ATTACHMENT 1

GUIDE PAGE FOR INCORPORATING

REVISION 6

INTO 8-120B SAR

GUIDE PAGE FOR INCORPORATING REVISION 6 INTO 8-120B SAR

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ATTACHMENT 2

8-120B SAR
REVISION 6

CHANGE PAGES

SAFETY ANALYSIS REPORT

For

MODEL CNS 8-120B TYPE B SHIPPING PACKAGING

REVISION 6

APRIL 2003

Submitted by:

Duratek, Inc.
140 Stoneridge Dr.
Columbia, S.C. 29210

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2.0 STRUCTURAL EVALUATION

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8.0 ACCEPTANCE TESTS AND MAINTENANCE

$$\sigma_p = \frac{6}{t^2}\left(\frac{wr_2^2\left(1-\nu^2\right)}{r_1}\right)\frac{2\frac{r_1}{r_2}\left[\frac{1+\nu}{2}\left(\ln\left(\frac{r_2}{r_1}\right)\right)+\frac{1-\nu}{4}\left(1-\left(\frac{r_1}{r_2}\right)^2\right)\right]}{\left(1-\nu^2\right)\left(\frac{r_2}{r_1}-\frac{r_1}{r_2}\right)}$$

$\sigma = \sigma_1 + \sigma_2$

where $\nu = 0.3$
$t = 3.25in$
$P = 25psi$
$r_1 = 16.5in$
$r_2 = 36.6in$
$w = (P)(r_1)/2 = 206.25lb/in$
and $\sigma_1 = 4996psi$
$\sigma_2 = 3189psi$
$\sigma = 8185psi$
Safety Factor $= {}^{34650}\!/_{8185} = 4.2$

2.5.2.4 Secondary Lid

See reference 3, p. 363, Table 24, case 10a.
$\sigma_t = (3/8)(P)(3+\nu)(r_1/t)^2$
$r_1 = 16.5in$
$t = 3.25in$
$P = 25psi$
$\nu = 0.3$
$\sigma = 797psi$
Safety Factor $= {}^{34650}\!/_{797} = 43$

2.5.2.5 Cylindrical Shell – Maximum Stress

For external pressure $\sigma = {}^{\mathrm{Pr}}\!/_{t}$
$\sigma = {}^{(25)(35.85)}\!/_{1.5} = 598psi$
Safety Factor $= {}^{23100}\!/_{598} = 39$

2.6 Normal Conditions of Transport

The package has been designed, constructed and the contents limited (as described in Section 1.2.3), such that the performance requirements specified in 10 CFR 71 will be met when the package is subjected to the normal conditions of transport specified in §71.71. The cask is evaluated with two seal configurations: (1) one in which the stainless steel seal ring is imbedded into the cask body bolting ring, and (2) the other with a raised seal ring. The ability of the package with the imbedded seal plate to satisfactorily withstand the normal conditions of transport has been assessed as described in this section. The ability of the package with the optional design raised seal plate to satisfactorily withstand the normal conditions of transport has been assessed as described in Appendix 2.10.6.

2.6.10 Conclusions

From the above assessment, under normal conditions of transport, the package complies with the five criteria set for in §71.71 as follows:

- There will be no release of radioactive material from the containment vessel.
- The effectiveness of the packaging will not be reduced.
- There will be no mixture of gases or vapors in the package which could, through any credible increase in pressure or an explosion, significantly reduce the effectiveness of the packaging.
- Radioactive contamination of the liquid or gaseous primary coolant will not exceed the limits specified in §71.71.. (This requirement is not applicable since no coolants are involved.)
- There will be no loss of coolant. (This requirement is not applicable since no coolants are involved.)

2.7 Hypothetical Accident Conditions

The package has been designed, constructed and the contents limited such that the performance requirements specified in 10 CFR 71 will be met when the package is subjected to the hypothetical accident conditions specified in §71.73.

To demonstrate the structural integrity of the cask and its ability to withstand accident conditions, a set of comprehensive loading, stress and deflection analyses have been made, addressing each of the specified accident conditions. For the 30-foot drop analyses, loads were derived by computing energy absorption of the foam overpacks and the distribution of stresses over the outer cask surface due to the overpacks. For the fire accident conditions, temperatures throughout the cask were computed using a lumped-parameter finite difference model of the cask. These loads were applied to an ANSYS finite element model in order to find stresses and deflections in the cask. Full descriptions of these analyses are contained in Appendix 2.10.1.

The cask is evaluated with two seal configurations: (1) one in which the stainless steel seal ring is imbedded into the cask body bolting ring, and (2) the other with a raised seal ring. The ability of the package with the imbedded seal plate to satisfactorily withstand the hypothetical accident conditions has been assessed as described in this section. The ability of the package with the optional design raised seal plate to satisfactorily withstand the hypothetical accident conditions has been assessed as described in Appendix 2.10.6.

2.10.6 Analysis For Optional Raised Seal Surface on Bolting Ring

1.0 OBJECTIVE

To perform the regulatory 10 CFR 71 evaluation of the CNS 8-120B cask with the optional raised seal-surface on the bolting ring.

2.0 INTRODUCTION

CNS 8-120B cask has been licensed by the US NRC for the shipment of Type B quantities of radioactive waste under 10 CFR 71 (C of C No. 9168 (Reference 1)). Following a request from Duratek, Inc., for an amendment to the license, NRC requested additional information through and RAI (Reference 2). It was pointed out that the analysis in the safety analysis Report (SAR) (Reference 3) did not include the optional geometry shown in the cask drawing (Reference 4). (Note: The SAR drawing reflecting the raised seal design had been previously submitted and approved by the NRC.) A request was made to include the analyses of the optional configuration in the SAR. This document provides the analyses of the cask with the optional seal surface configuration and will be included as an appendix in Revision 6 of the SAR.

Duratek operates a fleet of 8-120B casks that have two configurations of the bolting ring and sealing surface geometry. In one configuration the seal plate is imbedded into the bolting ring, providing a flush sealing-surface, and in another, the seal plate protrudes above the bolting ring, providing a raised sealing-surface. The 10 CFR 71 evaluation provided in the SAR addressed only the embedded seal. The optional raised sealing surface reduces the contact area between the primary lid and the bolting ring. This reduction in the contact area will have a minimal effect on the behavior of the cask components in the vicinity of the seal plate during both the normal and hypothetical accident conditions. The overall behavior of the cask will be affected insignificantly due to the difference in the geometry of the two configurations. The impact limiter performance, for thermal and shock protection will not be affected. Therefore, the cask overall performance results presented in the SAR – internal pressures, temperature distribution, decelerations during various normal and hypothetical accident drop conditions – are valid for both configurations and have been utilized in the analyses performed in this document.

Analyses for various loading conditions have been performed using ANSYS (Reference 5) finite element analyses program. The analyses of the thermal load cases (normal and fire accident) have been performed using a conservative temperature distribution in the cask body and appropriate internal pressure. The analyses for the hypothetical drop conditions have been performed using the corresponding inertia loads on various components of the cask along with the appropriate internal cask pressure.

The allowable stress limits have been set to be the same as those used in the SAR. These allowable values set the limits for the membrane and membrane plus bending stresses over a section as defined by the ASME B&PV Code (Reference 6). Since a detailed finite element model analysis predicts the total (peak) value of the stresses in the body, it was necessary to establish additional limits on these peak stresses. They have been conservatively established following the design philosophy of Reference 6 and have been explained in section 5 of this document.

The results of the analyses are presented in Section 10 of this document in a format that follows the section numbering of the corresponding analysis in the SAR. It is shown that the stresses in the 8-120B Cask with a raised sealing-surface meet the established allowable for all the normal and accident conditions loading.

3.0 REFERENCES

(1) Certificate of Compliance, No. 9168

(2) US NRC, Request for Additional Information (RAI), Dated February 5, 2003, Docket No. 71-9168, TAC No. L23526.

(3) Safety Analysis Report for CNS 8-120B Cask, Revision 5, December, 2000.

(4) CNS/Duratek Drawing C-110-E-0007, Rev.12,

(5) ANSYS Revision 6.1, ANSYS Inc., Canonsburg, Pennsylvania, 2001.

(6) ASME Boiler & Pressure Vessel Code, 2001, Sections and Divisions Identified in the Body of this Document.

(7) NUREG/CR-0481, An Assessment of Stress-Strain Data Suitable for Finite-Element Elastic-Plastic Analysis of Shipping Containers, Sandia National Laboratories, 1978.

(8) U.S. NRC Regulatory Guide 7.6, Rev. 1, March 1978, Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels.

4.0 MATERIAL PROPERTIES

Mechanical Properties

Material	Temp. (°F)	Strength (ksi)			Young's Modulus (10^6 psi)	Coef. of Thermal Expansion (10^{-6} in/in)
		Yield (S_y)	Ultimate (S_u)	Membrane Allowable (S_m)		
ASTM A516 Gr. 70	(1)	(1)	(1)	(1)	(1)	(1)
	70	38.0	70.0	23.3	27.9	6.50
(Inner & Outer Shells, Lids, Baseplates)	100	38.0	70.0	23.3	27.8	6.50
	200	34.6	70.0	23.1	27.7	6.67
	300	33.7	70.0	22.5	27.4	6.87
	400	32.6	70.0	21.7	27.0	7.07
	500	30.7	70.0	20.5	26.4	7.25
ASTM A240 Type 304L	(2)	(2)	(2)	(2)	(2)	(2)
	70	25.0	70.0	16.7	28.3	8.5
	100	25.0	70.0	16.7	28.1	8.6
(Seal Plate)	200	21.4	66.1	14.3	27.6	8.9
	300	19.2	61.2	12.8	27.0	9.2
	400	17.5	58.7	11.7	26.5	9.5
	500	16.4	57.5	10.9	25.8	9.7
ASTM A354 Gr. BD	(1)	(1)	(1)	(1)	(1)	(1)
(Primary Lid Bolts)	70	130	150	-	29.9	6.50
ASTM B29 Lead	(1)	(1)	(1)	(1)	(3)	(3)
	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) These values have been reproduced from the SAR (Reference 3), Table 2.3-1 (Page 2-17)

(2) From ASME B&PV Code 2001, Section II, Part D (Reference 6).

(3) From NUREG/CR 0481 (Reference 7)

Title 8-120B Cask Analyses - Optional Raised Seal Surface on Bolting Ring

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Thermal Properties

Material	Temp. (°F)	Specific Heat (Btu/lb-°F)	Conductivity $\times 10^{-4}$ (Btu/sec-in-°F)
ASTM A516 Gr. 70 (Inner & Outer Shells, Lids, Baseplates) (1)	70	0.1033	8.13
	100	0.1053	8.03
	200	0.1121	7.78
	300	0.1177	7.48
	400	0.1234	7.15
	500	0.1278	6.77
	600	0.1322	6.48
	700	0.1381	6.16
	800	0.1452	5.83
	900	0.1535	5.51
	1,000	0.1624	5.19
	1,100	0.1710	4.84
	1,200	0.1829	4.51
	1,300	0.2045	4.17
	1,400	0.4010	3.80
	1,500	0.1982	3.63
ASTM A240 Type 304L (Seal Plate) (2)	70	0.1165	1.99
	100	0.1170	2.01
	200	0.1219	2.15
	300	0.1252	2.27
	400	0.1289	2.41
	500	0.1311	2.52
ASTM B29 Lead (1)	32	0.0306	4.70
	212	0.0315	4.47
	392	0.0325	4.21
	572	0.0335	3.98
	752	0.0328	-

Notes:

(1) Same values as those used in the SAR (Reference 3-3 and 3-4).

(2) From ASME B&PV Code 2001, Section II, Part D (Reference 6).

