CALCULATION TITLE PAGE

ICCN NO./ PRELIM. CCN NO.	PAGE ___ OF ___

CCN CONVERSION:
CCN NO. CCN-

Calc. No. M-DSC-412 ECP No. & Rev. N/A

Subject SONGS UNIT 2 AND 3 PRESSURIZER THERMOWELL NOZZLE WELDING AND TRANSIENT ANALYSIS Sheet 1 of 93

System Number/Primary Station System Designator 1201 / BBB SONGS Unit 2 & 3 Q-Class I

Tech. Spec./LCS Affecting? ☒ NO ☐ YES, Section No. ______ Equipment Tag No. S2(3)1201ME087

Site Programs/Procedure Impact? ☒ NO ☐ YES, AR No. ______

10CFR50.59/72.48 REVIEW	CONTROLLED COMPUTER PROGRAM / DATABASE		
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AR No. 031100614-39	ACCORDING TO SO123-XXIV-5.1	ANSYS	8.0

RECORDS OF ISSUES

REV. DISC.	DESCRIPTION	TOTAL SHTS. LAST SHT.	PREPARED BY: (Print name/sign/date) Initial PQS Block - Requires PQS T3EN64	APPROVED BY: (Signature/date) Initial PQS Block - Requires PQS T3EN64
0	INITIAL ISSUE	93	ORIG. NABIL EL-AKILY PQS VER. BY: [signature] M. El-A 12/22/2005	FLS [signature] PQS VER. BY: [signature] 12/23/05
		93	IRE JUN GAO PQS VER. BY: J.G. J-Gao 12/23/05	Other PQS VER. BY: ___
			ORIG. PQS VER. BY: ___	FLS PQS VER. BY: ___
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Calc. rev. number and responsible FLS initials and date	INPUTS — These interfacing calculations and/or documents provide input to the subject calculation, and if revised may require revision of the subject calculation. Calc/Document No.	Rev. No.	OUTPUTS — Results and conclusion of the subject calculation are used in these interfacing calculations and/or documents. Calc/Document No.	Rev. No.	Does the output interface calc/document require Change? YES / NO	Identify output interface calc/document CCN, ECP, TCN/Rev., or tracking number.
Rel 12/23/05	Specification No. SO23-919-4, General Specification for a Pressurizer Assembly	1	Calculation M-DSC-414, SONGS Unit 2&3 Pressurizer Lower Level and Thermowell Nozzles J-Weld Fracture Mechanics Evaluation	0	No	
	Specification No. SO23-919-3, Project Specification for a Pressurizer Assembly	8				
	Drawing No. SO23-919-2, Pressurizer Outline, Unit II	9				
	Drawing No. SO23-919-57, Pressurizer Outline, Unit III	0				
	Drawing No. SO23-919-12, Vessel Welding and Machining, Unit II	3				
	Drawing No. SO23-919-128, Vessel Welding and Machining, Unit III	0				
	Drawing No. SO23-919-1, Pressurizer General Arrangement Unit III	10				
	Drawing No. SO23-919-79, Pressurizer General Arrangement Unit III	0				

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Calc. rev. number and responsible FLS initials and date	INPUTS These interfacing calculations and/or documents provide input to the subject calculation, and if revised may require revision of the subject calculation.		OUTPUTS Results and conclusion of the subject calculation are used in these interfacing calculations and/or documents.		Does the output interface calc/document require Change?	Identify output interface calc/document CCN, ECP, TCN/Rev., or tracking number.
	Calc/Document No.	Rev. No.	Calc/Document No.	Rev. No.	YES / NO	
RU 12/23/05	Drawing No. SO23-919-16, Nozzle Details, Unit II Drawing No. SO23-919-83, Nozzle Details, Unit III	3 2				

Title:	SONGS Unit 2 and 3 Pressurizer Thermowell Nozzle Welding and Transient Analysis
Task No.: 36-77	Calculation No.: C-3677-00-3 Revision No.: 0

SONGS Unit 2 and 3 Pressurizer Thermowell Nozzle Welding and Transient Analysis

Record of Revisions				
Rev.	Description	Prepared by Date	Checked by Date	Reviewed by Date
0	Original Issue	J.E. [signature] 11/11/05	[signature] 11/11/05	[signature] 11/11/05

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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List of Figures

List of Attachments

Att. No.		Last Mod. Rev.
1	File: "press.trans.addon.txt"	0
2	File: "PzSS.trans.addpost.txt"	0
3	File: "therm.hm.PzSS.trans.addon.txt"	0

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1.0 Purpose

The purpose of this calculation is to document the results of finite element stress analyses of the pressurizer thermowell nozzle penetration at SONGS Units 2 and 3. In these analyses, the welding residual stresses resulting from the fabrication of the nozzle penetration are first calculated, including the effects of removing the lower portion of the nozzle during a repair sequence. The nozzle penetration model is then used to simulate the effects of temperature and pressure variations from the plant design specification transients on the nozzle and weld region. The outputs from these analyses are ANSYS initial stress files that contain the combined effects of welding residual and thermal transient stresses. These initial stress files are then used in subsequent fracture mechanics calculations, which are documented in a separate calculation note.

2.0 Summary of Results

The residual stresses associated with fabricating the thermowell nozzle penetration in the SONGS pressurizer were simulated, as were the thermal and pressure stresses associated with the design specification transients. A summary of the results are as follows:

1. The residual hoop stresses in the model are presented in Figures 11a and 11b. As shown in these figures, the high hoop stresses in the weld and buttering dissipate and turn compressive within a short distance into the shell from the butter/shell interface. Figures 11a and 11b show a difference in residual hoop stress between the longitudinal and circumferential planes of the model; this difference results from the uneven stress concentration at the hole during the pressure loading (including the hydrotest).

2. The hoop stresses at the longitudinal and circumferential planes during each of the transients, as averaged across the weld and adjacent nozzle, are presented in Figure 10. These results show that the two planes of the model experience significantly different average stress values throughout the range of transients. This difference results from the cylindrical base shell geometry, where the applied pressure press in the longitudinal direction is one-half the applied stress in the circumferential (hoop) direction. Additionally, the Cooldown with Flooding transient has the largest range of stress as measured by averaging the hoop stress on the face of the weld and adjacent nozzle.

3. Hoop stress distributions and temperature distributions at the maximum and minimum stress points during the transients (listed in Table 7) are presented in Figures 12 through 24. These figures show a rotated view of the model, showing both the longitudinal and circumferential planes of the model.

3.0 Input Requirements

The following inputs are used for the generation of the welding residual stress analysis model:

1. The local configuration of the J-groove weld attaching the thermowell nozzle to the pressurizer side shell. The details of this configuration are obtained from SONGS design drawings (2b, 2c) and are summarized in Figure 2.

2. Detailed dimensions of the nozzle and shell penetration. These are as follows:

   a. Nozzle ID = 0.815" (2e, 4)
   b. Nozzle OD = 1.315" (2e, 4)
   c. Pressurizer cylindrical shell inside radius (to base metal) = 48-1/8" (4)
   d. Pressurizer cylindrical shell cladding thickness = 5/32" (2d)
   e. Shell penetration hole inside diameter = 1.325" (2b, 2c)
   f. Pressurizer cylindrical shell thickness = 4-7/8" (2b, 2c, 4)

The following inputs are used for the transient analysis performed on the model:

3. The temperatures and pressures for the SONGS pressurizer design specification transients were taken from (5) and (6). The values for the temperature and pressure taken from the curves in the specification are presented in Tables 1 through 6 and in Figures 3 through 8. The following transients were evaluated for this analysis:

   a. Heatup Transient (HU)
   b. Cooldown with Flooding Transient (CDF)
   c. Loading/Unloading and 10% Step Change Transient, 1 curve represents both (L/UL)
   d. Reactor Trip / Loss of Load / Loss of Flow (Trip/LL/LF)
   e. Loss of Secondary Pressure Transient (LOSP)
   f. Leak Test (LT)

4.0 Assumptions

The following modeling assumptions were used for the welding residual stress modeling of the Thermowell nozzle described in this calculation:

1. An input to the model is the nozzle yield strength, which is used to generate the multilinear isotropic hardening curve for the nozzle material. For small nozzles such as the pressurizer thermowell nozzle, this information is frequently difficult to obtain. Therefore, a nozzle yield strength of 50 ksi assumed, which is a sufficiently representative value for these analyses, given that they primarily are concerned with stresses in the weld and in the shell.

2. Based on the nominal dimensions for the shell penetration and the nozzle OD, a diametral clearance of 0.010" was input to the model.

3. Four passes of welding were performed for the pressurizer thermowell penetrations progressing from inside to outside. The model geometry was 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 (cylindrical 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. No credit was taken for the additional weld buildup thickness on the OD of the pressurizer cylindrical shell local to the thermowell nozzle.

The following modeling assumptions were used for the transient analysis work on the thermowell nozzle described in this calculation:

6. As described in greater detail in Section 5.3, the transient analyses were performed on the a version of the welding residual stress model that was modified to have only elastic material properties. It is appropriate to assume that the thermal and pressure effects of the transients are within the elastic range of the work-hardened material.

7. During simulation of the thermal transients, the model is loaded using varying bulk temperatures with a convective heat transfer surface (see Section 5.3 for further details). During all transients, a heat transfer coefficient of 500 BTU/hr-ft^2-°F was used to load the vessel inside surface, consistent with previous design basis analyses of the shell region. During a portion of Loss of Secondary Pressure transient, the liquid turns to steam; for this time period, a heat transfer coefficient of 10 BTU/hr-ft^2-°F was used to load the vessel inside surface. This value is consistent with steam convection loads in other pressurizer analyses.

5.0 Analysis

5.1 Finite Element Model

The SONGS pressurizer is a large cylinder with spherical end caps on each end. There are a number of penetrations in the top and bottom heads, as well as the cylindrical shell wall. Figure 1 presents an outline of the pressurizer, with the location of the thermowell nozzle indicated. As shown in Figure 1, the thermowell nozzle is a small penetration in the cylindrical shell, about three feet above the bottom of the cylindrical region.

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ANSYS finite element analyses of the pressurizer thermowell nozzle 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). The model geometry with node numbering is depicted in Figure 9a.

5.1.1 Model Description

The nozzle was analyzed using a 3D model. The model includes a sector from a horizontal cut through the pressurizer cylindrical shell 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 four "passes" of approximately equal volume. The stainless steel cladding layer was included in the model since this material has a significantly different coefficient of thermal conductivity compared to the low alloy steel vessel shell, and therefore influences the weld cooling process. The weld deposition of the stainless steel cladding layer was not included in this model (i.e., the cladding was assumed to be stress free at the beginning of the model). As shown in Figure 9b, the symmetry plane of the model is along a longitudinal section of the shell. Therefore, the view of the model in Figure 9a is looking down (plan view) on a horizontal cut through the cylindrical shell.

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

a. Thermal Analysis. For the 3-D thermal analysis, eight-node thermal solids (SOLID70) with no thermal conductivity at the interface between the nozzle and the penetration ID (i.e., the nozzle and penetration nodes are thermally decoupled). Thermally decoupling the nozzle and shell penetration has the effect of limiting heat transfer between the nozzle and shell to conduction through the J-groove region. This assumption was made because a clearance fit is specified between the nozzle OD and the shell penetration, and thermal communication between these surfaces will be limited to conduction through air or water. Using this assumption generally leads to higher temperature differentials between the nozzle and the shell during the transient analyses, and therefore is a conservative assumption.

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b. 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 elements replaced the SOLID70 elements from the thermal analysis and COMBIN40 elements were used to model the gap in the penetration region. 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).

The boundary conditions on the circumferential edges of the model are such that only radial deflections in the cylindrical coordinate system are permitted. These boundary conditions simulate the vessel shell stiffness and accurately simulate pressure stresses in the hoop direction remote from the penetrations. Additionally, end cap pressure loading is applied to the longitudinal face of the model opposite the symmetry plane, as described in Section 5.2.c. The nozzles are modeled as being installed in holes in the vessel shell with a 0.005" radial clearance using gap elements in the penetration region. For load steps where the nozzle OD and shell penetration ID surfaces are not in contact, the interface elements have no stiffness; when these surfaces are in contact, the interface elements are specified to have a very high stiffness. When in contact, the gap elements permit frictionless sliding in the vertical direction between the nozzle and hole in the vessel shell.

5.1.2 Model Refinement and Mesh Density

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:

a. 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, cylindrical 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.

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b. 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.

5.1.3 Materials and Material Properties

Four materials were used in the modeling. The vessel cylindrical shell is alloy steel, the nozzle is Inconel Alloy 600, the J-groove weld, and the weld buttering layer are Inconel Alloy 82/182, and the cladding on the inside surface of the shell is stainless steel. Specific information regarding the properties for these materials is as follows:

a. Alloy 600 Nozzle. The Alloy 600 nozzle material was assumed to strain-harden isotropically using the von Mises yield criterion with a multilinear input curve. Based on elevated temperature property data for Alloy 600 in Reference (15), the 600°F yield strength value used in defining the hardening curve is 87.7% of the input room temperature value. Material property data were taken from a number of sources, including the ASME Boiler and Pressure Vessel Code (9), data provided by EdF for EPRI analyses (10), Inconel product literature (11), and research papers by Rybicki (12) and Karlsson (13). A Poisson's ratio of 0.29 was used; this value was assumed to be invariant with temperature.

b. Alloy 82/182 Butter and J-Groove Weld Metal. The Alloy 82/182 cladding, butter and J-groove weld materials were modeled using elastic-perfectly plastic hardening laws. As noted above, this assumption gives more realistic stresses where a high degree of plastic strain occurs at elevated temperatures, such as within the welds. The elastic limit for these materials is based on an average of the yield and tensile strengths reported in Reference (11). An elastic limit of 75.0 ksi was used at 70°F, and an elastic limit of 60.0 ksi was used at 600°F. A Poisson's ratio of 0.29 was used; this value was assumed to be invariant with temperature.

c. Low-Alloy Steel Shell and Stainless Steel Cladding. The stainless steel cladding and alloy steel vessel shell are assumed to be stress free at room temperature at the start of the analysis. Because they undergo small strains during the analysis, these two base materials also make use of elastic-perfectly plastic hardening laws. The elastic limit values for these materials are based on the 0.2% offset yield strength for the material. For the low-alloy steel shell, an elastic limit of 70.0 ksi was used at 70°F, and an elastic limit of 57.6 ksi was used at 600°F. For the stainless steel cladding, an elastic limit of 40.0 ksi was used at 70°F, and an elastic limit of 28.9 ksi was used at 600°F. A Poisson's ratio of 0.29 was used; this value was assumed to be invariant with temperature.

5.1.4 Model Validation

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).

5.2 Welding Residual Stress Analysis

The analysis of the thermowell nozzle model involves five basic loading steps: (a) welding simulation, (b) thermal stress relief, (c) hydrostatic testing, (d) operating conditions, and (e) final residual stress including repair. These processes are simulated as follows:

a. Welding Simulation. A substantial portion of the analytical work in the base model involves the simulation of welding processes. The modeling of the butter weld deposition and the J groove welding make use of the same basic steps to simulate the thermal and mechanical effects of a weld.

The analytical simulation of a welding process consists of combined thermal and structural analyses. The thermal analysis is used to generate nodal temperature distributions at several points in time during the welding process. These nodal temperatures are then used as loading inputs to the structural analysis, which calculates the thermally induced stresses. This sequence of thermal analyses followed by structural analyses is used for each simulated weld pass. The following is a more detailed description of the welding process used for the analyses:

(i) Welding - Thermal Analysis

- Material comprising each weld pass is assumed to have normal thermal properties and is connected thermally to the surrounding base metal materials. The material comprising subsequent weld passes is included in the model, but is assigned zero thermal conductivity, specific heat, and density during the first welding pass, so that it effectively acts as a vacuum, i.e., it does not absorb or conduct heat. Similarly, for modeling the butter weld deposition, these conditions are applied to the nozzle and J-groove weld material, which do not exist at the time of butter deposition.

- Heat is rapidly input to the weld pass material, using internal volumetric heat generation, at a rate which raises the peak weld metal temperature to 3,000–3,500°F and the base metal adjacent to the weld to about 2,000°F. These are approximately the temperatures that the weld metal and surrounding base materials reach during welding (14). This rapid heating of the weld material is necessary in order to reach the desired peak weld puddle temperatures without overheating the surrounding base metal. Conversely, if the heat is applied too rapidly, the surrounding base metal materials do not reach a high enough temperature for good fusion. Thermal properties for the materials are specified in the model for temperatures up to 3,500°F; properties at elevated temperatures are estimated or extrapolated from lower temperatures.
- The internal heat generation is applied to the weld pass over approximately two seconds. After the weld heat input is stopped, the weld pass and surrounding material is allowed to cool for about 30 minutes. Nodal temperatures on the outermost vessel shell nodes are held at 70°F to simulate the heat sink effect of the surrounding low alloy steel shell, which is not modeled. Heat is assumed to be removed entirely through conduction to the outermost vessel shell nodes. All other free surfaces of the model (e.g., shell inside radius, nozzle edges, weld edges) are assumed to be adiabatic.
- This process is repeated for subsequent weld passes, as necessary.

(ii) Welding - Structural Analysis

- At the start of welding, each weld pass is assigned material properties simulating molten weld metal, i.e., it has greatly reduced stiffness (reduced by a factor of 10^6) and strength, and a thermal expansion coefficient of zero. This means that the weld material will be essentially stress free at the end of heat input. As in the thermal model, the material comprising subsequent weld passes is included in the model, but is assigned greatly reduced structural properties. In the case of the butter weld deposition, these conditions are applied to the nozzle and J-groove weld material, which do not exist at the time of butter deposition.
- Each weld pass is heated progressively over several load (time) steps, to the point where the material reaches its maximum temperature and heat input has stopped. The temperature distributions for each time step of the heating process are taken from the temperature file that was created during the thermal analysis. Mechanical properties for the materials are specified in the model for temperatures up to 3,500°F; properties at elevated temperatures are estimated or extrapolated from lower temperatures.
- Before starting the weld pass cooling load steps, the weld pass elements are assigned normal mechanical and thermal properties. The subsequent weld passes (and, in the case of the weld butter deposition, the nozzle and J groove weld material) retain their reduced properties, so that

they effectively have no influence on the stresses in the surrounding materials during the cooling of the ongoing weld pass.

- As the weld pass elements cool, they contract and gain strength effectively "locking in" some of the thermal expansion which occurred in the base metal during heat-up.
- This process is repeated for subsequent weld passes, as necessary.

b. Thermal Stress Relief. After completion of the butter deposition, the entire model is uniformly raised to 1,100°F then uniformly lowered to room temperature to simulate the effect of the thermal stress relief performed on the vessel shell. In order to simulate the stress relaxation caused by a multiple-hour stress relief at 1,100°F, the elastic limit values for the vessel shell and butter materials are reduced relative to the flow stress of the material at this temperature.

In order to account for stress-relief relaxation, elastic limit values consistent with strength reduction due to creep were estimated based on creep data for alloy steels and on rupture strength at temperature data for Inconel weld material. The estimated elastic limit values at 1,100°F used in the model are 25.0 ksi for the vessel shell material and 30.0 ksi for the weld butter material. These values are closer to the yield strength of the materials at the elevated temperature rather than the flow stress.

c. Hydrostatic Testing. Components are hydrostatically tested to approximately 3,125 psia after manufacturing and again after installation. These operations are included in the analysis since the applied hydrostatic pressure further yields the Alloy 600 nozzle material and results in a reduction in peak residual tensile stresses as the hydrostatic test pressure is released. In this manner, the hydrostatic testing represents a form of "mechanical stress improvement" in areas of high stress. Aside from applying pressure to all of the wetted internal surfaces, an axial tensile stress is applied to the top end of the nozzle equal to the longitudinal pressure stress in the nozzle wall, and an axial stress is applied to the longitudinal face of the model equal to the longitudinal pressure stress in the pressurizer cylinder wall. The same equation is used in each case to calculate the appropriate endcap stress load:

$$\sigma_{axial} = \frac{P\, r_i^2}{(r_o^2 - r_i^2)}$$

Where, P is the internal pressure and r_i and r_o are the inside and outside radii of the nozzle, or cylindrical shell, respectively.

d. Operating Condition. Operating conditions are simulated by pressurizing the inside surfaces of the model to 2,250 psia and heating all of the material to the uniform operating temperature of 653°F. Stresses produced by differential thermal expansion arising from the small temperature gradient within the vessel shell and nozzle during the heatup and cooldown transients are neglected for this portion of the analysis

Each weld pass, including weld butter deposition, occurs over a time increment of 2,000 seconds. The time at the end of weld butter deposition is 2,000 seconds; the time following stress relief is 3,000 seconds; the time following J-groove welding is 11,000 seconds. Static load steps that do not input thermal loads from the welding simulation use one-second time increments; the time at the application of operating conditions is 11,004 seconds.

e. Final Residual Stress Including Repair. Following completion of the base model welding residual stress simulation, the effect of the half nozzle repair on the thermowell nozzle remnant and the shell/weld region was simulated. In doing so, the portion of the nozzle from four element rows beyond the weld to the end of the nozzle was removed from the model using the ANSYS "EKILL" command. The repair simulation was performed at zero load conditions. As noted below, boundary conditions were adjusted in the transient analysis to account for the new model state, including pressurizing the annular space between the nozzle remnant and the shell and pressurizing the shell penetration hole region. The model time at the completion of repair is 11,006 seconds.

5.3 Transient Analysis

The residual stress state of the model following the repair was written to an ANSYS initial stress file using the "ISWRITE,ON" command. An initial stress file is a record of the full stress state at each of the Gauss points within each element in the model at the completed SOLVE state. The initial stress file may be read into the model using the ISFILE,READ command provided that the model mesh and element numbering is the same as recorded in the initial stress file. According to the ANSYS manual (8), the initial stresses are read in as if they are elastic model stresses. The solution step removing the lower portion of the nozzle is the last solution step using elastic plastic properties in the model. The welding residual stress model (with the lower portion of the nozzle EKILLed) is converted to an elastic-only model by deleting the appropriate material property tables. The post repair initial stress file and converted elastic model are saved for use as restart files during the transient analyses. The resulting thermal and structural models are used to simulate the effect of thermal and structural transients on the post-repair geometry.

5.3.1 Thermal Transients

The thermal portion of the pressurizer design specification transients, as defined by the temperature curves in Figures 3 through 8, was simulated by ramping the bulk temperatures on the convection boundary conditions at the wetted surfaces of the model. A heat transfer coefficient of 500 BTU/hr-ft^2-°F was assumed for the convection surfaces, with the exception of during a portion of the Loss of Secondary Pressure transient. As noted on Figure 7, for a time during the transient, the water in the pressurizer turns entirely to steam, and the heat transfer coefficient is adjusted accordingly to 10 BTU/hr-ft^2-°F during this time period. All other surfaces in the model were assumed adiabatic. Each of the thermal transients included the use of static cases (TIMINT,OFF) at the first and last load step of the analysis to enforce steady-state solutions. Additionally, the Loading/Unloading and Leak Test transients, each of which is formed by combining two independent transients, included a static load step after the first portion of the transient to ensure that the second portion started from uniform conditions.

5.3.2 Structural Transients

The results of the thermal transient analyses were applied as nodal temperature loads to the structural model. The structural model for each transient was a new analysis, starting from the elastic model defined at the end of repair simulation. With the exception of the cooldown with flooding transient (CDF, as described below), the model read in the initial stress results from the end of repair simulation. In this way, the structural analysis for each transient is a separate model starting from the same load condition. Each structural transient begins at Time 20000 seconds. The time steps within each transient are documented in Tables 1 through 6.

5.3.3 Cooldown with Flooding Transient – Special Considerations

Unlike the other transients, the cooldown with flooding (CDF) transient is sufficiently severe that it is capable of generating additional plasticity in the weld region. Therefore, for the CDF transient only, an initial step was performed to "shakedown" the elastic-plastic model analysis state prior to its use in the CDF transient simulation. The purpose of this step is to adjust the zero load stress state for the CDF transient model so that it behaves in an elastic manner through the entire range of the transient, as do the other transients. As noted above, this step is applied only for the CDF transient and is not included in the residual stress distributions described in Section 5.4 below. The "shakedown" model is considered separately, and the results are not kept following the transient analysis.

In the case of the CDF transient, the incremental plasticity produces additional "mechanical stress improvement" at the zero load state (70°F and zero pressure), similar to that described previously in Section 5.2.c for hydrostatic testing. Initial investigation of the CDF transient demonstrated that after a single application of the transient to the elastic-plastic model, a subsequent application had a less than 1% effect of average weld region hoop stress throughout the transient. Additionally, it was found that the peak stress during the transient was not reduced during the subsequent application of the CDF transient. As noted above, the zero load stress state for the model was essentially adjusted so that the model behaved in an elastic manner through the entire range of the transient.

After completion of the model shakedown, the thermal and structural transient analysis for the CDF transient was performed elastically as described in Sections 5.3.1 and 5.3.2 above.

5.3.4 Transient Analysis Run Summary

The purpose of the transient analyses described in this calculation is to produce a set of initial stress files that can be mapped into the fracture mechanics models used to evaluate the effect of the transients on a hypothetical flaw in the nozzle remnant and weld. In order to appropriately simulate the pressure and thermal/residual loads, the initial stress files must be written during a structural simulation of a thermal-only (i.e., no pressure) transient, since the pressure loads of the transient will be applied to the fracture mechanics model as a live load. However, in order to correctly select the key time steps during the transient, it is necessary to first run the transient simulation using both pressure and temperature. Therefore, the structural transient was run two different ways in order to accommodate the needs of the fracture mechanics work supported by these analyses.

In the first run, both the temperature and pressure loads are input into the structural model. Pressure loading for the appropriate time during the transient, as defined by the pressure curves in Figures 3 through 8, is also applied to the structural model. The results for the full (temperature and pressure) transient analyses are post-processed, then used to identify the key time steps during each of the transients evaluated. These full transient analysis results are described in greater detail in Section 5.4 below. Once the key time steps have been selected, the transient analysis is run a second time, but this time only with temperature loads applied to the model (i.e., no pressure loads). Initial stress results files are written during the thermal-only transient analysis at the key time steps selected from the temperature plus pressure transient results post-processing. Further discussion of the files saved and the time steps from which they were taken is provided in Sections 5.4 and 5.5 below.

5.4 *Analytical Results Summary*

Figure 10 presents the results of the transient analysis model that includes pressure for all transients considered. This figure displays the hoop stress averaged over the buttering, weld, and adjacent nozzle region (see Figures 9a and 9b). The results presented in this figure are an estimate of the trends that would be expected for the fracture mechanics analysis of a flaw in the weld and lower nozzle region, since it presents the average load on the crack face over time. Stress results are presented as a function of load step during the transient, rather than time, in order to allow comparison between the relative magnitudes of stresses among the various transients. It is noted that any discontinuities in stress values between the transients plotted in Figure 10 are due to each transient starting from its own initial load state (temperature and pressure set), which many times does not correspond to the final load state of the previous transient.

Figures 11a and 11b present the hoop stress in the nozzle and weld at the initial time step prior to starting each transient (i.e., the residual stress in the zero-load state). In Figure 11a, the stress contours are consistent with the other stress figures described below for comparison between stress figures. In Figure 11b, the stress contours are automatically generated, with even contours enforced between maximum and minimum stresses. The stress state at this initial time step represents the condition following the steps described in Sections 5.2.a through 5.2.e, which are as follows: 1) butter simulation followed by stress relief, 2) weld simulation, 3) hydrotest, 4) uniform application of operating conditions, 5) zero load, and 6) nozzle repair cutting. The figure is a rotated view showing both the longitudinal plane as well as the orthogonal circumferential plane in the same view; each plane is identified on the figure. As shown in Figures 11a and 11b, the high hoop stresses in the weld region dissipate and turn compressive within a short distance into the shell from the butter/shell interface. Figures 11a and 11b also shows a difference in residual hoop stress between the longitudinal and circumferential planes of the model; this difference results from the uneven stress concentration at the hole during the pressure loading (including the hydrotest).

It is demonstrated in Figure 10 that the Cooldown with Flooding transient has the most severe stress range. The results also show that the two planes of the model experience significantly different average stress values throughout the range of transients. This difference results from the cylindrical base shell geometry, where the applied pressure press in the longitudinal direction is one-half the applied stress in the circumferential (hoop) direction. However, the times of maximum and minimum stress for the two model planes are the same, despite the differences in overall magnitude, in all but one case. As demonstrated by Figure 10, the Loss of Secondary Pressure transient shows a peak stress at time step 27 for the circumferential cut plane, and a peak stress at time step 21 for the longitudinal cut plane.

Figure 10 and the data used to generate it may also be used to determine the key time steps during each transient. As noted below, the stress information at these time steps was saved during a second structural analysis using thermal loads only. Table 7 lists the key time steps used to record initial stresses for each transient. As discussed above, the LOSP transient has two maximum stress time steps: one for the longitudinal plane and one for the circumferential plane. Additionally, Figures 12 through 24 present the hoop stress (top) and temperature (bottom) distributions in the model at each of these key time steps. As noted above for Figures 11a and 11b, the stress figures are displayed in a rotated view showing both the longitudinal plane as well as the orthogonal circumferential plane; each plane is identified on the figures.

5.5 *ANSYS Input Listings and Output Files*

The base welding residual stress analysis, which includes analysis steps detailed previously in Sections 5.2.a through 5.2.d, was performed using an ANSYS input listing file called "cirse.base," version 2.4.8. This standard input listing was developed by Dominion Engineering, Inc. outside of this scope of work. The input listing file is included in the 36-77 project file and is available for on-site review by SONGS/SCE personnel in our offices. The repair and transient analysis steps were performed using the file "press.trans.addon.txt," which is included as Attachment 1 to this calculation. All post-processing was performed using the file "PzSS.trans.addpost.txt," which is included as Attachment 2 to this calculation. An additional input listing file "therm.hm.PzSS.trans.addon.txt" was used to generate initial stress files for a half model geometry, as described below. This file is included as attachment 3 to this calculation.

