TRANSNUCLEAR WEST

ENCLOSURE NO. 2

NON-PROPRIETARY CALCULATIONS TO SUPPORT AHSM SAR ANUH-01.0150

VOLUME 2 OF 2

TRANSNUCLEAR WEST	CALCULATION PACKAGE	CALC. NO: SCE-01.0204 PROJECT NO: SCE-01 PAGE: 1 of 138

PROJECT NAME:	CLIENT:
San Onofre Unit 1 Dry Cask Storage	Southern California Edison

CALCULATION TITLE:

Advanced NUHOMS® FO-DSC (Dry Shielded Canister) Shell Assembly Structural Analysis

UNCONTROLLED COPY
FOR INFORMATION ONLY

SUMMARY DESCRIPTION:

The objective of this calculation is to demonstrate the structural adequacy of the Advanced NUHOMS® FO-DSC Shell Assembly.

Note: All references to FO-DSC in this package are directly applicable to the 24PT1-DSC.

DOCUMENT REVISION	TOTAL PAGES	APPROVAL DATE	APPROVER NAME AND SIGNATURE	NAMES AND INITIALS OF PREPARERS AND VERIFIERS
A	132 Appendix A1-A32 Appendix B1-B32 Appendix C Appendix D (892 pg.) CD #1-#7	5/15/00	Ian McInnes	Michael Cohen Steve Streutker
0	136 Appendix A1-A33 Appendix B1-B33 Appendix C Appendix D (921pg.) CD #1-#8	7/24/00	Ian McInnes	Michael Cohen Steve Streutker
1	138 Appendix A1-A34 Appendix B1-B34 Appendix C Appendix D (952pg.) CD #1-#8	9/26/00	Ian D McInnes REGISTERED PROFESSIONAL ENGINEER IAN D. MCINNES No. C031375 Expires 12/31/00 CIVIL STATE OF CALIFORNIA	MICHAEL COHEN MSC CRAIG STANDAFER CMS

Revision History

Revision	Changes	Pages Affected	Discs Affected
A	preliminary issue	all	
0	Revision 0 is a general revision. It incorporates comments from documents SCE S01-207-1-C17 (SDC comments), Design Review Checklist for SCE-01.0204 Rev A (Calvin Wong, 5/30/00), and the Design Review Checklist at Review (5/23/00). Revisions based on comments from verifier are also in Rev 0. ANSYS® thermal runs were re-run to include correct grapple ring temperatures and shell material properties (b24therm, b24ther2 [new], t24pth, t24pth2, t24pthp, t24ptp2, t24ptp3, b24pth, b24pth2, b24pthg, b24pth-g, b24pthr, b24ptr2, and b24ptr3). ANSYS® runs b24p1g and t24p1g rerun with updated pressure load which includes fuel AND basket weight.	general revision	8 discs
1	Revision 1 is a general revision. 1. It incorporates comments from "SCE Comments: DSC Shell Assembly Calculation SCE-01.0204, Rev. 0 (SCE S01-207-1-C17, Rev. 0)." 2. ANSYS run QT24PED was rerun with correct pressure load. 3. ANSYS run QB24PED was run to provide data for bounding data for Corner Drop and Part 71 analysis. 4. Analysis of the outer top cover plate was added to determine stresses on outer pressure boundary when applicable. 5. Stresses determined by ANSYS for internal pressures of 20 and 60 psi were erroneous. Scaled stresses from 10 psi ANSYS results for 20 and 60 psi cases.	**General Revision:** Main Body, Appendix A3, Appendix B3, Appendix C, and Appendix D. **New:** Appendix A34 and Appendix B34 All other documents remain at "Rev. 0."	Added new and revised ANSYS runs to "CD #1"

CONTENTS

	Page
CONTENTS	3
LIST OF TABLES	5
LIST OF FIGURES	8
1. PURPOSE	9
2. CONSERVATISM	15
3. ASSUMPTIONS	17
4. DESIGN INPUT/DATA	19
4.1 Geometry/Critical Interfaces	19
4.2 Material Properties	20
4.3 Load Conditions & Combinations	22
5. METHODOLOGY	30
5.1 Acceptance Criteria	30
5.2 Model Description	[illegible]
6. REFERENCES	[illegible]
7. NOMENCLATURE	52
8. COMPUTATIONS	53
8.1 FO-DSC Seismic Analysis	53
8.2 Fatigue Evaluation	55
8.3 Draining and Drying	58
8.4 DSC Natural Frequency	65
8.5 Outer Top Cover Plate Stresses due to Internal Pressure	65
9. RESULTS/CONCLUSIONS AND RECOMMENDATIONS	67
9.1 Stress Analysis	67
9.2 Code Compliance	94
10. SUMMARY	107

Appendices A1 thru A34: ANSYS Analysis Run Summaries and Input Listings A1-1

Appendix A Total Pages = 628

Appendices B1 thru B34: ANSYS Temperature & Stress Intensity Contour Plots B1-1

Appendix B Total Pages = 310

Appendix C: ANSYS Run Descriptions C-1

Appendix C Total Pages = 6

Appendix D: Safety Analysis Report Tables D-1

Appendix D Total Pages = 6

Attachment #1 Miscellaneous Input Total Pages = 2

Total Appendices Pages = 952

LIST OF TABLES

Page

Table 1-1 - FO-DSC ANSYS® File Names 11
Table 2-1 - Nominal Versus ANSYS model Plate Thicknesses 16
Table 4-1 - FO-DSC Shell Assembly Materials 20
Table 4-2 - Density & Poisson's Ratio for FO-DSC Shell Assembly Materials 21
Table 4-3 - SA-240 Type 316 Material Properties 21
Table 4-4 - A36 Carbon Steel Material Properties 22
Table 4-5 - FO-DSC Thermal Conditions 27
Table 4-6 - Summary of FO-DSC Load Combinations 28
Table 5-1 - Summary of Design Criteria for FO-DSC Pressure Boundary Components 34
Table 5-2 - Level A & B Allowable Stresses for SA-240 Type 316 Pressure Boundary Components 35
Table 5-3 - Level C Allowable Stresses for SA-240 Type 316 Pressure Boundary Components 35
Table 5-4 - Level D Elastic Allowable Stresses for SA-240 Type 316 Pressure Boundary Components 36
Table 5-5 - Level D Elastic/Plastic Allowable Stresses for SA-240 Type 316 Pressure Boundary Components 36
Table 5-6 - Level A & B Allowable Stresses for SA-36 Treated As Pressure Boundary Material 37
Table 5-7 - Level C Allowable Stresses for SA-36 Treated As Pressure Boundary Material 37
Table 5-8 - Level D Elastic Allowable Stresses for SA-36 Treated As Pressure Boundary Material 38
Table 5-9 Level D Elastic/Plastic Allowable Stresses for SA-36 Treated As Pressure Boundary Material 38
Table 5-10 - Stability Criteria for the FO-DSC Shell 39
Table 5-11 Allowable Stresses in Partial Penetration Outer Bottom Cover Plate Weld 39
Table 5-12 Allowable Stresses in Partial Penetration Top Inner Cover Plate Welds(1) 40
Table 5-13 Allowable Stresses in Partial Penetration Top Outer Cover Plate Welds(1) 40
Table 5-14 Subsection NF Criteria for Partial Penetration & Fillet Welds [4] 41
Table 5-15 - Allowable Base Metal Stresses for Partial Penetration & Fillet Welds Type 316 Base Metal [4] 41
Table 5-16 - Allowable Weld Metal Stresses for Partial Penetration & Fillet Welds 42
Table 8-1 - Summary of the draining and drying load cases 58
Table 8-2 - Geometry and Load Terms for DSC Shell analyses 58
Table 8-3 - Geometry and Load Terms for Top Cover Plate Analysis 59
Table 8-4 - Summary of the stresses in the DSC shell (stresses in psi) 62

Table 8-5 - Summary of the Maximum stresses in the Inner Top Cover Plate (stresses in psi) 62
Table 8-6 - Summary of Draining and Drying Operations Allowable Stress Comparisons 63
Table 8-7 - Summary of Draining and Drying Operations Allowable Pressure and Compressive Stress Comparisons 64
Table 8-8 - Geometry and Load Terms for Top Cover Plate Analysis 66
Table 8-9 - Summary Outer Pressure Boundary Stress Intensities 66
Table 9-1 ANSYS Run Summary for Top End 71
Table 9-2 ANSYS Run Summary for Bottom End 72
Table 9-3 - Top End Boundary Conditions 74
Table 9-4 - Bottom End Boundary Conditions 75
Table 9-5 Load Condition Stress[1] Results for Cylindrical Shell (Top Half) 76
Table 9-6 Load Condition Stress[1] Results for Outer Top Cover Plate 77
Table 9-7 Load Condition Stress[1] Results for Outer Top Cover Plate Weld 78
Table 9-8 Load Condition Stress[1] Results for Inner Top Cover Plate 79
Table 9-9 Load Condition Stress[1] Results for Top Shield Plug 80
Table 9-10 - Load Condition Stress[1] Results for Support Ring 81
Table 9-11 - Load Condition Stress[1] Results for Cylindrical Shell (Bottom Half) 82
Table 9-12 - Load Condition Stress[1] Results for Outer Bottom Cover Plate 83
Table 9-13 - Load Condition Stress[1] Results for Outer Bottom Cover Plate Weld 84
Table 9-14 - Load Condition Stress[1] Results for Bottom Shield Plug 85
Table 9-15 - Load Condition Stress[1] Results for Inner Bottom Cover Plate 86
Table 9-16 - Load Condition Stress[1] Results for Grapple Ring Support 87
Table 9-17 - Load Condition Stress[1] Results for Grapple Ring 88
Table 9-18 - Load Condition Force[1] Results for Outer Top Cover Plate Weld 89
Table 9-19 - Load Condition Force[1] Results for Inner Top Cover Plate Weld 90
Table 9-20 - Load Condition Force[1] Results for Support Ring Weld (Continuous) 91
Table 9-21 - Load Condition Force[1] Results for Support Ring Weld (Intermittent) 92
Table 9-22 - Load Condition Force[1] Results for Outer Bottom Cover Plate Weld 93
Table 9-23 - 10 Psi Design Pressure Stress Results 94
Table 9-24 Correlation of Load Combinations to Analysis Runs for Top End Models 99
Table 9-25 Correlation of Load Combinations to Analysis Runs for Bottom End Models 103
Table 10-1 Controlling Load Combination Stress Results for Cylindrical Shell (Top Half) 109
Table 10-2 - Controlling Load Combination Stress Results for Outer Top Cover Plate 111
Table 10-3 Controlling Load Combination Stress Results for Inner Top Cover Plate 112

Table 10-4 Controlling Load Combination Stress Results for Top Shield Plug 114
Table 10-5 Controlling Load Combination Stress Results for Support Ring 115
Table 10-6 Controlling Load Combination Stress Results for Shell (Bottom Half) 116
Table 10-7 Controlling Load Combination Stress Results for Outer Bottom Cover Plate 119
Table 10-8 Controlling Load Combination Stress Results for Bottom Shield Plug 121
Table 10-9 Controlling Load Combination Stress Results for Inner Bottom Cover Plate 123
Table 10-10 Controlling Load Combination Stress Results for Grapple Ring Support 125
Table 10-11 Controlling Load Combination Stress Results for Grapple Ring 127
Table 10-12 Controlling Load Combination Stress Results for Weld of Outer Top Cover Plate (Primary Stress[1]) 129
Table 10-13 Controlling Load Combination Stress Results for Weld of Outer Top Cover Plate (Primary + Secondary Stress[1]) 130
Table 10-14 Controlling Load Combination Stress Results for Weld of Inner Top Cover Plate 131
Table 10-15 Controlling Load Combination Stress Results for Upper (Continuous) Weld of Support Ring (Base Metal Evaluation[1]) 132
Table 10-16 Controlling Load Combination Stress Results for Upper (Continuous) Weld of Support Ring (Weld Metal Evaluation[1]) 134
Table 10-17 Controlling Load Combination Stress Results for Lower (Intermittent) Weld of Support Ring (Base Metal Evaluation[1]) 135
Table 10-18 Controlling Load Combination Stress Results for Lower (Intermittent) Weld of Support Ring (Weld Metal Evaluation[1]) 136
Table 10-19 Controlling Load Combination Stress Results for Weld of Outer Bottom Cover Plate (Primary Stress[1]) 137
Table 10-20 Controlling Load Combination Stress Results for Weld of Outer Bottom Cover Plate (Primary + Secondary Stress[1]) 138

LIST OF FIGURES

Page

Figure 1-1 – FO-DSC Shell 12
Figure 1-2 – FO-DSC Shell, Top Detail 13
Figure 1-3 – FO-DSC Shell, Bottom Detail 14
Figure 5-1 - FO-DSC Shell Assembly Top End 90° Analysis Model 44
Figure 5-2 - FO-DSC Shell Assembly Top End 90° Analysis Model (End Plates) 45
Figure 5-3 - FO-DSC Shell Assembly Top End 90° Analysis Model (End Plates and Support Ring) 46
Figure 5-4 - FO-DSC Shell Assembly Bottom End 90° Analysis Model 47
Figure 5-5 - FO-DSC Shell Assembly Bottom End 90° Analysis Model (End Plates) 48
Figure 5-6 - FO-DSC Shell Assembly Bottom End 90° Analysis Model (End Plates and Grapple Assembly) 49
Figure 5-7 - FO-DSC Shell Assembly Bottom End 180° Analysis Model – Refined (End Plates and Grapple Assembly) 50

1. PURPOSE

The objective of this calculation package is to demonstrate the structural adequacy of the Advanced NUHOMS® FO-DSC shell assembly and to demonstrate conformance to applicable structural criteria. The FO-DSC shell assembly is evaluated for normal, off-normal and hypothetical accident conditions in accordance with 10CFR72 requirements.

The Advanced NUHOMS® FO-DSC is a high integrity welded structure, which encapsulates the spent fuel assemblies during transfer and storage operations. The FO-DSC pressure boundary consists of a 5/8" thick cylindrical shell, the inner and outer top cover plates, and the inner bottom cover plate. All pressure boundary components are constructed of Type 316 stainless steel. A solid SA36 carbon steel shield plug, which is a non-pressure boundary component, is included at each end of the assembly to reduce radiation doses. The shield plug is constrained without being mechanically fastened to the stainless steel FO-DSC shell components, resulting in free thermal expansion of the dissimilar materials. A grapple ring is welded to the outer bottom cover plate for the purpose of pulling the FO-DSC from the Advanced Horizontal Storage Module (AHSM). The non-pressure boundary basket assembly, which supports the fuel within the FO-DSC shell assembly, is evaluated in separate calculation packages. Additionally, the DSC is suitable for storing Greater Than Class C (GTCC) waste provided that a 3/4" thick shell (minimum) which assures uniform loading on the canister lines the FO-DSC shell and that the maximum gross weight of the DSC and its components does not exceed 82,000 lbs.

The major structural components, which comprise the FO-DSC shell assembly, are shown in Figure 1-1 through Figure 1-3, and consist of the following (see Reference 1, Table 7-5 for a complete listing of the components and code classifications):

- FO-DSC Shell
- Outer Bottom Cover Plate
- Bottom Shield Plug
- Inner Bottom Cover Plate
- Grapple Ring
- Grapple Ring Support
- Outer Top Cover Plate
- Inner Top Cover Plate
- Top Shield Plug
- Support Ring

Four non-safety related lifting lugs are provided on the inside of the FO-DSC shell under the top end plates. The lugs are used for vertical lifts of the FO-DSC while installing an empty canister into the transfer cask. Lifts using these lugs are performed without the top end components installed and without fuel. The lifting lugs and welds are evaluated in a separate calculation package [15].

The shell assembly components are evaluated using the guidelines presented in the Design Criteria Document [1]. The structural analysis criteria takes guidance from the rules of the ASME Code, Section III (1992 Edition through Winter 1994 Addenda) with exceptions from Code Case N-595-1 [2]. Per Table 7-5 of Reference 1, all pressure boundary components listed above are evaluated per Subsection NB of the Code. For welds of non-pressure boundary parts, criteria are guided by the Code rules for component supports. The allowable stress limits for all FO-DSC components, as well as the applicable weld stress allowables, are summarized in Section 5.1. Load conditions considered in the evaluation are discussed in Section 4.3.

Appendices A1 thru A34, B1 thru B34, and C are structured in an order consistent with Table 1-1.

Table 1-1 - FO-DSC ANSYS® File Names

Appendix Number	Analysis Run I.D.	POST1 Run I.D.	Load Description
			Top End Models
1	QT24PIP	PT24PIP	10 psi, 20 psi & 60 psi internal pressure on inner pressure boundary
2	QT24PFL	PT24PFL	22 psi external flood pressure, + 10 psi internal pressure
3	QT24PED	PT24PED	1g axial, 60g bottom-end drop acceleration, + 20 psi internal pressure
4	QT24P1G	PT24P1G	1g axial acceleration outward + 14.6 psi pressure on shield plug (fuel/sleeves inertial load)
5	T24PDW	PT24PDW	1g vertical acceleration on horizontal FO-DSC
6	T24THERM	N/A	Steady State temperature solution for thermal load cases 15, 16, and 26
7	T24PSD	PT24PSD	75g side drop acceleration
8	T24PSDP	PT24PSDP	75g side drop acceleration + 20 psi internal pressure
9	T24PTH	PT24PTH	Thermal load cases 7, 8, 15, & 16
10	T24PTH2	PT24PTH2	Thermal load case 26
11	T24PTHP	PT24PTHP	Thermal load case 7 + 10 psi internal pressure
12	T24PTP2	PT24PTP2	Thermal load cases 8, 15, & 16 + 10 psi internal pressure
13	T24PTP3	PT24PTP3	Thermal cases 26 + 10 psi internal pressure
			Bottom End Models
14	QB24PLT	PB24PLT	14.7 psi external + 155 k axial load (shell & inner bottom cover plate only)
15	QB24PIP	PB24PIP	10 psi, 20 psi, & 60 psi internal pressure on inner pressure boundary
16	QB24PFL	PB24PFL	22 psi external flood pressure, + 10 psi internal pressure
17	QB24P1G	PB24P1G	1g axial acceleration outward + 14.6 psi on inner cover plate (fuel/sleeves inertia load)
18	B24PDW	PB24PDW	1g vertical acceleration on horizontal FO-DSC
19	T24THERM	N/A	Steady State temperature solution for thermal load cases 15, 16, and 26
20	B24PSID2	PB24PSD2	75g side drop acceleration
21	B24PSID3	PB24PSD3	75g side drop acceleration + 20 psi internal pressure
22	B24PTH	PB24PTH	Thermal load cases 7, 8, 15, & 16
23	B24PTH2	PB24PTH2	Thermal load case 26
24	B24PGP1	PB24PGP1	60 kip, 80 kip Grapple pull (grapple assembly model only; for primary stress determination)
25	B24PGP2	PB24PGP2	60 kip, 80 kip Grapple pull, + 20 psi on outer boundary (w/o grapple assy; for primary stress)
26	B24PGP3	PB24PGP3	60 kip Grapple pull (w/o grapple assy; axisymm. boundaries for comparison to B24PGP2)
27	B24PTHG	PB24PTHG	60 kip Grapple pull + Thermal load cases 15, 16, & 26
28	B24PT-G	PB24PT-G	-(60 kip Grapple pull) + Thermal load cases 15, 16, & 26 (to capture stress range)
29	B24PRAM	PB24PRAM	60 kip, 80 kip Ram push
30	B24PTHR	PB24PTHR	60 kip Ram push + Thermal load cases 7 & 8
31	B24PTR2	PB24PTR2	60 kip Ram push + Thermal load cases 7 & 8
32	B24PTR3	PB24PTR3	80 kip Ram push + Thermal load cases 7 & 8
33	B24THER2	N/A	Steady State temperature solution for thermal load cases 15, 16, and 26 for the refined mesh model.
34	QB24PED	PB24PED	1g axial, 60g top-end drop acceleration, + 20 psi internal pressure

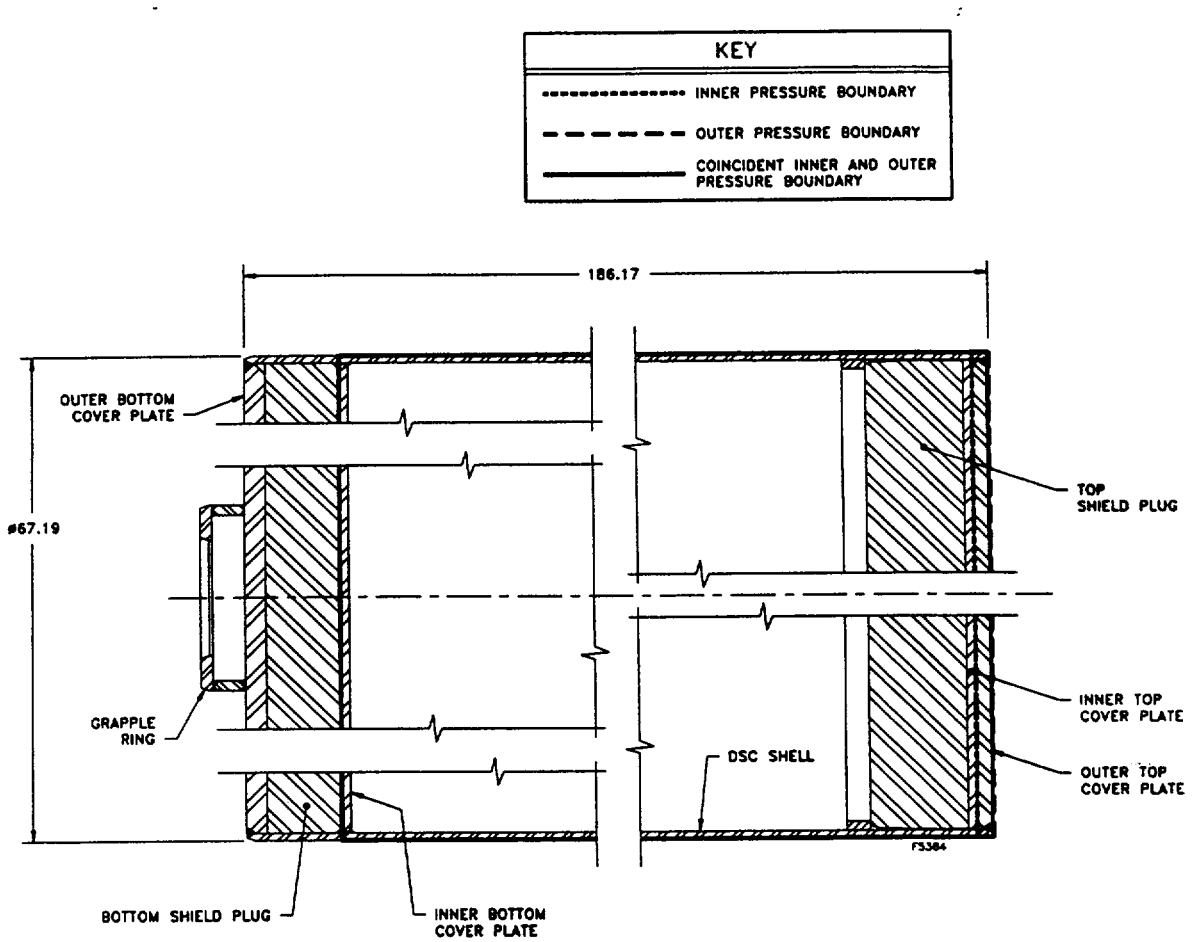


Figure 1-1 – FO-DSC Shell

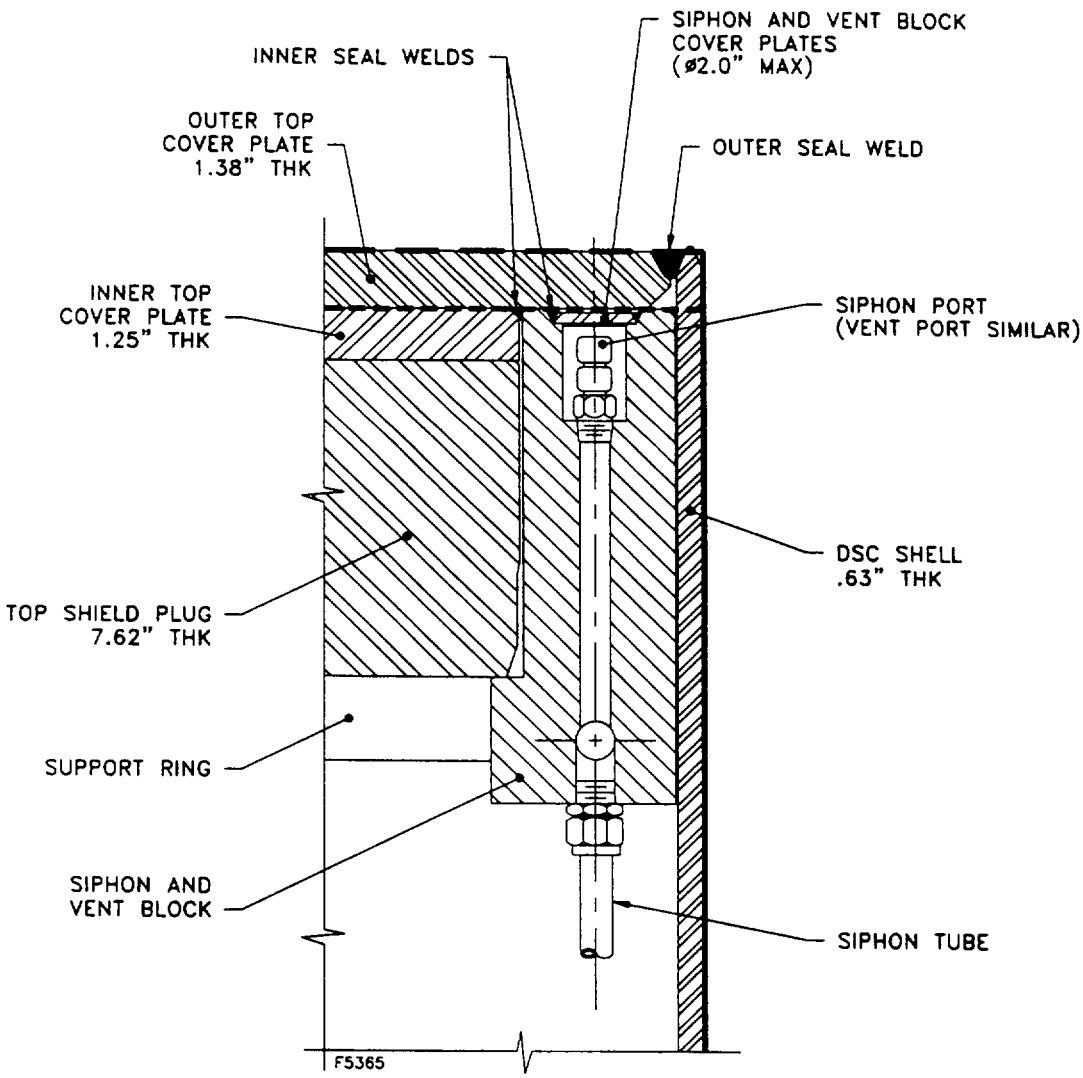


Figure 1-2 – FO-DSC Shell, Top Detail

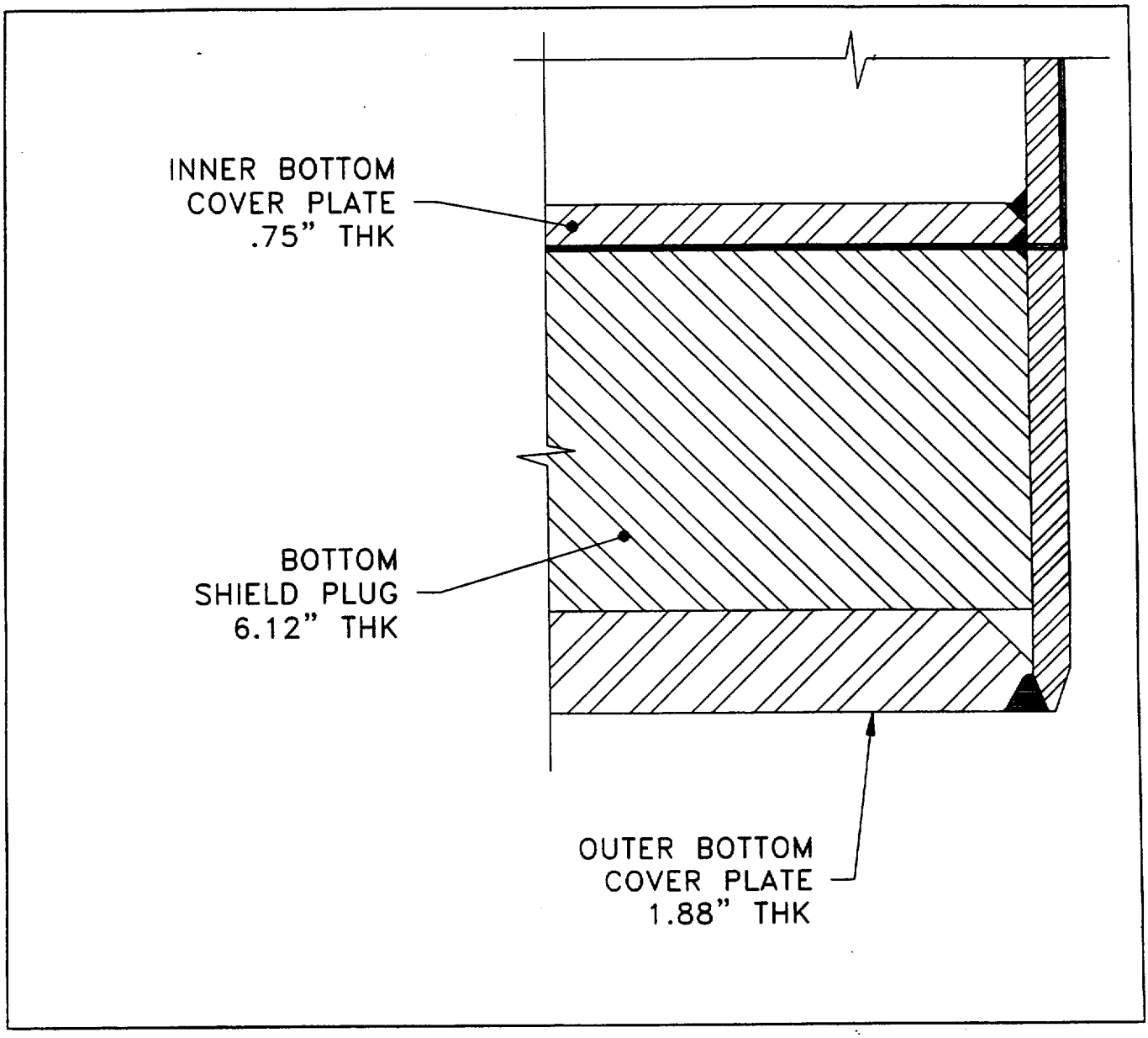


Figure 1-3 – FO-DSC Shell, Bottom Detail

2. CONSERVATISM

The following conservatisms are applied to the analysis and results:

1. In most cases, allowable stresses are based on an overall bounding maximum temperature (650 °F [Reference 9]), which is conservatively higher than the design temperature (500 °F [Reference 1]). Otherwise allowable stresses are based on the maximum temperature for the specific load combination (rounded up to the nearest 50 degrees). Stress results tables (Table 10-1 through Table 10-20 identify any exceptions).

2. For load combinations where combining results from the sum of multiple ANSYS® [Reference 5] runs is necessary, maximum component stress intensities are added to determine the load combination's total stress intensity. This is more conservative than determining the stress intensity from the sum of the component stresses from each run. Exceptions are noted in Chapter 9. Additionally, maximum stress intensities are combined irrespective of location within a component.

3. Each of the analyses conservatively assumes minimum thicknesses and includes corrosion allowances, as defined in the DCD (Reference 1). This corresponds to a minimum 1/16" corrosion allowance on all exposed surfaces and a 0.03 fabrication tolerance reduction on the DSC shell. Table 2-1 details key plate thicknesses included in the ANSYS® model.

4. Thermal load cases which take place in the transfer cask use bounding temperature profiles corresponding to the DSC in the OS 197 Transfer Cask [Reference 10]. The heat source in Reference 10 is a conservative 24 kW, and the SCE heat source is 14 kW [1].

5. For partial penetration welds where Code Case N-595-1 applies, a conservative joint efficiency factor of 0.6 is used instead of the specified 0.8 or 0.9 factors.

6. For the FO-DSC in a horizontal position (e.g., dead weight, side drop, transfer to AHSM) the FO-DSC is conservatively assumed to be resting (or dropping) on one rail. For loadings distributed on two AHSM rails (each 35° from the vertical axis [17]), the maximum normal force imposed on one rail is

$$F_N = F_V/(2(\cos 35°)) = 0.61F_V < 1.0F_V$$

The normal force for the FO-DSC resting on two cask rails at 18.5° is less than the above normal force. Therefore, applying the entire side load on one rail is conservative.

Table 2-1 - Nominal Versus ANSYS model Plate Thicknesses

Components	Nominal Thickness	Thickness as Modeled in ANSYS®	Comments
FO-DSC Shell	5/8"	0.53"	Includes 1/16" corrosion allowance and 0.03 fab. tolerance
Outer Bottom Cover Plate	1 7/8"	1 3/4"	Includes 1/16" corrosion allowance plus an additional 1/16".
Bottom Shield Plug	6 1/8"	6 ¼"	Thicker by 1/8". Load due to its weight is conservative. Its ability to transfer the load is not affected by its stiffness.
Inner Bottom Cover Plate	3/4"	3/4"	
Grapple Ring	1 1/8"	1"	Includes 1/8" corrosion allowance
Grapple Ring Support	7/8"	¾"	Includes 1/8" corrosion allowance
Outer Top Cover Plate	1 3/8"	1.31	Includes 1/16" corrosion allowance
Inner Top Cover Plate	1 1/4"	1 1/4"	
Top Shield Plug	7 5/8"	7 5/8"	
Support Ring	3/4"	3/4"	

3. ASSUMPTIONS

1. The FO-DSC shell assembly is analyzed using separate models of the top and bottom halves. For most analyses of the FO-DSC, behavior is assumed to be symmetric across the mid-height of the shell. For analyses where grapple pull loading occurs, the mid-height of the shell is restrained at only a single point, thereby maximizing this effect. For analyses where ram loading occurs, the entire mid-height of the shell is restrained in the axial direction.

2. For analyses of load conditions that exclude the effects of thermal stresses, the temperature is assumed to be uniform such that the modulus of elasticity is constant for each material. Properties corresponding to the maximum temperature appropriate for the load case analyzed are assigned unless noted otherwise.

3. Both the top and bottom 1g ANSYS® runs apply a pressure load to the appropriate inner cover plate that represents the deadweight load due to the fuel weight [11]. The pressure is equal to the maximum basket and fuel weight divided by the area of the plate: $(35{,}568 + 7{,}631 + 10{,}889)/[(\pi)(32.97)^2] = 15.8$ psi). However, the ANSYS® runs use a value of 16.0 psi.

4. The mean radius used in the ANSYS® models (33.33 in) differs slightly from the actual mean radius (33.24 in). A comparison of the areas based on the two radii shows that difference in areas is negligible:

   $$2\pi t r_{ANSYS}/2\pi t r_{ACTUAL} - 1 = 33.33/33.24 - 1 = 0.27\%$$

   Similarly, a comparison of Moments of Inertia based on the two mean radii shows that the difference in Moments of Inertia is negligible:

   $$\tfrac{1}{4}\pi t(r_{ANSYS})^3/\tfrac{1}{4}\pi t(r_{ACTUAL})^3 - 1 = 33.33^3/33.24^3 - 1 = 0.81\%$$

   Thus, the effect of the slight difference in the mean radius used in the ANSYS® models is insignificant.

5. For seismic analyses, the FO-DSC shell is assumed to act as a simply supported beam.

6. The analysis of the bottom of the support ring to shell intermittent weld assumes that applicable force on the weld exists only in the axial direction.

7. The 6 1/8" thick bottom shield plug is modeled as 6 1/4" thick. Loads due to the mass of the shield plug are conservatively larger. Additionally, the shield plug's ability to transfer the load between the inner and outer bottom cover plates is not affected because of its large relative stiffness.

8. The one inch diameter leak test port located in the outer top cover plate is assumed to have no effect on stresses in the plate.

9. The 1/4" vent and siphon block cover plates, and the 3/16" partial penetration weld between the vent and siphon block cover plates (Figure 1-2) and the siphon and vent ports are not included in the analysis. Stresses in the weld are assumed to be smaller than stresses in the inner top cover plate weld which is smaller (1/4" partial penetration) and is around the circumference of a much larger plate. The ratio of the radius to the thickness squared for the inner top cover plate is equal to $66.13/1.25^2 = 42.3$, and the ratio of the radius to the thickness squared for the vent/siphon block cover plate is equal to $1.00/0.25^2 = 16.0$. A comparison of the relative bending stiffnesses shows that bending stresses in the inner top cover plate weld are higher than bending stresses in the vent/siphon block cover plate weld by a factor $42.3/16.0 = 2.6$. Thus, the main loading on the vent/siphon block cover plates is by internal pressure only.

Others as noted.

4. DESIGN INPUT/DATA

4.1 Geometry/Critical Interfaces

The Advanced NUHOMS® FO-DSC shell assembly (see Figure 1-1 through Figure 1-3) is a closed end cylindrical shell, nominally 186.2 inches in length and has an outer diameter of 67.19 inches. The FO-DSC pressure boundary consists of a 5/8" thick cylindrical shell, inner an outer top cover plate and the inner bottom cover plate. Non-pressure boundary carbon steel shield plugs are included at each end of the assembly. The bottom shield plug is confined between the inner and outer bottom cover plates. The inner top cover plate and a support ring, which is welded to the inside of the cylindrical shell, confine the top shield plug. A grapple ring is welded to the outer bottom cover plate.

The outer top and bottom cover plates are connected to the cylindrical shell using 1/2" and 5/8" partial penetration welds, respectively. The inner top cover plate is welded along the top perimeter only, using a 1/4" partial penetration weld. The inner bottom cover plate is welded using full penetration weld. The support ring is connected to the cylindrical shell at the top surface with a continuous 1/4" penetration weld reinforced with a 1/8" cover fillet. The bottom surface of the support ring is welded with an intermittent 1/4" fillet weld. Grapple ring assembly connections are all made using full penetration welds. (**Partial penetration weld sizes cited above are the minimum effective throats**)

The following FO-DSC shell assembly components are evaluated in this calculation package (plate thicknesses are shown in parentheses):

- FO-DSC Shell (5/8")
- Outer Bottom Cover Plate (1 7/8")
- Bottom Shield Plug (6 1/8")
- Inner Bottom Cover Plate (3/4")
- Grapple Ring (1 1/8")
- Grapple Ring Support (7/8")
- Outer Top Cover Plate (1⅜")
- Inner Top Cover Plate (1¼")
- Top Shield Plug (7⅝")
- Support Ring (3/4")
- Vent and Siphon Block Cover Plate (1/4")
- Welds (outer cover plates, inner cover plates, support ring, and grapple ring assembly)

As discussed in Reference 1, the FO-DSC is always to be fully loaded (all cells filled with fuel assemblies or dummy fuel assemblies). When loaded with fuel assemblies, the FO-DSC is either in a transfer cask or an AHSM (Advanced Horizontal Storage Module). Two 3.00" wide rails provide FO-DSC support within a horizontal cask at ±18.5° from the bottom centerline. Within a vertical cask, the FO-DSC is supported on the outer bottom cover plate by the bottom end plate of the cask.

The cask bottom end plate is cut out at the center such that the grapple ring assembly of the FO-DSC is not supported.

Two 3.00" wide rails provide FO-DSC support within an AHSM at ±35° from the bottom centerline per Reference 17. The axial restraints within the AHSM at front and back, resists seismic axial forces.

To load the FO-DSC into the AHSM, the FO-DSC is pushed out of the transfer cask using a hydraulic ram. The load is applied to the center of the FO-DSC outer bottom cover plate within the diameter of the grapple ring assembly. A 9.00" diameter, 0.50" thick stop plate serves as an interface between the ram and the FO-DSC. The stop plate has a 0.13" bevel around the edge. To unload the FO-DSC from the AHSM, the FO-DSC is pulled using grapples that fit into the grapple ring attached to the outer bottom cover plate. Approximate dimensions for the grapples are 6.5" wide with a maximum reach of 2.13".

FO-DSC lifting by the internal lugs is performed with the top end components (inner and outer top cover plates and top shield plug) not installed. No fuel exists in the FO-DSC for this condition. A spreader bar or long sling is used during the lift such that there is no significant radial component of load. As noted in Section 1, the lifting lugs are evaluated in a separate calculation package.

4.2 Material Properties

Materials used for each component of the FO-DSC shell assembly are summarized below in Table 4-1. Density and Poisson's Ratio for the FO-DSC materials are provided in Table 4-2. Temperature dependent properties are obtained from the ASME Code [3] and are listed in Table 4-3 and Table 4-4.

Table 4-1 - FO-DSC Shell Assembly Materials

Component	Material
FO-DSC Shell Outer Bottom Cover Plate Inner Bottom Cover Plate Grapple Ring Grapple Ring Support Outer Top Cover Plate Inner Top Cover Plate Support Ring	SA-240 Type 316 Stainless Steel (max 0.030% max. Carbon)
Bottom Shield Plug Top Shield Plug	SA36 Carbon Steel

Table 4-2 - Density & Poisson's Ratio for FO-DSC Shell Assembly Materials

Material	Density		Poisson's Ratio
Carbon Steel (SA-36)	490 lb/ft^3	0.284 lb/in^3	0.29
Stainless Steel (SA-240 Type 316)	493 lb/ft^3	0.285 lb/in^3	0.29

Table 4-3 - SA-240 Type 316 Material Properties

Temp. °F	ASME Code Material Properties						
	S_m (ksi)	S_y (ksi)	S_u (ksi)	E (x10^6 psi)	α_{inst} (1) °F^{-1}	α_{avg} °F^{-1}	k BTU/hr-ft-°F
-100	--	--	--	29.1	--	--	--
-20	20.0	30.0	75.0	--	--	--	--
70	--	--	--	28.3	8.42	--	7.7
100	20.0	30.0	75.0	--	8.59	8.54	7.9
150	--	--	--	--	8.84	8.64	8.2
200	20.0	25.8	75.0	27.6	9.09	8.76	8.4
250	--	--	--	--	9.33	8.88	8.7
300	20.0	23.3	73.4	27.0	9.56	8.97	9.0
350	--	--	--	--	9.76	9.11	9.2
400	19.3	21.4	71.8	26.5	9.95	9.21	9.5
450	--	--	--	--	10.10	9.32	9.8
500	18.0	19.9	71.8	25.8	10.25	9.42	10.0
550	--	--	--	--	10.38	9.50	10.3
600	17.0	18.8	71.8	25.3	10.51	9.60	10.5
650	16.7	18.5	71.8	--	10.64	9.69	10.7
700	16.3	18.1	71.8	24.8	10.76	9.76	11.0
750	16.1	17.8	71.4	--	10.87	9.81	11.2
800	15.9	17.6	70.9	24.1	10.98	9.90	11.5
Reference (ASME II)	Table 2A	Table Y-1	Table U	Table TM-1 Group G	Table TE-1 (18Cr-13Ni -3Mo & 16Cr-12Ni-2Mo).		Table TCD 16Cr-12Ni-2Mo

Notes: 1. Instantaneous values of α for use in NB-3222.4 fatigue evaluations.

Table 4-4 - A36 Carbon Steel Material Properties

Temp. °F	ASME Code Material Properties						
	S_m (ksi)	S_y (ksi)	S_u (2) (ksi)	E ($x10^6$ psi)	α_{inst} (1) $°F^{-1}$	α_{avg} $°F^{-1}$	k BTU/hr-ft-°F
-100	--	--	--	30.2	--	--	--
-20	19.3	36.0	58.0	--	--	--	--
70	--	--	--	29.5	5.42	--	23.6
100	19.3	36.0	58.0	--	5.65	5.53	23.9
150	--	--	--	--	6.03	5.71	24.2
200	19.3	32.8	58.0	28.8	6.39	5.89	24.4
250	--	--	--	--	6.73	6.09	24.4
300	19.3	31.9	58.0	28.3	7.04	6.26	24.4
350	--	--	--	--	7.33	6.43	24.3
400	19.3	30.8	58.0	27.7	7.60	6.61	24.2
450	--	--	--	--	7.85	6.77	23.9
500	19.3	29.1	58.0	27.3	8.07	6.91	23.7
550	--	--	--	--	8.28	7.06	23.4
600	17.7	26.6	58.0	26.7	8.46	7.17	23.1
650	17.4	26.1	58.0	--	8.62	7.30	22.7
700	17.3	25.9	58.0	25.5	8.75	7.41	22.4
750	not permitted at temperatures above 700°F				8.87	7.50	22.0
800	--	--	--	--	8.96	7.59	21.7
Reference (ASME II)	Table 2A	Table Y-1	Table U	Table TM-1 C ≤ 0.30%	Table TE-1 (Group C)		Table TCD (C-Mn-Si)

Notes: 1. Instantaneous values of α for use in NB-3222.4 fatigue evaluations.
2. S_u from Table Y-1, temperature dependence based on similar carbon steels.

4.3 Load Conditions & Combinations

Postulated FO-DSC load conditions are described below based on the detailed discussions provided in Table 7-15 of Reference 1. The application sequence of the various loads is presented in Reference 1. Loads are combined per the load combination summary provided in Table 4-6.

4.3.1 Fabrication Pressure and Leak Testing

Pressurization and leak testing is performed on the FO-DSC shell and inner bottom cover plate during fabrication. No other components are in place during this test. A seal plate is placed on the open top of the FO-DSC shell and preloaded through the application of torque on eight bolts. The resulting pre-load to be considered in the evaluation is 155 kips. The FO-DSC is then evacuated to a partial vacuum and then re-pressurized with helium. Therefore, two load conditions are evaluated for the FO-DSC shell and inner bottom cover plate:

155 kip axial compression + 14.7 psi external pressure (full vacuum) on the shell between the top edge and the inner-bottom cover plate + 14.7 psi external pressure on the inner bottom cover plate.

155 kip axial compression + 12.0 psi internal pressure on the shell between the top edge and the inner bottom cover plate + 12.0 psi internal pressure on the inner bottom cover plate.

4.3.2 Deadweight

FO-DSC deadweight is to be evaluated for both vertical and horizontal positions. The end plates are assembled such that no gaps exist between the cover plates and shield plugs. Based on the thickness of the top cover plates and top shield plug, under vertical loading the cover plates will bear on the shield plug. A portion of the load from the cover plates and the entire shield plug load will be transferred into the shell through the support ring, which is welded to the inside of the shell. The shell supports the entire weight of the top end components in addition to its self-weight. The weight of the fuel is assumed to be uniformly distributed over the area of the inner bottom cover plate. The fuel load and the weight of the bottom end components are transferred directly to the cask bottom through bearing between the inner bottom cover plate, bottom shield plug, and outer bottom cover plate. The pressure due to the basket and fuel load (including guide sleeves and over sleeves) is assumed to equal 16.0 psi at 1g.

When the FO-DSC is in a horizontal position, the end components and basket assembly bear against the FO-DSC shell. When in the transfer cask, the shell is supported by two 3" wide cask rails located at ±18.5° from the bottom centerline. When stored (horizontally) in the AHSM, two 3" wide rails support the FO-DSC shell at ±35° from the bottom centerline. Rails in the AHSM are a part of the FO-DSC support structure. Stresses in the region of the basket assembly spacer disks are determined in a separate calculation package (Reference 8).

4.3.3 Internal and External Pressure

The FO-DSC is evaluated for two pressure boundaries: the inner pressure boundary and the outer pressure boundary. The FO-DSC shell, the inner bottom cover plate, the inner top cover plate and the associated welds define the inner pressure boundary. Because there are no gaps between the top end components, the inner cover plate will bear against the outer cover. Therefore, the two plates, proportioned according to the relative stiffness of the two plates will share the pressure load. Similarly, the absence of gaps between the bottom end components allows the inner bottom cover plate to bear against the shield plug. The shield plug will in turn bear against the outer cover plate.

Table 7-1 of Reference 1 lists the internal pressures applicable to the FO-DSC. Included in the table are the following analysis pressures to be considered in the evaluation:

Normal (Level A)	10 psig	inner pressure boundary
Design (@500 °F)	±10 psig	inner pressure boundary
Off-Normal (Level B)	20 psig	inner pressure boundary
Accident (Level D)	60 psig	inner/outer pressure boundary

In addition to the internal pressure loads listed above, the FO-DSC will be subjected to hydrostatic, blowdown, vacuum, and test pressures during the fuel loading and draining/drying processes. Prior to loading fuel and without the top end components in place, the cask annulus is filled with water resulting in a hydrostatic external load on the FO-DSC shell. The hydrostatic load is then balanced by filling the FO-DSC with water. After the fuel is loaded, the top shield plug and inner top cover plate are installed along with a strongback to support the inner cover plate, and an internal blowdown pressure of 20 psig is applied to evacuate the FO-DSC of water. The FO-DSC interior is then dried under vacuum conditions. The FO-DSC is backfilled with helium at 12 psig. The pressure is then reduced to 5 psig, the strongback is removed, and the outer cover plate is welded in place.

4.3.4 Thermal

The shield plugs are made of SA36 carbon steel which has a lower coefficient of thermal expansion than the Type 316 stainless steel of the FO-DSC pressure boundary components (see Table 4-3 and Table 4-4). Because the dissimilar metals are not mechanically fastened, allowing free differential thermal growth, the thermal stresses in the FO-DSC shell components are due entirely to thermal gradients. A check for support rod and spacer disk interferences with the FO-DSC shell assembly due to thermal expansion is made in the basket assembly calculation package [8, 16]. Stresses resulting from thermal gradients are classified as secondary (Q) stresses, which need be evaluated only for Service Level A and B conditions.

The various thermal conditions evaluated are summarized in Table 4-5. Thermal cases 7 and 8 occur when the DSC is in the transfer cask. Temperature distributions are calculated by equations that relate the axial, tangential and radial locations on the FO-DSC assembly [see Tables 4-7 and 4-8 in Reference 9 for temperatures equations]. Thermal data is not available for the 0°F ambient cases. The -40°F cases are used for the 0°F cases and is conservative due to higher gradients. Thermal cases 15, 16, and 26 occur when the DSC is in an AHSM. Temperature distributions for these load cases are based on results in Reference 9. For the AHSM cases, thermal stresses in the grapple ring are based on maximum and minimum grapple ring temperatures from Table 5-3 of Revision 0 of Reference 9. Because the temperature gradients are slightly larger for Revision 1 of Reference 9, the thermal stresses in the grapple ring and grapple ring support are multiplied by the ratio of the Revision 1 maximum temperature differences to the Revision 0 maximum temperature differences. This results in a stress multiplying ratio of 1.30 for thermal case 15, 1.32 for thermal case 16, and 1.29 for thermal case 26.

Thermal conditions during vacuum drying and blowdown are discussed in Section 8.3.

In addition to stresses caused by temperature gradients, maximum component temperatures are used to determine material properties (e.g., elastic modulus and yield stress) for the stress analyses and for the calculation of allowable stresses. For the stress analyses, material properties are assigned to the maximum DSC temperature assuming that the temperature is uniform throughout the FO-DSC (i.e. for a given material, properties remain constant at all locations).