5.0 ALLOWABLE STRESSES

Material →		ASTM A516 Gr.70	ASTM A240 Type 304L	ASTM A354 Gr. BD
Yield Stress, S_y (psi)		38,000(1)	25,000(2)	130,000(1)
Ultimate Stress, S_u (psi)		70,000(1)	70,000(2)	150,000(1)
Design Stress Intensity, S_m (psi)		23,100(1)	16,700(2)	30,000(2)
Normal Conditions	Membrane Stress	23,100(3)	16,700(3)	60,000(4)
	Membrane + Bending Stress	34,650(3)	25,050(3)	90,000(4)
	Peak Stress	69,300(4)	50,100(4)	150,000(5)
Hypothetical Accident Conditions	Membrane Stress	49,000(3)	40,080(3)	105,000(5)
	Membrane + Bending Stress	70,000(3)	60,120(3)	150,000(5)
	Peak Stress	140,000(6)	140,000(6)	300,000(6)

Notes:

(1) Same value as those used in the SAR (Reference 3).

(2) From ASME B&PV Code 2001, Section II, Part D (Reference 6).

(3) Same as those established in the SAR (Reference 3).

(4) Not established in the SAR (Reference 3). Also, Regulatory Guide 7.6 (Reference 7) does not provide any criteria. These allowable values have been established here based on the ASME, Section III, Division 3, WB-3200 (Reference 6) criteria.

(5) Not explicitly established in the SAR (Reference 3). Also, 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) Not established in the SAR (Reference 3). Regulatory Guide 7.6 (Reference 7) does not provide any criteria. The ASME Section III, Division 3, WB-3200 (Reference 6) criteria of $2S_a$ @ 10 cycles results in an unreasonably high stress allowable. This criterion is conservatively set to be $2S_u$ for limiting the peak stresses.

6.0 MODELING DESCRIPTION

The finite element model used in the analyses presented in this document is shown in Figure 1. It is comprised of a 1/40th segment in the circumferential direction and a ½ section in the axial direction. The primary lid of the cask is secured to the body using 20 bolts. Therefore, a 1/40th geometric symmetry along the circumference of the cask occurs. It should be noted that the secondary lid is secured with only 12 bolts. Therefore, the geometry is not strictly 1/40th symmetric. Nonetheless since the effect of the secondary lid securement has a little or no influence on the cask component behavior near the primary lid seal-surface; this assumption is considered reasonable and has been employed in the analyses. Also the close geometric shape of the two combined lids and the basplate gives rise to a ½-symmetry along the axis of the cask.

The finite element model is made of 3-dimensional isoparametric solid elements (ANSYS SOILD45) to represent various components of the cask. Since the main objective of the analyses is to evaluate the cask with the optional raised-surface on the bolting ring, the modeling of this area has been performed with greater accuracy compared to the secondary lid which has been included in the model to account for its stiffness and its geometry has been slightly simplified to facilitate in the modeling. To accurately account for the welding, the solid models of the components are made with coincident nodes and have been rigidly-coupled at the weld locations. At other locations on the interface gap elements (ANSYS COMBIN40 & CONTAC49) have been used (see Figures 2, 3 & 4). These elements support only compressive load at the interface and allow the two surfaces to separate from each other. The bolts are also modeled with the solid elements and are connected to the other components at the thread locations by axial and radial coupling. The interfaces between the bolt-head and the other components are modeled by axial coupling if the bolts are known to have tensile loading; and by gap elements when the nature of loading was uncertain.

The material properties used in the model are as follows:

Material No.1 - Secondary Lid - A516 Gr. 70

Material No.2 - Primary Lid - A516 Gr. 70

Material No.3 - Bolts - A 354 Gr. BD

Material No.4 - Bolting Ring, Shells - A516 Gr. 70

Material No.5 - Seal Plate - A240 Type 304L

Material No.6 - Lead - B29

The printout of the model statistics is included in Appendix A of this document.

9.0 MODEL ANALYSES

The loadings analyzed using the finite element model, described in Section 6.0, are as listed below. The same model was used in all the analyses, except that the boundary conditions were modified to represent the loading analyzed. For the thermal analyses the model was restrained at the axial cut-plane in the axial direction. For the hypothetical end drop, the model was restrained in the axial direction at the impact limiter location. For the corner drop, the model was analyzed for the effect of the maximum bolt loading that occurs at a location diametrically opposite to the point of impact and for the circumferential payload inertia loading near the point of impact. For the corner drop loading, since the lead provides a beneficial effect to the stresses in the bolting ring and the shells, it has been removed from the model.

Normal Thermal Conditions

The nodal temperature in the cask body was obtained by converting the stress model to a thermal model, applying a conservative nodal temperature at various representative locations from the SAR and running it for a steady state solution. The temperature distribution in the cask body, thus obtained, is shown in Figure 5. This distribution compares favorably with the temperature distribution presented in the SAR (see Pages 3-16 and 2-381 through 2-383 of Reference 3).

Internal pressure in the cask = 8.95 psi (Reference 3, Page 3-3)

Using the above temperature distribution and the internal pressure, the model is statically analyzed for the stresses. The summary of the stresses obtained is given in Appendix B. Figures 6 to 8 present the stress intensity contour plots in various components of the cask.

Hypothetical End Drop

The model described in Section 6.0 is analyzed with inertia loading from the SAR.

Cask Deceleration,	a = 168.1 g	(Reference 3, Page 2-132)
Primary + Secondary Lids	= 7,080 lbs	(Reference 3, Page 2-16)
Payload	= 14,680 lbs	(Reference 3, Page 2-16)
Lids + Payload	= 21,760 lbs	

Distribute this load over the lid inside surface as shown in Figure 9. Therefore,

$$p_l = 168.1\times 21{,}760/(\pi\times 30.875^2)$$

$$= 1{,}221.4 \text{ psi} \Rightarrow \text{Use } 1{,}230 \text{ psi}$$

Outer Shell Mass $= \pi\,(36.6^2-35.1^2)\times 78.5\times 0.283 = 7{,}506$ lbs

Lead Mass $= \pi\,(35.1^2-31.75^2)\times 78.5\times 0.4109$ = 22,694 lbs

Impact Limiters (Total) = 9,720 lbs (Reference 3, Page 2-16)

Impact Limiter (Each) = 9,720/2 = 4,860 lbs

Total Package Mass = 74,000 lbs (Reference 3, page 2-16)

Distribute the outer shell inertia on the outer shell cut section shown in Figure 9. Thus,

$$p_2 = 168.1\times 78.5\times 0.283 = 3{,}734 \text{ psi}$$

Distribute the lead inertia on the lead cut section shown in Figure 9. Thus,

$$p_3 = 168.1\times 78.5\times 0.4109 = 5{,}422 \text{ psi}$$

On the inner shell apply a pressure that corresponds to the inner shell, baseplates, lower impact limiters and the miscellaneous items not accounted for.

Mass to be distributed = 74,000 – 7,506 – 22,694 – 7,080 – 14,680 – 4,860

= 17,180 lbs

Thus, $p_4 = 17{,}180\times 168.1/[\pi\times(31.75^2-31^2)] = 19{,}533$ psi

Cask internal pressure is 5.28 psi. (Reference 3, Page 3-56). Add this pressure to the lid pressure and apply it on the inner shell lateral surface.

Using the above pressure distribution, the model is statically analyzed for the stresses. The summary of the stresses obtained is given in Appendix B. Figures 10 to 16 present the stress intensity contour plots in various components of the cask.

Hypothetical Side Drop

Figure 17 show the loading on the cask under a side drop. It is seen that under this loading condition both the cask body inertia and the lid inertia are directly reacted by the impact limiter. The cask body ovalization causes a shear load transfer between the body and the lid. The bolts are primarily under shear load and little to no axial load transfer takes place at the interface. The SAR clearly shows this phenomenon (see Page 2-163 of Reference 3). It is, therefore, concluded that the analyses presented in the SAR adequately addresses both the cases of imbedded and raised seal-surface. No further analyses have been performed for this drop orientation.

Hypothetical Corner Drop

Figure 18 shows the loading and the reactions on the cask under a corner drop loading condition. Under this drop scenario, the critical components of the cask are the lids and the inner shell. Since the lid is supported only at the point of impact, its mass and the mass of the payload apply a large loading on the bolts. This loading results in a large tensile load on the bolts located at the diametrically opposite end of the point of impact. A compressive loading on the joint occurs at the point of impact. This phenomenon is analyzed here by simulating the largest bolt loading and applying it to the finite element model described above in a conservative manner. The lids are subjected to a uniform pressure that gives rise to the desired bolt loading. The two shells are restrained in the axial direction at the cut-plane which gives rise to the maximum bolt prying action.

To analyze the effect of the corner drop on the inner shell at the near end, the inertia of the payload is applied as a distributed load over the lower 90° of the shell and the finite element model is analyzed as before. For conservativeness, the elements representing the lead have been removed from the model.

Far-End Effect

Cask deceleration, $a = 60\ g$ (Reference 3, Page 2-168)

Inclination of the cask axis, $\alpha = 140.72°$ (Reference 3, Pages 2-169 & 2-170)

Inclination of the cask axis with the vertical,

$$\theta = 180-149.72 = 30.28°$$

Primary + Secondary Lids = 7,080 lbs (Reference 3, Page 2-16)

Payload = 14,680 lbs (Reference 3, Page 2-16)

Lids + Payload = 21,760 lbs

Primary Lid Bolt Circle Radius, $r = 34.125''$ (Reference 4)

Inertia Load Normal to the Lid Plane,

$$F = 60 \times 21{,}760 \times \text{Cos } 30.28°$$

$$= 1.13 \times 10^6 \text{ lbs}$$

Moment of the inertia load about near side bolt-circle periphery,

$$M = 1.13 \times 10^6 \times 34.125 = 3.86 \times 10^7 \text{ in-lbs}$$

Assuming a sinusoidal distribution of loading over the circumference of the bolt circle, the amplitude of the loading can be obtained as,

$$q = M/(\pi r^2)$$
$$= 3.86\times10^7/(\pi\times34.125^2)$$
$$= 10{,}551 \text{ lbs/in}$$

There are a total of 20 lid bolts (Reference 4). Therefore, the maximum load on the bolt located at the farthest point of the bolt-circle from the impact point is:

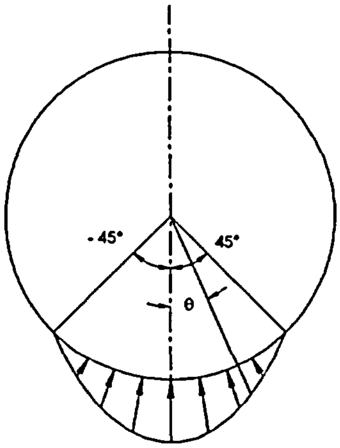
$$P = \frac{1.13\times10^6}{20} + \frac{2\pi\times34.125}{20}\times10{,}551$$
$$= 169{,}614 \text{ lbs}$$

Simulate this load with a uniform pressure on the lid inside surface. The magnitude of which is:

$$p = 169{,}614\times20/(\pi\times30.875^2) = 1{,}133 \text{ psi} \Rightarrow \text{Use } 1{,}150 \text{ psi}$$

Near-End Effect

Assuming that the inertia load of the payload is distributed over the lower 90° circumference of the inner shell of the cask, the circumferential load distribution shown in the sketch can be formulated as:



$$f(\theta) = f_0 \cos 2\theta \qquad \text{for } -\pi/4 \le \theta \le \pi/4$$

The vertical component of the total load can be calculated by integrating this function over the circumference. Thus,

$$F_y = \int_{-\pi/4}^{\pi/4} f_0 \cos\theta \cos 2\theta \, L\, r\, d\theta$$
$$= 0.9428\, f_0\, L\, r$$

where, L = Height of the cask cavity = 75 in (Reference 4)
r = Radius of the cask Inner Shell = 31 in (Reference 4)

The total load normal to the surface of the cask inner shell is:

$$= 60\times21{,}760\times\sin 30.28°$$
$$= 658{,}318 \text{ lbs}$$

Equating this load to the above load, we get,

$$f_0 = 658{,}318/(0.9428\times31\times75)$$
$$= 300.3 \text{ psi}$$

Internal cask pressure = 5.28 psi

Total pressure on the inner shell = 300.3 + 5.28 = 305.58 psi ⇒ Use 310 psi

Using the above loading distribution, the model is statically analyzed for the stresses. The summary of the stresses obtained is given in Appendix B. Figures 19 to 25 present the stress intensity contour plots in various components of the cask.

