JAFP-08-0131

James A. Fitzpatrick Nuclear Power Station
Docket No. 50-333

Enclosure 3

Structural Integrity Associates Calculation 0800769.316
Reconciliation of Recirculation Inlet N2 Nozzle-to-Safe End
Weld Overlay Repair with Nozzle Stress Report

Structural Integrity Associates, Inc. **CALCULATION PACKAGE**	**File No.: 0800769.316** **Project No.: 0800769** Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Fitzpatrick RO18 Weld Overlay Preparation

CONTRACT NO.:
10202970

CLIENT:	**PLANT:**
Entergy Nuclear Operations, Inc.	J.A. Fitzpatrick

CALCULATION TITLE:
Reconciliation of Recirculation Inlet N2 Nozzle-to-Safe End Weld Overlay Repair with Nozzle Stress Report

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 18 A-1 - A-2 Computer Files	Initial Issue	Terry J. Herrmann [TJH] 12/03/08	Trevor Krugman [TCK] 12/03/08 Tyler Novotny [TDN] 12/03/08 Terry J. Herrmann [TJH] 12/03/08 Jennifer Smith [JES] 12/03/08 Hal Gustin [HLG] 12/03/08

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1.0 OBJECTIVE

The objective of this calculation is to reconcile the effects of the weld overlay repair of nozzle N2 at the J.A. Fitzpatrick Nuclear Power Generating Station to the nozzle's Section III Stress Report [1]. This nozzle Stress Report addresses stresses in the nozzle, nozzle-to-safe end weld, and safe end. The basis for the design of the overlay is documented in Reference [2]. It was designed to the requirements of ASME Code Case N-504-3 [3] and ASME Code Case N-638-1 [4].

This calculation will evaluate the N2 recirculation inlet nozzle with and without the weld overlay repair under operating conditions using finite element analysis. It will also address item (f)(1) of Code Case N-504-3, which requires that the overlay be sized so that it is able to provide for load redistribution from the pipe into the deposited weld metal and back into the pipe without violating applicable stress limits of ASME Section III for primary local and bending stresses and secondary peak stresses.

2.0 TECHNICAL APPROACH

A two-dimensional, axisymmetric finite element model of the N2 nozzle was constructed using the ANSYS software package [5] in a previous calculation [6]. The model included a portion of the reactor vessel, the recirculation inlet nozzle, the inlet nozzle and reactor vessel cladding, and the safe end. The nozzle-to-safe end weld and butter were also modeled in detail, as was the final weld overlay repair. In addition, a three-dimensional finite element model was developed in the present calculation from the existing axisymmetric model for use in the evaluation of non-axisymmetric piping loads.

Multiple analyses consistent with the nozzle Stress Report [1] were performed with and without the applied weld overlay. The sudden start transient was used for the thermal transient analyses, since this transient provides the bounding stresses and fatigue usage as documented in Reference [1]. Internal pressure and piping loads were used for the static structural analyses. The resulting stresses were compared to Section III Code allowable stresses to reconcile the repair with Reference [1] stress results and calculated fatigue usage.

3.0 DESIGN INPUTS

An axisymmetric finite element model of the N2 nozzle and weld overlay repair was previously developed in Reference [6]. The resulting finite element model is represented by Figure 1. Reference [6] also provides the temperature dependent material property values for the various component of the nozzle, safe end, welds and weld overlay repair. Bilinear kinematic hardening material behavior properties were also included in Reference [6] but were excluded from the evaluations in this calculation package since only elastic analyses are required. Finally, the same boundary conditions previously

identified in Reference [6] are also used for all subsequent evaluations in this calculation package (see Figure 2 for the applied boundary conditions).

Weld residual stresses resulting from the original welding of the various components, the postulated weld repair to the nozzle-to-safe end weld, and the final weld overlay were ignored since they are not included in ASME Section III stress evaluations.

The thermal transients and operating pressure loads are provided in Reference [7] while the various piping loads are provided in Reference [8]. Additional details for each of these evaluations are included in the following sections.

4.0 CALCULATIONS

A series of thermal and structural stress analyses were performed to determine the effect of the weld overlay repair on the N2 nozzle. The basic finite element model geometry is developed using the input file previously developed in Reference [6]. The files RIN.INP and RIN_noWOL.INP construct the basic geometry for overlay and base analyses. The file RIN_noWOL.INP was created from RIN.INP by deleting the modeled weld overlay.

Additional details are provided in the following sections.

4.1 Pressure Analysis

A system design pressure of 1250 psi [Ref. 1, Sec. 2.1] was applied to the vessel region of the nozzle/thermal sleeve; while a recirculation system design pressure of 1423 psi [Ref. 1, Sec. 2.1] was applied to inside surfaces of the nozzle and safe end up to the location of the thermal sleeve connection to the nozzle. The dimensions used are based on Reference [6].

In addition, a cap pressure was applied to the free end of the safe end (see Figure 3). The pressure for the cap load was calculated as:

- Safe End Free End (model dimensions at end used)

$$P_{cap_pipe} = \frac{P \cdot r_{inside}^2}{\left(r_{outside}^2 - r_{inside}^2\right)} = \frac{1423 \cdot 5.71875^2}{\left(6.46875^2 - 5.71875^2\right)} = 5{,}091.33 \text{ psi}$$

The input file for the base case analysis is RIN_PRES_NO.INP and for the overlay analysis is RIN_PRES_W.INP. Both files are included in the project computer files.

4.2 Sudden Start Thermal Transient Analysis

The sudden start thermal transient analysis consists of two separate analyses. The first determines the thermal temperature time history and is termed the thermal analysis. The second analysis maps the resulting time-dependent temperature data to the structural model to determine the stresses. This analysis is termed the stress analysis.

The sudden start transient consists of a step change from 527°F to 130°F inlet water temperature for 34 seconds followed by instantaneous recovery to 527°F while RPV temperature remains at 527°F (Reference [7], Figure 5-6). Film coefficients for this transient were obtained from Reference [7], Table 6-2. Since this is to be a comparative analysis where resulting stresses will not be specifically used, the thermal sleeve and annulus heat transfer effects were not modeled and an equivalent film coefficient was applied to the nozzle surfaces where the annulus would be. The external surfaces are assumed to be perfectly insulated (approximated using a value of 0.2 Btu/hr-ft^2-°F with a constant ambient temperature of 100°F). The free edges at the ends of the safe end and vessel are assumed to be completely insulated. See Figure 4 for an example of the applied film surfaces.

The input files for the base analysis are RIN_SudSt_PreWOL_T.INP and RIN_SudSt_PreWOL_S.INP for the thermal and stress analyses, respectively. The output files for the overlay analyses are RIN_SudSt_PostWOL_T.INP and RIN_SudSt_PostWOL_S.INP. These files are included in the project computer files.

4.3 Unit Piping Loads

The axisymmetric finite element model developed in Reference [6] was converted into a 3-dimensional finite element model in order to evaluate non-axisymmetric axial and moment end loads resulting from the attached piping. The finite element model was constructed by rotating the original axisymmetric model about its center axis using the SOLID45 elements. The finite element model is shown in Figure 5.