4.3.5 FO-DSC Handling & Transfer Loads

There are two categories of handling loads: (1) inertial loads associated with moving the FO-DSC and (2) the loads associated with inserting the FO-DSC into and retrieving the FO-DSC from the AHSM.

4.3.5.1 HSM Transfer Loads

Handling loads are inertial loads on the loaded FO-DSC resulting from on-site handling and transportation between the fuel handling/loading area and the AHSM. Four inertial conditions are defined as follows:

± 1.0g Axial

± 1.0g Transverse

± 1.0g Vertical

± ½g Axial ± ½g Transverse ± ½g Vertical (cask horizontal)

Under axial handling loads, the fuel and sleeves are assumed to bear against the inner bottom cover plate or the top shield plug. This results in a pressure on the top or bottom inner cover plate (depending on the direction of the axial loading) equal to 16.0 psi at 1g.

4.3.5.2 AHSM Loading / Unloading

To load the FO-DSC into the AHSM, the FO-DSC is pushed out of the transfer cask using a hydraulic ram. The load is applied to the center of the FO-DSC outer bottom cover at the center of the grapple ring assembly. A 9.00 inch diameter, 0.50 inch thick 'Stop Plate' serves as an interface between the ram and the FO-DSC. The stop plate is backed by a 9 inch diameter barrel that houses the grapple arm assembly. The ram load is applied to the cover plate in the form of two arcs, assuming that the load is concentrated at the barrel diameter, excluding the cutouts for extension of the grapple arms. Based on the relative stiffnesses of the cover plates and shield plug, a portion of the insertion load will be transferred through the shield plug to the inner bottom cover plate (and associated welds).

To unload the AHSM, the FO-DSC is pulled using grapples which fit into the grapple ring on the outer bottom cover. Approximate dimensions for the grapples are a width of 6.5 inches and a maximum reach of 2.13". Thus the withdrawal loads should be imposed over two 6.5" wide sections of the grapple ring.

Grapple loads are defined as:

Operating Condition	Insertion	Retrieval	ASME Service Level
Normal	60 kips	60 kips	A
Off-Normal	80 kips	60 kips	B
Accident	N/A	80 kips	C/D

The loads applied by the hydraulic ram are balanced by friction between the FO-DSC shell and the Cask and/or AHSM rails.

4.3.6 Cask Drop

Drop loads are defined in Reference 1 as accelerations applied statically. Drops are only postulated for the FO-DSC when positioned inside the transfer cask. Four drop conditions are considered in the analysis:

1. 75g Side Drop (SD)
2. 25g Corner Drop
3. 60g Bottom End Drop (BED)
4. 60g Top End Drop (TED)

The 25g corner drop is bounded by the 75g side drop, the 60g bottom end drop, and the 60g top end drop. Thus further analysis is not required. The 60g Bottom End Drop (Load Combination TR-9) and the 60g Top End Drop (Load Combination TR-12) are not required by Reference 1, but are included in this calculation package for future calculations. The load path for the side drop will be identical to that described in Section 4.3.2 for deadweight in a horizontal position.

4.3.7 Seismic Loads

Seismic accelerations for the FO-DSC are equal to 3.0g in the vertical, transverse, and longitudinal directions [1]. However, this calculation assumes that the seismic accelerations inside the AHSM are:

±6.0g vertical

±6.0g transverse

±6.0g longitudinal

Seismic loads equal to 0.33g are considered for fatigue effects on the shell [1].

4.3.8 Flood Loads

The flood condition is defined in Reference 1 as a 50 foot static head of water. This equates to an external pressure on the FO-DSC of 22 psi and is applied uniformly.

4.3.9 FO-DSC Reflood

FO-DSC reflood occurs only when fuel has to be removed from the FO-DSC. While positioned vertically in the cask in the fuel handling area, the annulus between the cask and FO-DSC is filled with water and water is added to the FO-DSC. (Holes are drilled in the outer top cover plate to access the vent and siphon ports.) The reflood procedure requires that the water flow rate be controlled such that the pressure is maintained below 20 psig. Therefore, concurrent loads to be considered for the reflood condition, as shown in Table 7-15of Reference 1, are:

1. External hydrostatic pressure
2. 20 psig internal pressure

Both top cover plates are in place for this loading. In addition, a strongback may be installed to provide additional support for the inner top cover plate. These loads are enveloped by the loads that occur during FO-DSC draining and drying. Therefore, no specific evaluation is required.

Table 4-5 - FO-DSC Thermal Conditions

Ambient Temperature	Location	Orientation	Thermal Case No.	Reference
-40°F	OS 197 Transfer Cask	Horizontal	7	Reference 10.
100°F	OS 197 Transfer Cask	Horizontal	8	Reference 10.
-40°F	AHSM	Horizontal	15	Reference 9.
104°F	AHSM	Horizontal	16	Reference 9.
117°F	AHSM	Horizontal	26	Reference 9.
0°F	Transfer Cask / AHSM	Horizontal	Note 2	Note 2
117°F	AHSM with Blocked Vents	Horizontal	Note 3	Note 3
117°F	Transfer Cask (Sunshade Required)	Horizontal	Note 4	Note 4

Notes:

1. Temperature data for thermal cases 15, 16, and 26 are based on results documented in Reference 10.
2. Temperature data is not available for the 0° condition. Per Section 4.3.4 the -40° condition is used.
3. The 117° blocked vents condition in the AHSM is an accident condition (Level D). Because there are no secondary stress limits applicable to Level D conditions, thermal stress evaluation is not required. For the determination of allowable stresses, maximum component temperatures for this condition are included in Reference 9.
4. The 117°F condition in the transfer cask with the required sunshade is enveloped by the 104°F condition without a sunshade because insolation causes higher thermal gradients along the circumference of the shell.
5. Temperatures conditions for vacuum drying and blowdown are documented in Section 8.3.

Table 4-6 - Summary of FO-DSC Load Combinations

		Horizontal DW		Vertical DW		Internal	External	Thermal	Lifting	Other	Service
		DSC	Fuel	DSC	Fuel	Pressure(4)	Pressure	Condition	Loads	Loads	Level
NON-Operational Load Cases											
NO-1	Fab. Leak Testing	--	--	--	--	--	14.7 psi	70°F	--	155 kip axial	Test
NO-2	Fab. Leak Testing	--	--	--	--	12 psi	--	70°F	--	155 kip axial	Test
NO-3	DSC Uprighting	x	--	--	--	--	--	70°F	x	--	A
NO-4	DSC Vertical Lift	--	--	x	--	--	--	70°F	x	--	A
FUEL LOADING LOAD CASES											
FL-1	DSC/Cask Filling	--	--	Cask	--	--	Hydrostatic	120°F Cask	--	--	A
FL-2	DSC/Cask Filling	--	--	Cask	--	Hydrostatic	Hydrostatic	120°F Cask	--	--	A
FL-3	DSC/Cask Xfer	--	--	Cask	--	Hydrostatic	Hydrostatic	120°F Cask	--	--	A
FL-4	Fuel Loading	--	--	Cask	x	Hydrostatic	Hydrostatic	120°F Cask	--	--	A
FL-5	Xfer to Decon	--	--	Cask	x	Hydrostatic	Hydrostatic	120°F Cask	--	--	A
FL-6	Inner Cover Plate Welding	--	--	Cask	x	Hydrostatic	Hydrostatic	120°F Cask	--	--	A
FL-7	Fuel Deck Seismic Loading	--	--	Cask	x	Hydrostatic	Hydrostatic	120°F Cask	--	--	C
DRAINING AND DRYING LOAD CASES											
DD-1	DSC Blowdown	--	--	Cask	x	Hydrostatic + 20 psi	Hydrostatic	120°F Cask	--	--	B
DD-2	Vacuum Drying	--	--	Cask	x	0 psi	Hydrostatic + 14.7 psi	120°F Cask	--	--	B
DD-3	Helium Backfill	--	--	Cask	x	12 psi	Hydrostatic	120°F Cask	--	--	B
DD-4	Final Helium Backfill	--	--	Cask	x	5.0 psi	Hydrostatic	120°F Cask	--	--	B
DD-5	Outer Cover Plate Welding	--	--	Cask	x	5.0 psi	Hydrostatic	120°F Cask	--	--	A
TRANSFER TRAILER LOADING											
TL-1	Vertical Xfer to Trailer			Cask	x	10.0 psi	--	0°F Cask	--	--	A
TL-2	"			Cask	x	10.0 psi	--	120°F Cask	--	--	A
TL-3	Laydown	Cask	x			10.0 psi	--	0°F Cask	--	--	A
TL-4	"	Cask	x			10.0 psi	--	120°F Cask	--	--	A
TRANSFER TO / FROM ISFSI											
TR-1	Axial Load - Cold	Cask	x	--	--	10.0 psi	--	0°F Cask	1g Axial	--	A
TR-2	Transverse Load - Cold	Cask	x	--	--	10.0 psi	--	0°F Cask	1g Transverse	--	A
TR-3	Vertical Load - Cold	Cask	x	--	--	10.0 psi	--	0°F Cask	1g Vertical	--	A
TR-4	Oblique Load - Cold	Cask	x	--	--	10.0 psi	--	0°F Cask	1/2g Axial +1/2g Trans + 1/2g Vert	--	A
TR-5	Axial Load - Hot	Cask	x	--	--	10.0 psi	--	104°F Cask	1g Axial	--	A
TR-6	Transverse Load - Hot	Cask	x	--	--	10.0 psi	--	104°F Cask	1g Transverse	--	A
TR-7	Vertical Load - Hot	Cask	x	--	--	10.0 psi	--	104°F Cask	1g Vertical	--	A
TR-8	Oblique Load - Hot	Cask	x	--	--	10.0 psi	--	104°F Cask	1/2g Axial +1/2g Trans + 1/2g Vert	--	A
TR-9	Bottom End Drop	This drop is not credible for the horizontal NUHOMS system.								60g Drop(1)	D
TR-10	Side Drop	Note 1		--	--	20.0 psi	--	104°F Cask		75g Drop(1)	D
TR-11	Corner Drop	Note 1		--	--	20.0 psi	--	104°F Cask		25g Drop(1)	D
TR-12	Top End Drop	This drop is not credible for the horizontal NUHOMS system.								60g Drop(1)	
HSM LOADING											
LD-1	Normal Loading - Cold	Cask	x	--	--	10.0 psi	--	0°F Cask	+60 Kip(4)	--	A
LD-2	Normal Loading - Hot	Cask	x	--	--	10.0 psi	--	104°F Cask	+60 Kip(4)	--	A
LD-3	Off-Normal Loading - Cold	Cask	x	--	--	20.0 psi	--	0°F Cask	+80 Kip(4)	10% Failed Fuel	B
LD-4	Off-Normal Loading - Hot	Cask	x	--	--	20.0 psi	--	117°F Cask	+80 Kip(4)	10% Failed Fuel	B

Table 4-6 - Summary of DSC Load Combinations (continued)

HSM STORAGE											
HSM-1	Normal Storage - Cold	HSM	x	–	–	10.0 psi	–	0°F Cask	–	–	A
HSM-2	Normal Storage - Hot	HSM	x	–	–	10.0 psi	–	104°F Cask	–	–	A
HSM-3	Off-Normal Storage - Cold	HSM	x	–	–	20.0 psi	–	-40°F Cask	–	10% Failed Fuel	B
HSM-4	Off-Normal Storage - Hot	HSM	x	–	–	20.0 psi	–	117°F Cask	–	10% Failed Fuel	B
HSM-5	Off-Normal Storage/Outer - Cold	HSM	x	–	–	20.0 psi	–	-40°F Cask	–	10% Failed Fuel	B
HSM-6	Off-Normal Storage/Outer - Hot	HSM	x	–	–	20.0 psi	–	117°F Cask	–	10% Failed Fuel	B
HSM-9	3.0g EQ - Cold	HSM	x	–	–	20.0 psi	–	-40°F Cask	–	3.0g EQ + 10% FF	D
HSM-10	3.0g EQ - Hot	HSM	x	–	–	20.0 psi	–	117°F Cask	–	3.0g EQ + 10% FF	D
HSM-11	Blocked Vent Storage	HSM	x	–	–	60.0 psi	–	117°F AHSM/BV(3)	–	100% Failed Fuel	D
HSM-12	Flood Load (50' H_2O) - Cold	HSM	x	–	–	0 psi	22 psi(2)	0°F Cask	–	Flood(2)	C
HSM-13	Flood Load (50' H_2O) - Hot	HSM	x	–	–	0 psi	22 psi(2)	117°F Cask	–	Flood(2)	C
HSM Unloading											
UL-1	Normal Unloading - Cold	HSM	x	–	–	10.0 psi	–	0°F Cask	-60 Kip	–	A
UL-2	Normal Unloading - Hot	HSM	x	–	–	10.0 psi	–	104°F Cask	-60 Kip	–	A
UL-3	Off-Normal Unloading - Cold	HSM	x	–	–	20.0 psi	–	0°F Cask	-60 Kip	–	B
UL-4	Off-Normal Unloading - Hot	HSM	x	–	–	20.0 psi	–	117°F Cask	-60 Kip	–	B
UL-5	Accident Unloading - FF/Hot	HSM	x	–	–	20.0 psi	–	104°F Cask	-80 Kip	10% Failed Fuel	C
DSC Unloading/Reflood											
RF-1	DSC Reflood	–	–	Cask	x	20.0 psi	Hydrostatic	120°F Cask	–	–	D

Notes

1. Drop accelerations include gravity effects. Therefore, it is not necessary to add an additional 1g (gravity) load.
2. Flood load is external pressure equivalent to 50 ft. of water.
3. BV = AHSM Vents are blocked
4. HSM insertion loads and internal pressure loads are in opposite directions.

5. METHODOLOGY

5.1 Acceptance Criteria

The FO-DSC is designed using the criteria of Subsection NB of the ASME Code [2], as described in the Design Criteria Document [1]. Non-pressure boundary components, which are not required for the pressure related structural performance of the FO-DSC, criteria are guided by the Code rules for component supports.

5.1.1 Pressure Boundary Components

5.1.1.1 Stress Criteria

The FO-DSC pressure boundary components include the FO-DSC shell and top and bottom inner and top outer plates. The shell and cover plates (top and bottom, inner and outer) are designed to the stress criteria of Subsection NB of the Code. Stress criteria for these components are summarized in Table 5-1. The criteria of Table 5-1 are combined with the Code properties of Table 4-3 to provide temperature-dependent allowable stresses which are summarized in, Table 5-2 (Level A and B), Table 5-3 (Level C), Table 5-4 (Level D, elastic), and Table 5-5 (Level D, elastic/plastic). Stresses are classified in accordance with section NB-3210 of the Code.

For vessels with flat heads, the Code permits two methods of classifying stresses in the head to shell region (See note 2 to Table NB-3217-1). The Code requires that, if the bending moment at the edge of a flat head (and the corresponding moment in the shell) is required to maintain stresses in the center of the head within acceptable limits, then the bending moment stress at the edge of the plate and in the shell shall be classified as a primary bending stress (P_b). If stresses at the center of the flat head are within acceptable limits for a pinned edge condition, the bending stresses at the edge can be classified as secondary stresses (Q).

5.1.1.2 Stability Criteria

Stability criteria for Level A load conditions are from NB-3133. Criteria for external pressure and axial compression are provided in NB-3133.3 and NB-3133.6, respectively. The results of the following calculations are summarized in Table 5-10.

5.1.1.2.1 External Pressure

For determination of the allowable service level A external pressure for the FO-DSC, the following dimensions are used:

D_o = 67.19 inches

T = 0.530 inches

L = 186.2 inches

The dimensionless ratios from Step 1 of NB-3133.3 are:

$$\frac{L}{D_o} = \frac{186.2}{67.19} = 2.8$$

$$\frac{D_o}{T} = \frac{67.19}{0.530} = 126.8$$

Using the above values and Fig. G from Section II, Part D, Subpart 3 [2].

Factor A = 0.00032

Knowing Factor A, Factor B is determined using Fig. HA-2, Section II, Part D, Subpart 3 [2] is determined at temperatures of, 100°F, 400°F and 700°F.

Factor B @ 100°F = 4,400 psi

Factor B @ 400°F = 4,100 psi

Factor B @ 700°F = 3,750 psi

The bounding pressure is determined as follows:

$$P_a = \frac{4B}{3\frac{D_o}{T}}$$

For the 100° case, P_a is equal to 46 psi. Results for other cases are listed in Table 5-10.

5.1.1.2.2 Axial Compression

For determination of the allowable service level A axial compression for the FO-DSC, the following dimensions are used:

D_o = 67.19 inches

$$R = \frac{D_o}{2} - 0.625 = 32.97 \text{ inches (minimized)}$$

T = 0.530 inches

Using the above values,

$$\text{Factor A} = \frac{0.125}{\frac{R}{T}} = 0.002$$

Knowing Factor A, Factor B is determined using Fig. HA-2, Section II, Part D, Subpart 3 [2] is determined at temperatures of, 100°F, 400°F and 700°F.

Factor B @ 100°F = 11.7 ksi

Factor B @ 400°F = 10.4 ksi

Factor B @ 700°F = 9.3 ksi

Factor B is the allowable axial compression for service level A and B. Service level C, Test, and D are determined by multiplying by 120%, 135%, and 150%, respectively.

5.1.2 Pressure Boundary Welds

The shell longitudinal and circumferential welds do not require explicit evaluation because they are fully inspected full penetration welds designed in accordance with Subsection NB and Code Case N-595-1 [2]. The qualification of the shell qualifies the welds. Pressure boundary welds are shown in Figure 1-2 and Figure 1-3.

The top cover plates to shell welds and the outer bottom cover plate to shell weld, which are all partial penetration welds, may be evaluated using the joint efficiency factor specified in Code Case N-595-1. The code case permits a joint efficiency of 0.9 to 0.8, depending on the type of weld and inspection level. However, allowables, as summarized in Table 5-11, Table 5-12, and Table 5-13, are conservatively determined by applying a joint efficiency factor of 0.6 to the allowable stress of the base material. The inner bottom cover plate weld is a full penetration weld and is full strength.

5.1.3 Support Ring

The support ring is evaluated for the stress criteria of Subsection NB of the Code [2]. NB-3364 and NB-3135 require that attachments meet the stress criteria of NB. The criteria and allowable stress values are summarized in Table 5-1 through Table 5-5.

5.1.4 Support Ring to Shell Weld

The support ring to shell weld is not a pressure boundary weld and is conservatively evaluated using the Subsection NF criteria for partial penetration and fillet welds, summarized in Table 5-14. The allowable base metal and weld metal stress values are summarized in Table 5-15 and Table 5-16, respectively.

5.1.5 Shield Plugs

Shield plugs are non-pressure boundary components and need only to maintain their structural integrity. Conservatively, the criteria of Subsection NB of the Code for pressure boundary parts are applied for the plugs. The criteria are summarized in Table 5-1. Allowable stress values are summarized in Table 5-6 through Table 5-9.

5.1.6 Grapple Ring and Grapple Ring Support Plate

The grapple ring and grapple ring support plate are fabricated using shell material (Type 316 stainless steel) and are connected to the outer bottom cover plate using full penetration welds. These components are evaluated using the Subsection NB requirements of the Code for pressure boundary parts. The criteria and allowable stress values are summarized in Table 5-1 through Table 5-5.

5.1.7 Grapple Welds

Welds of the grapple assembly are full penetration welds. The welds are evaluated using the same criteria as the grapple and shell base metal.

Table 5-1 - Summary of Design Criteria for FO-DSC Pressure Boundary Components

Service Level	Criteria	Reference [2]
Design (NB-3221)	$P_m \le 1.0S_m$ $P_L \le 1.5S_m$ P_m (or P_L) + $P_b \le 1.5S_m$ $F_p \le 1.5S_y$ External Pressure: NB-3133	NB-3221.1 NB-3221.2 NB-3221.3 NB-3227.1 NB-3227.4
Level A	$P_m \le 1.0S_m$ $P_L \le 1.5S_m$ P_m (or P_L) + $P_b \le 1.5S_m$ P_m (or P_L) + P_b + $Q \le 3.0S_m$ (Note 1 & 2) $F_p \le 1.5S_y$ (bearing) External Pressure: NB-3133	NB-3222 NB-3227.1 NB-3227.4
Level B	$P_m \le 1.0S_m$ $P_L \le 1.5S_m$ $P_m + P_b \le 1.5S_m$ $P_m + P_b + Q \le 3.0S_m$ (Note 1) $F_p \le 1.5S_y$ (bearing)	NB-3223 NB-3227.1 NB-3227.4
Level C	$P_m \le \max(1.2S_m, S_y)$ $P_L \le \max(1.8S_m, 1.5S_y)$ $P_m + P_b \le \max(1.8S_m, 1.5S_y)$ $P_m + P_b + Q$ evaluation not required $F_p \le 1.5S_y$ (bearing)	NB-3224 NB-3227.1 NB-3227.4
Carbon (Ferritic) Steel Components (e.g., shield plugs)		
Level D (Elastic Analysis)	$P_m \le 0.7S_u$ $P_L \le 1.0S_u$ $P_m + P_b \le 1.0S_u$ $P_m + P_b + Q$ - evaluation not required F_p (bearing) - evaluation not required.	F-1331.1 F-1341.6
Level D (Elastic/Plastic Analysis)	$P_m \le 0.7S_u$ $P_L \le 0.9S_u$ $P_m + P_b \le 0.9S_u$ $P_m + P_b + Q$ evaluation not required	F-1341.2
Austenitic Steel Components (e.g., shell)		
Level D (Elastic Analysis)	$P_m \le \min(2.4S_m, 0.7S_u)$ $P_L \le \min(3.6S_m, 1.0S_u)$ $P_m + P_b \le \min(3.6S_m, 1.0S_u)$ $P_m + P_b + Q$ - evaluation not required F_p (bearing) - evaluation not required.	F-1331.1 & F-1341.6
Level D (Elastic/Plastic Analysis)	$P_m \le \max(0.7S_u, S_y + 1/3(S_u - S_y))$ $P_L \le 0.9S_u$ $P_m + P_b \le 0.9S_u$ $P_m + P_b + Q$ - evaluation not required F_p (bearing) - evaluation not required.	F-1341.2

Notes:

1. The NB-3222.2 limit of $3S_m$ on the range of primary + secondary stress intensity may be exceeded providing the criteria of NB-3228.5 are satisfied.
2. There are no specific limits on primary stresses for Level A events. However, the stresses due to primary loads during normal service must be computed and combined with the effects of other loadings in satisfying other limits. See NB-3222.1.

Table 5-2 - Level A & B Allowable Stresses for SA-240 Type 316 Pressure Boundary Components

Temp. °F	Code Value		Stress Category				
			P_m	P_L	$P_L + P_b$	$P_L + P_b + Q$	F_p
	S_m	S_y	$1.0S_m$	$1.5S_m$	$1.5S_m$	$3.0S_m$	$1.5S_y$
-20	20.0	30.0	20.0	30.00	30.00	60.00	45.00
100	20.0	30.0	20.0	30.00	30.00	60.00	45.00
200	20.0	25.8	20.0	30.00	30.00	60.00	38.70
300	20.0	23.3	20.0	30.00	30.00	60.00	34.95
400	19.3	21.4	19.3	28.95	28.95	57.90	32.10
500	18.0	19.9	18.0	27.00	27.00	54.00	29.85
600	17.0	18.8	17.0	25.50	25.50	51.00	28.20
650	16.7	18.5	16.7	25.05	25.05	50.10	27.75
700	16.3	18.1	16.3	24.45	24.45	48.90	27.15
750	16.1	17.8	16.1	24.15	24.15	48.30	26.70
800	15.9	17.6	15.9	23.85	23.85	47.70	26.40

Table 5-3 - Level C Allowable Stresses for SA-240 Type 316 Pressure Boundary Components

Temp. °F	Code Value		Stress Category				
			P_m	P_L	$P_L + P_b$	$P_L + P_b + Q$	F_p
	S_m	S_y	$\max(1.2S_m, S_y)$	$\max(1.8S_m, 1.5S_y)$	$\max(1.8S_m, 1.5S_y)$	Note 1	$1.5S_y$
-20	20.0	30.0	30.00	45.00	45.00	--	45.00
100	20.0	30.0	30.00	45.00	45.00	--	45.00
200	20.0	25.8	25.80	38.70	38.70	--	38.70
300	20.0	23.3	24.00	36.00	36.00	--	34.95
400	19.3	21.4	23.16	34.74	34.74	--	32.10
500	18.0	19.9	21.60	32.40	32.40	--	29.85
600	17.0	18.8	20.40	30.60	30.60	--	28.20
650	16.7	18.5	20.04	30.06	30.06	--	27.75
700	16.3	18.1	19.56	29.34	29.34	--	27.15
750	16.1	17.8	19.32	28.98	28.98	--	26.70
800	15.9	17.6	19.08	28.62	28.62	--	26.40

Notes:

1. Evaluation not required.

Table 5-4 - Level D Elastic Allowable Stresses for SA-240 Type 316 Pressure Boundary Components

Temp. °F	Code Value		Stress Category				
	S_m	S_u	P_m min(2.4S_m, 0.7S_u)	P_L min(3.6S_m, S_u)	$P_L + P_b$ min(3.6S_m, S_u)	$P_L + P_b + Q$ Note 1	F_p Note 1
-20	20.0	75.0	48.00	72.00	72.00	--	--
100	20.0	75.0	48.00	72.00	72.00	--	--
200	20.0	73.4	48.00	72.00	72.00	--	--
300	20.0	71.8	48.00	71.80	71.80	--	--
400	19.3	71.8	46.32	69.48	69.48	--	--
500	18.0	71.8	43.20	64.80	64.80	--	--
600	17.0	71.8	40.80	61.20	61.20	--	--
650	16.7	71.8	40.08	60.12	60.12	--	--
700	16.3	71.8	39.12	58.68	58.68	--	--
750	16.1	71.4	38.64	57.96	57.96	--	--
800	15.9	70.9	38.16	57.24	57.24	--	--

Notes:
1. Evaluation not required.

Table 5-5 - Level D Elastic/Plastic Allowable Stresses for SA-240 Type 316 Pressure Boundary Components

Temp. °F	Code Value		Stress Category				
	S_y	S_u	P_m Note 1	P_L 0.9S_u	$P_L + P_b$ 0.9S_u	$P_L + P_b + Q$ Note 2	F_p Note 2
-20	30.0	75.0	52.50	67.5	67.5	--	--
100	30.0	75.0	52.50	67.5	67.5	--	--
200	25.8	73.4	51.38	66.06	66.06	--	--
300	23.3	71.8	50.26	64.62	64.62	--	--
400	21.4	71.8	50.26	64.62	64.62	--	--
500	19.9	71.8	50.26	64.62	64.62	--	--
600	18.8	71.8	50.26	64.62	64.62	--	--
650	18.5	71.8	50.26	64.62	64.62	--	--
700	18.1	71.8	50.26	64.62	64.62	--	--
750	17.8	71.4	49.98	64.26	64.26	--	--
800	17.6	70.9	49.63	63.81	63.81	--	--

Notes:
1. Greater of 0.7Su or Sy+1/3(Su-Sy)
2. Evaluation not required.

Table 5-6 - Level A & B Allowable Stresses for SA-36 Treated As Pressure Boundary Material

Temp. °F	Code Value		Stress Category				
			P_m	P_L	$P_L + P_b$	$P_L + P_b + Q$	F_p
	S_m	S_y	$1.0S_m$	$1.5S_m$	$1.5S_m$	$3.0S_m$	$1.5S_y$
-20	19.3	36.0	19.3	29.0	29.0	58.0	54.0
100	19.3	36.0	19.3	29.0	29.0	58.0	54.0
200	19.3	32.8	19.3	29.0	29.0	58.0	49.2
300	19.3	31.9	19.3	29.0	29.0	58.0	47.9
400	19.3	30.8	19.3	29.0	29.0	58.0	46.2
500	19.3	29.1	19.3	29.0	29.0	58.0	43.7
600	17.7	26.6	17.7	26.6	26.6	53.2	39.9
650	17.4	26.1	17.4	26.1	26.1	52.2	39.2
700	17.3	25.9	17.3	25.9	25.9	51.8	38.9

Table 5-7 - Level C Allowable Stresses for SA-36 Treated As Pressure Boundary Material

Temp. °F	Code Value		Stress Category				
			P_m	P_L	$P_L + P_b$	$P_L + P_b + Q$	F_p
	S_m	S_y	$\max(1.2S_m, S_y)$	$\max(1.8S_m, 1.5S_y)$	$\max(1.8S_m, 1.5S_y)$	Note 1	$1.5S_y$
-20	19.3	36.0	36.0	54.0	54.0	--	54.0
100	19.3	36.0	36.0	54.0	54.0	--	54.0
200	19.3	32.8	32.8	49.2	49.2	--	49.2
300	19.3	31.9	31.9	47.9	47.9	--	47.9
400	19.3	30.8	30.8	46.2	46.2	--	46.2
500	19.3	29.1	29.1	43.7	43.7	--	43.7
600	17.7	26.6	26.6	39.9	39.9	--	39.9
650	17.4	26.1	26.1	39.2	39.2	--	39.2
700	17.3	25.9	25.9	38.9	38.9	--	38.9

Notes:

1. Evaluation not required.

Table 5-8 - Level D Elastic Allowable Stresses for SA-36 Treated As Pressure Boundary Material

Temp. °F	Code Value		Stress Category				
	S_m	S_u	P_m min(2.4S_m, 0.7S_u)	P_L min(3.6S_m, S_u)	$P_L + P_b$ min(3.6S_m, S_u)	$P_L + P_b + Q$ Note 1	F_p Note 1
-20	19.3	58.0	40.6	58.0	58.0	--	--
100	19.3	58.0	40.6	58.0	58.0	--	--
200	19.3	58.0	40.6	58.0	58.0	--	--
300	19.3	58.0	40.6	58.0	58.0	--	--
400	19.3	58.0	40.6	58.0	58.0	--	--
500	19.3	58.0	40.6	58.0	58.0	--	--
600	17.7	58.0	40.6	58.0	58.0	--	--
650	17.4	58.0	40.6	58.0	58.0	--	--
700	17.3	58.0	40.6	58.0	58.0	--	--

Notes:
Evaluation not required.

Table 5-9
Level D Elastic/Plastic Allowable Stresses for SA-36 Treated As Pressure Boundary Material

Temp. °F	Code Value		Stress Category				
	S_y	S_u	P_m 0.7S_u	P_L 0.9S_u	$P_L + P_b$ 0.9S_u	$P_L + P_b + Q$ Note 1	F_p Note 1
-20	36.0	58.0	40.6	52.2	52.2	n/a	n/a
100	36.0	58.0	40.6	52.2	52.2	n/a	n/a
200	32.8	58.0	40.6	52.2	52.2	n/a	n/a
300	31.9	58.0	40.6	52.2	52.2	n/a	n/a
400	30.8	58.0	40.6	52.2	52.2	n/a	n/a
500	29.1	58.0	40.6	52.2	52.2	n/a	n/a
600	26.6	58.0	40.6	52.2	52.2	n/a	n/a
650	26.1	58.0	40.6	52.2	52.2	n/a	n/a
700	25.9	58.0	40.6	52.2	52.2	n/a	n/a

Notes:
1. Evaluation not required.

Table 5-10 - Stability Criteria for the FO-DSC Shell

Temperature	Allowable External Pressure, P_a (psi)				Allowable Compressive Stress (ksi)	
	Level A/B [NB-3133.3]	Test [NB-3226(c)]	Level C [NB-3224.2]	Level D [F-1331.5]	Level A [NB-3133.6]	Level D [F-1331.5]
100°F	46	63	56	70	11.7	17.6
400°F	43	58	52	65	10.4	15.6
700°F	39	53	47	59	9.3	14.0

Notes:

1. Under combined axial compression and external pressure, a linear interaction should be applied as follows:

$$\frac{\textit{applied axial stress}}{\textit{allowable axial stress}} + \frac{\textit{applied external pressure}}{\textit{allowable external pressure}} \leq 1.0$$

Table 5-11 Allowable Stresses in Partial Penetration Outer Bottom Cover Plate Weld

Temp. °F	Code Value for Type 316 Base Metal (ksi)			Primary Allowable Stress (ksi)					Primary + Secondary
	S_m	S_y	S_u	Level A (.6)S_m	Level B (.6)S_m	Level C Note 2	Level D Elastic (3)	Level D E/P (4)	.6(3.0S_m)
-20	20.0	30.0	75.0	12.0	12.0	18.0	28.8	31.5	36.0
100	20.0	30.0	75.0	12.0	12.0	18.0	28.8	31.5	36.0
200	20.0	25.8	73.4	12.0	12.0	15.5	28.8	30.8	36.0
300	20.0	23.3	71.8	12.0	12.0	14.4	28.8	30.2	36.0
400	19.3	21.4	71.8	11.6	11.6	13.9	27.8	30.2	34.7
500	18.0	19.9	71.8	10.8	10.8	13.0	25.9	30.2	32.4
600	17.0	18.8	71.8	10.2	10.2	12.2	24.5	30.2	30.6
650	16.7	18.5	71.8	10.0	10.0	12.0	24.0	30.2	30.1
700	16.3	18.1	71.8	9.8	9.8	11.7	23.5	30.2	29.3

Notes:

1. Per Code Case N-595-1, a stress reduction factor of 0.8 is applied to all of the service level primary allowable stresses for the partial penetration outer bottom cover plate weld. However, a conservative stress reduction factor of 0.6 is used in this analysis.
2. Level C allowable is 0.6 times the greater of $1.2S_m$ or S_y.
3. Allowable for Level D elastic analysis is 0.6 times the lesser of $2.4S_m$ or $0.7S_u$.
4. Allowable for Level D elastic/plastic analysis is 0.6 times the greater of $0.7S_u$ or $S_y+1/3(S_u-S_y)$.

Table 5-12 Allowable Stresses in Partial Penetration Top Inner Cover Plate Welds[1]

Temp. °F	Code Value for Type 316 Base Metal (ksi)			Primary Allowable Stress (ksi)					Primary + Secondary
	S_m	S_y	S_u	Level A (.6)S_m	Level B (.6)S_m	Level C Note 2	Level D Elastic [3]	Level D E/P [4]	.6(3.0S_m)
-20	20.0	30.0	75.0	12.0	12.0	18.0	28.8	31.5	36.0
100	20.0	30.0	75.0	12.0	12.0	18.0	28.8	31.5	36.0
200	20.0	25.8	73.4	12.0	12.0	15.5	28.8	30.8	36.0
300	20.0	23.3	71.8	12.0	12.0	14.4	28.8	30.2	36.0
400	19.3	21.4	71.8	11.6	11.6	13.9	27.8	30.2	34.7
500	18.0	19.9	71.8	10.8	10.8	13.0	25.9	30.2	32.4
600	17.0	18.8	71.8	10.2	10.2	12.2	24.5	30.2	30.6
650	16.7	18.5	71.8	10.0	10.0	12.0	24.0	30.2	30.1
700	16.3	18.1	71.8	9.8	9.8	11.7	23.5	30.2	29.3

Notes:
1. Per Code Case N-595-1, a stress reduction factor of 0.8 is applied to all of the service level primary allowable stresses for the partial penetration inner top cover plate weld. However, a conservative stress reduction factor of 0.6 is used in this analysis.
2. Level C allowable is 0.6 times the greater of $1.2S_m$ or S_y.
3. Allowable for Level D elastic analysis is 0.6 times the lesser of $2.4S_m$ or $0.7S_u$.
4. Allowable for Level D elastic/plastic analysis is 0.6 times the greater of $0.7S_u$ or $S_y+1/3(S_u-S_y)$.

Table 5-13 Allowable Stresses in Partial Penetration Top Outer Cover Plate Welds[1]

Temp. °F	Code Value for Type 316 Base Metal (ksi)			Primary Allowable Stress (ksi)					Primary + Secondary
	S_m	S_y	S_u	Level A (.6)S_m	Level B (.6)S_m	Level C Note 2	Level D Elastic [3]	Level D E/P [4]	.6(3.0S_m)
-20	20.0	30.0	75.0	12.0	12.0	18.0	28.8	31.5	36.0
100	20.0	30.0	75.0	12.0	12.0	18.0	28.8	31.5	36.0
200	20.0	25.8	73.4	12.0	12.0	15.5	28.8	30.8	36.0
300	20.0	23.3	71.8	12.0	12.0	14.4	28.8	30.2	36.0
400	19.3	21.4	71.8	11.6	11.6	13.9	27.8	30.2	34.7
500	18.0	19.9	71.8	10.8	10.8	13.0	25.9	30.2	32.4
600	17.0	18.8	71.8	10.2	10.2	12.2	24.5	30.2	30.6
650	16.7	18.5	71.8	10.0	10.0	12.0	24.0	30.2	30.1
700	16.3	18.1	71.8	9.8	9.8	11.7	23.5	30.2	29.3

Notes:
1. Per Code Case N-595-1, a stress reduction factor of 0.8 is applied to all of the service level primary allowable stresses for the partial penetration outer top cover plate weld. However, a conservative stress reduction factor of 0.6 is used in this analysis.
2. Level C allowable is 0.6 times the greater of $1.2S_m$ or S_y.
3. Allowable for Level D elastic analysis is 0.6 times the lesser of $2.4S_m$ or $0.7S_u$.
4. Allowable for Level D elastic/plastic analysis is 0.6 times the greater of $0.7S_u$ or $S_y+1/3(S_u-S_y)$.

Table 5-14 Subsection NF Criteria for Partial Penetration & Fillet Welds [4]

Service Level	Allowable Stress (1,2)	Basis
Level A	F_w=0.30S_u (weld metal) F_w=0.40S_y (base metal)	Table NF-3324.5(a)-1
Level B	F_w=0.40S_u (weld metal) F_w=0.53S_y (base metal)	Table NF-3324.5(a)-1 and Table NF-3522(b)-1 (K = 1.33)
Level C	F_w=0.45S_u (weld metal) F_w=0.60S_y (base metal)	Table NF-3324.5(a)-1 and Table NF-3522(b)-1 (K = 1.5)
Level D	F_w=0.60S_u (weld metal) F_w=0.80S_y (base metal)	F-1334 and Table 1 of Ref. 2

Notes:
1. Weld metal stress is stress at the minimum section through the weld
2. Base metal stress is stress at the weld leg
3. Calculated stresses, f_w, are the maximum stresses at the weld throat/leg, determined as the resultant force over the weld area.
4. Both sets of criteria (weld metal and base metal) must be satisfied. For bimetallic joints, the base metal criteria must be satisfied for both base materials.

Table 5-15 - Allowable Base Metal Stresses for Partial Penetration & Fillet Welds Type 316 Base Metal [4]

Temp. (°F)	S_y (ksi) Type 316	Level A F_W = .40S_y	Level B F_W = .53S_y	Level C F_W = .60S_y	Level D F_W = .80S_y
-20	30.0	12.00	15.90	18.00	24.00
100	30.0	12.00	15.90	18.00	24.00
200	25.8	10.32	13.67	15.48	20.64
300	23.3	9.32	12.35	13.98	18.64
400	21.4	8.56	11.34	12.84	17.12
500	19.9	7.96	10.55	11.94	15.92
600	18.8	7.52	9.96	11.28	15.04
650	18.5	7.40	9.81	11.10	14.80
700	18.1	7.24	9.59	10.86	14.48

Notes:
1. Level A, B, and C weld allowables based on Tables NF-3224.5 and NF-3522(b)-1 (K = 1.33 & 1.50 for Level B & C, respectively).
2. Level D allowables based on an increase factor of 2.0 determined from F-1334 for Type 316 base material.

Table 5-16 - Allowable Weld Metal Stresses for Partial Penetration & Fillet Welds

Temp. (°F)	S_u (ksi)	Level A $F_W = .30S_u$	Level B $F_W = .40S_u$	Level C $F_W = .45S_u$	Level D $F_W = .60S_u$
-20	75.0	22.50	30.00	33.75	45.00
100	75.0	22.50	30.00	33.75	45.00
200	73.4	22.02	29.36	33.03	44.04
300	71.8	21.54	28.72	32.31	43.08
400	71.8	21.54	28.72	32.31	43.08
500	71.8	21.54	28.72	32.31	43.08
600	71.8	21.54	28.72	32.31	43.08
650	71.8	21.54	28.72	32.31	43.08
700	71.8	21.27	28.36	31.91	42.54

Notes:
1. Level A, B, and C weld allowables based on Tables NF-3224.5 and NF-3522(b)-1 (K = 1.33 & 1.50 for Level B & C, respectively) [4].
2. Level D allowables based on an increase factor of 2.0 determined from F-1334 for Type 316 base material.

5.2 Model Description

The FO-DSC shell assembly is analyzed for the postulated load conditions using two basic models: a top end model and a bottom end model. For each of the models, a 90° (quarter symmetric) representation is used to analyze axisymmetric loads and a 180°(half symmetric) representation is used to analyze non-axisymmetric loads. All models include half of the height of the cylindrical shell. Geometry plots of the analysis models are presented in Figure 5-1 through Figure 5-7. Boundary conditions specific to the loads analyzed are discussed in Section 9.1.

Each of the shell assembly components is modeled using (ANSYS [5] SOLID45) 3-D solid elements. The elements have translational-only degrees of freedom at each of the eight nodes. Therefore, pinned connections can be represented by merging nodes of connected elements at the pin location. The top end of the FO-DSC is assembled such that no gaps initially exist between the outer cover plate, inner cover plate, shield plug, and support ring. Similarly, the bottom end of the FO-DSC is assembled such that no gaps initially exist between the outer cover plate, shield plug, and inner cover plate. The interfaces between the mating surfaces are modeled using (ANSYS CONTAC49) 3-D point-to-surface contact elements that allow only the transfer of compressive (bearing) loads. The contact elements are defined to allow the surfaces to slide freely (no shear transfer) assuming that there is no friction. The two thermal models use the same geometry to model the top and bottom halves of the DSC, but use 3-D solid thermal elements (ANSYS® SOLID70 [5]).

To avoid unnecessary refinement, the grapple assembly is modeled such that the mesh does not coincide with that of the outer bottom cover plate (see Figure 5-6). Constraint equations are generated to connect the grapple ring assembly to the outer bottom cover plate. This results in a slight increase in stiffness in the region of the interface. For analysis of grapple pull loading, which controls the design of the grapple assembly and outer bottom cover plate, the grapple assembly and cover plate meshes are refined such that nodes are coincident and constraint equations are not needed. The refined model is shown in Figure 5-7.

The partial penetration welds of the outer cover plates to the shell are modeled using 3-D solid elements to capture the maximum bending stresses in the shell and cover plates in the region of the connection. The stresses resulting from this configuration are categorized as primary + secondary stresses. To determine the primary stresses, the weld elements are "killed" leaving a pinned connection at the root of each weld. See Section 9.1 for further discussion and verification that stresses at the center of the cover plate remain within acceptable limits for the pinned edge condition. Note that the minimum effective throat of 1/2" is modeled for the weld of the outer top cover plate rather than the nominal size of 5/8".

The weld of the inner top cover plate to the shell is a partial penetration weld that is small relative to the plate thickness. Therefore, this connection is assumed to be pinned which is accomplished by merging the line of nodes at the top surface of the plate with the shell nodes. The inner bottom cover plate is connected to the shell with full penetration welds, reinforced with fillet welds. This connection will resist bending moments. Therefore, all nodes through the thickness of the plate along the perimeter are merged with the shell nodes. The support ring is connected to the shell using a continuous partial penetration weld along the top edge, with a reinforcing fillet weld, and an intermittent fillet weld along the bottom edge. The continuous weld is represented in the model by merging all nodes along the top edge of the support ring with the shell nodes while the intermittent weld is modeled by merging only selected nodes along the bottom edge. The grapple ring is assembled and connected to the outer bottom cover plate using full penetration welds. Therefore, the components are modeled to be continuous through the connections.

When in the horizontal position, the fuel-loaded spacer discs bear on the inner surface of the FO-DSC shell. Shell stresses in the region of the spacer discs result from the bearing load and from local deformations at the cask rails. These stresses are determined in a separate calculation package that utilizes a detailed model of the spacer disc, FO-DSC shell, and the transfer cask (rail and inner liner) [8].

