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November 29, 2007

U. S. Nuclear Regulatory Commission
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SUBJECT: Duke Power Company LLC d/b/a Duke Energy Carolinas, LLC (Duke)
Oconee Nuclear Station, Unit 1, 2, and 3
Docket Number 50-269, -270, -287
Relief Request 07-ON-004

On September 13, 2007 Duke submitted Relief Request 07-ON-004 pursuant to 10 CFR 50.55a(a)(3)(i), requesting NRC approval to use alternatives to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI inservice inspection (ISI) requirements for the Oconee Nuclear Station, Unit 1, 2, & 3. This proposed alternative approach is to support application of full structural weld overlays on the Decay Heat Removal (DHR) line to Hot Leg Nozzle welds in the Reactor Coolant System for all three Oconee units.

In accordance with that submittal, enclosed is a summary of the results of the stress analyses demonstrating that the preemptive full structural weld overlay will not hinder the components from performing their design function. This summary report is applicable to all three Oconee units.

If you have any questions or require additional information, please contact Randy Todd at (864)-885-3418.

Sincerely,

Bruce Hamilton

Bruce H. Hamilton
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Enclosure

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ONS MasterFile ON-801.01 (ON03DM)
ELL

Duke Power Company, LLC
Oconee Nuclear Station
Units 1, 2, and 3
Request for Relief 07-ON-004

November 29, 2007

Enclosure 1

Summary of Analysis Calculations for Hot Leg Decay Heat Nozzle Containing Alloy 600 Material at Oconee Nuclear Station, Units 1, 2 and 3

1.0 INTRODUCTION

Duke Energy is applying a full structural weld overlay (WOL) on the dissimilar metal weld (DMW) of the 12" hot leg decay heat line nozzle at the Oconee Nuclear Station, Units 1, 2 and 3. The purpose of this overlay is to eliminate dependence on the primary water stress corrosion cracking (PWSCC) susceptible Alloy 82/182 weld as a pressure boundary weld and to mitigate any potential future PWSCC in this weld. The overlay is installed using a PWSCC resistant weld filler material, Alloy 52M [1].

The requirements for design of weld overlay repairs are defined in ASME Code Case N-504-2 [2], supplemented for this application by the Relief Request [3]. Weld overlay repairs 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 and is completely through the original component wall. A combination of internal pressure, deadweight, seismic and mechanical load stresses is applied to the overlaid nozzle containing this assumed design basis flaw, and the resulting overlay design must meet the requirements of ASME Code, Section XI, IWB-3641 [4].

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 design Code for the Reactor Coolant Piping and the Decay Heat Piping is the ASME Boiler & Pressure Vessel Code, Section III, 1983 Edition, no addenda [9]. ASME Code Section III, 1989 Edition, with no addenda [5] was used for these analyses and the results were then reconciled with the 1983 Code.

In addition to providing structural reinforcement to the 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 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 will be performed at a later date, based on as-built measurements taken after the overlay is applied, to 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 will include comparison of overlay dimensions to design dimensions and evaluation of shrinkage stresses.

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 Duke Energy. Both normal operating/upset (Level A/B) 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 carbon steel nozzle, a dilution weld layer is specified, in addition to the thickness required for structural reinforcement, to allow for the possibility that the minimum required chromium content for PWSCC resistance (24%) may not be achieved in the first layer.

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 Code Case N-504-2, 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-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. The weld overlay shape and material information for the Oconee Units 1, 2 and 3 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	0.5417
	Pipe Side	0.375
Minimum** Length (in.)	Nozzle Side	1.137
	Pipe Side	1.170

* Weld dilution layer (.08") must be added

** 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).

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], respectively and reconciled with the design Code [9]. 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 location for the Section III stress analyses was found to be the section of the original pipe at the end of the overlay (Paths 2 and 4 in Figure 2-2).

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)*	39.70	50.88
	Fatigue	Cumulative Usage Factor	0.006	1.000

* - 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 for the 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 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 2-5).