Two evaluations were performed for both the base case model, defined as the nozzle prior to weld overlay, and overlay repaired model. The first was a 15,000 lb axial load (7,500 lbs for the 180° model) applied to the free end of the recirculation piping. The second was a 250,000 in-lb moment (125,000 in-lb applied to the 180° model) which was applied to the free end of the recirculation piping. These unit loads were selected to be high enough to establish a comparison between pre-WOL and post-WOL conditions and have the stress remain within the linear elastic regime (i.e., below yield). The loads were applied via a series of nodal loads applied to the mid-wall of the nozzle around its circumference. See Figure 6 for an example of the applied loads and boundary conditions.

The input file for the base analysis is RIN_PL_N.INP and for the overlay analysis is RIN_PL_W.INP. Both files are included in the project computer files.

5.0 RESULTS OF ANALYSIS

A series of through-wall linearized stress paths were extracted from the various evaluations. The locations of the paths are shown in Figure 7 and are based on areas of interest where there is a concern for effect from the weld such as the dissimilar metal weld interface and geometric stress concentrations from the weld. For the three-dimensional models used for the piping loads, the paths are located at top dead center, 90 degrees off of top, and bottom dead center of the nozzle. The resulting stress intensities are shown in Table 1.

5.1 ASME Section III Reconciliation

The results from the ASME Code Evaluation Stress Report [1] for the nozzle/safe end/piping configuration are summarized in the table on pages 16 and A-643 of Reference [1]. The table includes results for primary membrane (P_m), local primary membrane-plus-bending ($P_L + P_b$), primary-plus-secondary stresses ($P_L + P_b + Q$) and fatigue usage factors for the controlling locations on the Ni-Cr-Fe Weld and the Type 304 Safe End. Although the exact location of the nozzle end and safe end in Reference [1] are not known (they are represented on page A-593 of Reference [1]), Path 1 was taken to correspond to the nozzle end and Path 3 to the safe end. Path 4 provides the stresses at the interface between the weld overlay end and the safe end, which was not previously analyzed. The impact on each of these results is discussed in detail in the following sections.

5.1.1 Primary Membrane Stress Intensity

The Stress Report [1] indicates that the maximum resulting primary membrane stress intensity is 12.7 ksi and 11.2 ksi for Design loads for the nozzle end and safe end, respectively. The corresponding Code allowable stress intensity values are 26.7 ksi and 15.8 ksi for Design [1]. Examination of results shown in Table 1 for the load cases that contribute to primary membrane (i.e., piping loads and pressure) indicate that for all the evaluated paths, the addition of the weld overlay produced a ratio less than or equal to 1.00. Therefore, the results are bounded by the original Stress Report [1] which demonstrated Code compliance for Paths 1 and 3. The maximum primary stress intensity at Path 4 is 11.3 ksi. This was obtained by scaling for the unit piping loads of 8,200 lbs axial (4,100 lbs for the 180° model) and 616,252 in-lb moment loads (308,126 in-lb for the 180° model) from Reference [2]. 616,252 in-lbs is obtained by taking the sum of the square root of the sum of the squares for each of the bending moment components given in Section 2 of Reference [2] (DW, OBE and Shear). 11.3 ksi is below the allowable stress intensity value of 15.8 ksi reported in Reference [1].

5.1.2 Local Primary Membrane-Plus-Bending Stress Intensity

The Stress Report [1] indicates that the maximum resulting local primary membrane-plus-bending stress intensity is 12.7 ksi and 11.2 ksi for Design loads for the nozzle end and safe end, respectively. The

corresponding Code allowable values listed in the Stress Report [1] are 40.0 ksi and 23.7 ksi for Design for the nozzle end and safe end, respectively. Examination of results shown in Table 1 for the load cases that contribute to local primary membrane-plus-bending (i.e., piping loads and pressure) indicate that for all Paths 1 through 3, the addition of the weld overlay reduced the resulting local primary membrane-plus-bending stress intensity. Therefore, the results are bounded by the original Stress Report [1] which demonstrated Code compliance for Paths 1 and 3. Path 4 has a maximum stress intensity of 8.94 ksi (after scaling for unit piping loads), which remains below the allowable value of 23.7 ksi.

5.1.3 Primary-Plus-Secondary Stress Intensity Range

The Stress Report [1] indicates that the maximum resulting primary-plus-secondary stress intensity range (P_L+P_b+Q) is 38.5 ksi and 34.6 ksi for Normal Loads, for the nozzle end and safe end, respectively. The corresponding Code allowable values are 80.1 ksi and 47.4 ksi. Examination of results shown in Table 1 for the load cases that contribute to primary-plus-secondary stress intensity range (i.e., deadweight, seismic piping loads, pressure and thermal) indicate that Path 3 has higher secondary stress intensity ranges resulting from thermal loading following the application of the weld overlay repair, but overall (P_L+P_b+Q) stresses are lower. Path 1 exhibits lower thermal membrane-plus-bending stress intensities.

For Path 1, section 5.1.2 indicates that the local primary membrane plus bending stress intensity is also lower with the weld overlay. Therefore, as observed in Table 1, the combined (P_L+P_b+Q) stress intensity is lower for Path 1 and the results shown in the Stress Report [1] remain bounding for the overlaid nozzle.

For Path 3, the largest resulting secondary stress intensity ratio of pre-overlay to post overlay stress intensity for thermal loading is 1.02 for the Sudden Start transient, which is essentially unchanged and within the accuracy of the analysis. In addition, as shown in Table 1, the combined (P_L+P_b+Q) stress intensity is lower for Path 3 and the results shown in the Stress Report [1] remain bounding for the overlaid nozzle.

For Path 4, the largest combined (P_L+P_b+Q) stress intensity value is 28.47 ksi, which is below the allowable value of 47.4 ksi.

5.1.4 Fatigue Evaluation

Only the Sudden Start transient was evaluated, since this was the only transient that resulted in usage in the locations being evaluated as shown on page A-643 of Reference [1].

The above sections show a decrease in the stress intensity ranges at the nozzle end location (Path 1). Therefore, fatigue usage is unchanged at this location.

Section 5.1.3 indicates that Path 3 resulted in lower combined stress intensities (P_L+P_b+Q) as a result of the weld overlay. Since the primary stresses and secondary stress intensities are lower, the overlay does not result in a change to fatigue usage at the limiting safe end location evaluated.

Path 4 passes through the toe of the weld overlay repair (a location that was not previously evaluated for fatigue). Due to the presence of a structural discontinuity (the weld overlay to safe end weld transition), fatigue is evaluated at this location. The stress value was scaled by multiplying the FEA result by the ratio of the unit piping load and the original piping loads from section 2 of reference [2]. A fatigue strength reduction factor was not applied per NB-3300 [9], because the detailed ANSYS model adequately represents the stress concentration effects. The maximum peak stress at this location is 23.25 ksi, which when added to the (P_L+P_b+Q) value of 28.47 ksi gives a peak stress range of 51.72 ksi. This value gives an alternating stress of 25.86 ksi, which is lower than 30.2 ksi as shown on page A-643 of Reference [1]. Therefore, the limiting fatigue location in the safe end region is unchanged.

5.2 Evaluation of Code Case N-504-3 Stress Requirements

Code Case N-504-3, Item (f)(1) indicates that the axial length and end slope of the weld reinforcement must be sufficient to provide for load redistribution from the pipe into the deposited weld metal and back into the pipe without violating applicable stress limits of Section III for local primary and bending stresses and secondary peak stresses.

