Omaha Public Power District

444 South 16th Street Mall
Omaha NE 68102-2247

April 19, 2005
LIC-05-0048

U.S. Nuclear Regulatory Commission
ATTN.: Document Control Desk
Washington, D.C. 20555-0001

References:
1. Docket No. 50-285
2. Letter from Ralph L. Phelps (OPPD) to Document Control Desk (NRC) dated April 7, 2005, Fort Calhoun Station Unit No. 1, Relaxation Request for First Revised Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors (LIC-05-0040)
3. Letter from R. William Borchardt (NRC) to Ross Ridenoure (OPPD) dated February 20, 2004, Issuance of First Revised NRC Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors (NRC-04-0022) (ML040220181)
4. Letter from Ralph L. Phelps (OPPD) to Document Control Desk (NRC) dated April 15, 2005, Fort Calhoun Station Unit No. 1, Supplemental Information for Relaxation Request for First Revised Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors (LIC-05-0043)

SUBJECT: Fort Calhoun Station Unit No. 1, Additional Information for Relaxation Request for First Revised Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors

In Reference 4, the Omaha Public Power District (OPPD) provided information in support of a relaxation request with respect to Reference 3. Attachment 1 of Reference 4 referred to the Dominion Engineering Inc. Calculation Number C-8718-00-1, "Fort Calhoun CEDM and ICI Nozzle Stress Analysis," April 2005, Rev. 0 (as Reference 1). As requested by the NRC staff, OPPD is providing a copy of the referenced calculation as Attachment 1 to this letter.

If you have any questions or require additional information, please contact Thomas R. Byrne at (402) 533-7368.

Sincerely,

R L Phelps 4-19-05

Ralph L. Phelps
Division Manager
Nuclear Engineering

RLP/TRB/trb

Attachment 1 - Dominion Engineering Inc. Calculation Number C-8718-00-1, "Fort Calhoun CEDM and ICI Nozzle Stress Analysis," April 2005, Rev. 0.

Attachment 1

Dominion Engineering Inc. Calculation Number C-8718-00-1, "Fort Calhoun CEDM and ICI Nozzle Stress Analysis," April 2005, Rev. 0.

Fort Calhoun CEDM and ICI Nozzle Stress Analysis

Record of Revisions

Rev.	Description	Prepared by Date	Checked by Date	Reviewed by Date
0	Original Issue	J.E. Broussard 4/18/05	4/18/05	4/18/05

The last revision number to reflect any changes for each section of the calculation is shown in the Table of Contents. The last revision numbers to reflect any changes for tables and figures are shown in the List of Tables and the List of Figures. Changes made in the latest revision, except for Rev. 0 and revisions which change the calculation in its entirety, are indicated by a double line in the right hand margin as shown here.

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Att. No.		Last Mod. Rev.
1	Fort Calhoun CEDM and ICI Model Results Summaries	0
2	File "Westpost7.txt"	0

1.0 Purpose

The purpose of this calculation is to document the results of finite element stress analyses of the CEDM and ICI reactor vessel penetrations at Fort Calhoun. In this analysis, a number of nozzle geometries spanning the range of penetration angles in the Fort Calhoun reactor head design are investigated.

2.0 Summary of Results

Four cases were run which bound the CEDM penetration angles in the Fort Calhoun reactor vessel head; in addition, the single ICI geometry case was also analyzed. These cases support the following conclusions:

1. The maximum nozzle ID hoop stresses are in the vicinity of the J-groove weld, and are in excess of the corresponding axial stresses, suggesting that PWSCC cracking should be axially oriented.

2. Maximum hoop and axial stresses tend to increase with increasing angle.

3.0 Input Requirements

The following values are used in this calculation:

1. The local configuration of the J-groove weld attaching the CEDM nozzles and ICI nozzle to the RPV head. The details used for each model are taken from Combustion Engineering (CE) drawings for Fort Calhoun (References 2b, 2d).

2. Detailed dimensions of the RPV head and CEDM and ICI nozzles. These values are taken from the CE drawings and are as follows:

   Nozzles:
   - CEDM Nozzle OD = 3.500 inches – Ref. (2c)
   - CEDM Nozzle ID = 2.728 inches – Ref. (2c)
   - ICI Nozzle OD = 6.625 inches – Ref. (2c)
   - ICI Nozzle ID = 5.189 inches – Ref. (2c)

   Reactor Vessel:
   - Cladding thickness = 7/32 inch – Ref. (2a)
   - RPV Head Inner Radius (to base metal) = 69-25/32 inches – Ref. (2a)
   - RPV Head Thickness (minimum; excluding cladding) = 6-3/16 inches – Ref. (2a)
   - Per Ref. (2d), the RPV Head Thickness is increased by 1-5/16 inches for the ICI nozzle model due to the local weld buildup.

3. Operating temperature and pressure. The operating head temperature at Fort Calhoun is 588°F per Table 2-2 of MRP-48 (5). A 2,235 psig operating pressure was assumed for this calculation.

4.0 Assumptions and Analysis Method

The following modeling assumptions were used for the CEDM nozzle modeling described in this calculation:

1. Operating pressure was assumed to be 2,235 psig.
2. The nozzle was assumed to be flush with the penetration for both the CEDM and ICI models. No clearance or interference fit was assumed. Previous analyses have shown that assuming no interference fit produces conservative nozzle stresses as compared to stresses calculated with interference fits typically specified for CEDM nozzles.
3. Two passes of welding were performed for the CEDM and ICI penetrations: an inner pass and an outer pass. Both the CEDM and ICI model geometries were designed such that each weld pass is approximately the same volume.
4. Based on experimental stress-strain data and certified mill test report data for the materials listed below, the following room-temperature and 600°F elastic limit values were used in association with the elastic-perfectly plastic hardening laws described in Section 5.1:

Material	70°F	600°F
Alloy 182 Welds (Including Butter)	75.0 ksi	60.0 ksi
Low-Alloy Steel Shell	70.0 ksi	57.6 ksi
Stainless Steel Cladding	40.0 ksi	28.9 ksi

   The elastic limit values for the base materials (head shell and cladding), which undergo small strains during the analysis, are based on the 0.2% offset yield strength for the material. The elastic limit values for the weld materials, which undergo large strains during the analysis, are based on an average of the reported yield and tensile strengths.

5. Based on high temperature yield strength data for Alloy 600 bar in Ref. (6), the following temperature scaling factors were applied to the Alloy 600 multi-linear isotropic hardening curve described in Section 5.1:

   - 70 °F: 1.15
   - 600 °F: 1.00
   - 1,200 °F: 0.83
   - 1,600 °F: 0.29
   - 2,300 °F: 0.05
   - 3,500 °F: 0.05

6. The model geometry was based on the nominal dimensions presented in the design drawings listed in Section 6 (References 2a through 2d). The minimum reactor vessel head thickness and nominal head cladding thickness (per Reference 2a as listed in Section 3) were used for the models employed for this calculation. However, as noted in Section 3, the RV head thickness was increased by 1-5/16 inches (Ref. 2d) for the ICI nozzle model due to the local weld buildup.

5.0 Analysis

5.1 Finite Element Analyses

Finite element analyses of the CEDM and ICI nozzles were performed for a total of four cases, selected to bracket the range of CEDM penetration angles in the Fort Calhoun reactor vessel head. The four CEDM geometry cases analyzed are: 0° (penetration no. 1), 24.6° (penetration nos. 14 through 17), 37.3° (penetration nos. 30 through 37), and 41.7° (penetration nos. 38 through 41). Figure 5-1 shows the element geometry and node numbering scheme for the 37.3° CEDM nozzle model. The numbering scheme used for the CEDM model is identical for all four cases considered in this calculation. In addition to the CEDM nozzles, the single ICI nozzle (54.4°) penetration was modeled for this analysis. Figure 5-2 shows the element geometry and node numbering scheme for the ICI case. Figures 5-1 and 5-2 also depict the positive radial and axial axes.

ANSYS finite element analyses were performed using a model based on work developed for commercial customers and described in a 1994 EPRI report on the subject of PWSCC of Alloy 600 components in PWR primary system service (Ref. 1).

All nozzles were analyzed using 3D models. The model includes a sector of the alloy steel head with stainless steel cladding on the inside surface, the Alloy 600 nozzle, the Inconel buttering layer in the J-groove weld preparation (simulated as a single weld pass for this analysis), and the Inconel weld material divided into two "passes" of approximately equal volume. The stainless steel cladding and Inconel buttering layers were included in the model since these materials have significantly different coefficients of thermal conductivity compared to the carbon steel vessel head, and therefore influence the weld cooling process.

The boundary conditions on the conical surfaces are such that only radial deflections in the spherical coordinate system are permitted. The nozzles are modeled as being installed in holes in the vessel head with no interference fit (as discussed in Section 4.0) using gap elements with zero initial clearance in the interference region.

The current analysis model simulates the butter weld deposition process and the 1,100°F thermal stress relief of the head shell and butter (prior to J-groove welding). The butter weld deposition process is

simulated using a single pass; i.e., the butter region is deposited as a single ring of material. After completion of the butter deposition step, the entire model (with the exception of the nozzle and J-groove weld elements, which are not yet active in the model) is uniformly raised to 1,100°F. As noted below, the elastic limit material properties of the head shell and butter at 1,100°F are reduced relative to those used in Reference (1) in order to simulate the stress relaxation caused by a multiple-hour stress relief at 1,100°F.

This analysis includes steps for weld depositing the butter and stress relieving the head and butter prior to the J-groove welding steps. In order to accurately model the stress relaxation in the weld region due to time at elevated temperature, the elastic limit for the Alloy 182 weld and stainless steel cladding at temperatures near 1,100°F are reduced relative to curves used in the Reference (1) analyses. The reduced elastic limits are set at values consistent with the lower residual stress levels brought about by the multiple-hour stress relief. This reduction in elastic limit allows stresses in the pressurizer shell, cladding, and buttering to redistribute at the lower residual stress levels.

The welds (both the weld butter and J-groove weld) are modeled as rings of weld metal which are heated and cooled. As noted above, weld buttering is simulated as a single weld pass; the J-groove weld is simulated as two weld passes. The welding process is simulated by combined thermal and structural analyses. The thermal analysis is used to generate nodal temperature distributions throughout the model at several points in time during the welding process. These nodal temperatures are then used as input conditions to the structural analysis, which calculates the thermally induced stresses. Once welding is completed, a hydrostatic pressure load is applied to, then removed from, the wetted regions of the model at ambient temperature. Finally, the model is loaded with operating temperature and pressure.

The combination of thermal and structural analyses required the use of both thermal and structural finite element types, as follows:

- Thermal Analysis. For the 3-D thermal analysis, eight-node thermal solids (SOLID70) and null elements (Type 0) were used. Use of null elements between the nozzle and head penetration has the effect of limiting heat transfer between the nozzle and head to conduction through the J-groove region. This assumption was made because the head penetrations are counterbored both at the upper and lower portions of the penetration, and because thermal communication between the surfaces that are nominally in contact was assumed to be poor.

- Structural Analysis. Eight-node 3-D isoparametric solid elements (SOLID45) and two-node interface elements (COMBIN40) were used for the 3-D structural analyses. The SOLID45 and COMBIN40 elements replaced the SOLID70 and null elements, respectively, which had been used for the thermal analysis. Degenerate four- and six-node solid elements were not used in areas of high stress gradient since they can lead to significant errors when used in these regions (8). Higher order elements were not used since they provide no greater accuracy for elastic-plastic analyses than the eight-node solids (8). Further details of the finite element modeling process are available in Reference (1).

In Reference (1), the analytical results of the finite element model were correlated with the experimental and field data that were available at the time. This study showed that the locations of observed cracking correlated well with regions of highest stress in the analytical model. Additionally, the measured ovality at EdF and Ringhals CEDM nozzles was found to correlate well with the analytically predicted ovality for these nozzles. Further details of the correlation between analytical and experimental/field data are available in Reference (1).

It is noted that the finite element model has been improved and refined since it was described in Reference (1). Among the improvements over the model described in Reference (1) are the following:

1. While the material properties used for the nozzle material continue to make use of multi-linear isotropic hardening, the material properties for the weld and weld buttering, head shell, and stainless steel cladding are now modeled using elastic-perfectly plastic hardening laws. Experience has shown that using multi-linear hardening properties in the analysis of materials that experience a high degree of plastic strain at elevated temperatures (such as those within the J-groove welds) results in significant work hardening once the material has cooled to lower temperatures. Using elastic-perfectly plastic hardening laws does not allow this artificial work hardening to occur, which yields more realistic stresses in the weld portions of the model.

2. The ability to refine the mesh in the various regions of the model. The model geometry used in this calculation makes use of approximately four times the mesh refinement in the J-groove weld areas as is shown in Reference (1), and uses greater mesh refinement in other areas of the model, such as the nozzle.

3. The ability to perform four-pass welding, as an alternative to two passes. This feature produces more satisfactory results with J-groove welds that are deep compared to the wall thickness of the adjacent nozzle, such as for some ICI and thermocouple RPV head penetrations.

In addition to these improvements, the finite element model has been modified for work specific to Westinghouse. In particular, the stress versus strain values for the multi-linear isotropic hardening used for the Alloy 600 nozzle material have been changed to be consistent with Alloy 600 cyclic stress-strain curve (CSSC) data obtained in Reference (3). The curve input for the analytical model is found in Figure 2-29 of (3), and is labeled "Reference Curve for Analysis." Because the CSSC curve in (3) is for only one temperature (600 °F), the reference curve was scaled to a number of other temperatures as follows. At each of the five strain values used to define the multi-linear isotropic hardening behavior of the nozzle material at 600 °F, the corresponding stress was linearly scaled up or down according to the scaling factors listed in Section 4.0, which are based on high temperature yield strength data for Alloy 600 in Reference (6). These scaling factors are consistent with the work performed using the version of the finite element model that is not specific to Westinghouse work. The ANSYS code that creates the finite element model with these changes has now been incorporated into DEI's "cirse.base" file. Version 2.4.7 of the cirse.base code was used for the five cases considered in this calculation.

5.2 Analytical Results Summary

Summaries of the analytical results for each of the models analyzed are contained in Attachment 1 to this calculation. These summaries show the maximum hoop and axial stresses at the ID of the nozzle, at the "uphill" (closest to the top of the head) and "downhill" circumferential planes, as well as "above" the weld (axial portion of the nozzle including the weld region and extending through the head shell) and "below" the weld (axial portion of the nozzle extending into the RPV). Plots of the hoop (SY) and axial (SZ) stresses in each of the four CEDM model cases and ICI case are shown in Figures 5-3 through 5-7.

Figures 5-3 through 5-7 and Attachment 1 show that the maximum hoop stresses are in the vicinity of the J-groove weld, and are in excess of the corresponding axial stresses, suggesting that PWSCC cracking should be axially oriented. The results also show that operating plus residual stresses are influenced by penetration angle, with higher angles generally leading to higher maximum hoop and axial stresses.

5.3 Additional Post-Processing of Analysis Results

In addition to the condensed post-processing included in Attachment 1 to this calculation, further post-processing was performed to determine the stresses and deflections at a number of other locations specified by Westinghouse personnel. The additional post-processing was performed using the file "Westpost7.txt," included as Attachment 2 to this calculation.

The results of the additional post-processing are presented in Tables 5-1 through 5-8 and in Figures 5-8 through 5-12. With the exception of Table 5-4, all data and stress plots are for the operating plus weld residual stress load condition. The tables are summarized as follows.

- Table 5-1. Table 5-1 presents the hoop stress distribution through the nozzle thickness at five specific axial locations for both the downhill and uphill sides of the nozzle. These locations are: 0.5" below the bottom of the weld, the bottom of the weld, the middle of the weld, the top of the weld, and 0.5" above the top of the weld.

- Table 5-2. Table 5-2 presents the axial stress distribution through the nozzle thickness at the top of the weld, following the sweep of the weld from downhill to uphill. Data are tabulated for each of the nine circumferential planes in the model. For Table 5-2, stress results are reported in an element-oriented coordinate system which follows the path of the weld. Therefore, the axial stress results presented in Table 5-2 are normal to the path of the weld.

- Tables 5-3. Tables 5-3a through 5-3e present the hoop stress distribution along the ID and the OD of the five nozzle geometries at both the downhill and uphill sides.

- Table 5-4. Table 5-4 presents the weld residual deflection at the inner diameter of the nozzle at each of the nine circumferential planes in the model for four axial locations. These data are used to calculate the change in inner diameter at each of the locations. The four axial locations are presented as defined in Reference (4), and are as follows: Location 2 – 0.5" below the bottom of the downhill weld, Location 3 – bottom of the downhill weld, Location 4 – top of the downhill weld, and Location "X" – bottom of the uphill weld.

- Table 5-5. Table 5-5 presents the forces in the gap elements at the interference region between the nozzle and the head under operating conditions. Note that since the initial fit in this region is assumed to be zero interference (flush fit), a large number of the gap forces are zero.

- Table 5-6. Table 5-6 presents additional hoop stress distributions through the nozzle thickness for the 37.3° and 41.7° nozzle cases. The hoop stress distributions are taken at nodal cut planes located as noted in the table above the top of the uphill weld.

- Table 5-7. Table 5-7 presents the hoop stress along the downhill and uphill nodal lines depicted in Figure 5-2, which run through the weld and head shell parallel to the head penetration. The radial and axial locations of the nodes along the lines are also reported in the table.
- Table 5-8. Table 5-8 presents the hoop stress along the weld and buttering wetted surfaces for the downhill side of selected penetrations.

Figures 5-8 through 5-12 are axial stress plots of the nozzle wall cross section at the top of the weld and following the sweep of the weld from downhill to uphill. As in Table 5-2, the stresses are in an element-oriented coordinate system which follows the path of the weld; the axial stress results presented are normal to the path of the weld.

It is important to note that while results are reported for the nodes at the interface between the nozzle OD and the J-groove weld, these nodes lie on the interface between two different materials. Therefore, the stress results at these nodes vary depending on which portions of the model are selected at the time of reporting. When nodal stress data are reported, they are always reported with the entire model selected.

5.4 Additional Files Stored Electronically

In addition to the condensed post-processing included in this calculation, more voluminous output results have been saved electronically in the following directories and filenames:

/data/t8718/FC-0A/FC-0A.nodelocs.txt
/data/t8718/FC-0A/FC-0A.results.txt

/data/t8718/FC-24A/FC-24A.nodelocs.txt
/data/t8718/FC-24A/FC-24A.results.txt

/data/t8718/FC-37A/FC-37A.nodelocs.txt
/data/t8718/FC-37A/FC-37A.results.txt

/data/t8718/FC-41A/FC-41A.nodelocs.txt
/data/t8718/FC-41A/FC-41A.results.txt

/data/t8718/FC-ICIA/FC-ICIA.nodelocs.txt
/data/t8718/FC-ICIA/FC-ICIA.results.txt

These files (created using "Westpost7.txt"—see Attachment 2) have been transmitted to Westinghouse via e-mail and on CD-ROM on disk D-8718-00-1, Revision 0.

