RTL-001-CALC-ST-0403 Rev 4_Redacted

ENERCON *Excellence—Every project. Every day.*	CALCULATION COVER SHEET	CALC. NO. RTL-001-CALC-ST-0403 REV. 4 PAGE NO. 1 of 16

Title:	Pin Puncture Evaluation	**Client:**	Robatel Technologies, LLC
		Project:	RTL-001

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions that require confirmation? (If **YES**, Identify the assumptions) ______	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, Identify the design verified calculation.) **Design Verified Calculation No.** ______	☐	☒
3	Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.** ______	☐	☒

Scope of Revision:

Revision 4 is being made to update reference drawing and calculation revision level.

Revision Impact on Results:

N/A

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☒ **Non-Safety Related** ☐

(Print Name and Sign)

Originator: David Hartmangruber [signature]	**Date: 01/03/2014**
Design Verifier: Curt Lindner [signature]	**Date: 01/03/2014**
Approver: Nand Lambha [signature]	**Date: 01/03/2014**

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0	10/07/2012	Initial Issue
1	8/28/2013	Updated material allowables based on RAI responses
2	9/05/2013	Incorporated customer comments
3	9/12/2013	Updated calculation and drawing references
4	1/03/2014	Updated calculation and drawing references

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
All	4		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
1	1-3	3			
2	1-1	3			
3	1-3	3			

Calculation Design Verification Plan:

Calculation to be reviewed for correctness of inputs, design criteria, analytical methods, acceptance criteria and numerical accuracy.

Stated objectives and conclusions shall be confirmed to be reasonable and valid.

Any assumptions shall be clearly documented and confirmed to be appropriate and verified based on sound engineering principles and practices.

(Print Name and Sign for Approval – mark "N/A" if not required)

Approver: Nand Lambha [signature]	**Date: 01/03/2014**

Calculation Design Verification Summary:

Calculation has been designated as **Safety Related** as noted on the cover sheet.

Calculation has been verified to be mathematically correct and performed in accordance with appropriate design inputs, assumptions, analytical methods, design criteria and acceptance criteria.

The conclusions developed in the calculation are reasonable, valid and consistent with the purpose and scope.

Assumptions are appropriate and correct.

Based On The Above Summary, The Calculation Is Determined To Be Acceptable.

(Print Name and Sign)

Design Verifier: Curt Lindner [signature]	**Date: 01/03/2014**
Others:	**Date:**

Item	CHECKLIST ITEMS	Yes	No	N/A
1	**Design Inputs -** Were the design inputs correctly selected, referenced (latest revision), consistent with the design basis, and incorporated in the calculation?	X		
2	**Assumptions** - Were the assumptions reasonable and adequately described, justified and/or verified, and documented?	X		
3	**Quality Assurance** - Were the appropriate QA classification and requirements assigned to the calculation?	X		
4	**Codes, Standards, and Regulatory Requirements** - Were the applicable codes, standards, and regulatory requirements, including issue and addenda, properly identified and their requirements satisfied?	X		
5	**Construction and Operating Experience** - Have applicable construction and operating experience been considered?			X
6	**Interfaces** - Have the design-interface requirements been satisfied, including interactions with other calculations?	X		
7	**Methods** - Was the calculation methodology appropriate and properly applied to satisfy the calculation objective?	X		
8	**Design Outputs** - Was the conclusion of the calculation clearly stated, did it correspond directly with the objectives, and are the results reasonable compared to the inputs?	X		
9	**Radiation Exposure** - Has the calculation properly considered radiation exposure to the public and plant personnel?			X
10	**Acceptance Criteria** - Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?	X		
11	**Computer Software**- Is a computer program or software used, and if so, are the requirements of CSP 3.02 met?	X		

COMMENTS

(Print Name and Sign)	
Design Verifier: Curt Lindner [signature]	**Date: 01/03/2014**
Others:	**Date:**

