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SCE&G®
A SCANA COMPANY

May 23, 2008

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

Dear Sir / Madam:

Subject: VIRGIL C. SUMMER NUCLEAR STATION (VCSNS)
DOCKET NO. 50-395
OPERATING LICENSE NO. NPF-12
INSERVICE INSPECTION RELIEF REQUEST RR-III-05
WELD OVERLAY REPAIR STRESS ANALYSIS SUMMARY

References:
1. Jeffrey B. Archie (SCE&G) letter to Document Control Desk (NRC), Request to Use Alternatives to ASME Code Section XI Requirements for Application of Weld Overlay Repairs (RR-III-05), June 1, 2007
2. R. E. Martin (NRC) Letter to J. B. Archie (SCE&G) - Proposed Alternative for the Application of Weld Overlay on Dissimilar Metal Welds of Pressurizer Nozzles (TAC No. MD5765), March 25, 2008

On June 1, 2007, South Carolina Electric & Gas Company (SCE&G) 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 VCSNS's installation of full structural weld overlays on dissimilar metal welds of pressurizer nozzles during Refueling Outage 17. This request was approved by the NRC on March 25, 2008 (Reference 2).

As part of that request, SCE&G committed to submitting a stress analysis summary demonstrating that the pressurizer spray nozzles will perform their intended 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 17.

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 June 1, 2007, letter (Reference 1) has been fulfilled.

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In addition to the above commitment, VCSNS has performed evaluations, assessments, and reviews of the applied weld overlays on the pressurizer nozzles. The following provides supplemental information to the stress analysis summary that reflects the actual field implementation of the weld overlays on the pressurizer nozzles:

- Weld shrinkage was calculated for each of the nozzles based on pre and post weld overlay nozzle and piping measurements. The impacts of the axial shrinkage were evaluated relative to the respective piping connections and supports. No adverse impacts were identified due to the shrinkage as a result of the welding process.

- Piping measurements were taken on the safety valve nozzle piping to assess the impacts of the nozzle shrinkage due to the weld overlays, and the potential impact on the safety valve nozzles. The shrinkage was evaluated along with measured piping movement before and after the weld application. The piping movement measurements were negligible. The impact is minimal and may provide a beneficial "cold spring" stress condition for the respective lines.

- Piping supports in the vicinity of the weld overlay nozzles were evaluated and observed for potential impacts. The resulting loads on the supports are within their design capabilities and no adverse impacts were identified in field walk-downs.

- The weight added to the pressurizer nozzles due to the weld overlays is insignificant relative to the weight of the attached piping systems. An assessment of the added weight is documented in the design change package.

- The as-built dimensions of the weld overlay were recorded for both the pre and post weld conditions to determine the precise amount of weld metal applied. The thickness and length measurements are within the minimum and maximum design values demonstrating that the application meets the design requirements.

This document contains no new regulatory commitment.

Should you have any questions, please call Mr. Bruce Thompson at (803) 931-5042.

Very truly yours,

Jeffrey B. Archie

JT/JBA/jt

Attachment: Summary of Design and Analyses of Weld Overlays for Pressurizer Nozzle Dissimilar Metal Welds for Alloy 600 Mitigation, as provided by Structural Integrity Associates, Inc.

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Files (810.19-1, 815.02 [IEB2004-01])
PRSF (RC-08-0078)

Virgil C. Summer Nuclear Station (VCSNS)

Inservice Inspection Relief Request RR-III-05

Summary of Design and Analyses

of

Weld Overlays

for

Pressurizer Nozzle Dissimilar Metal Welds for Alloy 600 Mitigation

Prepared by:

Structural Integrity Associates, Inc.

(17 Pages)

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May 13, 2008
SIR-08-123-NPS, Rev. 0

Mr. A. Pitts Turbeville
South Carolina Electric & Gas
V. C. Summer Nuclear Station
PO Box 88
Jenkinsville, SC 29065

Subject: Summary of Design and Analyses of Weld Overlays for Pressurizer Nozzle Dissimilar Metal Welds for Alloy 600 Mitigation at Virgil C. Summer Nuclear Station

Reference: Request to Use Alternatives to ASME Code Section XI Requirements for Application of Weld Overlay Repairs (RR-III-05), Virgil C. Summer Nuclear Station, Docket No. 50/395, Operating License No. NPF-12

Dear Mr. Turbeville:

The following attachment is transmitted in support of the South Carolina Electric & Gas response to commitments in the above-referenced request for alternative:

Commitment:

South Carolina Electric & Gas will 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 the Virgil C. Summer Nuclear Station's seventeenth refueling outage (RF17), Spring 2008.

