Progress Energy

Robert J. Duncan, II
Vice President
Harris Nuclear Plant
Progress Energy Carolinas, Inc.

OCT 1 9 2007

Serial: HNP-07-143
10 CFR 50.55a

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

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT NO. 1
DOCKET NO. 50-400/LICENSE NO. NPF-63
INSERVICE INSPECTION RELIEF REQUEST 1
WELD OVERLAY REPAIR STRESS ANALYSIS SUMMARY

References:
1. Letter from R. J. Duncan, II to the Nuclear Regulatory Commission (Serial: HNP-07-041), "Inservice Inspection Relief Request 1 Proposed Alternative to ASME Code Requirements for Weld Overlay Repairs," dated May 14, 2007
2. Letter from T. J. Natale to the Nuclear Regulatory Commission (Serial: HNP-07-100), "Response to the Request for Additional Information on the Inservice Inspection Relief Request 1 Proposed Alternative to ASME Code Requirements for Weld Overlay Repairs," dated July 19, 2007
3. Letter from Thomas H. Boyce, Nuclear Regulatory Commission to Robert J. Duncan, II, "Inservice Inspection Relief Request No. 1 Regarding Proposed Alternative to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code Requirements for Pressurizer Nozzle Weld Overlay Repairs (TAC No. MD5535)," dated October 10, 2007

Ladies and Gentlemen:

On May 14, 2007, Carolina Power and Light Company, doing business as Progress Energy Carolinas, Inc., submitted a letter to the Nuclear Regulatory Commission (NRC) requesting relief from the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," Article IWA-4000, "Repair/Replacement Activities" (Reference 1). The proposed alternative, based on ASME Code Case N-740, was requested to support Harris Nuclear Plant's installation of full structural weld overlays on dissimilar metal welds of pressurizer nozzles during Refueling Outage 14 for mitigation of primary water stress corrosion cracking.

As part of this request, Progress Energy Carolinas, Inc., committed to submitting a stress analysis summary demonstrating that the pressurizer nozzles will perform their intended design functions after the weld overlay installation. The commitment required submittal of this report to the NRC prior to entry into plant operating Mode 4 following Refueling Outage 14.

P.O. Box 165
New Hill, NC 27562

T> 919.362.2502
F> 919.362.2095

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NRR

The Attachment to this letter contains the required weld overlay stress analysis report. With the completion of the scheduled structural weld overlays on the pressurizer nozzles, commitment number 2 of the May 14, 2007, letter (Reference 1) has been fulfilled.

This document contains no new regulatory commitment.

Please refer any questions regarding this submittal to Mr. Dave Corlett at (919) 362-3137.

Sincerely,

R. J. Duncan, II
Vice President
Harris Nuclear Plant

RJD/kms

Attachment: Summary of Design and Analyses of Preemptive Weld Overlays for Pressurizer Nozzle Locations Containing Alloy 600 Materials, as provided by Structural Integrity Associates, Inc.

cc:
Mr. P. B. O'Bryan, NRC Sr. Resident Inspector
Ms. B. O. Hall, N.C. DENR Section Chief
Ms. M. G. Vaaler, NRC Project Manager
Dr. W. D. Travers, NRC Regional Administrator

ATTACHMENT

HARRIS NUCLEAR PLANT (HNP)
INSERVICE INSPECTION RELIEF REQUEST 1
SUMMARY OF DESIGN AND ANALYSES OF PREEMPTIVE WELD OVERLAYS FOR PRESSURIZER NOZZLE LOCATIONS CONTAINING ALLOY 600 MATERIALS

(14 pages)

Structural Integrity Associates, Inc.

3315 Almaden Expressway
Suite 24
San Jose, CA 95118-1557
Phone: 408-978-8200
Fax: 408-978-8964
www.structint.com
mtaylor@structint.com

October 19, 2007
SIR-07-309-NPS, Rev. 0

Mr. Joe Davis
Progress Energy
Harris Nuclear Plant
5413 Shearon Harris Road
New Hill, NC 27562

Subject: Summary of Weld Overlay Design and Analysis Calculations for Pressurizer Surge, Spray and Safety/Relief Nozzle-to-Safe End Welds at Shearon Harris Nuclear Plant, Unit 1

Reference: Progress Energy, Shearon Harris Nuclear Plant, Unit 1, Proposed Alternative to ASME Code Requirements for Weld Overlay Repairs, HNP-07-041, May 14, 2007

Dear Mr. Davis:

The following attachment is transmitted in support of Progress Energy's response to commitments in the above-referenced request for alternative:

Commitment:

HNP will also submit to the NRC a stress analysis summary demonstrating that the pressurizer nozzles will perform their intended design functions after the weld overlay installation. The stress analysis report will include results showing that the requirements of 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 will not adversely affect the integrity of the overlaid welds. This information will be submitted to the NRC prior to entry into Mode 4 start-up from HNP's Refueling Outage 14.