Fire Accident Condition

The nodal temperature in the cask body was obtained by converting the stress model to a thermal model, applying a conservative nodal temperature at various representative locations from the SAR and running it for a steady state solution. The temperature distribution in the cask body, thus obtained, is shown in Figure 26. This distribution compares favorably with the temperature distribution presented in the SAR (see Pages 3-1 and 2-384 through 2-389 of Reference 3).

Internal pressure in the cask = 21.4 psi (Reference 3, Page 3-3)

Using the above temperature distribution and the internal pressure the model is statically analyzed for the stresses. The summary of the stresses obtained is given in Appendix B. Figures 27 to 32 present the stress intensity contour plots in various components of the cask.

10.0 RESULTS

The results from the analyses described above are presented in this report in a manner consistent with the SAR chapters. The stresses in the cask components are presented in tabular form that compares the stress components with the corresponding allowable values. To minimize the computational effort, if a nodal stress at a location was small enough to meet the smallest allowable, (i.e. the membrane S.I. allowable), this value was conservatively reported as membrane, membrane plus bending, and peak S.I. If the stresses were high they were linearized over thickness using ANSYS Linearization option, which is consistent with the ASME B&PV code procedure.

§ 2.6.1 Heat

The results for this case are presented in Table 1. All the stress intensities are low, except in the thin portion of the bolting ring. The stresses are linearized over a section as shown in Figure 8.

§ 2.6.6 Free Drop

As in the SAR, the stress intensities for these loading conditions are ratioed from the hypothetical condition loading in proportion of the decelerations.

§ 2.6.6.1 End Drop

Deceleration for 1-foot end drop = 68.5 g (Reference 3, Page 2-125)

Deceleration for 30-foot end drop = 168.1 g (Reference 3, Page 2-132)

The results from the hypothetical end drop are ratioed by 68.5/168.1 = 0.407.

The results for this case are presented in Table 2.

§ 2.6.6.2 Side Drop

No new analysis has been performed for this load case. See Section 7 for explanation.

§ 2.6.6.1 Corner Drop

Deceleration for 1-foot corner drop = 9 g (Reference 3, Page 2-125)

Deceleration for 30-foot corner drop = 60 g (Reference 3, Page 2-168)

The results from the hypothetical end drop are ratioed by 9/60 = 0.15.

The results for this case are presented in Table 3.

§ 2.7.1 Hypothetical Free Drop

Results from the hypothetical drop using the finite element model described here are presented in this section.

§ 2.7.1.1 End Drop

The stress intensities in the cask due to a deceleration of 168.1g and an internal pressure of 5.28 psi are presented in Table 4. All the stress intensities meet the established allowable limits. The cross-sections where the stresses have been linearized are identified in the corresponding stress intensity contour plots. It should be noted that the outer edge of the seal-plate undergoes a local high compression as shown in Figure xx. The average value of the compressive stress over the seal surface is calculated as follows:

Referring to Figure 9, the total load reacted by the seal plate is:

$$F = p_2 \times \text{Outer shell thickness} + p_3 \times \text{Lead thickness} + p_4 \times \text{Inner shell thickness}$$

$$= 3{,}734 \times 1.5 + 5{,}413.5 \times 3.35 + 19{,}533 \times 0.75 = 38{,}386 \text{ lbs/in circumference}$$

Width of the seal plate = 1.875 in

Uniform compressive stress in the seal plate, = 38,386/1.875 = 20,473 psi

This value is reported in Table 4 as the membrane stress intensity. Since the entire cross-section is subjected to this compressive stress, it is also reported as membrane plus bending stress intensity also in this table. The high compressive stress near the outside edge of the seal-plate is not of a concern because the high local stresses predicted by linear model actually redistribute themselves by slight yielding. Since this area is far away from the cask containment seal, a local yielding at this location under the hypothetical drop conditions will be acceptable.

§ 2.7.1.2 Side Drop

No new analysis has been performed for this load case. See Section 7 for explanation.

§ 2.7.1.1 Corner Drop

The stress intensities in the cask due to a deceleration of 60g and an internal pressure of 5.28 psi are presented in Table 5. All the stress intensities meet the established allowable limits. The cross-sections where the stresses have been linearized are identified in the corresponding stress intensity contour plots.

§ 2.7.3 Fire Accident

The results for this case are presented in Table 6. Stress intensities everywhere, except at the thin portion of the bolting ring meet the established allowable limits. At the intersection of the bottom of the bolthole and the outer shell the model predicts a high local stress, the magnitude of which meets the peak stress allowable value. The membrane plus bending portion of the stress over the cross-section slightly exceeds the allowable value. Noting the thermal loading causes the major portion of the stresses during the fire accident, these stresses are classified as secondary (or displacement controlled) by the ASME code for which there are no membrane plus bending allowable. Therefore, classifying the stresses to membrane plus bending is extremely conservative. It should also be noted that local high stresses predicted by a linear analysis will actually relieve themselves by slight yielding. Since the location of this high stress is outside the containment boundary of the cask, its existence is not considered unacceptable for the purpose of qualifying the cask for fire accident under which a local deformation is acceptable as long as the containment boundary is not compromised.

11.0 CONCLUSIONS

It has been demonstrated in this report that the structural components of the 8-120B Cask, with the optional raised-face sealing-surface configuration, meet the same allowable values as those established for the imbedded seal-surface in the SAR. Thus, the cask with the optional raised-face seal-surface satisfies the requirements of the 10 CFR 71 for Type B, radioactive waste packages.

Table 1

8-120B Cask Stress Intensities in Various Components
Loading Condition – Normal Thermal

Component	Stress Category [1]	Allowable S.I. (psi)	Calculated S.I. (psi)	F.S.
Primary Lid	P_m	23,100	3,514[2]	6.57
	$P_m + P_b$	34,650	3,514[2]	9.86
	F	69,300	3,514	19.72
Bolting Ring	P_m	23,100	16,090	1.44
	$P_m + P_b$	34,650	18,220	1.90
	F	69,300	60,116	1.15
Seal Plate	P_m	16,700	10,191[2]	1.64
	$P_m + P_b$	25,050	10,191[2]	2.46
	F	50,100	10,191	4.92
Inner Shell	P_m	23,100	18,562[2]	1.24
	$P_m + P_b$	34,650	18,562[2]	1.87
	F	69,300	18,562	3.73
Outer Shell	P_m	23,100	16,831[2]	1.37
	$P_m + P_b$	34,650	16,831[2]	2.06
	F	69,300	16,831	4.12
Primary Lid Bolts	P_m	60,000	16,701[2]	3.59
	$P_m + P_b$	90,000	16,701[2]	5.39
	F	150,000	16,701	8.98

Notes:

(1) Stresses are categorized based on ASME B&PV Code (referenced by Regulatory Guide) as follows. P_m is primary membrane stress intensity, $P_m + P_b$ is primary membrane plus bending stress intensity, and, F is the peak stress intensity.

(2) The peak S.I. obtained from the ANSYS analysis has been conservatively reported as membrane and membrane plus bending S.I.

Table 2

8-120B Cask Stress Intensities in Various Components
Loading Condition – Normal End Drop

Component	Stress Category (1)	Allowable S.I. (psi)	Calculated S.I. (psi)	F.S.
Primary Lid	P_m	23,100	10,879	2.12
	$P_m + P_b$	34,650	20,586	1.68
	F	69,300	25,786	2.69
Bolting Ring	P_m	23,100	13,370	1.73
	$P_m + P_b$	34,650	22,593	1.53
	F	69,300	22,593	3.07
Seal Plate	P_m	16,700	8,333	2.00
	$P_m + P_b$	25,050	8,333	3.00
	F	50,100	49,357	1.02
Inner Shell	P_m	23,100	13,711(2)	1.68
	$P_m + P_b$	34,650	13,711(2)	2.53
	F	69,300	13,711	5.05
Outer Shell	P_m	23,100	10,154(2)	2.28
	$P_m + P_b$	34,650	10,154(2)	3.41
	F	69,300	10,154	6.83
Primary Lid Bolts	P_m	60,000	7,598(2)	7.90
	$P_m + P_b$	90,000	7,598(2)	11.85
	F	150,000	7,598	19.74

Notes:

(1) Stresses are categorized based on ASME B&PV Code (referenced by Regulatory Guide) as follows. P_m is primary membrane stress intensity, $P_m + P_b$ is primary membrane plus bending stress intensity, and, F is the peak stress intensity.

(2) The peak S.I. obtained from the ANSYS analysis has been conservatively reported as membrane and membrane plus bending S.I.

Table 3

8-120B Cask Stress Intensities in Various Components
Loading Condition – Normal Corner Drop

Component	Stress Category [1]	Allowable S.I. (psi)	Calculated S.I. (psi)	F.S.
Primary Lid	P_m	23,100	4,671	4.95
	$P_m + P_b$	34,650	10,289	3.37
	F	69,300	18,189	3.81
Bolting Ring	P_m	23,100	4,737	4.88
	$P_m + P_b$	34,650	7,611	4.55
	F	69,300	13,350	5.19
Seal Plate	P_m	16,700	4,583	3.64
	$P_m + P_b$	25,050	5,729	4.37
	F	50,100	6,053	8.28
Inner Shell	P_m	23,100	3,394(2)	6.81
	$P_m + P_b$	34,650	3,394(2)	10.21
	F	69,300	3,394	20.42
Outer Shell	P_m	23,100	4,071(2)	5.67
	$P_m + P_b$	34,650	4,071(2)	8.51
	F	69,300	4,071	17.02
Primary Lid Bolts	P_m	60,000	4,949	12.12
	$P_m + P_b$	90,000	9,399	9.58
	F	150,000	27,381	5.48

Notes:

(1) Stresses are categorized based on ASME B&PV Code (referenced by Regulatory Guide) as follows. P_m is primary membrane stress intensity, $P_m + P_b$ is primary membrane plus bending stress intensity, and, F is the peak stress intensity.

(2) The peak S.I. obtained from the ANSYS analysis has been conservatively reported as membrane and membrane plus bending S.I.

Table 4

8-120B Cask Stress Intensities in Various Components
Loading Condition – Hypothetical End Drop

Component	Stress Category [1]	Allowable S.I. (psi)	Calculated S.I. (psi)	F.S.
Primary Lid	P_m	49,000	26,730	1.83
	$P_m + P_b$	70,000	50,580	1.38
	F	140,000	63,356	2.21
Bolting Ring	P_m	49,000	32,850	1.49
	$P_m + P_b$	70,000	55,510	1.26
	F	140,000	55,510	2.52
Seal Plate	P_m	40,080	20,473	1.96
	$P_m + P_b$	60,120	20,473	2.94
	F	140,000	121,270	1.15
Inner Shell	P_m	49,000	33,688[2]	1.45
	$P_m + P_b$	70,000	33,688[2]	2.08
	F	140,000	33,688	4.16
Outer Shell	P_m	49,000	24,948[2]	1.96
	$P_m + P_b$	70,000	24,948[2]	2.81
	F	140,000	24,948	5.61
Primary Lid Bolts	P_m	105,000	18,668[2]	5.62
	$P_m + P_b$	150,000	18,668[2]	8.04
	F	300,000	18,668	16.07

Notes:

(1) Stresses are categorized based on ASME B&PV Code (referenced by Regulatory Guide) as follows. P_m is primary membrane stress intensity, $P_m + P_b$ is primary membrane plus bending stress intensity, and, F is the peak stress intensity.