ANSYS initial stress files were generated and saved for the thermal-only transient analysis at the time steps listed in Table 7. Each file was named according to the transient and the time step within the transient. The following files were saved, and used as inputs to the fracture mechanics modeling performed for this nozzle geometry: Two sets of files were generated, one for the full 180° model geometry and one for a half-model geometry. The full model files were used as inputs for the longitudinal cut plane flaw evaluation, and the half-model geometry files were used as inputs for the circumferential cut plane flaw.

PzSS-0A.trans1.7200.ist	PzSS-0A.trans4.50.ist
PzSS-0A.trans1.28800.ist	PzSS-0A.trans4.2000.ist
PzSS-0A.trans2.4428.ist	PzSS-0A.trans5.200.ist
PzSS-0A.trans2.10309.6.ist	PzSS-0A.trans5.2000.ist
PzSS-0A.trans3.180.ist	PzSS-0A.trans6.14400.ist
PzSS-0A.trans3.7380.ist`	PzSS-0A.trans6.36000.ist
PzSS-0A.trans1.7200.hm.ist	PzSS-0A.trans4.50.hm.ist
PzSS-0A.trans1.28800.hm.ist	PzSS-0A.trans4.2000.hm.ist
PzSS-0A.trans2.4428.hm.ist	PzSS-0A.trans5.200.hm.ist
PzSS-0A.trans2.10309.6.hm.ist	PzSS-0A.trans5.10000.hm.ist
PzSS-0A.trans3.180.hm.ist	PzSS-0A.trans6.14400.hm.ist
PzSS-0A.trans3.7380.hm.ist	PzSS-0A.trans6.36000.hm.ist

5.6 *Quality Assurance Software Controls*

The SONGS pressurizer thermowell nozzle analyses described in this calculation 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 (7).[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

[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.

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 36-77).

6.0 References

1. *PWSCC of Alloy 600 Materials in PWR Primary System Penetrations*, EPRI TR-103696, July 1994.
2. SONGS Units 2/3 Pressurizer Drawings:
   a. SONGS Drawing No. SO23-919-2, Rev. 9, Pressurizer Outline, Unit II
   b. SONGS Drawing No. SO23-919-12, Rev. 3, Vessel Welding and Machining, Unit II
   c. SONGS Drawing No. SO23-919-128, Rev. 0, Vessel Welding and Machining, Unit III
   d. SONGS Drawing No. SO23-919-79, Rev. 0, Pressurizer General Arrangement, Unit III
   e. SONGS Drawing No. SO23-919-16, Rev. 3, Nozzle Details, Unit II
4. SONGS Pressurizer Design Report, Report No. SS 21986, Rev. 0, p. A-453
5. SONGS Specification No. SO23-919-4, Rev. 1, "General Specification For A Pressurizer Assembly."
6. SONGS Specification No. SO23-919-3, Rev. 8, "Project Specification For A Pressurizer Assembly."
7. *Dominion Engineering, Inc. Quality Assurance Manual for Safety-Related Nuclear Work*, DEI-002, Revision 16.
8. "Modeling and Meshing Guide," ANSYS 8.0 Documentation, ANSYS, Inc.
9. ASME Boiler and Pressure Vessel Code, Section II, Part D, Properties, 2001 Revision.
10. M. H. Duc. "Specification de Calcul de Maquettes d'adaptateurs." EdF Specification MS-92-090-A-GPE: A667M.
11. *Inconel Alloy 600*, Special Metals Corporation Publication No. SMC 027, September 2002.
12. E. F. Rybicki and R. B. Stonesifer, "Computation of Residual Stresses due to Multipass Welds in Piping Systems," Journal of Pressure Vessel Technology, Volume 101, May 1979, pp. 149-154.
13. L. Karlsson, M. Jonsson, L-E. Lindgren, M. Näsström, and L. Troive, "Residual Stresses and Deformations in a Welded Thin-Walled Pipe.", *ASME Pressure Vessels & Piping Conference*, Honolulu, Hawaii, USA, July 1989.

14. "Welding Handbook," Volume One, Seventh Edition, p. 94, American Welding Society, 1981.

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

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Table 1

Pressurizer Heatup Transient: Pressure and Temperature Values
(Transient #1)

Time Step	Time (s)	Temperature (°F)	Pressure (psig)
1	0.1	70	0
2	1,800	170	0
3	3,600	270	5
4	5,400	370	200
5	7,200	470	500
6	8,640	550	1,000
7	9,432	594	1,500
8	10,080	630	1,950
9	10,494	653	2,235
10	11,394	653	2,235
11	12,294	653	2,235
12	14,094	653	2,235
13	17,694	653	2,235
14	28,800	653	2,235

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Table 2

Pressurizer Cooldown with Flooding Transient: Pressure and Temperature Values
(Transient #2)

Time Step	Time (s)	Temperature (°F)	Pressure (psig)
1	0.1	653	2,235
2	756	610	1,876
3	1,512	568	1,517
4	2,268	525	1,157
5	3,024	483	798
6	3,780	440	439
7	3,780	440	0
8	3,888	383	0
9	3,996	327	0
10	4,104	270	0
11	4,212	213	0
12	4,320	157	0
13	4,428	100	0
14	5,542	100	0
15	6,657	100	0
16	7,771	100	0
17	8,886	100	0
18	10,000	100	0
19	10,062	135	0
20	10,124	170	0
21	10,186	205	0
22	10,248	240	0
23	10,310	275	0
24	10,310	275	439
25	11,047	234	351
26	11,784	193	263
27	12,521	152	176
28	13,259	111	88
29	13,996	70	0
30	14,497	70	0
31	14,998	70	0
32	15,499	70	0
33	16,000	70	0

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Table 3

Pressurizer Loading/Unloading & 10% Step Change: Pressure and Temperature Values
(Transient #3)

Time Step	Time (s)	Temperature (°F)	Pressure (psig)
1	0.1	633	2,135
2	1	653	2,235
3	15	653	2,235
4	60	653	2,235
5	180	653	2,235
6	600	653	2,235
7	1,800	653	2,235
8	3,600	653	2,235
9	7,200	653	2,235
10	7,201	633	2,135
11	7,215	633	2,135
12	7,260	633	2,135
13	7,380	633	2,135
14	7,800	633	2,135
15	9,000	633	2,135
16	10,800	633	2,135
17	14,400	633	2,135

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Table 4

Pressurizer Reactor Trip/Loss of Load/Loss of Flow: Pressure and Temperature Values
(Transient #4)

Time Step	Time (s)	Temperature (°F)	Pressure (psig)
1	0.1	653	2,235
2	10	645	2,295
3	20	637	2,355
4	30	629	2,415
5	40	621	2,475
6	50	613	2,535
7	100	611	1,685
8	150	609.2	1,699
9	200	607.4	1,713
10	300	603.8	1,740
11	400	600.2	1,768
12	500	596.6	1,795
13	600	593	1,823
14	740	599	1,861
15	880	605	1,900
16	1,160	617	1,977
17	1,440	629	2,054
18	1,720	641	2,131
19	1,860	647	2,169
20	2,000	653	2,208
21	2,100	653	2,235
22	2,600	653	2,235
23	3,600	653	2,235
24	5,400	653	2,235
25	7,200	653	2,235

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Table 5

Pressurizer Loss of Secondary Pressure Transient: Pressure and Temperature Values
(Transient #5)

Time Step	Time (s)	Temperature (°F)	Pressure (psig)
1	0.1	653	2,235
2	6	635	2,173
3	7	632	2,163
4	23	585.5	2,000
5	38	539	1,837
6	54	492.5	1,674
7	69	446	1,511
8	85	399.5	1,348
9	100	353	1,186
10	125	356.75	923
11	150	360.5	660
12	175	364.25	398
13	200	368	135
14	300	380.5	160
15	400	393	185
16	600	408	235
17	800	423	285
18	1,000	433	335
19	1,550	458	434
20	1,551	458	434
21	2,000	473	515
22	2,667	491	622
23	3,333	510	728
24	4,000	528	835
25	6,200	590.5	1,535
26	8,400	653	2,235
27	10,000	653	2,235

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Table 6

Pressurizer Leak Test Transient: Pressure and Temperature Values
(Transient #6)

Time Step	Time (s)	Temperature (°F)	Pressure (psig)
1	0.1	100	385
2	1,800	100	385
3	3,600	100	385
4	5,760	160	385
5	7,920	220	385
6	10,080	280	385
7	12,240	340	385
8	14,400	400	385
9	14,401	400	2,235
10	16,200	400	2,235
11	18,000	400	2,235
12	19,800	400	2,235
13	21,600	400	2,235
14	23,400	400	2,235
15	25,200	400	2,235
16	27,360	340	2,235
17	29,520	280	2,235
18	31,680	220	2,235
19	33,840	160	2,235
20	36,000	100	2,235
21	36,001	100	385
22	37,440	100	385
23	38,880	100	385
24	40,320	100	385
25	41,760	100	385
26	43,200	100	385

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Table 7

Pressurizer Thermowell Nozzle Transient Analysis: Key Time Steps

Transient	Load Step	Time	Max/Min
Heatup	5	7,200	Min
	14	28,800	Max
Cooldown w/ Flooding	13	4,428	Max
	23	10,309.6	Min
Loading/Unloading & Step Change	5	180	Min
	13	7,380	Max
Trip, Loss of Load, Loss of Flow	6	50	Max
	20	2,000	Min
Loss of Secondary Pressure	13	200	Min
	21	2,000	Max (long)
	27	10,000	Max (circ)
Leak Test	8	14,400	Min
	20	36,000	Max

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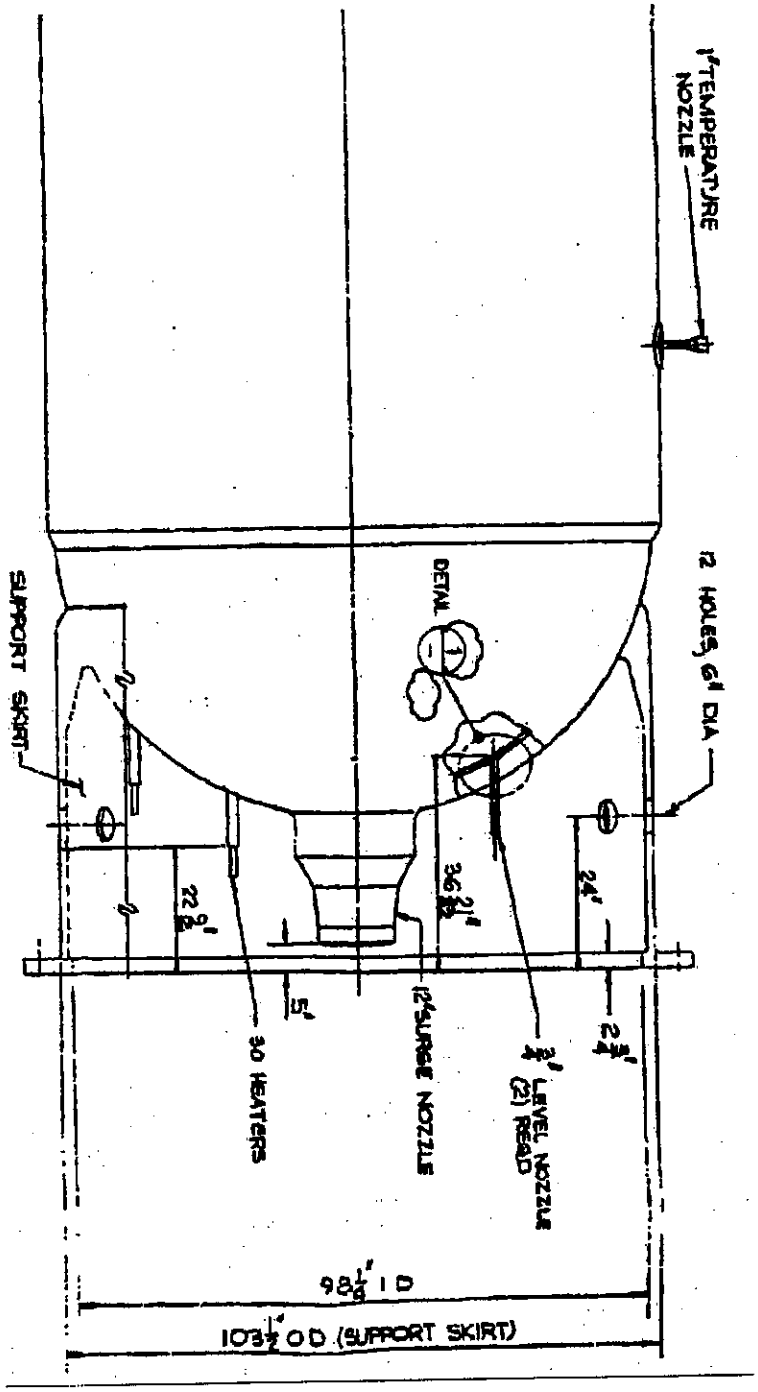

SONGS Pressurizer Outline Showing Thermowell Nozzle Location

Figure 1

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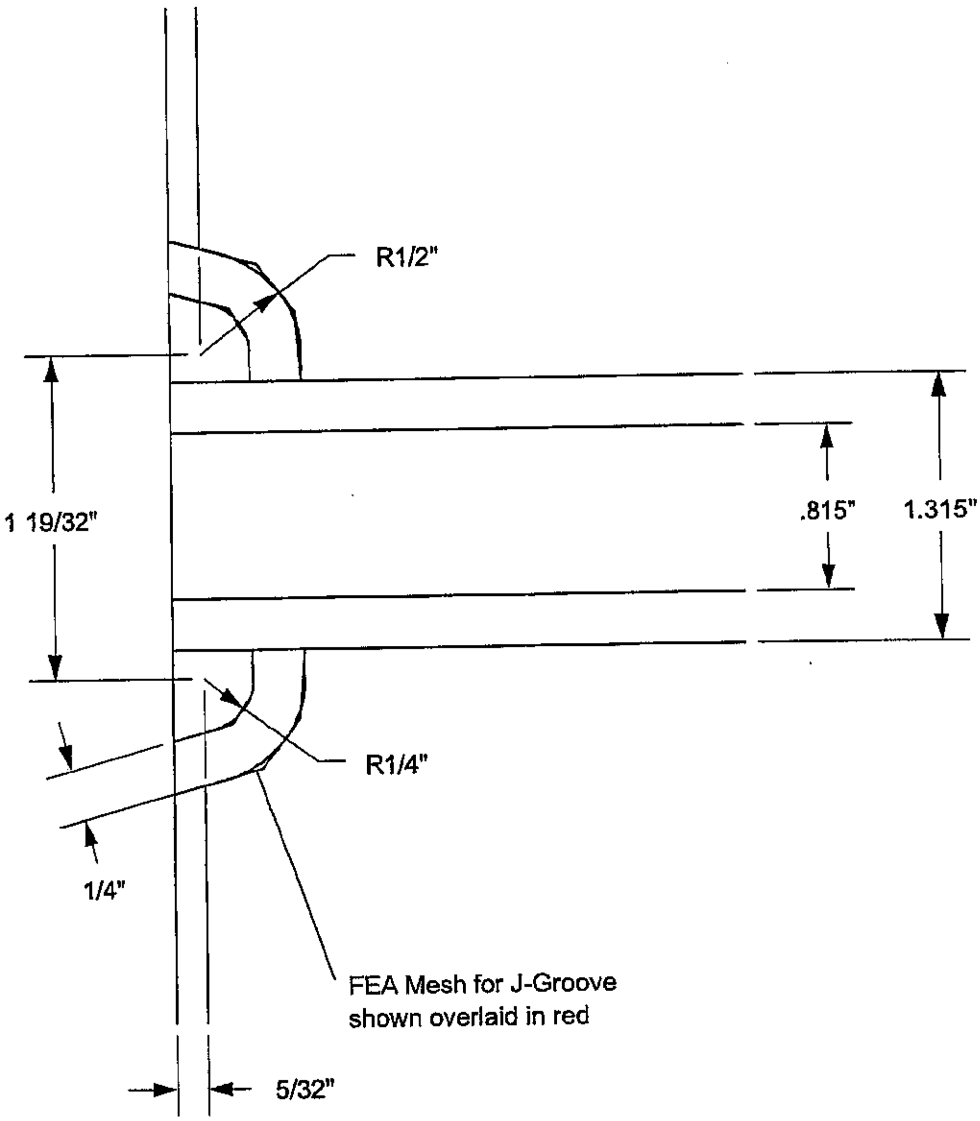

SONGS Pressurizer Thermowell Nozzle Geometry Summary

Figure 2

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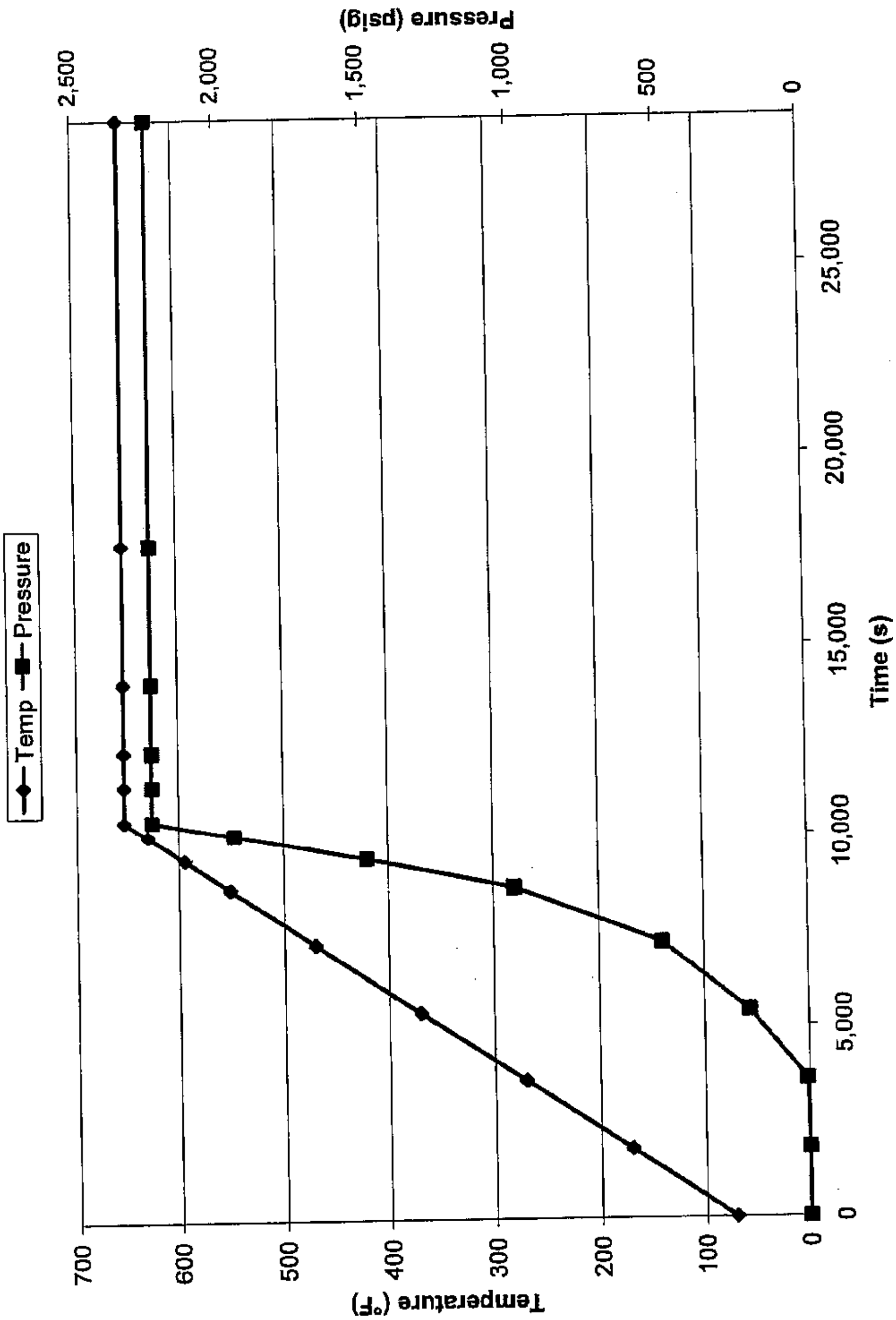
sht. 33



Pressurizer Heatup Transient: Pressure and Temperature vs. Time

Figure 3

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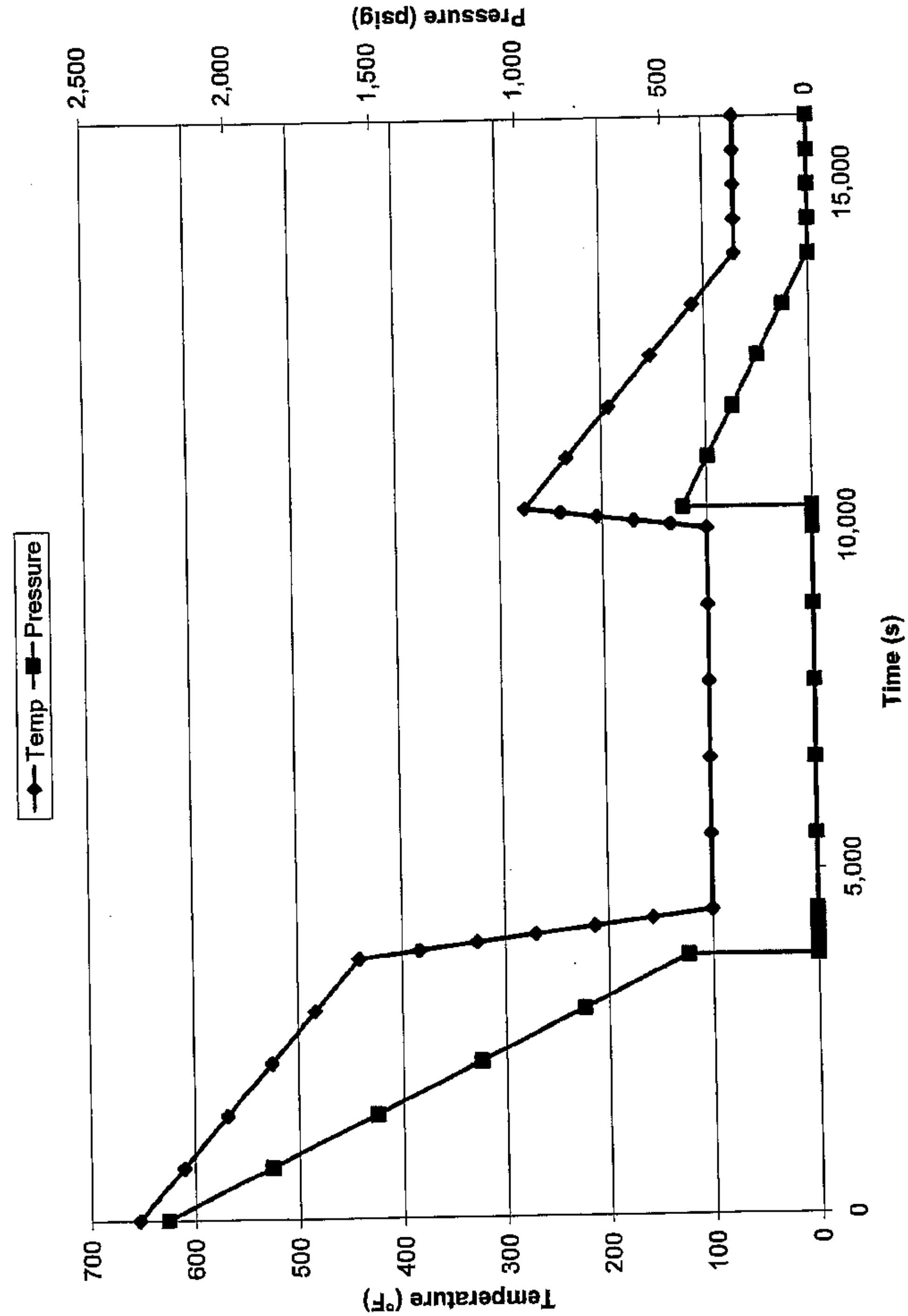
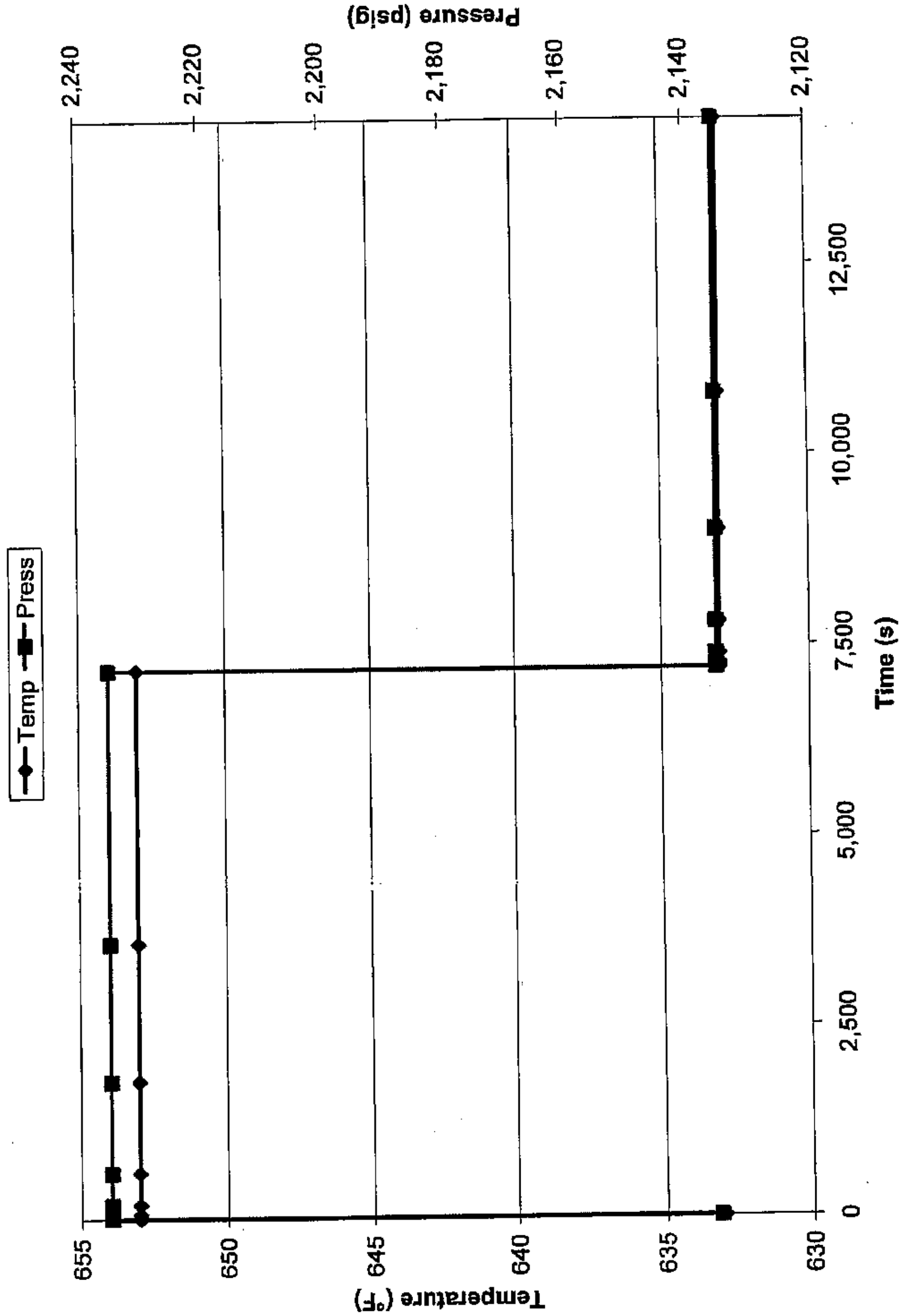
sht. 34



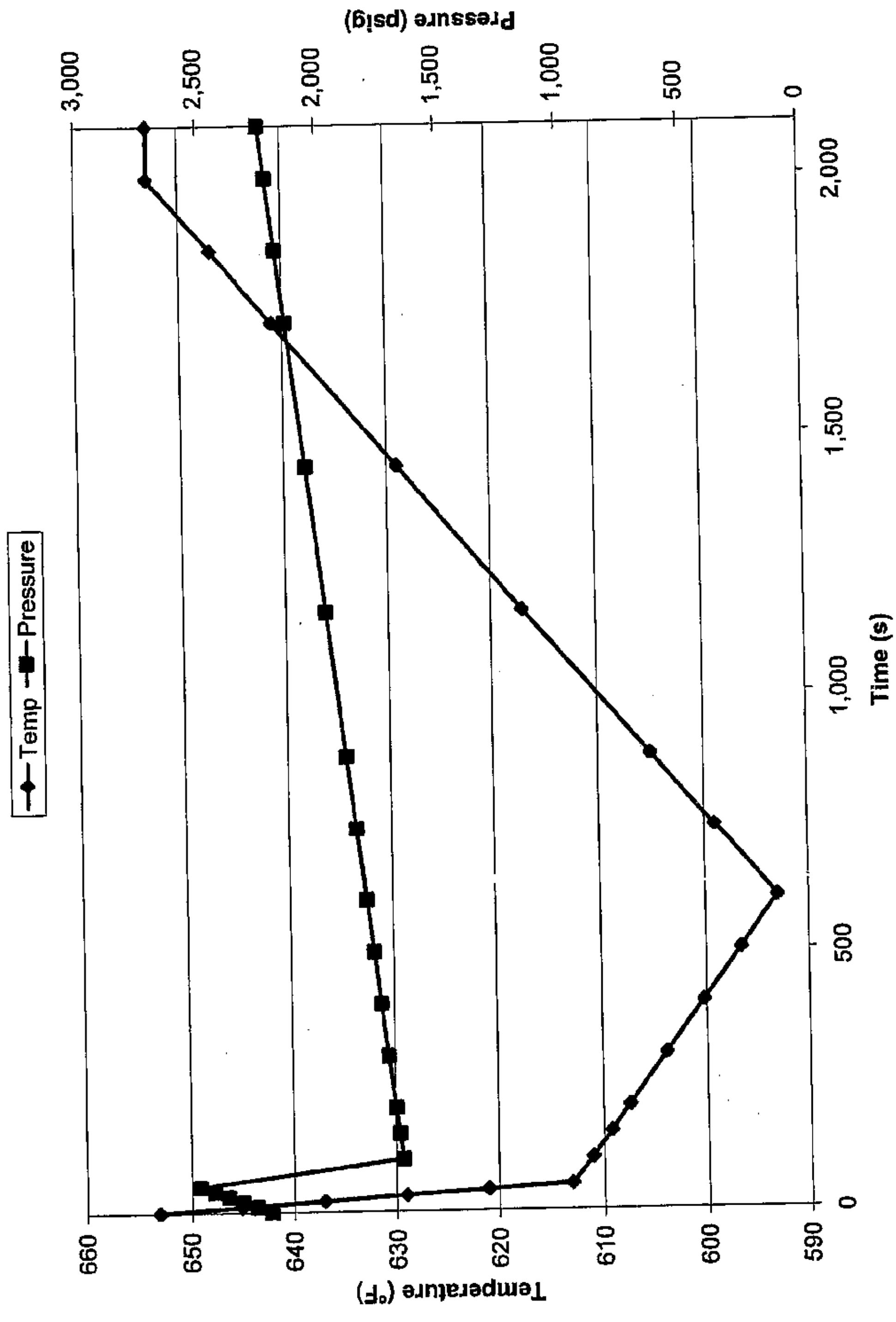
Pressurizer Cooldown with Flooding Transient: Pressure and Temperature vs. Time