If you have any questions or comments regarding this summary, please contact one of the undersigned.

Prepared by:

James W. Axline, P.E. — 10/19/07 (Date)
Senior Consulting Engineer

Verified by:

Chris Lohse — 10/19/07 (Date)
Engineering Analyst

Approved by:

Moses Taylor, P.E. — 10/19/07 (Date)
Senior Associate

ml

Attachment

cc: L. Nguyen
A. Saccavino

Project File: HNP-02Q

Attachment

Summary of Design and Analyses of Preemptive Weld Overlays for Pressurizer Nozzle Locations Containing Alloy 600 Materials

1.0 Introduction

Progress Energy has applied full structural weld overlays (WOLs) on dissimilar metal welds (DMWs) of four 6" pressurizer safety/relief nozzles, one 4" pressurizer spray line nozzle, and one 14" pressurizer surge line nozzle at the Shearon Harris Nuclear Power Plant, Unit 1. The purpose of these overlays is to eliminate dependence on the primary water stress corrosion cracking (PWSCC) susceptible Alloy 82/182 welds as pressure boundary welds and to mitigate any potential future PWSCC in these welds. The overlays were installed using a PWSCC resistant weld filler material; Alloy 52M [1].

The requirements for design of weld overlays are defined in ASME Code Case N-740 [2], supplemented for this application by HNP Inservice Inspection Relief Request No. 1 [3]. Weld overlays are considered to be acceptable long-term repairs for PWSCC susceptible weldments if they meet a conservative set of design assumptions which qualify them as "full structural" weld overlays. The design basis flaw assumption for full structural weld overlays is a circumferentially oriented flaw that extends 360° around the component, completely through the original component wall. A combination of internal pressure, deadweight, seismic, and other dynamic stresses is applied to the overlaid nozzles containing this assumed design basis flaw, and they must meet the requirements of ASME Code, Section XI, IWB 3641 [4].

ASME Section III stress and fatigue usage evaluations are also performed that supplement existing piping, safe end, and nozzle stress reports, to demonstrate that the overlaid components continue to meet ASME Code, Section III. The original construction Code for the pressurizer was ASME Section III, 1971 Edition through Summer 1972 Addenda. However, as allowed by ASME Section XI, Code Editions and Addenda later than the original construction Code may be used. ASME Section III, 2001 Edition with Addenda through 2003 [5] was used for these analyses.

In addition to providing structural reinforcement to the PWSCC susceptible locations with a resistant material, weld overlays have also been shown to produce beneficial residual stresses that mitigate PWSCC in the underlying DMWs. The weld overlay approach has been used to repair stress corrosion cracking in U.S. nuclear plants on hundreds of welds, and there have been no reports of subsequent crack extension after application of weld overlays. Thus, the compressive stresses caused by the weld overlay have been effective in mitigating new crack initiation and/or growth of existing cracks. In addition, the weld residual stresses from the overlays act as compressive mean stresses in fatigue crack growth assessments.

Finally, evaluations are performed, based on as-built measurements taken after the overlays are applied, to demonstrate that the overlays meet their design basis requirements, and that they will not have an adverse effect on the balance of the piping systems. These include comparison of overlay dimensions to design dimensions, evaluations of shrinkage stresses, and added weight effects on the piping systems.

2.0 Analysis Summary and Results

2.1 Weld Overlay Structural Sizing Calculations

Detailed sizing calculations for weld overlay thickness were performed using the ASME Code, Section XI, IWB-3640 evaluation methodology. Loads and stress combinations were provided by Progress Energy. Both normal operating (Level A), upset (Level B), emergency (Level C), and faulted (Level D) load combinations were considered in this evaluation, and the design was based on the more limiting results. The resulting minimum required overlay thicknesses are summarized in Table 2-1. Because of weld metal dilution concerns over the low alloy steel nozzle, the welding contractor performed mockup testing that demonstrated that a minimum required chromium content for PWSCC resistance (24%) was achieved in the first layer. No dilution layer was added.