Figure 5-1 - FO-DSC Shell Assembly Top End 90° Analysis Model

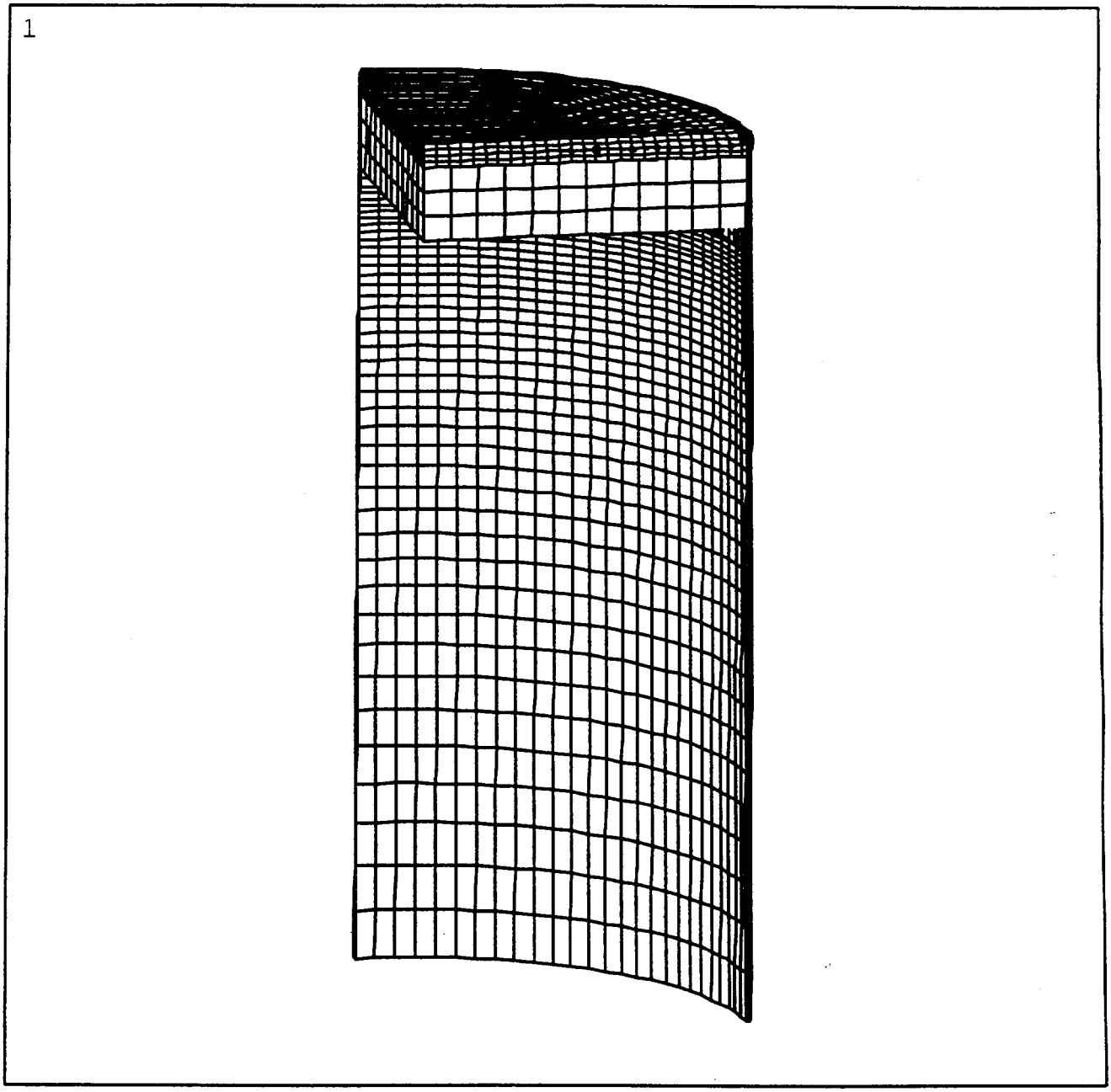


Figure 5-2 - FO-DSC Shell Assembly Top End 90° Analysis Model (End Plates)

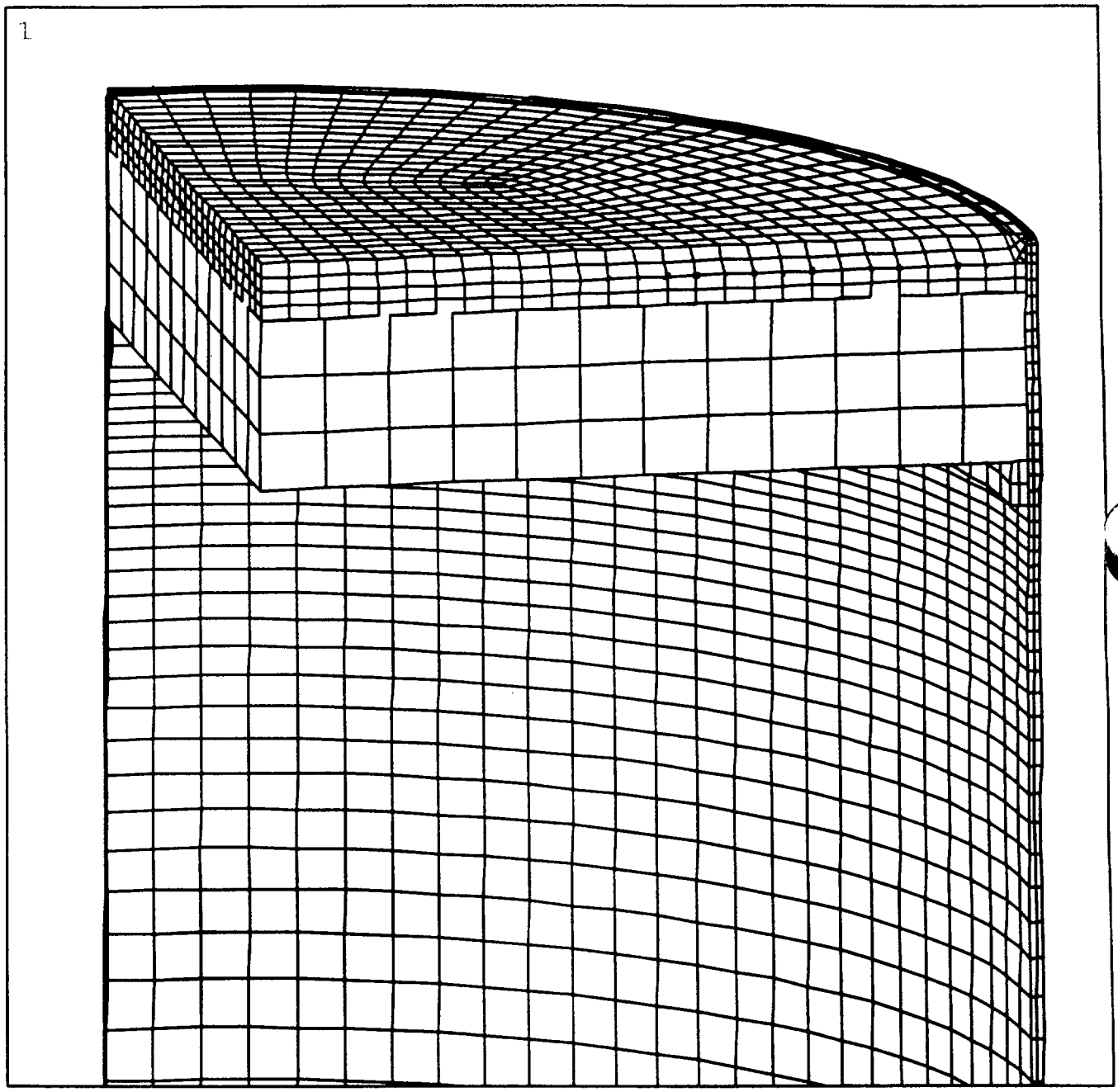


Figure 5-3 - FO-DSC Shell Assembly Top End 90° Analysis Model (End Plates and Support Ring)

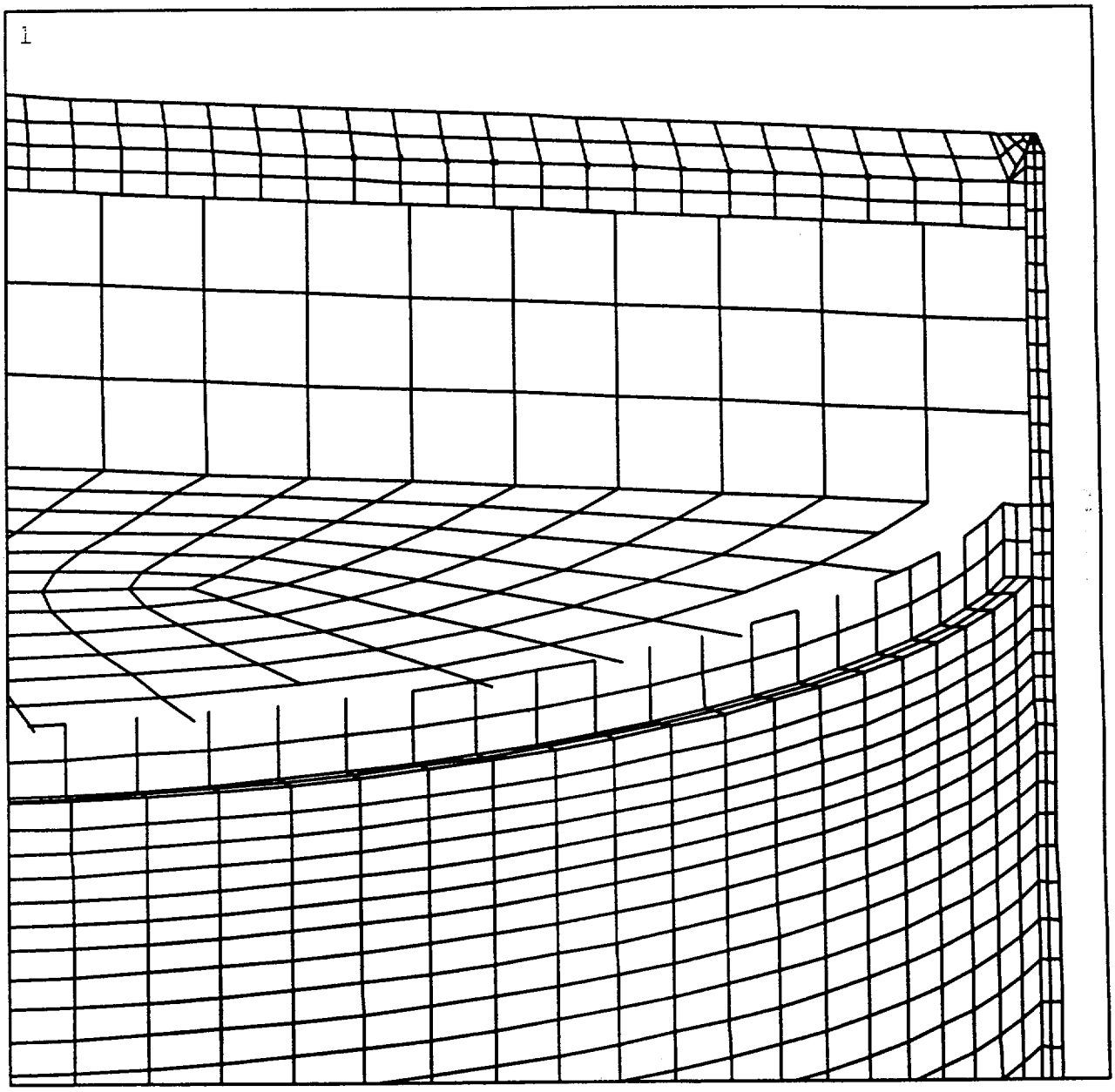


Figure 5-4 - FO-DSC Shell Assembly Bottom End 90° Analysis Model

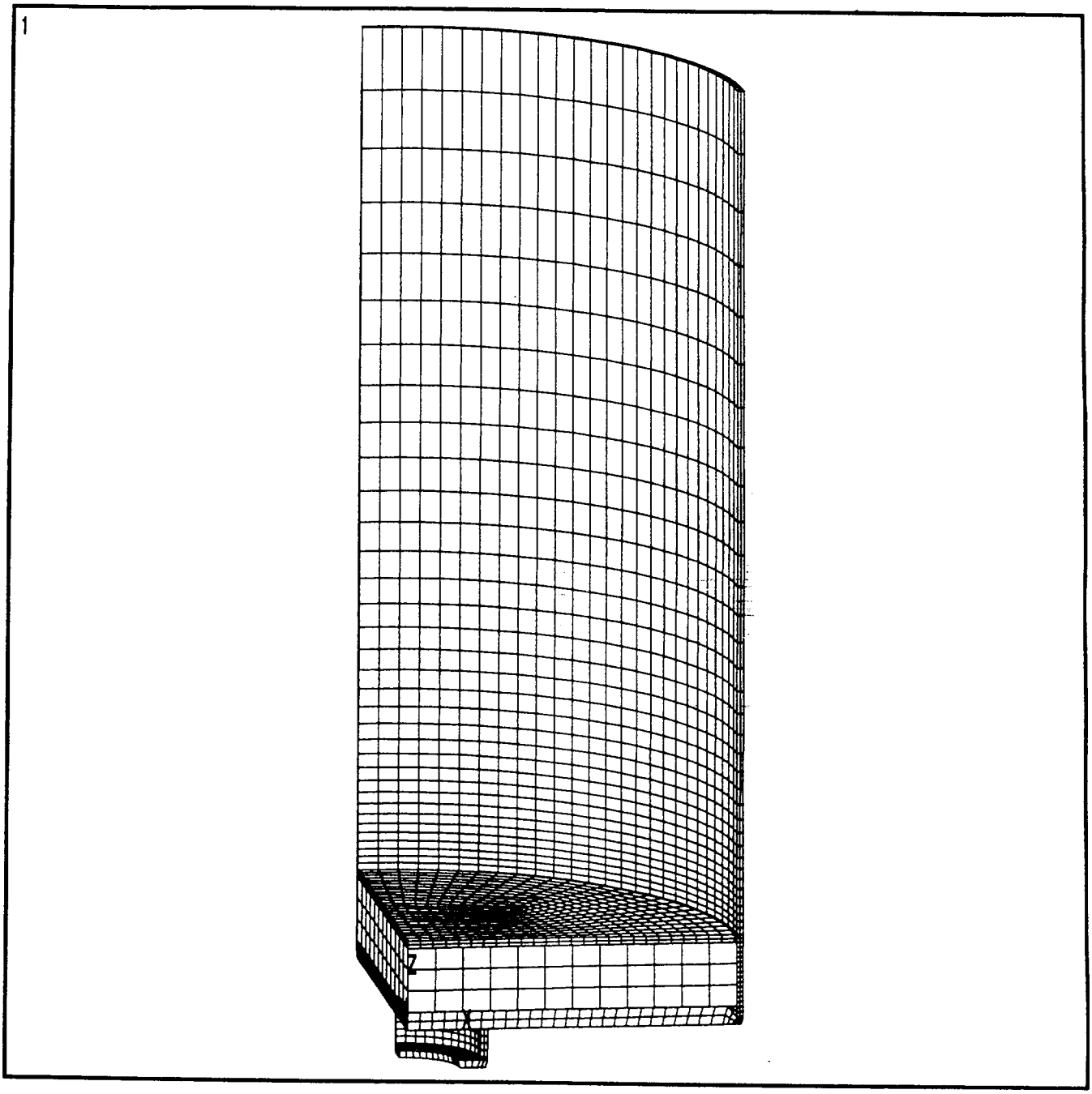


Figure 5-5 - FO-DSC Shell Assembly Bottom End 90° Analysis Model (End Plates)

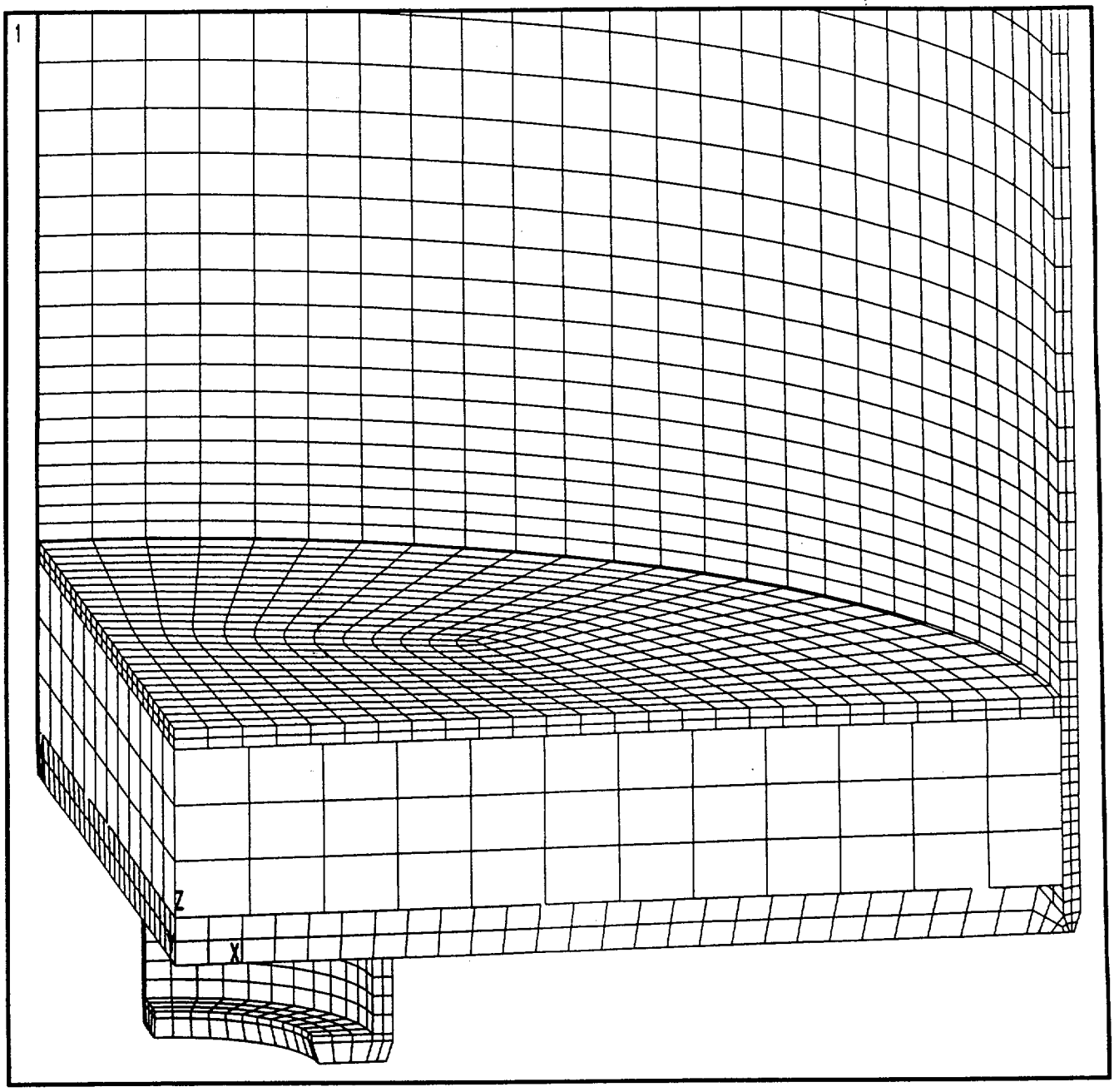


Figure 5-6 - FO-DSC Shell Assembly Bottom End 90° Analysis Model (End Plates and Grapple Assembly)

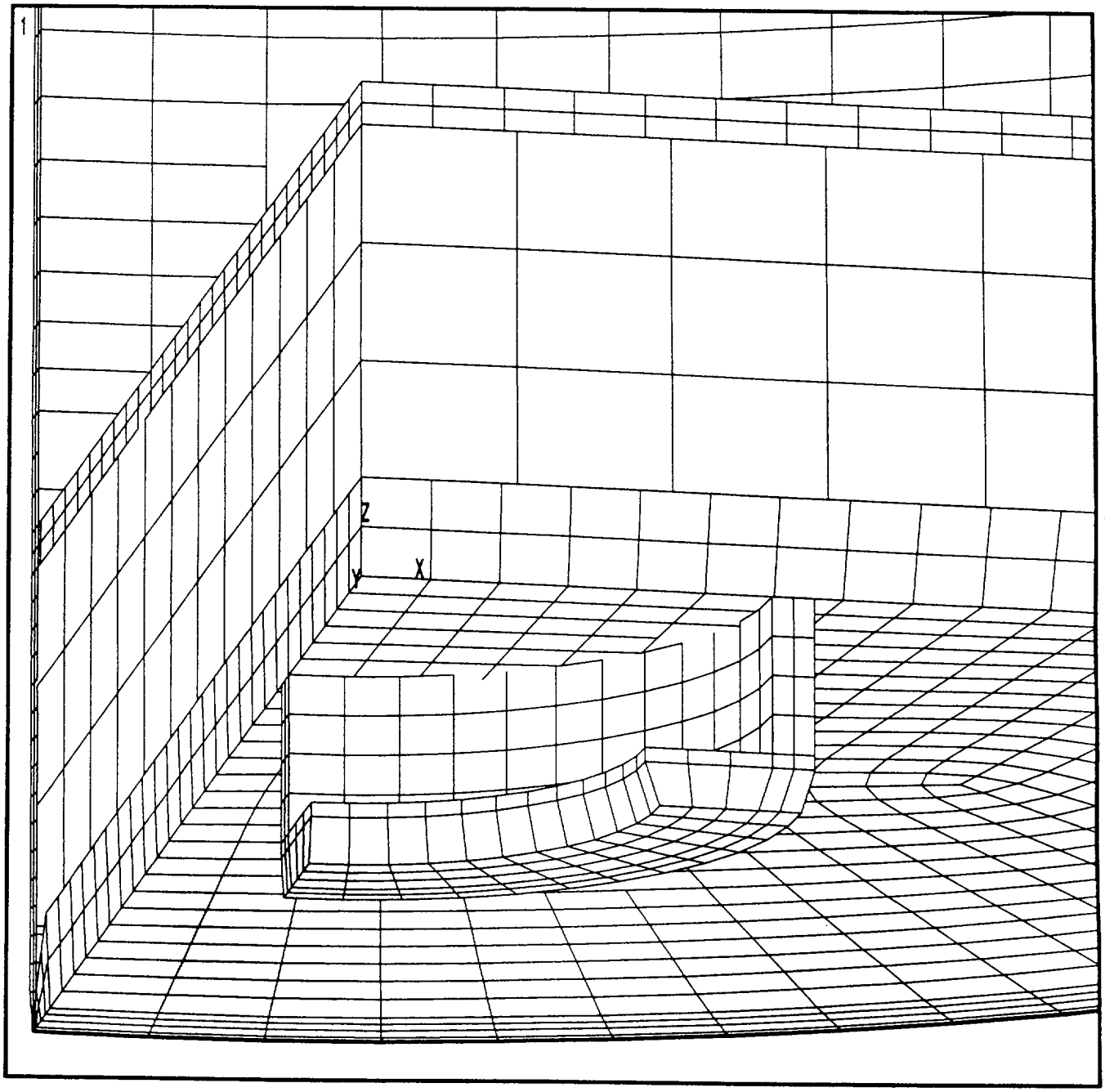
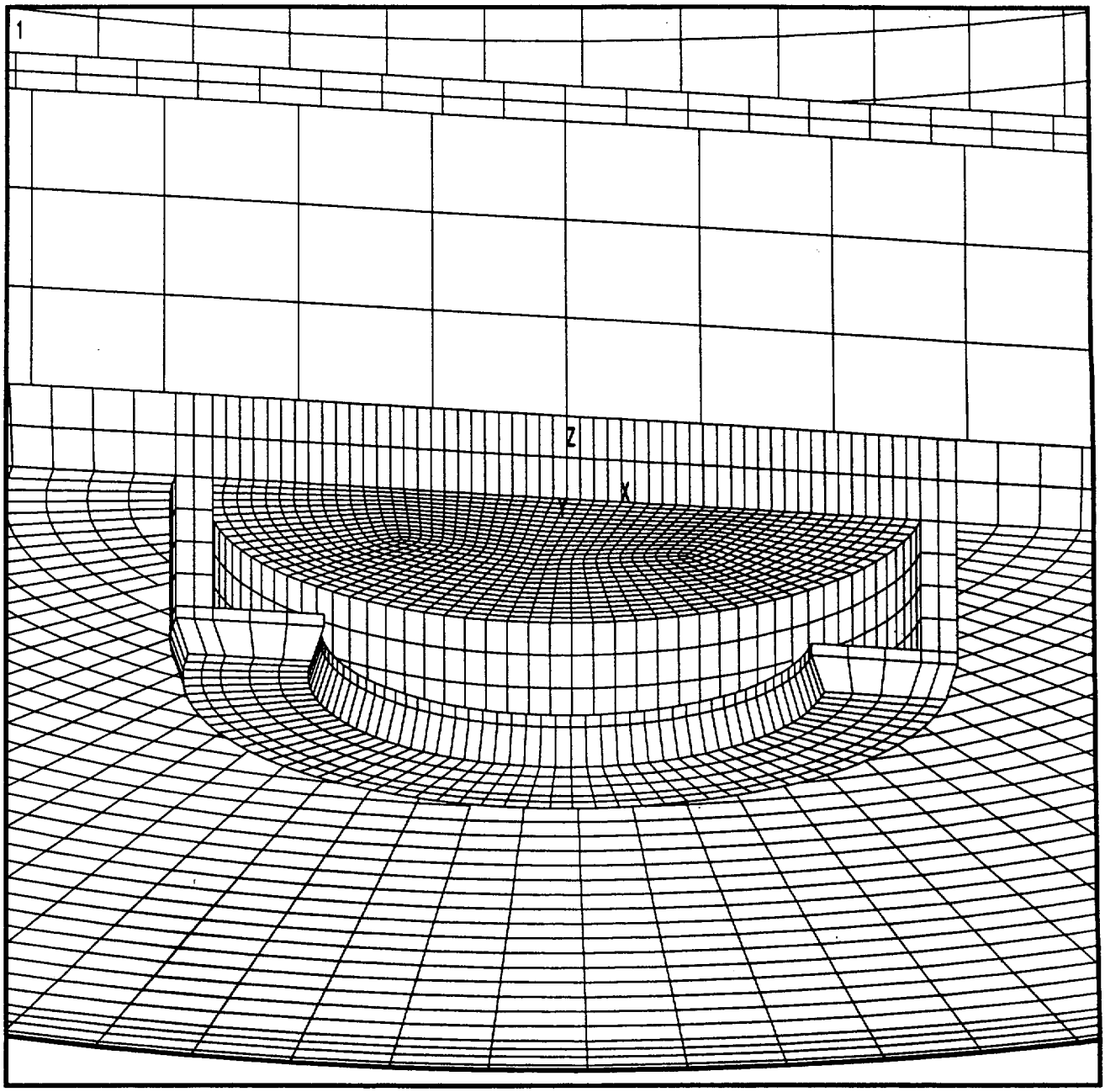


Figure 5-7 - FO-DSC Shell Assembly Bottom End 180° Analysis Model – Refined (End Plates and Grapple Assembly)



6. REFERENCES

1. Transnuclear, Inc. "Design Criteria for the Advanced NUHOMS® Dual Purpose System", SCE-01.0101, Revision 1.
2. "Rules for Construction of Nuclear Power Plant Components, Division I - Subsection NB, Class 1 Components", ASME Boiler and Pressure Vessel Code, 1992 Edition through 1994 Addenda including exceptions allowed by proposed Code Case N-595-1, "Requirements for Spent Fuel Storage Canister."
3. "Materials – Properties, Section II, Part D", ASME Boiler and Pressure Vessel Code, 1992 Edition through 1994 Addenda.
4. "Rules for Construction of Nuclear Power Plant Components, Division I - Subsection NF, Supports", ASME Boiler and Pressure Vessel Code, 1992 Edition through 1994 Addenda.
5. Swanson Analysis Systems, Inc., ANSYS Release 5.3, June, 1996.
6. Young, Warren C., Roark's Formulas for Stress and Strain, 6th Edition, McGraw-Hill Book Company, New York, 1989.
7. Not used.
8. "FO-DSC Dry Shielded Canister Basket Assembly Spacer Disc Structural Analysis", Transnuclear West Calculation No. SCE-01.0208 Revision 1.
9. "Advanced NUHOMS® DSC Thermal Evaluation", Transnuclear West Calculation No. SCE-01.0404, Revision 1.
10. "OS-197 Transfer Cask Thermal Analysis for SCE Unit 1," Transnuclear West Calculation No. SCE-01.0406, Rev. 0.
11. "DSC/AHSM/OS197 Cask Component Weights, Mass Properties, and Lift Weight Calculations and Evaluations," Transnuclear West Calculation No. SCE-01.0200, Rev. 0.
12. Transnuclear, Inc. "NUHOMS® Standard Design Dry Shielded Canister – Structural Analysis Design Requirements Document", Doc. No. NUH-03-140, Revision 2, September, 1998
13. Not used.
14. Not Used.
15. "Evaluation of FO-DSC Lifting Lugs," Transnuclear West Calculation No. SCE-01.0202, Rev. 0.
16. "Evaluation of Support Rod Assemblies for FO DSCs," Transnuclear West Calculation No. SCE-01.0207, Revision 0.
17. "DSC/AHSM Seismic Interaction," Transnuclear West Calculation No. SCE-01.0214, Revision 0.

7. NOMENCLATURE

AHSM – Advanced Horizontal Storage Module

DCD – Design Criteria Document

DSC – Dry Shielded Canister

FEA – Finite Element Analysis

GTCC – Greater Than Class C

PWR – Pressurized Water Reactor

SI – Stress intensity

8. COMPUTATIONS

The following sub-sections provide the analyses performed without the use of the FEA models. The FO-DSC seismic analysis and the draining and drying operations are analyzed using 'classical' hand calculations. The majority of the calculations are performed with assistance from Roark, Reference 6.

8.1 FO-DSC Seismic Analysis

8.1.1 Shell

8.1.1.1 Geometric Parameters of the Shell

OD = 67.19 in

Max Thk = 0.625 in

Min Thk = 0.530 in

Length = 186.2

$$R = \frac{67.19 - 0.625}{2} = 33.28\,\text{in}$$

$$t = 0.530\,\text{in}$$

$$I_{Shell} = \pi \cdot R^3 \cdot t = \pi \cdot 33.28^3 \cdot 0.530 = 61.4 \times 10^3\ \text{in}^4\ \text{(Minimized)}$$

$$A_{shell} = \pi \cdot \left(\left(\frac{67.19}{2}\right)^2 - \left(\frac{67.19}{2} - 0.530\right)^2 \right) = 111.0\,\text{in}^2\ \text{(Minimized)}$$

8.1.1.2 Loads

Seismic equivalent static acceleration = ±6g

Weights are conservatively based on values found in Calculation Package SCE-01-0200 [11].

Bounding Weight =82,000 lb.

Shell Weight =26,000 lb. (includes shield plugs, top and bottom plates)

8.1.1.3 Horizontal/Lateral Loads on the FO-DSC Shell:

$$w = \frac{82{,}000\,\text{lb} \cdot 6g}{186.2\,\text{in}} = \pm 2{,}642\ \text{lb/in}$$

Assuming Simply Supported Boundary Conditions (Roark, Table 3, Case 2e):

$$\text{Maximum Moment, } M_{max} = \frac{w \cdot l^2}{8} = \frac{2{,}642 \cdot 186.2^2}{8} = \pm 11.4 \times 10^6\ \text{in-lb}$$

$$\text{Bending Stress, } \sigma_b = \frac{M_{max} \cdot c}{I_{shell}} = \frac{11.4 \times 10^6 \cdot \left(\frac{67.19}{2}\right)}{61.4 \times 10^3} = \pm 6.2 \text{ ksi}$$

Conservatisms: Considers longest possible length, minimized I_{shell}, and weight which is slightly above the maximum.

8.1.1.4 Axial Loads on the FO-DSC shell

Maximum axial load, $P = 26{,}000 \text{ lb} \cdot (-6g) = -156{,}000 \text{ lb}$

$$\text{Axial Stress, } \sigma_a = \frac{P}{A_{shell}} = \frac{-156{,}000}{111.0} = -1.4 \text{ ksi}$$

Conservatisms: Considers the entire weight of the shell, the axial load is rounded up, and the minimized A_{shell}.

8.1.1.5 Combined Stresses:

During the seismic event, an equivalent static acceleration is assumed to act on the FO-DSC in all three Cartesian axis directions simultaneously. Using the stress calculated above, the combined load stress is conservatively calculated by the vector summation of two lateral load added directly to the absolute value of the axial load result:

$$\text{combined stress: } \sigma_{total,shell} = \sqrt{2 \cdot \sigma_b^2} + \text{abs}(\sigma_a) = 10.2 \text{ ksi}$$

Compared to service level D primary membrane stress allowable

$P_m = 43{,}200$ psi @ 500°F (See Table 5-4)

$$\text{Stress Ratio} = \frac{10.2}{43.2} = 0.24$$

Conservatisms: Directly adds the axial stress to the vector sum of the bending stress.

8.1.2 End Plates

8.1.2.1 Geometric Parameters of the end plates:

$OD_{max} = 67.19 - 2 \cdot 0.530 = 66.13 \text{ in}$ (Maximized)

$OD_{min} = 67.19 - 2 \cdot 0.625 = 65.94 \text{ in}$ (Minimized)

$throat_{weld} = 3/16 \text{ in}$ (minimum throat of all end plate welds)

plate thickness, 0.75 in (minimum nominal thickness of all the end (cover) plates)

8.1.2.2 Loads:

Seismic equivalent static acceleration = ±6g

Total Weight = 82,000 lb.

Basket Weight = 7,631+10,889 lb. = 18520 lb.

Fuel Weight = 35,600 lb.

Shell Weight = 26,000 lb. (includes shield plugs, top and bottom plates)

Shield-plug Weight = 7,950 lb.

8.1.2.3 Check the welds:

Load on inner top plate (fuel & basket weight) @ 6g,

$P = 6 \cdot (35{,}600 + 18{,}520 + 7{,}950) = 372 \text{ kips}$ (Reference 11)

Area of weld, $A_{weld} = \pi \cdot OD_{min} \cdot throat_{weld} = 38.84 \text{ in}^2$

$$\text{weld stress, } \sigma_w = \frac{P}{A_{weld}} = 9.6 \text{ ksi}$$

The service level D allowable for the top inner cover plate weld (see Table 5-12) is:

$S_a = 25.9$ ksi

$$\text{Stress Ratio} = \frac{9.6}{25.9} = 0.37$$

Notes: Due to the top shield plug thickness, it is assumed that the loads of significance on the inner top cover and outer top cover plates are bounded by the above calculations. The calculations on the inner bottom cover plate (below) also show the structural capacity of the cover plates are acceptable.

8.1.2.4 Check the plates

The inner and outer plates are primarily loaded in shear at the weld to the FO-DSC shell. As shown above, a 3/16 in. effective throat weld easily withstands the seismic load. Therefore no further analyses of the cover plates are required for the seismic load cases.

8.2 Fatigue Evaluation

Fatigue effects on the DSC are addressed using the criteria contained in NB-3222.4 of the ASME Code [2]. Fatigue effects need not be specifically evaluated provided the criteria contained in NB-3222.4(d) are met. A summary of the six criteria and their application to the DSC are presented in the paragraphs which follow:

A. The first criterion states that the DSC is adequate for fatigue effects provided that the total number of atmospheric-to-operating pressure cycles during normal operation (including startup and

shutdown) does not exceed the number of cycles on the applicable fatigue curve corresponding to an S_a value of three times the S_m value of the material at operating temperatures. This condition is satisfied for the DSC since the pressure is not cycled during its design life. The pressure established at the time that the DSC is sealed following fuel loading and DSC closure operations is maintained during normal storage in the AHSM.

B. The second criterion states that the DSC is adequate for fatigue effects provided that the specified full range of pressure fluctuations during normal operation does not exceed the quantity (1/3) x design pressure x (S_a/S_m), where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant pressure fluctuations, and S_m is the allowable stress intensity for the material at operating temperatures. Significant pressure fluctuations are those for which the total excursion exceeds (1/3) x design pressure x (S/S_m), where S equals the value of S_a for 10^6 cycles. For a DSC design pressure of 10.0 psig [Ref 1], an S_m value of 18,000 psi, and an S value of 28,200 psi, the total range for a significant pressure fluctuation is 5.2 psig. This small pressure fluctuation may occur during normal storage as a result of seasonal ambient temperature changes. Ambient temperature cycles significant enough to cause a measurable pressure fluctuation are assumed to occur five times per year for 50 years. The number of fluctuations with this pressure range is expected to be 250 for the DSC. The value of S_a associated with this number of cycles is 186 ksi. Hence the value of (1/3) x design pressure x (S_a/S_m) is equal to 55.0 psig. Clearly this value will not be exceeded during the pressure fluctuation of the DSC. Therefore the second criterion is satisfied for the DSC.

C. The third criterion states that the DSC is adequate for fatigue effects provided that the temperature differences between any two adjacent points on the DSC during normal operation do not exceed $S_a/2E\alpha$, where S_a is the value obtained from the applicable fatigue curve for the specified number of startup-shutdown cycles, α is the instantaneous coefficient of thermal expansion at the mean value of temperatures at the two points, and E is the modulus of elasticity at the mean value of the temperatures at the two points. For an operation cycle of the DSC, thermal gradients occur during fuel loading, DSC closure, transport to the AHSM, and transfer of the DSC to the AHSM. This half cycle is approximately reversed for DSC unloading operations. However, this normal operational cycle occurs only once in the 50 year design service life of a DSC. Since there is only one startup-shutdown cycle associated with the DSC, the value of S_a is very large (>800 ksi). Hence the value of $S_a/2E\alpha$ is very large (>1500 °F). This is far greater than the temperature difference between any two adjacent points on the canister. Thus, the third criterion is satisfied for the DSC.

D. The fourth criterion states that the DSC is adequate for fatigue effects provided that the temperature difference between any two adjacent points on the DSC does not change during normal operation by more than the quantity $S_a/2E\alpha$, where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant temperature-difference fluctuations. Small fluctuations in the DSC thermal gradients during normal storage in the AHSM occur as a result of seasonal ambient temperature changes. Ambient temperature cycles significant enough to cause a measurable thermal gradient fluctuation are assumed to occur five times per year for 50 years (250 cycles). The DSC stresses resulting for thermal gradient fluctuations are small since the structural capacity of the DSC is designed for extreme accident

loads such as cask drop loads which are postulated to be a one time occurrence. A temperature difference fluctuation is considered to be significant if its total algebraic range exceeds the quantity $S/2E\alpha$, where S is the value of Sa obtained from the applicable fatigue curve for a conservative 500 cycles. Taking the value of $S = 345 \times 10^3$ psi, $E = 25.8 \times 10^6$ psi and $\alpha = 10.25 \times 10^{-6}$ in./in./°F, the value of $S/2E\alpha = 653$ °F. The most significant fluctuation is normal operating temperature occurs during a change in ambient temperature from 0°F to 104°F. This fluctuation is conservatively bounded by the fluctuation between -40°F and 104°F which results in an change of temperature difference of 128°F [9]. The effects of this temperature difference is not significant, therefore the fourth condition is satisfied for the DSC.

E. The fifth criterion states that for components fabricated from materials of differing moduli of elasticity or coefficients of thermal expansion, the total algebraic range of temperature fluctuation experienced by the component during normal operation must not exceed the magnitude $S_a/2(E_1\alpha_1 - E_2\alpha_2)$, where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant temperature fluctuations, E_1 and E_2 are the moduli of elasticity, and α_1 and α_2 are the values of instantaneous coefficients of thermal expansion at the mean temperature value involved for the two materials of construction. A temperature fluctuation is considered to be significant if its total excursion exceeds the quantity $S/2(E_1\alpha_1 - E_2\alpha_2)$, where S is the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. If the two materials used have different applicable design fatigue curves, the lower value of S_a shall be used. Since the structural material used to construct the DSC is homogeneous (all materials are stainless steel), the fifth condition does not apply.

F. The sixth criterion states that the DSC is adequate for fatigue effects provided that the specified full range of mechanical loads do not result in a stress range which exceeds the S_a value obtained from the applicable fatigue curve for the total specified number of significant load fluctuations. If the total specified number of significant load fluctuations exceeds 10^6, the S_a value at $N = 10^6$ may be used. A load fluctuation is considered to be significant if the total excursion of stresses exceed the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. The only mechanical loads which affect the DSC are those associated with handling loads and a seismic event. One handling load cycle and a major seismic event are postulated during the design life of the DSC. The DSC stresses resulting from these mechanical load fluctuations are small since the structural capacity of the DSC is designed for extreme accident loads such as a postulated cask drop. The maximum stress intensity in the DSC due to its dead weight at 1g is 3,102 psi located in the bottom half of the shell (see Table 9-11). Scaling this stress intensity to 0.33g (the seismic load specified in Reference 1), the maximum stress is equal to 1,023 psi (1.02 ksi). The number of significant cycles associated with mechanical load fluctuations is conservatively assumed to be 10^6. The value of S_a association with this number of cycles is 28.2 ksi. Since the stress ratio is very small (0.04), this sixth condition is satisfied for the DSC.

The evaluation presented in the preceding paragraphs demonstrates that the six criteria contained in NB-3222.4(d) are satisfied for all components of the DSC.

8.3 Draining and Drying

The draining and drying load cases are evaluated below. The load cases included in the draining and drying operations are summarized in Table 8-1. The analyses are initially performed on a unit load basis, then multiplied by the appropriate factor and combined for each load case at the end of the section.

Table 8-1 - Summary of the draining and drying load cases

Load Case	Internal Pressure	External Hydrostatic Pressure	Thermal Stress
Draining (Blowdown)	20 psig	no	no
Vacuum Drying	-14.7 psig	7.07 psig max	no
Helium Backfill	12 psig	7.07 psig max	no
Final Helium Backfill	5 psig	7.07 psig max	no

The DSC shell stresses are determined using Table 28, Case 1c and 1d of Roark [6]. All of the DSC shell stresses determined in the following analyses are classified as primary membrane.

Table 8-2 - Geometry and Load Terms for DSC Shell analyses

Term	Value	Notes
Input Variables		
R=	33.065 in	Shell Radius
t=	0.530 in	Shell Thickness
q=	1 psi	Unit Pressure
Unit Value Stress for Table 28, Case 1c (Uniform Internal or External Pressure)		
σ_1=	31 psi	Meridional Stress
σ_2=	62 psi	Circumferential Stress
Unit Value Stress for Table 28, Case 1d (Linearly Varying Pressure)		
σ_1=	0 psi	Meridional Stress
σ_2=	62 psi	Circumferential Stress

For each of the internal pressure stress calculations below, Table 31, Case 4 of Roark is used for the junction between the inner top plate and the shell. The following assumes that the end plate of the pressure boundary is the inner top cover plate. For the external pressure cases, the monolithic, solid steel shield plug constrains the inner top cover plate. The bottom cover plates are constrained by the bottom of the transfer cask externally, and by the payload internally. Therefore the bottom cover plates do not require specific consideration. Geometry and load terms for each of the pressure load cases are presented below.

During each of the draining and drying operations, the bottom shield plug for all internal pressures restrains the inner Bottom Cover Plate, whereas external pressures are restrained by the weight of the payload. The inner top cover plate must be able to support the full bending moment due to internal pressures as though the plate were simply supported. The top shield plug restrains the inner top cover plate from external pressures. Pressure loading on the inner top cover plate is analyzed using Roark, Table 24, Case 10 for pinned conditions as performed in Table 8-3.

The plate thickness assumed is the nominal 1.25 inches minus a conservative 0.06 inches for 1.19 in.

Table 8-3 - Geometry and Load Terms for Top Cover Plate Analysis

Term	Value	Notes
Input Variables		
a=	33.07 in	Plate Radius
t=	1.19 in	Plate Thickness
ν=	0.29	Poisson Ratio
q=	1 psi	Unit Pressure
Unit Value Stress for Table 24, Case 10a (Pinned Edge Condition)		
$M_C A$	225 in-lb.	Bending Moment (at Center of Plate)
σ_c=	953 psi	Unit pressure stress (at Center of Plate)

The stress in the 3/16 inch partial penetration weld inner top cover plate to shell weld (effective throat 0.133 inches) is due entirely to shear along the length of the weld as follows. The pressure used is the blow down pressure of 20 psi.

$$\sigma_{weld} \frac{P}{A} = \frac{q\pi R^2}{2\pi R t_{weld}} = \frac{qR}{2t_{weld}} = \frac{(20)(33.065)}{2(0.133)} = 2{,}486 \text{ psi}$$

This stress is compared to the allowable stress for partial penetration welds at 500° F from Table 5-12.

2,486 psi / 10,800 psi = 0.23

During vacuum drying, secondary thermal stresses are created by constrained thermal expansion of the hotter inner top cover plate relative to the cooler DSC shell. The temperatures for the thermal expansion are taken from Figure 12 of the NUHOMS® Design Criteria Document (Reference 12) (See Attachment 1). The analyses that support Reference 12 consider fuel with a decay heat of 24 kW, whereas the required heat load for SCE is 14 kW; therefore, the input for this calculation are conservative.

The temperatures of the inner top cover plate and the shell are calculated.

Inner Top Cover Plate (ITCP)

$T_{ITCP} = -0.068\ Z\ R + 7.67\ R - 2.166\ Z + 863.5.$

where: Z = 175.8 inches (axial location of inner top cover plate)
R = 0 inches and 33.07 inches (center and outside edge of cover plate respectively)

$T_{edge} = (-0.068)(175.8)(33.07) + (7.67)(33.07) - (2.166)(175.8) + 863.5. \quad = 341°\ F$

$T_{center} = (-0.068)(175.8)(0) + (7.67)(0) - (2.166)(175.8) + 863.5. \quad = 483°\ F$

The average temperature of the inner top cover plate is 412° F.

Temperature of DSC Shell

$T_{shell} = -4.414\ Z + 1117$

where Z = 175.8 inches

$T_{shell} = (-4.414)(175.8) + 1117 \quad = 341°\ F$

This yields a difference in temperature between the top plate and the shell of 71°F.

The constrained thermal expansion between the inner to cover plate and the DSC shell is now computed. The coefficients of thermal expansion (α) are taken from Table 4-3. The shell uses α at 300° and the cover plate uses α at 500°. The elastic modulus is taken at 200° F for all components to provide the stiffest possible configuration.

$\alpha_{Type316@200°} = 8.76 \times 10^{-6}\ °F^{-1}$
$\alpha_{Type316@500°} = 9.42 \times 10^{-6}\ °F^{-1}$
$E_{Type316@200°} = 27.6 \times 10^{6}$ psi

$\delta_{ITCP} = R\alpha\Delta T = (33.07\ \text{inches})(9.42 \times 10^{-6}\ °F^{-1})(412°\ F - 70°\ F) \quad = 0.107$ inches

$\delta_{shell} = R\alpha\Delta T = (33.07\ \text{inches})(8.76 \times 10^{-6}\ °F^{-1})(341°\ F - 70°\ F) \quad = 0.0785$ inches

The difference between the expansion of the inner top cover plate and the shell is as follows:

$\Delta = 0.0285$ inches.

The equation for stress due to a forced displacement is computed below.

$$\Delta = \frac{PL}{AE};\ \sigma = \frac{P}{A} \Rightarrow \Delta = \frac{\sigma L}{E} \Rightarrow \sigma = \frac{\Delta E}{L}$$

The stress in the inner top cover plate is as follows where L is the radius of the inner top cover plate and Δ is computed above.

$$\sigma = \frac{\Delta E}{L} = \frac{(0.0285)(27.6x10^6)}{33.07} = 23.8\,\text{ksi}$$

The hoop stress in the shell is computed from Roark Table 29 as follows where the term y is Δ computed above.

$$\sigma = \frac{yE}{L} = \frac{(0.0285)(27.6x10^6)}{33.07} = 23.8\,\text{ksi}$$

Therefore the maximum thermal stress during the vacuum drying case in the DSC shell and the inner top cover plate due to constrained thermal expansion is 23.8 ksi. This secondary stress is conservatively applied to all draining and drying load combinations.

Table 8-4 - Summary of the stresses in the DSC shell (stresses in psi)

Load Case	Internal Pressure		External Hydrostatic Pressure		Combined		
	ϕ	θ	ϕ	θ	ϕ	θ	SI
Draining (Blowdown)	620	1,240	0	0	620	1,240	1,240
Vacuum Drying	-456	-911	-219	-438	-675	-1,349	1,349
Helium Backfill	372	744	-219	-438	153	306	306
Final Helium Backfill	155	310	-219	-438	-64	-128	128

Table 8-5 - Summary of the Maximum stresses in the Inner Top Cover Plate (stresses in psi)

Load Case	Inner Top $P_m + P_b$
Draining (Blowdown)	19,060
Vacuum Drying	n/a(1)
Helium Backfill	11,436
Final Helium Backfill	4,765

Note 1: The inner top cover plate bears against the stiff top shield plug during external pressure loads.

Table 8-6 - Summary of Draining and Drying Operations Allowable Stress Comparisons

Load Case	Stress Intensity (psi)	Stress Category	Allowable (psi)[2]	Stress Ratio
DSC Shell				
Draining (Blowdown)	1,240	P_m	18,000	0.07
Vacuum Drying	1,349	P_m	18,000	0.07
Helium Backfill	306	P_m	18,000	0.02
Final Helium Backfill	128	P_m	18,000	0.01
Vacuum Drying[1]	25,149	P_m+P_b+Q	54,000	0.47
Helium Backfill[1]	24,106	P_m+P_b+Q	54,000	0.45
Final Helium Backfill[1]	23,928	P_m+P_b+Q	54,000	0.44
Bending Stresses in the Inner Top Plate				
Draining (Blowdown)	19,060	P_m+P_b	27,000	0.71
Vacuum Drying	n/a[3]	P_m+P_b	27,000	--
Helium Backfill	11,436	P_m+P_b	27,000	0.42
Final Helium Backfill	4,765	P_m+P_b	27,000	0.18
Draining (Blowdown)	42,860	P_m+P_b+Q	54,000	0.79
Helium Backfill	35,236	P_m+P_b+Q	54,000	0.65
Final Helium Backfill	28,565	P_m+P_b+Q	54,000	0.53

Notes:

1. Includes thermal stresses.
2. A bounding temperature of 500° F is used for the maximum temperature during draining and drying. This conservatively bounds the temperatures reported in Table 9-1 of Reference 9.
3. The inner top cover plate bears against the stiff top shield plug during external pressure loads, so there is no bending stress in the inner top cover plate.

For the stability analysis performed in Table 8-7, the compressive stress in the shell is equivalent to the weight of the top shield plug and inner top cover plate:

[7950 + 730 = 8680 lbs. -- Use 10,000 lbs.] (Reference 11)

This weight is distributed evenly through the thickness and around the circumference of the DSC shell.

$$\frac{10{,}000\text{ lbs.}}{\pi\left[(67.19\text{ in.})^2-(67.19\text{ in.}-2(0.530\text{ in.}))^2\right]/4}=90\text{ psi}$$

Table 8-7 - Summary of Draining and Drying Operations Allowable Pressure and Compressive Stress Comparisons

Load Case	Pressure (psi)		Compressive Stress (ksi)		Stress Ratio
	Applied	Allowable	Applied	Allowable	
Draining (Blowdown)	20	43	0.09	10.4	0.47
Vacuum Drying	14.7 + 7.1	43	0.09	10.4	0.52
Helium Backfill	12	43	0.09	10.4	0.29
Final Helium Backfill	5	43	0.09	10.4	0.12

Notes:

1. Under combined axial compression and external pressure, a linear interaction should be applied as follows:

$$\frac{\textit{applied axial stress}}{\textit{allowable axial stress}}+\frac{\textit{applied external pressure}}{\textit{allowable external pressure}}\le 1.0$$

8.4 DSC Natural Frequency

The natural frequency of the DSC is calculated for use in other calculation packages.

The longitudinal natural frequency is based on the assumption that the DSC is a simply supported beam under a uniform load equal to the gross weight of the package (assumed to be equal to 82,000 lbs). From Roark [6], the first natural frequency mode is equal to:

$$f_n = \frac{K_n}{2\pi}\sqrt{\frac{EIg}{wl^4}}$$

where K_n is equal to 9.87 for mode 1 [6], E is the shell's modulus of elasticity at 500° F (25.8 x 10^6 psi), I is the shell's moment of inertia (61.4 x 10^3 in^4 from Section 8.1.1.1), g is acceleration due to gravity, w is the weight per unit length, and l is the length of the DSC. Thus, the first mode is equal to:

$$f_{n,bending} = \frac{9.87}{2\pi}\sqrt{\frac{(25.8\times10^6)(61.4\times10^3)(386.4)}{(82{,}000/186.2)(186.2)^4}} = 53.4\,\text{Hz}$$

The axial natural frequency of the DSC shell assumes a simple spring-mass system with the canister suspended from its upper end, and is based on the axial stiffness of the DSC ($A_{shell}E/L$) and the mass of the bounding mass of the DSC and its contents (82,000 lbs.). Thus,

$$f_{n,axial} = \frac{1}{2\pi}\sqrt{\frac{A_{shell}E/L}{w}g} = \frac{1}{2\pi}\sqrt{\frac{\frac{\pi}{4}(67.19^2-66.13^2)(25.8\times10^6)/186.2}{82{,}000}386.4} = 42.8\text{ Hz}$$

8.5 Outer Top Cover Plate Stresses due to Internal Pressure

It is assumed that the 20 psi internal pressure in load combinations HSM-5 and HSM-6 and the 60 psi internal pressure in load combination HSM-11 act on either the inner or outer pressure boundary. However, the ANSYS model only applies the pressure load on the inner pressure boundary. Thus, the outer top cover plate must be evaluated when loaded by the full 20 and 60 psi pressures. The outer cover plate and weld stresses are determined by the same method as determining inner top cover plate stresses in Section 8.3.

Table 8-8 - Geometry and Load Terms for Top Cover Plate Analysis

Term	Value	Notes
Input Variables		
a=	33.07 in	Plate Radius
t=	1.31 in	Plate Thickness
ν=	0.29	Poisson Ratio
q=	1 psi	Unit Pressure
Unit Value Stress for Table 24, Case 10a (Pinned Edge Condition)		
$M_C A$	225 in-lb.	Bending Moment (at Center of Plate)
σ_c=	787 psi	Unit pressure stress (at Center of Plate)

The unit stress in the 1/2 inch partial penetration outer top cover plate to shell weld (effective throat 0.354 inches) is due entirely to shear along the length of the weld as follows. The pressure used is the blow down pressure of 20 psi.

$$\sigma_{weld} \frac{P}{A} = \frac{q}{2}\frac{R^2}{Rt_{weld}} = \frac{qR}{2t_{weld}} = \frac{(1)(33.07)}{2(0.354)} = 46.7\ psi$$

This stresses are compared to the allowable stresses for the plate and the partial penetration weld at 650° F from Table 5-12. Stresses and stress ratios are as follows:

Table 8-9 - Summary Outer Pressure Boundary Stress Intensities

Internal Pressure (psi)	Outer Top Cover Plate			OTCP to Shell Weld		
	$P_m + P_b$ (Ksi)	Allowable Stress (Ksi)	Stress Ratio	SI (Ksi)	Allowable Stress (Ksi)	Stress Ratio
20	15.7	25.0	0.63	0.93	10.0	0.09
60	47.2	60.12	0.79	2.80	24.0	0.12

9. RESULTS/CONCLUSIONS AND RECOMMENDATIONS

9.1 Stress Analysis

Static analyses were performed using the models described in Section 5.2 for the loads discussed in Section 4.3. A summary of analysis runs is provided in Table 9-1 and Table 9-2 for the top end models and bottom end models, respectively. Included in the summary tables are descriptions of the applied loads and the boundary conditions for each run. As noted in assumption 5 (Section 3), the FO-DSC is conservatively analyzed for side drop on one rail. Contact elements defining the interface between mating surfaces of the end components are excluded where it is clear that surfaces will not bear against each other for the loading specified, thus removing unnecessary nonlinearity in the model. ANSYS input listings and run summaries are provided in Appendices A1 through A33. This appendix describes the individual load steps referred to by the results summaries in Table 9-5 through Table 9-22.

For vessels with flat heads, the Code (Table NB-3217-1 of Reference 2) allows stresses at the juncture of the flat head to shell to be classified as secondary if the moment connection is not required to maintain stresses at the center of the flat head within acceptable limits. As discussed in Section 5.2, partial penetration welds of the outer top and outer bottom cover plates are modeled with solid elements for consideration of primary + secondary stresses in the region of the connection. Each analysis run also includes load steps that consider the welds as pinned (through the use of the ANSYS [5] EKILL command) to obtain primary stress results and to verify that the outer cover plates will still remain within primary stress limits for pinned conditions.

The grapple ring assembly (grapple ring and grapple ring support) behaves as a stiffener to the outer bottom cover plate for loads normal to the cover plate surface. The portion of the grapple ring assembly stresses caused by displacement in the center region of the cover plate is secondary, as it is not needed for stability of the cover plate. Several sub-models of the FO-DSC were utilized to identify primary stresses alone and in combination with secondary stresses under FO-DSC unloading operations (UL-1 through UL-8):

<u>B24PGP1:</u> A model of the grapple assembly only was analyzed for grapple pull using fixed base conditions to determine primary stresses in the grapple assembly.

<u>B24PGP2:</u> To determine the primary stresses in the outer cover plate, the grapple assembly was excluded from the complete model and pull loads were applied at the base of the grapple ring support.

<u>B24PTHG:</u> The complete model was analyzed for thermal load cases in combination with the grapple pull to determine the primary + secondary stresses in the FO-DSC components.

<u>B24PT-G:</u> In order to ensure that the full range of primary plus secondary stress intensity is reported for the grapple pull plus thermal conditions, the possibility of sign reversal is addressed by applying a reverse grapple pull load to the complete model. By excluding gap elements between the inner and outer cover plates, this effectively reverses the sign of the grapple pull stress components such that when thermal stresses are superimposed the resulting effect provides the range (or difference)

between the grapple pull and each of the applicable thermal conditions. The maximum primary plus secondary stress intensity range for the Grapple Pull and Thermal conditions is determined from the maximum of (Thermal + Grapple Pull) and (Thermal - Grapple Pull).

