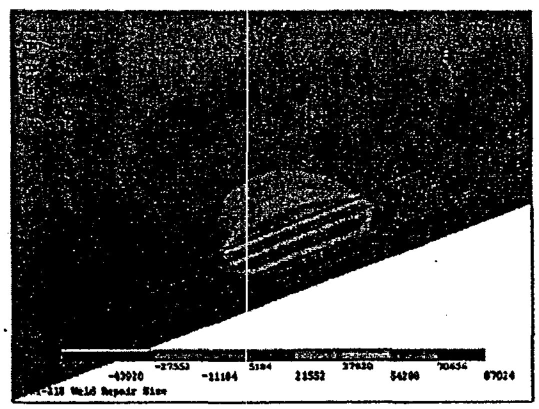


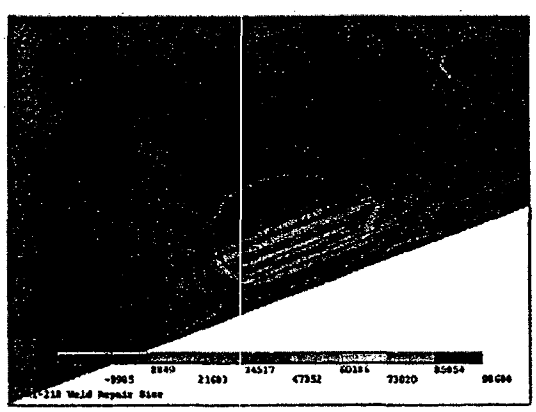
Figure 9 Stress Contour, Sz, at 50 °F After 500 in^2 Repair



a. Radial Stress (S_x)

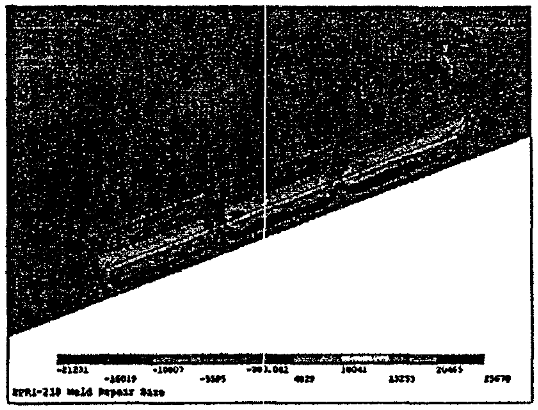


b. Hoop Stress (S_y)

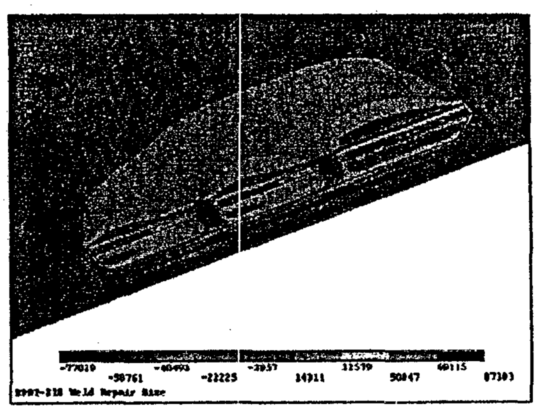


c. Axial Stress (S_z)

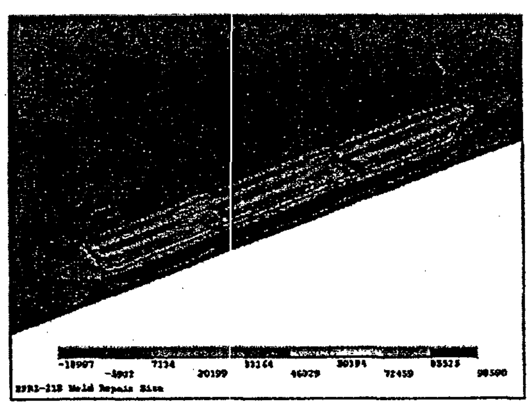
Fig.10 Stress Contour, at 70°F After 1st 100 in^2 Repair



a. Radial Stress (S_x)



b. Hoop Stress (S_y)



c. Axial Stress (S_z)

