Progress Energy

Crystal River Nuclear Plant
Docket No. 50-302
Operating License No. DPR-72

Ref: 10 CFR 50.55a

May 15, 2008
3F0508-12

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Crystal River Unit 3 – Relief Request #08-001-RR, Revision 1
60-Day Response – Summary of Analysis Calculations

References:
1. Florida Power Corporation (FPC) to Nuclear Regulatory Commission (NRC) letter, 3F0308-04, dated March 12, 2008, "Crystal River Unit 3 – Relief Request #08-001-RR, Revision 1"
2. FPC to NRC letter, 3F0308-07, dated March 26, 2008, "Crystal River Unit 3 – Relief Request #08-001-RR, Revision 1: Reports of Weld Overlay Examination Results"

Dear Sir:

In Reference 1, FPC, doing business as Progress Energy Florida, Inc., submitted Relief Request #08-001-RR to support the application of a structural weld overlay to the decay heat drop line at Crystal River Unit 3 (CR3). Enclosure 3 of Reference 1 contained four regulatory commitments. Three of these were addressed by Reference 2. The remaining commitment, shown below, is addressed by this letter. This commitment is as follows:

> *Provide a report documenting a stress analysis summary demonstrating that the subject piping will perform its 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.*

Reference 1 committed the delivery of this report to be sixty days after entry into Mode 4 during the start-up from the March 2008 maintenance outage. Since entry into Mode 4 occurred on March 19, 2008, delivery of the report is due on or before May 18, 2008. In accordance with the provisions of 10 CFR 50.55a, FPC hereby provides this required report, satisfying the above commitment.

A047
NRR

Progress Energy Florida, Inc.
Crystal River Nuclear Plant
15760 W. Powerline Street
Crystal River, FL 34428

This submittal contains no new regulatory commitments.

If you have any questions regarding this submittal, please contact Dennis Herrin, Acting Supervisor, Licensing and Regulatory Programs at (352) 563-4633.

Sincerely,

/ Berry Foster (acting)

Stephen Cahill
Engineering Manager

SJC/dar

Attachment: Summary of Analysis Calculations for Repair Overlay of the Hot Leg Decay Heat Nozzle at Crystal River Unit 3

xc: NRR Project Manager
Regional Administrator, Region II
Senior Resident Inspector

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50 - 302 / LICENSE NUMBER DPR - 72

RELIEF REQUEST #08-001-RR, REVISION 1
60-DAY RESPONSE – SUMMARY OF ANALYSIS CALCULATIONS

ATTACHMENT

Summary of Analysis Calculations for
Repair Overlay of the Hot Leg Decay Heat Nozzle at
Crystal River Unit 3

Summary of Analysis Calculations for Repair Overlay of the Hot Leg Decay Heat Nozzle at Crystal River Unit 3

1.0 INTRODUCTION

During a maintenance outage at the Crystal River Unit 3 (CR3) Nuclear Power Station that commenced March 1, 2008, an indication was detected via linear phased array ultrasonic testing (UT) in the "B" hot leg decay heat nozzle-to-pipe weld. The indication originates from the inner diameter of the weld and is approximately 65% through-wall at the outermost extent. Florida Power Corporation (FPC) concluded that the application of a full-structural weld overlay (FSWOL) over the decay heat nozzle Alloy 82/182 weld was the most appropriate course of action to ensure the integrity of the reactor coolant pressure boundary. FPC applied a FSWOL during this outage.

The basis for FSWOL repair sizing for this application is American Society of Mechanical Engineers (ASME) draft Code Case N-740-2 [2], and the ASME Code, Section XI, Division 1, Class 1 [4] rules for allowable flaw size in austenitic piping (IWB-3640). Tables IWB-3641-1 and IWB-3641-2 are the controlling allowable flaw size tables from IWB-3640. These tables present allowable flaw depth-to-thickness ratios for flaw lengths ranging from 0 to 50% of the circumference or greater, as a function of the stress ratio (primary membrane plus bending stress (Pm+Pb) divided by the design stress intensity, Sm). For purposes of designing the overlay, a circumferential flaw is assumed to be 100% through the original wall thickness for the entire circumference of the item being overlaid, as required by draft Code Case N-740-2 for a full structural overlay. The overlay thickness must thus be established so that this flaw assumption meets the allowable flaw depth-to-thickness ratio requirement of Tables IWB-3641-1 and IWB-3641-2, for the thickness of the weld overlaid item.

