



September 25, 2008

L-2008-210  
10 CFR 50.4  
10 CFR 50.55a

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

Re: St. Lucie Unit 1  
Docket No. 50-335  
In-Service Inspection Plans  
RAI Reply for Fourth Ten-Year Interval Unit 1 Relief Request 2


On April 29, 2008, Florida Power & Light (FPL) submitted a relief request, pursuant to the provisions of 10 CFR 50.55a(a)(3)(i), for the use of structural weld overlays (SWOLs) as an alternative repair method. FPL and the NRC discussed the submittal during a teleconference held on September 16, 2008. On September 18, 2008, the NRC issued a request for additional information (RAI), and this letter provides the FPL response.

Attachment 1 contains the RAI responses, and Attachment 2 contains the relief request revision that provides administrative corrections to the original document.

In addition to the commitment to submit a report of the SWOL UT examinations within 60 days from the end of the SL1-22 refueling outage, this letter makes the additional commitment to submit a summary report for the required evaluations of fatigue, residual stresses, and flaw growth of the repaired weldments.

FPL requests approval of the relief request prior to entering Mode 4 during the fall 2008 St. Lucie Unit 1 refueling outage, SL1-22, tentatively scheduled for early November 2008. Please contact Ken Frehafer at 772-467-7748 if there are any questions about this submittal.

Sincerely,

  
for Eric S. Katzman  
Licensing Manager  
St. Lucie Plant

Attachments  
ESK/KWF

A047  
LRR

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By letter dated April 29, 2008, Florida Power & Light proposed an alternative Relief Request 2 (RR-2) to the requirements of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, for mitigating primary water stress corrosion cracking on dissimilar metal welds using full structural weld overlays (SWOL) at St. Lucie, Unit 1 (SL-1). Currently, the U.S. Nuclear Regulatory Commission (NRC) staff has approved the use of Code Case N-504-3, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping Section XI, Division 1,; and N-638-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique Section XI, Division 1."

The NRC staff used the requirements of Code Cases N-504-3 and N-638-1 as NRC-approved criteria associated with similar full SWOL applications to aid in the evaluation of the SL-1, RR-2 Attachment 2. To complete its review, the staff is requesting the following additional information:

RAI 1:

Discuss whether the subject nozzles have been ultrasonically examined under the Inservice Inspection (ISI) program or Electric Power Research Institute (EPRI) report, MRP-139 in previous refueling outages. If so, discuss whether flaws have been detected in the subject nozzles.

FPL Response:

FPL has performed ISI UT examinations of these welds, and has not found any indications:

FPL has not performed Appendix VIII qualified UT examinations of these welds in previous refueling outages.

As stated in FPL's relief request, "ASME Section XI, Appendix VIII, Supplement 10 ultrasonic examination will not be performed on the DMWs prior to the SWOLs being applied. Since the structural integrity at the DMW locations will be restored by the SWOLs the ultrasonic examination of the DMWs prior to SWOL application is unnecessary and the increased personnel dose that would be incurred performing the examinations is also undesirable and not consistent with good ALARA practice. All welds have postulated 100% through-wall cracks for both the SWOL design and for the flaw growth evaluations."

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RAI 2:

In Section 1.1, page 1. The Examination Category for the subject welds is identified as R-A. This is a risk-informed ISI examination category.

- (A) Discuss whether after the weld overlay installation, will the ISI examinations be based on the RI-ISI program or the proposed RR-2?
- (B) Discuss whether the subject welds will be removed from the RI-ISI program after the weld overlay installation.

FPL Response:

As stated in FPL's Revised Risk Informed Relief Request #1 (Letter L-2008-189), "The PWSCC damage mechanism will be addressed separately from RI-ISI by FPL's augmented alloy 600 program. FPL's augmented alloy 600 inspection program implements the MRP-139 selection criteria and response to degradation identification. FPL's alloy 600 inspection program will not be subsumed into RI-ISI and the inspections will not be credited to satisfy inspections required under the ASME Section XI, 4th Interval, RI-ISI program. Weld locations currently within the scope of FPL's alloy 600 program that are mitigated by replacement of the susceptible material will be placed back into the RI-ISI program. Weld locations that are mitigated by methods other than removal of the susceptible material will continue to be examined in accordance with FPL's alloy 600 program during the 4th Interval."

RAI 3:

Paragraph 2(a) of Attachment 2 of RR-2 states that the size of all flaws detected or postulated in the original weldment shall be projected to the end of the expected life of the overlay. Provide/describe the expected life of the overlay.

FPL Response:

As stated in FPL's relief request, "all welds have postulated 100% through-wall cracks for both the SWOL design and for the flaw growth evaluations." The flaw growth evaluations, for fatigue and PWSCC crack growth into the overlay material, demonstrate adequate remaining WOL ligament at the end of the 40 year plant design life plus the 20 year license extension period, to meet the minimum WOL design thickness.

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RAI 4:

Paragraphs g(2) and g(3) of American Society of Mechanical Engineers (ASME) Code Case N-504-3 require evaluations of residual stresses and flaw growth of the repaired weldments. Section 2 of Attachment 2 to RR-2 requires similar evaluations. Section 2(b)7 of Attachment 2 states that effects of any changes in applied loads, as a result of weld shrinkage from the entire SWOL on other items in the piping system, shall be evaluated.

- (A) Confirm that the analysis will be performed to show that the requirements of Subarticles NB-3200 and NB-3600 of the ASME Code, Section III are satisfied.
- (B) Confirm that the analysis includes the crack growth calculations to demonstrate that crack growth in the weld overlay or base metal is acceptable and residual stress distribution in the weld overlay and original weld demonstrate favorable stress distribution.
- (C) The staff requests that the licensee submit the preliminary results of the evaluations prior to entry into Mode 4 from the refueling outage and the final evaluations within 60 days of the plant restart.

FPL Response:

- (A) Evaluations of the subject nozzle weld overlay repairs have been performed in accordance with the requirements the ASME Boiler and Pressure Vessel Code, Section III, for Class 1 components to show that the requirements of Subarticles NB-3200 and NB-3600 of the Code are satisfied.
- (B) Flaw growth evaluations, for fatigue and PWSCC crack growth into the overlay material have been performed and include the residual stress results. These evaluations demonstrate adequate remaining WOL ligament at the end of the 40 year plant design life plus the 20 year license extension period, to meet the minimum WOL design thickness.  
Analysis of the residual stress, due to the WOL, which demonstrate the favorable stress distribution in the original weld have also been performed.
- (C) FPL will have the requested evaluations completed and available at the PSL site prior to entry into Mode 4 from the refueling outage for NRC review. A summary report of the analysis methodology and results will be issued within 60 days of the plant restart.

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RAI 5:

Paragraph I-2.1(g)(2) of Mandatory Appendix I of Attachment 2 to RR-2 provides a means of determining an Adjustment Temperature for the welding procedure qualification. This Adjustment Temperature was not a part of Code Case N-638-1 and, therefore, has not been approved by the staff. Explain the technical basis of this requirement.

FPL Response:

Paragraph I-2.1(g)(2) of Mandatory Appendix I of Attachment 2 does not apply since the welding procedure qualification to be used is already qualified and acceptable for the lowest service temperature for this component. Therefore, an Adjustment Temperature is not required.

RAI 6:

Section 5.2 of RR-2, states that a barrier layer of austenitic stainless steel filler metal across the austenitic stainless steel base metal to reduce the risk of cracks.

- (A) Discuss whether paragraph (e) of Code Case N-504-3 is applicable to the barrier layer if austenitic stainless steel filler metal is applied. Paragraph (e) requires existence of certain delta ferrite content in the welded metal when austenitic stainless steel weld metal is used.
- (B) Identify the austenitic stainless steel weld filler metal that will be used for the butter layer.
- (C) Confirm that the Certified Material Test Report (CMTR) for the austenitic stainless steel filler wire shows a minimum delta ferrite of a specified amount. Provide the maximum and minimum delta ferrite content for the heat of austenitic stainless steel filler wire to be used, as stated on the CMTR.

FPL Response:

- (A) The delta ferrite requirement from Code Case 504-3 is not applicable because the barrier layer is not considered part of the structural overlay. The delta ferrite requirement is only applicable when including the stainless steel barrier layer in the thickness of the overlay.
- (B) FPL may utilize either ER 308L or ER 309L as a buffer layer.
- (C) Not applicable – see answer to 6(A).

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RAI 7:

What are the beginning and end dates for the fourth 10-year ISI interval at SL-1?

FPL Response:

The Fourth Inservice Inspection Interval starts on February 11, 2008 and ends on February 10, 2018.

RAI 8:

The following typographical errors were identified in the proposed alternative and should be corrected:

- (A) On page 6, on the second line of the first full paragraph 2(b)(6) should be 2(b)(5), on the third line of the same paragraph 2(b)(7) should be 2(b)(6), on the eighth line of the paragraph 2(a)(2)(b) should be 2(a)(2)(a).
- (B) On page 25, Section 2(a)(2)(b) in the third line "(b) or (c) above" should be deleted.
- (C) On page 26, Section 2(b)(6) in the sixth line 2(b)(4), (5), or (6) should be 2(b)(3), (4), or (5).
- (D) On page 36, Section I-2.1(f) should be changed to I-2.1(f)(4).

FPL Response:

The identified typographical errors are corrected. See attachment 2.

RAI 9:

Mandatory Appendix I to Attachment 2 of RR-2 Section I-3(e) lists a number of methods that can be used in the welding procedure to determine interpass temperature. The staff's position is that the temperature measurement in 1-3(e)(1) should be used. If 1-3(e)(1) cannot be performed, 1-3(e)(2) or 1-3(e)(3) may be used. Please describe the method that will be used at SL-1 and provide a discussion of its acceptability.