The weld overlay length must consider: (1) length required for structural reinforcement, (2) length required for access for preservice and inservice examinations of the overlaid weld, and (3) residual stress improvement. In accordance with the HNP Relief Request [3], which references ASME Code Case N-740, the minimum weld overlay length required for structural reinforcement was established by evaluating the axial-radial shear stress due to transfer of primary axial loads from the pipe into the overlay and back into the nozzle, on either side of the weld(s) being overlaid. Axial weld overlay lengths were established such that this stress is less than the ASME Section III limit for pure shear stress. The resulting minimum length requirements are summarized in Table 2-1.

The overlay length and profile must also be such that the required post-WOL examination volume can be inspected using Performance Demonstration Initiative (PDI) qualified nondestructive examination (NDE) techniques. This requirement can cause required overlay lengths to be longer than the minimums for structural reinforcement. A typical weld overlay design for the Harris Unit 1 pressurizer nozzles is illustrated in Figure 2-1. Because of the relatively short lengths of the original safe-ends, it was necessary to extend the overlay over both the DMW and the adjacent stainless steel (SS) welds, to ensure sufficient overlay length for inspectability and residual stress improvement. The designs were reviewed by qualified NDE personnel to ensure that they meet inspectability requirements for both welds, and the overlays were designed to satisfy full structural requirements for both the DMWs and the SS welds.

Table 2-1: Weld Overlay Structural Thickness and Length Requirements

	Location	**Safety/Relief Nozzle**	**Spray Nozzle**	**Surge Nozzle**
Minimum Thickness (in.)	Nozzle Side	0.45"	0.30"	0.55"
	Pipe Side	0.36"	0.29"	0.44"
Minimum* Length (in.)	Nozzle Side	0.75"	0.44"	0.98"
	Pipe Side	1.19"	0.69"	1.39"

* - The lengths shown are the minimum structural lengths, additional length may be required for inspectability

2.2 Section III Stress Analyses

Stress intensities for the weld overlaid Safety/Relief, Spray and Surge nozzles were determined from finite element analyses for the various specified load combinations and transients using the ANSYS software package [6]. Linearized stresses were evaluated at various sections along the weld overlays. Both 3-dimensional and 2-dimensional, axisymmetric models are used. The stress intensities at these locations were evaluated in accordance with ASME Code, Section III, Sub-articles NB-3200 and NB-3600 [5], and compared to applicable Code limits. A summary of the stress and fatigue usage comparisons for the most limiting locations is provided in Table 2-2. The stresses and fatigue usage in the weld overlaid nozzles are within the applicable Code limits. Figure 2-2 illustrates a typical finite element model and the stress paths evaluated. In general, the limiting location for the Section III stress analyses was found to be the section of the original pipe at the end of the overlay (Path 3 in Figure 2-2).

Table 2-2: Limiting Stress Results for Weld Overlaid Nozzles

Nozzle	Load Combination	Type	Calculated	Allowable
Safety/ Relief	Level A/B	Eqn.12/13: Simplified Elastic-Plastic Analysis (P +Q) (ksi)*	26.828	40.248 **
	Fatigue	**Cumulative Usage Factor**	**0.0113**	**1.00**
Spray	Level A/B	Eqn.12/13: Simplified Elastic-Plastic Analysis (P +Q) (ksi)*	37.935	41.820 **
	Fatigue	**Cumulative Usage Factor**	**0.486**	**1.00**
Surge	Level A/B	Eqn.12/13: Simplified Elastic-Plastic Analysis (P +Q) (ksi)*	33.981	55.701 **
	Fatigue	**Cumulative Usage Factor**	**0.727**	**1.00**

* - Primary stress acceptance criteria are met via the sizing calculations discussed in Section 2.1.

** - Elastic analysis exceeds the allowable value of $3S_m$; however, criteria for simplified elastic-plastic analysis and thermal ratchet are met.

2.3 Residual Stress and Section XI Crack Growth Analyses

Weld residual stresses for the Harris Unit 1 pressurizer nozzle weld overlays were determined by detailed elastic-plastic finite element analyses. The analysis approach has been previously documented to provide predictions of weld residual stresses that are in reasonable agreement with experimental measurements [7]. Two-dimensional, axisymmetric finite element models were developed for each of the nozzles. Modeling of weld nuggets used in the analysis to lump the combined effects of several weld beads is illustrated in Figure 2-3. The models simulated an inside surface (ID) repair at the DMW location with a depth of approximately 50% of the original wall thickness. This assumption is considered to conservatively bound any weld repairs that may have been performed during plant construction from the standpoint of producing tensile residual stresses on the ID of the weld. The models also simulated the SS pipe to safe-end weld.

