1.0 OBJECTIVE

Perform the structural analyses of the Energy*Solutions* 8-120B Cask under drop conditions, using a 3-dimensional finite element model.

2.0 INTRODUCTION

Energy*Solutions* 8-120B Cask (Reference 1) is designed as a Type B radioactive-material shipping package. To be certified by the U.S.N.R.C., the cask needs to meet the requirements of 10 CFR 71 (Reference 2) and follow the guidelines of U.S.N.R.C. Regulatory Guide 7.8 (Reference 3).

This document presents the structural analysis of the 8-120B Cask under various drop conditions required by the code. The analyses in this document are performed using the finite element modeling techniques. A three-dimensional model of the cask that includes all its major components has been employed in the analyses. Temperature dependent material properties of the major components of the cask are used in the analyses.

Analyses of the 8-120B Cask package have been performed for hypothetical accident condition (HAC) and normal condition of transport (NCT) drop test using the methodology developed by Energy*Solutions*. The details of the analyses are documented in the proprietary document of Reference 4. The resultant impact loads during various drop tests are obtained from this document and applied to the detailed finite element model of the cask body. Every component of the cask is evaluated for its integrity during the drop tests by comparing the stress intensities with their corresponding allowable values.

The results of the analyses for various load cases are presented pictorially in stress intensity contour plots as well as in table form, with the corresponding safety factors in each component of the cask body.

3.0 REFERENCES

1. Energy*Solutions* Drawing No. C-110-E-0007, Rev. 15, 8-120B Shipping Cask.
2. Code of Federal Regulations, Title 10, Part 71, Packaging and Transportation of Radioactive Material, January 2003.
3. U.S. NRC Regulatory Guide 7.8, Revision 1, March 1989, Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material.
4. Energy*Solutions* Document No. ST-625, Rev.0, Drop Analyses of the 8-120B Cask Package Using LS-DYNA Program.
5. ASME Boiler & Pressure Vessel Code, Section II, Part D, Materials, The American Society of Mechanical Engineers, New York, NY, 2001.
6. NUREG 0481/SAND77-1872, An Assessment of Stress-Strain Data Suitable for Finite Element Elastic-Plastic Analysis of Shipping Containers, Sandia National Laboratories, 1978.
7. U.S. NRC Regulatory Guide 7.6, Revision 1, Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels, 1978.
8. ANSYS, Release 12.1, ANSYS Inc., Canonsburg, PA, 2009.

9. Energy*Solutions* Document ST-626, Rev.0, Structural Analyses of the 8-120B Cask under Normal Conditions of Transport.

10. Energy*Solutions* Document TH-027, Rev. 0, Steady State Thermal Analyses of the 8-120B Cask Using a 3-D Finite Element Model.

11. Energy Solutions Document No. ST-608, Rev. 0, 3-60B Cask ANSYS Finite Element Model Grid Convergence Study.

12. Roark & Young, Formulas for Stress and Strain, Fifth Edition, McGraw-Hill Book Company, New York, 1975.

4.0 MATERIAL PROPERTIES

Material	Temp. (°F)	Strength (ksi)			Young's Modulus (10^6 psi)	Coefficient of Thermal Expansion (10^{-6} in/ in °F)
		Yield (S_y)	Ultimate (S_u)	Membrane Allowable (S_m)		
ASTM A240 Type 304L		(1)	(1)	(1)	(1)	(1)
	-20	25.0	70.0	16.7	28.8	-
	70	25.0	70.0	16.7	28.3	8.5
	100	25.0	70.0	16.7	-	8.6
	200	21.4	66.1	16.7	27.5	8.9
	300	19.2	61.2	16.7	27.0	9.2
	400	17.5	58.7	15.8	26.4	9.5
	500	16.4	57.5	14.7	25.9	9.7
ASTM A516 Gr. 70 Steel		(1)	(1)	(1)	(1)	(1)
	-20	38.0	70.0	20.0	30.3	-
	70	38.0	70.0	20.0	29.4	6.4
	100	38.0	70.0	20.0	-	6.5
	200	34.8	70.0	20.0	28.8	6.7
	300	33.6	70.0	20.0	28.3	6.9
	400	32.5	70.0	20.0	27.9	7.1
	500	31.0	70.0	20.0	27.3	7.3
ASTM A354 Gr. BD (Lid Bolts)		(1)	(1)	(1)	(1)	(1)
	-20	130	150	30	29.7	-
	70	130	150	30	29.2	6.4
	100	130	150	30	-	6.5
	200	119.1	150	30	28.6	6.7
	300	115	150	30	28.1	6.9
	400	111	150	30	27.7	7.1
	500	105.9	150	30	27.1	7.3
ASTM B29 Lead		(2)			(2)	(2)
	-20	-	-	-	2.43	15.65
	70	5	-	-	2.27	16.06
	100	-	-	-	2.21	16.22
	200	-	-	-	2.01	16.70
	300	-	-	-	1.85	17.33
	400	-	-	-	1.70	18.16
	500	-	-	-	1.52	19.12

Notes:

(1) From ASME B&PV Code 2001, Section II, Part D (Reference 5).

(2) From NUREG/CR 0481 (Reference 6)

5.0 ALLOWABLE STRESSES

Material →		ASTM A240 Type 304L	ASTM A516 Gr. 70	ASTM A354 Gr. BD
Yield Stress, S_y (psi)		25,000[(1)]	38,000[(1)]	130,000[(1)]
Ultimate Stress, S_u (psi)		70,000[(1)]	70,000[(1)]	150,000[(1)]
Design Stress Intensity, S_m (psi)		16,700[(1)]	20,000[(1)]	30,000[(1)]
Normal Conditions	Membrane Stress	16,700[(2)]	20,000[(2)]	60,000[(3)]
	Mem. + Bending Stress	25,050[(2)]	30,000[(2)]	90,000[(3)]
Hypothetical Accident Conditions	Membrane Stress	40,080[(4)]	48,000[(4)]	105,000[(5)]
	Mem. + Bending Stress	60,120[(4)]	70,000[(4)]	150,000[(5)]

Notes:

(1) From ASME B&PV Code 2001, Section II, Part D (Reference 5).

(2) Established from Regulatory Guide 7.6 (Reference 7), Position 2.

(3) Regulatory Guide 7.6 (Reference 7) does not provide any criteria. ASME B&PV Code, Section III, Subsection ND has been used to establish these criteria.

(4) Established from Regulatory Guide 7.6 (Reference 7), Position 6.

(5) Regulatory Guide 7.6 (Reference 7) does not provide any criteria. ASME B&PV Code, Section III, Appendix F has been used to establish these criteria.

6.0 MODEL DESCRIPTION

The structural analyses of the 8-120B Cask under various drop test conditions have been performed using finite element modeling techniques. ANSYS finite element analysis code (Reference 8) has been employed to perform the analyses. Since for all the drop orientations (end, side, corner, and slap-down), at least one plane of symmetry exists, a 180° model has been employed in all the analyses. This model has been developed from the one-half model developed in References 9 and 10 for the structural and thermal analyses of the cask during normal conditions of transport.

The model of the cask is made using 3-dimensional 8-node structural solid elements (ANSYS SOLID185) to represent the major components of the cask, the bolting ring, the lid, and the bolts. The shell components of the cask - the inner and outer shells, and the baseplates have been represented in the finite element model by SOLSH190 elements.

The fire shield does not provide any structural strength to the cask. Therefore, it is not included in the model.

The poured lead in the body is not bonded to the steel. It is free to slide over the steel surface. Therefore, the interface between the lead and the steel is modeled by pairs of 3-d 8 node contact element (CONTA174) and 3-d target segment (TARGE170) elements. These elements allow the lead to slide over the steel at the same time prevent it from penetrating the steel surface. The interface between the two plates that form the lid is also modeled by the contact-target pairs. The transition from a coarser mesh to a finer mesh, as well as bondage between various parts of the model, is also modeled using these elements.

Figure 1 shows the outline of the model depicting the material numbering. Figure 2 shows partial finite element grid of the lid, seal plate, bolts and the cask. Figure 3 shows the finite element grid of the cask body without the lead and Figure 4 shows that of the lead. The interface between various components of the cask is modeled by target-contact surface definition. Figure 5 shows contact elements of various contact-target pairs. The printout of the pertinent model quantities is included in Appendix 1.

Boundary Conditions

Since the model of the cask includes 180° geometry, symmetry boundary conditions are used on the cut-plane of the model in all the analyses. Also, the rigid body motion is prevented in the model by restraining it at the locations where such restraints have insignificant effect on the overall behavior of the model. This is necessary since the quasi-static analyses performed for every drop condition will result in a small net force in the plane of symmetry that will give rise to a rigid body motion.

Modeling Technique Validation and Grid Convergence Study

The finite element modeling techniques used in the 8-120B Cask have been previously used in the 3-60B cask analyses. A comprehensive modeling technique validation and the grid convergence study had been performed in Reference 11. The solid element types, grid size and the use of contact elements for modeling the interfaces used in the 8-120B Cask analyses are similar to those in the 3-60B Cask analyses. Therefore, the modeling technique validation and the grid convergence/sensitivity results provided in Reference 11 are also applicable to the 8-120B Cask finite element models used in the current analyses.

Loading

Applied loading is described for each drop orientation under the corresponding analysis section.

Temperature

The temperature distribution under various drop conditions is obtained from the thermal analyses performed in Reference 10 and is applied as the nodal temperature in the finite element model.

Internal Pressure

The cask internal pressure of 35 psig is applied over the nodes representing the cavity of the cask under various drop conditions in the hot environment. No internal pressures are applied during all drop conditions in the cold environment, with or without the internal decay heat.

Inertia Load

Cask body inertia, under various drop conditions, is applied as a body load. The magnitude of the inertia load is given in the corresponding analysis section. It should be noted that because of the segmentation of arc length in the finite element models, the mass of the model is always lower than the actual mass. To account for this, as well as to include the mass of miscellaneous items not included in the model, an adjustment is made in the value of acceleration due to gravity.

Cask Body Mass = 74,000 – 14,680 -2×4,860 = 49,600 lb

Mass of the FEM = 2×23,938 = 47,876 lb

Use acceleration due to gravity = 49,600/47,876 = 1.03g

7.0 ANALYSES

The finite element model (FEM) described above is analyzed for the accelerations obtained from the EnergySolutions proprietary analyses documented in Reference 4. The distribution of various loading components is described in details in the following sections.

7.1 HAC Drop Tests

7.1.1 End Drop

The following impact limiter reactions are obtained from Reference 4.

Cold Conditions = 5.359×10^6 lb (Table 3 and Figure 31 of Reference 4)

Hot Conditions = 4.427×10^6 lb (Table 3 and Figure 35 of Reference 4)

Conservatively use the maximum of the two reactions for the analyses of all environmental conditions. The impact limiter reaction is converted to the rigid body acceleration by dividing the reaction by that portion of the mass of the package which causes this reaction. During the end drop test the impact limiter reaction is caused by the total mass of the package less the mass of one impact limiter, i.e. 49,300 + 14,680 + 4,860 = 68,840 lb (Reference 8-120B SAR Section 2.2). Since the FEM represents only ½ of the package, the total mass is divided by 2 in the calculation of the rigid body acceleration.

Rigid body acceleration = $2\times5.359\times10^6/68,840 = 155.7$ » Use 160g

For the quasi-static analysis of the cask under end drop test conditions the inertia loads and reactions are distributed to the cask body as shown in Figure 6.

Impact limiter Inertia

The inertia load of the lower impact limiter is included as the uniform pressure on the surface where the impact limiter contacts the cask.

Mass of each Impact Limiter = 4,860 lb

Inside Radius of the Impact Limiter = 25.0 in

Outside Radius of the Cask = 36.6 in

Pressure on the cask due to impact limiter inertia,

$p_{I.L.}$ = 160×4,860/[π×(36.6^2 – 25.0^2)] = 346.4 psi

Payload Inertia

The payload inertia is applied as a uniform surface pressure over the lid inside surfaces. The primary lid has an inside radius of 14.625 in and an outside radius of 30.75 in. The exposed radius of the secondary lid is 16.25 in. For 14,680 lb total mass of payload, the magnitude of the pressure is:

p_{lid} = 160×14,680/[π×{(30.75^2 - 14.625^2) + 16.25^2}] = 750.85 psi

Cask Body Inertia

Cask body inertia is applied as the body force. As explained earlier, to account for the total mass of the package a factor of 1.03 is used to increase the FEM mass.

Cask Body Acceleration = 160×1.03 = 164.8 g

Impact Limiter Reaction

The impact limiter reaction is applied as a uniform pressure over the primary lid-impact limiter interface. The impact limiter opening has 25 in radius and the lid outside radius is 36.6 in.

$$p_O = \frac{2 \times 5.5 \times 10^6}{\pi \times \left(36.6^2 - 25^2\right)} = 4{,}900\, psi$$

The primary lid upper surface has cut outs for the bolts. To account for the reduction in area, the ratio of the actual surface to that of the annulus was graphically calculated. This was established to be 0.8063. The calculated uniform pressure was divided by this ratio for application to the finite element model.

$$p_{react} = \frac{4{,}900}{0.8063} = 6{,}077\, psi$$

Model Analyses

The FEM is analyzed under the above loading for hot (Load Case 1), cold with maximum decay heat (Load Case 2), and cold with no decay heat, environmental conditions. The cask body temperature for Load Cases 1 and 2 are obtained from the hot and cold environmental loading conditions of Reference 10. For Load Case 3 (no internal heat), the entire cask is assumed to be at -20°F. Figures 7 through 9 show the cask body temperature profile and the pressure distributions used in the FEM for Load Cases 1 through 3. Figure 10 shows the displacement boundary conditions used to represent the impact limiter reaction.

Figures 11 through 13 show the stress intensity plot in the cask body for the three load cases. Stress intensities are calculated in each major component of the cask and are presented in Tables 10 through 12. These tables also categorize the stresses based on the ASME code and compare them with the corresponding allowable value established in Section 5.0. Factors of safety based on the ratio of allowable stress to the calculated stress are also calculated.

7.1.2 Side Drop

The following impact limiter reactions are obtained from Reference 4.

Cold Conditions = 3.937×10^6 lb (Table 3 and Figure 39 of Reference 4)

Hot Conditions = 3.403×10^6 lb (Table 3 and Figure 43 of Reference 4)

Conservatively use the maximum of the two reactions for the analyses of all environmental conditions. The impact limiter reaction is converted to the rigid body acceleration by dividing the reaction by that portion of the mass of the package which causes this reaction. During the side drop test the impact limiter reaction is caused by the total mass of the package less the mass of the two impact limiters, i.e. 74,000 - 2×4,860 = 64,280 lb (Reference 8-120B SAR Section 2.2). Since the FEM represents only ½ of the package the total mass is divided by 2 in the calculation of the rigid body acceleration.

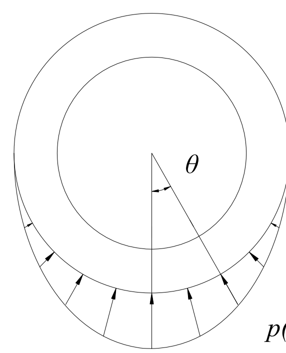
Rigid body acceleration = $2\times3.927\times10^6/64{,}280 = 122.5$g » Use 150g

For the quasi-static analysis of the cask under side drop test conditions reactions and the inertia loads are distributed to the cask body as shown in Figure 14.

Impact Limiter Reactions

The impact limiter reactions are applied as surface pressure on the lower half of the impact limiter-cask interface. This pressure is assumed to be uniform along the axis of the cask but varies sinusoidally along the circumference. For such a distribution, the following mathematical derivation is used:

$p(\theta) = p_0 \, Cos\, \theta \qquad -\pi/2 \le \theta \le \pi/2$



$$F_v = \int_{-\pi/2}^{\pi/2} p_0 \cdot Cos\theta \cdot r \cdot d\theta \cdot Cos\theta$$

$$= p_0 \cdot r \int_{-\pi/2}^{\pi/2} Cos^2\theta \cdot d\theta$$

$$= p_0 \cdot r \int_{-\pi/2}^{\pi/2} \tfrac{1}{2} \cdot \left(1 + Cos\, 2\theta\right) \cdot d\theta$$

$$= \frac{p_0 \cdot r}{2} \left[\theta + \frac{Sin\;2\theta}{2} \right]_{-\pi/2}^{\pi/2}$$

$$= \frac{\pi \cdot r \cdot p_0}{2}$$

$$F_h = \int_{-\pi/2}^{\pi/2} p_0 \cdot Cos\,\theta \cdot r \cdot d\theta \cdot Sin\,\theta$$

$$= p_0 \cdot r \int_{-\pi/2}^{\pi/2} \tfrac{1}{2} \cdot Sin\ 2\theta \cdot d\theta$$

$$= \frac{p_0 \cdot r}{2}\left[\frac{-Cos\ 2\theta}{2}\right]_{-\pi/2}^{\pi/2}$$

$$= 0$$

Reaction of the cask at the two impact limiter locations, 2R = (49,300 + 14,680) × 150

Reaction at each impact limiter location, R = ½ × (49,300 + 14,680) × 150 = 4.799×10^6 lb

The top impact limiter reaction is applied at the surface that has a radius of 36.6 in and extends in the axial direction over a length of 18 in. Thus,

$p_0 = (2 \times 4.799 \times 10^6)/(\pi \times 36.6 \times 18) = 4{,}637$ psi

The bottom impact limiter reaction is applied at the surface that has a radius of 36.6 in and extends in the axial direction over a length of 18 in. Thus,

$p_0 = (2 \times 4.799 \times 10^6)/(\pi \times 36.6 \times 18) = 4{,}637$ psi

Payload Inertia

The pay load inertia load is applied as surface pressure on the lower half of the inner shell of the cask. This pressure is assumed to be uniform along the axis of the cask but varies sinusoidally along the circumference. The radius of the inner shell is 31 in and its length is 73.9025 in. Thus,

$p_0 = (2 \times 150 \times 14{,}680)/(\pi \times 31 \times 73.9025) = 611.9$ psi

Cask Body Inertia

Cask body inertia is applied as the body force. As explained earlier, to account for the total mass of the package a factor of 1.03 is used to increase the FEM mass.

Cask Body Acceleration = 150×1.03 = 154.5 g

Model Analyses

The FEM is analyzed under the above loading for hot (Load Case 1), cold with maximum decay heat (Load Case 2), and cold with no decay heat, environmental conditions. The cask body temperature for Load Cases 1 and 2 are obtained from the hot and cold environmental loading conditions of Reference 10. For Load Case 3 (no internal heat), the entire cask is assumed to be at -20°F. Figures 15 through 17 show the cask body temperature profile and the pressure distributions used in the FEM for Load Cases 1 through 3. Figure 18 shows the displacement boundary conditions used to prevent the rigid body motion of the cask.

Figures 19 through 21 show the stress intensity plot in the cask body for the three load cases. Stress intensities are calculated in each major component of the cask and are presented in Tables 13 through 15. These tables also categorize the stresses based on the ASME code and

compare them with the corresponding allowable value established in Section 5.0. Factors of safety based on the ratio of allowable stress to the calculated stress are also calculated.

7.1.3 Corner Drop

The following impact limiter reactions are obtained from Reference 4.

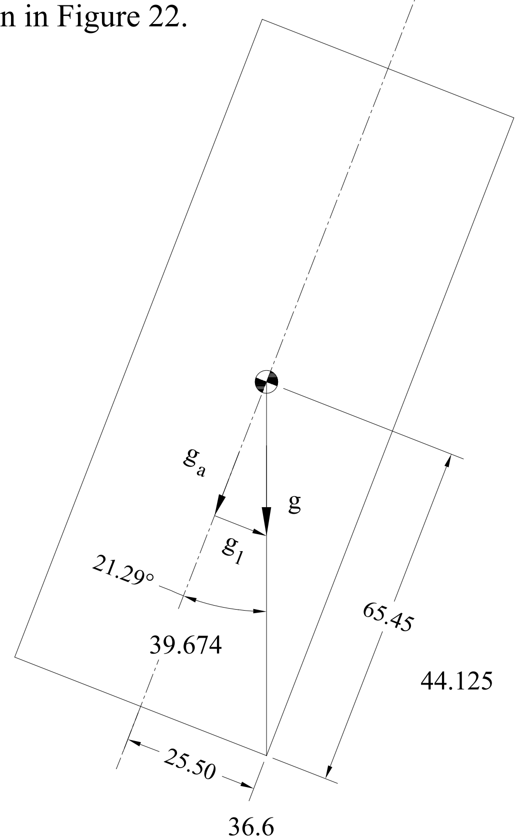
Cold Conditions = 2.103×10^6 lb (Table 3 and Figure 47 of Reference 4)

Hot Conditions = 2.000×10^6 lb (Table 3 and Figure 51 of Reference 4)

Conservatively use the maximum of the two reactions for the analyses of all environmental conditions. The impact limiter reaction is converted to the rigid body acceleration by dividing the reaction by that portion of the mass of the package which causes this reaction. During the corner drop test the impact limiter reaction is caused by the total mass of the package less the mass of one impact limiter, i.e. 49,300 + 14,680 + 4,860 = 68,840 lb (Reference 8-120B SAR Section 2.2). Since the FEM represents only ½ of the package, the total mass is divided by 2 in the calculation of the rigid body acceleration.

Rigid body acceleration = $2\times2.103\times10^6/68{,}840 = 61.1$ » Use 75g

For the quasi-static analysis of the cask under corner drop test conditions reactions and the inertia loads are distributed to the cask body as shown in Figure 22.



Assume that the cask C.G. is located at the geometrical C.G. of the package. The cask has a radius of 36.6 in and a half length of 44.125 in. Therefore, for the C.G. to be directly above the corner, the cask axis will be inclined from the vertical axis by an angle,

$$\alpha = \tan^{-1}(36.6/44.125) = 39.674°$$

Thus, the axial acceleration,

$$g_a = 75\times\text{Cos } 39.674° = 57.73 \text{ g}$$

Lateral acceleration,

$$g_l = 75\times\text{Sin } 39.674° = 47.88 \text{ g}$$

Impact Limiter Reaction

The impact limiter reaction is resolved into an axial and a lateral component. The axial component is applied to the lid surface at the interface with the impact limiter. The pressure is assumed to vary sinusoidally along the tangential direction. Mathematically this pressure may be represented by:

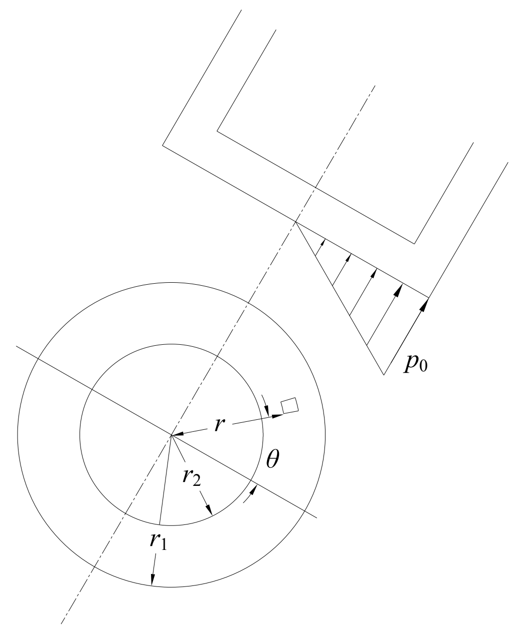
$$p(r,\theta) = p_0 \cdot \frac{r \cdot Cos\,\theta}{r_2} \cdot r \cdot d\theta \cdot dr \qquad -\pi/2 \le \theta \le \pi/2$$

This distribution results in the total axial load, F that can be calculated by integration as

$$F = \int_{-\pi/2}^{\pi/2}\int_{r_1}^{r_2} \frac{p_0}{r_2} \cdot r \cdot Cos\theta \cdot r \cdot dr \cdot d\theta$$

follows: $$= \frac{p_0}{r_2} \cdot \int_{-\pi/2}^{\pi/2} Cos\theta \cdot d\theta \cdot \int_{r_1}^{r_2} r^2 \cdot dr$$

$$= \frac{2}{3} \cdot \frac{p_0}{r_2} \cdot \left(r_2^{\,3} - r_1^{\,3}\right)$$



The axial component of the impact limiter reaction,

R_a = (68,840) × 57.73 = 3.974×10^6 lb

The reaction is distributed over the lid surface annulus having an inside radius of 25 in and outside radius of 36.6 in. To get the total load R_a on the lid surface, p_0 must be,

$$p_0 = 3.974 \times 10^6 \cdot \frac{3}{2} \cdot \left(\frac{36.6}{36.6^3 - 25^3}\right) = 6{,}531.5 \text{ psi}$$

Since the lid has the bolt-hole cut-outs in this region, thereby reducing the area over which this load is applied, adjustment in the above pressure value must be made. This adjustment was manually made using the FEM. To obtain the total load of 3.974×10^6 lb, the value for p_0 was increased to 8,312.6 psi.

The lateral component of the impact limiter reaction was applied in the manner as described under side drop loading with the exception that the magnitude of the pressure is also varied linearly from the maximum value to zero at the top of the impact limiter edge.

The lateral component of the impact limiter reaction is:

R_l = 68,840 × 47.88 = 3.296×10^6 lb

This reaction is applied at the surface that has a radius of 36.6 in and extends in the axial direction over a length of 18 in. Following the derivation under side drop,

p_0 = (2×3.296×10^6)/(π×36.6×18) = 3,185 psi

To account for the axial variation of the pressure, FEM of the cask was used to obtain the magnitude of the pressure that resulted in the lateral reaction of 3.296×10^6 lb. This value was found to be 3,887 psi.

Impact Limiter Inertia

The upper impact limiter inertia is resolved into an axial component and a lateral component. The axial component is applied in the same manner as described under end drop and the lateral component is applied in the same manner as described for the side drop impact limiter reaction.

Magnitude of the uniform pressure representing the impact limiter axial inertia is:

$p_{I.L.} = 57.73 \times 4{,}860/[\pi \times (36.6^2 - 25.0^2)] = 124.98$ psi

Amplitude of the sinusoidally varying pressure, representing the impact limiter lateral inertia,

$p_0 = (2 \times 47.88 \times 4{,}860)/(\pi \times 36.6 \times 18) = 225$ psi

Payload Inertia

The payload inertia is resolved into an axial component and a lateral component. The axial component is applied to the lid in the same manner as described under the end drop. The lateral component is applied to the lower half of the inner shell as described under side drop.

Magnitude of the uniform pressure representing the payload axial inertia is:

$p_{lid} = 57.73 \times 14{,}680/[\pi(30.75^2 - 14.625^2 + 16.25^2)] = 270.9$ psi

Amplitude of the sinusoidally varying pressure, representing the payload lateral inertia,

$p_0 = (2 \times 47.88 \times 14{,}680)/(\pi \times 31 \times 73.9025) = 195.3$ psi

Cask Body Inertia

Cask body inertia is applied as the body force. As explained earlier, to account for the total mass of the package a factor of 1.03 is used to increase the FEM mass.

Cask Body Axial Acceleration = 57.73×1.03 = 59.46 g

Cask Body Lateral Acceleration = 47.88×1.03 = 49.32 g

Model Analyses

The FEM is analyzed under the above loading for hot (Load Case 1), cold with maximum decay heat (Load Case 2), and cold with no decay heat, environmental conditions. The cask body temperature for Load Cases 1 and 2 are obtained from the hot and cold environmental loading conditions of Reference 10. For Load Case 3 (no internal heat), the entire cask is assumed to be at -20°F. Figures 23 through 25 show the cask body temperature profile and the pressure distributions used in the FEM for Load Cases 1 through 3. Figure 26 shows the displacement boundary conditions used to prevent the rigid body motion of the cask.

Figures 27 through 29 show the stress intensity plot in the cask body for the three load cases. Stress intensities are calculated in each major component of the cask and are presented in Tables 16 through 18. These tables also categorize the stresses based on the ASME code and compare them with the corresponding allowable value established in Section 5.0. Factors of safety based on the ratio of allowable stress to the calculated stress are also calculated.

7.2 NCT Drop Tests

The distribution of the NCT drop test loading on various components of the cask, under all the drop orientations, have been obtained by linearly proportioning the corresponding loading from the HAC drop tests.

7.2.1 End Drop

The following impact limiter reactions are obtained from Reference 4.

Cold Conditions = 1.556×10^6 lb (Table 2 and Figure 13 of Reference 4)

Hot Conditions = 1.286×10^6 lb (Table 2 and Figure 16 of Reference 4)

Conservatively use the maximum of the two reactions for the analyses of all environmental conditions. The NCT end drop rigid body acceleration is:

$$= 2\times1.556\times10^6/68{,}840 = 45.2 \text{ g}$$

The acceleration used in the HAC end drop analyses is 160 g. The mechanical loading applied in the HAC end drop analyses may be proportioned with 45.2 g. The ratio of the two loadings is:

$$R_{\text{end}} = 45.2/160 = 0.2825 \quad » \text{ For conservatism use 0.3}$$

Impact limiter Inertia

$p_{\text{I.L.}} = 0.3\times346.4 = 103.92$ psi

Payload Inertia

$p_{\text{lid}} = 0.3\times750.85 = 225.3$ psi

Cask Body Inertia

Cask Body Acceleration = $0.3\times164.8 = 49.44$ g

Model Analyses

The FEM is analyzed under the above loading for hot (Load Case 1), cold with maximum decay heat (Load Case 2), and cold with no decay heat, environmental conditions. The cask body temperature for Load Cases 1 and 2 are obtained from the hot and cold environmental loading conditions of Reference 10. For Load Case 3 (no internal heat), the entire cask is assumed to be at -20°F. Figures 30 through 32 show the cask body temperature profile and the pressure distributions used in the FEM for Load Cases 1 through 3.

Figures 33 through 35 show the stress intensity plot in the cask body for the three load cases. Stress intensities are calculated in each major component of the cask and are presented in Tables 1 through 3. These tables also categorize the stresses based on the ASME code and compare them with the corresponding allowable value established in Section 5.0. Factors of safety based on the ratio of allowable stress to the calculated stress are also calculated.

7.2.2 Side Drop

The following impact limiter reactions are obtained from Reference 4.

Cold Conditions = 859,600 lb (Table 2 and Figure 19 of Reference 4)

Hot Conditions = 710,400 lb (Table 2 and Figure 22 of Reference 4)

Conservatively use the maximum of the two reactions for the analyses of all environmental conditions. The NCT side drop rigid body acceleration is:

$$= 2\times859{,}600/64{,}280 = 26.75 \text{ g}$$

The acceleration used in the HAC side drop analyses is 150 g. The mechanical loading applied in the HAC side drop analyses may be proportioned with 26.75 g. The ratio of the two loadings is:

$$R_{\text{side}} = 26.75/150 = 0.1783 \quad » \text{ For conservatism use } 0.2$$

Impact Limiter Reactions

Top impact limiter pressure amplitude,

$$p_0 = 0.2 \times 4{,}637 = 927.4 \text{ psi}$$

Bottom impact limiter pressure amplitude,

$$p_0 = 0.2 \times 4{,}637 = 927.4 \text{ psi}$$

Payload Inertia

Payload inertia pressure amplitude,

$$p_0 = 0.2 \times 611.9 = 122.38 \text{ psi}$$

Cask Body Inertia

Cask Body Acceleration = 0.2×154.5 = 30.9 g

Model Analyses

The FEM is analyzed under the above loading for hot (Load Case 1), cold with maximum decay heat (Load Case 2), and cold with no decay heat, environmental conditions. The cask body temperature for Load Cases 1 and 2 are obtained from the hot and cold environmental loading conditions of Reference 10. For Load Case 3 (no internal heat), the entire cask is assumed to be at -20°F. Figures 36 through 38 show the cask body temperature profile and the pressure distributions used in the FEM for Load Cases 1 through 3.

Figures 39 through 41 show the stress intensity plot in the cask body for the three load cases. Stress intensities are calculated in each major component of the cask and are presented in Tables 4 through 6. These tables also categorize the stresses based on the ASME code and compare them with the corresponding allowable value established in Section 5.0. Factors of safety based on the ratio of allowable stress to the calculated stress are also calculated.

7.2.3 Corner Drop

The following impact limiter reactions are obtained from Reference 4.

Cold Conditions = 318,800 lb (Table 2 and Figure 25 of Reference 4)

Hot Conditions = 278,500 lb (Table 2 and Figure 28 of Reference 4)

Conservatively use the maximum of the two reactions for the analyses of all environmental conditions. The NCT corner drop rigid body acceleration is:

$$= 2 \times 318{,}800/68{,}840 = 9.26 \text{ g}$$

The acceleration used in the HAC corner drop analyses is 75 g. The mechanical loading applied in the HAC corner drop analyses may be proportioned with 9.26 g. The ratio of the two loadings is:

R_{corner} = 9.26/75 = 0.1235 » For conservatism use 0.15

Impact Limiter Reactions

Lid pressure magnitude,

p_{lid} = 0.15×8,312.6 = 1,246.9 psi

Wall pressure amplitude,

p_0 = 0.15×3,185 = 477.75 psi

Impact Limiter Inertia

Base plate pressure magnitude,

$p_{I.L.}$ = 0.15×124.98 = 18.75 psi

Wall pressure amplitude,

p_0 = 0.15×225 = 33.75 psi

Payload Inertia

Lid pressure magnitude

p_{lid} = 0.15×270.9 = 40.64 psi

Wall pressure amplitude,

p_0 = 0.15×195.3 = 29.3 psi

Cask Body Inertia

Cask Body Axial Acceleration = 0.15×59.46 = 8.92 g

Cask Body Lateral Acceleration = 0.15×49.32 = 7.40 g

Model Analyses

The FEM is analyzed under the above loading for hot (Load Case 1), cold with maximum decay heat (Load Case 2), and cold with no decay heat, environmental conditions. The cask body temperature for Load Cases 1 and 2 are obtained from the hot and cold environmental loading conditions of Reference 10. For Load Case 3 (no internal heat), the entire cask is assumed to be at -20°F. Figures 42 through 44 show the cask body temperature profile and the pressure distributions used in the FEM for Load Cases 1 through 3.

Figures 45 through 47 show the stress intensity plot in the cask body for the three load cases. Stress intensities are calculated in each major component of the cask and are presented in Tables 7 through 9. These tables also categorize the stresses based on the ASME code and compare them with the corresponding allowable value established in Section 5.0. Factors of safety based on the ratio of allowable stress to the calculated stress are also calculated.

7.3 Primary Lid Bolt Evaluation

The loads for the primary lid bolts of the 8-120B Cask were obtained from FEM results. The individual loads for the bolts are given in Tables 19 through 30. Loads are calculated at two locations where the highest stresses occur; the root of the bolt shank and the lid interfaces.

Locations of bolts on the primary lid are identified by angle according to Reference 1. Maximum stresses in the bolts by location during the corner and side drops are shown in Figures 48 and 49.

Below is a sample calculation for the bolt stresses from the tabulated FEM data. A sample of bolt load data from the FEM as given in Tables 19 through 30 is below:

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in-lbs	in-lbs	in-lbs
bolt4	-114,222	-4,322	-70,317	-3,492	-92,463	-2,618

$$F_{Axial} = FZ = 70{,}317 \text{ lbs}$$

$$V_{Shear} = \sqrt{(FX)^2 + (FY)^2} = \sqrt{114{,}222^2 + 4{,}322^2} = 114{,}304 \text{ lbs}$$

$$M = \sqrt{(MX)^2 + (MY)^2} = \sqrt{3{,}492^2 + 92{,}463^2} = 92{,}529 \text{ in-lbs}$$

T = MZ=-2,618 in-lbs (Neglected)

The bolts are 2" - 8 UN:

Bolt diameter = d_{bolt} = 2.0 in

Bolt area = $A_{stress\ area}$ = 2.7665 in^2

$$\sigma_{axial} = \frac{F_{axial}}{A_{stress\ area}} = \frac{F_{axial}}{2.7665} = \frac{70{,}317}{2.7665} = 25{,}417 \text{ psi}$$

Allowable bolt axial (average) stress = Allowable membrane stress = 105,000 psi (per Section 5)

$\sigma_{axial} = \sigma_{average}$ = 25,417 psi < 105,000 psi O.K.

$$\sigma_{bending} = \frac{M}{S} = \frac{M}{\frac{\pi \times d^3_{bolt}}{32}} = \frac{32 \times 92{,}529}{\pi \times 2^3} = 117{,}812 \text{ psi}$$

$$\tau = \frac{V_{shear}}{A_{stress\ area}} = \frac{114{,}304}{2.7665} = 41{,}317 \text{ psi}$$

Allowable bolt shear stress = Smaller of ($0.42S_u$ and $0.6S_y$) = 63,000 psi

τ = 41,317 psi < 63,000 psi O.K.

$$\sigma_{axial+bending} = \sigma_{axial} + \sigma_{bending} = 25{,}417 + 117{,}812 = 143{,}229 \text{ psi}$$

Allowable membrane + bending stress = 150,000 psi (per Section 5)

$\sigma_{axial+bending} = 143{,}229$ psi < 150,000 psi O.K.

Bolt axial-shear interaction (I.C.) is:

$$\text{I.C.} = \left(\frac{\sigma_{axial}}{105{,}000}\right)^2 + \left(\frac{\tau}{63{,}000}\right)^2 = \left(\frac{25{,}417}{105{,}000}\right)^2 + \left(\frac{41{,}317}{63{,}000}\right)^2 = 0.4887 < 1.0$$ O.K.

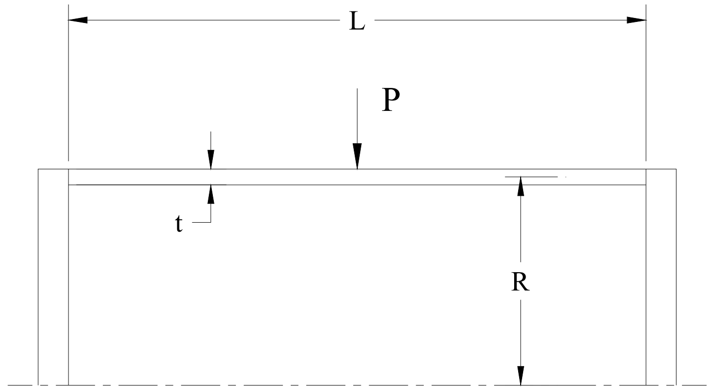
7.4 Lead Slump Evaluation

The 8-120B package experiences the largest acceleration during the 30-ft end drop test. During this test the lead column which is not bonded to the steel shells undergoes a relative deformation with respect to the two shells it is sandwiched between. This may result in the slump of the lead column. The finite element model used to perform the 30-ft end drop structural analyses under various environment conditions appropriately represents the relative movement of the lead column with respect to the shells. The nodal displacements of these components can be used to conservatively estimate the amount of lead slump during these tests. The displacements of the lead and steel nodes for the three environmental conditions are listed in Appendix 2. The largest relative displacement of 0.141" occurs during the cold environment with no heat load. It should be noted that this is the total relative displacement. In considering this to be the lead slump, the elastic recovery of the lead and steel has been neglected. Figure 55 shows the displacement plot during this drop test.

7.5 Puncture Drop Lead Shielding Evaluation

After the puncture drop test the 8-120B cask may experience denting of the sidewall. The lead shielding behind the dent may experience a slight flattening which may result in a shielding loss in this region. In order to calculate the maximum loss of shielding after the puncture drop test, analytical formulae for the local stiffness of the cask wall has been used for calculating the absorbed energy in the package. With the assumption that the entire potential energy of 40" drop during the puncture drop test is converted to the strain energy, the maximum wall deformation is calculated. From the total deformation of the wall the lead deformation is calculated based on its relative stiffness.

The largest deformation of the sidewall will occur when the puncture bar is located at the mid-length of the cask. The cask may be considered as a closed cylinder subjected to a concentrated load at its midspan. The deformation under the load may be obtained from Roark (Reference 12), Table 31, Case 9. The formula is applicable for the case of a "radial load *P* uniformly distributed over small area *A*, approximately square or round near midspan". The terminology used in the formula is based on the geometry as shown below.



The deflection under the load, y, is given by the formula,

$$y = \frac{P}{Et}\left[0.48\times\left(\frac{L}{R}\right)^{0.5}\times\left(\frac{R}{t}\right)^{1.22}\right]$$

Where,

L = length of the cylinder

R = mean radius of the wall

t = thickness of the wall

P = applied load

E = Young's modulus of the material

The stiffness at the point is, therefore,

$$k = \frac{P}{y} = \frac{Et}{\left[0.48\times\left(\frac{L}{R}\right)^{0.5}\times\left(\frac{R}{t}\right)^{1.22}\right]}$$

The 8-120B cask wall can be considered as a composite cylinder comprising of the outer shell, the lead, and, the inner shell. The stiffness of each component is calculated as follows:

<u>Outer Shell</u>

L = 78.25", R = 35.85", t = 1.5"

$$k_1 = \frac{29.4\times10^6\times1.5}{\left[0.48\times\left(\frac{78.25}{35.85}\right)^{0.5}\times\left(\frac{35.85}{1.5}\right)^{1.22}\right]} = 1.294\times10^6\ \text{lb/in}$$

<u>Lead</u>

L = 78.25", R = 33.425", t = 3.35"

$$k_2 = \frac{2.27\times10^6\times3.35}{\left[0.48\times\left(\frac{78.25}{33.425}\right)^{0.5}\times\left(\frac{33.425}{3.35}\right)^{1.22}\right]} = 0.626\times10^6 \text{ lb/in}$$

Inner Shell

L = 78.25", R = 31.375", t = 0.75"

$$k_3 = \frac{29.4\times10^6\times0.75}{\left[0.48\times\left(\frac{78.25}{31.375}\right)^{0.5}\times\left(\frac{31.375}{0.75}\right)^{1.22}\right]} = 0.306\times10^6 \text{ lb/in}$$

The effective stiffness of the composite section can be calculated by adding the above stiffness values together. Thus,

$k_{eff} = k_1 + k_2 + k_3 = 2.226\times10^6$ lb/in

The total energy absorbed by a linear spring undergoing a deflection δ, is:

$U = ½\, k_{eff} \times\delta^2$

The maximum package mass is 74,000 lb and it drops from the height of 40". Therefore, the maximum potential energy in the system is:

P.E. = 74,000×40 in-lb

Equating the absorbed energy with the potential energy, we get,

$½\times2.226\times10^6\times\delta^2 = 74,000\times40$

Solving which we get,

δ = 1.63 in

The deformation of the lead can be calculated from its relative stiffness. Thus,

$$\delta_{lead} = \delta \times \frac{k_2}{k_{eff}}$$

= 1.63×0.626/2.226 = 0.458 in (say, 0.5 in)

This deformation comprises of an elastic, and an inelastic part. The elastic deformation will be recovered after the load is removed and the inelastic deformation will remain as the permanent deformation. For conservatism the entire deformation is considered to be permanent.

8.0 CONCLUSIONS

The results of the analyses performed in this document show that the 8-120B Cask meets the design requirements during all the drop test scenarios specified in 10 CFR 71 code. Therefore, it is concluded that the cask can withstand the drop test requirements during the normal conditions of transport and the hypothetical accident conditions. It is noted that slight deformation of the cask at certain locations is expected during the hypothetical drop tests.

9.0 ANSYS PRINTOUT AND DATA FILES

The printout of the important data from the program is included with this document in electronic form as Appendix 3.

10.0 APPENDICES

Appendix 1 Partial Print-out of the ANSYS Finite Element Model Data

Appendix 2 Summary Print-Out of the ANSYS Results and Stress Reconciliations

Appendix 3 Electronic data on DVD

Tables

(31 Pages)

Table 1

Stress Intensities in 8-120B Cask under 1-ft End Drop - Hot Condition

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [(1)] (psi)	F.S. [(2)]
Primary Lid	P_m	20,000	15,086	1.33
	$P_m + P_b$	30,000	15,086	1.99
Secondary Lid	P_m	20,000	12,890	1.55
	$P_m + P_b$	30,000	12,890	2.33
Bolting Ring	P_m	20,000	12,994	1.54
	$P_m + P_b$	30,000	12,994	2.31
Inner Shell	P_m	20,000	16,983	1.18
	$P_m + P_b$	30,000	16,983	1.77
Outer Shell	P_m	20,000	6,837	2.93
	$P_m + P_b$	30,000	6,837	4.39
Baseplate	P_m	20,000	8,980	2.23
	$P_m + P_b$	30,000	8,980	3.34
Primary Lid Bolts	P_m	60,000	6,209	9.66
	$P_m + P_b$	90,000	6,209	14.50
Secondary Lid Bolts	P_m	60,000	15,983	3.75
	$P_m + P_b$	90,000	15,983	5.63

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

Table 2
Stress Intensities in 8-120B Cask under 1-ft End Drop - Cold Condition (Max. Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [1] (psi)	F.S. [2]
Primary Lid	P_m	20,000	14,272	1.40
	$P_m + P_b$	30,000	14,272	2.10
Secondary Lid	P_m	20,000	11,767	1.70
	$P_m + P_b$	30,000	11,767	2.55
Bolting Ring	P_m	20,000	8,791	2.28
	$P_m + P_b$	30,000	8,791	3.41
Inner Shell	P_m	20,000	15,787[3]	1.27
	$P_m + P_b$	30,000	15,787[3]	1.90
Outer Shell	P_m	20,000	6,301	3.17
	$P_m + P_b$	30,000	6,301	4.76
Baseplate	P_m	20,000	14,723	1.36
	$P_m + P_b$	30,000	14,723	2.04
Primary Lid Bolts	P_m	60,000	3,654	16.42
	$P_m + P_b$	90,000	3,654	24.63
Secondary Lid Bolts	P_m	60,000	13,075	4.59
	$P_m + P_b$	90,000	13,075	6.88

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) The stress intensity values reported here have been obtained by averaging the values in the vicinity of the highest local stress. The high local stresses resulted from the modeling constraint in this area. See Figure 50 and Appendix 2.

Table 3

Stress Intensities in 8-120B Cask under 1-ft End Drop - Cold Condition (No Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	20,000	14,529	1.38
	$P_m + P_b$	30,000	14,529	2.06
Secondary Lid	P_m	20,000	11,732	1.70
	$P_m + P_b$	30,000	11,732	2.56
Bolting Ring	P_m	20,000	9,959	2.01
	$P_m + P_b$	30,000	9,959	3.01
Inner Shell	P_m	20,000	15,534(3)	1.29
	$P_m + P_b$	30,000	15,534(3)	1.93
Outer Shell	P_m	20,000	6,655	3.01
	$P_m + P_b$	30,000	6,655	4.51
Baseplate	P_m	20,000	15,550	1.29
	$P_m + P_b$	30,000	15,550	1.93
Primary Lid Bolts	P_m	60,000	4,115	14.58
	$P_m + P_b$	90,000	4,115	21.87
Secondary Lid Bolts	P_m	60,000	12,985	4.62
	$P_m + P_b$	90,000	12,985	6.93

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) The stress intensity values reported here have been obtained by averaging the values in the vicinity of the highest local stress. The high local stresses resulted from the modeling constraint in this area. See Figure 51 and Appendix 2.