Figure 4 M-DSC-412, Rev. 0 sht. 35



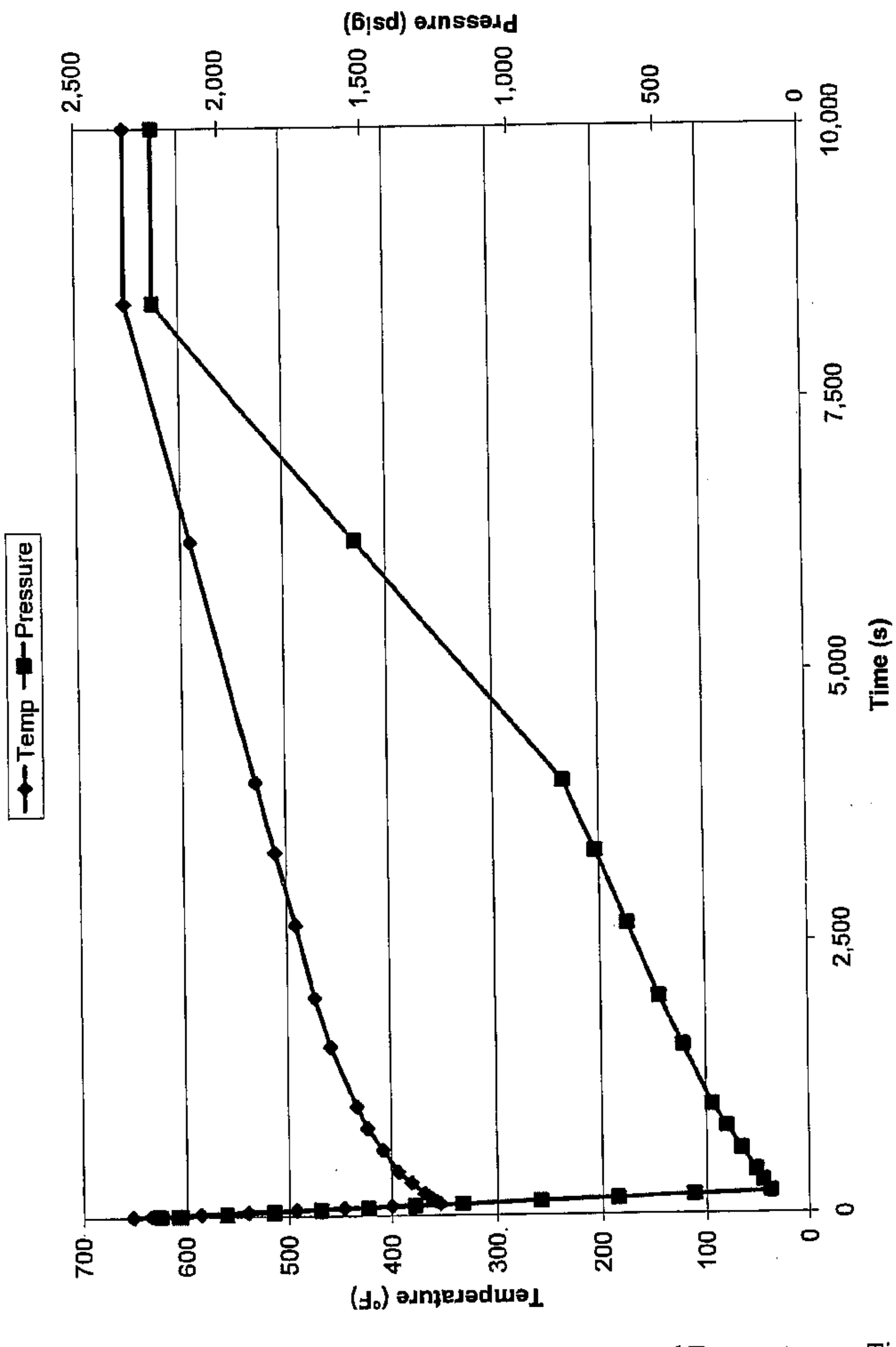
Pressurizer Loading/Unloading & 10% Step Change: Pressure and Temperature vs. Time

Figure 5 M-DSC-412, Rev. 0
sht. 36



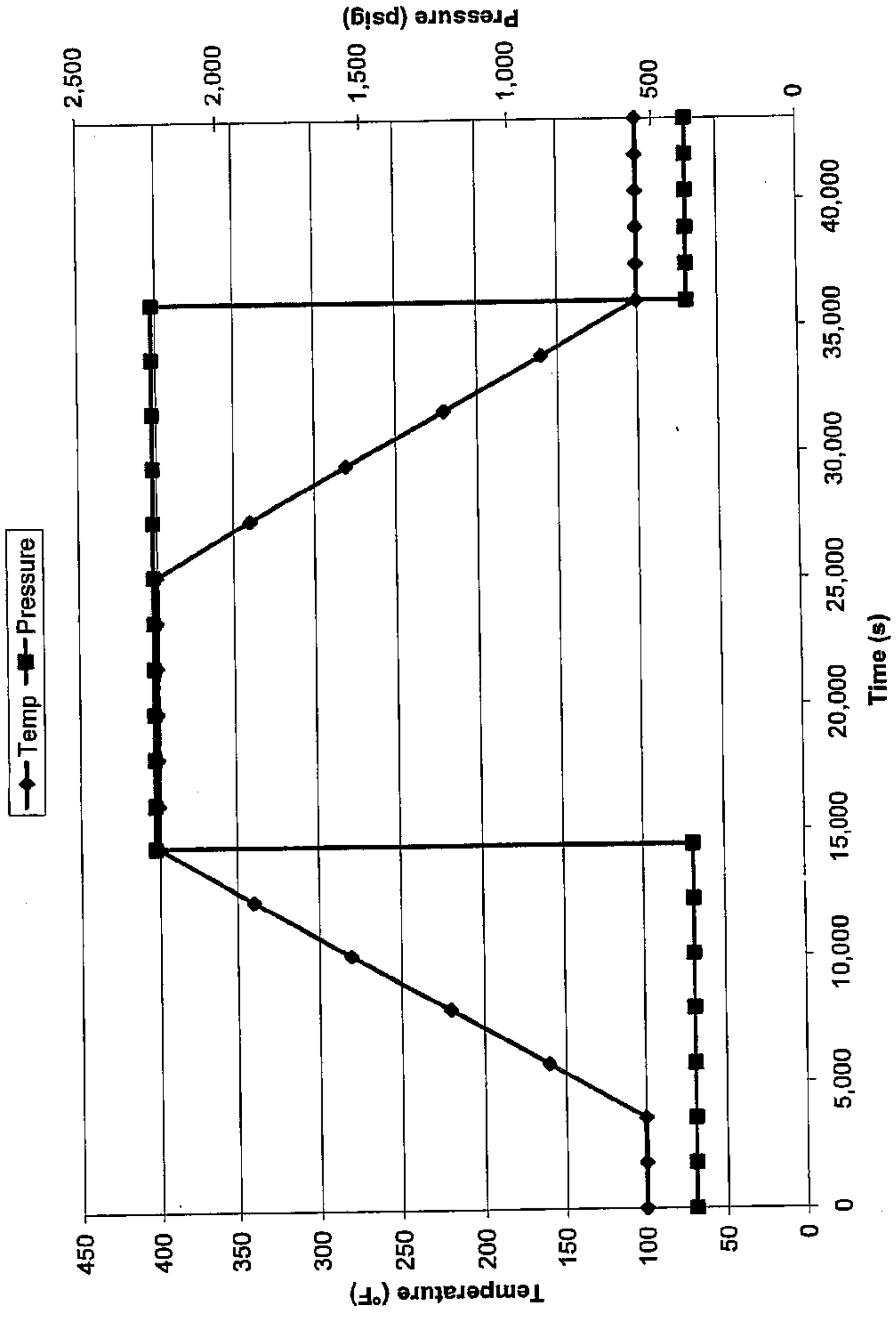
Pressurizer Reactor Trip/Loss of Load/Loss of Flow: Pressure and Temperature vs. Time

Figure 6 M-DSC-412, Rev.0 sht. 37



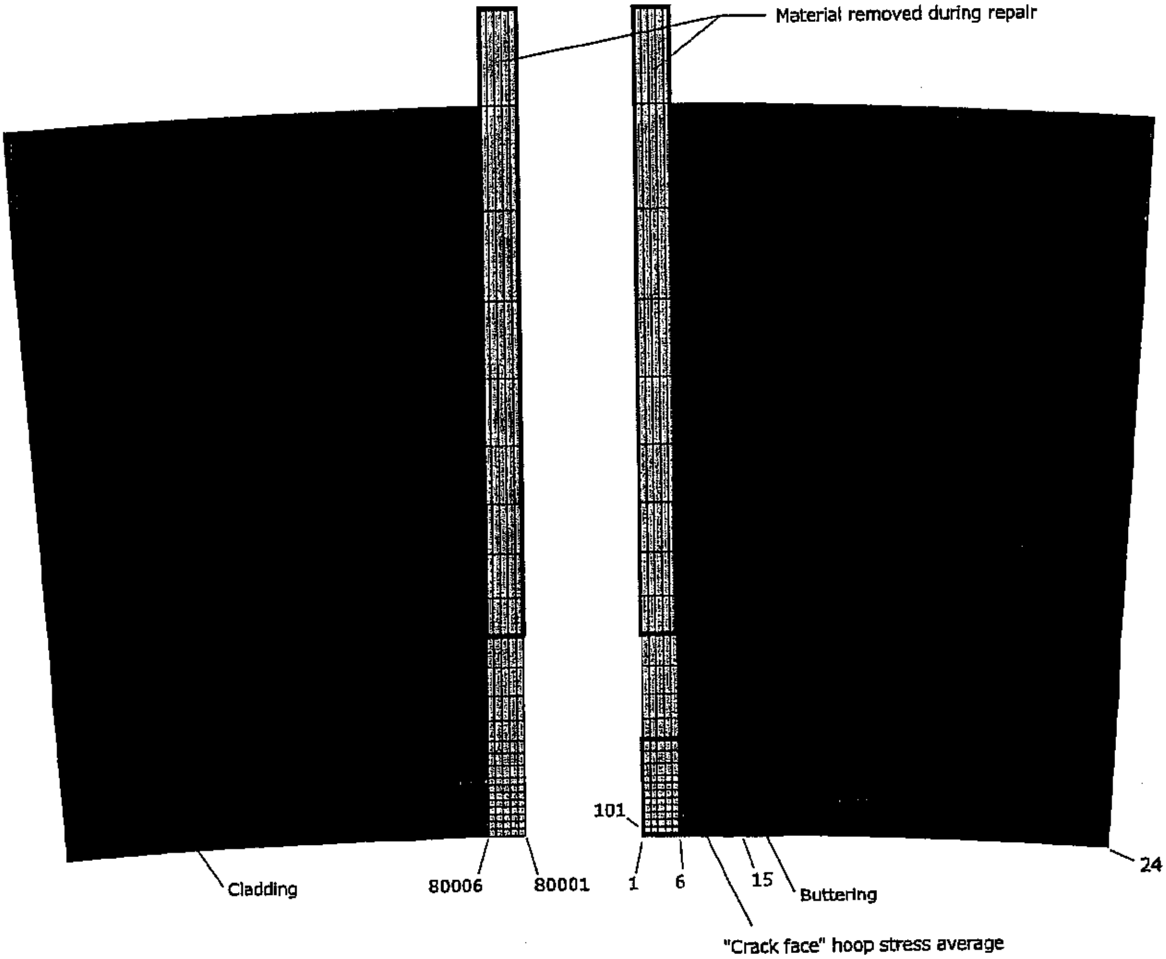
Pressurizer Loss of Secondary Pressure Transient: Pressure and Temperature vs. Time

Figure 7 M-DSC-412, Rev.0 sht. 38



Pressurizer Leak Test Transient: Pressure and Temperature vs. Time

Figure 8 M-DSC-412, Rev.0 sht. 39



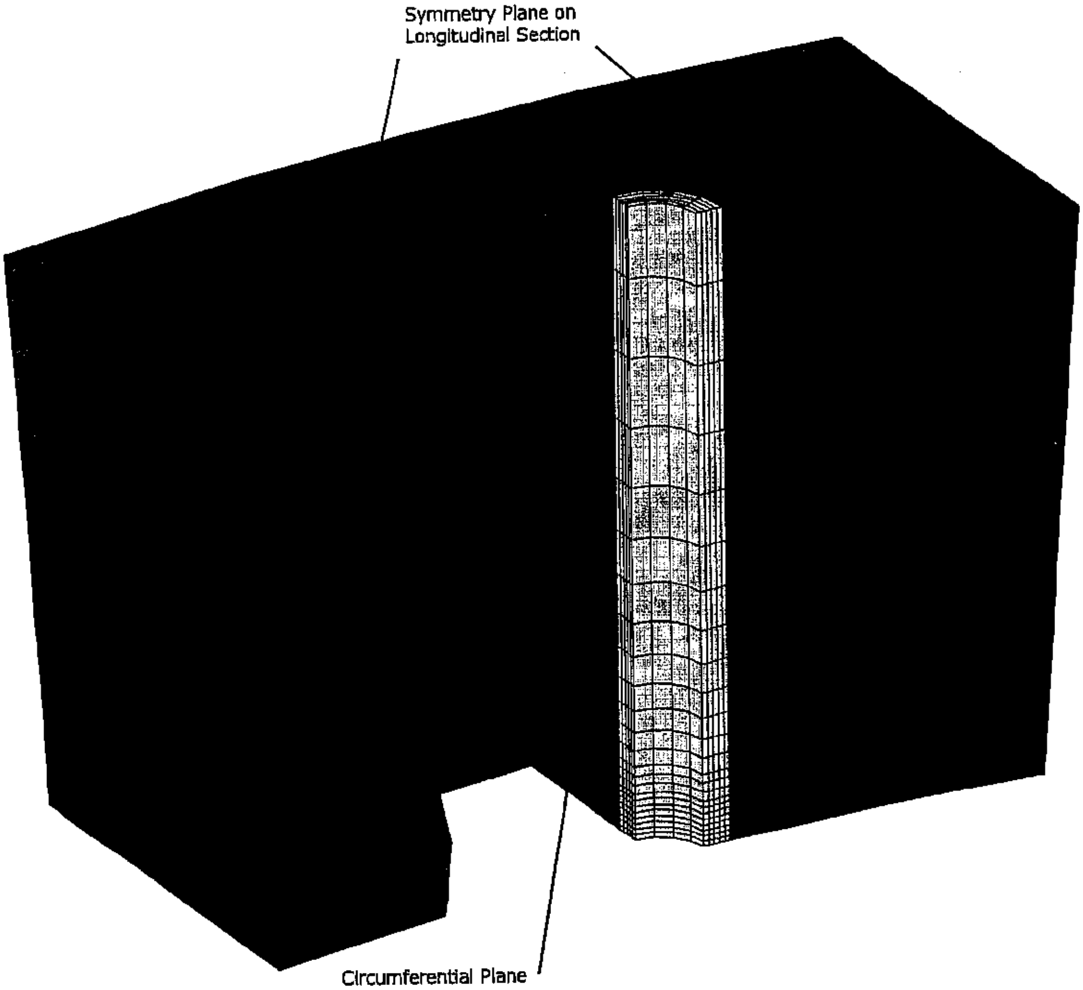
Uphill Plane Nodes are 0's Series
Downhill Plane Nodes are 80,000's Series

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
24'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

SONGS Pressurizer Thermowell Nozzle Model Node Numbering Scheme

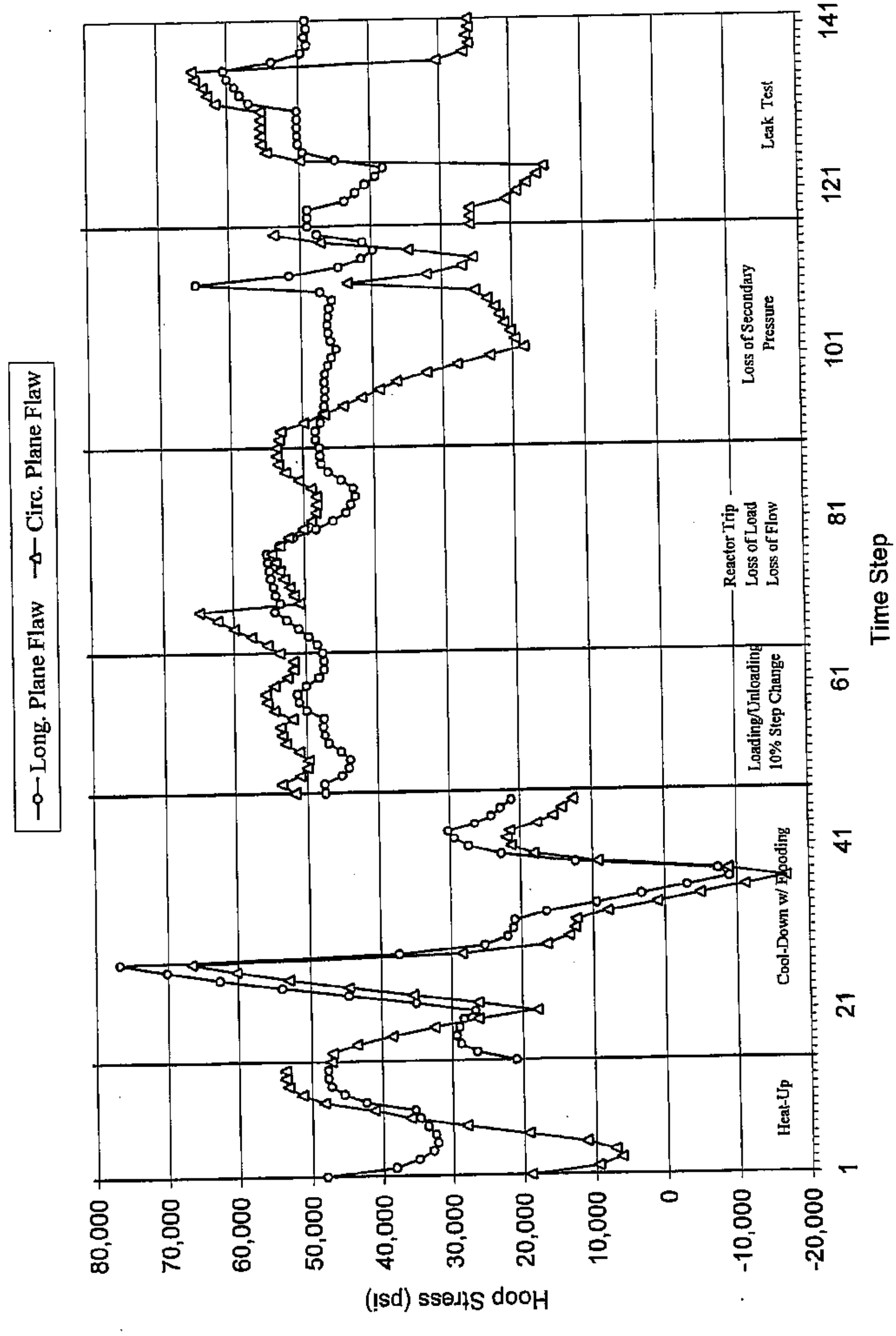
Figure 9a M-DSC-412, Rev.0
sht. 40



SONGS Pressurizer Thermowell Nozzle Model Rotated and Cut-Away View

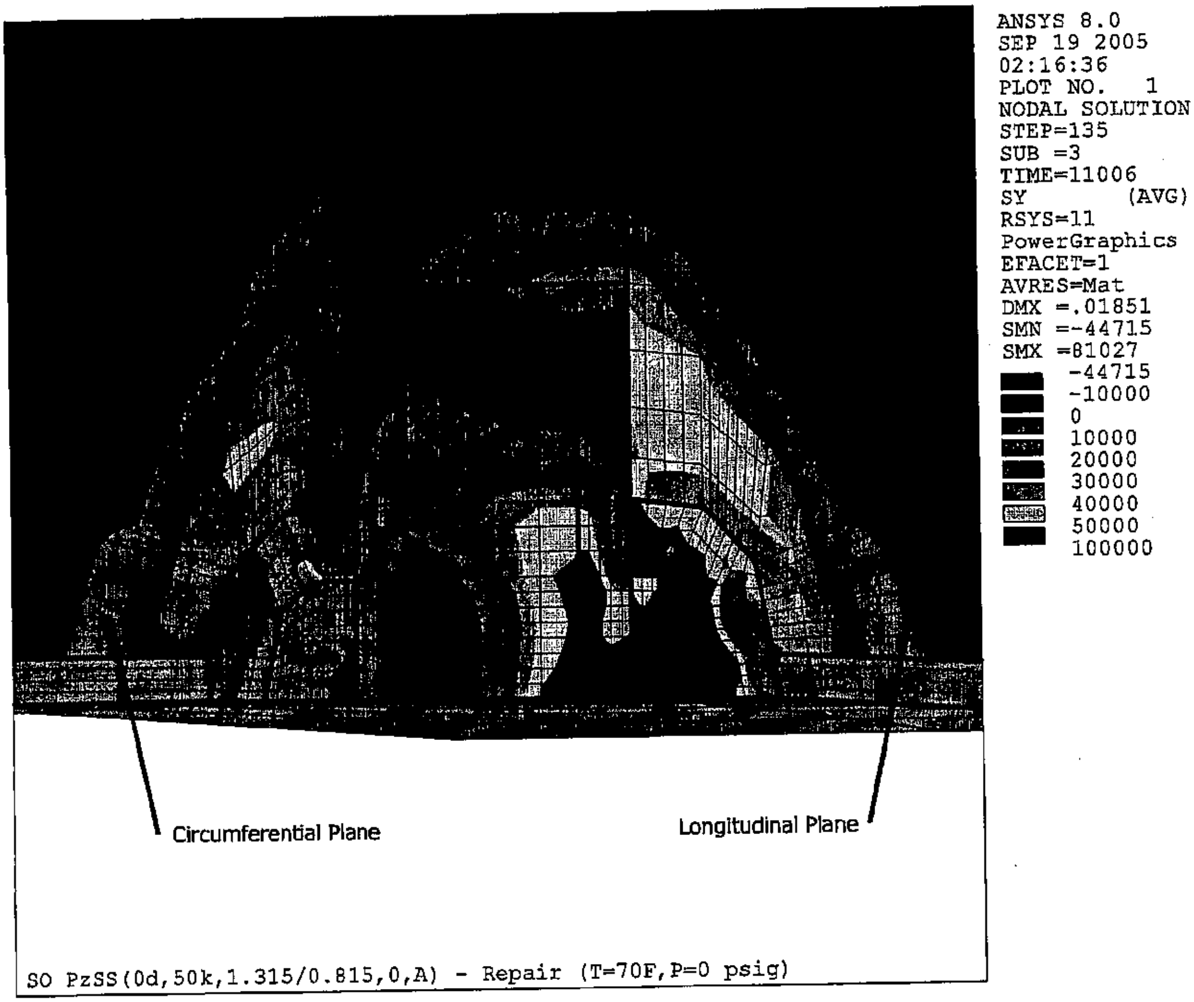
Figure 9b

M-DSC-412, Rev. 0
sht. 41



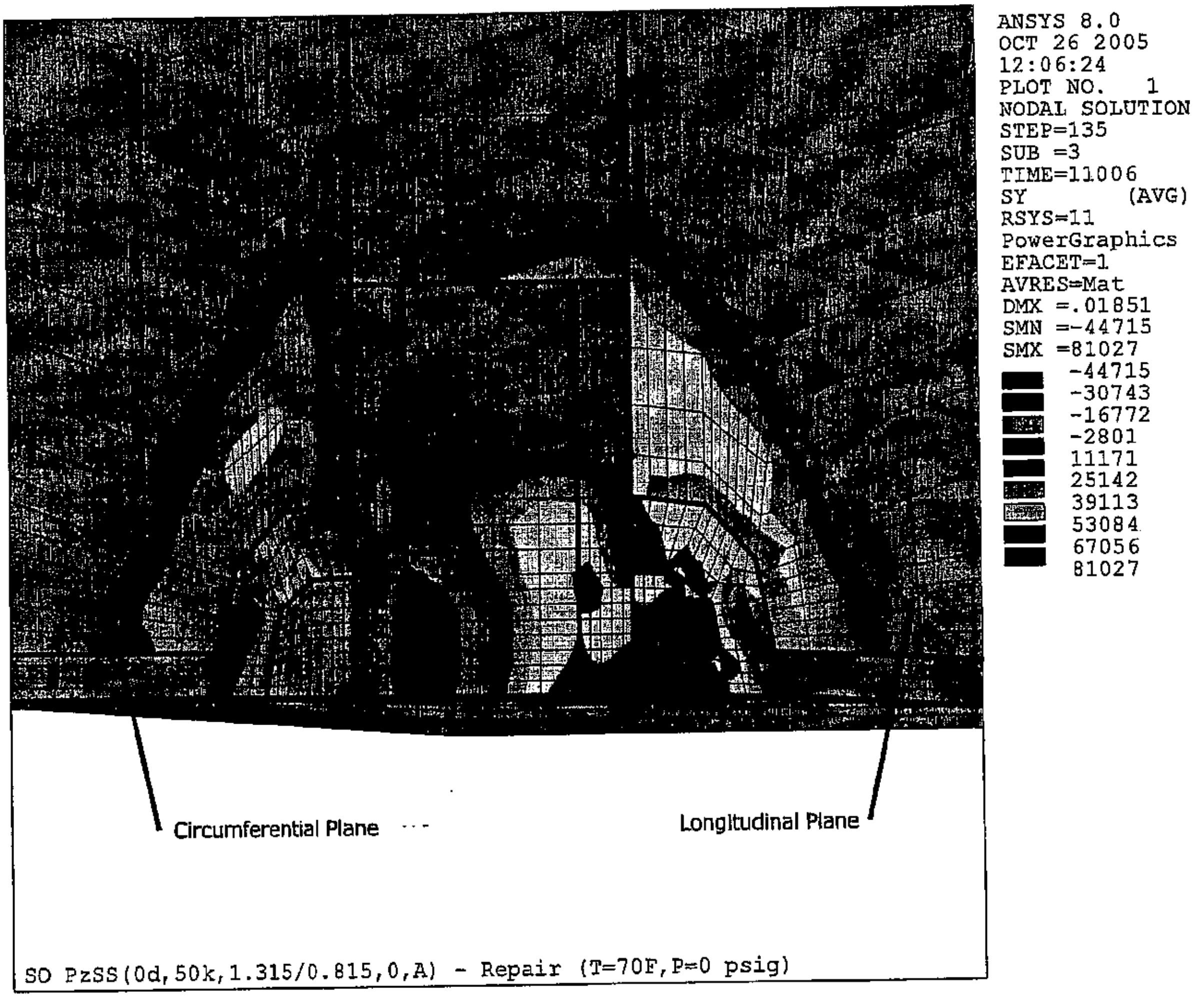
SONGS Pressurizer Transients Average Hoop Stress Over Weld + Adjacent Nozzle