Table of Contents

1.0 Purpose and Scope

The purpose of this report is to document the Robatel Technologies RT-100 cask body analyses and show that the design meets the requirements of 10 CFR Part 71 (1). Specifically, the evaluation addresses the loads associated with Part 71.73(c)(3) hypothetical accident condition (HAC) puncture. The puncture load includes:

> *"A free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 in), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical. Two thermal conditions are evaluated, a hot and cold case. The hot case represents 38°C (100°F) ambient temperature and maximum insolance and heat load. The cold case represents -40°C (-40°F) with maximum heat load."*

The pin puncture evaluation includes classic calculations and finite elements analyses to show the RT-100 cask meets the pin puncture load requirements. The finite element analysis results of the lid pin puncture analysis is 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.

Proprietary Information Content Withheld Under 10 CFR 2.390

2.0 Summary of Results and Conclusions

Structural analyses were performed for the Robatel Technologies RT-100 cask for hypothetical accident conditions pin puncture. To evaluate the RT-100 cask, classical calculations and a 3-D ANSYS model are used to analyze the governing puncture cases. All structural members have a positive margin of safety under worst case loading conditions. It is concluded that the RT-100 cask is structurally adequate for the HAC pin puncture loading conditions. The requirements of 10 CFR 71 covered by this calculation have been satisfied.

3.0 References

1. **NRC.** *"Title 10, Part 71—Packaging and Transportation of Radioactive Material".* 10 CFR 71.
2. **Baumeister T. and Marks, L.S.** *"Standard Handbook for Mechanical Engineers, 7th Edition".* New York : McGraw-Hill Book Co., 1967.
3. **Shappert, L.B.** *"The Radioactive Materials Packaging Handbook".* Oak Ridge, Tennessee : Oak Ridge National Laboratory, 1988. ORNL/M-5003.
4. **NAC.** *"SAR - UMS Transport Cask".* Docket No. 71-9270.
5. **ENERCON.** *"RT-100 Cask Weight and Center of Gravity Calculation".* RTL-001-CALC-ST-0101, Rev. 0.
6. —. *"RT-100 Cask Body Analysis".* RTL-001-CALC-ST-0402, Rev. 4.
7. **ASME.** *"2007 & 2010 ASME Boiler & Pressure Vessel Code, Section II, Part D, Properties (Metric) Materials.*
8. **Rack, H.J., Knorovsky, G.A.** *"An Assessment of Stress-Strain Data Suitable for Finite-Element Elastic Plastic Analysis of Shipping Containers".* 1978. NUREG/CR-0481.
9. **Baumeister T. and Marks, L.S.** *"Standard Handbook for Mechanical Engineers, 9th Edition".* New York : McGraw-Hill Book Co., 1987.
10. **ANSYS®.** *Mecahnical, Revision 14.* s.l. : ANSYS, Inc.
11. **Roark, Raymond J.** *"Roark's Formulas for Stress & Strain".* 5th Edition. New York : McGraw-Hill, 1975.
12. **Robatel.** "ROBATEL Transport Package RT100 - General Assy", Drawing RT100 PE 1001 Sht. 1 & 2 Rev. H.

4.0 Assumptions

4.1 The weight of the cask for the analytical evaluation of the hypothetical accident is considered as the total weight of the cask and the maximum payload. The damage sustained by the cask and the impact limiters during the free drop evaluations does not result in any significant reduction in load, so no reduction is considered. **Basis:** This is a conservative assumption without further evaluation required.

4.2 For the drop in the vertical orientation, the mild steel bar/pin is assumed to impact directly at the center cask lid. **Basis:** This loading configuration imposes the worst case prying force in the lid and closure bolts.

4.3 The flow stress for the mild steel pin used in this evaluation is 324 MPa (approximately 47,000 psi) per Chapter 5 of Reference (2) and Reference (3). **Basis:** Standard equation used to evaluate the puncture response of a cask.

4.4 For the end puncture case, the total load is limited by the flow stress of the puncture probe. **Basis:** Previous designs submitted to the NRC successfully adopted this methodology per Reference (4).