The residual stress analysis approach consists of a thermal pass to determine the temperature response of the model to each individual lumped weld nugget as it is added in sequence, followed by an elastic-plastic stress pass to calculate the residual stress due to the temperature cycling from the application of each nugget. Since residual stress is a function of welding history, the stress passes for each nugget are performed sequentially, over the residual stress fields induced from all previously applied weld nuggets. The resulting residual stresses were evaluated on the inside surface of the original welds and safe-end components, as well as on several paths through the DMW and SS welds (Figures 2-4 and 2-5).

The residual stress calculations were then utilized, along with stresses due to applied loadings and thermal transients, to demonstrate that assumed cracks that could be missed by inspections will not exceed the overlay design basis during the ASME Section XI inservice inspection interval due to fatigue or PWSCC. Since the minimum exam volume for the PDI qualified post-overlay UT inspections includes the weld overlay plus the outer 25% of the original wall thickness, a 75% through wall flaw is the largest flaw that could escape detection by this examination. In the fatigue crack growth analyses, 25% of the original 40 year design quantity of each applied transient was assumed to be applied in the 10 year interval. Initial flaw sizes for the crack growth assessments were assumed consistent with the post-overlay UT inspections performed.

Fatigue crack growth (FCG) results are summarized in Table 2-3, which shows the time duration necessary for the 75% thru-wall crack to reach the WOL interface. In all cases, the maximum crack depth at the end of the ten-year inspection interval is less than the weld overlay design basis flaw (the original wall thickness for the DMW and SS welds). To consider the material plasticity inherent in the sections analyzed, an elastic-plastic analysis of bounding thermal transients was run for the Spray and Surge.

For crack growth due to PWSCC, the total sustained stress intensity factor during normal plant operation was determined as a function of assumed crack depth, considering internal pressure stresses, residual stresses, steady state thermal stresses, and stresses due to sustained piping loads (including deadweight). Zero PWSCC growth is predicted for assumed crack depths at which the combined stress intensity factor due to sustained steady state operating conditions is less than zero. For all nozzles, considering the worst case paths in the DMWs, the sustained stress intensity factors remained negative for crack depths up to and beyond 75% of the original wall thickness. Therefore, no crack propagation due to PWSCC is predicted in the overlaid nozzles.

Table 2-3: Limiting Fatigue Crack Growth Results for Weld Overlaid Nozzles

	Safety/Relief Nozzles	**Spray Nozzle**	**Surge Nozzle**
Circumferential Flaw **DM** Weld	> 40 years	> 40 years	> 40 years
Axial Flaw **DM** Weld	> 40 years	> 40 years	> 40 years
Circumferential Flaw SS Weld	> 40 years	14 years	> 40 years
Axial Flaw SS Weld	> 40 years	13 years	> 40 years

Note: Times listed are time for 75% flaw to reach WOL interface.

2.4 As-Built Measurements and Reconciliations

The measured as-built thicknesses and lengths of the Harris Unit 1 overlays, after final machining, were determined in order to demonstrate the adequacy of the installed weld overlays. For each critical dimension listed in Table 2-1, the as-built measurements are within the relevant dimensions used in the analysis and documented in the Design Drawings. Thus, the as-built configurations of the overlays satisfied all established design requirements.

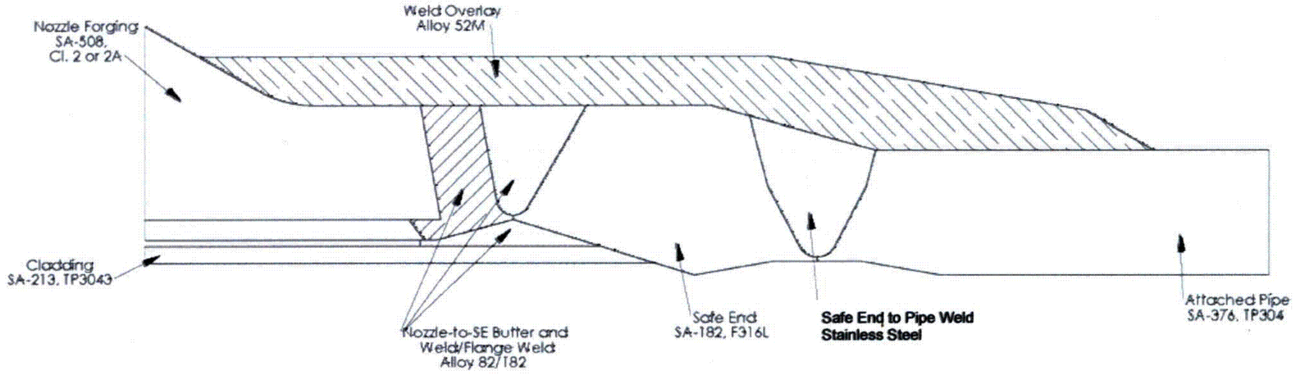


Figure 2-1.
Illustration of Typical Weld Overlay Design for Harris Unit 1 Pressurizer Nozzles