Figure 10 M-DSC-412, Rev.0 sht. 42



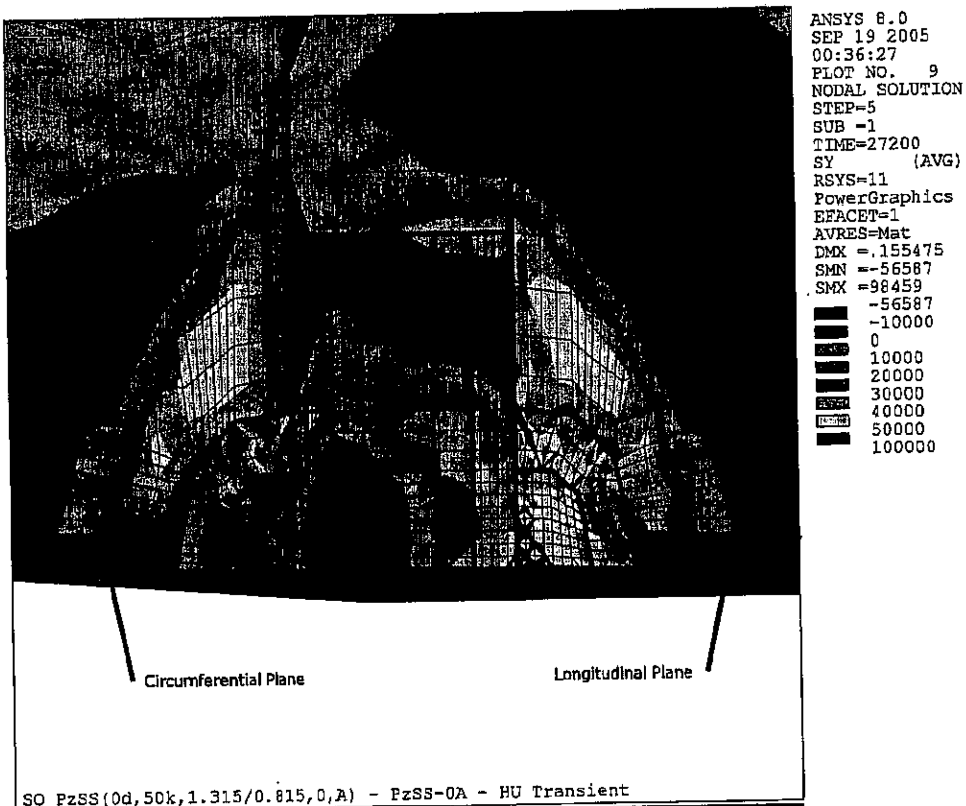
SONGS Pressurizer Thermowell Nozzle Welding Residual Hoop Stress – Standard Stress Contours

Figure 11a M-DSC-412, Rev. 0
sht. 43



SONGS Pressurizer Thermowell Nozzle Welding Residual Hoop Stress – Automatic Stress Contours

Figure 11b M-DSC-412, Rev.0
Sht. 44



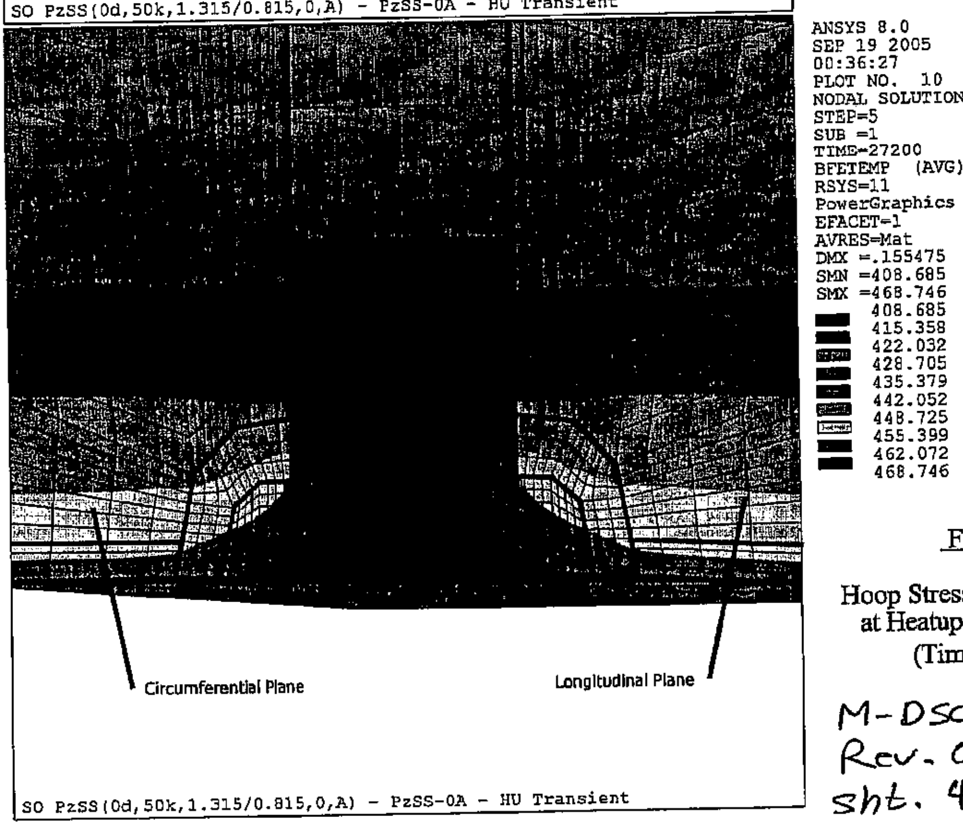
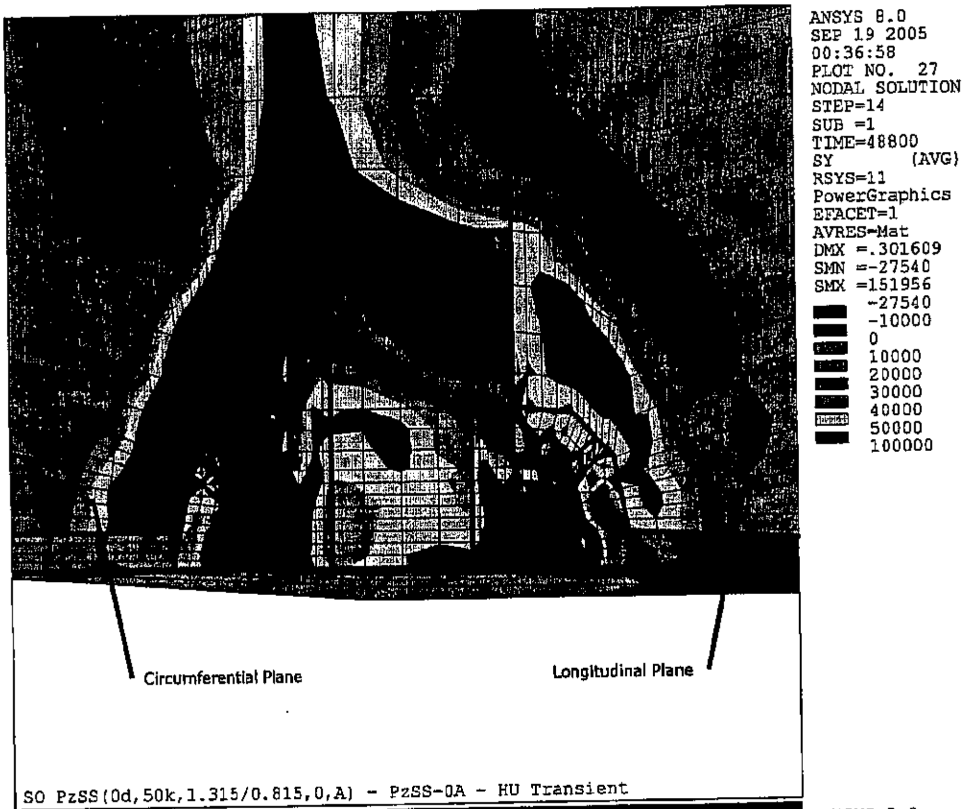


Figure 12

Hoop Stress and Temperature at Heatup Transient Step 5 (Time = 7,200 s)

M-DSC-412
Rev. 0
sht. 45



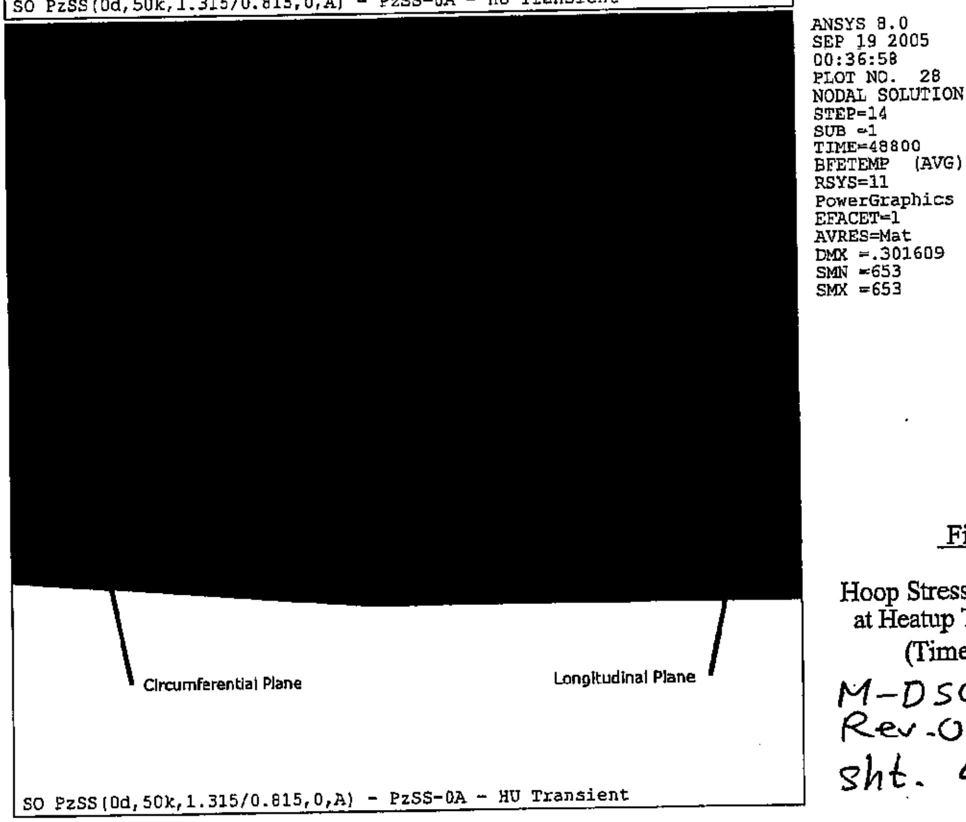
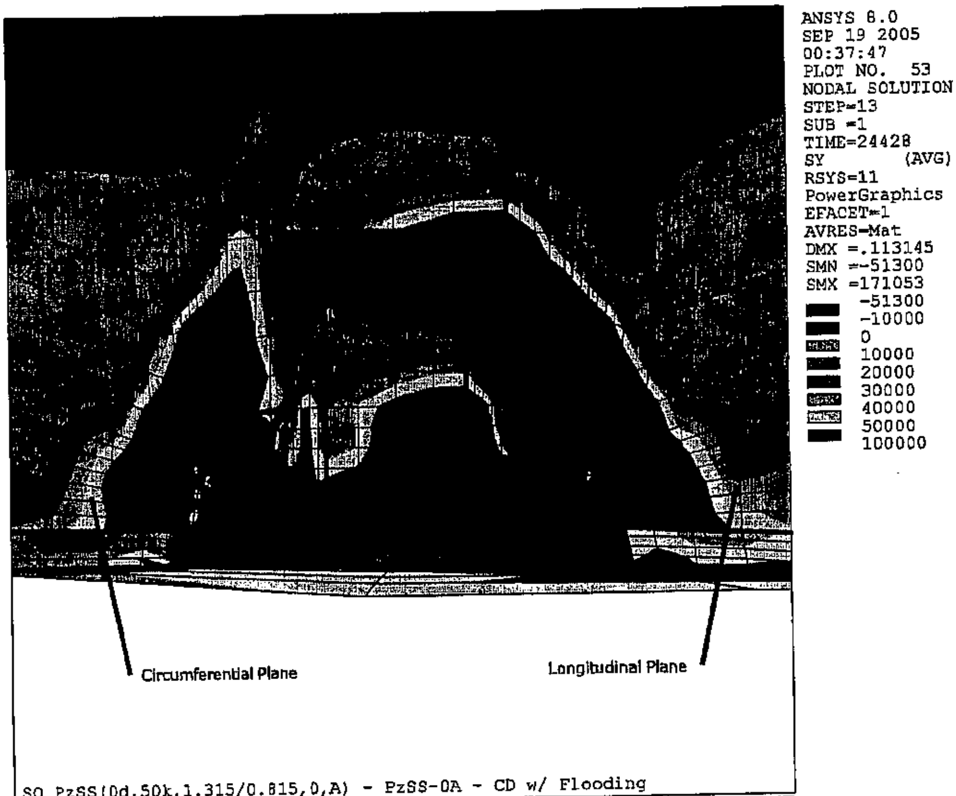


Figure 13

Hoop Stress and Temperature at Heatup Transient Step 14 (Time = 28,800 s)

M-DSC-412
Rev. 0
sht. 46



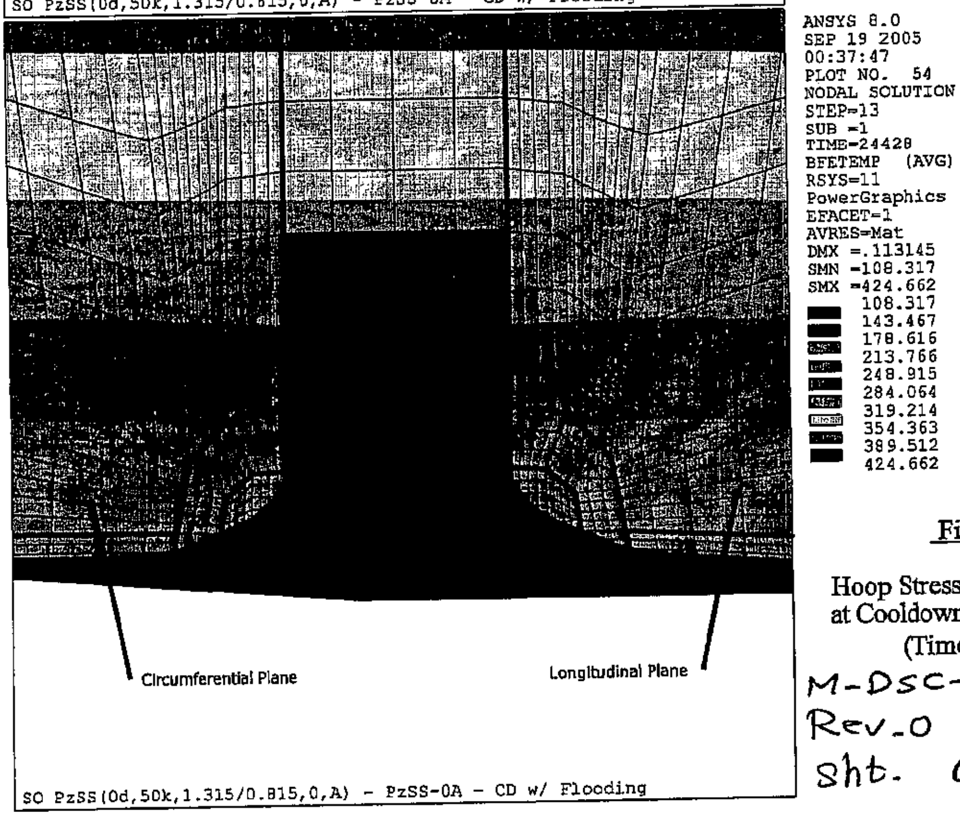
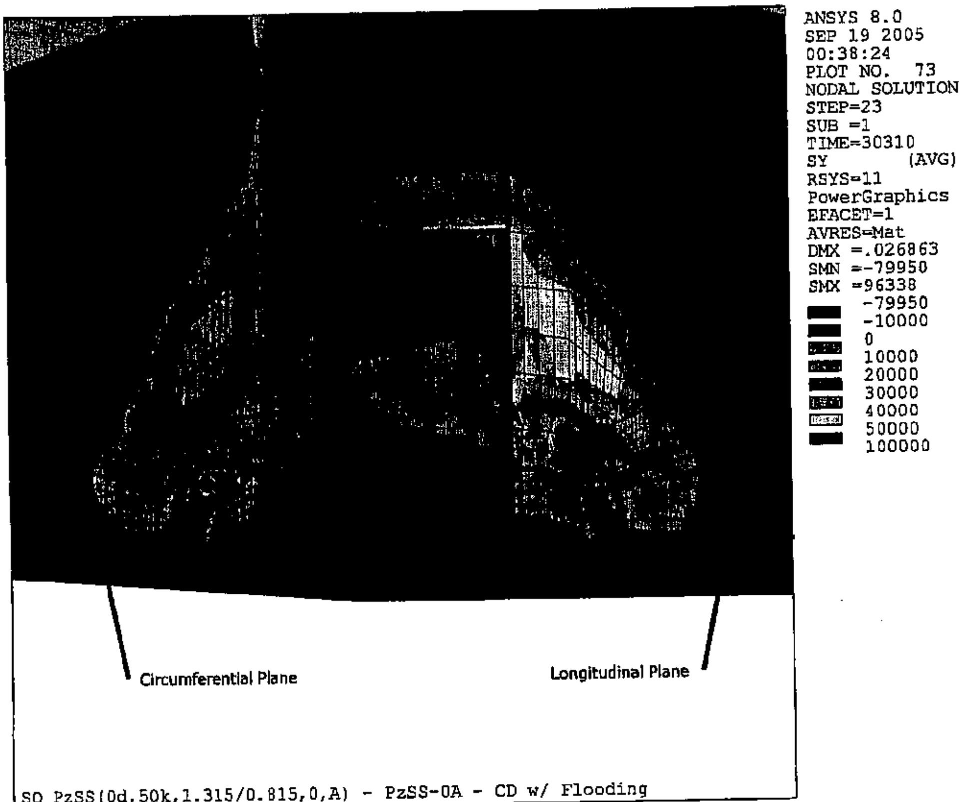


Figure 14

Hoop Stress and Temperature at CooldownTransient Step 13 (Time = 4,428 s)

M-DSC-412
Rev. 0
Sht. 47



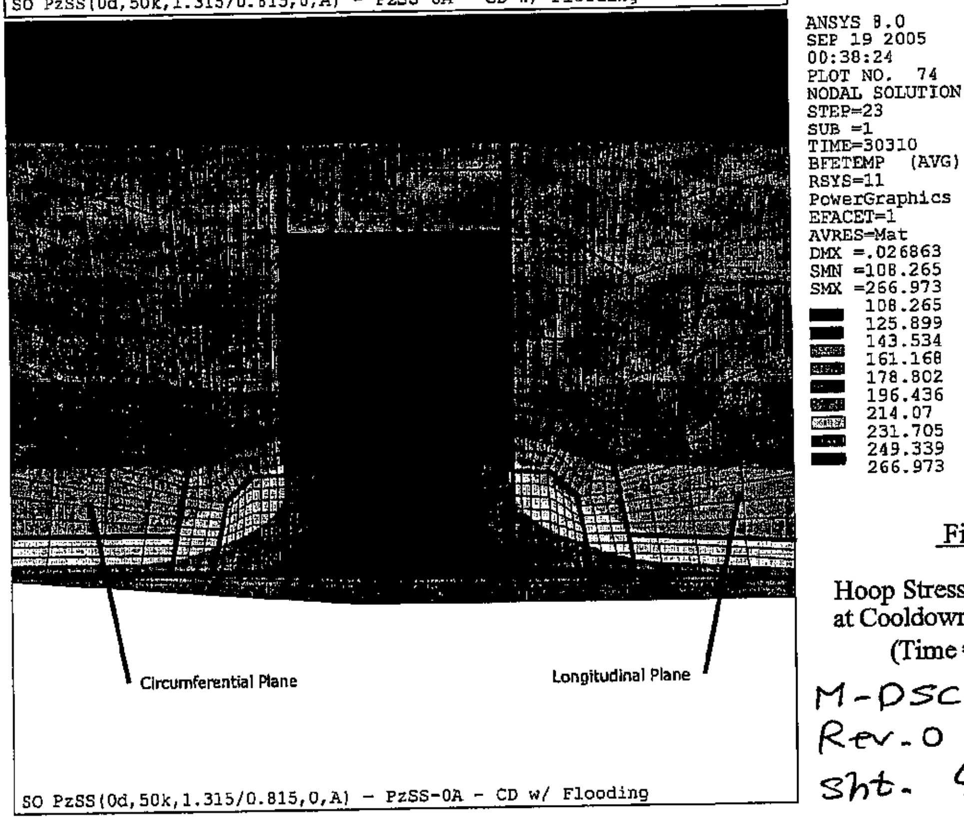
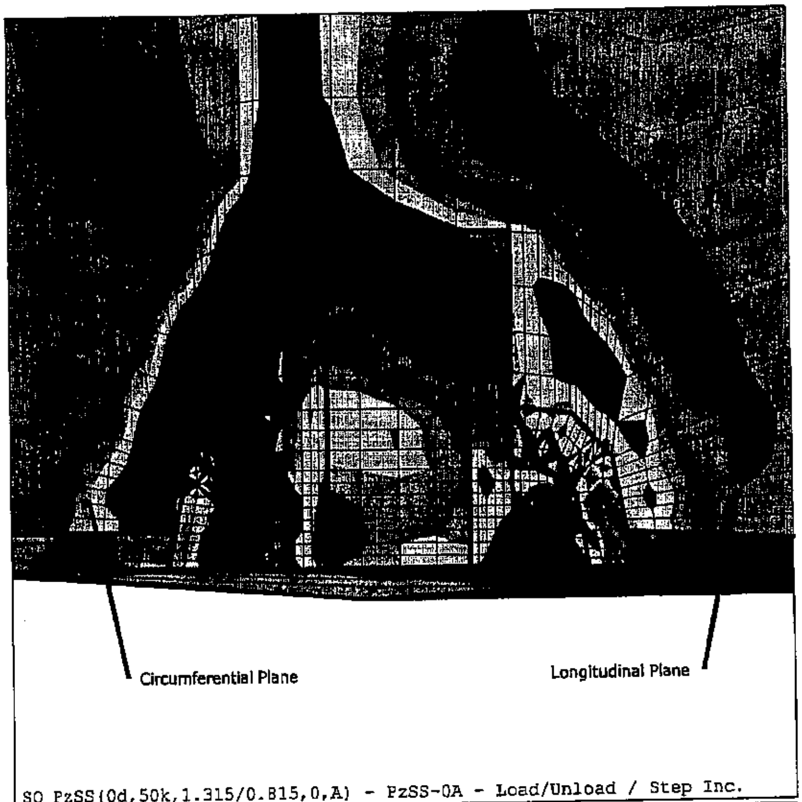


Figure 15

Hoop Stress and Temperature at CooldownTransient Step 23 (Time = 10,309.6 s)

M-DSC-412
Rev. 0
sht. 48



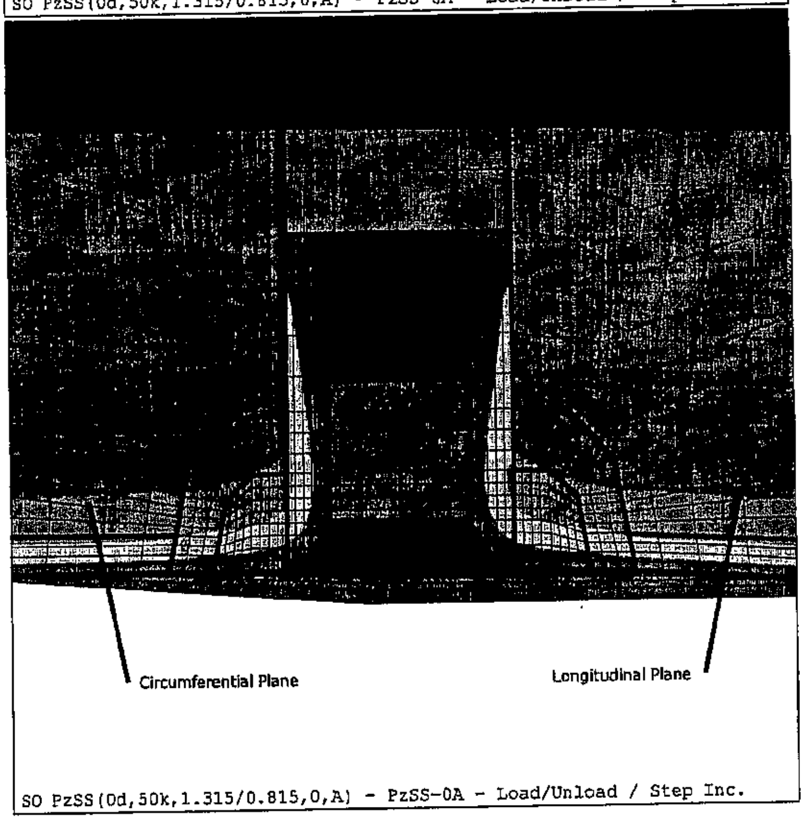
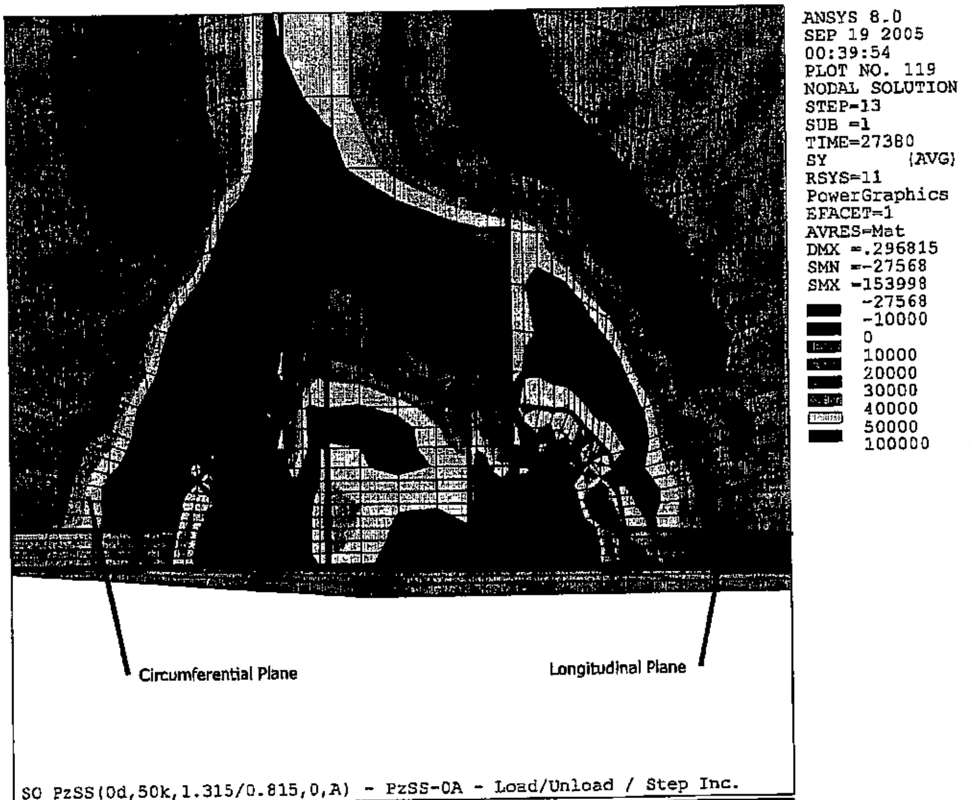


Figure 16

Hoop Stress and Temperature at L/UL Transient Step 5 (Time = 180 s)

M-DSC-412
Rev-0
sht. 49



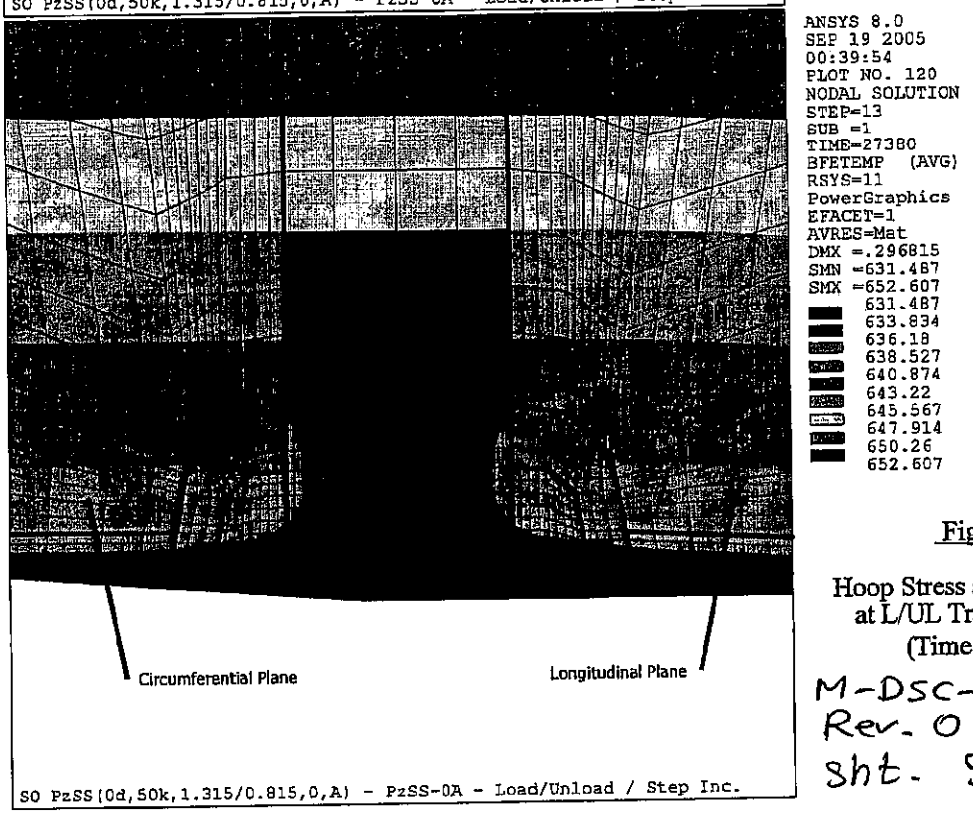
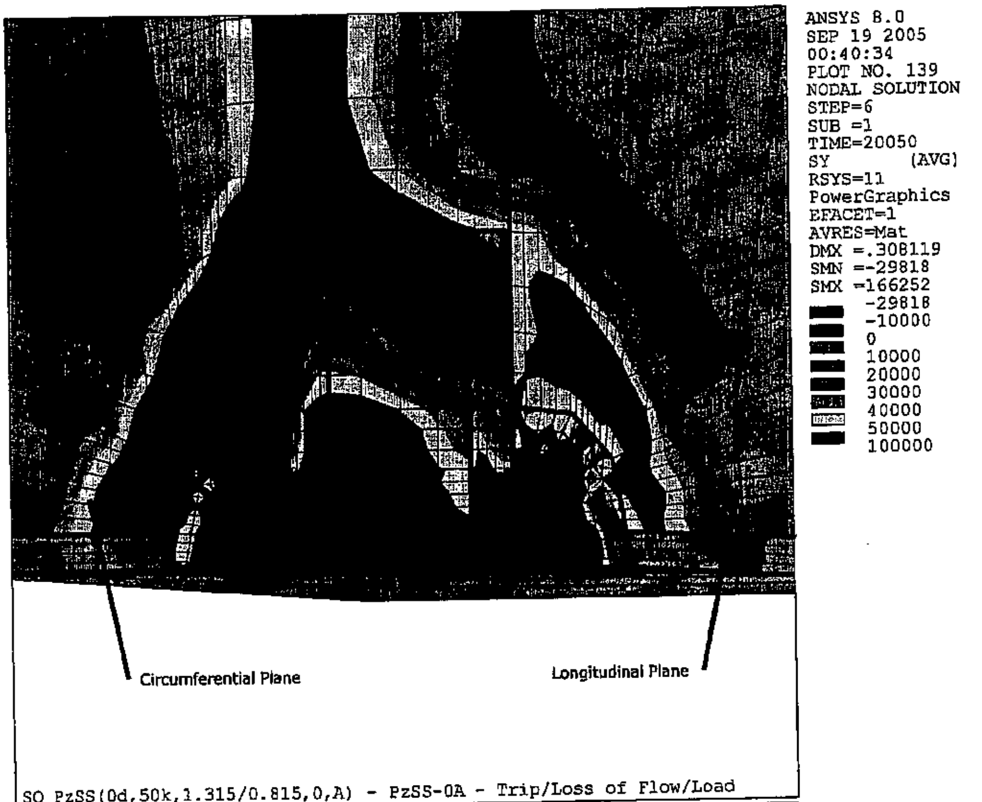