Table 4

Stress Intensities in 8-120B Cask under 1-ft Side Drop - Hot Condition

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	20,000	12,159(3)	1.64
	$P_m + P_b$	30,000	12,159(3)	2.47
Secondary Lid	P_m	20,000	6,058	3.30
	$P_m + P_b$	30,000	6,058	4.95
Bolting Ring	P_m	20,000	13,360	1.50
	$P_m + P_b$	30,000	13,360	2.25
Inner Shell	P_m	20,000	14,098	1.42
	$P_m + P_b$	30,000	14,098	2.13
Outer Shell	P_m	20,000	10,564	1.89
	$P_m + P_b$	30,000	10,564	2.84
Baseplate	P_m	20,000	10,536	1.90
	$P_m + P_b$	30,000	10,536	2.85
Primary Lid Bolts	P_m	60,000	34,995	1.71
	$P_m + P_b$	90,000	34,995	2.57
Secondary Lid Bolts	P_m	60,000	10,982	5.46
	$P_m + P_b$	90,000	10,982	8.20

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

Table 5

Stress Intensities in 8-120B Cask under 1-ft Side Drop - Cold Condition (Max. Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [1] (psi)	F.S. [2]
Primary Lid	P_m	20,000	12,428[3]	1.61
	$P_m + P_b$	30,000	12,428[3]	2.41
Secondary Lid	P_m	20,000	6,568	3.05
	$P_m + P_b$	30,000	6,568	4.57
Bolting Ring	P_m	20,000	15,164	1.32
	$P_m + P_b$	30,000	15,164	1.98
Inner Shell	P_m	20,000	15,376	1.30
	$P_m + P_b$	30,000	15,376	1.95
Outer Shell	P_m	20,000	15,085	1.33
	$P_m + P_b$	30,000	15,085	1.99
Baseplate	P_m	20,000	12,684	1.58
	$P_m + P_b$	30,000	12,684	2.37
Primary Lid Bolts	P_m	60,000	44,518	1.35
	$P_m + P_b$	90,000	44,518	2.02
Secondary Lid Bolts	P_m	60,000	10,373	5.78
	$P_m + P_b$	90,000	10,373	8.68

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

Table 6

Stress Intensities in 8-120B Cask under 1-ft Side Drop - Cold Condition (No Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	20,000	12,720(3)	1.57
	$P_m + P_b$	30,000	12,720(3)	2.36
Secondary Lid	P_m	20,000	6,849	2.92
	$P_m + P_b$	30,000	6,849	4.38
Bolting Ring	P_m	20,000	15,824	1.26
	$P_m + P_b$	30,000	15,824	1.90
Inner Shell	P_m	20,000	16,531	1.21
	$P_m + P_b$	30,000	16,531	1.81
Outer Shell	P_m	20,000	15,289	1.31
	$P_m + P_b$	30,000	15,289	1.96
Baseplate	P_m	20,000	13,015	1.54
	$P_m + P_b$	30,000	13,015	2.31
Primary Lid Bolts	P_m	60,000	43,855	1.37
	$P_m + P_b$	90,000	43,855	2.05
Secondary Lid Bolts	P_m	60,000	10,604	5.66
	$P_m + P_b$	90,000	10,604	8.49

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

Table 7

Stress Intensities in 8-120B Cask under 1-ft Corner Drop - Hot Condition

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [(1)] (psi)	F.S. [(2)]
Primary Lid	P_m	20,000	9,642	2.07
	$P_m + P_b$	30,000	9,642	3.11
Secondary Lid	P_m	20,000	6,664	3.00
	$P_m + P_b$	30,000	6,664	4.50
Bolting Ring	P_m	20,000	9,559	2.09
	$P_m + P_b$	30,000	9,559	3.14
Inner Shell	P_m	20,000	12,201	1.64
	$P_m + P_b$	30,000	12,201	2.46
Outer Shell	P_m	20,000	6,847	2.92
	$P_m + P_b$	30,000	6,847	4.38
Baseplate	P_m	20,000	5,307	3.77
	$P_m + P_b$	30,000	5,307	5.65
Primary Lid Bolts	P_m	60,000	24,600	2.44
	$P_m + P_b$	90,000	24,600	3.66
Secondary Lid Bolts	P_m	60,000	13,534	4.43
	$P_m + P_b$	90,000	13,534	6.65

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

Table 8

Stress Intensities in 8-120B Cask under 1-ft Corner Drop - Cold Condition (Max. Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [1] (psi)	F.S. [2]
Primary Lid	P_m	20,000	9,065	2.21
	$P_m + P_b$	30,000	9,065	3.31
Secondary Lid	P_m	20,000	4,372	4.57
	$P_m + P_b$	30,000	4,372	6.86
Bolting Ring	P_m	20,000	8,381	2.39
	$P_m + P_b$	30,000	8,381	3.58
Inner Shell	P_m	20,000	8,930	2.24
	$P_m + P_b$	30,000	8,930	3.36
Outer Shell	P_m	20,000	6,741	2.97
	$P_m + P_b$	30,000	6,741	4.45
Baseplate	P_m	20,000	3,136	6.38
	$P_m + P_b$	30,000	3,136	9.57
Primary Lid Bolts	P_m	60,000	17,360	3.46
	$P_m + P_b$	90,000	17,360	5.18
Secondary Lid Bolts	P_m	60,000	8,322	7.21
	$P_m + P_b$	90,000	8,322	10.81

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

Table 9
Stress Intensities in 8-120B Cask under 1-ft Corner Drop - Cold Condition (No Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	20,000	9,634	2.08
	$P_m + P_b$	30,000	9,634	3.11
Secondary Lid	P_m	20,000	3,941	5.07
	$P_m + P_b$	30,000	3,941	7.61
Bolting Ring	P_m	20,000	8,668	2.31
	$P_m + P_b$	30,000	8,668	3.46
Inner Shell	P_m	20,000	8,260	2.42
	$P_m + P_b$	30,000	8,260	3.63
Outer Shell	P_m	20,000	8,437	2.37
	$P_m + P_b$	30,000	8,437	3.56
Baseplate	P_m	20,000	4,637	4.31
	$P_m + P_b$	30,000	4,637	6.47
Primary Lid Bolts	P_m	60,000	17,271	3.47
	$P_m + P_b$	90,000	17,271	5.21
Secondary Lid Bolts	P_m	60,000	7,696	7.80
	$P_m + P_b$	90,000	7,696	11.69

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

Table 10

Stress Intensities in 8-120B Cask under 30-ft End Drop - Hot Condition

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	48,000	22,900(3)	2.10
	$P_m + P_b$	70,000	50,220(3)	1.40
Secondary Lid	P_m	48,000	39,223	1.22
	$P_m + P_b$	70,000	39,223	1.78
Bolting Ring	P_m	48,000	36,835	1.30
	$P_m + P_b$	70,000	36,835	1.90
Inner Shell	P_m	48,000	45,432	1.06
	$P_m + P_b$	70,000	45,432	1.54
Outer Shell	P_m	48,000	23,422	2.05
	$P_m + P_b$	70,000	23,422	2.99
Baseplate	P_m	48,000	42,473	1.13
	$P_m + P_b$	70,000	42,473	1.65
Primary Lid Bolts	P_m	105,000	14,241	7.37
	$P_m + P_b$	150,000	14,241	10.53
Secondary Lid Bolts	P_m	105,000	45,267	2.32
	$P_m + P_b$	150,000	45,267	3.31

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) Obtained from the stress linearization over the cross-section. See Appendix 2.

Table 11

Stress Intensities in 8-120B Cask under 30-ft End Drop - Cold Condition (Max. Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	48,000	23,040(3)	2.08
	$P_m + P_b$	70,000	49,880(3)	1.40
Secondary Lid	P_m	48,000	38,045	1.26
	$P_m + P_b$	70,000	38,045	1.84
Bolting Ring	P_m	48,000	27,095	1.77
	$P_m + P_b$	70,000	27,095	2.58
Inner Shell	P_m	48,000	35,030	1.37
	$P_m + P_b$	70,000	35,030	2.00
Outer Shell	P_m	48,000	24,104	1.99
	$P_m + P_b$	70,000	24,104	2.90
Baseplate	P_m	48,000	45,248	1.06
	$P_m + P_b$	70,000	45,248	1.55
Primary Lid Bolts	P_m	105,000	8,528	12.31
	$P_m + P_b$	150,000	8,528	17.59
Secondary Lid Bolts	P_m	105,000	42,463	2.47
	$P_m + P_b$	150,000	42,463	3.53

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) Obtained from the stress linearization over the cross-section. See Appendix 2.

Table 12

Stress Intensities in 8-120B Cask under 30-ft End Drop - Cold Condition (No Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (1) (psi)	F.S. (2)
Primary Lid	P_m	48,000	23,190(3)	2.07
	$P_m + P_b$	70,000	50,170(3)	1.40
Secondary Lid	P_m	48,000	38,000	1.26
	$P_m + P_b$	70,000	38,000	1.84
Bolting Ring	P_m	48,000	27,167	1.77
	$P_m + P_b$	70,000	27,167	2.58
Inner Shell	P_m	48,000	38,466	1.25
	$P_m + P_b$	70,000	38,466	1.82
Outer Shell	P_m	48,000	26,337	1.82
	$P_m + P_b$	70,000	26,337	2.66
Baseplate	P_m	48,000	47,147	1.02
	$P_m + P_b$	70,000	47,147	1.48
Primary Lid Bolts	P_m	105,000	8,360	12.56
	$P_m + P_b$	150,000	8,360	17.94
Secondary Lid Bolts	P_m	105,000	42,415	2.48
	$P_m + P_b$	150,000	42,415	3.54

Notes:

(1) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

(2) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(3) Obtained from the stress linearization over the cross-section. See Appendix 2.

Table 13

Stress Intensities in 8-120B Cask under 30-ft Side Drop - Hot Condition

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (6) (psi)	F.S. (5)
Primary Lid	P_m	48,000	34,749(1)	1.38
	$P_m + P_b$	70,000	60,341(1)	1.16
Secondary Lid	P_m	48,000	32,887	1.46
	$P_m + P_b$	70,000	32,887	2.13
Bolting Ring	P_m	48,000	40,748(2)	1.19
	$P_m + P_b$	70,000	40,748(2)	1.73
Inner Shell	P_m	48,000	36,700(3)	1.31
	$P_m + P_b$	70,000	61,810(3)	1.13
Outer Shell	P_m	48,000	38,000(3)	1.26
	$P_m + P_b$	70,000	55,470(3)	1.26
Baseplate	P_m	48,000	43,554	1.10
	$P_m + P_b$	70,000	43,554	1.61
Primary Lid Bolts	P_m	105,000	24,034(4)	4.37
	$P_m + P_b$	150,000	136,480(4)	1.10
Secondary Lid Bolts	P_m	105,000	50,990	2.06
	$P_m + P_b$	150,000	50,990	2.94

Notes:

(1) Obtained from the model after removing the elements in the bolt hole vicinity. P_m value reported here is the average value over the thickness. See Figure 52 and Appendix 2.

(2) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

(3) Obtained from the stress linearization over the cross-section. See Appendix 2.

(4) Bolt stresses reported here have been obtained from the bolt section evaluation using the loading obtained from the FEM analyses. See Section 7.3 and Table 19.

(5) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(6) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

Table 14

Stress Intensities in 8-120B Cask under 30-ft Side Drop - Cold Condition (Max. Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [(6)] (psi)	F.S. [(5)]
Primary Lid	P_m	48,000	35,220[(1)]	1.36
	$P_m + P_b$	70,000	62,070[(1)]	1.28
Secondary Lid	P_m	48,000	35,673	1.35
	$P_m + P_b$	70,000	35,673	1.96
Bolting Ring	P_m	48,000	41,908[(2)]	1.15
	$P_m + P_b$	70,000	41,908[(2)]	1.67
Inner Shell	P_m	48,000	29,850[(3)]	1.61
	$P_m + P_b$	70,000	57,280[(3)]	1.22
Outer Shell	P_m	48,000	40,450[(3)]	1.19
	$P_m + P_b$	70,000	58,560[(3)]	1.20
Baseplate	P_m	48,000	41,288	1.16
	$P_m + P_b$	70,000	41,288	1.70
Primary Lid Bolts	P_m	105,000	25,399[(4)]	4.13
	$P_m + P_b$	150,000	142,709[(4)]	1.05
Secondary Lid Bolts	P_m	105,000	54,926	1.91
	$P_m + P_b$	150,000	54,926	2.73

Notes:

(1) Obtained from the model after removing the elements in the bolt hole vicinity. P_m value reported here is the average value over the thickness. See Figure 53 and Appendix 2.

(2) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

(3) Obtained from the stress linearization over the cross-section. See Appendix 2.

(4) Bolt stresses reported here have been obtained from the bolt section evaluation using the loading obtained from the FEM analyses. See Section 7.3 and Table 20.

(5) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(6) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

Table 15

Stress Intensities in 8-120B Cask under 30-ft Side Drop - Cold Condition (No Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (6) (psi)	F.S. (5)
Primary Lid	P_m	48,000	35,483(1)	1.35
	$P_m + P_b$	70,000	62,481(1)	1.12
Secondary Lid	P_m	48,000	35,835	1.34
	$P_m + P_b$	70,000	35,835	1.95
Bolting Ring	P_m	48,000	42,444(2)	1.13
	$P_m + P_b$	70,000	42,444(2)	1.65
Inner Shell	P_m	48,000	30,040(3)	1.60
	$P_m + P_b$	70,000	57,670(3)	1.21
Outer Shell	P_m	48,000	41,310(3)	1.16
	$P_m + P_b$	70,000	59,250(3)	1.18
Baseplate	P_m	48,000	41,047	1.17
	$P_m + P_b$	70,000	41,047	1.71
Primary Lid Bolts	P_m	105,000	25,417(4)	4.13
	$P_m + P_b$	150,000	143,229(4)	1.05
Secondary Lid Bolts	P_m	105,000	55,207	1.90
	$P_m + P_b$	150,000	55,207	2.72

Notes:

(1) Obtained from the model after removing the elements in the bolt hole vicinity. P_m value reported here is the average value over the thickness. See Figure 54 and Appendix 2.

(2) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

(3) Obtained from the stress linearization over the cross-section. See Appendix 2.

(4) Bolt stresses reported here have been obtained from the bolt section evaluation using the loading obtained from the FEM analyses. See Section 7.3 and Table 21.

(5) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(6) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

Table 16

Stress Intensities in 8-120B Cask under 30-ft Corner Drop - Hot Condition

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. (5) (psi)	F.S. (4)
Primary Lid	P_m	48,000	30,100(1)	1.60
	$P_m + P_b$	70,000	69,570(1)	1.01
Secondary Lid	P_m	48,000	29,808	1.61
	$P_m + P_b$	70,000	29,808	2.35
Bolting Ring	P_m	48,000	46,432(2)	1.03
	$P_m + P_b$	70,000	46,432(2)	1.51
Inner Shell	P_m	48,000	32,880(1)	1.46
	$P_m + P_b$	70,000	49,750(1)	1.41
Outer Shell	P_m	48,000	31,931	1.50
	$P_m + P_b$	70,000	31,931	2.19
Baseplate	P_m	48,000	12,150	3.95
	$P_m + P_b$	70,000	12,150	5.76
Primary Lid Bolts	P_m	105,000	22,261(3)	4.72
	$P_m + P_b$	150,000	95,433(3)	1.57
Secondary Lid Bolts	P_m	105,000	56,020	1.87
	$P_m + P_b$	150,000	56,020	2.68

Notes:

(1) Obtained from the stress linearization over the cross-section. See Appendix 2.

(2) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

(3) Bolt stresses reported here have been obtained from the bolt section evaluation using the loading obtained from the FEM analyses. See Section 7.3 and Tables 25 and 28.

(4) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(5) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

Table 17
Stress Intensities in 8-120B Cask under 30-ft Corner Drop - Cold Condition (Max. Heat Load)

Component	Stress Category	Allowable S.I. (psi)	Calculated S.I. [5] (psi)	F.S. [4]
Primary Lid	P_m	48,000	30,140[1]	1.59
	$P_m + P_b$	70,000	68,900[1]	1.02
Secondary Lid	P_m	48,000	27,743	1.73
	$P_m + P_b$	70,000	27,743	2.52
Bolting Ring	P_m	48,000	42,151[2]	1.14
	$P_m + P_b$	70,000	42,151[2]	1.66
Inner Shell	P_m	48,000	38,757	1.24
	$P_m + P_b$	70,000	38,757	1.81
Outer Shell	P_m	48,000	39,052	1.23
	$P_m + P_b$	70,000	39,052	1.79
Baseplate	P_m	48,000	21,984	2.18
	$P_m + P_b$	70,000	21,984	3.18
Primary Lid Bolts	P_m	105,000	20,445[3]	5.14
	$P_m + P_b$	150,000	90,545[3]	1.66
Secondary Lid Bolts	P_m	105,000	51,222	2.05
	$P_m + P_b$	150,000	51,222	2.93

Notes:

(1) Obtained from the stress linearization over the cross-section. See Appendix 2.

(2) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

(3) Bolt stresses reported here have been obtained from the bolt section evaluation using the loading obtained from the FEM analyses. See Section 7.3 and Tables 26 and 29.

(4) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(5) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

Table 18

Stress Intensities in 8-120B Cask under 30-ft Corner Drop - Cold Condition (No Heat Load)

Component	Stress Category (1)	Allowable S.I. (psi)	Calculated S.I. (4) (psi)	F.S. (3)
Primary Lid	P_m	48,000	30,250(1)	1.59
	$P_m + P_b$	70,000	69,090(1)	1.01
Secondary Lid	P_m	48,000	27,645	1.74
	$P_m + P_b$	70,000	27,645	2.53
Bolting Ring	P_m	48,000	41,460(2)	1.16
	$P_m + P_b$	70,000	41,460(2)	1.69
Inner Shell	P_m	48,000	37,866	1.27
	$P_m + P_b$	70,000	37,866	1.85
Outer Shell	P_m	48,000	40,893	1.17
	$P_m + P_b$	70,000	40,893	1.71
Baseplate	P_m	48,000	26,335	1.82
	$P_m + P_b$	70,000	26,335	2.66
Primary Lid Bolts	P_m	105,000	20,456	5.13
	$P_m + P_b$	150,000	89,944	1.67
Secondary Lid Bolts	P_m	105,000	51,172	2.05
	$P_m + P_b$	150,000	51,172	2.93

Notes:

(1) Obtained from the stress linearization over the cross-section. See Appendix 2.

(2) Obtained from the model after removing the elements in the bolt hole vicinity. See Appendix 2.

(3) Factor of Safety, F.S. = (Allowable S.I.) / (Calculated S.I.)

(4) Unless otherwise indicated in this column, the maximum stress intensity values have been conservatively reported as P_m and $P_m + P_b$ stress intensities.

Table 19

Primary Lid Bolt Evaluation (loads are taken at the Root of the Bolt Shank)

30ft Side Drop, Hot Conditions

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-110,792	-4,556	-66,491	-3,556	88,243	-2,171
bolt2	-96,615	-11,556	-57,363	-9,082	75,937	-3,837
bolt3	-65,994	-6,829	-37,768	-4,776	50,792	-5,012
bolt4	-32,054	15,371	-17,787	12,241	22,303	-6,245
bolt5	-6,782	39,151	-18,552	28,071	4,008	-2,682
bolt6	6,990	50,810	-23,673	36,198	-3,554	4,079
bolt7	21,013	41,395	-20,880	29,582	-11,659	6,584
bolt8	35,770	28,108	-21,650	20,865	-23,927	4,425
bolt9	44,012	17,909	-26,394	14,054	-33,734	1,928
bolt10	62,395	9,740	-23,492	8,659	-58,319	47

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-66,491	110,886	88,315	-2,171	24,034	112,446	40,082	136,480	0.4572
bolt2	-57,363	97,304	76,478	-3,837	20,735	97,375	35,172	118,110	0.3507
bolt3	-37,768	66,346	51,016	-5,012	13,652	64,956	23,982	78,608	0.1618
bolt4	-17,787	35,549	25,441	-6,245	6,429	32,393	12,850	38,822	0.0454
bolt5	-18,552	39,734	28,356	-2,682	6,706	36,104	14,363	42,810	0.0561
bolt6	-23,673	51,289	36,372	4,079	8,557	46,310	18,539	54,867	0.0932
bolt7	-20,880	46,423	31,797	6,584	7,547	40,485	16,780	48,032	0.0761
bolt8	-21,650	45,492	31,747	4,425	7,826	40,421	16,444	48,247	0.0737
bolt9	-26,394	47,516	36,544	1,928	9,541	46,530	17,176	56,070	0.0826
bolt10	-23,492	63,151	58,958	47	8,492	75,068	22,827	83,560	0.1378

Note:

(1) See the general notes on Page 31.

Table 20
Primary Lid Bolt Evaluation (loads are taken at the Root of the Bolt Shank)
30ft Side Drop, Cold Conditions (Max. Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-113,406	-4,254	-70,266	-3,435	92,071	-2,616
bolt2	-99,095	-12,017	-61,319	-10,025	79,750	-3,743
bolt3	-64,823	-7,458	-41,828	-6,235	54,659	-5,042
bolt4	-33,980	15,469	-20,474	11,654	25,550	-6,666
bolt5	-7,804	39,844	-19,118	28,069	5,169	-3,231
bolt6	5,926	51,581	-24,117	36,205	-3,242	3,507
bolt7	20,095	41,117	-21,048	28,934	-12,148	6,490
bolt8	36,292	25,837	-21,225	19,055	-24,519	5,480
bolt9	57,460	13,571	-24,960	10,622	-34,187	2,591
bolt10	76,025	7,303	-14,490	6,624	-69,358	157

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-70,266	113,486	92,135	-2,616	25,399	117,310	41,021	142,709	0.4825
bolt2	-61,319	99,821	80,378	-3,743	22,165	102,340	36,082	124,505	0.3726
bolt3	-41,828	65,251	55,013	-5,042	15,119	70,045	23,586	85,165	0.1609
bolt4	-20,474	37,335	28,082	-6,666	7,401	35,756	13,496	43,156	0.0509
bolt5	-19,118	40,601	28,541	-3,231	6,911	36,339	14,676	43,250	0.0586
bolt6	-24,117	51,920	36,350	3,507	8,718	46,282	18,768	55,000	0.0956
bolt7	-21,048	45,765	31,381	6,490	7,608	39,955	16,542	47,563	0.0742
bolt8	-21,225	44,550	31,053	5,480	7,672	39,538	16,103	47,210	0.0707
bolt9	-24,960	59,041	35,799	2,591	9,022	45,581	21,341	54,603	0.1221
bolt10	-14,490	76,375	69,674	157	5,238	88,711	27,607	93,949	0.1945

Note:

(1) See the general notes on Page 31.

Table 21
Primary Lid Bolt Evaluation (loads are taken at the Root of the Bolt Shank)
30ft Side Drop, Cold Conditions (No Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-114,222	-4,322	-70,317	-3,492	92,463	-2,618
bolt2	-100,061	-12,247	-61,539	-10,182	80,297	-3,743
bolt3	-69,455	-7,864	-42,089	-6,487	55,260	-5,111
bolt4	-34,645	15,109	-20,355	11,414	25,800	-6,997
bolt5	-8,136	39,404	-18,735	27,732	5,264	-3,612
bolt6	5,822	50,675	-23,373	35,511	-2,966	3,462
bolt7	20,287	38,772	-19,183	27,190	-11,180	7,085
bolt8	37,121	22,909	-18,819	16,939	-22,938	6,627
bolt9	48,655	11,971	-23,145	9,457	-32,851	3,643
bolt10	81,648	6,658	-10,149	6,207	-73,947	122

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-70,317	114,304	92,529	-2,618	25,417	117,812	41,317	143,229	0.4887
bolt2	-61,539	100,808	80,940	-3,743	22,244	103,056	36,439	125,300	0.3794
bolt3	-42,089	69,899	55,639	-5,111	15,214	70,842	25,266	86,056	0.1818
bolt4	-20,355	37,796	28,212	-6,997	7,358	35,921	13,662	43,278	0.0519
bolt5	-18,735	40,235	28,227	-3,612	6,772	35,940	14,544	42,712	0.0575
bolt6	-23,373	51,008	35,635	3,462	8,449	45,371	18,438	53,820	0.0921
bolt7	-19,183	43,759	29,399	7,085	6,934	37,432	15,817	44,366	0.0674
bolt8	-18,819	43,621	28,515	6,627	6,802	36,306	15,768	43,108	0.0668
bolt9	-23,145	50,106	34,185	3,643	8,366	43,526	18,112	51,892	0.0890
bolt10	-10,149	81,919	74,207	122	3,669	94,483	29,611	98,152	0.2221

Note:

(1) See the general notes on Page 31.

Table 22

Primary Lid Bolt Evaluation (loads are taken at the interface of Primary Lid and Bolting Ring)

30ft Side Drop, Hot Conditions

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-110,930	-4,556	-66,491	2,595	-61,420	-2,171
bolt2	-96,754	-11,556	-57,363	6,519	-54,587	-3,837
bolt3	-66,132	-6,829	-37,768	4,443	-38,393	-5,012
bolt4	-32,192	15,371	-17,787	-8,511	-21,062	-6,245
bolt5	-6,921	39,151	-18,552	-24,783	-5,241	-2,682
bolt6	6,852	50,810	-23,673	-32,396	5,790	4,079
bolt7	20,875	41,395	-20,880	-26,302	16,615	6,584
bolt8	35,632	28,108	-21,650	-17,081	24,269	4,425
bolt9	43,874	17,909	-26,394	-10,123	25,589	1,928
bolt10	62,256	9,740	-23,492	-4,490	25,820	47

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-66,491	111,024	61,475	-2,171	24,034	78,272	40,131	102,306	0.4582
bolt2	-57,363	97,442	54,975	-3,837	20,735	69,996	35,222	90,731	0.3516
bolt3	-37,768	66,484	38,649	-5,012	13,652	49,210	24,032	62,862	0.1624
bolt4	-17,787	35,673	22,717	-6,245	6,429	28,924	12,895	35,353	0.0456
bolt5	-18,552	39,758	25,331	-2,682	6,706	32,253	14,371	38,959	0.0561
bolt6	-23,673	51,270	32,909	4,079	8,557	41,901	18,532	50,458	0.0932
bolt7	-20,880	46,361	31,110	6,584	7,547	39,611	16,758	47,158	0.0759
bolt8	-21,650	45,384	29,677	4,425	7,826	37,786	16,405	45,612	0.0734
bolt9	-26,394	47,388	27,519	1,928	9,541	35,038	17,129	44,578	0.0822
bolt10	-23,492	63,013	26,207	47	8,492	33,368	22,777	41,860	0.1373

Note:

(1) See the general notes on Page 31.

Table 23

Primary Lid Bolt Evaluation (loads are taken at the interface of Primary Lid and Bolting Ring)

30ft Side Drop, Cold Conditions (Max. Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-113,545	-4,254	-70,266	2,308	-61,121	-2,616
bolt2	-99,233	-12,017	-61,319	6,198	-54,121	-3,743
bolt3	-68,561	-7,458	-41,828	3,834	-37,806	-5,042
bolt4	-34,028	15,469	-20,474	-9,229	-20,295	-6,666
bolt5	-7,943	39,844	-19,118	-25,720	-5,461	-3,231
bolt6	5,787	51,581	-24,117	-33,429	4,665	3,507
bolt7	19,957	41,117	-21,048	-26,573	14,887	6,490
bolt8	36,154	25,837	-21,225	-15,825	24,383	5,840
bolt9	47,422	13,571	-24,960	-7,699	29,925	2,591
bolt10	75,887	7,303	-14,490	-3,234	33,182	157

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-70,266	113,625	61,165	-2,616	25,399	77,877	41,072	103,276	0.4835
bolt2	-61,319	99,958	54,475	-3,743	22,165	69,359	36,132	91,524	0.3735
bolt3	-41,828	68,965	38,000	-5,042	15,119	48,383	24,929	63,502	0.1773
bolt4	-20,474	37,379	22,295	-6,666	7,401	28,387	13,511	35,787	0.0510
bolt5	-19,118	40,628	26,293	-3,231	6,911	33,478	14,686	40,388	0.0587
bolt6	-24,117	51,905	33,753	3,507	8,718	42,976	18,762	51,693	0.0956
bolt7	-21,048	45,704	30,459	6,490	7,608	38,782	16,521	46,390	0.0740
bolt8	-21,225	44,437	29,068	5,840	7,672	37,011	16,063	44,683	0.0703
bolt9	-24,960	49,326	30,900	2,591	9,022	39,342	17,830	48,365	0.0875
bolt10	-14,490	76,238	33,339	157	5,238	42,449	27,557	47,686	0.1938

Note:

(1) See the general notes on Page 31.

Table 24

Primary Lid Bolt Evaluation (loads are taken at the interface of Primary Lid and Bolting Ring)
30ft Side Drop, Cold Conditions (No Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-114,361	-4,322	-70,317	2,344	-61,831	-2,618
bolt2	-100,199	-12,247	-61,539	6,352	-54,878	-3,743
bolt3	-69,593	-7,864	-42,089	4,130	-38,597	-5,111
bolt4	-34,784	15,109	-20,355	-8,983	-21,064	-6,997
bolt5	-8,274	39,404	-18,735	-25,463	-5,813	-3,612
bolt6	5,684	50,675	-23,373	-32,900	4,800	3,462
bolt7	20,148	38,772	-19,183	-25,152	16,114	7,085
bolt8	36,983	22,909	-18,819	-13,988	27,082	6,627
bolt9	48,517	11,971	-23,145	-6,704	32,740	3,643
bolt10	81,510	6,658	-10,149	-2,781	36,185	122

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-70,317	114,443	61,875	-2,618	25,417	78,782	41,367	104,200	0.4898
bolt2	-61,539	100,945	55,244	-3,743	22,244	70,339	36,488	92,584	0.3803
bolt3	-42,089	70,036	38,817	-5,111	15,214	49,424	25,316	64,638	0.1825
bolt4	-20,355	37,924	22,899	-6,997	7,358	29,157	13,708	36,514	0.0523
bolt5	-18,735	40,263	26,118	-3,612	6,772	33,255	14,554	40,027	0.0575
bolt6	-23,373	50,993	33,248	3,462	8,449	42,333	18,432	50,782	0.0921
bolt7	-19,183	43,695	29,871	7,085	6,934	38,033	15,794	44,967	0.0672
bolt8	-18,819	43,504	30,481	6,627	6,802	38,810	15,725	45,612	0.0665
bolt9	-23,145	49,972	33,419	3,643	8,366	42,551	18,063	50,917	0.0886
bolt10	-10,149	81,781	36,292	122	3,669	46,208	29,561	49,877	0.2214

Note:

(1) See the general notes on Page 31.

Table 25

Primary Lid Bolt Evaluation (loads are taken at the Root of the Bolt Shank)

30ft Corner Drop, Hot Conditions

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-52,793	8,389	-61,530	9,948	37,251	-517
bolt2	-54,038	22,886	-60,774	27,524	38,953	-1,411
bolt3	-53,553	32,885	-58,673	40,334	39,571	-2,306
bolt4	-50,769	36,792	-53,024	45,407	39,066	-2,370
bolt5	-44,007	24,343	-35,521	32,106	35,056	-1,115
bolt6	-11,718	611	-4,325	4,690	5,214	-10,024
bolt7	225	0	-272	0	169	0
bolt8	225	0	-272	0	169	0
bolt9	225	0	-272	0	169	0
bolt10	225	0	-272	0	169	0

	F_{Axial}	V_{shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-61,530	53,455	38,556	-517	22,241	49,092	19,322	71,333	0.1389
bolt2	-60,774	58,685	47,696	-1,411	21,968	60,728	21,213	82,696	0.1571
bolt3	-58,673	62,844	56,504	-2,306	21,208	71,943	22,716	93,151	0.1708
bolt4	-53,024	62,699	59,899	-2,370	19,166	76,266	22,664	95,433	0.1627
bolt5	-35,521	50,291	47,536	-1,115	12,840	60,525	18,179	73,365	0.0982
bolt6	-4,325	11,734	7,013	-10,024	1,563	8,929	4,241	10,493	0.0048
bolt7	-272	225	169	0	98	215	81	313	0.0000
bolt8	-272	225	169	0	98	215	81	313	0.0000
bolt9	-272	225	169	0	98	215	81	313	0.0000
bolt10	-272	225	169	0	98	215	81	313	0.0000

Note:

(1) See the general notes on Page 31.

Table 26

Primary Lid Bolt Evaluation (loads are taken at the Root of the Bolt Shank)

30ft Corner Drop, Cold Conditions (Max. Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-53,681	8,261	-56,507	9,002	43,399	-575
bolt2	-53,552	22,785	-55,778	24,889	43,009	-1,603
bolt3	-52,081	33,979	-53,698	37,146	41,466	-2,468
bolt4	-48,896	39,189	-48,462	42,189	38,856	-2,442
bolt5	-44,100	27,235	-33,532	29,729	34,906	-347
bolt6	-12,938	2,413	-4,797	4,477	6,294	-9,156
bolt7	225	0	-272	0	169	0
bolt8	225	0	-272	0	169	0
bolt9	225	0	-272	0	169	0
bolt10	225	0	-272	0	169	0

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-56,507	54,313	44,323	-575	20,425	56,434	19,632	76,859	0.1350
bolt2	-55,778	58,198	49,691	-1,603	20,162	63,269	21,037	83,431	0.1484
bolt3	-53,698	62,185	55,671	-2,468	19,410	70,882	22,478	90,293	0.1615
bolt4	-48,462	62,663	57,356	-2,442	17,517	73,028	22,650	90,545	0.1571
bolt5	-33,532	51,832	45,850	-347	12,121	58,378	18,736	70,499	0.1018
bolt6	-4,797	13,161	7,724	-9,156	1,734	9,834	4,757	11,568	0.0060
bolt7	-272	225	169	0	98	215	81	313	0.0000
bolt8	-272	225	169	0	98	215	81	313	0.0000
bolt9	-272	225	169	0	98	215	81	313	0.0000
bolt10	-272	225	169	0	98	215	81	313	0.0000

Note:

(1) See the general notes on Page 31.

Table 27

Primary Lid Bolt Evaluation (loads are taken at the Root of the Bolt Shank)

30ft Corner Drop, Cold Conditions (No Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-54,686	7,960	-56,538	8,849	43,643	-631
bolt2	-55,018	21,820	-55,816	24,354	43,589	-1,673
bolt3	-53,299	32,213	-53,697	36,264	41,878	-2,694
bolt4	-49,267	37,117	-48,364	41,337	38,873	-2,791
bolt5	-43,619	25,899	-33,280	29,207	34,599	-648
bolt6	-12,499	2,016	-4,538	4,227	5,954	-9,268
bolt7	225	0	-272	0	169	0
bolt8	225	0	-272	0	169	0
bolt9	225	0	-272	0	169	0
bolt10	225	0	-272	0	169	0

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-56,538	55,262	44,531	-631	20,437	56,699	19,976	77,135	0.1384
bolt2	-55,816	59,187	49,931	-1,673	20,176	63,574	21,394	83,750	0.1522
bolt3	-53,697	62,277	55,397	-2,694	19,410	70,534	22,511	89,944	0.1618
bolt4	-48,364	61,684	56,744	-2,791	17,482	72,248	22,297	89,730	0.1530
bolt5	-33,280	50,728	45,278	-648	12,030	57,650	18,337	69,680	0.0978
bolt6	-4,538	12,661	7,302	-9,268	1,640	9,297	4,576	10,937	0.0055
bolt7	-272	225	169	0	98	215	81	313	0.0000
bolt8	-272	225	169	0	98	215	81	313	0.0000
bolt9	-272	225	169	0	98	215	81	313	0.0000
bolt10	-272	225	169	0	98	215	81	313	0.0000

Note:

(1) See the general notes on Page 31.

Table 28
Primary Lid Bolt Evaluation (loads are taken at interface of Primary Lid and Bolting Ring)
30ft Corner Drop, Hot Conditions

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-52,749	8,389	-61,584	-1,377	-33,990	-517
bolt2	-53,394	22,886	-60,827	-3,372	-33,969	-1,411
bolt3	-53,508	32,885	-58,726	-4,061	-32,695	-2,306
bolt4	-50,725	36,792	-53,077	-4,262	-29,442	-2,370
bolt5	-43,962	24,343	-35,574	-757	-24,323	-1,115
bolt6	-11,674	611	-4,378	3,865	-10,575	-10,024
bolt7	270	0	-325	0	503	0
bolt8	270	0	-325	0	503	0
bolt9	270	0	-325	0	503	0
bolt10	270	0	-325	0	503	0

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-61,584	53,412	34,018	-517	22,261	43,313	19,307	65,574	0.1389
bolt2	-60,827	58,092	34,136	-1,411	21,987	43,463	20,998	65,450	0.1549
bolt3	-58,726	62,805	32,946	-2,306	21,228	41,948	22,702	63,176	0.1707
bolt4	-53,077	62,663	29,749	-2,370	19,186	37,877	22,651	57,063	0.1627
bolt5	-35,574	50,252	24,335	-1,115	12,859	30,984	18,164	43,843	0.0981
bolt6	-4,378	11,690	11,259	-10,024	1,583	14,336	4,226	15,918	0.0047
bolt7	-325	270	503	0	117	640	98	758	0.0000
bolt8	-325	270	503	0	117	640	98	758	0.0000
bolt9	-325	270	503	0	117	640	98	758	0.0000
bolt10	-325	270	503	0	117	640	98	758	0.0000

Note:

(1) See the general notes on Page 31.

Table 29

Primary Lid Bolt Evaluation (loads are taken at interface of Primary Lid and Bolting Ring)

30ft Corner Drop, Cold Conditions (Max. Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-53,637	8,261	-56,561	-2,151	-29,040	-575
bolt2	-53,508	22,785	-55,831	-5,871	-29,257	-1,603
bolt3	-52,037	33,979	-53,751	-8,725	-28,814	-2,468
bolt4	-48,852	39,189	-48,515	-10,716	-27,124	-2,442
bolt5	-44,056	27,235	-33,586	-7,039	-24,559	-347
bolt6	-12,894	2,413	-4,850	1,220	-11,143	-9,156
bolt7	270	0	-325	0	503	0
bolt8	270	0	-325	0	503	0
bolt9	270	0	-325	0	503	0
bolt10	270	0	-325	0	503	0

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-56,561	54,269	29,120	-575	20,445	37,076	19,617	57,521	0.1349
bolt2	-55,831	58,157	29,840	-1,603	20,181	37,994	21,022	58,175	0.1483
bolt3	-53,751	62,148	30,106	-2,468	19,429	38,332	22,465	57,761	0.1614
bolt4	-48,515	62,628	29,164	-2,442	17,537	37,133	22,638	54,669	0.1570
bolt5	-33,586	51,795	25,548	-347	12,140	32,529	18,722	44,669	0.1017
bolt6	-4,850	13,118	11,210	-9,156	1,753	14,272	4,742	16,026	0.0059
bolt7	-325	270	503	0	117	640	98	758	0.0000
bolt8	-325	270	503	0	117	640	98	758	0.0000
bolt9	-325	270	503	0	117	640	98	758	0.0000
bolt10	-325	270	503	0	117	640	98	758	0.0000

Note:

(1) See the general notes on Page 31.

Table 30

Primary Lid Bolt Evaluation (loads are taken at the interface of Primary Lid and Bolting Ring)

30ft Corner Drop, Cold Conditions (No Heat Load)

Load	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**
	lbs	lbs	lbs	in lbs	in lbs	in lbs
bolt1	-54,641	7,960	-56,591	-1,897	-30,153	-631
bolt2	-54,973	21,820	-55,870	-5,103	-30,655	-1,673
bolt3	-53,225	32,213	-53,751	-7,224	-30,046	-2,694
bolt4	-49,223	37,117	-48,417	-8,770	-27,608	-2,791
bolt5	-43,574	25,899	-33,333	-5,757	-24,256	-648
bolt6	-12,455	2,016	-4,591	1,505	-10,889	-9,268
bolt7	270	0	-325	0	503	0
bolt8	270	0	-325	0	503	0
bolt9	270	0	-325	0	503	0
bolt10	270	0	-325	0	503	0

	F_{Axial}	V_{Shear}	M	T	$\sigma_{tensile}$	$\sigma_{bending}$	τ	$\sigma_{tensile+bending}$	Axial-Shear Interaction
	lbs	lbs	in lbs	in lbs	psi	psi	psi	psi	
bolt1	-56,591	55,218	30,213	-631	20,456	38,468	19,959	58,924	0.1383
bolt2	-55,870	59,145	31,077	-1,673	20,195	39,568	21,379	59,763	0.1522
bolt3	-53,751	62,214	30,902	-2,694	19,429	39,346	22,488	58,775	0.1617
bolt4	-48,417	61,649	28,967	-2,791	17,501	36,883	22,284	54,384	0.1529
bolt5	-33,333	50,690	24,930	-648	12,049	31,742	18,323	43,790	0.0978
bolt6	-4,591	12,617	10,993	-9,268	1,659	13,996	4,561	15,656	0.0055
bolt7	-325	270	503	0	117	640	98	758	0.0000
bolt8	-325	270	503	0	117	640	98	758	0.0000
bolt9	-325	270	503	0	117	640	98	758	0.0000
bolt10	-325	270	503	0	117	640	98	758	0.0000

Note:

(1) See the general notes on Page 31.

General Notes

Primary Lid Bolt Evaluation, Tables 19 Through 30

Notes:

(1) Bolt axial load = $F_{Axial} = FZ$

(2) Bolt horizontal shear load = $V_{Shear} = \sqrt{(FX)^2 + (FY)^2}$

(3) Bolt bending moment = $M = \sqrt{(MX)^2 + (MY)^2}$

(4) Bolt torsion = T = MZ

(5) Bolt axial plus bending stress = $\sigma_{axial+bending} = \sigma_{axial} + \sigma_{bending}$

(6) Allowable bolt axial (average) stress = Allowable membrane stress = 105,000 psi (per Section 5)

(7) Allowable bolt shear stress = Smaller of ($0.42S_u$ and $0.6S_y$) = 63,000 psi

(8) Allowable membrane + bending stress = 150,000 psi (per Section 5)

(9) Bolt axial-shear interaction ratio = $(\frac{\sigma_{axial}}{105,000})^2 + (\frac{\tau}{63,000})^2$

Figures

(55 Pages)

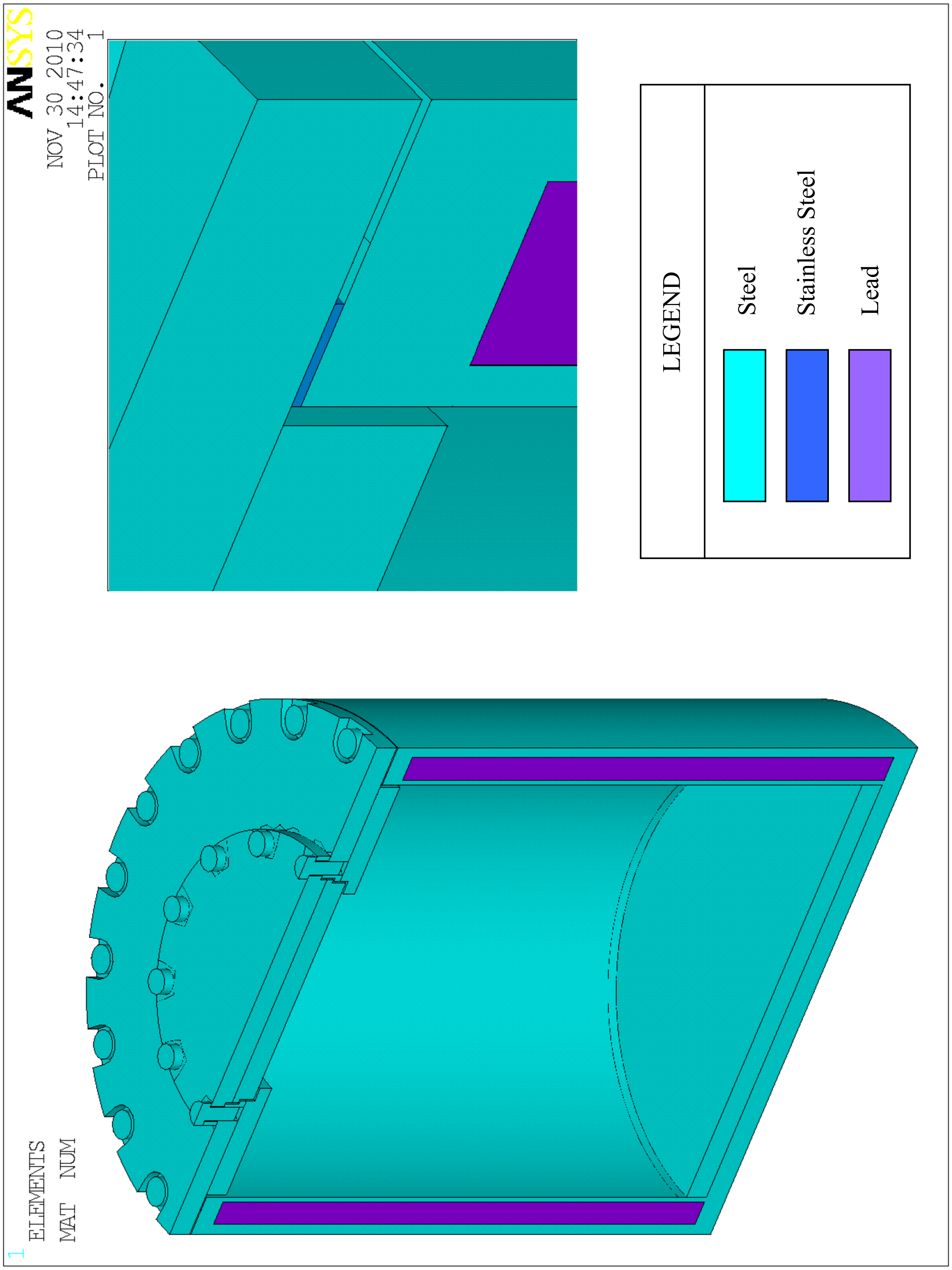


Figure 1

Finite Element Model of the 8-120B Cask Identifying the Cask Components with Material Numbers