(2) The peak S.I. obtained from the ANSYS analysis has been conservatively reported as membrane and membrane plus bending S.I.

Table 5

8-120B Cask Stress Intensities in Various Components
Loading Condition – Hypothetical Corner Drop

Component	Stress Category (1)	Allowable S.I. (psi)	Calculated S.I. (psi)	F.S.
Primary Lid	P_m	49,000	31,140	1.57
	$P_m + P_b$	70,000	68,590	1.02
	F	140,000	121,260	1.15
Bolting Ring	P_m	49,000	31,580	1.55
	$P_m + P_b$	70,000	50,740	1.38
	F	140,000	88,998	1.57
Seal Plate	P_m	40,080	30,550	1.31
	$P_m + P_b$	60,120	38,190	1.57
	F	140,000	40,353	3.47
Inner Shell	P_m	49,000	22,629(2)	2.17
	$P_m + P_b$	70,000	22,629(2)	3.09
	F	140,000	22,629	6.19
Outer Shell	P_m	49,000	27,138(2)	1.81
	$P_m + P_b$	70,000	27,138(2)	2.58
	F	140,000	27,138	5.16
Primary Lid Bolts	P_m	105,000	32,990	3.18
	$P_m + P_b$	150,000	62,660	2.39
	F	300,000	182,540	1.64

Notes:

(1) Stresses are categorized based on ASME B&PV Code (referenced by Regulatory Guide) as follows. P_m is primary membrane stress intensity, $P_m + P_b$ is primary membrane plus bending stress intensity, and, F is the peak stress intensity.

(2) The peak S.I. obtained from the ANSYS analysis has been conservatively reported as membrane and membrane plus bending S.I.

Table 6

8-120B Cask Stress Intensities in Various Components
Loading Condition – Hypothetical Fire Accident

Component	Stress Category (1)	Allowable S.I. (psi)	Calculated S.I. (psi)	F.S.
Primary Lid	P_m	49,000	12,181(2)	4.02
	$P_m + P_b$	70,000	12,181(2)	5.75
	F	140,000	12,181	11.49
Bolting Ring	P_m	49,000	40,210	1.22
	$P_m + P_b$	70,000	97,190	0.72(3)
	F	140,000	106,060	1.32
Seal Plate	P_m	40,080	14,908(2)	2.69
	$P_m + P_b$	60,120	14,908(2)	4.03
	F	140,000	14,908	9.39
Inner Shell	P_m	49,000	21,460	2.28
	$P_m + P_b$	70,000	44,460	1.57
	F	140,000	53,624	2.61
Outer Shell	P_m	49,000	29,072(2)	1.69
	$P_m + P_b$	70,000	29,072(2)	2.41
	F	140,000	29,072	4.82
Primary Lid Bolts	P_m	105,000	28,652(2)	3.66
	$P_m + P_b$	150,000	28,652(2)	5.24
	F	300,000	28,652	10.47

Notes:

(1) Although the major portion of the stresses in the cask under fire accident is secondary, all the stresses have been conservatively categorized as primary based on ASME B&PV Code.

(2) The peak S.I. obtained from the ANSYS analysis has been conservatively reported as membrane and membrane plus bending S.I.

(3) See Section 8 for the rationale of acceptance of this value.

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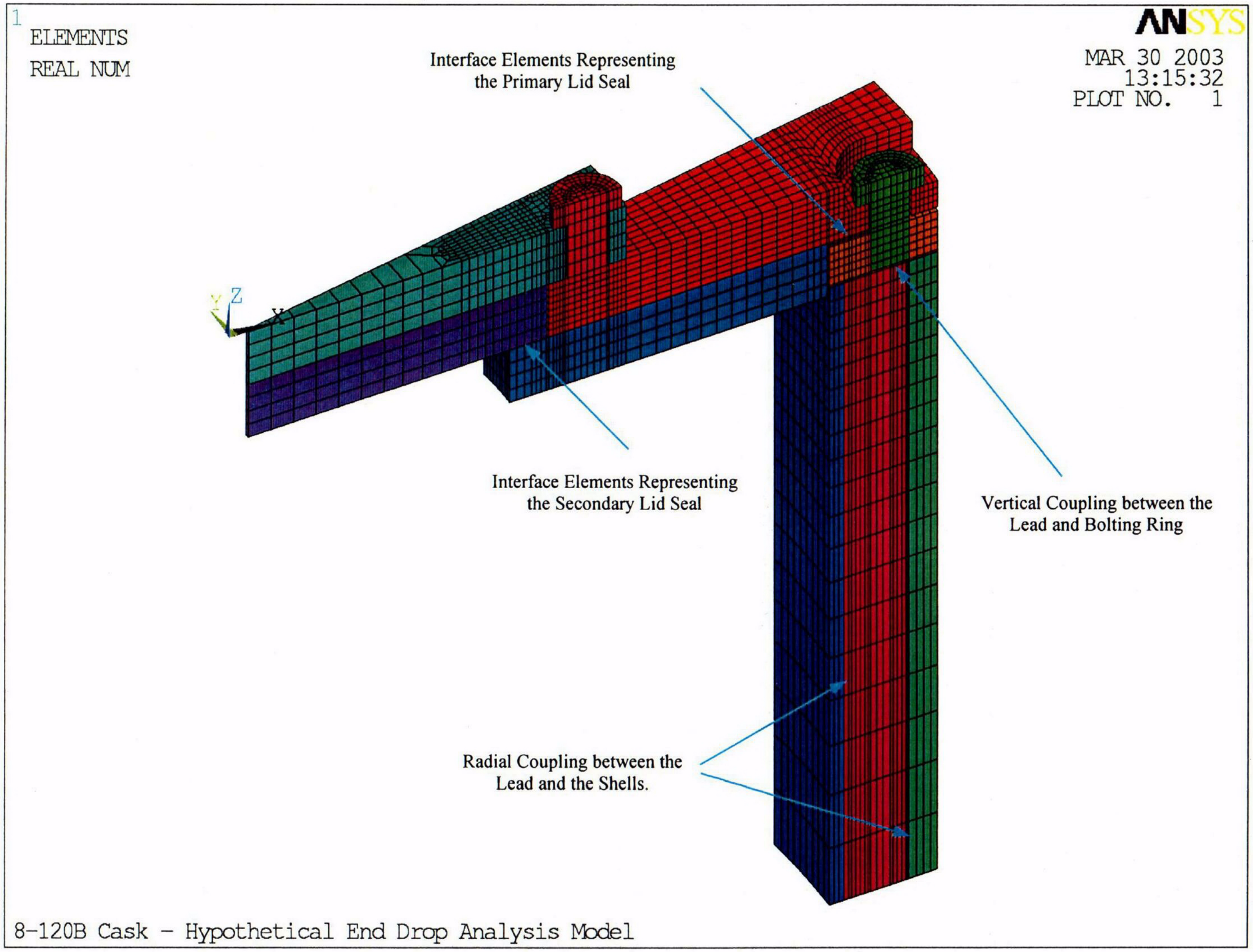