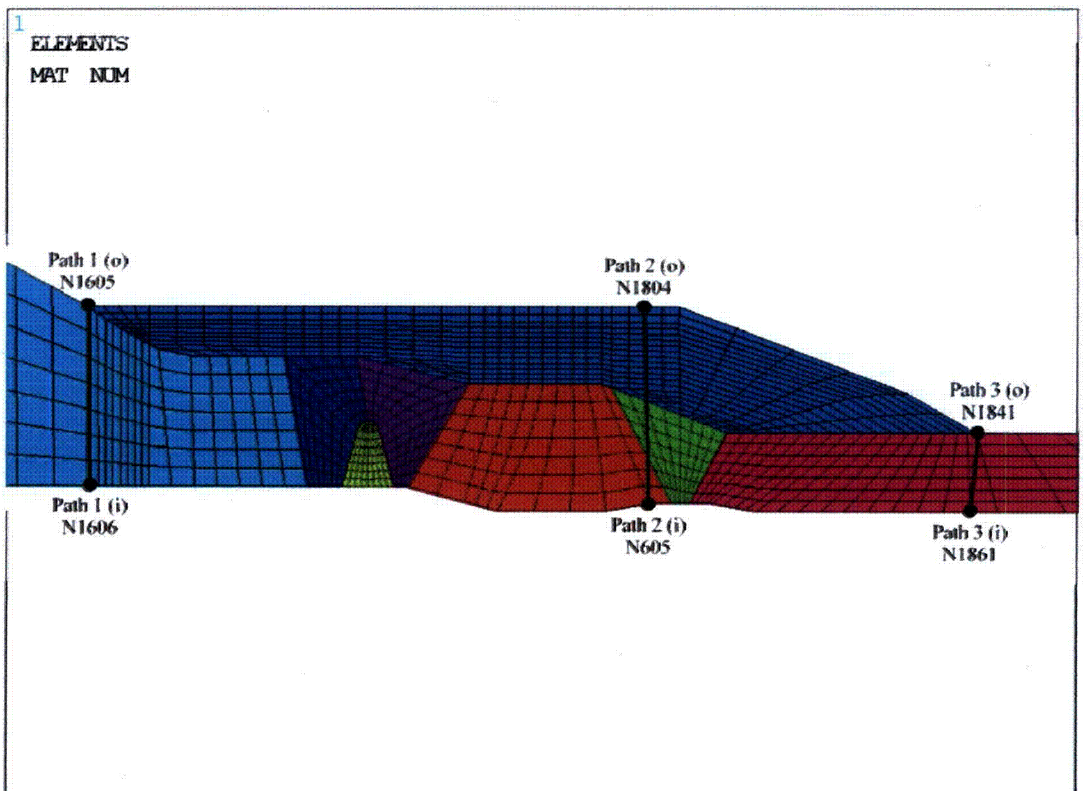


Figure 2-2.

Typical Finite Element Model for Section III Stress Evaluation showing Stress Paths

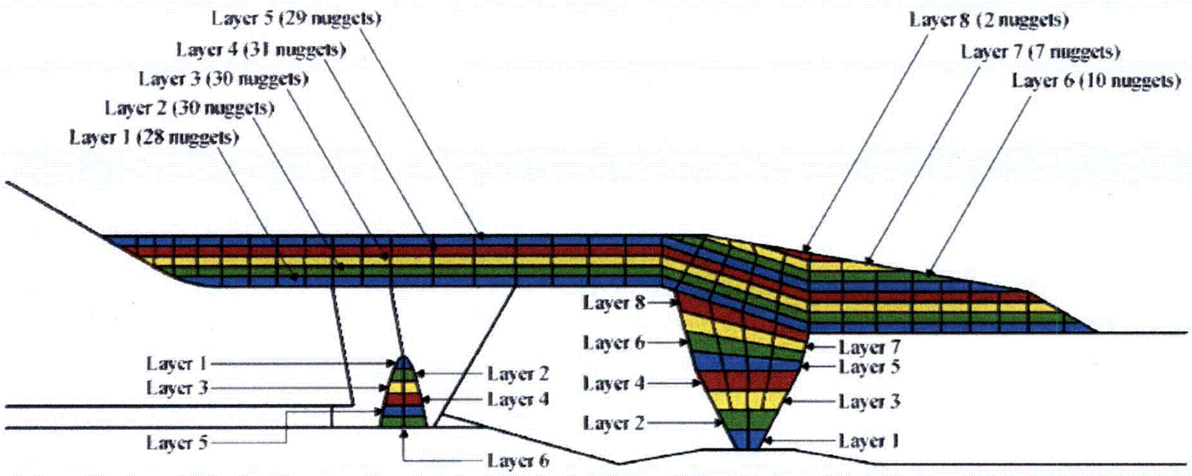


Figure 2-3.
Typical Finite Element Model for Residual Stress Analysis showing Nuggets used for Welding Simulations