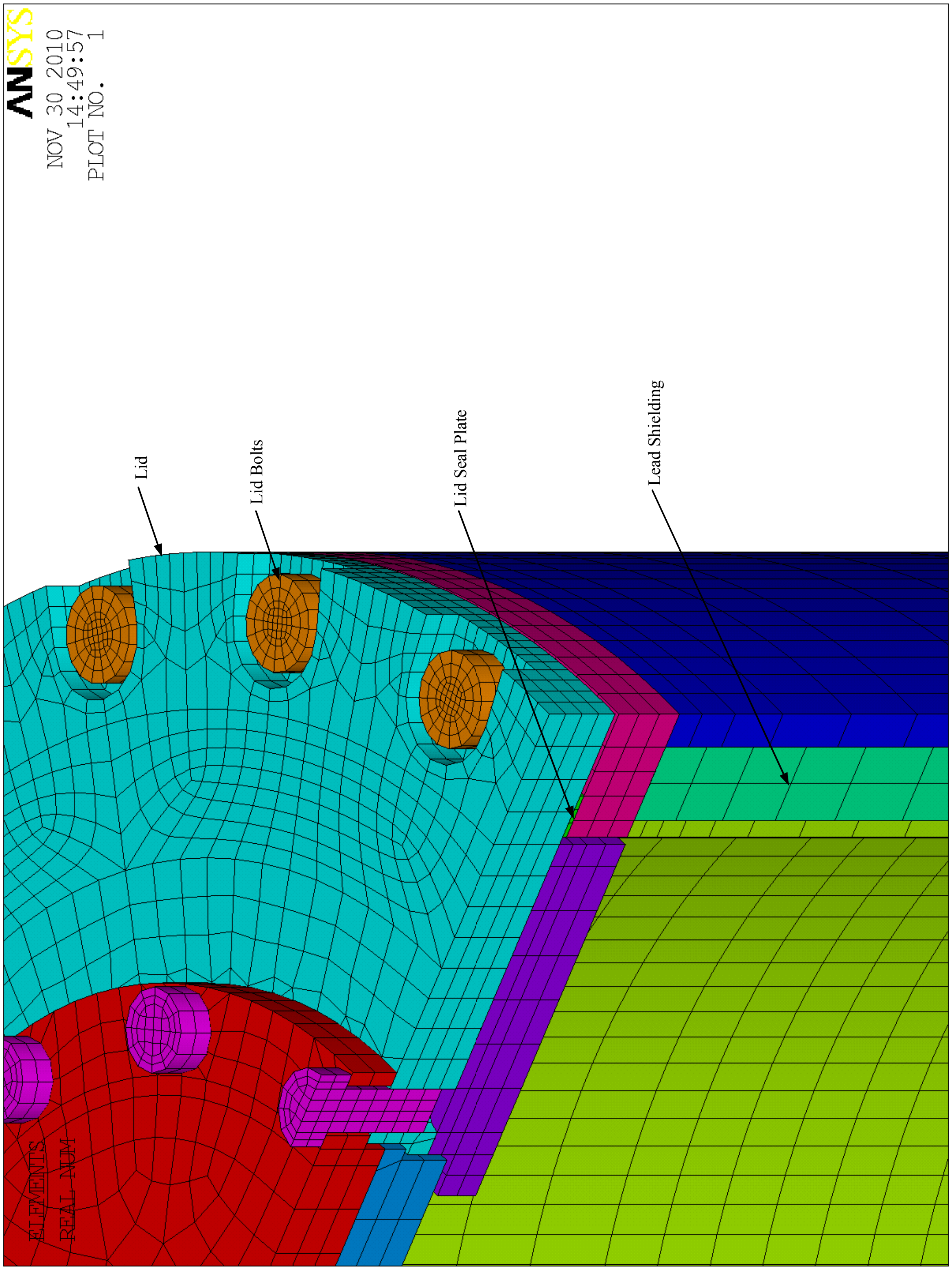


Figure 2
Finite Element Model of the Lid, Seal Plate, Bolts and the Cask

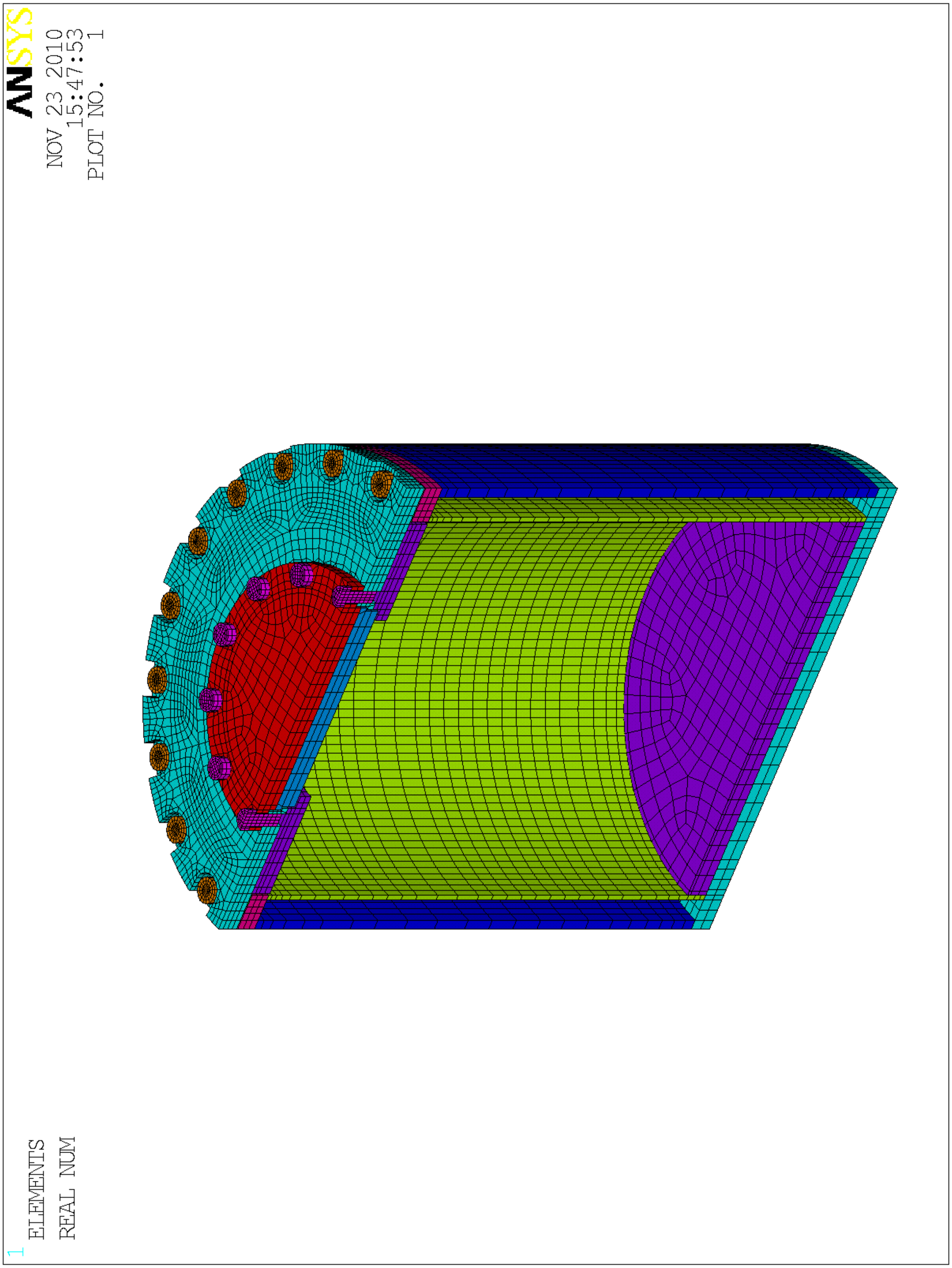


Figure 3

Finite Element Model of the cask Body without the Lead

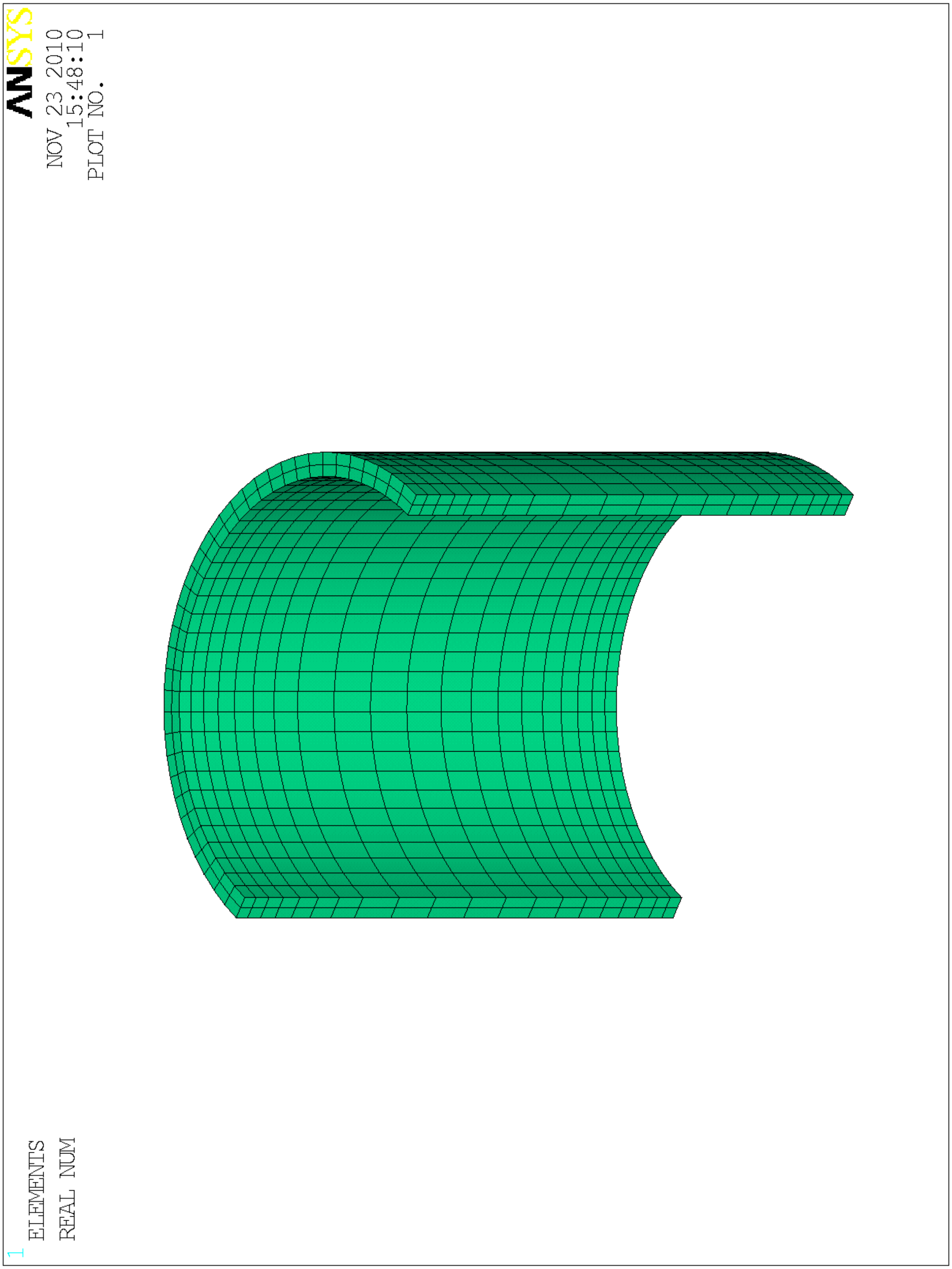


Figure 4
Finite Element Model of the Lead

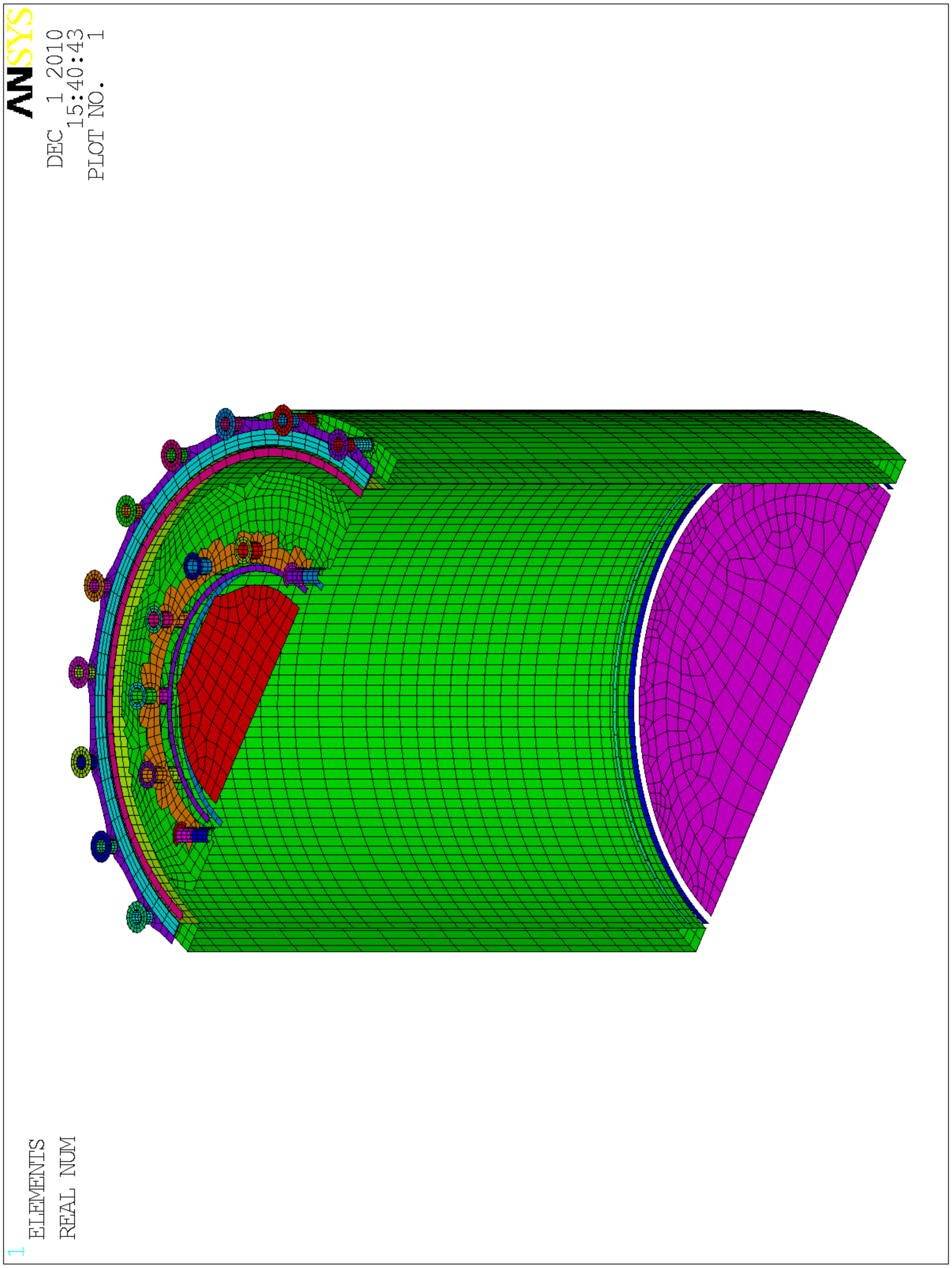


Figure 5

Finite Element Model of the Contact-Target Elements (Only Contact Elements Shown)

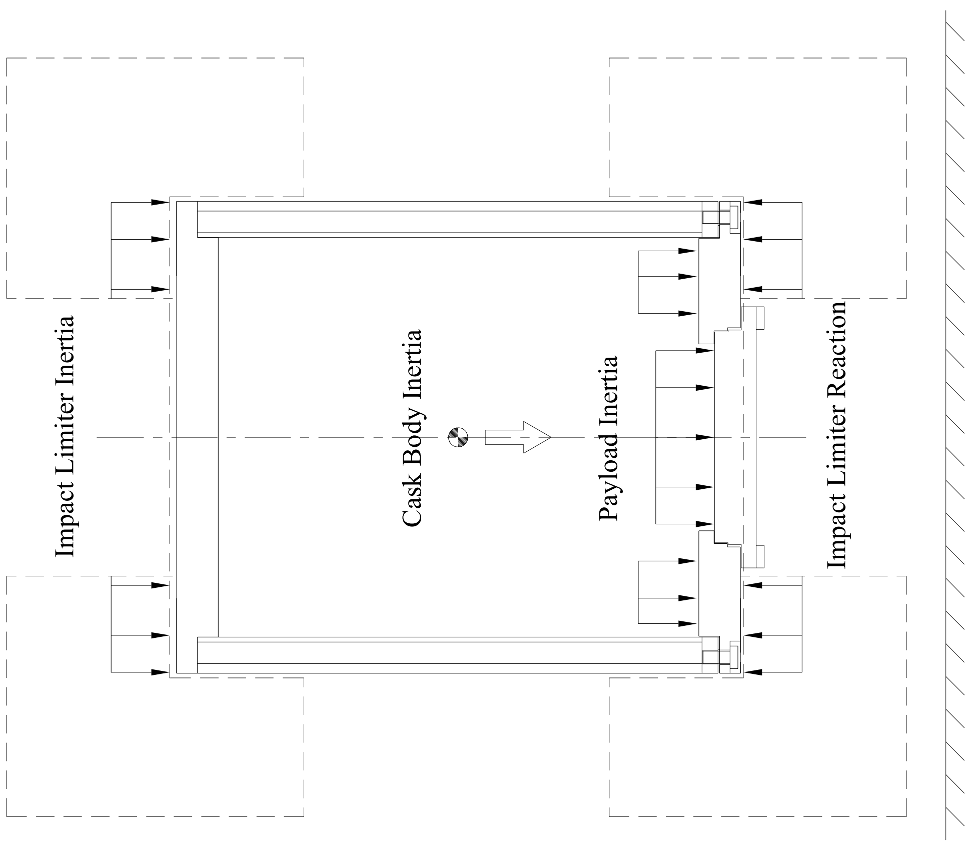


Figure 6

Load Distribution on the Model during End Drop

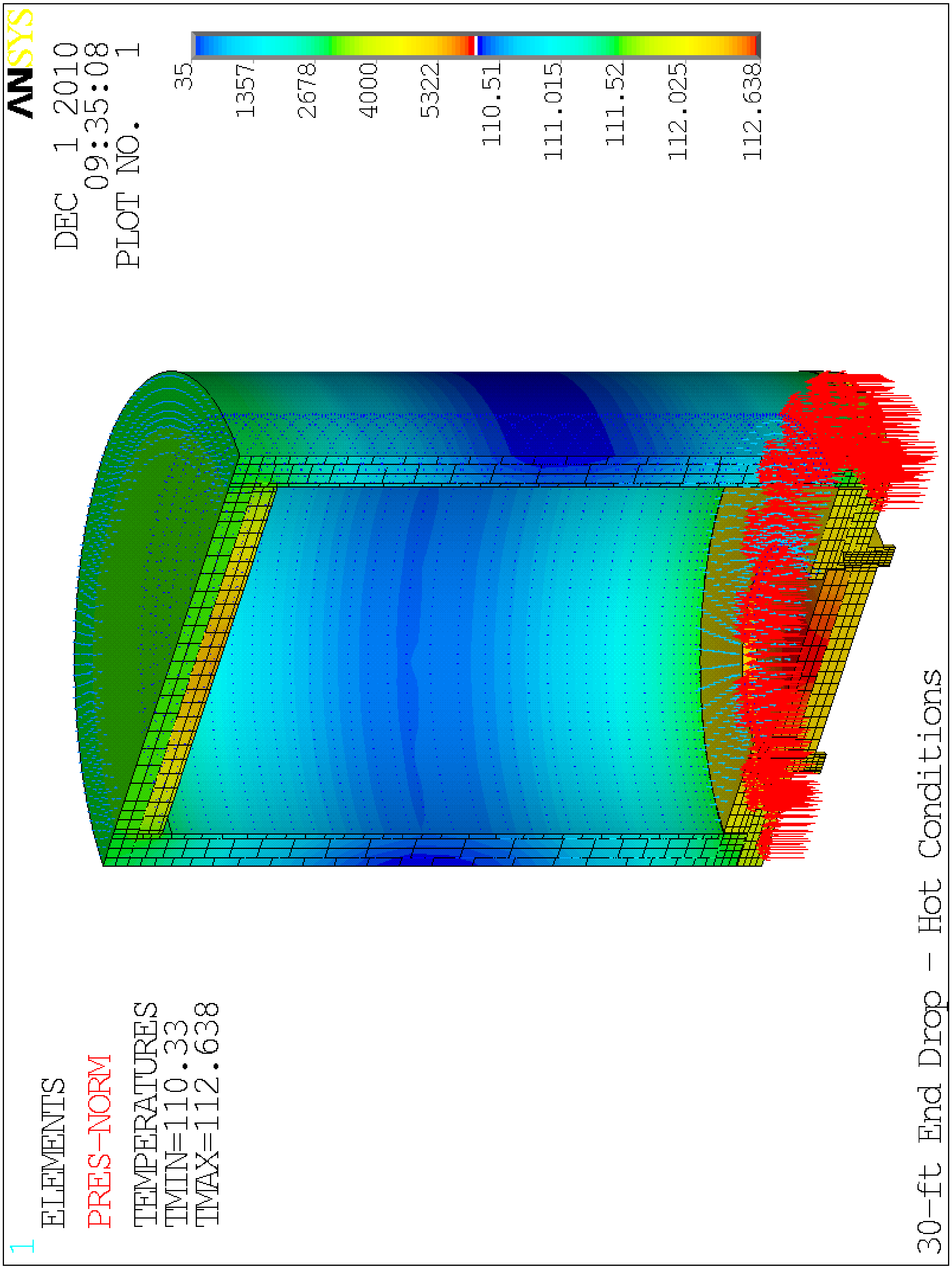


Figure 7

Temperature Profile and Pressure Distribution Used for 30-ft End Drop – Hot Condition

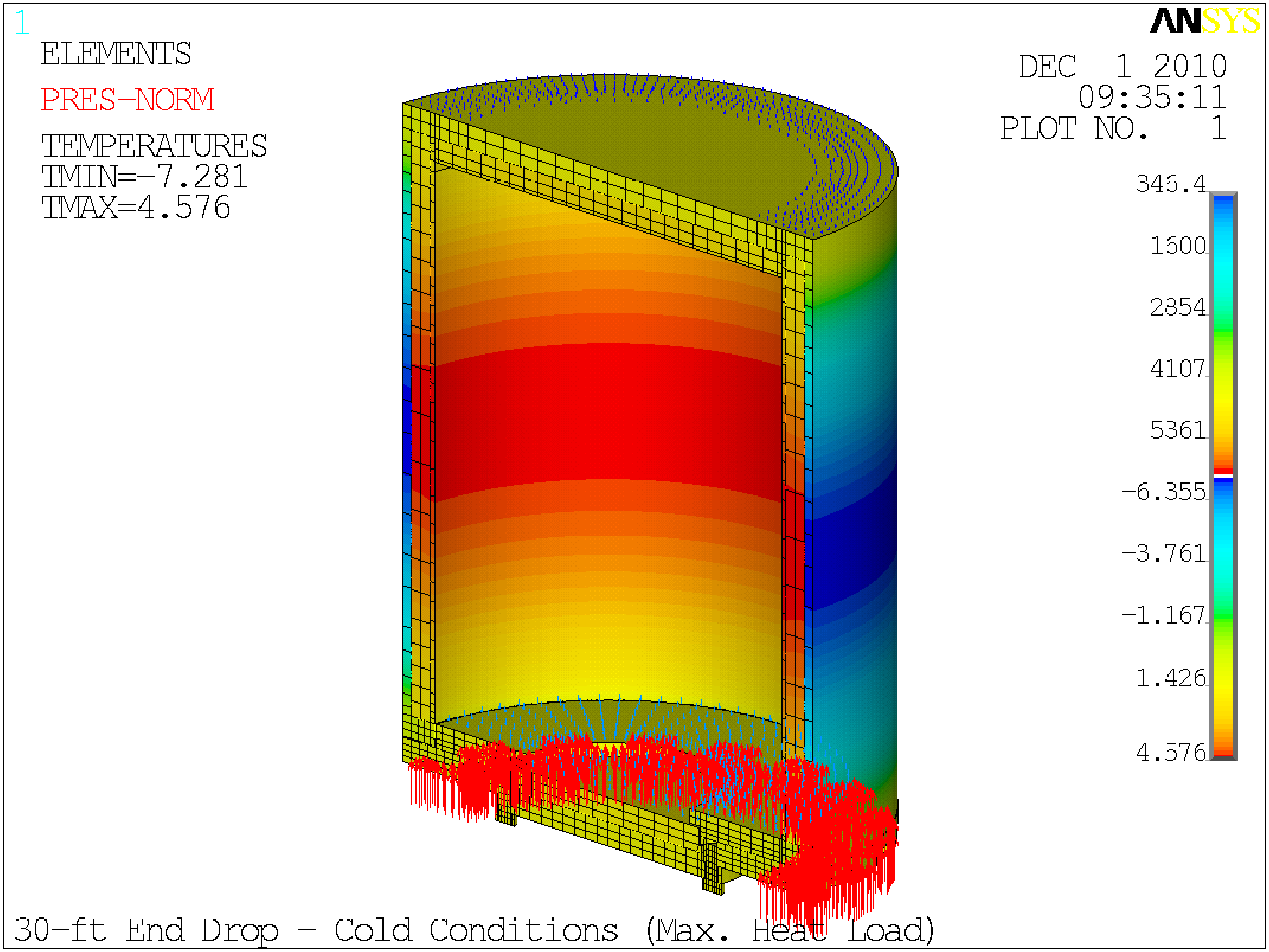


Figure 8

Temperature Profile and Pressure Distribution Used for 30-ft End Drop – Cold Condition (Max. Heat Load)

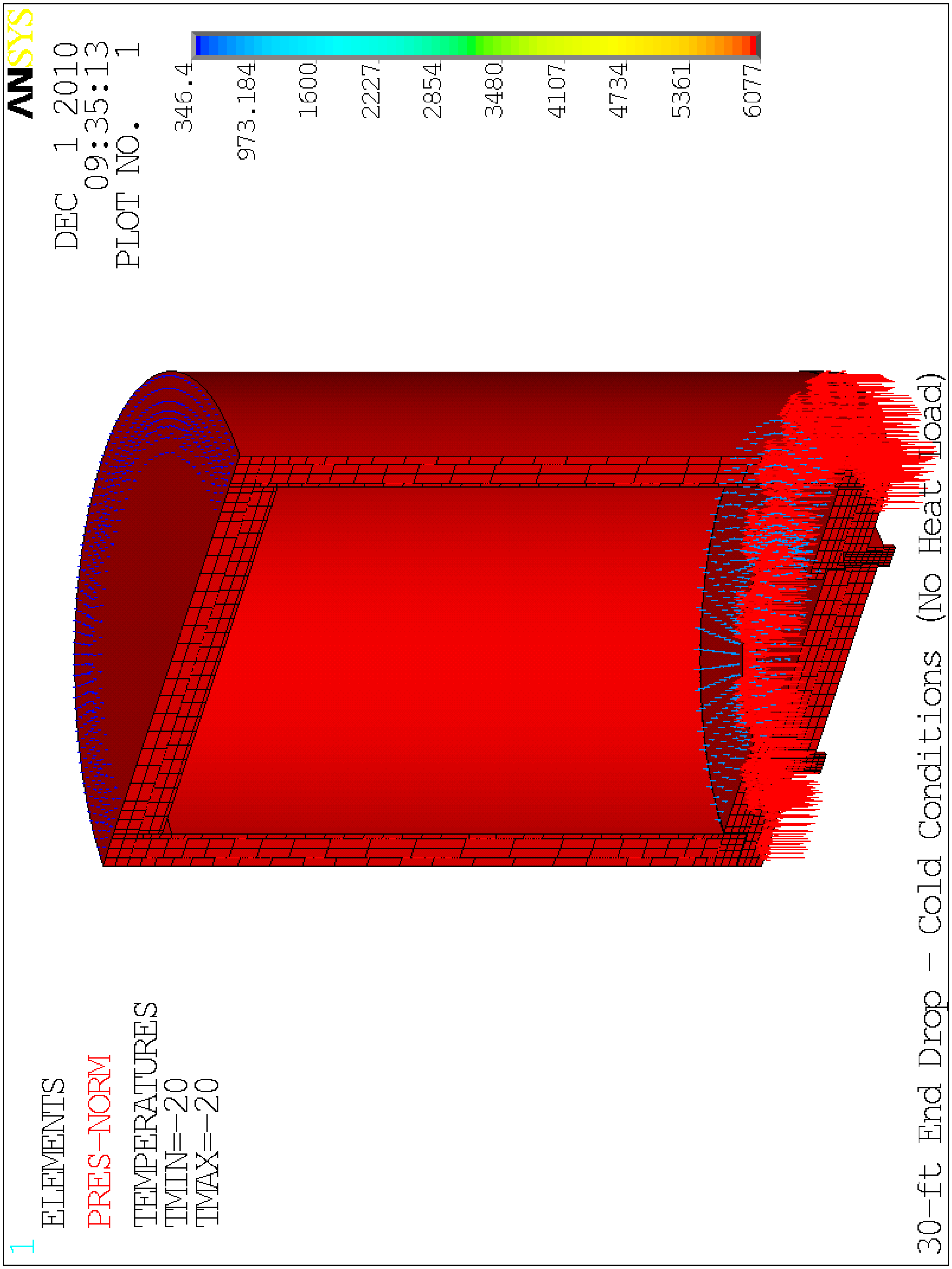


Figure 9

Temperature Profile and Pressure Distribution Used for 30-ft End Drop – Cold Condition (No Heat Load)

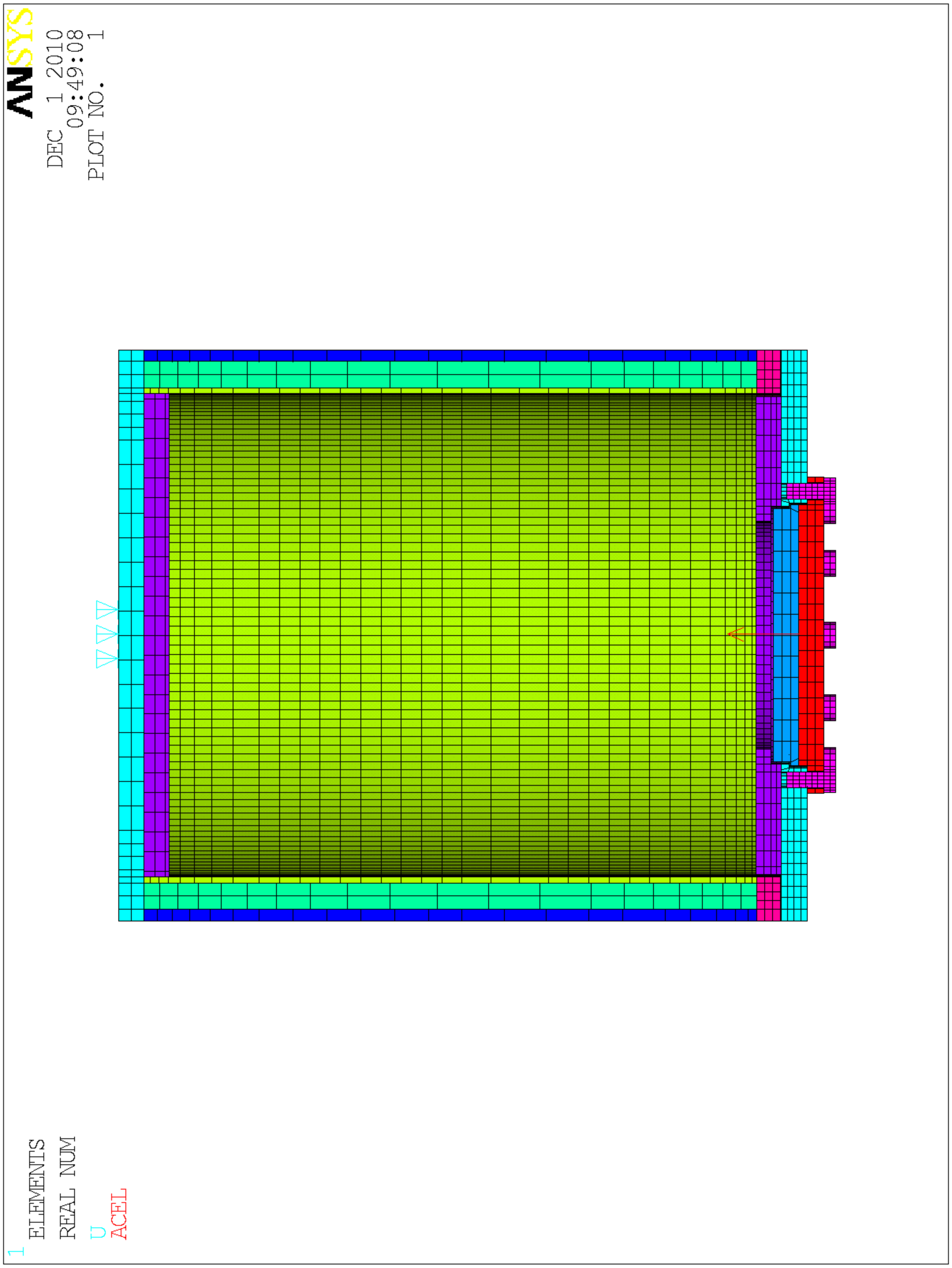


Figure 10
Stress Intensity Plot – 30-ft End Drop – Displacement Boundary Conditions Used to Represent the Impact Limiter

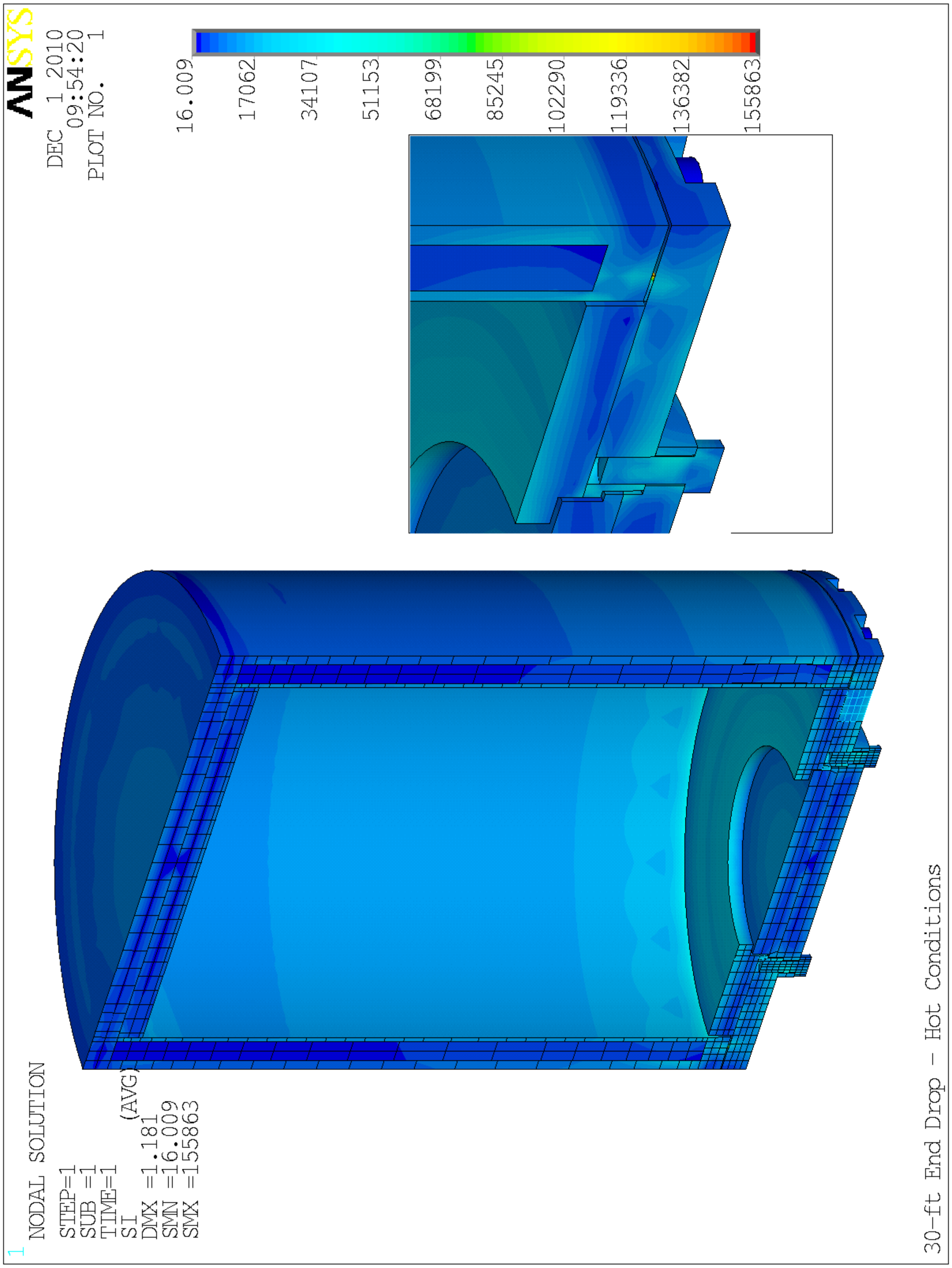


Figure 11

Stress Intensity Plot – 30-ft End Drop – Hot Condition

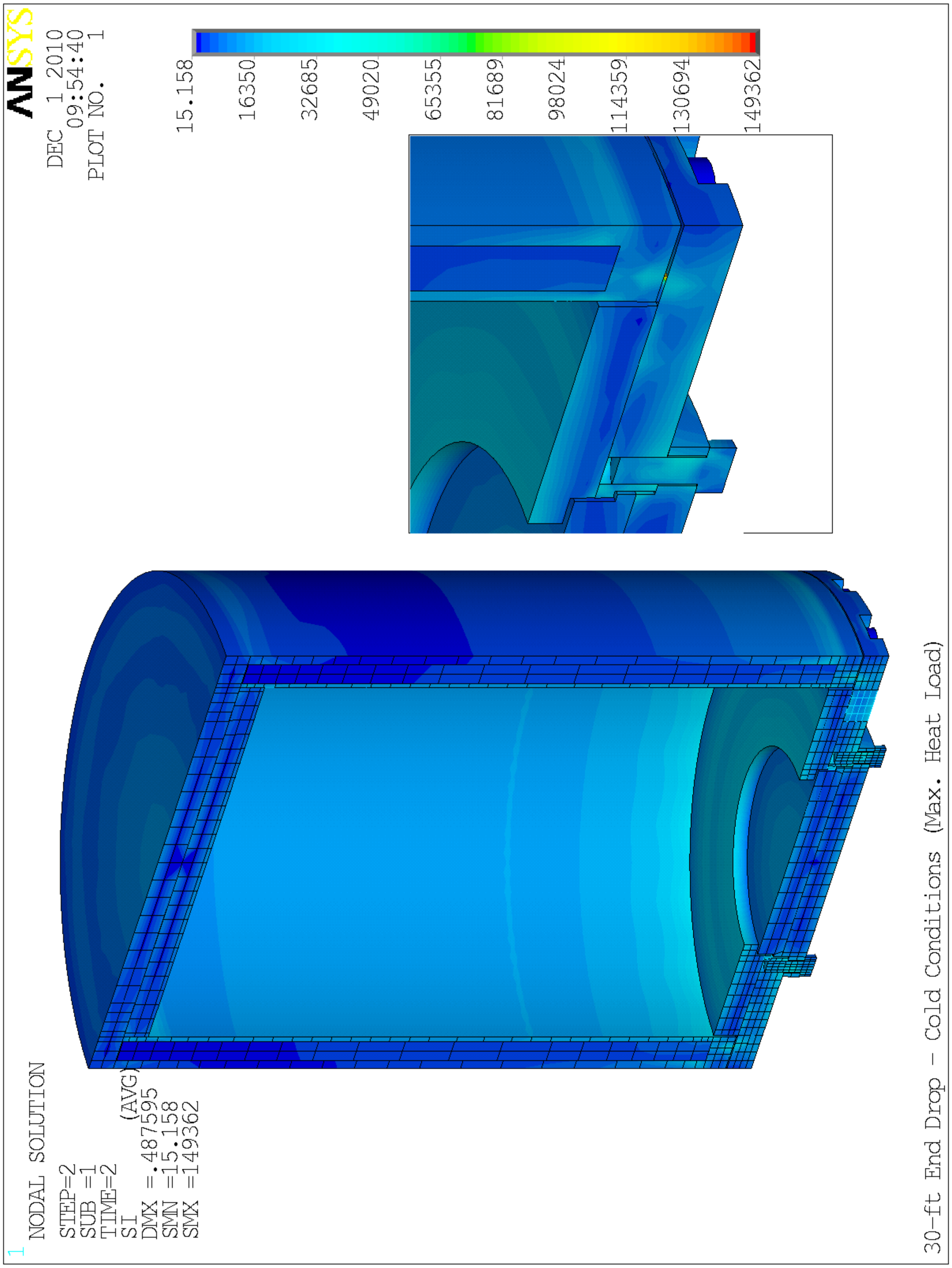


Figure 12

Stress Intensity Plot – 30-ft End Drop – Cold Condition (Max. Heat Load)

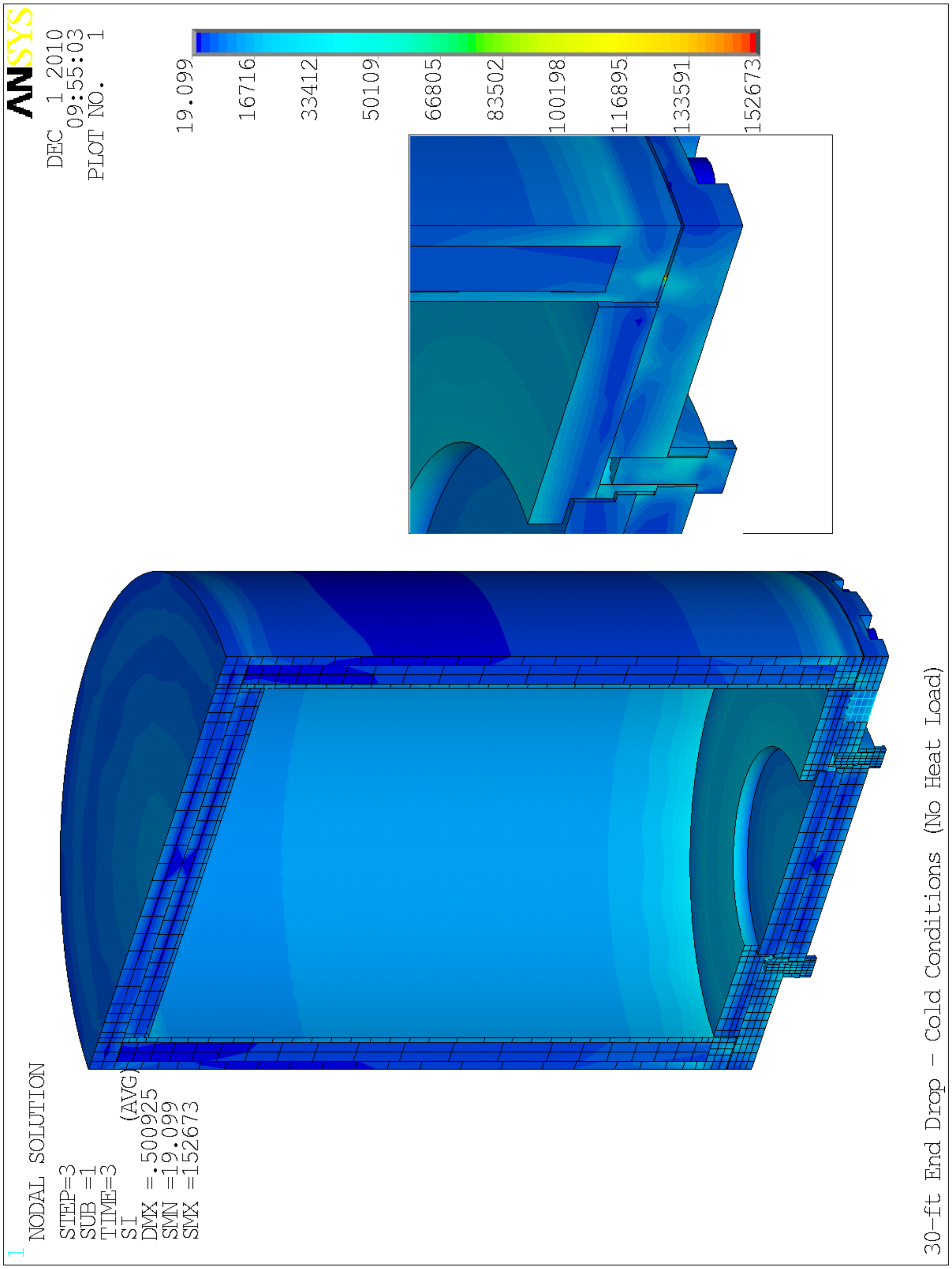


Figure 13

Stress Intensity Plot – 30-ft End Drop – Cold Condition (No Heat Load)

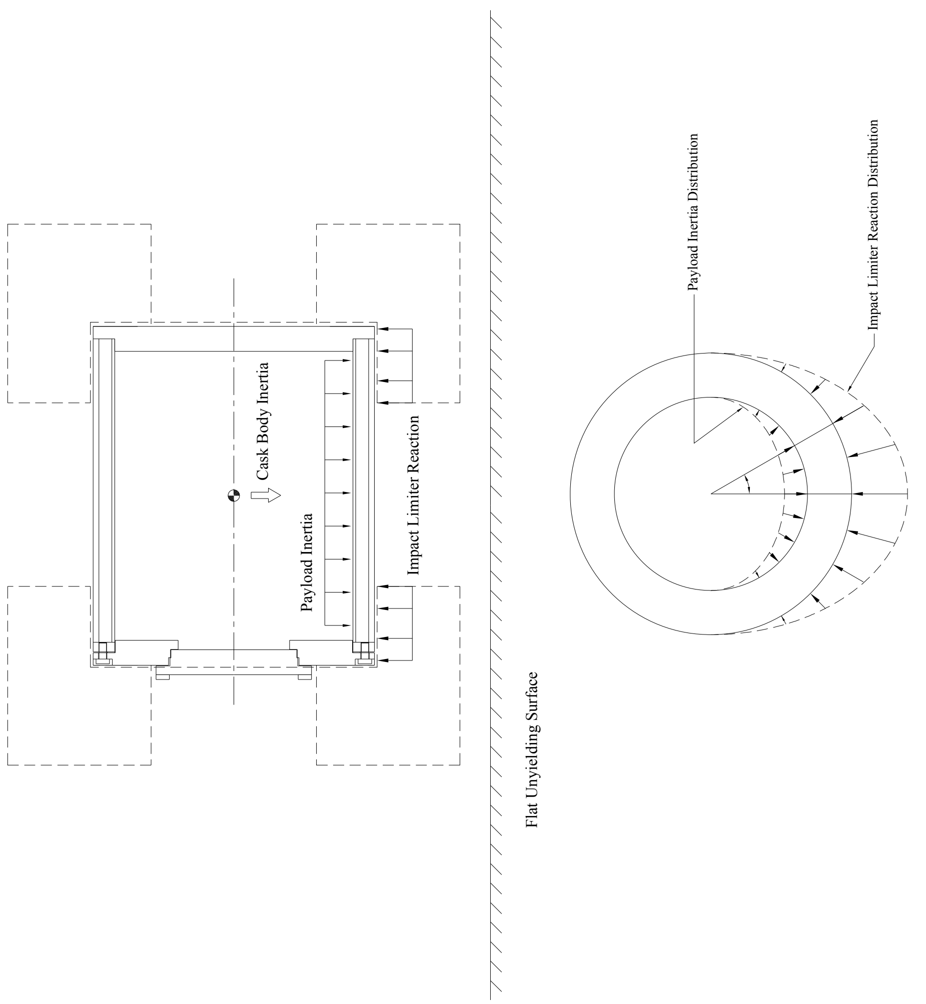


Figure 14

Load Distribution on the Model during Side Drop

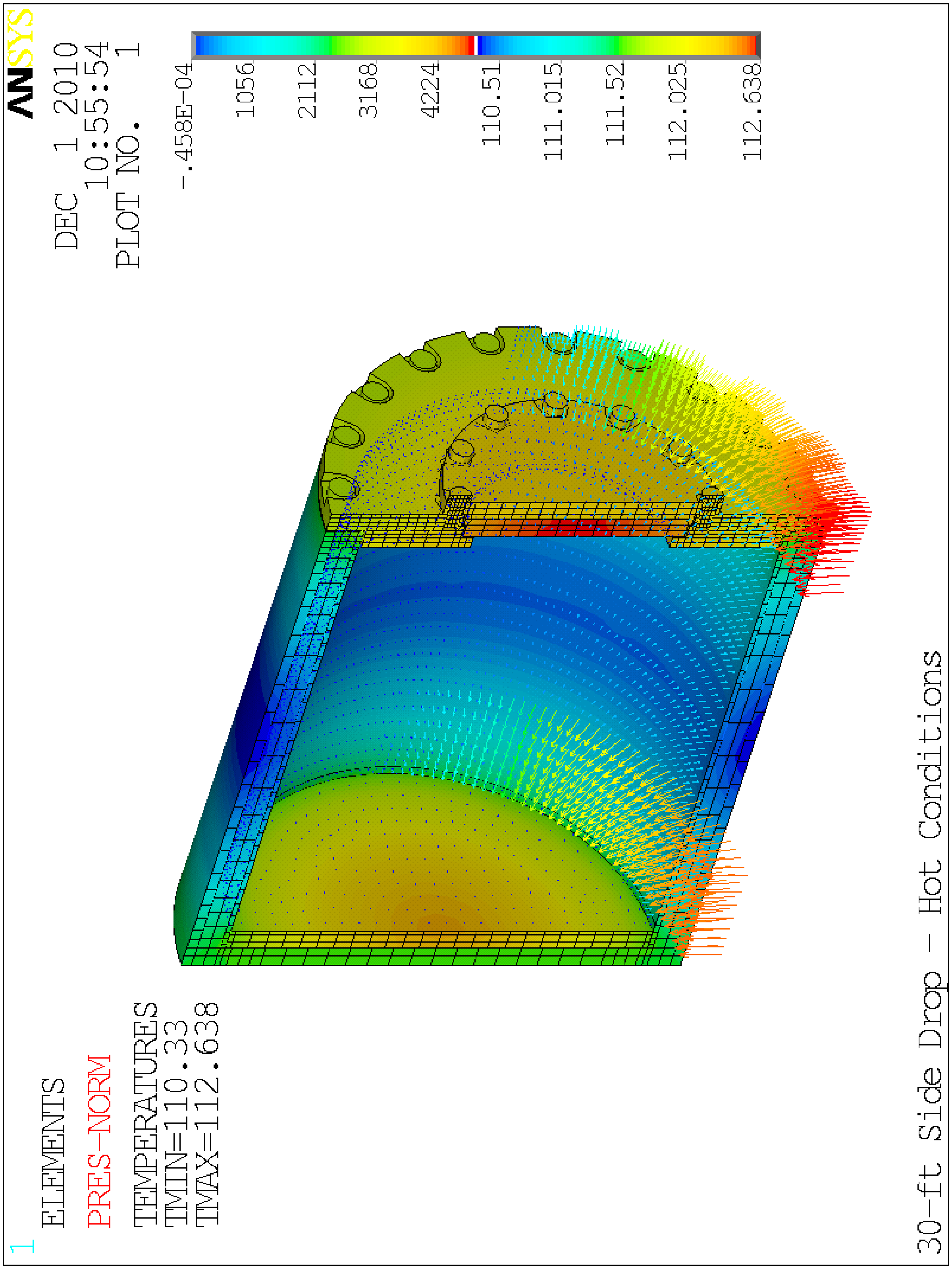


Figure 15
Temperature Profile and Pressure Distribution Used for 30-ft Side Drop – Hot Condition