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

Prepared by:

Chris Lohse, Engineering Analyst — Date: 05/13/08

Verified by:

Moses Taylor, P.E., Senior Associate — Date: 05/13/08

Approved by:

Barry Smith, P.E., Senior Consultant — Date: 05/13/08

Attachment
cc: G. Meyer (SCE&G)
R. Woodard (WSI)
Project File No. VCS-07Q-401

Attachment

Summary of Design and Analyses of Weld Overlays for Pressurizer Nozzle Dissimilar Metal Welds for Alloy 600 Mitigation

1.0 Introduction

South Carolina Electric & Gas (SCE&G) applied full structural weld overlays (WOLs) on dissimilar metal welds (DMWs) between the carbon steel nozzles and stainless steel safe ends of the nozzles listed below. The WOLs were also applied to the similar metal stainless steel welds (SSWs) between the safe end and the connecting piping component.

- One pressurizer surge nozzle
- One pressurizer spray nozzle
- Three pressurizer safety valve nozzles
- One pressurizer relief valve nozzle

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 are extended to cover the similar metal weld between the safe end and connecting piping component to provide sufficient length to meet ASME Code, Section XI inspection coverage requirements for the DMWs. The overlays were installed using a PWSCC resistant weld filler material Alloy 52M [1].

The requirements for design of weld overlay repairs are defined in the Relief Request [2], which is based on ASME Code Case N-740 [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; that is, completely through the original component wall thickness. 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 Code, 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 requirements. The original construction Code is the ASME Code, Section III, 1971 Edition with Addenda through Summer 1971 for the pressurizer nozzles. However, as allowed by ASME Section XI, Code Editions and Addenda later than the original construction Code may be used. ASME Code, 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.

Finally, evaluations will be performed, based on as-built measurements taken after the overlays are applied, to confirm 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 field measured overlay dimensions to design dimensions, evaluations of shrinkage stresses and added weight effects on the piping systems. The as-built field dimensions will confirm that the WOL meets all design (structural) requirements prior to plant operation.

2.0 Analysis Summary and Results

2.1 Weld Overlay Structural Sizing Calculations

Detailed sizing calculations for weld overlay thickness were 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 SCE&G. 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 for the nozzles.

As stated in Section 1.0, preemptive weld overlays were installed using Alloy 52M filler metal. However, Alloy 52M weld metal has demonstrated sensitivity to certain impurities, such as sulfur, when deposited onto austenitic stainless steel base materials. The first 3 beads of Alloy 52M will be dye penetrant tested to ensure that no cracking occurs. Application of a butter (transitional) layer of austenitic stainless steel filler metal may be required.

Design of the weld overlay length considered: (1) length required for structural reinforcement, (2) length required for access for preservice and inservice examinations of the overlaid weld, and (3) limitation on the area of the nozzle that can be overlaid. Because of the short safe end length on the overlaid nozzles, it is necessary to extend the overlay length over both the nozzle-to-safe end DMW and the safe end-to-pipe weld for all nozzles. In accordance with the Relief Request [2] and ASME Code Case N-740 [3], the minimum weld overlay length required for structural reinforcement was established by evaluating the axial 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 welds 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 for the nozzles.

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 is illustrated in Figure 2-1. The designs were reviewed by qualified NDE personnel to ensure that they meet inspectability requirements, and the overlays were designed to satisfy full structural requirements for the DMWs and the SSWs. The design thickness and length specified on the design drawings bound the calculated minimum values, and may be greater to facilitate the desired geometry for examination. The NDE scans will be performed prior to the welding personnel leaving the plant site to ensure that any adjustments are made per approved process procedures.