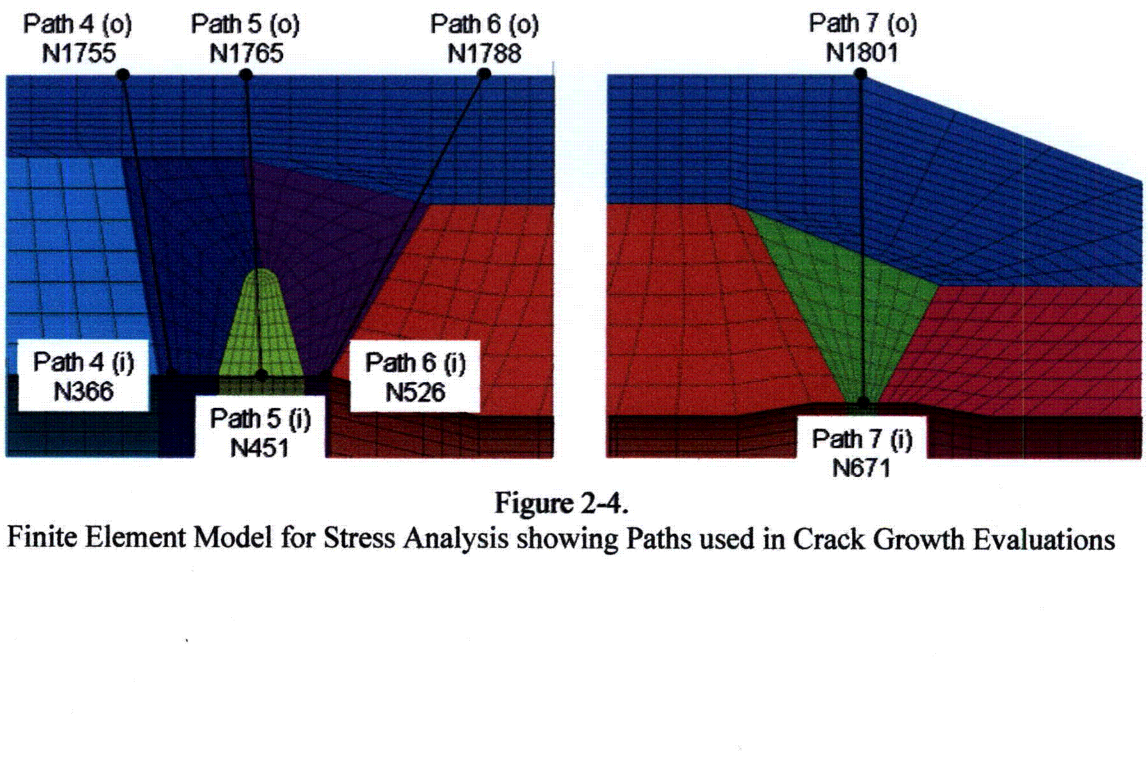
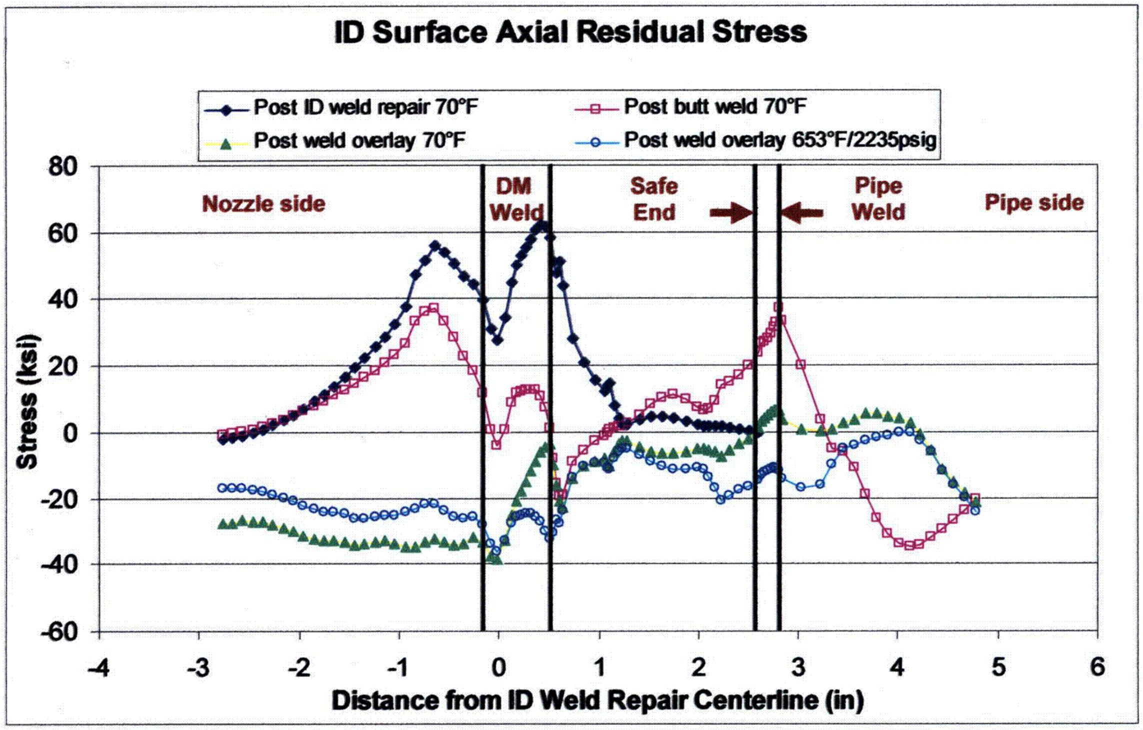