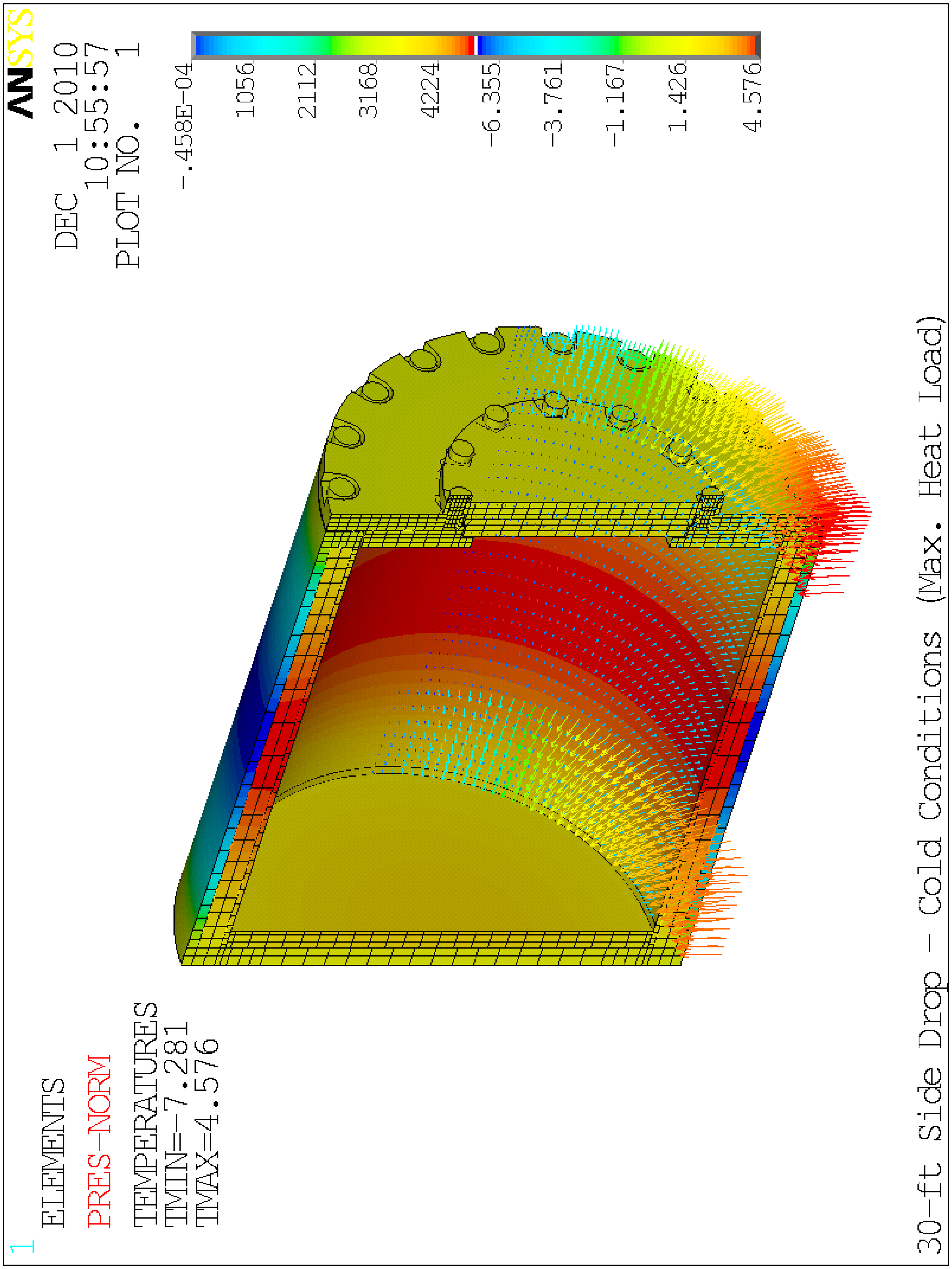


Figure 16

Temperature Profile and Pressure Distribution Used for 30-ft Side Drop – Cold Condition (Max. Heat Load)

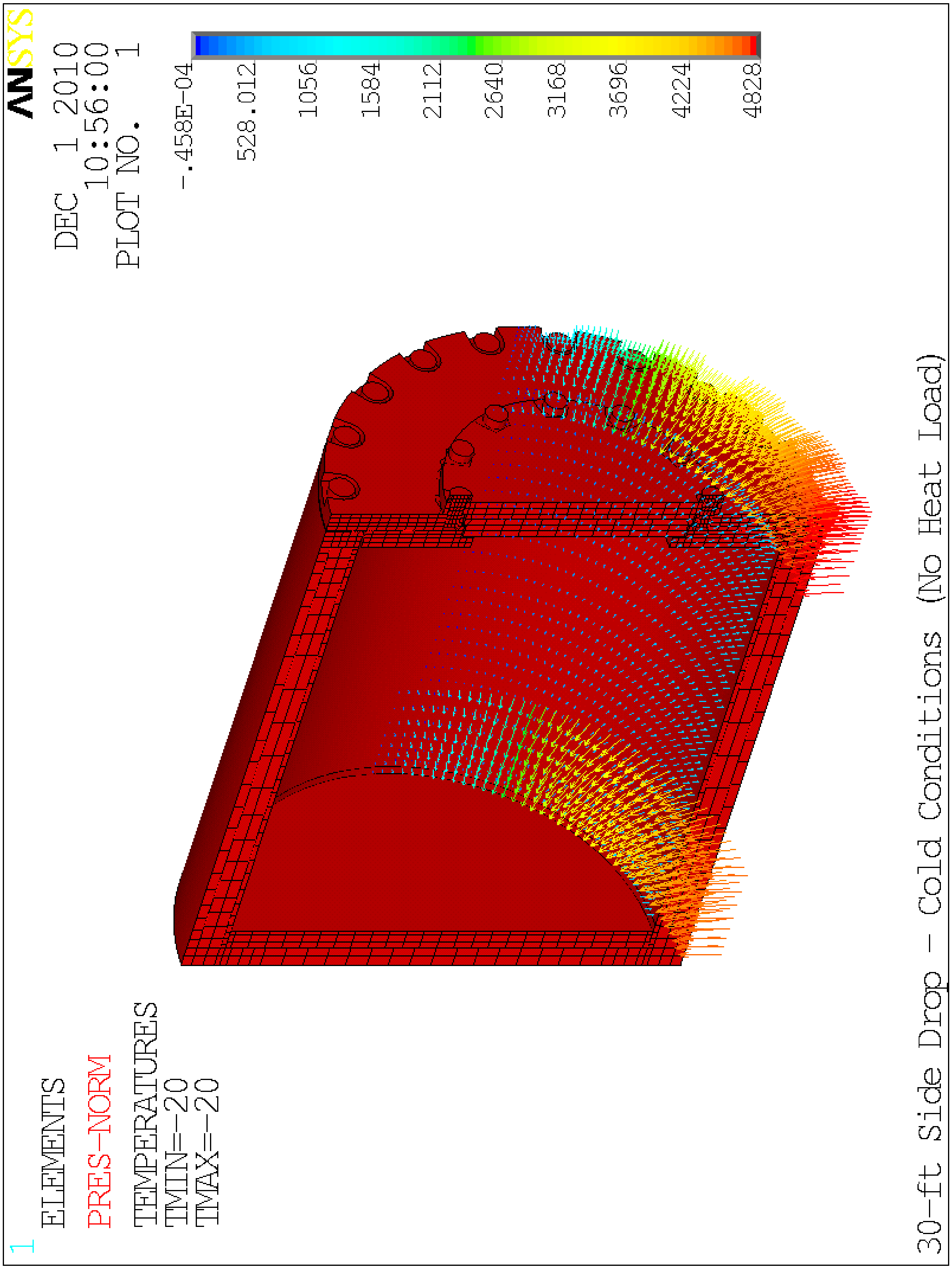


Figure 17

Temperature Profile and Pressure Distribution Used for 30-ft Side Drop – Cold Condition (No Heat Load)

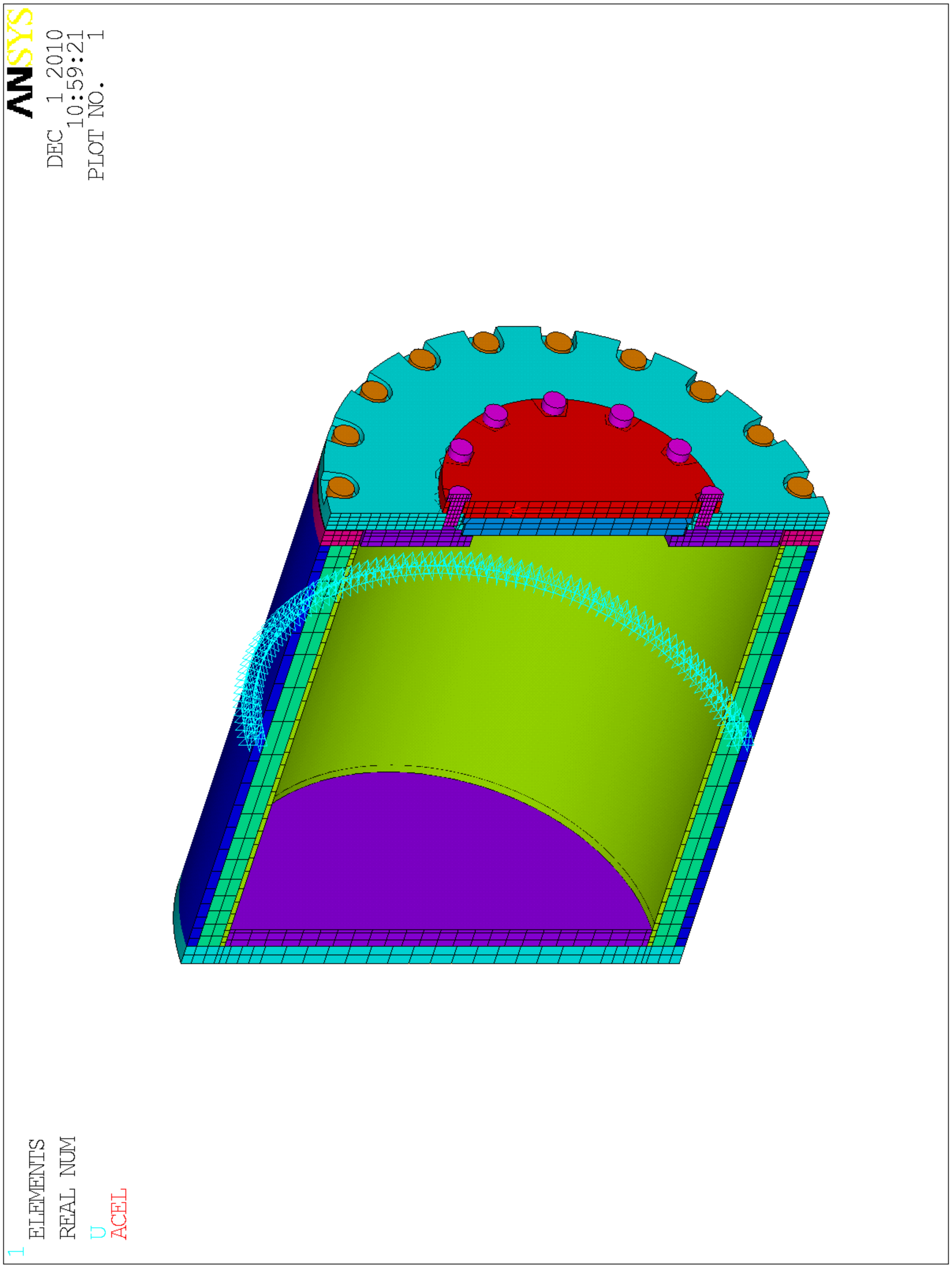


Figure 18

Stress Intensity Plot – 30-ft Side Drop – Displacement Boundary Conditions Used to Prevent Rigid Body Motion

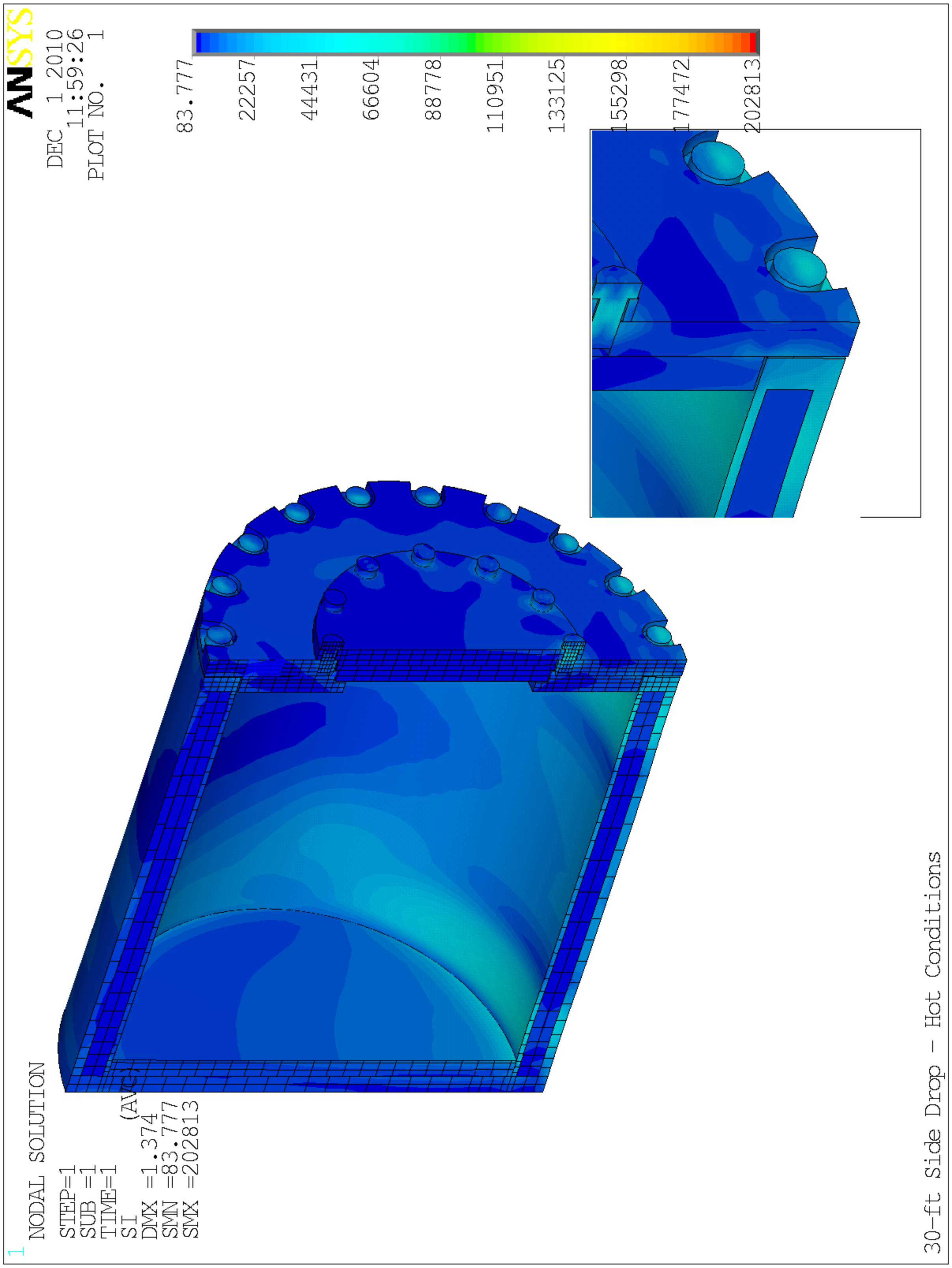


Figure 19

Stress Intensity Plot – 30-ft Side Drop – Hot Condition

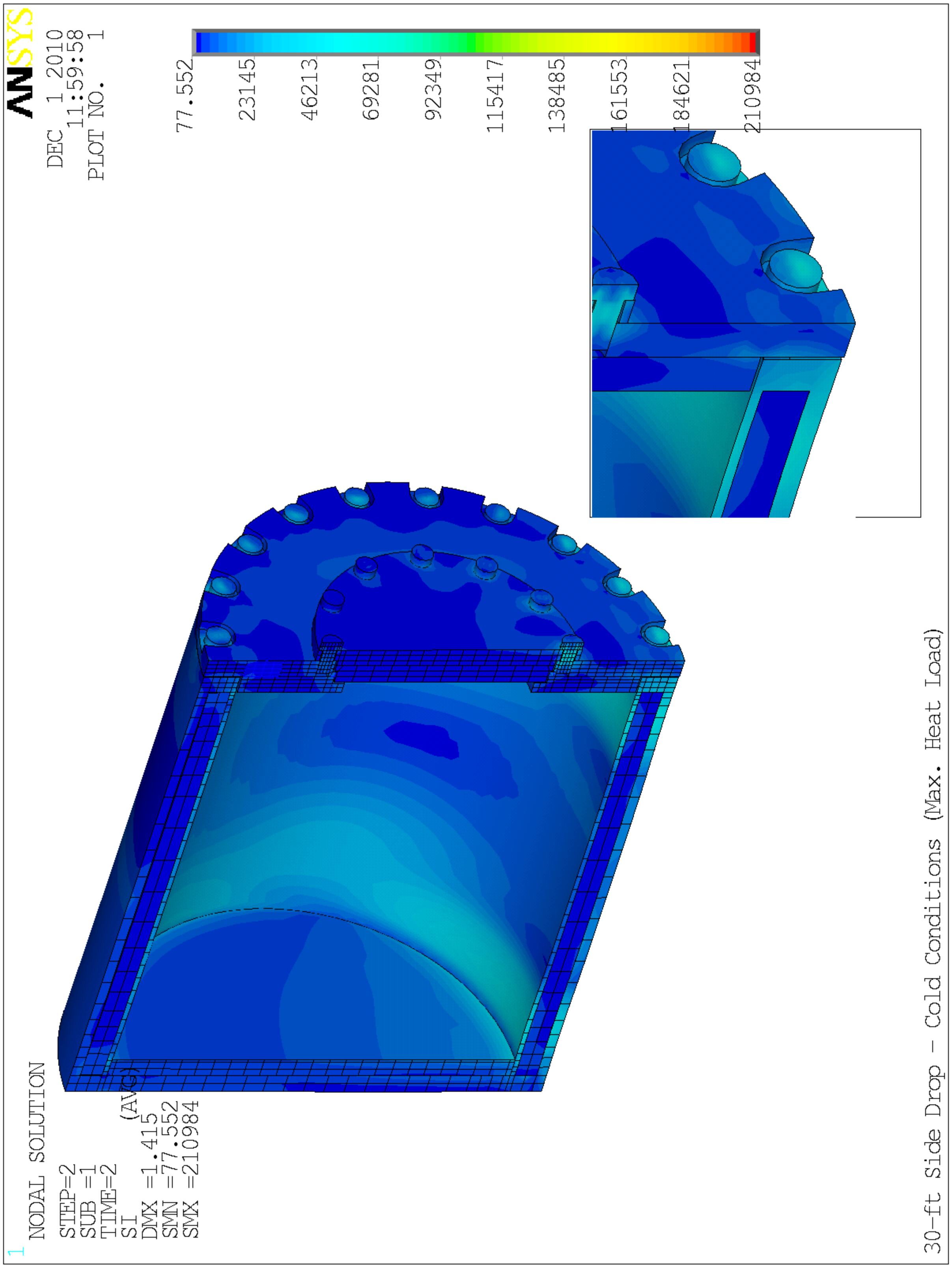


Figure 20
Stress Intensity Plot – 30-ft Side Drop – Cold Condition (Max. Heat Load)

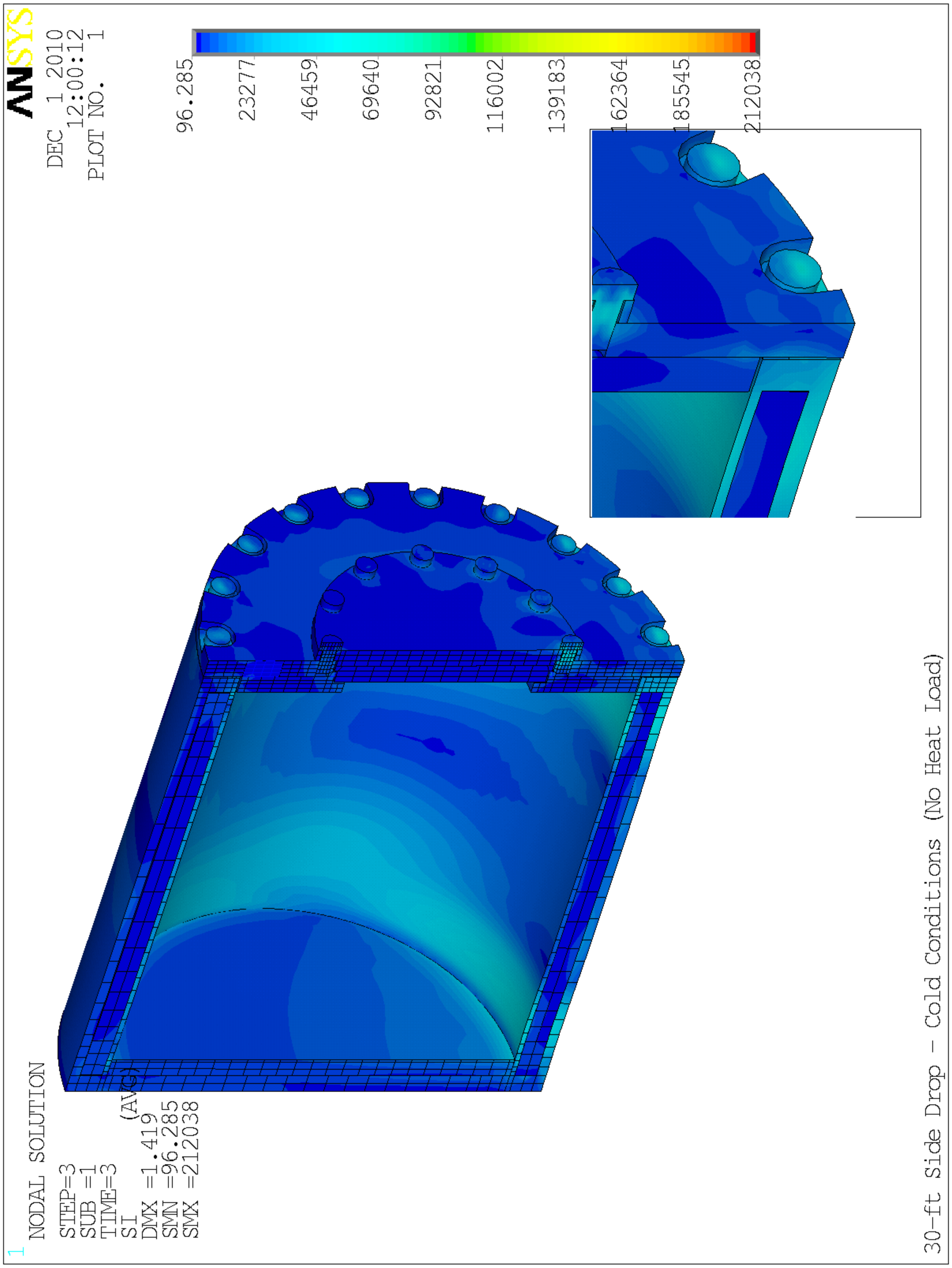


Figure 21

Stress Intensity Plot – 30-ft Side Drop – Cold Condition (No Heat Load)

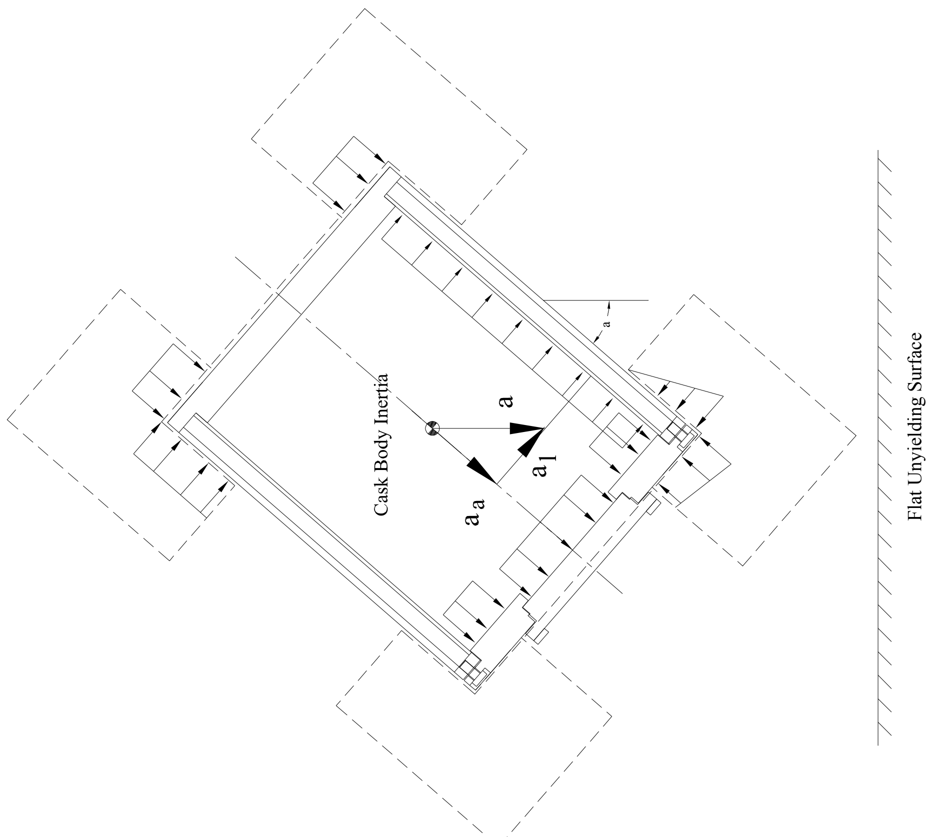


Figure 22

Load Distribution on the Model during Corner Drop

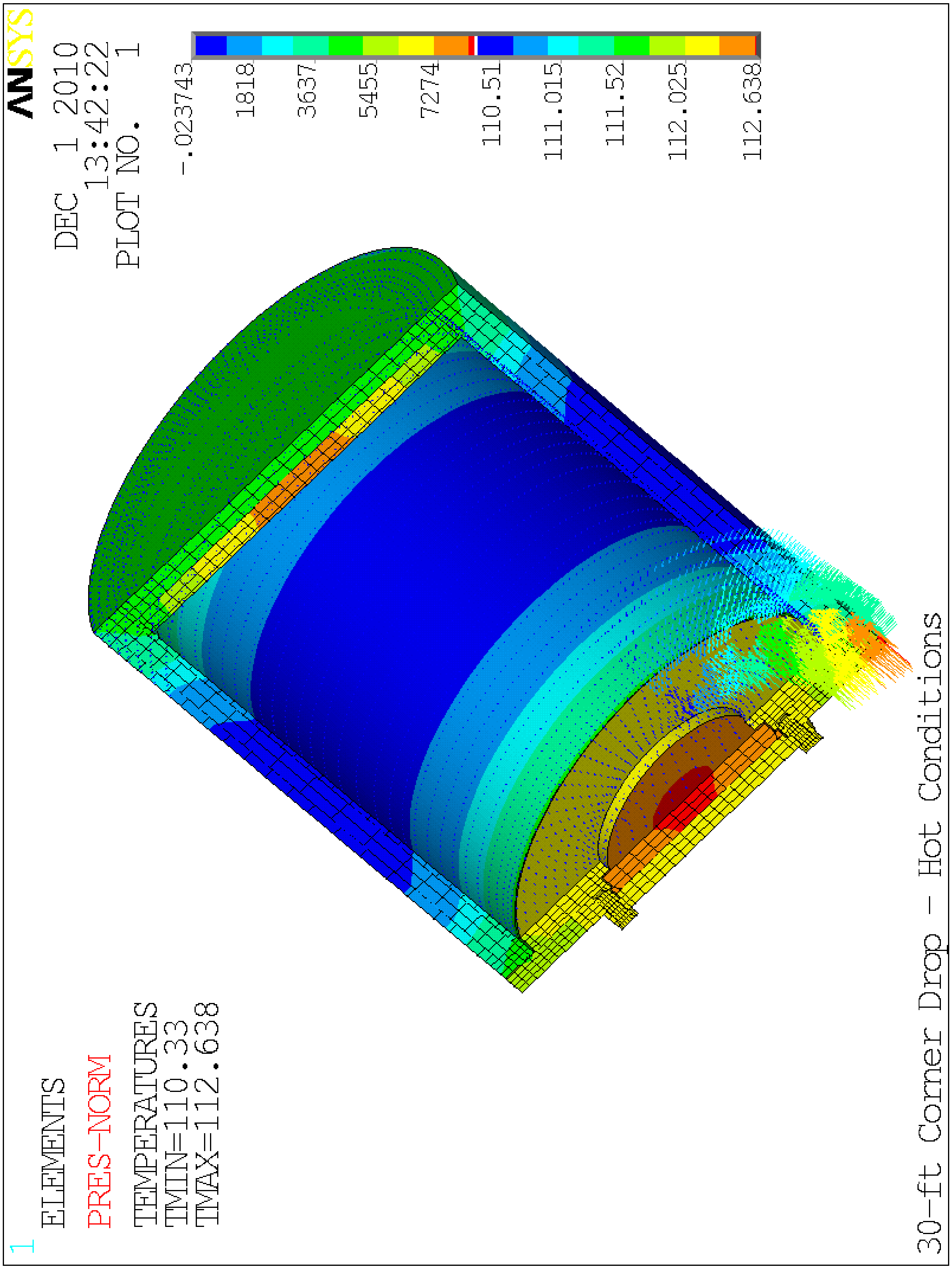


Figure 23

Temperature Profile and Pressure Distribution Used for 30-ft Corner Drop – Hot Condition

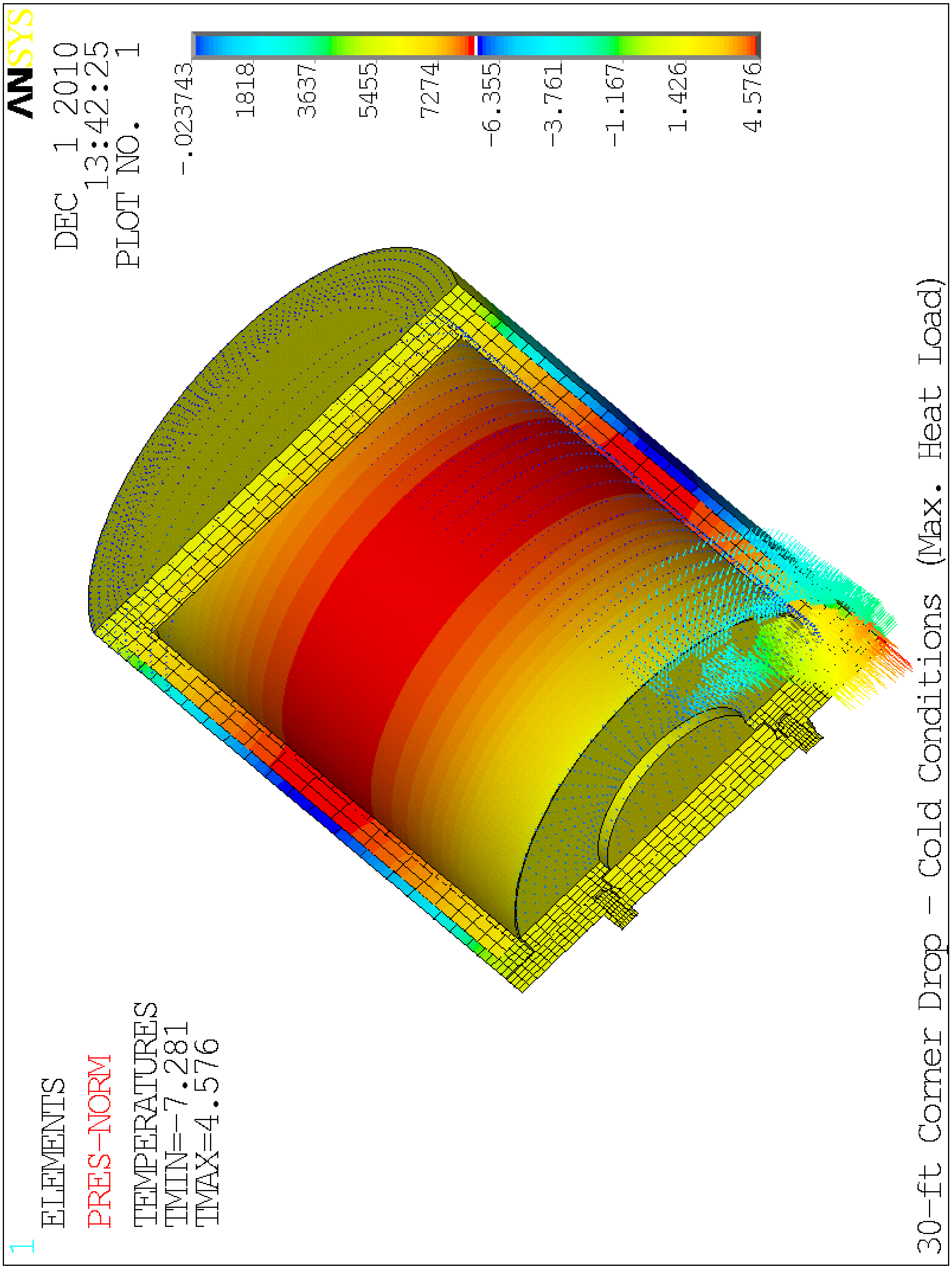


Figure 24

Temperature Profile and Pressure Distribution Used for 30-ft Corner Drop – Cold Condition (Max. Heat Load)

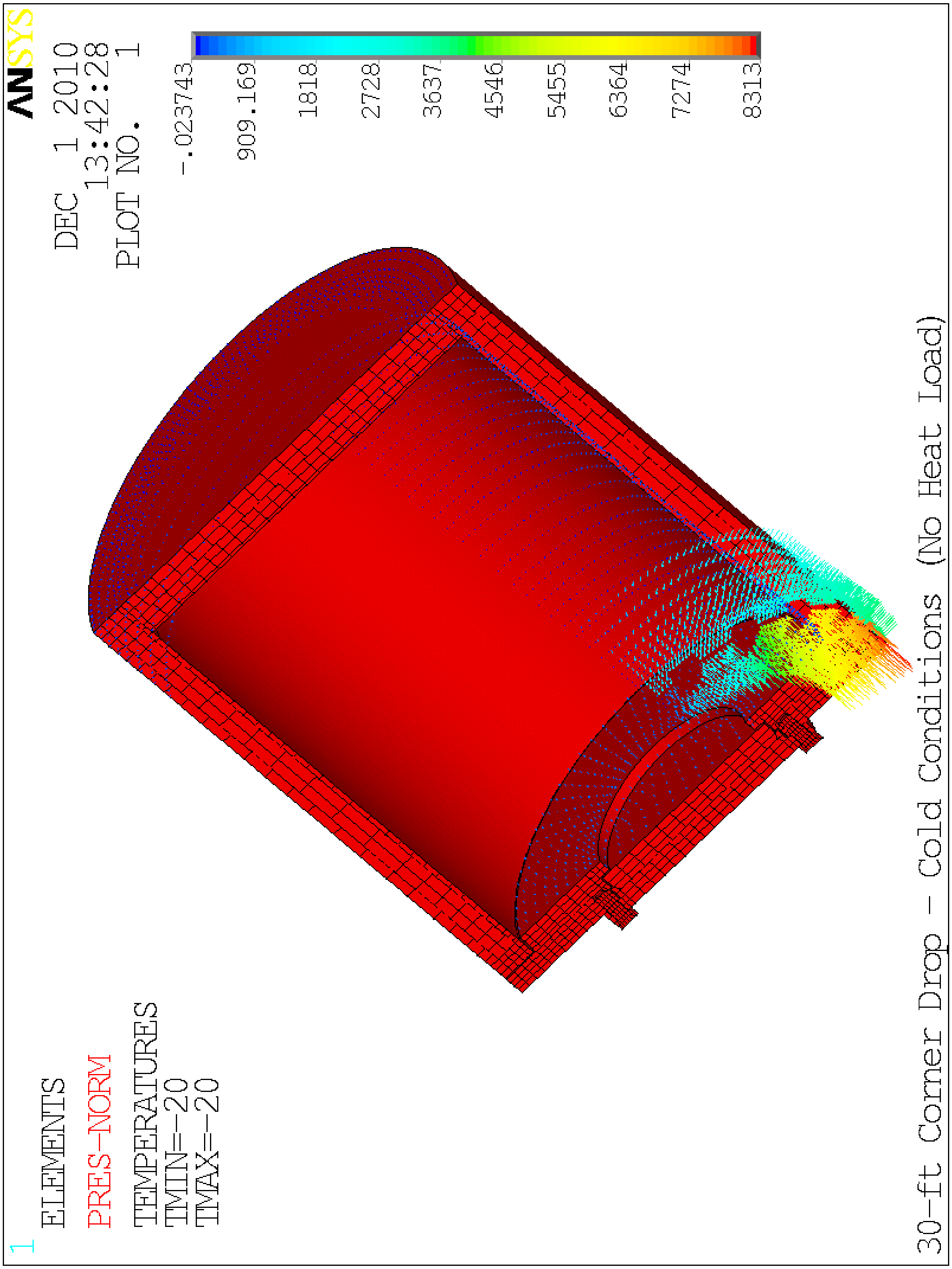


Figure 25

Temperature Profile and Pressure Distribution Used for 30-ft Corner Drop – Cold Condition (No Heat Load)

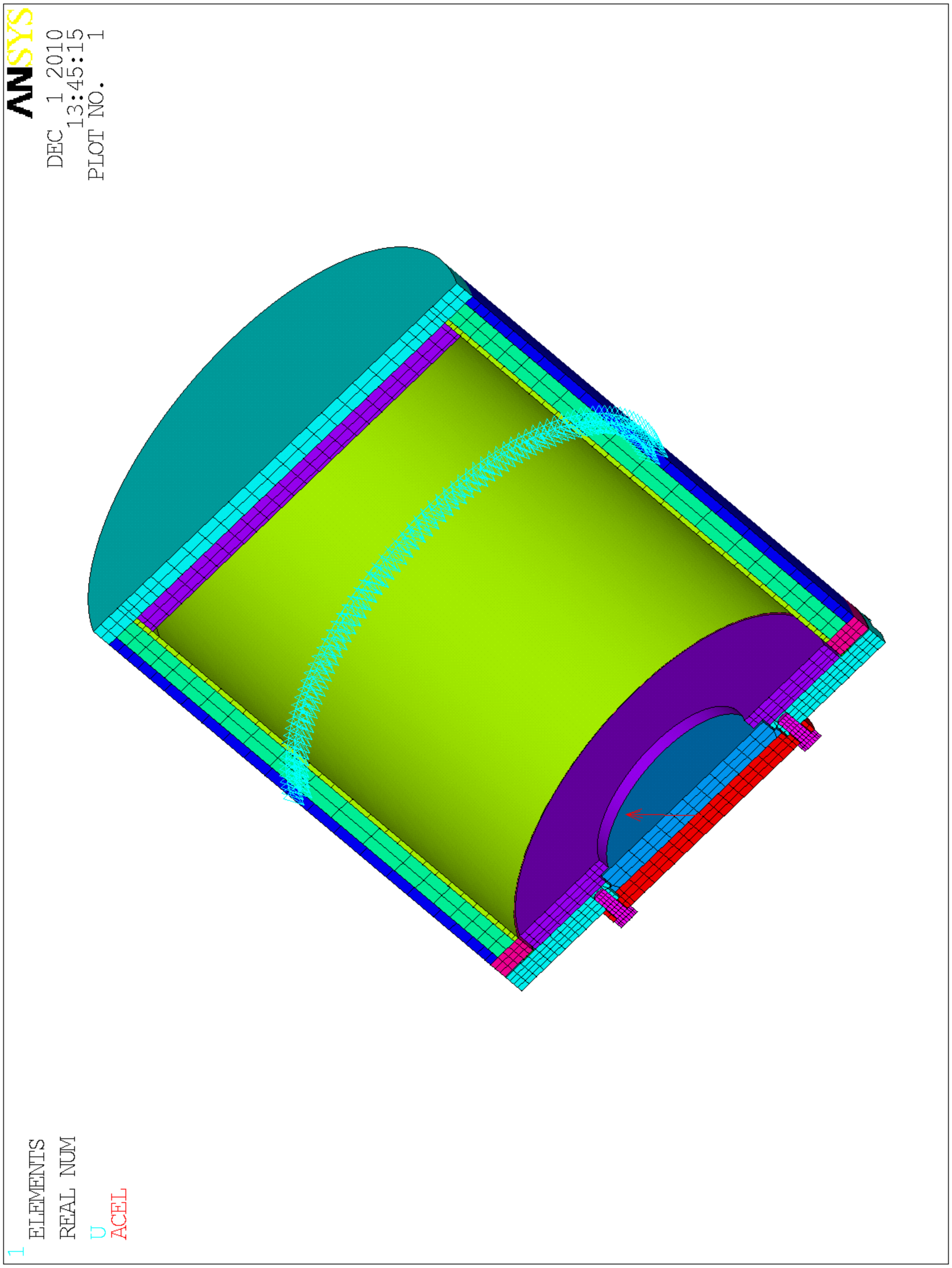


Figure 26

Stress Intensity Plot – 30-ft Corner Drop – Displacement Boundary Conditions Used to Prevent Rigid Body Motion

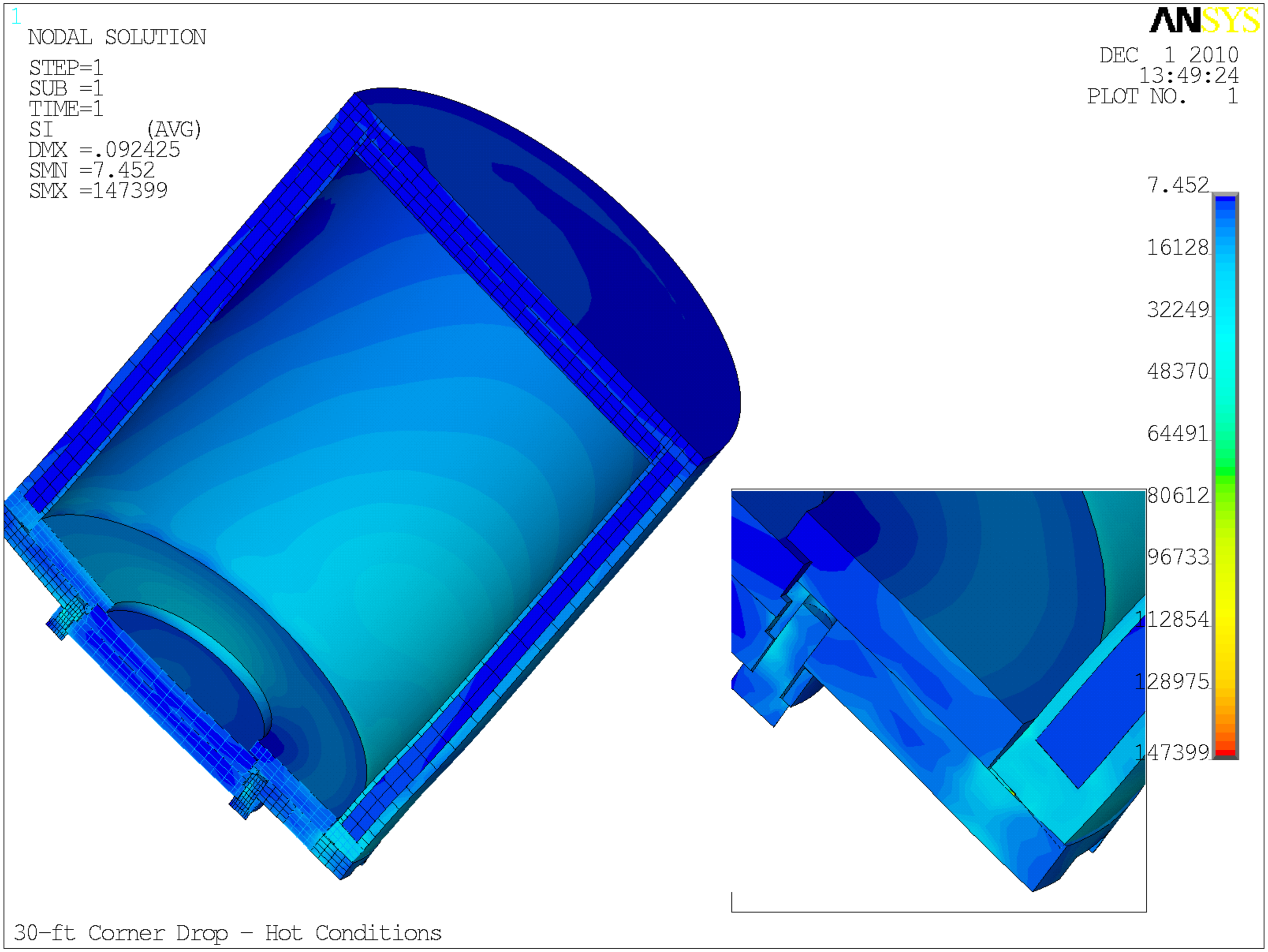


Figure 27

Stress Intensity Plot – 30-ft Corner Drop – Hot Condition

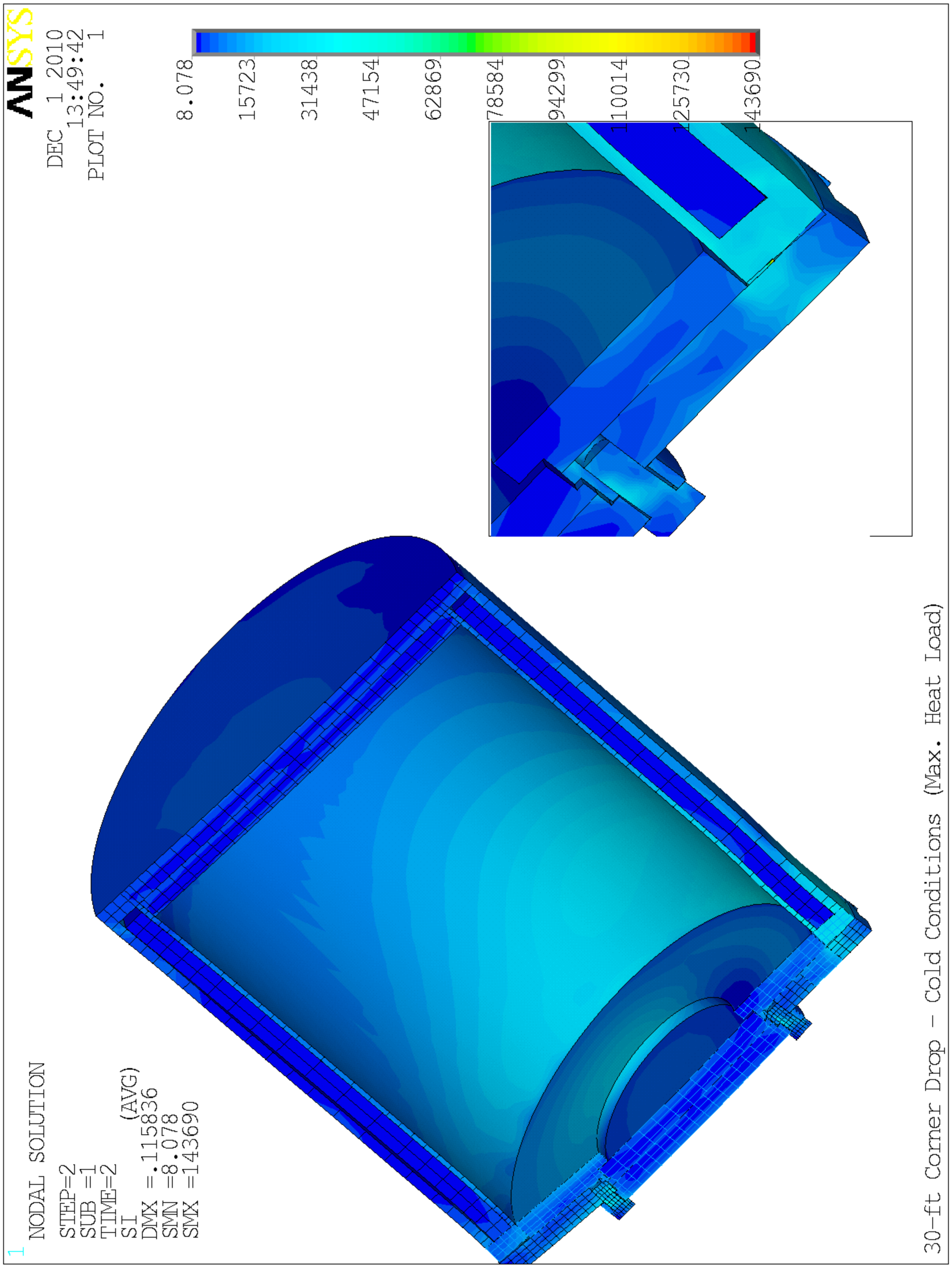


Figure 28

Stress Intensity Plot – 30-ft Corner Drop – Cold Condition (Max. Heat Load)