Fig. 11 Stress Contour, at 70 °F After 3rd 100 in^2 Repair

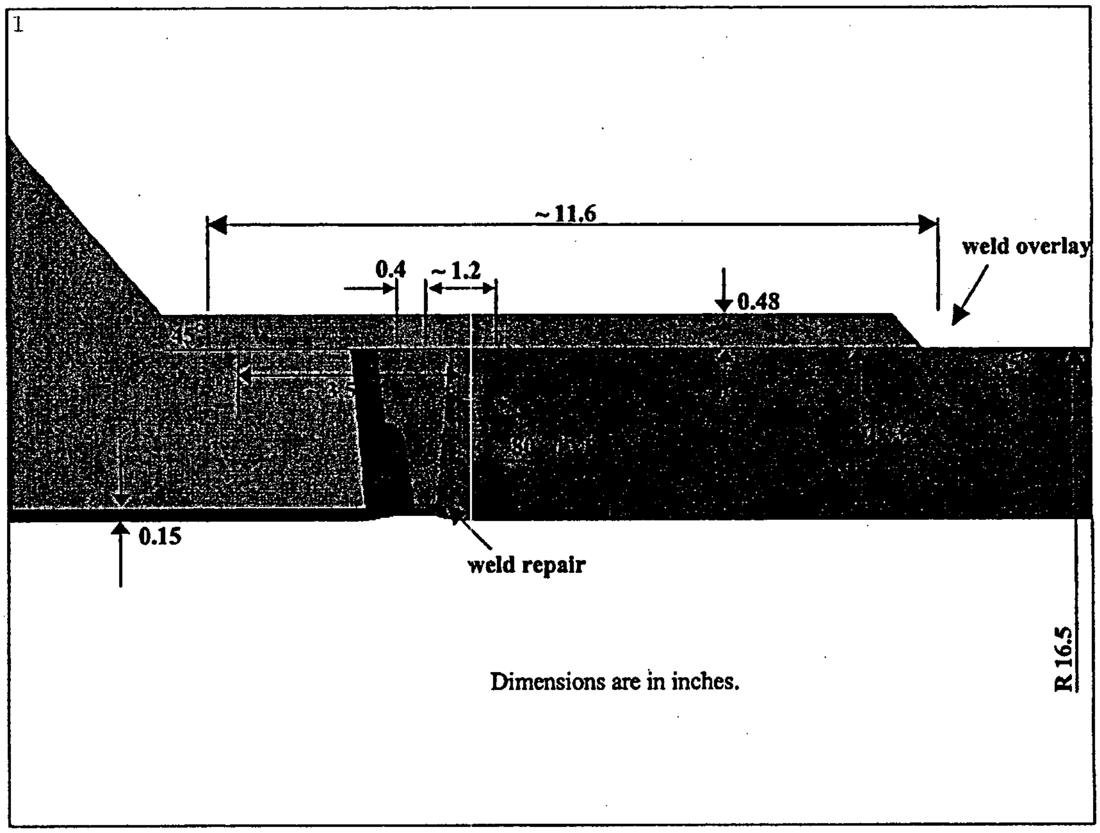
