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U. S. Nuclear Regulatory Commission  
ATTN: Document Control Desk  
Washington, D. C. 20555-0001

Joseph M. Farley Nuclear Plant - Unit 2  
Pressurizer Nozzle Structural Weld Overlay Mode 4 Report

Ladies and Gentlemen:

Southern Nuclear Operating Company (SNC) completed the installation and examination of the five remaining pressurizer nozzle full-structural weld overlays during the 2R20 refueling outage. The pressurizer surge nozzle to safe-end weld was previously overlaid and examined during the spring 2007 outage. The activity for these five overlays was accomplished in accordance with SNC's alternative ISI-GEN-ALT-07-01, Version 2, which was approved per NRC safety evaluation report (SER) dated March 10, 2008 (NRC Accession Number: ML080580291).

ISI-GEN-ALT-07-01, Version 2 requires that 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, changes in system flexibility and weight due to the weld overlay) to be evaluated.

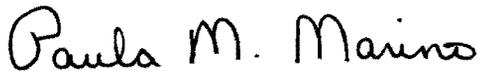
Commitment 4.4.1.1 in the SER states:

"The licensee will provide to the NRC, prior to entering Mode 4, the stress analysis report which will include results showing that the requirements of Subarticles NB-3200 and NB-3600 of the ASME Code, Section III are satisfied. The stress analysis will also include results showing that the requirements of IWB-3000 of the ASME Code, Section XI, are satisfied. The results will show that the postulated crack including its growth in the nozzles do not adversely affect the integrity of the overlaid welds."

The Farley Nuclear Plant Unit 2 pressurizer nozzle structural weld overlay evaluation report, required by the SER for the five weld overlays, is enclosed.

This letter contains no NRC commitments. If you have any questions, please contact Jack Stringfellow at (205)992-7037.

Sincerely,



P. M. Marino  
Vice President – Engineering

PMM/TAH/phr

Enclosure: Farley Nuclear Plant Unit 2 Pressurizer Nozzle Structural Weld Overlay Evaluation Report

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**Joseph M. Farley Nuclear Plant Unit 2**

**Enclosure**

**Pressurizer Nozzle Structural Weld Overlay Evaluation Report**

Westinghouse Non-Proprietary Class 3

**LTR-PAFM-10-54-NP**  
**Revision 0**

**FARLEY UNIT 2 PRESSURIZER SPRAY AND SAFETY/RELIEF  
NOZZLES FULL STRUCTURAL WELD OVERLAY  
EVALUATION**

**May 2010**

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## Introduction

Structural weld overlay is a repair and/or mitigation technique used to reinforce nozzle safe-end regions and piping susceptible to Primary Water Stress Corrosion Cracking (PWSCC). Southern Nuclear Operating Company (SNC) had already installed a full structural weld overlay on the pressurizer surge nozzle at Farley Unit 2 during the Spring 2007 refueling outage. Full structural weld overlay implementation for the remaining five pressurizer nozzles (4 safety/relief nozzles and spray nozzle) have now been completed during the current Spring 2010 refueling outage. Schematics of the typical safety/relief nozzle and spray nozzle configurations are shown in Figures 1 and 2 respectively. The alternative [1] submitted by SNC to the NRC was used as the basis for the full structural weld overlay design and qualification.

The structural weld overlay involved applying a specified thickness and length of weld material over the dissimilar metal weld in a configuration that ensured structural integrity was maintained. The applied weld material (Alloy 52/52M) forms a structural barrier to primary water stress corrosion cracking (PWSCC) and produces a compressive residual stress condition at the inner portion of the nozzle/safe end region that mitigates future crack initiation and/or propagation. Due to the proximity of the stainless steel butt weld (safe end to pipe) to the dissimilar metal butt weld (nozzle to safe end) for the five remaining Farley Unit 2 pressurizer nozzles, the weld overlay not only covers the dissimilar metal butt weld, but also covers and extends past the stainless steel butt weld.

The purpose of this report is to fulfill the following commitment stated in the NRC safety evaluation report [2] for the alternative submitted by SNC.

