Southern Nuclear
Operating Company, Inc.
Post Office Box 1295
Birmingham, Alabama 35201-1295

Tel 205.992.5000

SOUTHERN COMPANY
Energy to Serve Your World℠

November 2, 2007

Docket No.: 50-348 NL-07-2065

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

Joseph M. Farley Nuclear Plant Unit 1
Pressurizer Nozzle Structural Weld Overlay Evaluation Report

Ladies and Gentlemen:

Southern Nuclear Operating Company (SNC) completed the installation and examination of the six pressurizer full-structural weld overlays during refueling outage 1R21. This activity was accomplished in accordance with SNC's alternative ISI-GEN-ALT-06-03, which was approved per NRC safety evaluation report (SER) dated April 3, 2007 (TAC Nos. MD2794, MD2795, MD2796, and MD2797). The last paragraph on page 8 and the first paragraph on page 9 of the SER states:

> "The licensee is required to evaluate residual stresses and flaw growth of the repaired weldments to demonstrate that the pressurizer nozzles after the weld overlay installation will perform their intended design function. The licensee agreed to submit a stress analysis report similar to the one required to meet paragraphs g(2) and g(3) in Code Case N-504-2. Calculations shall be performed in accordance with IWB-3640. If the flaw is at or near the boundary of two different materials, evaluation of flaw growth in both materials is required. The size of all flaws will be projected to the end of the design life of the overlay. The licensee noted that there are no existing flaws in the Farley or Vogtle units that required acceptance by analytical evaluation at this time.
>
> The staff expects the results to show that the postulated crack, including its growth in the nozzles, will not adversely affect the integrity of the overlaid welds. The licensee agreed to submit the evaluations prior to entry into Mode 4 from the refueling outage. The staff finds that the licensee's response is acceptable because it will perform a stress analysis which will be available for staff review."

The Farley Nuclear Plant Unit 1 pressurizer nozzle structural weld overlay evaluation report, requested per the SER, is enclosed.

This letter contains no NRC commitments. If you have any questions, please advise.

Sincerely,

B. J. George
Manager, Nuclear Licensing

BJG/JLS/daj

Enclosure: Farley Nuclear Plant Unit 1 Pressurizer Nozzle Structural Weld Overlay Evaluation Report

cc: Southern Nuclear Operating Company
Mr. J. T. Gasser, Executive Vice President
Mr. J. R. Johnson, Vice President – Farley
Mr. D. H. Jones, Vice President – Engineering
RTYPE: CFA04.054; LC# 14666

U. S. Nuclear Regulatory Commission
Dr. W. D. Travers, Regional Administrator
Ms. K. R. Cotton, NRR Project Manager – Farley
Mr. E. L. Crowe, Senior Resident Inspector – Farley

Joseph M. Farley Nuclear Plant Unit 1

Enclosure

Pressurizer Nozzle Structural Weld Overlay Evaluation Report

Westinghouse Electric Company
Nuclear Services
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

November 1, 2007

ALA-07-144

Ref: (1) PO QP060344
(2) LTR-PAFM-07-131

Mr. J. R. Johnson
Vice President Farley Project
Southern Nuclear Operating Company
Farley Nuclear Plant
US Highway 95, 5 Miles South Of Columbia
Columbia, AL 36319

Attention: Mr. Keith Wooten
Mr. Randy Andrews

SOUTHERN NUCLEAR OPERATING COMPANY
JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1
Transmittal of Pressurizer Nozzle Structural Weld Overlay Evaluation Report

Dear Mr. Johnson:

Attached for your information and use please find the Plant Farley Unit 1, pressurizer nozzle structural weld overlay evaluation report. The purpose of this report is to fulfill the SNC commitment prior to entry into Mode 4 from the 1R21 refueling outage as stated in the NRC safety evaluation report for the proposed alternatives submitted by SNC for application of pressurizer nozzle full structural weld overlay. The report incorporates resolution of comments obtained during review by SNC of a draft version of the report.

Should you have any comments or questions, please contact Christopher Ng at (724) 722-6030, Mark Urso at (412) 374-4349, or me at (412) 374-3365.

Very truly yours,

E. C. Arnold, Manager
Southern Nuclear Projects

PLANT FARLEY UNIT 1 FULL STRUCTURAL WELD OVERLAY EVALUATION

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) has installed a full structural weld overlay on each of the six pressurizer nozzles at Farley Unit 1 during the Fall 2007 refueling outage. Sketches for the surge nozzle, typical safety/relief nozzle and spray nozzle configurations are shown in Figures 1, 2 and 3 respectively. The alternatives [1-5] submitted by SNC to the NRC were 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 all of the Farley Unit 1 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 requirement stated in the NRC safety evaluation report [6] for the alternatives submitted by SNC.