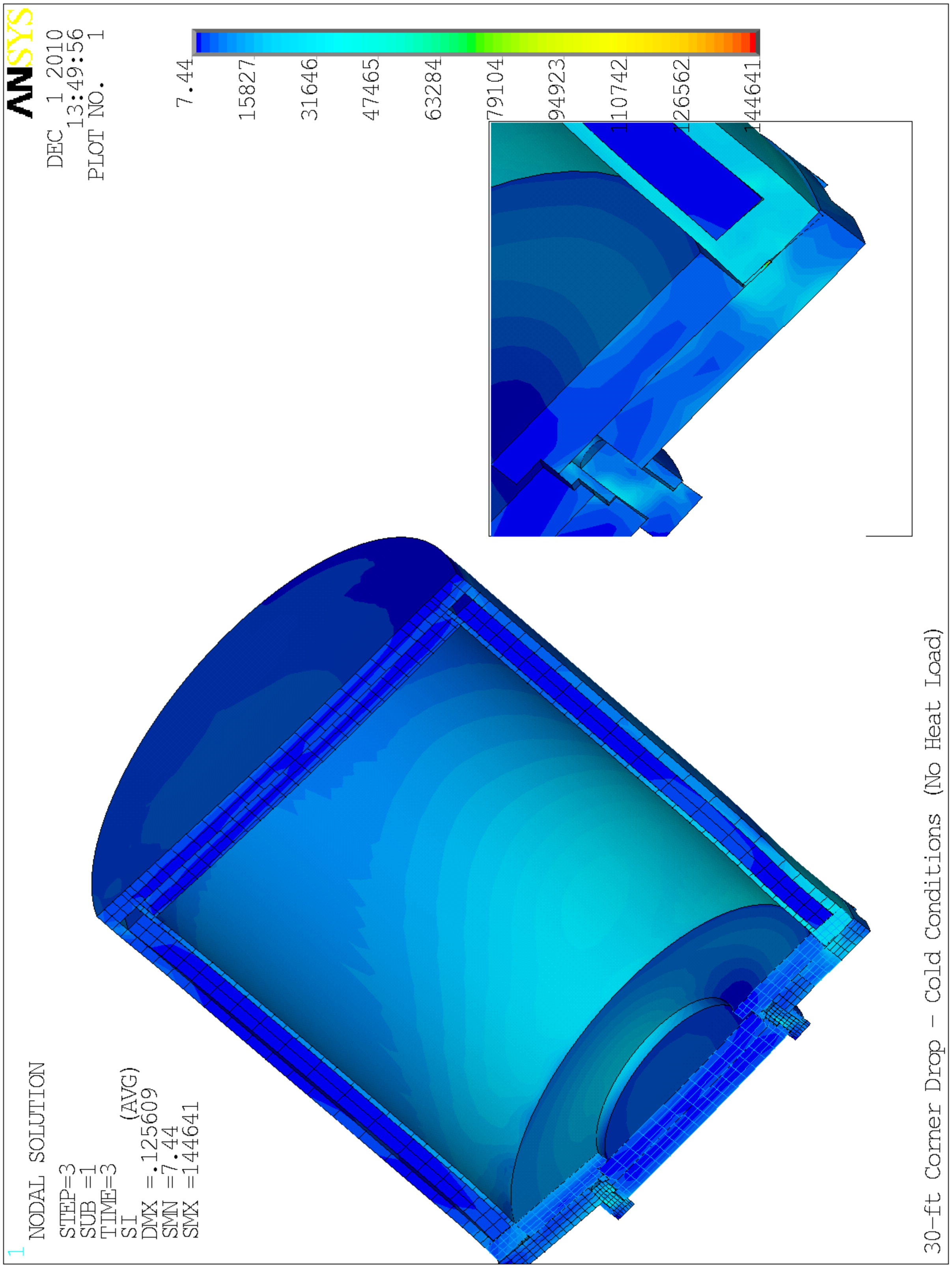


Figure 29

Stress Intensity Plot – 30-ft Corner Drop – Cold Condition (No Heat Load)

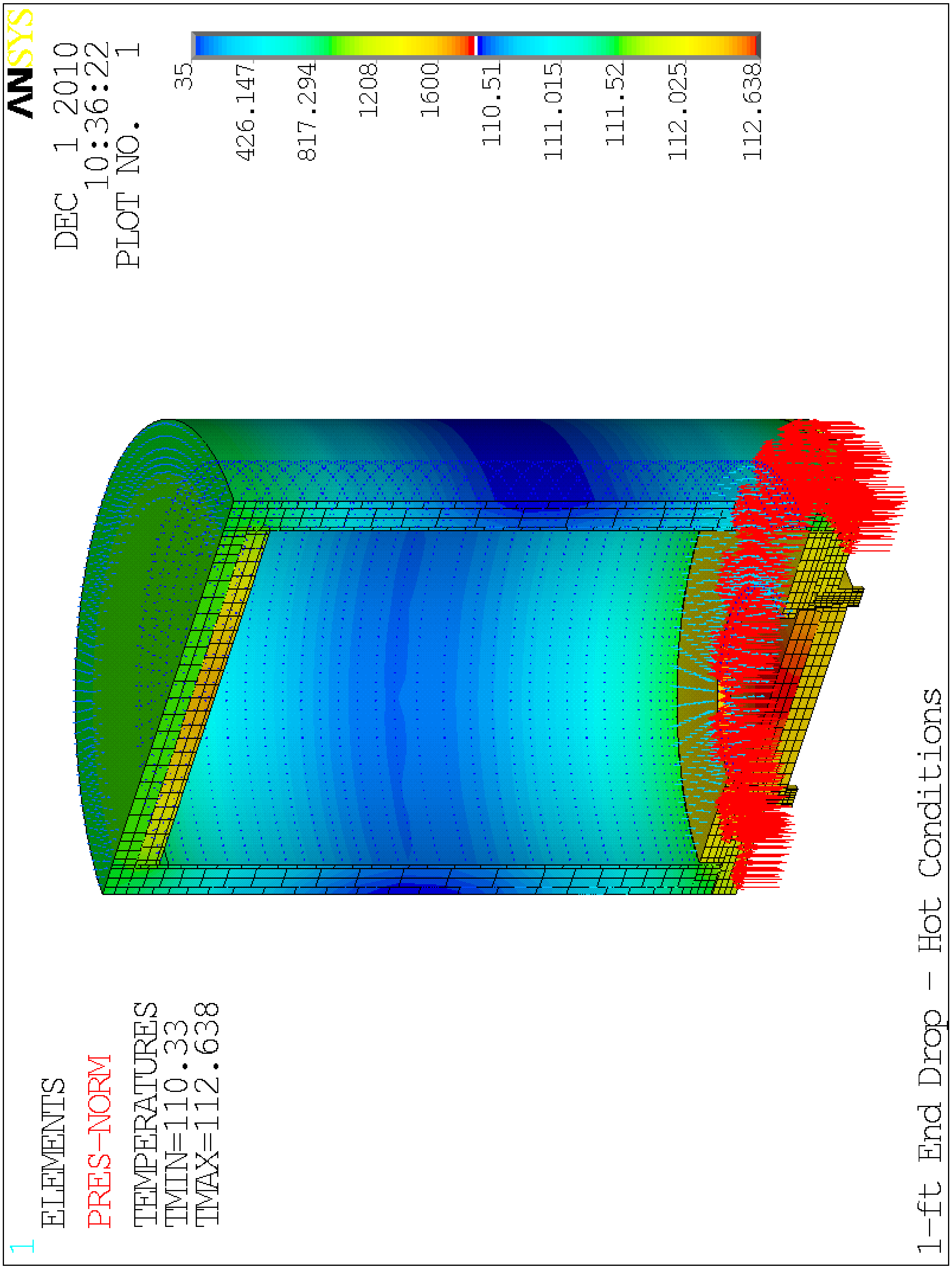


Figure 30

Temperature Profile and Pressure Distribution Used for 1-ft End Drop – Hot Condition

Title	Structural Analyses of the 8-120B Cask Under Drop Conditions
Calc. No. ST-627 (Figures)	**Rev.** 1	**Sheet** 31 of 55

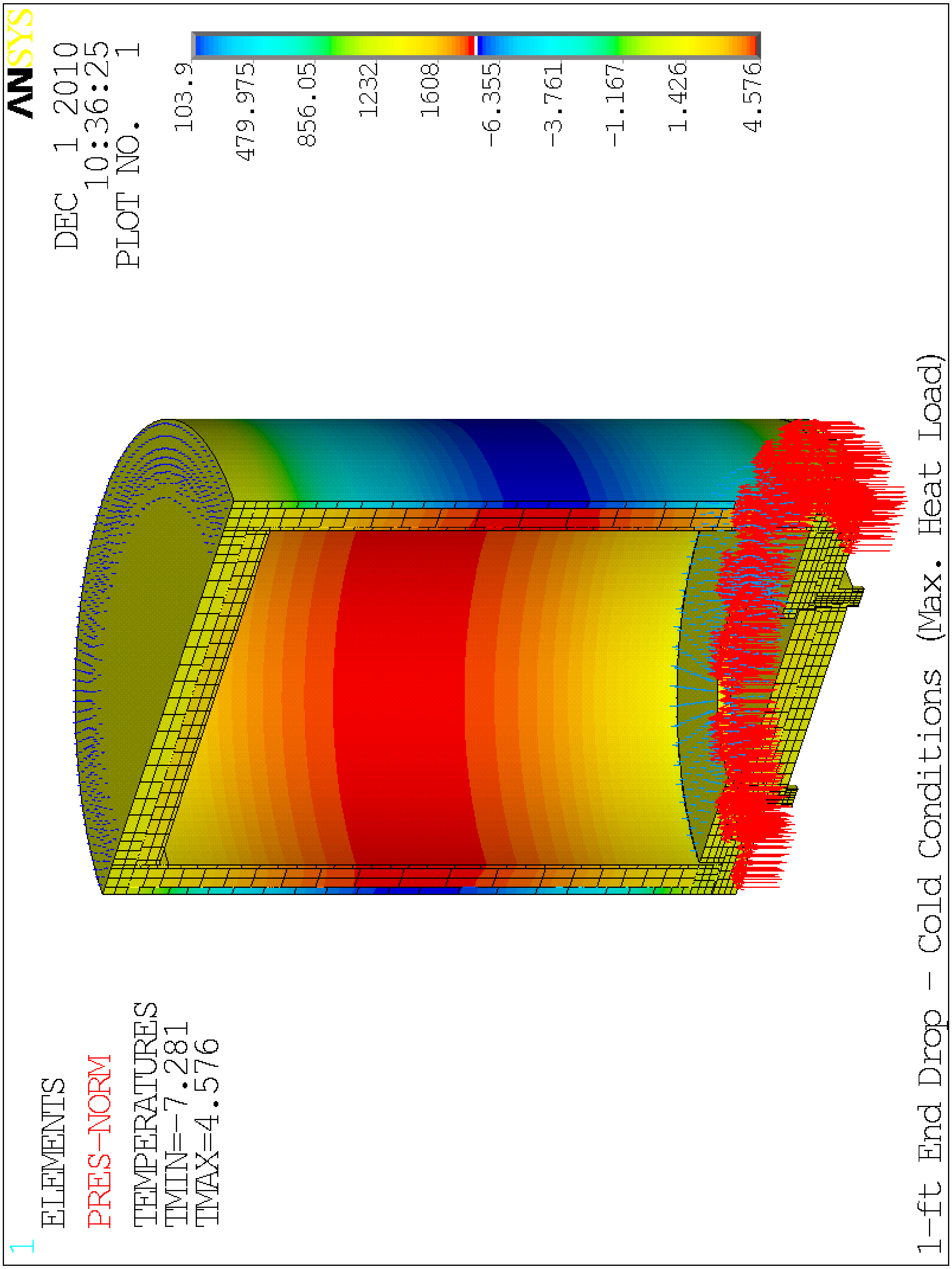


Figure 31

Temperature Profile and Pressure Distribution Used for 1-ft End Drop – Cold Condition (Max. Heat Load)

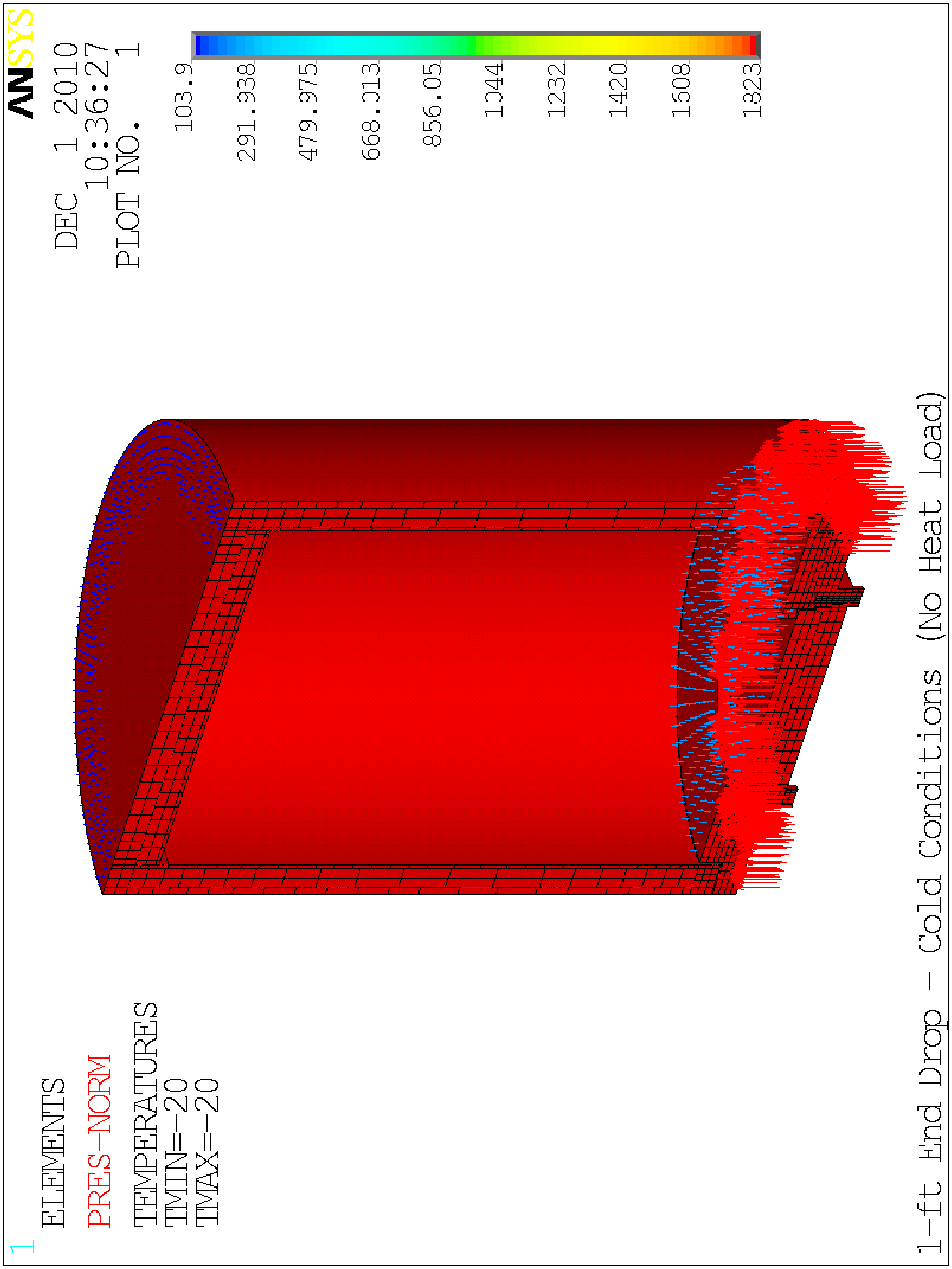


Figure 32

Temperature Profile and Pressure Distribution Used for 1-ft End Drop – Cold Condition (No Heat Load)

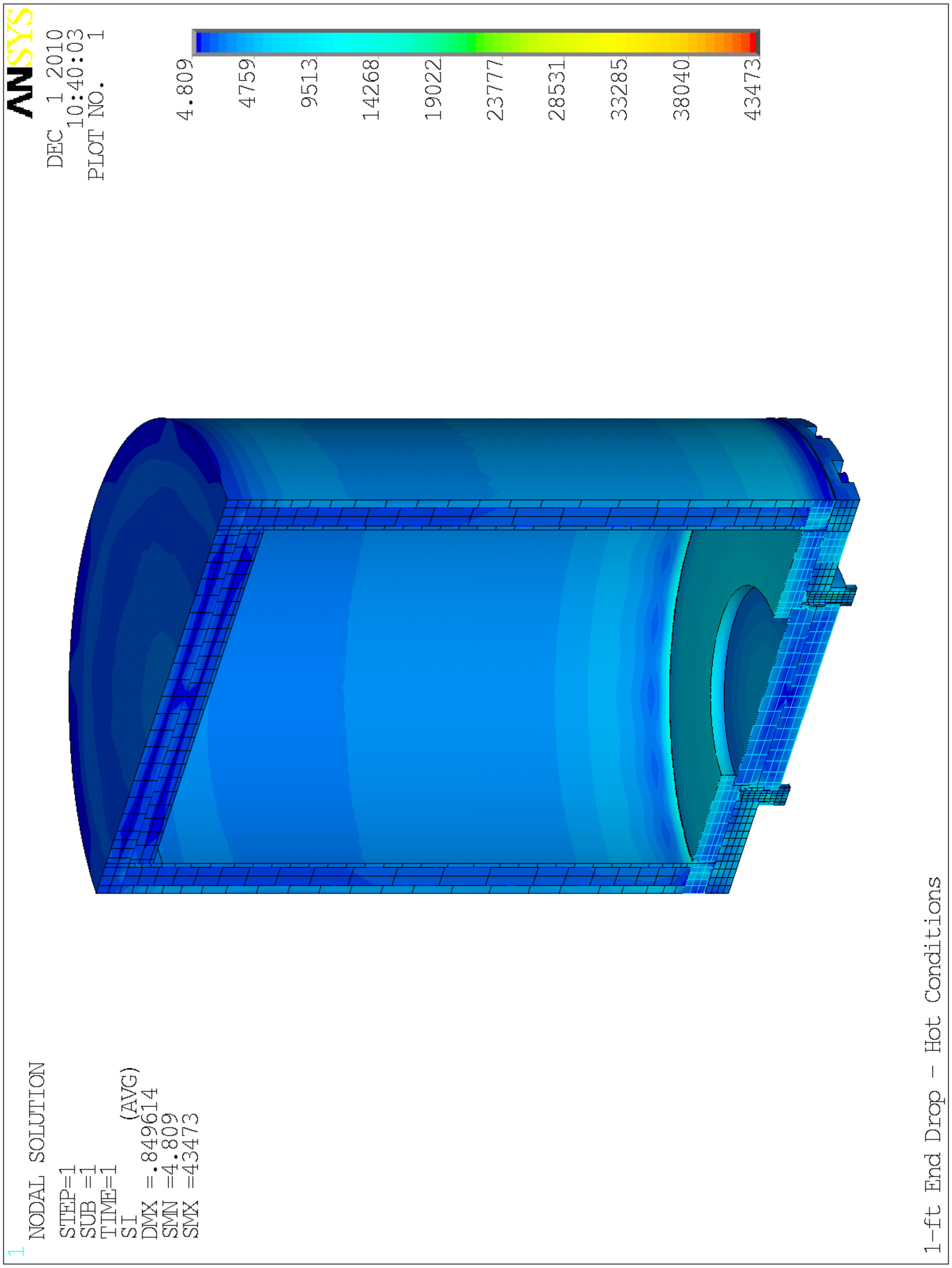


Figure 33

Stress Intensity Plot – 1-ft End Drop – Hot Condition

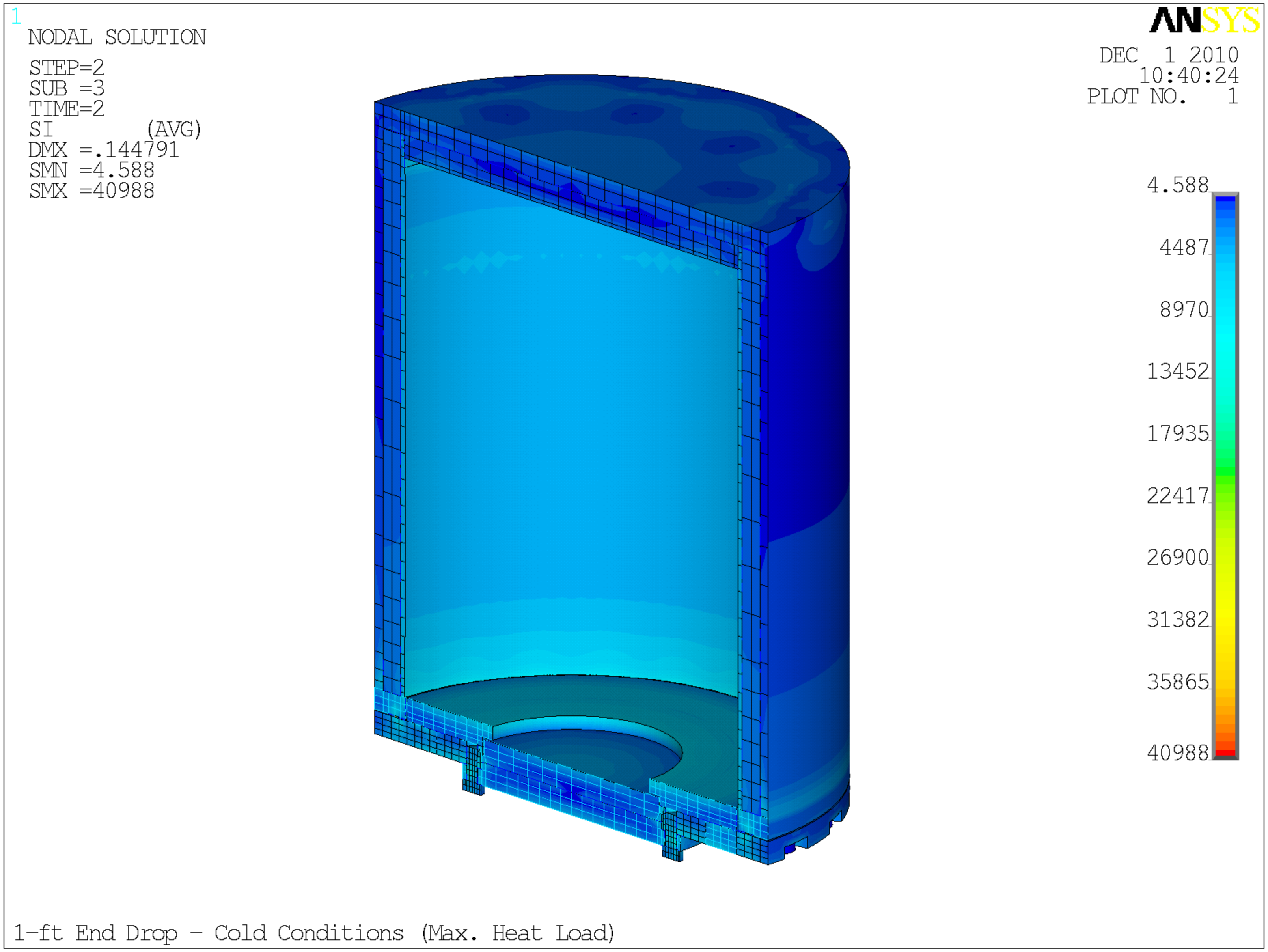


Figure 34

Stress Intensity Plot – 1-ft End Drop – Cold Condition (Max. Heat Load)

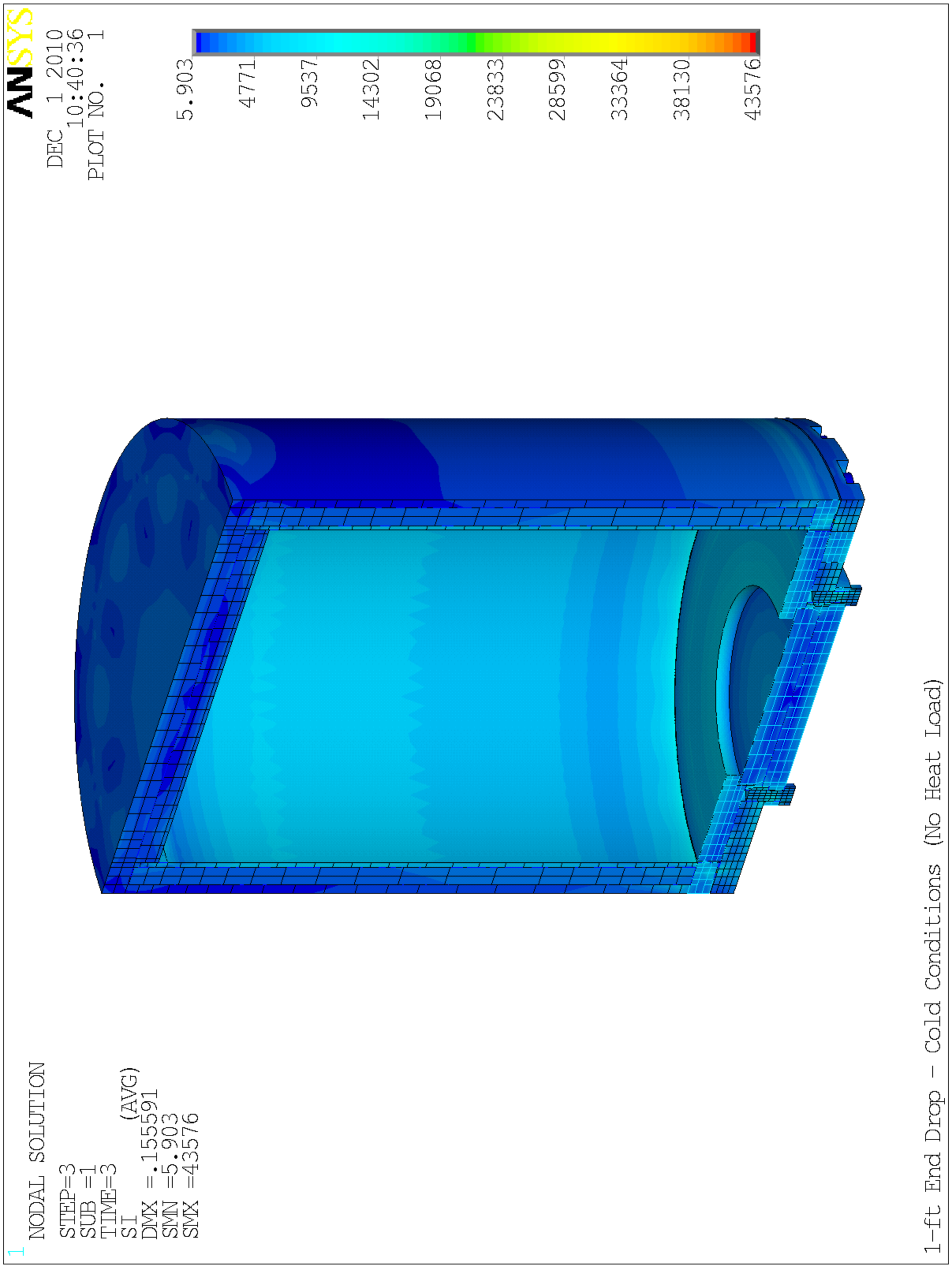


Figure 35

Stress Intensity Plot – 1-ft End Drop – Cold Condition (No Heat Load)

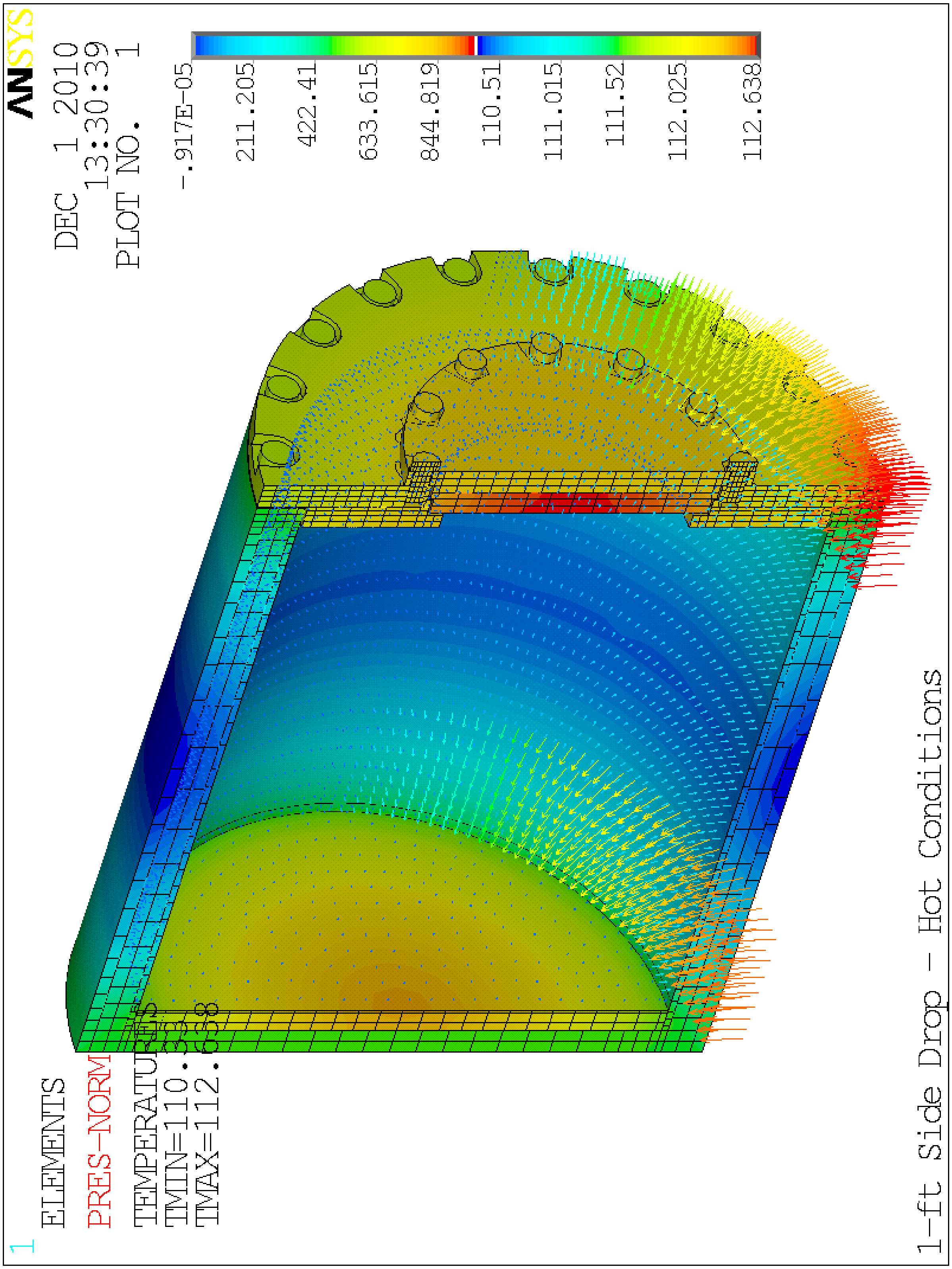


Figure 36

Temperature Profile and Pressure Distribution Used for 1-ft Side Drop – Hot Condition

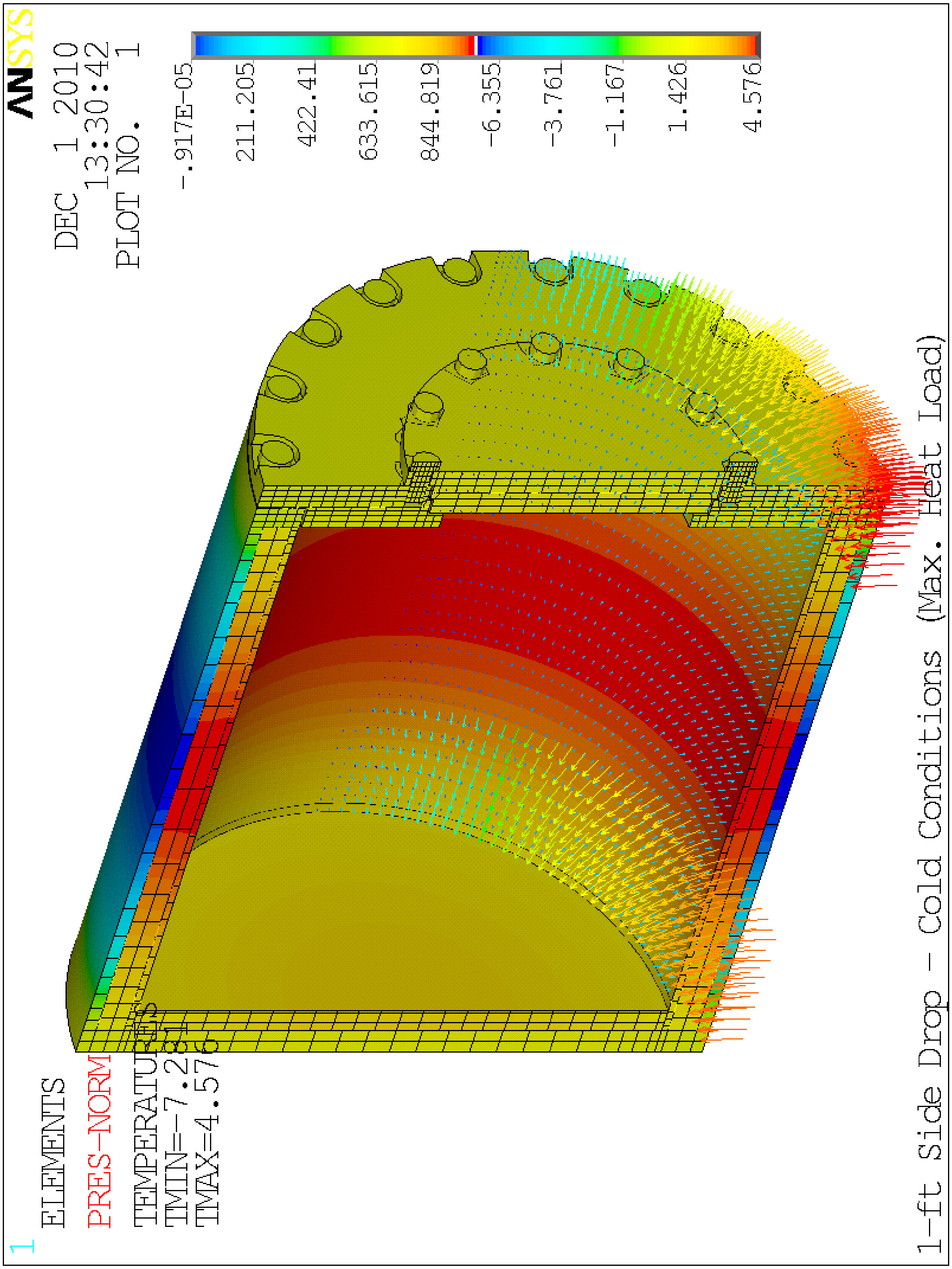


Figure 37

Temperature Profile and Pressure Distribution Used for 1-ft Side Drop – Cold Condition (Max. Heat Load)

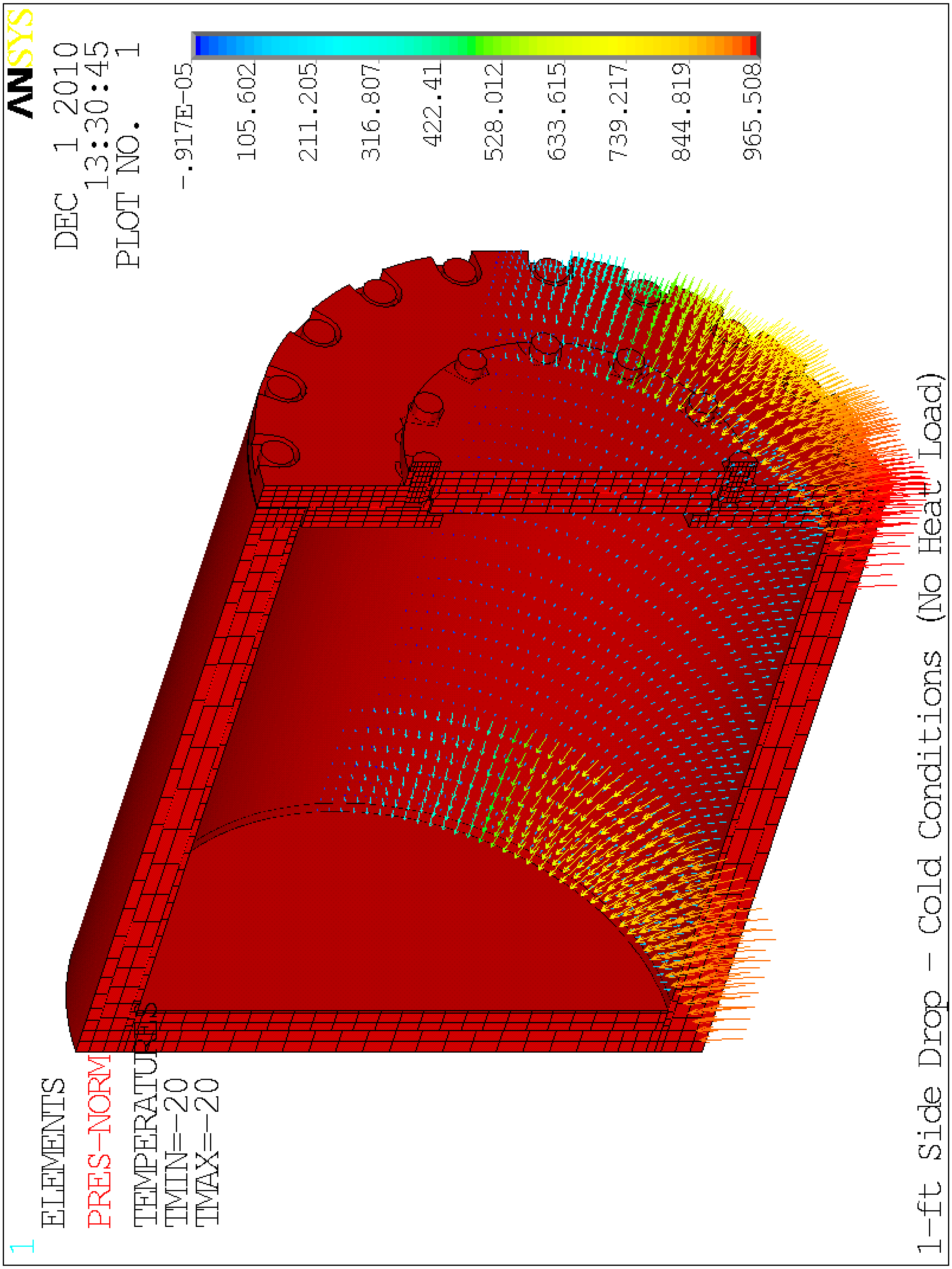


Figure 38

Temperature Profile and Pressure Distribution Used for 1-ft Side Drop – Cold Condition (No Heat Load)

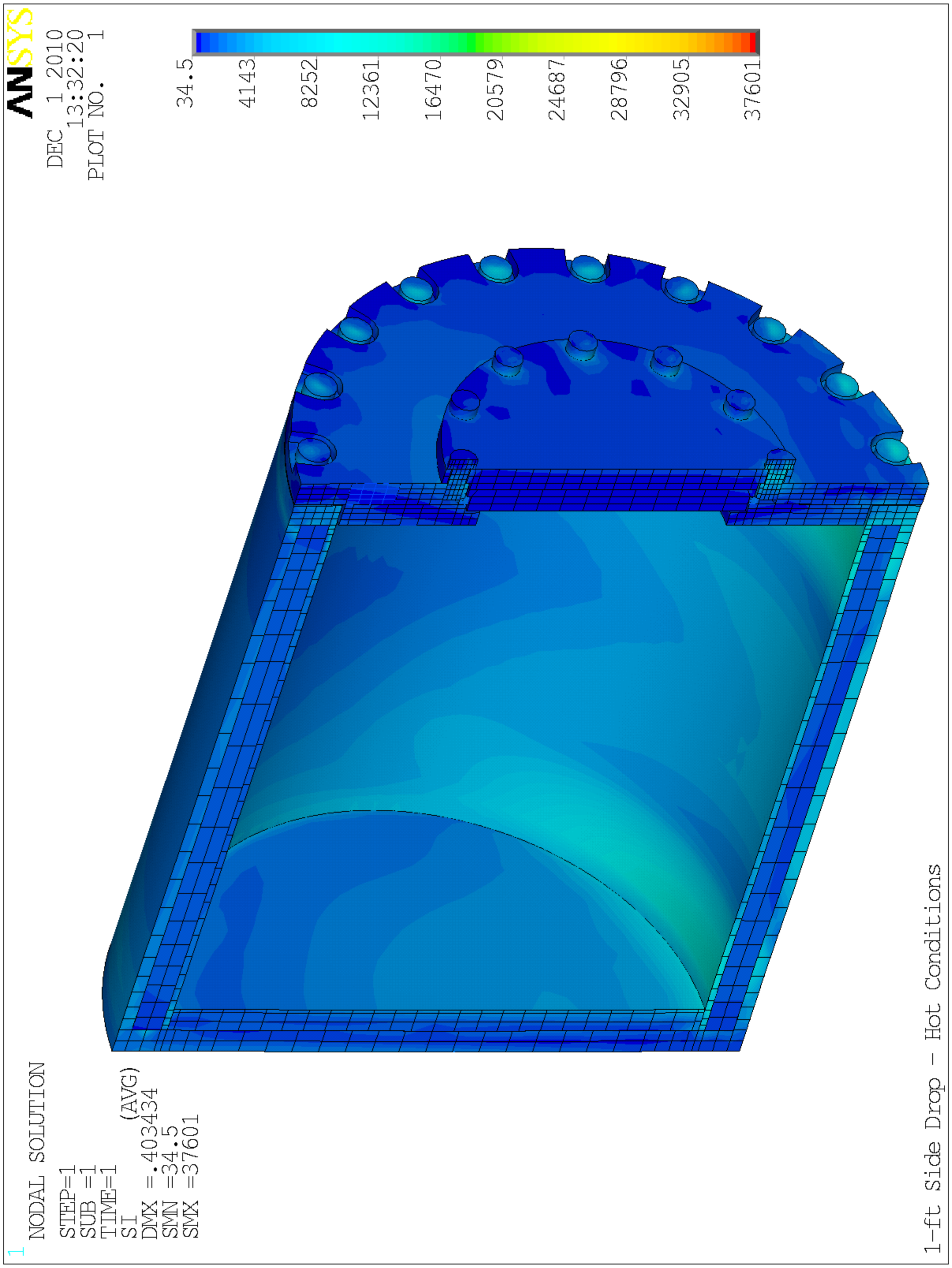


Figure 39

Stress Intensity Plot – 1-ft Side Drop – Hot Condition

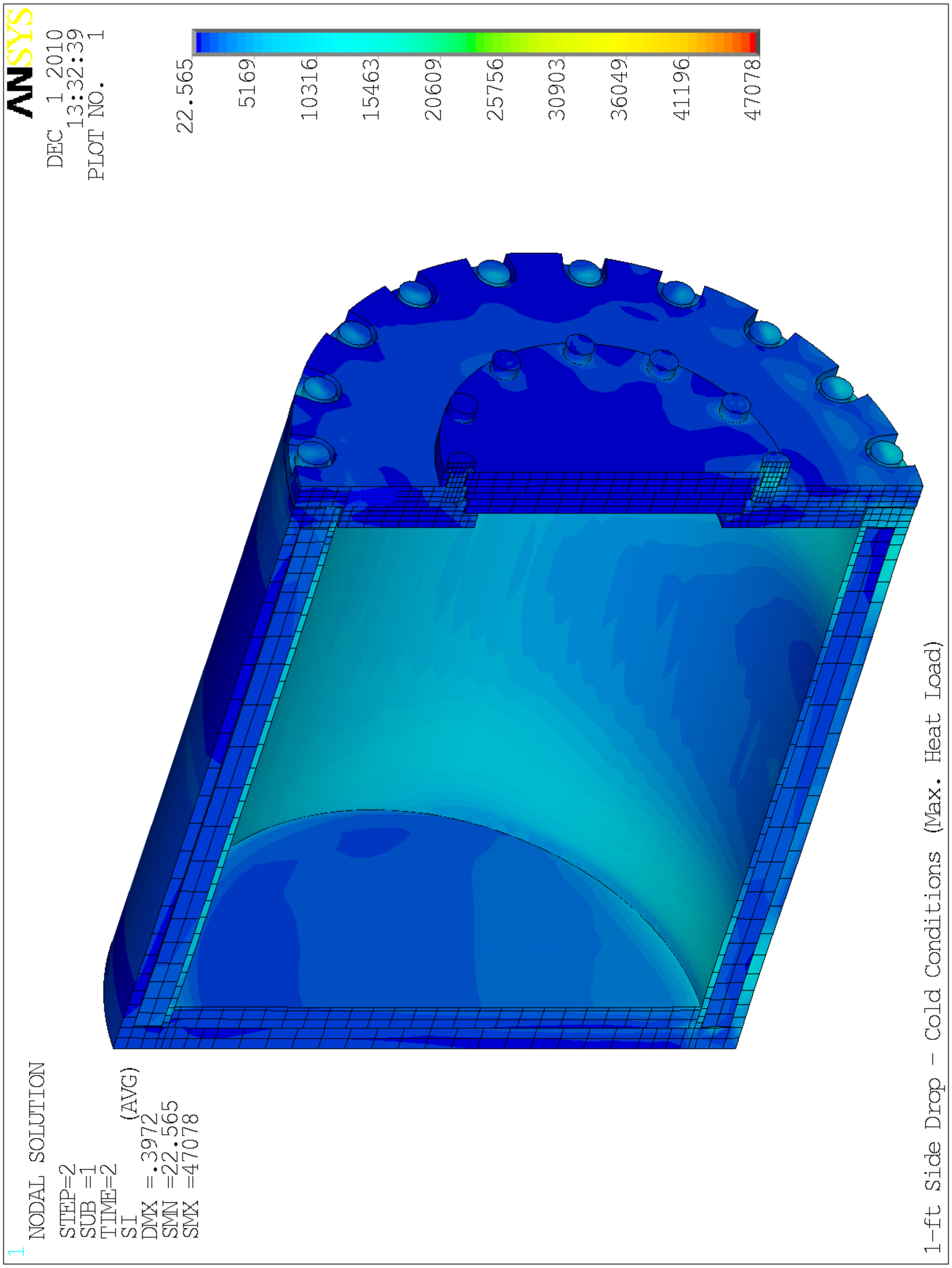


Figure 40

Stress Intensity Plot – 1-ft Side Drop – Cold Condition (Max. Heat Load)