5.5 Quality Assurance Software Controls

The Fort Calhoun reactor vessel head nozzle analyses were performed on an HP J6700 workstation, under the HP-UX 11.0 operating system and ANSYS Revision 8.0, which is maintained in accordance with the provisions for control of software described in Dominion Engineering, Inc.'s (DEI's) quality assurance (QA) program for safety-related nuclear work (9).[1] In addition to QA controls associated with the procurement and use of the ANSYS software (e.g., maintenance of the ANSYS Inc. as an approved supplier of the software based on formal auditing and surveillance, formal periodic verification of ANSYS software installation), QA controls associated with all ANSYS batch input listings are also carried out by DEI. These include independent checks of a batch input listing each time it is used; review of all ANSYS Class 3 error reports and QA notices to assess their potential impact on a batch listing; and independent "check calculations"[2] to ensure that the project-specific application of the analysis is appropriate. The review of ANSYS error reports and QA notices as well as the project-specific check calculations are documented formally in a QA memo to the project file (this project is DEI Task 87-18).

[1] DEI's quality assurance program for safety-related work (DEI-002) commits to applicable requirements of 10 CFR 21, Appendix B of 10 CFR 50, and ASME/ANSI NQA-1. This QA program is independently audited periodically by both NUPIC (the Nuclear Procurement Issues Committee) and NIAC (the Nuclear Industry Assessment Committee).

[2] "Check calculations" for a given project may include comparison of model-computed nozzle and reactor vessel head stresses to theoretical closed-form solutions; confirmation that computed weld pass temperatures fall within target temperature ranges; and, for symmetric (0° nozzle angle) geometry cases, confirmation of the applied pressure loading and results symmetry.

6.0 References

1. *PWSCC of Alloy 600 Materials in PWR Primary System Penetrations*, EPRI TR-103696, July 1994.

2. Combustion Engineering (CE) Drawings for Omaha Power 140" ID PWR:
   a. CE Drawing No. E-232-415, Rev. 6, Closure Head Forming and Welding
   b. CE Drawing No. E-232-416, Rev. 11, Closure Head Assembly
   c. CE Drawing No. E-232-417, Rev. 11, Closure Head Housing Details
   d. CE Drawing No. E-232-418, Rev. 3, Closure Head Penetration Details

3. Ball, M. G., et al., "RV Closure Head Penetration Alloy 600 PWSCC," WCAP-13525, Revision 1, Westinghouse Electric Corporation, 1992.

4. Incoming Correspondence IC-7736-00-3, Fax from Warren Bamford (Westinghouse) to John Broussard (Dominion Engineering, Inc.) defining diameter measurement elevations, dated January 8, 2002. (Note: This document was transmitted to DEI in support of work performed for Task 7736 and is filed in the Task 77-36 Project File.)

5. *PWR Materials Reliability Program Response to NRC Bulletin 2001-01 (MRP-48)*, EPRI, Palo Alto, CA: 2001. 1006284.

6. *Properties and Selection: Stainless Steels, Tool Materials, and Special-Purpose Metals*, ASM Materials Handbook Volume 3, Ninth Edition, p. 218, 1980.

7. *Flow of Fluids Through Valves, Fittings, and Pipe,* Technical Paper 410, Crane Company, 1988.

8. "Modeling and Meshing Guide," ANSYS 8.0 Documentation, ANSYS, Inc.

9. *Dominion Engineering, Inc. Quality Assurance Manual for Safety-Related Nuclear Work*, DEI-002, Revision 16.

Table 5-1

Nozzle Through Wall Hoop Stress at Selected Axial Locations

Nozzle Angle	Percent Through Wall	Downhill Side Hoop Stress (psi)					Uphill Side Hoop Stress (psi)				
		0.5" Below Weld	Bottom of Weld	Middle of Weld	Top of Weld	0.5" Above Weld	0.5" Below Weld	Bottom of Weld	Middle of Weld	Top of Weld	0.5" Above Weld
0.0 (CEDM)	ID	31,434	52,233	27,389	54,222	51,549	31,434	52,233	27,389	54,222	51,549
0.0 (CEDM)	20%	30,760	46,515	31,299	53,581	46,947	30,760	46,515	31,299	53,581	46,947
0.0 (CEDM)	40%	27,478	42,008	38,335	53,961	42,153	27,478	42,008	38,335	53,961	42,153
0.0 (CEDM)	60%	18,269	41,061	45,080	54,731	34,317	18,269	41,061	45,080	54,731	34,317
0.0 (CEDM)	80%	5,414	46,938	54,138	57,387	22,556	5,414	46,938	54,138	57,387	22,556
0.0 (CEDM)	OD	-2,523	50,945	57,659	59,383	11,665	-2,523	50,945	57,659	59,383	11,665
24.6 (CEDM)	ID	23,097	49,924	36,322	58,009	52,587	50,542	57,849	42,307	55,682	46,758
24.6 (CEDM)	20%	22,382	46,437	38,212	60,403	47,952	46,817	53,811	43,790	52,834	42,426
24.6 (CEDM)	40%	18,938	44,462	43,876	63,873	43,302	41,740	51,063	47,952	52,171	30,996
24.6 (CEDM)	60%	14,365	45,419	49,246	66,640	39,551	33,458	49,512	52,361	51,744	18,715
24.6 (CEDM)	80%	9,435	54,073	55,468	70,416	30,310	21,920	53,731	59,342	52,013	7,758
24.6 (CEDM)	OD	4,475	59,517	56,693	68,977	20,084	15,525	55,654	61,485	65,363	1,866
37.3 (CEDM)	ID	16,399	47,124	41,979	57,403	51,281	49,645	58,639	49,727	55,618	43,677
37.3 (CEDM)	20%	17,228	47,881	43,414	61,001	47,261	46,574	55,566	51,401	51,965	37,197
37.3 (CEDM)	40%	16,041	49,631	47,553	66,650	41,322	40,759	53,282	55,093	50,948	26,077
37.3 (CEDM)	60%	15,157	54,027	51,671	71,214	37,933	31,734	50,415	58,897	49,557	14,588
37.3 (CEDM)	80%	14,294	65,480	56,444	75,076	33,601	15,939	56,740	64,404	47,990	3,779
37.3 (CEDM)	OD	12,150	76,908	57,358	62,989	24,372	2,031	54,527	63,662	62,193	-2,531
41.7 (CEDM)	ID	7,590	49,159	40,250	57,030	50,877	49,648	57,834	53,192	55,879	40,706
41.7 (CEDM)	20%	8,594	47,527	42,344	61,020	47,183	46,736	55,152	54,678	52,030	34,268
41.7 (CEDM)	40%	8,445	48,060	47,132	67,017	40,935	40,727	53,268	57,959	50,795	24,011
41.7 (CEDM)	60%	8,893	52,073	51,142	71,898	36,977	30,093	50,243	61,256	48,895	13,310
41.7 (CEDM)	80%	9,972	63,824	55,650	74,798	33,574	10,960	56,325	65,929	45,999	2,802
41.7 (CEDM)	OD	10,116	72,462	56,136	58,868	23,977	-8,309	51,837	63,896	60,149	-3,447
54.4 (ICI)	ID	-23,982	26,011	34,809	53,938	48,043	49,258	50,524	51,251	44,802	39,068
54.4 (ICI)	20%	-14,546	35,796	35,587	55,893	43,339	45,892	49,889	52,639	42,562	33,930
54.4 (ICI)	40%	-2,605	42,722	41,013	61,063	39,766	41,325	49,558	56,834	44,957	25,251
54.4 (ICI)	60%	8,889	52,080	45,694	64,629	35,661	38,628	52,402	63,229	47,926	15,821
54.4 (ICI)	80%	20,514	62,921	50,785	64,958	31,180	37,776	51,650	66,589	42,728	5,428
54.4 (ICI)	OD	26,419	54,149	50,187	42,239	27,121	33,837	40,326	67,792	41,547	-6,350

Note: Nozzle yield strength at 600°F operating temperature is 39.3 ksi.

Table 5-2

Nozzle Through Wall Axial Stress Along the Top of the Weld -- Element-Oriented Coordinate System

Nozzle Angle	Percent Through Wall	Local Axial Stress (psi) at Circumferential Location								
		Downhill -90°	-67.5°	-45°	-22.5°	0°	22.5°	45°	67.5°	Uphill 90°
0.0 (CEDM)	ID	8,583	8,586	8,588	8,588	8,588	8,588	8,588	8,586	8,583
0.0 (CEDM)	20%	5,743	5,744	5,745	5,746	5,745	5,746	5,745	5,744	5,743
0.0 (CEDM)	40%	465	464	465	465	465	465	465	464	465
0.0 (CEDM)	60%	-2,718	-2,721	-2,720	-2,719	-2,719	-2,719	-2,720	-2,721	-2,718
0.0 (CEDM)	80%	-1,737	-1,743	-1,743	-1,742	-1,742	-1,742	-1,743	-1,743	-1,737
0.0 (CEDM)	OD	430	427	425	426	426	426	425	427	430
24.6 (CEDM)	ID	16,197	15,906	14,117	11,830	10,310	9,895	10,457	11,668	12,770
24.6 (CEDM)	20%	18,279	16,627	13,152	9,242	6,301	5,019	4,749	4,897	5,073
24.6 (CEDM)	40%	16,213	14,028	9,574	4,809	1,398	-309	-917	-1,179	-1,544
24.6 (CEDM)	60%	15,241	12,619	7,626	2,347	-1,743	-4,292	-5,558	-6,473	-7,305
24.6 (CEDM)	80%	18,247	15,292	9,435	2,815	-2,394	-5,934	-7,788	-8,818	-9,992
24.6 (CEDM)	OD	20,471	18,247	13,218	7,499	3,016	1,233	2,057	2,775	3,777
37.3 (CEDM)	ID	19,736	17,988	13,415	9,231	7,424	7,570	9,580	12,664	15,093
37.3 (CEDM)	20%	23,325	19,743	13,554	7,305	3,817	2,926	4,143	5,578	6,079
37.3 (CEDM)	40%	24,894	20,194	11,679	4,008	-105	-1,842	-1,353	-781	-1,442
37.3 (CEDM)	60%	27,542	22,335	12,457	3,389	-2,073	-5,305	-6,192	-6,876	-8,418
37.3 (CEDM)	80%	34,024	28,914	17,924	5,938	-2,199	-6,921	-9,590	-10,725	-12,537
37.3 (CEDM)	OD	27,977	24,301	14,270	3,413	-2,102	-3,376	-522	2,538	4,757
41.7 (CEDM)	ID	21,026	18,553	12,904	8,360	6,325	6,577	9,871	14,063	17,232
41.7 (CEDM)	20%	24,411	20,343	13,118	6,481	3,001	2,129	4,461	6,798	7,533
41.7 (CEDM)	40%	27,140	21,724	11,943	3,981	-186	-2,116	-1,008	265	-559
41.7 (CEDM)	60%	31,127	25,308	13,967	4,207	-1,641	-5,180	-6,002	-6,318	-8,248
41.7 (CEDM)	80%	38,193	32,883	20,783	7,483	-1,388	-6,443	-9,997	-11,081	-13,225
41.7 (CEDM)	OD	28,618	25,136	14,056	2,373	-2,789	-3,943	-1,315	3,430	6,192
54.4 (ICI)	ID	25,321	24,216	18,739	11,934	4,485	2,522	11,131	22,220	22,606
54.4 (ICI)	20%	23,640	19,155	7,944	-171	-1,383	-484	4,221	11,859	13,569
54.4 (ICI)	40%	22,264	17,794	5,855	-1,695	-3,448	-2,310	-580	3,200	4,736
54.4 (ICI)	60%	25,344	20,946	11,005	4,429	340	-2,937	-5,127	-4,869	-4,583
54.4 (ICI)	80%	35,234	31,039	22,261	14,603	8,142	2,273	-4,289	-8,665	-13,109
54.4 (ICI)	OD	13,454	12,238	9,921	5,623	4,454	4,449	2,020	3,315	5,949

Table 5-3a

Nozzle ID and OD Hoop Stress (0° CEDM Case)

	Downhill Side				Uphill Side			
	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)
Nozzle Bottom	1,6	0.00	250	-1,168	80001, 80006	0.00	250	-1,168
	101, 106	0.71	-6,432	-7,898	80101, 80106	0.71	-6,432	-7,898
	201, 206	1.28	-3,048	-11,748	80201, 80206	1.28	-3,048	-11,748
	301, 306	1.74	11,443	-12,369	80301, 80306	1.74	11,443	-12,369
	401, 406	2.10	31,434	-2,523	80401, 80406	2.10	31,434	-2,523
	501, 506	2.39	45,996	21,117	80601, 80606	2.39	45,996	21,117
Weld Bottom	601, 606	2.63	52,233	50,945	80601, 80606	2.63	52,233	50,945
	701, 706	2.80	44,440	61,733	80701, 80706	2.80	44,440	61,733
	801, 806	2.97	34,965	56,381	80801, 80806	2.97	34,965	56,381
	901, 906	3.15	26,742	61,171	80901, 80906	3.15	26,742	61,171
	1001, 1006	3.32	27,389	57,659	81001, 81006	3.32	27,389	57,659
	1101, 1006	3.49	36,183	55,544	81101, 81006	3.49	36,183	55,544
	1201, 1206	3.66	45,774	49,904	81201, 81206	3.66	45,774	49,904
	1301, 1306	3.84	51,616	50,527	81301, 81306	3.84	51,616	50,527
Weld Top	1401, 1406	4.01	54,222	59,383	81401, 81406	4.01	54,222	59,383
	1501, 1506	4.13	55,254	46,440	81501, 81506	4.13	55,254	46,440
	1601, 1606	4.26	56,296	23,118	81601, 81606	4.26	56,296	23,118
	1701, 1706	4.43	51,549	11,665	81701, 81706	4.43	51,549	11,665
	1801, 1806	4.62	41,705	7,571	81801, 81806	4.62	41,705	7,571
	1901, 1906	4.85	24,311	-802	81901, 81906	4.85	24,311	-802
	2001, 2006	5.11	6,537	-5,340	82001, 82006	5.11	6,537	-5,340
	2101, 2106	5.41	-904	-1,045	82101, 82106	5.41	-904	-1,045
	2201, 2206	5.77	3,649	4,444	82201, 82206	5.77	3,649	4,444
	2301, 2306	6.17	7,184	7,142	82301, 82306	6.17	7,184	7,142
	2401, 2406	6.64	9,008	7,612	82401, 82406	6.64	9,008	7,612
	2501, 2506	7.18	9,270	7,074	82501, 82506	7.18	9,270	7,074
	2601, 2606	7.81	8,974	6,605	82601, 82606	7.81	8,974	6,605
	2701, 2706	8.54	8,810	6,507	82701, 82706	8.54	8,810	6,507
	2801, 2806	9.39	8,826	6,569	82801, 82806	9.39	8,826	6,569
	2901, 2906	10.27	8,849	6,595	82901, 82906	10.27	8,849	6,595
Nozzle Top	3001, 3006	11.16	8,826	6,581	83001, 83006	11.16	8,826	6,581

Table 5-3b

Nozzle ID and OD Hoop Stress (24.6° CEDM Case)

	Downhill Side				Uphill Side			
	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)
Nozzle Bottom	1,6	0.00	-11,950	3,679	80001, 80006	0.00	-11,926	4,090
	101, 106	0.71	-12,499	-1,437	80101, 80106	1.14	-9,035	1,562
	201, 206	1.27	-8,475	-5,938	80201, 80206	2.06	-8,583	-10,507
	301, 306	1.73	4,122	-7,845	80301, 80306	2.79	5,181	-20,428
	401, 406	2.09	23,097	4,475	80401, 80406	3.38	31,752	-17,373
	501, 506	2.38	41,211	30,019	80601, 80606	3.85	50,542	15,525
Weld Bottom	601, 606	2.61	49,924	59,517	80601, 80606	4.22	57,849	55,654
	701, 706	2.81	41,543	67,411	80701, 80706	4.43	52,355	64,440
	801, 806	3.00	33,338	62,152	80801, 80806	4.65	48,485	59,055
	901, 906	3.20	30,287	60,785	80901, 80906	4.86	42,981	62,211
	1001, 1006	3.39	36,322	56,693	81001, 81006	5.07	42,307	61,485
	1101, 1006	3.59	48,042	50,997	81101, 81006	5.28	46,444	58,187
	1201, 1206	3.78	56,011	45,916	81201, 81206	5.50	50,091	54,943
	1301, 1306	3.98	58,342	53,638	81301, 81306	5.71	53,389	62,436
Weld Top	1401, 1406	4.17	58,009	68,977	81401, 81406	5.92	55,682	65,363
	1501, 1506	4.30	56,684	50,220	81501, 81506	6.04	56,673	30,346
	1601, 1606	4.42	56,829	36,867	81601, 81606	6.17	57,824	10,366
	1701, 1706	4.60	52,587	20,084	81701, 81706	6.31	55,864	5,897
	1801, 1806	4.81	41,356	8,989	81801, 81806	6.48	46,758	1,866
	1901, 1906	5.05	30,420	-6,034	81901, 81906	6.69	28,485	-1,429
	2001, 2006	5.33	15,400	-7,161	82001, 82006	6.93	9,286	-4,006
	2101, 2106	5.66	4,820	-3,759	82101, 82106	7.22	752	-3,509
	2201, 2206	6.04	3,156	3,041	82201, 82206	7.56	2,933	3,318
	2301, 2306	6.48	5,802	5,334	82301, 82306	7.97	8,657	6,672
	2401, 2406	6.99	9,072	6,788	82401, 82406	8.45	10,970	6,740
	2501, 2506	7.59	10,976	6,581	82501, 82506	9.03	11,668	5,622
	2601, 2606	8.29	11,788	5,845	82601, 82606	9.71	11,902	4,809
	2701, 2706	9.10	12,149	2,649	82701, 82706	10.52	12,016	4,648
	2801, 2806	10.04	8,858	-2,557	82801, 82806	11.48	11,676	4,949
	2901, 2906	11.65	11,432	5,205	82901, 82906	12.37	11,011	5,399
Nozzle Top	3001, 3006	13.25	9,856	6,094	83001, 83006	13.25	10,152	5,414

Table 5-3c

Nozzle ID and OD Hoop Stress (37.3° CEDM Case)