"*The licensee is required to evaluate residual stresses and flaw growth of the repaired weldments to demonstrate that the pressurizer nozzles after the weld overlay installation will perform their intended design function. The licensee agreed to submit a stress analysis report similar to the one required to meet paragraphs g(2) and g(3) in Code Case N-504-2. Calculations shall be performed in accordance with IWB-3640. If the flaw is at or near the boundary of two different materials, evaluation of flaw growth in both materials is required. The size of all flaws will be projected to the end of the design life of the overlay... The staff expects the results to show that the postulated crack, including its growth in the nozzles, will not adversely affect the integrity of the overlaid welds. The licensee agreed to submit the evaluations prior to entry into Mode 4 from the refueling outage.*"

Additional request [7] regarding the NRC approved alternative for application of pressurizer nozzle full structural weld overlay was submitted pertaining to the start of the 48-hour clock prior to performing examinations of the full structural weld overlay. Verbal approval of this request was received on October 5, 2007.

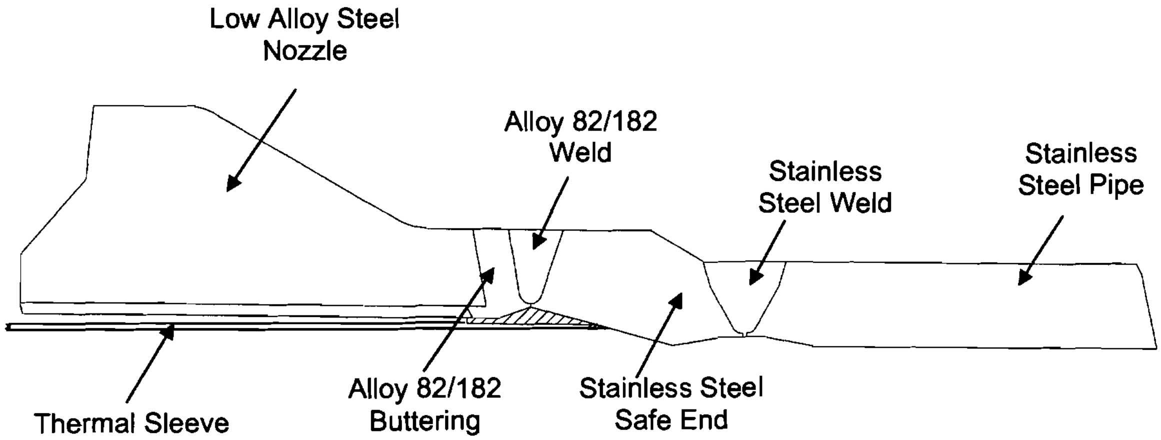

Figure 1 Sketch of Pressurizer Surge Nozzle Configuration

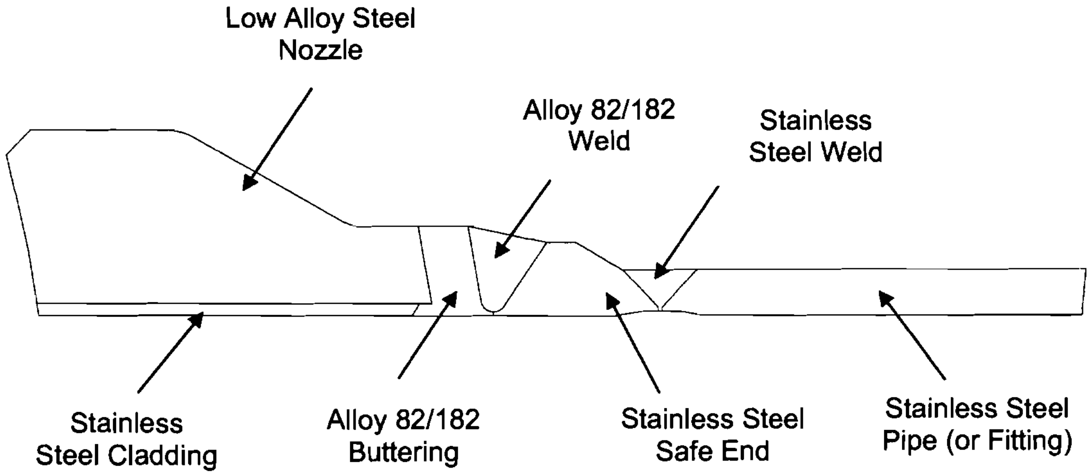

Figure 2 Sketch of Typical Pressurizer Safety and Relief Nozzle Configuration

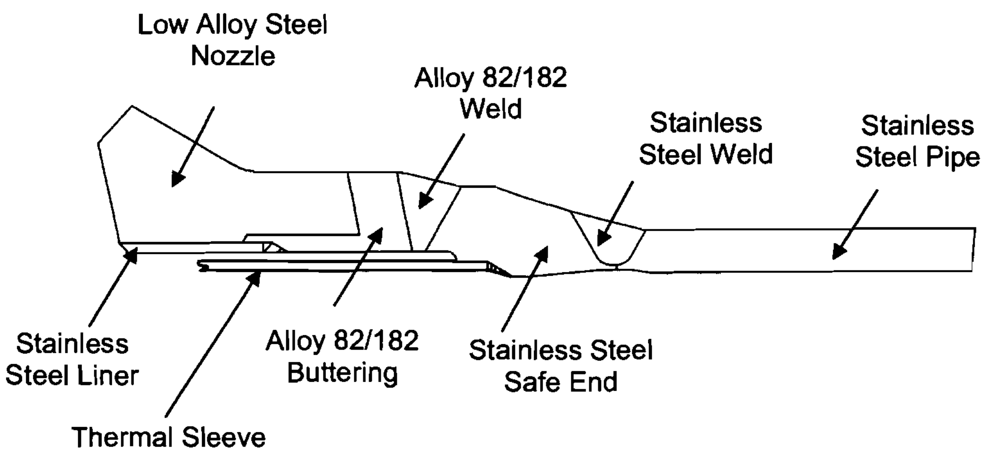

Figure 3 Sketch of Typical Pressurizer Spray Nozzle Configuration

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 postulated 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 a concern for potential weld dilution, a sacrificial layer was applied prior to the addition of the required full structural weld overlay thickness to ensure that the Chromium (Cr) content in the first layer exceeded 24% for PWSCC resistance. The minimum full-structural weld overlay thickness did not take credit for the sacrificial layer.

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 respectively of the pipe/nozzle. 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 in 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 material.

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

Table 1: Minimum Structural Weld Overlay Mitigation Design Dimensions

	Alloy 82/182 Weld Overlay		Stainless Steel Weld Overlay	