The primary shear allowable, per Section III, Subparagraph NB-3227.2, is $0.6S_m$ or 0.6*15.8 ksi = 9.48 ksi. The maximum primary shear stress from ANSYS is one half the maximum stress intensity of 12.81 ksi. One half of 12.81 ksi is 6.41 ksi, which is below the primary shear stress allowable.

The values provided above are contained in the file RIN_SudSt_PostWOL-p5.csv.

6.0 CONCLUSIONS AND DISCUSSIONS

An evaluation has been performed to reconcile the weld overlay repair of Recirculation Inlet Nozzle N2 on the original ASME Section III Code evaluation [1]. The evaluation considered primary and secondary stress intensities, fatigue usage and applicable Code Case N-504-3 requirements. This evaluation concludes that the impact of the overlay is minor and generally produces a more favorable stress condition. In those cases where stresses were less favorable, it was determined that the revised stresses are still within Code allowables and fatigue usage is not significant for the balance of plant life. Therefore, the original Stress Report [1] which demonstrated Code compliance remains valid for the nozzle with weld overlay repair.

7.0 REFERENCES

1. Combustion Engineering, Inc., Report No. CENC-1159, "Analytical Report for PASNY Reactor Vessel for Fitzpatrick Station", August 1971, SI File No. 0800769.210.

2. Structural Integrity Calculation 0800769.302, Rev. 3, "Contingency Dissimilar Metal Weld Overlay Design for Recirculation Inlet Nozzle for Fitzpatrick."

3. ASME Section XI Code Case N-504-3, "Alternative Rules for Repair of Classes 1, 2, and 3 Austenitic Stainless Steel Piping, Section XI, Division 1," Approved August 4, 2004.

4. ASME Boiler and Pressure Vessel Code, Code Case N-638-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, Section XI, Division 1," Approved February 13, 2003.

5. ANSYS, Release 8.1 (w/Service Pack 1), ANSYS Inc., June 2004.

6. Structural Integrity Calculation 0800769.307, Rev. 2, "Residual Stress Analysis of Recirculation Inlet Nozzle with and without Weld Overlay Repair."

7. Structural Integrity Calculation 0800769.301, Rev. 0, "Design Input for RPV Recirculation Inlet & Outlet Nozzle Finite Element Analyses and Flaw Evaluation Readiness."

8. General Electric APED Specification 22A2622, Revision 1, "Design Report - Recirculation System", December 6, 1976, SI File No. 0800769.211.

Table 1: Linearized Stress Intensity Results

Stress Type	Stress Intensity (psi)											
	Path 1			Path 2			Path 3			Path 4		
	Overlay			Overlay			Overlay			Overlay		
	With	Without	Ratio	With	Without	Ratio	With	Without	Ratio	With	Scaled	Peak
Piping Load-Axial (7500 lbs)												
P_M	256.7	309.2	0.83	277	329.9	0.84	281.2	336.8	0.83	326.5	178.5	Peak
P_L+P_B (Outside) [1]	187.8	285.3	0.66	208.8	306.9	0.68	212.5	307	0.69	257.7	140.9	78.7
Piping Load-Moment (125000 in-lbs)												
Pm	1412	1747	0.81	1519	1861	0.82	1552	1912	0.81	1875	4622	Peak
P_L+P_B (Outside) [1]	1163	1758	0.66	1275	1882	0.68	1297	1892	0.69	1598	3939	92.6
Pressure Load (1423 psi)												
Pm	5451	7427	0.73	5646	7719	0.73	5442	7103	0.77	6520	6520	Peak
P_L+P_B (Outside)[1]	4036	6322	0.64	4038	6516	0.62	3983	5781	0.69	4856	4856	459
Pressure + Piping (Moment + Axial)												
Pm	7120	9483.2	0.75	7442	9909.9	0.75	7275.2	9351.8	0.78	8721.5	11320	Peak
P_L+P_B (Outside)[1]	5387	8365.3	0.64	5522	8704.9	0.63	5492.5	7980	0.69	6711.7	8936	630.3
Sudden Start Thermal Load (Maximums)												
Q (Outside) [1]	8779	13240	0.66	10680	12250	0.87	20260	19800	1.02	19530	19530	22620
Primary Local Membrane + Bending Plus Secondary Membrane + Bending (Maximums)												
P_L+P_B+Q (Outside) [1]	14166	21605.3	0.66	16202	20954.9	0.77	25753	27780	0.93	26242	28466	23250

[1] Outside indicates outside surface, shown as (O) in Figure 7.

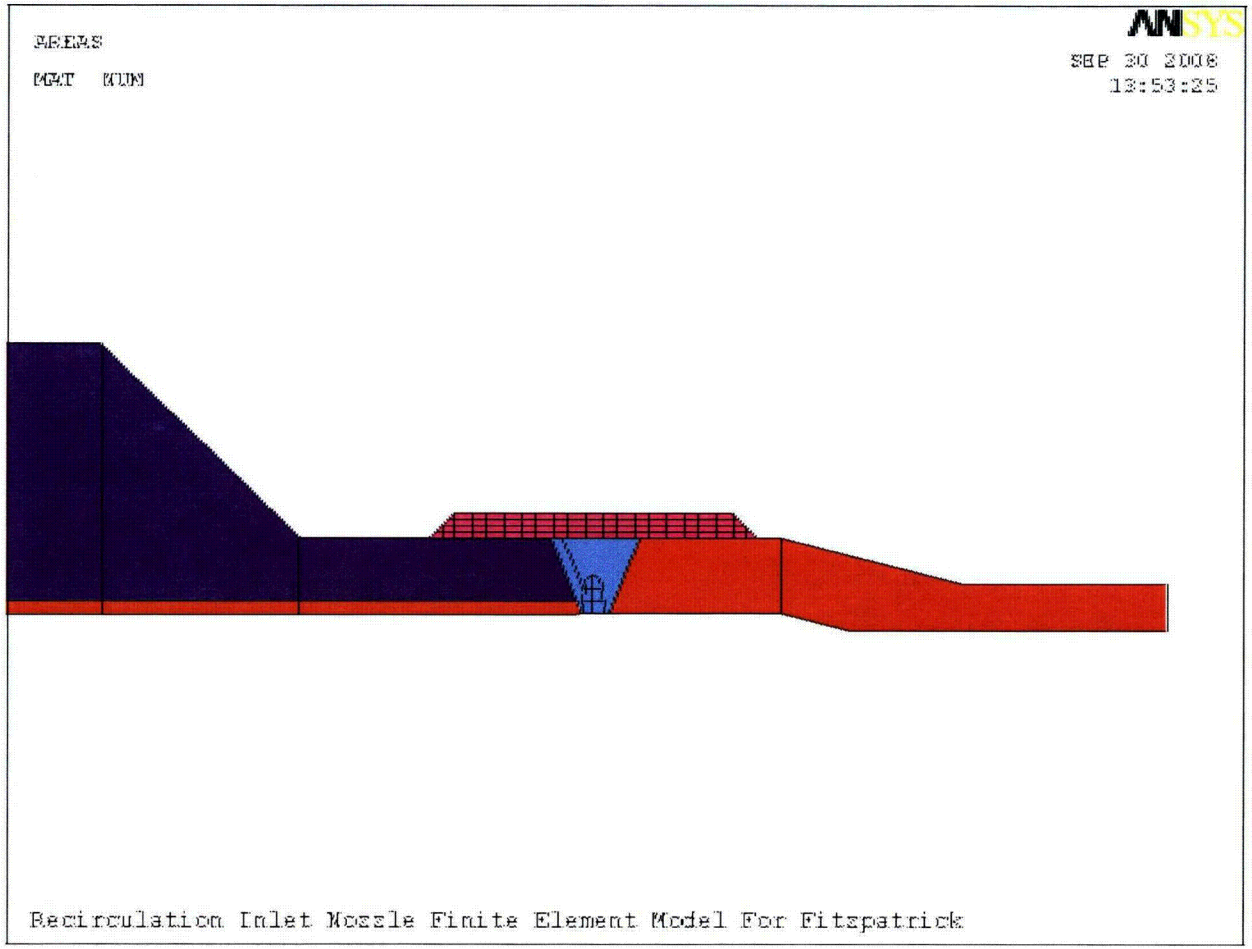

Figure 1: Post-WOL As-Modeled N2 Finite Element Model [6].