*“The licensee will provide to the NRC, prior to entering Mode 4, the stress analysis report which will include results showing that the requirements of Subarticles NB-3200 and NB-3600 of the ASME Code, Section III are satisfied. The stress analysis will also include results showing that the requirements of IWB-3000 of the ASME Code, Section XI, are satisfied. The results will show that the postulated crack including its growth in the nozzles do not adversely affect the integrity of the overlaid welds.”*

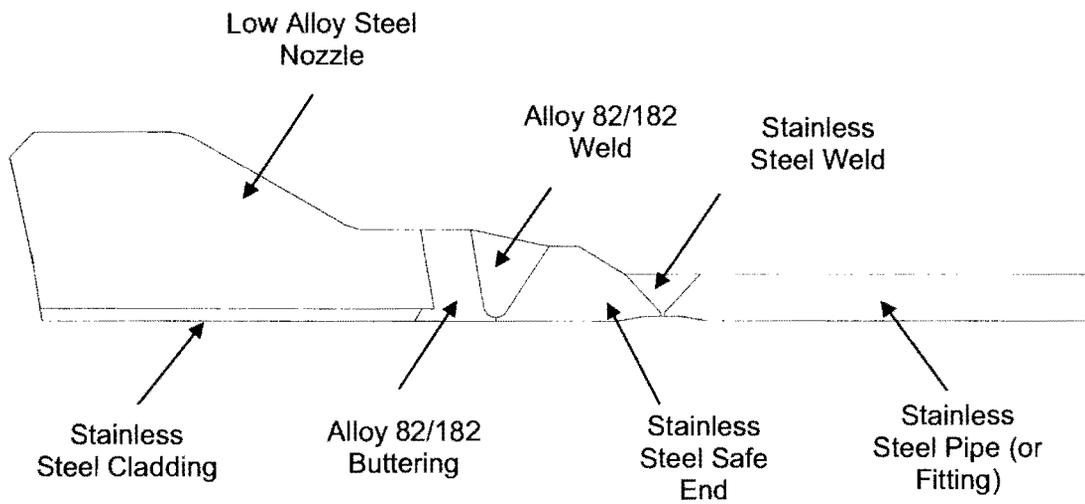


Figure 1 Schematic of Typical Pressurizer Safety and Relief Nozzle Configuration

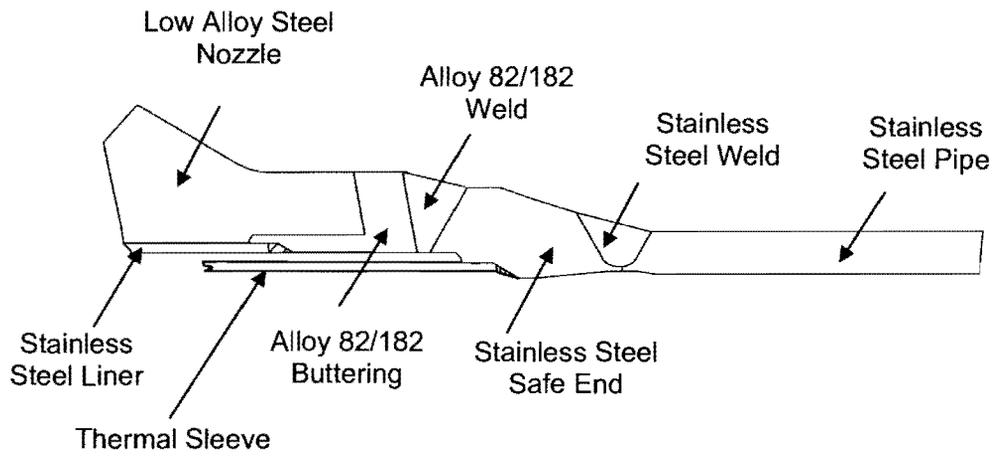


Figure 2 Schematic of Pressurizer Spray Nozzle Configuration

## Weld Overlay Design

Based on the Farley plant specific loadings at the nozzles, the minimum required full structural weld overlay thickness was determined in accordance with the SNC alternative requirements. Per the alternative, a flaw was assumed to be 100% through the original wall thickness for the entire circumference. The thickness of the full structural weld overlay applied meets the criteria of IWB-3640. Due to the concern that the components subject to being overlaid contain levels of trace chemicals (e.g., sulfur) that could cause unacceptable indications in the weld overlay material, an initial layer of low carbon austenitic stainless steel and austenitic nickel alloy was applied as a buffer between the base metal and the weld overlay material. This buffer will be considered as a “non-credited” layer and will provide an acceptable chemical composition to apply the full structural weld overlay.