Nozzle	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
Surge	0.68	2.57	0.47	2.35

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 stainless steel piping. The limiting results from the stress evaluation 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 Mitigated Nozzles

Nozzle	**Primary Stress Plus Secondary Stress Intensity**		**Expansion Stress Intensity**		**Fatigue Usage**	
	Calculated (ksi)	Allowable $3S_m$ (ksi)	Calculated (ksi)	Allowable $3S_m$ (ksi)	Calculated	Allowable
Spray	34.8	54.3	20.6	48.6	0.94	1.0
Safety/Relief	46.9	52.9	29.8	48.6	0.06	1.0
Surge	51.5	54.3	42.3	48.6	0.08	1.0

Weld Overlay Residual Stress Evaluation

In order to simulate the initial residual stress state, the pressurizer nozzles were conservatively analyzed to include an assumed 50% through-wall weld repair made from the inside surface around the full circumference during the initial fabrication process. 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 similar to most weld simulation analyses in the industry. Each weld area applied represents one or more weld beads.

These 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 model, the pressurizer 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 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 reactivated 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 reactivates the elements that were 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 generated for the mitigated pressurizer nozzles are compressive on the inside surface of the nozzle over the entire length of the PWSCC-susceptible material and up to at least 80% through the original wall thickness; 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 [8] 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 flaws were subjected to cyclic loading due to the applicable plant specific thermal transients and 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 was obtained from NUREG/CR-6721 [9].

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 1 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 weld. The crack growth rate reference curves used in the crack growth evaluation for the stainless steel materials were obtained from ASME publications [8, 10]. The results of the crack growth evaluation are shown in Table 3. The full structural weld overlay designs for the pressurizer 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 1 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.