	Downhill Side				Uphill Side			
	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)
Nozzle Bottom	1,6	0.00	-21,720	8,662	80001, 80006	0.00	-21,649	8,228
	101, 106	0.71	-20,204	3,578	80101, 80106	1.40	-13,670	5,204
	201, 206	1.29	-14,720	-783	80201, 80206	2.53	-6,213	-9,409
	301, 306	1.75	-1,956	-1,308	80301, 80306	3.43	8,180	-23,672
	401, 406	2.11	16,399	12,150	80401, 80406	4.15	34,577	-28,583
	501, 506	2.41	40,405	39,036	80601, 80606	4.72	49,645	2,031
Weld Bottom	601, 606	2.64	47,124	76,908	80601, 80606	5.19	58,639	54,527
	701, 706	2.83	36,152	76,254	80701, 80706	5.41	59,131	62,522
	801, 806	3.01	32,445	68,504	80801, 80806	5.64	58,680	59,562
	901, 906	3.19	32,797	61,873	80901, 80906	5.87	53,922	62,670
	1001, 1006	3.37	41,979	57,358	81001, 81006	6.10	49,727	63,662
	1101, 1006	3.55	52,744	48,186	81101, 81006	6.32	49,750	61,110
	1201, 1206	3.73	58,467	43,436	81201, 81206	6.55	51,084	60,198
	1301, 1306	3.91	58,861	50,163	81301, 81306	6.78	52,822	65,136
Weld Top	1401, 1406	4.10	57,403	62,989	81401, 81406	7.01	55,618	62,193
	1501, 1506	4.22	55,518	44,049	81501, 81506	7.13	55,654	23,657
	1601, 1606	4.35	55,114	44,457	81601, 81606	7.25	56,801	8,756
	1701, 1706	4.56	51,281	24,372	81701, 81706	7.40	52,911	-1,366
	1801, 1806	4.80	42,494	1,711	81801, 81806	7.59	43,677	-2,531
	1901, 1906	5.08	33,491	-11,806	81901, 81906	7.81	21,045	-3,805
	2001, 2006	5.41	22,586	-13,038	82001, 82006	8.07	5,391	-3,994
	2101, 2106	5.79	12,425	-6,657	82101, 82106	8.39	1,257	-1,643
	2201, 2206	6.24	7,057	265	82201, 82206	8.78	8,155	4,599
	2301, 2306	6.76	7,150	3,946	82301, 82306	9.24	11,633	6,020
	2401, 2406	7.32	10,051	5,597	82401, 82406	9.79	13,107	5,072
	2501, 2506	8.08	12,328	5,695	82501, 82506	10.45	13,622	4,011
	2601, 2606	8.90	13,804	4,146	82601, 82606	11.24	13,703	3,670
	2701, 2706	9.87	14,126	-1,546	82701, 82706	12.19	13,118	4,008
	2801, 2806	10.99	9,715	-4,485	82801, 82806	13.32	11,707	4,881
	2901, 2906	13.05	11,816	5,864	82901, 82906	14.22	10,433	5,774
Nozzle Top	3001, 3006	15.11	8,353	6,051	83001, 83006	15.11	9,009	5,999

Table 5-3d

Nozzle ID and OD Hoop Stress (41.7° CEDM Case)

	Downhill Side				Uphill Side			
	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)
Nozzle Bottom	1,6	0.00	-25,960	10,640	80001, 80006	0.00	-25,164	10,236
	101, 106	0.68	-23,603	6,081	80101, 80106	1.51	-15,746	6,148
	201, 206	1.23	-17,937	2,231	80201, 80206	2.72	-4,466	-9,960
	301, 306	1.67	-7,239	-174	80301, 80306	3.69	10,642	-24,634
	401, 406	2.02	7,590	10,116	80401, 80406	4.47	37,454	-31,782
	501, 506	2.30	36,847	39,683	80601, 80606	5.09	49,648	-8,309
Weld Bottom	601, 606	2.53	49,159	72,462	80601, 80606	5.59	57,834	51,837
	701, 706	2.72	41,217	76,714	80701, 80706	5.83	60,318	59,758
	801, 806	2.92	34,355	68,829	80801, 80806	6.06	61,120	59,568
	901, 906	3.11	32,058	61,811	80901, 80906	6.29	57,580	63,342
	1001, 1006	3.30	40,250	56,136	81001, 81006	6.53	53,192	63,896
	1101, 1006	3.49	52,021	46,425	81101, 81006	6.76	51,978	61,717
	1201, 1206	3.69	58,685	41,412	81201, 81206	7.00	52,314	62,074
	1301, 1306	3.88	59,216	47,627	81301, 81306	7.23	53,345	65,947
Weld Top	1401, 1406	4.07	57,030	58,868	81401, 81406	7.47	55,879	60,149
	1501, 1506	4.20	54,800	40,774	81501, 81506	7.59	55,281	20,318
	1601, 1606	4.33	54,620	44,656	81601, 81606	7.71	55,962	8,307
	1701, 1706	4.55	50,877	23,977	81701, 81706	7.87	51,539	-5,279
	1801, 1806	4.81	43,141	-2,007	81801, 81806	8.06	40,706	-3,447
	1901, 1906	5.11	34,546	-13,909	81901, 81906	8.29	17,622	-4,569
	2001, 2006	5.47	24,911	-14,875	82001, 82006	8.57	3,990	-4,197
	2101, 2106	5.88	15,138	-7,595	82101, 82106	8.91	3,317	-274
	2201, 2206	6.36	8,025	-371	82201, 82206	9.31	9,758	4,897
	2301, 2306	6.92	8,445	4,096	82301, 82306	9.80	12,727	5,491
	2401, 2406	7.58	10,342	5,409	82401, 82406	10.39	13,888	4,372
	2501, 2506	8.34	12,438	5,117	82501, 82506	11.09	14,269	3,492
	2601, 2606	9.23	14,703	3,707	82601, 82606	11.94	14,127	3,399
	2701, 2706	10.27	14,771	-3,195	82701, 82706	12.95	13,154	3,948
	2801, 2806	11.48	10,783	-4,780	82801, 82806	14.18	11,410	5,027
	2901, 2906	13.72	11,863	6,007	82901, 82906	15.07	10,082	6,010
Nozzle Top	3001, 3006	15.97	7,842	6,042	83001, 83006	15.97	8,608	6,284

Table 5-3e

Nozzle ID and OD Hoop Stress (54.4° ICI Case)

	Downhill Side				Uphill Side			
	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)	Nodes	Axial Height	ID Hoop Stress (psi)	OD Hoop Stress (psi)
Nozzle Bottom	1,6	0.00	-36,916	7,821	80001, 80006	0.00	-27,156	12,641
	101, 106	0.63	-30,772	15,813	80101, 80106	4.36	8,008	-15,471
	201, 206	1.03	-23,982	26,419	80201, 80206	7.11	34,765	-29,941
	301, 306	1.28	-5,449	40,816	80301, 80306	8.85	43,158	-32,165
	401, 406	1.44	7,588	53,593	80401, 80406	9.94	47,302	-16,755
	501, 506	1.54	19,331	59,160	80601, 80606	10.63	49,258	33,837
Weld Bottom	601, 606	1.61	26,011	54,149	80601, 80606	11.07	50,524	40,326
	701, 706	1.94	35,620	80,253	80701, 80706	11.30	50,958	52,310
	801, 806	2.28	26,924	76,724	80801, 80806	11.54	50,530	61,800
	901, 906	2.62	25,784	65,450	80901, 80906	11.77	50,500	66,752
	1001, 1006	2.96	34,809	50,187	81001, 81006	12.01	51,251	67,792
	1101, 1006	3.30	51,801	34,935	81101, 81006	12.24	50,708	65,477
	1201, 1206	3.64	60,492	36,994	81201, 81206	12.48	50,029	68,003
	1301, 1306	3.97	58,846	44,823	81301, 81306	12.72	47,568	59,801
Weld Top	1401, 1406	4.31	53,938	42,239	81401, 81406	12.95	44,802	41,547
	1501, 1506	4.45	51,179	47,693	81501, 81506	13.06	43,308	14,394
	1601, 1606	4.59	51,670	38,255	81601, 81606	13.17	42,358	16,593
	1701, 1706	4.93	48,043	27,121	81701, 81706	13.40	39,068	-6,350
	1801, 1806	5.33	43,578	7,154	81801, 81806	13.68	31,396	-4,210
	1901, 1906	5.80	39,374	-6,450	81901, 81906	14.02	19,821	-8,090
	2001, 2006	6.35	35,573	-14,629	82001, 82006	14.43	16,494	-5,444
	2101, 2106	6.99	29,445	-17,368	82101, 82106	14.92	16,799	-2,197
	2201, 2206	7.74	22,037	-12,178	82201, 82206	15.52	17,446	19
	2301, 2306	8.61	17,655	-5,941	82301, 82306	16.25	17,769	1,399
	2401, 2406	9.63	13,430	-679	82401, 82406	17.12	17,252	2,190
	2501, 2506	10.82	13,721	2,313	82501, 82506	18.18	15,955	2,840
	2601, 2606	12.22	16,193	-338	82601, 82606	19.47	14,063	3,659
	2701, 2706	13.85	13,444	-2,253	82701, 82706	21.02	12,015	4,737
	2801, 2806	15.75	7,510	-6,247	82801, 82806	22.90	10,235	5,993
	2901, 2906	21.09	10,495	8,050	82901, 82906	24.66	9,002	7,005
Nozzle Top	3001, 3006	26.43	7,328	6,423	83001, 83006	26.43	7,782	7,353

Table 5-4

Change in Inner Diameter at Selected Axial Locations

		Location 2 0.5" Below Downhill Weld Bottom		Location 3 Downhill Weld Bottom		Location 4 Downhill Weld Top		Location "X" Uphill Weld Bottom	
	Circ Location	Radial Deflection (mils)	Change in Diameter (mils)	Radial Deflection (mils)	Change in Diameter (mils)	Radial Deflection (mils)	Change in Diameter (mils)	Radial Deflection (mils)	Change in Diameter (mils)
Downhill	-90.0	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
	-67.5	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
	-45.0	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
	-22.5	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
0° Nozzle	0.0	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
	22.5	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
	45.0	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
	67.5	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
Uphill	90.0	2.77	5.54	9.46	18.92	5.77	11.54	9.46	18.92
Downhill	-90.0	19.99	0.86	23.62	4.39	7.01	5.09	5.54	4.95
	-67.5	18.43	0.78	22.03	4.45	8.88	9.89	7.37	9.79
	-45.0	14.19	0.77	17.41	4.45	13.26	21.70	12.14	21.70
	-22.5	7.67	0.55	10.67	5.01	17.72	33.72	16.89	33.54
24.6° Nozzle	0.0	0.24	0.48	2.52	5.04	19.83	39.66	19.86	39.72
	22.5	-7.12	0.55	-5.66	5.01	16.00	33.72	16.65	33.54
	45.0	-13.42	0.77	-12.96	4.45	8.44	21.70	9.56	21.70
	67.5	-17.65	0.78	-17.58	4.45	1.01	9.89	2.42	9.79
Uphill	90.0	-19.13	0.86	-19.23	4.39	-1.92	5.09	-0.59	4.95
Downhill	-90.0	26.68	1.97	29.25	4.31	8.05	-15.21	-4.26	-8.60
	-67.5	24.43	1.53	27.00	4.07	10.81	-8.92	-3.75	-3.21
	-45.0	18.36	0.62	20.79	3.60	16.39	7.32	-1.92	8.96
	-22.5	9.53	-0.44	11.71	3.05	20.91	25.71	2.85	20.32
37.3° Nozzle	0.0	-0.26	-0.52	1.26	2.52	17.09	34.18	12.77	25.54
	22.5	-9.97	-0.44	-8.66	3.05	4.80	25.71	17.47	20.32
	45.0	-17.74	0.62	-17.19	3.60	-9.07	7.32	10.88	8.96
	67.5	-22.90	1.53	-22.93	4.07	-19.73	-8.92	0.54	-3.21
Uphill	90.0	-24.71	1.97	-24.94	4.31	-23.26	-15.21	-4.34	-8.60
Downhill	-90.0	30.14	2.31	31.68	3.95	8.48	-18.02	-4.40	-9.52
	-67.5	27.60	1.75	29.08	3.47	11.50	-11.37	-4.04	-3.67
	-45.0	20.47	0.32	22.05	2.45	17.48	4.45	-2.77	8.77
	-22.5	10.53	-0.91	12.08	1.84	21.61	23.49	-0.06	16.49
41.7° Nozzle	0.0	-0.82	-1.64	0.70	1.40	16.07	32.14	9.02	18.04
	22.5	-11.44	-0.91	-10.24	1.84	1.88	23.49	16.55	16.49
	45.0	-20.15	0.32	-19.60	2.45	-13.03	4.45	11.54	8.77
	67.5	-25.85	1.75	-25.61	3.47	-22.87	-11.37	0.37	-3.67
Uphill	90.0	-27.83	2.31	-27.73	3.95	-26.50	-18.02	-5.12	-9.52
Downhill	-90.0	48.38	13.32	48.03	13.19	13.23	-20.44	-0.27	6.21
	-67.5	42.65	9.32	42.39	9.52	17.70	-12.59	-0.38	9.45
	-45.0	28.52	0.57	29.00	2.08	25.70	5.24	-0.87	8.66
	-22.5	11.33	-7.26	12.44	-4.59	24.37	18.40	-1.33	-1.08
54.4° ICI	0.0	-5.18	-10.36	-3.53	-7.06	9.84	19.68	-1.47	-2.94
	22.5	-18.59	-7.26	-17.03	-4.59	-5.97	18.40	0.25	-1.08
	45.0	-27.95	0.57	-26.92	2.08	-20.46	5.24	9.53	8.66
	67.5	-33.33	9.32	-32.87	9.52	-30.29	-12.59	9.83	9.45
Uphill	90.0	-35.06	13.32	-34.84	13.19	-33.67	-20.44	6.48	6.21

Table 5-5

Force in Gap Elements in Interference Region

Nozzle Angle	Downhill -90°		-67.5°		-45°		-22.5°		0°		22.5°		45°		67.5°		Uphill 90°	
	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)	Axial height	Gap Force (lbf)
0.0 (CEDM)	4.43	0.00	4.43	0.00	4.43	0.00	4.43	0.00	4.43	0.00	4.43	0.00	4.43	0.00	4.43	0.00	4.43	0.00
0.0 (CEDM)	4.62	0.00	4.62	0.00	4.62	0.00	4.62	0.00	4.62	0.00	4.62	0.00	4.62	0.00	4.62	0.00	4.62	0.00
0.0 (CEDM)	4.85	0.00	4.85	0.00	4.85	0.00	4.85	0.00	4.85	0.00	4.85	0.00	4.85	0.00	4.85	0.00	4.85	0.00
0.0 (CEDM)	5.11	0.00	5.11	0.00	5.11	0.00	5.11	0.00	5.11	0.00	5.11	0.00	5.11	0.00	5.11	0.00	5.11	0.00
0.0 (CEDM)	5.41	0.00	5.41	0.00	5.41	0.00	5.41	0.00	5.41	0.00	5.41	0.00	5.41	0.00	5.41	0.00	5.41	0.00
0.0 (CEDM)	5.77	0.00	5.77	0.00	5.77	0.00	5.77	0.00	5.77	0.00	5.77	0.00	5.77	0.00	5.77	0.00	5.77	0.00
0.0 (CEDM)	6.17	0.00	6.17	0.00	6.17	0.00	6.17	0.00	6.17	0.00	6.17	0.00	6.17	0.00	6.17	0.00	6.17	0.00
0.0 (CEDM)	6.64	0.00	6.64	0.00	6.64	0.00	6.64	0.00	6.64	0.00	6.64	0.00	6.64	0.00	6.64	0.00	6.64	0.00
0.0 (CEDM)	7.18	0.00	7.18	0.00	7.18	0.00	7.18	0.00	7.18	0.00	7.18	0.00	7.18	0.00	7.18	0.00	7.18	0.00
0.0 (CEDM)	7.81	0.00	7.81	0.00	7.81	0.00	7.81	0.00	7.81	0.00	7.81	0.00	7.81	0.00	7.81	0.00	7.81	0.00
0.0 (CEDM)	8.54	0.00	8.54	0.00	8.54	0.00	8.54	0.00	8.54	0.00	8.54	0.00	8.54	0.00	8.54	0.00	8.54	0.00
0.0 (CEDM)	9.39	0.00	9.39	0.00	9.39	0.00	9.39	0.00	9.39	0.00	9.39	0.00	9.39	0.00	9.39	0.00	9.39	0.00
24.6 (CEDM)	6.23	0.00	6.23	0.00	6.23	0.00	6.23	0.00	6.23	0.00	6.23	0.00	6.23	0.00	6.23	0.00	6.31	0.00
24.6 (CEDM)	6.48	0.00	6.53	0.00	6.69	0.00	6.50	0.00	6.44	0.00	6.43	0.00	6.44	0.00	6.41	0.00	6.48	0.00
24.6 (CEDM)	6.99	0.00	7.04	0.00	7.20	0.00	6.93	0.00	6.80	0.00	6.73	0.00	6.69	0.00	6.62	0.00	6.69	0.00
24.6 (CEDM)	7.59	0.00	7.64	0.00	7.79	0.00	7.44	0.00	7.22	0.00	7.09	0.00	6.99	0.00	6.86	0.00	6.93	0.00
24.6 (CEDM)	8.29	0.00	8.33	0.00	8.49	0.00	8.03	0.00	7.72	0.00	7.51	0.00	7.34	0.00	7.16	0.00	7.22	0.00
24.6 (CEDM)	9.10	-45.67	9.15	0.00	9.30	0.00	8.72	0.00	8.31	0.00	8.00	0.00	7.75	0.00	7.50	0.00	7.56	0.00
24.6 (CEDM)	10.04	-601.78	10.09	-1156.90	10.25	-812.31	9.53	0.00	9.00	0.00	8.59	0.00	8.24	0.00	7.91	0.00	7.97	0.00
24.6 (CEDM)	---	---	---	---	---	---	10.49	0.00	9.81	0.00	9.27	0.00	8.82	0.00	8.40	0.00	8.45	0.00
24.6 (CEDM)	---	---	---	---	---	---	---	---	10.76	0.00	10.08	0.00	9.50	0.00	8.97	0.00	9.03	0.00
24.6 (CEDM)	---	---	---	---	---	---	---	---	---	---	11.04	0.00	10.31	0.00	9.66	0.00	9.71	0.00
24.6 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	11.27	0.00	10.47	0.00	10.52	0.00
24.6 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	11.42	0.00	11.48	0.00
37.3 (CEDM)	7.32	0.00	7.32	0.00	7.32	0.00	7.32	0.00	7.32	0.00	7.32	0.00	7.32	0.00	7.32	0.00	7.40	0.00
37.3 (CEDM)	8.08	0.00	8.16	0.00	7.71	0.00	8.11	0.00	8.00	0.00	7.59	0.00	7.67	0.00	7.46	0.00	7.59	0.00
37.3 (CEDM)	8.90	0.00	8.98	0.00	8.41	0.00	8.80	0.00	8.58	0.00	7.99	0.00	8.01	0.00	7.69	0.00	7.81	0.00
37.3 (CEDM)	9.87	-273.55	9.95	-521.55	9.24	0.00	9.62	0.00	9.26	0.00	8.47	0.00	8.40	0.00	7.96	0.00	8.07	0.00
37.3 (CEDM)	10.99	-723.32	11.08	-1415.90	10.20	-103.36	10.58	0.00	10.07	0.00	9.04	0.00	8.87	0.00	8.29	0.00	8.39	0.00
37.3 (CEDM)	---	---	---	---	11.34	-1120.70	11.72	0.00	11.03	0.00	9.72	0.00	9.44	0.00	8.68	0.00	8.78	0.00
37.3 (CEDM)	---	---	---	---	---	---	---	---	12.17	0.00	10.52	0.00	10.11	0.00	9.14	0.00	9.24	0.00
37.3 (CEDM)	---	---	---	---	---	---	---	---	---	---	11.48	0.00	10.90	0.00	9.70	0.00	9.79	0.00
37.3 (CEDM)	---	---	---	---	---	---	---	---	---	---	12.61	0.00	11.85	0.00	10.36	0.00	10.45	0.00
37.3 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	12.99	0.00	11.15	0.00	11.24	0.00
37.3 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12.10	0.00	12.19	0.00
37.3 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13.24	0.00	13.32	0.00
41.7 (CEDM)	7.78	0.00	7.78	0.00	7.78	0.00	7.78	0.00	7.78	0.00	7.78	0.00	7.78	0.00	7.78	0.00	7.87	0.00
41.7 (CEDM)	8.34	0.00	8.43	0.00	8.73	0.00	8.44	0.00	8.36	0.00	7.98	0.00	8.11	0.00	7.92	0.00	8.06	0.00
41.7 (CEDM)	9.23	0.00	9.32	0.00	9.62	0.00	9.18	0.00	8.98	0.00	8.40	0.00	8.46	0.00	8.16	0.00	8.29	0.00
41.7 (CEDM)	10.27	-408.37	10.37	-727.72	10.66	-219.87	10.06	0.00	9.72	0.00	8.92	0.00	8.88	0.00	8.44	0.00	8.57	0.00
41.7 (CEDM)	11.48	-754.17	11.59	-1432.70	11.89	-1028.60	11.10	0.00	10.59	0.00	9.52	0.00	9.38	0.00	8.79	0.00	8.91	0.00
41.7 (CEDM)	---	---	---	---	---	---	12.33	0.00	11.62	0.00	10.25	0.00	9.98	0.00	9.20	0.00	9.31	0.00
41.7 (CEDM)	---	---	---	---	---	---	---	---	12.85	0.00	11.11	0.00	10.70	0.00	9.69	0.00	9.80	0.00
41.7 (CEDM)	---	---	---	---	---	---	---	---	---	---	12.14	0.00	11.55	0.00	10.28	0.00	10.39	0.00
41.7 (CEDM)	---	---	---	---	---	---	---	---	---	---	13.36	0.00	12.57	0.00	10.99	0.00	11.09	0.00
41.7 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	13.79	0.00	11.84	0.00	11.94	0.00
41.7 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12.86	0.00	12.95	0.00
41.7 (CEDM)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	14.08	0.00	14.18	0.00
54.4 (ICI)	13.26	-677.68	13.26	0.00	13.26	0.00	13.26	0.00	13.26	0.00	13.26	0.00	13.26	0.00	13.26	0.00	13.40	0.00
54.4 (ICI)	15.75	-4234.60	14.11	-4181.60	14.92	-4711.00	14.53	-372.24	14.63	0.00	14.05	0.00	13.90	0.00	13.43	0.00	13.68	0.00
54.4 (ICI)	---	---	16.04	-4884.80	16.86	-5805.20	16.15	-1126.30	15.97	0.00	14.96	0.00	14.51	0.00	13.77	0.00	14.02	0.00
54.4 (ICI)	---	---	---	---	---	---	18.06	-2147.30	17.55	0.00	16.06	0.00	15.26	0.00	14.19	0.00	14.43	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	19.45	0.00	17.36	0.00	16.15	0.00	14.69	0.00	14.92	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	18.93	0.00	17.22	0.00	15.29	0.00	15.52	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	20.80	0.00	18.51	0.00	16.02	0.00	16.25	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	---	---	20.06	0.00	16.90	0.00	17.12	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	---	---	21.91	0.00	17.97	0.00	18.18	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	19.24	0.00	19.47	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	20.79	0.00	21.02	0.00
54.4 (ICI)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	22.65	0.00	22.90	0.00