5.0 Design Inputs

5.1 The maximum payload weight is 6,804 kg (15,000 lb) (5).

5.2 The material properties used for the cask shell, the lead shielding and the lid bolts are given in Tables 6-1 through 6-3 of Section 6.0.

5.3 Cask performance criteria 10 CFR 71. 73 (1).

5.4 A value of 9.81 m/s^2 will be used for the gravitational acceleration.

5.5 Robatel Drawings:

- RT100-NM-1000, Rev. F, RT-100 Bill of Materials
- RT100-PE-1001-1, Rev. H, RT-100 General Assembly, Sheet 1
- RT100-PE-1001-2, Rev. H, RT-100 General Assembly, Sheet 2
- RT100-PRS-1011, Rev. E, RT-100 Cask Body Weld Map
- RT100-PRS-1013, Rev. C, RT-100 Secondary Lid Weld Map
- RT100-PRS-1031, Rev. D, RT-100 Lower Impact Limiter Weld Map
- RT100-PRS-1032, Rev. D, RT-100 Upper Impact Limiter Weld Map

6.0 Methodology

To evaluate the puncture impact of the RT-100 cask, a combination of classic calculations and finite element analyses are used. For the finite element portion of the evaluation, refer to the cask body analysis calculation for explanation of modeling methodology and load combinations in Reference (6).

Table 6-1 – Properties of SA-240, Type 304/304L (dual certified), Stainless Steel per Reference (7)

Property*	Value									
Temperature (°C)	-40	21	38	93	149	204	260	343	427	482
Ultimate strength, S_u (MPa)	517.1	517.1	517.1	489.5	456.4	441.3	437.1	437.1	433.0	419.2
Yield strength, S_y (MPa)	206.8	206.8	206.8	172.4	154.4	142.7	133.8	124.1	116.5	111.7
Design Stress Intensity, S_m (MPa)	137.9	137.9	137.9	137.9	137.9	128.2	120.7	111.7	104.8	100.7
Modulus of Elasticity, E (GPa)	198.6	195.1	194.0	190.3	186.2	182.7	177.9	173.1	166.2	162.0
Coefficient of Thermal Expansion, α ($\times 10^{-5}$ m/m/°C)	1.4634	1.5300	1.5480	1.6020	1.6560	1.7100	1.7460	1.7820	1.8180	1.8360
Thermal Conductivity, k (W/m•°C)	—	15.164	15.410	16.217	17.025	—	—	—	—	—
Specific Heat, (J/kg•°C)	—	6.977	4.916	2.510	1.706	—	—	—	—	—
Poisson's Ratio	0.31									
Density (kg/m³)	8027.2									

* SA-182, Type 304 stainless steel may be substituted for SA-240 Type 304 stainless steel provided that the SA-182 material yield and ultimate strengths are equal to or greater than those of the SA-240 material. The SA-182 forging material and the SA-240 plate material are both Type 304 austenitic stainless steels. Austenitic stainless steels do not experience a ductile-to-brittle transition for the range of temperatures considered in this Safety Analysis Report. Therefore, fracture toughness is not a concern.

Table 6-2 – Properties of SA-354, Grade BD, Carbon Steel Per Reference (7)

Property*	Value									
Temperature (°C)	-40	21	38	93	149	204	260	343	427	482
Ultimate strength, S_u (MPa)	1034.2	1034.2	1034.2	1034.2	1034.2	1034.2	1034.2	1034.2	946.7	767.4
Yield strength, S_y (MPa)	896.3	896.3	896.3	821.2	792.9	765.3	730.2	663.3	599.8	564.7
Modulus of Elasticity, E (GPa)	206.7	202.7	201.7	198.6	195.1	192.4	188.2	178.9	—	—
Coefficient of Thermal Expansion, α ($\times 10^{-5}$ m/m/°C)	1.1214	1.1520	1.1647	1.2060	1.2420	1.2780	1.3140	1.3140	—	—
Thermal Conductivity, k (W/m•°C)	—	60.405	60.054	58.327	55.904	—	—	—	—	—
Specific Heat, (J/kg•°C)	—	16.270	16.751	17.998	18.822	—	—	—	—	—
Poisson's Ratio	0.3									
Density (kg/m³)	8220.9									