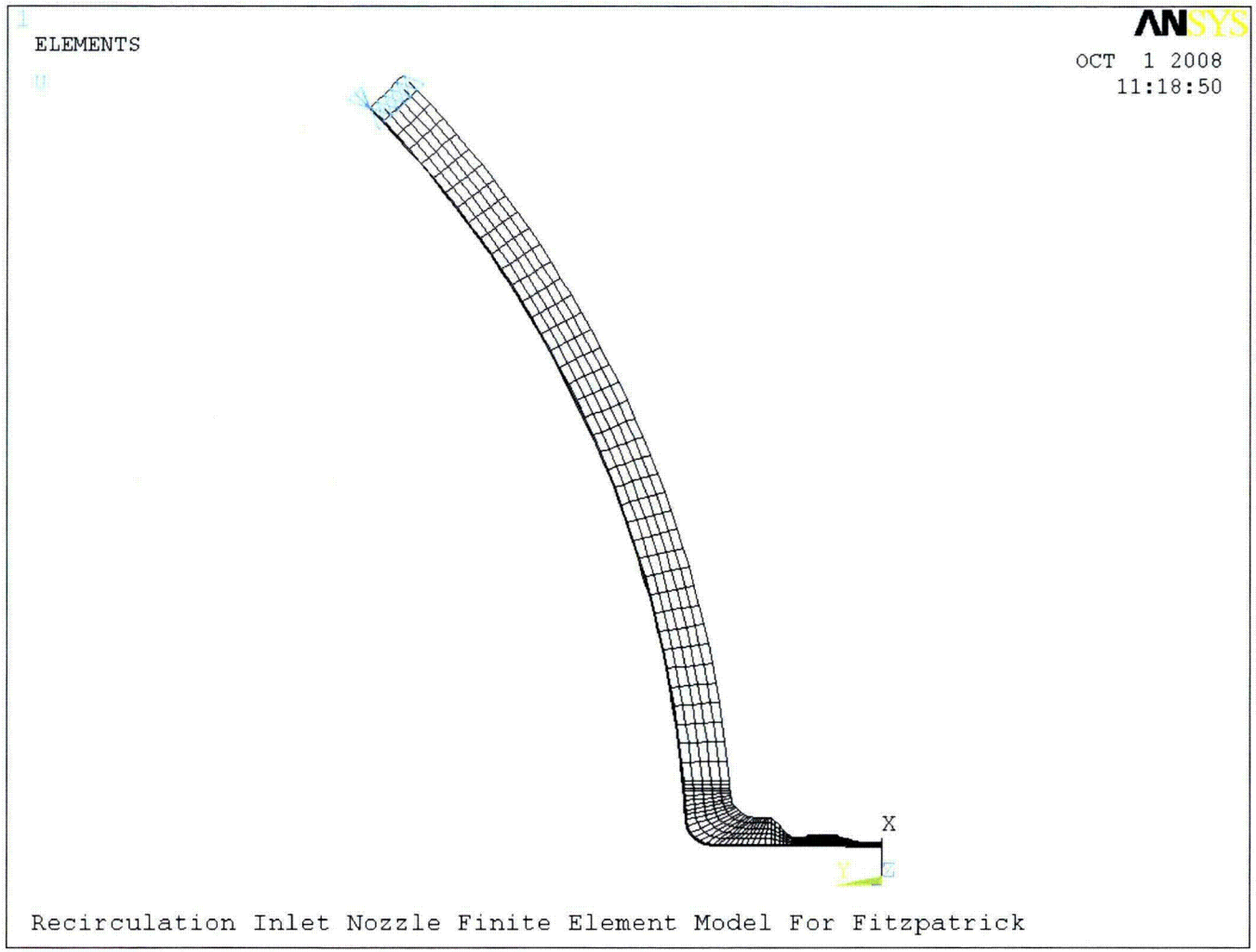

Figure 2: Boundary Conditions [6].