Table 5-6

Additional Through-Wall Data Post-Processing for Selected Nozzles

Nozzle Angle	Percent Through Wall	Downhill Side Hoop Stress (psi)			Uphill Side Hoop Stress (psi)		
		1.07" Above Top of Uphill Weld	1.90" Above Top of Uphill Weld	2.86" Above Top of Uphill Weld	1.07" Above Top of Uphill Weld	1.39" Above Top of Uphill Weld	2.23" Above Top of Uphill Weld
37.3 (CEDM)	ID	12,328	13,804	14,126	5,391	1,257	11,633
37.3 (CEDM)	20%	10,520	11,401	10,027	3,634	328	10,081
37.3 (CEDM)	40%	9,159	9,356	6,858	1,418	-292	8,904
37.3 (CEDM)	60%	7,927	7,486	3,954	-885	-865	7,859
37.3 (CEDM)	80%	6,791	5,728	1,201	-3,014	-1,340	6,928
37.3 (CEDM)	OD	5,695	4,146	-1,546	-3,994	-1,643	6,020

Nozzle Angle	Percent Through Wall	Downhill Side Hoop Stress (psi)			Uphill Side Hoop Stress (psi)		
		0.87" Above Top of Uphill Weld	1.76" Above Top of Uphill Weld	2.80" Above Top of Uphill Weld	1.10" Above Top of Uphill Weld	1.44" Above Top of Uphill Weld	2.33" Above Top of Uphill Weld
41.7 (CEDM)	ID	12,438	14,703	14,771	3,990	3,317	12,727
41.7 (CEDM)	20%	10,482	11,936	10,115	2,296	2,433	10,779
41.7 (CEDM)	40%	9,000	9,611	6,489	284	1,620	9,265
41.7 (CEDM)	60%	7,649	7,492	3,152	-1,699	847	7,907
41.7 (CEDM)	80%	6,387	5,504	-29	-3,472	190	6,685
41.7 (CEDM)	OD	5,117	3,707	-3,195	-4,197	-274	5,491

Note: Nozzle yield strength at 600°F operating temperature is 39.3 ksi.

Table 5-7

Hoop Stresses Along Penetration Path Line (54.4° ICI Case)

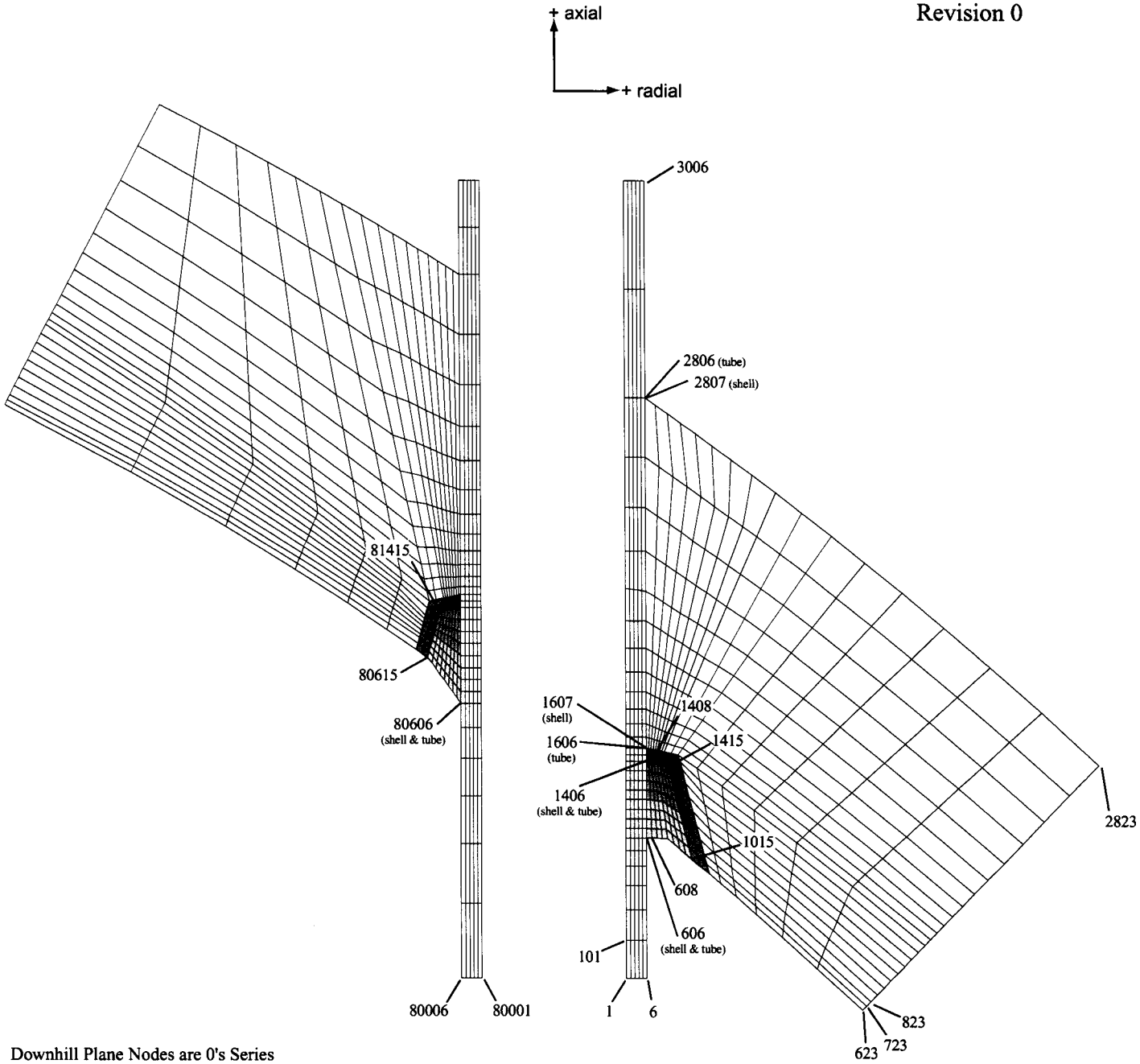
	Downhill Side				Uphill Side			
	Node	Radial Loc.	Axial Loc.	Hoop Stress (psi)	Node	Radial Loc.	Axial Loc.	Hoop Stress (psi)
Weld Bottom	608	3.43	34.82	66,741	80608	3.40	44.47	38,600
	708	3.42	35.15	90,681	80708	3.39	44.69	47,956
	808	3.42	35.49	85,905	80808	3.39	44.90	45,068
	908	3.42	35.83	71,118	80908	3.38	45.11	47,311
	1008	3.42	36.16	56,691	81008	3.38	45.32	46,072
	1108	3.42	36.50	47,788	81108	3.38	45.53	50,953
	1208	3.42	36.84	36,735	81208	3.37	45.75	53,568
	1308	3.42	37.17	51,412	81308	3.37	45.96	48,249
Weld Top	1408	3.42	37.51	38,936	81408	3.37	46.17	60,489
	1508	3.44	37.64	45,567	81508	3.38	46.28	60,018
	1608	3.46	37.77	40,644	81608	3.39	46.39	44,797
	1708	3.45	38.11	48,861	81708	3.39	46.65	44,090
	1808	3.44	38.44	48,425	81808	3.39	46.91	44,223
	1908	3.46	38.89	26,196	81908	3.40	47.25	15,859
	2008	3.47	39.41	18,511	82008	3.40	47.67	15,884
	2108	3.49	40.03	15,571	82108	3.41	48.17	17,189
	2208	3.51	40.74	14,608	82208	3.41	48.78	18,750
	2308	3.54	41.58	14,957	82308	3.42	49.52	19,801
	2408	3.57	42.55	16,155	82408	3.43	50.42	20,301
	2508	3.60	43.69	17,389	82508	3.45	51.50	20,478
	2608	3.64	45.03	21,037	82608	3.46	52.81	19,930
	2708	3.69	46.07	24,922	82708	3.48	54.40	18,232

Radial and Axial nodal locations given in cylindrical coordinate system centered on the nozzle.

Table 5-8

Hoop Stresses Along Downhill Weld Wetted Surface

	Hoop stress (psi)			
	Node	37.3° CEDM	41.7° CEDM	54.4° ICI
Tube/Weld	606	76,908	72,462	54,149
	608	68,923	68,045	66,741
	609	75,774	76,830	73,238
	610	60,265	58,507	51,235
	611	59,898	57,677	47,526
	612	57,955	57,711	55,746
	613	46,719	40,358	26,208
	614	39,334	38,613	37,939
Weld/Butter	615	41,988	39,706	42,574
	616	26,211	28,450	24,502
Butter/Head	617	10,027	14,135	18,907



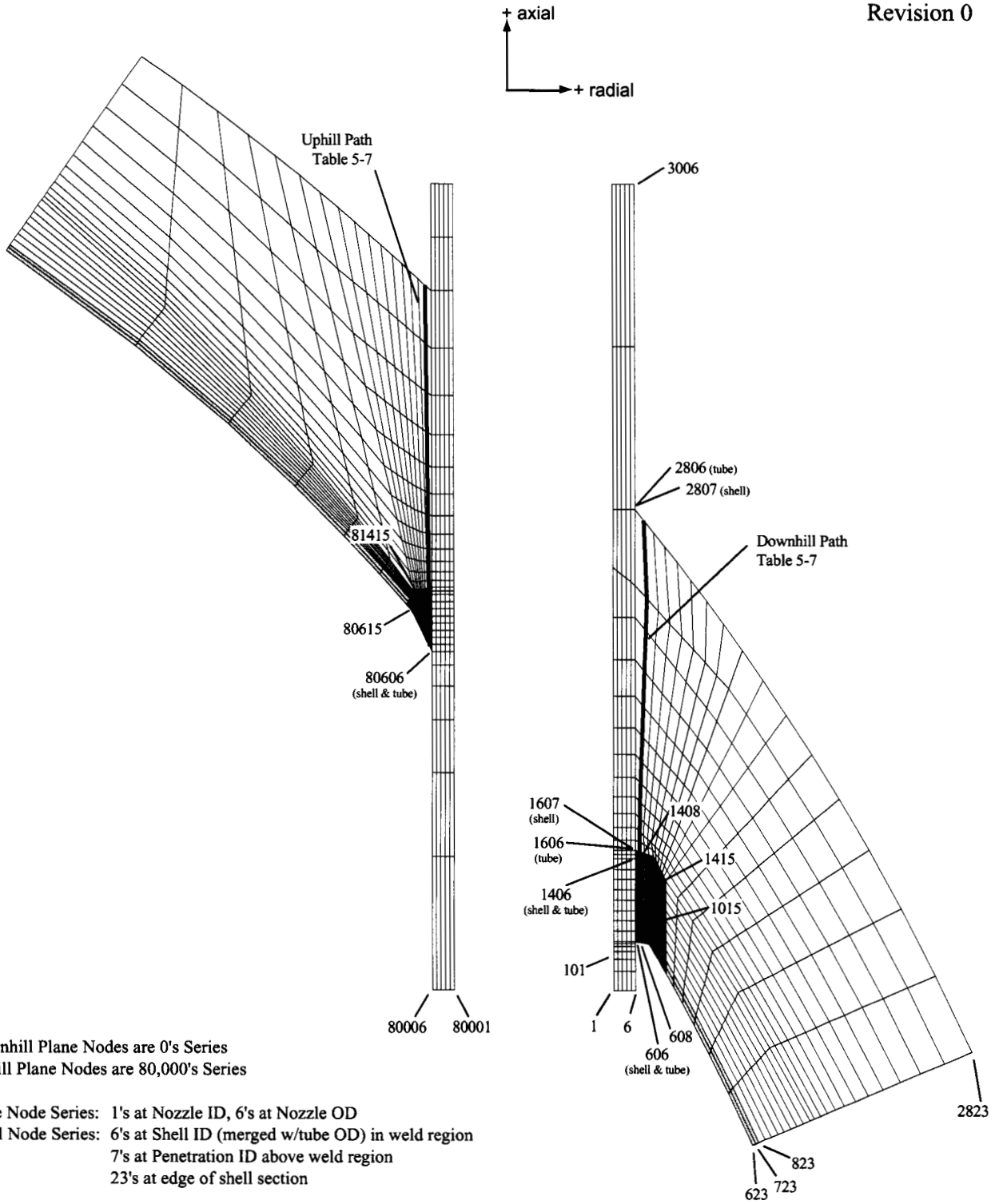
Downhill Plane Nodes are 0's Series
Uphill Plane Nodes are 80,000's Series

Tube Node Series: 1's at Nozzle ID, 6's at Nozzle OD
Shell Node Series: 6's at Shell ID (merged w/tube OD) in weld region
7's at Penetration ID above weld region
23's at edge of shell section

Node Numbers Increase by 100 up the length of the nozzle and shell
Node Numbers Increase by 1 radially through nozzle wall and out to shell edge

CEDM Nozzle Node Numbering Scheme

Figure 5-1



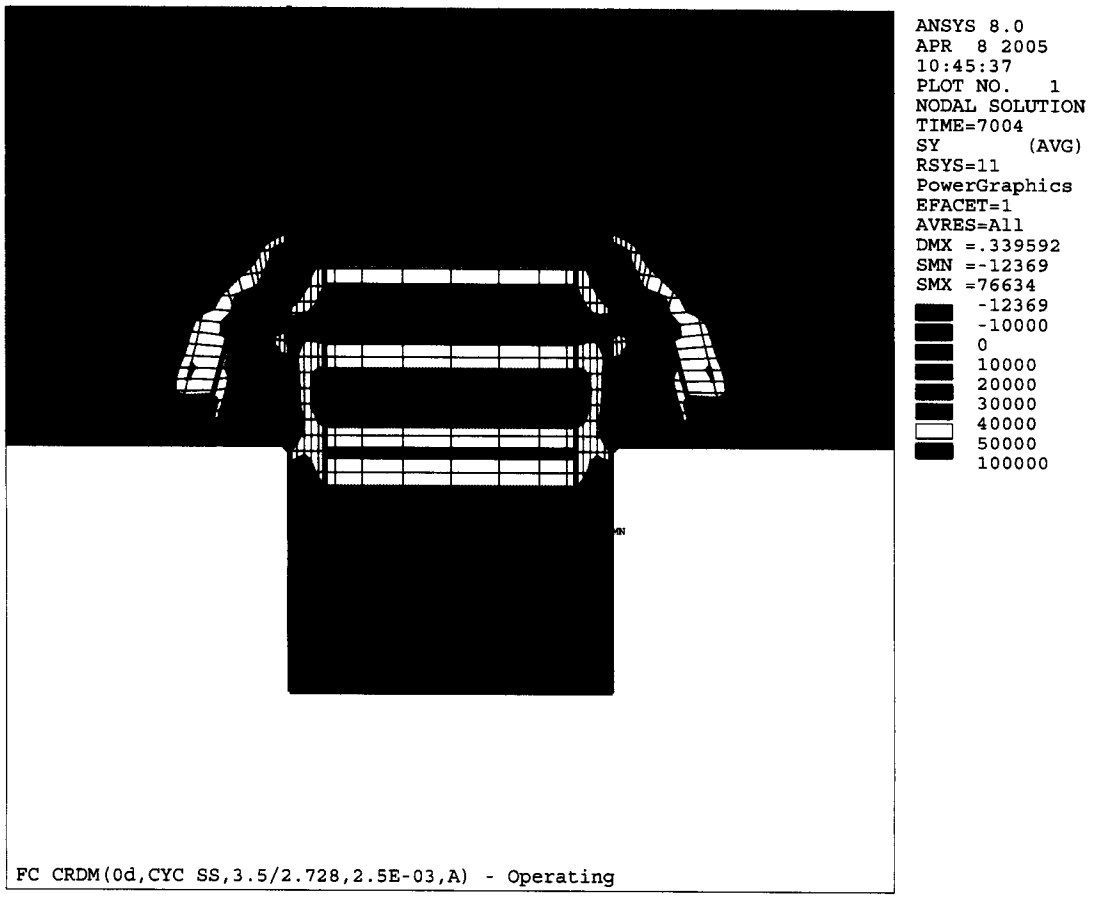
Downhill Plane Nodes are 0's Series
Uphill Plane Nodes are 80,000's Series

Tube Node Series: 1's at Nozzle ID, 6's at Nozzle OD
Shell Node Series: 6's at Shell ID (merged w/tube OD) in weld region
7's at Penetration ID above weld region
23's at edge of shell section

Node Numbers Increase by 100 up the length of the nozzle and shell
Node Numbers Increase by 1 radially through nozzle wall and out to shell edge