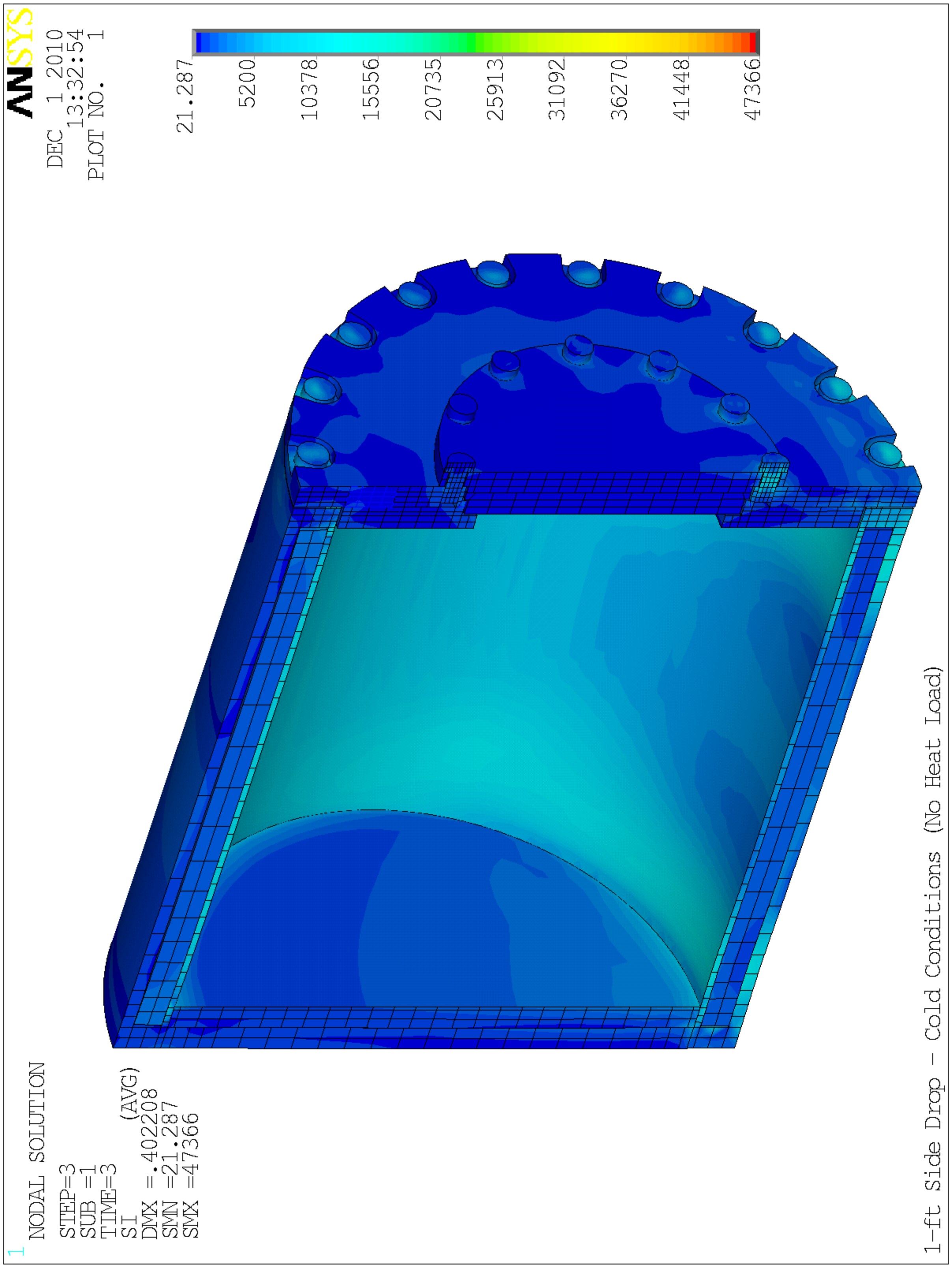


Figure 41

Stress Intensity Plot – 1-ft Side Drop – Cold Condition (No Heat Load)

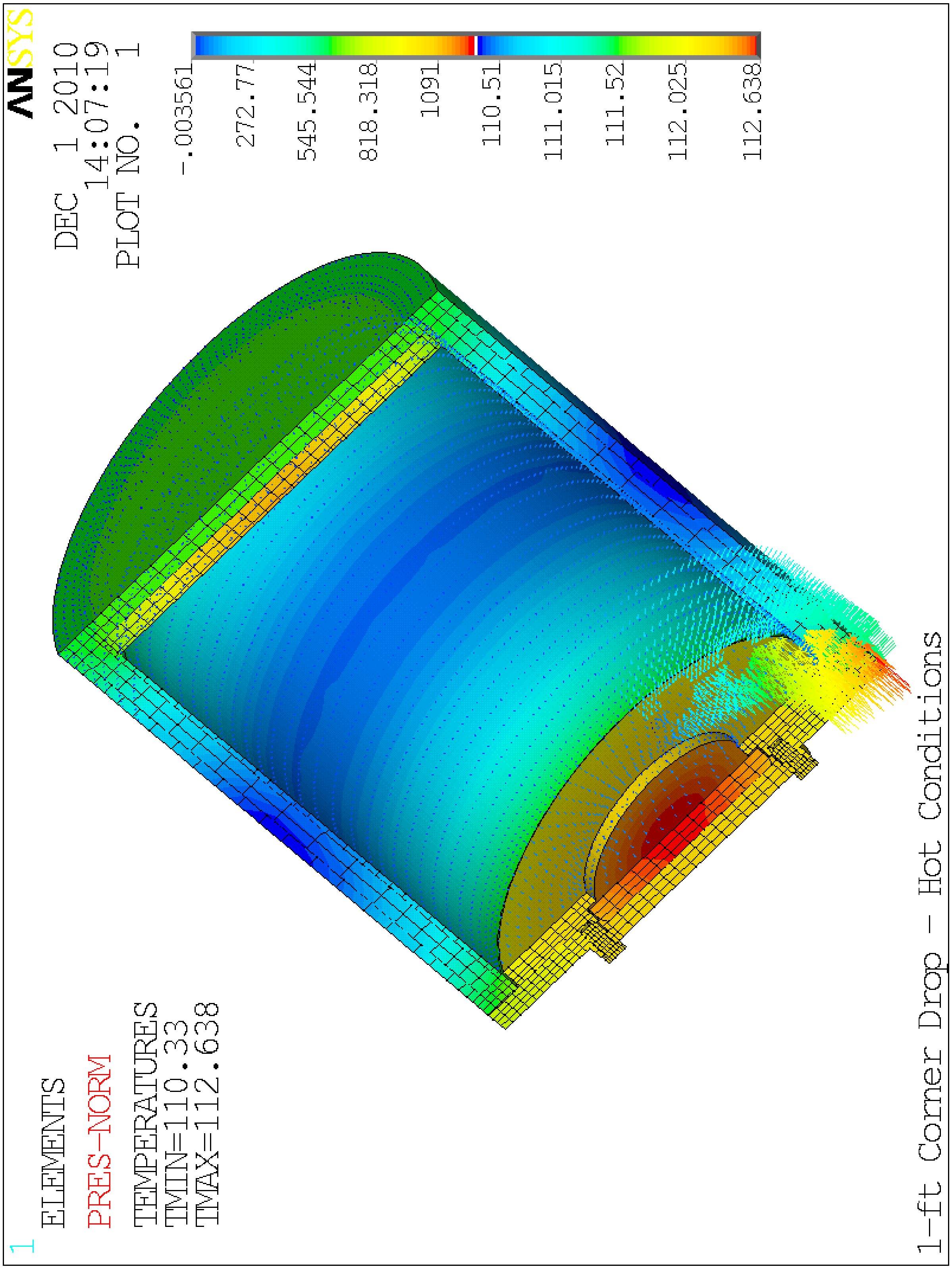


Figure 42
Temperature Profile and Pressure Distribution Used for 1-ft Corner Drop – Hot Condition

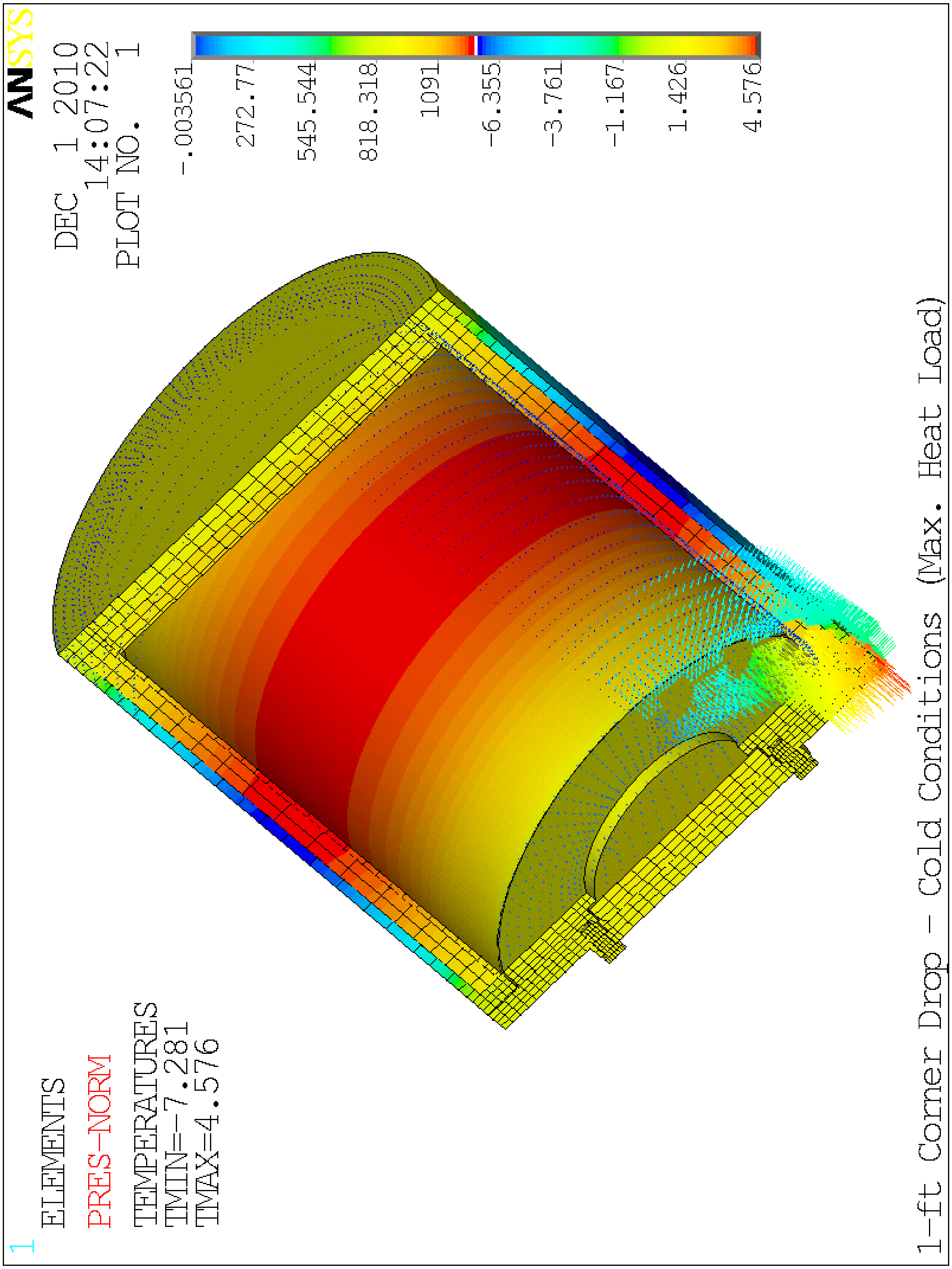


Figure 43
Temperature Profile and Pressure Distribution Used for 1-ft Corner Drop – Cold Condition (Max. Heat Load)

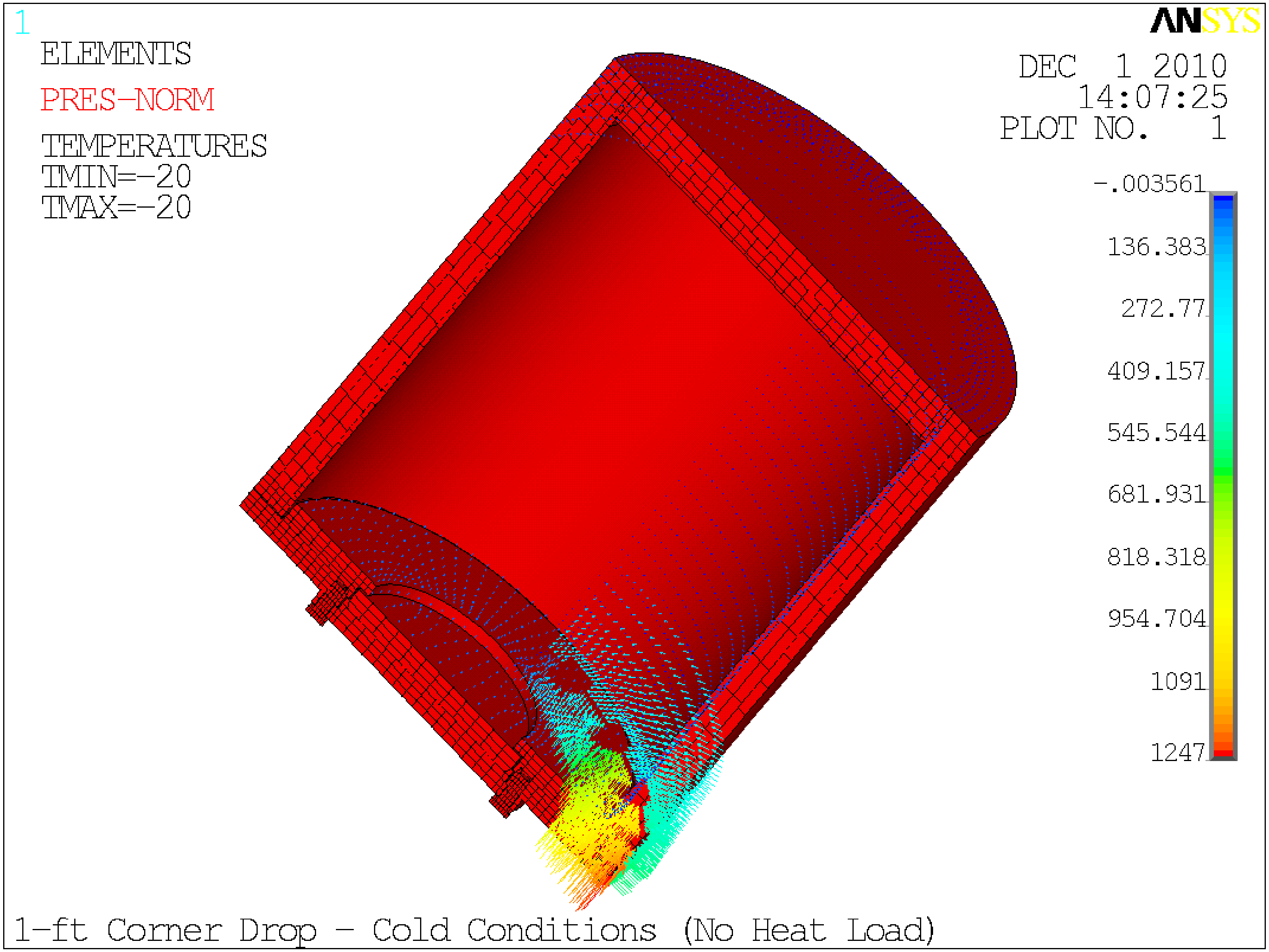


Figure 44

Temperature Profile and Pressure Distribution Used for 1-ft Corner Drop – Cold Condition (No Heat Load)

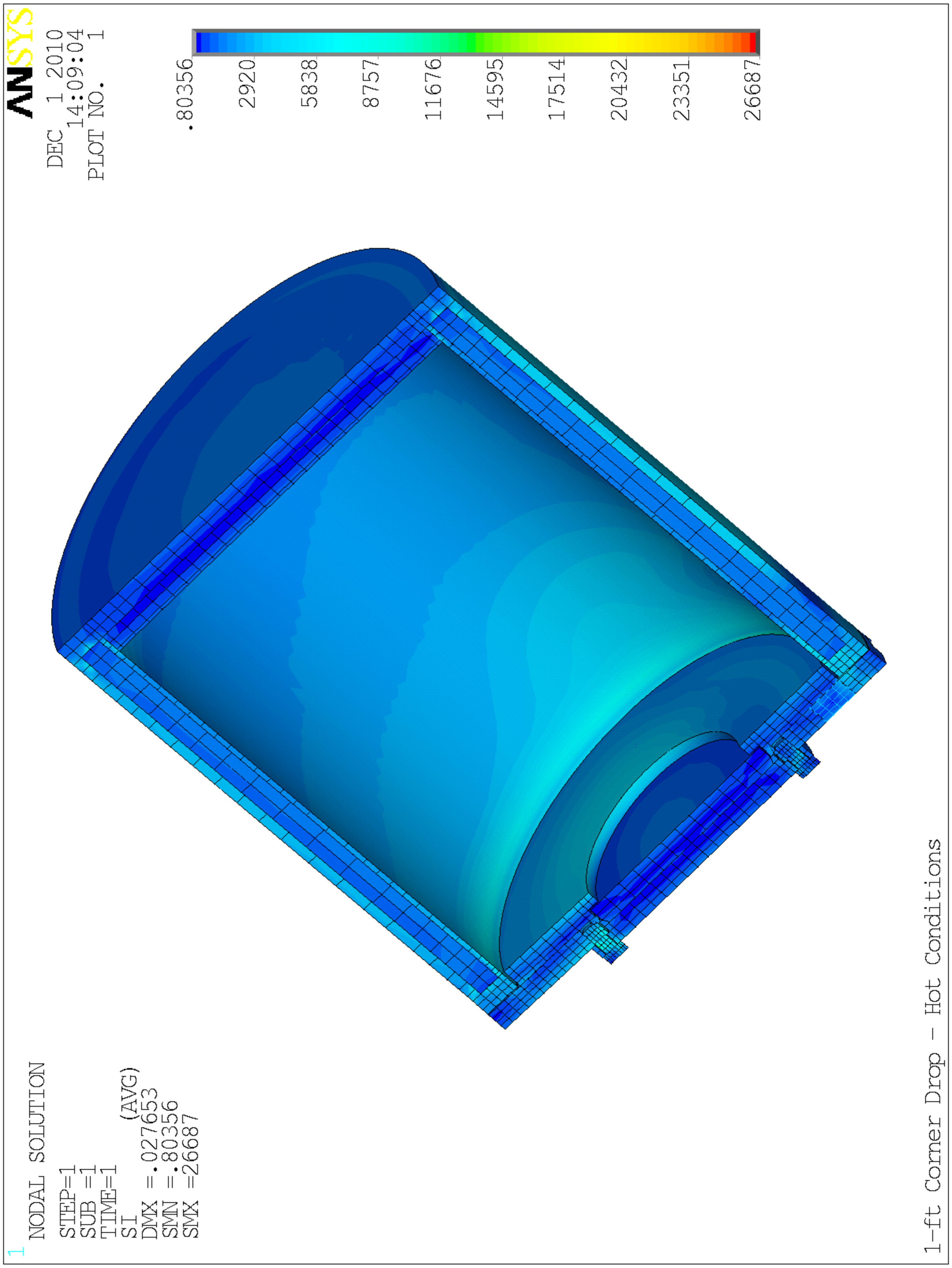


Figure 45

Stress Intensity Plot – 1-ft Corner Drop – Hot Condition

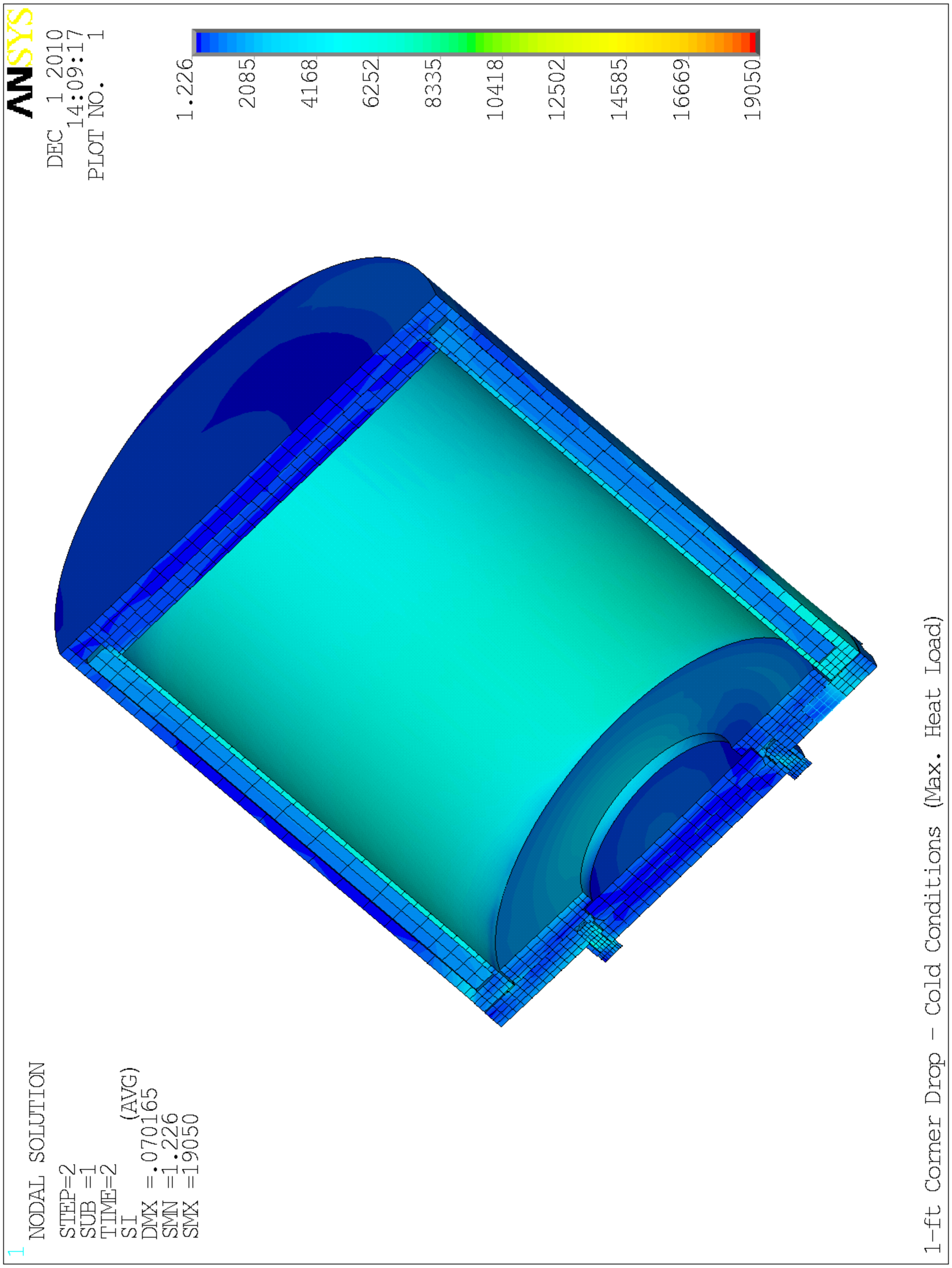


Figure 46

Stress Intensity Plot – 1-ft Corner Drop – Cold Condition (Max. Heat Load)

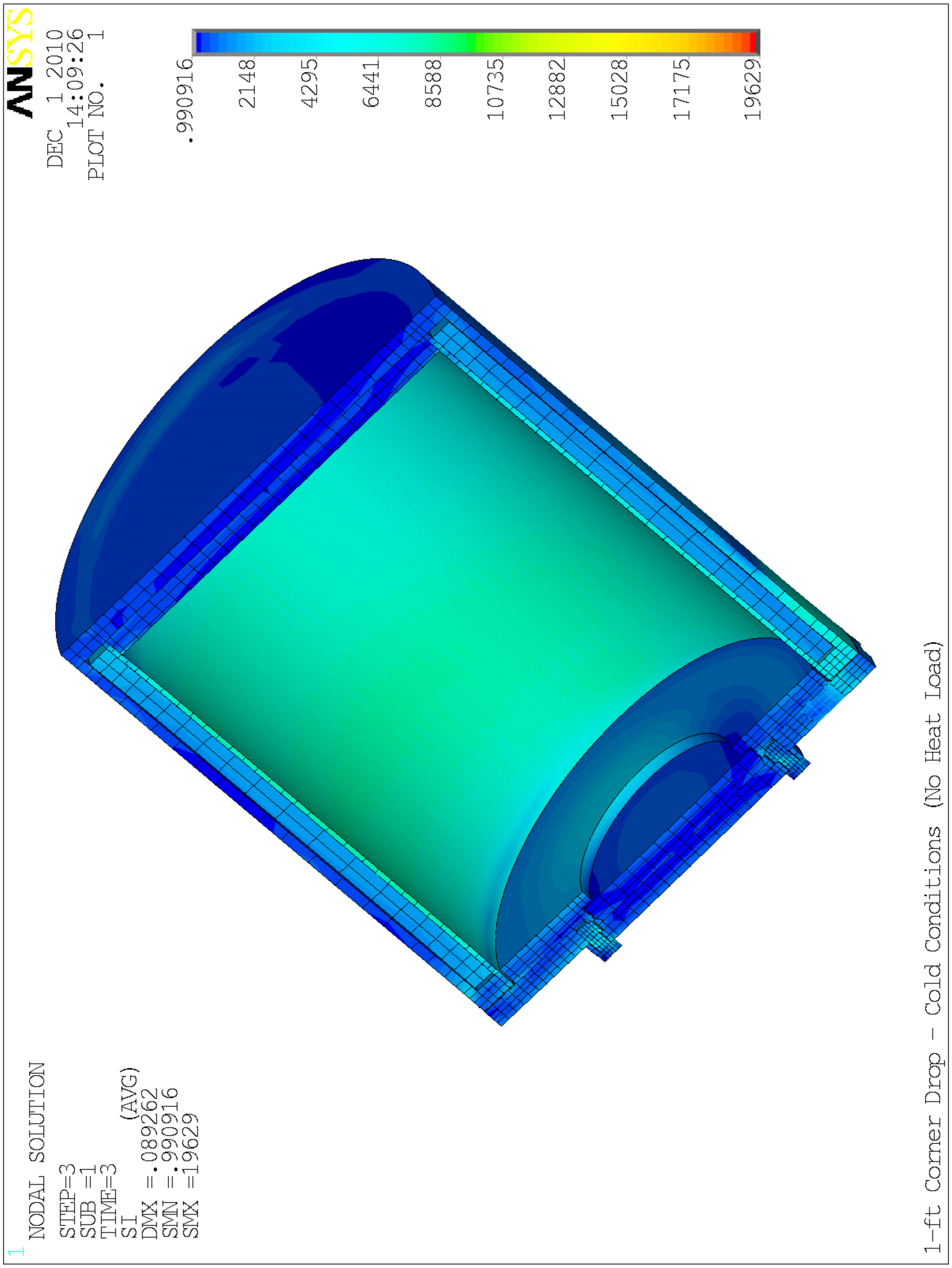


Figure 47

Stress Intensity Plot – 1-ft Corner Drop – Cold Condition (No Heat Load)

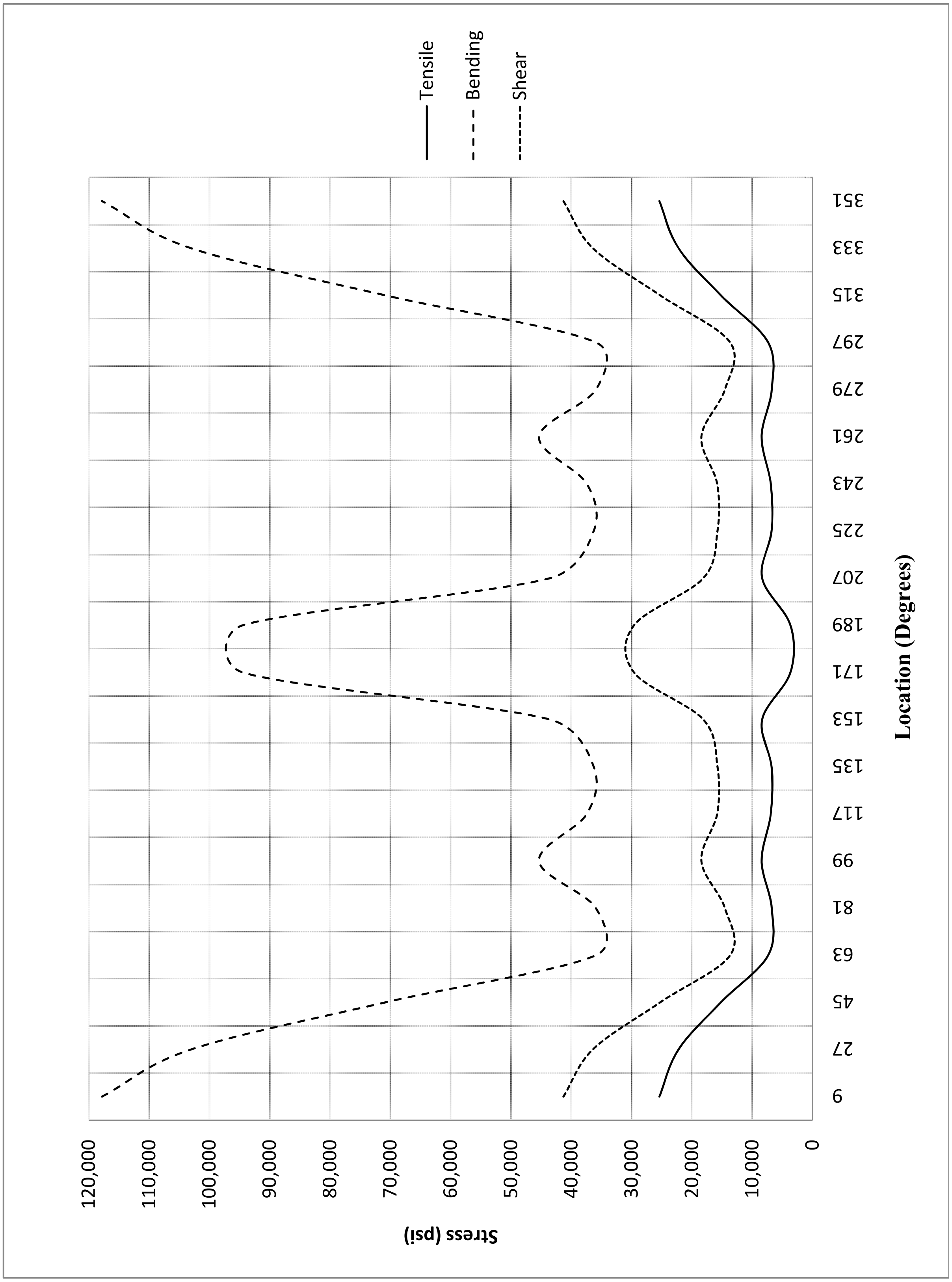


Figure 48

Stresses in Primary Lid Bolts During 30ft Side Drop, Cold Conditions (No Heat Load)

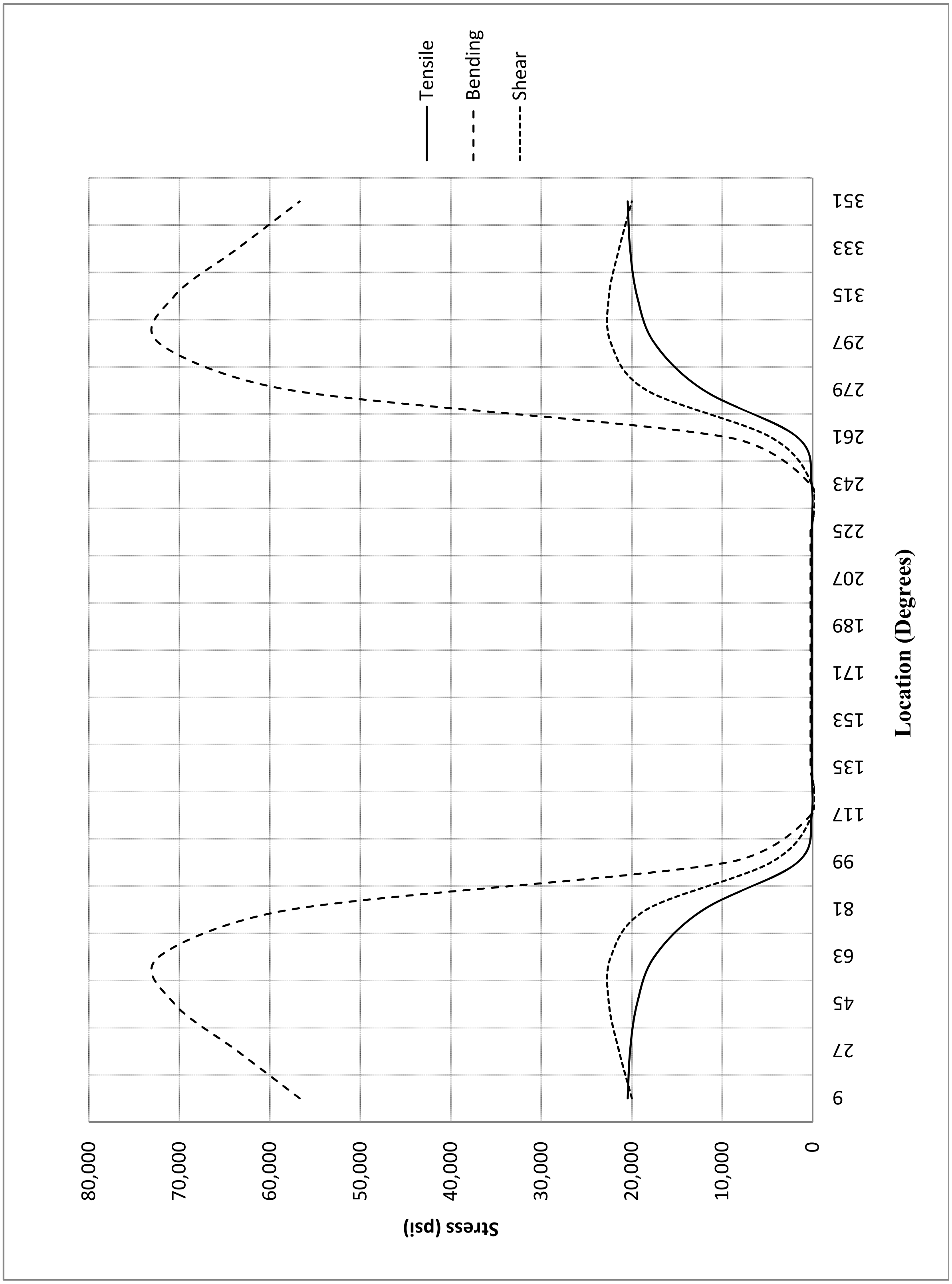


Figure 49

Stresses in Primary Lid Bolts During 30ft Corner Drop, Cold Conditions (No Heat Load)

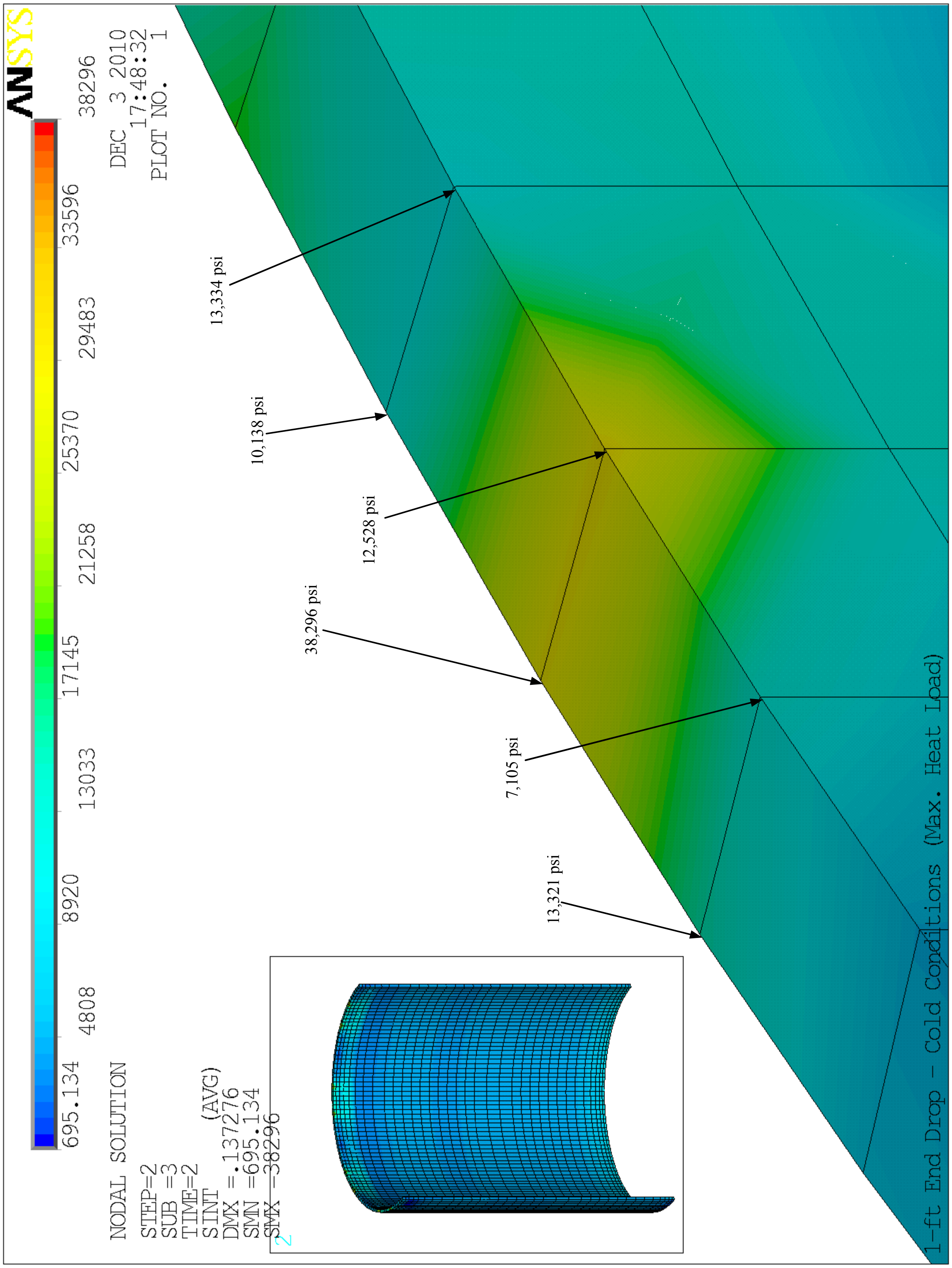


Figure 50

Inner Shell, Averaging of Local Stresses During 1ft End Drop, Cold Conditions (Max. Heat Load)

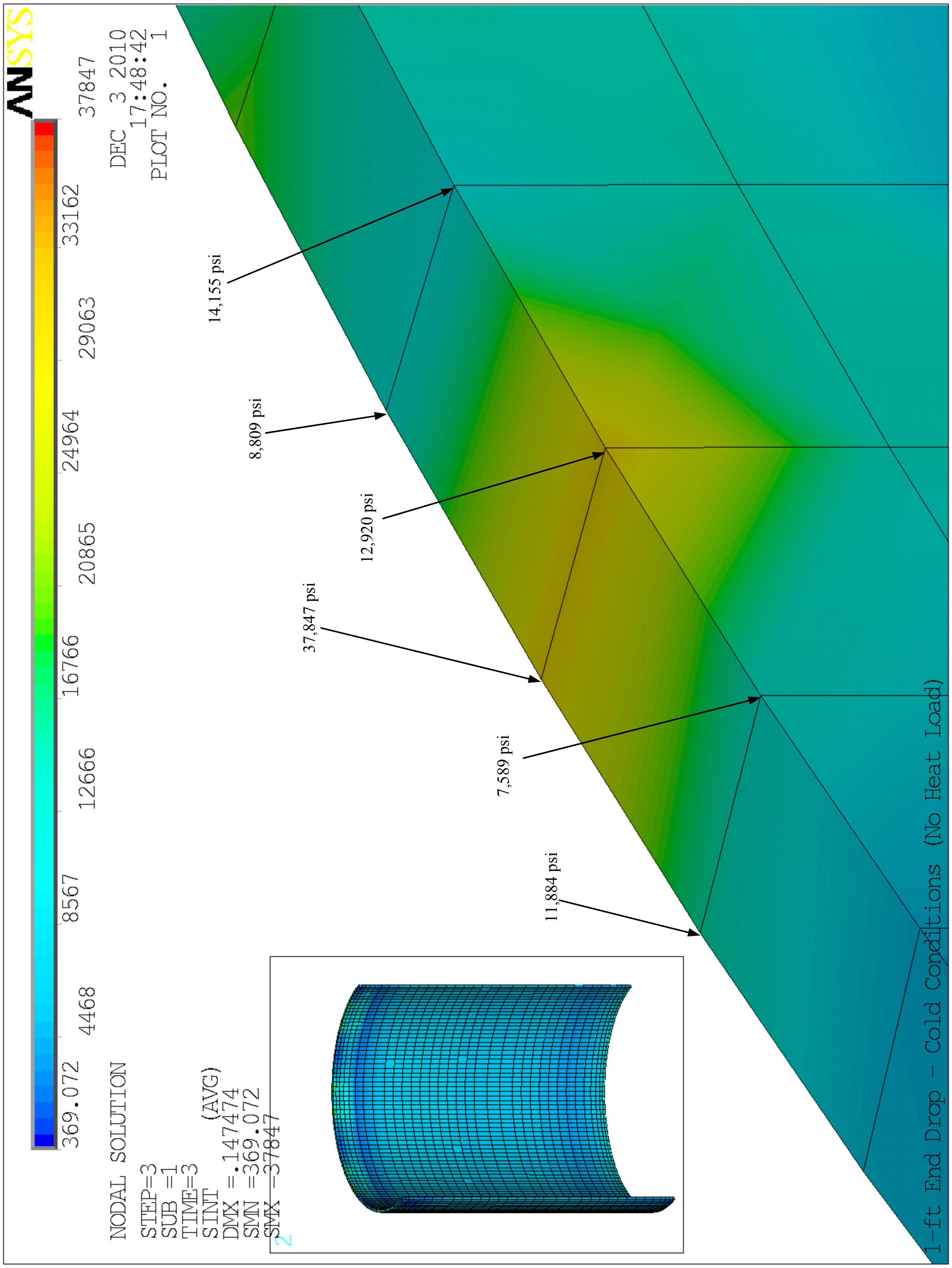


Figure 51

Inner Shell, Averaging of Local Stresses During 1ft End Drop, Cold Conditions (No Heat Load)

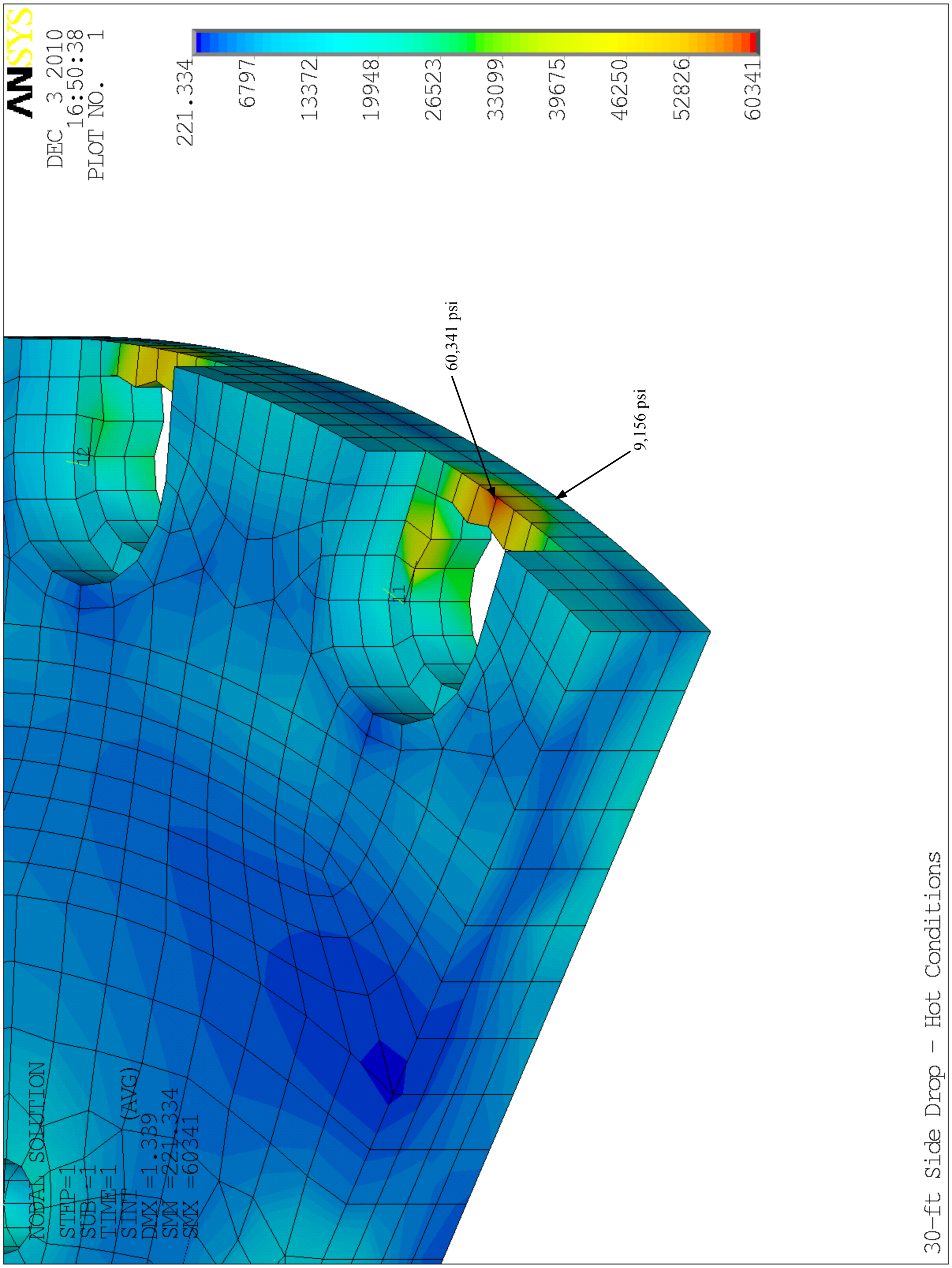


Figure 52

Primary Lid, Averaging of Local Stresses During 30ft Side Drop, Hot Conditions

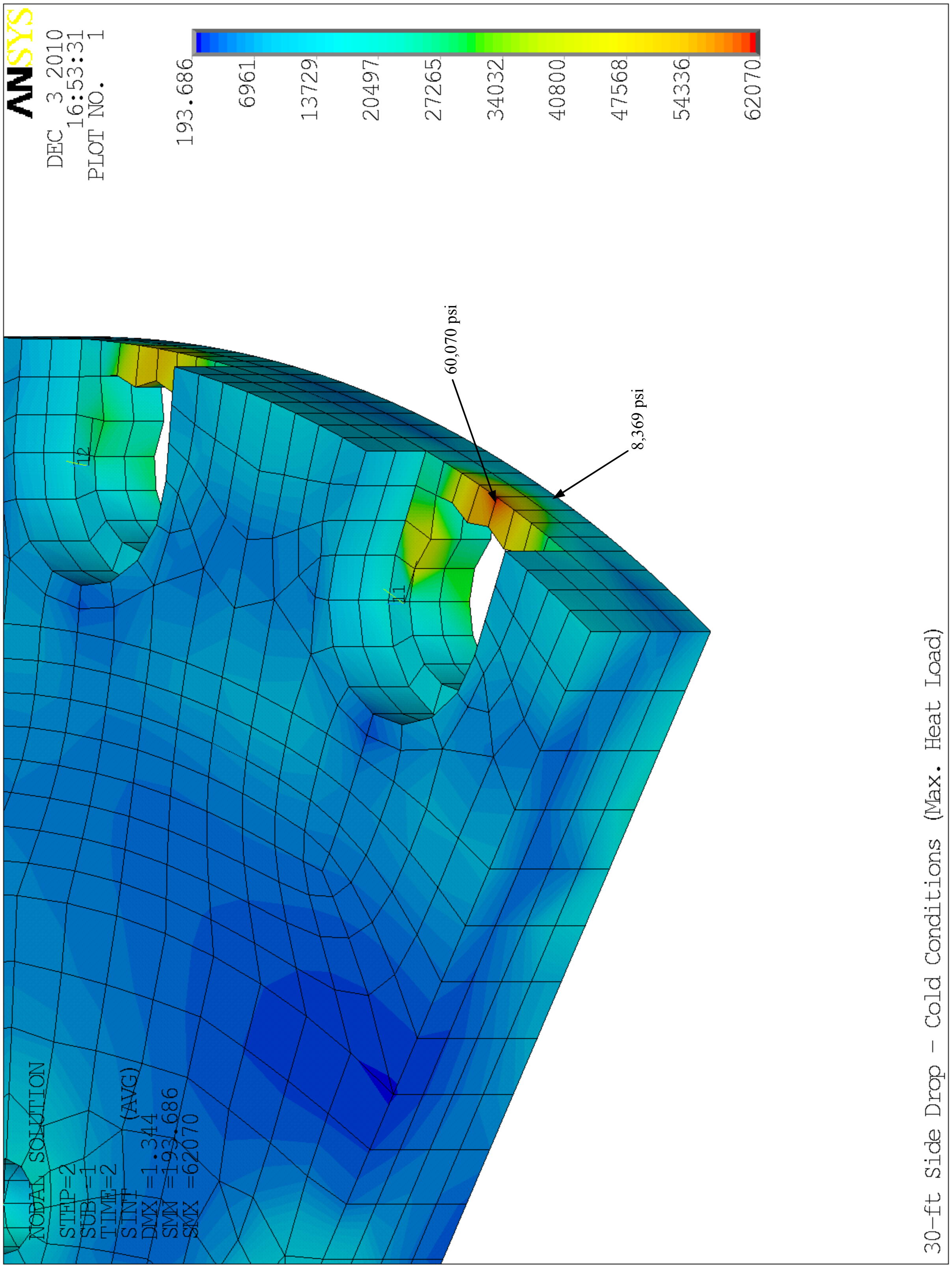


Figure 53

Primary Lid, Averaging of Local Stresses During 30ft Side Drop, Cold Conditions (Max. Heat Load)