FPL Response:

FPL agrees with the staff's position that the interpass temperatures shall and will be determined according to 1-3(e)(1) by measurement.

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RAI 10:

Section 3(c)2 of Attachment 2 of RR-2 states no credit can be given in any portion of the examination volume where the ultrasonic beam passes through the cast stainless steel material.

- (A) Provide the weld overlay thickness.
- (B) Provide reduction in ultrasonic testing (UT) volume coverage for the weld overlay locations which involve cast stainless steel safe-ends, including estimated total UT examination coverage for preservice and inservice inspection per sections 3(b) and 3(C) of RR-2. Discuss why reduction in examination coverage is acceptable.
- (C) Discuss whether a phased-array UT technique will be used in the volumetric examination.

FPL Response:

- (A) The minimum weld overlay thicknesses at the dissimilar metal Alloy 82/182 welds are as follows:  
Hot Leg Surge Nozzle: 0.78"  
Hot Leg Shutdown Cooling Nozzle: 0.73"
- (B) The approximate percent (%) reduction in Ultrasonic (UT) coverage of the ISI volume, of the dissimilar metal Alloy 82/182 welds, due to the cast stainless steel safe-ends, are as follows:

Weld Location	Reduction in UT coverage due to cast safe-end.
Surge Nozzle	< 10%
Shutdown Cooling Nozzle	< 10%

The SWOLs will be designed as full structural overlays. Postulated 100% through-wall flaws shall be assumed as specified in 2(b)(5), Attachment 2, for SWOL length and thickness sizing per 2(b)(6) Attachment 2 of FPL's relief request. For flaw growth evaluations, since no ultrasonic examination will be performed prior to SWOL application, and the post SWOL ultrasonic examination is not qualified for flaw detection and sizing in cast stainless steel base material on some of the nozzles, postulated 100% through-wall flaws will be assumed as specified in 2(a)(2) and 2(a)(2)(a), Attachment 2, for the welds on all nozzle locations where SWOLs will be applied. Planar flaws detected during the

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acceptance examination will be characterized and flaw growth calculations performed using the flaw(s) detected plus the postulated 100% through-wall flaws.

- (C) FPL is planning to implement Appendix VIII qualified Phased Array UT for the final overlay examination.

RAI 11:

Attachment 2 of RR-2, page 23, first paragraph, states that, "...All Section XI references are to the 2004 Edition with the 2006 Addenda..." This statement is not applicable to SL-1 and should be eliminated because the code of record for the SL-1 fourth 10-year ISI interval in which RR-2 is applicable is the 2001 Edition thru 2003 Addenda. In addition, Table 1 of Attachment 2 can be deleted since the additional code references do not apply. The staff notes that the NRC has not incorporated by reference the 2005 and 2006 Addenda of the ASME Code in Title 10, *Code of Federal Regulations*, Section 50.55a.

FPL Response:

FPL Agrees to the deletion of Table 1 and reference to 2004 Edition with 2006 Addenda to Section XI. This page will be revised to delete this table.

RAI 12:

Section 2.0 of Attachment 2 of RR-2 states that the code of record for the current ISI 10-year interval is, "...Section XI, 2001 Edition including Addenda through 2003 and 2001 with 2001 Addenda for Appendix VIII..." Please clarify the ASME Code Edition and Addenda that will be used for PDI examination per the ASME Code, Section XI, Appendix VIII because the 2001 Addenda of the ASME Code do not exist.

FPL Response:

FPL agrees that this is a typographical error and should refer to ASME Code Section XI Appendix VIII, 2001 Edition (not Addenda). The relevant pages of the relief request, were corrected as shown in Attachment 2.



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Proposed Alternative in Accordance with 10 CFR 50.55a(a)(3)(i)

Alternative Provides Acceptable Level of Quality and Safety

USE OF WELD OVERLAYS AS AN ALTERNATIVE REPAIR TECHNIQUE

1.0 ASME Code Components Affected

Code components associated with this request are three (3) Class 1 safe end-to-nozzle dissimilar metal welds (DMWs) with Alloy 82/182 weld metal that are believed to be susceptible to Primary Water Stress Corrosion Cracking (PWSCC). Preemptive full structural weld overlays (SWOLs) are planned to be applied to these DMWs. In addition, the SWOLs will extend across the three (3) adjacent stainless steel pipe elbow-to-safe end similar metal welds. These welds are scheduled to have SWOLs applied during the upcoming St. Lucie Unit 1 SL1-22 refueling outage.

1.1 Category and System Details:

Code Class:	Class 1
System Welds:	Reactor Coolant System
Examination Categories:	R-A*

\*As submitted by St. Lucie Unit 1, 4<sup>th</sup> 10-year ISI Program Relief Request 1

1.2 Component Descriptions:

The application of this alternative is to apply SWOLs on two (2) safe end-to-hot leg shutdown cooling outlet nozzle welds (one in each hot leg) and one (1) safe end-to-hot leg B surge nozzle weld. The SWOLs will also extend outward from the nozzle across the adjacent stainless steel pipe elbow-to-safe end welds. The applicable weld identifications are as follows in Table 1.

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**TABLE 1**

Item	Location	Weld Nos.	
		Nozzle-to-Safe End Weld	Safe End-to-Pipe Elbow
1	Surge Line to Hot Leg B Pipe Nozzle	RC-6-509	RC-108-FW-3
2	Shutdown Cooling Outlet to Hot Leg 'A' Pipe Nozzle	10-509-B	RC-162-FW-1
3	Shutdown Cooling Outlet to Hot Leg 'B' Pipe Nozzle	10-509-A	RC-147-FW-1

1.3 Component Materials:

The specific materials are shown in Table 2:

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**TABLE 2**

Item	Location	Materials				
		Nozzle	Safe End	Pipe Elbow	Buttering	Pipe Elbow-to-Safe End Weld
1	Surge Line to Hot Leg 'B' Pipe Nozzle	P-No. 1 Group 2 Carbon Steel SA-105 Grade II	P-No.8 Cast Stainless Steel SA-351 CF8M.	P-No.8 Cast Stainless Steel SA-351 CF8M.	F-No. 43 Alloy 82/182	E308L or ER308L
2	Shutdown Cooling Outlet to Hot Leg 'A' Pipe Nozzle	P-No. 1 Group 2 Carbon Steel SA-105 Grade II	P-No.8 Cast Stainless Steel SA-351 CF8M.	P-No. 8 SA-312 TP304 Stainless Steel	F-No. 43 Alloy 82/182	E308 or E308L or ER308 or ER308L
3	Shutdown Cooling Outlet to Hot Leg 'B' Pipe Nozzle	P-No. 1 Group 2 Carbon Steel SA-105 Grade II	P-No.8 Cast Stainless Steel SA-351 CF8M.	P-No. 8 SA-312 TP304 Stainless Steel	F-No. 43 Alloy 82/182	E308 or E308L or ER308 or ER308L

### **2.0 Applicable Code Edition and Addenda**

St. Lucie Unit 1 is currently in the 4<sup>th</sup> 10-year Inservice Inspection (ISI) interval. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) of record for the current 10-year ISI interval is Section XI, 2001 Edition, including Addenda through 2003 (Reference 1) and 2001 Edition for Appendix VIII. The 2001 Edition with Addenda through 2003 is applicable for the Repair/Replacement Program.

### **3.0 Applicable Code Requirement**

The applicable Code requirement for which the relief is requested is ASME Code, Section XI, 2001 Edition including Addenda through 2003 (Reference 1), IWA-4410(a), IWA-4611.1(a) and Section XI, 2001 Edition for Appendix VIII Supplement 11.

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IWA-4410(a) states in part the following:

“Welding, brazing, defect removal, and installation activities shall be performed in accordance with IWA-4420 or IWA-4430, and the other requirements of this Subarticle.....”

IWA-4611.1(a) states in part the following:

“Defects shall be removed or reduced in size in accordance with this Paragraph.”

Appendix VIII provides requirements for performance demonstration for ultrasonic examination systems. Supplement 11 provides qualification requirements for full structural overlaid wrought austenitic piping welds.

#### **4.0 Reason for Request**

Dissimilar metal welds (DMWs), primarily consisting of Alloy 82/182 weld metal are frequently used in pressurized water reactor (PWR) construction to connect stainless steel pipe and safe ends to vessel and pipe nozzles, generally constructed of carbon or low alloy ferritic steel. These welds have shown a propensity for PWSCC degradation, especially in components subjected to higher operating temperatures, such as the pressurizer. See EPRI MRP-169 “Technical basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs,” September 2005 (Reference 2).

For the upcoming SL1-22 refueling outage, three (3) DMWs located on the hot leg piping are currently scheduled to have SWOLs applied. Repair/replacement activities associated with SWOL repairs are required to address the materials, welding parameters, ALARA concerns, operational constraints, examination techniques and procedure requirements for repairs.

ASME Code, Section XI, 2001 Edition including Addenda through 2003 (Reference 1), IWA-4410(a) and IWA-4611.1(a) do not address all the needed requirements for this type of repair since potential existing defects will not be removed or reduced in size, and weld overlay of potential existing flaws in DMWs will be performed. Also comprehensive and generic NRC approved criteria are not currently available for application of SWOL repairs to DMWs constructed of Alloy 82/182 weld material for mitigation of potential PWSCC.

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In addition, ASME Code Section XI, 2001 Edition including Addenda through 2003 (References 1 & 6), and 2001 Edition of Appendix VIII Supplement 11 cannot be implemented as written for ultrasonic examination of a structural weld overlay repair. Attachment 1 includes a discussion of the Performance Demonstration Initiative (PDI) Program alternatives and their bases with respect to Appendix VIII Supplement 11 requirements.