Table 3: Crack Growth Results for Mitigated 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	1.0	1.03
		Circumferential	1.00	1.0	1.00
	Stainless Steel	Axial	0.53	1.0	0.53
		Circumferential	0.53	1.0	0.53
Safety/Relief	A82/182	Axial	1.32	1.0	1.32
		Circumferential	1.32	1.0	1.32
	Stainless Steel	Axial	0.72	1.0	0.72
		Circumferential	0.72	1.0	0.72
Surge	A82/182	Axial	1.56	1.0	1.56
		Circumferential	1.56	1.0	1.65
	Stainless Steel	Axial	1.41	1.0	1.41
		Circumferential	1.41	1.0	1.43

Effect of Weld Overlay Repair for Pressurizer Safety Nozzle "4501"

Weld overlay repair simulation analyses have been performed to determine the impact due to the weld overlay repair [11] performed at the pressurizer safety nozzle “4501”. 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 PWSCC as discussed in MRP-169 [12], 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 1 pressurizer nozzle full structural weld overlay designs have been demonstrated to meet the requirements in the SNC alternatives through finite element analysis and fracture mechanics evaluation. There were no unacceptable planar flaws detected in the weld overlay material of any of the mitigated nozzles. There were laminar flaws detected in Safety Nozzle "4501" that require weld overlay repairs and as discussed in this report, there was no significant impact on the existing residual stress profiles and the crack growth results. Laminar indications were also discovered in the weld overlay material of Safety Nozzle "4501" and Relief Nozzle "4504". These laminar indications were found to be acceptable in accordance with the flaw acceptance standards of IWB 3514-3 for laminar indications [8]. SNC Proposed Alternatives [1-5] require that flaws be postulated under the laminar indication, which might be masked from UT examination. All the postulated masked flaws resulting from the laminar flaws were shown to be acceptable in accordance with Table IWB-3514-2, Pre-Service Examination Standards or the IWB-3640 acceptance criteria [8].

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 1 pressurizer nozzles are adequate for the next in-service inspection period. The postulation of an initial 100% through-wall flaw would not adversely affect the integrity of the full structural weld overlay implemented during the Fall 2007 outage.

Since the requirements in the SNC alternatives are met, the structural integrity of the dissimilar-metal butt weld region for the Farley Unit 1 mitigated pressurizer nozzles is maintained with the full structural weld overlay. 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 1 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. Southern Nuclear Operating Company Letter NL-06-1713 dated August 10, 2006, "Joseph M. Farley Nuclear Plant, Vogtle Electric Generating Plant, Proposed Alternative for Application of Pressurizer Nozzle Full-Structural Weld Overlays."

2. Southern Nuclear Operating Company Letter NL-06-2434 dated October 20, 2006, "Joseph M. Farley Nuclear Plant, Vogtle Electric Generating Plant, Response to Request for Additional Information Regarding Proposed Alternative for Application of Full Structural Weld Overlays on Pressurizer Nozzles."

3. Southern Nuclear Operating Company Letter NL-06-2768 dated January 3, 2007, "Joseph M. Farley Nuclear Plant, Vogtle Electric Generating Plant, Proposed Alternative for Application of Pressurizer Nozzle Full-Structural Weld Overlays and Response to Request for Additional Information."

4. SNC Letter NL-07-0366 dated February 21, 2007, "Joseph M. Farley Nuclear Plant, Vogtle Electric Generating Plant, Proposed Alternative for Application of Pressurizer Nozzle Full-Structural Weld Overlays – Revision 2.0."

5. SNC Letter NL-07-0626 dated March 15, 2007, "Joseph M. Farley Nuclear Plant, Vogtle Electric Generating Plant, Additional Information Regarding the Proposed Alternative for Application of Pressurizer Nozzle Full-Structural Weld Overlays – Revision 2.0."

6. NRC Letter dated April 3, 2007, NRC to Southern Nuclear Operating Company, Subject: "Joseph M. Farley Nuclear Plant, Units 1 and 2, and Vogtle Electric Generating Plant, Units 1 and 2 – Alternative for Application of Pressurizer Nozzle Full-Structural Weld Overlays (TAC Nos. MD2794, MD2795, MD2796 and MD2797)."

7. SNC Letter NL-07-1179 dated June 27, 2007, "Joseph M. Farley Nuclear Plant Units 1 and 2, Additional Request Regarding the NRC Approved Alternative for Application of Pressurizer Nozzle Full-Structural Weld Overlays".

8. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components." Appendix C, 2001 Edition with 2003 Addenda.

9. 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, April 2001.

10. 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.

11. PCI Inspection Report No. VT-900756-08 dated 10/22/2007 and PCI Step 2 Sketch from Traveler R4501-01 dated 10/22/2007.

12. Material Reliability Program: Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs (MRP-169). EPRI, Palo Alto, CA: 2005. 1012843.