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

Dimension	**Location**	**Pressurizer Surge Nozzle**	**Pressurizer Spray Nozzle**	**Pressurizer Safety/Relief Valve Nozzle**
Minimum Thickness (in.)	Nozzle Side	0.489	0.292	0.397
	Safe End Side (at DMW)	0.526	0.228	0.313
	Safe End Side (at SSW)	0.553	0.248	0.317
	Pipe Side	0.505	0.161	0.239
Minimum* Length (in.)	Nozzle Side	1.342	0.375	0.465
	Pipe Side	2.274	0.638	0.748

* Length shown is the minimum required for structural acceptance and does not include additional length necessary to meet inspectability requirements.

2.2 Section III Stress Analyses

Stress intensities for the weld overlaid nozzles were determined from finite element analyses for the various specified load combinations and transients using the ANSYS software package [7]. Linearized stresses were evaluated at various stress locations using 2-dimensional, axisymmetric models. A typical finite element model showing stress path locations is provided in Figure 2-2. 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 for the nozzles. The stresses and fatigue usage in the weld overlaid nozzles are within the applicable Code limits.

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

Nozzle	Load Combination	Type	Calculated	Allowable
Pressurizer Surge	Level A/B	Primary + Secondary (P + Q) (ksi)*	98.48 (44.83)**	55.47 (55.47)**
	Fatigue	Cumulative Usage Factor	0.418	1.000
Pressurizer Spray	Level A/B	Primary + Secondary (P + Q) (ksi)*	115.99 (35.21)**	48.84 (41.84)**
	Fatigue	Cumulative Usage Factor	0.047	1.000
Pressurizer Safety/ Relief Valve	Level A/B	Primary + Secondary (P + Q) (ksi)*	58.72 (46.22)**	48.19 (48.19)**
	Fatigue	Cumulative Usage Factor	0.021	1.000

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

** Elastic analysis exceeds the allowable value of 3Sm, however, criteria for simplified elastic-plastic analysis are met, as shown by the value in parentheses.

2.3 Residual Stress and Section XI Crack Growth Analyses

Weld residual stresses for the 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 [8]. Two-dimensional, axisymmetric finite element models were developed for each of the nozzle configurations. 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.

An analysis was performed to simulate the welding process of the ID weld repair, the safe end-to-pipe weld, the overlay welding process, and finally, a slow heatup to operating temperature. The analysis consisted of a thermal pass to determine the temperature response of the model to each individual lumped weld nugget as it was added in sequence, followed by a non-linear elastic-plastic stress pass to calculate the residual stress due to the temperature cycling from the application of each lumped weld pass. Since residual stress is a function of the welding history, the stress pass for each nugget was applied to the residual stress field induced from all previously applied weld nuggets.

After completion of the weld overlay simulation, the model was allowed to cool to a uniform steady state temperature of 70°F, and then heated up to the operating temperature; a corresponding operating pressure was also applied to obtain the residual stresses at operating conditions.

The resulting residual stresses were evaluated on the inside surface of the original welds and safe-end components, as well as on several typical paths (Figure 2-4) through the DMWs and stainless steel welds. Note that PWSCC susceptible regions are marked by solid vertical lines in the inside surface stress plots shown in Figure 2-5 for the DMW.

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. In the fatigue crack growth analyses, the 40-year design quantity of each applied transient was assumed to be applied since this quantity was considered applicable to the extended operating life of 60 years. Since the examination volume for the PDI qualified post-overlay UT inspections includes the weld overlay thickness plus the outer 25% of the original wall thickness, an inside surface connected flaw that is 75% of the original weld thickness was assumed as the largest flaw that could escape detection by this examination. Thus, crack growth was computed assuming an initial flaw depth of 75% of the original weld thickness. The amount of time it takes for the flaw to reach the base material/overlay interface was then calculated. The crack growth results are shown in Table 2-3 for the nozzles.

For crack growth due to PWSCC, the total sustained stress intensity factor during normal steady state plant operating conditions 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 was predicted for assumed crack depths at which the combined stress intensity factor due to sustained steady state operating conditions was less than zero.

Table 2-3: Crack Growth Results

Flaw[(1)]	**Time to Reach Overlay**		
	Pressurizer Surge Nozzle	**Pressurizer Spray Nozzle**	**Pressurizer Safety/Relief Valve Nozzle**
Circumferential (DMW)	15 years	>60 years	>60 years
Axial (DMW)	>60 years	>60 years	>60 years
Circumferential (SSW)	33 years	13 years	10 years
Axial (SSW)	>60 years	29 years	>60 years

Notes: 1. DMW = Dissimilar metal weld; SSW = Stainless steel weld.