In general, major loads are combined within the ANSYS analyses while stress intensities from minor loads (i.e., deadweight, low-g value, and pressure (bottom end only) are added (absolutely) by hand. This approach minimizes the conservatism of adding stress intensities, for which signs are lost, while also minimizing the number of analysis load steps. Combining load condition stress intensities at the resultant level gives higher load combination stress intensity values when compared to combining stresses (σ_x, σ_y, etc.) at the component level to determine load combination stress intensities. This method of combination is analogous to adding vector scalar values, which always gives larger values than the absolute scalar value of the vector sum. In a few instances, stress components were combined before determining the stress intensity. The load combinations which use this method are noted in the appropriate tables in Section 9.2.

When the FO-DSC is in a vertical position, the bottom-end components are evenly supported by the bottom of the cask. The cover plates and shield plug bear against each other. The stresses resulting from the self-weight of the end components can be calculated as the product of the material density and the supported thickness. Considering the total thickness of 8.75" of the cover plates and shield plug, the deadweight stresses will be negligible. The deadweight of the basket assembly and fuel is supported by the bottom end components when the FO-DSC is in the vertical position. The load is assumed to be distributed evenly on the inner bottom cover plate. From Reference 11, the weight of the PWR 17x17 fuel is 35,568 lbs and the weight of the basket assembly is 18,520 lbs. Considering a load area based on the inside radius of the shell, the deadweight stress

$$P_m = (35{,}568 + 18{,}520 \text{ lb}) / \pi(32.97)^2$$

$$= 16 \text{ psi.}$$

This stress is small and is neglected in the analysis.

9.1.1 FO-DSC Components

Component stress results were post-processed using the ANSYS LPATH and PRSECT commands which linearize the stress distribution through a requested section, resulting in a breakdown of the various stress components. Included in the ANSYS stress summaries are the membrane and membrane + bending stresses. Stress sections were taken through the shortest possible path through the thickness of each FO-DSC component based on the location of the nodes. For the 90° models, which consider axisymmetric loading and boundary conditions, stress sections were taken at every node location along the 0° symmetry plane, except for the shell. Shell stress sections were limited to the region of the end components (approximately to within 5 inches inside of the support ring and the inner bottom cover plate) and at the shell mid-height. For the 180° models, stress sections were taken at essentially every node location, with limitations of the shell as noted above for the 90° models.

Stress contour plots, included in Appendices B1 through B33, indicate the critical locations of stress for each component, for each applicable load case. Stress values provided on the contour plots correspond to the total stress, which includes peak effects.

Maximum membrane and membrane plus bending stress intensities were obtained by post-processing output files. Table 9-5 through Table 9-17 summarize the maximum stress intensities for each analysis run and for each applicable load step. Also included in the postprocessed results are nodal forces applicable to locations of welds, obtained using the ANSYS NFORC command. The maximum weld forces for each analysis run are summarized in Table 9-18 through Table 9-22.

Bottom end drop loading was analyzed only for the top end model. In this orientation, the end plates are supported at the perimeter by the shell. For end plates on the drop end, uniform support is assumed to be provided by the end plate of the transfer cask. Therefore, bending stresses will be minimal. However, the weight of fuel and basket compresses the end plates. As calculated in the previous section, the compressive stress due to deadweight of the fuel and basket is 16 psi. Scaling the deadweight stress for a conservative drop acceleration of 60g, the compressive stress is 916 psi. Additionally, for a maximum total end plate / shield plug thickness of 10.25 in. (top end), stress due to the accelerated deadweight of the end plates is

$$P_m = (0.285\ \text{lb/in}^3)(10.25\ \text{in.})60g$$
$$= 175\ \text{psi}$$

Therefore, the total maximum compressive stress on the end plates is 916 + 175 = 1,091 psi. This compressive stress is entered as membrane stress in the stress summary tables for the outer top cover plate and inner top cover plate (Table 10-2 and *Stresses based on results listed in Table 8-9 for pressure applied to the outer pressure boundary.

Table 10-3). Membrane stresses for the top shield plug are greater than 1,091 psi for the drop conditions analyzed, and therefore, control.

For the analysis of end drops, stress sections considered include the mid-height of the shell which is the boundary of the top end and bottom end models. Additional membrane stress due to the accelerated weight of the "missing" half of the shell is calculated as follows:

$$P_m = (0.285\ \text{lb/in}^3)(186.17\ \text{in./2})60g$$
$$= 1{,}591\ \text{psi}$$

Membrane stresses at the shell mid-height were compared to those at the controlling location for both the top and bottom end models and were found to be lower by a margin greater than 1,591 psi. Therefore, the stress summary tables are unaffected.

Note that during the end drop, the shield plug contact with the support ring occurs at support ring nodes midway through the thickness of the support ring. Thus, shell stresses due to the eccentric loading of the support ring are taken into consideration when evaluating the shell.

For load combinations UL-3, UL-4, and UL-5 in the bottom shell and load combination UL-5 in the outer bottom cover plate, the net stress intensity is determined by combining the stress components

corresponding to the maximum stress intensity for each ANSYS® run. This stress intensity is slightly conservative due to the fact that the maximum stress intensity in a particular ANSYS® run is not necessarily located at the same location for other runs contributing to the total stress intensity.

9.1.2 Welds

Nodal weld forces are included in the postprocessing output files. Table 9-18 through Table 9-22 summarize the maximum resultant nodal force for each load step of each run. Weld stresses are calculated as

$$f_w = F_{resultant} / (L_{tributary})(T_{weld})$$

where

$F_{resultant}$ = maximum resultant nodal force
$L_{tributary}$ = minimum tributary length associated with the node
= 1.50 in. for horizontal deadweight and side drop models (= rail width)
= 1.99 in. for all other models based in the inner radius of the shell
T_{weld} = appropriate weld throat or base metal dimension

Table 9-1 ANSYS Run Summary for Top End

Analysis Run I.D. (1,2,3) (POST1 Run I.D.)	Load Description	Boundary Conditions	Plot Files
QT24PIP (PT24PIP)	10 psi, 20 psi & 60 psi internal pressure on inner pressure boundary	a	pt24pip.pic
QT24PFL (PT24PFL)	22 psi external flood pressure, + 10 psi internal pressure	a	pt24pfl.pic
QT24PED (PT24PED)	1g axial, 60g bottom-end drop acceleration, + 20 psi internal pressure	a	pt24ped.pic
QT24P1G (PT24P1G)	1g axial acceleration outward + 10 psi pressure on shield plug (fuel/sleeves inertial load)	a	pt24p1g.pic
T24PDW (PT24PDW)	1g vertical acceleration on horizontal DSC	a + c	pt24pdw.pic
T24PSD (PT24PSD)	75g side drop acceleration	a + c	pt24psd.pic
T24PSDP (PT24PSDP)	75g side drop acceleration + 20 psi internal pressure	a + c	pt24psdp.pic
T24PTH (PT24PTH)	Thermal load cases 7, 8, 15, & 16	a	pt24pth.pic
T24PTH2 (PT24PTH2)	Thermal load cases 26	a	pt24pth2.pic
T24PTHP (PT24PTHP)	Thermal load case 7 + 10 psi internal pressure	a	pt24pthp.pic
T24PTP2 (PT24PTP2)	Thermal load cases 8, 15, & 16 + 10 psi internal pressure	a	pt24ptp2.pic
T24PTP3 (PT24PTP3)	Thermal case 26 + 10 psi internal pressure	a	pt24ptp3.pic

Boundary Conditions (see Table 9-3 for sketches):

a) Axial restraint of all nodes at mid-height of the DSC (end of model). An additional node is restrained in the u_x-direction for stability of the 180° models.
b) Radial restraint of one node at top-end of shell. Radial and axial restraint of one node at shell mid-height. (All restraints are at plane of symmetry)
c) Radial restraint along two lines of nodes at outer radius: at plane of symmetry and at 1.5" (half-rail width).

Notes:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Analysis Run I.D.s beginning with *Q* indicate that a 90° (quarter) model is used. All other models are 180°. Postprocessing Run I.D.s begin with *P*.
3. List of ANSYS® runs does not include thermal runs.

Table 9-2 ANSYS Run Summary for Bottom End

Analysis Run I.D. [1,2,3] (POST1 Run I.D.)	Load Description	Boundary Conditions	Plot Files
QB24PLT (PB24PLT)	14.7 psi external + 155 k axial load (shell & inner bottom cover plate only)	a	pb24plt.pic
QB24PIP (PB24PIP)	10 psi & 60 psi internal pressure on inner pressure boundary[4]	a	pb24pip.pic
QB24PFL (PB24PFL)	22 psi external flood pressure, + 10 psi internal pressure	a	pb24pfl.pic
QB24PED (PB24PED)	1g axial, 60g top-end drop acceleration, + 10 psi internal pressure	a	pb24ped.pic
QB24P1G (PB24P1G)	1g axial acceleration outward + 10 psi pressure on inner cover plate (fuel/sleeves inertial load)	a	pb24p1g.pic
B24PDW (PB24PDW)	1g vertical acceleration on horizontal DSC	a + c	pb24pdw.pic
B24PSID2 (PB24PSD2)	75g side drop acceleration	a + c	pb24psd2.pic
B24PSID3 (PB24PSD3)	75g side drop acceleration + 20 psi internal pressure	a + c	pb24psd3.pic
B24PTH (PB24PTH)	Thermal load cases 7, 8, 15, & 16	a	pb24pth.pic
B24PTH2 (PB24PTH2)	Thermal load case 26	a	pb24pth2.pic
B24PGP1 (PB24PGP1)	60 kip, 80 kip Grapple pull (grapple assembly model only; for primary stress determination)	d	pb24pgp1.pic
B24PGP2 (PB24PGP2)	60 kip, 80 kip Grapple pull, + 20 psi internal pressure on outer pressure boundary (w/o grapple assembly; for primary stress determination)	b	pb24pgp2.pic
B24PGP3 (PB24PGP3)	60 kip Grapple pull (w/o grapple assembly; axisymm. boundaries for comparison to B24PGP2)	a	pb24pgp3.pic
B24PTHG (PB24PTHG)	60 kip Grapple pull + Thermal load cases 15, 16, & 26	a	pb24pthg.pic
B24PT-G (PB24PT-G)	-(60 kip Grapple pull) + Thermal load cases 15, 16, & 26 (to capture stress range)	a	pb24pt-g.pic

(continued on next page)

Table 9-2 - ANSYS Run Summary for Bottom End (continued)

Analysis Run I.D. [1,2] (POST1 Run I.D.)	Load Description	Boundary Conditions	Plot Files
B24PRAM (PB24PRAM)	60 kip, 80 kip Ram push	a	pb24pram.pic
B24PTHR (PB24PTHR)	60 kip Ram push + Thermal load cases 7 & 8	a	pb24pthr.pic
B24PTR2 (PB24PTR2)	60 kip Ram push + Thermal load cases 7 & 8	b	pb24ptr2.pic
B24PTR3 (PB24PTR3)	80 kip Ram push + Thermal load cases 7 & 8	b	pb24ptr3.pic
QB24PED (PB24PED)	1g axial, 60g top-end drop acceleration, + 20 psi internal pressure[4]	a	pb24ped.pic

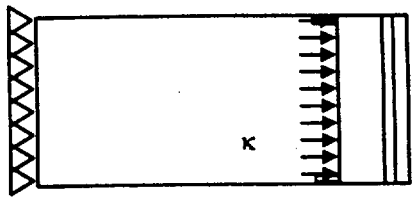
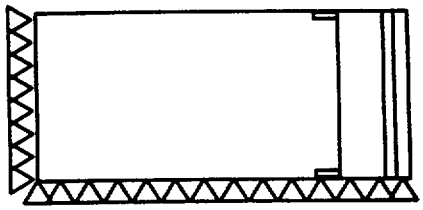
Boundary Conditions (see Table 9-4 for sketches):

a) Axial restraint at all nodes at mid-height of the DSC (end of model). An additional node is restrained in the ux-direction for stability of the 180° models.
b) Radial restraint of one node at bottom-end of shell. Radial and axial restraint of one node at shell mid-height. (All restraints are at plane of symmetry).
c) Radial restraint along two lines of nodes at outer radius: at plane of symmetry and at 1.5" (half-rail width).
d) Grapple assembly base fixed.

Notes:

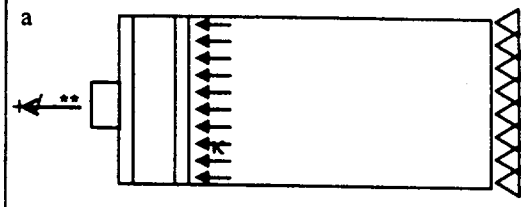
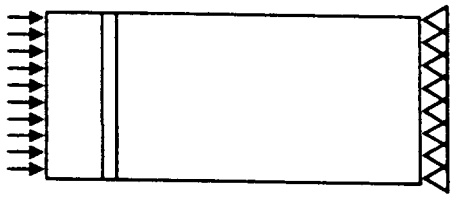
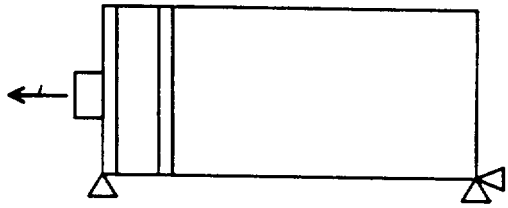
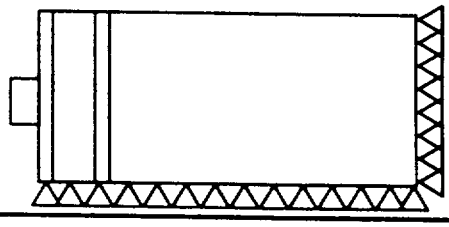
1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Analysis Run I.D.s beginning with *Q* indicate that a 90° (quarter) model is used. All other models are 180°. Postprocessing Run I.D.s begin with *P*.
3. List of ANSYS® runs does not include thermal runs.
4. Results for 20 psi load combinations are linearly scaled from the 10 psi load case.

Table 9-3 - Top End Boundary Conditions

ANSYS Run I.D. / Loading Description*	Boundary Conditions
QT24PIP, QT24PFL, QT24PED, QT24P1G, T24PTH, T24PTH2, T24PTHP, T24PTP2, T24PTP3 Pressure, Thermal, +/- 1 g axial, , 1g fuel/sleeves	a  Fuel and basket load (κ) QT24P1G only
T24PDW, T24PSD, T24PSDP 1g vertical/lateral, 75g Side Drop including Pressure	a+c 

* Pressure, Thermal & g-loads not shown on the sketch. Other g-loads (e.g., 0.5g) are scaled from the 1-g loading.

Table 9-4 - Bottom End Boundary Conditions

ANSYS Run I.D. / Loading Description*	Boundary Conditions
QB24PIP, QB24PFL, QB24P1G, B24PTH, B24PTH2, B24PGP3, B24PTHG, B24PT-G, B24PTHR, B24PRAM, B24PTR2, B24PTR3, QB24PED Pressure, Thermal, +/- 1 g axial, End Drop, 60 kip Grapple Pull+Thermal, 60 kip / 80 kip Ram Push+Thermal, κ 1g fuel/sleeves	a  ** as applicable, pressure due to weight of basket and fuel (κ) QB24P1G only
QB24PLT Leak Test including Pressure + 155 kip Preload	a 
B24PGP1***, B24PGP2, 60 kip / 80 kip Grapple Pull (60 psi on outer press. Boundary, 60 kip +Thermal) *** Grapple assembly only, fixed at base	b, d 
B24PDW, B24PSID2, B24PSID3 1g vertical / lateral, 75g Side Drop including Pressure	a+c 

* Pressure, Thermal & g-loads are not shown on the sketch. Other g-loads (e.g., 0.5g) are scaled from the 1-g loading.

Table 9-5 Load Condition Stress[1] Results for Cylindrical Shell (Top Half)

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PT24PIP.out	P_m	-	5,138	1,699	-	-	-	-
	P_m+P_b	-	8,210	4,430	-	-	-	-
PT24PFL.out	P_m	-	1,526	1,577	869	871	-	-
	P_m+P_b	-	2,807	2,865	1,556	1,594	-	-
PT24PED.out	P_m	-	149	8,983	9,049	9,159	9,164	-
	P_m+P_b	-	355	21,350	21,620	19,140	19,150	-
PT24P1G.out	P_m	-	677	650	-	-	-	-
	P_m+P_b	-	1,156	1,049	-	-	-	-
PT24PDW.out	P_m	-	2,447	2,581	-	-	-	-
	P_m+P_b	-	2,744	3,007	-	-	-	-
PT24PSD.out	P_m	-	-	33,780	29,220	-	-	-
	P_m+P_b	-	-	41,610	38,210	-	-	-
PT24PSDP.out	P_m	-	-	-	33,240	29,050	-	-
	P_m+P_b	-	-	-	41,380	37,660	-	-
PT24PTH.out	P_m	14,490	10,480	6,922	7,422	-	-	-
	P_m+P_b	15,020	11,020	10,250	11,810	-	-	-
PT24PTH2.out	P_m	7,618	-	-	-	-	-	-
	P_m+P_b	12,100	-	-	-	-	-	-
P24PTHP.out	P_m	-	14,330	-	-	-	-	-
	P_m+P_b	-	14,800	-	-	-	-	-
PT24PTP2.out	P_m	-	10,330	9,184	9,693	-	-	-
	P_m+P_b	-	12,900	15,160	16,250	-	-	-
PT24PTP3.out	P_m	-	9,893	-	-	-	-	-
	P_m+P_b	-	16,320	-	-	-	-	-

Notes:
1. Stress Intensities shown in Psi.
2. Origin is located at the center of the outer bottom cover plate, at the outer surface. Theta=0 is along the positive x-axis.
3. Deadweight (horizontal) results are scaled to obtain stresses for vertical and lateral seismic and handling loads.
4. Maximum thermal stresses of PT24PTH (cases 7,8,15,16) and PT24PTH2 (case 26) are reported.
5. The maximum stresses of PT24P1G, steps 3 & 2 (outward) and PT24PED, step 2 (inward) are reported for 1g axial handling load.

Table 9-6 Load Condition Stress[1] Results for Outer Top Cover Plate

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PT24PIP.out	P_m	-	1,657	1,306	-	-	-	-
	P_m+P_b	-	4,510	4,078	-	-	-	-
PT24PFL.out	P_m	-	374	204	151	158	-	-
	P_m+P_b	-	549	460	277	304	-	-
PT24PED.out	P_m	-	21	1,309	753	617	617	-
	P_m+P_b	-	43	2,621	1,770	1,321	1,321	-
PT24P1G.out	P_m	-	147	164	-	-	-	-
	P_m+P_b	-	337	383	-	-	-	-
PT24PDW.out	P_m	-	966	1,141	-	-	-	-
	P_m+P_b	-	1,204	1,728	-	-	-	-
PT24PSD.out	P_m	-	-	36,850	35,350	-	-	-
	P_m+P_b	-	-	52,520	52,100	-	-	-
PT24PSDP.out	P_m	-	-	-	37,000	35,400	-	-
	P_m+P_b	-	-	-	52,620	51,740	-	-
PT24PTH.out	P_m	13,080	9,628	3,531	3,162	-	-	-
	P_m+P_b	13,210	9,813	3,783	3,500	-	-	-
PT24PTH2.out	P_m	3,194	-	-	-	-	-	-
	P_m+P_b	3,561	-	-	-	-	-	-
P24PTHP.out	P_m	-	12,980	-	-	-	-	-
	P_m+P_b	-	13,160	-	-	-	-	-
PT24PTP2.out	P_m	-	9,251	3,499	3,173	-	-	-
	P_m+P_b	-	10,510	4,965	5,522	-	-	-
PT24PTP3.out	P_m	-	3,222	-	-	-	-	-
	P_m+P_b	-	5,615	-	-	-	-	-

Notes:
1. Stress Intensities shown in Psi.
2. Origin is located at the center of the outer bottom cover plate, at the outer surface. Theta=0 is along the positive x-axis.
3. Deadweight (horizontal) results are scaled to obtain stresses for vertical and lateral seismic and handling loads.
4. Maximum thermal stresses of PT24PTH (cases 7,8,15,16) and PT24PTH2 (case 26) are reported.
5. The maximum stresses of PT24P1G, steps 3 & 2 (outward) and PT24PED, step 2 (inward) are reported for 1g axial handling load.

Table 9-7 Load Condition Stress[1] Results for Outer Top Cover Plate Weld

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PT24PIP.out	P_m	-	5,427	0	-	-	-	-
	P_m+P_b	-	8,527	0	-	-	-	-
PT24PFL.out	P_m	-	932	0	0	24	-	-
	P_m+P_b	-	1,411	0	0	32	-	-
PT24PED.out	P_m	-	58	3,523	0	0	4	-
	P_m+P_b	-	92	5,540	0	0	6	-
PT24P1G.out	P_m	-	241	0	-	-	-	-
	P_m+P_b	-	407	0	-	-	-	-
PT24PDW.out	P_m	-	678	0	-	-	-	-
	P_m+P_b	-	941	0	-	-	-	-
PT24PSD.out	P_m	-	-	3,146	3,867	-	-	-
	P_m+P_b	-	-	3,737	4,690	-	-	-
PT24PSDP.out	P_m	-	-	-	10,720	3,564	-	-
	P_m+P_b	-	-	-	16,460	9,591	-	-
PT24PTH.out	P_m	14,290	10,350	6,603	7,019	-	-	-
	P_m+P_b	15,020	10,920	8,135	9,731	-	-	-
PT24PTH2.out	P_m	7,212	-	-	-	-	-	-
	P_m+P_b	10,040	-	-	-	-	-	-
P24PTHP.out	P_m	-	14,110	-	-	-	-	-
	P_m+P_b	-	14,790	-	-	-	-	-
PT24PTP2.out	P_m	-	10,040	5,146	5,556	-	-	-
	P_m+P_b	-	11,580	8,568	9,447	-	-	-
PT24PTP3.out	P_m	-	5,699	-	-	-	-	-
	P_m+P_b	-	9,661	-	-	-	-	-

Notes
1. Stress Intensities shown in Psi.
2. Origin is located at the center of the outer bottom cover plate, at the outer surface. Theta=0 is along the positive x-axis.
3. Deadweight (horizontal) results are scaled to obtain stresses for vertical and lateral seismic and handling loads.
4. Maximum thermal stresses of PT24PTH (cases 7,8,15,16) and PT24PTH2 (case 26) are reported.
5. The maximum stresses of PT24P1G, step 2 (outward) and PT24PED, step 2 (inward) are reported for 1g axial handling load.

Table 9-8 Load Condition Stress[1] Results for Inner Top Cover Plate

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PT24PIP.out	P_m	-	729	431	-	-	-	-
	P_m+P_b	-	3,139	3,935	-	-	-	-
PT24PFL.out	P_m	-	155	224	112	111	-	-
	P_m+P_b	-	377	503	283	283	-	-
PT24PED.out	P_m	-	6	368	342	205	206	-
	P_m+P_b	-	33	2,018	1,992	1,493	1,494	-
PT24P1G.out	P_m	-	1,649	1,665	-	-	-	-
	P_m+P_b	-	1,853	1,846	-	-	-	-
PT24PDW.out	P_m	-	571	588	-	-	-	-
	P_m+P_b	-	1,632	1,680	-	-	-	-
PT24PSD.out	P_m	-	-	24,360	25,280	-	-	-
	P_m+P_b	-	-	37,870	38,350	-	-	-
PT24PSDP.out	P_m	-	-	-	24,000	24,910	-	-
	P_m+P_b	-	-	-	39,060	41,820	-	-
PT24PTH.out	P_m	10,750	7,106	3,270	2,929	-	-	-
	P_m+P_b	11,200	7,715	3,705	3,079	-	-	-
PT24PTH2.out	P_m	2,945	-	-	-	-	-	-
	P_m+P_b	3,157	-	-	-	-	-	-
P24PTHP.out	P_m	-	10,760	-	-	-	-	-
	P_m+P_b	-	11,580	-	-	-	-	-
PT24PTP2.out	P_m	-	7,268	4,061	3,292	-	-	-
	P_m+P_b	-	12,740	9,896	9,256	-	-	-
PT24PTP3.out	P_m	-	3,288	-	-	-	-	-
	P_m+P_b	-	9,221	-	-	-	-	-

Notes
1. Stress Intensities shown in Psi.
2. Origin is located at the center of the outer bottom cover plate, at the outer surface. Theta=0 is along the positive x-axis.
3. Deadweight (horizontal) results are scaled to obtain stresses for vertical and lateral seismic and handling loads.
4. Maximum thermal stresses of PT24PTH (cases 7,8,15,16) and PT24PTH2 (case 26) are reported.
5. The maximum stresses of PT24P1G, steps 3 & 2 (outward) and PT24PED, step 2 (inward) are reported for 1g axial handling load.

Table 9-9 Load Condition Stress[1] Results for Top Shield Plug

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PT24PIP.out	P_m	-	0	0	-	-	-	-
	P_m+P_b	-	0	0	-	-	-	-
PT24PFL.out	P_m	-	161	168	92	93	-	-
	P_m+P_b	-	490	500	273	274	-	-
PT24PED.out	P_m	-	24	1,465	1,487	1,348	1,348	-
	P_m+P_b	-	64	3,841	3,879	3,429	3,429	-
PT24P1G.out	P_m	-	170	170	-	-	-	-
	P_m+P_b	-	421	421	-	-	-	-
PT24PDW.out	P_m	-	243	243	-	-	-	-
	P_m+P_b	-	398	398	-	-	-	-
PT24PSD.out	P_m	-	-	21,740	21,980	-	-	-
	P_m+P_b	-	-	37,680	37,230	-	-	-
PT24PSDP.out	P_m	-	-	-	21,920	22,120	-	-
	P_m+P_b	-	-	-	38,230	37,710	-	-
PT24PTH.out	P_m	0	0	0	0	-	-	-
	P_m+P_b	0	0	0	0	-	-	-
PT24PTH2.out	P_m	0	-	-	-	-	-	-
	P_m+P_b	0	-	-	-	-	-	-
P24PTHP.out	P_m	-	0	-	-	-	-	-
	P_m+P_b	-	0	-	-	-	-	-
PT24PTP2.out	P_m	-	0	0	0	-	-	-
	P_m+P_b	-	0	0	0	-	-	-
PT24PTP3.out	P_m	-	0	-	-	-	-	-
	P_m+P_b	-	0	-	-	-	-	-

Notes
1. Stress Intensities shown in Psi.
2. Origin is located at the center of the outer bottom cover plate, at the outer surface. Theta=0 is along the positive x-axis.
3. Deadweight (horizontal) results are scaled to obtain stresses for vertical and lateral seismic and handling loads.
4. Maximum thermal stresses of PT24PTH (cases 7,8,15,16) and PT24PTH2 (case 26) are reported.
5. The maximum stresses of PT24P1G, steps 3 & 2 (outward) and PT24PED, step 2 (inward) are reported for 1g axial handling load.

Table 9-10 - Load Condition Stress[1] Results for Support Ring

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PT24PIP.out	P_m	-	492	532	-	-	-	-
	P_m+P_b	-	559	564	-	-	-	-
PT24PFL.out	P_m	-	1,355	1,375	758	756	-	-
	P_m+P_b	-	1,883	1,936	1,063	1,064	-	-
PT24PED.out	P_m	-	100	6,043	6,123	6,123	5,962	-
	P_m+P_b	-	174	10,430	10,600	10,600	9,534	-
PT24P1G.out	P_m	-	307	309	-	-	-	-
	P_m+P_b	-	334	336	-	-	-	-
PT24PDW.out	P_m	-	200	208	-	-	-	-
	P_m+P_b	-	225	234	-	-	-	-
PT24PSD.out	P_m	-	-	14,150	5,322	-	-	-
	P_m+P_b	-	-	24,900	9,899	-	-	-
PT24PSDP.out	P_m	-	-	-	12,840	3,775	-	-
	P_m+P_b	-	-	-	23,390	6,591	-	-
PT24PTH.out	P_m	3,644	2,657	1,459	1,381	-	-	-
	P_m+P_b	4,229	2,739	2,408	1,827	-	-	-
PT24PTH2.out	P_m	1,279	-	-	-	-	-	-
	P_m+P_b	1,759	-	-	-	-	-	-
P24PTHP.out	P_m	-	3,691	-	-	-	-	-
	P_m+P_b	-	4,276	-	-	-	-	-
PT24PTP2.out	P_m	-	2,683	1,908	1,846	-	-	-
	P_m+P_b	-	2,939	2,828	2,289	-	-	-
PT24PTP3.out	P_m	-	1,744	-	-	-	-	-
	P_m+P_b	-	2,221	-	-	-	-	-

Notes
1. Stress Intensities shown in Psi.
2. Origin is located at the center of the outer bottom cover plate, at the outer surface. Theta=0 is along the positive x-axis.
3. Deadweight (horizontal) results are scaled to obtain stresses for vertical and lateral seismic and handling loads.
4. Maximum thermal stresses of PT24PTH (cases 7,8,15,16) and PT24PTH2 (case 26) are reported.
5. The maximum stresses of PT24P1G, steps 3 & 2 (outward) and PT24PED, step 2 (inward) are reported for 1g axial handling load.

Table 9-11 - Load Condition Stress[1] Results for Cylindrical Shell (Bottom Half)

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PB24PLT.out	P_m	8,226	-	-	-	-	-	-
	P_m+P_b	17,820	-	-	-	-	-	-
PB24PIP.out	P_m	-	629	629	-	-	-	-
	P_m+P_b	-	1,287	1,344	-	-	-	-
PB24PFL.out	P_m	-	1,383	1,383	755	755	-	-
	P_m+P_b	-	2,558	2,717	1,437	1,462	-	-
PB24PED.out	P_m	-	184	10,870	10,860	10,860	10,860	-
	P_m+P_b	-	397	24,160	24,160	24,160	24,160	-
PB24P1G.out	P_m	-	852	834	-	-	-	-
	P_m+P_b	-	2,853	2,732	-	-	-	-
PB24PDW.out	P_m	2,501	2,565	-	-	-	-	-
	P_m+P_b	2,809	3,102	-	-	-	-	-
PB24PSD2.out	P_m	32,630	26,290	-	-	-	-	-
	P_m+P_b	39,190	43,290	-	-	-	-	-
PB24PSD3.out	P_m	32,530	26,170	-	-	-	-	-
	P_m+P_b	39,100	43,160	-	-	-	-	-
PB24PTH.out	P_m	21,390	15,630	6,990	7,259	-	-	-
	P_m+P_b	22,150	16,330	10,470	10,560	-	-	-
PB24PTH2.out	P_m	7,507	-	-	-	-	-	-
	P_m+P_b	10,810	-	-	-	-	-	-
PB24PGP1.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP2.out	P_m	16,970	22,630	25,660	-	-	-	-
	P_m+P_b	22,960	30,610	34,850	-	-	-	-
PB24PGP3.out	P_m	2,149	-	-	-	-	-	-
	P_m+P_b	2,549	-	-	-	-	-	-
PB24PTHG.out	P_m	9,549	10,340	10,370	10,480	-	-	-
	P_m+P_b	20,460	21,040	21,580	21,770	-	-	-
PB24PT-G.out	P_m	9,547	12,680	12,700	-	-	-	-
	P_m+P_b	20,460	25,090	25,120	-	-	-	-
PB24RAM.out	P_m	-	814	2,661	-	-	-	-
	P_m+P_b	-	1,822	2,429	-	-	-	-
PB24PTHR.out	P_m	-	813	21,040	15,440	-	-	-
	P_m+P_b	-	1,821	22,040	15,930	-	-	-
PB24PTR2.out	P_m	-	-	21,810	16,130	-	-	-
	P_m+P_b	-	-	23,190	17,420	-	-	-
PB24PTR3.out	P_m	-	-	21,990	16,300	-	-	-
	P_m+P_b	-	-	23,790	17,990	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-12 - Load Condition Stress[1] Results for Outer Bottom Cover Plate

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PB24PLT.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PIP.out	P_m	-	396	617	-	-	-	-
	P_m+P_b	-	874	1,069	-	-	-	-
PB24PFL.out	P_m	-	373	304	267	271	-	-
	P_m+P_b	-	439	470	402	429	-	-
PB24PED.out	P_m	-	27	1,649	1,649	1,649	1,649	-
	P_m+P_b	-	51	3,127	3,126	3,127	3,127	-
PB24P1G.out	P_m	-	845	1,264	-	-	-	-
	P_m+P_b	-	1,836	2,178	-	-	-	-
PB24PDW.out	P_m	658	695	-	-	-	-	-
	P_m+P_b	1,101	1,174	-	-	-	-	-
PB24PSD2.out	P_m	23,340	23,150	-	-	-	-	-
	P_m+P_b	33,400	34,080	-	-	-	-	-
PB24PSD3.out	P_m	23,160	22,980	-	-	-	-	-
	P_m+P_b	32,960	33,630	-	-	-	-	-
PB24PTH.out	P_m	18,810	13,720	3,660	3,068	-	-	-
	P_m+P_b	19,640	14,050	4,424	3,555	-	-	-
PB24PTH2.out	P_m	3,097	-	-	-	-	-	-
	P_m+P_b	3,602	-	-	-	-	-	-
PB24PGP1.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP2.out	P_m	15,080	20,110	23,300	-	-	-	-
	P_m+P_b	23,890	31,850	41,050	-	-	-	-
PB24PGP3.out	P_m	4,633	-	-	-	-	-	-
	P_m+P_b	22,750	-	-	-	-	-	-
PB24PTHG.out	P_m	5,723	8,711	7,927	7,954	-	-	-
	P_m+P_b	22,860	24,180	23,540	23,520	-	-	-
PB24PT-G.out	P_m	5,722	5,809	5,838	-	-	-	-
	P_m+P_b	22,850	24,240	24,310	-	-	-	-
PB24RAM.out	P_m	-	3,528	4,703	-	-	-	-
	P_m+P_b	-	7,256	9,674	-	-	-	-
PB24PTHR.out	P_m	-	3,481	18,320	13,270	-	-	-
	P_m+P_b	-	7,229	19,280	13,830	-	-	-
PB24PTR2.out	P_m	-	-	18,610	13,530	-	-	-
	P_m+P_b	-	-	19,850	14,760	-	-	-
PB24PTR3.out	P_m	-	-	18,600	13,510	-	-	-
	P_m+P_b	-	-	19,960	16,910	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-13 - Load Condition Stress[1] Results for Outer Bottom Cover Plate Weld

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PB24PLT.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PIP.out	P_m	-	289	0	-	-	-	-
	P_m+P_b	-	425	0	-	-	-	-
PB24PFL.out	P_m	-	799	0	0	22	-	-
	P_m+P_b	-	987	0	0	30	-	-
PB24PED.out	P_m	-	72	4,445	4,444	4,445	4,445	-
	P_m+P_b	-	89	5,442	5,442	5,442	5,442	-
PB24P1G.out	P_m	-	640	0	-	-	-	-
	P_m+P_b	-	946	0	-	-	-	-
PB24PDW.out	P_m	528	0	-	-	-	-	-
	P_m+P_b	679	0	-	-	-	-	-
PB24PSD2.out	P_m	22,340	0	-	-	-	-	-
	P_m+P_b	27,230	0	-	-	-	-	-
PB24PSD3.out	P_m	22,010	0	-	-	-	-	-
	P_m+P_b	26,930	0	-	-	-	-	-
PB24PTH.out	P_m	21,080	15,220	6,169	5,804	-	-	-
	P_m+P_b	21,710	15,750	7,544	7,990	-	-	-
PB24PTH2.out	P_m	5,930		-	-	-	-	-
	P_m+P_b	8,220		-	-	-	-	-
PB24PGP1.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP2.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP3.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PTHG.out	P_m	8,945	10,100	10,460	10,570	-	-	-
	P_m+P_b	10,960	14,120	14,490	14,690	-	-	-
PB24PT-G.out	P_m	8,946	12,060	12,070	-	-	-	-
	P_m+P_b	10,960	15,090	15,120	-	-	-	-
PB24RAM.out	P_m	-	373	497	-	-	-	-
	P_m+P_b	-	455	606	-	-	-	-
PB24PTHR.out	P_m	-	377	20,690	14,960	-	-	-
	P_m+P_b	-	459	21,480	15,360	-	-	-
PB24PTR2.out	P_m	-	-	21,360	15,560	-	-	-
	P_m+P_b	-	-	22,370	16,080	-	-	-
PB24PTR3.out	P_m	-	-	21,500	15,690	-	-	-
	P_m+P_b	-	-	22,620	16,320	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-14 - Load Condition Stress[1] Results for Bottom Shield Plug

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PB24PLT.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PIP.out	P_m	-	104	106	-	-	-	-
	P_m+P_b	-	312	313	-	-	-	-
PB24PFL.out	P_m	-	163	164	89	90	-	-
	P_m+P_b	-	718	731	424	425	-	-
PB24PED.out	P_m	-	19	1,188	1,188	1,188	1,188	-
	P_m+P_b	-	74	4,479	4,479	4,479	4,479	-
PB24P1G.out	P_m	-	216	215	-	-	-	-
	P_m+P_b	-	574	574	-	-	-	-
PB24PDW.out	P_m	311	311	-	-	-	-	-
	P_m+P_b	315	314	-	-	-	-	-
PB24PSD2.out	P_m	24,720	24,660	-	-	-	-	-
	P_m+P_b	25,590	25,520	-	-	-	-	-
PB24PSD3.out	P_m	24,770	24,710	-	-	-	-	-
	P_m+P_b	26,400	26,440	-	-	-	-	-
PB24PTH.out	P_m	0	0	0	0	-	-	-
	P_m+P_b	0	0	0	0	-	-	-
PB24PTH2.out	P_m	0	-	-	-	-	-	-
	P_m+P_b	0	-	-	-	-	-	-
PB24PGP1.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP2.out	P_m	0	0	0	-	-	-	-
	P_m+P_b	0	0	0	-	-	-	-
PB24PGP3.out	P_m	0	-	-	-	-	-	-
	P_m+P_b	0	-	-	-	-	-	-
PB24PTHG.out	P_m	0	2,848	2,434	2,492	-	-	-
	P_m+P_b	0	3,178	2,587	2,644	-	-	-
PB24PT-G.out	P_m	0	2,434	2,492	-	-	-	-
	P_m+P_b	0	2,587	2,644	-	-	-	-
PB24RAM.out	P_m	-	349	465	-	-	-	-
	P_m+P_b	-	2,199	2,933	-	-	-	-
PB24PTHR.out	P_m	-	346	10,340	8,383	-	-	-
	P_m+P_b	-	2,194	11,080	9,359	-	-	-
PB24PTR2.out	P_m	-	-	10,030	8,291	-	-	-
	P_m+P_b	-	-	10,510	8,841	-	-	-
PB24PTR3.out	P_m	-	-	10,040	8,290	-	-	-
	P_m+P_b	-	-	10,380	8,710	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-15 - Load Condition Stress[1] Results for Inner Bottom Cover Plate

Run I.D	Stress	Load Step 1	2	3	4	5	6	7
PB24PLT.out	P_m	1,255	-	-	-	-	-	-
	P_m+P_b	18,990	-	-	-	-	-	-
PB24PIP.out	P_m	-	272	274	-	-	-	-
	P_m+P_b	-	731	737	-	-	-	-
PB24PFL.out	P_m	-	795	806	587	597	-	-
	P_m+P_b	-	1,478	1,560	969	978	-	-
PB24PED.out	P_m	-	89	5,804	5,802	5,804	5,804	-
	P_m+P_b	-	332	19,260	19,250	19,260	19,260	-
PB24P1G.out	P_m	-	229	240	-	-	-	-
	P_m+P_b	-	826	827	-	-	-	-
PB24PDW.out	P_m	693	705	-	-	-	-	-
	P_m+P_b	811	819	-	-	-	-	-
PB24PSD2.out	P_m	38,050	39,130	-	-	-	-	-
	P_m+P_b	38,980	40,070	-	-	-	-	-
PB24PSD3.out	P_m	37,750	38,820	-	-	-	-	-
	P_m+P_b	38,720	39,810	-	-	-	-	-
PB24PTH.out	P_m	15,950	10,070	6,766	4,903	-	-	-
	P_m+P_b	17,250	10,700	7,420	5,371	-	-	-
PB24PTH2.out	P_m	4,921		-	-	-	-	-
	P_m+P_b	5,386		-	-	-	-	-
PB24PGP1.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP2.out	P_m	9,891	13,190	15,450	-	-	-	-
	P_m+P_b	12,520	16,690	19,240	-	-	-	-
PB24PGP3.out	P_m	188	-	-	-	-	-	-
	P_m+P_b	216	-	-	-	-	-	-
PB24PTHG.out	P_m	785	7,302	5,444	5,462	-	-	-
	P_m+P_b	1,146	8,235	6,198	6,219	-	-	-
PB24PT-G.out	P_m	785	4,979	4,995	-	-	-	-
	P_m+P_b	1,146	5,257	5,285	-	-	-	-
PB24RAM.out	P_m	-	1,996	2,661	-	-	-	-
	P_m+P_b	-	2,866	3,821	-	-	-	-
PB24PTHR.out	P_m	-	1,991	16,110	11,920	-	-	-
	P_m+P_b	-	2,860	17,750	13,160	-	-	-
PB24PTR2.out	P_m	-	-	15,790	10,120	-	-	-
	P_m+P_b	-	-	17,420	11,540	-	-	-
PB24PTR3.out	P_m	-	-	15,850	10,220	-	-	-
	P_m+P_b	-	-	17,860	12,000	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-16 - Load Condition Stress[1] Results for Grapple Ring Support

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PB24PLT.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PIP.out	P_m	-	182	195	-	-	-	-
	P_m+P_b	-	474	508	-	-	-	-
PB24PFL.out	P_m	-	243	237	141	141	-	-
	P_m+P_b	-	628	619	365	365	-	-
PB24PED.out	P_m	-	25	1,507	1,507	1,507	1,507	-
	P_m+P_b	-	66	4,009	4,009	4,009	4,009	-
PB24P1G.out	P_m	-	485	534	-	-	-	-
	P_m+P_b	-	1,272	1,404	-	-	-	-
PB24PDW.out	P_m	35	36	-	-	-	-	-
	P_m+P_b	52	55	-	-	-	-	-
PB24PSD2.out	P_m	2,103	2,034	-	-	-	-	-
	P_m+P_b	3,152	3,198	-	-	-	-	-
PB24PSD3.out	P_m	2,081	1,904	-	-	-	-	-
	P_m+P_b	2,633	2,386	-	-	-	-	-
PB24PTH.out	P_m	8,421	6,271	1,311	1,301	-	-	-
	P_m+P_b	9,790	7,696	4,083	3,453	-	-	-
PB24PTH2.out	P_m	1,360	-	-	-	-	-	-
	P_m+P_b	3,520	-	-	-	-	-	-
PB24PGP1.out	P_m	6,060	8,080	-	-	-	-	-
	P_m+P_b	21,930	29,240	-	-	-	-	-
PB24PGP2.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP3.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PTHG.out	P_m	12,870	13,550	13,240	13,230	-	-	-
	P_m+P_b	35,410	37,620	36,590	36,550	-	-	-
PB24PT-G.out	P_m	12,860	12,850	12,870	-	-	-	-
	P_m+P_b	35,410	34,300	34,330	-	-	-	-
PB24RAM.out	P_m	-	1,169	1,558	-	-	-	-
	P_m+P_b	-	3,001	4,002	-	-	-	-
PB24PTHR.out	P_m	-	1,199	8,639	6,956	-	-	-
	P_m+P_b	-	3,074	12,550	10,670	-	-	-
PB24PTR2.out	P_m	-	-	10,570	8,937	-	-	-
	P_m+P_b	-	-	21,400	19,590	-	-	-
PB24PTR3.out	P_m	-	-	11,860	10,010	-	-	-
	P_m+P_b	-	-	25,230	23,390	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-17 - Load Condition Stress[1] Results for Grapple Ring

Run I.D	Stress	Load Step						
		1	2	3	4	5	6	7
PB24PLT.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PIP.out	P_m	-	14	15	-	-	-	-
	P_m+P_b	-	63	68	-	-	-	-
PB24PFL.out	P_m	-	17	17	9	9	-	-
	P_m+P_b	-	91	91	54	54	-	-
PB24PED.out	P_m	-	3	183	183	183	183	-
	P_m+P_b	-	8	528	529	528	528	-
PB24P1G.out	P_m	-	38	43	-	-	-	-
	P_m+P_b	-	169	187	-	-	-	-
PB24PDW.out	P_m	7	5	-	-	-	-	-
	P_m+P_b	9	9	-	-	-	-	-
PB24PSD2.out	P_m	359	245	-	-	-	-	-
	P_m+P_b	498	477	-	-	-	-	-
PB24PSD3.out	P_m	773	633	-	-	-	-	-
	P_m+P_b	799	667	-	-	-	-	-
PB24PTH.out	P_m	2,645	1,710	664	588	-	-	-
	P_m+P_b	3,747	2,535	2,756	2,277	-	-	-
PB24PTH2.out	P_m	631	-	-	-	-	-	-
	P_m+P_b	2,240	-	-	-	-	-	-
PB24PGP1.out	P_m	9,973	13,300	-	-	-	-	-
	P_m+P_b	17,310	23,080	-	-	-	-	-
PB24PGP2.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PGP3.out	P_m	-	-	-	-	-	-	-
	P_m+P_b	-	-	-	-	-	-	-
PB24PTHG.out	P_m	9,902	10,010	9,904	9,903	-	-	-
	P_m+P_b	16,310	15,350	15,560	15,570	-	-	-
PB24PT-G.out	P_m	9,982	9,898	9,899	-	-	-	-
	P_m+P_b	15,780	17,170	17,130	-	-	-	-
PB24RAM.out	P_m	-	317	423	-	-	-	-
	P_m+P_b	-	635	846	-	-	-	-
PB24PTHR.out	P_m	-	327	3,085	2,125	-	-	-
	P_m+P_b	-	654	4,498	3,200	-	-	-
PB24PTR2.out	P_m	-	-	3,841	3,119	-	-	-
	P_m+P_b	-	-	6,440	5,381	-	-	-
PB24PTR3.out	P_m	-	-	4,303	3,578	-	-	-
	P_m+P_b	-	-	7,388	6,322	-	-	-

Notes
1. Stress Intensities shown in Psi.

Table 9-18 - Load Condition Force[1] Results for Outer Top Cover Plate Weld

Run I.D	Load Step						
	1	2	3	4	5	6	7
PT24PIP.out	-	3,426	637	-	-	-	-
PT24PFL.out	-	558	110	71	82	-	-
PT24PED.out	-	38	2,277	398	372	373	-
PT24P1G.out	-	235	139	-	-	-	-
PT24PDW.out	-	913	1,076	-	-	-	-
PT24PSD.out	-	-	6,263	12,187	-	-	-
PT24PSDP.out	-	-	-	11,274	12,124	-	-
PT24PTH.out	1,816	1,248	1,370	1,698	-	-	-
PT24PTH2.out	1,730	-	-	-	-	-	-
PT24PTHP.out	-	1,530	-	-	-	-	-
PT24PTP2.out	-	2,615	3,617	3,977	-	-	-
PT24PTP3.out	-	4,034	-	-	-	-	-

Notes
1. Resultant forces shown in lbs.

Table 9-19 - Load Condition Force[1] Results for Inner Top Cover Plate Weld

Run I.D	Load Step						
	1	2	3	4	5	6	7
PT24PIP.out	-	1,173	851	-	-	-	-
PT24PFL.out	-	109	194	125	122	-	-
PT24PED.out	-	16	935	562	551	552	-
PT24P1G.out	-	629	625	-	-	-	-
PT24PDW.out	-	952	978	-	-	-	-
PT24PSD.out	-	-	8,413	8,545	-	-	-
PT24PSDP.out	-	-	-	9,141	8,964	-	-
PT24PTH.out	1,475	878	999	1,032	-	-	-
PT24PTH2.out	1,031	-	-	-	-	-	-
PT24PTHP.out	-	1,664	-	-	-	-	-
PT24PTP2.out	-	2,861	2,981	3,012	-	-	-
PT24PTP3.out	-	3,012	-	-	-	-	-

Notes
1. Resultant forces shown in lbs.

Transnuclear West Inc.

Calculation Sheet

PROJECT NO:	SCE-01	REVISION:	1
CALCULATION NO:	SCE-01.0204	PAGE:	91 of 138

Table 9-20 - Load Condition Force[1] Results for Support Ring Weld (Continuous)

Run I.D	Load Step						
	1	2	3	4	5	6	7
PT24PIP.out	-	63	100	-	-	-	-
PT24PFL.out	-	539	567	309	311	-	-
PT24PED.out	-	95	5,692	5,772	5,303	5,303	-
PT24P1G.out	-	73	74	-	-	-	-
PT24PDW.out	-	40	41	-	-	-	-
PT24PSD.out	-	-	11,602	11,789	-	-	-
PT24PSDP.out	-	-	-	11,683	11,919	-	-
PT24PTH.out	516	448	545	330	-	-	-
PT24PTH2.out	316	-	-	-	-	-	-
PT24PTHP.out	-	528	-	-	-	-	-
PT24PTP2.out	-	455	503	451	-	-	-
PT24PTP3.out	-	438	-	-	-	-	-

Notes
1. Resultant forces shown in lbs.

Transnuclear West Inc.

Calculation Sheet

PROJECT NO:	SCE-01	REVISION:	1
CALCULATION NO:	SCE-01.0204	PAGE:	92 of 138

Table 9-21 - Load Condition Force[1] Results for Support Ring Weld (Intermittent)

Run I.D	Load Step						
	1	2	3	4	5	6	7
PT24PIP.out	-	106	158	-	-	-	-
PT24PFL.out	-	666	685	375	382	-	-
PT24PED.out	-	84	4,996	5,070	4,488	4,489	-
PT24P1G.out	-	94	95	-	-	-	-
PT24PDW.out	-	18	18	-	-	-	-
PT24PSD.out	-	-	4,179	2,511	-	-	-
PT24PSDP.out	-	-	-	772	617	-	-
PT24PTH.out	686	738	1,105	474	-	-	-
PT24PTH2.out	452	-	-	-	-	-	-
PT24PTHP.out	-	704	-	-	-	-	-
PT24PTP2.out	-	630	731	656	-	-	-
PT24PTP3.out	-	633	-	-	-	-	-

Notes
1. Resultant forces shown in lbs.

Table 9-22 - Load Condition Force[1] Results for Outer Bottom Cover Plate Weld

Run I.D	Load Step						
	1	2	3	4	5	6	7
PB24PLT.out	-	-	-	-	-	-	-
PB24PIP.out	-	331	393	-	-	-	-
PB24PFL.out	-	604	206	188	190	-	-
PB24PED.out	-	46	2,783	2,782	2,783	2,783	-
PB24P1G.out	-	716	797	-	-	-	-
PB24PDW.out	1,016	1,029	-	-	-	-	-
PB24PSD2.out	7,613	8,211	-	-	-	-	-
PB24PSD3.out	7,429	8,295	-	-	-	-	-
PB24PTH.out	4,377	3,006	2,154	2,246	-	-	-
PB24PTH2.out	2,266	-	-	-	-	-	-
PB24PGP1.out	-	-	-	-	-	-	-
PB24PGP2.out	8,856	11,807	13,356	-	-	-	-
PB24PGP3.out	584	-	-	-	-	-	-
PB24PTHG.out	5,272	5,580	5,879	5,951	-	-	-
PB24PT-G.out	5,272	7,456	7,477	-	-	-	-
PB24RAM.out	-	216	288	-	-	-	-
PB24PTHR.out	-	219	4,598	3,332	-	-	-
PB24PTR2.out	-	-	5,133	3,825	-	-	-
PB24PTR3.out	-	-	5,371	4,059	-	-	-

Notes
1. Resultant forces shown in lbs.