Table 6-3 – Lead Properties

Property*	Value									
Temperature (°C)	-40	-29	20	21	27	70	77	93	149	316
Modulus of Elasticity, E (GPa) (8)	16.9	16.7	—	15.7	—	—	—	14.2	13.4	10.3
Coefficient of Thermal Expansion, α (×10^{-5} m/m/°C) (8)	2.8080	2.8260	—	2.8980	—	—	—	2.9880	3.0960	3.6360
Thermal Conductivity, k (W/m•°C) (8)	—	—	35.335	—	35.246	34.655	34.565	—	—	—
Specific Heat, (J/kg•°C) (8)	—	—	127.70	—	128.12	129.79	130.21	—	—	—
Poisson's Ratio (2)	0.4									
Density (kg/m^3) (2)	11340									

7.0 Calculation

The RT-100 cask inner shell, shield annulus and outer shell are designed to provide required shielding with minimum weight. A benefit of this configuration is that the outer shell provides protection from pin puncture so that the inner shell is not deformed. Therefore, the lead layer acts as a shock-absorbing medium distributing the puncture impact energy, which propagates inward from the outer shell.

7.1 Lid Puncture

Finite element analysis methods are used to perform the stress evaluation of the RT-100 Cask for the end puncture conditions. The end puncture is analyzed using a three-dimensional finite element model using the computational modeling software ANSYS as described in Reference (10). The end puncture model description is provided in Reference (6). To simplify the pin puncture analysis, only the upper end of the cask is considered for this evaluation. Figure 7-1 shows the pin puncture model.

7.1.1 Lid Puncture—Boundary conditions

The puncture load is applied to a 152 mm (6 in) diameter region which corresponds to a 152 mm diameter pin. The load is simulated with an evenly distributed pressure load equal to the dynamic flow stress of the pin, which is taken to be 324 MPa (47,000 psi) as specified in Reference (2). As discussed in the cask body analysis, the preload generated from the torque of the closure bolts is included as an initial condition. In addition, the maximum normal operating pressure of 241 KPa (35 psig) is applied to the interior surface of the cask.

7.1.2 Lid Puncture—Results

Stress results for the 1-meter pin puncture combined loading conditions are documented in Table 7-1. The table documents the primary membrane (P_m), primary membrane plus primary bending (P_m+P_b) stresses in accordance with the criteria presented in Regulatory Guide 7.6. Stresses are linearized across critical sections to determine the membrane and bending stresses which are compared with allowable stress intensities.

As shown in Table 7-1, the margins of safety when compared to the stress intensity for each category are positive. The most critically stressed component in the system is the flange, which is due to bending as a result of the pin puncture probe striking the center of the lid. The minimum margin of safety is found to be +0.2 for primary membrane plus bending stress intensity. The locations of the critical sections correspond to the maximum stress location shown in Figure 7-2.

Table 7-1. HAC Pin Puncture Stress Summary

Stress State	Location	S1	S2	S3	SINT	Allowable Stress	Margin of Safety
INNER LID		MPa	MPa	MPa	MPa	MPa	
Pm		-108.6	-109.8	-191.5	82.9	331	3.0
Pm + Pb	*Inside*	383.4	382.9	-37.7	421.1	485	0.2
	Center	-108.6	-109.8	-191.5	82.9	485	4.9
	Outside	-342.9	-602.3	-603.3	260.4	485	0.9