The full structural weld overlay length was based conservatively on the length of  $0.75\sqrt{Rt}$  per the SNC alternative, where R and t are the outer radius and wall thickness of the pipe/nozzle respectively. In addition, the full structural weld overlay was extended to include the stainless steel butt weld region. The ability to examine the weld overlay was a controlling factor in the structural weld overlay design; therefore additional weld metal was added to improve the ability to examine the overlay, beyond that required for repair and/or mitigation. As a result, the final full structural weld overlay length and thickness exceeded the requirements for a full structural weld overlay designed in accordance with the SNC alternative.

Since the full structural weld overlay was applied before any Performance Demonstration Initiative (PDI) qualified UT examinations were performed, the possibility of discovering an almost through-wall flaw at the Alloy 82/182 weld during the final PDI qualified UT examination of the completed weld overlay was considered. To allow for this possibility, the approach used was to further increase the required full structural weld overlay thickness over the Alloy 82/182 weld to account for at least 10 years of crack growth into the weld overlay. This was conservative, since no PWSCC indications were detected in the upper 25% of the original weld material during the PDI qualified examinations after the structural weld overlay was applied. No increase in the full structural weld overlay thickness was necessary over the stainless steel weld, since PWSCC is not an active mechanism in stainless steel.

The minimum full structural weld overlay design dimensions are shown in Table 1 for all the mitigated pressurizer nozzles, and do not include any required dilution or sacrificial layers.

**Table 1: Minimum Structural Weld Overlay Repair Design Dimensions**

Nozzle	Alloy 82/182 Weld Overlay		Stainless Steel Weld Overlay	
	Thickness (in)	Length (in)	Thickness (in)	Length (in)
Spray	0.38	1.30	0.18	0.82
Safety/Relief	0.47	1.78	0.24	1.16

**ASME Section III Stress Evaluation**

The effects of the full structural weld overlay were evaluated to demonstrate that the mitigated pressurizer nozzles continue to meet the applicable ASME Code Section III NB-3200 and NB-3600 requirements and the conclusions documented in the existing piping and pressurizer nozzle stress reports remain valid. The limiting stress intensity and fatigue usage factor, reflecting the impact of the full structural weld overlay for the mitigated pressurizer nozzles, were found to be at the tapered end of the weld overlay on the original stainless steel piping. The limiting results from the stress evaluations are summarized in Table 2. These results show that the mitigated pressurizer nozzles still meet the applicable ASME Code Section III requirements.

**Table 2: ASME Section III Stress Results for Mitigation Nozzles**

Nozzle	Primary Stress Plus Secondary Stress Intensity		Expansion Stress Intensity		Fatigue Usage	
	Calculated (ksi)	Allowable 3Sm (ksi)	Calculated (ksi)	Allowable 3Sm (ksi)	Calculated	Allowable
Spray	34.8	54.3	20.6	48.6	0.940	1.0
Safety/Relief	46.9	52.9	29.8	48.6	0.064	1.0

**Weld Overlay Residual Stress Evaluation**

The pressurizer nozzles were conservatively analyzed to include an assumed 50% through-wall full circumferential (360°) weld repair, made from the inside surface during the initial fabrication process, to simulate the initial residual stress state. Finite element analyses were performed to determine the residual stresses in the pressurizer nozzle dissimilar metal butt weld regions resulting from the structural weld overlay in order to support the subsequent crack growth evaluations. Weld passes were grouped into weld areas as has been done in most weld simulation analyses in the industry. Each weld area applied represents one or more weld beads.

The weld areas were added to the model using the ANSYS "birth and death" options. These options are useful in simulating the structural weld overlay process in which each weld overlay area is added to the original nozzle configuration sequentially. For the structural weld overlay finite element models, each nozzle is modeled to include the final nozzle configuration with the structural weld overlay. All the finite elements used to model the structural weld overlay are present in the model at the start of the weld overlay simulation analysis. Element "death" option is activated at the beginning of the weld overlay process when all the finite elements pertaining to the weld overlay are being artificially deactivated, but not physically removed from the finite element model. This means that the elements are still present in the model but they have no stiffness or conductivity. During the weld overlay process, each weld area is then activated sequentially using the "birth" option of ANSYS to simulate the application of weld passes. The

“birth” option does not actually introduce any additional finite elements to the model, but only activates the elements that were being deactivated at the beginning of the weld overlay process. This process using the “birth” option continues until the full structural weld overlay has been applied to the original nozzle configuration.