ASME Code, Section III stress and fatigue usage evaluations are also performed that supplement existing piping and nozzle stress reports, to demonstrate that overlaid components continue to meet ASME Code, Section III. The weld overlay repair is designed to the requirements of the ASME Code, Section III for Class 1 components. As such, the rules of Article NB-3000 of Section III of the ASME Code, 2001 Edition with Addenda through 2003 [5], are used.

The weld overlay repair region affects the hot leg decay heat nozzle and cladding as well as decay heat piping. All of these components are considered piping components and the rules of Subarticle NB-3600 of the ASME Code are used to satisfy NB-3200 acceptance criteria.

In addition to providing structural reinforcement to the Primary Water Stress Corrosion Cracking (PWSCC) susceptible location with a resistant material, the weld overlay process has also been shown to produce beneficial residual stresses that mitigate PWSCC in the underlying dissimilar metal welds (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 overlay act as compressive mean stresses in fatigue crack growth assessments.

This design report summarizes the analysis calculations that have been performed to ensure that the as-designed weld overlay meets all imposed design requirements. Further evaluations based on as-built measurements taken after application of the overlay demonstrate that the overlay meets its design basis requirements, and that it will not have an adverse effect on the balance of the piping system. These evaluations include comparison of overlay dimensions to design dimensions.

2.0 ANALYSIS SUMMARY AND RESULTS

2.1 WELD OVERLAY STRUCTURAL SIZING CALCULATIONS

A detailed sizing calculation for weld overlay thickness was performed using the "Codes and Standards" module of the **pc-CRACK** computer program [6], which incorporates ASME Code, Section XI, IWB-3640 evaluation methodology. Loads and stress combinations were provided by FPC. Both normal operating/upset and emergency/faulted 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. ASME draft Code Case N-740-2 permits the deposition of a stainless steel buffer layer in those cases where the chemistry of the underlying pipe material may contribute to hot cracking of the diluted nickel base overlay layers. As indicated in Figure 2-1, such a layer was deposited on the stainless steel pipe at CR3. No credit is taken for this layer in determining the weld overlay size.

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, (3) residual stress improvement, and (4) inspectability of any adjacent welds. In accordance with ASME draft Code Case N-740-2, 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 being overlaid. Axial weld overlay length was established such that this stress is less than the ASME Code, 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-FSWOL 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. The weld overlay shape and material information for the CR3 hot leg decay heat nozzle is illustrated in Figure 2-1. The actual design dimensions were reviewed by qualified NDE personnel to ensure that the design meets inspectability requirements.

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

		Hot Leg Decay Heat Line Nozzle
Minimum Thickness (in.)	Nozzle Side	0.577
	Pipe Side	0.437
Minimum* Length (in.)	Nozzle Side	1.176
	Pipe Side	1.258

* Additional length requirements apply for inspectability

2.2 *SECTION III STRESS ANALYSES*

Stress intensities for the weld overlaid nozzle were determined from finite element analyses for the various specified load combinations and transients using the ANSYS software package [8]. A three-dimensional model was used for the hot leg decay heat nozzle (Figure 2-2), since the geometry is not axisymmetric. Linearized stresses were evaluated at four stress paths (Paths 1 through 4 in Figure 2-2 and 2-5).

The stress intensities at the nozzle and piping locations were evaluated in accordance with ASME Code, Section III, Subarticles NB-3200 and NB-3600 [5]. A summary of the stress and fatigue usage comparisons for the most limiting location is provided in Table 2-2. The stresses and fatigue usage in the weld overlaid nozzle is within the applicable Code limits. The limiting locations for the Section III stress analyses were found to be the section of the original pipe at the ends of the overlay (Paths 2 inside surface and 3 outside surface in Figures 2-2 and 2-6).