The residual stress calculations were then utilized, along with stresses due to applied loadings and thermal transients, to demonstrate that an assumed 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 a postulated initial flaw size of 75% of the original wall thickness, which is consistent with the post-overlay UT inspection criteria. For both the circumferential and axial postulated 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, which is equal to 75% of the total original weld plus overlay thickness. Conservatively, the crack growth analyses do not include the dilution layer. Had the dilution layer been credited in the analyses, it would add an estimated 8 months to the Axial Flaw value shown in Table 2-3.

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

Calculated Years*	
Circumferential Flaw	Axial Flaw
> 60	33.6

* - Limiting value due to PWSCC and fatigue for this nozzle.

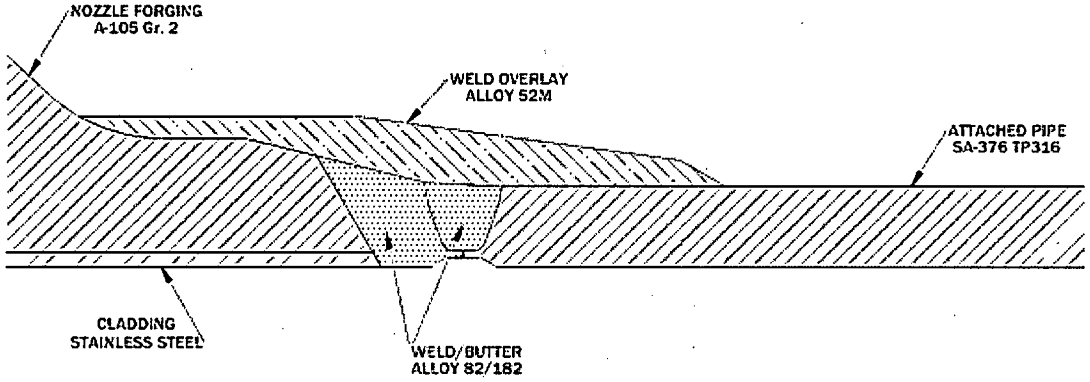


Figure 2-1: Pressurizer Hot Leg Decay Heat Line Nozzle Weld Overlay

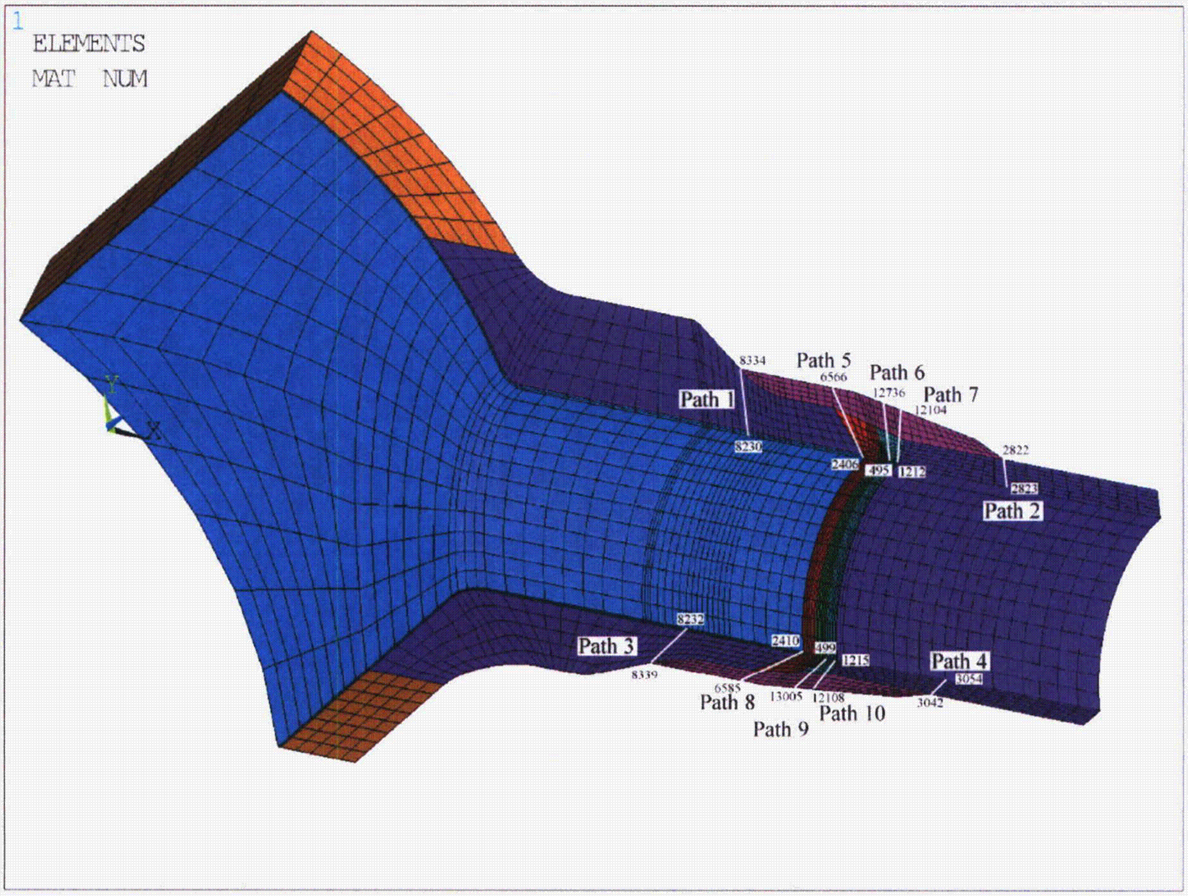


Figure 2-2: Stress Path Definitions for Section III Stress Analysis (Hot Leg Decay Heat Nozzle Weld Overlay)