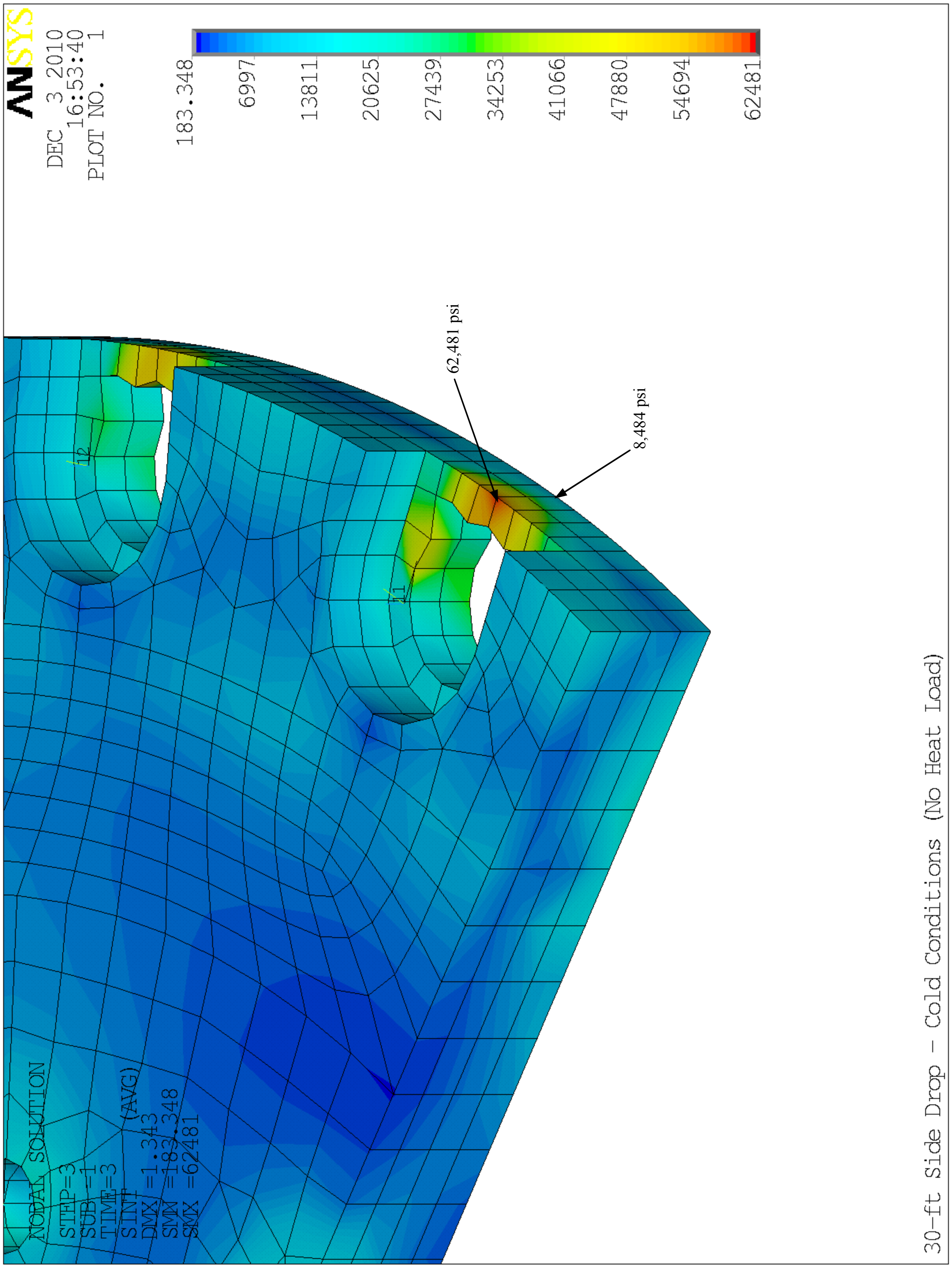


Figure 54

Primary Lid, Averaging of Local Stresses During 30 ft Side Drop, Cold Conditions (No Heat Load)

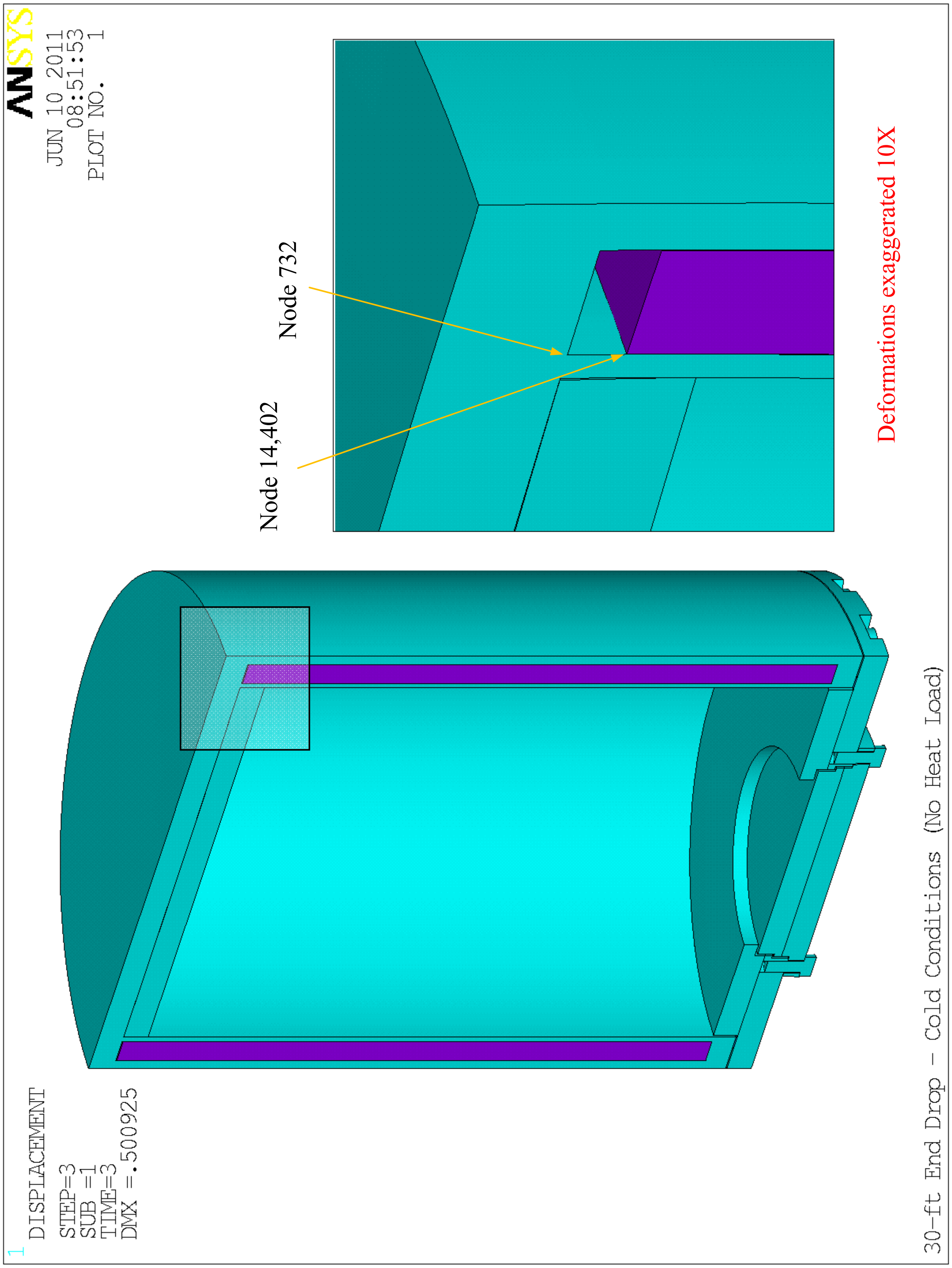


Figure 55
Lead-Slump during the 30-ft End Drop Test

Appendix 1

Partial Printout of the ANSYS Finite Element Model Data

(32 Pages)

ANSYS Finite Element Model Partial Printout

(Note: The complete data printout is included on the file Model.out, which is included on the electronic media included in the package)

```
    ***** TITLES *****

 *** YOU ARE IN   ANSYS - ENGINEERING ANALYSIS SYSTEM ***
 ANSYS Mechanical
 RELEASE  12.1      UPDATE 20091102   CUSTOMER  00222442

 INITIAL JOBNAME = file
 CURRENT JOBNAME = file

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 TITLE= 30-ft End Drop - Cold Conditions (No Heat Load)

 MENULIST File: C:\Program Files\ANSYS Inc\v121\ANSYS\gui\en-
us\UIDL\menulist121.ans

                           G L O B A L   S T A T U S

 ANSYS - Engineering Analysis System           Nov 24, 2010          11:51
 Release 12.1                00222442                 WINDOWS x64  Version

 Current working directory: D:\ANSYS Analyses\8-120B\Assembly\Drop\End\30-ft


 MENULIST File: C:\Program Files\ANSYS Inc\v121\ANSYS\gui\en-
us\UIDL\menulist121.ans

 Product(s) enabled: ANSYS Mechanical


 Total connect time. . . . .   0 hours  0 minutes
 Total CP usage. . . . . . .   0 hours  0 minutes  1.8 seconds

 J O B   I N F O R M A T I O N ------------------------------------------------

30-ft End Drop - Cold Conditions (No Heat Load)

 Current jobname . . . . . .file
 Initial jobname . . . . . .file

 Units . . . . . . . . . . .unknown

                                Available              Used
 Scratch Memory Space. . . .     512.000 mb         31.222 mb (  6.1%)
 Database space  . . . . . .   65535.750 mb        144.355 mb (  0.2%)

 User menu file in use . . .%ANSYS121_DIR%\gui\en-us\UIDL\UIMENU.GRN
 User menu file in use . . .%ANSYS121_DIR%\gui\en-us\UIDL\UIFUNC1.GRN
 User menu file in use . . .%ANSYS121_DIR%\gui\en-us\UIDL\UIFUNC2.GRN
 User menu file in use . . .%ANSYS121_DIR%\gui\en-us\UIDL\MECHTOOL.AUI
```

Beta features . . . . . . .are not shown in the user interface

M O D E L   I N F O R M A T I O N ---

Solid model summary:

	Largest Number	Number Defined	Number Selected
Keypoints	0	0	0
Lines	0	0	0
Areas	0	0	0
Volumes	0	0	0

Finite element model summary:

	Largest Number	Number Defined	Number Selected
Nodes	50003	37899	37899
Elements.	39118	38147	38147
Element types	150	138	n.a.
Real constant sets.	150	68	n.a.
Material property sets. . .	4	3	n.a.
Coupling.	0	0	n.a.
Constraint equations. . . .	0	0	n.a.
Master DOFs	0	0	n.a.
Dynamic gap conditions. . .	0	0	n.a.

B O U N D A R Y   C O N D I T I O N   I N F O R M A T I O N -----------------

	Number Defined
Constraints on nodes.	1695
Constraints on keypoints.	0
Constraints on lines.	0
Constraints on areas.	0
Forces on nodes	0
Forces on keypoints	0
Surface loads on elements	1992
Number of element flagged surfaces . . .	0
Surface loads on lines.	0
Surface loads on areas.	0
Body loads on elements.	656
Body loads on areas	0
Body loads on lines	0
Body loads on nodes	0
Body loads on keypoints	0

Temperatures

Uniform temperature.	-20.000
Reference temperature.	70.000
Offset from absolute scale	0.000

```
                                                X           Y           Z
Linear acceleration . . . . . . . . . . .  0.0000      0.0000     -164.80
Angular velocity (about global CS). . . .  0.0000      0.0000      0.0000
Angular acceleration (about global CS). .  0.0000      0.0000      0.0000
Location of reference CS. . . . . . . . .  0.0000      0.0000      0.0000
Angular velocity (about reference CS) . .  0.0000      0.0000      0.0000
Angular acceleration (about reference CS)  0.0000      0.0000      0.0000

R O U T I N E   I N F O R M A T I O N ---------------------------------------

Current routine. . . . . . . . . . . .Preprocessing (PREP7)

Active coordinate system . . . . . . .  27 (Cartesian)

Display coordinate system. . . . . . .   0 (Cartesian)

Current element attributes:
   Type number . . . . . . . . . . . .   150  (COMBIN14)
   Real number . . . . . . . . . . . .   150
   Material number . . . . . . . . . .     1
   Element coordinate system number. .     0

Current mesher type. . . . . . . . . .based on default element shape

Current element meshing shape 2D . . .use default element shape.

Current element meshing shape 3D . . .use default element shape.

SmrtSize Level  . . . . . . . . . . . . OFF

Global element size. . . . . . . . .     0 divisions per line

Active coordinate system . . . . . . .  27 (Cartesian)

Display coordinate system. . . . . . .   0 (Cartesian)

Analysis type. . . . . . . . . . . . .Static (steady-state)

Active options for this analysis type:
   Large deformation effects . . . . .Not included
   Plasticity. . . . . . . . . . . . .Not included
   Creep . . . . . . . . . . . . . . .Not included
   Equation solver to use. . . . . . .Program Chosen

Results file . . . . . . . . . . . . .file.rst

Load step number . . . . . . . . . .     4

Number of substeps . . . . . . . . .     1
   Step change boundary conditions . .No

                      S O L U T I O N   O P T I O N S

  PROBLEM DIMENSIONALITY. . . . . . . . . . . . .3-D
  DEGREES OF FREEDOM. . . . . . UX   UY   UZ   ROTX ROTY ROTZ
  ANALYSIS TYPE . . . . . . . . . . . . . . . . .STATIC (STEADY-STATE)
  NEWTON-RAPHSON OPTION . . . . . . . . . . . . .PROGRAM CHOSEN
```

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  GLOBALLY ASSEMBLED MATRIX . . . . . . . . . . . .SYMMETRIC

                     L O A D   S T E P   O P T I O N S

  LOAD STEP NUMBER. . . . . . . . . . . . . . . .      4
  TIME AT END OF THE LOAD STEP. . . . . . . . . .  4.0000
  NUMBER OF SUBSTEPS. . . . . . . . . . . . . . .      1
  MAXIMUM NUMBER OF EQUILIBRIUM ITERATIONS. . . .     15
  STEP CHANGE BOUNDARY CONDITIONS . . . . . . . .     NO
  TERMINATE ANALYSIS IF NOT CONVERGED . . . . . .YES (EXIT)
  CONVERGENCE CONTROLS. . . . . . . . . . . . . .USE DEFAULTS
  INERTIA LOADS                         X            Y            Z
     ACEL . . . . . . . . . . . .  0.0000       0.0000     -164.80
  PRINT OUTPUT CONTROLS . . . . . . . . . . . . .NO PRINTOUT
  DATABASE OUTPUT CONTROLS. . . . . . . . . . . .ALL DATA WRITTEN
                                                 FOR THE LAST SUBSTEP


LIST ELEMENT TYPES FROM      1 TO    150 BY      1

ELEMENT TYPE      1 IS SHELL63      ELASTIC SHELL
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE      2 IS SOLID45      3-D STRUCTURAL SOLID
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE      3 IS SOLSH190     3-D 8-NODE SOLID SHELL
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE      7 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE      8 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     11 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     12 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     15 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
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 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     16 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     17 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     18 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     19 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     20 IS CONTA175     NODE-TO-SURFACE CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     21 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     22 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     23 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     24 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     25 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     26 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0
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ELEMENT TYPE     27 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     28 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     29 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     30 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     31 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     32 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     33 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     34 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     35 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     36 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     37 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     38 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
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```
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     39 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     40 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     41 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     42 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     43 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     44 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     45 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     46 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     47 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     48 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     49 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
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```
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     50 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     51 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     52 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     53 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     54 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     55 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     56 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     57 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     58 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     59 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE     60 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0
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ELEMENT TYPE     61 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     62 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     63 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     64 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     65 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     66 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     67 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     68 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     69 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     70 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     71 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     72 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
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 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     73 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     74 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     75 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     76 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     77 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     78 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     79 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     80 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     81 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     82 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE     83 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0
```

```
ELEMENT TYPE      84 IS CONTA174      3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      85 IS TARGE170      3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      86 IS CONTA174      3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      89 IS TARGE170      3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      90 IS CONTA174      3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      91 IS TARGE170      3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      92 IS CONTA174      3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      93 IS TARGE170      3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      94 IS CONTA174      3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      95 IS TARGE170      3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0       0       0         0       0       0
 KEYOPT( 7-12)=        0       0       0         0       0       0
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      96 IS CONTA174      3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0       0       0         0       3       0
 KEYOPT( 7-12)=        0       0       1         2       0       3
 KEYOPT(13-18)=        0       0       0         0       0       0

ELEMENT TYPE      97 IS TARGE170      3-D TARGET SEGMENT
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```
  KEYOPT( 1- 6)=        0      0      0        0      0      0
  KEYOPT( 7-12)=        0      0      0        0      0      0
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE      98 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
  KEYOPT( 1- 6)=        0      0      0        0      3      0
  KEYOPT( 7-12)=        0      0      1        2      0      3
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE      99 IS TARGE170     3-D TARGET SEGMENT
  KEYOPT( 1- 6)=        0      0      0        0      0      0
  KEYOPT( 7-12)=        0      0      0        0      0      0
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     100 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
  KEYOPT( 1- 6)=        0      0      0        0      3      0
  KEYOPT( 7-12)=        0      0      1        2      0      3
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     101 IS TARGE170     3-D TARGET SEGMENT
  KEYOPT( 1- 6)=        0      0      0        0      0      0
  KEYOPT( 7-12)=        0      0      0        0      0      0
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     102 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
  KEYOPT( 1- 6)=        0      0      0        0      3      0
  KEYOPT( 7-12)=        0      0      1        2      0      3
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     103 IS TARGE170     3-D TARGET SEGMENT
  KEYOPT( 1- 6)=        0      0      0        0      0      0
  KEYOPT( 7-12)=        0      0      0        0      0      0
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     104 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
  KEYOPT( 1- 6)=        0      0      0        0      3      0
  KEYOPT( 7-12)=        0      0      1        2      0      3
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     105 IS TARGE170     3-D TARGET SEGMENT
  KEYOPT( 1- 6)=        0      0      0        0      0      0
  KEYOPT( 7-12)=        0      0      0        0      0      0
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     106 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
  KEYOPT( 1- 6)=        0      0      0        0      3      0
  KEYOPT( 7-12)=        0      0      1        2      0      3
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     109 IS TARGE170     3-D TARGET SEGMENT
  KEYOPT( 1- 6)=        0      0      0        0      0      0
  KEYOPT( 7-12)=        0      0      0        0      0      0
  KEYOPT(13-18)=        0      0      0        0      0      0

 ELEMENT TYPE     110 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
  KEYOPT( 1- 6)=        0      0      0        0      3      0
  KEYOPT( 7-12)=        0      0      1        2      0      3
```

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 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    111 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    112 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    113 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    114 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    115 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    116 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    117 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    118 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    119 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    120 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    121 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0
```

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ELEMENT TYPE    122 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      1       2      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    123 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      0       0      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    124 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      1       2      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    125 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      0       0      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    126 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      1       2      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    127 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      0       0      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    128 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      1       2      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    129 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      0       0      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    130 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      1       2      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    131 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      0       0      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    132 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
 KEYOPT( 7-12)=        0      0      1       2      0      0
 KEYOPT(13-18)=        0      0      0       0      0      0

ELEMENT TYPE    133 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0       0      0      0
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```
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    134 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    135 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    136 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    137 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    138 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    139 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    140 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    141 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    142 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    143 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    144 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0
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ELEMENT TYPE    145 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    146 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      1        2      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    147 IS TARGE170     3-D TARGET SEGMENT
 KEYOPT( 1- 6)=        0      0      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    148 IS CONTA174     3D 8-NODE SURF-SURF CONTACT
 KEYOPT( 1- 6)=        0      0      0        0      3      0
 KEYOPT( 7-12)=        0      0      1        2      0      3
 KEYOPT(13-18)=        0      0      0        0      0      0

ELEMENT TYPE    150 IS COMBIN14     SPRING-DAMPER
 KEYOPT( 1- 6)=        0      3      0        0      0      0
 KEYOPT( 7-12)=        0      0      0        0      0      0
 KEYOPT(13-18)=        0      0      0        0      0      0

CURRENT NODAL DOF SET IS  UX    UY    UZ    ROTX  ROTY  ROTZ
 THREE-DIMENSIONAL MODEL

LIST REAL SETS       1 TO     150 BY       1

REAL CONSTANT SET      17  ITEMS   1 TO   6
   0.0000       0.0000       1.0000       0.10000     -0.10000       0.0000

REAL CONSTANT SET      17  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      17  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      17  ITEMS  19 TO  24
   0.0000       0.0000       1.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      19  ITEMS   1 TO   6
   0.0000       0.0000       1.0000       0.10000     -0.10000       0.0000

REAL CONSTANT SET      19  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      19  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      19  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      21  ITEMS   1 TO   6
   0.0000       0.0000       1.0000       0.10000     -0.10000       0.0000
```

```
REAL CONSTANT SET      21  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      21  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      21  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      22  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      22  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      22  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      22  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      23  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      23  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      23  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      23  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      23  ITEMS  25 TO  30
   10.000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      24  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      24  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      24  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      24  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      25  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      25  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      25  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000
```

```
REAL CONSTANT SET      25  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      26  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      26  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      26  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      26  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      27  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      27  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      27  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      27  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      28  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      28  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      28  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      28  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      29  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      29  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      29  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      29  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      30  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      30  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000
```

```
REAL CONSTANT SET      30  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      30  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      31  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      31  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      31  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      31  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      32  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      32  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      32  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      32  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      33  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      33  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      33  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      33  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      34  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      34  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      34  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      34  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      35  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000
```

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REAL CONSTANT SET      35  ITEMS   7 TO  12
   0.0000      0.0000      0.10000E+21   0.0000      1.0000      0.0000

REAL CONSTANT SET      35  ITEMS  13 TO  18
   0.0000      0.0000      1.0000        0.0000      1.0000      0.50000

REAL CONSTANT SET      35  ITEMS  19 TO  24
   0.0000      1.0000      1.0000        0.0000      0.0000      1.0000

REAL CONSTANT SET      36  ITEMS   1 TO   6
   0.0000      0.0000      1.0000        0.10000    -0.10000     0.0000

REAL CONSTANT SET      36  ITEMS   7 TO  12
   0.0000      0.0000      0.10000E+21   0.0000      1.0000      0.0000

REAL CONSTANT SET      36  ITEMS  13 TO  18
   0.0000      0.0000      1.0000        0.0000      1.0000      0.50000

REAL CONSTANT SET      36  ITEMS  19 TO  24
   0.0000      1.0000      1.0000        0.0000      0.0000      1.0000

REAL CONSTANT SET      37  ITEMS   1 TO   6
   0.0000      0.0000      1.0000        0.10000    -0.10000     0.0000

REAL CONSTANT SET      37  ITEMS   7 TO  12
   0.0000      0.0000      0.10000E+21   0.0000      1.0000      0.0000

REAL CONSTANT SET      37  ITEMS  13 TO  18
   0.0000      0.0000      1.0000        0.0000      1.0000      0.50000

REAL CONSTANT SET      37  ITEMS  19 TO  24
   0.0000      1.0000      1.0000        0.0000      0.0000      1.0000

REAL CONSTANT SET      38  ITEMS   1 TO   6
   0.0000      0.0000      1.0000        0.10000    -0.10000     0.0000

REAL CONSTANT SET      38  ITEMS   7 TO  12
   0.0000      0.0000      0.10000E+21   0.0000      1.0000      0.0000

REAL CONSTANT SET      38  ITEMS  13 TO  18
   0.0000      0.0000      1.0000        0.0000      1.0000      0.50000

REAL CONSTANT SET      38  ITEMS  19 TO  24
   0.0000      1.0000      1.0000        0.0000      0.0000      1.0000

REAL CONSTANT SET      39  ITEMS   1 TO   6
   0.0000      0.0000      1.0000        0.10000    -0.10000     0.0000

REAL CONSTANT SET      39  ITEMS   7 TO  12
   0.0000      0.0000      0.10000E+21   0.0000      1.0000      0.0000

REAL CONSTANT SET      39  ITEMS  13 TO  18
   0.0000      0.0000      1.0000        0.0000      1.0000      0.50000

REAL CONSTANT SET      39  ITEMS  19 TO  24
   0.0000      1.0000      1.0000        0.0000      0.0000      1.0000
```

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REAL CONSTANT SET      40  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      40  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      40  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      40  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      41  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      41  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      41  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      41  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      42  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      42  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      42  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      42  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      43  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      43  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      43  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      43  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      44  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      44  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      44  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000
```

```
REAL CONSTANT SET      44  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      45  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      45  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      45  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      45  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      46  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      46  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      46  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      46  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      47  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      47  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      47  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      47  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      48  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      48  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      48  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      48  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      49  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      49  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21   0.0000       1.0000       0.0000
```

```
REAL CONSTANT SET      49  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      49  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      50  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      50  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21    0.0000       1.0000       0.0000

REAL CONSTANT SET      50  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      50  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      51  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      51  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21    0.0000       1.0000       0.0000

REAL CONSTANT SET      51  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      51  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      52  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      52  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21    0.0000       1.0000       0.0000

REAL CONSTANT SET      52  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      52  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      53  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      53  ITEMS   7 TO  12
   0.0000       0.0000     0.10000E+21    0.0000       1.0000       0.0000

REAL CONSTANT SET      53  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      53  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      54  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000
```

```
REAL CONSTANT SET      54  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      54  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      54  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      55  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      55  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      55  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      55  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      56  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      56  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      56  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      56  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      58  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      58  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      58  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      58  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      59  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      59  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      59  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      59  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000
```

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REAL CONSTANT SET      60  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      60  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      60  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      60  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      61  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      61  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      61  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      61  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      62  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      62  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      62  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      62  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      63  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      63  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      63  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      63  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      64  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      64  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      64  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000
```

```
REAL CONSTANT SET      64  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      65  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      65  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      65  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      65  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      66  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      66  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      66  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      66  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      68  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000     -0.10000       0.0000

REAL CONSTANT SET      68  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      68  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      68  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      69  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      69  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      69  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      69  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      70  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      70  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
```

```
REAL CONSTANT SET      70  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      70  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      71  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      71  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      71  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      71  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      72  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      72  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      72  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      72  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      73  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      73  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      73  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      73  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      74  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      74  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      74  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      74  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      75  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
```

```
REAL CONSTANT SET      75  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      75  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      75  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      76  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      76  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      76  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      76  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      77  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      77  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      77  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      77  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      78  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      78  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      78  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      78  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      79  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      79  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      79  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      79  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
```

```
REAL CONSTANT SET      80  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      80  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      80  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      80  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      81  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      81  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      81  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      81  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      82  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      82  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      82  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      82  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      83  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      83  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      83  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      83  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      84  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      84  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      84  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
```

```
REAL CONSTANT SET      84  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      85  ITEMS   1 TO   6
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      85  ITEMS   7 TO  12
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      85  ITEMS  13 TO  18
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      85  ITEMS  19 TO  24
   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

REAL CONSTANT SET      86  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      86  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      86  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      86  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET      87  ITEMS   1 TO   6
   0.0000       0.0000       1.0000      0.10000       0.0000       0.0000

REAL CONSTANT SET      87  ITEMS   7 TO  12
   0.0000       0.0000      0.10000E+21   0.0000       1.0000       0.0000

REAL CONSTANT SET      87  ITEMS  13 TO  18
   0.0000       0.0000       1.0000       0.0000       1.0000      0.50000

REAL CONSTANT SET      87  ITEMS  19 TO  24
   0.0000       1.0000       1.0000       0.0000       0.0000       1.0000

REAL CONSTANT SET     150  ITEMS   1 TO   6
   1000.0       0.0000       0.0000       0.0000       0.0000       0.0000

LIST MATERIALS       1 TO       4 BY       1
 PROPERTY= ALL

MATERIAL NUMBER       1

     TEMP        EX
   -100.00     0.30300E+08
    70.000     0.29400E+08
    200.00     0.28800E+08
    300.00     0.28300E+08
    400.00     0.27900E+08
    500.00     0.27300E+08
    600.00     0.26500E+08
```

```
     TEMP         NUXY
               0.3000000

     TEMP         ALPX          REFERENCE TEMP. =  70.00
    70.000      0.64000E-05
    100.00      0.65000E-05
    150.00      0.66000E-05
    200.00      0.67000E-05
    250.00      0.68000E-05
    300.00      0.69000E-05
    350.00      0.70000E-05
    400.00      0.71000E-05
    450.00      0.72000E-05
    500.00      0.73000E-05
    550.00      0.73000E-05
    600.00      0.74000E-05

     TEMP         DENS
               0.2830000

MATERIAL NUMBER       2

     TEMP         EX
   -40.000      0.24600E+07
   -20.000      0.24300E+07
    70.000      0.22700E+07
    100.00      0.22100E+07
    200.00      0.20100E+07
    300.00      0.18500E+07
    400.00      0.17000E+07
    500.00      0.15200E+07

     TEMP         NUXY
               0.4000000

     TEMP         ALPX          REFERENCE TEMP. =  70.00
   -40.000      0.15560E-04
   -20.000      0.15650E-04
    70.000      0.16060E-04
    100.00      0.16220E-04
    200.00      0.16700E-04
    300.00      0.17330E-04
    400.00      0.18160E-04
    500.00      0.19120E-04

     TEMP         DENS
               0.4100000

MATERIAL NUMBER       4

     TEMP         EX
   -100.00      0.29200E+08
    70.000      0.28300E+08
    200.00      0.27500E+08
    300.00      0.27000E+08
    400.00      0.26400E+08
    500.00      0.25900E+08
```

```
   600.00     0.25300E+08

    TEMP         NUXY
             0.3000000

    TEMP         ALPX        REFERENCE TEMP. =  70.00
   70.000     0.85000E-05
   100.00     0.86000E-05
   150.00     0.88000E-05
   200.00     0.89000E-05
   250.00     0.91000E-05
   300.00     0.92000E-05
   350.00     0.94000E-05
   400.00     0.95000E-05
   450.00     0.96000E-05
   500.00     0.97000E-05
   550.00     0.98000E-05
   600.00     0.98000E-05

    TEMP         DENS
             0.2830000


       **** CENTER OF MASS, MASS, AND MASS MOMENTS OF INERTIA ****

 CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

 TOTAL MASS =   23938.

                          MOM. OF INERTIA         MOM. OF INERTIA
 CENTER OF MASS            ABOUT ORIGIN        ABOUT CENTER OF MASS

 XC =  0.77768E-06      IXX =   0.7933E+08      IXX =   0.2363E+08
 YC =   19.491          IYY =   0.7933E+08      IYY =   0.3272E+08
 ZC =  -44.124          IZZ =   0.2352E+08      IZZ =   0.1443E+08
                        IXY =   0.1906          IXY =   0.5535
                        IYZ =   0.2069E+08      IYZ =   0.1049E+06
                        IZX =    1.132          IZX =   0.3106

 *** MASS SUMMARY BY ELEMENT TYPE ***

 TYPE      MASS
    2   18544.5
    3   5393.98
```

Appendix 2

Summary Print-Out of the ANSYS Results and Stress Reconciliations

(24 Pages)

ANSYS FEM Analyses Result Summary

1-ft End Drop - Hot Conditions

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	15086.	14528.	2395.
Secondary Lid	12890.	6984.	645.
Bolting Ring	12994.	6050.	513.
Inner Shell	16983.	7952.	2131.
Outer Shell	6837.	5167.	625.
Baseplates	8980.	10443.	1534.
Primary Lid Bolts	6209.	5608.	219.
Secondary Lid Bolts	15983.	15185.	5047.

1-ft End Drop - Cold Conditions (Max. Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	14272.	12071.	1937.
Secondary Lid	11767.	6293.	583.
Bolting Ring	8791.	2759.	29.
Inner Shell	38296.(*)	25603.	13079.
Outer Shell	6301.	4261.	161.
Baseplates	14723.	16421.	1732.
Primary Lid Bolts	3654.	2967.	239.
Secondary Lid Bolts	13075.	12442.	4319.

1-ft End Drop - Cold Conditions (No Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	14529.	12074.	1926.
Secondary Lid	11732.	6229.	580.
Bolting Ring	9959.	3364.	-303.
Inner Shell	37847.(*)	26480.	13564.
Outer Shell	6655.	4082.	150.
Baseplates	15550.	17406.	1898.
Primary Lid Bolts	4115.	3537.	285.
Secondary Lid Bolts	12985.	12355.	4315.

1-ft Side Drop - Hot Conditions

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	20804.(*)	7145.	1692.
Primary Lid (No Holes)	12159.	9474.	1692.
Secondary Lid	6058.	3371.	383.
Bolting Ring	13360.	14939.	2530.
Inner Shell	14098.	11989.	1887.
Outer Shell	10564.	8819.	1633.
Baseplates	10536.	4517.	1747.
Primary Lid Bolts	34995.	42818.	10882.
Secondary Lid Bolts	10982.	12840.	3432.

1-ft Side Drop - Cold Conditions (Max. Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	23416.(*)	8086.	1236.
Primary Lid (No Holes)	12428.	8578.	1236.
Secondary Lid	6568.	4133.	356.

Bolting Ring	15164.	18079.	3593.
Inner Shell	15376.	10637.	2097.
Outer Shell	15085.	7137.	421.
Baseplates	12684.	7418.	705.
Primary Lid Bolts	44518.	46395.	13702.
Secondary Lid Bolts	10373.	12669.	2692.

1-ft Side Drop - Cold Conditions (No Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	24089.(*)	7919.	832.
Primary Lid (No Holes)	12720.	6794.	832.
Secondary Lid	6849.	4264.	346.
Bolting Ring	15824.	18837.	3440.
Inner Shell	16531.	15795.	2945.
Outer Shell	15289.	7079.	201.
Baseplates	13015.	7616.	925.
Primary Lid Bolts	43855.	48523.	13632.
Secondary Lid Bolts	10604.	12977.	2732.

1-ft Corner Drop - Hot Conditions

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	9642.	7695.	1825.
Secondary Lid	6664.	3071.	238.
Bolting Ring	9559.	11946.	2386.
Inner Shell	12201.	9867.	1933.
Outer Shell	6846.	8060.	1680.
Baseplates	5307.	3609.	1794.
Primary Lid Bolts	24600.	21796.	6778.
Secondary Lid Bolts	13534.	14913.	5397.

1-ft Corner Drop - Cold Conditions (Max. Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	9065.	4979.	1137.
Secondary Lid	4372.	2041.	242.
Bolting Ring	8381.	10473.	2177.
Inner Shell	8930.	2893.	306.
Outer Shell	6741.	4958.	750.
Baseplates	3136.	1365.	225.
Primary Lid Bolts	17360.	19970.	5541.
Secondary Lid Bolts	8322.	8997.	3302.

1-ft Corner Drop - Cold Conditions (No Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	9634.	4606.	1052.
Secondary Lid	3941.	1833.	237.
Bolting Ring	8668.	10287.	2639.
Inner Shell	8260.	6994.	1318.
Outer Shell	8437.	5690.	681.
Baseplates	4637.	3586.	558.
Primary Lid Bolts	17271.	20085.	5506.
Secondary Lid Bolts	7696.	8256.	3027.

30-ft End Drop - Hot Conditions

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	49334.(*)	47920.	6052.
Secondary Lid	39223.	19768.	1736.
Bolting Ring	36835.	14456.	1624.
Inner Shell	45432.	22679.	3007.
Outer Shell	23422.	14631.	-60.
Baseplates	42473.	49322.	6991.
Primary Lid Bolts	14241.	14475.	703.
Secondary Lid Bolts	45267.	43410.	21964.

30-ft End Drop - Cold Conditions (Max. Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	48728.(*)	45075.	5762.
Secondary Lid	38045.	19098.	1680.
Bolting Ring	27095.	10836.	939.
Inner Shell	35030.	24346.	-609.
Outer Shell	24104.	16832.	683.
Baseplates	45248.	53818.	8758.
Primary Lid Bolts	8528.	8402.	1116.
Secondary Lid Bolts	42463.	40675.	20718.

30-ft End Drop - Cold Conditions (No Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	49084.(*)	45113.	5759.
Secondary Lid	38000.	19037.	1677.
Bolting Ring	27167.	12169.	923.
Inner Shell	38466.	25628.	1335.
Outer Shell	26337.	18752.	776.
Baseplates	47147.	55717.	8769.
Primary Lid Bolts	8360.	8175.	1298.
Secondary Lid Bolts	42415.	40627.	20713.

30-ft Side Drop - Hot Conditions

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	112023.(*)	29968.	5181.
Primary Lid (No Holes)	60341.	38495.	5181.
Secondary Lid	32887.	20567.	1803.
Bolting Ring	74521.(*)	83727.	17688.
Bolting Ring (No Holes)	40478.	31486.	2445.
Inner Shell	61816.(*)	37581.	3894.
Outer Shell	55480.(*)	25810.	1254.
Baseplates	43554.	14546.	2805.
Primary Lid Bolts	195553.(*)	237913.	60037.
Secondary Lid Bolts	50990.	62376.	13293.

30-ft Side Drop - Cold Conditions (Max. Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	114813.(*)	31648.	4896.
Primary Lid (No Holes)	62070.	38794.	4896.
Secondary Lid	35673.	21936.	1726.
Bolting Ring	77019.(*)	87346.	17730.
Bolting Ring (No Holes)	41908.	30866.	7679.

Inner Shell	57296.(*)	42721.	7361.
Outer Shell	58569.(*)	24113.	732.
Baseplates	41288.	17196.	3891.
Primary Lid Bolts	197939.(*)	243281.	62216.
Secondary Lid Bolts	54926.	66670.	13790.

30-ft Side Drop - Cold Conditions (No Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	115384.(*)	31682.	4691.
Primary Lid (No Holes)	62481.	37747.	4691.
Secondary Lid	35835.	22026.	1733.
Bolting Ring	77906.(*)	88252.	17549.
Bolting Ring (No Holes)	42444.	31983.	8772.
Inner Shell	57680.(*)	50089.	8592.
Outer Shell	59259.(*)	23963.	782.
Baseplates	41047.	17353.	4042.
Primary Lid Bolts	199776.(*)	245514.	62807.
Secondary Lid Bolts	55207.	67086.	13838.

30-ft Corner Drop - Hot Conditions

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	68971.(*)	34388.	4878.
Secondary Lid	29808.	13317.	902.
Bolting Ring	65652.(*)	75870.	16862.
Bolting Ring (No Holes)	46432.	42519.	2020.
Inner Shell	49762.(*)	22424.	3116.
Outer Shell	31931.	18173.	1826.
Baseplates	12150.	13551.	1801.
Primary Lid Bolts	128716.(*)	143097.	46050.
Secondary Lid Bolts	56020.	63717.	26246.

30-ft Corner Drop - Cold Conditions (Max. Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	68173.(*)	32478.	4551.
Secondary Lid	27743.	12352.	931.
Bolting Ring	63267.(*)	72769.	15470.
Bolting Ring (No Holes)	42151.	41083.	2613.
Inner Shell	38757.(*)	15260.	2068.
Outer Shell	39052.	22262.	1867.
Baseplates	21984.	24285.	2800.
Primary Lid Bolts	119602.(*)	134429.	44347.
Secondary Lid Bolts	51222.	59171.	23807.

30-ft Corner Drop - Cold Conditions (No Heat Load)

	Max. S.I.	Max. Sig1	Max. Sig3
Primary Lid	68379.(*)	32346.	4542.
Secondary Lid	27645.	12311.	929.
Bolting Ring	63591.(*)	73294.	15449.
Bolting Ring (No Holes)	41460.	41129.	2791.
Inner Shell	37866.(*)	20189.	2832.
Outer Shell	40893.	23879.	1851.
Baseplates	26335.	29743.	3702.
Primary Lid Bolts	119190.(*)	136837.	44249.
Secondary Lid Bolts	51172.	58940.	23701.

Notes:

(1) The detail printout of the stress components for each load case are listed in files named ls1post.out, ls2post.out, and, l3post.out. The summary of the data is listed in files named summary.out and summary-1.out, if applicable. These files are included in the electronic media attached with this document.
(2) The quantities marked with asterisk (*) have been qualified alternatively.
(3) Primary lid bolt stresses have been qualified alternatively. See Section xx.xx.