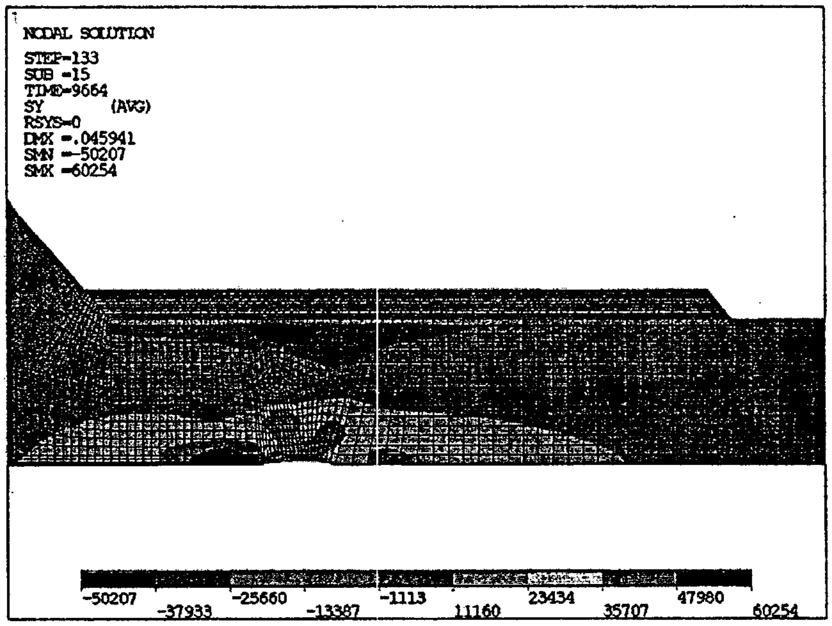
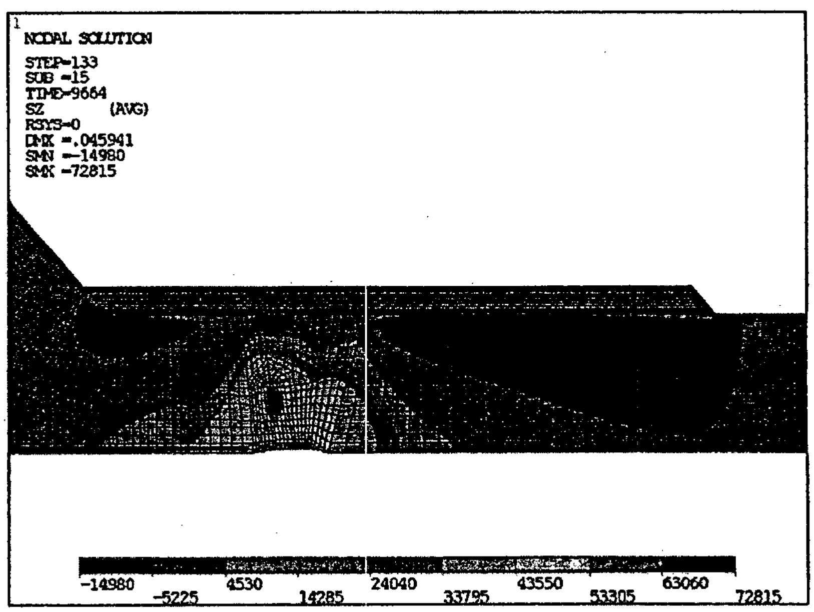