7.2 Puncture—Cask Side Puncture

7.2.1 Minimum Wall Thickness

A series of pin puncture tests performed at Oak Ridge National Laboratory were used to develop an empirical equation for the stress in the outer wall of a multi wall cask as a function of the mass of the cask and the thickness of the cask outer wall material (3). This equation (Nelm's equation) applies to steel-lead-steel cask wall construction and is used to demonstrate-pin puncture adequacy for casks with stainless steel walls, and this equation has been the basis for the puncture analysis of several licensed casks. Solving Nelm's equation for the RT-100 outer shell:

$$t = \left(\frac{W}{S}\right)^{0.71} = 1.16 \text{ in (29 mm)} < 35 \text{ mm}$$

where

W = 92,594 lb (42,000 kg), maximum gross weight of the package

S = 75,000 psi (517.1 MPa), ultimate tensile strength of the outer shell.

Nelm's equation shows that the cask outer shell is sufficient to resist puncture.

7.2.2 Cask Sidewall Bending Stresses

When the cask sidewall impacts the puncture pin, the bending force is:

$$\sigma_b = \frac{M \times c}{I} = 15.3 \text{ MPa}$$

Conservatively assuming the compressive and tensile stresses occur at the same location, the stress intensity is doubled to 30.6 MPa. Therefore, the factor of safety is:

$$FS = \frac{517.1}{30.6} = 15.7 > 1$$

where

$M = \frac{F_i \times m}{4}$ = 1589.2 kN-m, moment due to impact force

$m = \frac{L}{2}$ = 1.16 m, moment arm resulting from impact

$L = h_{tot} - h_u - h_L$ = 2.32 m, sidewall length

h_{tot} = 3312.8 mm, cask total height

h_U = 498 mm, upper impact limiter height

h_L = 494 mm, lower impact limiter height

$Fi = K_s \times A_i$ = 5478.2 kN, impact force

K_s = 324 MPa, dynamic flow stress for mild steel (3)

$A_i = \frac{\pi}{4} \times d_P^2$ = 0.0177 m^2, puncture probe area

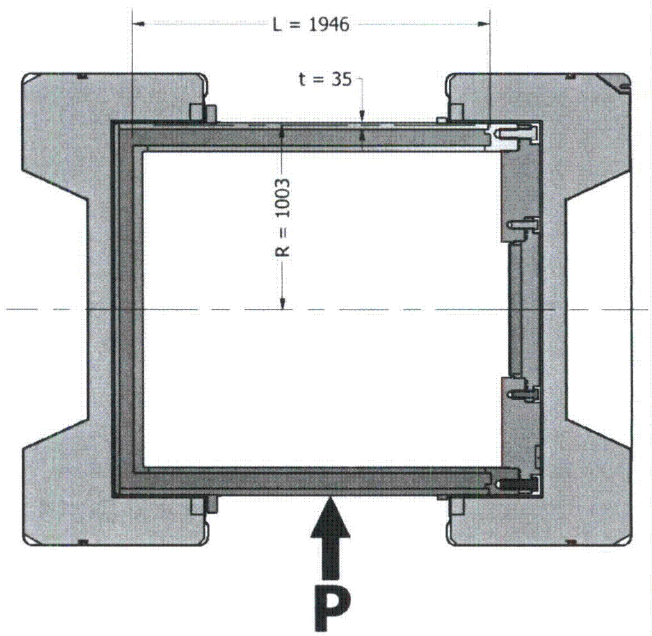
d_P = 0.15 m, puncture probe diameter

Therefore, the RT-100 cask sidewall successfully resists the regulatory puncture drop.

7.3 Puncture—Lead Deformation during Side Puncture

Following the postulated side puncture of The RT-100 cask, the cask may experience localized deformation of the outer shell. Behind this localized deformation a slight flattening may occur, which results in shielding loss. To quantify this loss, the local stiffness of the cask wall is determined to calculate the energy absorbed by the package. To calculate the total deformation of the lead shield, it is conservatively assumed that the available potential energy of the 1 meter puncture drop is converted to strain energy.