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

Nozzle	Load Combination	Type	Calculated	Allowable
Hot Leg Decay Heat	Level A/B	Primary + Secondary (P +Q) (ksi)*	27.1	50.1
	Fatigue	Cumulative Usage Factor	0.007	1

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

2.3 *RESIDUAL STRESS AND SECTION XI CRACK GROWTH ANALYSES*

Weld residual stresses for the hot leg decay heat nozzle weld overlay were determined by detailed elastic-plastic finite element analysis. The analysis approach has been previously documented to provide predictions of weld residual stresses that are in reasonable agreement with experimental measurements [7]. A two-dimensional, axisymmetric finite element model was developed for the nozzle. Modeling of weld nuggets used in the analysis to lump the combined effects of several weld beads is illustrated in Figure 2-3. The model simulated an inside surface (ID) repair at the DMW location with a depth of approximately 50% of the original wall thickness and extending 360 degrees around the nozzle. 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 inner diameter (ID) of the DMW.

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 weld (Figure 2-4), as well as on several paths through the thickness (e.g., Paths 1, 2 and 3 in Figure 2-6).

The residual stress calculations were then utilized, along with stresses due to applied loadings and thermal transients, to demonstrate that the existing crack will not exceed the overlay design basis during the ASME Code, Section XI inservice inspection interval due to fatigue and PWSCC. In the fatigue crack growth analyses, a uniform distribution of the design cycles of each applied transient was assumed to be applied in the 60 year plant design life. The 60 year design cycles are divided by 60 to get the equivalent number of design cycles per year. Crack growth is then evaluated until the end of 60 years or until the crack grows to the structural limit, whichever occurs first. Crack growth results due to fatigue and PWSCC are summarized in Table 2-3. For the postulated circumferential and axial flaws, the maximum crack depth at the end of the ten-year inspection interval does not intrude into the required structural thickness of the weld overlay.

Table 2-3: Calculated Years for Initial Flaw Size of 75% of the Original Weld to Grow to the Overlay

Flaw *	Time to Reach Overlay
Circumferential (DMW)	>42 Years
Axial (DMW)	>60 Years

Notes:

* Initial flaw depth = 75% of original base metal thickness at the sections analyzed = 1.1997".