Figure 17

Hoop Stress and Temperature at L/UL Transient Step 13 (Time = 7,380 s)

M-DSC-412
Rev. 0
sht. 50



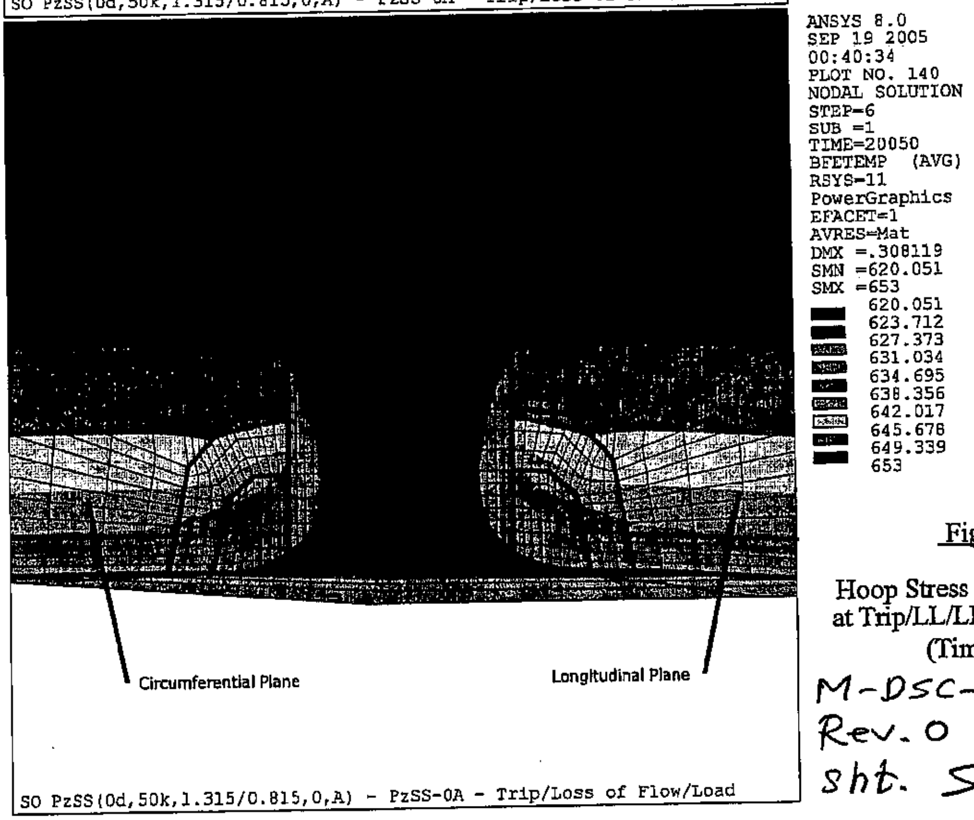
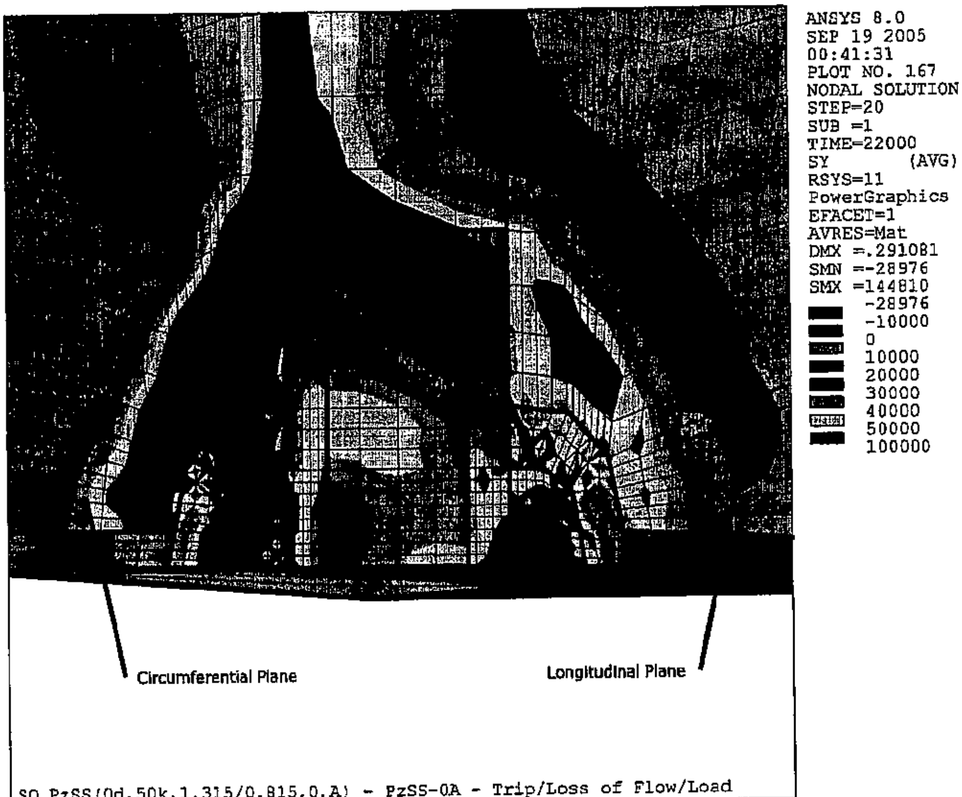


Figure 18

Hoop Stress and Temperature at Trip/LL/LF Transient Step 6 (Time = 50 s)

M-DSC-412
Rev. 0
sht. 51



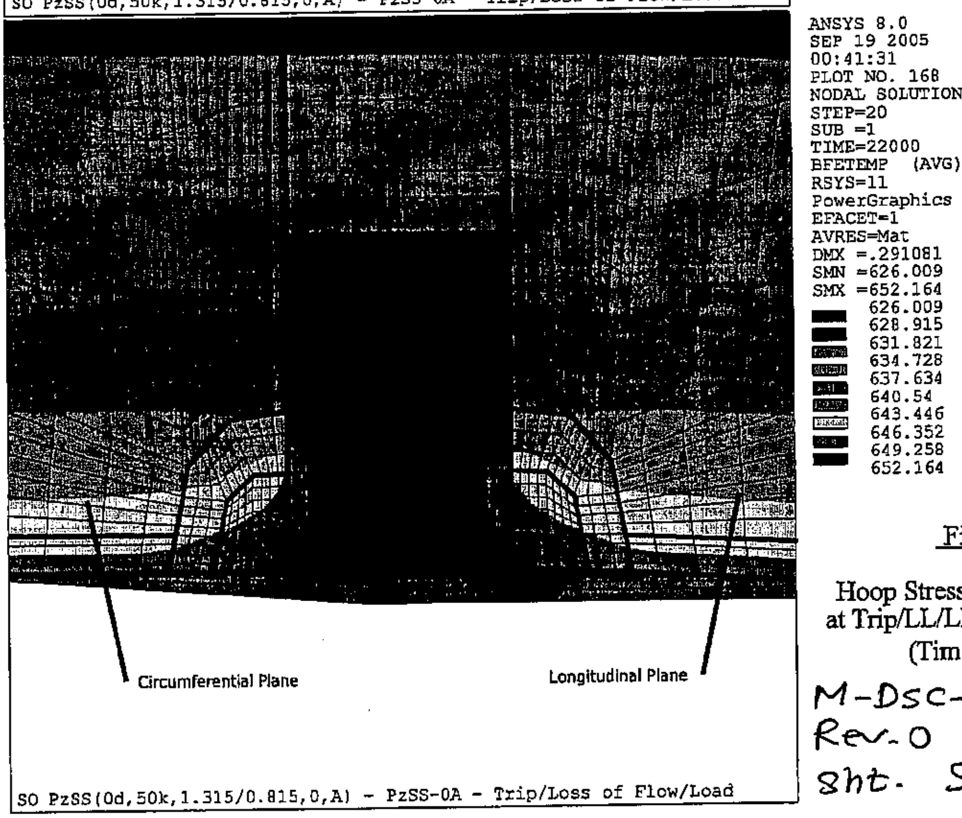
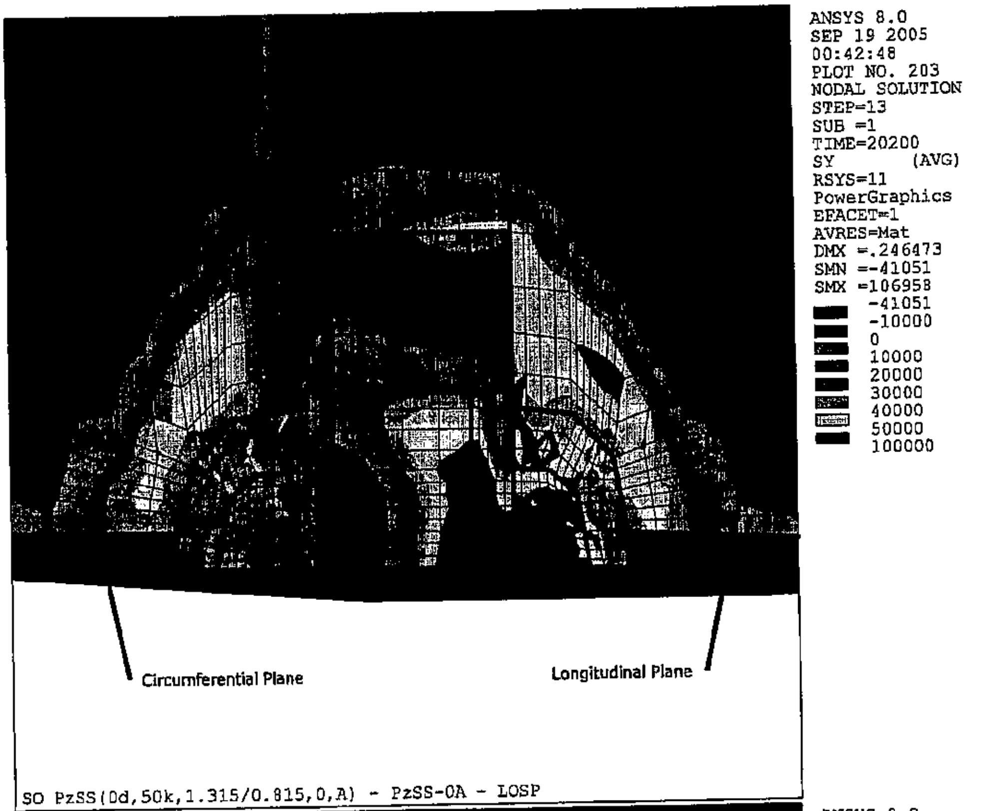


Figure 19

Hoop Stress and Temperature at Trip/LL/LF Transient Step 20 (Time = 2,000 s)

M-DSC-412
Rev. 0
sht. 52



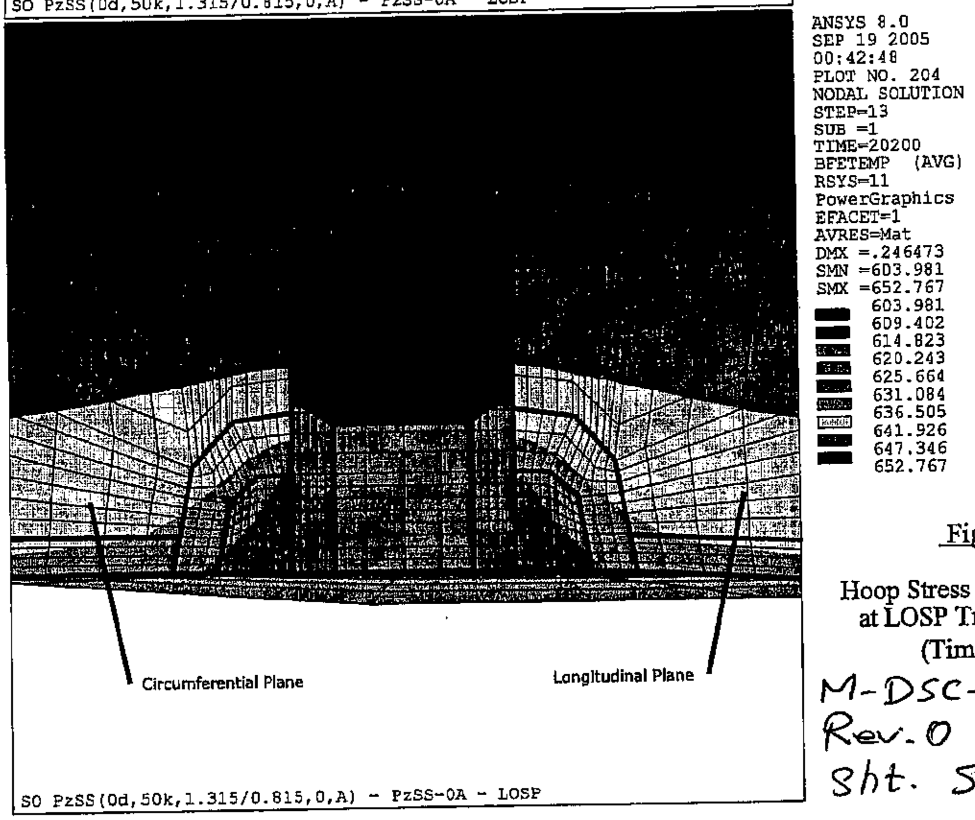
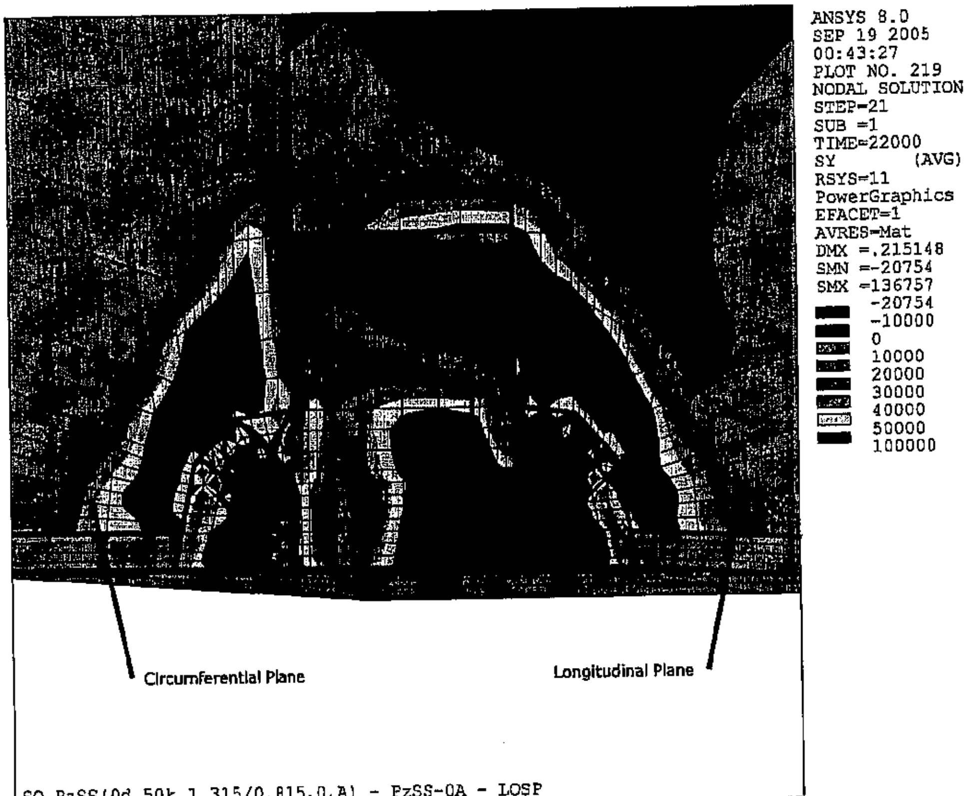


Figure 20

Hoop Stress and Temperature at LOSP Transient Step 13 (Time = 200 s)

M-DSC-412
Rev. 0
Sht. 53



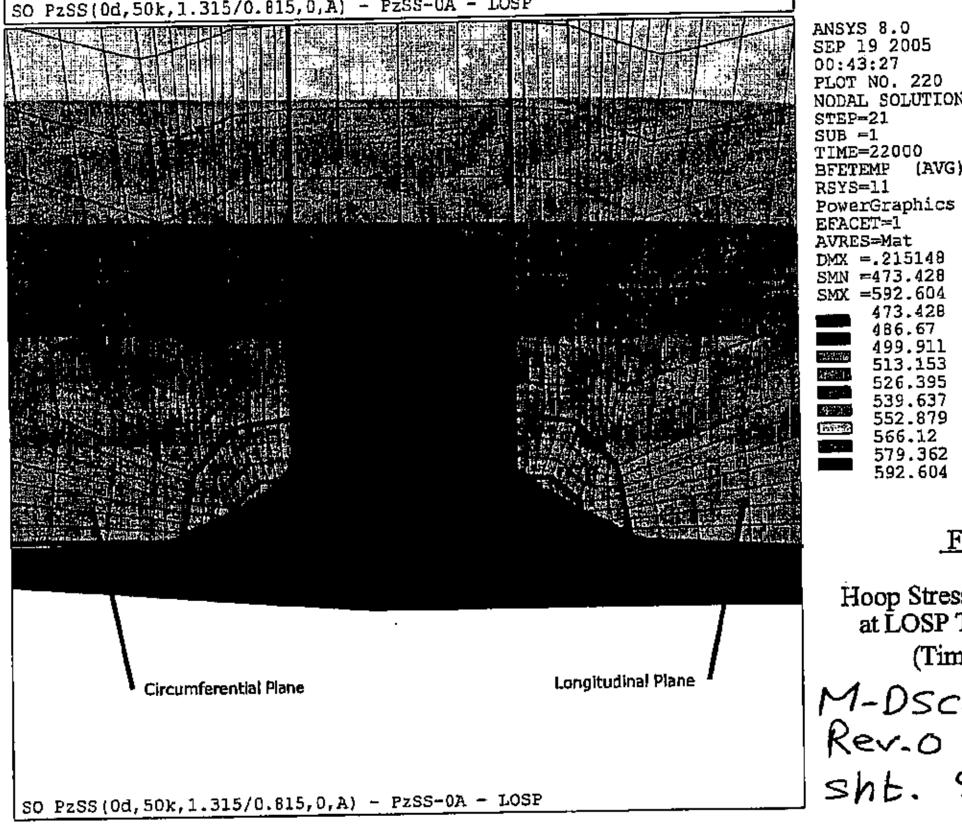
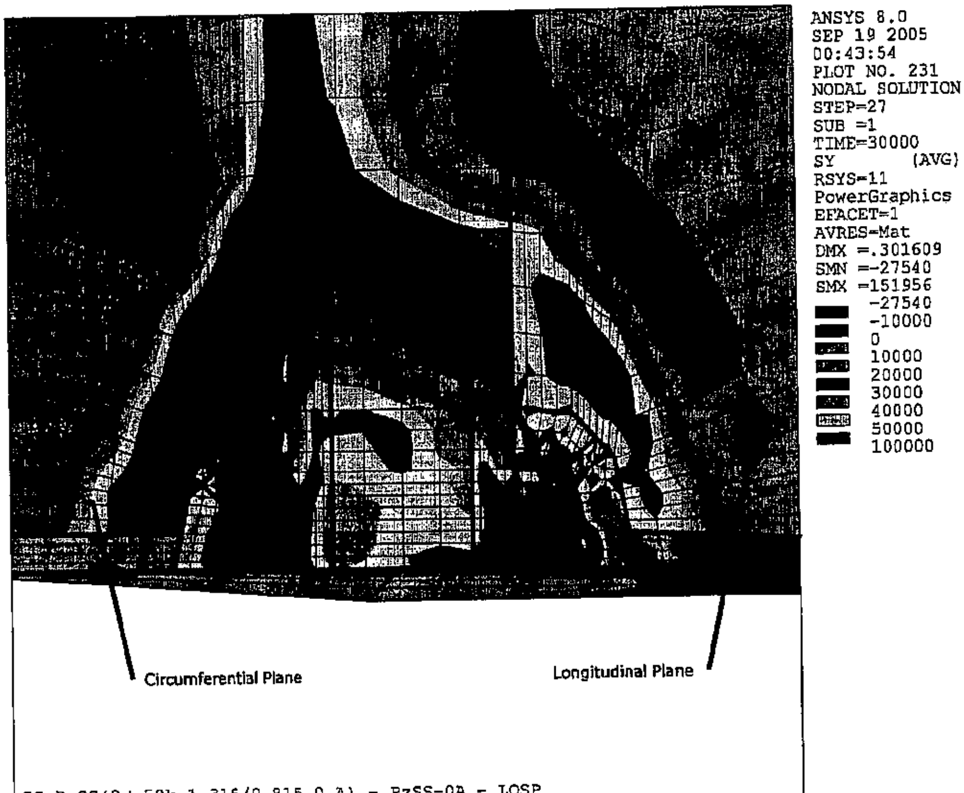


Figure 21

Hoop Stress and Temperature at LOSP Transient Step 21 (Time = 2,000 s)

M-DSC-412
Rev.0
sht. 54



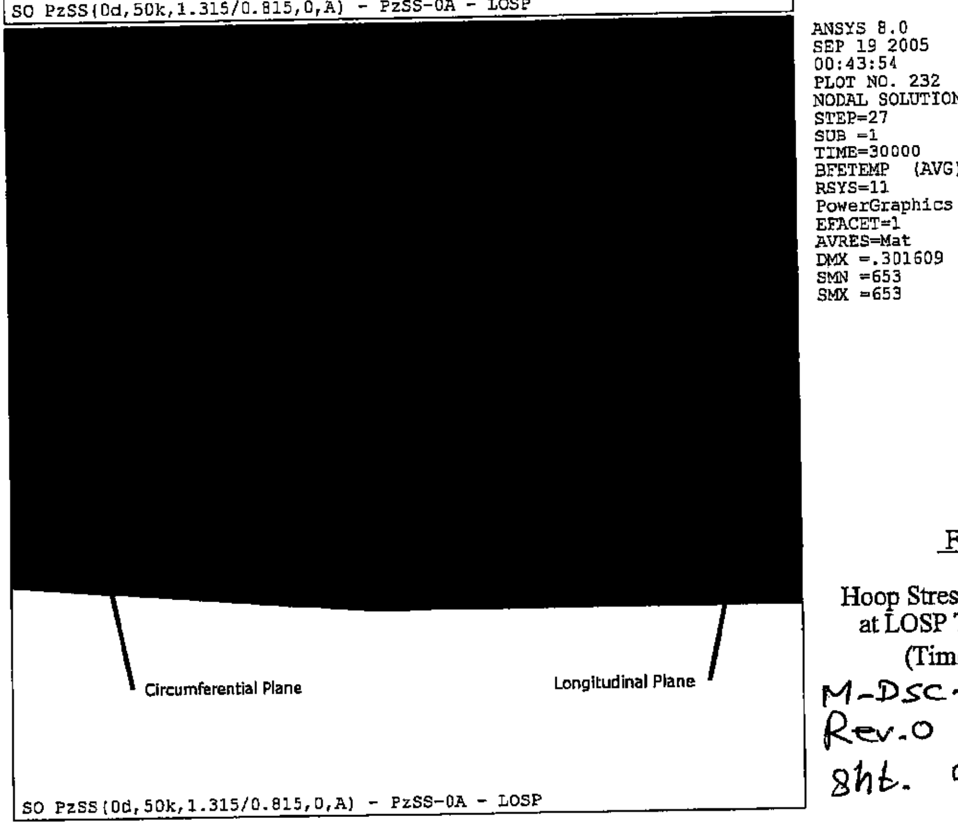
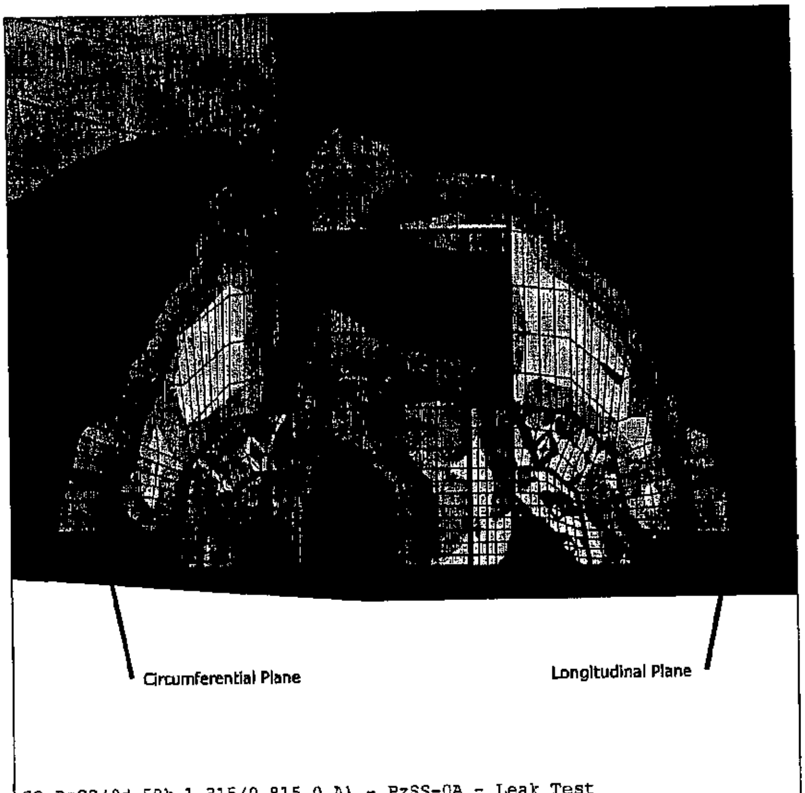


Figure 22

Hoop Stress and Temperature at LOSP Transient Step 27 (Time = 10,000 s)