The maximum deformation occurs during postulated puncture event when the cask strikes the puncture probe approximately mid-span on the cask outer shell. For the purposes of this evaluation, the cask is considered a closed cylinder subjected to a concentrated load at the mid-span. The deformation is obtained from Roark's, Table 31, Case 9 (10). The deflection of the outer shell due to the applied load is:



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

where

L = length of the cylinder
R = mean radius of the shell
P = applied load
E = Young's modulus

Solving for the stiffness:

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

The RT-100 is considered a composite cylinder comprised of an outer shell, lead shield, and inner shell. The resulting stiffness of each component is:

7.3.1 Outer Shell Stiffness

$$k_1 = \frac{1.989 \times 10^{10} \times 3.505 \times 10^{-2}}{\left[0.48 \times \left(\frac{1.946}{1.003}\right)^{0.5} \times \left(\frac{1.003}{3.505 \times 10^{-2}}\right)^{1.22}\right]} = 1.743 \times 10^{7}\ \text{N/m}$$

where

L = 1.946 m
R = 1.003 m
t = 3.505×10^{-2} m
P = 6.972×10^{8} N
E = 1.989×10^{10} Pa

7.3.2 Lead Stiffness

$$k_2 = \frac{1.602 \times 10^{9} \times 8.992 \times 10^{-2}}{\left[0.48 \times \left(\frac{1.946}{9.401 \times 10^{-1}}\right)^{0.5} \times \left(\frac{9.401 \times 10^{-1}}{8.992 \times 10^{-2}}\right)^{1.22}\right]} = 1.191 \times 10^{7}\ \text{N/m}$$

where

$$L = 1.946\ m$$
$$R = 9.401 \times 10^{-1}\ m$$
$$t = 8.992 \times 10^{-2}\ m$$
$$P = 1.441 \times 10^{8}\ N$$
$$E = 1.602 \times 10^{9}\ Pa$$

7.3.3 Inner Shell Stiffness

$$k_3 = \frac{1.989 \times 10^{10} \times 1.905 \times 10^{-2}}{\left[0.48 \times \left(\frac{1.946}{8.801 \times 10^{-1}}\right)^{0.5} \times \left(\frac{8.801 \times 10^{-1}}{1.905 \times 10^{-2}}\right)^{1.22}\right]} = 4.945 \times 10^{6}\ N/m$$

where

$$L = 1.946\ m$$
$$R = 8.801 \times 10^{-1}\ m$$
$$t = 1.905 \times 10^{-2}\ m$$
$$P = 3.789 \times 10^{8}\ N$$
$$E = 1.989 \times 10^{10}\ Pa$$

7.3.4 Lead Deformation due to Puncture Load

The effective stiffness of the composite section of the cask is:

$$k_{eff} = k_1 + k_2 + k_3 = 3.428 \times 10^{7}\ N/m$$

The energy absorbed during impact is:

$$U = \tfrac{1}{2} k_{eff} \times \delta^2$$

Assuming the energy absorbed is equal to the total potential energy, the potential energy is calculated as:

$$P.E. = W \times h$$

Setting the energy absorbed during impact equal to the total potential energy the outer shell deformation is:

$$\tfrac{1}{2} k_{eff} \times \delta^2 = W \times h \Rightarrow \delta = \sqrt{\frac{2(W \times h)}{k_{eff}}} = 0.050\ m$$

where

$$W = 42{,}000\ kg$$
$$H = 1.016\ m$$

The deformation of the lead is calculated from the ratio of the effective stiffness and lead stiffness:

$$\delta_{lead} = \delta \times \frac{k_2}{k_{eff}} = 0.017\ m$$

Even though the deformation is comprised of and elastic and inelastic component, the entire deformation is conservatively assumed to be permanent.