9.2 Code Compliance

Table 9-24 and Table 9-25 associate the analysis runs with load combinations for the top end models and bottom end models, respectively. Included in the tables are the maximum temperatures expected for each load combination, as provided in References 9 and 10. Allowable stresses for each load combination are determined based on the appropriate maximum temperature, rounded to the nearest 50°F, unless noted otherwise.

9.2.1 Design Pressure

As per Section NB-3221 of Reference 2, stresses due to the design pressure of 10 psi shall be within allowable stress limits at the design temperature 500 °F. Table 9-23 summarizes the stress intensities and stress ratios for pressure boundary components. Stresses for non-weld components are taken from tables in Section 9.1. The Stress Intensity for the Inner Top Cover Plate Weld is from Table 10-14. The Inner Bottom Cover Plate to Shell Weld is a full penetration weld and does not require analysis. All stress intensities are within acceptable limits.

Table 9-23 - 10 Psi Design Pressure Stress Results

Component	Stress	Stress Intensity at 10 Psi (ksi)	Allowable Stress (ksi)	Stress Ratio)
Shell (top)	P_m	1.70	18	0.09
	P_m+P_b	4.43	27	0.16
Shell (Bottom)	P_m	0.63	18	0.04
	P_m+P_b	1.34	27	0.05
Inner Top Cover Plate	P_m	0.43	18	0.02
	P_m+P_b	3.94	27	0.15
Inner Bottom Cover Plate	P_m	0.27	18	0.02
	P_m+P_b	0.74	27	0.03
Inner Top Cover Plate Weld	P_m	2.3	10.8	0.21

9.2.2 FO-DSC Components

The FO-DSC components are evaluated for primary membrane and membrane + bending stress and for primary + secondary stress. Stress contour plots for the individual analyses are provided in Appendices B1 through B33. Results of the component evaluation are summarized in Table 10-1 through Table 10-11 of Section 10 for the controlling load combinations.

For load conditions involving axial loading and non-axisymmetric boundaries resulting in framing action of the FO-DSC, the analyses considered displacement constraints at a single node at the end of the FO-DSC and at the mid-length. This results in artificial highly localized stresses adjacent to the restraints. Stress paths at these locations were not included in the evaluation.

Stress intensities for side drop loadings in the immediate vicinity of a rail (within one or two elements) near the outer cover plate are very localized, as shown in selected figures Appendix B7, B8, B20, and B21. At the corner of the beveled edge of the FO-DSC shell and directly above in the outer cover plate is a very localized peak stress caused by conservative nodal restraint of infinite stiffness to represent contact with the rail. The basic characteristic of a peak stress is that it does not cause any noticeable distortion and is objectionable only as a possible source of a fatigue crack or a brittle fracture (NB-3213.11). A portion of this stress may also be considered secondary in that local yielding and minor distortions can satisfy the conditions which cause the stress to occur and failure from one application of the stress is not to be expected (NB-3213.9). Along the rail length, high stress intensities are due to high bearing stresses between the FO-DSC shell and rail. Because these peak, secondary and bearing stresses are not required to be evaluated for the Level D drop conditions, the FO-DSC shell, outer cover plate and inner cover plate elements in the immediate vicinity and directly above the rail are not included in selected Appendix B figures (see Appendix B).

Similarly, weld locations in the immediate vicinity of and directly above the rail are not considered for maximum weld forces tabulated in Table 9-18 through Table 9-22. Near the rail the outer cover plates, inner cover plates and support ring bear directly against the FO-DSC shell such that local distortions in the welded connections would allow the load to be carried in bearing between the cover plates and the FO-DSC shell. As stated previously, such bearing is not required to be evaluated for the Level D drop conditions.

9.2.3 Welds

Results of the weld evaluation are summarized in Table 10-12 through Table 10-20 of Section 10 for the controlling load cases.

The weld of the support ring to the shell cannot be qualified for bottom end drop (Load Comb. TR-9) using the conservative approach taken for the other welds (see Section 9.1.2). In a bottom end drop, the support ring supports the shield plug and a portion of the inner and outer top cover plate inertia. The chamfer at the bottom of the shield plug results in a loading the support ring eccentric to the shell interface. The eccentric load causes a moment on the ring that loads the bottom (intermittent) weld in compression, against the cylindrical shell, and the top (continuous) weld in tension. In the evaluation below, it is assumed that the top weld takes the entire vertical force and the pullout load associated with the moment. The bottom weld is assumed to take no load. The load is assumed to be uniformly distributed along the support ring. Conservatively, the load is applied at the inside edge of the support ring (0.75" cantilever). The applied support ring force corresponding to the drop loading is determined from the sum of the nodal reaction forces taken from output file PT24PED.out, load step 4.

$P_{vertical}$ = 99.0 kip + 36.4 kip (upper and lower weld forces, summation of F_z forces)
= 135.4 kip

Weld forces:

f_x = (135.4 kip)(0.75 in.) / 2 in.
= 50.8 kip (radial force based on the 2" ht. of the support ring)
f_v = 135.4 kip (vertical force)
f_r = $(50.8^2 + 135.4^2)^{1/2}$
= 144.6 kip (resultant weld force)

L = 2π(32.97 in.)/4
= 51.8 in (weld length: inside radius, 90 degree model)

For a 1/4 in. partial penetration groove weld with a 1/8 in. cover fillet:

t = $0.25(2)^{1/2}$
= 0.353 in. (base metal thickness)

t_{eff} = $(0.25^2 + 0.125^2)^{1/2}$
= 0.280 in. (effective weld throat)

Weld stresses:

f_w = f_r / L t
= (144.6 kip) / (51.8 in.)(0.353 in.)
= 7.91 ksi (base metal stress)
< 15.9 ksi (allowable base metal stress, Level D, 500°F)

f_w = f_r / L t_{eff}
= (144.6 kip) / (51.8 in.)(0.280 in.)
= 9.97 ksi (weld metal stress)
< 43.0 ksi (allowable weld metal stress, Level D, 500°F)

Therefore, the support ring weld is adequate for end drop loading. Note that the weld stresses reported in Table 10-15 and Table 10-16 for the upper weld of the support ring include concentrated load effects that result from intermittent welding along the lower edge of the ring. Thus, the base metal weld stress in Table 10-15 is higher than the above values.

9.2.4 Bearing Stress

Bearing stresses are evaluated below for the most significant bearing loads (ram compression, axial retainer load, and canister stop plate load). Note that a bearing stress evaluation is not required for Service Level D accident conditions (i.e., seismic, end drop and side drop).

Ram Compression

The maximum ram compression load to be considered for bearing stress is 60 kips (Load Comb. LD-1 through LD-3). Considering the backing stiffness provided to the ram stop plate by the barrel

cylinder, the bearing area is conservatively assumed to be the area of the barrel, reduced by 50% to account for the grapple arm cutouts.

Area, A = $0.5\pi(9.0^2 - 8.0^2)/4$
= $6.68\ in^2$

f_p, bearing = $60\ kip / 6.68\ in^2$
= 9.0 ksi < 29.85 ksi (Level A/B, 500°F)

Ratio = 0.31

Axial Restrainer Load

Two axial restrainer provides axial support to the FO-DSC when seismically loaded toward the door of the AHSM. The axial 6g seismic load on the DSC shell is supported by the axial restrainers. The stresses in the DSC shell resulting from the axial seismic load are enveloped by the stresses due to the 60g bottom end drop load. Additionally, the maximum stress due to contact with the axial restrainers occurs where the two 1-1/2" set screws with a 1.125" half dog point load bear against the DSC shell. However, Service Level D events do not require the evaluation of bearing stresses. Therefore, analysis of the bearing stress on the DSC due to the set screws is not required.

9.2.5 FO-DC Shell Stability

FO-DSC shell stability is evaluated for loads involving significant external pressure and/or axial load. Tabulated below are comparisons of axial stress and external pressure to the allowables identified in Table 5-10. Loads associated with fabrication leak testing (Load Comb. NO-1) and flood (Load Comb. HSM-10) are defined in Sections 4.3.1 and 4.3.8, respectively. Axial stresses associated with the end drop are taken from file PT24PED.out, load step 4, for the shell at mid-height (section through nodes 1 and 1000). Additional membrane stress due the accelerated weight of the lower end of the shell is calculated as follows:

S_z = $(0.285\ lb/in^3)(186.17\ in./2)60g$
= 1,591 psi
= 1.6 ksi

Added to the 7.0 ksi axial stress reported in the output file, the total shell axial stress due to the 60g end drop loading is 8.6 ksi.

The 155 kip axial load applied during fabrication leak testing corresponds to a stress of 1.2 ksi.

Load Condition	Service Level	External Pressure or Axial Stress	Allowable External Pressure	Allowable Axial Stress	Ratio
Fabrication Leak Test	Test	14.7 psi ext. pressure	63.0 psi	--	0.23
		1.2 ksi axial stress	--	17.6 ksi	0.07
		Interaction of the above pressure and axial stress			0.30
Flood	C	21.7 psi ext. pressure	47.0 psi	--	0.46
60g End Drop	D	8.6 ksi axial stress	--	14.0 ksi	0.61

Table 9-24 Correlation of Load Combinations to Analysis Runs for Top End Models

Load Comb.[1]	Service Level	P/P+S (Note 2)	Loads [3]	Run ID	Max Temp.
NO-1	Test	P	$P_{E(14.7)}$+ 155k Axial	Enveloped by Bottom End	70°F
		P + S	N/A	N/A	
NO-2	Test	P	$P_{I(12)}$ + 155k Axial	Enveloped by Bottom End	70°F
		P + S	$P_{I(12)}$+ 155k Axial	N/A	
NO-3	A	P	Lifting Loads	Other Calculation Package	70°F
		P + S	Lifting Loads	Other Calculation Package	
NO-4	A	P	Lifting Loads	Other Calculation Package	70°F
		P + S	Lifting Loads	Other Calculation Package	
FL-1	A	P	DW_V+ $P_{E(HS)}$	Enveloped by Bottom End	212°F
		P + S	N/A	N/A	
FL-2	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	N/A	N/A	
FL-3	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	N/A	N/A	
FL-4	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + TH_8	Enveloped by TL-2 or DD-2	
FL-5	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + TH_8	Enveloped by TL-2 or DD-2	
FL-6	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + TH_8	Enveloped by TL-2 or DD-2	
FL-7	C	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + Seismic	Enveloped by TR-5 thru TR-8	212°F
		P + S	N/A	N/A	
DD-1	B	P	DW_V + $P_{I(HS+20)}$ + $P_{E(HS)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{I(HS+20)}$ + $P_{E(HS)}$+ TH_8	See Calculation in Section 8.3	
DD-2	B	P	DW_V + $P_{E(HS+14.7)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{E(HS+14.7)}$ + TH_8	See Calculation in Section 8.3	
DD-3	B	P	DW_V + $P_{I(12)}$ + $P_{E(HS)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{I(12)}$ + $P_{E(HS)}$ + TH_8	See Calculation in Section 8.3	
DD-4	B	P	DW_V + $P_{I(5)}$ + $P_{E(HS)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{I(5)}$ + $P_{E(HS)}$ + TH_8	See Calculation in Section 8.3	
DD-5	A	P	DW_V + $P_{I(5)}$ + $P_{E(HS)}$	Enveloped by DD-2	366°F
		P + S	DW_V + $P_{I(5)}$ + $P_{E(HS)}$ + TH_8	Enveloped by DD-2	
TL-1	A	P	DW_V + $P_{I(10)}$	Enveloped by TL-2	393°F
		P + S	DW_V + $P_{I(10)}$ + TH_8	Enveloped by TL-2	
TL-2	A	P	DW_V + $P_{I(10)}$	QT24PIP [4]	443°F
		P + S	DW_V + $P_{I(10)}$ + TH_8	T24PTH, T24PTH2, T24PTP2, T24PTP3 [4,5]	
TL-3	A	P	DW_H + $P_{I(10)}$	Enveloped by TL-4	393°F[illegible]
		P + S	DW_H + $P_{I(10)}$ + TH_7	T24PTH, T24PTHP [4,5]	

Load Comb.[1]	Service Level	P/P+S (Note 2)	Loads [3]	Run ID	Max Temp.
TL-4	A	P	$DW_H + P_{I(10)}$	QT24PIP[4,5]	443°F
		P + S	$DW_H + P_{I(10)} + TH_8$	T24PTH, T24PTHP, T24PTP2 [4,5]	
TR-1	A	P	$DW_H + P_{I(10)}$ + 1g Axial	Enveloped by TR-5	271°F
		P + S	$DW_H + P_{I(10)}$ + 1g Axial + TH_7	T24PTH, T24PTHP, + Primary Load Runs (see TR-5) [4,5]	
TR-2	A	P	$DW_H + P_{I(10)}$ + 1g Trans.	Enveloped by TR-6	271°F[6]
		P + S	$DW_H + P_{I(10)}$ + 1g Trans + TH_7	T24PTH, T24PTHP, + Primary Load Runs (see TR-6) [5]	
TR-3	A	P	$DW_H + P_{I(10)}$ + 1g Vert.	Enveloped by TR-7	271°F[6]
		P + S	$DW_H + P_{I(10)}$ + 1g Vert. + TH_7	T24PTH, T24PTHP, + Primary Load Runs (see TR-7) [5]	
TR-4	A	P	$DW_H + P_{I(10)}$ + ½g X, Y, Z	Enveloped by TR-8	271°F[6]
		P + S	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_7	T24PTH, T24PTHP, + Primary Load Runs (see TR-8) [5]	
TR-5	A	P	$DW_H + P_{I(10)}$ + 1g Axial	QT24PIP, QT24PED (+ axial), QT24P1G (-axial) [4,5]	399°F
		P + S	$DW_H + P_{I(10)}$ + 1g Axial + TH_8	T24PTH, T24PTHP, T24PTP2 + Primary Load Runs [4,5]	
TR-6	A	P	$DW_H + P_{I(10)}$ + 1g Trans.	QT24PIP, T24PDW [5]	399°F
		P + S	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	T24PTH, T24PTHP, T24PTP2 + Primary Load Runs [5]	
TR-7	A	P	$DW_H + P_{I(10)}$ + 1g Vert.	QT24PIP, T24PDW [5]	399°F
		P + S	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	T24PTH, T24PTHP, T24PTP2 + Primary Load Runs [5]	
TR-8	A	P	$DW_H + P_{I(10)}$ + ½g X, Y, Z	QT24PIP, QT24PED (+axial), QT24P1G (-axial) , T24PDW (trans & vert)[5]	399°F
		P + S	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	T24PTH, T24PTHP, T24PTP2 + Primary Load Runs[5]	
TR-9	D	P	$P_{I(20)}$ + 60g BED	QT24PED	399°F
		P + S	N/A	N/A	
TR-10	D	P	$P_{I(20)}$ + 75g SD	T24PSD, T24PSDP	399°F
		P + S	N/A	N/A	
TR-11	D	P	$P_{I(20)}$ + 25g SD	Enveloped by TR-10	399°F
		P + S	N/A	N/A	
TR-12	D	P	$P_{I(20)}$ + 60g TED	Not Limiting for Top End	399°F
		P + S	N/A	N/A	
LD-1	A	P	$DW_H + P_{I(10)}$ + 60k Ram	Not Limiting for Top End	393°F[6]
		P + S	$DW_H + P_{I(10)}$ + 60k Ram + TH_7	Not Limiting for Top End	
LD-2	A	P	$DW_H + P_{I(10)}$ + 60k Ram	Not Limiting for Top End	439°F
		P + S	$DW_H + P_{I(10)}$ + 60k Ram + TH_8	Not Limiting for Top End	

Transnuclear West Inc.

Calculation Sheet

PROJECT NO:	SCE-01	REVISION:	1
CALCULATION NO:	SCE-01.0204	PAGE:	101 of 138

Load Comb.[1]	Service Level	P/P+S (Note 2)	Loads [3]	Run ID	Max Temp.
LD-3	B	P	$DW_H + P_{I(20)}$ + 80k Ram	Not Limiting for Top End	393°F
		P + S	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	Not Limiting for Top End	
LD-4	B	P	$DW_H + P_{I(20)}$ + 80k Ram	Not Limiting for Top End	439°F[6]
		P + S	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	Not Limiting for Top End	
HSM-1	A	P	$DW_H + P_{I(10)}$	Enveloped by HSM-3	271°F
		P + S	$DW_H + P_{I(10)} + TH_{15}$	Enveloped by HSM-3	
HSM-2	A	P	$DW_H + P_{I(10)}$	Enveloped by HSM-3	399°F
		P + S	$DW_H + P_{I(10)} + TH_{16}$	Enveloped by HSM-3	
HSM-3	B	P	$DW_H + P_{I(20)}$	T24PDW, QT24PIP [5]	271°F
		P + S	$DW_H + P_{I(20)} + TH_{15}$	T24PTH, T24PTP2 [4,5]	
HSM-4	B	P	$DW_H + P_{I(20)}$	T24PDW, QT24PIP [5]	408°F
		P + S	$DW_H + P_{I(20)} + TH_{26}$	T24PTH2, T24PTP3 [4,5]	
HSM-5	B	P	$DW_H + P_{I(20)}$	Enveloped by HSM-3	271°F
		P + S	$DW_H + P_{I(20)} + TH_{15}$	Enveloped by HSM-3	
HSM-6	B	P	$DW_H + P_{I(20)}$	Enveloped by HSM-4	408°F
		P + S	$DW_H + P_{I(20)} + TH_{26}$	Enveloped by HSM-4	
HSM-7	B	P	$DW_H + P_{I(20)}$ + Seismic	Enveloped by HSM-10	271°F
		P + S	N/A	N/A	
HSM-8	B	P	$DW_H + P_{I(20)}$ + Seismic	Enveloped by HSM-10	408°F
		P + S	N/A	N/A	
HSM-9	D	P	$DW_H + P_{I(20)}$ + Seismic	Enveloped by HSM-10	271°F
		P + S	N/A	N/A	
HSM-10	D	P	$DW_H + P_{I(20)}$ + Seismic	See Calculation in Section 8.1	408°F
		P + S	N/A	N/A	
HSM-11	D	P	$DW_H + P_{I(60)}$	QT24PIP, T24PDW[5]	646°F
		P + S	N/A	N/A	
HSM-12	C	P	DW_H + Flood	Enveloped by HSM-13	271°F
		P + S	N/A	N/A	
HSM-13	C	P	DW_H + Flood	T24PDW, QT24PFL [4,5]	408°F
UL-1	A	P	$DW_H + P_{I(10)}$ + 60k Grapple	Not Limiting for Top End	271°F
		P + S	$DW_H + P_{I(10)}$ + 60k Grap + TH_{15}	Not Limiting for Top End	
UL-2	A	P	$DW_H + P_{I(10)}$ + 60k Grapple	Not Limiting for Top End	399°F
		P + S	$DW_H + P_{I(10)}$ + 60k Grap + TH_{16}	Not Limiting for Top End	
UL-3	B	P	$DW_H + P_{I(20)}$ + 60k Grapple	Not Limiting for Top End	271°F
		P + S	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	Not Limiting for Top End	
UL-4	B	P	$DW_H + P_{I(20)}$ + 60k Grapple	Not Limiting for Top End	408°F
		P + S	$DW_H + P_{I(20)}$ + 60k Grap + TH_{26}	Not Limiting for Top End	
UL-5	C	P	$DW_H + P_{I(20)}$ + 80k Grapple	Not Limiting for Top End	399°F
		P + S	$DW_H + P_{I(20)}$ + 80k Grap + TH_{16}	Not Limiting for Top End	

Transnuclear West Inc.

Calculation Sheet

PROJECT NO:	SCE-01	REVISION:	1
CALCULATION NO:	SCE-01.0204	PAGE:	102 of 138

Load Comb.(1)	Service Level	P/P+S (Note 2)	Loads (3)	Run ID	Max Temp.
RF-1	D	P	$DW_V + P_{I(20)} + P_E$	Enveloped by DD-1	212°F
		P + S	$DW_V + P_{I(20)} + P_E + TH_S$	Enveloped by DD-1	

Notes:

1. Load Combination groupings are as follows:
   - NO Non-Operational
   - FL Fuel Loading
   - DD Draining and Drying
   - TL Transfer Trailer Loading
   - TR Transfer To/From ISFSI
   - LD HSM Loading
   - HSM HSM Storage
   - UL HSM Unloading
   - RF FO-DSC Unloading/Reflood
2. Stress categories are noted as follows:
   - P Primary Stresses
   - P + S Primary + Secondary Stresses.
3. Loads are designated as follows:
   - DW_V Deadweight in the vertical position
   - DW_H Deadweight in the horizontal position
   - P_I Internal Pressure (value in psi in parentheses; HS = hydrostatic)
   - P_E External Pressure (value in psi in parentheses; HS = hydrostatic)
   - TH Thermal (subscript is case number (7, 8, 15, 16, or 26)
4. DW to be added by hand from run QT24PED for DW_V and from run T24PDW for DW_H.
5. Total stress intensity is obtained from summation of individual run results, except for (a) stresses resulting from the combination of thermal with internal pressure loads, which are combined within the finite element analyses.
6. Per Reference 10, thermal data is not available for the 0° ambient cases. Therefore, data for the -40° ambient cases are used instead because they produce higher thermal gradients.

Table 9-25 Correlation of Load Combinations to Analysis Runs for Bottom End Models

Load Comb.[1]	Service Level	P/P+S (Note 2)	Loads [3]	Run ID	Max Temp.
NO-1	Test	P	$P_{E(14.7)}$+ 155k Axial	QB24PLT	70°F
		P + S	N/A	N/A	
NO-2	Test	P	$P_{I(12)}$ + 155k Axial	Enveloped by NO -1	70°F
		P + S	$P_{I(12)}$+ 155k Axial	N/A	
NO-3	A	P	Lifting Loads	Other Calculation Package	70°F
		P + S	Lifting Loads	Other Calculation Package	
NO-4	A	P	Lifting Loads	Other Calculation Package	70°F
		P + S	Lifting Loads	Other Calculation Package	
FL-1	A	P	DW_V+ $P_{E(HS)}$	QB24PFL from HSM-13 [4]	212°F
		P + S	N/A	N/A [8]	
FL-2	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	N/A	N/A [8]	
FL-3	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	N/A	N/A [8]	
FL-4	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + TH_8	Enveloped by TL-2 or DD-2	
FL-5	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + TH_8	Enveloped by TL-2 or DD-2	
FL-6	A	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$	Enveloped by FL-1	212°F
		P + S	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + TH_8	Enveloped by TL-2 or DD-2	
FL-7	C	P	DW_V + $P_{I(HS)}$ + $P_{E(HS)}$ + Seismic	Enveloped by TR-5 thru TR-8	212°F
		P + S	N/A	N/A	
DD-1	B	P	DW_V + $P_{I(HS+20)}$ + $P_{E(HS)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{I(HS+20)}$ + $P_{E(HS)}$+ TH_8	See Calculation in Section 8.3	
DD-2	B	P	DW_V + $P_{E(HS+14.7)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{E(HS+14.7)}$ + TH_8	See Calculation in Section 8.3	
DD-3	B	P	DW_V + $P_{I(12)}$ + $P_{E(HS)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{I(12)}$ + $P_{E(HS)}$ + TH_8	See Calculation in Section 8.3	
DD-4	B	P	DW_V + $P_{I(5)}$ + $P_{E(HS)}$	See Calculation in Section 8.3	366°F
		P + S	DW_V + $P_{I(5)}$ + $P_{E(HS)}$ + TH_8	See Calculation in Section 8.3	
DD-5	A	P	DW_V + $P_{I(5)}$ + $P_{E(HS)}$	Enveloped by DD-2	366°F
		P + S	DW_V + $P_{I(5)}$ + $P_{E(HS)}$ + TH_8	Enveloped by DD-2	
TL-1	A	P	DW_V + $P_{I(10)}$	Enveloped by TL-2	393°F
		P + S	DW_V + $P_{I(10)}$ + TH_8	Enveloped by TL-2	
TL-2	A	P	DW_V + $P_{I(10)}$	QB24PIP [4]	443°F
		P + S	DW_V + $P_{I(10)}$ + TH_8	QB24PIP, B24PTH, B24PTH2 [4,5]	
TL-3	A	P	DW_H + $P_{I(10)}$	Enveloped by TL-4	393°F
		P + S	DW_H + $P_{I(10)}$ + TH_7	QB24PIP, B24PTH[4,5]	

Load Comb.[1]	Service Level	P/P+S (Note 2)	Loads [3]	Run ID	Max Temp.
TL-4	A	P	$DW_H + P_{I(10)}$	QB24PIP[4,5]	443°F
		P + S	$DW_H + P_{I(10)} + TH_8$	QB24PIP, B24PTH[4,5]	
TR-1	A	P	$DW_H + P_{I(10)}$ + 1g Axial	Enveloped by TR-5	271°F[7]
		P + S	$DW_H + P_{I(10)}$ + 1g Axial + TH_7	B24PTH + Primary Load Runs (see TR-5) [4,5]	
TR-2	A	P	$DW_H + P_{I(10)}$ + 1g Trans.	Enveloped by TR-6	271°F[7]
		P + S	$DW_H + P_{I(10)}$ + 1g Trans + TH_7	B24PTH + Primary Load Runs (see TR-6) [5]	
TR-3	A	P	$DW_H + P_{I(10)}$ + 1g Vert.	Enveloped by TR-7	271°F[7]
		P + S	$DW_H + P_{I(10)}$ + 1g Vert. + TH_7	B24PTH + Primary Load Runs (see TR-7) [5]	
TR-4	A	P	$DW_H + P_{I(10)}$ + ½g X, Y, Z	Enveloped by TR-8	271°F[7]
		P + S	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_7	B24PTH + Primary Load Runs (see TR-8) [5]	
TR-5	A	P	$DW_H + P_{I(10)}$ + 1g Axial	QB24PIP, QB24PED (+ axial), QB24P1G (-axial) [4,5]	399°F
		P + S	$DW_H + P_{I(10)}$ + 1g Axial + TH_8	B24PTH + Primary Load Runs [4,5]	
TR-6	A	P	$DW_H + P_{I(10)}$ + 1g Trans.	QB24PIP, B24PDW [5]	399°F
		P + S	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	B24PTH + Primary Load Runs [5]	
TR-7	A	P	$DW_H + P_{I(10)}$ + 1g Vert.	QB24PIP, B24PDW [5]	399°F
		P + S	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	B24PTH + Primary Load Runs [5]	
TR-8	A	P	$DW_H + P_{I(10)}$ + ½g X, Y, Z	QB24PIP, QB24PED (+axial), QB24P1G (-axial) , B24PDW (trans & vert)[5]	399°F
		P + S	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	B24PTH + Primary Load Runs[5]	
TR-9	D	P	$P_{I(20)}$ + 60g BED	Not Limiting for Bottom End	399°F
		P + S	N/A	N/A	
TR-10	D	P	$P_{I(20)}$ + 75g SD	PB24PSDP	399°F
		P + S	N/A	N/A	
TR-11	D	P	$P_{I(20)}$ + 25g SD	Enveloped by TR-10	399°F
		P + S	N/A	N/A	
TR-12	D	P	$P_{I(20)}$ + 60g TED	QB24PED	399°F
		P + S	N/A	N/A	
LD-1	A	P	$DW_H + P_{I(10)}$ + 60k Ram	Enveloped by LD-3	393°F[7]
		P + S	$DW_H + P_{I(10)}$ + 60k Ram + TH_7	Enveloped by LD-4	
LD-2	A	P	$DW_H + P_{I(10)}$ + 60k Ram	Enveloped by LD-3	439°F
		P + S	$DW_H + P_{I(10)}$ + 60k Ram + TH_8	Enveloped by LD-4	
LD-3	B	P	$DW_H + P_{I(20)}$ + 80k Ram	QB24PIP, B24PRAM [4,5]	393°F
		P + S	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	QB24PIP, B24PTR3 [4,5]	
LD-4	B	P	$DW_H + P_{I(20)}$ + 80k Ram	QB24PIP, B24PRAM [4,5]	439°F[7]
		P + S	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	QB24PIP, 24PTR3 [4,5]	

Load Comb.[1]	Service Level	P/P+S (Note 2)	Loads [3]	Run ID	Max Temp.
HSM-1	A	P	$DW_H + P_{I(10)}$	Enveloped by HSM-3	271°F
		P + S	$DW_H + P_{I(10)} + TH_{15}$	Enveloped by HSM-3	
HSM-2	A	P	$DW_H + P_{I(10)}$	Enveloped by HSM-3	399°F
		P + S	$DW_H + P_{I(10)} + TH_{16}$	Enveloped by HSM-3	
HSM-3	B	P	$DW_H + P_{I(20)}$	QB24PIP [4,5]	271°F
		P + S	$DW_H + P_{I(20)} + TH_{15}$	QB24PIP, B24PTH [4,5]	
HSM-4	B	P	$DW_H + P_{I(20)}$	QB24PIP [4,5]	408°F
		P + S	$DW_H + P_{I(20)} + TH_{26}$	QB24PIP, B24PTH2 [4,5]	
HSM-5	B	P	$DW_H + P_{I(20)}$	Enveloped by HSM-3	271°F
		P + S	$DW_H + P_{I(20)} + TH_{15}$	Enveloped by HSM-3	
HSM-6	B	P	$DW_H + P_{I(20)}$	Enveloped by HSM-4	408°F
		P + S	$DW_H + P_{I(20)} + TH_{26}$	Enveloped by HSM-4	
HSM-7	B	P	$DW_H + P_{I(20)}$ + Seismic	Enveloped by HSM-10	271°F
		P + S	N/A	N/A	
HSM-8	B	P	$DW_H + P_{I(20)}$ + Seismic	Enveloped by HSM-10	408°F
		P + S	N/A	N/A	
HSM-9	D	P	$DW_H + P_{I(20)}$ + Seismic	Enveloped by HSM-10	271°F
		P + S	N/A	N/A	
HSM-10	D	P	$DW_H + P_{I(20)}$ + Seismic	See Calculation in Section 8.1	408°F
		P + S	N/A	N/A	
HSM-11	D	P	$DW_H + P_{I(60)}$	QB24PIP, B24PDW (trans/vert) [5]	646°F
		P + S	N/A	N/A	
HSM-12	C	P	DW_H + Flood	Enveloped by HSM-13	271°F
		P + S	N/A	N/A	
HSM-13	C	P	DW_H + Flood	QB24PFL [4,5]	408°F
UL-1	A	P	$DW_H + P_{I(10)}$ + 60k Grapple	Enveloped by UL-3	271°F
		P + S	$DW_H + P_{I(10)}$ + 60k Grap + TH_{15}	Enveloped by UL-3	
UL-2	A	P	$DW_H + P_{I(10)}$ + 60k Grapple	Enveloped by UL-4	399°F
		P + S	$DW_H + P_{I(10)}$ + 60k Grap + TH_{16}	Enveloped by UL-4	
UL-3	B	P	$DW_H + P_{I(20)}$ + 60k Grapple	QB24PIP, B24PDW, B24PGP2	271°F
		P + S	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	QB24PIP, B24PTHG, B24PT-G [4,5]	
UL-4	B	P	$DW_H + P_{I(20)}$ + 60k Grapple	QB24PIP, B24PDW, B24PGP2	408°F
		P + S	$DW_H + P_{I(20)}$ + 60k Grap + TH_{26}	QB24PIP, B24PTHG, B24PT-G [4,5]	
UL-5	C	P	$DW_H + P_{I(20)}$ + 80k Grapple	QB24PIP, B24PDW, B24PGP2	399°F
		P + S	$DW_H + P_{I(20)}$ + 80k Grap + TH_{16}	QB24PIP, B24PDW, B24PGP2	
RF-1	D	P	$DW_V + P_{I(20)} + P_E$	Enveloped by DD-1	212°F
		P + S	$DW_V + P_{I(20)} + P_E + TH_8$	Enveloped by DD-1	

Notes:

1. Load Combination groupings are as follows:
   - NO Non-Operational
   - FL Fuel Loading
   - DD Draining and Drying
   - TL Transfer Trailer Loading
   - TR Transfer To/From ISFSI
   - LD HSM Loading
   - HSM HSM Storage
   - UL HSM Unloading
   - RF FO-DSC Unloading/Reflood
2. Stress categories are noted as follows:
   - P Primary Stresses
   - P + S Primary + Secondary Stresses.
3. Loads are designated as follows:
   - DW_V Deadweight in the vertical position
   - DW_H Deadweight in the horizontal position
   - P_I Internal Pressure (value in psi in parentheses; HS = hydrostatic)
   - P_E External Pressure (value in psi in parentheses; HS = hydrostatic)
   - TH Thermal (subscript is case number (7, 8, 15, 16, or 26)
4. DW to be added by hand from QT24PED for DW_V and from run B24PDW for DW_H.
5. Total stress intensity is obtained from summation of individual run results, except for (a) the stresses resulting from the combination of thermal with grapple pull loads and thermal with ram push loads, which are combined within the finite element analyses, (b) stresses in the shell for load cases UL-3, UL-4, and UL-5, which determine a stress intensities based on combined component stresses, and (c) stresses in the outer bottom cover plate for load case UL-5, which determines a stress intensity based on combined component stresses.
6. Additional membrane stress due to missing (upper) portion of shell (hand calc) is added by hand.
7. Per Reference 10, thermal data is not available for the 0° ambient cases. Therefore, data for the -40° ambient cases are used instead because they use higher thermal gradients.
8. Because there are no thermal loads for Load Combinations FL-1, FL-2, and FL-3, primary + secondary stresses are not limiting and therefore, are not evaluated.

10. SUMMARY

For the controlling load combinations, stress results for each component of the FO-DSC shell assembly are summarized in Table 10-1 through Table 10-11. Weld stress results are summarized in Table 10-12 through Table 10-20. The maximum stress ratio is 0.97. This occurs in the bottom half of the shell for Load combination UL-5 (Accident Unloading, Level C).

From Section 9.2.4, the maximum bearing stress ratio is 0.31 which results from the ram compression load combination. From Section 9.2.5, the maximum FO-DSC shell stability stress ratio is 0.64 and is the result of axial stress due to the 60g end drop.

Additionally, the DSC is suitable for storing Greater Than Class C (GTCC) waste provided that a 3/4" thick shell (minimum) which assures uniform loading on the canister lines the FO-DSC shell and that the maximum gross weight of the DSC and its components does not exceed 82,000 lbs.

<u>Shell Stresses due to Spacer Discs</u>

Shell stresses in the region of the spacer discs are determined in Reference 8 for horizontal deadweight and side drops. The following maximum stresses are reported in Reference 8:

Deadweight, DW:	membrane	=	0.91 ksi	
	membrane + bending	=	3.57 ksi	
DW + 20 psi:	membrane	=	2.00 ksi	
	membrane + bending	=	4.66 ksi	
75g Drop:	membrane	=	28.7 ksi	(18.5° Drop)
	membrane + bending	=	33.1 ksi	(18.5° Drop)
75g Drop + 20 psi:	membrane	=	29.8 ksi	(18.5° Drop)
	membrane + bending	=	34.2 ksi	(18.5° Drop)

The above deadweight + operating pressure stresses are enveloped by the top-half cylindrical shell results summarized in Table 10-1 for Load Combinations TL-3, TL-4, and HSM-3. Therefore, for all other combinations, except HSM-13, that include deadweight and 20 psi internal pressure, the top-half shell results computed herein envelop stresses in the region of the spacer discs. Stresses for Load Combination HSM-13 are maximum when deadweight and external pressure are combined assuming the internal pressure is zero. From Table 9-5, the membrane + bending stress due to horizontal deadweight is 3.00 ksi in the top-half of the shell, which is 1.99 ksi less than the above 4.66 ksi deadweight stress in the region of the spacer disc. Conservatively adding the 1.99 ksi difference to the Load Combination HSM-13 stress, the maximum membrane + bending stress becomes

$$5.87 + 1.99 = 7.86 \text{ ksi} < 30.0 \text{ ksi} \quad (\text{ratio} = 0.26)$$

The above membrane + bending stress due to deadweight + pressure in the region of the spacer discs (4.66 ksi) exceeds the corresponding stress values summarized in Table 10-6 bottom of the top-half of the cylindrical shell (4.45 ksi) by 0.21 ksi. Of the load combinations potentially affected by the

higher deadweight + pressure stress, the combination listed below is most affected by the stress increase.

Service Level A/B Combination TR-3: 7.55 + 0.21 = 7.76 ksi < 25.0 ksi (ratio = 0.31)

The membrane stresses and the membrane + bending stress for the side drop are higher in the region of the spacer disc than both the membrane and membrane + bending stresses predicted by ANSYS. Thus, Table 10-1 and Table 10-6 are updated for the controlling stresses (P_m = 29.8 ksi and P_L+P_b = 34.2 ksi).

Seismic Stresses

Seismic stresses on cover plate are scaled from the 1g vertical deadweight up to 6gs. These results are summarized in the SAR Table Appendix D (Table D-2).

Table 10-1 Controlling Load Combination Stress Results for Cylindrical Shell (Top Half)

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
DD-1	B	P_m	$DW_V + P_{I(HS+20)} + P_{E(HS)}$	1.24	18.0	0.07
		P_L+P_b	$DW_V + P_{I(HS+20)} + P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V + P_{I(HS+20)} + P_{E(HS)} + TH_8$	N/A	N/A	N/A
DD-2	B	P_m	$DW_V + P_{I(14.7)}$	1.35	18.0	0.07
		P_L+P_b	$DW_V + P_{I(14.7)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V + P_{I(14.7)} + TH_8$	25.1	54.0	0.46
DD-3	B	P_m	$DW_V + P_{I(12)} + P_{E(HS)}$	0.31	18.0	0.02
		P_L+P_b	$DW_V + P_{I(12)} + P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V + P_{I(12)} + P_{E(HS)} + TH_8$	24.1	54.0	0.45
DD-4	B	P_m	$DW_V + P_{I(5)} + P_{E(HS)}$	0.13	18.0	0.01
		P_L+P_b	$DW_V + P_{I(5)} + P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V + P_{I(5)} + P_{E(HS)} + TH_8$	23.9	54.0	0.44
TL-2	A	P_m	$DW_V + P_{I(10)}$	1.85	16.7	0.11
		P_L+P_b	$DW_V + P_{I(10)}$	4.79	25.0	0.19
		P_L+P_b+Q	$DW_V + P_{I(10)} + TH_8$	15.38	50.1	0.31
TL-3	A	P_m	$DW_H + P_{I(10)}$	4.28	16.7	0.26
		P_L+P_b	$DW_H + P_{I(10)}$	7.44	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_7$	17.76	50.1	0.35
TL-4	A	P_m	$DW_H + P_{I(10)}$	4.28	16.7	0.26
		P_L+P_b	$DW_H + P_{I(10)}$	7.44	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_8$	15.64	50.1	0.31
TR-1	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	4.93	16.7	0.30
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	8.49	25.0	0.34
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_7	18.92	50.1	0.38
TR-2	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	5.35	16.7	0.32
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	8.68	25.0	0.35
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_7	18.90	50.1	0.38
TR-3	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	6.86	16.7	0.41
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	10.44	25.0	0.42
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_7	20.51	50.1	0.41
TR-4	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	6.10	16.7	0.37
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	9.71	25.0	0.39
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_7	19.94	50.1	0.40
TR-5	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	4.93	16.7	0.30
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	8.49	25.0	0.34
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_8	16.80	50.1	0.34
TR-6	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	5.35	16.7	0.32
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	8.68	25.0	0.35
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	16.78	50.1	0.33
TR-7	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	6.86	16.7	0.41
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	10.44	25.0	0.42
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	18.39	50.1	0.37
TR-8	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	6.10	16.7	0.37
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	9.71	25.0	0.39
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	17.82	50.1	0.36
TR-9	D	P_m	$P_{I(20)}$ + 60g BED	9.16	40.0	0.23
		P_L+P_b	$P_{I(20)}$ + 60g BED	21.62	60.1	0.36

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-10	D	P_m	$P_{I(20)}$ + 75g SD (elastic/plastic)	29.8*	50.2	0.59
		P_L+P_b	$P_{I(20)}$ + 75g SD (elastic/plastic)	38.2	64.6	0.59
HSM-3	B	P_m	$DW_H + P_{I(20)}$	12.9	16.7	0.77
		P_L+P_b	$DW_H + P_{I(20)}$	19.4	25.0	0.78
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{15}$	29.7	50.1	0.59
HSM-4	B	P_m	$DW_H + P_{I(20)}$	12.9	16.7	0.77
		P_L+P_b	$DW_H + P_{I(20)}$	19.4	25.0	0.78
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{16}$	31.2	50.1	0.62
HSM-10	D	P_m	$DW_H + P_{I(20)}$ + Seismic	10.2	43.2	0.24
HSM-11	D	P_m	$DW_H + P_{I(60)}$	12.8	50.2	0.25
		P_L+P_b	$DW_H + P_{I(60)}$	29.6	64.6	0.46
HSM-13	C	P_m	DW_H + Flood	4.16	20.0	0.21
		P_L+P_b	DW_H + Flood	5.87	30.0	0.20

* Stress in region of spacer discs, per Reference 8

Table 10-2 - Controlling Load Combination Stress Results for Outer Top Cover Plate

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P_m	$DW_V + P_{K(10)}$	1.33	16.7	0.08
		P_L+P_b	$DW_V + P_{K(10)}$	4.12	25.0	0.16
		P_L+P_b+Q	$DW_V + P_{K(10)} + TH_8$	13.3	50.1	0.26
TL-3	A	P_m	$DW_H + P_{K(10)}$	2.45	16.7	0.15
		P_L+P_b	$DW_H + P_{K(10)}$	5.81	25.0	0.23
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_7$	14.4	50.1	0.29
TL-4	A	P_m	$DW_H + P_{K(10)}$	2.45	16.7	0.15
		P_L+P_b	$DW_H + P_{K(10)}$	5.81	25.0	0.23
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_8$	11.7	50.1	0.23
TR-1	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	2.61	16.7	0.16
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	6.19	25.0	0.25
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_7	14.8	50.1	0.29
TR-2	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	2.92	16.7	0.17
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	6.52	25.0	0.26
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_7	14.9	50.1	0.30
TR-3	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	3.59	16.7	0.21
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	7.53	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_7	15.6	50.1	0.31
TR-4	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	3.19	16.7	0.19
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	7.00	25.0	0.28
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_7	15.3	50.1	0.31
TR-5	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	2.61	16.7	0.16
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	6.19	25.0	0.25
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_8	12.1	50.1	0.24
TR-6	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	2.92	16.7	0.17
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	6.52	25.0	0.26
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_8	12.2	50.1	0.24
TR-7	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	3.59	16.7	0.21
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	7.53	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_8	12.9	50.1	0.26
TR-8	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	3.19	16.7	0.19
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	7.00	25.0	0.28
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_8	12.6	50.1	0.25
TR-9	D	P_m	$P_{K(20)}$ + 60g BED	1.14	40.0	0.03
		P_L+P_b	$P_{K(20)}$ + 60g BED	1.77	60.1	0.03
TR-10	D	P_m	$P_{K(20)}$ + 75g SD (elastic/plastic)	35.40	50.2	0.71
		P_L+P_b	$P_{K(20)}$ + 75g SD (elastic/plastic)	52.10	64.6	0.81
HSM-3	B	P_m	$DW_H + P_{K(20)}$	4.46	16.7	0.27
		P_L+P_b	$DW_H + P_{K(20)}$	15.7*	25.0	0.63
		P_L+P_b+Q	$DW_H + P_{K(20)} + TH_{15}$	15.7*	50.1	0.31
HSM-4	B	P_m	$DW_H + P_{K(20)}$	4.46	16.7	0.27
		P_L+P_b	$DW_H + P_{K(20)}$	15.7*	25.0	0.63
		P_L+P_b+Q	$DW_H + P_{K(20)} + TH_{16}$	15.7*	50.1	0.31
HSM-11	D	P_m	$DW_H + P_{K(60)}$	8.98	50.2	0.18
		P_L+P_b	$DW_H + P_{K(60)}$	47.2*	60.1	0.79
HSM-13	C	P_m	DW_H + Flood	1.34	20.0	0.07
		P_L+P_b	DW_H + Flood	2.19	30.0	0.07

*Stresses based on results listed in Table 8-9 for pressure applied to the outer pressure boundary.