Figure 1
Basic Finite Element Model Used in Various Analyses in this Document

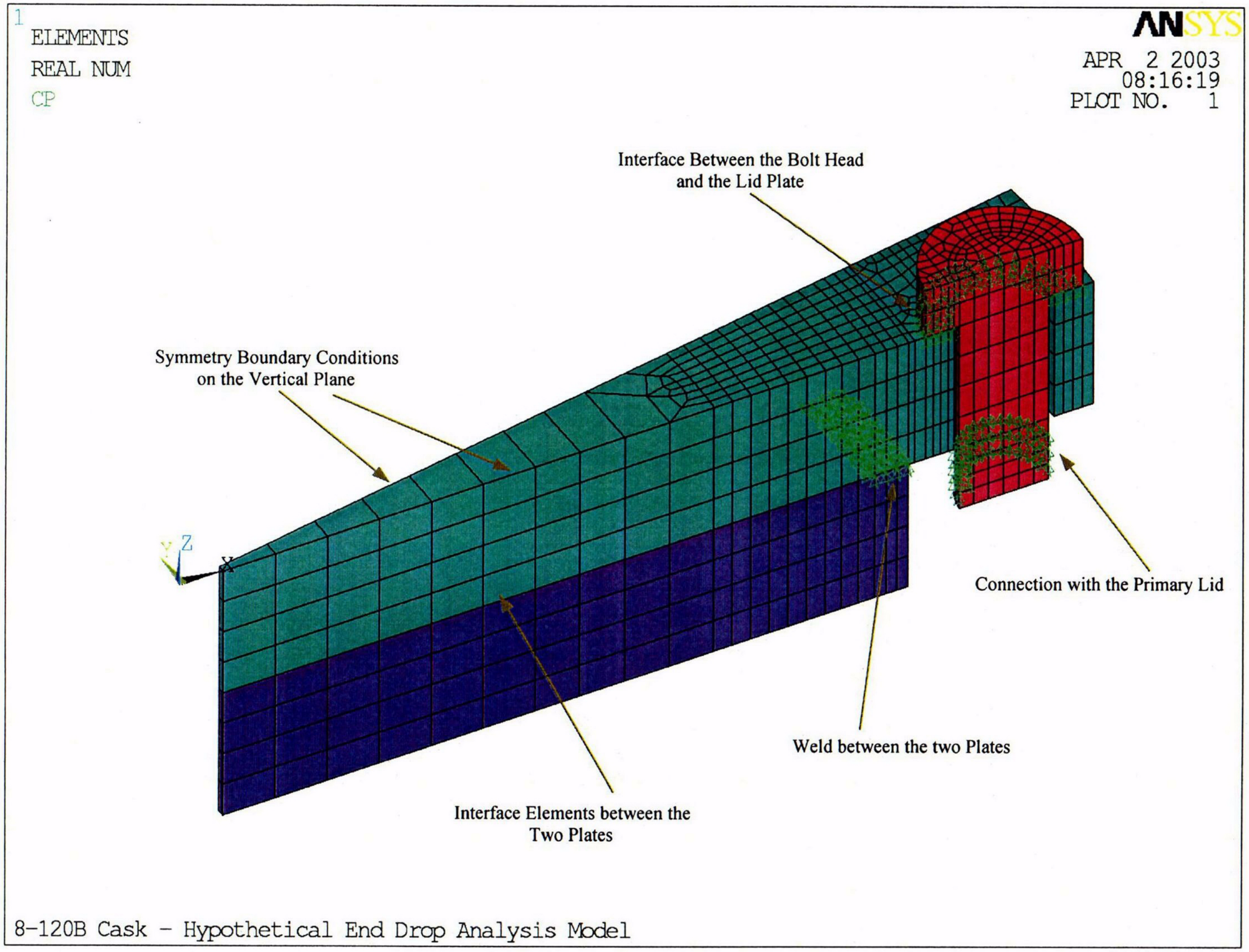

Figure 2

Finite Element Model of the Secondary Lid and Secondary Lid Bolts

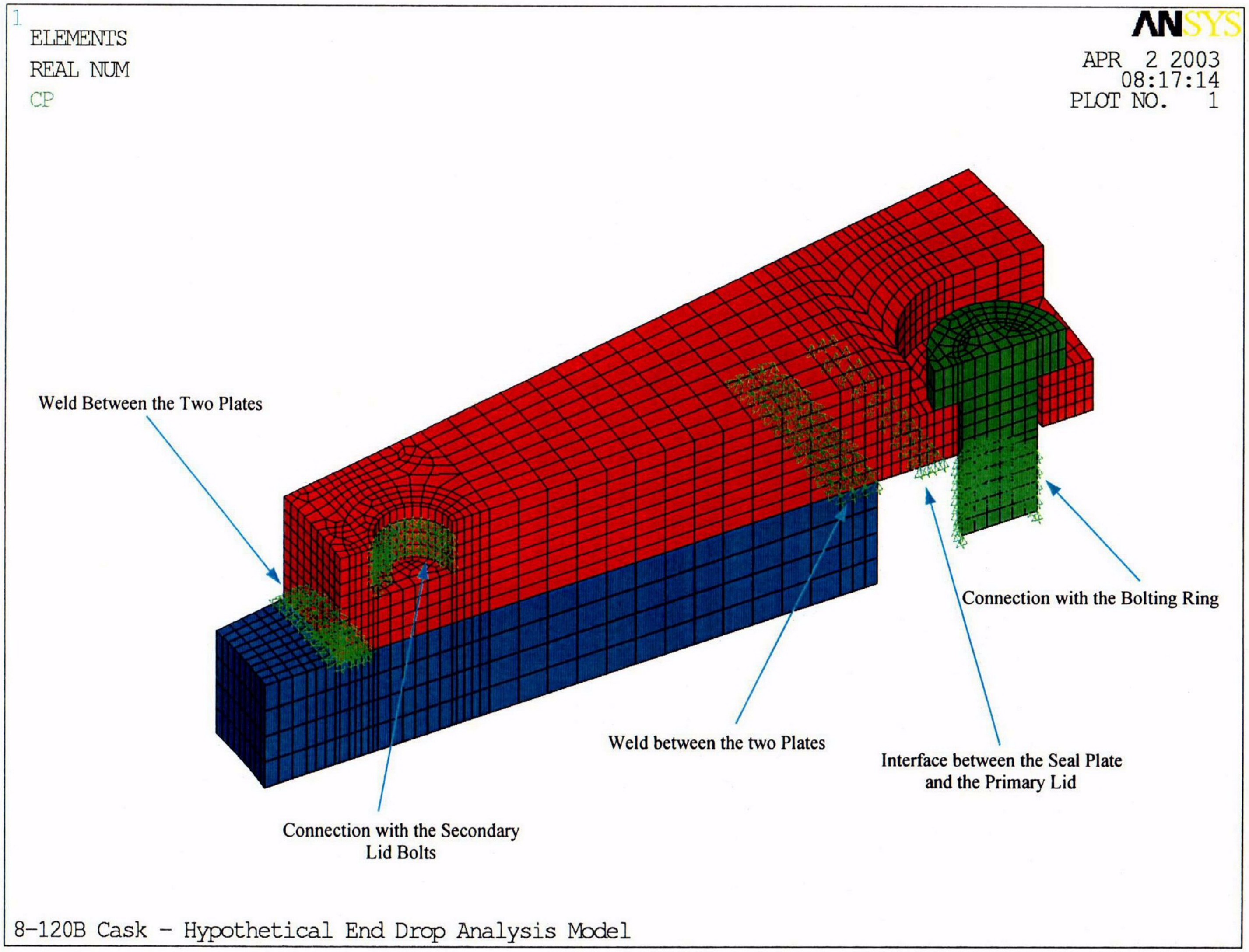

Figure 3
Finite Element Model of the Primary Lid and Primary Lid Bolts

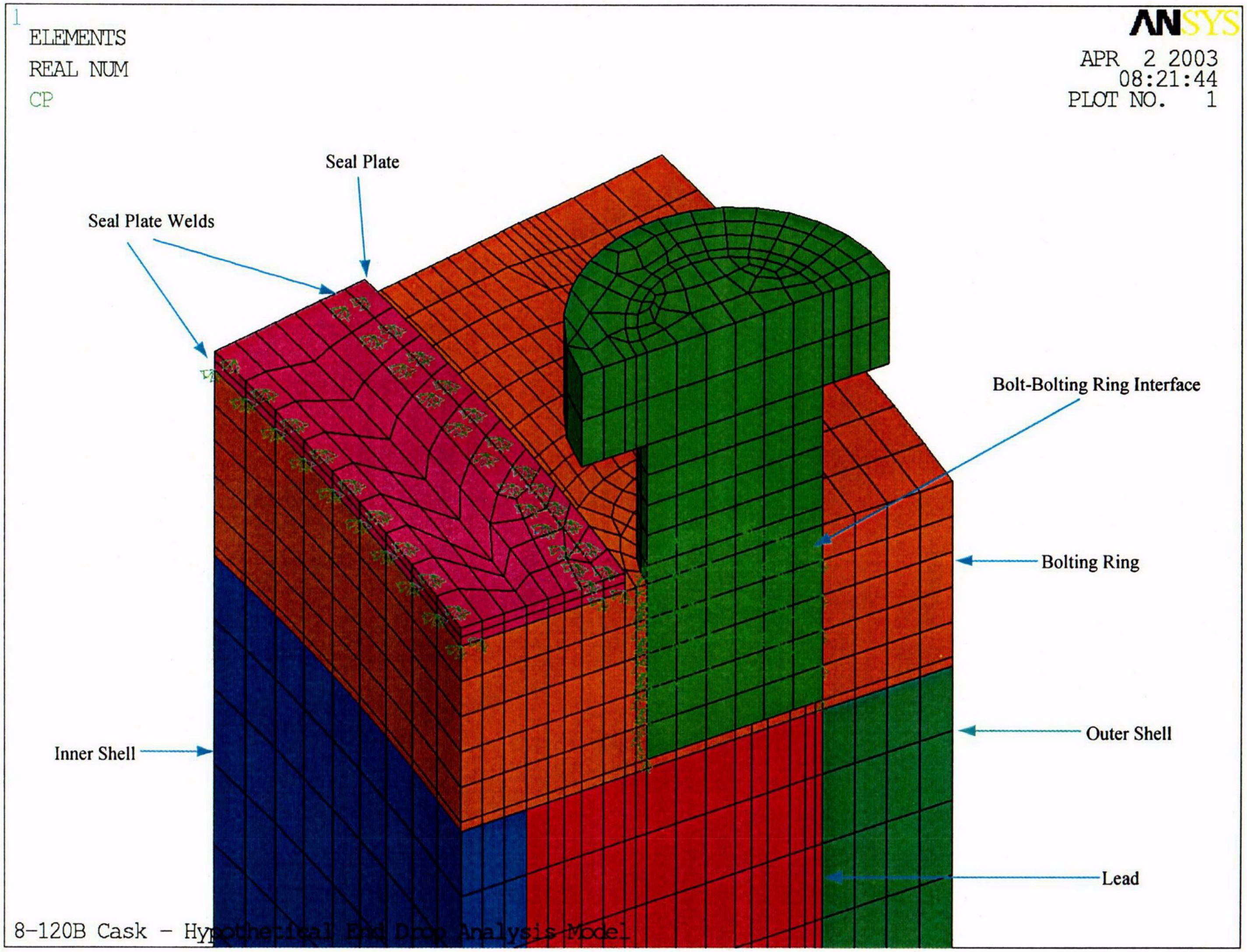

Figure 4
Finite Element Model of the Seal Plate, Bolting Ring Inner and Outer Shells and the Lead

C04

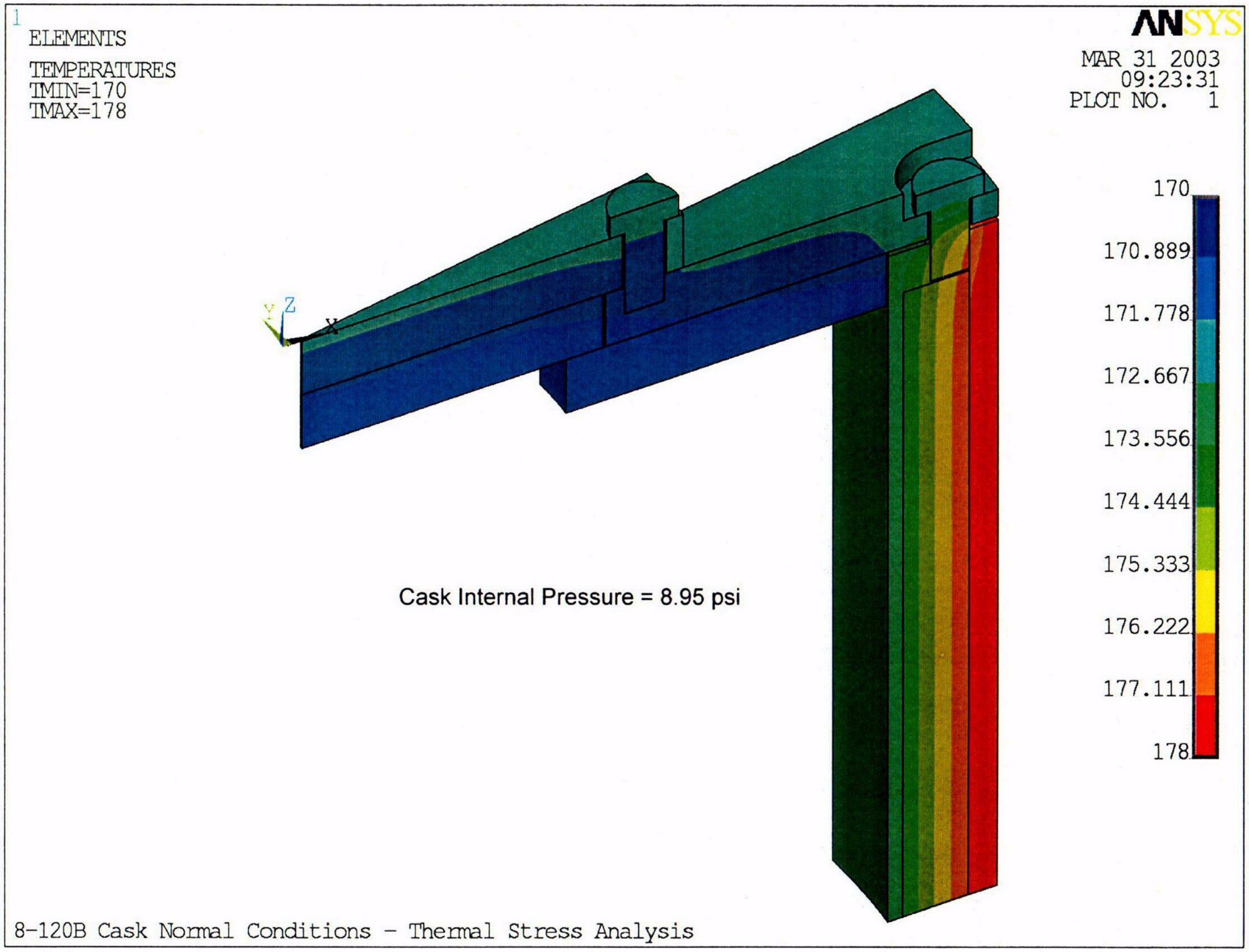

Figure 5
Temperature Distribution in the Cask Under Normal Conditions Heat Loading