APPENDIX 1—Figures

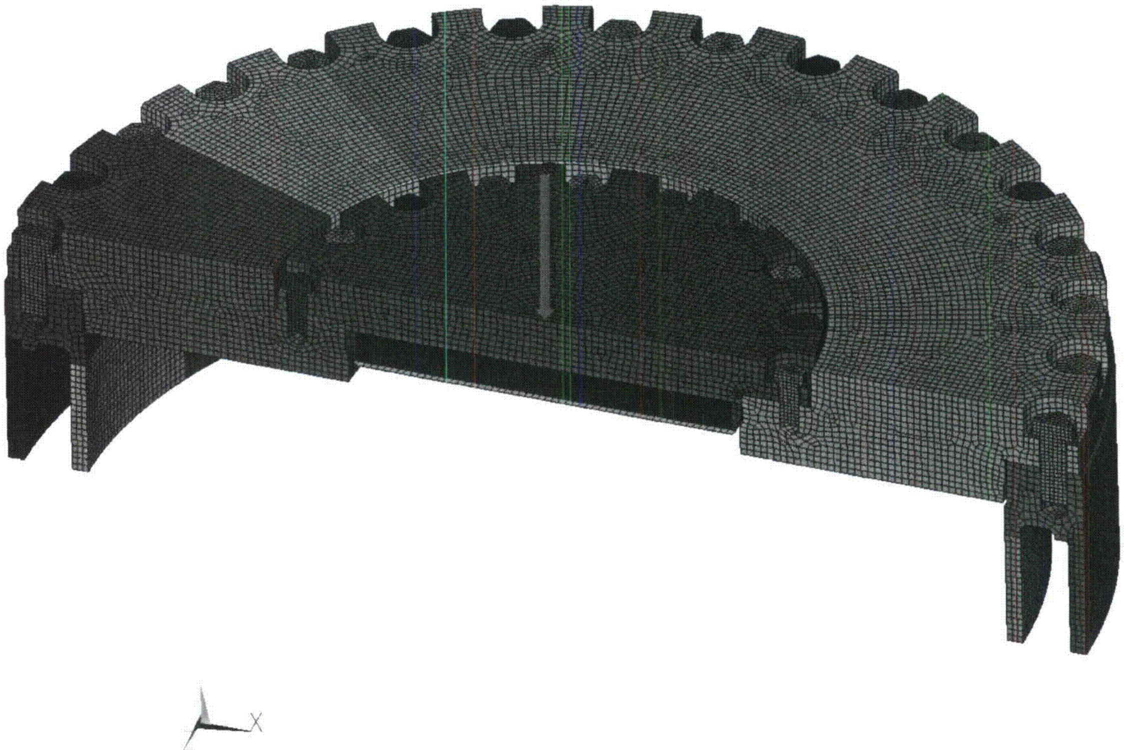


Figure 7-1. RT-100 ANSYS Puncture Model.

Figure 7-2. RT-100 Pin Puncture Stress Intensity Results.

APPENDIX 2—Input and Output File Organization

The following table shows the call sequence and which files are created during the ANSYS solution process.