The resulting residual weld stresses for the mitigated pressurizer nozzles are compressive on the inside surface of the nozzles, over the entire length of the PWSCC-susceptible material; thereby, minimizing the potential for any future PWSCC crack initiation and/or crack propagation.

### **Crack Growth Evaluation**

Using the through-wall stress distribution consisting of residual stresses resulting from the full structural weld overlay, thermal transient stresses and applicable mechanical loadings, crack growth analyses were performed for the mitigated nozzles. The following summarizes the crack growth results for the dissimilar metal and stainless steel welds for the mitigated nozzles.

#### Dissimilar Metal Weld (Alloy 82/182)

The crack growth analysis performed in accordance with the IWB-3640 requirement [3] involved postulating a flaw at the region of concern. The objective of the analysis was to determine the service life required for the flaw to propagate to an allowable flaw depth without adversely impacting the integrity of the structural weld overlay. A 100% through wall flaw was postulated in the original weld (versus the 75% required in the alternative) and only fatigue crack growth was considered in the weld overlay material since it is PWSCC resistant.

The postulated flaw was subjected to cyclic loading due to the applicable plant specific thermal transients including the residual stresses resulting from the structural weld overlay mitigation process. The thermal transients considered in the analysis were distributed equally over the plant design life. The crack growth rate reference curve used in the crack growth evaluation for the austenitic nickel alloy material was obtained from NUREG/CR 6721 [4].

Since the full structural weld overlay was applied before any PDI-qualified UT examinations were performed, the possibility of discovering an almost through the original wall flaw during the final PDI-qualified UT examination of the completed weld overlay was considered in the crack growth evaluation. Even though this is a highly unlikely scenario, the required full structural weld overlay thickness for the pressurizer nozzles has taken into account at least 10 years of fatigue crack growth into the weld overlay material resulting from a postulated 100% initial through-wall flaw. Crack growth analyses into the weld overlay material have been performed to confirm that the full structural weld overlay designs for all the mitigated pressurizer nozzles are adequate for at least 10 years even for postulated 100% initial through-wall flaws in the Alloy 82/182 weld. The results of the crack growth evaluation are shown in Table 3. Since final PDI-qualified UT examination for all the Farley Unit 2 mitigated pressurizer nozzles did not identify any unacceptable indications in the outer 25% of the original wall thickness, the assumptions and therefore the results of the crack growth calculations are conservative.

Stainless Steel Weld

Similar crack growth evaluations were performed for the stainless steel butt welds. The crack growth rate reference curve used in the crack growth evaluation for the stainless steel material was obtained from ASME publications [3, 5]. The results of the crack growth evaluation are shown in Table 3. The full structural weld overlay designs for the spray and safety/relief nozzles are adequate for at least 10 years, even for postulated 100% initial through-wall flaws in the stainless steel welds. Since final PDI-qualified UT examination for all the Farley Unit 2 mitigated pressurizer nozzles did not identify any flaws in the outer 25% of the original wall thickness, the assumptions and therefore the results of the crack growth calculations are conservative.

**Table 3: Crack Growth Results for Mitigation Pressurizer Nozzles**

Nozzle	Weld	Flaw Configuration	Initial Flaw Depth (in.)	Initial Flaw Depth / Original Wall Thickness Ratio	Final Flaw Depth (in.) in 10 years
Spray	A82/182	Axial	1.00	1.00	1.03
		Circumferential	1.00	1.00	1.00
	Stainless Steel	Axial	0.53	1.00	0.53
		Circumferential	0.53	1.00	0.53
Safety/Relief	A82/182	Axial	1.32	1.00	1.32
		Circumferential	1.32	1.00	1.32
	Stainless Steel	Axial	0.72	1.00	0.72
		Circumferential	0.72	1.00	0.72

**Effect of Weld Overlay Repair for Pressurizer Safety Nozzles "4502" and "4503"**

Weld overlay repair simulation analyses have been performed to determine the impact due to the weld overlay repair [6] performed at the pressurizer safety nozzles "4502" and "4503". The weld overlay repair region used in the simulation analyses was conservatively assumed to be larger than the actual weld overlay repair implemented. The same methodology used for the Finite Element Analysis simulation of the original structural weld overlay process was used for the weld overlay repair.