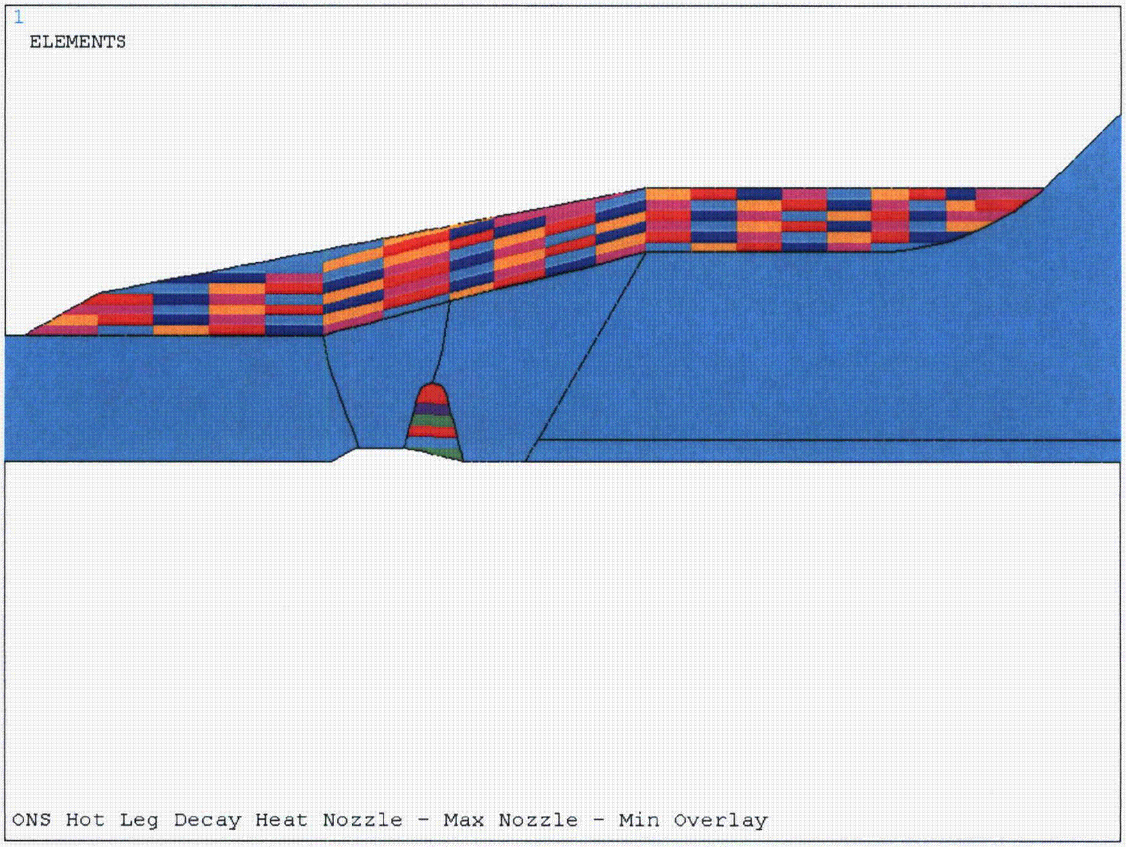