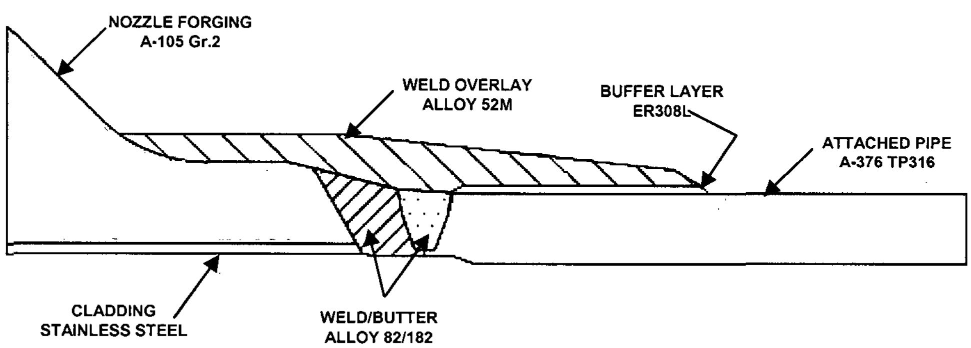
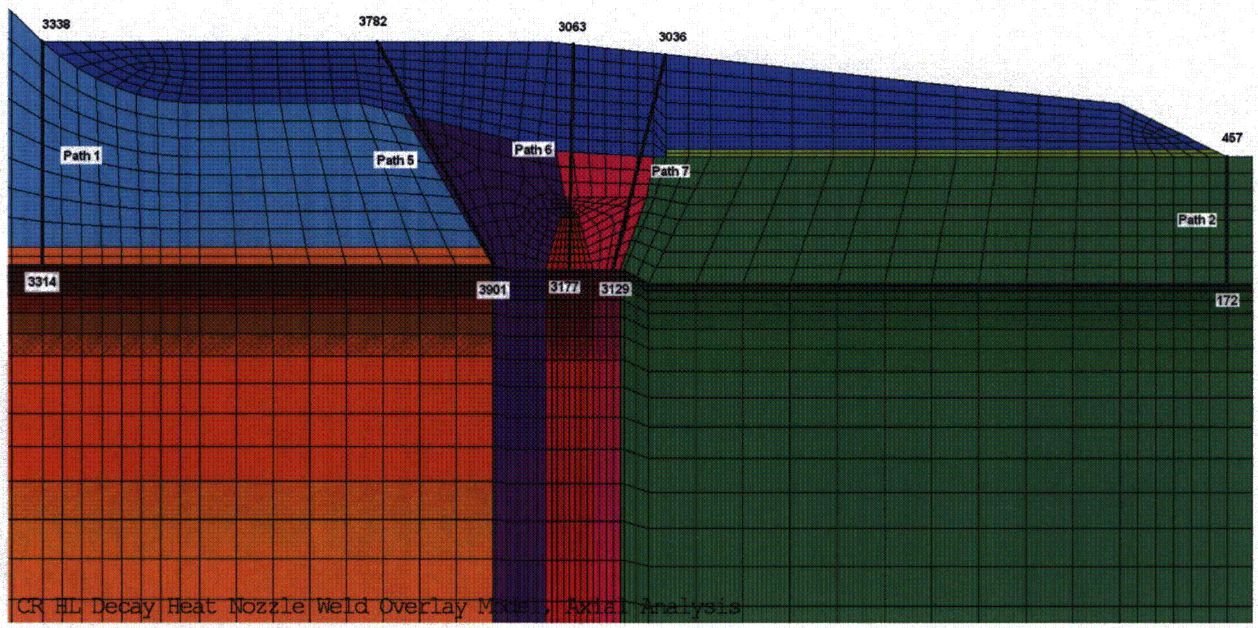


Figure 2-1: Pressurizer Hot Leg Decay Heat Line Nozzle Weld Overlay



Note: Paths 1-4 are for ASME Code, Section III evaluations, Paths 5-10 are for crack growth evaluations. The inside node is located on the inside face of the nozzle/piping for all paths

Figure 2-2: Stress Path Definitions for Section III Stress Analysis (0 Degrees) (Hot Leg Decay Heat Nozzle Weld Overlay)