Based on the results of the weld overlay repair simulation analysis, there is no significant impact on the existing residual stress profiles. The resulting residual weld stress profiles with the weld overlay repair still meet the requirements for mitigating Primary Water Stress Corrosion Cracking (PWSCC) as discussed in MRP-169 [7], similar to the original residual stress profiles.

Crack growth evaluations were also performed using the revised residual stress profiles to determine the impact on the crack growth results shown in Table 3. Based on the results of the evaluation, there is no impact on the crack growth results shown in Table 3.

## Conclusion

The Farley Unit 2 pressurizer nozzle full structural weld overlay designs have been demonstrated to meet the requirements in the SNC alternative through finite element analysis and fracture mechanics evaluation. There were no planar flaws detected in the weld overlay material of any of the mitigated nozzles. However, laminar flaws were detected in the weld overlay material of both Safety Nozzles "4502" and "4503". Some of the laminar indications detected were found to be acceptable in accordance with the flaw acceptance standards of IWB 3514-3 for laminar indications [3] and no repair is necessary. However, some of the laminar flaws detected require weld overlay repairs and as discussed in this report, there were no significant impacts on the existing residual stress profiles and the crack growth results. SNC Proposed Alternative [1] requires that flaws be postulated under the laminar indication, which might be masked from UT examination. All the postulated masked flaws resulting from those laminar flaws that are acceptable in accordance with the flaw acceptance standards of IWB 3514-3 were shown to be acceptable in accordance with the acceptance criteria in paragraph IWB-3640 and Appendix C of the ASME Section XI Code.

Since the final PDI-qualified UT examinations did not detect any flaw in the upper 25% of the original Alloy 82/182 and stainless steel weld material in any of the pressurizer nozzles, the full structural weld overlay designs for all the Farley Unit 2 pressurizer nozzles are adequate before the next in-service inspection period.

The structural integrity of the dissimilar-metal butt weld region for all the Farley Unit 2 mitigated pressurizer nozzles is maintained with the full structural weld overlay since the requirements in the SNC alternative are met. The full structural weld overlay design was developed based on the assumption of a 360° through-wall flaw. The use of Alloy 52/52M PWSCC-resistant weld material for the structural weld overlay will prevent any future PWSCC crack growth into the structural weld overlay even if any indications were to grow through the existing pipe wall thickness. Consequently, the full structural weld overlay implemented for Farley Unit 2 pressurizer nozzles will mitigate future PWSCC crack initiation and/or propagation and thus maintain structural integrity of the dissimilar-metal butt weld regions.

## References

1. SNC Letter NL-07-2206 dated December 26, 2007, "Joseph M. Farley Nuclear Plant – Unit 2, Vogtle Electric Generating Plant – Unit 1, Proposed Alternative for Application of Full-Structural Weld Overlays on Pressurizer Nozzles"
2. SNC Letter NL-08-0405 dated March 10, 2008, Subject: "Farley Unit 2 and Vogtle Unit 1 RE: Safety Evaluation of Proposed Alternative To Apply Weld Overlay to Dissimilar Metal Welds of Pressurizer Nozzles (TAC Nos. MD6307 and MD6308)."
3. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 2001 Edition through the 2003 Addenda.
4. Chopra, O. K., Soppet, W. K., and Shack, W. J., "Effects of Alloy Chemistry, Cold Work, and Water Chemistry on Corrosion Fatigue and Stress Corrosion Cracking of Nickel Alloys and Welds," NUREG/CR 6721, May 2001.
5. Bamford, W. H., "Fatigue Crack Growth of Stainless Steel Piping in a Pressurized Water Reactor Environment," Trans ASME, Journal of Pressure Vessel Technology, February 1979.
6. PCI VT Report No. 900758-038 dated 5/5/2010 and PCI VT Report No. 900758-039 dated 5/6/2010.
7. Material Reliability Program: Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs (MRP-169) Revision 1. EPRI, Palo Alto, CA: 2008. 1016602.