ICI Nozzle Node Numbering Scheme

Figure 5-2



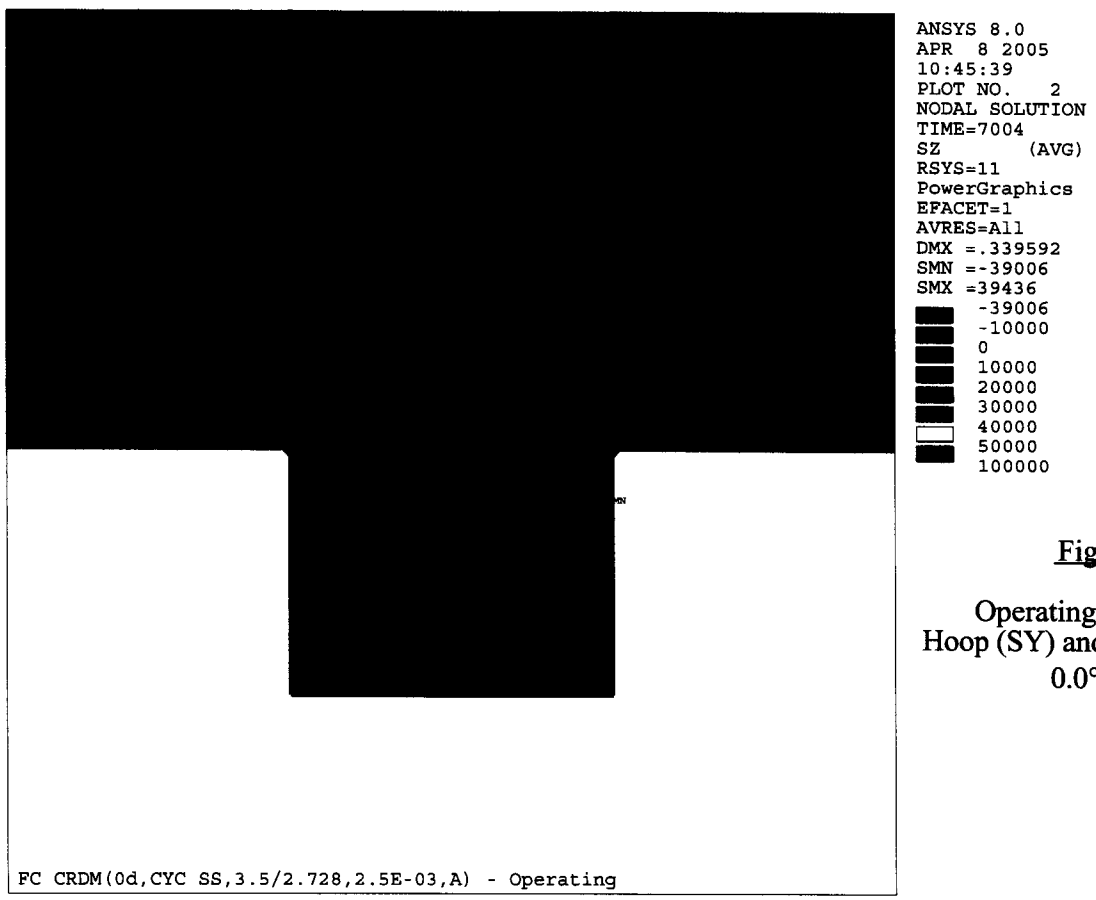
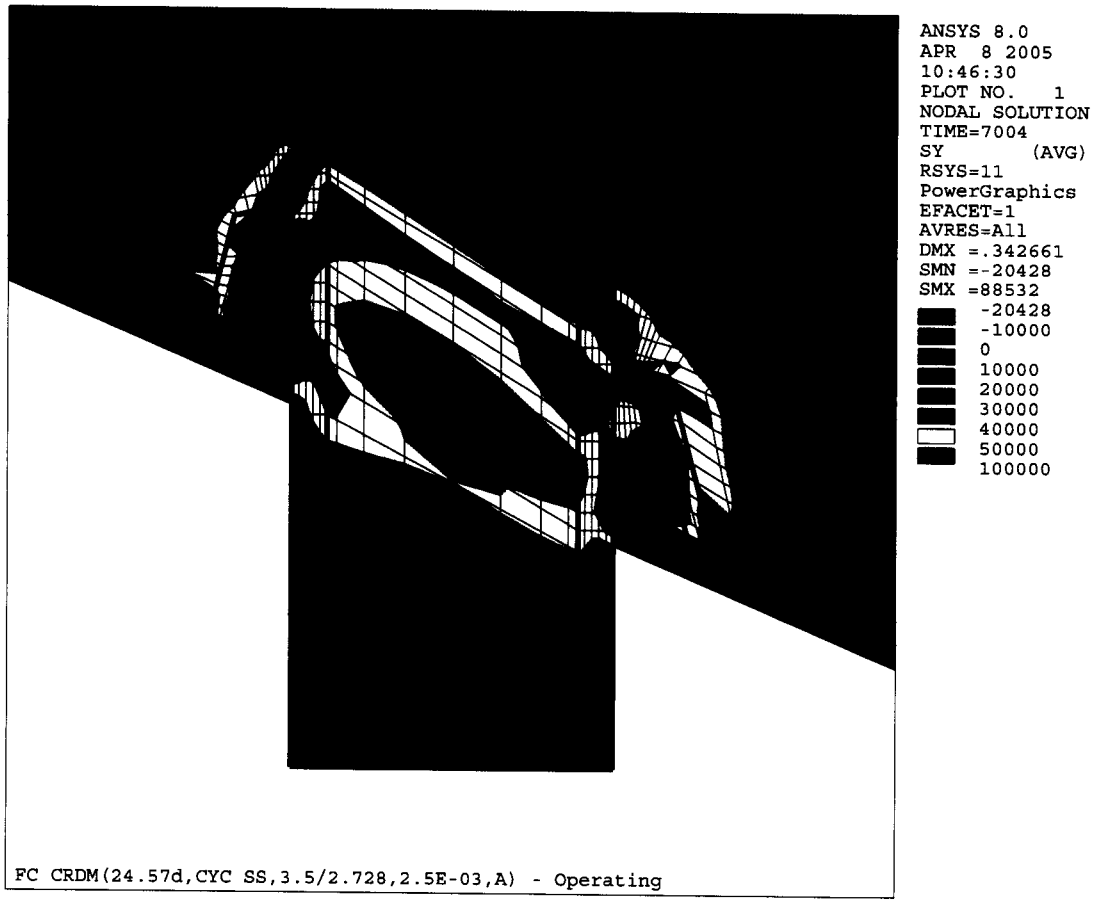


Figure 5-3

Operating plus Residual
Hoop (SY) and Axial (SZ) Stress
0.0° CEDM



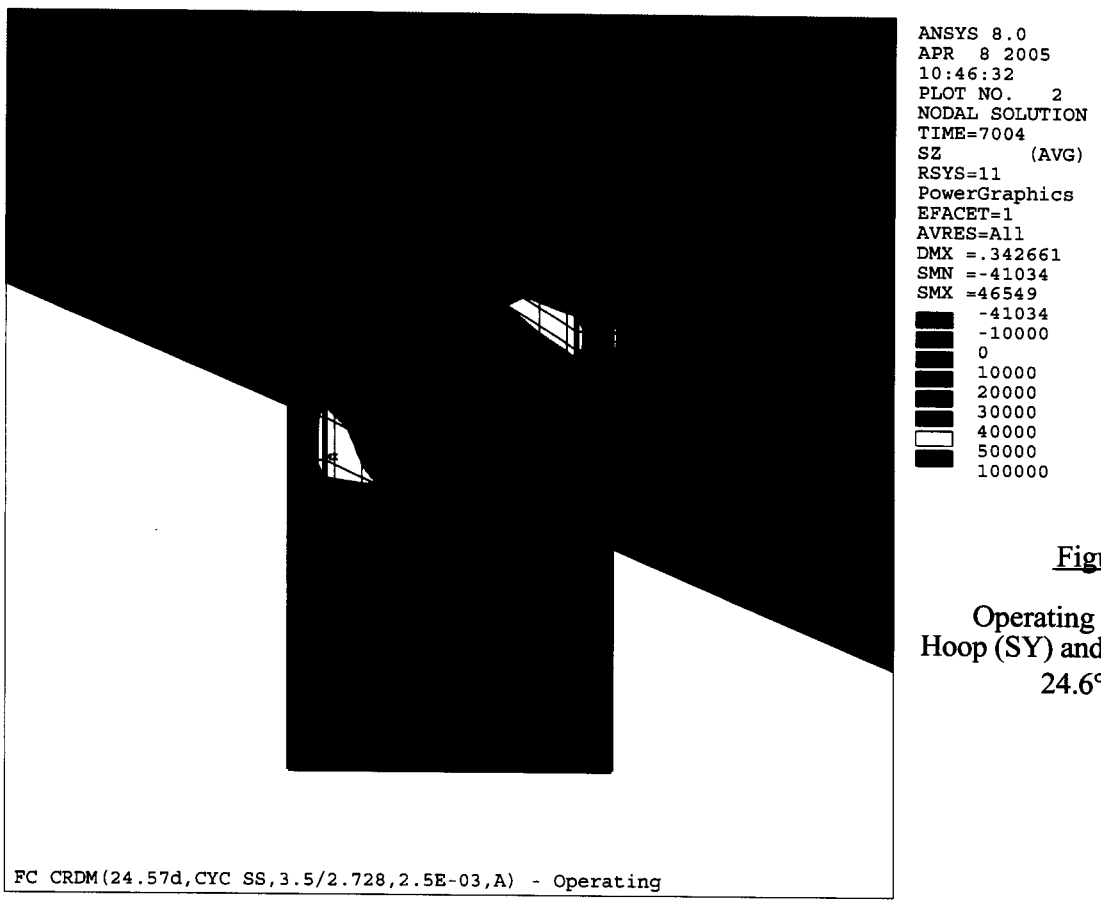
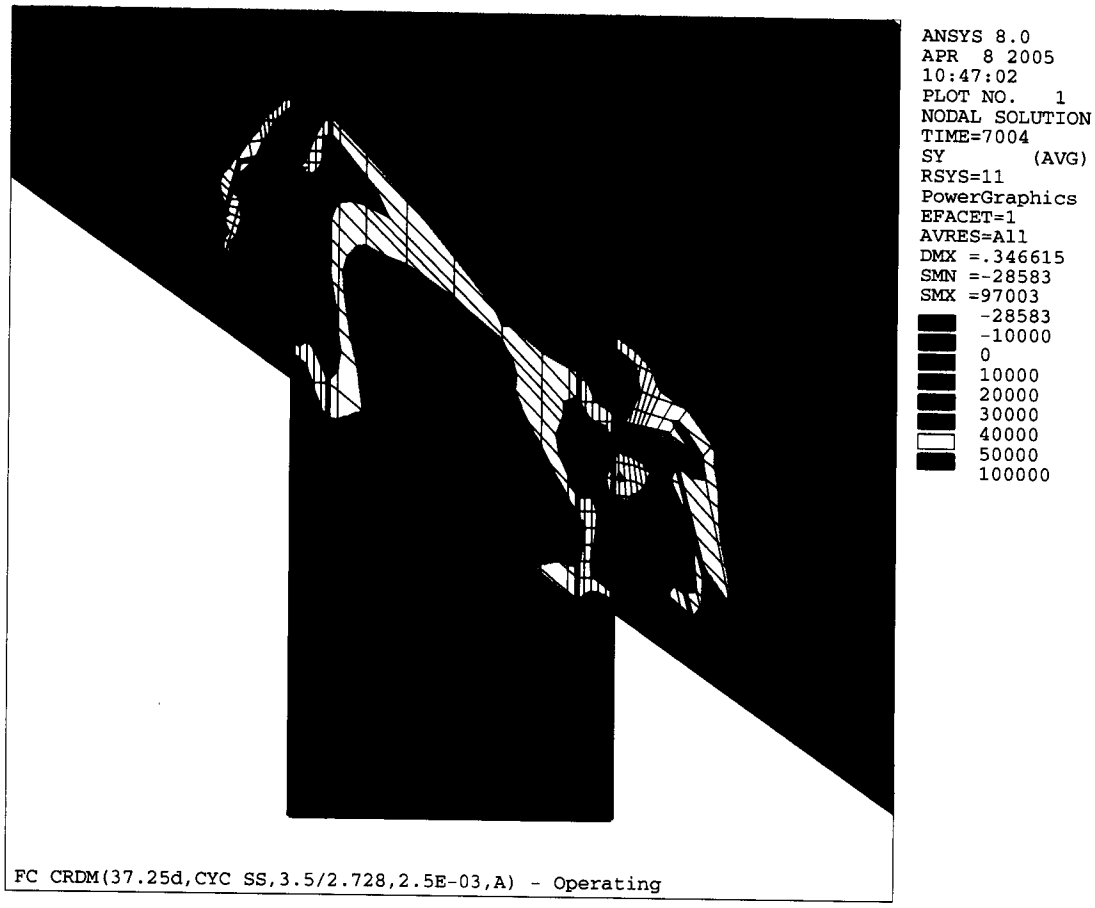


Figure 5-4

Operating plus Residual
Hoop (SY) and Axial (SZ) Stress
24.6° CEDM



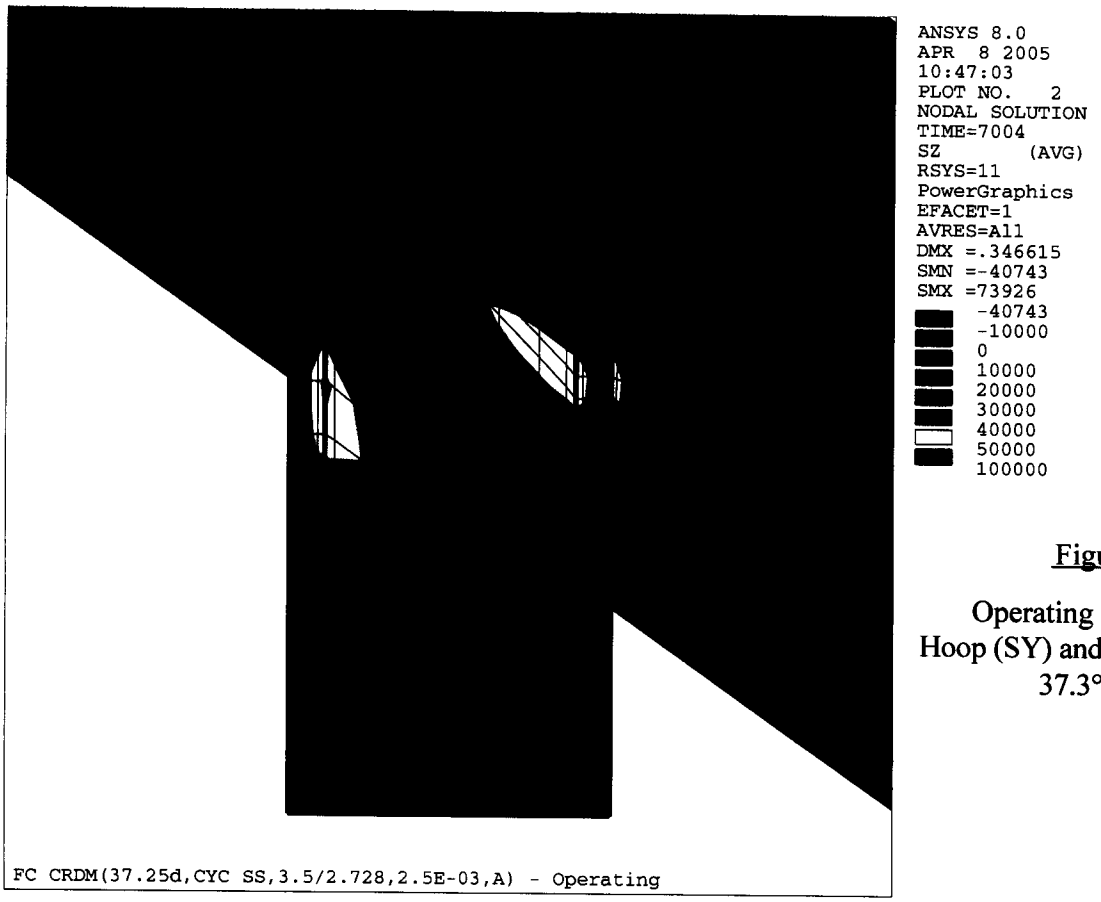
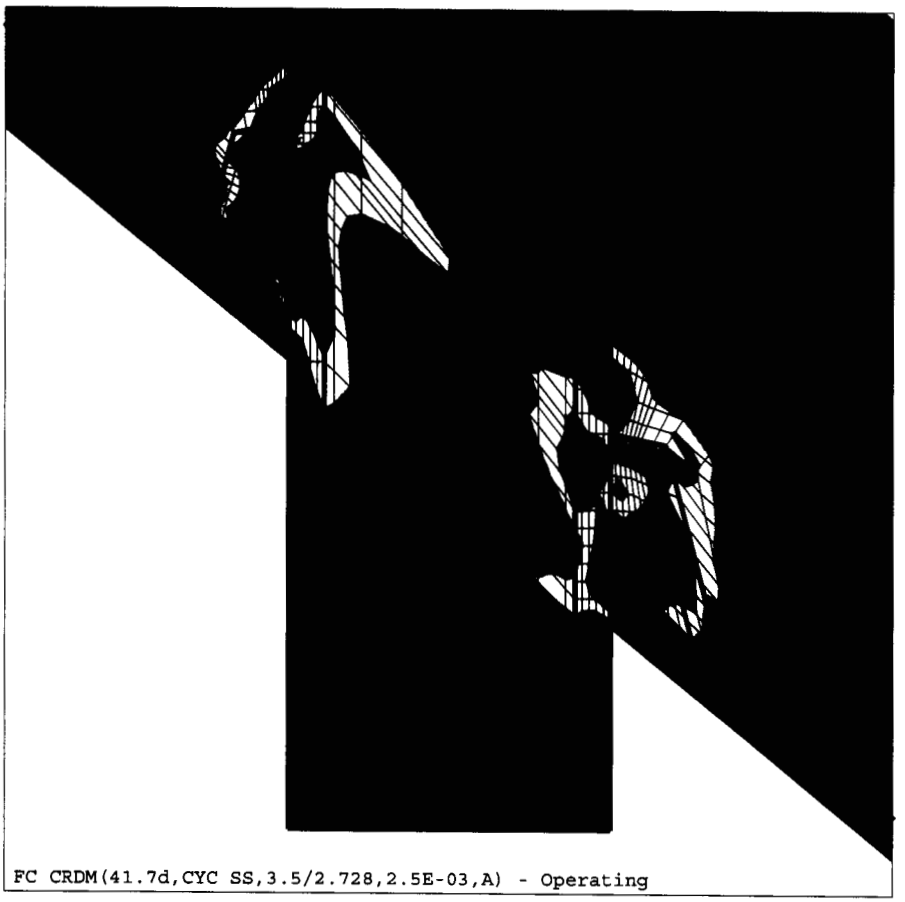