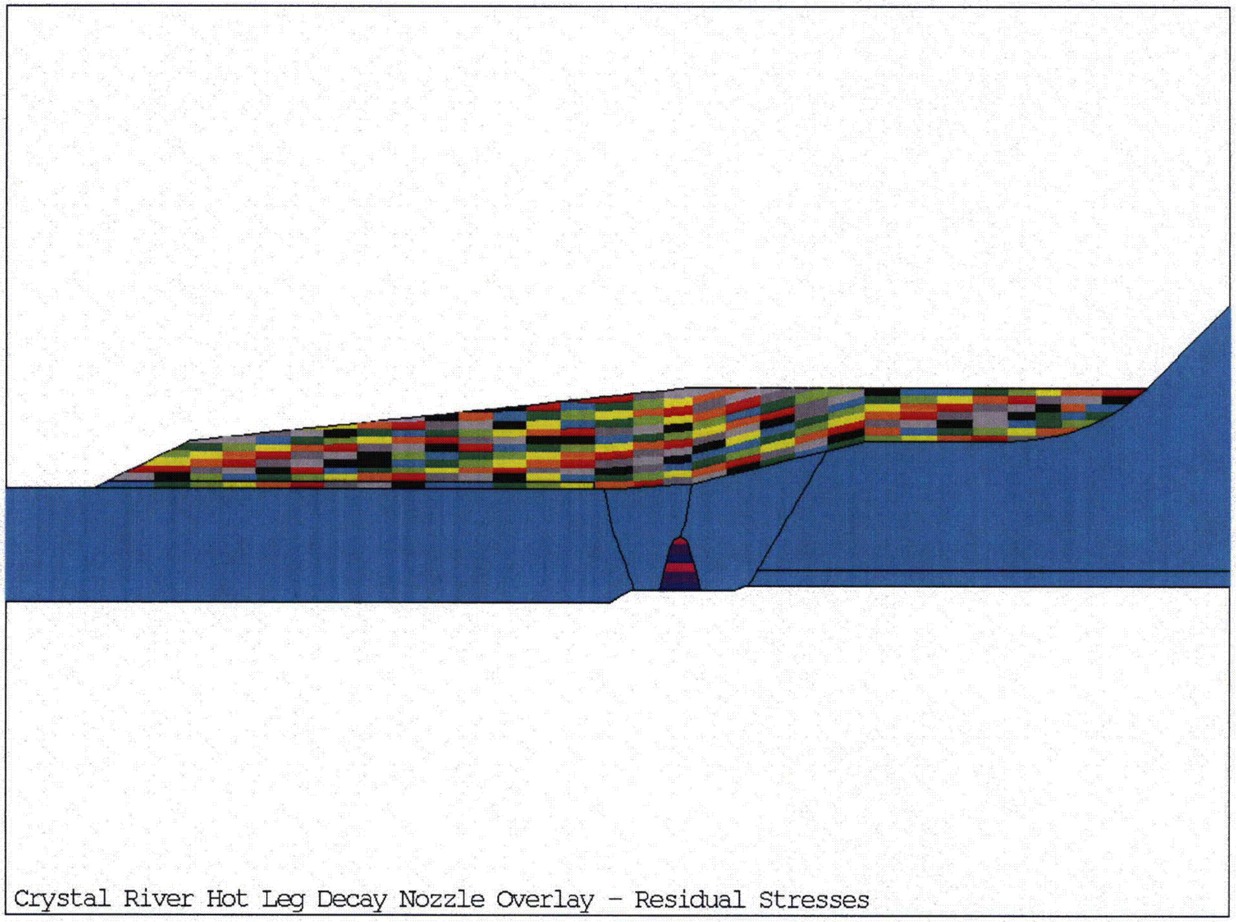