Stress Reconciliation 1-ft End Drop

Stresses in the Vicinity of High Stress Area of the Inner Shell

Cold Conditions (Max. Heat Load)

```
PRINT S    NODAL SOLUTION PER NODE

  ***** POST1 NODAL STRESS LISTING *****
  PowerGraphics Is Currently Enabled

  LOAD STEP=     2  SUBSTEP=     3
   TIME=    2.0000      LOAD CASE=   0
  SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

    NODE    S1          S2          S3          SINT        SEQV
   10144  -4350.6     -6091.7     -14489.      10138.      9389.3
   10145   21104.     -7987.7     -17191.      38296.      34624.
   10146   807.83     -5397.5     -12513.      13321.      11545.
   10711   6841.7      997.27     -6491.9      13334.      11577.
   10712   25603.      13561.      13074.      12528.      12292.
   10713   6503.2      4270.2     -601.54      7104.8      6292.8

 MINIMUM VALUES
 NODE      10144       10145       10145       10713       10713
 VALUE   -4350.6     -7987.7     -17191.      7104.8      6292.8

 MAXIMUM VALUES
 NODE      10712       10712       10712       10145       10145
 VALUE    25603.      13561.      13074.      38296.      34624.

     Average S.I. = (10,138+38,296+13,321+13,334+12,528+7,105)/6
                  = 15,787 psi
```

Cold Conditions (Max. Heat Load)

```
 PRINT S    NODAL SOLUTION PER NODE

  ***** POST1 NODAL STRESS LISTING *****
  PowerGraphics Is Currently Enabled

  LOAD STEP=     3  SUBSTEP=     1
   TIME=    3.0000      LOAD CASE=   0
  SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

    NODE    S1          S2          S3          SINT        SEQV
   10144  -4564.3     -5958.5     -13373.      8809.1      8201.4
   10145   21777.     -7721.4     -16070.      37847.      34440.
   10146   658.98     -5040.2     -11225.      11884.      10295.
   10711   7173.6      1089.3     -6981.8      14155.      12299.
   10712   26480.      14040.      13560.      12920.      12687.
   10713   6769.5      4362.8     -819.25      7588.8      6717.0
```

```
 MINIMUM VALUES
 NODE      10144       10145       10145       10713       10713
 VALUE   -4564.3     -7721.4     -16070.      7588.8      6717.0

 MAXIMUM VALUES
 NODE      10712       10712       10712       10145       10145
 VALUE    26480.      14040.      13560.      37847.      34440.

      Average S.I. = (8,809+37,848+11,884+14,155+12,920+7,589)/6
                   = 15,534 psi
```

Stress Reconciliation 30-ft End Drop

Primary Lid Stress Linearization

Hot Conditions

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SEC1
DSYS=  0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  27761     OUTSIDE NODE =  27756

  LOAD STEP     1  SUBSTEP=     1
  TIME=    1.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY          SZ          SXY         SYZ         SXZ
  -2871.      -3328.      -2018.      -1229.      -9342.      -6515.
     S1          S2          S3          SINT        SEQV
   8275.      -1867.     -0.1462E+05  0.2290E+05  0.1987E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
 I  0.2490E+05  0.1360E+05  -2970.      0.1411E+05   2576.       2472.
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O -0.2490E+05 -0.1360E+05   2970.     -0.1411E+05  -2576.      -2472.
     S1          S2          S3          SINT        SEQV
 I  0.3477E+05   4122.      -3368.      0.3814E+05  0.3500E+05
 C   0.000       0.000       0.000       0.000       0.000
 O   3368.      -4122.     -0.3477E+05  0.3814E+05  0.3500E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
 I  0.2203E+05  0.1027E+05  -4988.      0.1288E+05  -6765.      -4043.
 C  -2871.      -3328.      -2018.      -1229.      -9342.      -6515.
 O -0.2777E+05 -0.1693E+05   951.6     -0.1534E+05 -0.1192E+05  -8986.
     S1          S2          S3          SINT        SEQV
 I  0.3169E+05   3211.      -7586.      0.3927E+05  0.3514E+05
 C   8275.      -1867.     -0.1462E+05  0.2290E+05  0.1987E+05
 O   6968.      -7461.     -0.4325E+05  0.5022E+05  0.4478E+05
```

```
             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I   2581.       3972.       600.5      -1356.       916.6      -779.5
 C  -2570.      -3966.      -601.8       1362.      -915.5       780.6
 O   2559.       3960.       603.1      -1368.       914.4      -781.6
      S1          S2          S3          SINT        SEQV
 I   5114.       1774.       265.3       4848.       4297.
 C  -266.1      -1760.      -5112.       4846.       4298.
 O   5110.       1745.       266.8       4843.       4299.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I  0.2461E+05  0.1424E+05  -4388.      0.1153E+05  -5849.      -4822.
 C  -5441.      -7294.      -2620.       132.9     -0.1026E+05  -5734.
 O -0.2521E+05 -0.1297E+05   1555.     -0.1671E+05 -0.1100E+05  -9768.
      S1          S2          S3          SINT        SEQV        TEMP
 I  0.3345E+05   7170.      -6159.      0.3961E+05  0.3491E+05   111.7
 C   7274.      -5977.     -0.1665E+05  0.2392E+05  0.2076E+05
 O   7502.      -2470.     -0.4165E+05  0.4916E+05  0.4501E+05   111.7
```

<u>Cold Conditions (Max. Heat Load)</u>

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SEC1
DSYS=  0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  27761     OUTSIDE NODE =  27756

  LOAD STEP     2  SUBSTEP=     1
  TIME=    2.0000          LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
  -3018.      -3620.      -1986.      -1221.      -9381.      -6557.
      S1          S2          S3          SINT        SEQV
   8241.      -2069.     -0.1480E+05  0.2304E+05  0.1999E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I  0.2507E+05  0.1342E+05  -2769.      0.1397E+05   2462.       2061.
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O -0.2507E+05 -0.1342E+05   2769.     -0.1397E+05  -2462.      -2061.
      S1          S2          S3          SINT        SEQV
 I  0.3463E+05   4221.      -3135.      0.3776E+05  0.3468E+05
 C   0.000       0.000       0.000       0.000       0.000
 O   3135.      -4221.     -0.3463E+05  0.3776E+05  0.3468E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
```

```
 I  0.2205E+05   9798.      -4755.      0.1275E+05  -6919.      -4496.
 C  -3018.      -3620.      -1986.      -1221.      -9381.      -6557.
 O -0.2808E+05 -0.1704E+05   782.2     -0.1519E+05 -0.1184E+05  -8617.
      S1          S2          S3          SINT        SEQV
 I  0.3162E+05   3001.      -7535.      0.3916E+05  0.3510E+05
 C   8241.      -2069.     -0.1480E+05  0.2304E+05  0.1999E+05
 O   6728.      -7915.     -0.4315E+05  0.4988E+05  0.4441E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I   2895.       3948.       701.5      -1287.       885.1      -517.9
 C  -2884.      -3942.      -702.7       1293.      -884.0       518.8
 O   2873.       3936.       703.9      -1299.       882.9      -519.6
      S1          S2          S3          SINT        SEQV
 I   5052.       2033.       458.3       4594.       4044.
 C  -459.6      -2018.      -5051.       4591.       4044.
 O   5049.       2003.       460.9       4588.       4044.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I  0.2494E+05  0.1375E+05  -4054.      0.1146E+05  -6034.      -5014.
 C  -5902.      -7562.      -2689.       72.16     -0.1026E+05  -6038.
 O -0.2521E+05 -0.1310E+05   1486.     -0.1649E+05 -0.1096E+05  -9137.
      S1          S2          S3          SINT        SEQV        TEMP
 I  0.3358E+05   7045.      -5992.      0.3957E+05  0.3493E+05  0.8670
 C   7246.      -6377.     -0.1702E+05  0.2427E+05  0.2107E+05
 O   7361.      -2991.     -0.4120E+05  0.4856E+05  0.4430E+05  0.8879
```

<u>Cold Conditions (No Heat Load)</u>

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SEC1
DSYS=  0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  27761     OUTSIDE NODE =  27756

  LOAD STEP     3  SUBSTEP=     1
  TIME=    3.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
  -2978.      -3678.      -2013.      -1257.      -9445.      -6598.
      S1          S2          S3          SINT        SEQV
   8274.      -2027.     -0.1492E+05  0.2319E+05  0.2013E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I  0.2508E+05  0.1338E+05  -2846.      0.1401E+05   2501.       2178.
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O -0.2508E+05 -0.1338E+05   2846.     -0.1401E+05  -2501.      -2178.
```

```
     S1           S2           S3          SINT        SEQV
I  0.3469E+05   4153.       -3223.       0.3791E+05  0.3481E+05
C   0.000       0.000        0.000        0.000       0.000
O   3223.      -4153.      -0.3469E+05  0.3791E+05  0.3481E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ          SXY         SYZ         SXZ
I  0.2210E+05   9706.       -4859.       0.1275E+05  -6944.      -4420.
C  -2978.      -3678.       -2013.       -1257.      -9445.      -6598.
O -0.2806E+05 -0.1706E+05   832.5      -0.1527E+05 -0.1195E+05  -8776.
     S1           S2           S3          SINT        SEQV
I  0.3162E+05   2991.       -7658.       0.3927E+05  0.3518E+05
C   8274.      -2027.      -0.1492E+05  0.2319E+05  0.2013E+05
O   6852.      -7818.      -0.4332E+05  0.5017E+05  0.4468E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ          SXY         SYZ         SXZ
I   2831.       3973.        679.9       -1312.       897.8      -591.0
C  -2820.      -3967.       -681.1        1318.      -896.7       592.0
O   2809.       3961.        682.3       -1324.       895.6      -592.9
     S1           S2           S3          SINT        SEQV
I   5094.       1971.        418.2        4676.       4125.
C  -419.4      -1956.       -5092.        4673.       4125.
O   5091.       1941.        420.6        4670.       4126.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ          SXY         SYZ         SXZ
I  0.2493E+05  0.1368E+05  -4179.       0.1144E+05  -6046.      -5011.
C  -5798.      -7645.       -2694.        60.65     -0.1034E+05  -6006.
O -0.2525E+05 -0.1310E+05   1515.      -0.1659E+05 -0.1105E+05  -9369.
     S1           S2           S3          SINT        SEQV        TEMP
I  0.3354E+05   7014.       -6120.       0.3966E+05  0.3499E+05  -20.00
C   7273.      -6299.      -0.1711E+05  0.2438E+05  0.2116E+05
O   7463.      -2848.      -0.4145E+05  0.4891E+05  0.4466E+05  -20.00
```

<u>Stress Reconciliation 30-ft Side Drop</u>

<u>Primary Lid Stress Averaging</u>

<u>Hot Conditions</u>

```
PRINT S    NODAL SOLUTION PER NODE

  ***** POST1 NODAL STRESS LISTING *****
  PowerGraphics Is Currently Enabled

  LOAD STEP=      1  SUBSTEP=     1
   TIME=    1.0000      LOAD CASE=   0
  SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

    NODE    S1          S2          S3          SINT        SEQV
   27326   2067.9     -3636.6     -7087.8      9155.7      8008.7
   27326   2067.9     -3636.6     -7087.8      9155.7      8008.7
```

```
  27398   14075.      11630.     -46266.      60341.      59156.
  27398   14075.      11630.     -46266.      60341.      59156.

 MINIMUM VALUES
 NODE      27326       27326       27398       27326       27326
 VALUE    2067.9     -3636.6     -46266.      9155.7      8008.7

 MAXIMUM VALUES
 NODE      27398       27398       27326       27398       27398
 VALUE    14075.      11630.     -7087.8      60341.      59156.

      Average S.I. = (9,156+60,341)/2
                   = 34,749 psi
```

<u>Cold Conditions (Max. Heat Load)</u>

```
PRINT S    NODAL SOLUTION PER NODE

  ***** POST1 NODAL STRESS LISTING *****
  PowerGraphics Is Currently Enabled

  LOAD STEP=     2  SUBSTEP=     1
   TIME=    2.0000      LOAD CASE=   0
  SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

    NODE    S1          S2          S3          SINT        SEQV
  27326   2175.2     -3681.5     -6194.1      8369.3      7438.4
  27326   2175.2     -3681.5     -6194.1      8369.3      7438.4
  27398   14396.      11949.     -47674.      62070.      60884.
  27398   14396.      11949.     -47674.      62070.      60884.

 MINIMUM VALUES
 NODE      27326       27326       27398       27326       27326
 VALUE    2175.2     -3681.5     -47674.      8369.3      7438.4

 MAXIMUM VALUES
 NODE      27398       27398       27326       27398       27398
 VALUE    14396.      11949.     -6194.1      62070.      60884.

      Average S.I. = (8,369+62,070)/2
                   = 35,220 psi
```

<u>Cold Conditions (No Heat Load)</u>

```
 PRINT S    NODAL SOLUTION PER NODE

  ***** POST1 NODAL STRESS LISTING *****
  PowerGraphics Is Currently Enabled

  LOAD STEP=     3  SUBSTEP=     1
   TIME=    3.0000      LOAD CASE=   0
  SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1
```

```
  NODE    S1         S2          S3          SINT        SEQV
 27326   2182.3     -3695.9     -6301.9      8484.2      7527.5
 27326   2182.3     -3695.9     -6301.9      8484.2      7527.5
 27398   14518.      12064.     -47964.      62481.      61291.
 27398   14518.      12064.     -47964.      62481.      61291.

MINIMUM VALUES
NODE      27326       27326       27398       27326       27326
VALUE    2182.3     -3695.9     -47964.      8484.2      7527.5

MAXIMUM VALUES
NODE      27398       27398       27326       27398       27398
VALUE    14518.      12064.     -6301.9      62481.      61291.

     Average S.I. = (8,484+62,481)/2
                  = 35,483 psi
```

Inner Shell Stress Linearization

Hot Conditions

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  10181     OUTSIDE NODE =  10174

  LOAD STEP     1  SUBSTEP=     1
  TIME=    1.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

              ** MEMBRANE **
     SX          SY          SZ          SXY         SYZ         SXZ
-0.2460E+05 -0.1417E+05  0.1091E+05  -3611.      -183.3      -964.9
     S1          S2          S3          SINT        SEQV
 0.1094E+05 -0.1304E+05 -0.2576E+05  0.3670E+05  0.3228E+05

              ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  -829.2      -7852.     -0.2663E+05  -781.6      -669.7      0.7606E-02
C   0.000       0.000       0.000       0.000       0.000       0.000
O   829.2       7852.      0.2663E+05   781.6       669.7     -0.7606E-02
     S1          S2          S3          SINT        SEQV
I  -743.0      -7914.     -0.2666E+05  0.2592E+05  0.2318E+05
C   0.000       0.000       0.000       0.000       0.000
O  0.2666E+05   7914.       743.0      0.2592E+05  0.2318E+05

              ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I -0.2543E+05 -0.2202E+05 -0.1572E+05  -4393.      -853.0      -964.8
C -0.2460E+05 -0.1417E+05  0.1091E+05  -3611.      -183.3      -964.9
```

```
 O -0.2378E+05  -6317.      0.3755E+05  -2830.       486.4      -964.9
      S1          S2          S3          SINT        SEQV
 I -0.1559E+05 -0.1902E+05 -0.2857E+05  0.1298E+05  0.1165E+05
 C  0.1094E+05 -0.1304E+05 -0.2576E+05  0.3670E+05  0.3228E+05
 O  0.3757E+05  -5879.     -0.2424E+05  0.6181E+05  0.5498E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I -0.3600      -3.409      -11.57      -0.3394     -0.2908      0.3303E-05
 C  0.1091E-10  0.4729E-10  0.1583E-09  0.5457E-11  0.4064E-11  0.1137E-12
 O  0.3600       3.409       11.57       0.3394      0.2908     -0.3303E-05
      S1          S2          S3          SINT        SEQV
 I -0.3226      -3.436      -11.58       11.25       10.06
 C  0.1584E-09  0.4795E-10  0.1011E-10  0.1483E-09  0.1335E-09
 O   11.58       3.436      0.3226       11.25       10.06

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I -0.2543E+05 -0.2202E+05 -0.1573E+05  -4393.      -853.3      -964.8
 C -0.2460E+05 -0.1417E+05  0.1091E+05  -3611.      -183.3      -964.9
 O -0.2378E+05  -6313.      0.3756E+05  -2829.       486.7      -964.9
      S1          S2          S3          SINT        SEQV        TEMP
 I -0.1560E+05 -0.1902E+05 -0.2857E+05  0.1297E+05  0.1164E+05   111.6
 C  0.1094E+05 -0.1304E+05 -0.2576E+05  0.3670E+05  0.3228E+05
 O  0.3758E+05  -5875.     -0.2423E+05  0.6182E+05  0.5499E+05   111.5
```

<u>Cold Conditions (Max. Heat Load)</u>

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  10181     OUTSIDE NODE =  10174

  LOAD STEP     2  SUBSTEP=     1
  TIME=    2.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
 -0.2359E+05 -0.1502E+05   4891.      -3445.      -345.0      -1488.
      S1          S2          S3          SINT        SEQV
   4970.     -0.1381E+05 -0.2488E+05  0.2985E+05  0.2614E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I  -802.9      -8619.     -0.2909E+05  -728.9      -715.4     -0.5132E-02
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O   802.9       8619.      0.2909E+05   728.9       715.4      0.5132E-02
      S1          S2          S3          SINT        SEQV
 I  -735.4      -8662.     -0.2911E+05  0.2838E+05  0.2536E+05
```

```
 C   0.000        0.000        0.000        0.000        0.000
 O  0.2911E+05   8662.        735.4       0.2838E+05  0.2536E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX           SY           SZ           SXY          SYZ          SXZ
 I -0.2439E+05 -0.2364E+05 -0.2420E+05  -4174.       -1060.       -1488.
 C -0.2359E+05 -0.1502E+05   4891.      -3445.       -345.0       -1488.
 O -0.2279E+05  -6398.      0.3398E+05  -2716.        370.4       -1488.
      S1           S2           S3           SINT         SEQV
 I -0.1981E+05 -0.2351E+05 -0.2891E+05   9094.        7921.
 C   4970.     -0.1381E+05 -0.2488E+05  0.2985E+05  0.2614E+05
 O  0.3402E+05  -5968.     -0.2326E+05  0.5728E+05  0.5089E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX           SY           SZ           SXY          SYZ          SXZ
 I -0.3486       -3.743       -12.63      -0.3165      -0.3106      -0.2228E-05
 C   0.000       0.5457E-10  0.1746E-09  0.4093E-11  0.4263E-11 -0.4547E-12
 O  0.3486        3.743       12.63       0.3165      0.3106       0.2228E-05
      S1           S2           S3           SINT         SEQV
 I -0.3193       -3.761       -12.64       12.32        11.01
 C  0.1748E-09  0.5473E-10 -0.3086E-12  0.1751E-09  0.1551E-09
 O   12.64        3.761       0.3193       12.32        11.01

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX           SY           SZ           SXY          SYZ          SXZ
 I -0.2439E+05 -0.2364E+05 -0.2421E+05  -4174.       -1061.       -1488.
 C -0.2359E+05 -0.1502E+05   4891.      -3445.       -345.0       -1488.
 O -0.2279E+05  -6394.      0.3399E+05  -2716.        370.7       -1488.
      S1           S2           S3           SINT         SEQV         TEMP
 I -0.1981E+05 -0.2352E+05 -0.2891E+05   9096.        7922.        1.801
 C   4970.     -0.1381E+05 -0.2488E+05  0.2985E+05  0.2614E+05
 O  0.3404E+05  -5965.     -0.2326E+05  0.5730E+05  0.5090E+05   1.843
```

Cold Conditions (No. Heat Load)

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  10181     OUTSIDE NODE =  10174

  LOAD STEP     3  SUBSTEP=     1
  TIME=    3.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX           SY           SZ           SXY          SYZ          SXZ
 -0.2327E+05 -0.1468E+05   5426.      -3412.      -367.6      -1463.
      S1           S2           S3           SINT         SEQV
   5503.     -0.1349E+05 -0.2454E+05  0.3004E+05  0.2632E+05
```

```
             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I  -819.6      -8686.     -0.2928E+05  -715.4      -717.9      0.1333E-03
C   0.000       0.000       0.000       0.000       0.000       0.000
O   819.6       8686.      0.2928E+05   715.4       717.9     -0.1333E-03
     S1           S2           S3           SINT         SEQV
I  -754.9      -8725.     -0.2931E+05  0.2855E+05  0.2552E+05
C   0.000       0.000       0.000       0.000       0.000
O  0.2931E+05   8725.       754.9      0.2855E+05  0.2552E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I -0.2409E+05 -0.2336E+05 -0.2386E+05  -4128.      -1086.      -1463.
C -0.2327E+05 -0.1468E+05   5426.      -3412.      -367.6      -1463.
O -0.2245E+05  -5992.      0.3471E+05  -2697.       350.4      -1463.
     S1           S2           S3           SINT         SEQV
I -0.1957E+05 -0.2317E+05 -0.2857E+05   8994.       7841.
C   5503.     -0.1349E+05 -0.2454E+05  0.3004E+05  0.2632E+05
O  0.3475E+05  -5570.     -0.2292E+05  0.5767E+05  0.5125E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I -0.3559      -3.771      -12.71      -0.3107     -0.3117      0.5787E-07
C  0.7276E-11  0.5639E-10  0.1746E-09  0.3638E-11  0.4434E-11   0.000
O  0.3559       3.771       12.71       0.3107      0.3117     -0.5787E-07
     S1           S2           S3           SINT         SEQV
I -0.3278      -3.789      -12.73       12.40       11.08
C  0.1748E-09  0.5649E-10  0.7007E-11  0.1678E-09  0.1493E-09
O   12.73       3.789      0.3278       12.40       11.08

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I -0.2409E+05 -0.2337E+05 -0.2387E+05  -4128.      -1086.      -1463.
C -0.2327E+05 -0.1468E+05   5426.      -3412.      -367.6      -1463.
O -0.2245E+05  -5988.      0.3472E+05  -2697.       350.7      -1463.
     S1           S2           S3           SINT         SEQV         TEMP
I -0.1958E+05 -0.2318E+05 -0.2857E+05   8996.       7842.      -20.00
C   5503.     -0.1349E+05 -0.2454E+05  0.3004E+05  0.2632E+05
O  0.3476E+05  -5566.     -0.2292E+05  0.5768E+05  0.5126E+05  -20.00
```

<u>Outer Shell Stress Linearization</u>

<u>Hot Conditions</u>

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  11231     OUTSIDE NODE =  11227

  LOAD STEP     1  SUBSTEP=     1
  TIME=    1.0000         LOAD CASE=  0
```

```
 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

              ** MEMBRANE **
     SX           SY           SZ           SXY          SYZ          SXZ
  -3291.     -0.3934E+05  -1476.        734.8        73.11        487.4
     S1           S2           S3           SINT         SEQV
  -1352.      -3400.     -0.3935E+05  0.3800E+05  0.3702E+05

              ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
 I  -5.029       8537.       0.2613E+05  -165.5       -2.293      -0.3053E-03
 C   0.000       0.000        0.000        0.000        0.000        0.000
 O   5.029      -8537.      -0.2613E+05   165.5        2.293       0.3053E-03
     S1           S2           S3           SINT         SEQV
 I  0.2613E+05   8540.       -8.235      0.2613E+05  0.2308E+05
 C   0.000       0.000        0.000        0.000        0.000
 O   8.235      -8540.      -0.2613E+05  0.2613E+05  0.2308E+05

              ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
 I  -3296.     -0.3080E+05  0.2465E+05   569.3        70.82        487.4
 C  -3291.     -0.3934E+05  -1476.       734.8        73.11        487.4
 O  -3286.     -0.4788E+05 -0.2760E+05   900.3        75.40        487.4
     S1           S2           S3           SINT         SEQV
 I  0.2466E+05  -3293.     -0.3081E+05  0.5547E+05  0.4804E+05
 C  -1352.      -3400.     -0.3935E+05  0.3800E+05  0.3702E+05
 O  -3258.     -0.2761E+05 -0.4789E+05  0.4464E+05  0.3871E+05

              ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
 I -0.2184E-02   3.707       11.34      -0.7187E-01 -0.9959E-03 -0.1326E-06
 C -0.4547E-12  0.7276E-10  0.2608E-09 -0.4547E-12 -0.1137E-12   0.000
 O  0.2184E-02  -3.707      -11.34       0.7187E-01  0.9959E-03  0.1326E-06
     S1           S2           S3           SINT         SEQV
 I   11.34       3.708     -0.3576E-02   11.35        10.02
 C  0.2608E-09  0.7276E-10 -0.4576E-12  0.2613E-09  0.2334E-09
 O  0.3576E-02  -3.708      -11.34       11.35        10.02

              ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
 I  -3296.     -0.3080E+05  0.2466E+05   569.2        70.82        487.4
 C  -3291.     -0.3934E+05  -1476.       734.8        73.11        487.4
 O  -3286.     -0.4788E+05 -0.2761E+05   900.3        75.40        487.4
     S1           S2           S3           SINT         SEQV         TEMP
 I  0.2467E+05  -3293.     -0.3081E+05  0.5548E+05  0.4805E+05   111.2
 C  -1352.      -3400.     -0.3935E+05  0.3800E+05  0.3702E+05
 O  -3258.     -0.2762E+05 -0.4790E+05  0.4464E+05  0.3871E+05   111.2
```

Cold Conditions (Max. Heat Load)

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0
```

```
         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  11231     OUTSIDE NODE =  11227

 LOAD STEP     2  SUBSTEP=     1
 TIME=    2.0000         LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX           SY           SZ           SXY          SYZ          SXZ
 -3166.     -0.4344E+05  -4161.       830.8        59.76        407.9
     S1           S2           S3           SINT         SEQV
 -3004.      -4305.     -0.4345E+05  0.4045E+05  0.3981E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I  -1.195       8990.      0.2826E+05  -176.7       -1.571      -0.1362E-03
C   0.000       0.000       0.000       0.000        0.000        0.000
O   1.195      -8990.     -0.2826E+05   176.7        1.571       0.1362E-03
     S1           S2           S3           SINT         SEQV
I  0.2826E+05   8994.      -4.666      0.2826E+05  0.2501E+05
C   0.000       0.000       0.000       0.000       0.000
O   4.666      -8994.     -0.2826E+05  0.2826E+05  0.2501E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I  -3167.     -0.3445E+05  0.2409E+05   654.1        58.19        407.9
C  -3166.     -0.4344E+05  -4161.       830.8        59.76        407.9
O  -3164.     -0.5243E+05 -0.3242E+05   1007.        61.34        407.9
     S1           S2           S3           SINT         SEQV
I  0.2410E+05  -3159.     -0.3446E+05  0.5856E+05  0.5075E+05
C  -3004.      -4305.     -0.4345E+05  0.4045E+05  0.3981E+05
O  -3138.     -0.3242E+05 -0.5245E+05  0.4931E+05  0.4295E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I -0.5190E-03   3.904       12.27      -0.7672E-01 -0.6822E-03 -0.5912E-07
C -0.4547E-12  0.8004E-10  0.2838E-09 -0.3411E-12 -0.9237E-13 -0.5684E-13
O  0.5190E-03  -3.904      -12.27       0.7672E-01  0.6822E-03  0.5912E-07
     S1           S2           S3           SINT         SEQV
I   12.27       3.905     -0.2026E-02   12.27        10.86
C  0.2838E-09  0.8004E-10 -0.4562E-12  0.2842E-09  0.2537E-09
O  0.2026E-02  -3.905      -12.27       12.27        10.86

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I  -3167.     -0.3444E+05  0.2411E+05   654.0        58.19        407.9
C  -3166.     -0.4344E+05  -4161.       830.8        59.76        407.9
O  -3164.     -0.5243E+05 -0.3243E+05   1008.        61.34        407.9
     S1           S2           S3           SINT         SEQV         TEMP
I  0.2411E+05  -3159.     -0.3446E+05  0.5857E+05  0.5076E+05  -1.874
C  -3004.      -4305.     -0.4345E+05  0.4045E+05  0.3981E+05
```

```
 O  -3138.      -0.3243E+05 -0.5245E+05  0.4931E+05  0.4296E+05  -1.878
```

Cold Conditions (No Heat Load)

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  11231     OUTSIDE NODE =  11227

  LOAD STEP     3  SUBSTEP=     1
  TIME=    3.0000          LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY           SZ          SXY          SYZ          SXZ
  -3181.     -0.4435E+05  -4727.       851.5       50.83       424.1
     S1          S2           S3          SINT         SEQV
  -3055.      -4835.     -0.4437E+05  0.4131E+05  0.4045E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY           SZ          SXY          SYZ          SXZ
 I -0.7632E-01   9067.      0.2867E+05  -178.5      -2.605      0.1585E-08
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O  0.7632E-01  -9067.     -0.2867E+05   178.5       2.605     -0.1585E-08
     S1          S2           S3          SINT         SEQV
 I  0.2867E+05   9070.      -3.588      0.2867E+05  0.2538E+05
 C   0.000       0.000       0.000       0.000       0.000
 O   3.588      -9070.     -0.2867E+05  0.2867E+05  0.2538E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY           SZ          SXY          SYZ          SXZ
 I  -3181.     -0.3529E+05  0.2394E+05   673.0       48.22       424.1
 C  -3181.     -0.4435E+05  -4727.       851.5       50.83       424.1
 O  -3181.     -0.5342E+05 -0.3340E+05   1030.       53.43       424.1
     S1          S2           S3          SINT         SEQV
 I  0.2395E+05  -3174.     -0.3530E+05  0.5925E+05  0.5137E+05
 C  -3055.      -4835.     -0.4437E+05  0.4131E+05  0.4045E+05
 O  -3154.     -0.3340E+05 -0.5344E+05  0.5029E+05  0.4385E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY           SZ          SXY          SYZ          SXZ
 I -0.3314E-04   3.937       12.45     -0.7750E-01 -0.1131E-02  0.6821E-12
 C  0.4547E-12  0.7276E-10  0.2865E-09 -0.3411E-12 -0.5684E-13   0.000
 O  0.3314E-04  -3.937      -12.45      0.7750E-01  0.1131E-02 -0.6821E-12
     S1          S2           S3          SINT         SEQV
 I   12.45       3.938     -0.1558E-02   12.45       11.02
 C  0.2865E-09  0.7276E-10  0.4531E-12  0.2860E-09  0.2576E-09
 O  0.1558E-02  -3.938      -12.45       12.45       11.02

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
```

```
     SX          SY          SZ          SXY         SYZ         SXZ
 I  -3181.     -0.3528E+05  0.2396E+05   673.0       48.22       424.1
 C  -3181.     -0.4435E+05  -4727.       851.5       50.83       424.1
 O  -3181.     -0.5342E+05 -0.3341E+05   1030.       53.44       424.1
     S1          S2          S3          SINT        SEQV        TEMP
 I  0.2396E+05  -3174.     -0.3530E+05  0.5926E+05  0.5138E+05  -20.00
 C  -3055.      -4835.     -0.4437E+05  0.4131E+05  0.4045E+05
 O  -3154.     -0.3342E+05 -0.5344E+05  0.5029E+05  0.4385E+05  -20.00
```

Stress Reconciliation 30-ft Corner Drop

Primary Lid Stress Linearization

Hot Conditions

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  31314     OUTSIDE NODE =  31316

  LOAD STEP     1  SUBSTEP=     1
  TIME=    1.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY          SZ          SXY         SYZ         SXZ
  -6483.     -0.3283E+05  -4802.      -173.4      -330.1       2775.
     S1          S2          S3          SINT        SEQV
  -2738.      -8542.     -0.3283E+05  0.3010E+05  0.2765E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
 I  -9273.     -0.2992E+05  0.1145E+05  -133.9      -215.4      -846.1
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O   9273.      0.2992E+05 -0.1145E+05   133.9       215.4       846.1
     S1          S2          S3          SINT        SEQV
 I  0.1149E+05  -9307.     -0.2992E+05  0.4141E+05  0.3586E+05
 C   0.000       0.000       0.000       0.000       0.000
 O  0.2992E+05   9307.     -0.1149E+05  0.4141E+05  0.3586E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
 I -0.1576E+05 -0.6275E+05   6649.      -307.3      -545.4       1929.
 C  -6483.     -0.3283E+05  -4802.      -173.4      -330.1       2775.
 O   2791.      -2913.     -0.1625E+05  -39.52      -114.7       3621.
     S1          S2          S3          SINT        SEQV
 I   6819.     -0.1592E+05 -0.6275E+05  0.6957E+05  0.6144E+05
 C  -2738.      -8542.     -0.3283E+05  0.3010E+05  0.2765E+05
 O   3457.      -2913.     -0.1692E+05  0.2038E+05  0.1805E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
```

```
     SX           SY           SZ           SXY          SYZ          SXZ
I   1173.        2052.        1612.       -97.90        4.887       -2140.
C  -1177.       -2065.       -1607.        97.85       -4.981        2140.
O   1181.        2078.        1603.       -97.79        5.074       -2139.
     S1           S2           S3           SINT         SEQV
I   3547.        2050.       -760.3        4308.        3788.
C   760.0       -2063.       -3546.        4306.        3789.
O   3545.        2076.       -759.6        4304.        3790.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I -0.1458E+05 -0.6070E+05   8262.       -405.2       -540.6       -210.9
C  -7660.     -0.3489E+05  -6410.       -75.58       -335.1        4915.
O   3972.      -835.1     -0.1465E+05  -137.3       -109.6        1482.
     S1           S2           S3           SINT         SEQV         TEMP
I   8268.     -0.1458E+05 -0.6070E+05  0.6897E+05  0.6085E+05   111.6
C  -2077.     -0.1199E+05 -0.3490E+05  0.3282E+05  0.2916E+05
O   4093.      -838.7     -0.1477E+05  0.1886E+05  0.1694E+05   111.7
```

Cold Conditions (Max. Heat Load)

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  31314     OUTSIDE NODE =  31316

  LOAD STEP     2  SUBSTEP=     1
  TIME=    2.0000          LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX           SY           SZ           SXY          SYZ          SXZ
  -6582.     -0.3291E+05  -4397.      -177.4       -336.7       2478.
     S1           S2           S3           SINT         SEQV
  -2776.      -8198.     -0.3291E+05  0.3014E+05  0.2782E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I  -9556.     -0.2932E+05  0.1092E+05  -144.5       -216.9       -690.1
C   0.000        0.000        0.000        0.000        0.000        0.000
O   9556.      0.2932E+05 -0.1092E+05   144.5        216.9        690.1
     S1           S2           S3           SINT         SEQV
I  0.1094E+05  -9578.     -0.2932E+05  0.4026E+05  0.3487E+05
C   0.000        0.000        0.000        0.000        0.000
O  0.2932E+05   9578.     -0.1094E+05  0.4026E+05  0.3487E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY           SZ           SXY          SYZ          SXZ
I -0.1614E+05 -0.6222E+05   6523.       -321.9       -553.6        1788.
C  -6582.     -0.3291E+05  -4397.       -177.4       -336.7        2478.
```

```
 O   2973.      -3590.     -0.1532E+05  -32.85      -119.8       3169.
      S1          S2          S3         SINT        SEQV
 I   6668.     -0.1628E+05 -0.6223E+05  0.6890E+05  0.6077E+05
 C  -2776.      -8198.     -0.3291E+05  0.3014E+05  0.2782E+05
 O   3507.      -3590.     -0.1585E+05  0.1936E+05  0.1696E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I   1359.       2166.       1579.      -98.97       4.650      -2006.
 C  -1363.      -2178.      -1574.       98.90      -4.744       2006.
 O   1367.       2191.       1569.      -98.84       4.839      -2005.
      S1          S2          S3         SINT        SEQV
 I   3482.       2163.      -542.2       4024.       3553.
 C   542.0      -2176.      -3481.       4023.       3555.
 O   3480.       2189.      -541.7       4022.       3556.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I -0.1478E+05 -0.6006E+05   8101.      -420.8      -548.9      -217.8
 C  -7945.     -0.3508E+05  -5971.      -78.45      -341.4       4484.
 O   4340.      -1399.     -0.1375E+05  -131.7      -115.0       1163.
      S1          S2          S3         SINT        SEQV        TEMP
 I   8108.     -0.1478E+05 -0.6007E+05  0.6817E+05  0.6009E+05  0.7583
 C  -2363.     -0.1155E+05 -0.3509E+05  0.3273E+05  0.2924E+05
 O   4418.      -1402.     -0.1382E+05  0.1824E+05  0.1614E+05  0.8675
```

<u>Cold Conditions (No Heat Load)</u>

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  31314     OUTSIDE NODE =  31316

  LOAD STEP     3  SUBSTEP=     1
  TIME=    3.0000          LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
  -6597.     -0.3304E+05  -4462.      -176.0      -330.5       2517.
      S1          S2          S3         SINT        SEQV
  -2791.      -8263.     -0.3304E+05  0.3025E+05  0.2792E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I  -9537.     -0.2938E+05  0.1099E+05  -138.4      -215.6      -707.3
 C   0.000       0.000       0.000       0.000       0.000       0.000
 O   9537.      0.2938E+05 -0.1099E+05   138.4       215.6       707.3
      S1          S2          S3         SINT        SEQV
 I  0.1101E+05  -9560.     -0.2938E+05  0.4039E+05  0.3498E+05
```

```
 C   0.000       0.000       0.000       0.000       0.000
 O  0.2938E+05   9560.     -0.1101E+05  0.4039E+05  0.3498E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I -0.1613E+05 -0.6241E+05   6524.      -314.4      -546.1       1809.
 C  -6597.     -0.3304E+05  -4462.      -176.0      -330.5       2517.
 O   2940.      -3661.     -0.1545E+05  -37.54      -114.9       3224.
      S1          S2          S3          SINT        SEQV
 I   6672.     -0.1628E+05 -0.6242E+05  0.6909E+05  0.6095E+05
 C  -2791.      -8263.     -0.3304E+05  0.3025E+05  0.2792E+05
 O   3489.      -3661.     -0.1600E+05  0.1949E+05  0.1707E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I   1339.       2154.       1579.      -98.42       4.673      -2026.
 C  -1344.      -2166.      -1575.       98.36      -4.767       2026.
 O   1348.       2179.       1570.      -98.30       4.860      -2025.
      S1          S2          S3          SINT        SEQV
 I   3493.       2151.      -571.8       4065.       3587.
 C   571.5      -2164.      -3492.       4063.       3589.
 O   3491.       2177.      -571.2       4062.       3590.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
 I -0.1479E+05 -0.6026E+05   8104.      -412.8      -541.4      -216.6
 C  -7941.     -0.3520E+05  -6036.      -77.61      -335.3       4542.
 O   4287.      -1482.     -0.1388E+05  -135.8      -110.1       1199.
      S1          S2          S3          SINT        SEQV        TEMP
 I   8110.     -0.1479E+05 -0.6027E+05  0.6838E+05  0.6028E+05  -20.00
 C  -2344.     -0.1163E+05 -0.3521E+05  0.3286E+05  0.2934E+05
 O   4370.      -1485.     -0.1396E+05  0.1833E+05  0.1621E+05  -20.00
```

<u>Inner Shell Stress Linearization</u>

<u>Hot Conditions</u>

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECT1
DSYS=  0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =   5393     OUTSIDE NODE =   5404

  LOAD STEP     1  SUBSTEP=     1
  TIME=    1.0000          LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
   5639.     -0.2240E+05 -0.2630E+05  -596.2      -644.1       3723.
      S1          S2          S3          SINT        SEQV
```

```
   6083.      -0.2234E+05 -0.2680E+05  0.3288E+05  0.3090E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  -22.96      -5716.     -0.1725E+05  -111.2       114.4     -0.2906E-03
C   0.000       0.000       0.000       0.000       0.000       0.000
O   22.96       5716.      0.1725E+05   111.2      -114.4      0.2906E-03
     S1          S2          S3         SINT        SEQV
I  -20.79      -5717.     -0.1725E+05  0.1723E+05  0.1521E+05
C   0.000       0.000       0.000       0.000       0.000
O  0.1725E+05   5717.       20.79      0.1723E+05  0.1521E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I   5616.     -0.2812E+05 -0.4355E+05  -707.4      -529.6       3723.
C   5639.     -0.2240E+05 -0.2630E+05  -596.2      -644.1       3723.
O   5662.     -0.1669E+05  -9045.      -485.0      -758.5       3723.
     S1          S2          S3         SINT        SEQV
I   5913.     -0.2812E+05 -0.4384E+05  0.4975E+05  0.4405E+05
C   6083.     -0.2234E+05 -0.2680E+05  0.3288E+05  0.3090E+05
O   6569.      -9876.     -0.1676E+05  0.2333E+05  0.2076E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I -0.9971E-02  -2.482      -7.491     -0.4828E-01  0.4969E-01 -0.1262E-06
C   0.000       0.000      0.1819E-10   0.000       0.000     -0.4547E-12
O  0.9971E-02   2.482       7.491      0.4828E-01 -0.4969E-01  0.1262E-06
     S1          S2          S3         SINT        SEQV
I -0.9029E-02  -2.482      -7.491       7.482       6.603
C  0.1820E-10 -0.3109E-19 -0.1136E-13  0.1821E-10  0.1821E-10
O   7.491       2.482      0.9029E-02   7.482       6.603

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I   5616.     -0.2812E+05 -0.4355E+05  -707.4      -529.6       3723.
C   5639.     -0.2240E+05 -0.2630E+05  -596.2      -644.1       3723.
O   5662.     -0.1669E+05  -9038.      -485.0      -758.6       3723.
     S1          S2          S3         SINT        SEQV        TEMP
I   5913.     -0.2812E+05 -0.4385E+05  0.4976E+05  0.4406E+05   111.5
C   6083.     -0.2234E+05 -0.2680E+05  0.3288E+05  0.3090E+05
O   6569.      -9869.     -0.1676E+05  0.2333E+05  0.2076E+05   111.5
```

Lead Slump Calculations

Hot Conditions

```
 ***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

 LOAD STEP=     1  SUBSTEP=     1
  TIME=    1.0000      LOAD CASE=   0

 THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN THE GLOBAL COORDINATE SYSTEM

   NODE      UX          UY          UZ          ROTX        ROTY        ROTZ
    732 -0.10584E-01 0.12962E-17 -1.1502      0.0000      0.0000      0.0000
  14402 -0.10519E-01 0.12882E-17 -1.1368      0.0000      0.0000      0.0000

MAXIMUM ABSOLUTE VALUES
NODE        732         732         732           0           0           0
VALUE  -0.10584E-01 0.12962E-17 -1.1502      0.0000      0.0000      0.0000
```

Cold Conditions (Max. Heat Load)

```
 ***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

 LOAD STEP=     2  SUBSTEP=     1
  TIME=    2.0000      LOAD CASE=   0

 THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN THE GLOBAL COORDINATE SYSTEM

   NODE      UX          UY          UZ          ROTX        ROTY        ROTZ
    732  0.12448E-01-0.15244E-17-0.40180      0.0000      0.0000      0.0000
  14402  0.96084E-02-0.11767E-17-0.28480      0.0000      0.0000      0.0000

MAXIMUM ABSOLUTE VALUES
NODE        732         732         732           0           0           0
VALUE   0.12448E-01-0.15244E-17-0.40180      0.0000      0.0000      0.0000
```

Cold Conditions (No Heat Load)

```
 ***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

 LOAD STEP=     3  SUBSTEP=     1
  TIME=    3.0000      LOAD CASE=   0

 THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN THE GLOBAL COORDINATE SYSTEM

   NODE      UX          UY          UZ          ROTX        ROTY        ROTZ
    732  0.16584E-01-0.20310E-17-0.40493      0.0000      0.0000      0.0000
  14402  0.13607E-01-0.16663E-17-0.26436      0.0000      0.0000      0.0000

MAXIMUM ABSOLUTE VALUES
NODE        732         732         732           0           0           0
VALUE   0.16584E-01-0.20310E-17-0.40493      0.0000      0.0000      0.0000
```

Lead Slump, $\delta = 0.40493 - 0.26436 = 0.14057 \cong 0.1451$”

Appendix 3

Electronic Data on CDROM

(3 Pages & 1 DVD)

```
 Volume in drive E is ST-627 Rev1
 Volume Serial Number is B2CA-8215

 Directory of E:\

06/10/2011  12:04 PM    <DIR>          1-ft Drop
06/10/2011  12:06 PM    <DIR>          30-ft Drop
               0 File(s)            352 bytes

 Directory of E:\1-ft Drop

06/10/2011  12:04 PM    <DIR>          .
06/10/2011  12:23 PM    <DIR>          ..
06/10/2011  12:03 PM    <DIR>          Corner
06/10/2011  12:04 PM    <DIR>          End
06/10/2011  12:05 PM    <DIR>          Side
               0 File(s)          2,736 bytes

 Directory of E:\1-ft Drop\Corner

06/10/2011  12:03 PM    <DIR>          .
06/10/2011  12:04 PM    <DIR>          ..
11/04/2010  04:38 PM       152,109,056 file.db
11/04/2010  04:37 PM       311,951,360 file.rst
12/01/2010  03:07 PM           189,683 file000.png
12/01/2010  03:07 PM           155,336 file001.png
12/01/2010  03:07 PM           111,744 file002.png
12/01/2010  03:09 PM           197,481 file003.png
12/01/2010  03:09 PM           207,512 file004.png
12/01/2010  03:09 PM           212,474 file005.png
11/22/2010  10:51 AM               579 ishell-comp-stress.out
11/11/2010  03:36 PM         2,964,493 ls1post.out
11/11/2010  03:36 PM         2,964,493 ls2post.out
11/11/2010  03:36 PM         2,964,493 ls3post.out
12/02/2010  11:30 AM             2,184 summary.out
              13 File(s)    474,031,784 bytes

 Directory of E:\1-ft Drop\End

06/10/2011  12:04 PM    <DIR>          .
06/10/2011  12:04 PM    <DIR>          ..
11/04/2010  04:06 PM       151,650,304 file.db
11/04/2010  04:05 PM       312,016,896 file.rst
12/01/2010  11:36 AM           136,840 file000.png
12/01/2010  11:36 AM           107,294 file001.png
12/01/2010  11:36 AM            72,743 file004.png
12/01/2010  11:40 AM           164,997 file005.png
12/01/2010  11:40 AM           162,787 file006.png
12/01/2010  11:40 AM           167,273 file007.png
12/03/2010  06:48 PM           195,581 file009.png
12/03/2010  06:48 PM           201,409 file010.png
11/19/2010  12:59 PM             1,260 IS ls2.lis
11/19/2010  01:00 PM             1,260 IS ls3.lis
11/19/2010  06:44 PM               579 ishell-comp-stress.out
11/04/2010  04:06 PM         2,964,490 ls1post.out
11/04/2010  04:06 PM         2,964,490 ls2post.out
11/04/2010  04:06 PM         2,964,490 ls3post.out
12/02/2010  11:35 AM             2,184 summary.out
              17 File(s)    473,775,981 bytes

 Directory of E:\1-ft Drop\Side

06/10/2011  12:05 PM    <DIR>          .
```

```
06/10/2011  12:04 PM    <DIR>          ..
11/04/2010  04:23 PM       151,715,840 file.db
11/04/2010  04:22 PM       312,016,896 file.rst
12/01/2010  02:30 PM           221,954 file000.png
12/01/2010  02:30 PM           160,081 file004.png
12/01/2010  02:30 PM           107,374 file005.png
12/01/2010  02:32 PM           198,590 file007.png
12/01/2010  02:32 PM           189,739 file008.png
12/01/2010  02:32 PM           191,234 file009.png
11/22/2010  10:53 AM               579 ishell-comp-stress.out
11/04/2010  04:23 PM         2,964,491 ls1post.out
11/04/2010  04:23 PM         2,964,491 ls2post.out
11/04/2010  04:23 PM         2,964,491 ls3post.out
12/02/2010  06:39 PM               858 summary-1.out
12/02/2010  11:38 AM             2,184 summary.out
              14 File(s)    473,699,750 bytes

 Directory of E:\30-ft Drop

06/10/2011  12:06 PM    <DIR>          .
06/10/2011  12:23 PM    <DIR>          ..
06/10/2011  12:05 PM    <DIR>          Corner
06/10/2011  12:18 PM    <DIR>          End
06/10/2011  12:07 PM    <DIR>          Side
               0 File(s)          4,288 bytes

 Directory of E:\30-ft Drop\Corner

06/10/2011  12:05 PM    <DIR>          .
06/10/2011  12:06 PM    <DIR>          ..
11/04/2010  10:14 AM       149,749,760 file.db
09/28/2010  08:34 AM       273,481,728 file.rst
12/01/2010  02:42 PM           117,694 file000.png
12/01/2010  02:42 PM           147,645 file005.png
12/01/2010  02:42 PM           106,873 file006.png
12/01/2010  02:45 PM           140,778 file007.png
12/01/2010  02:49 PM           213,877 file008.png
12/01/2010  02:49 PM           215,396 file009.png
12/01/2010  02:49 PM           221,486 file010.png
11/15/2010  02:57 PM             3,117 IS ls1.lis
11/22/2010  06:35 PM               579 ishell-comp-stress.out
11/02/2010  11:38 AM         2,970,354 ls1post.out
09/28/2010  11:59 AM         2,970,355 ls2post.out
09/28/2010  11:59 AM         2,970,355 ls3post.out
11/15/2010  02:19 PM             3,117 PL ls1.lis
11/15/2010  01:01 PM             3,117 PL ls2.lis
11/15/2010  02:21 PM             3,117 PL ls3.lis
11/18/2010  04:55 PM             9,043 primary-bolt-load.out
11/18/2010  06:17 PM             6,801 secondary-bolt-load.out
12/02/2010  06:38 PM               858 summary-1.out
12/02/2010  11:33 AM             2,184 summary.out
              21 File(s)    433,339,566 bytes

 Directory of E:\30-ft Drop\End

06/10/2011  12:18 PM    <DIR>          .
06/10/2011  12:06 PM    <DIR>          ..
10/14/2010  02:48 PM       149,225,472 file.db
09/24/2010  11:29 AM       274,071,552 file.rst
12/01/2010  10:35 AM           140,680 file000.png
12/01/2010  10:35 AM           113,840 file001.png
12/01/2010  10:35 AM            76,603 file002.png
12/01/2010  10:49 AM           108,737 file003.png
```

```
12/01/2010  10:54 AM           217,178 file004.png
12/01/2010  10:54 AM           218,339 file005.png
12/01/2010  10:55 AM           218,107 file006.png
11/22/2010  06:35 PM               579 ishell-comp-stress.out
09/28/2010  01:20 PM         2,964,492 ls1post.out
09/28/2010  01:20 PM         2,964,492 ls2post.out
09/28/2010  01:20 PM         2,964,492 ls3post.out
11/24/2010  12:51 PM         1,208,795 model.out
06/03/2011  12:09 PM               812 PRDISP-1.lis
06/03/2011  12:09 PM               812 PRDISP-2.lis
06/03/2011  12:10 PM               812 PRDISP-3.lis
11/02/2010  11:53 AM             3,117 Primary Lid Linearized-LS1.lis
11/02/2010  11:56 AM             3,117 Primary Lid Linearized-LS2.lis
11/02/2010  11:57 AM             3,117 Primary Lid Linearized-LS3.lis
11/18/2010  04:57 PM             9,043 primary-bolt-load.out
11/18/2010  06:19 PM             6,801 secondary-bolt-load.out
12/02/2010  11:36 AM             2,184 summary.out
              23 File(s)    434,524,713 bytes

 Directory of E:\30-ft Drop\Side

06/10/2011  12:07 PM    <DIR>          .
06/10/2011  12:06 PM    <DIR>          ..
11/03/2010  03:00 PM       149,356,544 file.db
11/04/2010  10:28 AM       312,016,896 file.rst
12/01/2010  11:55 AM           173,136 file000.png
12/01/2010  11:55 AM           131,326 file009.png
12/01/2010  11:56 AM            87,375 file010.png
12/01/2010  11:59 AM           106,129 file011.png
12/01/2010  12:59 PM           185,249 file012.png
12/01/2010  12:59 PM           186,488 file013.png
12/01/2010  01:00 PM           185,508 file014.png
11/12/2010  10:21 AM             3,117 Inner Shell-1.lis
11/12/2010  10:20 AM             3,117 Inner Shell-2.lis
11/12/2010  10:21 AM             3,117 Inner Shell-3.lis
11/22/2010  06:34 PM               579 ishell-comp-stress.out
11/04/2010  10:29 AM         2,964,492 ls1post.out
11/04/2010  10:29 AM         2,964,492 ls2post.out
11/04/2010  10:29 AM         2,964,492 ls3post.out
11/12/2010  10:25 AM             3,117 Outer Shell-1.lis
11/12/2010  10:26 AM             3,117 Outer Shell-2.lis
11/12/2010  10:26 AM             3,117 Outer Shell-3.lis
11/11/2010  05:39 PM             1,118 Primary Lid-1.lis
11/11/2010  05:53 PM             1,118 Primary Lid-2.lis
11/11/2010  05:54 PM             1,118 Primary Lid-3.lis
11/18/2010  04:50 PM             9,043 primary-bolt-load.out
11/18/2010  06:15 PM             6,801 secondary-bolt-load.out
12/02/2010  06:37 PM               858 summary-1.out
12/02/2010  11:40 AM             2,184 summary.out
              26 File(s)    471,365,276 bytes

     Total Files Listed:
             114 File(s)  2,760,744,446 bytes
              24 Dir(s)               0 bytes free
```