Figure 5-5

Operating plus Residual
Hoop (SY) and Axial (SZ) Stress
37.3° CEDM



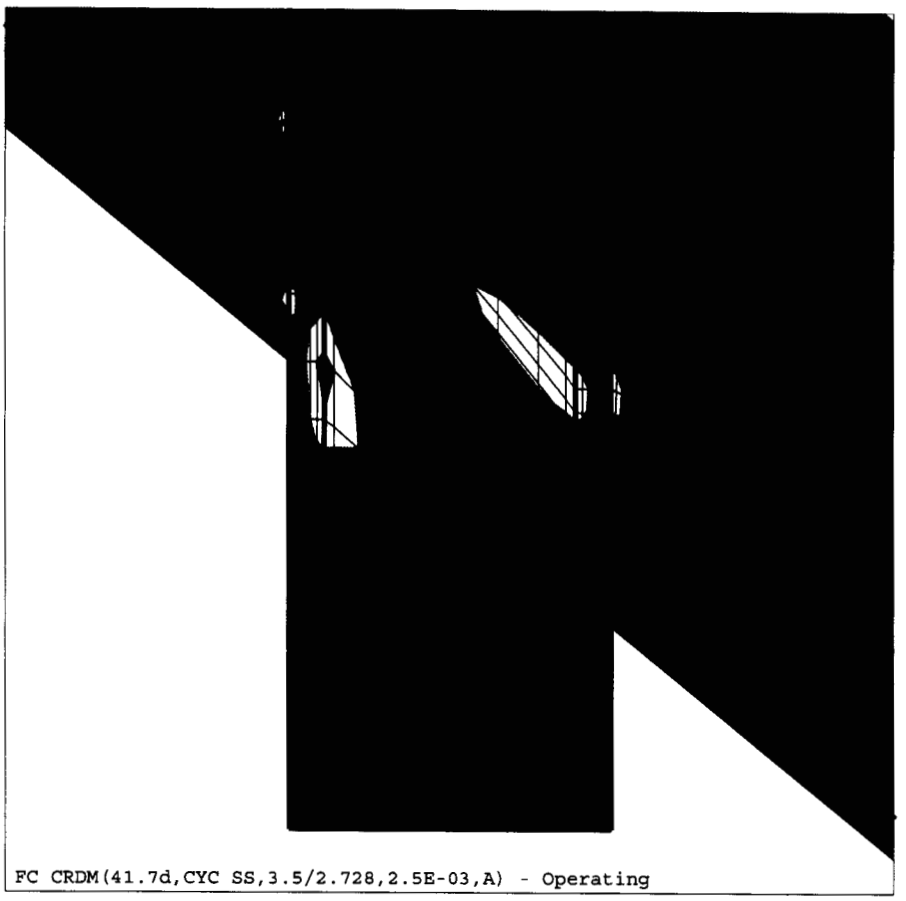
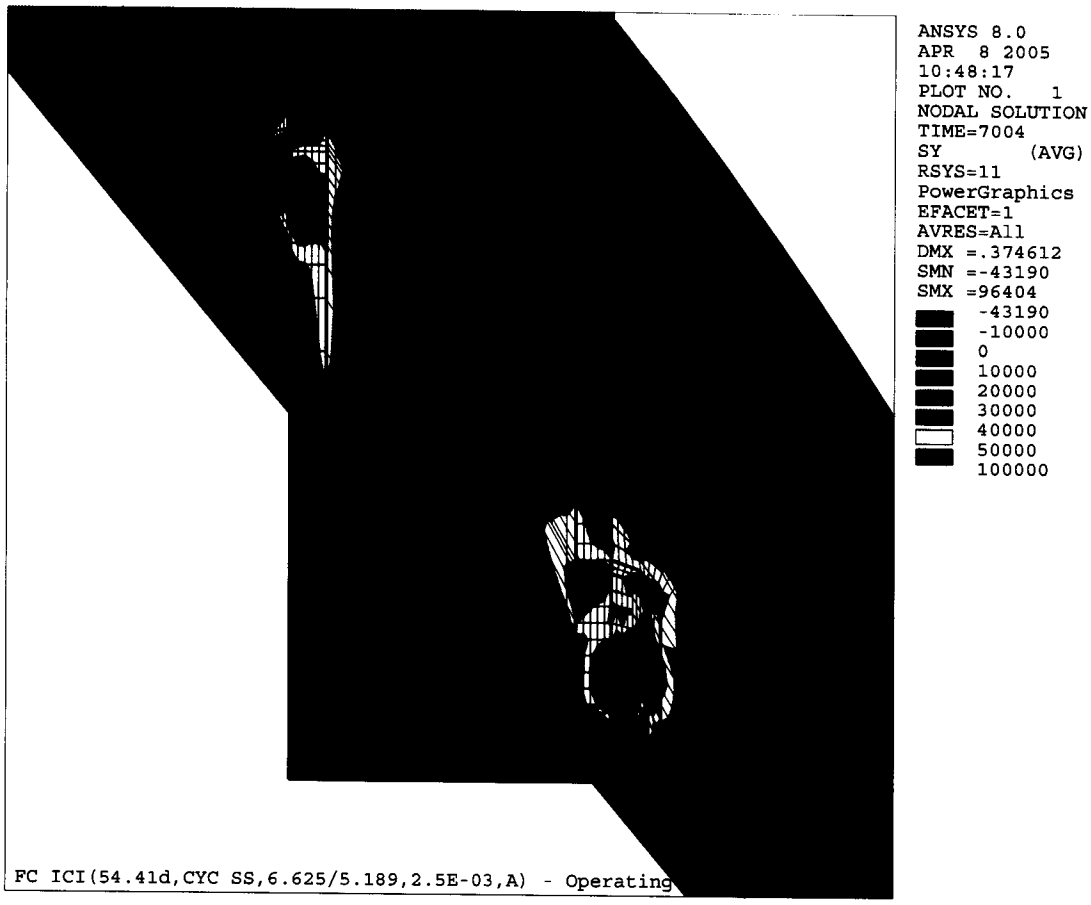


Figure 5-6

Operating plus Residual
Hoop (SY) and Axial (SZ) Stress
41.7° CEDM



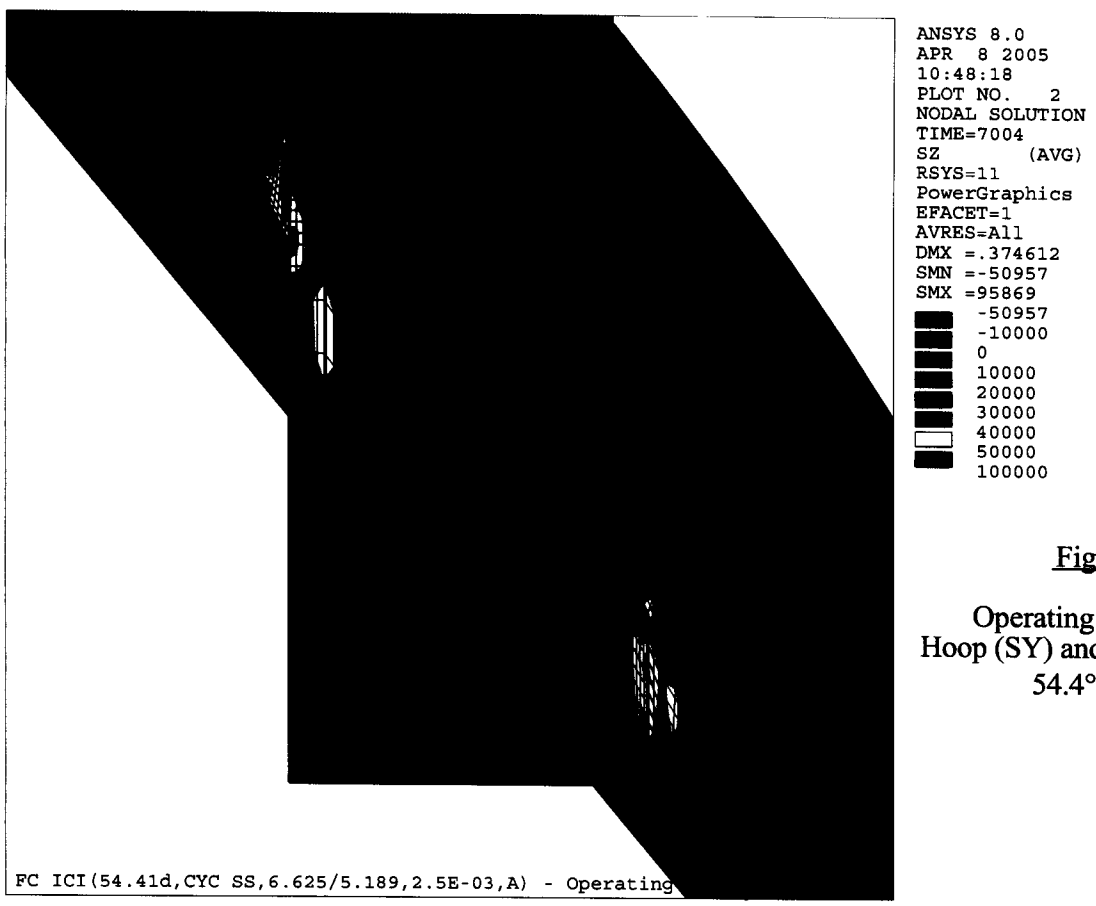
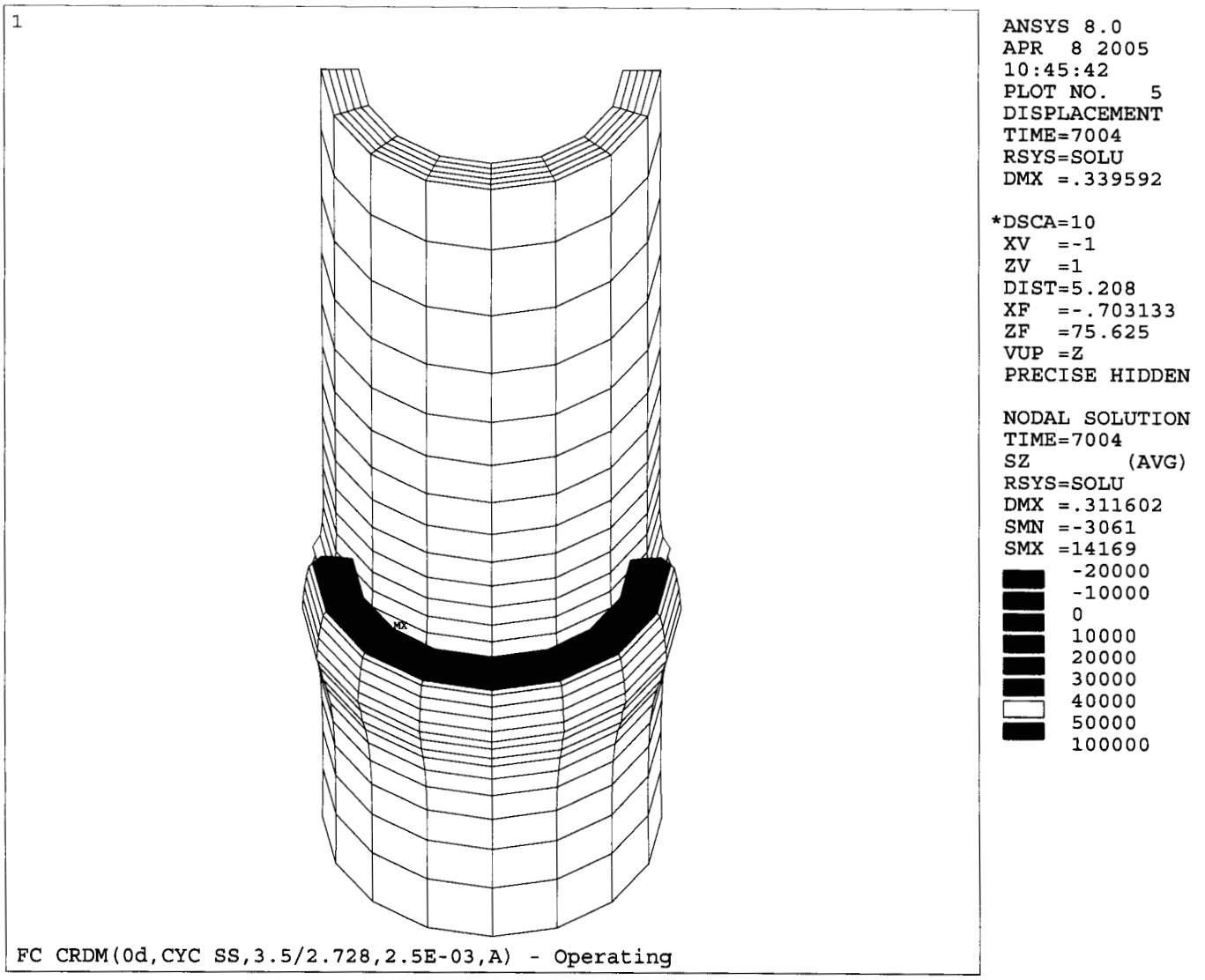


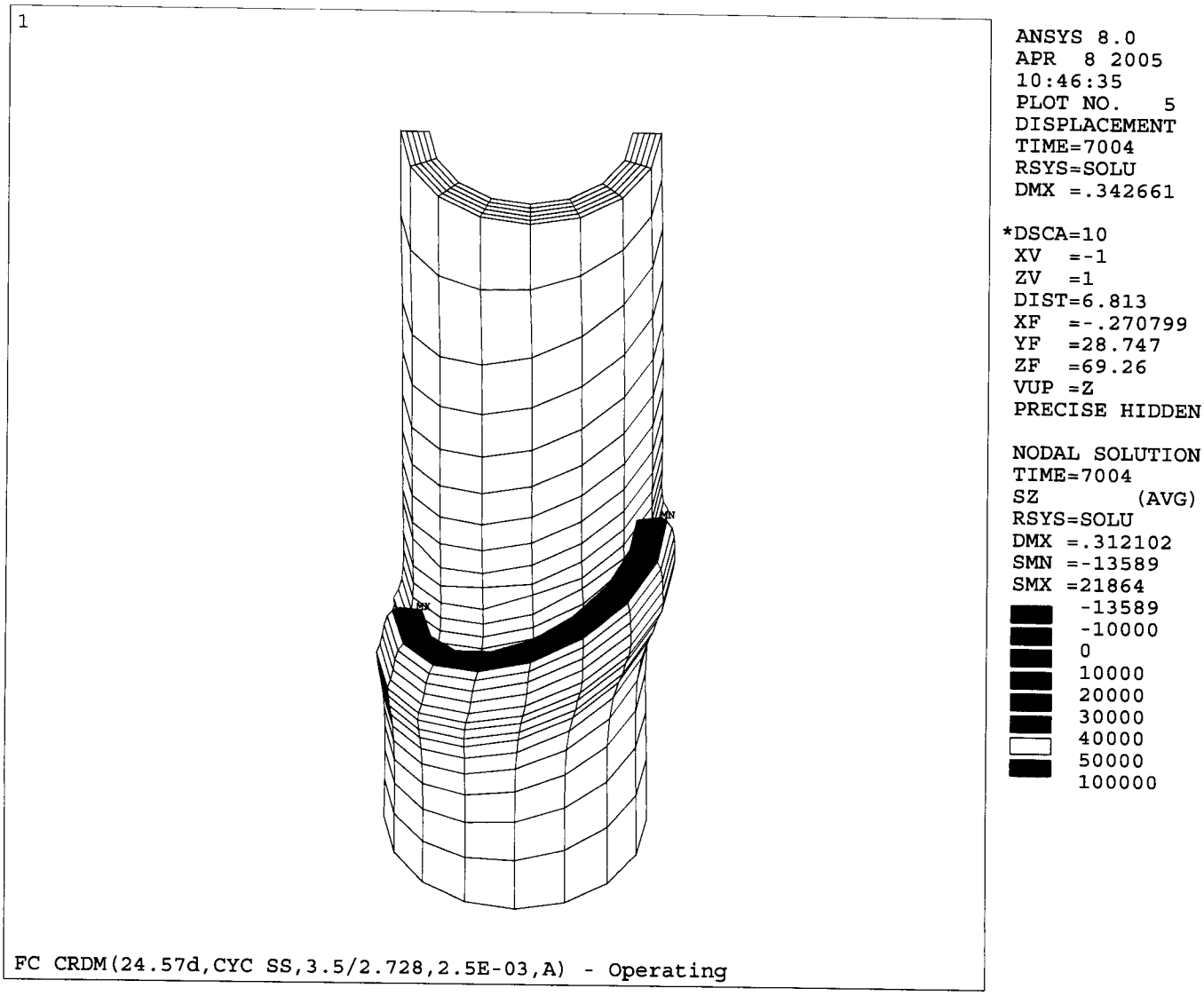
Figure 5-7

Operating plus Residual
Hoop (SY) and Axial (SZ) Stress
54.4° ICI Case



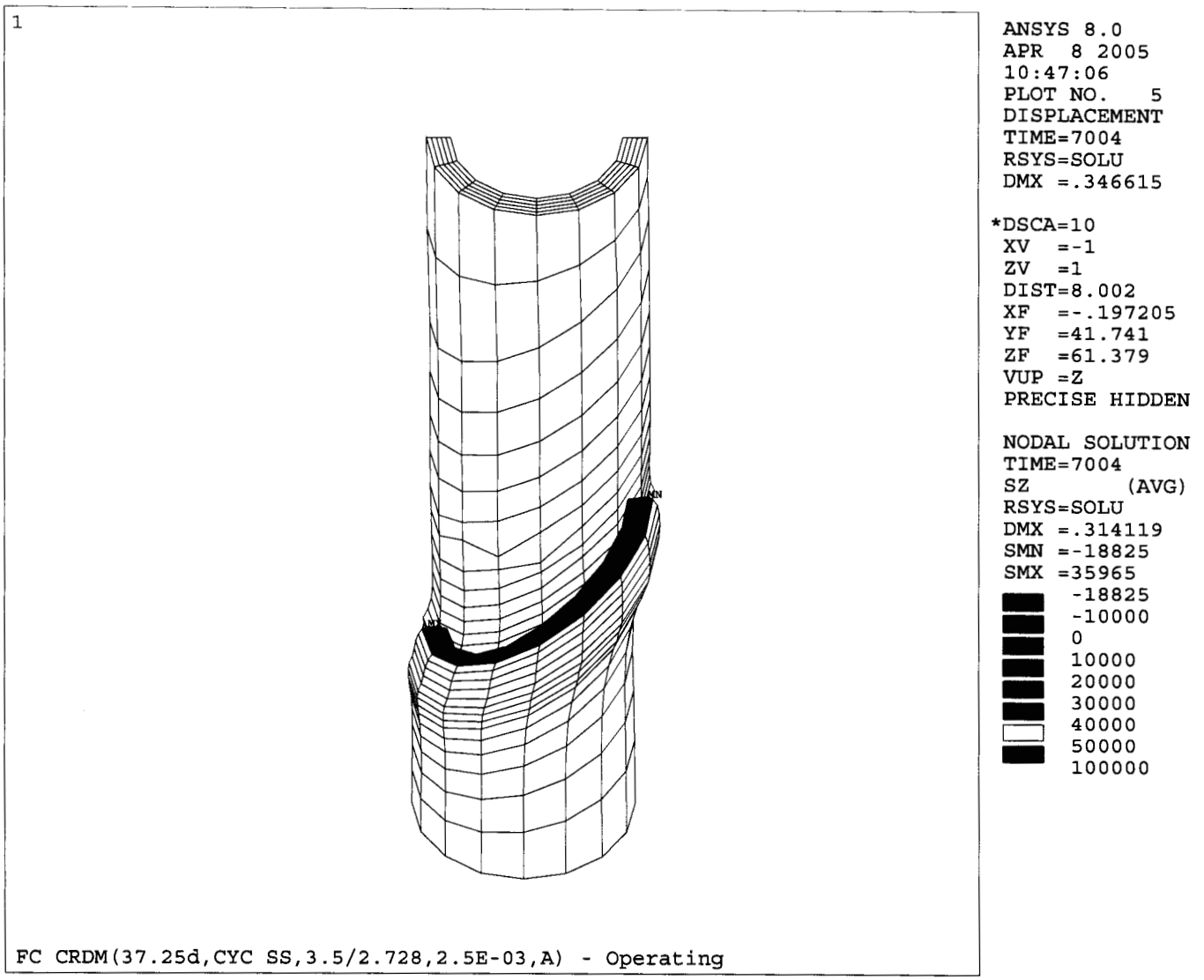
Operating Plus Residual Axial Stress at Top of Weld - Element-Oriented Coordinate System - 0.0° CEDM