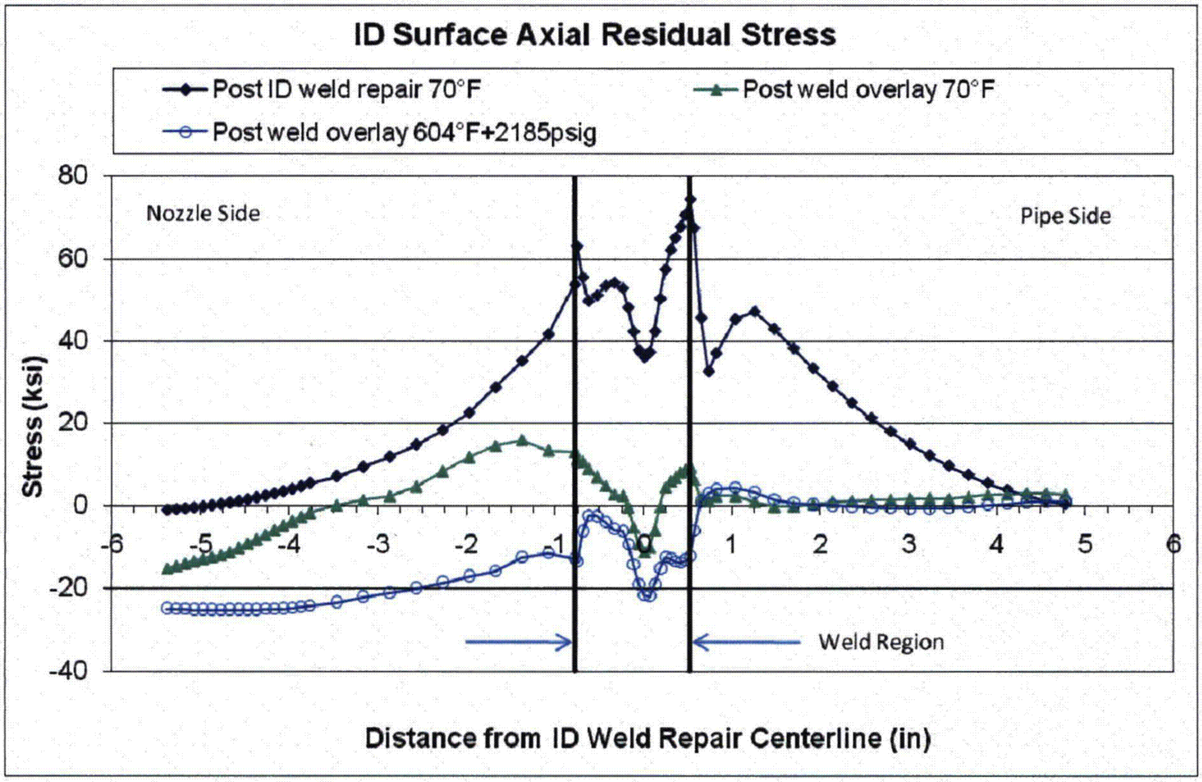