2.4 Evaluation of As-Built Conditions

The Relief Request [2] and Code Case N-740 [3] require evaluation of the as-built weld overlays to determine 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. The effect of the added weight of the overlays on the adjacent piping systems, based on as-built dimensions will be evaluated. These evaluations will be performed and documented separately from this report and will include the effects of the disposition of any non-conformances that occurred during weld overlay installation.

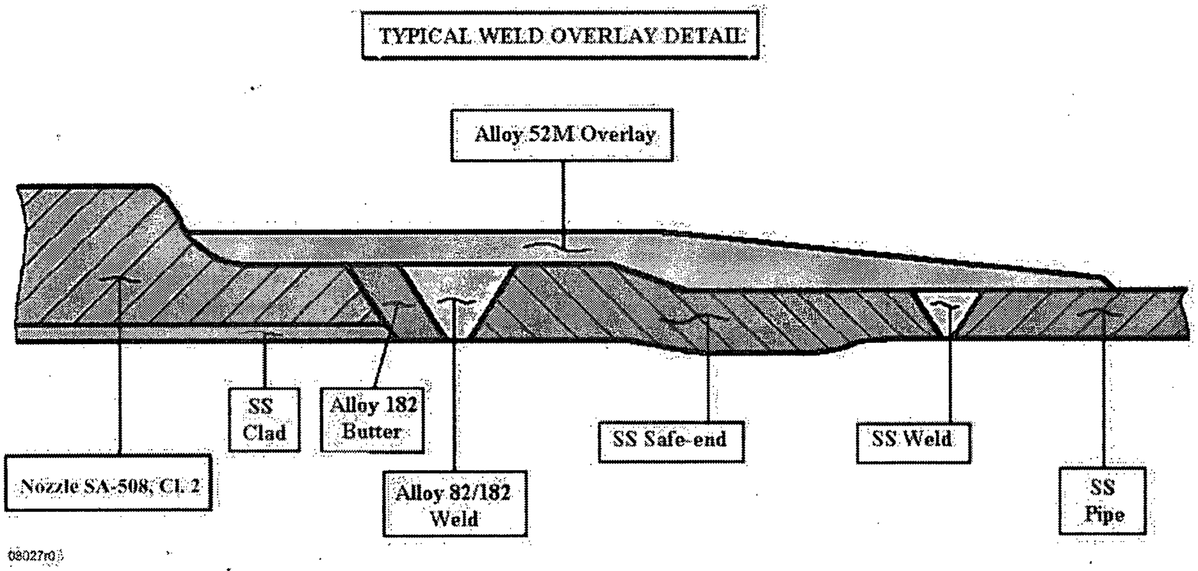


Figure 2-1: Illustration of Typical Weld Overlay Design

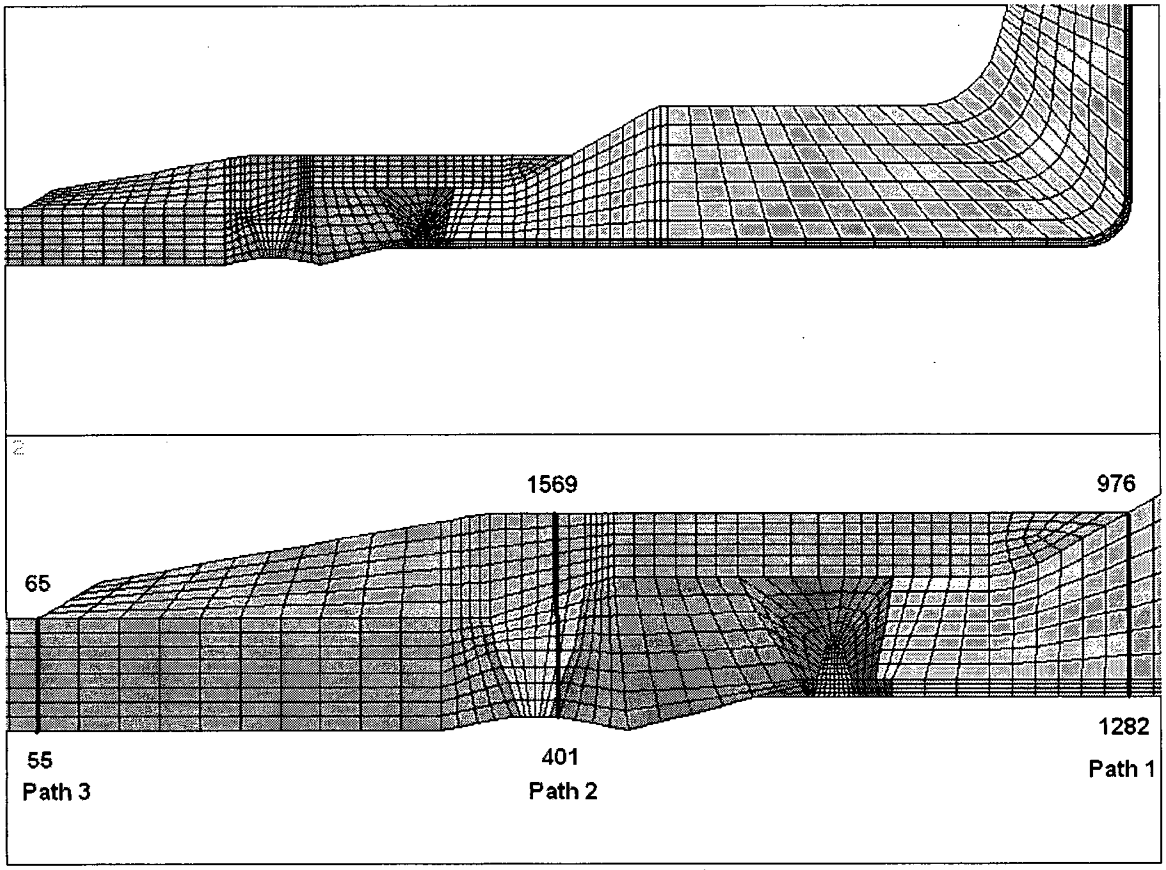


Figure 2-2: Typical Finite Element Model for Section III Stress Evaluation showing Stress Paths