M-DSC-412
Rev.0
Sht. 55



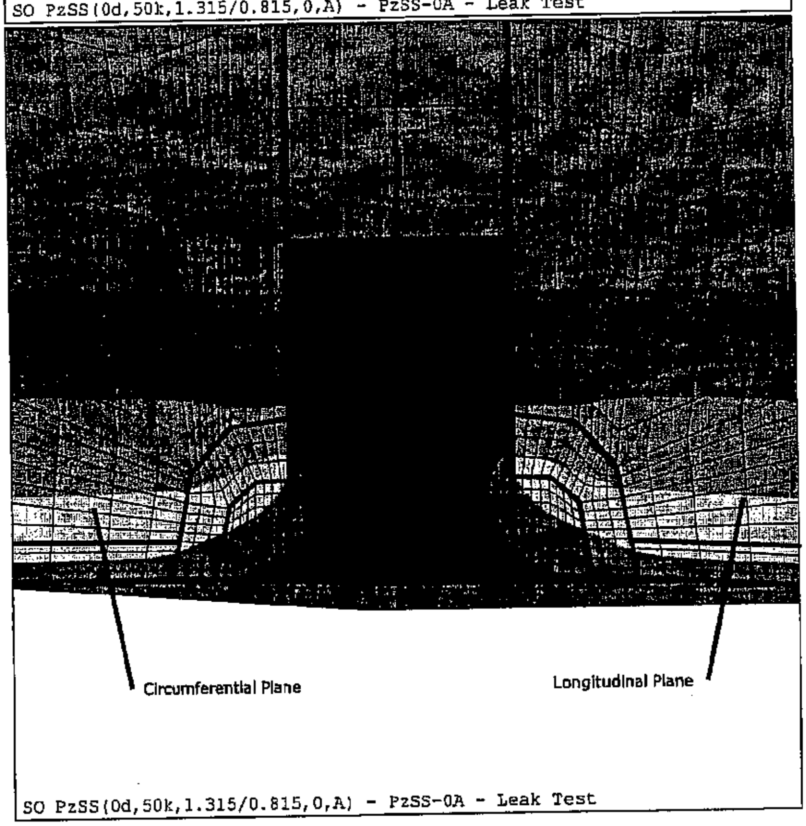
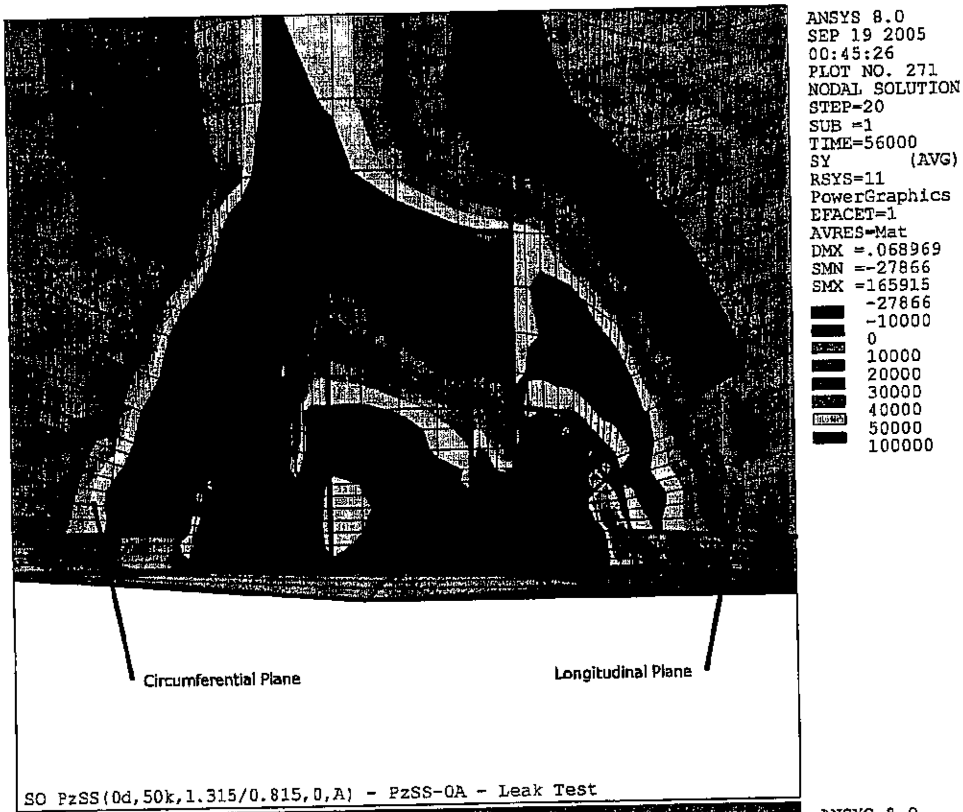


Figure 23

Hoop Stress and Temperature at Leak Test Transient Step 8 (Time = 14,400 s)

M-DSC-412
Rev. 0
Sht. 56



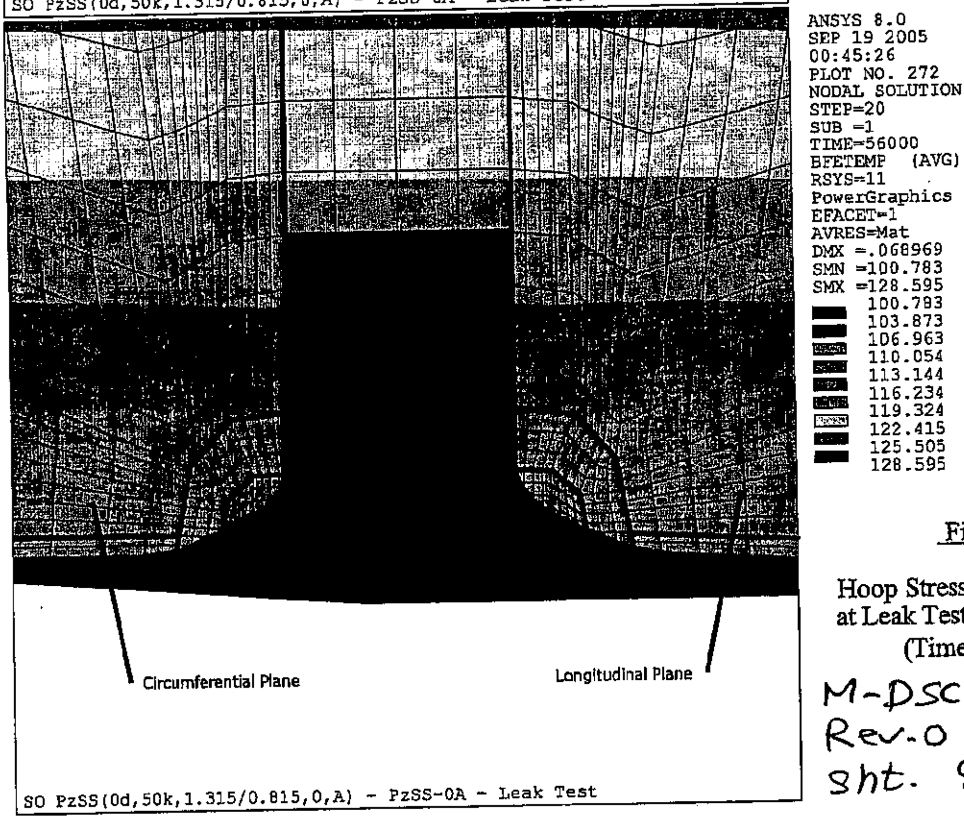


Figure 24

Hoop Stress and Temperature at Leak Test Transient Step 20 (Time = 36,000 s)

M-DSC-412
Rev.0
sht. 57

Attachment 1: File "press.trans.addon.txt"

```
/BATCH,LIST
!
/FILN,PzSS-0A
RESU,,dbs,../../
!
/COM,*****************************************************************
/COM,
/COM,   Description:  Transient Add-on Code
/com,
/com,   This batch listing does the following:
/com,     A.  Runs cooldown w/ flooding transient to shakedown model
/com,     B.  Solves preliminary static case with nozzle repaired
/com,       *  Static cases w/nozzle killed (repair):     T=70F    & P=0 psig    at t=36001s
/com,       *  Writes PzBH-30A.ist file for resuming during elastic transients
/com,   C.  Defines and solves six (6) transient cases, as follows:
/com,       1. Heatup Transient
/com,       2. Cooldown Transient w/ Flooding
/com,       3. Unit loading/unloading / 10% Step Change
/com,       4. Reactor Trip/Loss of Load/Loss of Flow
/com,       5. Loss of Secondary Pressure
/com,       6. Leak Test
/com,   D.  This code creates the following macros:
/com,       1. tload:  selects appropriate nozzle and RV shell surfaces
/com,          and applies the specified temperature and convection
/com,          coefficient boundary conditions
/com,       2. tload2:  applies h consistent with steam convection conditions
/com,          tload surfaces
/com,       3. tplod: selects appropriate nozzle and RV shell surfaces
/com,          and applies the specified pressure at the specified time
/com,          and temperature.  No nozzle "end cap" force due to repair
/com,       4. tplod_nop: same as tplod but no pressure applied
/com,       5. plod2: applies pressure only to same surfaces as tplod
/com,
/com,   Notes:
/com,   A.  This code does not perform any post-processing.  Instead, it
/com,       saves files after each transient is solved to facilitate post-
/com,       processing with a separate batch listing.
/com,
/com,   DEI task no:  36-77
/com,
/com,   Current Version by:  JEB                    Date:  9/1/2005
/com,
! ***************************************************************************************
!
/COPY,%FNAME%,dbt,../../,thermal,db        ! create copy of "*.dbt" and call it "thermal.db"
/show,transplots,grph                      ! send graphical output to transplots.grph
!
/out,%FNAME%.transient,out                 ! create blank *.transient.out file
                                             (will write results to it later)
!
/out,                                      ! redirect output back to std (command line) *.out file
!
!
! ***************************************************************************************
!
*CREATE,tload                              ! tload macro: ARG1 = bulk temp (F); ARG2 = time (sec.)
   /NOPR
   ESEL,S,LIVE
   NSEL,NONE
   !
   hcoeff1 = 500/(144*3600)                ! Head IR h in BTU/sec-in^2-F
   !
   NSEL,A,,,NNUM2,NNUM6,1                  ! Grab shell IR nodes (includes weld underside)
   *REPEAT,ncirc+1,,,,10000,10000
   SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
   !
```

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Attachment 1: File "press.trans.addon.txt"

```
  *IF,TRIMFLAG,GT,0.5,THEN                ! i.e., if nozzle is trimmed to be flush with RVH
     NSEL,NONE
     NSEL,A,,,NNUM1,NNUM2,1
     *REPEAT,ncirc+1,,,,10000,10000
     SF,ALL,CONV,hcoeff1,ARG1              ! ARG1 = temperature (F)
  *ELSE                                    ! i.e., if nozzle end not trimmed (normal CRDM/CEDM cases)
     NSEL,NONE
     NSEL,A,,,1,NRTUBE+1,1                 ! grab tube bottom nodes
     *REPEAT,ncirc+1,,,,10000,10000
     NSEL,A,,,NRTUBE+1,NNUM2,100           ! grab lower tube OR nodes
     *REPEAT,ncirc+1,,,,10000,10000
     SF,ALL,CONV,hcoeff1,ARG1              ! ARG1 = temperature (F)
  *ENDIF
  !
  NSEL,A,NODE,,NNUM1,NNUM17+400,100
  *REPEAT,ncirc+1,,,,10000,10000          ! Grab nozzle ID in remnant nozzle
  SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
  !
  NSEL,ALL
  ESEL,ALL
  DDELE,ALL,TEMP                          ! Deletes temp constraints on all nodes
  TIME,ARG2                               ! sets the time to ARG2 value when macro is called
  /GOPR                                   ! reactivates suppressed printout
  SOLVE                                   ! solve model at ARG1 temp and ARG2 time
*END
*CREATE,tload2                            ! tload macro: ARG1 = bulk temp (F); ARG2 = time (sec.)
  /NOPR
  ESEL,S,LIVE
  NSEL,NONE
  !
  hcoeff1 = 10/(144*3600)                 ! Head IR h in BTU/sec-in^2-F
  !
  NSEL,A,,,NNUM2,NNUM6,1                  ! Grab shell IR nodes (includes weld underside)
  *REPEAT,ncirc+1,,,,10000,10000
  SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
  !
  *IF,TRIMFLAG,GT,0.5,THEN                ! i.e., if nozzle is trimmed to be flush with RVH
     NSEL,NONE
     NSEL,A,,,NNUM1,NNUM2,1
     *REPEAT,ncirc+1,,,,10000,10000
     SF,ALL,CONV,hcoeff1,ARG1              ! ARG1 = temperature (F)
  *ELSE                                    ! i.e., if nozzle end not trimmed (normal CRDM/CEDM cases)
     NSEL,NONE
     NSEL,A,,,1,NRTUBE+1,1                 ! grab tube bottom nodes
     *REPEAT,ncirc+1,,,,10000,10000
     NSEL,A,,,NRTUBE+1,NNUM2,100           ! grab lower tube OR nodes
     *REPEAT,ncirc+1,,,,10000,10000
     SF,ALL,CONV,hcoeff1,ARG1              ! ARG1 = temperature (F)
  *ENDIF
  !
  NSEL,A,NODE,,NNUM1,NNUM17+400,100
  *REPEAT,ncirc+1,,,,10000,10000          ! Grab nozzle ID in remnant nozzle
  SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
  !
  NSEL,ALL
  ESEL,ALL
  DDELE,ALL,TEMP                          ! Deletes temp constraints on all nodes
  TIME,ARG2                               ! sets the time to ARG2 value when macro is called
  /GOPR                                   ! reactivates suppressed printout
  SOLVE                                   ! solve model at ARG1 temp and ARG2 time
*END
!
! *****************************************************************************
!
/COM, Create Temperature & Pressure Loading Macro
*CREATE,tplod                             ! tpload macro: ARG1 = pressure (psi); ARG2 = time (sec.)
  /NOPR
```

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Attachment 1: File "press.trans.addon.txt"

```
ESEL,ALL
NSEL,NONE
!
NSEL,A,NODE,,NNUM2,NNUM6,1              ! Grab shell IR nodes (NNUM2+1 node is actually collapsed out)
*REPEAT,ncirc+1,,,,10000,10000
NSEL,A,NODE,,NNUM1,NNUM2,1              ! Grab underside of nozzle wall
*REPEAT,ncirc+1,,,,10000,10000
!
NSEL,A,NODE,,NNUM15,NNUM15
*REPEAT,ncirc+1,,,,10000,10000
NSEL,A,NODE,,NNUM15+101,NNUM24,100
*REPEAT,ncirc+1,,,,10000,10000          ! Grab head penetration ID nodes
!
NSEL,A,NODE,,NNUM1,NNUM17+400,100
*REPEAT,ncirc+1,,,,10000,10000          ! Grab nozzle ID in remnant nozzle
NSEL,A,NODE,,NNUM15,NNUM18+400,100
*REPEAT,ncirc+1,,,,10000,10000          ! Grab nozzle OD in remnant nozzle
NSEL,A,NODE,,NNUM17+400,NNUM18+400,1
*REPEAT,ncirc+1,,,,10000,10000          ! Grab nozzle top in remnant nozzle
!
ESEL,S,LIVE
SF,ALL,PRES,ARG1                        ! ARG1=pressure
NSEL,ALL
ESEL,ALL
*IF,CYLSHELL,EQ,1,THEN
   /COM,  ***  Apply Vessel axial pressure
   CSYS,32
   NSEL,S,LOC,Z,ZSIZE/2+0.02,ZSIZE/2-0.02
   NSEL,A,LOC,Z,-ZSIZE/2+0.02,-ZSIZE/2-0.02
   SF,ALL,PRES,-(SIR**2/(SOR**2-SIR**2))*ARG1
   CSYS,0
*ENDIF
/GOPR
NSEL,ALL
LDREAD,TEMP,,,ARG2,,,rth                ! read temps (use time rather than loadstep and substep)
TIME,ARG2+20000                         ! offset time by 20000 for structural model
*if,ARG3,EQ,1,THEN
   ISWRITE,ON
   solve
   ISWRITE,OFF
   *GET,NMTMP,ACTIVE,0,JOBNAM
   /RENAME,%NMTMP%,ist,,%NMTMP%.%ARG2%,ist
*else
   SOLVE
*endif
*END
!
*CREATE,tplod_nop                        ! tplod macro: ARG1 = pressure (psi) (ignored); ARG2 = time (se
  NSEL,ALL
  ESEL,ALL
  LDREAD,TEMP,,,ARG2,,,rth               ! read temps (use time rather than loadstep and substep)
  TIME,ARG2                              ! same time for structural model
  *if,ARG3,EQ,1,THEN
     ISWRITE,ON
     solve
     ISWRITE,OFF
     *GET,NMTMP,ACTIVE,0,JOBNAM
     /RENAME,%NMTMP%,ist,,%NMTMP%.%ARG2%,ist
  *else
     SOLVE
  *endif
*END
!
!   ***********************************************************************************
!
!              ANALYZE STATIC CASES WITH AND WITHOUT NOZZLE REMOVED
!
```

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Attachment 1: File "press.trans.addon.txt"

```
!    **********************************************************************************
!
!
resu,%FNAME%,dbs,../../
/COPY,%FNAME%,emat,../../,%FNAME%,emat
/COPY,%FNAME%,esav,../../,%FNAME%,esav
/COPY,plod,,../../,plod
!
/SOLUTION
ANTYPE,,RESTART
!
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - Post Operating (T=70F,P=0psig)
!
DELTIM,0.01,0.01,1.0,OFF
!
/com,  Take model down to room temperature and pressure
TIME,T0+5                              ! set t=7005s (not a transient, so time is arbitrary)
BF,ALL,TEMP,70                         ! set T=70F
*USE,plod,0                            ! P=0; use orig "plod" macro (includes solve) since nozzle stil:
!
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - Repair (T=70F,P=0 psig)
!
/com,  Delete upper nozzle (simulate repair)
esel,none
*do,i,0,ncirc-1,1
   esel,a,elem,,i*10000+nnum17+400,i*10000+10000,100
   *repeat,nrtube,,,,1
*enddo
ekill,all                              ! kills all selected elements, ie, the nozzle
esel,all
!
!  Apply temperature and pressure to nozzle-free model (T=70F; P=0 psig)
!
sfdele,all,pres
!
DELTIM,0.25,0.25,1.0,OFF
TIME,T0+6                  ! set t=7006s
BF,ALL,TEMP,70             ! set T=70F
ISWRITE,ON                 ! write solution to *.ist file
SOLVE
ISWRITE,OFF
finish                     ! exit SOLU (back out/up to BEGIN level)
PARSAV,ALL                 ! saves parameter values to *.parm file
!                          ! being post-repair at operating temperature and pressure.
!
save,,dbp                  ! save *.dbp for elastic-plastic model use
!
/prep7
tbdele,all,all             ! Remove elastic-plastic mat properties
save,,dbe                  ! use *.dbe for elastic model restarts, use isfile for init. stresses
!
resu,thermal,db
/com,  Delete upper nozzle (simulate repair)
esel,none
*do,i,0,ncirc-1,1
   esel,a,elem,,i*10000+nnum17+400,i*10000+10000,100
   *repeat,nrtube,,,,1
*enddo
ekill,all                   ! kills all selected elements, ie, the nozzle
esel,all
save,thermal,db             ! save thermal model with lower nozzle portion killed
finish
!
!
!    **********************************************************************************
!                     ANALYZE THE SERIES OF SPECIFIED TRANSIENTS
!
!
```

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Attachment 1: File "press.trans.addon.txt"

```
!
!   ************************************************************
!   Transient 1 : Heatup Transient (temperature only)
!   ------------------------------------------------------------
!
!
/COM, Hop back to thermal model
RESU,thermal,db                          ! Resumes from the file copy we make at beginning
/FILN,%FNAME%.trans1                     ! Set filename to "*.trans1"
/SOLU
ANTYPE,TRANS,NEW                         ! new transient analysis
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - HU Transient
OUTPR,BASIC,NONE                         ! don't print substep results
OUTRES,ALL,LAST                          ! write solution only for last substep of each load step
AUTOTS,ON                                ! use automatic time stepping
PRED,ON,,ON                              ! use predictor, including on first substep
/COM,
/COM, Establish initial conditions and do transient
TIMINT,OFF,THERM                         ! turn off transient effects for thermal DOFs
*USE,tload,70,0.1
KBC,0                                    ! Linearly interpolate (ramp) loads for each substep
TIMINT,ON,THERM                          ! turn on transient effects for thermal DOFs
DELTIM,60,60,1800,ON
*USE,tload,170,1800
*USE,tload,270,3600
*USE,tload,370,5400
*USE,tload,470,7200
*USE,tload,550,8640
*USE,tload,594,9432
*USE,tload,630,10080
*USE,tload,653,10494
Time,11394     $SOLVE
Time,12294     $SOLVE
Time,14094     $SOLVE
Time,17694     $SOLVE
TIMINT,OFF,THERM                         ! turn off transient effects for thermal DOFs
DELTIM,28800-17694,,28800-17694,OFF
Time,28800     $SOLVE
FINISH
SAVE
!
!   ******************************************************************
!   Transient 1  : Heatup Transient (temperature and pressure)
!   ------------------------------------------------------------------
!
!
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans1
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - HU Transient
AUTOTS,OFF                          ! do not use automatic time stepping
DELTIM                              ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou
NSUBST,1                            ! specifies single substep (since effect of pressure is not tim
!
esel,s,type,,1                      ! read in residual stress state from welding residual stress mo
isfile,read,%FNAME%,ist,,1
esel,all
*USE,tplod,0,0.1
*USE,tplod,0,1800
*USE,tplod,5,3600
*USE,tplod,200,5400
*USE,tplod,500,7200
*USE,tplod,1000,8640
*USE,tplod,1500,9432
*USE,tplod,1950,10080
*USE,tplod,2235,10494
```

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Attachment 1: File "press.trans.addon.txt"

```
*USE,tplod,2235,11394
*USE,tplod,2235,12294
*USE,tplod,2235,14094
*USE,tplod,2235,17694
*USE,tplod,2235,28800
FINISH
!
PARSAV,ALL
SAVE,,dbs1
!
!   *************************************************************
!   Transient 3 : Load/Unload / Step Change  (temperature only)
!   -------------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db                       ! Resumes from the file copy we make at beginning
/FILN,%FNAME%.trans3                  ! Set filename to "*.trans3"
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Load/Unload / Step Inc.
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM
*USE,tload,633,0.1
KBC,0                                 ! linearly interpolate loads
TIMINT,ON,THERM                       ! turn on thermal transient effects
*USE,tload,653,1
Time,15      $SOLVE
Time,60      $SOLVE
Time,180     $SOLVE
Time,600     $SOLVE
Time,1800    $SOLVE
Time,3600    $SOLVE
TIMINT,OFF,THERM
DELTIM,7200-3600,,7200-3600,OFF
Time,7200    $SOLVE
TIMINT,ON,THERM                       ! turn on thermal transient effects
DELTIM,5,,1800,ON
*USE,tload,633,7201
Time,7215    $SOLVE
Time,7260    $SOLVE
Time,7380    $SOLVE
Time,7800    $SOLVE
Time,9000    $SOLVE
Time,10800    $SOLVE
TIMINT,OFF,THERM
DELTIM,14400-10800,,14400-10800,OFF
Time,14400    $SOLVE
!
FINISH
SAVE
!
!   **************************************************************************
!   Transient 3  : Load/Unload / Step Change  (temperature and pressure)
!   --------------------------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans3
/COM,
/SOLU
ANTYPE,,NEW
```

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Attachment 1: File "press.trans.addon.txt"

```
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Load/Unload / Step Inc.
AUTOTS,OFF                          ! do not use automatic time stepping
DELTIM                              ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previously specif:
NSUBST,1                            ! specifies single substep (since effect of pressure is not time dependent
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1          ! read in residual stress state from welding residual stress model
esel,all
*USE,tplod,2135,0.1
*USE,tplod,2235,1
*USE,tplod,2235,15
*USE,tplod,2235,60
*USE,tplod,2235,180
*USE,tplod,2235,600
*USE,tplod,2235,1800
*USE,tplod,2235,3600
*USE,tplod,2235,7200
*USE,tplod,2135,7201
*USE,tplod,2135,7215
*USE,tplod,2135,7260
*USE,tplod,2135,7380
*USE,tplod,2135,7800
*USE,tplod,2135,9000
*USE,tplod,2135,10800
*USE,tplod,2135,14400
FINISH
!
PARSAV,ALL
SAVE,,dbs3
!
!   ********************************************************
!   Transient 4 : Reactor Trip/Loss of Load/Loss of Flow Transient (temperature only)
!   --------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db
/FILN,%FNAME%.trans4
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Trip/Loss of Flow/Load
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM
*USE,tload,653,0.1
KBC,0                                 ! linearly interpolate loads
TIMINT,ON,THERM                       ! turn on thermal transient effects
DELTIM,5,1,1800,ON
*USE,tload,645,10
*USE,tload,637,20
*USE,tload,629,30
*USE,tload,621,40
*USE,tload,613,50
DELTIM,25,1,1800,ON
*USE,tload,611,100
*USE,tload,609.2,150
*USE,tload,607.4,200
*USE,tload,603.8,300
*USE,tload,600.2,400
*USE,tload,596.6,500
*USE,tload,593,600
*USE,tload,599,740
*USE,tload,605,880
*USE,tload,617,1160
```

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Attachment 1: File "press.trans.addon.txt"

```
*USE,tload,629,1440
*USE,tload,641,1720
*USE,tload,647,1860
*USE,tload,653,2000
Time,2100.    $SOLVE
Time,2600     $SOLVE
Time,3600     $SOLVE
Time,5400     $SOLVE
TIMINT,OFF,THERM
DELTIM,7200-5400,,7200-5400,OFF
Time,7200     $SOLVE
FINISH
SAVE
!
!
!   **************************************************************
!   Transient 4  : Reactor Trip/Loss of Load/Loss of Flow Transient (temperature and pressure)
!   --------------------------------------------------------------
!
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans4
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Trip/Loss of Flow/Load
AUTOTS,OFF                    ! do not use automatic time stepping
DELTIM                        ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previously specif:
NSUBST,1                      ! specifies single substep (since effect of pressure is not time dependen
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1    ! read in residual stress state from welding residual stress model
esel,all
*USE,tplod,2235,0.1
*USE,tplod,2295,10
*USE,tplod,2355,20
*USE,tplod,2415,30
*USE,tplod,2475,40
*USE,tplod,2535,50
*USE,tplod,1685,100
*USE,tplod,1698.75,150
*USE,tplod,1712.5,200
*USE,tplod,1740,300
*USE,tplod,1767.5,400
*USE,tplod,1795,500
*USE,tplod,1822.5,600
*USE,tplod,1861,740
*USE,tplod,1899.5,880
*USE,tplod,1976.5,1160
*USE,tplod,2053.5,1440
*USE,tplod,2130.5,1720
*USE,tplod,2169,1860
*USE,tplod,2207.5,2000
*USE,tplod,2235,2100
*USE,tplod,2235,2600
*USE,tplod,2235,3600
*USE,tplod,2235,5400
*USE,tplod,2235,7200
FINISH
!
PARSAV,ALL
SAVE,,dbs4
!
!   **********************************************************
!   Transient 5 : Loss of Secondary Pressure (temperature only)
!   ----------------------------------------------------------
```

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Attachment 1: File "press.trans.addon.txt"

```
!
/COM, Hop back to thermal model
RESU,thermal,db
/FILN,%FNAME%.trans5
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - LOSP
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do Transient
TIMINT,OFF,THERM
*USE,tload,653,0.1
KBC,0                                   ! linearly interpolate loads
TIMINT,ON,THERM                         ! turn on thermal transient effects
DELTIM,0.5,0.1,1800,ON
*USE,tload,635,6
*USE,tload2,632,7
*USE,tload2,585.5,22.5
*USE,tload2,539,38
*USE,tload2,492.5,53.5
*USE,tload2,446,69
*USE,tload2,399.5,84.5
*USE,tload2,353,100
*USE,tload2,356.75,125
*USE,tload2,360.5,150
*USE,tload2,364.25,175
*USE,tload2,368,200
*USE,tload2,380.5,300
*USE,tload2,393,400
*USE,tload2,408,600
*USE,tload2,423,800
*USE,tload2,433,1000
*USE,tload2,458,1550
*USE,tload,458,1551
*USE,tload,473,2000
*USE,tload,491,2667
*USE,tload,510,3333
*USE,tload,528,4000
*USE,tload,590.5,6200
*USE,tload,653,8400
TIMINT,OFF,THERM
DELTIM,10000-8400,,10000-8400,OFF
*USE,tload,653,10000
FINISH
SAVE
/COM,
!
!   *******************************************************************
!   Transient 5 : Loss of Secondary Pressure (temperature and pressure)
!   -------------------------------------------------------------------
!
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans5
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - LOSP
AUTOTS,OFF              ! do not use automatic time stepping
DELTIM                  ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previously specified va:
NSUBST,1                ! specifies single substep (since effect of pressure is not time dependent)
!
esel,s,type,,1
```

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Attachment 1: File "press.trans.addon.txt"

```
isfile,read,%FNAME%,ist,,1                    ! read in residual stress state from welding residual stress mo(
esel,all
*USE,tplod,2235,0.1
*USE,tplod,2173,6
*USE,tplod,2163,7
*USE,tplod,2000,22.5
*USE,tplod,1837,38
*USE,tplod,1674,53.5
*USE,tplod,1511,69
*USE,tplod,1348,84.5
*USE,tplod,1186,100
*USE,tplod,923,125
*USE,tplod,660,150
*USE,tplod,398,175
*USE,tplod,135,200
*USE,tplod,160,300
*USE,tplod,185,400
*USE,tplod,235,600
*USE,tplod,285,800
*USE,tplod,335,1000
*USE,tplod,434,1550
*USE,tplod,434.18,1551
*USE,tplod,515,2000
*USE,tplod,622,2667
*USE,tplod,728,3333
*USE,tplod,835,4000
*USE,tplod,1535,6200
*USE,tplod,2235,8400
*USE,tplod,2235,10000
FINISH
!
PARSAV,ALL
SAVE,,dbs5
!
!    ************************************************************
!    Transient 6 : Leak Test (temperature only)
!    ------------------------------------------------------------
!
!
/COM, Hop back to thermal model
RESU,thermal,db                               ! Resumes from the file copy we make at beginning
/FILN,%FNAME%.trans6                          ! Set filename to "*.trans6"
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Leak Test
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM
*USE,tload,100,0.1
KBC,0                                         ! linearly interpolate loads
TIMINT,ON,THERM                               ! turn on thermal transient effects
*USE,tload,100,1800
*USE,tload,100,3600
*USE,tload,160,5760
*USE,tload,220,7920
*USE,tload,280,10080
*USE,tload,340,12240
*USE,tload,400,14400
Time,14401     $SOLVE
Time,16200     $SOLVE
Time,18000     $SOLVE
Time,19800     $SOLVE
TIMINT,OFF,THERM
DELTIM,21600-19800,,21600-19800,OFF
```

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Attachment 1: File "press.trans.addon.txt"

```
Time,21600     $SOLVE
TIMINT,ON,THERM                              ! turn on thermal transient effects
DELTIM,5,,1800,ON
*USE,tload,400,23400
*USE,tload,400,25200
*USE,tload,340,27360
*USE,tload,280,29520
*USE,tload,220,31680
*USE,tload,160,33840
*USE,tload,100,36000
Time,36001     $SOLVE
Time,37440     $SOLVE
Time,38880     $SOLVE
Time,40320     $SOLVE
Time,41760     $SOLVE
TIMINT,OFF,THERM
DELTIM,43200-41760,,43200-41760,OFF
Time,43200     $SOLVE
!
FINISH
SAVE
!
!   ***********************************************************************
!   Transient 6 : Leak Test (temperature and pressure)
!   -----------------------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans6
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Leak Test
AUTOTS,OFF                   ! do not use automatic time stepping
DELTIM                       ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previously speci:
NSUBST,1                     ! specifies single substep (since effect of pressure is not time depende:
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1   ! read in residual stress state from welding residual stress model
esel,all
*USE,tplod,385,0.1
*USE,tplod,385,1800
*USE,tplod,385,3600
*USE,tplod,385,5760
*USE,tplod,385,7920
*USE,tplod,385,10080
*USE,tplod,385,12240
*USE,tplod,385,14400
*USE,tplod,2235,14401
*USE,tplod,2235,16200
*USE,tplod,2235,18000
*USE,tplod,2235,19800
*USE,tplod,2235,21600
*USE,tplod,2235,23400
*USE,tplod,2235,25200
*USE,tplod,2235,27360
*USE,tplod,2235,29520
*USE,tplod,2235,31680
*USE,tplod,2235,33840
*USE,tplod,2235,36000
*USE,tplod,385,36001
*USE,tplod,385,37440
*USE,tplod,385,38880
*USE,tplod,385,40320
*USE,tplod,385,41760
*USE,tplod,385,43200
```