Figure 2-3: Finite Element Model for Residual Stress Analysis Showing Nuggets used for Welding Simulation of Hot Leg Decay Heat Nozzle



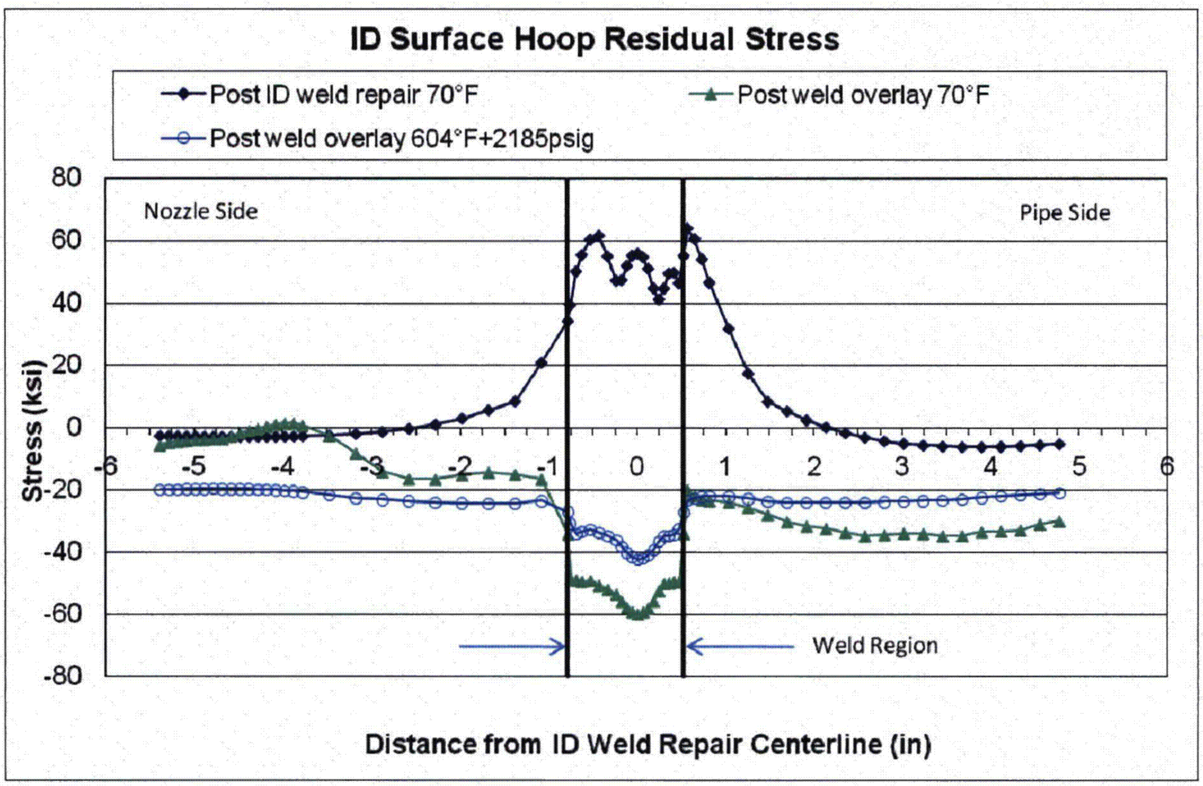
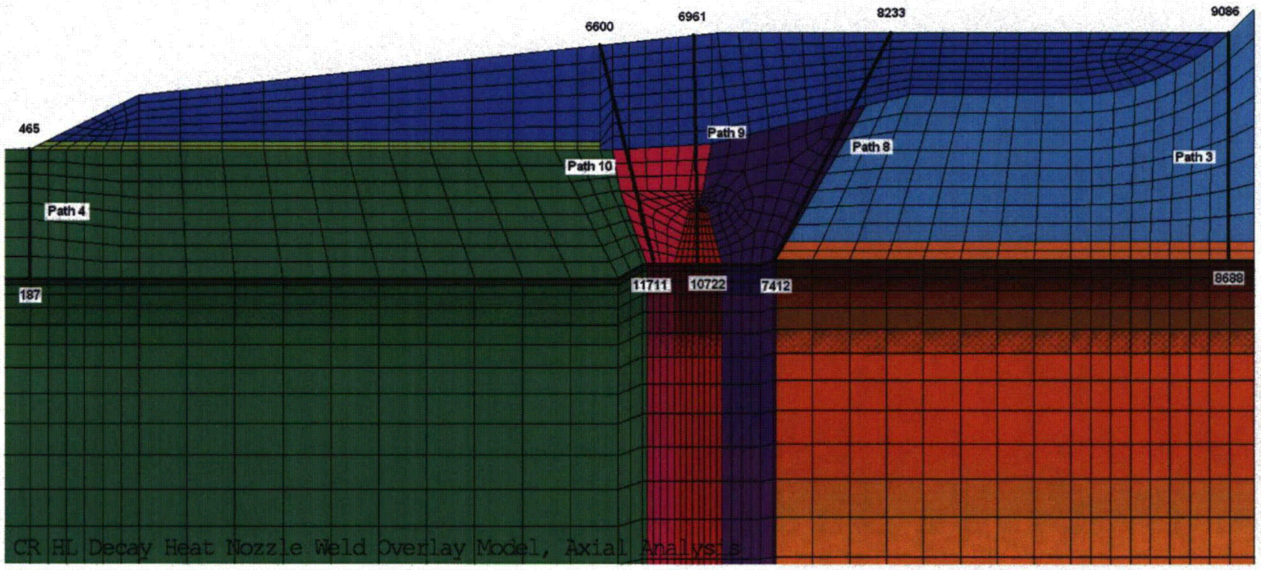


Figure 2-4: Typical Residual Stress Results along Inside Surface of Original Butt Weld Hot Leg Decay Heat Nozzle



Note: Paths 1-4 are for ASME Code, Section III evaluations, Paths 5-10 are for crack growth evaluations. The inside node is located on the inside face of the nozzle/piping for all paths

Figure 2-5: Stress Path Definitions for Section III Stress Analysis (90 Degrees) (Hot Leg Decay Heat Nozzle Weld Overlay)