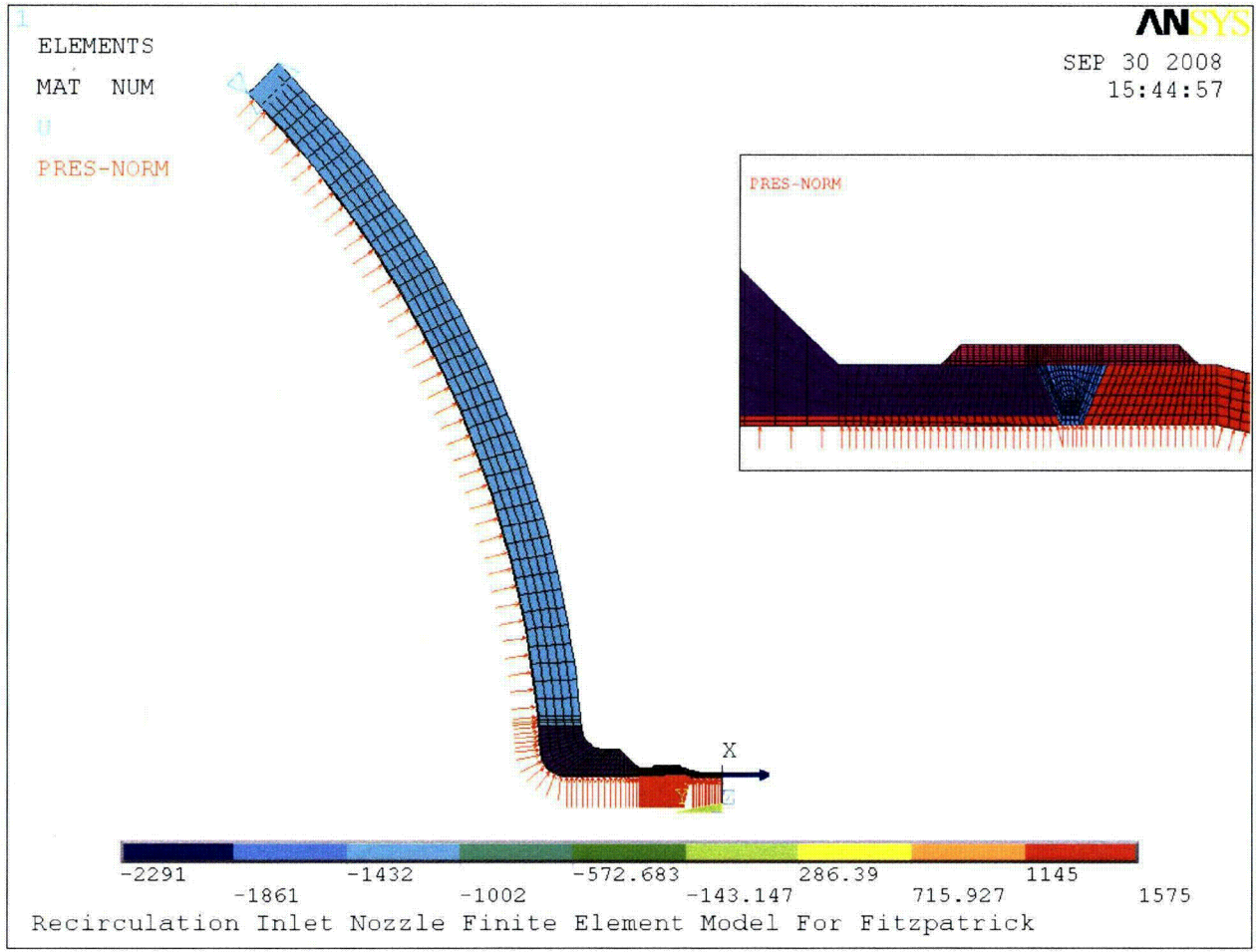

Figure 3: Pressure Loading Example (Overlay Case).

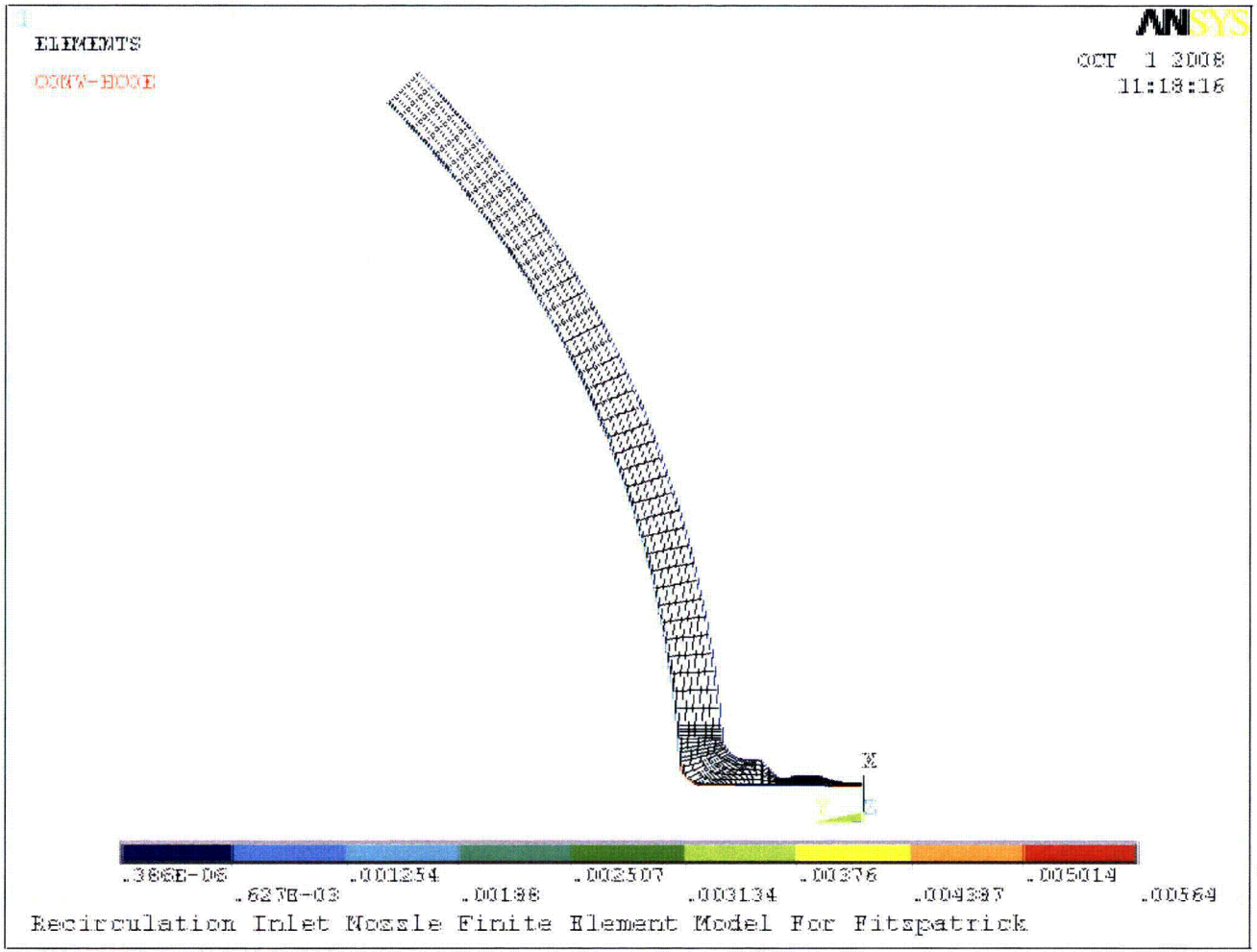

Figure 4: Thermal Transient Film Coefficient Example (Overlay Case).