Figure 5-8



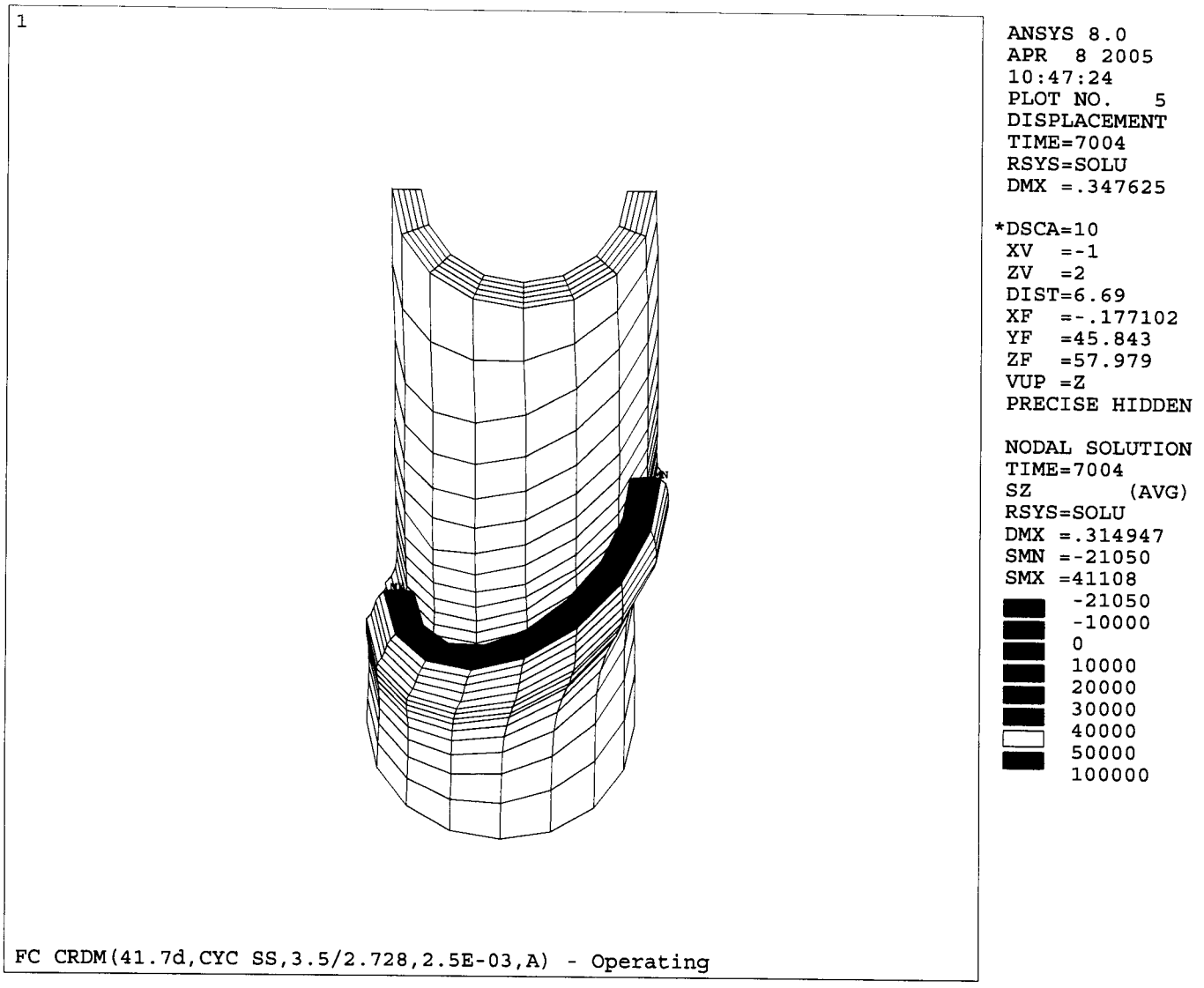
Operating Plus Residual Axial Stress at Top of Weld - Element-Oriented Coordinate System - 24.6° CEDM

Figure 5-9



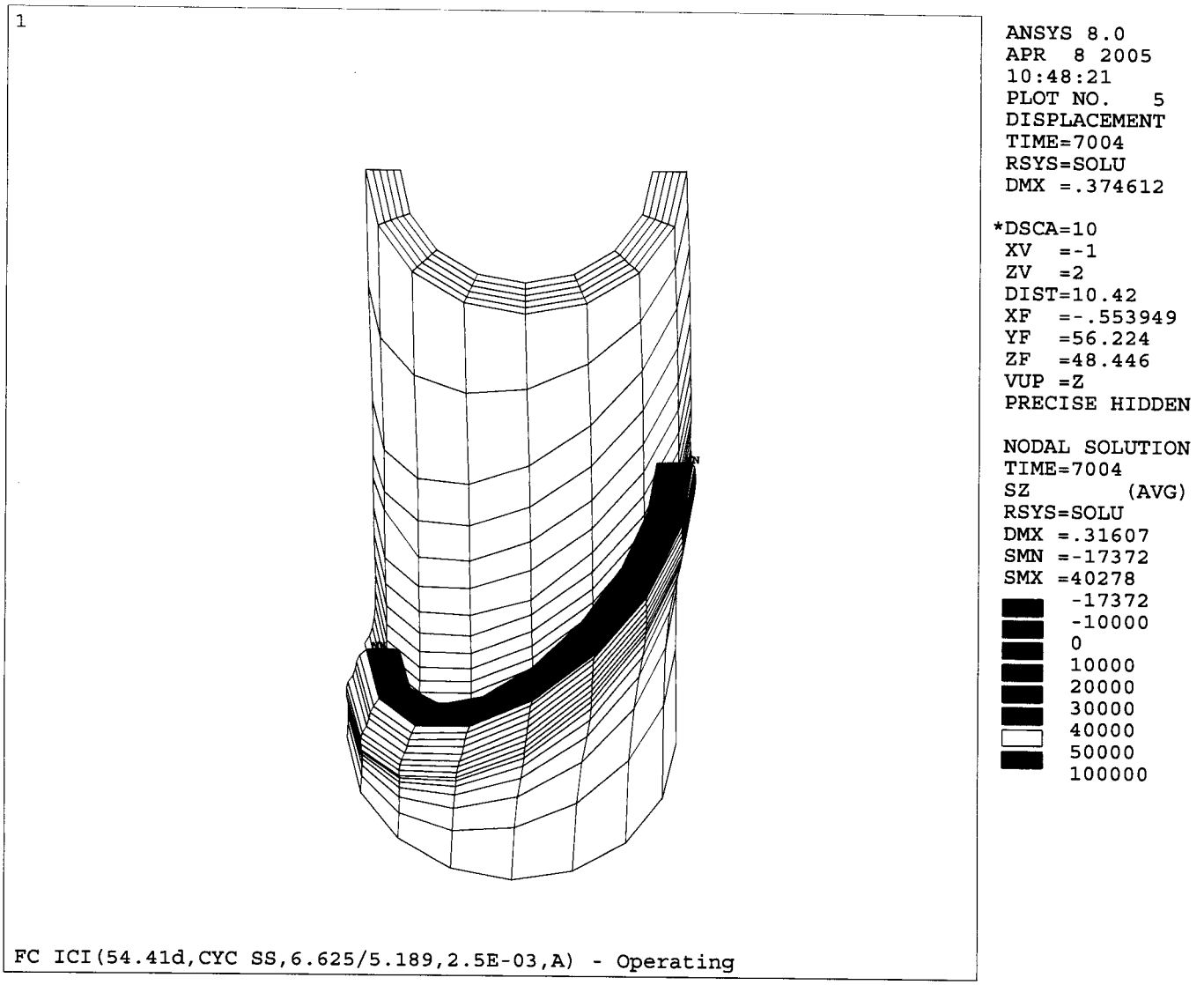
Operating Plus Residual Axial Stress at Top of Weld - Element-Oriented Coordinate System - 37.3° CEDM

Figure 5-10



Operating Plus Residual Axial Stress at Top of Weld - Element-Oriented Coordinate System - 41.7° CEDM

Figure 5-11



Operating Plus Residual Axial Stress at Top of Weld - Element-Oriented Coordinate System - 54.4° ICI Case