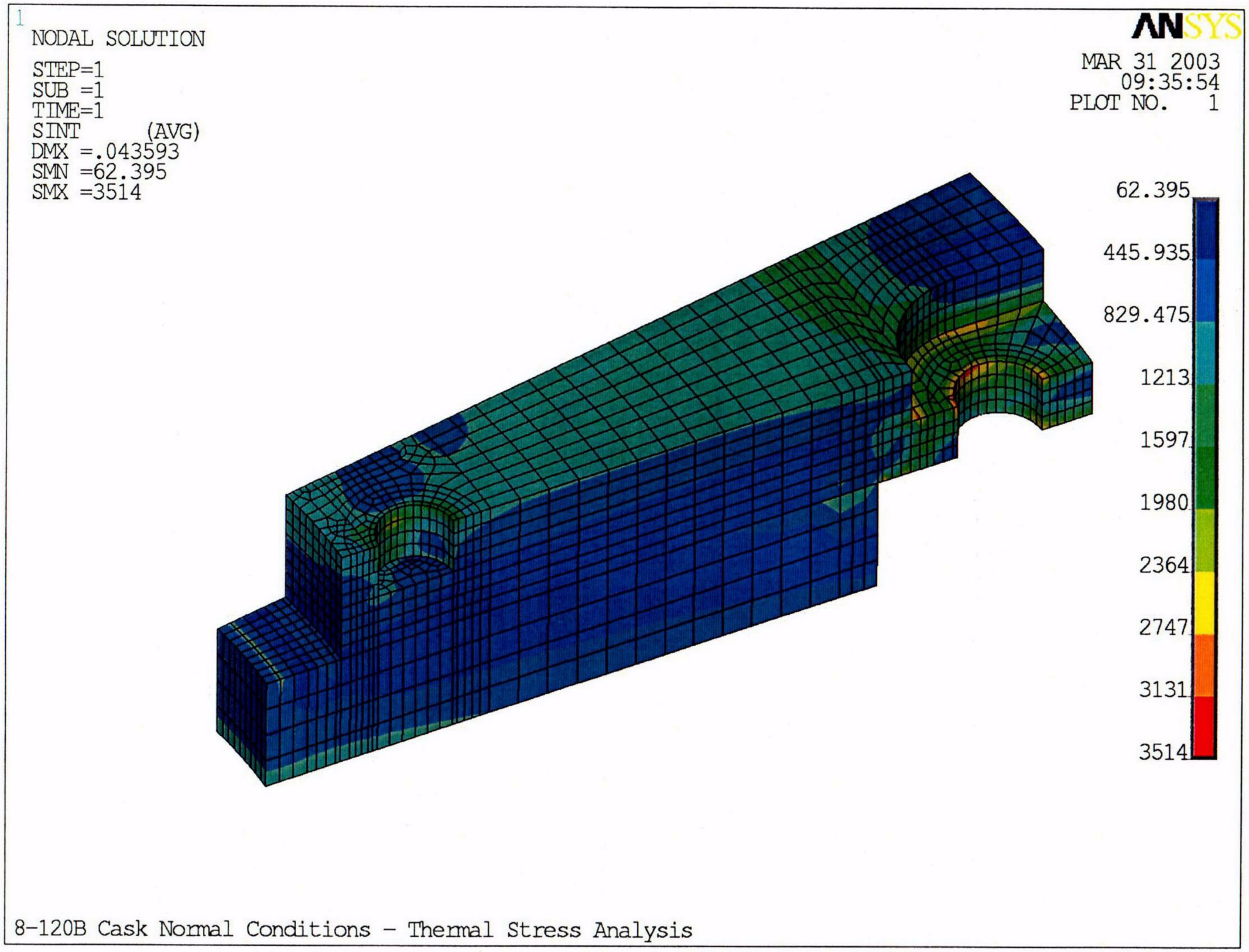

Figure 6

S.I. Distribution in the Primary Lid - Normal Conditions Thermal Loading

Title 8-120B Cask Analyses - Optional Raised Seal Surface on Bolting Ring

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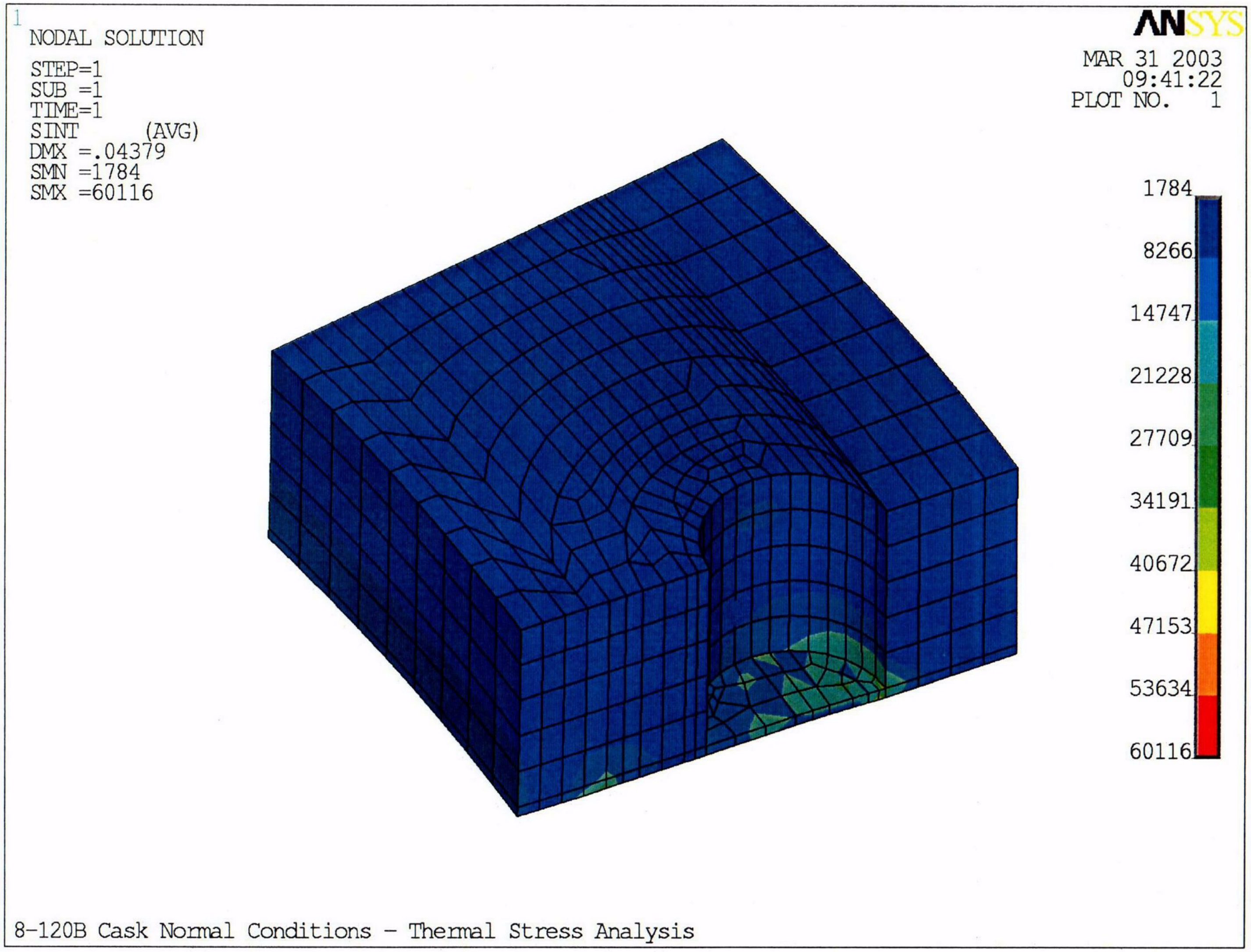


Figure 7
S.I. Distribution in the Bolting Ring- Normal Conditions Thermal Loading

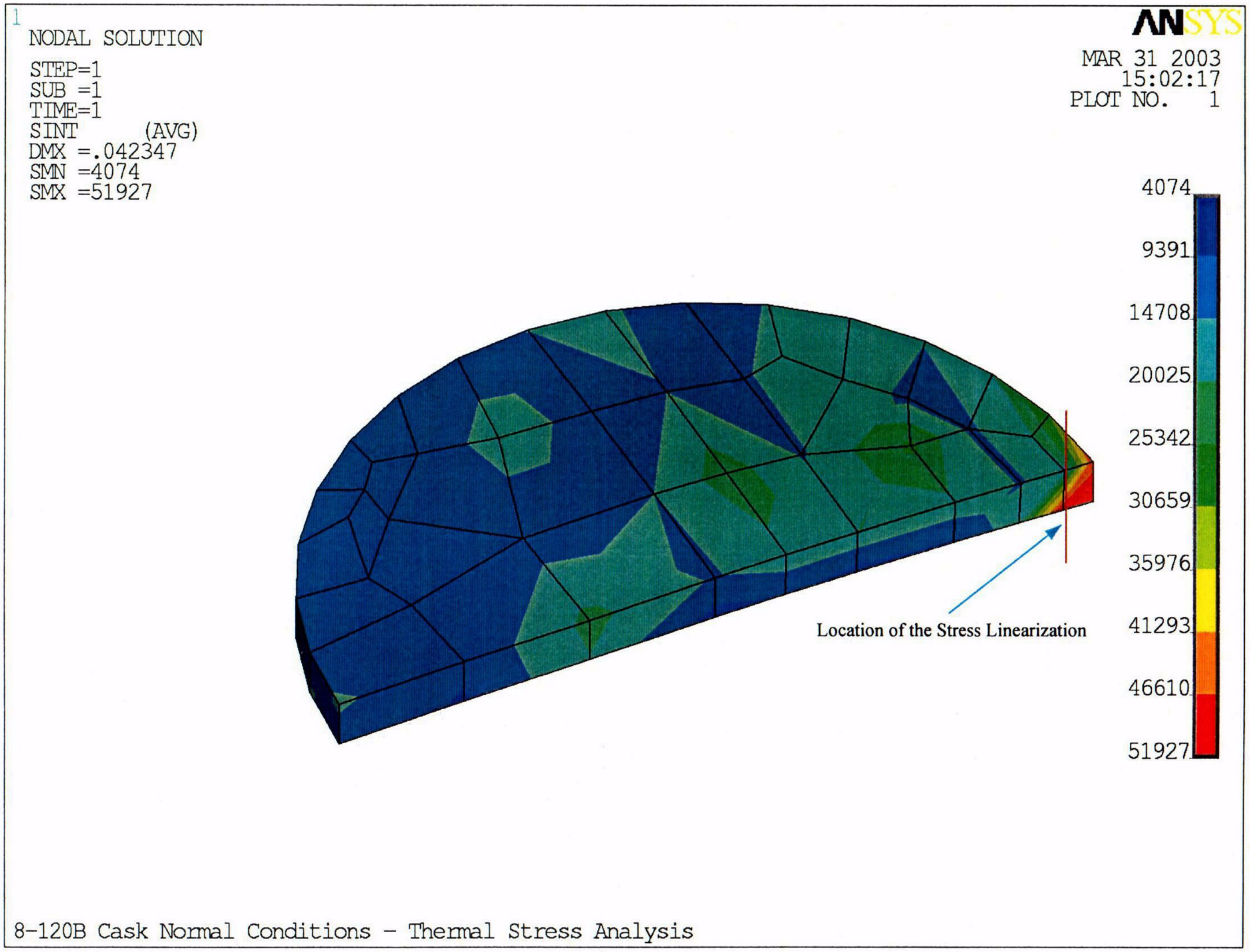


Figure 8
Stress Linearization in the Bolting Ring- Normal Conditions Thermal Loading