Table 10-3 Controlling Load Combination Stress Results for Inner Top Cover Plate

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
DD-1	B	P_m	$DW_V + P_{I(HS+20)} + P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V + P_{I(HS+20)} + P_{E(HS)}$	19.1	27.0	0.71
		P_L+P_b+Q	$DW_V + P_{I(HS+20)} + P_{E(HS)} + TH_8$	42.9	54.0	0.79
DD-2	B	P_m	$DW_V + P_{I(14.7)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V + P_{I(14.7)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V + P_{I(14.7)} + TH_8$	N/A	N/A	N/A
DD-3	B	P_m	$DW_V + P_{I(12)} + P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V + P_{I(12)} + P_{E(HS)}$	11.4	27.0	0.42
		P_L+P_b+Q	$DW_V + P_{I(12)} + P_{E(HS)} + TH_8$	35.2	54.0	0.65
DD-4	B	P_m	$DW_V + P_{I(5)} + P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V + P_{I(5)} + P_{E(HS)}$	4.8	27.0	0.18
		P_L+P_b+Q	$DW_V + P_{I(5)} + P_{E(HS)} + TH_8$	28.6	54.0	0.53
TL-2	A	P_m	$DW_V + P_{I(10)}$	0.44	16.7	0.03
		P_L+P_b	$DW_V + P_{I(10)}$	3.97	25.0	0.16
		P_L+P_b+Q	$DW_V + P_{I(10)} + TH_8$	12.8	50.1	0.25
TL-3	A	P_m	$DW_H + P_{I(10)}$	1.02	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$	5.62	25.0	0.22
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_7$	13.2	50.1	0.26
TL-4	A	P_m	$DW_H + P_{I(10)}$	1.02	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$	5.62	25.0	0.22
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_8$	14.4	50.1	0.29
TR-1	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	2.68	16.7	0.16
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	7.46	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_7	15.1	50.1	0.30
TR-2	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	1.26	16.7	0.08
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	6.31	25.0	0.25
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_7	13.9	50.1	0.28
TR-3	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	1.61	16.7	0.10
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	7.30	25.0	0.29
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_7	14.8	50.1	0.30
TR-4	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	2.19	16.7	0.13
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	7.51	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_7	15.1	50.1	0.30
TR-5	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	2.68	16.7	0.16
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	7.46	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_8	16.2	50.1	0.32
TR-6	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	1.26	16.7	0.08
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	6.31	25.0	0.25
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	15.1	50.1	0.30
TR-7	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	1.61	16.7	0.10
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	7.30	25.0	0.29
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	16.0	50.1	0.32
TR-8	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	2.19	16.7	0.13
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	7.51	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	16.3	50.1	0.32
TR-9	D	P_m	$P_{I(20)}$ + 60g BED	1.14	40.0	0.03
		P_L+P_b	$P_{I(20)}$ + 60g BED	1.99	60.1	0.03

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-10	D	P_m	$P_{I(20)}$ + 75g SD (elastic/plastic)	25.28	50.2	0.50
		P_L+P_b	$P_{I(20)}$ + 75g SD (elastic/plastic)	41.82	64.6	0.65
HSM-3	B	P_m	$DW_H + P_{I(20)}$	2.05	16.7	0.12
		P_L+P_b	$DW_H + P_{I(20)}$	7.96	25.0	0.32
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{15}$	11.7	50.1	0.23
HSM-4	B	P_m	$DW_H + P_{I(20)}$	2.05	16.7	0.12
		P_L+P_b	$DW_H + P_{I(20)}$	7.96	25.0	0.32
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{16}$	11.04	50.1	0.22
HSM-10	D	P_m	$DW_H + P_{I(20)}$ + Seismic	10.2	50.2	0.20
HSM-11	D	P_m	$DW_H + P_{I(60)}$	3.17	50.2	0.06
		P_L+P_b	$DW_H + P_{I(60)}$	25.3	64.6	0.39
HSM-13	C	P_m	DW_H + Flood	0.22	20.0	0.01
		P_L+P_b	DW_H + Flood	0.50	30.0	0.02

Table 10-4 Controlling Load Combination Stress Results for Top Shield Plug

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P_m	$DW_V + P_{K(10)}$	0.02	17.4	0.00
		P_L+P_b	$DW_V + P_{K(10)}$	0.06	26.1	0.00
		P_L+P_b+Q	$DW_V + P_{K(10)} + TH_8$	0.06	52.2	0.00
TL-3	A	P_m	$DW_H + P_{K(10)}$	0.24	17.4	0.01
		P_L+P_b	$DW_H + P_{K(10)}$	0.40	26.1	0.02
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_7$	0.40	52.2	0.01
TL-4	A	P_m	$DW_H + P_{K(10)}$	0.24	17.4	0.01
		P_L+P_b	$DW_H + P_{K(10)}$	0.40	26.1	0.02
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_8$	0.40	52.2	0.01
TR-1	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	0.41	17.4	0.02
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	0.82	26.1	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_7	0.82	52.2	0.02
TR-2	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	0.34	17.4	0.02
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	0.56	26.1	0.02
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_7	0.56	52.2	0.01
TR-3	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	0.49	17.4	0.03
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	0.80	26.1	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_7	0.80	52.2	0.02
TR-4	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.47	17.4	0.03
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.84	26.1	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_7	0.84	52.2	0.02
TR-5	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	0.41	17.4	0.02
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	0.82	26.1	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_8	0.82	52.2	0.02
TR-6	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	0.34	17.4	0.02
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	0.56	26.1	0.02
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_8	0.56	52.2	0.01
TR-7	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	0.49	17.4	0.03
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	0.80	26.1	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_8	0.80	52.2	0.02
TR-8	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.47	17.4	0.03
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.84	26.1	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_8	0.84	52.2	0.02
TR-9	D	P_m	$P_{K(20)}$ + 60g BED	1.49	40.6	0.04
		P_L+P_b	$P_{K(20)}$ + 60g BED	3.88	58.0	0.07
TR-10	D	P_m	$P_{K(20)}$ + 75g SD (elastic/plastic)	22.12	40.6	0.54
		P_L+P_b	$P_{K(20)}$ + 75g SD (elastic/plastic)	37.71	52.2	0.72
HSM-3	B	P_m	$DW_H + P_{K(20)}$	0.24	17.4	0.01
		P_L+P_b	$DW_H + P_{K(20)}$	0.40	26.1	0.02
		P_L+P_b+Q	$DW_H + P_{K(20)} + TH_{15}$	0.40	52.2	0.01
HSM-4	B	P_m	$DW_H + P_{K(20)}$	0.24	17.4	0.01
		P_L+P_b	$DW_H + P_{K(20)}$	0.40	26.1	0.02
		P_L+P_b+Q	$DW_H + P_{K(20)} + TH_{16}$	0.40	52.2	0.01
HSM-11	D	P_m	$DW_H + P_{K(60)}$	0.24	40.6	0.01
		P_L+P_b	$DW_H + P_{K(60)}$	0.40	58.0	0.01
HSM-13	C	P_m	DW_H + Flood	0.41	20.0	0.02
		P_L+P_b	DW_H + Flood	0.90	30.0	0.03

Table 10-5 Controlling Load Combination Stress Results for Support Ring

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P_m	$DW_V + P_{I(10)}$	0.63	16.7	0.04
		P_L+P_b	$DW_V + P_{I(10)}$	0.74	25.0	0.03
		P_L+P_b+Q	$DW_V + P_{I(10)} + TH_8$	4.45	50.1	0.09
TL-3	A	P_m	$DW_H + P_{I(10)}$	0.74	16.7	0.04
		P_L+P_b	$DW_H + P_{I(10)}$	0.80	25.0	0.03
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_7$	4.50	50.1	0.09
TL-4	A	P_m	$DW_H + P_{I(10)}$	0.74	16.7	0.04
		P_L+P_b	$DW_H + P_{I(10)}$	0.80	25.0	0.03
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_8$	3.16	50.1	0.06
TR-1	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	1.05	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	1.13	25.0	0.05
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_7	4.83	50.1	0.10
TR-2	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	0.83	16.7	0.05
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	0.90	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_7	4.59	50.1	0.09
TR-3	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	0.95	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	1.03	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_7	4.73	50.1	0.09
TR-4	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	1.01	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	1.10	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_7	4.80	50.1	0.10
TR-5	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	1.05	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	1.13	25.0	0.05
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_8	3.50	50.1	0.07
TR-6	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	0.83	16.7	0.05
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	0.90	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	3.26	50.1	0.07
TR-7	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	0.95	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	1.03	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	3.39	50.1	0.07
TR-8	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	1.01	16.7	0.06
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	1.10	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	3.46	50.1	0.07
TR-9	D	P_m	$P_{I(20)}$ + 60g BED	6.12	40.0	0.15
		P_L+P_b	$P_{I(20)}$ + 60g BED	10.60	60.1	0.18
TR-10	D	P_m	$P_{I(20)}$ + 75g SD (elastic/plastic)	5.32	50.2	0.11
		P_L+P_b	$P_{I(20)}$ + 75g SD (elastic/plastic)	9.90	64.6	0.15
HSM-3	B	P_m	$DW_H + P_{I(20)}$	1.19	16.7	0.07
		P_L+P_b	$DW_H + P_{I(20)}$	1.35	25.0	0.05
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{15}$	3.76	50.1	0.08
HSM-4	B	P_m	$DW_H + P_{I(20)}$	1.19	16.7	0.07
		P_L+P_b	$DW_H + P_{I(20)}$	1.35	25.0	0.05
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{16}$	3.18	50.1	0.06
HSM-11	D	P_m	$DW_H + P_{I(60)}$	3.40	40.6	0.08
		P_L+P_b	$DW_H + P_{I(60)}$	3.62	58.0	0.06
HSM-13	C	P_m	DW_H + Flood	1.58	20.0	0.08
		P_L+P_b	DW_H + Flood	2.17	30.0	0.07

Table 10-6 Controlling Load Combination Stress Results for Shell (Bottom Half)

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
NO-1	Test	P_m	$P_{E(14.7)}$+ 155k Axial	8.23	27.0	0.30
		P_L+P_b	$P_{E(14.7)}$+ 155k Axial	17.82	40.5	0.44
		P_L+P_b+Q	N/A	N/A	N/A	N/A
FL-1	A	P_m	$DW_V+P_{E(HS)}$	1.53	16.7	0.09
		P_L+P_b	$DW_V+P_{E(HS)}$	3.07	25.0	0.12
		P_L+P_b+Q	N/A	N/A	N/A	N/A
DD-1	B	P_m	$DW_V+P_{I(HS+20)}+P_{E(HS)}$	1.24	18.0	0.07
		P_L+P_b	$DW_V+P_{I(HS+20)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(HS+20)}+P_{E(HS)}+TH_8$	N/A	N/A	N/A
DD-2	B	P_m	$DW_V+P_{I(14.7)}$	1.35	18.0	0.07
		P_L+P_b	$DW_V+P_{I(14.7)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(14.7)}+TH_8$	25.1	54.0	0.47
DD-3	B	P_m	$DW_V+P_{I(12)}+P_{E(HS)}$	0.31	18.0	0.02
		P_L+P_b	$DW_V+P_{I(12)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(12)}+P_{E(HS)}+TH_8$	24.1	54.0	0.45
DD-4	B	P_m	$DW_V+P_{I(5)}+P_{E(HS)}$	0.13	18.0	0.01
		P_L+P_b	$DW_V+P_{I(5)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(5)}+P_{E(HS)}+TH_8$	23.9	54.0	0.44
TL-2	A	P_m	$DW_V+P_{I(10)}$	0.78	16.7	0.05
		P_L+P_b	$DW_V+P_{I(10)}$	1.70	25.0	0.07
		P_L+P_b+Q	$DW_V+P_{I(10)}+TH_8$	23.8	50.1	0.47
TL-3	A	P_m	$DW_H+P_{I(10)}$	3.19	16.7	0.19
		P_L+P_b	$DW_H+P_{I(10)}$	4.45	25.0	0.18
		P_L+P_b+Q	$DW_H+P_{I(10)}+TH_7$	26.3	50.1	0.52
TL-4	A	P_m	$DW_H+P_{I(10)}$	3.19	16.7	0.19
		P_L+P_b	$DW_H+P_{I(10)}$	4.45	25.0	0.18
		P_L+P_b+Q	$DW_H+P_{I(10)}+TH_8$	20.4	50.1	0.41
TR-1	A	P_m	$DW_H+P_{I(10)}$ + 1g Axial	4.03	16.7	0.24
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Axial	7.18	25.0	0.29
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Axial + TH_7	29.1	50.1	0.58
TR-2	A	P_m	$DW_H+P_{I(10)}$ + 1g Trans.	4.26	16.7	0.25
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Trans.	5.73	25.0	0.23
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Trans + TH_7	27.4	50.1	0.55
TR-3	A	P_m	$DW_H+P_{I(10)}$ + 1g Vert.	5.76	16.7	0.34
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Vert.	7.55	25.0	0.30
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Vert. + TH_7	29.1	50.1	0.58
TR-4	A	P_m	$DW_H+P_{I(10)}$ + ½g X, Y, Z	5.10	16.7	0.31
		P_L+P_b	$DW_H+P_{I(10)}$ + ½g X, Y, Z	7.61	25.0	0.30
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + ½g X,Y,Z + TH_7	29.3	50.1	0.58
TR-5	A	P_m	$DW_H+P_{I(10)}$ + 1g Axial	4.03	16.7	0.24
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Axial	7.18	25.0	0.29
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Axial + TH_8	23.3	50.1	0.46

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-6	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	4.26	16.7	0.25
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	5.73	25.0	0.23
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	21.6	50.1	0.43
TR-7	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	5.76	16.7	0.34
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	7.55	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	23.2	50.1	0.46
TR-8	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	5.10	16.7	0.31
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	7.61	25.0	0.30
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	23.5	50.1	0.47
TR-10	D	P_m	$P_{I(10)}$ + 75g SD (elastic/plastic)	29.8	50.2	0.59
		P_L+P_b	$P_{I(10)}$ + 75g SD (elastic/plastic)	43.3	64.6	0.67
TR-12	D	P_m	$P_{I(20)}$ + 60g TED	10.9	40.0	0.27
		P_L+P_b	$P_{I(20)}$ + 60g TED	24.2	60.1	0.40
LD-3	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	6.48	16.7	0.39
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	8.22	25.0	0.33
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	29.2	50.1	0.58
LD-4	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	6.48	16.7	0.39
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	8.22	25.0	0.33
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	23.4	50.1	0.47
HSM-3	B	P_m	$DW_H + P_{I(20)}$	3.82	16.7	0.23
		P_L+P_b	$DW_H + P_{I(20)}$	5.79	25.0	0.23
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{15}	14.6	50.1	0.29
HSM-4	B	P_m	$DW_H + P_{I(20)}$	3.82	16.7	0.23
		P_L+P_b	$DW_H + P_{I(20)}$	5.79	25.0	0.23
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{26}	16.2	50.1	0.32
HSM-10	D	P_m	$DW_H + P_{I(20)}$ + Seismic	10.2	43.2	0.24
HSM-11	D	P_m	$DW_H + P_{I(60)}$	6.34	40.0	0.16
		P_L+P_b	$DW_H + P_{I(60)}$	11.17	60.1	0.19
HSM-13	C	P_m	DW_H + Flood	3.95	20.0	0.20
		P_L+P_b	DW_H + Flood	5.82	30.0	0.19
UL-3	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	17.1	20.0(1),(4)	0.86
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	24.3	30.0(1),(4)	0.81
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	26.4	60.0(1)	0.44
UL-4	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	17.1	18.6(2),(4)	0.92
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	24.3	27.9(2),(4)	0.87
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{16}	30.5	55.9(2)	0.55
UL-5	C	P_m	$DW_H + P_{I(20)}$ + 80k Grapple	22.5	23.2(3),(4)	0.97
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Grapple	31.8	34.7(3)	0.92

Notes:
1. Allowable stress evaluated at 300 °F.
2. Allowable stress evaluated at 450 °F.
3. Allowable stress evaluated at 400 °F.
4. Stress intensity based on sum of stress components from ANSYS® runs.

Table 10-7 Controlling Load Combination Stress Results for Outer Bottom Cover Plate

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
NO-1	Test	P_m	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b+Q	N/A	N/A	N/A	N/A
FL-1	A	P_m	DW_V+ $P_{E(HS)}$	0.30	16.7	0.02
		P_L+P_b	DW_V+ $P_{E(HS)}$	0.47	25.0	0.02
		P_L+P_b+Q	N/A	N/A	N/A	N/A
TL-2	A	P_m	$DW_V + P_{I(10)}$	0.62	16.7	0.04
		P_L+P_b	$DW_V + P_{I(10)}$	1.07	25.0	0.04
		P_L+P_b+Q	$DW_V + P_{I(10)} + TH_8$	20.5	50.1	0.41
TL-3	A	P_m	$DW_H + P_{I(10)}$	1.31	16.7	0.08
		P_L+P_b	$DW_H + P_{I(10)}$	2.24	25.0	0.09
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_7$	21.6	50.1	0.43
TL-4	A	P_m	$DW_H + P_{I(10)}$	1.31	16.7	0.08
		P_L+P_b	$DW_H + P_{I(10)}$	2.24	25.0	0.09
		P_L+P_b+Q	$DW_H + P_{I(10)} + TH_8$	16.0	50.1	0.32
TR-1	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	2.58	16.7	0.15
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	4.42	25.0	0.18
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_7	23.5	50.1	0.47
TR-2	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	1.60	16.7	0.10
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	2.73	25.0	0.11
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_7	22.1	50.1	0.44
TR-3	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	2.01	16.7	0.12
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	3.42	25.0	0.14
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_7	22.7	50.1	0.45
TR-4	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	2.35	16.7	0.14
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	4.01	25.0	0.16
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_7	23.2	50.1	0.46
TR-5	A	P_m	$DW_H + P_{I(10)}$ + 1g Axial	2.58	16.7	0.15
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Axial	4.42	25.0	0.18
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Axial + TH_8	17.9	50.1	0.36
TR-6	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	1.60	16.7	0.10
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	2.73	25.0	0.11
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	16.5	50.1	0.33
TR-7	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	2.01	16.7	0.12
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	3.42	25.0	0.14
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	17.1	50.1	0.34
TR-8	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	2.35	16.7	0.14
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	4.01	25.0	0.16
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	17.6	50.1	0.35
TR-10	D	P_m	$P_{I(10)}$ + 75g SD (elastic/plastic)	23.15	50.2	0.46
		P_L+P_b	$P_{I(10)}$ + 75g SD (elastic/plastic)	34.08	64.6	0.53

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-12	D	P_m	$P_{I(20)}$ + 60g TED	1.65	40.0	0.04
		P_L+P_b	$P_{I(20)}$ + 60g TED	3.13	60.1	0.05
LD-3	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	6.63	16.7	0.40
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	13.0	25.0	0.52
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	22.8	50.1	0.46
LD-4	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	6.63	16.7	0.40
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	13.0	25.0	0.52
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	19.8	50.1	0.39
HSM-3	B	P_m	$DW_H + P_{I(20)}$	1.93	16.7	0.12
		P_L+P_b	$DW_H + P_{I(20)}$	3.31	25.0	0.13
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{15}$	7.27	50.1	0.15
HSM-4	B	P_m	$DW_H + P_{I(20)}$	1.93	16.7	0.12
		P_L+P_b	$DW_H + P_{I(20)}$	3.31	25.0	0.13
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{26}$	6.45	50.1	0.13
HSM-11	D	P_m	$DW_H + P_{I(60)}$	4.40	40.0	0.11
		P_L+P_b	$DW_H + P_{I(60)}$	7.59	60.1	0.13
HSM-13	C	P_m	DW_H + Flood	1.00	20.0	0.05
		P_L+P_b	DW_H + Flood	1.64	30.0	0.05
UL-3	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	17.0	20.0(1)	0.85
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	27.2	30.0(1)	0.91
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	27.2	60.0(1)	0.45
UL-4	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	17.0	18.6(2)	0.91
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	27.2	27.9(2)	0.97(5)
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{16}	27.2	55.9(2)	0.49
UL-5	C	P_m	$DW_H + P_{I(20)}$ + 80k Grapple	21.6	23.2(3)	0.93
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Grapple	32.8	34.7(3), (4)	0.95

Notes:
1. Allowable stress evaluated at 300 °F.
2. Allowable stress evaluated at 450 °F.
3. Allowable stress evaluated at 400 °F.
4. Stress intensity based on sum of stress components from ANSYS® runs.
5. This load combination in ANSYS conservatively includes a 20 psi internal pressure on both in the inner and outer bottom cover plates. The stress intensity produced by the ANSYS analyses in 27.2 ksi, giving a stress ratio of +0.97. However, ignoring the fictitious 2.1 ksi stress due to the 20 psi internal pressure results in a stress intensity equal to 25.0 ksi. Thus, the actual stress ratio is equal to 0.90.

Table 10-8 Controlling Load Combination Stress Results for Bottom Shield Plug

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
NO-1	Test	P_m	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b+Q	N/A	N/A	N/A	N/A
FL-1	A	P_m	$DW_V+P_{E(HS)}$	0.16	16.7	0.01
		P_L+P_b	$DW_V+P_{E(HS)}$	0.73	25.0	0.03
		P_L+P_b+Q	N/A	N/A	N/A	N/A
TL-2	A	P_m	$DW_V+P_{I(10)}$	0.11	16.7	0.01
		P_L+P_b	$DW_V+P_{I(10)}$	0.31	25.0	0.01
		P_L+P_b+Q	$DW_V+P_{I(10)}+TH_8$	0.31	50.1	0.01
TL-3	A	P_m	$DW_H+P_{I(10)}$	0.42	16.7	0.03
		P_L+P_b	$DW_H+P_{I(10)}$	0.63	25.0	0.03
		P_L+P_b+Q	$DW_H+P_{I(10)}+TH_7$	0.63	50.1	0.01
TL-4	A	P_m	$DW_H+P_{I(10)}$	0.42	16.7	0.03
		P_L+P_b	$DW_H+P_{I(10)}$	0.63	25.0	0.03
		P_L+P_b+Q	$DW_H+P_{I(10)}+TH_8$	0.63	50.1	0.01
TR-1	A	P_m	$DW_H+P_{I(10)}$ + 1g Axial	0.63	16.7	0.04
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Axial	1.20	25.0	0.05
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Axial + TH_7	1.20	50.1	0.02
TR-2	A	P_m	$DW_H+P_{I(10)}$ + 1g Trans.	0.55	16.7	0.03
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Trans.	0.76	25.0	0.03
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Trans + TH_7	0.76	50.1	0.02
TR-3	A	P_m	$DW_H+P_{I(10)}$ + 1g Vert.	0.73	16.7	0.04
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Vert.	0.94	25.0	0.04
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Vert. + TH_7	0.94	50.1	0.02
TR-4	A	P_m	$DW_H+P_{I(10)}$ + ½g X, Y, Z	0.70	16.7	0.04
		P_L+P_b	$DW_H+P_{I(10)}$ + ½g X, Y, Z	1.10	25.0	0.04
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + ½g X,Y,Z + TH_7	1.10	50.1	0.02
TR-5	A	P_m	$DW_H+P_{I(10)}$ + 1g Axial	0.63	16.7	0.04
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Axial	1.20	25.0	0.05
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Axial + TH_8	1.20	50.1	0.02
TR-6	A	P_m	$DW_H+P_{I(10)}$ + 1g Trans.	0.55	16.7	0.03
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Trans.	0.76	25.0	0.03
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Trans + TH_8	0.76	50.1	0.02
TR-7	A	P_m	$DW_H+P_{I(10)}$ + 1g Vert.	0.73	16.7	0.04
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Vert.	0.94	25.0	0.04
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Vert. + TH_8	0.94	50.1	0.02
TR-8	A	P_m	$DW_H+P_{I(10)}$ + ½g X, Y, Z	0.70	16.7	0.04
		P_L+P_b	$DW_H+P_{I(10)}$ + ½g X, Y, Z	1.10	25.0	0.04
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + ½g X,Y,Z + TH_8	1.10	50.1	0.02
TR-10	D	P_m	$P_{I(10)}$ + 75g SD (elastic/plastic)	24.7	50.2	0.49
		P_L+P_b	$P_{I(10)}$ + 75g SD (elastic/plastic)	26.4	64.6	0.41

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-12	D	P_m	$P_{I(20)}$ + 60g TED	1.19	40.0	0.03
		P_L+P_b	$P_{I(20)}$ + 60g TED	4.48	60.1	0.07
LD-3	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	0.99	16.7	0.06
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	3.87	25.0	0.15
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	11.3	50.1	0.23
LD-4	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	0.99	16.7	0.06
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	3.87	25.0	0.15
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	9.65	50.1	0.19
HSM-3	B	P_m	$DW_H + P_{I(20)}$	0.52	16.7	0.03
		P_L+P_b	$DW_H + P_{I(20)}$	0.94	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{15}	0.94	50.1	0.02
HSM-4	B	P_m	$DW_H + P_{I(20)}$	0.52	16.7	0.03
		P_L+P_b	$DW_H + P_{I(20)}$	0.94	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{26}	0.94	50.1	0.02
HSM-11	D	P_m	$DW_H + P_{I(60)}$	0.95	40.0	0.02
		P_L+P_b	$DW_H + P_{I(60)}$	2.19	60.1	0.04
HSM-13	C	P_m	DW_H + Flood	0.47	20.0	0.02
		P_L+P_b	DW_H + Flood	1.05	30.0	0.04
UL-3	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	0.52	16.7	0.03
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	0.94	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	4.12	50.1	0.08
UL-4	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	0.52	16.7	0.03
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	0.94	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{16}	3.58	50.1	0.07
UL-5	C	P_m	$DW_H + P_{I(20)}$ + 80k Grapple	0.52	20.0	0.03
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Grapple	0.94	30.0	0.03

Table 10-9 Controlling Load Combination Stress Results for Inner Bottom Cover Plate

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
NO-1	Test	P_m	$P_{E(14.7)}$+ 155k Axial	1.26	27.0	0.05
		P_L+P_b	$P_{E(14.7)}$+ 155k Axial	19.0	30.0	0.63
		P_L+P_b+Q	N/A	N/A	N/A	N/A
FL-1	A	P_m	$DW_V+P_{E(HS)}$	0.81	16.7	0.05
		P_L+P_b	$DW_V+P_{E(HS)}$	1.56	25.0	0.06
		P_L+P_b+Q	N/A	N/A	N/A	N/A
DD-1	B	P_m	$DW_V+P_{I(HS+20)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V+P_{I(HS+20)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(HS+20)}+P_{E(HS)}+TH_8$	N/A	N/A	N/A
DD-2	B	P_m	$DW_V+P_{I(14.7)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V+P_{I(14.7)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(14.7)}+TH_8$	N/A	N/A	N/A
DD-3	B	P_m	$DW_V+P_{I(12)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V+P_{I(12)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(12)}+P_{E(HS)}+TH_8$	N/A	N/A	N/A
DD-4	B	P_m	$DW_V+P_{I(5)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b	$DW_V+P_{I(5)}+P_{E(HS)}$	N/A	N/A	N/A
		P_L+P_b+Q	$DW_V+P_{I(5)}+P_{E(HS)}+TH_8$	N/A	N/A	N/A
TL-2	A	P_m	$DW_V+P_{I(10)}$	0.27	16.7	0.02
		P_L+P_b	$DW_V+P_{I(10)}$	0.74	25.0	0.03
		P_L+P_b+Q	$DW_V+P_{I(10)}+TH_8$	18.0	50.1	0.36
TL-3	A	P_m	$DW_H+P_{I(10)}$	0.98	16.7	0.06
		P_L+P_b	$DW_H+P_{I(10)}$	1.56	25.0	0.06
		P_L+P_b+Q	$DW_H+P_{I(10)}+TH_7$	18.8	50.1	0.38
TL-4	A	P_m	$DW_H+P_{I(10)}$	0.98	16.7	0.06
		P_L+P_b	$DW_H+P_{I(10)}$	1.56	25.0	0.06
		P_L+P_b+Q	$DW_H+P_{I(10)}+TH_8$	12.2	50.1	0.24
TR-1	A	P_m	$DW_H+P_{I(10)}$ + 1g Axial	1.22	16.7	0.07
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Axial	2.38	25.0	0.10
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Axial + TH_7	19.6	50.1	0.39
TR-2	A	P_m	$DW_H+P_{I(10)}$ + 1g Trans.	1.27	16.7	0.08
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Trans.	1.89	25.0	0.08
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Trans + TH_7	19.1	50.1	0.38
TR-3	A	P_m	$DW_H+P_{I(10)}$ + 1g Vert.	1.68	16.7	0.10
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Vert.	2.37	25.0	0.09
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Vert. + TH_7	19.6	50.1	0.39
TR-4	A	P_m	$DW_H+P_{I(10)}$ + ½g X, Y, Z	1.51	16.7	0.09
		P_L+P_b	$DW_H+P_{I(10)}$ + ½g X, Y, Z	2.45	25.0	0.10
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + ½g X,Y,Z + TH_7	19.7	50.1	0.39
TR-5	A	P_m	$DW_H+P_{I(10)}$ + 1g Axial	1.22	16.7	0.07
		P_L+P_b	$DW_H+P_{I(10)}$ + 1g Axial	2.38	25.0	0.10
		P_L+P_b+Q	$DW_H+P_{I(10)}$ + 1g Axial + TH_8	13.1	50.1	0.26

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-6	A	P_m	$DW_H + P_{I(10)}$ + 1g Trans.	1.27	16.7	0.08
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Trans.	1.89	25.0	0.08
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Trans + TH_8	12.6	50.1	0.25
TR-7	A	P_m	$DW_H + P_{I(10)}$ + 1g Vert.	1.68	16.7	0.10
		P_L+P_b	$DW_H + P_{I(10)}$ + 1g Vert.	2.37	25.0	0.09
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + 1g Vert. + TH_8	13.1	50.1	0.26
TR-8	A	P_m	$DW_H + P_{I(10)}$ + ½g X, Y, Z	1.51	16.7	0.09
		P_L+P_b	$DW_H + P_{I(10)}$ + ½g X, Y, Z	2.45	25.0	0.10
		P_L+P_b+Q	$DW_H + P_{I(10)}$ + ½g X,Y,Z + TH_8	13.1	50.1	0.26
TR-10	D	P_m	$P_{I(10)}$ + 75g SD (elastic/plastic)	39.13	50.2	0.78
		P_L+P_b	$P_{I(10)}$ + 75g SD (elastic/plastic)	40.07	64.6	0.62
TR-12	D	P_m	$P_{I(20)}$ + 60g TED	5.80	40.0	0.15
		P_L+P_b	$P_{I(20)}$ + 60g TED	19.26	60.1	0.32
LD-3	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	3.91	16.7	0.23
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	6.11	25.0	0.24
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	20.1	50.1	0.40
LD-4	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	3.91	16.7	0.23
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	6.11	25.0	0.24
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	14.3	50.1	0.28
HSM-3	B	P_m	$DW_H + P_{I(20)}$	1.25	16.7	0.08
		P_L+P_b	$DW_H + P_{I(20)}$	2.29	25.0	0.09
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{15}	8.96	50.1	0.18
HSM-4	B	P_m	$DW_H + P_{I(20)}$	1.25	16.7	0.08
		P_L+P_b	$DW_H + P_{I(20)}$	2.29	25.0	0.09
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{26}	7.66	50.1	0.15
HSM-10	D	P_m	$DW_H + P_{I(20)}$ + Seismic	1.2	40.0	0.03
HSM-11	D	P_m	$DW_H + P_{I(60)}$	2.35	40.0	0.06
		P_L+P_b	$DW_H + P_{I(60)}$	5.24	60.1	0.09
HSM-13	C	P_m	DW_H + Flood	1.51	20.0	0.08
		P_L+P_b	DW_H + Flood	2.38	30.0	0.08
UL-3	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	11.1	16.7	0.67
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	14.8	25.0	0.59
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	14.8	50.1	0.30
UL-4	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	11.1	16.7	0.67
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	14.8	25.0	0.59
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{16}	14.8	50.1	0.30
UL-5	C	P_m	$DW_H + P_{I(20)}$ + 80k Grapple	14.4	20.0	0.72
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Grapple	19.0	30.0	0.63

Table 10-10 Controlling Load Combination Stress Results for Grapple Ring Support

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
NO-1	Test	P_m	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b+Q	N/A	N/A	N/A	N/A
FL-1	A	P_m	$DW_V + P_{E(HS)}$	0.24	16.7	0.01
		P_L+P_b	$DW_V + P_{E(HS)}$	0.62	25.0	0.02
		P_L+P_b+Q	N/A	N/A	N/A	N/A
TL-2	A	P_m	$DW_V + P_{K(10)}$	0.00	16.7	0.00
		P_L+P_b	$DW_V + P_{K(10)}$	0.00	25.0	0.00
		P_L+P_b+Q	$DW_V + P_{K(10)} + TH_8$	10.26	50.1	0.20
TL-3	A	P_m	$DW_H + P_{K(10)}$	0.04	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$	0.05	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_7$	10.32	50.1	0.21
TL-4	A	P_m	$DW_H + P_{K(10)}$	0.04	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$	0.05	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_8$	8.22	50.1	0.16
TR-1	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	0.57	16.7	0.03
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	1.46	25.0	0.06
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_7	11.6	50.1	0.23
TR-2	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	0.05	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	0.08	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_7	10.3	50.1	0.21
TR-3	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	0.07	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	0.11	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_7	10.4	50.1	0.21
TR-4	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.32	16.7	0.02
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.79	25.0	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_7	11.0	50.1	0.22
TR-5	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	0.57	16.7	0.03
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	1.46	25.0	0.06
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_8	9.49	50.1	0.19
TR-6	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	0.05	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	0.08	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_8	8.24	50.1	0.16
TR-7	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	0.07	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	0.11	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_8	8.27	50.1	0.17
TR-8	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.32	16.7	0.02
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.79	25.0	0.03
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_8	8.89	50.1	0.18

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-10	D	P_m	$P_{I(10)}$ + 75g SD (elastic/plastic)	2.03	50.2	0.04
		P_L+P_b	$P_{I(10)}$ + 75g SD (elastic/plastic)	3.20	64.6	0.05
TR-12	D	P_m	$P_{I(20)}$ + 60g TED	1.51	40.0	0.04
		P_L+P_b	$P_{I(20)}$ + 60g TED	4.01	60.1	0.07
LD-3	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	1.98	19.3	0.10
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	5.07	29.0	0.18
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	26.2	57.9	0.45
LD-4	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	1.98	18.6	0.11
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	5.07	27.9	0.18
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	24.4	55.9	0.44
HSM-3	B	P_m	$DW_H + P_{I(20)}$	0.04	16.7	0.00
		P_L+P_b	$DW_H + P_{I(20)}$	0.05	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{15}	5.83	50.1	0.12
HSM-4	B	P_m	$DW_H + P_{I(20)}$	0.04	16.7	0.00
		P_L+P_b	$DW_H + P_{I(20)}$	0.05	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + TH_{26}	5.07	50.1	0.10
HSM-11	D	P_m	$DW_H + P_{I(60)}$	0.04	40.0	0.00
		P_L+P_b	$DW_H + P_{I(60)}$	0.05	60.1	0.00
HSM-13	C	P_m	DW_H + Flood	0.04	20.0	0.00
		P_L+P_b	DW_H + Flood	0.05	30.0	0.00
UL-3	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	6.10	16.7	0.37
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	22.0	25.0	0.88
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	39.85	50.1	0.80
UL-4	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	6.10	16.7	0.37
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	22.0	25.0	0.88
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{16}	38.57	50.1	0.77
UL-5	C	P_m	$DW_H + P_{I(20)}$ + 80k Grapple	8.12	23.2[1]	0.35
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Grapple	29.3	34.7[1]	0.84

Notes:
1. Allowable stress evaluated at 400 °F.

Table 10-11 Controlling Load Combination Stress Results for Grapple Ring

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
NO-1	Test	P_m	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b	$P_{E(14.7)}$+ 155k Axial	N/A	N/A	N/A
		P_L+P_b+Q	N/A	N/A	N/A	N/A
FL-1	A	P_m	DW_V+ $P_{E(HS)}$	0.02	16.7	0.00
		P_L+P_b	DW_V+ $P_{E(HS)}$	0.09	25.0	0.00
		P_L+P_b+Q	N/A	N/A	N/A	N/A
TL-2	A	P_m	$DW_V + P_{K(10)}$	0.00	16.7	0.00
		P_L+P_b	$DW_V + P_{K(10)}$	0.00	25.0	0.00
		P_L+P_b+Q	$DW_V + P_{K(10)} + TH_8$	3.81	50.1	0.08
TL-3	A	P_m	$DW_H + P_{K(10)}$	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$	0.01	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_7$	3.82	50.1	0.08
TL-4	A	P_m	$DW_H + P_{K(10)}$	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$	0.01	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)} + TH_8$	2.61	50.1	0.05
TR-1	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	0.05	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	0.20	25.0	0.01
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_7	3.99	50.1	0.08
TR-2	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	0.01	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_7	3.82	50.1	0.08
TR-3	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	0.02	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_7	3.83	50.1	0.08
TR-4	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.03	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.11	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_7	3.91	50.1	0.08
TR-5	A	P_m	$DW_H + P_{K(10)}$ + 1g Axial	0.05	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Axial	0.20	25.0	0.01
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Axial + TH_8	2.78	50.1	0.06
TR-6	A	P_m	$DW_H + P_{K(10)}$ + 1g Trans.	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Trans.	0.01	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Trans + TH_8	2.61	50.1	0.05
TR-7	A	P_m	$DW_H + P_{K(10)}$ + 1g Vert.	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + 1g Vert.	0.02	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + 1g Vert. + TH_8	2.62	50.1	0.05
TR-8	A	P_m	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.03	16.7	0.00
		P_L+P_b	$DW_H + P_{K(10)}$ + ½g X, Y, Z	0.11	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{K(10)}$ + ½g X,Y,Z + TH_8	2.70	50.1	0.05

Load Comb.	Service Level	Stress Category	Loads	Stress Intensity (ksi)	Allowable Stress (ksi)	Stress Ratio
TR-10	D	P_m	$P_{I(10)}$ + 75g SD (elastic/plastic)	0.24	50.2	0.00
		P_L+P_b	$P_{I(10)}$ + 75g SD (elastic/plastic)	0.48	64.6	0.01
TR-12	D	P_m	$P_{I(20)}$ + 60g TED	0.18	40.0	0.00
		P_L+P_b	$P_{I(20)}$ + 60g TED	0.53	60.1	0.01
LD-3	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	0.46	16.7	0.03
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	0.99	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_7	7.52	50.1	0.15
LD-4	B	P_m	$DW_H + P_{I(20)}$ + 80k Ram	0.46	16.7	0.03
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Ram	0.99	25.0	0.04
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 80k Ram + TH_8	6.46	50.1	0.13
HSM-3	B	P_m	$DW_H + P_{I(20)}$	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{I(20)}$	0.01	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{15}$	3.65	50.1	0.07
HSM-4	B	P_m	$DW_H + P_{I(20)}$	0.01	16.7	0.00
		P_L+P_b	$DW_H + P_{I(20)}$	0.01	25.0	0.00
		P_L+P_b+Q	$DW_H + P_{I(20)} + TH_{26}$	2.96	50.1	0.06
HSM-11	D	P_m	$DW_H + P_{I(60)}$	0.01	40.0	0.00
		P_L+P_b	$DW_H + P_{I(60)}$	0.01	60.1	0.00
HSM-13	C	P_m	DW_H + Flood	0.01	20.0	0.00
		P_L+P_b	DW_H + Flood	0.01	30.0	0.00
UL-3	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	9.98	20.0	0.50
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	17.3	30.0	0.58
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{15}	17.32	60.0	0.29
UL-4	B	P_m	$DW_H + P_{I(20)}$ + 60k Grapple	9.98	20.0	0.50
		P_L+P_b	$DW_H + P_{I(20)}$ + 60k Grapple	17.3	30.0	0.58
		P_L+P_b+Q	$DW_H + P_{I(20)}$ + 60k Grap + TH_{16}	17.91	60.0	0.30
UL-5	C	P_m	$DW_H + P_{I(20)}$ + 80k Grapple	13.3	20.0	0.67
		P_L+P_b	$DW_H + P_{I(20)}$ + 80k Grapple	23.1	30.0	0.77

Table 10-12 Controlling Load Combination Stress Results for Weld of Outer Top Cover Plate (Primary Stress[1])

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P	DWV + $P_{I(10)}$	675	0.68	10.0	0.07
TL-3	A	P	DWH + $P_{I(10)}$	1,712	1.72	10.0	0.17
TL-4	A	P	DWH + $P_{I(10)}$	1,712	1.72	10.0	0.17
TR-1	A	P	DWH + $P_{I(10)}$ + 1g Axial	1,851	1.86	10.0	0.19
TR-2	A	P	DWH + $P_{I(10)}$ + 1g Trans.	2,158	2.17	10.0	0.22
TR-3	A	P	DWH + $P_{I(10)}$ + 1g Vert.	2,788	2.80	10.0	0.28
TR-4	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	2,407	2.42	10.0	0.24
TR-5	A	P	DWH + $P_{I(10)}$ + 1g Axial	1,851	1.86	10.0	0.19
TR-6	A	P	DWH + $P_{I(10)}$ + 1g Trans.	2,158	2.17	10.0	0.22
TR-7	A	P	DWH + $P_{I(10)}$ + 1g Vert.	2,788	2.80	10.0	0.28
TR-8	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	2,407	2.42	10.0	0.24
TR-9	D	P	$P_{I(20)}$ + 60g BED	398	0.40	24.0	0.02
TR-10	D	P	$P_{I(20)}$ + 75g SD (elastic/plastic)	12,187	12.25	30.2	0.41
HSM-3	B	P	DWH + $P_{I(20)}$	2,349	2.36	10.0	0.24
HSM-4	C	P	DWH + $P_{I(20)}$	2,349	2.36	10.0	0.24
HSM-11	D	P	DWH + $P_{I(60)}$	4,896	4.92	24.0	0.21
HSM-13	C	P	DWH + Flood	1,186	1.19	12.0	0.10

Notes:

1. Stress is based on a weld thickness of 0.5 in. and a nodal tributary length of 1.99 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.

Table 10-13 Controlling Load Combination Stress Results for Weld of Outer Top Cover Plate (Primary + Secondary Stress[1])

Load Case	Service Level	Stress Category	Loads	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P_L+P_b+Q	DWV + $P_{I(10)}$ + $TH_{7,8}$	15.1	30.1	0.50
TL-3	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + TH_7	16.0	30.1	0.53
TL-4	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + TH_8	12.5	30.1	0.42
TR-1	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Axial + TH_7	16.4	30.1	0.54
TR-2	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Trans + TH_7	16.4	30.1	0.54
TR-3	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	16.9	30.1	0.56
TR-4	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	16.7	30.1	0.56
TR-5	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Axial + TH_8	12.9	30.1	0.43
TR-6	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Trans + TH_8	12.9	30.1	0.43
TR-7	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	13.5	30.1	0.45
TR-8	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	13.3	30.1	0.44
HSM-3	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + TH_{15}	9.1	30.1	0.30
HSM-4	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + TH_{26}	10.7	30.1	0.35

Notes

1. Primary+Secondary stress intensities are summarized to evaluate membrane+bending in the weld. Primary weld stresses are evaluated in Table 10-12.

Table 10-14 Controlling Load Combination Stress Results for Weld of Inner Top Cover Plate

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
Design	A	P	$P_{I(10)}$	851	2.28	10.8	0.21
TL-2	A	P	DWV + $P_{I(10)}$	867	2.32	10.0	0.23
		P + S	DWV + $P_{I(10)}$ + $TH_{7.8}$	2,877	7.71	30.1	0.26
TL-3	A	P	DWH + $P_{I(10)}$	1,829	4.90	10.0	0.49
		P + S	DWH + $P_{I(10)}$ + TH_7	2,616	7.01	30.1	0.23
TL-4	A	P	DWH + $P_{I(10)}$	1,829	4.90	10.0	0.49
		P + S	DWH + $P_{I(10)}$ + TH8	3,813	10.22	30.1	0.34
TR-1	A	P	DWH + $P_{I(10)}$ + 1g Axial	2,454	6.58	10.0	0.66
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_7	3,245	8.70	30.1	0.29
TR-2	A	P	DWH + $P_{I(10)}$ + 1g Trans.	2,234	5.99	10.0	0.60
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_7	3,010	8.07	30.1	0.27
TR-3	A	P	DWH + $P_{I(10)}$ + 1g Vert.	2,807	7.52	10.0	0.75
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	3,568	9.56	30.1	0.32
TR-4	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	2,710	7.26	10.0	0.73
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	3,484	9.34	30.1	0.31
TR-5	A	P	DWH + $P_{I(10)}$ + 1g Axial	2,454	6.58	10.0	0.66
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_8	4,442	11.91	30.1	0.40
TR-6	A	P	DWH + $P_{I(10)}$ + 1g Trans.	2,234	5.99	10.0	0.60
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_8	4,207	11.28	30.1	0.37
TR-7	A	P	DWH + $P_{I(10)}$ + 1g Vert.	2,807	7.52	10.0	0.75
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	4,765	12.77	30.1	0.42
TR-8	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	2,710	7.26	10.0	0.73
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	4,681	12.55	30.1	0.42
TR-9	D	P	$P_{I(20)}$ + 60g BED	562	1.51	24.0	0.06
TR-10	D	P	$P_{I(20)}$ + 75g SD (elastic/plastic)	8,964	24.02	30.2	0.80
HSM-3	B	P	DWH + $P_{I(20)}$	2,681	7.18	10.0	0.72
		P + S	DWH + $P_{I(20)}$ + TH_{15}	3,933	10.54	30.1	0.35
HSM-4	B	P	DWH + $P_{I(20)}$	2,681	7.18	10.0	0.72
		P + S	DWH + $P_{I(20)}$ + TH_{26}	3,964	10.62	30.1	0.35
HSM-10	D	P	DWH + $P_{I(60)}$ + Seismic	N/A	9.6	25.9	0.37
HSM-11	D	P	DWH + $P_{I(60)}$	6,086	16.31	24.0	0.68
HSM-13	C	P	DWH + Flood	1,172	3.14	12.0	0.26

Notes

1. P = Stress due to Primary loads
   P + S = Stress due to Primary + Secondary loads.
2. Stress is based on a weld thickness of 3/16 in. and a nodal tributary length of 1.99 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.

Table 10-15 Controlling Load Combination Stress Results for Upper (Continuous) Weld of Support Ring (Base Metal Evaluation[1])

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P	DWV + $P_{I(10)}$	195	0.28	7.40	0.04
		P + S	DWV + $P_{I(10)}$ + TH_8	610	0.87	7.40	0.12
TL-3	A	P	DWH + $P_{I(10)}$	141	0.20	7.40	0.03
		P + S	DWH + $P_{I(10)}$ + TH_7	568	0.81	7.40	0.11
TL-4	A	P	DWH + $P_{I(10)}$	141	0.20	7.40	0.03
		P + S	DWH + $P_{I(10)}$ + TH_8	495	0.70	7.40	0.10
TR-1	A	P	DWH + $P_{I(10)}$ + 1g Axial	236	0.34	7.40	0.05
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_7	663	0.94	7.40	0.13
TR-2	A	P	DWH + $P_{I(10)}$ + 1g Trans.	158	0.22	7.40	0.03
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_7	585	0.83	7.40	0.11
TR-3	A	P	DWH + $P_{I(10)}$ + 1g Vert.	182	0.26	7.40	0.03
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	608	0.86	7.40	0.12
TR-4	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	212	0.30	7.40	0.04
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	639	0.91	7.40	0.12
TR-5	A	P	DWH + $P_{I(10)}$ + 1g Axial	236	0.34	7.40	0.05
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_8	590	0.84	7.40	0.11
TR-6	A	P	DWH + $P_{I(10)}$ + 1g Trans.	158	0.22	7.40	0.03
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_8	512	0.73	7.40	0.10
TR-7	A	P	DWH + $P_{I(10)}$ + 1g Vert.	182	0.26	7.40	0.03
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	535	0.76	7.40	0.10
TR-8	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	212	0.30	7.40	0.04
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	566	0.80	7.40	0.11
TR-9	D	P	$P_{I(20)}$ + 60g BED	5,772	8.20	14.8	0.55
TR-10	D	P	$P_{I(20)}$ + 75g SD (elastic/plastic)	Note 5	Note 5	Note 5	Note 5
HSM-3	B	P	DWH + $P_{I(20)}$	241	0.34	9.81	0.03
		P + S	DWH + $P_{I(20)}$ + TH_{15}	585	0.83	9.81	0.08
HSM-4	B	P	DWH + $P_{I(20)}$	241	0.34	9.81	0.03
		P + S	DWH + $P_{I(20)}$ + TH_{26}	478	0.68	9.81	0.07
HSM-11	D	P	DWH + $P_{I(60)}$	643	0.91	14.8	0.06
HSM-13	C	P	DWH + Flood	608	0.86	11.1	0.08

Notes:

1. See Table 10-16 for weld metal evaluation.
2. P = Stress due to Primary loads
   P + S = Stress due to Primary + Secondary loads.
3. Stress is based on base metal thickness of $0.25\sqrt{2} = 0.354$ in. and a nodal tributary length of 1.99 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.
4. Allowable stress is based on a maximum temperature of 350°F in the high stress region of the weld.
5. Side drop loads between shell and support ring are directly transmitted between components. Therefore, the weld is not loaded significantly.

Table 10-16 Controlling Load Combination Stress Results for Upper (Continuous) Weld of Support Ring (Weld Metal Evaluation[1])

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P	DWV + $P_{I(10)}$	195	0.28	21.5	0.01
		P + S	DWV + $P_{I(10)}$ + TH_8	610	0.87	21.5	0.04
TL-3	A	P	DWH + $P_{I(10)}$	141	0.20	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + TH_7	568	0.81	21.5	0.04
TL-4	A	P	DWH + $P_{I(10)}$	141	0.20	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + TH_8	495	0.70	21.5	0.03
TR-1	A	P	DWH + $P_{I(10)}$ + 1g Axial	236	0.34	21.5	0.02
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_7	663	0.94	21.5	0.04
TR-2	A	P	DWH + $P_{I(10)}$ + 1g Trans.	158	0.22	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_7	585	0.83	21.5	0.04
TR-3	A	P	DWH + $P_{I(10)}$ + 1g Vert.	182	0.26	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	608	0.86	21.5	0.04
TR-4	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	212	0.30	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	639	0.91	21.5	0.04
TR-5	A	P	DWH + $P_{I(10)}$ + 1g Axial	236	0.34	21.5	0.02
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_8	590	0.84	21.5	0.04
TR-6	A	P	DWH + $P_{I(10)}$ + 1g Trans.	158	0.22	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_8	512	0.73	21.5	0.03
TR-7	A	P	DWH + $P_{I(10)}$ + 1g Vert.	182	0.26	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	535	0.76	21.5	0.04
TR-8	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	212	0.30	21.5	0.01
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	566	0.80	21.5	0.04
TR-9	D	P	$P_{I(20)}$ + 60g BED	5,772	8.20	43.1	0.19
TR-10	D	P	$P_{I(20)}$ + 75g SD (elastic/plastic)	11,919	16.94	43.1	0.39
HSM-3	B	P	DWH + $P_{I(20)}$	241	0.34	28.7	0.01
		P + S	DWH + $P_{I(20)}$ + TH_{15}	585	0.83	28.7	0.03
HSM-4	B	P	DWH + $P_{I(20)}$	241	0.34	28.7	0.01
		P + S	DWH + $P_{I(20)}$ + TH_{26}	478	0.68	28.7	0.02
HSM-11	D	P	DWH + $P_{I(60)}$	643	0.91	43.1	0.02
HSM-13	C	P	DWH + Flood	608	0.86	32.3	0.03

Notes:
1. See Table 10-15 for base metal evaluation.
2. P = Stress due to Primary loads
   P + S = Stress due to Primary + Secondary loads.
3. Stress is based on an effective weld throat of $(0.25^2+0.125^2)^{1/2}$ = 0.280 in. and a nodal tributary length of 1.99 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.

Table 10-17 Controlling Load Combination Stress Results for Lower (Intermittent) Weld of Support Ring (Base Metal Evaluation[1])

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P	DWV + $P_{I(10)}$	242	0.97	7.40	0.13
		P + S	DWV + $P_{I(10)}$ + TH_8	822	3.30	7.40	0.45
TL-3	A	P	DWH + $P_{I(10)}$	176	0.71	7.40	0.10
		P + S	DWH + $P_{I(10)}$ + TH_7	722	2.90	7.40	0.39
TL-4	A	P	DWH + $P_{I(10)}$	176	0.71	7.40	0.10
		P + S	DWH + $P_{I(10)}$ + TH_8	755	3.04	7.40	0.41
TR-1	A	P	DWH + $P_{I(10)}$ + 1g Axial	271	1.09	7.40	0.15
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_7	815	3.28	7.40	0.44
TR-2	A	P	DWH + $P_{I(10)}$ + 1g Trans.	183	0.74	7.40	0.10
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_7	729	2.93	7.40	0.40
TR-3	A	P	DWH + $P_{I(10)}$ + 1g Vert.	194	0.78	7.40	0.11
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	739	2.97	7.40	0.40
TR-4	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	234	0.94	7.40	0.13
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	779	3.13	7.40	0.42
TR-5	A	P	DWH + $P_{I(10)}$ + 1g Axial	271	1.09	7.40	0.15
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_8	849	3.41	7.40	0.46
TR-6	A	P	DWH + $P_{I(10)}$ + 1g Trans.	183	0.74	7.40	0.10
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_8	763	3.07	7.40	0.41
TR-7	A	P	DWH + $P_{I(10)}$ + 1g Vert.	194	0.78	7.40	0.11
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	773	3.11	7.40	0.42
TR-8	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	234	0.94	7.40	0.13
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	812	3.27	7.40	0.44
TR-9	D	P	$P_{I(20)}$ + 60g BED	note 4	note 4	note 4	note 4
TR-10	D	P	$P_{I(20)}$ + 75g SD	2,511	10.10	16.6	0.61
HSM-3	B	P	DWH + $P_{I(20)}$	333	1.34	9.81	0.14
		P + S	DWH + $P_{I(20)}$ + TH_{15}	1,123	4.51	9.81	0.46
HSM-4	B	P	DWH + $P_{I(20)}$	333	1.34	9.81	0.14
		P + S	DWH + $P_{I(20)}$ + TH_{26}	651	2.62	9.81	0.27
HSM-11	D	P	DWH + $P_{I(60)}$	964	3.87	14.8	0.26
HSM-13	C	P	DWH + Flood	703	2.83	11.1	0.25

Notes:
1. See Table 10-18 for weld metal evaluation.
2. P = Stress due to Primary loads
   P + S = Stress due to Primary + Secondary loads.
3. Stress is based on base metal thickness of 0.25 in. and a nodal tributary length of 0.995 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.
4. See hand evaluation of support ring weld for end drop loading.

Table 10-18 Controlling Load Combination Stress Results for Lower (Intermittent) Weld of Support Ring (Weld Metal Evaluation[1])

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P	DWV + $P_{I(10)}$	242	0.97	21.5	0.05
		P + S	DWV + $P_{I(10)}$ + TH_8	822	3.30	21.5	0.15
TL-3	A	P	DWH + $P_{I(10)}$	176	0.71	21.5	0.03
		P + S	DWH + $P_{I(10)}$ + TH_7	722	2.90	21.5	0.13
TL-4	A	P	DWH + $P_{I(10)}$	176	0.71	21.5	0.03
		P + S	DWH + $P_{I(10)}$ + TH_8	755	3.04	21.5	0.14
TR-1	A	P	DWH + $P_{I(10)}$ + 1g Axial	271	1.09	21.5	0.05
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_7	815	3.28	21.5	0.15
TR-2	A	P	DWH + $P_{I(10)}$ + 1g Trans.	183	0.74	21.5	0.03
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_7	729	2.93	21.5	0.14
TR-3	A	P	DWH + $P_{I(10)}$ + 1g Vert.	194	0.78	21.5	0.04
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	739	2.97	21.5	0.14
TR-4	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	234	0.94	21.5	0.04
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	779	3.13	21.5	0.15
TR-5	A	P	DWH + $P_{I(10)}$ + 1g Axial	271	1.09	21.5	0.05
		P + S	DWH + $P_{I(10)}$ + 1g Axial + TH_8	849	3.41	21.5	0.16
TR-6	A	P	DWH + $P_{I(10)}$ + 1g Trans.	183	0.74	21.5	0.03
		P + S	DWH + $P_{I(10)}$ + 1g Trans + TH_8	763	3.07	21.5	0.14
TR-7	A	P	DWH + $P_{I(10)}$ + 1g Vert.	194	0.78	21.5	0.04
		P + S	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	773	3.11	21.5	0.14
TR-8	A	P	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	234	0.94	21.5	0.04
		P + S	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	812	3.27	21.5	0.15
TR-9	D	P	$P_{I(20)}$ + 60g BED	5,070	20.38	43.1	0.47
TR-10	D	P	$P_{I(20)}$ + 75g SD (elastic/plastic)	2,511	10.10	43.1	0.23
HSM-3	B	P	DWH + $P_{I(20)}$	333	1.34	28.7	0.05
		P + S	DWH + $P_{I(20)}$ + TH_{15}	1,123	4.51	28.7	0.16
HSM-4	B	P	DWH + $P_{I(20)}$	333	1.34	28.7	0.05
		P + S	DWH + $P_{I(20)}$ + TH_{26}	651	2.62	28.7	0.09
HSM-11	D	P	DWH + $P_{I(60)}$	964	3.87	43.1	0.09
HSM-13	C	P	DWH + Flood	703	2.83	32.3	0.09

Notes:
1. See Table 10-17 for base metal evaluation.
2. P = Stress due to Primary loads
   P + S = Stress due to Primary + Secondary loads.
3. Stress is based on an effective weld throat of 0.25(0.7071) = 0.177 in. and a nodal tributary length of 0.995 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.