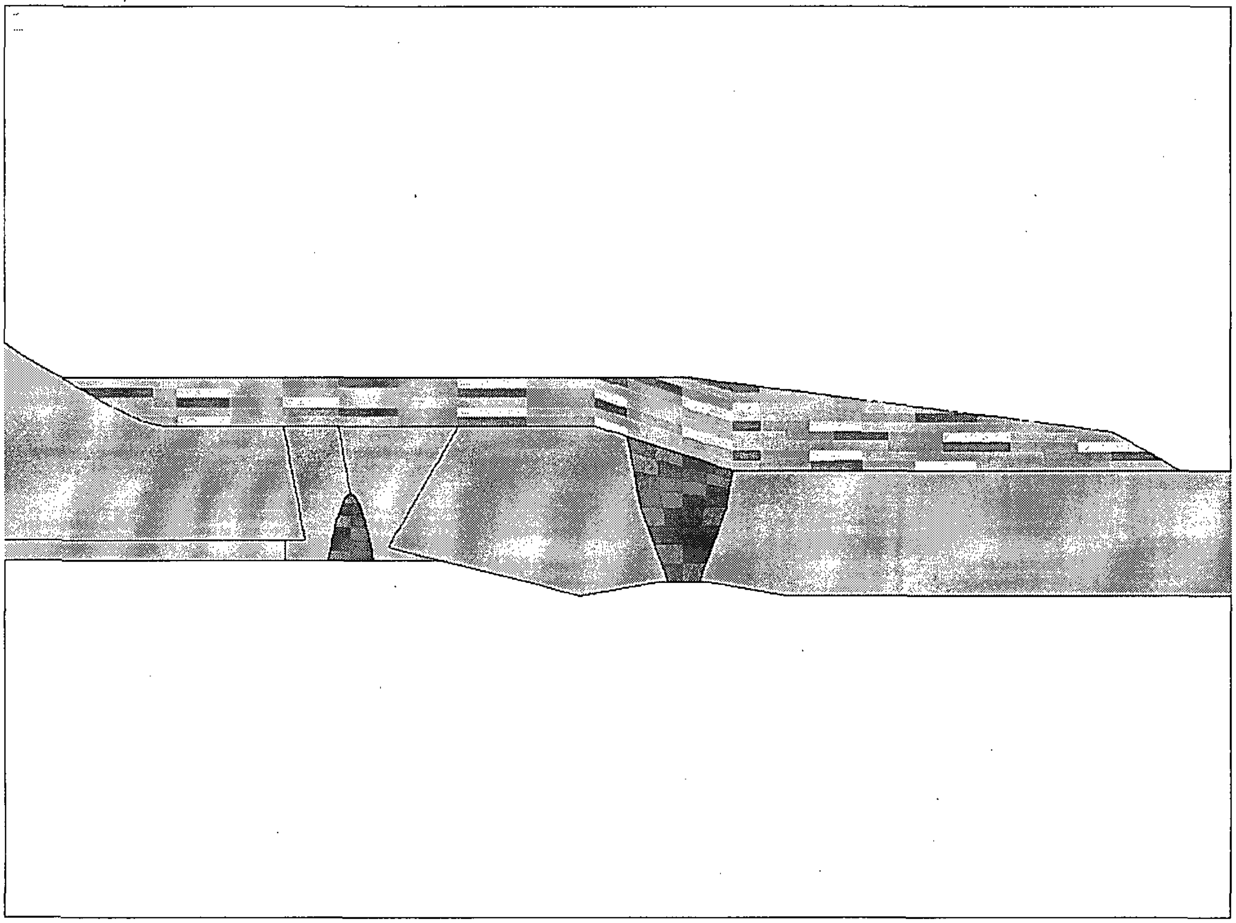


Figure 2-3: Typical Finite Element Model for Residual Stress Analysis showing Nuggets used for Welding Simulations