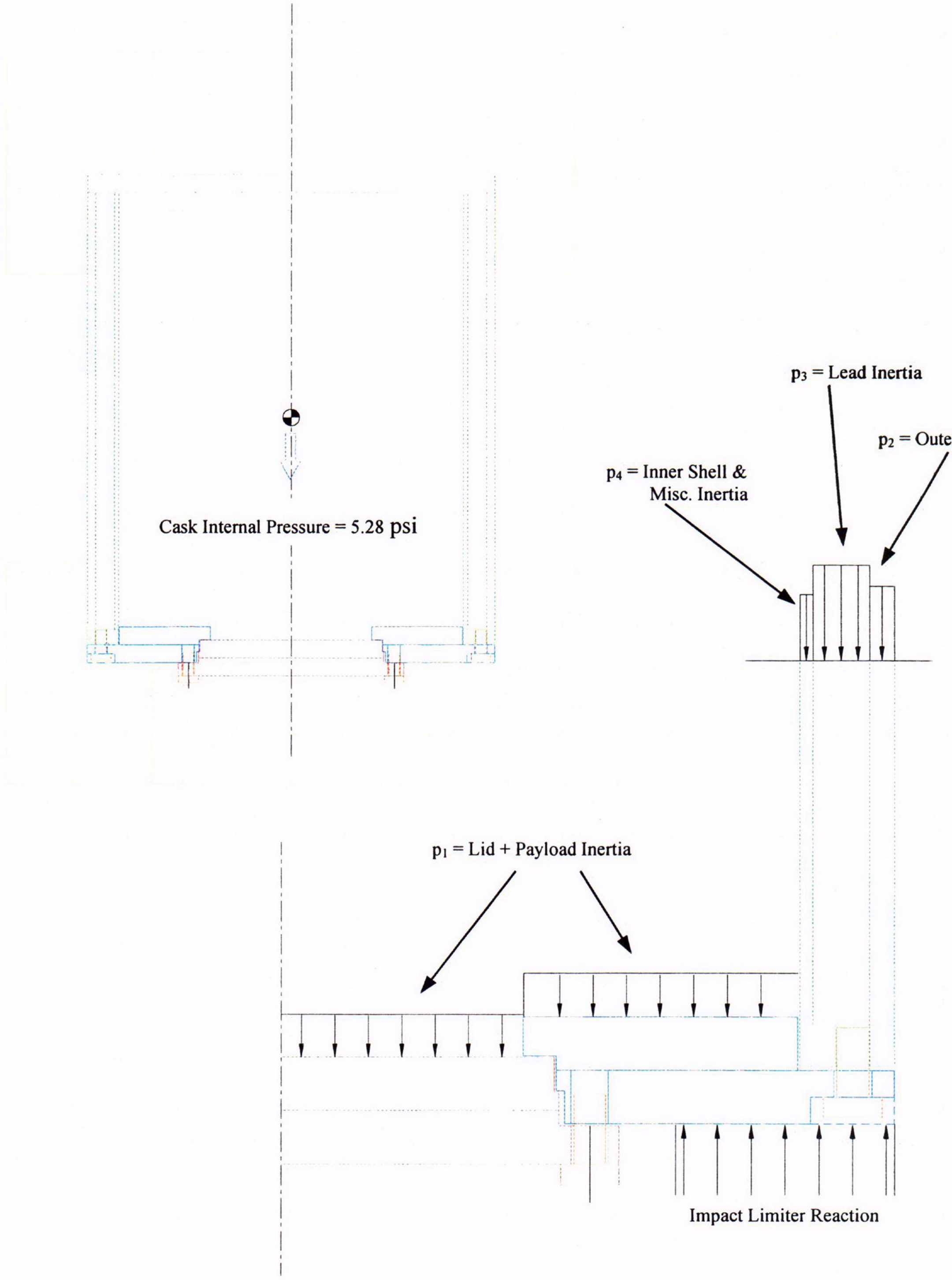


Figure 9

Inertia Loading and Impact Limiter Reaction on the Cask During End Drop

C09

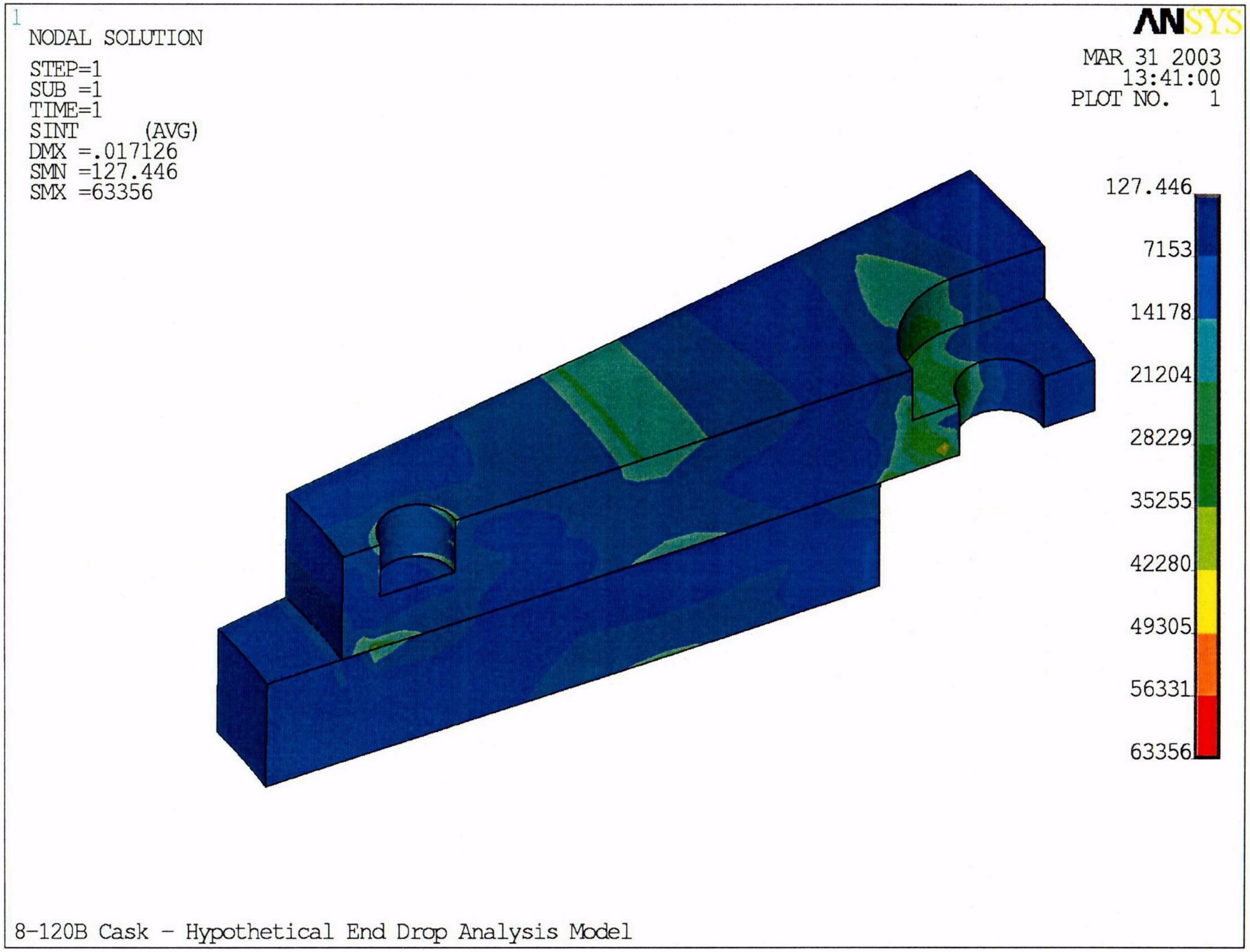
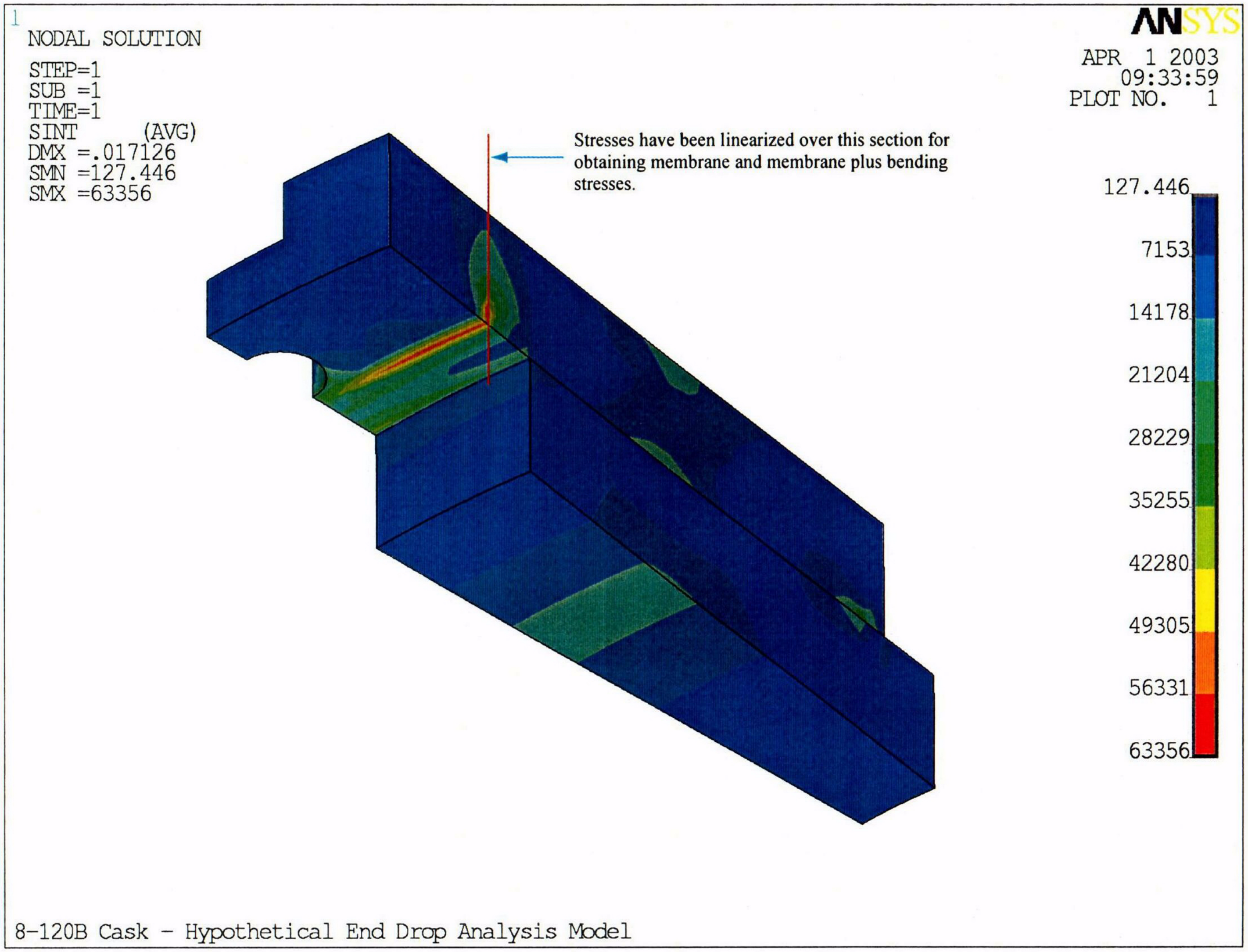


Figure 10
S.I. Distribution in the Primary Lid – Hypothetical Accident – End Drop



Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 11

Location of Stress Linearization in the Primary Lid – Hypothetical Accident – End Drop