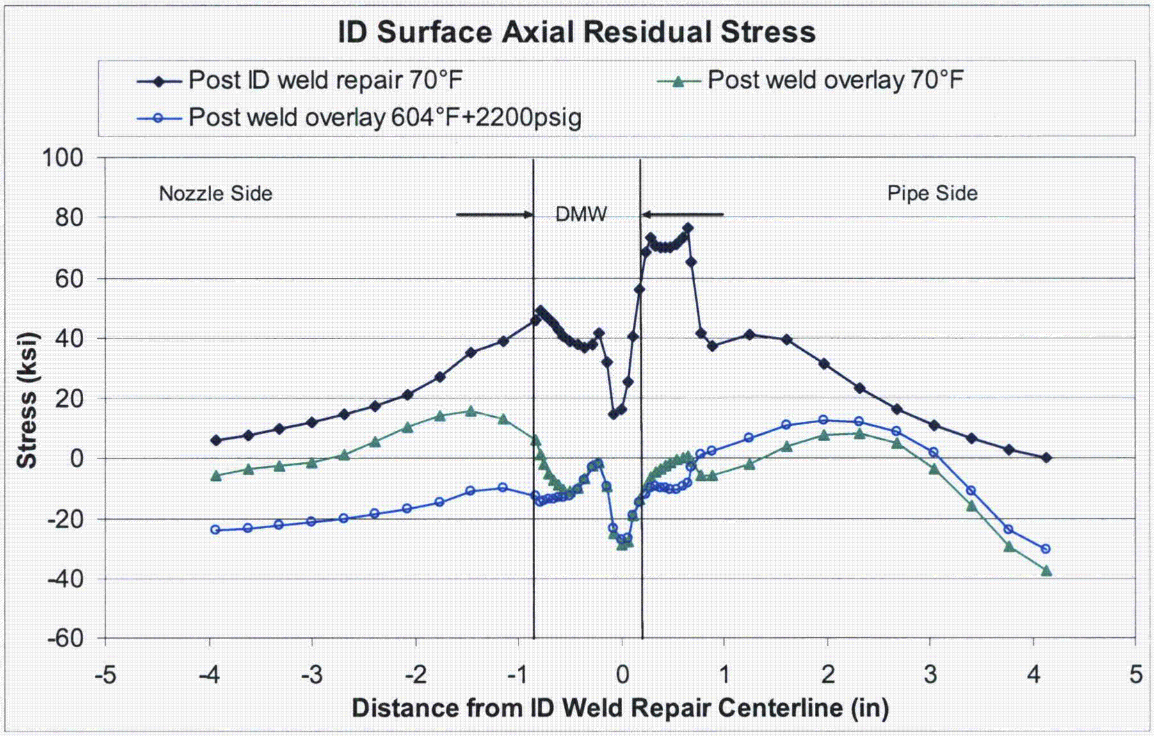