The alternative described in Section 5.0 is proposed to permit the implementation of SWOLs at St. Lucie Unit 1, as an alternative for the repair/replacement requirements of the ASME Code Section XI, 2001 Edition, including Addenda through 2003 (Reference 1), IWA-4410(a), IWA-4611.1(a) and 2001 Edition, Appendix VIII, Supplement 11.

## **5.0 Proposed Alternative and Basis for Use**

This proposal requests the use of the Alternative Requirements shown in Attachment 2 for implementing the three (3) scheduled SWOLs for potentially PWSCC susceptible safe end-to-nozzle welds of the reactor coolant hot leg piping. These SWOLs will include the three (3) adjacent stainless steel pipe elbow-to-safe end welds. This request applies to each of the welds listed in Section 1.2, which are generically depicted in Figure 1. The proposed Alternative is scheduled to be performed during the SL1-22 Fall 2008 refueling outage.

This proposed alternative (Attachment 2) is the result of industry's experience with weld overlay modifications for flaws suspected or confirmed to be caused by PWSCC and directly applies to the Alloy 52 or 52M weld material that is primarily being used for these SWOLs.

The ultrasonic examination of the completed SWOLs will be accomplished with personnel and procedures qualified in accordance with ASME Code, Section XI, 2001 Edition, (Reference 5 and 6) for Appendix VIII, Supplement 11 (as specified in Attachment 2, Section 3 therein), with the alternatives used for complying with the PDI Program. See Attachment 1 for the PDI Program changes to Appendix VIII Supplement 11.

### **5.1 Structural Weld Overlay (SWOL) Design**

The SWOLs satisfy all the structural design requirements of the pipe as specified in the Alternative Requirements shown in Attachment 2 for the original safe end-to-nozzle welds and the pipe elbow-to-safe end welds. As shown in Figure 1, the SWOLs will

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completely cover the existing Alloy 82/182 weld and will extend onto the ferritic nozzle and austenitic stainless steel material on each end of the weld, including the adjacent pipe elbow-to-safe end weld. The SWOLs extend around the entire circumference of the nozzle. Alloy 52M and 52 filler metals are compatible with all the wrought and cast base materials and the DMW and similar metal welds that will be covered by the SWOL.

The SWOLs will be designed as full structural overlays. Postulated 100% through-wall flaws shall be assumed as specified in 2(b)(5), Attachment 2, for SWOL length and thickness sizing per 2(b)(6) Attachment 2. No ultrasonic examination will be performed prior to SWOL application. For flaw growth evaluations, since no ultrasonic examination will be performed prior to SWOL application, and the post SWOL ultrasonic examination is not qualified for flaw detection and sizing in cast stainless steel base material on some of the nozzles, postulated 100% through-wall flaws will be assumed as specified in 2(a)(2) and 2(a)(2)(a), Attachment 2, for the welds on all nozzle locations where SWOLs will be applied. Planar flaws detected during the acceptance examination will be characterized and flaw growth calculations performed using the flaw(s) detected plus the postulated 100% through-wall flaws.

Note that the details surrounding the design analysis for the SWOLs are being developed to support the St. Lucie Unit 1 Fall 2008 refueling outage and our vendor has committed to supplying this analysis to FPL. The analysis will be available at the plant for NRC review at the beginning of the SL1-22 refuel outage.

Paragraph 3(a)(3) of Attachment 2 states that "for planar indications outside this examination volume, the nominal wall thickness shall be " $t_2$ " as shown in Fig 1(c) for volumes A-E-H-D and F-B-C-G." For the cast stainless steel material, UT is not currently qualified to examine the base metal following weld overlay installation. Initial 100% through-wall axial and circumferential flaws are assumed for both SWOL design and flaw growth evaluations at all nozzle locations where SWOLs will be installed. " $t_2$ " is  $\frac{1}{2}$  in. outside the PWSCC susceptible DMW. The portion of the pipe, safe end or nozzle material outside the PWSCC susceptible material is assumed unflawed. These volumes are also outside any other Section XI ISI volume other than associated with the original weld ISI as shown in Figure IWB-2500-8(c) so service related flaws therein are not expected to occur. Surface examination is also performed on these areas before the SWOLs are applied to verify absence of surface flaws. The volume of the overlay which is more than  $\frac{1}{2}$  inch from the susceptible region is treated as a cross section which is the SWOL thickness plus the original underlying base metal wall thickness. The acceptance standard for a flaw in the SWOL from Table IWB-3514-2 is thus based on " $t_2$ ". The approach is consistent with other examinations in Section XI including pipe to pipe welds where the examination volume does not include the entire thickness but the acceptance

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criteria does. Furthermore indications in the overlay will be required to be sized. This requirement will assure that the indications which may extend into the base metal are not excluded.

## 5.2 Welding

The welding will be performed in accordance with Attachment 2 using a machine gas tungsten-arc welding (GTAW) process and using the ambient temperature temper bead method with ERNiCrFe-7A (Alloy 52M) weld metal. Manual GTAW, using ERNiCrFe-7 (Alloy 52) or Alloy 52M may be used if local repairs of weld defects are necessary or additional weld metal is required locally to form the final SWOL contour in locations at least 3/16 in. away from the low alloy or carbon steel nozzles.

During recent dissimilar metal weld (DMW) overlay activities, where ERNiCrFe-7A (Alloy 52M) and ERNiCrFe-7 (Alloy 52) have been used for the filler metal, flaws in the first layer have occurred in the portion of the overlay deposited on the austenitic stainless steel portions (safe ends, pipe etc.) of the assemblies in some cases.

The flaw characteristics observed above are indicative of hot cracking. This phenomenon has not been observed on the ferritic steel or ENiCrFe-3 (Alloy 182) DMW portions of the assemblies when welding Alloy 52M thereon.

Further studies have determined that this problem may occur when using Alloy 52M filler metal on austenitic stainless steel materials with high sulfur content.

Extensive tests and field experience from WSI indicate that hot cracking can be a concern when the sulfur and phosphorus content in the diluted weld puddle equals or exceeds 0.014%. The impurity hot cracking threshold level is a function of both the composition of the weld filler materials and the welding parameters that are used because these two factors control the dilution of the solidified weld deposit. This suggests that a combined sulfur plus phosphorus content of the base material approximately 0.046% will represent a threshold for hot cracking with the weld parameters WSI will use at St. Lucie.

St. Lucie Unit 1 will use the barrier layer on all the stainless steel items prior to overlay. The barrier layer will use ER308L or ER309L on the stainless steel and may incorporate Alloy 82 on the stainless steel near the DMW to stainless steel fusion zone only.

The barrier layer will not be used in the structural analysis. The inside diameter of the portion of the SWOL over the barrier layer will be the outside diameter of the barrier

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layer that is applied over the stainless steel material beneath the SWOL. See Attachment 3 for more information.

The Cr content of the 1st layer was verified by direct measurement of weld overlay deposits on ASTM A106 Grade B mockups. Welding was performed using a double up progression (starting at the bottom and welding upward to the top on each side) for 5G and 6G mockups and orbital progression for 2G mockups. The Cr content was measured at 90 degree intervals. All welding parameters were recorded and the 24% minimum Cr value specified in 1(e), Attachment 2, was attained in all cases. The attainment of the minimum 24% Cr threshold level has been demonstrated many times on similar mockups using the same WSI welding parameters. The same heat of wire, or a wire heat with equal or greater chrome content than that used in qualification, will be used in situ for the first layer and the same welding parameters will be specified in the WPS as was used in the mockup for the first layer. It should be noted that the deposition of Alloy 52M over base material already having significant Cr content will have higher deposited Cr content.

The SWOL will require welding on more than 100 square inches of surface on the hot leg surge nozzle and shutdown cooling ferritic carbon steel nozzles but less than 300 square inches which is permitted in Appendix I, I-1(b), Attachment 2. The SWOL will extend toward the hot leg onto the ferritic steel nozzle base material for a sufficient length so that qualified ultrasonic examination of the required volume can be performed after the SWOL is applied.

There have been a number of temper bead SWOLs applied to safe end-to-nozzle welds in the nuclear industry, and SWOLs having more than 100 square inch surface area on the nozzle ferritic steel surfaces have been used. The ASME Committee has indicated the inside diameter compressive stress levels remain essentially the same for both 100 square inches and 500 square inches related to SWOL applications. The justification entitled "Bases for 500 Sq. In. Weld Overlay Over Ferritic Material", was provided to the NRC staff in the January 10, 2007 meeting (Accession No. ML070470565). Additional justification is provided in Appendix F of EPRI Report 1014351, Repair and Replacement Applications Center: Topical Report Supporting Expedited NRC Review of Code Cases for Dissimilar Metal Weld Overlay Repairs" December 2006 (Reference 4).

The thickness of the SWOLs may exceed  $\frac{1}{2}$  the carbon and low alloy ferritic steel nozzle base metal thickness as specified in Code Case N-638-1. The requirement therein applies to excavated cavities in the ferritic steel base material that are subsequently welded flush. This requirement is not applicable to SWOLs since they are applied to the nozzle surface and limited to  $\frac{3}{8}$  in. depth into the ferritic steel as specified in Attachment 2, Appendix I, I-1(d). Additional justification is provided in Appendix F of Reference 4.



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I-3.0(d), Appendix I, Attachment 2, specifies the maximum interpass temperature shall be limited to 350 °F maximum, even though the maximum interpass temperature is limited to 150 °F maximum for the first three layers in the test assembly specified in I-2.1(c). This is greater than the maximum 100 °F interpass temperature increase permitted by QW-406.3. The following is a clarification of the intent of Code Case N-638-1 that has been included in Code Case N-638-2. The limitation on the procedure qualification maximum interpass temperature (150 °F) is to ensure the cooling rates achieved during procedure qualification are more severe than those encountered during field welding (i.e., are not slower than those achievable during field welding). The higher interpass temperature is permitted during field welding because it would only result in slower cooling rates which could be helpful in producing more ductile transformation products in the ferritic steel heat affected zone (HAZ). Additional justification information is also included in Reference 4.