Table 10-19 Controlling Load Combination Stress Results for Weld of Outer Bottom Cover Plate (Primary Stress[1])

Load Case	Service Level	Stress Category	Loads	Nodal Force (lbs)	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
FL-1	A	P_m	DWV+ $P_{E(HS)}$	206	0.17	10.0	0.02
TL-2	A	P_m	DWV + $P_{I(10)}$	393	0.32	10.0	0.03
TL-3	A	P_m	DWH + $P_{I(10)}$	1,422	1.14	10.0	0.11
TL-4	A	P_m	DWH + $P_{I(10)}$	1,422	1.14	10.0	0.11
TR-1	A	P_m	DWH + $P_{I(10)}$ + 1g Axial	2,219	1.78	10.0	0.18
TR-2	A	P_m	DWH + $P_{I(10)}$ + 1g Trans.	1,848	1.49	10.0	0.15
TR-3	A	P_m	DWH + $P_{I(10)}$ + 1g Vert.	2,451	1.97	10.0	0.20
TR-4	A	P_m	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	2,418	1.94	10.0	0.19
TR-5	A	P_m	DWH + $P_{I(10)}$ + 1g Axial	2,219	1.78	10.0	0.18
TR-6	A	P_m	DWH + $P_{I(10)}$ + 1g Trans.	1,848	1.49	10.0	0.15
TR-7	A	P_m	DWH + $P_{I(10)}$ + 1g Vert.	2,451	1.97	10.0	0.20
TR-8	A	P_m	DWH + $P_{I(10)}$ + 0.5g X, Y, Z	2,418	1.94	10.0	0.19
TR-10	D	P_m	$P_{I(20)}$ + 75g SD (elastic/plastic)	8,295	6.67	30.2	0.22
TR-12	D	P_m	$P_{I(20)}$ + 60 TED	2,783	2.24	30.2	0.07
LD-3	B	P_m	DWH + $P_{I(20)}$ + 80k Ram	1,638	1.32	10.0	0.13
LD-4	B	P_m	DWH + $P_{I(20)}$ + 80k Ram	1,638	1.32	10.0	0.13
HSM-3	B	P_m	DWH + $P_{I(20)}$	1,814	1.46	10.0	0.15
HSM-4	B	P_m	DWH + $P_{I(20)}$	1,814	1.46	10.0	0.15
HSM-11	D	P_m	DWH + $P_{I(60)}$	3,386	2.72	24.0	0.11
HSM-13	C	P_m	DWH + Flood	1,235	0.99	12.0	0.08
UL-3	B	P_m	DWH + $P_{I(20)}$ + 60k Grapple	10,670	8.58	10.0	0.86
UL-4	B	P_m	DWH + $P_{I(20)}$ + 60k Grapple	10,670	8.58	10.0	0.86
UL-5	C	P_m	DWH + $P_{I(20)}$ + 80k Grapple	13,498	10.85	12.0	0.90

Notes:

1. Primary stresses are summarized to evaluate the shear capacity of the weld. Primary+Secondary stresses are summarized in Table 10-20.
2. Stress is based on a weld thickness of 5/8 in. and a nodal tributary length of 1.99 in. Horizontal deadweight and side drop nodal stresses are increased by 1.99/1.5 to account for a minimum tributary length of 1.5 in.

Table 10-20 Controlling Load Combination Stress Results for Weld of Outer Bottom Cover Plate (Primary + Secondary Stress[1])

Load Case	Service Level	Stress Category	Loads	Weld Stress (ksi)	Allowable Stress (ksi)	Stress Ratio
TL-2	A	P_L+P_b+Q	DWV + $P_{I(10)}$ + TH_8	22.14	30.1	0.74
TL-3	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + TH_7	22.81	30.1	0.76
TL-4	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + TH_8	16.85	30.1	0.56
TR-1	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Axial + TH_7	23.76	30.1	0.79
TR-2	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Trans + TH_7	23.09	30.1	0.77
TR-3	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Vert. + TH_7	23.49	30.1	0.78
TR-4	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_7	23.68	30.1	0.79
TR-5	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Axial + TH_8	17.80	30.1	0.59
TR-6	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Trans + TH_8	17.13	30.1	0.57
TR-7	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 1g Vert. + TH_8	17.53	30.1	0.58
TR-8	A	P_L+P_b+Q	DWH + $P_{I(10)}$ + 0.5g X,Y,Z + TH_8	17.72	30.1	0.59
LD-3	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + 80k Ram + TH_7	24.15	30.1	0.80
LD-4	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + 80k Ram + TH_8	17.85	30.1	0.59
HSM-3	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + TH_{15}	9.07	30.1	0.30
HSM-4	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + TH_{26}	9.75	30.1	0.32
UL-3	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + 60k Grap + TH_{15}	15.65	30.1	0.52
UL-4	B	P_L+P_b+Q	DWH + $P_{I(20)}$ + 60k Grap + TH_{16}	16.65	30.1	0.55

Notes

1. Primary+Secondary stress intensities are summarized to evaluate membrane+bending in the weld. Primary weld stresses are evaluated in Table 10-19.

Appendix A1

ANSYS Analysis Run Summary and Input Listings for QT24PIP

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QT24PIP (analysis) [1] PT24PIP (postprocessing) [1]

Date/Time: 4/19/00 10:07 PM 4/22/20 9:45 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ⊛PREP7 ⊛SOLUTION ⊛POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: Internal pressure on inner pressure boundary [2, 3]

Analysis Type: ⊛Static _Thermal _Other: _____

Materials: ⊛Linear _Non-Linear

Geometry: _Linear ⊛Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Load Steps 5 and 6 reverse an earlier "ekill" command used to pin the weld of the outer cover plate. Consideration of nonlinear geometry may yield inaccurate results for these load steps. However, results from Steps 5 and 6 are not used.

Run By: MECohen Date: 6/19/00
Michael E. Cohen

Checked By: SRStreutker Date: 6/19/00
Steven R. Streutker

QT24PIP.inp

```
/batch,list
/filname,qt24pip
/title,24P-FO DSC Shell Assembly (Top End, 90 degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1.0E+06,,,,5    ! normal stiffness of gap elem btwn inner & outer plates
! r,202,1.0E+07         ! normal stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
! r,204,1.0E+07         ! normal stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug


tref,700              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
mptemp,7,700
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,ex,1,7,24.8E+06                                               ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) *************************
mptemp,1,70,200,300,400,500,600
mptemp,7,700
dens,2,490/1728
mpdata,ex,2,1,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,ex,2,7,25.5E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53              ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
```

```
L_tplug=L_itc-T_itc        ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug     ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75   ! lug location (top interface with shell)

B_lug=3.25                 ! base height of the lifting lug
! H_lug=4.13                 ! radial height of the lifting lug
! R_lug=1.75                 ! radius of lug curvature
! R_thru=1.38/2              ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                       ! shell outer bottom
k,2,IR                       ! shell inner bottom
k,6,IR,,H_dsc/2              ! mid-heght of DSC
k,7,OR,,H_dsc/2              ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug         ! bottom base of the lifting lug
k,71,IR,,L_lug               ! top base of the lifting lug
k,72,IR,,L_ring-H_ring       ! bottom of the support ring
k,73,IR,,L_ring              ! top of the support ring
k,74,IR,,L_itc               ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw          ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc          ! shell inner top
k,77,OR-0.19,,L_otc          ! shell outer top
k,78,OR,,H_dsc-0.59          ! upper chamfer
k,79,OR,,L_itc               ! line up with KP74
k,80,OR,,L_ring              ! line up with KP73
k,81,OR,,L_ring-H_ring       ! line up with KP72
k,82,OR,,L_lug               ! line up with KP71
k,83,OR,,L_lug-B_lug         ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc               ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc          ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                ! center of top surface
k,95,0,,L_itc                ! center of bottom surface
k,96,IR-.44,,L_itc           ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc               ! center of top surface
k,102,0,,L_tplug             ! center of bottom surface
k,103,IR,,L_tplug            ! outer radius at bottom surface
k,104,IR-.44,,L_itc          ! radius at top cover plate contact
k,105,IR-.44,,L_tplug        ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug            ! outer radius at top surface
k,111,0,,L_tplug             ! center at top surface
k,112,0,,L_ring              ! center at bottom surface
k,113,IR,,L_ring             ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring               ! outer radius at top surface
k,121,IR-T_ring,,L_ring        ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring        ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
```

```
! k,133,IR-0.6,,L_lug-B_lug

klist

/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
```

```
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,               ! 1 division for horizontal lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                 ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2           ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3               ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring           ! select upper radial line
```

```
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                          ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring      ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                          ! lines contained in above areas
vdrag,all,,,,,,1                ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                  ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                     ! upper shell to weld to outer top cover plate

allsel


/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                          ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
```

```
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                 ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                 ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                 ! lower (intermittent) weld of support ring

csys,0                      ! cartesian coordinates
allsel


! /com reflect quarter geometry to generate half model
!
! *get,maxnode,node,,num,max   ! get maximum node number
! nsym,x,maxnode,all           ! reflect all nodes
! esym,,maxnode,all            ! reflect all elements
!
! *do,i,11,16,1                ! merge nodes at line of symmetry (top shell components)
!    /gopr
!     esel,s,type,,i
!     nsle
!     nummrg,node
! *enddo
!
! ! esel,s,type,,21
! ! nsle
! ! nummrg,node                  ! merge nodes at line of symmetry (lifting lug nodes)
!
! allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node              ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node              ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node              ! nodes of inner top cover plate

csys,1                      ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node              ! nodes of support ring at plug chamfer
nsle
```

```
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node              ! nodes of support ring at inner radius
csys,0                       ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node             ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node             ! top shield plug top surface nodes

csys,1                       ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node             ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1        ! mesh dependent
cm,targ1416,node             ! support ring inner top surface nodes

csys,0                       ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1      ! generate contact elem btwn inner & outer plates
! real,202
! gcgen,cont13,targ1413,1      ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1      ! generate contact elem btwn plug and shell
! real,204
! gcgen,cont16,targ1416,1      ! generate contact elem btwn support ring & plug
! gcgen,cont161,targ1416,1     ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
numcmp,node
numcmp,elem


/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                   ! symmetry about x-z plane
allsel

nsel,s,loc,x,-.01,.01
d,all,ux,0                   ! symmetry about y-z plane (90 degree model only!)
allsel

/com restrain center shield plug nodes for stability
/com ********* valid only for axisymmetry **********
esel,s,type,,14              ! shield plug only
nsle
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
d,all,ux,0
allsel
```

```
/com end of shell-boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell now ends at mid-height
d,all,uz
allsel

/com couple shield plug axially to support ring for stability
/com ********* valid for internal pressure loading **********
esel,s,type,,14,16,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
cp,next,uz,all
allsel
save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,100
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7

/com load step 1 - .0005 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Top End) .0005 psi Pressure on Shell & Inner Cover
nsubst,1,10
csys,1                        ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,.0005
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,.0005
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 10 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Top End) 10 psi Pressure on Shell & Inner Cover
nsubst,1,40
csys,1                        ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,10
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,10
csys,0                        ! cartesian coordinates
allsel
```

```
lswrite
save
solve
save

/com load step 3 - pin outer cover plate weld
/title,24P-FO DSC (Top End) 10 psi on Shell & Inner Cover (Outer Cover Pinned)
nsubst,1,20
esel,s,type,,15
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
save

/com load step 4 - 20 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Top End) 20 psi Shell & Inner Cover (Outer Cover Pinned)
nsubst,1,40
csys,1                       ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
csys,0                       ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 5 - unpin outer cover plate weld
/title,24P-FO DSC (Top End) 20 psi Pressure on Shell & Inner Cover
nsubst,1,20
ealive,all                   ! unkill weld elements
lswrite
save
solve
save

/com load step 6 - 60 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Top End) 60 psi Shell & Inner Cover
nsubst,1,40
csys,1                       ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,60
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,60
csys,0                       ! cartesian coordinates
allsel
lswrite
save
```

```
solve
save

/com load step 7 - pin outer cover plate weld
/title,24P-FO DSC (Top End) 60 psi Shell & Inner Cover (Outer Cover Pinned)
nsubst,1,20
esel,s,type,,15
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                   ! unkill weld elements for postprocessing
save

fini

/exit

/eof
```

PB24PIP.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, top end
/com  internal pressure load
resume,qt24pip,db
/post1
file,qt24pip,rst

/com element plots ------------------------------------------------------------
/show,pt24pip,pic,1            ! plot to file
/triad,lbot                    ! triad in lower left corner
/device,vector,1               ! vector plots
/num,2                         ! numbers, no colors
/vup,1,-x                      ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                      ! precise hidden
esel,u,type,,20                ! unselect contact elements
eplot                          ! plot elements
/zoom,1,rect,0.225,0.639,0.952,-0.380
/show,off                      ! discontinue plots to file
/auto,1                        ! zoom - fit

csys,1                         ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,7                   ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,y,0
esln
esel,r,type,,11
nsle
/com
/com shell adjacent to DSC end components
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(OR,0,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_ring+9.5,L_ring-H_ring-5,-.5
   inode=node(IR,0,iz)
   onode=node(OR,0,iz)
   *if,onode,eq,node(OR,0,iz+.5),cycle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
```

```
/com shell at mid-height
   inode=node(IR,0,H_dsc/2)
   onode=node(OR,0,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,y,0
esln
esel,r,type,,12
nsle
 *do,ix,0,IR-0.9,(IR-0.9)/26
   inode=node(ix,0,L_itc)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR-.22,0,185.17)
   onode=node(IR-.70,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,0,L_otc-T_tw)
   onode=node(IR-.49,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
esel,s,type,,15
nsle
nsel,r,loc,y,0
esln
esel,r,type,,15
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,y,0
esln
esel,r,type,,13
nsle
 *do,ix,0,IR-.44,(IR-.44)/26
   inode=node(ix,0,L_tplug)
   onode=node(ix,0,L_itc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR,0,L_tplug)
   onode=node(IR,0,L_itc)
   nlist,inode,onode,onode-inode
```

```
   lpath,inode,onode
   prsect

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,y,0
esln
esel,r,type,,14
nsle
 *do,ix,0,IR,IR/12
   inode=node(ix,0,L_ring)
   onode=node(ix,0,L_tplug)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,y,0
esln
esel,r,type,,16
nsle
 *do,ix,IR-T_ring,IR,T_ring/2
   inode=node(ix,0,L_ring-H_ring)
   onode=node(ix,0,L_ring)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com Nodal Forces for Weld of Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring ------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
```

```
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots -----------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,0.221,0.536,0.948,-0.468
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,0.251,0.411,0.940,-0.506
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,13
nsle
```

```
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A2

ANSYS Analysis Run Summary and Input Listings for QT24PFL

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QT24PFL (analysis) [1] PT24PFL (postprocessing) [1]

Date/Time: 4/20/00 12:38 AM 4/22/20 9:49 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ⊛PREP7 ⊛SOLUTION ⊛POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: External flood pressure, internal pressure [2, 3]

Analysis Type: ⊛Static _Thermal _Other: _____

Materials: ⊛Linear _Non-Linear

Geometry: _Linear ⊛Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Load Step 5 reverses an earlier "ekill" command used to pin the weld of the outer cover plate. Consideration of nonlinear geometry may yield inaccurate results for this load step. However, results from Step 5 are not used.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

QT24PFL.inp

```
/batch,list
/filname,qt24pfl
/title,24P-FO DSC Shell Assembly (Top End, 90 degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1.0E+06,,,,5    ! normal stiffness of gap elem btwn inner & outer plates
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug


tref,450              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53              ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)
```

```
B_lug=3.25                  ! base height of the lifting lug
! H_lug=4.13                 ! radial height of the lifting lug
! R_lug=1.75                 ! radius of lug curvature
! R_thru=1.38/2              ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                       ! shell outer bottom
k,2,IR                       ! shell inner bottom
k,6,IR,,H_dsc/2              ! mid-heght of DSC
k,7,OR,,H_dsc/2              ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug         ! bottom base of the lifting lug
k,71,IR,,L_lug               ! top base of the lifting lug
k,72,IR,,L_ring-H_ring       ! bottom of the support ring
k,73,IR,,L_ring              ! top of the support ring
k,74,IR,,L_itc               ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw          ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc          ! shell inner top
k,77,OR-0.19,,L_otc          ! shell outer top
k,78,OR,,H_dsc-0.59          ! upper chamfer
k,79,OR,,L_itc               ! line up with KP74
k,80,OR,,L_ring              ! line up with KP73
k,81,OR,,L_ring-H_ring       ! line up with KP72
k,82,OR,,L_lug               ! line up with KP71
k,83,OR,,L_lug-B_lug         ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc               ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc          ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                ! center of top surface
k,95,0,,L_itc                ! center of bottom surface
k,96,IR-.44,,L_itc           ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc               ! center of top surface
k,102,0,,L_tplug             ! center of bottom surface
k,103,IR,,L_tplug            ! outer radius at bottom surface
k,104,IR-.44,,L_itc          ! radius at top cover plate contact
k,105,IR-.44,,L_tplug        ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug            ! outer radius at top surface
k,111,0,,L_tplug             ! center at top surface
k,112,0,,L_ring              ! center at bottom surface
k,113,IR,,L_ring             ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring               ! outer radius at top surface
k,121,IR-T_ring,,L_ring        ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring        ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

klist
```

```
/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
```

```
cm,aouttop,area
cm,vouttop,volume.
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,                ! 1 division for horizontal lines
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                  ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2            ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3                ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring            ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                         ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring     ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
```

```
lsla,s                          ! lines contained in above areas
vdrag,all,,,,,,1                ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                  ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                     ! upper shell to weld to outer top cover plate

allsel


/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                          ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                     ! weld of inner cover plate to shell

esel,s,type,,11,16,5
```

```
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

csys,0                         ! cartesian coordinates
allsel


! /com reflect quarter geometry to generate half model
!
! *get,maxnode,node,,num,max   ! get maximum node number
! nsym,x,maxnode,all           ! reflect all nodes
! esym,,maxnode,all            ! reflect all elements
!
! *do,i,11,16,1                ! merge nodes at line of symmetry (top shell components)
!    /gopr
!     esel,s,type,,i
!     nsle
!     nummrg,node
! *enddo
!
! ! esel,s,type,,21
! ! nsle
! ! nummrg,node                  ! merge nodes at line of symmetry (lifting lug nodes)
!
! allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates
```

```
cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node              ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node              ! top shield plug top surface nodes

csys,1                        ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node              ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1        ! mesh dependent
cm,targ1416,node              ! support ring inner top surface nodes

csys,0                        ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
numcmp,node
numcmp,elem


/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

nsel,s,loc,x,-.01,.01
d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
allsel

/com restrain center shield plug nodes for stability
/com ********* valid only for axisymmetry **********
esel,s,type,,14               ! shield plug only
nsle
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
d,all,ux,0
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell now ends at mid-height
d,all,uz
```

```
allsel

/com UZ couple inner cover plate and shield plug at center
/com ******* valid for external pressure load *******
esel,s,type,,13,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
cp,next,uz,all                ! inner cover pl & shield plug
allsel

save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,500
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7

/com load step 1 - .0005 psi external pressure on shell & outer cover plate
/title,24p-FO DSC (Top End).0005 psi External Pressure
nsubst,1,10
csys,1                        ! cylindrical coordinates
esel,s,type,,12,15,3
esel,a,type,,11
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01 ! outer cover plate & weld
nsel,a,loc,x,OR-.20,OR+.01    ! shell
sf,all,pres,.0005
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 22 psi external pressure on shell & outer cover plate
/title,24p-FO DSC (Top End) 22 psi External Pressure
nsubst,1,20
r,202,1.0E+07,1E7/100     ! norm/tan stiff. of gap elem btwn plug & inner plate
r,204,1.0E+07,1E7/100     ! norm/tan stiff. of gap elem btwn support ring & plug
csys,1                        ! cylindrical coordinates
esel,s,type,,12,15,3
esel,a,type,,11
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01 ! outer cover plate & weld
nsel,a,loc,x,OR-.20,OR+.01    ! shell
sf,all,pres,22
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - pin outer cover plate weld
```

```
/title,24p-FO DSC (Top End) 22 psi External Pressure (Outer Cover Pinned)
nsubst,1,20
esel,s,type,,15
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
save

/com load step 4 - add 10 psi internal pressure on shell & inner cover plate
/title,24p-FO DSC (Top End) 22 psi Ext. + 10 psi Int. (Outer Cover Pinned)
nsubst,1,8
pred,off
pred,on
csys,1                       ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,10
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,10
csys,0                       ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 5 - unpin outer cover plate weld
/title,24p-FO DSC (Top End) 22 psi External + 10 psi Internal Pressure
nsubst,1,8
pred,off
pred,on,,on
ealive,all                   ! unkill weld elements
lswrite
save
solve
save

fini

/exit

/eof
```

PT24PFL.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, top end
/com  flood load
resume,qt24pfl,db
/post1
file,qt24pfl,rst

/com element plots ------------------------------------------------------------
/show,pt24pfl,pic,1          ! plot to file
/triad,lbot                  ! triad in lower left corner
/device,vector,1             ! vector plots
/num,2                       ! numbers, no colors
/vup,1,-x                    ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                    ! precise hidden
esel,u,type,,20              ! unselect contact elements
eplot                        ! plot elements
/zoom,1,rect,0.225,0.639,0.952,-0.380
/show,off                    ! discontinue plots to file
/auto,1                      ! zoom - fit

csys,1                       ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,5                 ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,y,0
esln
esel,r,type,,11
nsle
/com
/com shell adjacent to DSC end components
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(OR,0,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_ring+9.5,L_ring-H_ring-5,-.5
   inode=node(IR,0,iz)
   onode=node(OR,0,iz)
   *if,onode,eq,node(OR,0,iz+.5),cycle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
```

```
/com shell at mid-height
   inode=node(IR,0,H_dsc/2)
   onode=node(OR,0,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Post1 Results ------------------------------------
esel,s,type,,12
nsle
nsel,r,loc,y,0
esln
esel,r,type,,12
nsle
 *do,ix,0,IR-0.9,(IR-0.9)/26
   inode=node(ix,0,L_itc)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR-.22,0,185.17)
   onode=node(IR-.70,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,0,L_otc-T_tw)
   onode=node(IR-.49,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
esel,s,type,,15
nsle
nsel,r,loc,y,0
esln
esel,r,type,,15
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Inner Top Cover Plate Post1 Results ------------------------------------
esel,s,type,,13
nsle
nsel,r,loc,y,0
esln
esel,r,type,,13
nsle
 *do,ix,0,IR-.44,(IR-.44)/26
   inode=node(ix,0,L_tplug)
   onode=node(ix,0,L_itc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR,0,L_tplug)
   onode=node(IR,0,L_itc)
   nlist,inode,onode,onode-inode
```

```
   lpath,inode,onode
   prsect

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,y,0
esln
esel,r,type,,14
nsle
 *do,ix,0,IR,IR/12
   inode=node(ix,0,L_ring)
   onode=node(ix,0,L_tplug)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Support Ring Post1 Results ----------------------------------
esel,s,type,,16
nsle
nsel,r,loc,y,0
esln
esel,r,type,,16
nsle
 *do,ix,IR-T_ring,IR,T_ring/2
   inode=node(ix,0,L_ring-H_ring)
   onode=node(ix,0,L_ring)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com Nodal Forces for Weld of Outer Top Cover Plate ----------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ----------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
```

```
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots ---------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file

/dscale,,300                 ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/type,1,6                    ! z-buffered display
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,0.221,0.536,0.948,-0.468
/auto,1                      ! zoom - fit
/type,1,4                    ! precise hidden
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,0.251,0.411,0.940,-0.506
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
```

```
esel,s,type,,13
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A3

ANSYS Analysis Run Summary and Input Listings for QT24PED

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QB24PED (analysis) [1] PB24PED (postprocessing) [1]

Date/Time: 9/6/00 6:20 PM 9/6/00 7:13 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 3.51 (Build 1057)

CPU: PentiumPro 200

Analysis Modules Used: X PREP7 X SOLUTION X POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: 60g top end drop, internal pressure [2, 3]

Analysis Type: X Static __Thermal __Other: _____

Materials: X Linear __Non-Linear

Geometry: __Linear X Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Load Step 6 reverses an earlier "ekill" command used to pin the weld of the outer cover plate. Consideration of nonlinear geometry may yield inaccurate results for this load step. However, results from Step 6 are not used.

Run By: Michael E. Cohen Date: 9/8/00

Checked By: Craig M. Standafer Date: 9/8/00

QT24PED.inp

```
/batch,list
/filname,qt24ped
/title,24PT1-DSC Shell Assembly (Top End, 90 degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1.0E+05,,,,5    ! normal stiffness of gap elem btwn inner & outer plates
r,202,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell163        ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug


tref,500              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ********************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) ***************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)
```

```
B_lug=3.25                  ! base height of the lifting lug
! H_lug=4.13                 ! radial height of the lifting lug
! R_lug=1.75                 ! radius of lug curvature
! R_thru=1.38/2              ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                       ! shell outer bottom
k,2,IR                       ! shell inner bottom
k,6,IR,,H_dsc/2              ! mid-heght of DSC
k,7,OR,,H_dsc/2              ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug         ! bottom base of the lifting lug
k,71,IR,,L_lug               ! top base of the lifting lug
k,72,IR,,L_ring-H_ring       ! bottom of the support ring
k,73,IR,,L_ring              ! top of the support ring
k,74,IR,,L_itc               ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw          ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc          ! shell inner top
k,77,OR-0.19,,L_otc          ! shell outer top
k,78,OR,,H_dsc-0.59          ! upper chamfer
k,79,OR,,L_itc               ! line up with KP74
k,80,OR,,L_ring              ! line up with KP73
k,81,OR,,L_ring-H_ring       ! line up with KP72
k,82,OR,,L_lug               ! line up with KP71
k,83,OR,,L_lug-B_lug         ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc               ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc          ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                ! center of top surface
k,95,0,,L_itc                ! center of bottom surface
k,96,IR-.44,,L_itc           ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc               ! center of top surface
k,102,0,,L_tplug             ! center of bottom surface
k,103,IR,,L_tplug            ! outer radius at bottom surface
k,104,IR-.44,,L_itc          ! radius at top cover plate contact
k,105,IR-.44,,L_tplug        ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug            ! outer radius at top surface
k,111,0,,L_tplug             ! center at top surface
k,112,0,,L_ring              ! center at bottom surface
k,113,IR,,L_ring             ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring               ! outer radius at top surface
k,121,IR-T_ring,,L_ring        ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring        ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

klist
```

```
/com meshing ********************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
```

```
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,                ! 1 division for horizontal lines
vdrag,all,,,,,1                ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                  ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,2             ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3                ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,1                ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring            ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                         ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring     ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
```

```
lsla,s                          ! lines contained in above areas
vdrag,all,,,,,,1                ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                  ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                     ! upper shell to weld to outer top cover plate

allsel


/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                          ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                     ! weld of inner cover plate to shell

esel,s,type,,11,16,5
```

```
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

csys,0                         ! cartesian coordinates
allsel


! /com reflect quarter geometry to generate half model
!
! *get,maxnode,node,,num,max    ! get maximum node number
! nsym,x,maxnode,all            ! reflect all nodes
! esym,,maxnode,all             ! reflect all elements
!
! *do,i,11,16,1                 ! merge nodes at line of symmetry (top shell components)
!    /gopr
!     esel,s,type,,i
!     nsle
!     nummrg,node
! *enddo
!
! ! esel,s,type,,21
! ! nsle
! ! nummrg,node                   ! merge nodes at line of symmetry (lifting lug nodes)
!
! allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates
```

```
cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node              ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node              ! top shield plug top surface nodes

csys,1                        ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node              ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1         ! mesh dependent
cm,targ1416,node              ! support ring inner top surface nodes

csys,0                        ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
numcmp,node
numcmp,elem


/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

nsel,s,loc,x,-.01,.01
d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
allsel

/com restrain center shield plug nodes for stability
/com ********* valid only for axisymmetry **********
esel,s,type,,14               ! shield plug only
nsle
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
d,all,ux,0
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell now ends at mid-height
d,all,uz
```

```
allsel

/com UZ couple inner cover plate and shield plug at center
/com ******* valid for dead weight and end drop *******
esel,s,type,,13,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
cp,next,uz,all                  ! inner cover pl & shield plug
allsel

save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,500
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7

/com load step 1 - 0.001g bottom end drop
/title,24PT1-DSC (Top End) 0.001g Bottom End Drop
nsubst,1,8
acel,,,0.001                    ! 0.001g acceleration
lswrite
save
solve
save

/com load step 2 - 1g bottom end drop
/title,24PT1-DSC (Top End) 1g Bottom End Drop
nsubst,1,8
r,202,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
acel,,,1.                       ! 1g acceleration
lswrite
save
solve
save

/com load step 3 - 60g bottom end drop
/title,24PT1-DSC (Top End) 60g Bottom End Drop
nsubst,1,8
acel,,,60.                      ! 60g acceleration
lswrite
save
solve
save

/com load step 4 - pin outer cover plate weld
/title,24PT1-DSC (Top End) 60g Bottom End Drop (Outer Cover Pinned)
nsubst,1,8
esel,s,type,,15
nsle
ekill,all                       ! kill weld elements
esel,all
nsle
```

```
lswrite
save
solve
save

/com load step 5 - add 20 psi internal pressure to 60g top end drop
/title,24PT1-DSC (Top End) 60g Bottom End Drop + 20 psi (Outer Cover Pinned)
nsubst,1,8
pred,off
pred,on
csys,1                          ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 6 - unpin outer cover plate weld
/title,24PT1-DSC (Top End) 60g Bottom End Drop + 20 psi
nsubst,1,8
pred,off
pred,on,,on
ealive,all                      ! unkill weld elements
lswrite
save
solve
save

fini

/exit

/eof
```

PT24PED.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, top end
/com  bottom end drop with & without pressure
resume,qt24ped,db
/post1
file,qt24ped,rst

/com element plots ------------------------------------------------------------
/show,pt24ped,pic,1          ! plot to file
/triad,rtop                  ! triad in upper right corner
/device,vector,1             ! vector plots
/num,2                       ! numbers, no colors
/vup,1,z                     ! z-axis up
/view,,-0.2,-0.9,0.3
/type,1,4                    ! precise hidden
esel,u,type,,20              ! unselect contact elements
eplot                        ! plot elements
/zoom,1,rect,-0.399,0.917,0.392,0.221
/show,off                    ! discontinue plots to file
/auto,1                      ! zoom - fit

csys,1                       ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,6                 ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,y,0
esln
esel,r,type,,11
nsle
/com
/com shell adjacent to DSC end components
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(OR,0,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_ring+9.5,L_ring-H_ring-5,-.5
   inode=node(IR,0,iz)
   onode=node(OR,0,iz)
   *if,onode,eq,node(OR,0,iz+.5),cycle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
```

```
/com shell at mid-height
   inode=node(IR,0,H_dsc/2)
   onode=node(OR,0,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,y,0
esln
esel,r,type,,12
nsle
 *do,ix,0,IR-0.9,(IR-0.9)/26
   inode=node(ix,0,L_itc)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR-.22,0,185.17)
   onode=node(IR-.70,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,0,L_otc-T_tw)
   onode=node(IR-.49,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
esel,s,type,,15
nsle
nsel,r,loc,y,0
esln
esel,r,type,,15
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,y,0
esln
esel,r,type,,13
nsle
 *do,ix,0,IR-.44,(IR-.44)/26
   inode=node(ix,0,L_tplug)
   onode=node(ix,0,L_itc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR,0,L_tplug)
   onode=node(IR,0,L_itc)
   nlist,inode,onode,onode-inode
```

```
   lpath,inode,onode
   prsect

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,y,0
esln
esel,r,type,,14
nsle
 *do,ix,0,IR,IR/12
   inode=node(ix,0,L_ring)
   onode=node(ix,0,L_tplug)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,y,0
esln
esel,r,type,,16
nsle
 *do,ix,IR-T_ring,IR,T_ring/2
   inode=node(ix,0,L_ring-H_ring)
   onode=node(ix,0,L_ring)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com Nodal Forces for Weld of Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring ------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
```

```
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots --------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file

/dscale,,40                  ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.9,0.3
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.399,0.917,0.392,0.221
/auto,1                      ! zoom - fit
/type,1,6                    ! z-buffered display
/view,,-0.2,-0.9,-0.3
/replot
/zoom,1,rect,-0.399,0.917,0.392,0.221
/auto,1                      ! zoom - fit
/type,1,4                    ! precise hidden

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.4,-0.9,0.4
plnsol,s,int,0               ! plot stress intensity
/view,,0.9,0.6,0.4
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.9,0.4
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.9,-0.4
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.9,0.4
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.9,-0.4
/replot

/com inner cover plate elements
```

```
esel,s,type,,13
nsle
/view,,-0.2,-0.9,0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,-0.4
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.9,0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,-0.4
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.9,0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,-0.4
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A4

ANSYS Analysis Run Summary and Input Listings for QT24P1G

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QT24P1G (analysis) [1] PT24P1G (postprocessing) [1]

Date/Time: 3/9/00 5:28 PM 5/2/00 9:26 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: 1g axial outward acceleration, fuel inertial pressure [2]

Analysis Type: ❊Static __Thermal __Other: _____

Materials: ❊Linear __Non-Linear

Geometry: __Linear ❊Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

QT24PIG.inp

```
/batch,list
/filname,qt24plg
/title,24P-Standard DSC Shell Assembly (Top End, 90 degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1.0E+06,,,,5    ! normal stiffness of gap elem btwn inner & outer plates
! r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
! r,204,1.0E+06,1E7/100  ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell163         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2            ! half-thickness of lug

tref,500              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) *******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53              ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)

B_lug=3.25                ! base height of the lifting lug
```

```
! H_lug=4.13                  ! radial height of the lifting lug
! R_lug=1.75                  ! radius of lug curvature
! R_thru=1.38/2               ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                        ! shell outer bottom
k,2,IR                        ! shell inner bottom
k,6,IR,,H_dsc/2               ! mid-heght of DSC
k,7,OR,,H_dsc/2               ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug          ! bottom base of the lifting lug
k,71,IR,,L_lug                ! top base of the lifting lug
k,72,IR,,L_ring-H_ring        ! bottom of the support ring
k,73,IR,,L_ring               ! top of the support ring
k,74,IR,,L_itc                ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw           ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc           ! shell inner top
k,77,OR-0.19,,L_otc           ! shell outer top
k,78,OR,,H_dsc-0.59           ! upper chamfer
k,79,OR,,L_itc                ! line up with KP74
k,80,OR,,L_ring               ! line up with KP73
k,81,OR,,L_ring-H_ring        ! line up with KP72
k,82,OR,,L_lug                ! line up with KP71
k,83,OR,,L_lug-B_lug          ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc                ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc           ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                 ! center of top surface
k,95,0,,L_itc                 ! center of bottom surface
k,96,IR-.44,,L_itc            ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc                ! center of top surface
k,102,0,,L_tplug              ! center of bottom surface
k,103,IR,,L_tplug             ! outer radius at bottom surface
k,104,IR-.44,,L_itc           ! radius at top cover plate contact
k,105,IR-.44,,L_tplug         ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug             ! outer radius at top surface
k,111,0,,L_tplug              ! center at top surface
k,112,0,,L_ring               ! center at bottom surface
k,113,IR,,L_ring              ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring                ! outer radius at top surface
k,121,IR-T_ring,,L_ring         ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring  ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring         ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

klist

/com meshing ************************************************************
```

```
/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
```

```
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,                ! 1 division for horizontal lines
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                  ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2            ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3                ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring            ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                         ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring     ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                         ! lines contained in above areas
```

```
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arcl")
esize,H_ring/2                ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                   ! upper shell to weld to outer top cover plate

allsel


/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                        ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                   ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
```

```
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

csys,0                         ! cartesian coordinates
allsel


! /com reflect quarter geometry to generate half model
!
! *get,maxnode,node,,num,max    ! get maximum node number
! nsym,x,maxnode,all            ! reflect all nodes
! esym,,maxnode,all             ! reflect all elements
!
! *do,i,11,16,1                 ! merge nodes at line of symmetry (top shell components)
!    /gopr
!     esel,s,type,,i
!     nsle
!     nummrg,node
! *enddo
!
! ! esel,s,type,,21
! ! nsle
! ! nummrg,node                   ! merge nodes at line of symmetry (lifting lug nodes)
!
! allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates
```

```
cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node              ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node              ! top shield plug top surface nodes

csys,1                        ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node              ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1         ! mesh dependent
cm,targ1416,node              ! support ring inner top surface nodes

csys,0                        ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
! real,202
! gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
! real,204
! gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
! gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

nsel,s,loc,x,-.01,.01
d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell now ends at mid-height
d,all,uz
allsel

/com uz-couple all shield plug nodes & inner cover plate nodes at perimeter ...
/com at interface between the two components.
/com **** valid for 1g outward axial acceleration ****
csys,1                        ! cylindrical coordinates
esel,s,type,,13,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cp,next,uz,all
```

```
csys,0                          ! cartesian coordinates
allsel

save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,200
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7

/com load step 1 - 0.001g axial acceleration
/title,24P-s DSC (Top End) 0.001g Axial Acceleration
nsubst,1,8
acel,,,-0.001                   ! -0.001g acceleration
csys,1                          ! cylindrical coordinates
esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
sf,all,pres,0.01                ! distrib. fuel/sleeves load on inner plate
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 1g axial acceleration
/title,24P-s DSC (Top End) 1g Axial Acceleration
nsubst,1,8
acel,,,-1.                      ! -1g acceleration
csys,1                          ! cylindrical coordinates
esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
sf,all,pres,14.6                ! distrib. fuel/sleeves load on inner plate
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - pin outer cover plate weld
/title,24P-s DSC (Top End) 1g Axial Acceleration (Outer Cover Pinned)
nsubst,1,8
esel,s,type,,15
nsle
ekill,all                       ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                      ! unkill weld elements for postprocessing
save
```

```
fini

/exit

/eof
```

PT24P1G.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, top end
/com  1g axial handling load
resume,qt24p1g,db
/post1
file,qt24p1g,rst

/com element plots ------------------------------------------------------------
/show,pt24p1g,pic,1           ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,0.225,0.639,0.952,-0.380
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,3                  ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,y,0
esln
esel,r,type,,11
nsle
/com
/com shell adjacent to DSC end components
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(OR,0,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_ring+9.5,L_ring-H_ring-5,-.5
   inode=node(IR,0,iz)
   onode=node(OR,0,iz)
   *if,onode,eq,node(OR,0,iz+.5),cycle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
```

```
/com shell at mid-height
   inode=node(IR,0,H_dsc/2)
   onode=node(OR,0,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,y,0
esln
esel,r,type,,12
nsle
 *do,ix,0,IR-0.9,(IR-0.9)/26
   inode=node(ix,0,L_itc)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR-.22,0,185.17)
   onode=node(IR-.70,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,0,L_otc-T_tw)
   onode=node(IR-.49,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
esel,s,type,,15
nsle
nsel,r,loc,y,0
esln
esel,r,type,,15
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,0,L_otc-T_tw)
   onode=node(ix,0,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,y,0
esln
esel,r,type,,13
nsle
 *do,ix,0,IR-.44,(IR-.44)/26
   inode=node(ix,0,L_tplug)
   onode=node(ix,0,L_itc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR,0,L_tplug)
   onode=node(IR,0,L_itc)
   nlist,inode,onode,onode-inode
```

```
   lpath,inode,onode
   prsect

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,y,0
esln
esel,r,type,,14
nsle
 *do,ix,0,IR,IR/12
   inode=node(ix,0,L_ring)
   onode=node(ix,0,L_tplug)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,y,0
esln
esel,r,type,,16
nsle
 *do,ix,IR-T_ring,IR,T_ring/2
   inode=node(ix,0,L_ring-H_ring)
   onode=node(ix,0,L_ring)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com Nodal Forces for Weld of Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring ------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
```

```
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots -----------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,0.221,0.536,0.948,-0.468
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,0.251,0.411,0.940,-0.506
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,13
nsle
```

```
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0              ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0              ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0              ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                      ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A5

ANSYS Analysis Run Summary and Input Listings for T24PDW

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PDW (analysis) (1) PT24PDW (postprocessing) (1)

Date/Time: 3/11/00 10:10 AM 4/19/00 8:39 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: Deadweight acceleration on horizontal DSC (2)

Analysis Type: ❊Static _Thermal _Other: _____

Materials: ❊Linear _Non-Linear

Geometry: _Linear ❊Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

T24PDW.inp

```
/batch,list
/filname,t24pdw
/title,24P-Standard DSC Shell Assembly (Top End, 180 degree Model)
! /config,ncont,1500
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+05,,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

tref,500              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) *******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53              ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)
```

```
B_lug=3.25                  ! base height of the lifting lug
! H_lug=4.13                 ! radial height of the lifting lug
! R_lug=1.75                 ! radius of lug curvature
! R_thru=1.38/2              ! radius of lug thru hole


/com lower shell keypoints
! k,1,OR-0.25                  ! shell outer bottom
! k,2,IR+0.21                  ! shell inner bottom
k,1,OR                        ! shell outer bottom
k,2,IR                        ! shell inner bottom
k,6,IR,,H_dsc/2               ! mid-heght of DSC
k,7,OR,,H_dsc/2               ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug          ! bottom base of the lifting lug
k,71,IR,,L_lug                ! top base of the lifting lug
k,72,IR,,L_ring-H_ring        ! bottom of the support ring
k,73,IR,,L_ring               ! top of the support ring
k,74,IR,,L_itc                ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw           ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc           ! shell inner top
k,77,OR-0.19,,L_otc           ! shell outer top
k,78,OR,,H_dsc-0.59           ! upper chamfer
k,79,OR,,L_itc                ! line up with KP74
k,80,OR,,L_ring               ! line up with KP73
k,81,OR,,L_ring-H_ring        ! line up with KP72
k,82,OR,,L_lug                ! line up with KP71
k,83,OR,,L_lug-B_lug          ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc                ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc           ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                 ! center of top surface
k,95,0,,L_itc                 ! center of bottom surface
k,96,IR-.44,,L_itc            ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc                ! center of top surface
k,102,0,,L_tplug              ! center of bottom surface
k,103,IR,,L_tplug             ! outer radius at bottom surface
k,104,IR-.44,,L_itc           ! radius at top cover plate contact
k,105,IR-.44,,L_tplug         ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug             ! outer radius at top surface
k,111,0,,L_tplug              ! center at top surface
k,112,0,,L_ring               ! center at bottom surface
k,113,IR,,L_ring              ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring                ! outer radius at top surface
k,121,IR-T_ring,,L_ring         ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring  ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring         ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug
```

```
klist

/com meshing ****************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
! lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"
lesize,swp_arc1,,,26,2.67/1.5 ! 26 divisions on "swp_arc1", 1.5" elem. for rail

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

! (remove generation of lower shell elements)
! /com lower shell elements
! lsel,none
! asel,none
! vsel,none
! mat,1
! type,1
! a,1,2,6,7
! lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
! llist
! lesize,all,,,2                ! 2 divisions thru shell thickness
! vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
! esize,4.0                     ! 4" element height for unmeshed lines
! vmesh,all
! cm,alshell,area
! cm,vlshell,volume
! ksel,all

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
```

```
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,               ! 1 division for horizontal lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                 ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2           ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3               ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
```

```
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring           ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                        ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring    ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity
```

```
esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                    ! upper shell to weld to outer top cover plate

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                         ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                    ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

csys,0                         ! cartesian coordinates
allsel


/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max     ! get maximum node number
nsym,x,maxnode,all             ! reflect all nodes
esym,,maxnode,all              ! reflect all elements

*do,i,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)

allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node                 ! nodes of upper shell
```

```
esel,s,type,,12
nsle
cm,cont12,node                  ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                  ! nodes of inner top cover plate
csys,1                          ! cylindrical coordinates
nsel,r,loc,x,IR-.45,IR-.43
cm,cont131,node                 ! inner top cover plate nodes at outer pl. chamfer

esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                  ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                 ! nodes of support ring at inner radius
csys,0                          ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node                ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node                ! top shield plug top surface nodes
csys,1                          ! cylindrical coordinates
nsel,r,loc,x,10.5*IR/12,IR+.1   ! mesh dependent
cm,tar14131,node                ! shield plug out row of surface nodes

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node                ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1         ! mesh dependent
cm,targ1416,node                ! support ring inner top surface nodes

csys,0                          ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
real,202
! gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
gcgen,cont13,tar14131,1         ! gen contact btwn plug & inner plate (outer row 1)
gcgen,cont131,tar14131,1        ! gen contact btwn plug & inner plate (outer row 2)
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1         ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1        ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
```

```
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

! nsel,s,loc,x,-.01,.01
! d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
! allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell now ends at mid-height
d,all,uz
allsel

/com radial restraint along 2 longitudinal lines of shell nodes at perimeter
/com for side drop on 3" rail
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,-.01,.01
d,all,ux,0                ! restrain a longitudinal line of nodes at x=OR
csys,1                    ! cylindrical
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,2.4,2.8      ! mesh dependent
nrotat,all
d,all,ux,0                ! restrain a long. line of nodes 1.5" from symm. line
csys,0                    ! cartesian
allsel

/com ux-couple shield plug & shell nodes along drop contact line
/com valid for side loading only!
esel,s,type,,11,14,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-T_tplug/6,L_tplug+0.3       !6 is mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-T_tplug/2,L_tplug-T_tplug/6 !6 & 2 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-2*T_tplug/3,L_tplug-T_tplug/2 !2, 3 & 6 are mesh dependent
cp,next,ux,all
allsel

save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,500
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7
```

```
/com load step 1 - 1g/20 vertical load, horizontal DSC on rail
/title,24P-s DSC (Top End) 1g/20 vertical load, horizontal DSC on rail
nsubst,1,8
acel,-1/20
lswrite
save
solve
save

/com load step 2 - 1g gravity load, horizontal DSC on rail
/title,24P-s DSC (Top End) 1g gravity load, horizontal DSC on rail
nsubst,1,8
r,202,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
acel,-1
lswrite
save
solve
save

/com load step 3 - pin outer cover plate weld
/title,24P-s DSC (Top End) 1g grav.load, horiz.DSC on rail(outer cover pinned)
nsubst,1,8,1
esel,s,type,,15
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                   ! unkill weld elements for postprocessing
save

fini

/exit

/eof
```

PT24PDW.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  horizontal deadweight
resume,t24pdw,db
/post1
file,t24pdw,rst

/com element plots ------------------------------------------------------------
/show,pt24pdw,pic,1          ! plot to file
/triad,lbot                  ! triad in lower left corner
/device,vector,1             ! vector plots
/num,2                       ! numbers, no colors
/vup,1,-x                    ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                    ! precise hidden
esel,u,type,,20              ! unselect contact elements
eplot                        ! plot elements
/zoom,1,rect,0.03,0.75,0.94,-0.79
/show,off                    ! discontinue plots to file
/auto,1                      ! zoom - fit

csys,1                       ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,3                 ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,11
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com shell adjacent to DSC end components
theta=0
sf=1.02325
dtheta=2.5561/sf
*do,i,1,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,L_itc,H_dsc+.01
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,L_itc,H_dsc+.01
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com
/com shell at mid-height
theta=0
sf=1.02325
dtheta=2.5561/sf
```

```
*do,i,1,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,H_dsc/2,H_dsc/2+5
 esln
 esel,r,type,,11
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,H_dsc/2,H_dsc/2+5
 esln
 esel,r,type,,11
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop


/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(xt,yt,L_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
```

```
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
theta=0
sf=1.02325
dtheta=2.5561/sf
*do,i,1,27                   ! 26+1 nodes of graduated distribution
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                       ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                   ! 26 nodes of graduated distribution
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                       ! end i loop


/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
theta=0
sf=1.02325
dtheta=2.5561/sf
*do,i,1,27                   ! 26+1 nodes of graduated distribution
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
```

```
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                      ! 26 nodes of graduated distribution
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i loop


/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,outer,node                   ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,reminner,node                ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer                ! select outer surface nodes
   onode=node(xt,yt,L_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner             ! select remaining inner surface nodes
   nsel,u,node,,inode           ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_tplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,14
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com Nodal Forces for Weld of Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring ------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height --------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots -------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file

/dscale,,100                 ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.8,0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
```

```
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,13
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A6

ANSYS Analysis Run Summary and Input Listings for T24THERM

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24THERM (analysis) [1] PT24THRM (postprocessing) [1]

Date/Time: 3/30/00 7:20 PM 5/2/00 11:46 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-II 266 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: Steady State Thermal Solutions for Thermal cases 15, 16, and 26 [2]

Analysis Type: _Static ❊Thermal _Other: _____

Materials: ❊Linear _Non-Linear

Geometry: _Linear ❊Non-Linear

Element Types Used:

Solid70: 3-D thermal solid

Other Information:

1. Input filenames use *.inp* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Results from this calculation are read into the appropriate load step for runs requiring any of the above temperature loads.