Figure 2-3: Finite Element Model for Residual Stress Analysis Showing Nuggets used for Welding Simulation of Hot Leg Decay Heat Nozzle



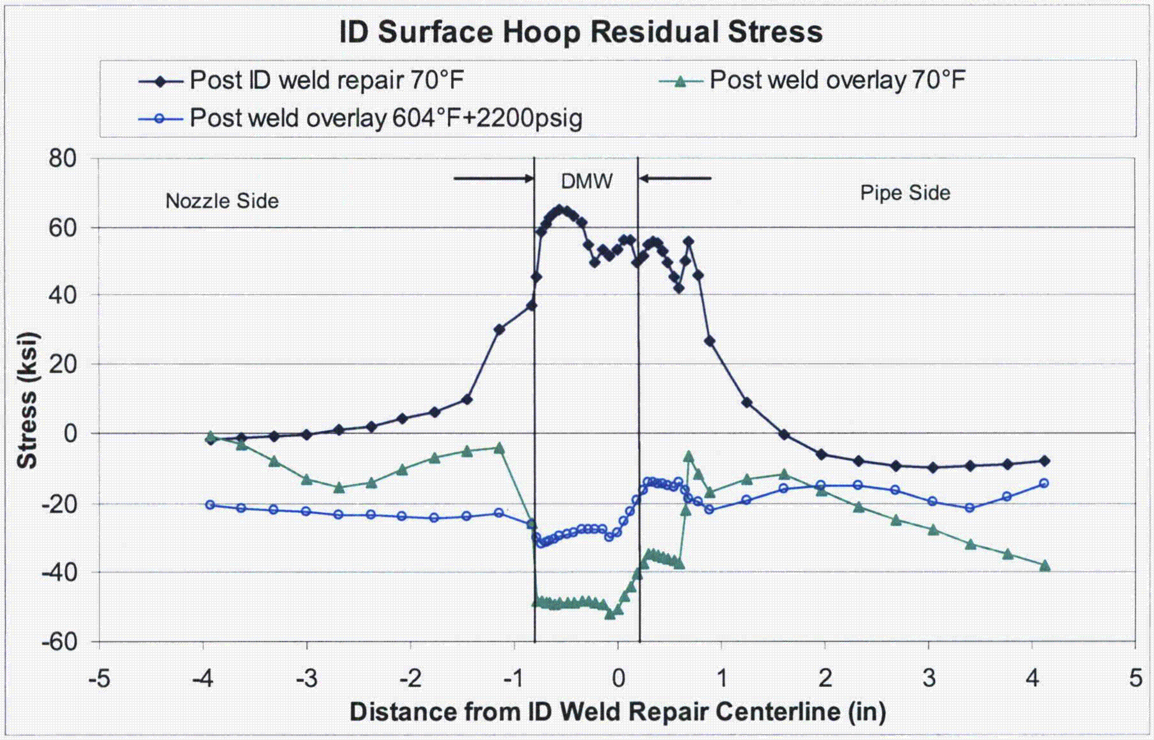


Figure 2-4: Typical Residual Stress Results along Inside Surface of Original Butt Weld Hot Leg Decay Heat Nozzle