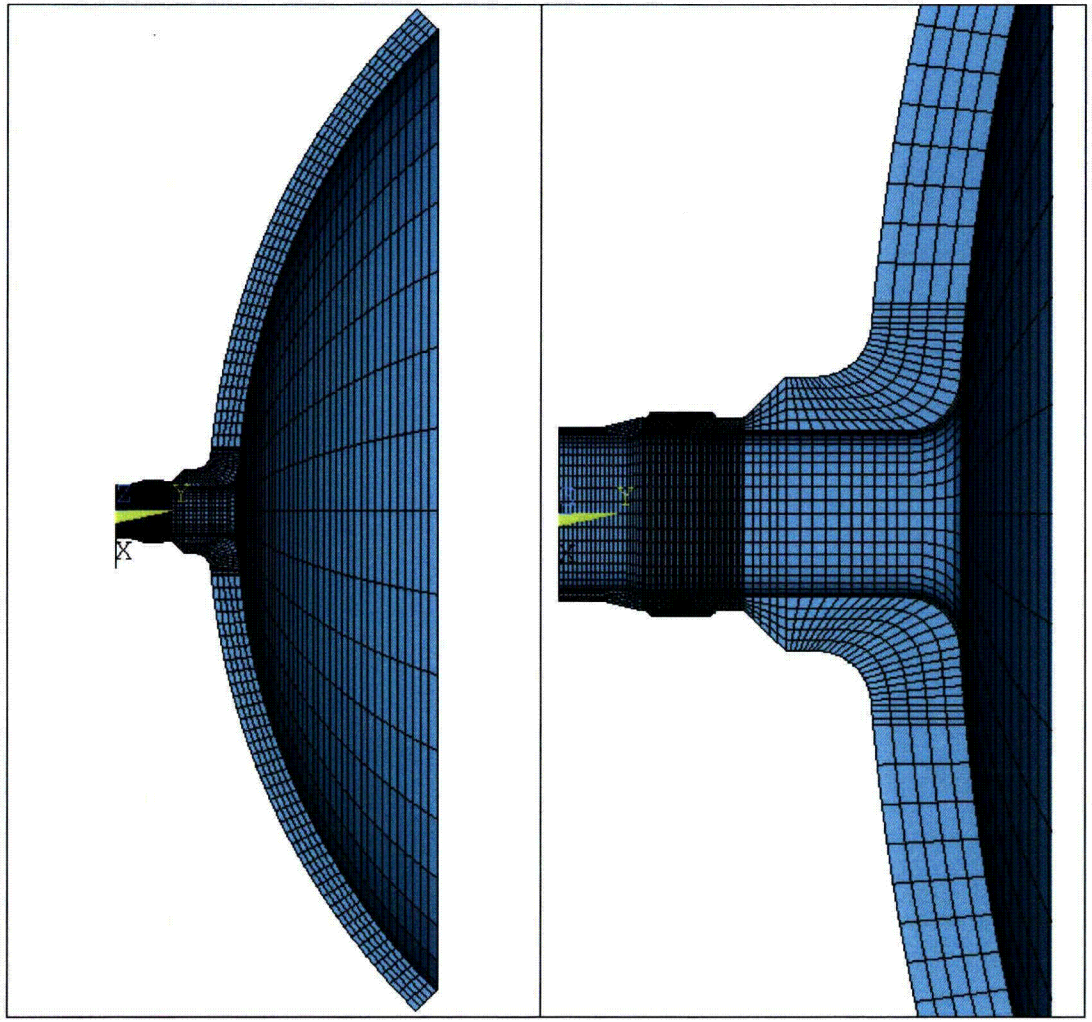

Figure 5: Finite Element Model for Piping Load Evalautions.

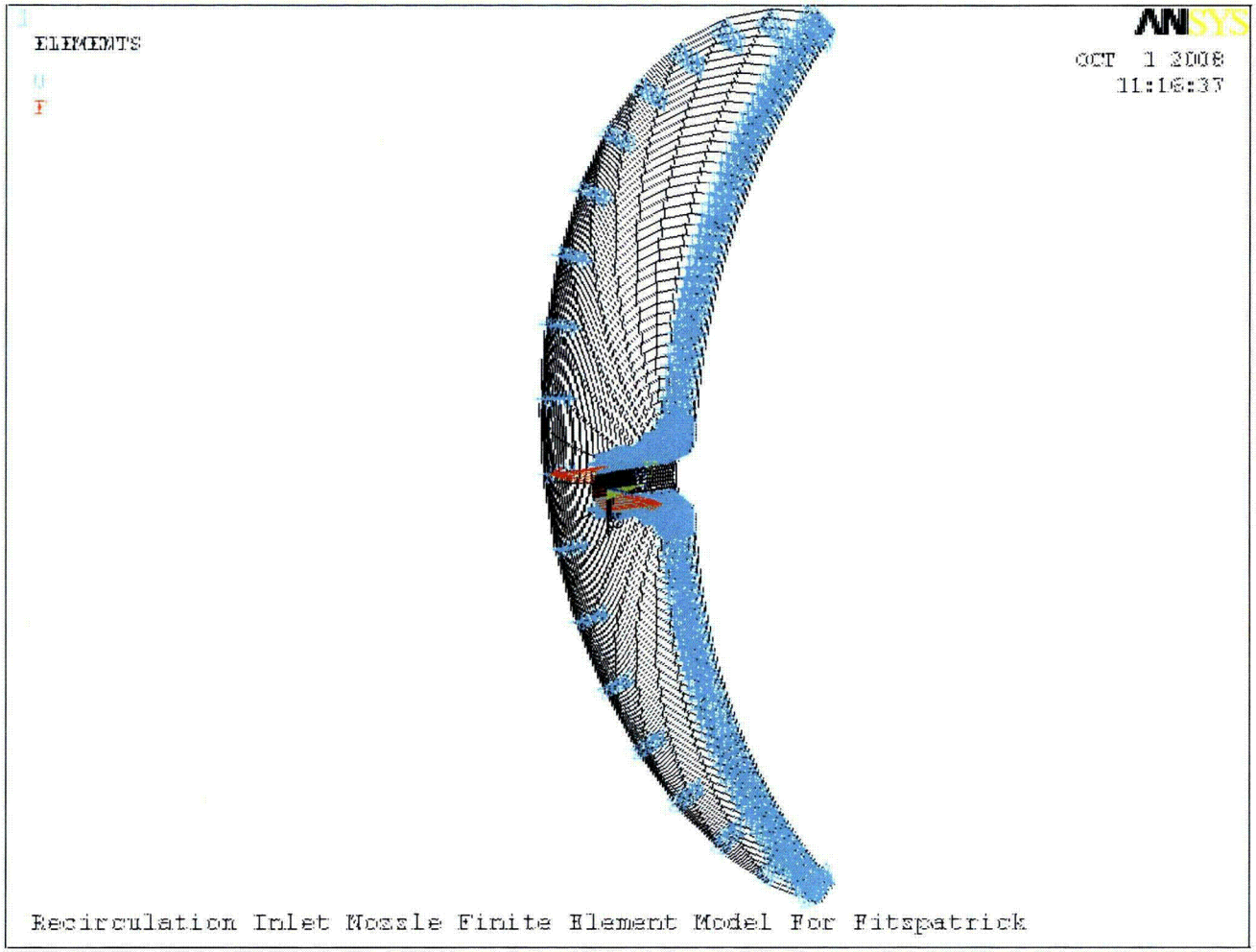

Figure 6: Applied Piping Load Example (w/Boundary Conditions).