Figure 2-4.
Finite Element Model for Stress Analysis showing Paths used in Crack Growth Evaluations



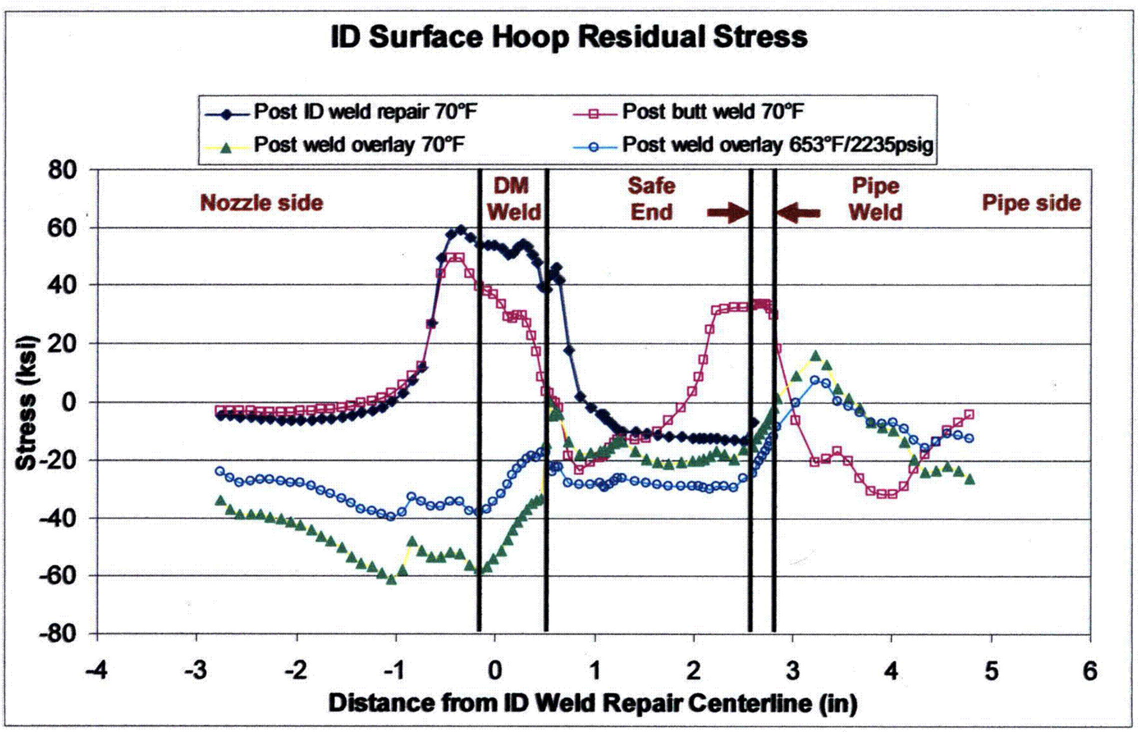


Figure 2-5.
Typical Residual Stress Results along Inside Surface of Original Butt Welds and Safe-End