For applicable cases where paragraph 1(c)(1), Attachment 2 applies, the final SWOL ultrasonic and surface examination will be performed after completion of welding since temper bead welding would not be required. The clarifications in this paragraph are conservative with respect to the intent of the Construction Code post weld heat treatment (PWHT) exemption requirements [Table NB-4622.7(b)-1] since all weld overlays are deposited on the surfaces of the ferritic steel nozzles instead of partial or complete through thickness welds applicable for the cases described in the Construction Code.

### 5.3 Examination

ASME Section XI, Appendix VIII, Supplement 10 ultrasonic examination will not be performed on the DMWs prior to the SWOLs being applied. Since the structural integrity at the DMW locations will be restored by the SWOLs the ultrasonic examination of the DMWs prior to SWOL application is unnecessary and the increased personnel dose that would be incurred performing the examinations is also undesirable and not consistent with good ALARA practice. All welds have postulated 100% through-wall cracks for both the SWOL design and for the flaw growth evaluations.

The ultrasonic and surface examinations will be performed on the temper bead portion of the SWOLs no sooner than 48 hours after completion of the third temper bead layer as specified in 3(a)(2) and 3(a)(3), Attachment 2.

The 48 hour delay is intended to provide time for potential delayed hydrogen cracking occurrence. Attachment 2, Appendix 1 requires the machine or automatic GTAW

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process to be used for temper bead welding thereby eliminating the use of welding processes requiring flux for arc shielding.

The machine GTAW temper bead process uses a welding process that is inherently free of hydrogen. The GTAW process relies on bare welding electrodes and bare wire filler metal with no flux to absorb moisture. An inert gas blanket provides shielding for the weld and surrounding metal, which protects the region during welding from the atmosphere and the moisture it may contain and typically produces porosity free welds. In accordance with the weld procedure qualification, welding grade argon is used for the inert gas blanket. To further reduce the likelihood of any hydrogen effects, specific controls will be used to ensure the welding electrodes, filler metal and weld region are free of all sources of hydrogen.

In addition, the use of the machine GTAW temper bead process provides precise control of heat input, bead placement, bead size and contour. The very precise control over these factors afforded by the machine GTAW process provides effective tempering of the nozzle ferritic steel HAZ resulting in achievement of lower hardness and tempered martensite. This further reduces susceptibility to hydrogen induced cracking.

EPRI Report 1013558, Temperbead Welding Applications, 48 Hour Hold Requirements for Ambient Temperature Temperbead Welding, Technical Update, December 2006 (Reference 3) provides justification for reducing the 48 hour hold time on P-No. 3 Group No. 3 ferritic steel base material to start after completion of the third temper bead layer. Report 1013558 addresses microstructural issues, hydrogen sources, tensile stress and temperature, and diffusivity and solubility of hydrogen in steels.

The base materials studied in the EPRI report are primarily P-No. 3. The hot leg piping nozzle base materials at St. Lucie Unit 1 are P-No. 1 Group No. 2. The concerns associated with hydrogen assisted cracking are generally more significant for P-No. 3 than P-No. 1 base materials due to the P-No. 3 base material's increased hardenability. Also, post weld heat treat exemptions shown in ASME Section III, Table NB-4622.7(b)-1 are provided for P-No. 1 Group No. 2 materials, including temper bead welding, whereas no post weld heat treat exemptions, other than temper bead welding, are permitted for P-No. 3 Group No. 3 materials.

Past industry experience with the use of the machine or automatic GTAW process has resulted in no detection of hydrogen induced cracking after the 48 hour hold NDE or subsequent in-service inspections.

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Code Case N-638-4, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique Section XI Division 1," specifies NDE to be performed on the final weld no sooner than 48 hours after completion of the third temper bead layer.

All examinations will meet the requirements of Attachment 2, excluding qualification of the ultrasonic examination for the completed SWOLs. The ultrasonic examination qualification will be in accordance with ASME Code Section XI, 2001 Edition (References 5 & 6), for Appendix VIII, Supplement 11 with the alternatives that are used to comply with the PDI Program. See Attachment 1 for the PDI Program changes to Appendix VIII Supplement 11. Inservice inspection will be performed as specified in Attachment 2 with the exceptions that:

- 1) the limitations associated with the cast stainless steel safe end material will adversely affect the examinations and
- 2) the ultrasonic examination procedures and personnel will be qualified in accordance Appendix VIII, Supplement 11 as modified by the PDI Program as specified in Attachment 1.

The cast stainless steel base material of the applicable safe ends and the surge line pipe at the surge line elbow at the hot leg B surge nozzle are not currently within the scope of PDI qualified ultrasonic examination procedures. Qualified representative mockups are not currently available, and examination procedures and personnel have not yet been demonstrated for the cast material. In these cases, an Appendix III ultrasonic examination will be performed, using the existing PDI qualified personnel and procedures as shown in Attachment 1. As stated previously, 100% through-wall flaws are assumed for both the SWOL design and the flaw growth evaluations at all nozzle locations where SWOLs are being applied.

The final ultrasonic examination report will be submitted to the NRC within 60 days after completion thereof. Any flaws detected that exceed the acceptance standards of Table IWB-3514-2 will be reported to the NRC as soon as possible. A discussion and reason for any SWOL or base metal repairs will be provided.

The ultrasonic examination requirements specified in NRC Regulatory Guide 1.147 Revision 15 as conditional acceptance of Code Case N-638-1 are not applicable to SWOLs. UT of the SWOLs will be performed in accordance with Section XI, Appendix VIII, Supplement 11 qualified procedures and personnel as modified by PDI and the limitations due to the underlying cast stainless steel base material. The PDI modifications are shown in Attachment 1. Supplement 11 was prepared to be specifically

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applicable to weld overlays. The ultrasonic examination requirements in Section 3, Attachment 2, are similar to the ultrasonic examination requirements provided in Appendix Q which have been developed specifically for austenitic weld overlays. The UT examination to be performed, in conjunction with the surface examinations to be performed, as specified in Section 3 Attachment 2 are based on the latest industry experience and practice and completely satisfactory for the SWOL application.

#### 5.4 Conclusion

The proposed alternative shown in Attachment 2 has been developed to cover the most recent operating experience and NRC approved criteria that are associated with similar SWOL applications. Similar NRC approved requests have been used to produce acceptable weld overlays when applied to dissimilar metal welds with Alloy 82/182 weld material. Therefore FPL considers that Attachment 2 and the PDI Program provides an acceptable level of quality and safety, consistent with provisions of 10 CFR 50.55a(a)(3)(i).

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## 6.0 Precedents

Similar requests have been submitted and approved to address the issues that are contained in this request. Florida Power & Light (FPL) submitted Relief Request #10 for St. Lucie Unit 2, on September 24, 2007 and received NRC's approval December 12, 2007 (TAC NO. MD5114, ADAMS Accession No. ML073400022) which included the application of full structural SWOLs to pressurizer and hot leg connection dissimilar metal butt welds.

Additionally, the following requests associated with weld overlay repairs have been approved by the NRC: AmerGen Energy Company, Three Mile Island Nuclear Station, Unit 1, on July 21, 2004;<sup>(1)</sup> Constellation Energy's Calvert Cliffs Nuclear Power Plant, Unit 1, on July 20, 2005;<sup>(2)</sup> Millstone Unit 3, on January 20, 2006;<sup>(3)</sup> and Indiana Michigan Power Company, Donald C. Cook Unit 1, on February 10, 2006.<sup>(4)</sup>

## 7.0 Duration of Proposed Alternative

The alternative requirements of this request will be applied for the duration of up to and including the last outage of the current 4<sup>th</sup> 10-year ISI interval which includes inservice examination requirements of Attachment 2 for any applied weld overlays. Future inservice examinations of weld overlays at St. Lucie Unit 1 beyond this inspection interval will be as required by the NRC in the regulations.

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- (1) NRC letter, Safety Evaluation of Request for Relief from Flaw Removal, Heat Treatment and Nondestructive Examination (NDE) Requirements for the Third 10-Year Inservice Inspection Interval, Three Mile Island Nuclear Station, Unit 1 (TMI-1), Docket No. 50-289, (TAC No. MC1201), dated: July 21, 2004, (ADAMS Accession No. ML041670510).
  - (2) NRC letter, Safety Evaluation for Calvert Cliffs Nuclear Power Plant, Unit No. 2, Docket No. 550-318, Relief Request for Use Weld Overlay and Associated Alternative Inspection Techniques (TAC Nos. MC6219 and MC6220), dated July 20, 2005, (ADAMS Accession No. ML051930316).
  - (3) NRC letter, Safety Evaluation of Relief Request IR-2-39 Pertaining to the Repair and Inspection of Nozzle-to-safe End Weld, Weld No. 03-X-5641-E-T at Millstone Power Station Unit No. 3 (MPS3) Docket No. 50-423, (TAC No. MC8609), dated January 20, 2006, (ADAMS Accession No. ML053260012).
  - (4) NRC letter, Safety Evaluation of Alternative Regarding Repair of Safe-End-To-Elbow Weld 1-RC-9-01F at the Donald C. Cook Nuclear Plant Unit 1, Docket No. 50-315, (TAC No. MC8807), dated February 10, 2006, (ADAMS Accession No. ML060240355).