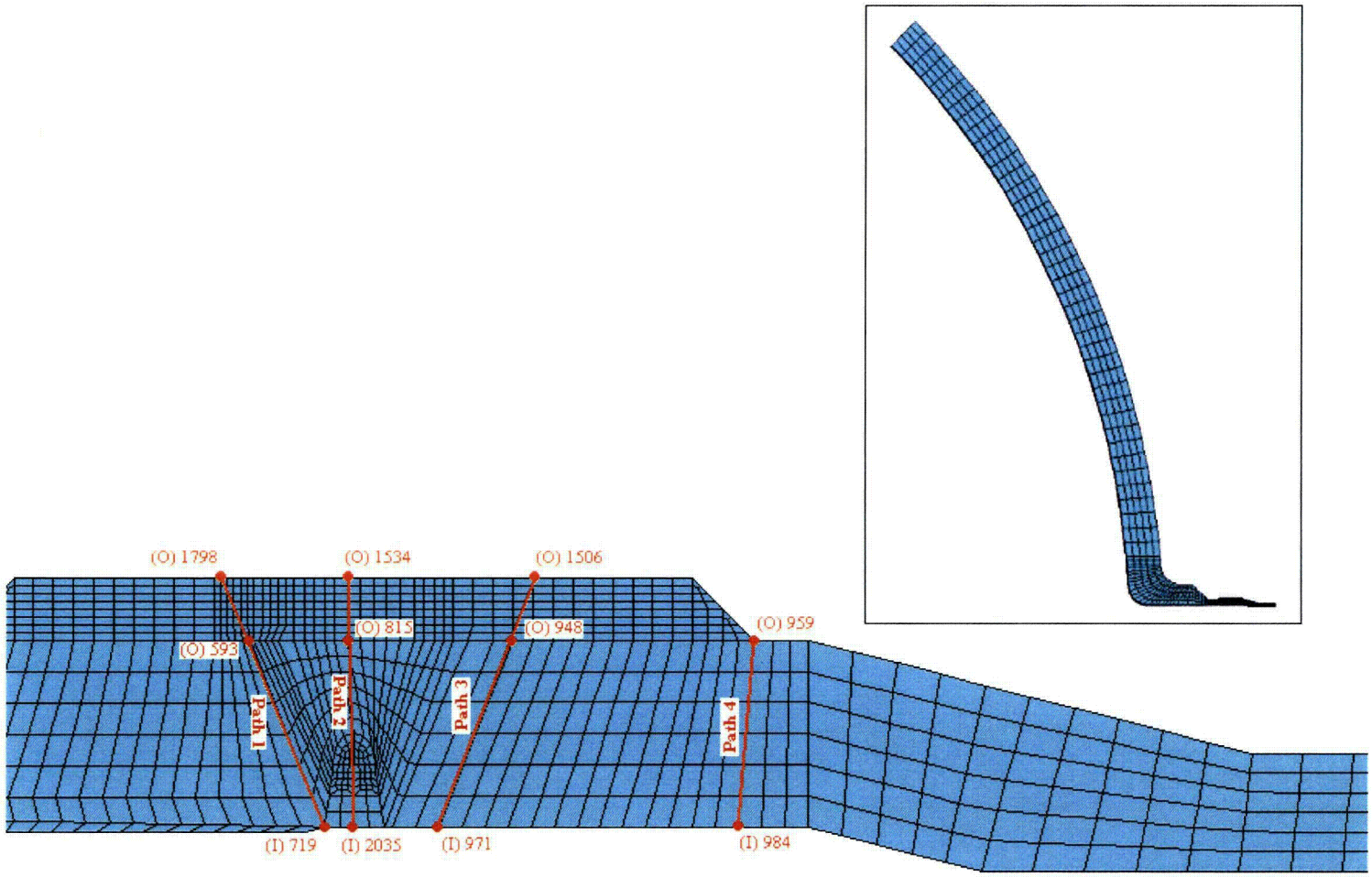

Figure 7: Linearized Stress Path.

Appendix A

ANSYS INPUT FILES

File Name	Description
RIN_noWOL.INP	Input File: Pre-WOL Geometry File
RIN.INP	Reference [6] Input File: Post-WOL Geometry File
RIN_PRES_NO.INP	Pressure Stress Analysis (without Overlay)
RIN_PRES_W.INP	Pressure Stress Analysis (with Overlay)
RIN_PL_N.INP	Unit Piping Loads Stress Analyses (without Overlay)
RIN_PL_W.INP	Unit Piping Loads Stress Analyses (with Overlay)
RIN_SudSt_PreWOL_T.INP	Sudden Start Thermal Transient – Thermal Analysis (without Overlay)
RIN_SudSt_PreWOL_S.INP	Sudden Start Thermal Transient – Stress Analysis (without Overlay)
RIN_SudSt_PostWOL_T.INP	Sudden Start Thermal Transient – Thermal Analysis (with Overlay)
RIN_SudSt_PostWOL_S.INP	Sudden Start Thermal Transient – Stress Analysis (with Overlay)

JAFP-08-0131

James A. Fitzpatrick Nuclear Power Station
Docket No. 50-333

Enclosure 4

Structural Integrity Associates Calculation 0800769.317
"C" Recirculation Riser N-2C-SE Weld Overlay Shrinkage Evaluation

Structural Integrity Associates, Inc. **CALCULATION PACKAGE**	**File No.: 0800769.317** **Project No.: 0800769** Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Fitzpatrick RO18 Weld Overlay Preparation

CONTRACT NO.:
10202970

CLIENT:	**PLANT:**
Entergy Nuclear Operations, Inc.	J.A. Fitzpatrick

CALCULATION TITLE:
"C" Recirculation Riser N-2C-SE Weld Overlay Shrinkage Evaluation

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
1	1 - 7	Minor editorial changes	T. J. Herrmann [TJH] 12/04/08	H. L. Gustin [HLG] 12/04/08 T. J. Herrmann [TJH] 12/04/08

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1.0 OBJECTIVE

The objective of this calculation is to evaluate the impact of the weld overlay repair of weld N-2C-SE on other locations in the "C" recirculation riser at the J. A. Fitzpatrick Nuclear Power Plant. The shrinkage of the weld overlay on the nozzle to safe end weld produces bending on the riser piping which may produce an increased stress on the "C" recirculation riser piping. This calculation will evaluate the limiting stress on the "C" recirculation riser and demonstrate that the stress is acceptable.

2.0 TECHNICAL APPROACH

A calculation of the stress created by the N-2C-SE weld overlay repair on the "C" recirculation riser was performed. The vertical recirculation riser pipe was modeled as a cantilevered beam and the weld overlay shrinkage was modeled as an end deflection of the cantilevered beam. Therefore, with deflection represented by the shrinkage, the equations below were used (taken from References 1 and 2):

$$I = \frac{\pi}{4}\left(OR^4 - IR^4\right) \qquad f = \frac{Wl^3}{3EI} \qquad M = Wl \qquad \sigma = \frac{MC}{I}$$

Where:

I	= moment of inertia of the pipe
OR	=outside radius of the pipe
IR	= inside radius of the pipe
f	=deflection of the beam (pipe)
l	= vertical length of the beam (pipe)
E	=Young's Modulus at 550 degrees Fahrenheit
W	=applied load (concentrated load at the end of the pipe)
M	=bending moment
C	=distance from neutral axis (maximum value at outside radius used)
σ	=final calculated stress

The applied equivalent load W is calculated from the observed deflection. This calculated stress was then added to the primary deadload, pressure, and seismic stresses of the pipe. This resulting stress was then compared to allowable yield stresses in ASME Section II Part D [7, p 86-88].

3.0 ASSUMPTIONS/DESIGN INPUTS

3.1 Assumptions

The following assumptions were made during the calculation.

1. The plant design temperature was assumed to be 550 degrees Fahrenheit and temperature-dependant material properties were determined at this temperature.

2. The "C" recirculation riser pipe was modeled as a cantilever beam of uniform circular cross section under stress. The junction of the recirculation riser and recirculation header was assumed to be a fixed end. This is conservative because it will maximize the stress at that location as compared to including the compliance of the entire recirculation system.

3. The pipe length measurement used for the calculation is a length more representative of recirculation risers "A", "B", "D", "E", than the "C" recirculation riser (see Figure 1). The use of a longer pipe length provides a conservative estimate of the stress acting on the riser since it results in a larger applied moment.

4. The maximum stress due to the weld overlay shrinkage occurs at the tee-to-pipe weld at the recirculation header, where the moment arm is greatest.

3.2 Design Inputs

The dimensions and materials used in the calculations are as follows (taken from References 3, 4, 5 and 6):

Outside Diameter:	12.662 inches
Inside Diameter:	11.442 inches
Thickness:	0.61 inch
Length:	136.0625 inches
Material:	Safe end: SA-182, Type F304 [6, p. 7]
	Pipe: SA-240 Type 304 [3, sheet 6]
Weld Shrinkage/Deflection:	0.059 inch maximum [4]
Initial Primary Stress*:	9,148 psi

*The initial primary stress is the combined deadload, pressure, and seismic stresses on the "C" recirculation riser, taken from the recirculation system stress report [3, page 173].

This recirculation system loop (which includes the N-2C riser) has other previously applied weld overlays which contribute to the overall stress on the riser. This value has been calculated to be 1,631 psi at weld 12-26 (riser to cross weld). This will be added to the initial primary stress and the stress calculated in this report to assess that the total stress on the system is within accepted parameters [8, Table 4-1].