3.0 Conclusions

The design of the Harris Unit 1 weld overlays was performed taking guidance from the requirements of ASME Code Case N-740 [2], amended in accordance with the Relief Request [3]. The weld overlays are demonstrated to be long-term mitigation of PWSCC in these welds based on the following:

- In accordance with the HNP Relief Request [3], which references ASME Code Case N-740, structural design of the overlays was performed to meet the requirements of ASME Section XI, IWB-3640 based on an assumed flaw 100% through and 360° around the original welds. The resulting full structural overlays thus maintain the original safety margins of the nozzles, with no credit taken for the underlying, PWSCC-susceptible material.
- The weld metal used for the overlay is Alloy 52M, which has been shown to be resistant to PWSCC [1], thus providing a PWSCC resistant barrier. Therefore, no PWSCC crack growth is expected into the overlay.
- Because of the short safe-end lengths in the original nozzle designs, the overlays were extended to cover the adjacent stainless steel pipe to safe-end welds. Although not susceptible to PWSCC, covering them with the overlays was necessary to ensure inspectability and effective residual stress improvement of the DMWs. The overlays were also designed as full structural over the stainless steel welds, thereby providing additional structural margin.
- Due to concerns over contamination-induced cracking of the initial layer of 52M onto the safe end and pipe, a stainless steel buffer layer was applied to the spray nozzle. A buffer layer was not necessary for the surge or safety relief nozzles.
- Application of the weld overlays was shown to not impact the conclusions of the existing nozzle Stress Reports. Following application of the overlay, all ASME Code, Section III stress and fatigue criteria are met.
- Nozzle specific residual stress analyses were performed, after first simulating severe ID weld repairs in the nozzle to safe-end welds, prior to applying the weld overlays. The post weld overlay residual stresses were shown to result in beneficial compressive stresses on the inside surface of the components, and well into the thickness of the original DMWs, assuring that future PWSCC initiation or crack growth into the overlay is highly unlikely.
- Fracture mechanics analyses were performed to determine the amount of future crack growth which would be predicted in the nozzles, assuming that cracks exist that are equal to or greater than the thresholds of the NDE techniques used on the nozzles. Both fatigue and PWSCC crack growth were considered, and found to be acceptable.
- Axial shrinkage was measured following the overlay applications and was found to be small. Therefore shrinkage induced stresses at other locations in the piping systems arising from the pressurizer nozzle weld overlays are not expected to have an adverse effect on the systems.
- Affected piping supports were verified to be within design ranges after the weld overlay implementation.

- The total added weight on the piping systems due to any individual overlay is insignificant compared to the weight of the piping systems and therefore does not adversely impact the piping system stresses nor their dynamic characteristics.
- The as-built dimensions of the overlays were within the maximum and minimum dimensions, thus demonstrating that the as-applied overlays satisfied the design requirements.

Based on the above observations and the fact that similar nozzle-to-safe end weld overlays have been applied to other plants since 1986 with no subsequent problems identified, it is concluded that the Shearon Harris Nuclear Plant, Unit 1 pressurizer surge, safety/relief, and spray nozzle dissimilar metal welds have received long term mitigation against PWSCC. Detailed calculations supporting the above conclusions will be documented in the design report.

4.0 References

1. "Materials Reliability Program (MRP): Resistance to Primary Water Stress Corrosion Cracking of Alloys 690, 52, and 152 in Pressurized Water Reactors (MRP-111)," EPRI, Palo Alto, CA: 2004. 1009801
2. ASME Code, Code Case N-740, "Dissimilar Metal Weld Overlay for Repair of Classes 1, 2, and 3 Items," Section XI, Division 1.
3. Progress Energy, Shearon Harris Nuclear Plant, Unit 1, Inservice Inspection Relief Request 1, Proposed Alternative to ASME Code Requirements for Weld Overlay Repairs, HNP-07-041, May 14, 2007.
4. ASME Boiler and Pressure Vessel Code, Section XI, 2001 Edition (with Addenda up to 2003).
5. ASME Boiler and Pressure Vessel Code, Section III, 2001 Edition through 2003 Addenda.
6. ANSYS/Mechanical, Release 8.1 (w/Service Pack 1), ANSYS Inc., June 2004.
7. "Materials Reliability Program: Technical Bases for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs (MRP-169)," EPRI, Palo Alto, CA, and Structural Integrity Associates, Inc., San Jose, CA: September 2005. 1012843.