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**8.0**    **References**

1.    ASME Code, Section XI, 2001 Edition, including Addenda through 2003
2.    EPRI MRP-169 "Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs," September 2005.
3.    EPRI Report 1013558, Temperbead Welding Applications, 48 Hour Hold Requirements for Ambient Temperature Temperbead Welding, Technical Update, December 2006.
4.    EPRI Report 1014351, Topical Report Supporting an Expedited NRC Review of the Content of the Code Case needed for Dissimilar Metal Weld Overlay Repairs, Final Report, July 2006
5.    10CFR50.55a, Nuclear Regulatory Commission Federal Register part II, Vol. 72, No. 243, effective date January 8, 2008, 10 CFR part 50 Industry Codes and Standards; Amended Requirements; Final Rule.
6.    ASME Code, Section XI, 2001 Edition, for Appendix VIII, Supplement 11 examinations as modified by 10CFR50.55a(b)(2)(xxiv).

**9.0**    **Attachments**

- Attachment 1    "PDI Program Modifications to Appendix VIII Supplement 11"
- Attachment 2    "Alternative Requirements for Dissimilar Metal Weld Overlays"
- Attachment 3    "Barrier Layer to Prevent Hot Cracking in High Sulfur Stainless Steel"

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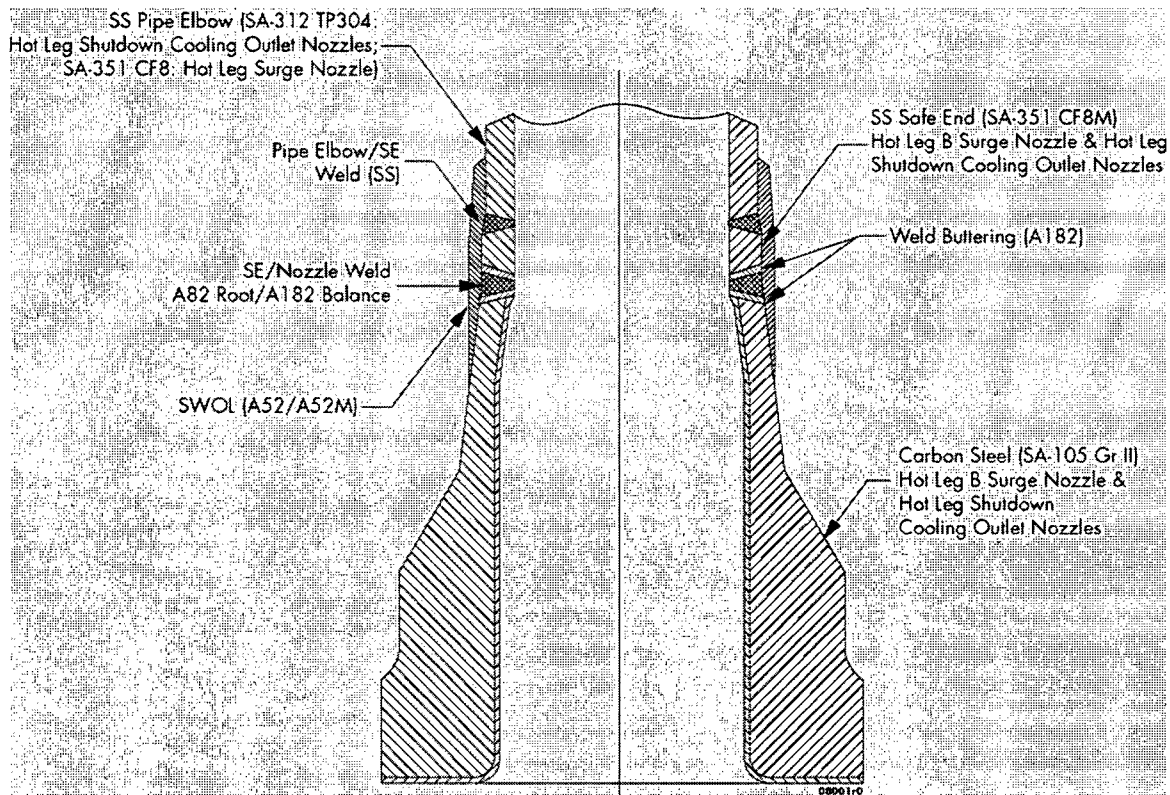


Figure 1 - Typical SWOL Configuration

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**Attachment 1**  
**PDI Program Modifications to Appendix VIII Supplement 11**

Appendix VIII, Supplement 11	PDI Modification
1.0 SPECIMEN REQUIREMENTS	
1.1 General	
<p>(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 inches or larger, the specimen set must include at least one specimen 24 inches or larger but need not include the maximum diameter. The specimen set must include at least one specimen with overlay thickness within -0.1 inches to +0.25 inches of the maximum nominal overlay thickness for which the procedure is applicable.</p>	<p><b>Modification:</b> (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 inches or larger, the specimen set must include at least one specimen 24 inches or larger but need not include the maximum diameter. The specimen set shall include specimens with overlays not thicker than 0.1 inches more than the minimum thickness, nor thinner than 0.25 inches of the maximum nominal overlay thickness for which the examination procedure is applicable.</p> <p><b>Basis:</b> 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).</p>
(d) Flaw Conditions	
<p>(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 IGSCC shall be used when available.</p>	<p><b>Modification:</b> (1) Base metal flaws. All flaws must be in or near the butt weld heat-affected zone, open to the inside surface, and extending at least 75% through the base metal wall. Intentional overlay fabrication flaws shall not interfere with ultrasonic detection or characterization of the base metal flaws. Specimens containing IGSCC 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</p>



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Appendix VIII, Supplement 11	PDI Modification
	<p>reflective characteristics and shall be limited by the following:</p> <p>(a) The use of alternative flaws shall be limited to when the implantation of cracks produces spurious reflectors that are uncharacteristic of actual flaws.</p> <p>(b) Flaws shall be semi elliptical with a tip width of less than or equal to 0.002 inches.</p> <p><b>Basis:</b> 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.</p>
(e) Detection Specimens	
(1) At least 20% but less than 40% of the flaws shall be oriented within $\pm 20$ degrees of the pipe axial direction. The remainder shall be oriented circumferentially. Flaws	<b>Modification:</b> (1) At least 20% but less than 40% of the base metal flaws shall be oriented within $\pm 20$ degrees of the pipe axial direction. The remainder shall be oriented circumferentially.

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<b>Appendix VIII, Supplement 11</b>	<b>PDI Modification</b>
<p>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.</p>	<p>Flaws shall not be open to any surface to which the candidate has physical or visual access. <b>Basis:</b> 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.</p>
<p>(2) Specimens shall be divided into base and overlay grading units. Each specimen shall contain one or both types of grading units.</p>	<p>(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.</p>
<p>(a)(1) A base grading unit shall include at least 3 inches 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.</p>	<p><b>Modification:</b> (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 inch 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 inch of the adjacent base material. <b>Basis:</b> 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</p>

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Appendix VIII, Supplement 11	PDI Modification
	inches.
<p>(a)(2) When base metal cracking penetrates into the overlay material, the base grading unit shall include the overlay metal within 1 inch of the crack location. This portion of the overlay material shall not be used as part of any overlay grading unit.</p>	<p><b>Modification:</b> (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.</p>
<p>(a)(3) When a base grading unit is designed to be unflawed, at least 1 inch 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.</p>	<p><b>Modification:</b> (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. <b>Basis:</b> 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.</p>
<p>(b)(l) An overlay grading unit shall include the overlay material and the base metal-to-overlay interface of at least 6 square inches. The overlay grading unit shall be rectangular, with minimum dimensions of 2 inches.</p>	<p><b>Modification:</b> (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 inch. <b>Basis:</b> 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.</p>
<p>(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 inch 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.</p>	<p><b>Modification:</b> (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 inch 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. <b>Basis:</b> Paragraph 1.1 (e)(2)(b)(2) states that</p>

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Appendix VIII, Supplement 11	PDI Modification
	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.
(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.	<b>Modification:</b> (b)(3) Detection sets shall be selected from Table VIII-S2-1. The minimum detection sample set is five flawed 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.	<b>Modification:</b> (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 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.	<b>Modification:</b> (3) Base metal flaws used for length sizing demonstrations shall be oriented 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 inch in the through-wall direction.	<b>Modification:</b> (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 inch in the through-wall direction.
2.0 CONDUCT OF PERFORMANCE DEMONSTRATION	

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<b>Appendix VIII, Supplement 11</b>	<b>PDI Modification</b>
<p>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.</p>	<p><b>Modification:</b> 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 overlay fabrication flaw test and the base metal flaw test may be performed separately.</p>
<p>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.</p>	<p><b>Modification:</b> 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 metal or overlay fabrication) that are present for each specimen.</p>
<p>2.2 Length Sizing Test</p>	
<p>(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.</p>	<p><b>Modification:</b> (d) For flaws in base metal grading units, the candidate shall estimate the length of that part of the flaw that is in the outer 25% of the base metal wall thickness.</p>
<p>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.</p>	<p><b>Modification:</b> 2.3 Depth Sizing Test. (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.</p>

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Appendix VIII, Supplement 11	PDI Modification
3.0 ACCEPTANCE CRITERIA	
<p>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.</p>	<p><b>Modification:</b> 3.1 Detection Acceptance Criteria. Examination procedures are qualified for detection when:</p> <p>(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.</p> <p>(b) At least one successful personnel demonstration has been performed meeting the acceptance criteria defined in (c).</p> <p>(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.</p> <p>(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.</p>
3.2 Sizing Acceptance Criteria.	
(a) The RMS 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.	<p><b>Modification:</b> (a) The RMS 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 flaws is measured at the 75% through-base-metal position.</p>
(b) All extensions of base metal cracking into the overlay material by at least 0.1 inch are reported as being intrusions into the overlay material.	<p><b>Modification:</b> This requirement is omitted.</p> <p><b>Basis:</b> 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.</p>

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**Attachment 2**  
**Alternative Requirements for Dissimilar Metal Weld Overlays**

In lieu of the requirements of IWA-4410 and IWA-4611, a defect in austenitic stainless steel or austenitic nickel alloy piping, components, or associated welds may be reduced to a flaw of acceptable size in accordance with IWB-3640 by the addition of a repair weld overlay. The weld overlay shall be applied by deposition of weld reinforcement (weld overlay) on the outside surface of the piping, component, or associated weld, including ferritic materials when necessary, provided the following requirements are met:

**1 GENERAL REQUIREMENTS**

(a) A full-structural weld overlay shall be applied by deposition of weld reinforcement (weld overlay) on the outside surface of circumferential welds in carbon steel (P-No. 1) to safe ends or piping components (P-No. 8 or 43), inclusive of the UNS N06082 or W86182 welds that join the two items. The design of the overlay may be extended to include the adjacent stainless steel to stainless steel welds (P-No. 8 to P-No. 8).