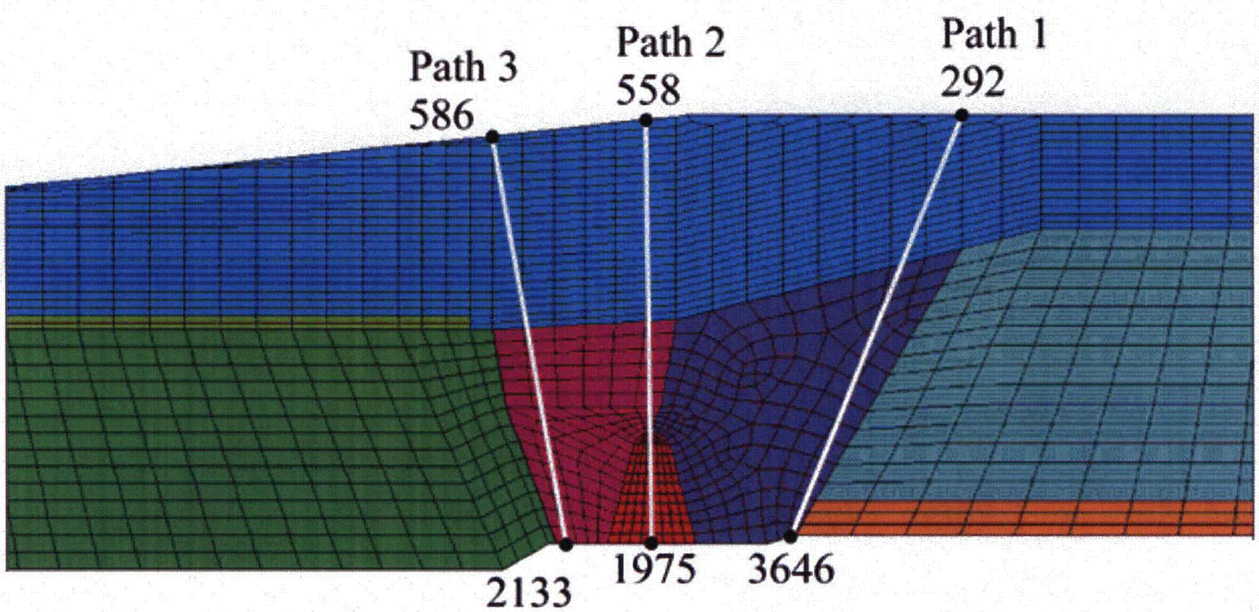


Figure 2-6: Stress Path Definitions for Residual Stress

3.0 CONCLUSIONS

The design of the CR3 hot leg decay heat nozzle weld overlays was performed taking guidance from the requirements of ASME draft Code Case N-740-2 [2], amended in accordance with the Relief Request [3]. The weld overlay is demonstrated to mitigate PWSCC in the overlaid weld based on the following:

- In accordance with ASME draft Code Case N-740-2, 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 restore 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.
- No credit was taken in the overlay designs for the buffer layer which was deposited to prevent hot cracking of the diluted nickel base overlay.
- Application of the weld overlay 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 analysis was performed, after first simulating a severe ID weld repair in the nozzle to pipe weld, prior to applying the weld overlay. 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 crack growth into the overlay is minimized.
- 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.

Based on the above observations and the fact that similar nozzle-to-pipe weld overlays have been applied to other plants since 1986 with no subsequent problems identified, it is concluded that the CR3 hot leg decay heat nozzle DMW has received mitigation against further PWSCC induced crack growth.

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 Boiler and Pressure Vessel Code, draft Code Case N-740-2, "Full Structural Dissimilar Metal Weld Overlay for Repair of Class 1, 2, and 3 Items, Section XI, Division 1."
3. Crystal River Unit 3 – Relief Request #08-001-RR, Revision 0 including response to Request for Additional Information, Weld Overlay of the Decay Heat Drop Line, Relief Request #08-001-RR, Revision 0, Crystal River Unit 3, Docket Number 50-302.
4. ASME Boiler and Pressure Vessel Code, Section XI, 1989 Edition.
5. ASME Code, Section III, 2001 Edition with Addenda through 2003.
6. **pc-CRACK** for Windows, Version 3.1-98348, Structural Integrity Associates, 1998.
7. Materials Reliability Program Report MRP-169, "Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs," August 2005.
8. ANSYS/Mechanical, Release 8.1 (w/Service Pack 1), ANSYS Inc., June 2004.