Figure 5-12

```
DESCRIPTION:  FEA of Fort Calhoun CRDM Nozzles (0.0 Degree)
              REVISION A: Westinghouse Cyclic Stress-Strain Nozzle Props

ANALYSIS DATE (YYMMDD): 20050407.     ANSYS VERSION:  8.0
cirse.base MODEL VERSION: 2.4.7
TITLE:  FC CRDM (  0.0d, 45.2k, 3.50/2.73, 0.002,A)

                       Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                         Uphill    Downhill         Uphill     Downhill
I.S. Above Weld          56296.      56296.         34888.       34888.
I.S. Below Weld          52233.      52233.         39436.       39436.
Midwall Above Weld       54346.      54346.
Midwall Below Weld       41534.      41534.
 ---------------
Max. Lateral Deflection:  0.0000"           Max. Ovality:  0.0000"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    601.  Hoop :  52233.  Axial:   8632.   Ratio:  6.05
Max Axial @ Node    401.  Axial:  39436.  Hoop :  31434.   Ratio:  0.80
 ** Downhill side, above weld **
Max Hoop  @ Node   1601.  Hoop :  56296.  Axial:  31294.   Ratio:  1.80
Max Axial @ Node   1701.  Axial:  34888.  Hoop :  51549.   Ratio:  1.48
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  52233.  Axial:   8632.   Ratio:  6.05
Max Axial @ Node  80401.  Axial:  39436.  Hoop :  31434.   Ratio:  0.80
 ** Uphill side, above weld **
Max Hoop  @ Node  81601.  Hoop :  56296.  Axial:  31294.   Ratio:  1.80
Max Axial @ Node  81701.  Axial:  34888.  Hoop :  51549.   Ratio:  1.48

 ************ INPUT PARAMETERS *********************

SYD=45172.    HDALLOY=533.    HPRESS=3110.    OPRESS=2235.
CTHK=0.2188   STHK=6.4063     SA=72.9844      THETA= 0.00     TOR=1.7500
TIR=1.3640    HCBORE=0.002    HCBOTZ=71.103   LTIP=3.0000
HGRATE= 78.   TRIMFLAG=0.     OTEMP=588.      BUTTFIX=0.
BOTZAUTO=1.   HCBOTINC= 0.313 PARATRIM=0.     TRIMANG=  0.00
FOURPASS=0.   PRESSFLG=0.
CYLSHELL=0.   NOBUTTER=0.   STRRLF=1.

DD1= 1.0313     DD2= 1.2813     DD3= 0.9700     DD4= 1.1890     DD5= 0.3957
DD6= 0.5959     DD7= 0.6557     DD8= 0.9145     DD9= 0.8559    DD10= 0.3500
DD11=-0.0000    DDRF= 0.3500

UU1= 1.0313     UU2= 1.2813     UU3= 0.9700     UU4= 1.1890     UU5= 0.3957
UU6= 0.5959     UU7= 0.6557     UU8= 0.9145     UU9= 0.8559    UU10= 0.3500
UU11=-0.0000    UURF= 0.3500

NCIRC= 8.     CIRC_EXT=180.  NRTUBE= 5.    NRWELD= 8.    NRBUTT= 2.
NRBASE= 6.    NATTIP= 6.    NACLAD= 2.    NAWELD= 8.    NAHOLE=12.
NAEXTN= 2.    GRAD1= 6.0    GRAD2= 4.0    GRAD3= 4.0    GRAD4= 5.0
GRAD5= 5.5    GRAD6= 7.9    GSTIF=0.50E+09

F_REP= 0.    W_REP= 0.

EMB_FLAW= 0.

Head Counterbore Unselect Flags (0-8 in order): 1. 1. 1. 1. 1. 1. 1. 1. 1.
Tube Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 0.

HGTARG=3250.0    PASS1MXT=3147.3    PASS2MXT=3322.1
```

```
DESCRIPTION:  FEA of Fort Calhoun CRDM Nozzles (24.6 Degree)
              REVISION A: Westinghouse Cyclic Stress-Strain Nozzle Props

ANALYSIS DATE (YYMMDD): 20050407.     ANSYS VERSION:  8.0
cirse.base MODEL VERSION: 2.4.7
TITLE:  FC CRDM ( 24.6d, 45.2k, 3.50/2.73, 0.002,A)

                        Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                          Uphill    Downhill         Uphill     Downhill
I.S. Above Weld           57849.      58342.         30778.       43120.
I.S. Below Weld           57849.      49924.         46549.       34298.
Midwall Above Weld        55177.      65256.
Midwall Below Weld        50288.      44941.
 ---------------
Max. Lateral Deflection:  0.0221"           Max. Ovality:  0.0341"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    601.  Hoop :  49924.  Axial:   3069.   Ratio: 16.27
Max Axial @ Node    401.  Axial:  34298.  Hoop :  23097.   Ratio:  0.67
 ** Downhill side, above weld **
Max Hoop  @ Node   1301.  Hoop :  58342.  Axial:  11449.   Ratio:  5.10
Max Axial @ Node   1701.  Axial:  43120.  Hoop :  52587.   Ratio:  1.22
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  57849.  Axial:  23648.   Ratio:  2.45
Max Axial @ Node  80401.  Axial:  46549.  Hoop :  31752.   Ratio:  0.68
 ** Uphill side, above weld **
Max Hoop  @ Node  80601.  Hoop :  57849.  Axial:  23648.   Ratio:  2.45
Max Axial @ Node  81601.  Axial:  30778.  Hoop :  57824.   Ratio:  1.88

 ************ INPUT PARAMETERS *********************

SYD=45172.    HDALLOY=533.    HPRESS=3110.    OPRESS=2235.
CTHK=0.2188   STHK=6.4063     SA=72.9844      THETA=24.57     TOR=1.7500
TIR=1.3640    HCBORE=0.002    HCBOTZ=65.895   LTIP=3.8000
HGRATE= 76.   TRIMFLAG=0.     OTEMP=588.      BUTTFIX=0.
BOTZAUTO=1.   HCBOTINC= 0.313 PARATRIM=0.     TRIMANG=  0.00
FOURPASS=0.   PRESSFLG=0.
CYLSHELL=0.   NOBUTTER=0.   STRRLF=1.

DD1= 1.0786     DD2= 1.3059     DD3= 1.1750     DD4= 1.4511     DD5= 0.3999
DD6= 0.6021     DD7= 0.7944     DD8= 1.0894     DD9= 1.0159    DD10= 0.3700
DD11=-0.0000    DDRF= 0.3215

UU1= 1.2432     UU2= 1.4706     UU3= 1.0000     UU4= 1.1044     UU5= 0.4018
UU6= 0.6049     UU7= 0.6642     UU8= 0.8948     UU9= 0.8374    UU10= 0.3257
UU11=-0.1608    UURF= 0.3215

NCIRC= 8.     CIRC_EXT=180.  NRTUBE= 5.    NRWELD= 8.    NRBUTT= 2.
NRBASE= 6.    NATTIP= 6.    NACLAD= 2.    NAWELD= 8.    NAHOLE=12.
NAEXTN= 2.    GRAD1= 6.0    GRAD2= 4.0    GRAD3= 4.0    GRAD4= 5.0
GRAD5= 5.5    GRAD6= 7.9    GSTIF=0.50E+09

F_REP= 0.    W_REP= 0.

EMB_FLAW= 0.

Head Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 1.
Tube Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 0.

HGTARG=3250.0    PASS1MXT=3164.1    PASS2MXT=3326.3
```

```
DESCRIPTION:  FEA of Fort Calhoun CRDM Nozzles (37.25 Degree)
              REVISION A: Westinghouse Cyclic Stress-Strain Nozzle Props

ANALYSIS DATE (YYMMDD): 20050407.     ANSYS VERSION:  8.0
cirse.base MODEL VERSION: 2.4.7
TITLE:  FC CRDM ( 37.3d, 45.2k, 3.50/2.73, 0.002,A)

                       Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                         Uphill    Downhill         Uphill     Downhill
I.S. Above Weld          59131.      58861.         37920.       43775.
I.S. Below Weld          58639.      47124.         52303.       32839.
Midwall Above Weld       60682.      68932.
Midwall Below Weld       51849.      51829.
 ---------------
Max. Lateral Deflection:  0.0272"          Max. Ovality:  0.0577"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    601.  Hoop :  47124.  Axial:  -7103.   Ratio: -6.63
Max Axial @ Node    401.  Axial:  32839.  Hoop :  16399.   Ratio:  0.50
 ** Downhill side, above weld **
Max Hoop  @ Node   1301.  Hoop :  58861.  Axial:  18164.   Ratio:  3.24
Max Axial @ Node   1801.  Axial:  43775.  Hoop :  42494.   Ratio:  0.97
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  58639.  Axial:  37920.   Ratio:  1.55
Max Axial @ Node  80501.  Axial:  52303.  Hoop :  49645.   Ratio:  0.95
 ** Uphill side, above weld **
Max Hoop  @ Node  80701.  Hoop :  59131.  Axial:  20173.   Ratio:  2.93
Max Axial @ Node  80601.  Axial:  37920.  Hoop :  58639.   Ratio:  1.55

 ************ INPUT PARAMETERS *********************

SYD=45172.     HDALLOY=533.     HPRESS=3110.     OPRESS=2235.
CTHK=0.2188    STHK=6.4063      SA=72.9844       THETA=37.25      TOR=1.7500
TIR=1.3640     HCBORE=0.002     HCBOTZ=58.533    LTIP=4.3310
HGRATE= 76.    TRIMFLAG=0.      OTEMP=588.       BUTTFIX=0.
BOTZAUTO=1.    HCBOTINC= 0.313  PARATRIM=0.      TRIMANG=  0.00
FOURPASS=0.    PRESSFLG=0.
CYLSHELL=0.    NOBUTTER=0.    STRRLF=1.

DD1= 0.8888      DD2= 1.0878      DD3= 1.0700      DD4= 1.3607      DD5= 0.3998
DD6= 0.6020      DD7= 0.8521      DD8= 1.1772      DD9= 1.0847     DD10= 0.4000
DD11=-0.0000     DDRF= 0.2421

UU1= 1.1334      UU2= 1.3324      UU3= 0.8400      UU4= 0.8906      UU5= 0.3972
UU6= 0.5980      UU7= 0.6321      UU8= 0.8471      UU9= 0.7859     UU10= 0.3160
UU11=-0.1761     UURF= 0.3522

NCIRC= 8.      CIRC_EXT=180.  NRTUBE= 5.     NRWELD= 8.     NRBUTT= 2.
NRBASE= 6.     NATTIP= 6.     NACLAD= 2.     NAWELD= 8.     NAHOLE=12.
NAEXTN= 2.     GRAD1= 6.0     GRAD2= 4.0     GRAD3= 4.0     GRAD4= 5.0
GRAD5= 5.5     GRAD6= 7.9     GSTIF=0.50E+09

F_REP= 0.     W_REP= 0.

EMB_FLAW= 0.

Head Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 1.
Tube Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 0.

HGTARG=3250.0     PASS1MXT=3164.5     PASS2MXT=3326.7
```

```
DESCRIPTION:  FEA of Fort Calhoun CRDM Nozzles (41.70 Degree)
              REVISION A: Westinghouse Cyclic Stress-Strain Nozzle Props

ANALYSIS DATE (YYMMDD): 20050407.     ANSYS VERSION:  8.0
cirse.base MODEL VERSION: 2.4.7
TITLE:  FC CRDM ( 41.7d, 45.2k, 3.50/2.73, 0.002,A)

                       Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                         Uphill    Downhill         Uphill     Downhill
I.S. Above Weld          61120.      59216.         40816.       43665.
I.S. Below Weld          57834.      49159.         52778.       30760.
Midwall Above Weld       62501.      69458.
Midwall Below Weld       51756.      50067.
 ---------------
Max. Lateral Deflection:  0.0321"          Max. Ovality:  0.0642"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    601.  Hoop :  49159.  Axial:   1715.   Ratio: 28.66
Max Axial @ Node    401.  Axial:  30760.  Hoop :   7590.   Ratio:  0.25
 ** Downhill side, above weld **
Max Hoop  @ Node   1301.  Hoop :  59216.  Axial:  20515.   Ratio:  2.89
Max Axial @ Node   1801.  Axial:  43665.  Hoop :  43141.   Ratio:  0.99
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  57834.  Axial:  40816.   Ratio:  1.42
Max Axial @ Node  80501.  Axial:  52778.  Hoop :  49648.   Ratio:  0.94
 ** Uphill side, above weld **
Max Hoop  @ Node  80801.  Hoop :  61120.  Axial:  19693.   Ratio:  3.10
Max Axial @ Node  80601.  Axial:  40816.  Hoop :  57834.   Ratio:  1.42

 ************ INPUT PARAMETERS *********************

SYD=45172.     HDALLOY=533.     HPRESS=3110.     OPRESS=2235.
CTHK=0.2188    STHK=6.4063      SA=72.9844       THETA=41.70      TOR=1.7500
TIR=1.3640     HCBORE=0.002     HCBOTZ=55.322    LTIP=4.5590
HGRATE= 76.    TRIMFLAG=0.      OTEMP=588.       BUTTFIX=0.
BOTZAUTO=1.    HCBOTINC= 0.313  PARATRIM=0.      TRIMANG=  0.00
FOURPASS=0.    PRESSFLG=0.
CYLSHELL=0.    NOBUTTER=0.    STRRLF=1.

DD1= 0.8198      DD2= 1.0064      DD3= 1.0300      DD4= 1.3230      DD5= 0.3992
DD6= 0.6011      DD7= 0.8847      DD8= 1.2247      DD9= 1.1216     DD10= 0.4000
DD11=-0.0000     DDRF= 0.3000

UU1= 1.0814      UU2= 1.2680      UU3= 0.7700      UU4= 0.7992      UU5= 0.3964
UU6= 0.5969      UU7= 0.6195      UU8= 0.8284      UU9= 0.7651     UU10= 0.3098
UU11=-0.1825     UURF= 0.3649

NCIRC= 8.      CIRC_EXT=180.  NRTUBE= 5.     NRWELD= 8.     NRBUTT= 2.
NRBASE= 6.     NATTIP= 6.     NACLAD= 2.     NAWELD= 8.     NAHOLE=12.
NAEXTN= 2.     GRAD1= 6.0     GRAD2= 4.0     GRAD3= 4.0     GRAD4= 5.0
GRAD5= 5.5     GRAD6= 7.9     GSTIF=0.50E+09

F_REP= 0.    W_REP= 0.

EMB_FLAW= 0.

Head Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 1.
Tube Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 0.

HGTARG=3250.0     PASS1MXT=3164.8     PASS2MXT=3328.0
```

```
DESCRIPTION:  FEA of Fort Calhoun ICI Nozzle (54.41 Degree)
              REVISION A: Westinghouse Cyclic Stress-Strain Nozzle Props

ANALYSIS DATE (YYMMDD): 20050408.     ANSYS VERSION:  8.0
cirse.base MODEL VERSION: 2.4.7
TITLE:  FC ICI  ( 54.4d, 45.2k, 6.62/5.19, 0.002,A)

                        Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                          Uphill    Downhill         Uphill     Downhill
I.S. Above Weld           51251.      60492.         26938.       37017.
I.S. Below Weld           50524.      26011.         44261.       15977.
Midwall Above Weld        60032.      62846.
Midwall Below Weld        50980.      47401.
 ---------------
Max. Lateral Deflection:  0.0432"          Max. Ovality:  0.0822"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    601.  Hoop :  26011.  Axial:   3338.   Ratio:  7.79
Max Axial @ Node    301.  Axial:  15977.  Hoop :  -5449.   Ratio: -0.34
 ** Downhill side, above weld **
Max Hoop  @ Node   1201.  Hoop :  60492.  Axial:  27088.   Ratio:  2.23
Max Axial @ Node   1901.  Axial:  37017.  Hoop :  39374.   Ratio:  1.06
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  50524.  Axial:  23355.   Ratio:  2.16
Max Axial @ Node  80401.  Axial:  44261.  Hoop :  47302.   Ratio:  1.07
 ** Uphill side, above weld **
Max Hoop  @ Node  81001.  Hoop :  51251.  Axial:   6839.   Ratio:  7.49
Max Axial @ Node  81601.  Axial:  26938.  Hoop :  42358.   Ratio:  1.57

 ************ INPUT PARAMETERS *********************

SYD=45172.    HDALLOY=533.    HPRESS=3110.    OPRESS=2235.
CTHK=0.2188   STHK=7.7188     SA=73.6406      THETA=54.41     TOR=3.3125
TIR=2.5945    HCBORE=0.002    HCBOTZ=46.494   LTIP=7.3790
HGRATE= 74.   TRIMFLAG=0.     OTEMP=588.      BUTTFIX=2.
BOTZAUTO=1.   HCBOTINC= 0.313 PARATRIM=0.     TRIMANG=  0.00
FOURPASS=0.   PRESSFLG=0.
CYLSHELL=0.   NOBUTTER=0.   STRRLF=1.

DD1= 1.0474     DD2= 1.1929     DD3= 1.2819     DD4= 1.5242     DD5= 0.7500
DD6= 1.0000     DD7= 0.7500     DD8= 1.0000     DD9= 1.0000    DD10= 0.4500
DD11=-0.0000    DDRF= 0.3500

UU1= 0.8441     UU2= 0.9896     UU3= 0.4600     UU4= 0.4587     UU5= 0.4199
UU6= 0.5804     UU7= 0.6725     UU8= 0.8322     UU9= 0.7121    UU10= 0.3362
UU11=-0.1855    UURF= 0.3709

NCIRC= 8.     CIRC_EXT=180.  NRTUBE= 5.    NRWELD= 8.    NRBUTT= 2.
NRBASE= 6.    NATTIP= 6.    NACLAD= 2.    NAWELD= 8.    NAHOLE=12.
NAEXTN= 2.    GRAD1= 6.0    GRAD2= 4.0    GRAD3= 4.0    GRAD4= 5.0
GRAD5= 5.5    GRAD6= 7.9    GSTIF=0.50E+09

F_REP= 0.    W_REP= 0.

EMB_FLAW= 0.

Head Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 1.
Tube Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 0.

HGTARG=3250.0    PASS1MXT=3253.5    PASS2MXT=3253.7
```

```
RESU,,dbs
*if,ncirc,lt,1,then
   ncirc=8
*endif
/PAGE,,,10000,200
/POST1
/GRAPHICS,FULL
CSYS,11
CLOCAL,71,1,0,0,NZ(1+NRTUBE)     ! Local CSYS at lower tube edge
CSYS,11
RSYS,11
/COM,
/COM,  ---------------------------------------------
/COM,  **** Get lateral deflection and ovality ****
/COM,  ---------------------------------------------
/COM,
SET,,,,,T0+1.0
*DO,I,0,ncirc,1
   *DIM,DEFCOL%I%,TABLE,(NNUM23-1)/100+1
*ENDDO
*DIM,LOC2DEF,ARRAY,ncirc+1       ! Location 2 is 0.5" below downhill weld
*DIM,LOC3DEF,ARRAY,ncirc+1       ! Location 3 is at the bottom of the downhill weld
*DIM,LOC4DEF,ARRAY,ncirc+1       ! Location 4 is at the top of the downhill weld
*DIM,LOCXDEF,ARRAY,ncirc+1       ! Location "X" is at the bottom of the uphill weld
RSYS,11
/COM,
/COM, ** Fill node axial distance vs. radial deflection table arrays
*DO,I,0,ncirc,1
   K=1
   *DO,J,I*10000+1,I*10000+NNUM23,100
      DEFCOL%I%(K)=UX(J)
      DEFCOL%I%(K,0)=NZ(J)
      K=K+1
   *ENDDO
*ENDDO
*DO,I,0,ncirc,1
   DEFCOL%I%(0,1)=1.0
*ENDDO
/COM,
/COM, ** Interpolate to get deflection and ovality at desired locations
*DO,I,0,ncirc,0
   LOC2DEF(I+1)=DEFCOL%I%(NZ(NNUM1)-0.5)
   LOC3DEF(I+1)=DEFCOL%I%(NZ(NNUM1))
   LOC4DEF(I+1)=DEFCOL%I%(NZ(NNUM14))
   LOCXDEF(I+1)=DEFCOL%I%(NZ(ncirc*10000+NNUM1))
*ENDDO
*GET,FNAME,ACTIVE,0,JOBNAM
/OUT,%FNAME%.W_Data,out
/COM,
/COM,          RADIAL DEF    RADIAL DEF    RADIAL DEF    RADIAL DEF
/COM,COL #      @ LOC 2       @ LOC 3       @ LOC 4       @ LOC "X"
*VWRITE,SEQU,LOC2DEF(1),LOC3DEF(1),LOC4DEF(1),LOCXDEF(1)
(F5.0,3X,5(F10.5,3X))
/COM,
/COM,  ---------------------------------------------
/COM,  *********************************************
/COM,  ---------------------------------------------
/COM,
/OUT
/COM,
/COM,  ---------------------------------------------
/COM,            **** Get gap force data ****
/COM,  ---------------------------------------------
/COM,
```

Attachment 2: File "Westpost7.txt"

```
!
SET,,,,,T0+4.0
!
ETABLE,GAPFORCE,SMISC,2
ESEL,S,TYPE,,2
ESEL,R,REAL,,1
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Force in all gap elements in interference region
PRETAB
/COM,
/COM,
/OUT,
NSLE
NSEL,R,NODE,,1+NRTUBE,(ncirc+1)*10000,100
NSEL,A,NODE,,1+NRTUBE
DSYS,71
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Location of all gap elements in interference region - Rel to tube bottom OD
NLIST
/COM,
/COM,  ------------------------------------------
/COM,
/OUT,
/COM,
/COM,  ------------------------------------------
/COM,            **** Get stress data ****
/COM,  ------------------------------------------
/COM,
NSEL,ALL
ESEL,ALL
NTMP1=NODE(NX(1),NY(1),NZ(NNUM1)-0.5)                    ! Node 0.5" below downhill weld
NTMP2=NODE(NX(ncirc*10000+1),NY(ncirc*10000+1),NZ(ncirc*10000+NNUM1)-0.5)      ! Node 0.5"
below uphill weld
NSEL,S,NODE,,NTMP1,NTMP1+NRTUBE
NSEL,A,NODE,,NTMP2,NTMP2+NRTUBE
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube through-thickness stress at 0.5" below weld bottom
PRNS,COMP
/COM,
/COM,  ------------------------------------------
/COM,
/OUT,
!
NSEL,S,NODE,,NNUM1,NNUM2
NSEL,A,NODE,,ncirc*10000+NNUM1,ncirc*10000+NNUM2
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube through-thickness stress at weld bottom
PRNS,COMP
/COM,
/COM,  ------------------------------------------
/COM,
/OUT,
!
NSEL,S,NODE,,NNUM9,NNUM10
NSEL,A,NODE,,ncirc*10000+NNUM9,ncirc*10000+NNUM10
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube through-thickness stress at weld middle
PRNS,COMP
/COM,
/COM,  ------------------------------------------
/COM,
/OUT,
!
NSEL,S,NODE,,NNUM14,NNUM15,1
```

Attachment 2: File "Westpost7.txt"

```
NSEL,A,NODE,,ncirc*10000+NNUM14,ncirc*10000+NNUM15,1
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube through-thickness stress at weld top
PRNS,COMP
/COM,
/COM,  -------------------------------------------
/COM,
/OUT,
!
NSEL,ALL
NTMP1=NODE(NX(1),NY(1),NZ(NNUM14)+0.5)                    ! Node 0.5" above downhill weld
NTMP2=NODE(NX(ncirc*10000+1),NY(ncirc*10000+1),NZ(ncirc*10000+NNUM14)+0.5)     ! Node 0.5"
above uphill weld
NSEL,S,NODE,,NTMP1,NTMP1+NRTUBE
NSEL,A,NODE,,NTMP2,NTMP2+NRTUBE
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube through-thickness stress at 0.5" above weld top
PRNS,COMP
/COM,
/COM,  -------------------------------------------
/COM,
/OUT,
!
NSEL,S,NODE,,1,NNUM23,100
NSEL,A,NODE,,ncirc*10000+1,ncirc*10000+NNUM23,100
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube ID stresses at uphill and downhill
PRNS,COMP
/COM,
/COM,
/COM, Location of ID nodes relative to tube bottom OD
NLIST
/OUT
NSEL,S,NODE,,1+NRTUBE,NNUM23+NRTUBE,100
NSEL,A,NODE,,ncirc*10000+1+NRTUBE,ncirc*10000+NNUM23+NRTUBE,100
/OUT,%FNAME%.W_Data,out,,APPEND
/COM,
/COM,
/COM, Tube OD stresses at uphill and downhill
PRNS,COMP
/COM,
/COM,
/COM, Location of OD nodes relative to tube bottom OD
NLIST
/COM,
/COM,  -------------------------------------------
/COM,
/OUT,
!
RSYS,SOLU
NSEL,NONE
NSEL,A,NODE,,NNUM14,NNUM15,1
*REPEAT,ncirc+1,,,,10000,10000
/OUT,%FNAME%.W_Data,out,,APPEND
/COM, Tube stresses along plane opposite top of weld (Element-oriented CS)
PRNS,COMP
/COM,
/COM,  -------------------------------------------
/COM,
/OUT,
!
nsel,all
esel,all
dsys,0
```

Attachment 2: File "Westpost7.txt"

```
csys,11
!
/show,pscr
pscr,color,1
pscr,scale,.180
pscr,tranx,60
pscr,trany,200
pscr,rotate,0
!
*CREATE,WELDPLOT
   /COM,
   /COM,  This macro makes tube stress plots with the geometry of the rest of
   /COM,  The model in the background.  Use the following arguments for ARG1:
   /COM,
   /COM,       ARG1 = 1       (hoop plot)
   /COM,       ARG1 = 2       (axial plot)
   /COM,       ARG1 = 3       (stress intensity plot)
   /COM,       ARG2 = results co-ordinate system (RSYS)
   /COM,
   /COM,
   /COM, Set up for frontal view of model:
   /VIEW,1,1
   /ANG,1,VANG
   /DIST,1,TW4*2.75*TOR
   /FOCUS,1,-8.02,Y,SQRT(FILLETR**2-Y**2)
   /DSC,1,OFF
   ESEL,S,LIVE
   NSLE                  ! Select tube nodes and elements
   /TYPE,1,4
   /EDGE,1,1             ! Alternate contours for stress plot
   /PLOPTS,DEFA          ! Standard legend
   /PLOPTS,INFO,1        ! !!!!!!!!!!!! Control style of EPLO
   /COLOR,DEFA
   /CVAL,1,-10000,0,10000,20000,30000,40000,50000,100000
   /graphics,power                                          ! ADDED THIS !!
   avres,1                                                  ! ADDED THIS !!
   RSYS,ARG2
   *IF,ARG1,EQ,1,THEN
      PLNS,S,Y        ! Make hoop plot
   *ELSEIF,ARG1,EQ,2,THEN
      PLNS,S,Z        ! Make axial plot
   *ELSE
      PLNS,S,INT      ! Make stress intensity plot
   *ENDIF
   ESEL,ALL
   NSEL,ALL
   /graphics,full
*END
!
SET,,,,,T0+4.0
*USE,WELDPLOT,1,11
*USE,WELDPLOT,2,11
*USE,WELDPLOT,3,11
!
RSYS,SOLU
/pnum,type,1
/num,1
/color,num,blac,1
/view,1,-1
/type,1,4
/ang,1
/vup,1,z
/CVAL,1,-10000,0,10000,20000,30000,40000,50000,100000
!
```

Attachment 2: File "Westpost7.txt"

```
/era
/auto
/edge,1
esel,s,mat,,1
nsle
*IF,THETA,LT,40.0,THEN
   /view,1,-1,,+1
*ELSE
   /view,1,-1,,+2
*ENDIF
/dsc,1,10
/type,1,4
pldi
/user
/noera
!
esel,all
!
esel,u,elem,,1,NNUM14-1
*repeat,ncirc,,,,10000,10000
esel,u,elem,,NNUM14+100,10000
*repeat,ncirc,,,,10000,10000
/edge,1,1
nsel,none
nsel,a,node,,nnum14,nnum15
*repeat,ncirc+1,,,,10000,10000
/type,1,0
plns,s,y
!
/era
/auto
/edge,1
esel,s,mat,,1
nsle
*IF,THETA,LT,40.0,THEN
   /view,1,-1,,+1
*ELSE
   /view,1,-1,,+2
*ENDIF
/dsc,1,10
/type,1,4
pldi
/user
/noera
!
esel,all
!
esel,u,elem,,1,NNUM14-1
*repeat,ncirc,,,,10000,10000
esel,u,elem,,NNUM14+100,10000
*repeat,ncirc,,,,10000,10000
/edge,1,1
nsel,none
nsel,a,node,,nnum14,nnum15
*repeat,ncirc+1,,,,10000,10000
/type,1,0
plns,s,z
!
/GRAPHICS,FULL
*CREATE,WELDTAB
   ESEL,S,LIVE
   NSLE
   PRNS,S,COMP
   NSEL,ALL
```

Attachment 2: File "Westpost7.txt"

```
   ESEL,ALL
*END
!
SET,,,,,T0+4.0
RSYS,SOLU
/OUT,%FNAME%.results,txt
*USE,WELDTAB
/OUT,%FNAME%.nodelocs,txt
DSYS,11
NLIST
/OUT
!
FINISH
/DELETE,WELDTAB
/DELETE,WELDPLOT
FINISH
/exit,nosav
```

Attachment 2: File "Westpost7.txt"