(b) Attachment 2 applies to dissimilar metal welds between P-No. 8 or 43 and P-Nos. 1, 3, 12A, 12B, or 12C<sup>1</sup> materials. Attachment 2 also applies to dissimilar metal welds between P-No. 8 and P-No. 43 materials joined with austenitic F-No. 43 filler metal, and to welds between P-No. 8 and P-No. 8 materials as described in 1(a) above.

(c) Weld overlay filler metal shall be austenitic nickel alloy (28% Cr min., ERNiCrFe-7 or ERNiCrFe-7A) applied 360 deg. around the circumference of the item, and deposited using a Welding Procedure Specification (WPS) for groove welding, qualified in accordance with the Construction Code and Owner's Requirements and identified in the Repair/Replacement Plan. As an alternative to the post weld heat treatment (PWHT) requirements of the Construction Code and Owner's requirements, the following provisions may be applied.

(1) For P-No. 1 base materials, the Construction Code PWHT exemptions permitted for circumferential butt welds may be applied to exempt the weld

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<sup>1</sup> P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified in a later Edition of Section IX.

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overlay from PWHT with the following clarifications:

(a) The nominal weld thickness is defined as the maximum overlay thickness applied over the ferritic base material.

(b) The base material thickness is defined as the maximum thickness of the ferritic material where the overlay is applied.

(2) Appendix I shall be used for ambient-temperature temper bead welding.

(d) Prior to deposition of the weld overlay, the surface to be weld overlaid shall be examined using the liquid penetrant method. Indications with major dimension greater than  $1/16$  in. (1.5 mm) shall be removed, reduced in size, or weld repaired in accordance with the following requirements:

(1) One or more layers of weld metal shall be applied to seal unacceptable indications in the area to be repaired with or without excavation. The thickness of these layers shall not be used in meeting weld reinforcement design thickness requirements. Peening the unacceptable indication prior to welding is permitted.

(2) If weld repair of indications identified in 1(d) is required, the area where the weld overlay is to be deposited, including any local weld repairs or initial weld overlay layer, shall be examined by the liquid penetrant method. The area shall contain no indications with major dimension greater than  $1/16$  in. (1.5 mm) prior to the application of the structural layers of the weld overlay.

(e) Weld overlay deposits shall meet the following requirements:

The austenitic nickel alloy weld overlay shall consist of at least two weld layers deposited *using* a filler material with a Cr content of at least 28%. The first layer of weld metal deposited may not be credited toward the required thickness. Alternatively, for PWR applications, a diluted first layer may be credited toward the required thickness, provided the portion of the layer over the austenitic base material, austenitic filler material weld and the associated dilution zone from an adjacent ferritic base material contain at least 24% Cr and the Cr content of the deposited weld metal is determined by chemical analysis taken from a mockup prepared in accordance with the WPS for the production weld.

(f) Attachment 2 is only for welding in applications predicted not to have exceeded thermal neutron fluence of  $1 \times 10^{17}$  ( $E < 0.5$  eV) neutrons per  $\text{cm}^2$  prior to welding.

(g) A new weld overlay shall not be installed over the top of an existing weld overlay that has been in service.



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## 2 CRACK GROWTH AND DESIGN

### (a) Crack Growth Calculation of Flaws in the Original Weld or Base Metal.

The size of all flaws postulated in the original weld or base metal shall be used to define the life of the overlay. In no case shall the inspection interval be longer than the life of the overlay. The inspection interval shall be as specified in 3(c). Crack growth in the original weld or base metal, due to both stress corrosion and fatigue, shall be evaluated. Flaw characterization and evaluation shall be based on the postulated flaw, if ultrasonic examination of the weld and base material is not performed.

(1) For repair overlays, the initial flaw size for crack growth in the original weld or base metal shall be based on the postulated flaw, if no pre-overlay ultrasonic examination is performed.

(2) For postulated flaws in the original weld or base metal the axial flaw length shall be set at 1.5 in. (38 mm) or the combined width of the weld plus buttering, whichever is greater. The circumferential flaw length shall be assumed to be 360 deg.

(a) If no examination is performed prior to application of the overlay, initial inside-surface-connected planar flaws equal to 100% through the original wall thickness shall be assumed, in both the axial and circumferential directions, consistent with the overlay examination volume in Fig. 2.

(b) In determining the expected life of the overlay, any inside surface connected planar flaw found by the overlay preservice inspection of 3(b) that exceeds the depth of (2)(a) above shall be used as part of the initial flaw depth. The flaw depth assumed is the detected flaw depth plus the postulated worst-case flaw depth in the unqualified ultrasonic examination region of the pipe wall thickness. An overlay meeting this condition shall be considered a repair.

(b) Structural Design and Sizing of the Overlay. The design of the weld overlay shall satisfy the following, using the assumptions and flaw characterization restrictions in 2(a). The following design analysis shall be completed in accordance with IWA-4311.

(1) The axial length and end slope of the weld overlay shall cover the weld and heat-affected zones on each side of the weld and shall provide for load redistribution from the item into the weld overlay and back into the item without violating applicable stress limits of NB-3200. Any laminar flaws in the weld overlay shall be evaluated in the analysis to ensure that load redistribution complies with the above. These requirements will usually be satisfied if the weld overlay full-thickness length extends axially beyond the projected flaw by at least  $2.5\sqrt{(Rt)}$ , where R is the outer radius of the item and t is the nominal wall

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thickness of the item.

(2) Unless specifically analyzed in accordance with 2(b)(1), the end transition taper of the overlay shall not exceed 30 deg. A slope of not more than 1:3 is recommended.

(3) For circumferentially oriented flaws, in the underlying base material or weld, the flaws shall be assumed to be 100% through the original wall thickness for the entire circumference of the item.

(4) For axial flaws in the underlying base material or weld, the flaws shall be assumed to be 100% through the original wall thickness of the item for the entire axial length of the flaw or combined flaws, as applicable."

(5) For full structural overlays, when ultrasonic examination is not performed prior to installation of the weld overlay, the assumed flaw in the underlying base material or weld shall be based on the limiting case of the two below:

- (a) 100% through-wall for the entire circumference, or
- (b) 100% through-wall for 1.5 in. (38 mm) or the combined width of the weld plus buttering, whichever is greater, in the axial direction.

(6) The overlay design thickness shall be verified using only the weld overlay thickness conforming to the deposit analysis requirements of 1(e). The combined wall thickness at the weld overlay and the effects of any discontinuities (e.g., another weld overlay or reinforcement for a branch connection) within a distance of  $2.5\sqrt{R_t}$  from the toes of the weld overlay, including the flaw size assumptions defined in 2(b)(3), (4), or (5) above, shall be evaluated and meet the requirements of IWB-3640.

(7) The effects of any changes in applied loads, as a result of weld shrinkage from the entire overlay, on other items in the piping system (e.g., support loads and clearances, nozzle loads, and changes in system flexibility and weight due to the weld overlay) shall be evaluated. Existing flaws previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640, IWC-3640, or IWD-3640, as applicable.

### 3 EXAMINATION

In lieu of all other examination requirements, the examination requirements herein shall be met for the life of the weld overlay. Nondestructive examination methods shall be in accordance with IWA-2200, except as specified herein. Nondestructive examination personnel shall be qualified in accordance with IWA-2300. Ultrasonic examination procedures and personnel shall be qualified in accordance with Appendix VIII, Supplement 11.

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For cast stainless steel materials the applicable volumes shall be examined in accordance with Appendix VIII Supplement 11 qualified procedures and personnel to the maximum extent practicable and the remaining volume may be examined in accordance with Appendix III.

(a) Acceptance Examination

(1) The weld overlay shall have a surface finish of 250 micro-in. (6.3 micrometers) RMS or better and a contour that provides for ultrasonic examination in accordance with procedures qualified in accordance with Appendix VIII. The weld overlay shall be inspected to verify acceptable configuration.

(2) The weld overlay and the adjacent base material for at least 1/2 in. (13 mm) from each side of the weld shall be examined using the liquid penetrant method. Surface examination shall be performed on weld attached thermocouple removal areas in accordance with NB-4435(b)(3). The weld overlay shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NB-5300. The adjacent base metal shall satisfy the surface examination acceptance criteria for base material of the Construction Code or NB-2500. If ambient-temperature temper bead welding is required, the liquid penetrant examination of the completed weld overlay shall be conducted after the three tempering layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr after completion of the third temper bead layer over the ferritic steel.