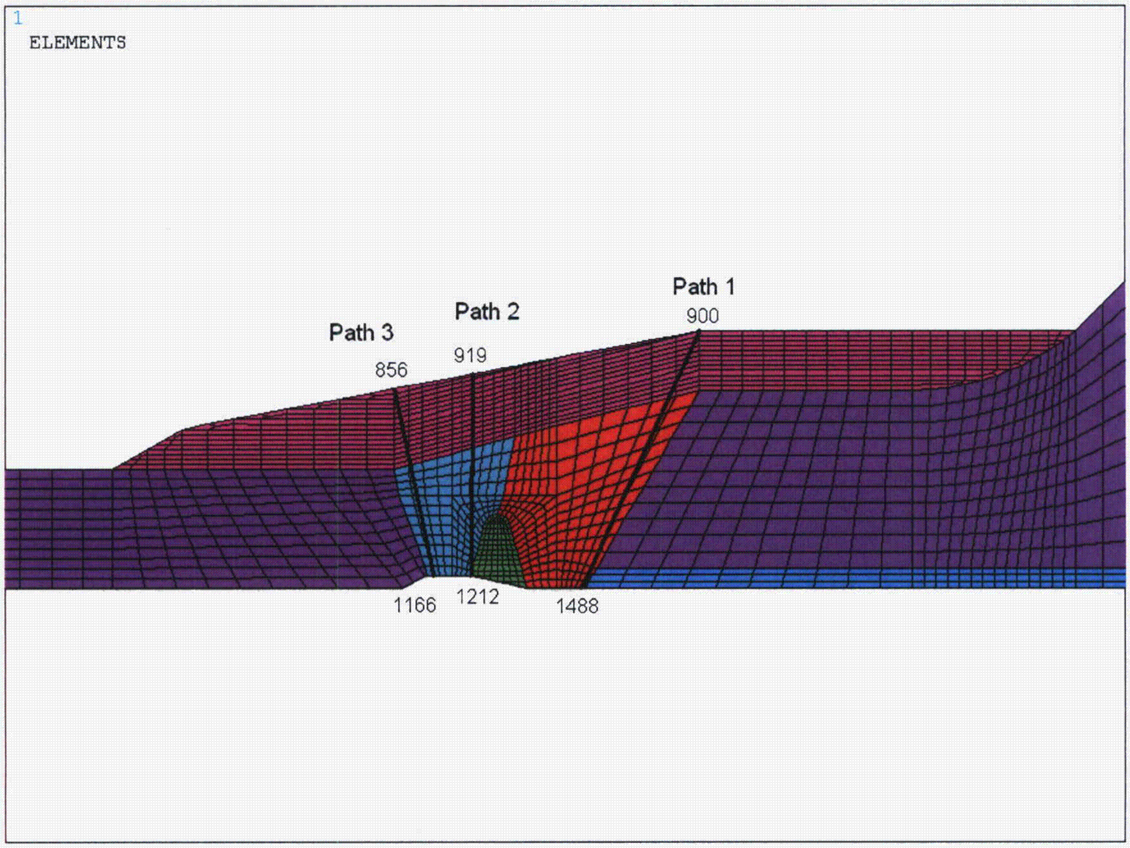


Figure 2-5: Through Wall Stress Paths Selected for Crack Growth Evaluation – Hot Leg Decay Heat Nozzle

3.0 CONCLUSIONS

The design of the Oconee Units 1, 2 and 3 hot leg decay heat nozzle weld overlays was performed taking guidance from the requirements of ASME Code Case N-504-2 [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 Code Case N-504-2, 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 first overlay layer, which could have been diluted by the base metal during the welding process.
- 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 initiation or 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 Oconee Nuclear Station Units 1, 2 and 3 hot leg decay heat nozzle dissimilar metal weld has received mitigation against PWSCC.

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-504-2, "Alternative Rules for Repair of Classes 1, 2, and 3 Austenitic Stainless Steel Piping, Section XI, Division 1."
3. Request for Alternative 07-ON-004 dated September 13, 2007, Duke Energy Corporation, Oconee Nuclear Station Units 1, 2 and 3.
4. ASME Boiler and Pressure Vessel Code, Section XI, 1998 Edition (with Addenda up to and including 2000).
5. ASME Boiler and Pressure Vessel Code, Section III, 1989 Edition with no Addenda.
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.
9. ASME Boiler and Pressure Vessel Code, Section III, 1983 Edition with no Addenda.