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Attachment 1: File "press.trans.addon.txt"

```
FINISH
!
PARSAV,ALL
SAVE,,dbs6
!
!
!   *****************************************************************************
!
!           SHAKEDOWN ELASTIC-PLASTIC MODEL USING COOLDOWN W/ FLOODING TRANSIENT
!           THIS SET OF INITIAL STRESSES IS ONLY FOR USE WITH THE CDF TRANSIENT!
!
!   *****************************************************************************
!
!
!   ****************************************************
!   Transient 0 : Cooldown w/ flooding transient (temperature only)
!   ----------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db
/filn,%FNAME%.cdf
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - CD w/ Flooding
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON                               ! use automatic time stepping
PRED,ON,,ON                             ! use predictor, including on first substep
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM                        ! turn off transient effects for thermal DOFs
*USE,tload,653,0.1
KBC,0                                   ! Linearly interpolate (ramp) loads for each substep
TIMINT,ON,THERM                         ! turn on transient effects for thermal DOFs
DELTIM,60,60,1800,ON
*USE,tload,610,756
*USE,tload,568,1512
*USE,tload,525,2268
*USE,tload,483,3024
*USE,tload,440,3780
*USE,tload,440,3780.1
*USE,tload,383,3888
*USE,tload,327,3996
*USE,tload,270,4104
*USE,tload,213,4212
*USE,tload,157,4320
*USE,tload,100,4428
Time,5542     $SOLVE
Time,6657     $SOLVE
Time,7771     $SOLVE
Time,8886     $SOLVE
Time,10000    $SOLVE
*USE,tload,135,10062
*USE,tload,170,10124
*USE,tload,205,10186
*USE,tload,240,10248
*USE,tload,275,10309.6
*USE,tload,275,10309.7
*USE,tload,234,11047
*USE,tload,193,11784
*USE,tload,152,12521
*USE,tload,111,13259
*USE,tload,70,13996
Time,14497    $SOLVE
Time,14998    $SOLVE
Time,15499    $SOLVE
TIMINT,OFF,THERM                        ! turn off transient effects for thermal DOFs
```

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Attachment 1: File "press.trans.addon.txt"

```
DELTIM,16000-15499,,16000-15499,OFF
Time,16000    $SOLVE
FINISH
/COM,
!
!   **********************************************************
!   Transient 0 : Cooldown w/ flooding transient: temperature and pressure
!   ----------------------------------------------------------
!
!                                                ! resume from elastic-plastic model
resu,%FNAME%,dbp                                 ! restart analysis from post-repair analysis model
/COPY,%FNAME%,emat,,%FNAME%.cdf,emat             !  ""
/COPY,%FNAME%,esav,,%FNAME%.cdf,esav
!
/SOLU
ANTYPE,,RESTART
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - CD w/ Flooding
PRED,ON,,ON                                  ! use predictor, including on first substep
AUTOTS,ON                                    ! use automatic time stepping
DELTIM,(20000-T0)/10,(20000-T0)/40,20000-T0
*USE,tplod,2235,0.1
AUTOTS,OFF                                   ! do not use automatic time stepping
DELTIM                                       ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou:
NSUBST,1                                     ! specifies single substep (since effect of pressure is not tim
*USE,tplod,1875.8,756
*USE,tplod,1516.6,1512
*USE,tplod,1157.4,2268
*USE,tplod,798.2,3024
*USE,tplod,439,3780
*USE,tplod,0,3780.1
*USE,tplod,0,3888
*USE,tplod,0,3996
*USE,tplod,0,4104
*USE,tplod,0,4212
*USE,tplod,0,4320
*USE,tplod,0,4428
*USE,tplod,0,5542
*USE,tplod,0,6657
*USE,tplod,0,7771
*USE,tplod,0,8886
*USE,tplod,0,10000
*USE,tplod,0,10062
*USE,tplod,0,10124
*USE,tplod,0,10186
*USE,tplod,0,10248
*USE,tplod,0,10309.6
*USE,tplod,439,10309.7
*USE,tplod,351.2,11047
*USE,tplod,263.4,11784
*USE,tplod,175.6,12521
*USE,tplod,87.8,13259
*USE,tplod,0,13996
*USE,tplod,0,14497
*USE,tplod,0,14998
*USE,tplod,0,15499
ISWRITE,ON                                   ! write shaken down solution to *.cdf.ist file
*USE,tplod,0,16000
ISWRITE,OFF
!
finish
!                                            ! Delete unneeded *.cdf.rst file
/sys, rm *.cdf.rst
!
/RENAME,%FNAME%.cdf,rth,,%FNAME%.trans2,rth    ! No need to re-run thermal model
!
!
!   **********************************************************
!   Transient 2 : Cooldown w/ flooding transient: temperature and pressure
```

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Attachment 1: File "press.trans.addon.txt"

```
!   ----------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans2
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - CD w/ Flooding
AUTOTS,OFF                              ! do not use automatic time stepping
DELTIM                                  ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou
NSUBST,1                                ! specifies single substep (since effect of pressure is not tim
!
esel,s,type,,1
isfile,read,%FNAME%.cdf,ist,,1          ! read in shaken down residual stress state from welding residu
esel,all
*USE,tplod,2235;0.1
*USE,tplod,1875.8,756
*USE,tplod,1516.6,1512
*USE,tplod,1157.4,2268
*USE,tplod,798.2,3024
*USE,tplod,439,3780
*USE,tplod,0,3780.1
*USE,tplod,0,3888
*USE,tplod,0,3996
*USE,tplod,0,4104
*USE,tplod,0,4212
*USE,tplod,0,4320
*USE,tplod,0,4428
*USE,tplod,0,5542
*USE,tplod,0,6657
*USE,tplod,0,7771
*USE,tplod,0,8886
*USE,tplod,0,10000
*USE,tplod,0,10062
*USE,tplod,0,10124
*USE,tplod,0,10186
*USE,tplod,0,10248
*USE,tplod,0,10309.6
*USE,tplod,439,10309.7
*USE,tplod,351.2,11047
*USE,tplod,263.4,11784
*USE,tplod,175.6,12521
*USE,tplod,87.8,13259
*USE,tplod,0,13996
*USE,tplod,0,14497
*USE,tplod,0,14998
*USE,tplod,0,15499
*USE,tplod,0,16000
FINISH
!
PARSAV,ALL
SAVE,,dbs2
!
!
!  ********************************************************************
!             END OF ANALYSIS OF WESTINGHOUSE-DEFINED CASES
!  ********************************************************************
!  file cleanup!
/SYS, rm *.BCS
/SYS, rm *.PVTS
/SYS, rm *.osav
/SYS, rm *.full
/SYS, rm *.trans?.esav
/SYS, rm *.trans?.emat
/SYS, rm *.trans?.osav
```

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Attachment 1: File "press.trans.addon.txt"

```
/SYS, rm *.trans?.rth
/SYS, rm *.trans?.tri
/SYS, rm *.trans?.stat
/SYS, rm *.trans?.db
/SYS, rm tload
/SYS, rm tplod
!
/inp,press.trans.addpost,txt
```

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Attachment 1: File "press.trans.addon.txt"

Attachment 2: File "PzSS.trans.addpost.txt"

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```
/BATCH,LIST
resu,PzSS-0A,dbe
!
/com,**************************************************************************************
/com,
/com,   Description:  press.trans.addpost.txt
/com,
/com,     This batch listing does the following:
/com,         A.  Performs post-processing of results which are computed by press.trans.addon file.
/com,             - Post-processing is done by "reaching into" files press.trans1.dbs1 through
/com,               press.trans6.dbs6 and writing select results to press.addpost.out
/com,
/com,     Notes:
/com,         A.  All results are written to *.addpost.out
/com,         B.  This file creates the following macros:
/com,             1. TRANSPLOTS    - generates stress and stress intensity plots
/com,             2. NODEPOP                                                    - populates an array
/com,             3. TRANSPOST                                                  - writes stress and
/com,             4. writedata          - writes out data to Sec5data.out
/com,
/com,   DEI task no:  30-10
/com,                                                      Date:  7/11/05
/com,   Current Version by:  JEB
/com,
/com,**************************************************************************************
!
/PAGE,,,,240                            ! set page width to widest possible setting
/com,
/com,  CREATE OUTPUT FILES TO WHICH RESULTS WILL BE WRITTEN (these are cleared each time press.trans.ad
/com,
/out,%FNAME%.addpost,out                  ! create/"re-set" blank file called "*.addpost.out"
/out,
/out,%FNAME%.Sec5data,out                 ! create/"re-set" blank file called "*.Sec5data.out"
/out,
!
!  ***********************************************************************************
!
/com,  "TRANSPLOTS" MACRO:  Creates SY, SZ, and SINT stress plots
/com,
/com,  This macro is called within the NONTRANSPOST and TRANSPOST macros
/com,  Arguments:  ARG1 = CASE NUMBER
/com,
*CREATE,TRANSPLOTS                       ! TRANSPLOTS macro
   /show,transplots,grph                 ! send graphical output to transplots.grph
   /page,,,10000,132                     ! define page size: 10000 lines/page; 132 chars/line
   /view,1,1                             ! set view direction from the x-axis
   /ang,1,vang                           ! vang is defined in cirse.base
   /type,1,4                             ! set (window 1) display type as "precise hidden"
   /edge,1,1                             ! set (window 1) display to show only edges
   /dsc,1,off                            ! remove displacement scaling
   /DIST,1,1.5*2.75*TOR                  ! specify viewing distance
   /FOCUS,1,-8.02,Y,NZ(NNUM17)       ! specify focus point
   /CVAL,1,-10000,0,10000,20000,30000,40000,50000,100000       ! establish stress contours
   /graphics,power                       ! activate power graphics (speeds up displays)
   !
   esel,r,live                           ! reselect set of els from current set that are alive
   nsle                                  ! select nodes associated with selected elements
   !
   rsys,11                               ! activate cylindrical CS for results printout/display
   plns,s,y                              ! plot hoop stress (y-component)
   /cval,1
   plns,bfe,temp
   !
   ESEL,S,LIVE                           ! select live elements
   NSLE                                  ! select nodes associated with selected (live) els
   /GRAPHICS,FULL                        ! display all model geometry and results (full: data averaging
```

```
                                       ! includes interior and surface results)
  NSEL,ALL                             ! select all nodes
  ESEL,ALL                             ! select all elements (need to have all nodes first)
*END
!
! ***********************************************************************************
!
/com,  "NODE_POP" MACRO:  Creates/populates SNODEAR and TNODEAR arrays of node numbers
/com,
/com,  Arguments:  There are no variable arguments required to use this macro
/com,
*CREATE,NODE_POP
!
   /NOPR
   SNodes=6
   *DIM,SNODEAR,ARRAY,SNodes                  ! dim array for nodes of interest (stress)
   !/com, POPULATE SNODEAR array
   SNODEAR(1)=NNUM1+NAWELD/2*100              ! Node at Nozzle ID at mid-height of weld
   SNODEAR(2)=NNUM2+NAWELD/2*100              ! Node at Nozzle OD at mid-height of weld
   SNODEAR(3)=NNUM3+NAWELD/2*100              ! Node at center of weld (radial and height directions)
   SNODEAR(4)=ncirc/2*10000+NNUM1+NAWELD/2*100  ! Node at Nozzle ID at mid-height of weld
   SNODEAR(5)=ncirc/2*10000+NNUM2+NAWELD/2*100  ! Node at Nozzle OD at mid-height of weld
   SNODEAR(6)=ncirc/2*10000+NNUM3+NAWELD/2*100  ! Node at center of weld (radial and height directions)
   !
   TNodes=6
   *DIM,TNODEAR,ARRAY,TNodes          ! dim array for surface nodes of interest (temperature)
   !
   /com, POPULATE TNODEAR array for temperature monitoring
   TNODEAR(1)=NNUM18+1+NRWELD/2       ! Node halfway along "top" of buttering
   TNODEAR(2)=NNUM19                           ! Node at buttering corner
   TNODEAR(3)=NNUM13                           ! Node halfway along "side" of buttering
   TNODEAR(4)=NCIRC/2*10000+NNUM18+1+NRWELD/2   ! Node halfway along "top" of buttering
   TNODEAR(5)=NCIRC/2*10000+NNUM19              ! Node at buttering corner
   TNODEAR(6)=NCIRC/2*10000+NNUM13              ! Node halfway along "side" of buttering
*END
!
! ***********************************************************************************
!
/com,  "TRANSPOST" MACRO:  POST-PROCESSING TO FILL TRANSIENT RESULTS ARRAYS
/com,  Notes:      This macro writes hoop and axial stress results for transient cases.
/com,  Arguments for this macro are as follows:
/com,  ARG1:  Transient no. (e.g., 1, 2, 3);
!
*CREATE,TRANSPOST
   !
   *USE,NODE_POP                      ! fill NODEAR array of node nos
   *DIM,NH,ARRAY,100,SNODES           ! 2-D array of hoop stresses in weld
   *DIM,NA,ARRAY,100,SNODES           ! 2-D array of axial stresses in weld
   *DIM,NT,ARRAY,100,TNODES           ! dimension the NTEM (nodal temperatures) array
   *DIM,TIMECNT,ARRAY,100             ! 1-D array of time (at each time step of a given transient)
   *dim,avg_sy,array,100,2            ! Array containing avg hoop for all transient steps
   !
   nsel,none
   nsel,a,node,,nnum1,nnum5
   *repeat,naweld+nrbutt+1,,,,100,100   ! Select weld/butter nodes and adjacent nozzle
   *get,max_num,node,0,num,max          ! Get max node number
   *dim,nod_sy1,array,max_num,1         ! Dimension array for node axial stress
   *dim,nod_mask1,array,max_num,1       ! Dimension mask for nodes
   *vget,nod_mask1(1),node,1,nsel       ! Set mask if node selected
   nsel,all
   !
   nsel,none
   nsel,a,node,,ncirc/2*10000+nnum1,ncirc/2*10000+nnum5
   *repeat,naweld+nrbutt+1,,,,100,100  ! Select weld/butter nodes and adjacent nozzle
   *get,max_num,node,0,num,max         ! Get max node number
   *dim,nod_sy2,array,max_num,1        ! Dimension array for node axial stress
   *dim,nod_mask2,array,max_num,1      ! Dimension mask for nodes
```

Attachment 2: File "PzSS.trans.addpost.txt"

```
*vget,nod_mask2(1),node,1,nsel          ! Set mask if node selected
nsel,all
!
SET,FIRST                               ! read the first data set (ignore load step and sub-step nos)
*GET,IND1,ACTIVE,,SET,LSTP              ! grab current (first) load step number (call it "IND1")
SET,LAST                                ! read the last data set (ignore load step and sub-step nos)
*GET,IND2,ACTIVE,,SET,LSTP              ! grab current (last) load step number (call it "IND2")
*DO,J,1,IND2-(IND1-1),1                 ! do loop from first to last sub-step #; shift J back to start a
   SET,IND1+(J-1)                       ! set to appropriate load step before grabbing results
   *GET,TIMECNT(J),ACTIVE,,SET,TIME     ! grab time associated w/given load step (+ transient); call it
   NSTEP = IND2-IND1+1
   RSYS,11                              ! set results coordinate sys. to nozzle cylindrical sys.
   /out,%FNAME%.addpost,out,,append
   /NOPR
   /PAGE,,,20000,100         ! sets the page parameters to display all data in one shot
   /COM,
   NSEL,S,NODE,,1,10000
   NSEL,A,NODE,,ncirc*10000+1,ncirc*10000+10000
   /GOPR
   /COM,  *** STRESSES FOR TRANSIENT CASE %ARG1% (%NSTEP% LOAD STEPS) ***
   PRNSOL,S,COMP
   /NOPR                     ! suppress output (so only requested data are written to file)
   NSEL,NONE
   NSEL,ALL
   ESEL,ALL
   /com,
   !Extract stresses and store in arrays NH, NA
   /com,
   *DO,I,1,SNodes,1                            ! loop through nodes of interest
      *GET,NH(J,I),NODE,SNODEAR(I),S,Y         ! extract hoop stresses
      *GET,NA(J,I),NODE,SNODEAR(I),S,Z         ! extract axial (parallel to nozzle axis) stresses
   *ENDDO
   *DO,I,1,TNodes,1
      *GET,NT(J,I),NODE,TNODEAR(I),BFE,TEMP
   *ENDDO
   !
   !Extract and calculate average hoop stress
   *DO,I,1,2,1
      *vmask,nod_mask%I%(1)                    ! Apply mask
      *vget,nod_sy%I%(1),node,1,s,y            ! Get hoop stress for selected
      *vmask,nod_mask%I%(1)                    ! Apply mask
      *vscfun,avg_sy(J,I),mean,nod_sy%I%(1)    ! Calculate average of hoop stress and store in avg_sy a
   *ENDDO
   !
   *USE,TRANSPLOTS,ARG1                        ! create stress plots for each time step
*ENDDO
!
*USE,writedata,ARG1
!
!
!  Erase large node stress arrays by re-dimming
!
*dim,nod_sy1,array,max_num,1            ! Dimension array for node axial stress
*dim,nod_mask1,array,max_num,1          ! Dimension mask for nodes
*dim,nod_sy2,array,max_num,1            ! Dimension array for node axial stress
*dim,nod_mask2,array,max_num,1          ! Dimension mask for nodes
*END
!
*create,writedata              ! ARG1 = transient number
  *do,i,1,SNodes
     NODE%I% = SNODEAR(I)
  *enddo
  *do,i,1,TNodes
     TNODE%I% = TNODEAR(I)
  *enddo
  !
  /NOPR
```

Attachment 2: File "PzSS.trans.addpost.txt"

```
/out,%FNAME%.Sec5data,out,,APPEND
/COM, ----------------------------------------------------------
/com,       Transient %ARG1% - %NSTEP% TIME STEPS
/COM, ----------------------------------------------------------
/COM,
/COM, ----------------------------------------------------------
/com,               Selected Node Hoop Stresses
/COM, ----------------------------------------------------------
/COM,
*vwrite,NODE1,NODE2,NODE3,NODE4,NODE5,NODE6
(12X,6(F6.0,'Hp',3x),' FRAvg.Hp',' MDAvg.Hp')
*VLEN,NSTEP
*vwrite,SEQU,NH(1,1),NH(1,2),NH(1,3),NH(1,4),NH(1,5),NH(1,6),avg_sy(1,1),avg_sy(1,2)
('Step: ',F3.0,8F11.0)
/COM,
/out,
!
/out,%FNAME%.Sec5data,out,,APPEND
/COM, ----------------------------------------------------------
/com,               Selected Node Axial Stresses
/COM, ----------------------------------------------------------
/COM,
*vwrite,NODE1,NODE2,NODE3,NODE4,NODE5,NODE6
(12X,4(F6.0,'Ax',3x,F6.0,'Ax',3x))
*VLEN,NSTEP
*vwrite,SEQU,NA(1,1),NA(1,2),NA(1,3),NA(1,4),NA(1,5),NA(1,6)
('Step: ',F3.0,6F11.0)
/COM,
/out,
!
/out,%FNAME%.Sec5data,out,,APPEND
/COM, ----------------------------------------------------------
/com,               Node Temperatures
/COM, ----------------------------------------------------------
/COM,
*vwrite,TNODE1,TNODE2,TNODE3,TNODE4,TNODE5,TNODE6
(12X,6(F6.0,'T',2x))
*VLEN,NSTEP
*vwrite,SEQU,NT(1,1),NT(1,2),NT(1,3),NT(1,4),NT(1,5),NT(1,6)
('Step: ',F3.0,6F9.0)
/com,
/com,
/out,
/GOPR
*end
!
! ******************************************************************************************
!
!       END OF MACRO GENERATION - START POSTPROCESSING FILES
!
! ******************************************************************************************
!
/COM,   RETRIEVE & WRITE STRESSES AND TEMPERATURES FOR TRANSIENTS
!
/filn,%FNAME%.trans1
RESU,,dbs1                  ! resume from database file associated with first transient
/POST1                      ! Enter post-processing
*USE,TRANSPOST,1            ! Post-process and write 1st transient results
/com,
finish                      ! exit out of POST module as exit macro
/NOPR
PARSAV,ALL
!
! ----------------------------------------------------------
/filn,%FNAME%.trans2
RESU,,dbs2               ! resume from database file associated with first transient
/POST1                   ! Enter post-processing
```

Attachment 2: File "PzSS.trans.addpost.txt"

```
*USE,TRANSPOST,2          ! Post-process and fill transient results arrays
/com,
finish                    ! exit out of POST module as exit macro
/NOPR
PARSAV,ALL
!
! ------------------------------------------------------------
/filn,%FNAME%.trans3
RESU,,dbs3                 ! resume from database file associated with first transient
/POST1                     ! Enter post-processing
*USE,TRANSPOST,3           ! Post-process and fill transient results arrays
/com,
finish                     ! exit out of POST module as exit macro
/NOPR
PARSAV,ALL
!
! ------------------------------------------------------------
/filn,%FNAME%.trans4
RESU,,dbs4                 ! resume from database file associated with first transient
/POST1                     ! Enter post-processing
*USE,TRANSPOST,4           ! Post-process and fill transient results arrays
/com,
finish                     ! exit out of POST module as exit macro
/NOPR
PARSAV,ALL
!
! ------------------------------------------------------------
/filn,%FNAME%.trans5
RESU,,dbs5                 ! resume from database file associated with first transient
/POST1                     ! Enter post-processing
*USE,TRANSPOST,5           ! Post-process and fill transient results arrays
/com,
finish                     ! exit out of POST module as exit macro
/NOPR
PARSAV,ALL
!
! ------------------------------------------------------------
/filn,%FNAME%.trans6
RESU,,dbs6                 ! resume from database file associated with first transient
/POST1                     ! Enter post-processing
*USE,TRANSPOST,6           ! Post-process and fill transient results arrays
/com,
finish                     ! exit out of POST module as exit macro
/NOPR
PARSAV,ALL

! *****************************************************************************************
!
!  File cleanup after all necessary post-processing has been done
!
/SYS, rm TRANSPLOTS
/SYS, rm TRANSPOST
/SYS, rm NODE_POP
/SYS, rm writedata
/EXIT,NOSAV
```

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Attachment 2: File "PzSS.trans.addpost.txt"

Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

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```
/BATCH,LIST
!
/FILN,PzSS-0A
RESU,,dbs,../../
!
/COM,*************************************************************
/COM,
/COM,   Description:  Transient Add-on Code
/com,
/com,   This batch listing does the following:
/com,     A.  Runs cooldown w/ flooding transient to shakedown model
/com,     B.  Solves preliminary static case with nozzle repaired
/com,        *  Static cases w/nozzle killed (repair):      T=70F    & P=0 psig    at t=36001s
/com,        *  Writes PzBH-30A.ist file for resuming during elastic transients
/com,   C.  Defines and solves six (6) transient cases, as follows:
/com,       1. Heatup Transient
/com,       2. Cooldown Transient w/ Flooding
/com,       3. Unit loading/unloading / 10% Step Change
/com,       4. Reactor Trip/Loss of Load/Loss of Flow
/com,       5. Loss of Secondary Pressure
/com,       6. Leak Test
/com,   D.  This code creates the following macros:
/com,       1. tload:  selects appropriate nozzle and RV shell surfaces
/com,          and applies the specified temperature and convection
/com,          coefficient boundary conditions
/com,       2. tload2:  applies h consistent with steam convection conditions
/com,          tload surfaces
/com,       3. tplod: selects appropriate nozzle and RV shell surfaces
/com,          and applies the specified pressure at the specified time
/com,          and temperature.  No nozzle "end cap" force due to repair
/com,       4. tplod_nop: same as tplod but no pressure applied
/com,       5. plod2: applies pressure only to same surfaces as tplod
/com,
/com,   Notes:
/com,   A.  This code does not perform any post-processing.  Instead, it
/com,       saves files after each transient is solved to facilitate post-
/com,       processing with a separate batch listing.
/com,
/com,   DEI task no:  36-77
/com,
/com,   Current Version by:  JEB                   Date:  9/1/2005
/com,
! ******************************************************************************************
!
/COPY,%FNAME%,dbt,../../,thermal,db        ! create copy of "*.dbt" and call it "thermal.db"
/COPY,thermal,db,,thermal,dbb              ! create a second copy of the full model thermal.db file
/show,transplots,grph                    ! send graphical output to transplots.grph
!
/out,%FNAME%.transient,out               ! create blank *.transient.out file
!                                          (will write results to it later)
/out,                                    ! redirect output back to std (command line) *.out file
!
!
! ******************************************************************************************
!
*CREATE,tload                             ! tload macro: ARG1 = bulk temp (F); ARG2 = time (sec.)
   /NOPR
   ESEL,S,LIVE
   NSEL,NONE
   !
   hcoeff1 = 500/(144*3600)               ! Head IR h in BTU/sec-in^2-F
   !
   NSEL,A,,,NNUM2,NNUM6,1                 ! Grab shell IR nodes (includes weld underside)
   *REPEAT,ncirc+1,,,,10000,10000
   SF,ALL,CONV,hcoeff1,ARG1               ! ARG1 = temperature (F)
```

```
   !
   *IF,TRIMFLAG,GT,0.5,THEN                 ! i.e., if nozzle is trimmed to be flush with RVH
      NSEL,NONE
      NSEL,A,,,NNUM1,NNUM2,1
      *REPEAT,ncirc+1,,,,10000,10000
      SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
   *ELSE                                      ! i.e., if nozzle end not trimmed (normal CRDM/CEDM cases)
      NSEL,NONE
      NSEL,A,,,1,NRTUBE+1,1                   ! grab tube bottom nodes
      *REPEAT,ncirc+1,,,,10000,10000
      NSEL,A,,,NRTUBE+1,NNUM2,100             ! grab lower tube OR nodes
      *REPEAT,ncirc+1,,,,10000,10000
      SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
   *ENDIF
   !
   NSEL,A,NODE,,NNUM1,NNUM17+400,100
   *REPEAT,ncirc+1,,,,10000,10000           ! Grab nozzle ID in remnant nozzle
   SF,ALL,CONV,hcoeff1,ARG1                 ! ARG1 = temperature (F)
   !
   NSEL,ALL
   ESEL,ALL
   DDELE,ALL,TEMP                           ! Deletes temp constraints on all nodes
   TIME,ARG2                                ! sets the time to ARG2 value when macro is called
   /GOPR                                    ! reactivates suppressed printout
   SOLVE                                    ! solve model at ARG1 temp and ARG2 time
*END
*CREATE,tload2                              ! tload macro: ARG1 = bulk temp (F); ARG2 = time (sec.)
   /NOPR
   ESEL,S,LIVE
   NSEL,NONE
   !
   hcoeff1 = 10/(144*3600)                  ! Head IR h in BTU/sec-in^2-F
   !
   NSEL,A,,,NNUM2,NNUM6,1                   ! Grab shell IR nodes (includes weld underside)
   *REPEAT,ncirc+1,,,,10000,10000
   SF,ALL,CONV,hcoeff1,ARG1                 ! ARG1 = temperature (F)
   !
   *IF,TRIMFLAG,GT,0.5,THEN                 ! i.e., if nozzle is trimmed to be flush with RVH
      NSEL,NONE
      NSEL,A,,,NNUM1,NNUM2,1
      *REPEAT,ncirc+1,,,,10000,10000
      SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
   *ELSE                                      ! i.e., if nozzle end not trimmed (normal CRDM/CEDM cases)
      NSEL,NONE
      NSEL,A,,,1,NRTUBE+1,1                   ! grab tube bottom nodes
      *REPEAT,ncirc+1,,,,10000,10000
      NSEL,A,,,NRTUBE+1,NNUM2,100             ! grab lower tube OR nodes
      *REPEAT,ncirc+1,,,,10000,10000
      SF,ALL,CONV,hcoeff1,ARG1                ! ARG1 = temperature (F)
   *ENDIF
   !
   NSEL,A,NODE,,NNUM1,NNUM17+400,100
   *REPEAT,ncirc+1,,,,10000,10000           ! Grab nozzle ID in remnant nozzle
   SF,ALL,CONV,hcoeff1,ARG1                 ! ARG1 = temperature (F)
   !
   NSEL,ALL
   ESEL,ALL
   DDELE,ALL,TEMP                           ! Deletes temp constraints on all nodes
   TIME,ARG2                                ! sets the time to ARG2 value when macro is called
   /GOPR                                    ! reactivates suppressed printout
   SOLVE                                    ! solve model at ARG1 temp and ARG2 time
*END
!
! **********************************************************************************
!
/COM,  Create Temperature & Pressure Loading Macro
*CREATE,tplod                               ! tpload macro: ARG1 = pressure (psi); ARG2 = time (sec.)
```

Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
/NOPR
ESEL,ALL
NSEL,NONE
!
NSEL,A,NODE,,NNUM2,NNUM6,1                ! Grab shell IR nodes (NNUM2+1 node is actually collapsed out)
*REPEAT,ncirc+1,,,,10000,10000
NSEL,A,NODE,,NNUM1,NNUM2,1                ! Grab underside of nozzle wall
*REPEAT,ncirc+1,,,,10000,10000
!
NSEL,A,NODE,,NNUM15,NNUM15
*REPEAT,ncirc+1,,,,10000,10000
NSEL,A,NODE,,NNUM15+101,NNUM24,100
*REPEAT,ncirc+1,,,,10000,10000            ! Grab head penetration ID nodes
!
NSEL,A,NODE,,NNUM1,NNUM17+400,100
*REPEAT,ncirc+1,,,,10000,10000            ! Grab nozzle ID in remnant nozzle
NSEL,A,NODE,,NNUM15,NNUM18+400,100
*REPEAT,ncirc+1,,,,10000,10000            ! Grab nozzle OD in remnant nozzle
NSEL,A,NODE,,NNUM17+400,NNUM18+400,1
*REPEAT,ncirc+1,,,,10000,10000            ! Grab nozzle top in remnant nozzle
!
ESEL,S,LIVE
SF,ALL,PRES,ARG1                          ! ARG1=pressure
NSEL,ALL
ESEL,ALL
*IF,CYLSHELL,EQ,1,THEN
   /COM,  ***  Apply Vessel axial pressure
   CSYS,32
   NSEL,S,LOC,Z,ZSIZE/2+0.02,ZSIZE/2-0.02
   NSEL,A,LOC,Z,-ZSIZE/2+0.02,-ZSIZE/2-0.02
   SF,ALL,PRES,-(SIR**2/(SOR**2-SIR**2))*ARG1
   CSYS,0
*ENDIF
/GOPR
NSEL,ALL
LDREAD,TEMP,,,ARG2,,,rth                  ! read temps (use time rather than loadstep and substep)
TIME,ARG2+20000                           ! offset time by 20000 for structural model
*if,ARG3,EQ,1,THEN
   ISWRITE,ON
   solve
   ISWRITE,OFF
   *GET,NMTMP,ACTIVE,0,JOBNAM
   /RENAME,%NMTMP%,ist,,%NMTMP%.%ARG2%.hm,ist
*else
   SOLVE
*endif
*END
!
*CREATE,tplod_nop                         ! tplod_nop macro: ARG1 = pressure (psi) (ignored); ARG2 = time
  NSEL,ALL
  ESEL,ALL
  LDREAD,TEMP,,,ARG2,,,rth                ! read temps (use time rather than loadstep and substep)
  TIME,ARG2                               ! same time for structural model
  *if,ARG3,EQ,1,THEN
     ISWRITE,ON
     solve
     ISWRITE,OFF
     *GET,NMTMP,ACTIVE,0,JOBNAM
     /RENAME,%NMTMP%,ist,,%NMTMP%.%ARG2%.hm,ist
  *else
     SOLVE
  *endif
*END
!
!   ***************************************************************************************
!
!                   ANALYZE STATIC CASES WITH AND WITHOUT NOZZLE REMOVED
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
!
!   *******************************************************************************
!
!
resu,%FNAME%,dbs,../../
/COPY,%FNAME%,emat,../../,%FNAME%,emat
/COPY,%FNAME%,esav,../../,%FNAME%,esav
/COPY,plod,,../../,plod
!
/SOLUTION
ANTYPE,,RESTART
!
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - Post Operating (T=70F,P=0psig)
!
DELTIM,0.01,0.01,1.0,OFF
!
/com,  Take model down to room temperature and pressure
TIME,T0+5                           ! set t=7005s (not a transient, so time is arbitrary)
BF,ALL,TEMP,70                      ! set T=70F
*USE,plod,0                         ! P=0; use orig "plod" macro (includes solve) since nozzle stil:
!
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - Repair (T=70F,P=0 psig)
!
/com,  Delete upper nozzle (simulate repair)
esel,none
*do,i,0,ncirc-1,1
   esel,a,elem,,i*10000+nnum17+400,i*10000+10000,100
   *repeat,nrtube,,,,1
*enddo
ekill,all                           ! kills all selected elements, ie, the nozzle
esel,all
!
!  Apply temperature and pressure to nozzle-free model (T=70F; P=0 psig)
!
sfdele,all,pres
!
DELTIM,0.25,0.25,1.0,OFF
TIME,T0+6                           ! set t=7006s
BF,ALL,TEMP,70                      ! set T=70F
ISWRITE,ON                          ! write solution to *.ist file
SOLVE
ISWRITE,OFF
finish                              ! exit SOLU (back out/up to BEGIN level)
PARSAV,ALL                          ! saves parameter values to *.parm file
!                                   ! being post-repair at operating temperature and pressure.
!
save,,dbp                           ! save *.dbp for elastic-plastic model use
/COPY,%FNAME%,emat,,%FNAME%.safe,emat   ! save *.emat and *.esave for CDF restart analysis from..
/COPY,%FNAME%,esav,,%FNAME%.safe,esav   ! ..post-repair analysis model
!
/prep7                              ! Remove elastic-plastic mat properties
tbdele,all,all                      ! use *.dbe for elastic model restarts, use isfile for init. st:
save,,dbe
!
resu,thermal,db
/com,  Delete upper nozzle (simulate repair)
esel,none
*do,i,0,ncirc-1,1
   esel,a,elem,,i*10000+nnum17+400,i*10000+10000,100
   *repeat,nrtube,,,,1
*enddo
ekill,all                           ! kills all selected elements, ie, the nozzle
esel,all
save,thermal,db                     ! save thermal model with lower nozzle portion killed
finish
!
!   *******************************************************************************
```

Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
!
!                NOW TURN FULL MODEL *.IST FILE INTO HALF MODEL *.IST FILE
!
!    *****************************************************************************
!
!
resu,%FNAME%,dbe                                ! Resume from elastic full model
/RENAME,%FNAME%,ist,,%FNAME%.full,ist
/COM,
/SOLU
ANTYPE,,NEW
AUTOTS,OFF                                      ! do not use automatic time stepping
DELTIM                                          ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou:
NSUBST,1                                        ! specifies single substep (since effect of pressure is not time
esel,s,type,,1
isfile,read,%FNAME%.full,ist,,1                 ! read in residual stress state from full welding residual stre:
!
esel,all
cpdele,all
esel,s,elem,,1,ncirc/2*10000
nsle                                            ! Solve will be done with only 1/2 model selected
!
csys,32
nsel,r,LOC,Z,ZSIZE/2+0.02,ZSIZE/2-0.02
cp,next,uz,all
nsle
nsel,r,loc,y,0
d,all,uy,0
nsle                                            ! Modify boundary conditions for 1/2 model
!
iswrite,on
time,1.0
solve                                           ! This solve writes an *.ist file for the half model
iswrite,off
finish
!
resu,%FNAME%,dbe                                ! Now turn the *.dbe file into a half model
/prep7
!
esel,s,elem,,1,ncirc/2*10000
nsle
esel,inve
nsel,inve
edele,all
ndele,all
csys,32
NSEL,S,LOC,Z,ZSIZE/2+0.02,ZSIZE/2-0.02
CP,NEXT,UZ,ALL
nsel,s,loc,y,0
d,all,uy,0
allsel
!
save,,dbe                                     ! use *.dbe for elastic model restarts, use isfile for init. stres:
!
resu,thermal,db
esel,s,elem,,1,ncirc/2*10000
nsle
esel,inve
nsel,inve
edele,all
ndele,all
allsel
save,thermal,db
!
finish
!
!
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
!
!   ***********************************************************************************
!                       ANALYZE THE SERIES OF SPECIFIED TRANSIENTS
!
!
!   ************************************************************
!   Transient 1 : Heatup Transient (temperature only)
!   ------------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db                            ! Resumes from the file copy we make at beginning
/FILN,%FNAME%.trans1                       ! Set filename to "*.trans1"
/SOLU
ANTYPE,TRANS,NEW                           ! new transient analysis
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - HU Transient
OUTPR,BASIC,NONE                           ! don't print substep results
OUTRES,ALL,LAST                            ! write solution only for last substep of each load step
AUTOTS,ON                                  ! use automatic time stepping
PRED,ON,,ON                                ! use predictor, including on first substep
/COM,
/COM, Establish initial conditions and do transient
TIMINT,OFF,THERM                           ! turn off transient effects for thermal DOFs
*USE,tload,70,0.1
KBC,0                                      ! Linearly interpolate (ramp) loads for each substep
TIMINT,ON,THERM                            ! turn on transient effects for thermal DOFs
DELTIM,60,60,1800,ON
*USE,tload,170,1800
*USE,tload,270,3600
*USE,tload,370,5400
*USE,tload,470,7200
*USE,tload,550,8640
*USE,tload,594,9432
*USE,tload,630,10080
*USE,tload,653,10494
Time,11394    $SOLVE
Time,12294    $SOLVE
Time,14094    $SOLVE
Time,17694    $SOLVE
TIMINT,OFF,THERM                           ! turn off transient effects for thermal DOFs
DELTIM,28800-17694,,28800-17694,OFF
Time,28800    $SOLVE
FINISH
SAVE
!
!   ************************************************************
!   Transient 1  : Heatup Transient (temperature and pressure)
!   ------------------------------------------------------------
!
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans1
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - HU Transient
AUTOTS,OFF                                 ! do not use automatic time stepping
DELTIM                                     ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou
NSUBST,1                                   ! specifies single substep (since effect of pressure is not tim
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1                 ! read in residual stress state from welding residual stress mo
esel,all
*USE,tplod_nop,0,0.1
*USE,tplod_nop,0,1800
*USE,tplod_nop,5,3600
*USE,tplod_nop,200,5400
*USE,tplod_nop,500,7200,1                  !! min
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
*USE,tplod_nop,1000,8640
*USE,tplod_nop,1500,9432
*USE,tplod_nop,1950,10080
*USE,tplod_nop,2235,10494
*USE,tplod_nop,2235,11394
*USE,tplod_nop,2235,12294
*USE,tplod_nop,2235,14094
*USE,tplod_nop,2235,17694
*USE,tplod_nop,2235,28800,1              !! max
FINISH
!
PARSAV,ALL
SAVE,,dbs1
!
!   ***********************************************************
!   Transient 3 : Load/Unload / Step Change  (temperature only)
!   -----------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db                           ! Resumes from the file copy we make at beginning
/FILN,%FNAME%.trans3                      ! Set filename to "*.trans3"
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Load/Unload / Step Inc.
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM
*USE,tload,633,0.1
KBC,0                                     ! linearly interpolate loads
TIMINT,ON,THERM                           ! turn on thermal transient effects
*USE,tload,653,1
Time,15      $SOLVE
Time,60      $SOLVE
Time,180     $SOLVE
Time,600     $SOLVE
Time,1800    $SOLVE
Time,3600    $SOLVE
TIMINT,OFF,THERM
DELTIM,7200-3600,,7200-3600,OFF
Time,7200    $SOLVE
TIMINT,ON,THERM                           ! turn on thermal transient effects
DELTIM,5,,1800,ON
*USE,tload,633,7201
Time,7215    $SOLVE
Time,7260    $SOLVE
Time,7380    $SOLVE
Time,7800    $SOLVE
Time,9000    $SOLVE
Time,10800    $SOLVE
TIMINT,OFF,THERM
DELTIM,14400-10800,,14400-10800,OFF
Time,14400    $SOLVE
!
FINISH
SAVE
!
!   ***********************************************************************
!   Transient 3  : Load/Unload / Step Change  (temperature and pressure)
!   -----------------------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
/FILN,%FNAME%.trans3
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Load/Unload / Step Inc.
AUTOTS,OFF                               ! do not use automatic time stepping
DELTIM                                   ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou:
NSUBST,1                                 ! specifies single substep (since effect of pressure is not time
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1               ! read in residual stress state from welding residual stress moc
esel,all
*USE,tplod_nop,2135,0.1
*USE,tplod_nop,2235,1
*USE,tplod_nop,2235,15
*USE,tplod_nop,2235,60
*USE,tplod_nop,2235,180,1                !! min
*USE,tplod_nop,2235,600
*USE,tplod_nop,2235,1800
*USE,tplod_nop,2235,3600
*USE,tplod_nop,2235,7200
*USE,tplod_nop,2135,7201
*USE,tplod_nop,2135,7215
*USE,tplod_nop,2135,7260
*USE,tplod_nop,2135,7380,1               !! max
*USE,tplod_nop,2135,7800
*USE,tplod_nop,2135,9000
*USE,tplod_nop,2135,10800
*USE,tplod_nop,2135,14400
FINISH
!
PARSAV,ALL
SAVE,,dbs3
!
!   *******************************************************
!   Transient 4 : Reactor Trip/Loss of Load/Loss of Flow Transient (temperature only)
!   -------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db
/FILN,%FNAME%.trans4
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Trip/Loss of Flow/Load
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM
*USE,tload,653,0.1
KBC,0                                    ! linearly interpolate loads
TIMINT,ON,THERM                          ! turn on thermal transient effects
DELTIM,5,1,1800,ON
*USE,tload,645,10
*USE,tload,637,20
*USE,tload,629,30
*USE,tload,621,40
*USE,tload,613,50
DELTIM,25,1,1800,ON
*USE,tload,611,100
*USE,tload,609.2,150
*USE,tload,607.4,200
*USE,tload,603.8,300
*USE,tload,600.2,400
*USE,tload,596.6,500
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
*USE,tload,593,600
*USE,tload,599,740
*USE,tload,605,880
*USE,tload,617,1160
*USE,tload,629,1440
*USE,tload,641,1720
*USE,tload,647,1860
*USE,tload,653,2000
Time,2100     $SOLVE
Time,2600     $SOLVE
Time,3600     $SOLVE
Time,5400     $SOLVE
TIMINT,OFF,THERM
DELTIM,7200-5400,,7200-5400,OFF
Time,7200     $SOLVE
FINISH
SAVE
!
!
!   ****************************************************************
!   Transient 4  : Reactor Trip/Loss of Load/Loss of Flow Transient (temperature and pressure)
!   ----------------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans4
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Trip/Loss of Flow/Load
AUTOTS,OFF                                ! do not use automatic time stepping
DELTIM                                    ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou
NSUBST,1                                  ! specifies single substep (since effect of pressure is not tim
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1                ! read in residual stress state from welding residual stress mo
esel,all
*USE,tplod_nop,2235,0.1
*USE,tplod_nop,2295,10
*USE,tplod_nop,2355,20
*USE,tplod_nop,2415,30
*USE,tplod_nop,2475,40
*USE,tplod_nop,2535,50,1                  !! max
*USE,tplod_nop,1685,100
*USE,tplod_nop,1698.75,150
*USE,tplod_nop,1712.5,200
*USE,tplod_nop,1740,300
*USE,tplod_nop,1767.5,400
*USE,tplod_nop,1795,500
*USE,tplod_nop,1822.5,600
*USE,tplod_nop,1861,740
*USE,tplod_nop,1899.5,880
*USE,tplod_nop,1976.5,1160
*USE,tplod_nop,2053.5,1440
*USE,tplod_nop,2130.5,1720
*USE,tplod_nop,2169,1860
*USE,tplod_nop,2207.5,2000,1              !! min
*USE,tplod_nop,2235,2100
*USE,tplod_nop,2235,2600
*USE,tplod_nop,2235,3600
*USE,tplod_nop,2235,5400
*USE,tplod_nop,2235,7200
FINISH
!
PARSAV,ALL
SAVE,,dbs4
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
!
!   ***********************************************************
!   Transient 5 : Loss of Secondary Pressure (temperature only)
!   -----------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db
/FILN,%FNAME%.trans5
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - LOSP
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do Transient
TIMINT,OFF,THERM
*USE,tload,653,0.1
KBC,0                                   ! linearly interpolate loads
TIMINT,ON,THERM                         ! turn on thermal transient effects
DELTIM,0.5,0.1,1800,ON
*USE,tload,635,6
*USE,tload2,632,7
*USE,tload2,585.5,22.5
*USE,tload2,539,38
*USE,tload2,492.5,53.5
*USE,tload2,446,69
*USE,tload2,399.5,84.5
*USE,tload2,353,100
*USE,tload2,356.75,125
*USE,tload2,360.5,150
*USE,tload2,364.25,175
*USE,tload2,368,200
*USE,tload2,380.5,300
*USE,tload2,393,400
*USE,tload2,408,600
*USE,tload2,423,800
*USE,tload2,433,1000
*USE,tload2,458,1550
*USE,tload,458,1551
*USE,tload,473,2000
*USE,tload,491,2667
*USE,tload,510,3333
*USE,tload,528,4000
*USE,tload,590.5,6200
*USE,tload,653,8400
TIMINT,OFF,THERM
DELTIM,10000-8400,,10000-8400,OFF
*USE,tload,653,10000
FINISH
SAVE
/COM,
!
!   ******************************************************************
!   Transient 5 : Loss of Secondary Pressure (temperature and pressure)
!   ------------------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans5
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - LOSP
AUTOTS,OFF                              ! do not use automatic time stepping
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
DELTIM                                  ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou:
NSUBST,1                                ! specifies single substep (since effect of pressure is not tim(
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1              ! read in residual stress state from welding residual stress mo(
esel,all
*USE,tplod_nop,2235,0.1
*USE,tplod_nop,2173,6
*USE,tplod_nop,2163,7
*USE,tplod_nop,2000,22.5
*USE,tplod_nop,1837,38
*USE,tplod_nop,1674,53.5
*USE,tplod_nop,1511,69
*USE,tplod_nop,1348,84.5
*USE,tplod_nop,1186,100
*USE,tplod_nop,923,125
*USE,tplod_nop,660,150
*USE,tplod_nop,398,175
*USE,tplod_nop,135,200,1                !! min
*USE,tplod_nop,160,300
*USE,tplod_nop,185,400
*USE,tplod_nop,235,600
*USE,tplod_nop,285,800
*USE,tplod_nop,335,1000
*USE,tplod_nop,434,1550
*USE,tplod_nop,434.18,1551
*USE,tplod_nop,515,2000,1               !! max
*USE,tplod_nop,622,2667
*USE,tplod_nop,728,3333
*USE,tplod_nop,835,4000
*USE,tplod_nop,1535,6200
*USE,tplod_nop,2235,8400
*USE,tplod_nop,2235,10000
FINISH
!
PARSAV,ALL
SAVE,,dbs5
!
!   ***************************************************************
!   Transient 6 : Leak Test (temperature only)
!   ---------------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,db                         ! Resumes from the file copy we make at beginning
/FILN,%FNAME%.trans6                    ! Set filename to "*.trans6"
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Leak Test
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON
PRED,ON,,ON
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM
*USE,tload,100,0.1
KBC,0                                   ! linearly interpolate loads
TIMINT,ON,THERM                         ! turn on thermal transient effects
*USE,tload,100,1800
*USE,tload,100,3600
*USE,tload,160,5760
*USE,tload,220,7920
*USE,tload,280,10080
*USE,tload,340,12240
*USE,tload,400,14400
Time,14401     $SOLVE
Time,16200     $SOLVE
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
Time,18000     $SOLVE
Time,19800     $SOLVE
TIMINT,OFF,THERM
DELTIM,21600-19800,,21600-19800,OFF
Time,21600     $SOLVE
TIMINT,ON,THERM                              ! turn on thermal transient effects
DELTIM,5,,1800,ON
*USE,tload,400,23400
*USE,tload,400,25200
*USE,tload,340,27360
*USE,tload,280,29520
*USE,tload,220,31680
*USE,tload,160,33840
*USE,tload,100,36000
Time,36001     $SOLVE
Time,37440     $SOLVE
Time,38880     $SOLVE
Time,40320     $SOLVE
Time,41760     $SOLVE
TIMINT,OFF,THERM
DELTIM,43200-41760,,43200-41760,OFF
Time,43200     $SOLVE
!
FINISH
SAVE
!
!   ***************************************************************************
!   Transient 6 : Leak Test (temperature and pressure)
!   ---------------------------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans6
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - Leak Test
AUTOTS,OFF                            ! do not use automatic time stepping
DELTIM                                ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou
NSUBST,1                              ! specifies single substep (since effect of pressure is not tim
!
esel,s,type,,1
isfile,read,%FNAME%,ist,,1            ! read in residual stress state from welding residual stress mo
esel,all
*USE,tplod_nop,385,0.1
*USE,tplod_nop,385,1800
*USE,tplod_nop,385,3600
*USE,tplod_nop,385,5760
*USE,tplod_nop,385,7920
*USE,tplod_nop,385,10080
*USE,tplod_nop,385,12240
*USE,tplod_nop,385,14400,1            !! min
*USE,tplod_nop,2235,14401
*USE,tplod_nop,2235,16200
*USE,tplod_nop,2235,18000
*USE,tplod_nop,2235,19800
*USE,tplod_nop,2235,21600
*USE,tplod_nop,2235,23400
*USE,tplod_nop,2235,25200
*USE,tplod_nop,2235,27360
*USE,tplod_nop,2235,29520
*USE,tplod_nop,2235,31680
*USE,tplod_nop,2235,33840
*USE,tplod_nop,2235,36000,1           !! max
*USE,tplod_nop,385,36001
*USE,tplod_nop,385,37440
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
*USE,tplod_nop,385,38880
*USE,tplod_nop,385,40320
*USE,tplod_nop,385,41760
*USE,tplod_nop,385,43200
FINISH
!
PARSAV,ALL
SAVE,,dbs6
!
!
!   ********************************************************************************
!
!            SHAKEDOWN ELASTIC-PLASTIC MODEL USING COOLDOWN W/ FLOODING TRANSIENT
!            THIS SET OF INITIAL STRESSES IS ONLY FOR USE WITH THE CDF TRANSIENT!
!
!   ********************************************************************************
!
!
!   ***********************************************************
!   Transient 0 : Cooldown w/ flooding transient (temperature only)
!   -----------------------------------------------------------
!
/COM, Hop back to thermal model
RESU,thermal,dbb                       ! resume from backup full thermal model
/filn,%FNAME%.cdf
/SOLU
ANTYPE,TRANS,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - CD w/ Flooding
OUTPR,BASIC,NONE
OUTRES,ALL,LAST
AUTOTS,ON                              ! use automatic time stepping
PRED,ON,,ON                            ! use predictor, including on first substep
/COM,
/COM, Establish Initial Conditions and do transient
TIMINT,OFF,THERM                       ! turn off transient effects for thermal DOFs
*USE,tload,653,0.1
KBC,0                                  ! Linearly interpolate (ramp) loads for each substep
TIMINT,ON,THERM                        ! turn on transient effects for thermal DOFs
DELTIM,60,60,1800,ON
*USE,tload,610,756
*USE,tload,568,1512
*USE,tload,525,2268
*USE,tload,483,3024
*USE,tload,440,3780
*USE,tload,440,3780.1
*USE,tload,383,3888
*USE,tload,327,3996
*USE,tload,270,4104
*USE,tload,213,4212
*USE,tload,157,4320
*USE,tload,100,4428
Time,5542     $SOLVE
Time,6657     $SOLVE
Time,7771     $SOLVE
Time,8886     $SOLVE
Time,10000     $SOLVE
*USE,tload,135,10062
*USE,tload,170,10124
*USE,tload,205,10186
*USE,tload,240,10248
*USE,tload,275,10309.6
*USE,tload,275,10309.7
*USE,tload,234,11047
*USE,tload,193,11784
*USE,tload,152,12521
*USE,tload,111,13259
*USE,tload,70,13996
```

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Attachment 3: File "therm.hm.PzSS.trans.addon.txt"

```
Time,14497    $SOLVE
Time,14998    $SOLVE
Time,15499    $SOLVE
TIMINT,OFF,THERM                        ! turn off transient effects for thermal DOFs
DELTIM,16000-15499,,16000-15499,OFF
Time,16000    $SOLVE
FINISH
/COM,
!
!   *********************************************************
!   Transient 0 : Cooldown w/ flooding transient: temperature and pressure
!   ---------------------------------------------------------
!
resu,%FNAME%,dbp                                  ! resume from elastic-plastic model
/COPY,%FNAME%.safe,emat,,%FNAME%.cdf,emat         ! restart analysis from post-repair analysis model
/COPY,%FNAME%.safe,esav,,%FNAME%.cdf,esav         !   ""
!
/SOLU
ANTYPE,,RESTART
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - CD w/ Flooding
PRED,ON,,ON                             ! use predictor, including on first substep
AUTOTS,ON                               ! use automatic time stepping
DELTIM,(20000-T0)/10,(20000-T0)/40,20000-T0
*USE,tplod,2235,0.1
AUTOTS,OFF                              ! do not use automatic time stepping
DELTIM                                  ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou
NSUBST,1                                ! specifies single substep (since effect of pressure is not tim
*USE,tplod,1875.8,756
*USE,tplod,1516.6,1512
*USE,tplod,1157.4,2268
*USE,tplod,798.2,3024
*USE,tplod,439,3780
*USE,tplod,0,3780.1
*USE,tplod,0,3888
*USE,tplod,0,3996
*USE,tplod,0,4104
*USE,tplod,0,4212
*USE,tplod,0,4320
*USE,tplod,0,4428
*USE,tplod,0,5542
*USE,tplod,0,6657
*USE,tplod,0,7771
*USE,tplod,0,8886
*USE,tplod,0,10000
*USE,tplod,0,10062
*USE,tplod,0,10124
*USE,tplod,0,10186
*USE,tplod,0,10248
*USE,tplod,0,10309.6
*USE,tplod,439,10309.7
*USE,tplod,351.2,11047
*USE,tplod,263.4,11784
*USE,tplod,175.6,12521
*USE,tplod,87.8,13259
*USE,tplod,0,13996
*USE,tplod,0,14497
*USE,tplod,0,14998
*USE,tplod,0,15499
ISWRITE,ON                              ! write shaken down solution to *.cdf.ist file
*USE,tplod,0,16000
ISWRITE,OFF
!
finish
!
/sys, rm *.cdf.rst                               ! Delete unneeded *.cdf.rst file
!
/RENAME,%FNAME%.cdf,rth,,%FNAME%.trans2,rth      ! No need to re-run thermal model
```

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```
!
!   ****************************************************************************************
!
!                NOW TURN FULL MODEL *.cdf.ist FILE INTO HALF MODEL *.cdf.ist FILE
!
!   ****************************************************************************************
!
!
/RENAME,%FNAME%.cdf,ist,,%FNAME%.full.cdf,ist
/COM,
/SOLU
ANTYPE,,NEW
AUTOTS,OFF                              ! do not use automatic time stepping
DELTIM                                  ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou:
NSUBST,1                                ! specifies single substep (since effect of pressure is not tim
esel,s,type,,1
isfile,read,%FNAME%.full.cdf,ist,,1        ! read in residual stress state from full welding residual :
!
esel,all
cpdele,all
esel,s,elem,,1,ncirc/2*10000
nsle                                    ! Solve will be done with only 1/2 model selected
!
csys,32
nsel,r,LOC,Z,ZSIZE/2+0.02,ZSIZE/2-0.02
cp,next,uz,all
nsle
nsel,r,loc,y,0
d,all,uy,0
nsle                                    ! Modify boundary conditions for 1/2 model
!
iswrite,on
time,1.0
solve                                   ! This solve writes an *.ist file for the half model
iswrite,off
finish
!
!
!
!    **********************************************************
!    Transient 2 : Cooldown w/ flooding transient: temperature and pressure
!    ----------------------------------------------------------
!
/COM,
/COM, Hop back to structural model and calc transient T + P's
resu,%FNAME%,dbe
/FILN,%FNAME%.trans2
/COM,
/SOLU
ANTYPE,,NEW
/TITLE,%TI1%%TI2%%TI3%%TI4%%TI5%%TI6%%TI7% - %FNAME% - CD w/ Flooding
AUTOTS,OFF                              ! do not use automatic time stepping
DELTIM                                  ! since AUTOTS,OFF and SOLCONTROL not used, defaults to previou:
NSUBST,1                                ! specifies single substep (since effect of pressure is not tim
!
esel,s,type,,1
isfile,read,%FNAME%.cdf,ist,,1          ! read in shaken down residual stress state from welding residu:
esel,all
*USE,tplod_nop,2235,0.1
*USE,tplod_nop,1875.8,756
*USE,tplod_nop,1516.6,1512
*USE,tplod_nop,1157.4,2268
*USE,tplod_nop,798.2,3024
*USE,tplod_nop,439,3780
*USE,tplod_nop,0,3780.1
*USE,tplod_nop,0,3888
*USE,tplod_nop,0,3996
```

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```
*USE,tplod_nop,0,4104
*USE,tplod_nop,0,4212
*USE,tplod_nop,0,4320
*USE,tplod_nop,0,4428,1                    !! max
*USE,tplod_nop,0,5542
*USE,tplod_nop,0,6657
*USE,tplod_nop,0,7771
*USE,tplod_nop,0,8886
*USE,tplod_nop,0,10000
*USE,tplod_nop,0,10062
*USE,tplod_nop,0,10124
*USE,tplod_nop,0,10186
*USE,tplod_nop,0,10248
*USE,tplod_nop,0,10309.6,1                 !! min
*USE,tplod_nop,439,10309.7
*USE,tplod_nop,351.2,11047
*USE,tplod_nop,263.4,11784
*USE,tplod_nop,175.6,12521
*USE,tplod_nop,87.8,13259
*USE,tplod_nop,0,13996
*USE,tplod_nop,0,14497
*USE,tplod_nop,0,14998
*USE,tplod_nop,0,15499
*USE,tplod_nop,0,16000
FINISH
!
PARSAV,ALL
SAVE,,dbs2
!
!
!  ***************************************************************************
!             END OF ANALYSIS OF WESTINGHOUSE-DEFINED CASES
!  ***************************************************************************
!  file cleanup!
/SYS, rm *.BCS
/SYS, rm *.PVTS
/SYS, rm *.osav
/SYS, rm *.full
/SYS, rm *.trans?.esav
/SYS, rm *.trans?.emat
/SYS, rm *.trans?.osav
/SYS, rm *.trans?.rth
/SYS, rm *.trans?.tri
/SYS, rm *.trans?.stat
/SYS, rm *.trans?.db
/SYS, rm tload
/SYS, rm tplod
!
/inp,PzSS.trans.addpost,txt
```

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