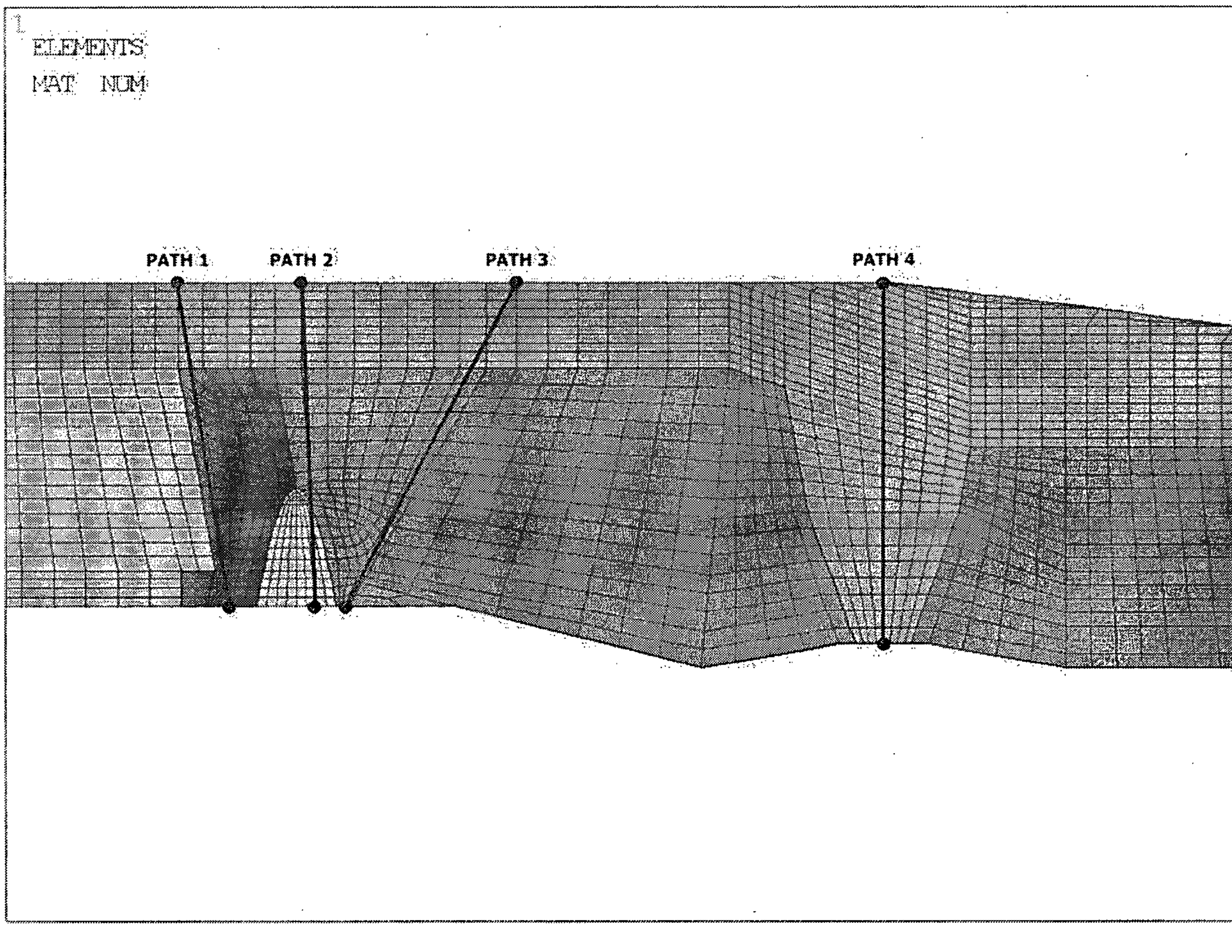
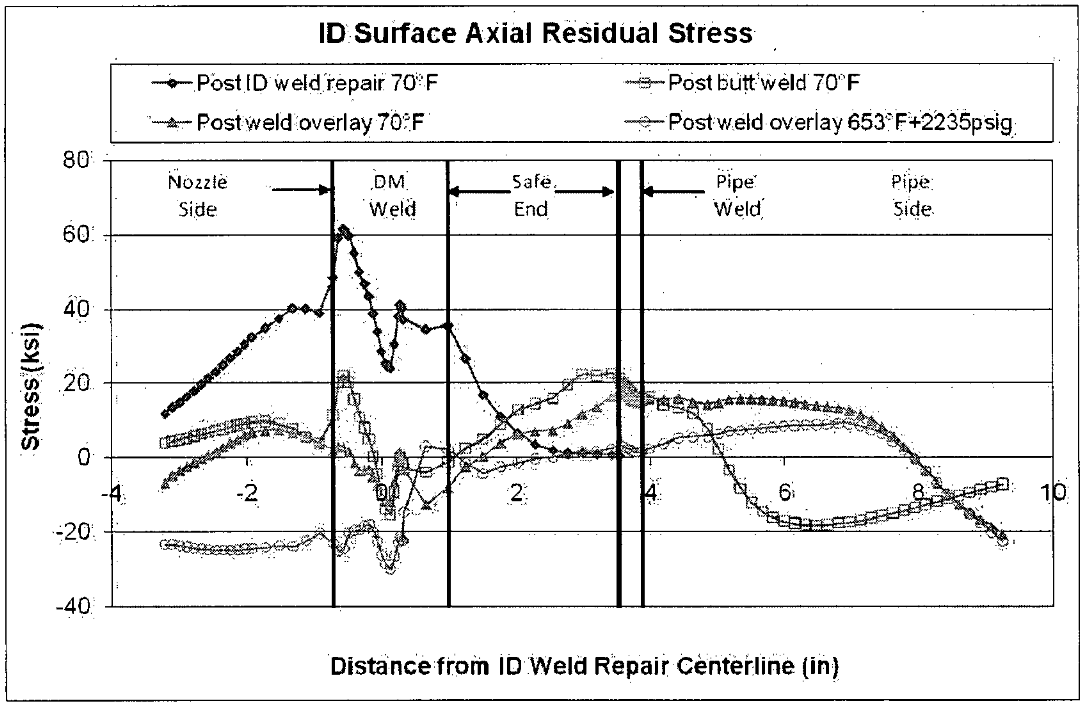


Figure 2-4: Typical Finite Element Model for Residual Stress Analysis showing Stress Paths