Run By: MEC Date: 6/19/00
Michael E. Cohen

Checked By: SRS Date: 6/19/00
Steven R. Streutker

T24THERM.inp

```
/batch,list
/filname,t24therm
/title,24P-FO DSC Shell Assembly (Top End, 180 degree Model)
/prep7
/VIEW, 1, -0.277758133299    , -0.861552971884    ,  0.424943403320
/ANG,  1,   21.4857656169

/com shell assembly components
et,1,solid45           ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45          ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45          ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45          ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45          ! 3-D Elastic/Plastic Solid - DSC Support Ring

!et,20,contac49         ! 3-D point to surface contact elements
!r,201,1.0E+07,,,,5     ! normal stiffness of gap elem btwn inner & outer plates
!r,202,1.0E+06          ! normal stiffness of gap elem btwn plug & inner plate
!r,203,1.0E+07          ! normal stiffness of gap elem btwn plug and shell
!r,204,1.0E+07          ! normal stiffness of gap elem btwn support ring & plug
!keyopt,20,7,1          ! keyopt (7)=1

! et,21,shell63          ! Elastic Shell - Lifting Lugs
! r,21,0.75/2            ! half-thickness of lug

!tref,198

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) *******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                     ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                 ! shell outside radius
IR=OR-T_shell              ! shell inside radius
H_dsc=186.17               ! height (length) of DSC

T_otc=1.3125               ! outer top cover plate thickness
T_itc=1.25                 ! inner top cover plate thickness
T_tplug=7.625              ! top shield plug thickness
T_tw=.50                   ! thickness of outer top cover plate weld (min.)

H_ring=2.00                ! height of support ring
T_ring=0.75                ! thickness of support ring

L_otc=H_dsc-0.12           ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc          ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc        ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug     ! support ring location (top surface)
```

```
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)

B_lug=3.25                ! base height of the lifting lug
! H_lug=4.13               ! radial height of the lifting lug
! R_lug=1.75               ! radius of lug curvature
! R_thru=1.38/2            ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                      ! shell outer bottom
k,2,IR                      ! shell inner bottom
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug        ! bottom base of the lifting lug
k,71,IR,,L_lug              ! top base of the lifting lug
k,72,IR,,L_ring-H_ring      ! bottom of the support ring
k,73,IR,,L_ring             ! top of the support ring
k,74,IR,,L_itc              ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw         ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc         ! shell inner top
k,77,OR-0.19,,L_otc         ! shell outer top
k,78,OR,,H_dsc-0.59         ! upper chamfer
k,79,OR,,L_itc              ! line up with KP74
k,80,OR,,L_ring             ! line up with KP73
k,81,OR,,L_ring-H_ring      ! line up with KP72
k,82,OR,,L_lug              ! line up with KP71
k,83,OR,,L_lug-B_lug        ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc              ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc         ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc               ! center of top surface
k,95,0,,L_itc               ! center of bottom surface
k,96,IR-.44,,L_itc          ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc              ! center of top surface
k,102,0,,L_tplug            ! center of bottom surface
k,103,IR,,L_tplug           ! outer radius at bottom surface
k,104,IR-.44,,L_itc         ! radius at top cover plate contact
k,105,IR-.44,,L_tplug       ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug           ! outer radius at top surface
k,111,0,,L_tplug            ! center at top surface
k,112,0,,L_ring             ! center at bottom surface
k,113,IR,,L_ring            ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring              ! outer radius at top surface
k,121,IR-T_ring,,L_ring       ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring       ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug
```

```
klist

/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
```

```
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,               ! 1 division for horizontal lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                 ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2           ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3               ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring           ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                        ! lines contained in above areas
```

```
lsel,r,loc,z,L_ring-H_ring   ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                       ! lines contained in above areas
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2               ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug       ! define arc
! a,70,71,122,121,131,132,133  ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru  ! define circular area of thru hole
! wpstyle,defa                 ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                       ! cylindrical coordinates
! esel,s,type,,21              ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0  ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                       ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to support ring nodes

! allsel

/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                  ! upper shell to weld to outer top cover plate

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                  ! weld of inner cover plate to shell

esel,s,type,,11,16,5
```

```
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

csys,0                         ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max     ! get maximum node number
nsym,x,maxnode,all             ! reflect all nodes
esym,,maxnode,all              ! reflect all elements

*do,i,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)
! allsel

allsel

/com change structural elements to thermal elements
etchg
keyopt,11,4,1
keyopt,12,4,1
keyopt,13,4,1
keyopt,14,4,1
keyopt,15,4,1
keyopt,16,4,1

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,100,150,200,250,300
mptemp,7,400,500,600,700
dens,1,493/1728
!mpdata,kxx,1,1,7.7/12,7.9/12,8.2/12,8.4/12,8.7/12,9.0/12 ! SA-240 Type 316
!mpdata,kxx,1,6,9.5/12,10.0/12,10.5/12,11.0/12                ! SA-240 Type 316
!mpdata,kyy,1,1,7.7/12,7.9/12,8.2/12,8.4/12,8.7/12,9.0/12 ! SA-240 Type 316
!mpdata,kyy,1,6,9.5/12,10.0/12,10.5/12,11.0/12                ! SA-240 Type 316
!mpdata,kzz,1,1,7.7/12,7.9/12,8.2/12,8.4/12,8.7/12,9.0/12 ! SA-240 Type 316
!mpdata,kzz,1,6,9.5/12,10.0/12,10.5/12,11.0/12                ! SA-240 Type 316

mpdata,kxx,1,1,7.7/12,7.7/12,7.7/12,7.7/12,7.7/12,7.7/12  ! SA-240 Type 316
mpdata,kxx,1,6,7.7/12,7.7/12,7.7/12,7.7/12                ! SA-240 Type 316

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) *************************
mptemp,1,70,100,150,200,250,300
mptemp,7,400,500,600,700
dens,2,490/1728
```

```
!mpdata,kxx,2,1,35.1/12,34.7/12,34.1/12,33.6/12,32.9/12,32.3/12 ! SA-36
!mpdata,kxx,2,6,30.9/12,29.5/12,28.0/12,26.6/12                 ! SA-36
!mpdata,kyy,2,1,35.1/12,34.7/12,34.1/12,33.6/12,32.9/12,32.3/12 ! SA-36
!mpdata,kyy,2,6,30.9/12,29.5/12,28.0/12,26.6/12                 ! SA-36
!mpdata,kzz,2,1,35.1/12,34.7/12,34.1/12,33.6/12,32.9/12,32.3/12 ! SA-36
!mpdata,kzz,2,6,30.9/12,29.5/12,28.0/12,26.6/12                 ! SA-36

mpdata,kxx,2,1,35.1/12,35.1/12,35.1/12,35.1/12,35.1/12,35.1/12  ! SA-36
mpdata,kxx,2,6,35.1/12,35.1/12,35.1/12,35.1/12                  ! SA-36

save

fini

alls

/solution

/com analysis parameters
antype,static
!nropt,auto
neqit,25
pred,on,,on
autots,on
!nlgeom
eqslv,iter,1e-8
!nsubst,10

!/com BC's at planes of symmetry
!nsel,s,loc,z,H_dsc/2
!sf,all,hflux,0
!f,all,heat,0
!allsel

!nsel,s,loc,y,0
!sf,all,hflux,0
!f,all,heat,0
!allsel

/com Define x, y, z location arrays (in cylindrical coordinates)
/com for nodal temperaturs
*dim,t_xloc,array,30
*dim,t_yloc,array,5
*dim,t_zloc,array,30
*dim,t_val,array,30,5

!Radial location array
t_xloc(1) = 33.33
t_xloc(2) = 33.33
t_xloc(3) = 33.33
t_xloc(4) = 33.33
t_xloc(5) = 33.33
t_xloc(6) = 33.33
t_xloc(7) = 33.33
t_xloc(8) = 33.33
t_xloc(9) = 33.33
t_xloc(10) = 33.33
t_xloc(11) = 33.33
t_xloc(12) = 33.275
t_xloc(13) = 0
t_xloc(14) = 0
t_xloc(15) = 13.608
t_xloc(16) = 13.803
t_xloc(17) = 32.625
```

```
t_xloc(18) = 32.165
t_xloc(19) = 0
t_xloc(20) = 0
t_xloc(21) = 13.803
t_xloc(22) = 13.803
t_xloc(23) = 33.065
t_xloc(24) = 33.065
t_xloc(25) = 0
t_xloc(26) = 0
t_xloc(27) = 13.777
t_xloc(28) = 13.777
t_xloc(29) = 33.065
t_xloc(30) = 33.065

!Angular location array
t_yloc(1) = 0
t_yloc(2) = 45
t_yloc(3) = 90
t_yloc(4) = 135
t_yloc(5) = 180

!Axial location array
t_zloc(1) = 93.085
t_zloc(2) = 118.89
t_zloc(3) = 137.3
t_zloc(4) = 155.52
t_zloc(5) = 163.44
t_zloc(6) = 169.86
t_zloc(7) = 173.86
t_zloc(8) = 175.86
t_zloc(9) = 180.3
t_zloc(10) = 183.26
t_zloc(11) = 184.7375
t_zloc(12) = 186.05
t_zloc(13) = 184.7375
t_zloc(14) = 186.05
t_zloc(15) = 186.05
t_zloc(16) = 184.7375
t_zloc(17) = 184.7375
t_zloc(18) = 186.05
t_zloc(19) = 183.4875
t_zloc(20) = 184.7375
t_zloc(21) = 183.4875
t_zloc(22) = 184.7375
t_zloc(23) = 183.4875
t_zloc(24) = 184.7375
t_zloc(25) = 175.8625
t_zloc(26) = 183.4875
t_zloc(27) = 175.8625
t_zloc(28) = 183.4875
t_zloc(29) = 175.8625
t_zloc(30) = 183.4875

/com
/com get angular locations for SHELL, OTCP, ITCP interpolation points
/com
csys,1
esel,s,type,,11
nsle
nsel,r,loc,x,OR
nsel,r,loc,z,H_dsc/2
cm,temp,node

*get,ubound,node,,count
```

```
*DIM,y_ang,array,ubound

*DO,i,1,ubound,1
    cmsel,s,temp
    *get,y_ang(i),node,,mnloc,y
    nsel,r,loc,y,y_ang(i)
    *get,nnum,node,,num,min
!   *get,y_ang(i),node,nnum,ang,xy
    cmsel,s,temp
    nsel,u,node,,nnum
    cm,temp,node
*ENDDO
alls

/com
/com get angular locations for SHIELD PLUG interpolation points
/com
esel,s,type,,14
nsle
nsel,r,loc,x,IR
nsel,r,loc,z,L_tplug
cm,temp,node

*get,ubound,node,,count
*DIM,sp_ang,array,ubound

*DO,i,1,ubound,1
    cmsel,s,temp
    *get,sp_ang(i),node,,mnloc,y
    nsel,r,loc,y,sp_ang(i)
    *get,nnum,node,,num,min
!   *get,sp_ang(i),node,nnum,ang,xy
    cmsel,s,temp
    nsel,u,node,,nnum
    cm,temp,node
*ENDDO
alls
csys,0

/com ------------------------------------------------------------
/com Temperature Case 15, -40 deg Ambient-------------------------
/title, 24P-FO DSC (Top End) Temperature Case 15, -40 deg Ambient--
/com ------------------------------------------------------------
/com Define nodal temps
csys,1

t_val(1,1) = 271
t_val(2,1) = 267
t_val(3,1) = 258
t_val(4,1) = 231
t_val(5,1) = 210
t_val(6,1) = 185
t_val(7,1) = 169
t_val(8,1) = 161
t_val(9,1) = 154
t_val(10,1) = 149
t_val(11,1) = 148
t_val(12,1) = 146

t_val(1,2) = 262
t_val(2,2) = 258
t_val(3,2) = 249
t_val(4,2) = 223
t_val(5,2) = 203
```

```
t_val(6,2) = 178
t_val(7,2) = 163
t_val(8,2) = 155
t_val(9,2) = 149
t_val(10,2) = 145
t_val(11,2) = 143
t_val(12,2) = 141

t_val(1,3) = 253
t_val(2,3) = 250
t_val(3,3) = 240
t_val(4,3) = 214
t_val(5,3) = 195
t_val(6,3) = 171
t_val(7,3) = 157
t_val(8,3) = 150
t_val(9,3) = 144
t_val(10,3) = 140
t_val(11,3) = 138
t_val(12,3) = 136

t_val(1,4) = 240
t_val(2,4) = 236
t_val(3,4) = 227
t_val(4,4) = 202
t_val(5,4) = 184
t_val(6,4) = 162
t_val(7,4) = 148
t_val(8,4) = 142
t_val(9,4) = 137
t_val(10,4) = 133
t_val(11,4) = 131
t_val(12,4) = 130

t_val(1,5) = 227
t_val(2,5) = 221
t_val(3,5) = 213
t_val(4,5) = 190
t_val(5,5) = 172
t_val(6,5) = 152
t_val(7,5) = 140
t_val(8,5) = 134
t_val(9,5) = 129
t_val(10,5) = 126
t_val(11,5) = 125
t_val(12,5) = 124

/inp,interp,inp

csys,0

! Define temperatures for DSC Top Shield Plug
alls
esel,s,type,,14
nsle
! -40 F temperatures at top, bottom, at 90° intervals

t1=190.0
t2=134.0
t3=150.0
t4=168.0
t5=126.0
t6=139.0
t7=161.0
```

```
t8=149.0
! R1 = OD of shield plug
R1 = 33.065
! Z0 = z minimum of Shield Plug
! Z1 = Thickness of Shield plug
Z0 = 175.86
Z1 = 7.63
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
```

```
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls


! Define temperatures for DSC Outer Top Cover
alls
esel,s,type,,12
nsle
! -40 F temperatures at top, bottom, at 90° intervals

t1=166.0
t2=125.0
t3=138.0
t4=164.0
t5=124.0
t6=136.0
t7=148.0
t8=146.0
! R1 = OD of Top Cover
R1 = 33.065
! Z0 = z minimum of Top Cover
! Z1 = Thickness of Top Cover
Z0 = 184.74
Z1 = 0.81
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
```

```
    F4=t4
    *if,tm,lt,0.0,then
      F5=2*rm/pi/R1*(t3-t7)*tm
    *else
      F5=-2*rm/pi/R1*(t3-t2)*tm
    *endif
    *if,tm,lt,0.0,then
      F6=-(t7-t1)/R1*rm
    *else
      F6=-(t2-t1)/R1*rm
    *endif
    F7=-t1
    F8=zm

    *if,tm,lt,0.0,then
      F9=-2*rm/pi/R1*(t3-t7)*tm
    *else
      F9=2*rm/pi/R1*(t3-t2)*tm
    *endif

    *if,tm,lt,0.0,then
      F10=+(t7-t1)/R1*rm
    *else
      F10=+(t2-t1)/R1*rm
    *endif
    F11=t1
    ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
    d,tnode,temp,ntemp
!    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Inner Top Cover
alls
esel,s,type,,13
nsle
! -40 F temperatures at top, bottom, at 90° intervals

t1=168.0
t2=126.0
t3=139.0
t4=166.0
t5=125.0
t6=138.0
t7=149.0
t8=148.0
! R1 = OD of Inner Top Cover
R1 = 33.065
! Z0 = z minimum of Inner Top Cover
! Z1 = Thickness of Inner Top Cover
Z0 = 183.49
Z1 = 1.25
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
    !/gopr
    tnode=node(0,0,0)
    *get,xt,node,tnode,loc,x
    *get,yt,node,tnode,loc,y
    *get,zt,node,tnode,loc,z
    rm=(xt**2+yt**2)**0.5
    *if,xt,eq,0.0,then
      tm=1.5707963267949
```

```
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

allsel

csys,0

lswrite                          ! end of load step 1
save

solve
save
```

```
stop=0
*if,stop,eq,0,then

/com Temperature Case 16, 104 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 16, 104 deg Ambient
/com define nodal temps

csys,1

t_val(1,1) = 399
t_val(2,1) = 396
t_val(3,1) = 387
t_val(4,1) = 362
t_val(5,1) = 342
t_val(6,1) = 317
t_val(7,1) = 301
t_val(8,1) = 294
t_val(9,1) = 286
t_val(10,1) = 282
t_val(11,1) = 280
t_val(12,1) = 278

t_val(1,2) = 387
t_val(2,2) = 384
t_val(3,2) = 376
t_val(4,2) = 351
t_val(5,2) = 332
t_val(6,2) = 308
t_val(7,2) = 293
t_val(8,2) = 286
t_val(9,2) = 279
t_val(10,2) = 275
t_val(11,2) = 273
t_val(12,2) = 272

t_val(1,3) = 376
t_val(2,3) = 373
t_val(3,3) = 364
t_val(4,3) = 340
t_val(5,3) = 321
t_val(6,3) = 299
t_val(7,3) = 285
t_val(8,3) = 278
t_val(9,3) = 272
t_val(10,3) = 268
t_val(11,3) = 267
t_val(12,3) = 265

t_val(1,4) = 358
t_val(2,4) = 355
t_val(3,4) = 347
t_val(4,4) = 324
t_val(5,4) = 307
t_val(6,4) = 287
t_val(7,4) = 274
t_val(8,4) = 268
t_val(9,4) = 263
t_val(10,4) = 260
t_val(11,4) = 258
t_val(12,4) = 257

t_val(1,5) = 341
t_val(2,5) = 338
```

```
t_val(3,5) = 330
t_val(4,5) = 309
t_val(5,5) = 293
t_val(6,5) = 274
t_val(7,5) = 263
t_val(8,5) = 257
t_val(9,5) = 254
t_val(10,5) = 251
t_val(11,5) = 250
t_val(12,5) = 249

eplot
/inp,interp,inp

csys,0

/com Define temps for DSC shell above active fuel region

! Define temperatures for DSC Top Shield Plug
alls
esel,s,type,,14
nsle
! 104 F temperatures at top, bottom, at 90° intervals

t1=315.0
t2=257.0
t3=278.0
t4=296.0
t5=251.0
t6=268.0
t7=294.0
t8=281.0
! R1 = OD of shield plug
R1 = 33.065
! Z0 = z minimum of Shield Plug
! Z1 = Thickness of Shield plug
Z0 = 175.86
Z1 = 7.63
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
```

```
      F2=2*rm/pi/R1*(t6-t5)*tm
    *endif
    *if,tm,lt,0.0,then
      F3=(t8-t4)/R1*rm
    *else
      F3=(t5-t4)/R1*rm
    *endif
    F4=t4
    *if,tm,lt,0.0,then
      F5=2*rm/pi/R1*(t3-t7)*tm
    *else
      F5=-2*rm/pi/R1*(t3-t2)*tm
    *endif
    *if,tm,lt,0.0,then
      F6=-(t7-t1)/R1*rm
    *else
      F6=-(t2-t1)/R1*rm
    *endif
    F7=-t1
    F8=zm

    *if,tm,lt,0.0,then
      F9=-2*rm/pi/R1*(t3-t7)*tm
    *else
      F9=2*rm/pi/R1*(t3-t2)*tm
    *endif

    *if,tm,lt,0.0,then
      F10=+(t7-t1)/R1*rm
    *else
      F10=+(t2-t1)/R1*rm
    *endif
    F11=t1
    ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
    d,tnode,temp,ntemp
!    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Outer Top Cover
alls
esel,s,type,,12
nsle
! 104 F temperatures at top, bottom, at 90° intervals

t1=293.0
t2=250.0
t3=267.0
t4=291.0
t5=249.0
t6=265.0
t7=280.0
t8=278.0
! R1 = OD of Top Cover
R1 = 33.065
! Z0 = z minimum of Top Cover
! Z1 = Thickness of Top Cover
Z0 = 184.74
Z1 = 0.81
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
```

```
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Inner Top Cover
alls
```

```
esel,s,type,,13
nsle
! 104 F temperatures at top, bottom, at 90° intervals

t1=296.0
t2=251.0
t3=268.0
t4=293.0
t5=250.0
t6=267.0
t7=281.0
t8=280.0
! R1 = OD of Inner Top Cover
R1 = 33.065
! Z0 = z minimum of Inner Top Cover
! Z1 = Thickness of Inner Top Cover
Z0 = 183.49
Z1 = 1.25
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm
```

```
   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel

csys,0

lswrite                          ! end of load step 2
save

solve
save

/com Temperature Case 26, 117 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 26, 117 deg Ambient
/com define nodal temps

csys,1

t_val(1,1) = 408
t_val(2,1) = 405
t_val(3,1) = 397
t_val(4,1) = 372
t_val(5,1) = 352
t_val(6,1) = 327
t_val(7,1) = 311
t_val(8,1) = 303
t_val(9,1) = 296
t_val(10,1) = 292
t_val(11,1) = 290
t_val(12,1) = 288

t_val(1,2) = 397
t_val(2,2) = 393
t_val(3,2) = 385
t_val(4,2) = 361
t_val(5,2) = 341
t_val(6,2) = 317
t_val(7,2) = 303
t_val(8,2) = 295
t_val(9,2) = 289
t_val(10,2) = 285
t_val(11,2) = 283
t_val(12,2) = 281

t_val(1,3) = 385
t_val(2,3) = 381
t_val(3,3) = 373
```

```
t_val(4,3) = 349
t_val(5,3) = 331
t_val(6,3) = 308
t_val(7,3) = 294
t_val(8,3) = 288
t_val(9,3) = 282
t_val(10,3) = 278
t_val(11,3) = 276
t_val(12,3) = 275

t_val(1,4) = 367
t_val(2,4) = 364
t_val(3,4) = 356
t_val(4,4) = 333
t_val(5,4) = 316
t_val(6,4) = 296
t_val(7,4) = 283
t_val(8,4) = 277
t_val(9,4) = 272
t_val(10,4) = 269
t_val(11,4) = 268
t_val(12,4) = 266

t_val(1,5) = 350
t_val(2,5) = 346
t_val(3,5) = 339
t_val(4,5) = 317
t_val(5,5) = 302
t_val(6,5) = 283
t_val(7,5) = 272
t_val(8,5) = 267
t_val(9,5) = 263
t_val(10,5) = 261
t_val(11,5) = 259
t_val(12,5) = 258

/inp,interp,inp

csys,0

/com Define temps for DSC shell above active fuel region

! Define temperatures for DSC Top Shield Plug
alls
esel,s,type,,14
nsle
! 117 F temperatures at top, bottom, at 90° intervals

t1=325.0
t2=267.0
t3=288.0
t4=305.0
t5=260.0
t6=278.0
t7=303.0
t8=291.0
! R1 = OD of shield plug
R1 = 33.065
! Z0 = z minimum of Shield Plug
! Z1 = Thickness of Shield plug
Z0 = 175.86
Z1 = 7.63
pi = 3.1416
*get,totnode,node,,count
```

```
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls
```

```
! Define temperatures for DSC Outer Top Cover
alls
esel,s,type,,12
nsle
! 117 F temperatures at top, bottom, at 90° intervals

t1=303.0
t2=259.0
t3=276.0
t4=301.0
t5=258.0
t6=275.0
t7=290.0
t8=288.0
! R1 = OD of Top Cover
R1 = 33.065
! Z0 = z minimum of Top Cover
! Z1 = Thickness of Top Cover
Z0 = 184.74
Z1 = 0.81
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
```

```
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Inner Top Cover
alls
esel,s,type,,13
nsle
! 117 F temperatures at top, bottom, at 90° intervals

t1=305.0
t2=260.0
t3=278.0
t4=303.0
t5=259.0
t6=276.0
t7=291.0
t8=290.0
! R1 = OD of Inner Top Cover
R1 = 33.065
! Z0 = z minimum of Inner Top Cover
! Z1 = Thickness of Inner Top Cover
Z0 = 183.49
Z1 = 1.25
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
```

```
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

allsel

csys,0

lswrite                          ! end of load step 3
save

solve
save

fini

/exit

/eof

*endif
```

PT24THRM.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal loads
resume,t24therm,db
/post1
file,t24therm,rth

*do,iset,1,3                  ! define steps to postprocess
/go
set,iset

/com Stress Plots ------------------------------------------------------------
/num,0                        ! numbers and colors
/device,vector,0              ! raster plots
ernorm,off
dsys,0
/show,file,,0                 ! plot to file

/dscale,,auto                 ! displacement scale

/com all elements (excluding contact elements)
/vup,1,-x                     ! x-axis down
/auto,1
/view,,-0.2,-0.8,0.5
plnsol,temp                        ! plot temperature distribution
/auto,1                       ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/auto,1                       ! zoom - fit

/dscale,,1                    ! displacement scale

dsys,1

*enddo                        ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A7

ANSYS Analysis Run Summary and Input Listings for T24PSD

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PSD (analysis) [1] PT24PSD (postprocessing) [1]

Date/Time: 3/11/00 11:11 AM 4/11/00 11:01 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: 75g side drop acceleration [2]

Analysis Type: ❊Static _Thermal _Other: _____

Materials: ❊Linear ❊Non-Linear

Geometry: _Linear ❊Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: MEC Michael E. Cohen Date: 6/19/00

Checked By: SRS Steven R. Streutker Date: 6/19/00

T24PSD.inp

```
/batch,list
/filname,t24psd
/title,24P-Standard DSC Shell Assembly (Top End, 180 degree Model)
! /config,ncont,1500
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+05,,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

tref,500              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29
/com non-linear properties - Type 316
etan1=.05                       ! slope of tangent modulus
tb,bkin,1,6
tbtemp,70
tbdata,,30000,etan1*28.3E+06    ! c1=sy, c2=tangent modulus
tbtemp,200
tbdata,,25800,etan1*27.6E+06    ! c1=sy, c2=tangent modulus
tbtemp,300
tbdata,,23300,etan1*27.0E+06    ! c1=sy, c2=tangent modulus
tbtemp,400
tbdata,,21400,etan1*26.5E+06    ! c1=sy, c2=tangent modulus
tbtemp,500
tbdata,,19900,etan1*25.8E+06    ! c1=sy, c2=tangent modulus
tbtemp,600
tbdata,,18800,etan1*25.3E+06    ! c1=sy, c2=tangent modulus

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC
```

```
T_otc=1.3125            ! outer top cover plate thickness
T_itc=1.25              ! inner top cover plate thickness
T_tplug=7.625           ! top shield plug thickness
T_tw=.50                ! thickness of outer top cover plate weld (min.)

H_ring=2.00             ! height of support ring
T_ring=0.75             ! thickness of support ring

L_otc=H_dsc-0.12        ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc       ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc     ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug  ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75 ! lug location (top interface with shell)

B_lug=3.25              ! base height of the lifting lug
! H_lug=4.13              ! radial height of the lifting lug
! R_lug=1.75              ! radius of lug curvature
! R_thru=1.38/2           ! radius of lug thru hole


/com lower shell keypoints
! k,1,OR-0.25               ! shell outer bottom
! k,2,IR+0.21               ! shell inner bottom
k,1,OR                    ! shell outer bottom
k,2,IR                    ! shell inner bottom
k,6,IR,,H_dsc/2           ! mid-heght of DSC
k,7,OR,,H_dsc/2           ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug      ! bottom base of the lifting lug
k,71,IR,,L_lug            ! top base of the lifting lug
k,72,IR,,L_ring-H_ring    ! bottom of the support ring
k,73,IR,,L_ring           ! top of the support ring
k,74,IR,,L_itc            ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw       ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc       ! shell inner top
k,77,OR-0.19,,L_otc       ! shell outer top
k,78,OR,,H_dsc-0.59       ! upper chamfer
k,79,OR,,L_itc            ! line up with KP74
k,80,OR,,L_ring           ! line up with KP73
k,81,OR,,L_ring-H_ring    ! line up with KP72
k,82,OR,,L_lug            ! line up with KP71
k,83,OR,,L_lug-B_lug      ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc            ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc       ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc             ! center of top surface
k,95,0,,L_itc             ! center of bottom surface
k,96,IR-.44,,L_itc        ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc            ! center of top surface
k,102,0,,L_tplug          ! center of bottom surface
k,103,IR,,L_tplug         ! outer radius at bottom surface
k,104,IR-.44,,L_itc       ! radius at top cover plate contact
k,105,IR-.44,,L_tplug     ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug         ! outer radius at top surface
k,111,0,,L_tplug          ! center at top surface
k,112,0,,L_ring           ! center at bottom surface
```

```
k,113,IR,,L_ring              ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring                ! outer radius at top surface
k,121,IR-T_ring,,L_ring         ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring         ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

klist

/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
! lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"
lesize,swp_arc1,,,26,2.67/1.5 ! 26 divisions on "swp_arc1", 1.5" elem. for rail

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

! (remove generation of lower shell elements)
! /com lower shell elements
! lsel,none
! asel,none
! vsel,none
! mat,1
! type,1
! a,1,2,6,7
! lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
! llist
! lesize,all,,,2                ! 2 divisions thru shell thickness
! vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
! esize,4.0                     ! 4" element height for unmeshed lines
! vmesh,all
! cm,alshell,area
! cm,vlshell,volume
! ksel,all

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
```

```
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2               ! 2 divisions thru shell thickness
ksel,s,,,6,70,64             ! select central shell line (inner)
lslk,s,1                     ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4      ! 4" to 0.625" element size
ksel,s,,,7,83,76             ! select central shell line (outer)
lslk,s,1                     ! lines containing selected keypoints
lesize,all,2.31,,,6.4        ! 0.5" to 4" element size
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
esize,0.75                   ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR       ! select lines for dividing
llist
lesize,all,,,2               ! 2 divisions for selected lines
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2             ! select centerline
lslk,s,1                     ! lines containing selected keypoints
lesize,all,,,2               ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,              ! 1 division for horizontal lines
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
```

```
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2          ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3              ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21     ! 2 divisions, generate node at IR
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring          ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                       ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring   ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                       ! lines contained in above areas
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2               ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug       ! define arc
! a,70,71,122,121,131,132,133  ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru  ! define circular area of thru hole
! wpstyle,defa                 ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                       ! cylindrical coordinates
! esel,s,type,,21              ! select lug elements & nodes
! allsel,below,elem
```

```
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0  ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                       ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                  ! upper shell to weld to outer top cover plate

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                  ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                  ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                  ! lower (intermittent) weld of support ring

csys,0                       ! cartesian coordinates
allsel


/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max   ! get maximum node number
nsym,x,maxnode,all           ! reflect all nodes
esym,,maxnode,all            ! reflect all elements

*do,i,11,16,1                ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
```

```
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)

allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.45,IR-.43
cm,cont131,node                ! inner top cover plate nodes at outer pl. chamfer

esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node               ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node               ! top shield plug top surface nodes
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,10.5*IR/12,IR+.1  ! mesh dependent
cm,tar14131,node               ! shield plug out row of surface nodes

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node               ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1        ! mesh dependent
cm,targ1416,node               ! support ring inner top surface nodes

csys,0                         ! cartesian coordinates

allsel
```

```
type,20
! real,201
! gcgen,cont12,targ1312,1      ! generate contact elem btwn inner & outer plates
real,202
! gcgen,cont13,targ1413,1      ! generate contact elem btwn plug & inner plate
gcgen,cont13,tar14131,1      ! gen contact btwn plug & inner plate (outer row 1)
gcgen,cont131,tar14131,1     ! gen contact btwn plug & inner plate (outer row 2)
! real,203
! gcgen,cont11,targ1411,1      ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1      ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1     ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
numcmp,node
numcmp,elem


/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                   ! symmetry about x-z plane
allsel

! nsel,s,loc,x,-.01,.01
! d,all,ux,0                   ! symmetry about y-z plane (90 degree model only!)
! allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2     ! shell now ends at mid-height
d,all,uz
allsel

/com radial restraint along 2 longitudinal lines of shell nodes at perimeter
/com for side drop on 3" rail
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,-.01,.01
d,all,ux,0                ! restrain a longitudinal line of nodes at x=OR
csys,1                    ! cylindrical
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,2.4,2.8      ! mesh dependent
nrotat,all
d,all,ux,0                ! restrain a long. line of nodes 1.5" from symm. line
csys,0                    ! cartesian
allsel

/com ux-couple shield plug & shell nodes along drop contact line
/com valid for side loading only!
esel,s,type,,11,14,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-T_tplug/6,L_tplug+0.3       !6 is mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-T_tplug/2,L_tplug-T_tplug/6 !6 & 2 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-2*T_tplug/3,L_tplug-T_tplug/2 !2, 3 & 6 are mesh dependent
cp,next,ux,all
allsel
```

```
save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,500
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7

/com load step 1 - 75g/2000 side drop on rail w/plasticity & nlgeom
/title,24P-s DSC (Top End) 75g/2000 side drop on rail
nsubst,1,8
acel,-75/2000
lswrite
save
solve
save

/com load step 2 - 75g/10 side drop on rail w/plasticity & nlgeom
/title,24P-s DSC (Top End) 75g/10 side drop on rail
nsubst,1,8
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
acel,-75/10
lswrite
save
solve
save

/com load step 3 - 75g side drop on rail w/plasticity & nlgeom
/title,24P-s DSC (Top End) 75g side drop on rail
nsubst,8,160,8
r,202,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
acel,-75
lswrite
save
solve
save

/com load step 4 - pin outer cover plate weld
/title,24P-s DSC (Top End) 75g side drop on rail (outer cover pinned)
nsubst,1,8,1
esel,s,type,,15
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                   ! unkill weld elements for postprocessing
save

fini

/exit
/eof
```

PT24PSD.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  side drop
resume,t24psd,db
/post1
file,t24psd,rst

/com element plots ------------------------------------------------------------
/show,pt24psd,pic,1          ! plot to file
/triad,lbot                  ! triad in lower left corner
/device,vector,1             ! vector plots
/num,2                       ! numbers, no colors
/vup,1,-x                    ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                    ! precise hidden
esel,u,type,,20              ! unselect contact elements
eplot                        ! plot elements
/zoom,1,rect,0.03,0.75,0.94,-0.79
/show,off                    ! discontinue plots to file
/auto,1                      ! zoom - fit

csys,1                       ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,3,4                 ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
nsel,u,loc,y,0,3
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
nsel,u,loc,y,0,3
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,11
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
```

```
   cm,reminner,node
*enddo
/com
/com shell adjacent to DSC end components
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,L_itc,H_dsc+.01
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,L_itc,H_dsc+.01
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com
/com shell at mid-height
```

```
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,H_dsc/2,H_dsc/2+5
 esln
 esel,r,type,,11
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,H_dsc/2,H_dsc/2+5
 esln
 esel,r,type,,11
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop


/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(xt,yt,L_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
```

```
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                   ! 26+1 nodes of graduated distribution
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                       ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                   ! 26 nodes of graduated distribution
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                       ! end i loop


/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                   ! 26+1 nodes of graduated distribution
```

```
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                      ! 26 nodes of graduated distribution
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i loop


/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.5,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cmsel,u,unnode
cm,outer,node                   ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cmsel,u,unnode
cm,reminner,node                ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer                ! select outer surface nodes
   onode=node(xt,yt,L_itc)
   nsel,s,node,,inode
```

```
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   nsle
   cmsel,u,unnode
   esln,,1
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_tplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,14
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_ring)
   nsel,s,node,,inode
```

```
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Outer Top Cover Plate ----------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ----------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots --------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
```

```
/dscale,,1                  ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20             ! unselect contact elements
/view,,-0.2,-0.8,0.5
plnsol,s,int,0              ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                     ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
/auto,1                     ! zoom - fit

/com all elements except contact elements and shell elements above rail
esel,s,type,,11
nsle
nsel,r,loc,y,0,3
cm,unnode,node
allsel
esel,u,type,,20
cmsel,u,unnode
esln,,1
/view,,-0.2,-0.8,0.5
plnsol,s,int,0              ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                     ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
/auto,1                     ! zoom - fit

/dscale,,1                  ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,0.5
plnsol,s,int,0              ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shell elements excluding those directly above rail
esel,s,type,,11
nsle
nsel,u,loc,y,0,3
esln,,1
/view,,-0.2,-0.8,0.5
plnsol,s,int,0              ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0              ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate elements excluding those in direct contact with shell
esel,s,type,,12
nsle
nsel,r,loc,x,IR-.01,IR+.01
```

```
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,13
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements excluding those in direct contact with shell
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.5,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                        ! end load step loop

allsel

fini
```

```
exit,nosave

/eof
```

Appendix A8

ANSYS Analysis Run Summary and Input Listings for T24PSDP

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PSDP (analysis) [1] PT24PSDP (postprocessing) [1]

Date/Time: 4/22/00 10:18 AM 5/2/00 9:22 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: 75 side drop acceleration with internal pressure [2]

Analysis Type: ❊Static _Thermal _Other: _____

Materials: ❊Linear ❊Non-Linear

Geometry: _Linear ❊Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

T24PSDP.inp

```
/batch,list
/filname,t24psdp
/title,24P-FO DSC Shell Assembly (Top End, 180 degree Model)
/config,ncont,1500
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1.0E+06,1E7/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell163        ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

tref,500              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29
/com non-linear properties - Type 316
etan1=.05                       ! slope of tangent modulus
tb,bkin,1,6
tbtemp,70
tbdata,,30000,etan1*28.3E+06    ! c1=sy, c2=tangent modulus
tbtemp,200
tbdata,,25800,etan1*27.6E+06    ! c1=sy, c2=tangent modulus
tbtemp,300
tbdata,,23300,etan1*27.0E+06    ! c1=sy, c2=tangent modulus
tbtemp,400
tbdata,,21400,etan1*26.5E+06    ! c1=sy, c2=tangent modulus
tbtemp,500
tbdata,,19900,etan1*25.8E+06    ! c1=sy, c2=tangent modulus
tbtemp,600
tbdata,,18800,etan1*25.3E+06    ! c1=sy, c2=tangent modulus

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC
```

```
T_otc=1.3125                ! outer top cover plate thickness
T_itc=1.25                  ! inner top cover plate thickness
T_tplug=7.625               ! top shield plug thickness
T_tw=.50                    ! thickness of outer top cover plate weld (min.)

H_ring=2.00                 ! height of support ring
T_ring=0.75                 ! thickness of support ring

L_otc=H_dsc-0.12            ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc           ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc         ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug      ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75    ! lug location (top interface with shell)

B_lug=3.25                  ! base height of the lifting lug
! H_lug=4.13                  ! radial height of the lifting lug
! R_lug=1.75                  ! radius of lug curvature
! R_thru=1.38/2               ! radius of lug thru hole


/com lower shell keypoints
! k,1,OR-0.25                  ! shell outer bottom
! k,2,IR+0.21                  ! shell inner bottom
k,1,OR                        ! shell outer bottom
k,2,IR                        ! shell inner bottom
k,6,IR,,H_dsc/2               ! mid-heght of DSC
k,7,OR,,H_dsc/2               ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug          ! bottom base of the lifting lug
k,71,IR,,L_lug                ! top base of the lifting lug
k,72,IR,,L_ring-H_ring        ! bottom of the support ring
k,73,IR,,L_ring               ! top of the support ring
k,74,IR,,L_itc                ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw           ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc           ! shell inner top
k,77,OR-0.19,,L_otc           ! shell outer top
k,78,OR,,H_dsc-0.59           ! upper chamfer
k,79,OR,,L_itc                ! line up with KP74
k,80,OR,,L_ring               ! line up with KP73
k,81,OR,,L_ring-H_ring        ! line up with KP72
k,82,OR,,L_lug                ! line up with KP71
k,83,OR,,L_lug-B_lug          ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc                ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc           ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                 ! center of top surface
k,95,0,,L_itc                 ! center of bottom surface
k,96,IR-.44,,L_itc            ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc                ! center of top surface
k,102,0,,L_tplug              ! center of bottom surface
k,103,IR,,L_tplug             ! outer radius at bottom surface
k,104,IR-.44,,L_itc           ! radius at top cover plate contact
k,105,IR-.44,,L_tplug         ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug             ! outer radius at top surface
k,111,0,,L_tplug              ! center at top surface
k,112,0,,L_ring               ! center at bottom surface
```

```
k,113,IR,,L_ring              ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring                ! outer radius at top surface
k,121,IR-T_ring,,L_ring         ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring         ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

klist

/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
! lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"
lesize,swp_arc1,,,26,2.67/1.5 ! 26 divisions on "swp_arc1", 1.5" elem. for rail

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

! (remove generation of lower shell elements)
! /com lower shell elements
! lsel,none
! asel,none
! vsel,none
! mat,1
! type,1
! a,1,2,6,7
! lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
! llist
! lesize,all,,,2                ! 2 divisions thru shell thickness
! vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
! esize,4.0                     ! 4" element height for unmeshed lines
! vmesh,all
! cm,alshell,area
! cm,vlshell,volume
! ksel,all

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
```

```
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2               ! 2 divisions thru shell thickness
ksel,s,,,6,70,64             ! select central shell line (inner)
lslk,s,1                     ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4      ! 4" to 0.625" element size
ksel,s,,,7,83,76             ! select central shell line (outer)
lslk,s,1                     ! lines containing selected keypoints
lesize,all,2.31,,,6.4        ! 0.5" to 4" element size
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
esize,0.75                   ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR       ! select lines for dividing
llist
lesize,all,,,2               ! 2 divisions for selected lines
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2             ! select centerline
lslk,s,1                     ! lines containing selected keypoints
lesize,all,,,2               ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,              ! 1 division for horizontal lines
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
```

```
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,2          ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3             ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21    ! 2 divisions, generate node at IR
vdrag,all,,,,,,1            ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring         ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                      ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring  ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                      ! lines contained in above areas
vdrag,all,,,,,,1            ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2              ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
```

```
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0  ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                       ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to support ring nodes

! allsel


/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                  ! upper shell to weld to outer top cover plate

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                  ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                  ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                  ! lower (intermittent) weld of support ring

csys,0                       ! cartesian coordinates
allsel


/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max   ! get maximum node number
nsym,x,maxnode,all           ! reflect all nodes
esym,,maxnode,all            ! reflect all elements

*do,i,11,16,1                ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
```

```
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)

allsel


/com define contact elements
/com top end plates

esel,s,type,,11
nsle
cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.45,IR-.43
cm,cont131,node                ! inner top cover plate nodes at outer pl. chamfer

esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node               ! inner top cover plate top surface nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node               ! top shield plug top surface nodes
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,10.5*IR/12,IR+.1   ! mesh dependent
cm,tar14131,node               ! shield plug out row of surface nodes

esel,s,type,,14
nsle
nsel,r,loc,x,IR-.01,IR+.01
cm,targ1411,node               ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1          ! mesh dependent
cm,targ1416,node               ! support ring inner top surface nodes

csys,0                         ! cartesian coordinates

allsel
```

```
type,20
real,201
gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
real,202
! gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
gcgen,cont13,tar14131,1       ! gen contact btwn plug & inner plate (outer row 1)
gcgen,cont131,tar14131,1      ! gen contact btwn plug & inner plate (outer row 2)
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)


/com compress node and element numbering
numcmp,node
numcmp,elem


/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

! nsel,s,loc,x,-.01,.01
! d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
! allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell now ends at mid-height
d,all,uz
allsel

/com radial restraint along 2 longitudinal lines of shell nodes at perimeter
/com for side drop on 3" rail
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,-.01,.01
d,all,ux,0                ! restrain a longitudinal line of nodes at x=OR
csys,1                    ! cylindrical
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,2.4,2.8      ! mesh dependent
nrotat,all
d,all,ux,0                ! restrain a long. line of nodes 1.5" from symm. line
csys,0                    ! cartesian
allsel

/com ux-couple shield plug & shell nodes along drop contact line
/com valid for side loading only!
esel,s,type,,11,14,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-T_tplug/6,L_tplug+0.3       !6 is mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-T_tplug/2,L_tplug-T_tplug/6 !6 & 2 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_tplug-2*T_tplug/3,L_tplug-T_tplug/2 !2, 3 & 6 are mesh dependent
cp,next,ux,all
allsel
```

```
save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,500
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7

/com load step 1 - (1g+20psi)/2000 side drop on rail w/plasticity & nlgeom
/title,24p-FO DSC (Top End) (1g+20psi)/2000 side drop on rail
nsubst,1,8
acel,-1/2000
csys,1                          ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20/2000
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20/2000
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 1g+20psi side drop on rail w/plasticity & nlgeom
/title,24p-FO DSC (Top End) 1g + 20psi side drop on rail
nsubst,1,8
acel,-1
csys,1                          ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - 7.5g+20psi side drop on rail w/plasticity & nlgeom
/title,24p-FO DSC (Top End) 7.5g + 20psi side drop on rail
nsubst,1,8
r,201,1.0E+06,1E7/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
acel,-75/10
```

```
csys,1                          ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 4 - 75g+20psi side drop on rail w/plasticity & nlgeom
/title,24p-FO DSC (Top End) 75g + 20psi side drop on rail
nsubst,8,50,8
acel,-75
csys,1                          ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 5 - pin outer cover plate weld
/title,24p-FO DSC (Top End) 75g + 20psi side drop on rail (outer cover pinned)
nsubst,1,8,1
esel,s,type,,15
nsle
ekill,all                       ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                      ! unkill weld elements for postprocessing
save


fini

/exit

/eof
```

PT24PSDP.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  side drop + pressure
resume,t24psdp,db
/post1
file,t24psdp,rst

/com element plots ------------------------------------------------------------
/show,pt24psdp,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,0.03,0.75,0.94,-0.79
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,4,5                  ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
nsel,u,loc,y,0,3
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
nsel,u,loc,y,0,3
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,11
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo
/com
/com shell adjacent to DSC end components
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,L_itc,H_dsc+.01
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,L_itc,H_dsc+.01
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com
/com shell at mid-height
theta=5.1719
```

```
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,H_dsc/2,H_dsc/2+5
 esln
 esel,r,type,,11
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,H_dsc/2,H_dsc/2+5
 esln
 esel,r,type,,11
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop


/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(xt,yt,L_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   nsle
```

```
    nlist,inode,onode,onode-inode
    lpath,inode,onode
    prsect
    cmsel,s,reminner          ! select remaining inner surface nodes
    nsel,u,node,,inode        ! unselect lpath nodes
    cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
    inode=node(IR-.22,theta,185.17)
    onode=node(IR-.70,theta,L_otc)
    nlist,inode,onode,onode-inode
    lpath,inode,onode
    prsect
    inode=node(IR,theta,L_otc-T_tw)
    onode=node(IR-.49,theta,L_otc)
    nlist,inode,onode,onode-inode
    lpath,inode,onode
    prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
    inode=node(IR-.22,theta,185.17)
    onode=node(IR-.70,theta,L_otc)
    nlist,inode,onode,onode-inode
    lpath,inode,onode
    prsect
    inode=node(IR,theta,L_otc-T_tw)
    onode=node(IR-.49,theta,L_otc)
    nlist,inode,onode,onode-inode
    lpath,inode,onode
    prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,15
```

```
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                      ! 26 nodes of graduated distribution
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i loop


/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.5,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cmsel,u,unnode
cm,outer,node                   ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cmsel,u,unnode
cm,reminner,node                ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer                ! select outer surface nodes
   onode=node(xt,yt,L_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
```

```
   esln
   esel,r,type,,13
   nsle
   cmsel,u,unnode
   esln,,1
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_tplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,14
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Support Ring Post1 Results ----------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
```

```
   esln
   esel,r,type,,16
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Outer Top Cover Plate ----------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ----------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots --------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
```

```
/dscale,,1                    ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20               ! unselect contact elements
/view,,-0.2,-0.8,0.5
plnsol,s,int,0                ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                       ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
/auto,1                       ! zoom - fit

/com all elements except contact elements and shell elements above rail
esel,s,type,,11
nsle
nsel,r,loc,y,0,3
cm,unnode,node
allsel
esel,u,type,,20
cmsel,u,unnode
esln,,1
/view,,-0.2,-0.8,0.5
plnsol,s,int,0                ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                       ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
/auto,1                       ! zoom - fit

/dscale,,1                    ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shell elements excluding those directly above rail
esel,s,type,,11
nsle
nsel,u,loc,y,0,3
esln,,1
/view,,-0.2,-0.8,0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate elements excluding those in direct contact with shell
esel,s,type,,12
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,3
```

```
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,13
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements excluding those in direct contact with shell
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.5,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                        ! end load step loop

allsel

fini

exit,nosave
```

/eof

Appendix A9

ANSYS Analysis Run Summary and Input Listings for T24PTH

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PTH (analysis) [1] PT24PTH (postprocessing) [1]

Date/Time: 6/1/00 4:19 PM 6/10/00 9:02 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: Thermal cases [2]

Analysis Type: ❊Static ❊Thermal _Other: _____

Materials: ❊Linear _Non-Linear

Geometry: _Linear ❊Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

T24PTH.inp

```
/batch,list
/filname,t24pth
/title,24P-FO DSC Shell Assembly (Top End, 180 degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
!r,201,1.0E+07,,,,5    ! normal stiffness of gap elem btwn inner & outer plates
r,202,1.0E+06         ! normal stiffness of gap elem btwn plug & inner plate
!r,203,1.0E+07         ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+07         ! normal stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

tref,70

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) *******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)
```

```
B_lug=3.25                  ! base height of the lifting lug
! H_lug=4.13                 ! radial height of the lifting lug
! R_lug=1.75                 ! radius of lug curvature
! R_thru=1.38/2              ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                        ! shell outer bottom
k,2,IR                        ! shell inner bottom
k,6,IR,,H_dsc/2               ! mid-heght of DSC
k,7,OR,,H_dsc/2               ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug          ! bottom base of the lifting lug
k,71,IR,,L_lug                ! top base of the lifting lug
k,72,IR,,L_ring-H_ring        ! bottom of the support ring
k,73,IR,,L_ring               ! top of the support ring
k,74,IR,,L_itc                ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw           ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc           ! shell inner top
k,77,OR-0.19,,L_otc           ! shell outer top
k,78,OR,,H_dsc-0.59           ! upper chamfer
k,79,OR,,L_itc                ! line up with KP74
k,80,OR,,L_ring               ! line up with KP73
k,81,OR,,L_ring-H_ring        ! line up with KP72
k,82,OR,,L_lug                ! line up with KP71
k,83,OR,,L_lug-B_lug          ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc                ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc           ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                 ! center of top surface
k,95,0,,L_itc                 ! center of bottom surface
k,96,IR-.44,,L_itc            ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc                ! center of top surface
k,102,0,,L_tplug              ! center of bottom surface
k,103,IR,,L_tplug             ! outer radius at bottom surface
k,104,IR-.44,,L_itc           ! radius at top cover plate contact
k,105,IR-.44,,L_tplug         ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug             ! outer radius at top surface
k,111,0,,L_tplug              ! center at top surface
k,112,0,,L_ring               ! center at bottom surface
k,113,IR,,L_ring              ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring                ! outer radius at top surface
k,121,IR-T_ring,,L_ring         ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring  ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring         ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

klist
```

```
/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
```

```
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,                ! 1 division for horizontal lines
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                  ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2            ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3                ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring            ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                         ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring     ! select lower radial line
```

```
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                          ! lines contained in above areas
vdrag,all,,,,,,1                ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                  ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel

/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                     ! upper shell to weld to outer top cover plate

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                          ! cylindrical coordinates

esel,s,type,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                     ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
```

```
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

csys,0                         ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max     ! get maximum node number
nsym,x,maxnode,all             ! reflect all nodes
esym,,maxnode,all              ! reflect all elements

*do,i,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)
! allsel

/com define contact elements
/com top end plates

!esel,s,type,,11
!nsle
!cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node               ! inner top cover plate top surface nodes
```

```
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node              ! top shield plug top surface nodes

csys,1                        ! cylindrical coordinates

!esel,s,type,,14
!nsle
!nsel,r,loc,x,IR-.01,IR+.01
!cm,targ1411,node              ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1        ! mesh dependent
cm,targ1416,node              ! support ring inner top surface nodes

csys,0                        ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont12,targ1312,1      ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1      ! generate contact elem btwn plug and shell
!real,204
gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)

/com compress node and element numbering
allsel
!numcmp,node
!numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

!nsel,s,loc,x,-.01,.01
!d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
!allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2       ! shell now ends at mid-height
d,all,uz
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to support ring for stability (one locations)
/com ********* valid only for temp & internal pressure loading **********

esel,s,type,,14,16,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
cp,next,ux,all
```

```
allsel

vclear,12
esel,s,type,,14
edele,all
esel,s,type,,20
edele,all
alls

save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,25
pred,on,,on
autots,on
nlgeom
eqslv,pcg,1e-7


/com Temperature Case 7, -40 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 7, -40 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,11
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-74.39*yt+379.6
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for DSC shell above active fuel region
esel,s,type,,11
nsle
nsel,r,loc,z,159.5,186.17
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-5.39*zt+.93*yt*zt-221.1*yt+1239.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
```

```
/com Define temps for DSC Support Ring
esel,s,type,,16
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-5.39*zt+.93*yt*zt-221.1*yt+1239.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Inner & Outer Cover Plates, and Weld
esel,s,type,,12,15,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=-.1284*zt*xt+.0281*yt*zt*xt
   ntemp2=-6.7289*yt*xt+23.33*xt-1.15*zt+469.2
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                        ! end of load step 3
save

solve
save

/com Temperature Case 8, 100 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 8, 100 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,11
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-60.05*yt+439.5
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
```

```
*enddo

/com Define temps for DSC shell above active fuel region
esel,s,type,,11
nsle
nsel,r,loc,z,159.5,186.17
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-4.666*zt+.854*yt*zt-196.3*yt+1184
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for DSC Support Ring
esel,s,type,,16
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-4.666*zt+.854*yt*zt-196.3*yt+1184
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Inner & Outer Cover Plates, and Weld
esel,s,type,,12,15,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=-.1077*zt*xt+.02588*yt*zt*xt
   ntemp2=-5.948*yt*xt+19.48*xt-1.113*zt+541.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                          ! end of load step 4
save

solve
save

/com Temperature Case 15, -40 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 15, -40 deg Ambient
```

```
nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,1,,,,t24therm,rth,d:\fo-dsc\newansys\top\

allsel
csys,0

lswrite                         ! end of load step 5
save

solve
save

/com Temperature Case 16, 104 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 16, 104 deg Ambient
nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,2,,,,t24therm,rth,d:\fo-dsc\newansys\top\

allsel
csys,0

lswrite                         ! end of load step 6
save

solve
save

fini

/exit

/eof
```

PT24PTH.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal loads
resume,t24pth,db
/post1
file,t24pth,rst

/com element plots ------------------------------------------------------------
/show,pt24pth,pic,1          ! plot to file
/triad,lbot                  ! triad in lower left corner
/device,vector,1             ! vector plots
/num,2                       ! numbers, no colors
/vup,1,-x                    ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                    ! precise hidden
esel,u,type,,20              ! unselect contact elements
eplot                        ! plot elements
/zoom,1,rect,0.03,0.75,0.94,-0.79
/show,off                    ! discontinue plots to file
/auto,1                      ! zoom - fit

csys,1                       ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,1,7                 ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,11
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com shell adjacent to DSC end components
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
 esel,s,type,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
/com shell at mid-height
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
```

```
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
 esel,s,type,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                         ! theta loop

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo

/com DSC Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_tplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln        ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,14
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com Nodal Forces for Weld of Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots --------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.8,0.5
plnsol,bfe,temp              ! plot temperature distribution
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
```

```
/zoom,1,rect,0.03,0.75,0.94,-0.79
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

/com shell elements
esel,s,type,,11
nsle
/view,,-0.2,-0.8,0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate elements
esel,s,type,,12
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,15
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,13
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave

/eof
```