Title 8-120B Cask Analyses - Optional Raised Seal Surface on Bolting Ring

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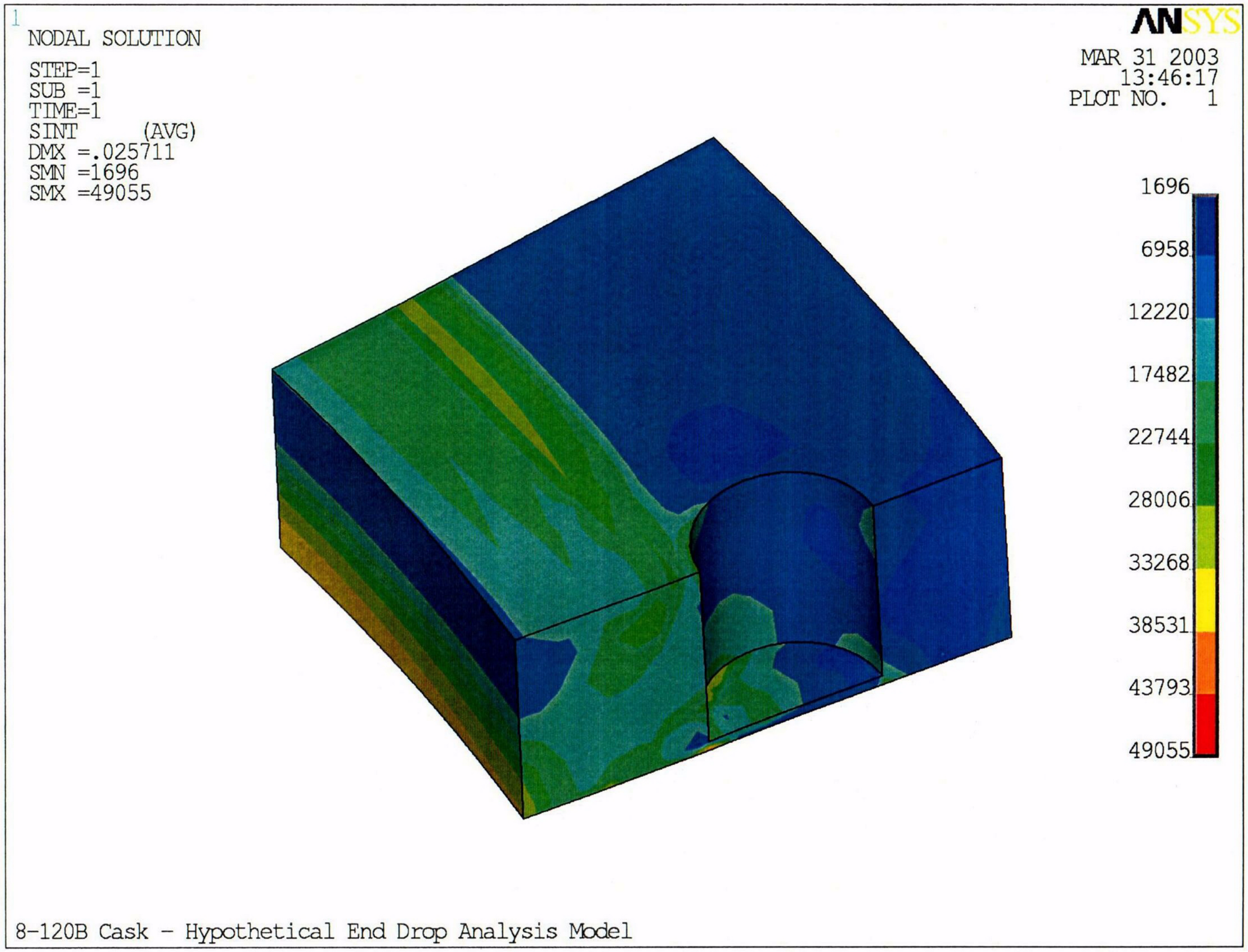

Figure 12

S.I. Distribution in the Bolting Ring – Hypothetical Accident – End Drop

Title 8-120B Cask Analyses - Optional Raised Seal Surface on Bolting Ring

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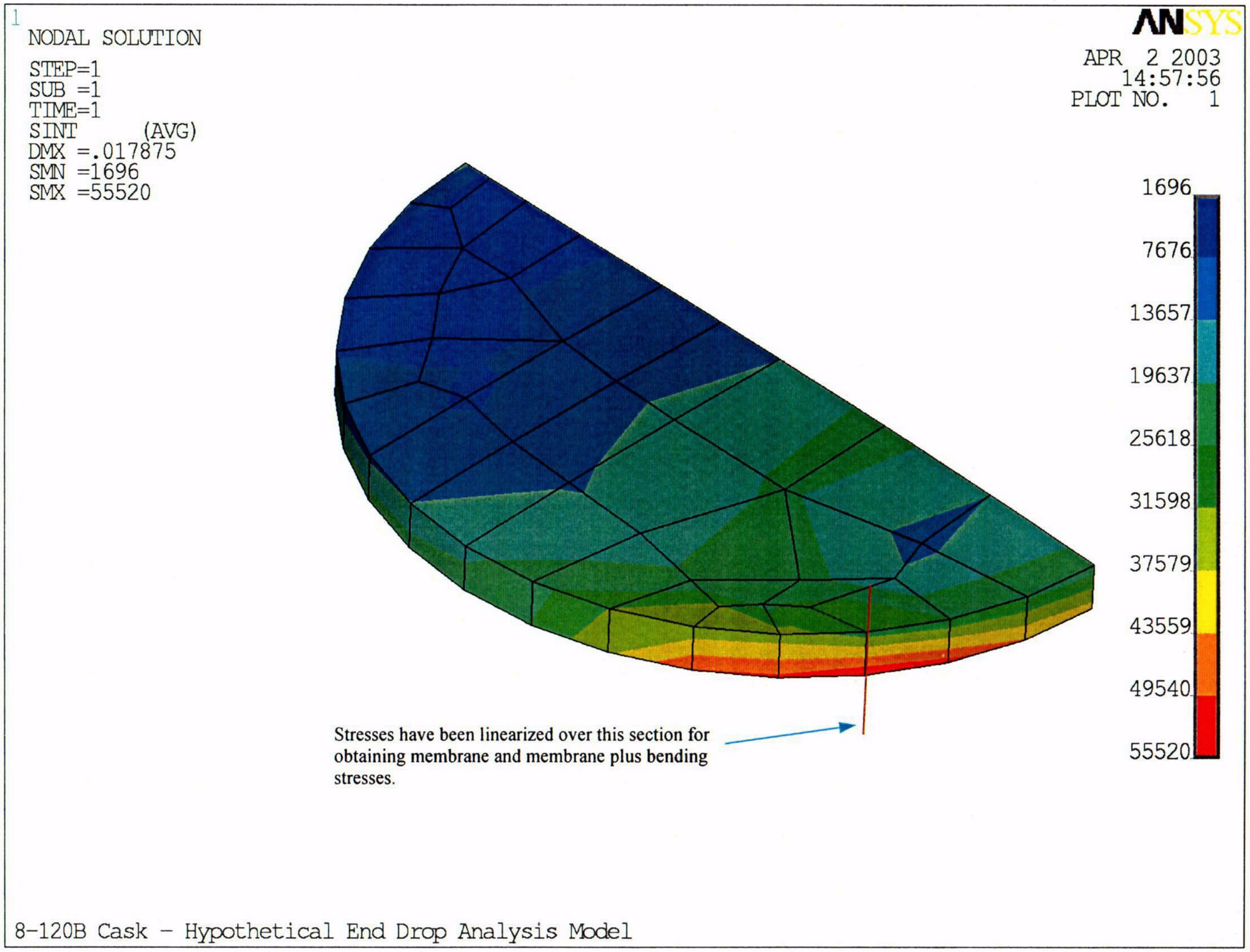

Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 13

Location of Stress Linearization in the Bolting Ring – Hypothetical Accident – End Drop

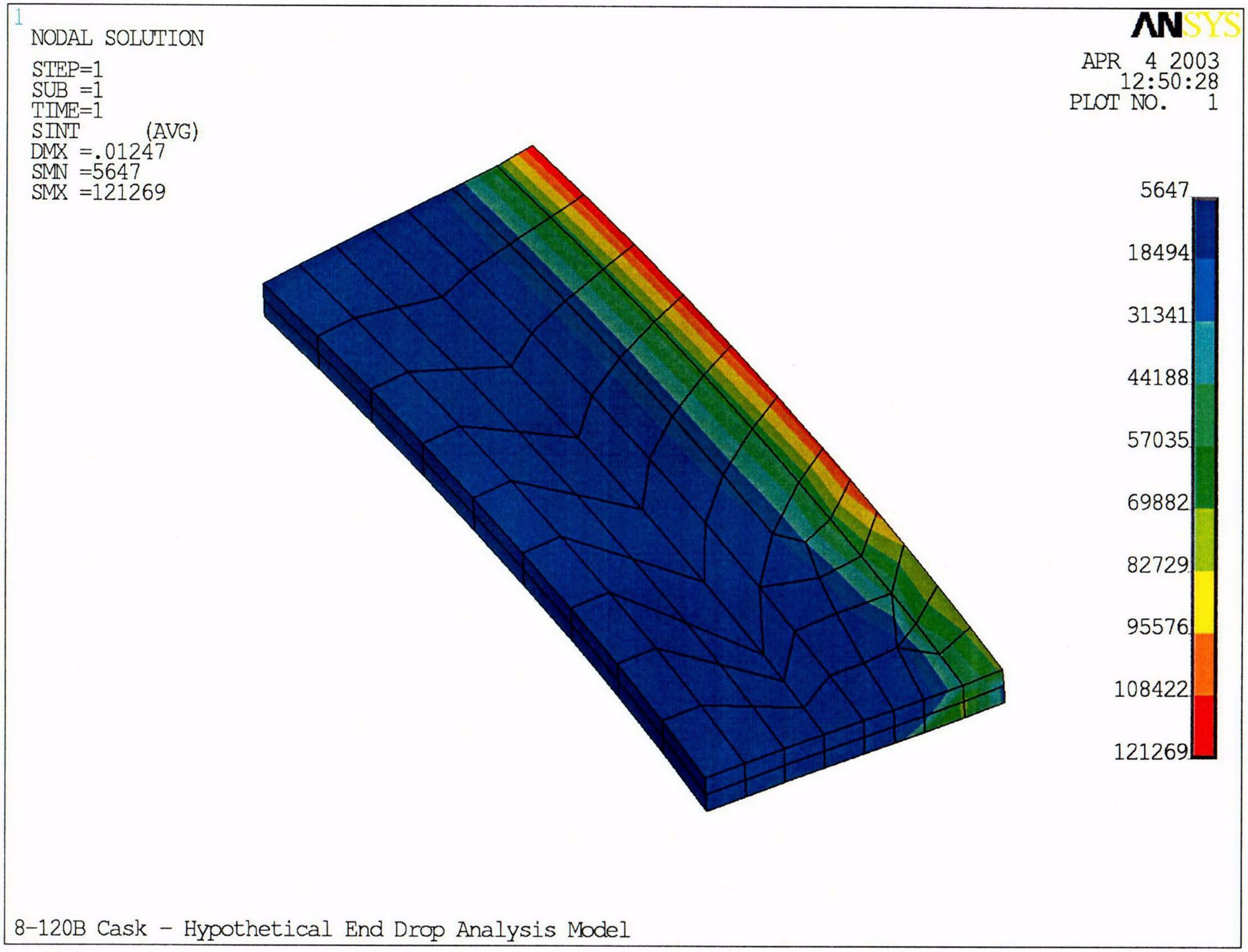

Figure 14
S.I. Distribution in the Seal-Plate – Hypothetical Accident – End Drop

C14