(3) The acceptance examination volume A-B-C-D in Fig. 1(a) plus the heat-affected zone beneath the fusion zone C-D shall be ultrasonically examined to assure adequate fusion (i.e., adequate bond) with the base metal and to detect welding flaws, such as interbead lack of fusion, inclusions, or cracks. Cast stainless steel base material heat-affected zones shall be ultrasonically examined to the extent practicable. If ambient-temperature temper bead welding is required, the ultrasonic examination of the completed weld overlay shall be conducted after the three tempering layers (i.e., layers 1, 2, and 3) over the ferritic steel have been in place for at least 48 hr.

Planar flaws detected in the weld overlay acceptance examination shall meet the preservice examination standards of Table IWB-3514-2. In applying the acceptance standards to planar indications within the volume E-F-G-H, in Fig. 1(b), the thickness " $t_1$ " shall be used as the nominal wall thickness in Table IWB-3514-2. For planar indications outside this examination volume, the nominal wall thickness shall be " $t_2$ " as shown in Fig. 1(c), for volumes A-E-H-D and F-B-C-G.

Laminar flaws in the weld overlay shall meet the following:

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(a) Laminar flaws shall meet the acceptance standards of Table IWB-3514-3 with the additional limitation that the total laminar flaw shall not exceed 10% of the weld surface area and that no linear dimension of the laminar flaw area exceeds 3.0 in. (76 mm) or 10 % of the nominal pipe circumference, whichever is greater.

(b) The reduction in coverage of the examination volume A-B-C-D in Fig. 1(a), due to laminar flaws shall be less than 10%. The uninspectable volume is the volume in the weld overlay underneath the laminar flaws for which coverage cannot be achieved with angle beam examination.

(c) Any uninspectable volume in the weld overlay shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed flaw shall meet the preservice examination acceptance standards of Table IWB-3514-2, with nominal wall thickness as defined above for planar flaws. Both axial and circumferential planar flaws shall be assumed.

(4) After completion of all welding activities, affected restraints, supports, and snubbers shall be VT-3 visually examined to verify that design tolerances are met.

(b) Preservice Inspection

(1) The examination volume in Fig. 2 shall be ultrasonically examined, except cast stainless steel base material within the examination volume shall be ultrasonically examined to the extent practicable. The angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions, to locate and size any planar flaws that might have propagated into the upper 25% of the base material or into the weld overlay.

(2) The pre-service examination acceptance standards of Table IWB-3514-2 shall be met for the weld overlay. In applying the acceptance standards, wall thickness,  $t_w$ , shall be the thickness of the weld overlay.

(3) The flaw evaluation requirements rules of IWB-3640 shall not be applied to planar flaws identified during pre-service examination that exceed the preservice examination acceptance standards of Table IWB-3514-2.

(c) Inservice Inspection

(1) The weld overlay examination volume in Fig. 2 shall be added to the inspection plan. The weld overlay inspection interval shall not be greater than the life of the overlay defined in 2(a) above. The weld overlay shall be ultrasonically examined during the first or second refueling outage following application.

(2) Subarticle Q-4300 will be used with exceptions as follows. The cast stainless steel volume beneath the SWOL will be UT examined on a "best effort" basis since qualified UT examination is not achievable at this time. Qualified

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procedures and personnel will be used in accordance with Appendix VIII, Supplement 11 as modified by the PDI Program. The weld overlay will be examined in accordance with the PDI qualified procedure from both sides to the fullest extent possible. However, no credit for examination coverage can be given in any portion of the examination volume where the ultrasonic beam passes through the cast stainless steel material.

(3) The weld overlay examination volume in Fig. 2 shall be ultrasonically examined, except cast stainless steel base material within the examination volume shall be ultrasonically examined to the extent practicable, to determine if any new or existing planar flaws have propagated into the outer 25% of the base metal thickness or into the overlay. The angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions.

(4) The inservice examination acceptance standards of Table IWB-3514-2 shall be met for the weld overlay. If flaw growth in the weld overlay occurs and inservice examination acceptance standards of Table IWB-3514-2 cannot be met, a determination will be made to prove that the flaw is not PWSCC. If the cause is determined to be PWSCC or the cause of the flaw cannot be determined, the flaw shall be repaired and IWB-3600, IWC-3600, or IWD-3600 shall not be used to accept these types of flaws. Flaws due to stress corrosion cracking in the weld overlay that exceed the inservice examination acceptance standards of Table IWB-3514-2 shall not be accepted and result in removal of the weld overlay and the item shall be repaired or replaced.

(5) Weld overlay examination volumes in Fig. 2 that show no indication of planar flaw growth or new planar flaws shall be placed into a population to be examined on a sample basis, except as required by 3(c)(1). Twenty-five percent of this population shall be examined at least once during every 10 years.

(6) If inservice examinations reveal planar flaw growth, or new planar flaws that meet the inservice examination acceptance standards of IWB-3514 or acceptance criteria of IWB-3600, the weld overlay examination volume shall be reexamined during the first or second refueling outage following discovery of the growth or new planar flaws.

(7) For weld overlay examination volumes with unacceptable indications in accordance with 3(c)(4), the weld overlay shall be removed, including the original defective weld, and the item shall be corrected by a repair/replacement activity in accordance with IWA-4000.

(d) Additional Examinations. If inservice examinations reveal unacceptable indications according to 3(c)(4), planar flaw growth into the weld overlay design thickness, or axial flaw growth beyond the specified examination volume, additional weld overlay examination volumes, equal to the number scheduled for

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the current inspection period, shall be examined prior to return to service. If additional unacceptable indications are found in the second sample, 50% of the total population of weld overlay examination volumes shall be examined prior to return to service. If additional unacceptable indications are found, the entire remaining population of weld overlay examination volumes shall be examined prior to return to service.

#### 4 PRESSURE TESTING

A system leakage test shall be performed in accordance with IWA-5000.

#### 5 DOCUMENTATION

Use of Attachment 2 shall be documented on Form NIS-2.

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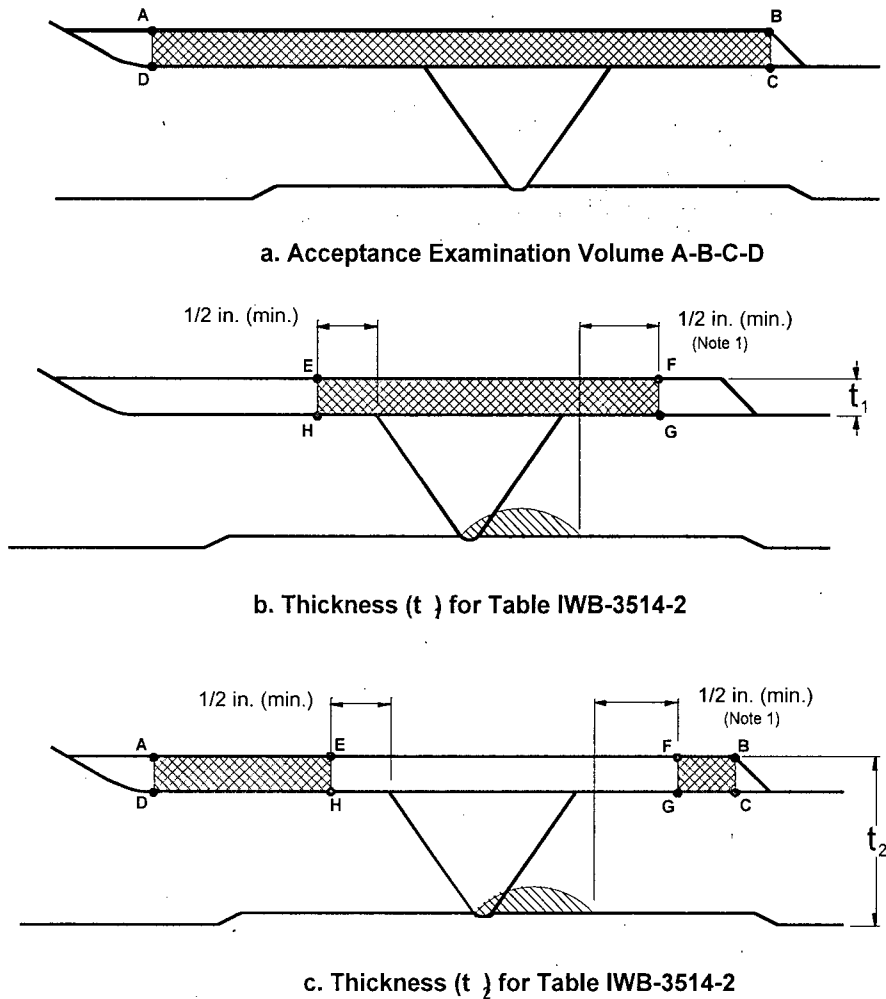


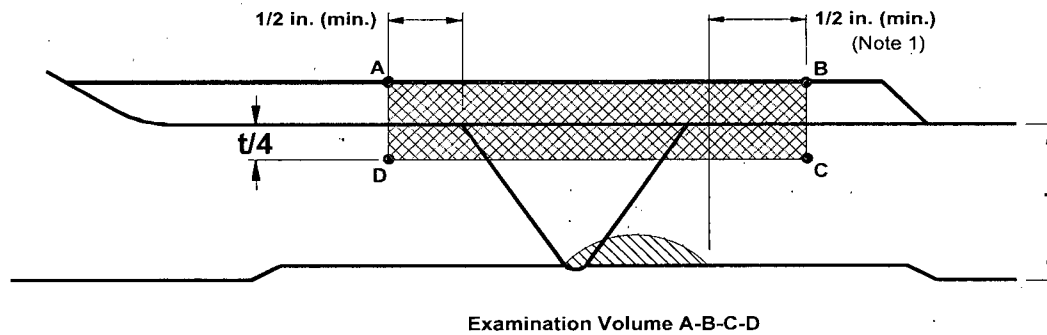
Fig. 1 Acceptance Examination Volume and Thickness Definitions

Notes:

- (1) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least 1/2 in. (13 mm) beyond the toes of the original weld.
- (2) The weld includes the weld end butter, where applied.