4.0 CALCULATIONS

The shrinkage stress on the recirculation riser was found by first calculating the moment of inertia of the pipe.

$$I = \frac{\pi}{4}\left(OR^4 - IR^4\right)$$
$$I = \frac{\pi}{4}\left((6.331)^4 - (5.721)^4\right)$$
$$I = 420.4150in^4$$

The resulting moment of inertia was used to calculate the applied load and the bending moment. Young's Modulus was linearly interpolated at 550 degrees Fahrenheit [6, p. 8].

$$f = \frac{Wl^3}{3EI}$$

$$0.059in = \frac{W(136.0625)^3}{3(25.6x10^6)(420.4150)}$$
$$W = 756.2686lb$$

$$M = Wl$$
$$M = (756.2686)(136.0625)$$
$$M = 102900in - lb$$

The results were used to calculate the stress as a result of the weld overlay shrinking.

$$\sigma = \frac{MC}{I}$$
$$\sigma = \frac{(102900)(6.331)}{420.4150}$$
$$\sigma = 1550psi$$

Then the stress caused by the weld shrinkage was added to the initial primary stress (9148 psi) and the stresses resulting from the previous weld overlays (1631 psi) performed on this recirculation system loop.

$$1550psi + 9148psi + 1631psi = 12329psi$$

To evaluate the effect of the shrinkage, the calculated shrinkage stress is combined with the maximum primary stress. The resulting total stress on the "C" recirculation riser was compared to the allowable stress intensity (Sm) for the piping material, which is 15,900 psi [3, sheet 30]. The resulting total stress, 12,329 psi, remains below the allowable stress intensity value, and therefore well below the material yield stress. Therefore, the shrinkage stress does not produce any plastic deformation and the system remains elastic. The ASME Code does not provide any allowable values or acceptance criteria for weld shrinkage stress.

5.0 CONCLUSION

The conservatively calculated maximum stress due to weld overlay shrinkage is approximately an order of magnitude lower than the primary stress intensity reported in [3] at the limiting location, and is considered negligible. Weld overlay shrinkage stress is a steady state secondary stress and is not limited by the Code. Furthermore, the displacement of the "C" riser due to weld overlay shrinkage is toward the reactor vessel. When the vessel expands upon heat-up, any stress due to weld overlay shrinkage will tend to self relieve.

6.0 REFERENCES

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2. Young, W. C., "Roark's Formulas for Stress and Strain," 6th Edition, McGraw-Hill Book Company, 1989, p. 67.

3. General Electric APED Specification 22A2622, Revision 1, "Design Report - Recirculation System", December 6, 1976, SI File No. 0800769.211, pp. 6, 30, 173.

4. N-2C Nozzle, Fitzpatrick Construction Drawing 407737, "As-Built Dimensions For N-2C-SE-Weld Overlay," September 26, 2008, Received from Thomas Moskalyk October 14, 2008. SI File No. 0800769.220

5. James A. Fitzpatrick Design Drawing 11825-6.11-48B, "Recirculation Loop Piping Details," December 16, 1969, SI File No. 0800769.221. See Figure 1.

6. SI Calculation No. 0800769.301, "Design Input for RPV Recirculation Inlet and Outlet Nozzle Finite Element Analyses and Flaw Evaluation Readiness".

7. ASME Boiler and Pressure Vessel Code, Section II, Part D, 2001 Edition with Addenda through 2003.

8. Structural Integrity Associates, Inc. Report SIR-93-011, "IGSCC Related Design and Analysis Activities at J. A. Fitzpatrick (1984-1992)", June 1993, SI File Nos. NYPA-34Q-401 / 0800769.222.

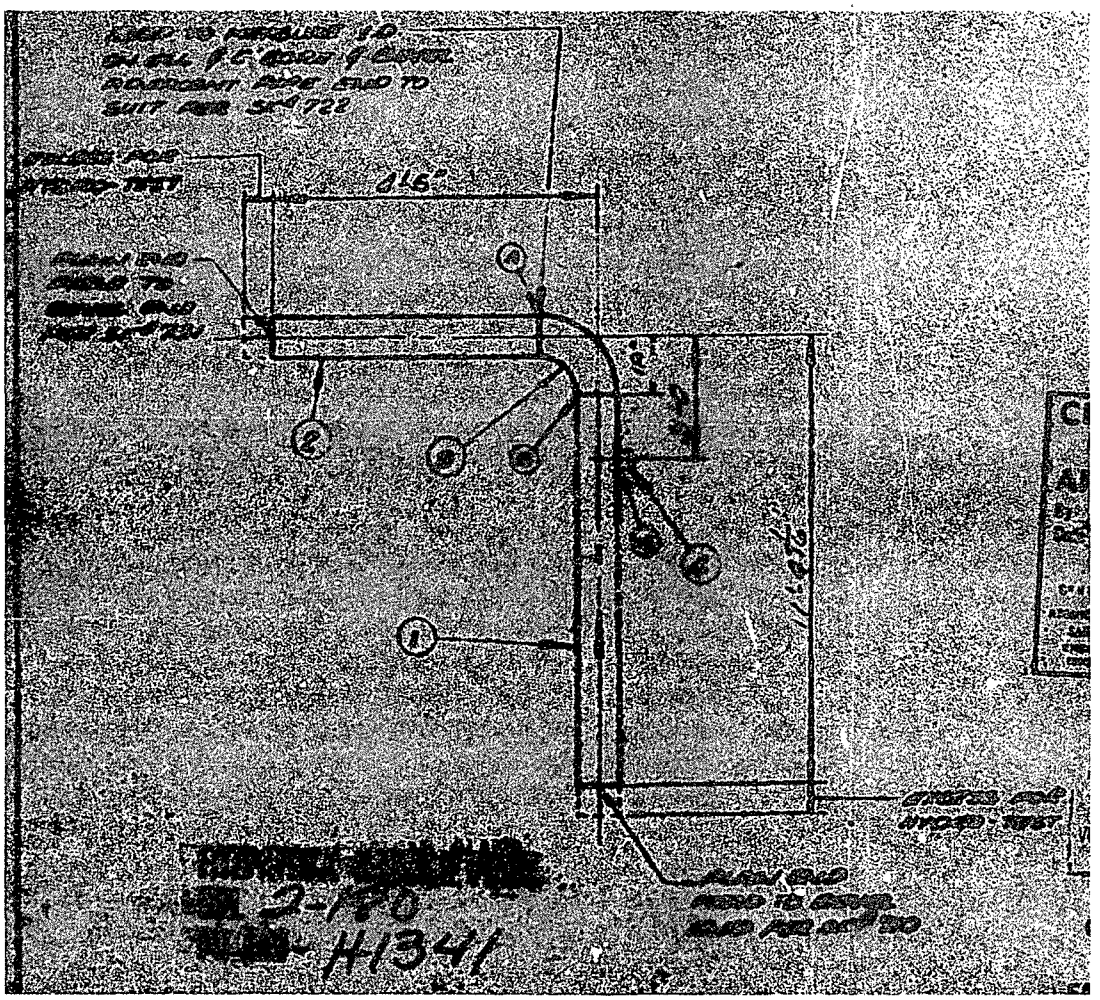

Figure 1. Recirculation Loop Piping Details