Fig. 12 Summary of Dimensions for the Weld Overlay Finite Element Model

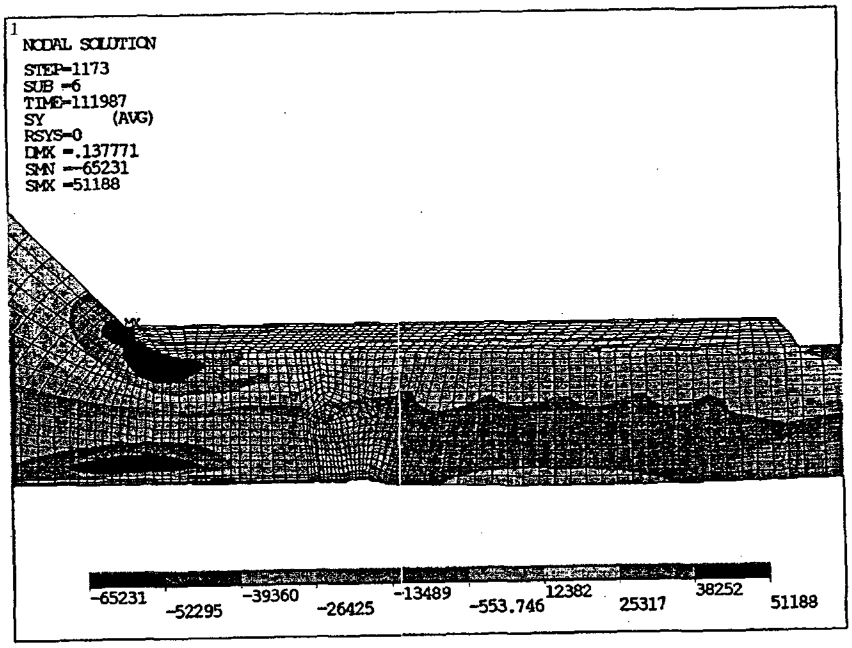


a. Axial

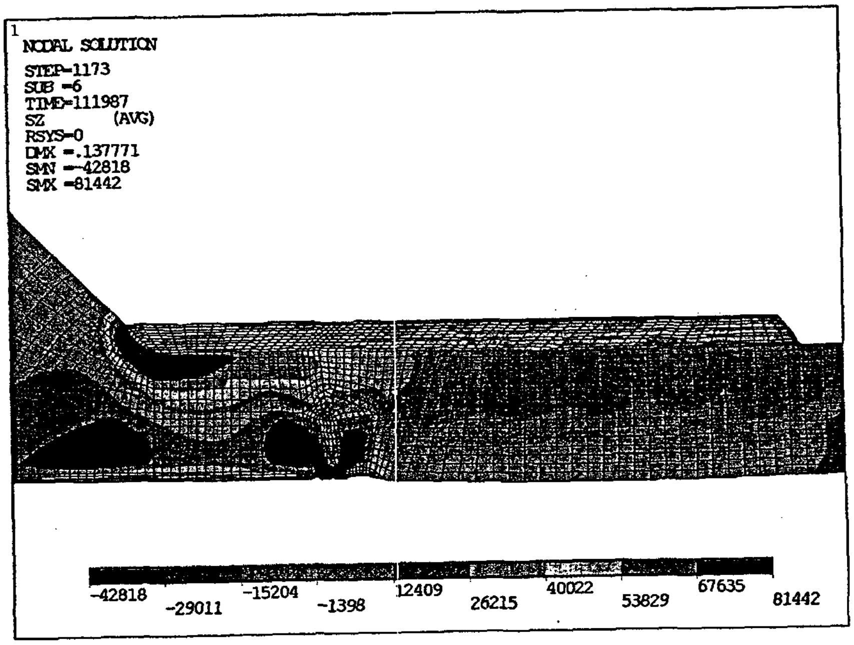


b. Hoop

Fig. 13 Pre-WOL Stress Contours, 70°

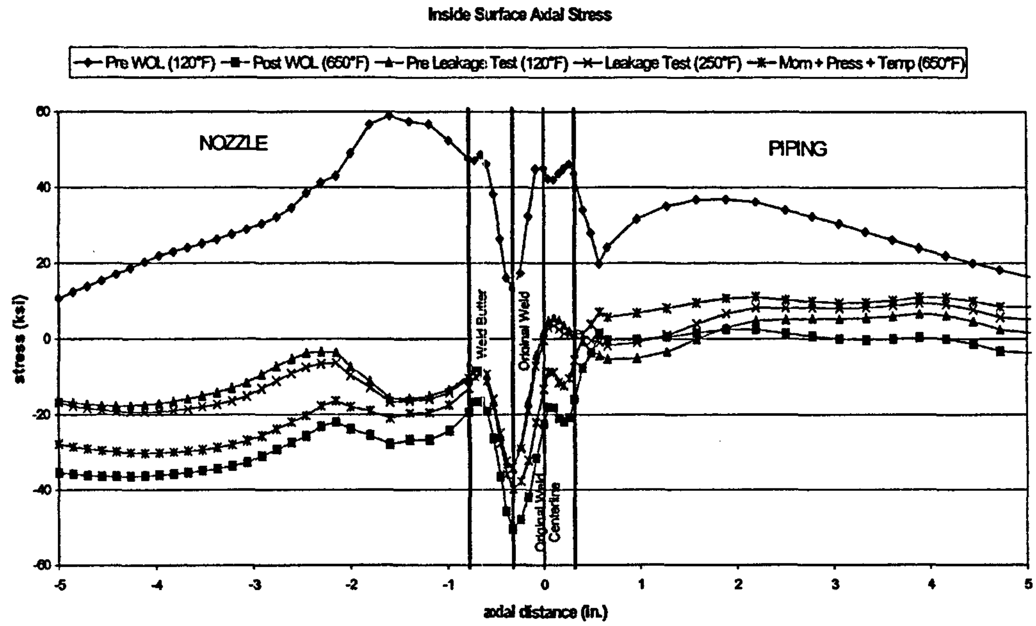


a. Axial



b. Hoop

Fig. 14 Post WOL Hoop Stress Contour, 70 F°



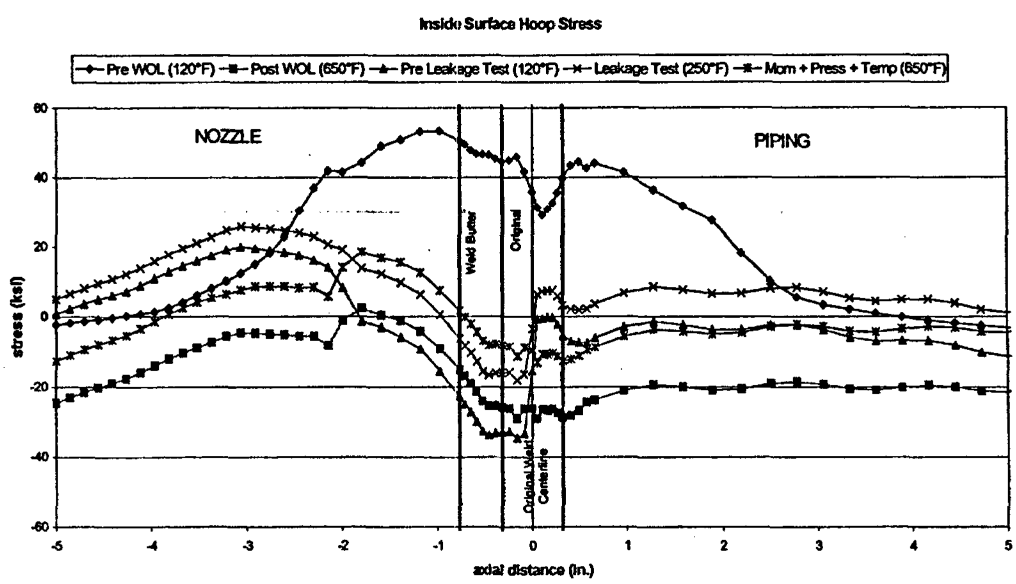


Fig. 15 Inside Surface Stresses at Different Conditions, 5 Layers, Long Overlay, Water Inside Pipe

4) References

1. "Inconel Weld-Overlay Repair for Low-Alloy Steel Nozzle to Safe-End Joint", EPRI NP-7085-D, January 1991.
2. "Justification for Extended Weld-Overlay Design Life", EPRI-NP-7103-D, January 1991.
3. "Justification for the Removal of the 100 Square Inch Limitation for Ambient Temperature Temper Bead Welding on P-3 Material", EPRI-NP-XXXX, February 2005.
4. "Calculation Package, Preemptive Weld Overlay Residual Stress Analysis", DEV-03-3xx, Structural Integrity Associates, Inc., San Jose, CA, January 2005.

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