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NOTES:

- (1) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least  $\frac{1}{2}$  in. (13 mm) beyond the as-found flaw and at least  $\frac{1}{2}$  in. (13 mm) beyond the toes of the original weld.
- (2) The weld includes weld end butter, where applied.

Fig. 2

Preservice and Inservice Examination Volume



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MANDATORY APPENDIX I  
AMBIENT TEMPERATURE TEMPER BEAD WELDING

I-1 GENERAL REQUIREMENTS

(a) This Appendix applies to dissimilar austenitic filler metal welds between P-Nos. 1, 3, 12A, 12B, and 12C<sup>1</sup> materials and their associated welds and welds joining P-Nos. 8 or 43 materials to P-Nos. 1, 3, 12A, 12B, and 12C<sup>2</sup> materials with the following limitation: This Appendix shall not be used to repair SA-302 Grade B material unless the material has been modified to include from 0.4% to 1.0% nickel, quenching, tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld overlay based on the finished surface over the ferritic base material shall be 300 in.<sup>2</sup> (195,000 mm<sup>2</sup>).

(c) Repair/replacement activities on a dissimilar-metal weld in accordance with this Appendix are limited to those along the fusion line of a nonferritic weld to ferritic base material on which 1/8 in. (3 mm) or less of nonferritic weld deposit exists above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Appendix, provided the depth of repair in the base material does not exceed 3/8 in. (10 mm).

(e) Prior to welding, the area to be welded and a band around the area of at least 1½ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

(f) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(g) Peening may be used, except on the initial and final layers.

I-2 WELDING QUALIFICATIONS

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

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<sup>2</sup> P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified in a later Edition of Section IX.

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I-2.1 Procedure Qualification

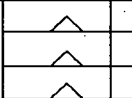
(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded. The materials shall be post weld heat treated to at least the time and temperature that was applied to the materials being welded.

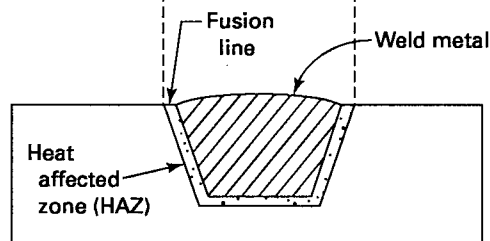
(b) The root width and included angle of the cavity in the test assembly shall be no greater than the minimum specified for the repair.

(c) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(d) The weld overlay shall be qualified using a groove weld coupon. The test assembly groove depth shall be at least 1 in. (25 mm). The test assembly thickness shall be at least twice the test assembly groove depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions on either side of the groove shall be at least 6 in. (150 mm). The qualification test plate shall be prepared in accordance with Fig. I-1.

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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.

FIG. I-1 QUALIFICATION TEST PLATE

(e) Ferritic base material for the procedure qualification test shall 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 I-2.1(f) below, but shall be in the base metal.

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(f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of I-2.1(d) above. Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture.

(2) When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(3) If the test material is in the form of a plate or forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(4) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall 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 shall be reported in the Procedure Qualification Record.

(g) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be equal to or greater than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this appendix, either of the following shall be performed.

(1) The welding procedure shall be requalified.

(2) An Adjustment Temperature for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with 2002 Addenda. The RT NDT or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the Adjustment Temperature.

## I-2.2 Performance Qualification

Welding operators shall be qualified in accordance with Section IX.

## I-3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements:

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(a) The weld metal shall be deposited by the automatic or machine GTAW process.

(b) Dissimilar metal welds shall be made using A-No. 8 weld metal (QW-442) for P-No. 8 to P-No. 1, 3, or 12 (A, B, or C)<sup>1</sup> weld joints or F-No. 43 weld metal (QW-432) for P-No. 8 or 43 to P-No. 1, 3, or 12 (A, B, or C)<sup>1</sup> weld joints.

(c) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least 1/8 in. (3 mm) overlay thickness with the heat input for each layer controlled to within  $\pm 10\%$  of that used in the procedure qualification test. The heat input of the first three layers shall not exceed 45 kJ/in. (1.8 kJ/mm) under any conditions. Particular care shall be taken in the placement of the weld layers of the austenitic overlay filler material at the toe of the overlay to ensure that the HAZ and ferritic base metal are tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(d) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers regardless of the interpass temperature used during qualification. The interpass temperature limitation of QW-406.3 need not be applied.

(e) The interpass temperature shall be determined by one of the following methods:

(1) Temperature measurement (e.g. contact pyrometers, temperature indicating crayons, or thermocouples) during welding. The interpass temperature shall be monitored to assure Code Compliance to limit radiation dose as follows: Interpass temperature measurements will be taken every three to five passes on the first three layers and every six to ten passes after the first three layers.

(2) heat flow calculations using the variables listed below as a minimum:

- (a) welding heat input
- (b) initial base material temperature
- (c) configuration, thickness, and mass of the item being welded
- (d) thermal conductivity and diffusivity of the materials being welded
- (e) arc time per weld pass and delay time between each pass
- (f) arc time to complete the weld

(3) measurement of the maximum interpass temperature on a test coupon that is equal to or less than the thickness of the item to be welded. The maximum heat input of the welding procedure shall be used in the weld testing of the test coupon.

(f) Particular care shall 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.

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## ATTACHMENT 3

### **Barrier Layer to Prevent Hot Cracking in High Sulfur Stainless Steel**

#### **Background**

During recent dissimilar metal weld (DMW) overlay activities, where use of ERNiCrFe-7A (Alloy 52M) and ERNiCrFe-7 (Alloy 52) has been used for the filler metal, flaws in the first layer have occurred in the portion of the overlay deposited on the austenitic stainless steel portions (safe ends, pipe etc.) of the assemblies in some cases.

#### **Discussion**

The flaw characteristics observed above are indicative of hot cracking. This phenomenon has not been observed on the ferritic steel or ENiCrFe-3 (Alloy 182) DMW portions of the assemblies when welding Alloy 52M thereon.

Further studies have determined that this problem may occur when using Alloy 52M filler metal on austenitic stainless steel materials with high sulfur content.

Extensive tests and field experience from WSI indicate that hot cracking can be a concern when the sulfur and phosphorus content in the diluted weld puddle equals or exceeds 0.014%. The impurity hot cracking threshold level is a function of both the composition of the weld filler materials and the welding parameters that are used because these two factors control the dilution of the solidified weld deposit. This suggests that a combined sulfur plus phosphorus content of the base material approximately 0.046% will represent a threshold for hot cracking with the weld parameters WSI will use at St. Lucie.

To reduce the susceptibility of hot cracking occurrence due to welding Alloy 52M on the stainless steel base materials with high sulfur, WSI has selected ER308L or ER309L filler metal as the preferred filler metals to provide a barrier layer between the Alloy 52M and the high sulfur stainless steel base material. These filler metals are compatible with the base material and promote primary weld metal solidification as ferrite rather than austenite. The ferrite is more

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accommodating of residual elements therein and in the underlying base material thereby significantly reducing the susceptibility to hot cracking. These filler metals are also compatible with the Alloy 52M subsequently welded thereon. However, the barrier layer may consist of ERNiCr-3 (Alloy 82) being used locally at the interface between the Alloy 182 DMW and the stainless steel item. ER308L or ER309L welding on Alloy 182 may result in cracking of the ER308L or ER309L weld. Welding on high sulfur stainless steel with Alloy 82 has not been a concern relevant to hot cracking occurrence.

WSI welded two mockups to evaluate the interactive effects, such as hot cracking and lack of fusion, between the Alloy 82/182 DMW, the stainless steel base material, the ER308L and the subsequent Alloy 52M weld overlay. One mockup assembly consisted of a stainless steel pipe (approximately 0.050 wt% sulfur and phosphorus combined) and an ASTM A106 Grade B pipe with an Alloy 82 groove weld joining them. The second mockup consisted of a stainless steel pipe joined to a cast stainless steel pipe with a stainless butt weld. The other end of the cast stainless steel pipe was joined to a P3 forging using an Alloy 82 groove weld.

For both mockups the barrier layer and overlay were welded in the same sequence as performed in the field (barrier layer ER308L to within 1/8" of the joining DMW and then four or more layers of Alloy 52M overlay). The barrier layer and overlay welding parameters used in the mockup were similar to those used in the field and controlled the weld dilution by controlling the weld heat input and the Power Ratio.

The following examinations were performed on the final mockup:

- PT was performed on the base materials and joining groove welds
- PT was performed on the ER308L barrier layer
- PT was performed on the first layer of Alloy 52M overlay and on the final layer of the weld overlay
- PDI qualified Phased Array UT was performed on the completed mockup

One recordable (not rejectable) planar UT indication of less than 0.200" in length was found on one of the mockups unrelated to the barrier layer. Subsequent metallographic examination found this likely to be porosity. Metallographic



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examination was conducted at EPRI searching for any type of discontinuity, flaw or other anomaly. All samples were removed from selected locations in both mockups and revealed no conditions of concern.

**Conclusion**

St. Lucie Unit 1 will use the barrier layer on all the stainless steel items prior to overlay. The barrier layer will use ER308L or ER309L on the stainless steel and may use Alloy 82 on the stainless steel near the DMW to stainless steel fusion zone only.

Structural credit will not be assumed for the barrier layer in determining the required minimum overlay thickness since the alternative does not address the use of stainless steel filler metal.

The barrier layer welding will be performed in accordance with ASME Section IX qualified welding procedure specification(s). PT will be performed on the barrier layer surface and its volume will be included in the final UT of the overlay.