Input File	Output File
RT100_puncture.inp	stress_pin_puncture.txt

APPENDIX 3—Output File Listing

Stress_pin_puncture.txt

```
****************************** Section 1 ********************************

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =1000000     OUTSIDE NODE =1000001

 LOAD STEP      1  SUBSTEP=      1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN THE GLOBAL COORDINATE SYSTEM.

             ** MEMBRANE **
     SX          SY          SZ          SXY          SYZ          SXZ
-0.1591E+05 -0.2758E+05 -0.1596E+05  -738.4      -1332.      0.3287E-01
     S1          S2          S3          SINT         SEQV
-0.1575E+05 -0.1593E+05 -0.2778E+05  0.1203E+05  0.1194E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY          SYZ          SXZ
I  0.7144E+05  0.2218E+05  0.7152E+05  -137.5       -428.3       -32.39
C   0.000       0.000       0.000       0.000        0.000        0.000
O -0.7144E+05 -0.2218E+05 -0.7152E+05  137.5        428.3        32.39
     S1          S2          S3          SINT         SEQV
I  0.7153E+05  0.7143E+05  0.2217E+05  0.4936E+05  0.4931E+05
C   0.000       0.000       0.000       0.000       0.000
O -0.2217E+05 -0.7143E+05 -0.7153E+05  0.4936E+05  0.4931E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY          SYZ          SXZ
I  0.5552E+05  -5408.      0.5556E+05  -875.9       -1760.       -32.35
C -0.1591E+05 -0.2758E+05 -0.1596E+05  -738.4       -1332.       0.3287E-01
O -0.8735E+05 -0.4976E+05 -0.8748E+05  -600.8       -903.2        32.42
     S1          S2          S3          SINT         SEQV
I  0.5561E+05  0.5553E+05  -5472.      0.6108E+05  0.6105E+05
C -0.1575E+05 -0.1593E+05 -0.2778E+05  0.1203E+05  0.1194E+05
O -0.4973E+05 -0.8736E+05 -0.8750E+05  0.3777E+05  0.3770E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY          SYZ          SXZ
I -0.5286E+05   774.2     -0.5288E+05   712.2        1451.        29.13
C   2443.      -1657.       2503.      -394.4       -670.7        25.24
O  0.7940E+05  0.5142E+05  0.8562E+05  -346.9        827.9       -229.0
     S1          S2          S3          SINT         SEQV
I   822.8     -0.5287E+05 -0.5292E+05  0.5374E+05  0.5372E+05
C   2651.       2435.      -1798.       4449.        4345.
O  0.8565E+05  0.7939E+05  0.5140E+05  0.3425E+05  0.3159E+05

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY          SYZ          SXZ
I   2665.      -4634.       2682.      -163.7       -309.3       -3.218
C -0.1347E+05 -0.2924E+05 -0.1346E+05  -1133.       -2002.        25.27
O  -7950.       1660.      -1860.      -947.8       -75.33       -196.6
     S1          S2          S3          SINT         SEQV         TEMP
I   2695.       2668.      -4651.       7346.        7333.        0.000
C -0.1311E+05 -0.1349E+05 -0.2957E+05  0.1646E+05  0.1627E+05
O   1753.      -1854.      -8049.       9803.        8588.        0.000


 ***** PATH VARIABLE SUMMARY *****

    S          PATH1
  0.0000      7346.3
 0.19685      58692.
 0.39370      51326.
 0.59056      44808.
```

```
 0.78741      39861.
 0.98426      34944.
  1.1811      31060.
  1.3780      27295.
  1.5748      23621.
  1.7717      20052.
  1.9685      16460.
  2.1654      12213.
  2.3622      8121.2
  2.5591      4025.5
  2.7559      5132.6
  2.9528      10449.
  3.1496      18097.
  3.3465      25875.
  3.5433      34741.
  3.7402      44514.
  3.9370      9802.9

PRINT ITERATION SUMMARY

          **** POST1 ITERATION SUMMARY ****

LOAD STEP    1  SUBSTEP    1        CUMULATIVE ITERATION    1
TIME =    1.00000              TIME INCREMENT =    1.00000
 NUMBER OF EQUILIBRIUM ITERATIONS =          1
 CONVERGENCE INDICATOR = 0
 MAXIMUM DEGREE OF FREEDOM VALUE =  -0.914944E-01
 RESPONSE FREQUENCY FOR 2ND ORDER SYSTEMS =    0.00000
 DESCENT PARAMETER =    0.00000
 FORCE CONVERGENCE VALUE =    89677.7
 MOMENT CONVERGENCE VALUE =    0.00000
 DISPLACEMENT CONVERGENCE VALUE =    0.00000
 ROTATION CONVERGENCE VALUE =    0.00000
 NUMBER OF NONCONVERGED 2D CONTACT ELEMENTS =          0
 NUMBER OF NONCONVERGED 3D CONTACT ELEMENTS =          0


NUMBER OF WARNING MESSAGES ENCOUNTERED=        388
NUMBER OF ERROR   MESSAGES ENCOUNTERED=          0
```