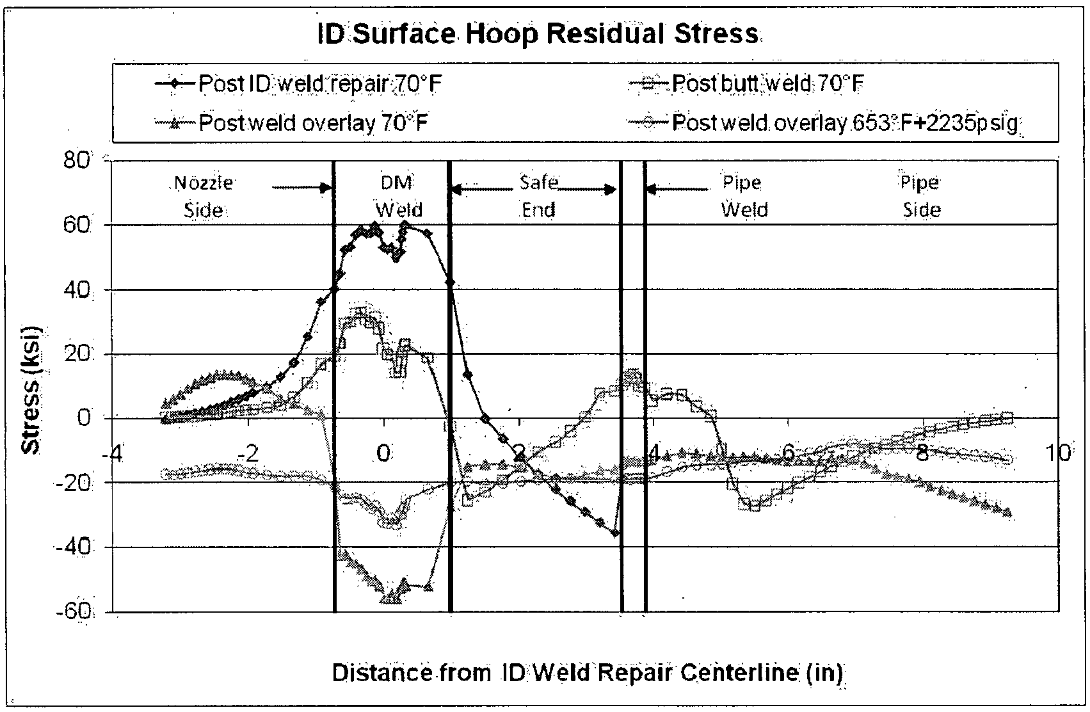


Figure 2-5: Residual Stress Results along Inside Surface of Original Butt Welds and Safe-End (Results Shown are for the Pressurizer Surge Nozzle and are Typical for the Other Nozzles)

3.0 Conclusions

The design of the Virgil C. Summer Nuclear Station weld overlays was performed in accordance with the requirements of the Relief Request [2], which is based on ASME Code Case N-740 [3]. The weld overlays are demonstrated to provide long-term mitigation of PWSCC in these welds based on the following:

- In accordance with the Relief Request [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. Therefore, no PWSCC crack growth is expected into the overlay.
- 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. In certain limited cases, where PWSCC may be present, 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.

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 Virgil C. Summer Nuclear Station pressurizer surge, pressurizer spray, and pressurizer safety/relief valve nozzle dissimilar metal welds have received long term 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. Request to Use Alternatives to ASME Code Section XI Requirements for Application of Weld Overlay Repairs (RR-III-05), Virgil C. Summer Nuclear Station, Docket No. 50/395, Operating License No. NPF-12, ADAMS Accession #ML071550420.
3. ASME Boiler and Pressure Vessel Code, Code Case N-740, "Dissimilar Metal Weld Overlay for Repair of Class 1, 2, and 3 Items, Section XI, Division 1."
4. ASME Boiler and Pressure Vessel Code, Section XI, 1998 Edition through 2000 Addenda.
5. ASME Boiler and Pressure Vessel Code, Section III, 2001 Edition through 2003 Addenda.
6. **pc-CRACK** for Windows, Version 3.1-98348, Structural Integrity Associates, 1998.
7. ANSYS/Mechanical, Release 8.1 (w/Service Pack 1), ANSYS Inc., June 2004.
8. "Materials Reliability Program (MRP): Technical Basis 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.