BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.09 File No.: VSC02.6.2.3.09 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

MTC Rail and Door Analysis.

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ________
Service:	☒ Storage	☐ Transportation		☐ Other ________
Conditions:	☒ Normal	☐ Off-Normal	☐ Accident	☐ Other ________

Component(s):

MTC support rail, support rail to rail weld, and rail to MTC shell weld.

Prepared by:

Name: Robert Keating

Signature: [signature]

Date: 2-1-2001

Verified by:

Name: Regina Parkerson

Signature: Regina Parkerson

Date: 2-1-2001

Engineering Manager Approval:

Name: Ram Srinivasan

Signature: R Srinivasan

Date: 3/26/01

Form QAP 3.2-1, Revision 1

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 20		Replaces Calculation WEP109-002.9, Rev. 3	Robert Keating	Regina Parkerson
1	1-25		Added Replacement of Calculation ANO-109.002.310, Rev 1 and Calculation ANO-109.002.301 Rev. 3 Incorporated ECN VSC02-ECN-008	Robert Keating	Regina Parkerson

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION			
	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Regina Parkerson / Regina Parkerson / 2-1-2001
Name/Signature/Date

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The design of MSB lifting devices must meet the requirements of NUREG 0612, Control of Heavy Loads at Nuclear Power Plants [Reference 3.2.7]. In addition to development of the safe load paths, procedures, etc., the NUREG also requires that the special lifting devices and lifting points on heavy loads qualify as "single-failure proof"; otherwise, consequences of the drop must be evaluated.

The MTC is designed as a special lifting device and the rails are a part of the load path because they support the weight of the loaded MSB and the shield doors. Therefore, these devices must meet the requirements of NUREG 0612.

The objective/purpose of this calculation is to determine whether the MTC rails support the single-failure proof design. The calculation scope includes an analysis of the MTC support rail, support rail to rail weld, and rail to MTC shell weld.

Revision 0 of this calculation was prepared to address technical issues concerning Calculation WEP-109.002.3, Revision 3 from CAR 98-50 (dated 10/2/98) and the Design Review Record (dated 7/31/98). This calculation supercedes WEP-109.002.9, Revision 3. The analysis also superceeds the analyses of the ANO MTC. These are provided in Calculation ANO-109.002.310, Revision 1, and Calculation ANO-109.002.301, Revision 3.

The principal modification in this revision is:

- The doors had been evaluated in a separate calculation, but they have been incorporated into this calculation for simplicity.

No calculations are known to be affected by this modified calculation.

2.0 REQUIREMENTS

2.1 Design Inputs

2.1.1 NUREG 0612, "Control of Heavy Loads at Nuclear Power Plants", 1980.
(Specifies the following criteria for single-failure proof devices:)

a) The ANSI N14.6 [Ref. 3.2.9] requirements must be met. For a dual load path design (i.e., a single-failure does not result in uncontrolled movement of the load), the stresses at any point shall not exceed 1/3 of material yield strength or 1/5 of its ultimate strength (safety factors of 3 on yield and 5 on ultimate). As an alternative, the double factors of safety of 6 and 10 must be provided if the lift point system does not have a load path redundancy. This alternative is used in this calculation.

b) On top of the ANSI N14.6 criteria above, the design shall include the dynamic load factor (but this factor is not specified by NUREG 0612). Based on discussions with the NRC, the increase of 10% was selected to meet this requirement.

2.2 Regulatory Commitments

See Section 2.1

3.0 REFERENCES

3.1 BFS Calculation Packages

3.1.1. VSC02.6.2.5.01, Rev. 1, "Weight and Center of Gravity".

3.1.2 SNC Calculation WEP-109-003.7, "MTC Thermal-Hydraulic Analysis", Rev 3.

3.1.3 VSC02.6.2.5.03, Rev. 0, "VSC-24 Design Parameters".

3.2 General References

3.2.1 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda.

3.2.2 Deleted

3.2.3 Deleted

3.2.4 Deleted

3.2.5 Deleted.

3.2.6 Deleted.

3.2.7 NUREG 0612, Control of Heavy Loads at Nuclear Power Plants, 1980.

3.2.8 Deleted.

3.2.9 ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More, 1986.

4.0 ASSUMPTIONS

There are two configurations considered in this calcuation. The first is the Point Beach MTC configuration (which also bounds Palisades), and the second is the ANO MTC configuration. Since it is not obvious which of these two configurations is controlling, they are both evaluated. The evaluation uses a two row matrix for the two configurations. In all cases, the first row is Point Beach, and the second row is the ANO configuration. To account for differences in the height between Point Beach and Palisades, the bounding weights from these two configurations are used.

4.1 Design Configuration

The weight of various components of the MTC are provided below. Because this is a stress analysis of the MTC rails, conservatively high weights are used in the calculation. The weights provided below are bounding values as compared to the nominal weights provided in Reference 3.1.1. All dimensions are provided in the Deisgn Parameters (3.1.3).

Weight of the MTC Doors $M_{door} := \begin{bmatrix} 14000 \\ 11000 \end{bmatrix} lbf$

Weight of the MTC Rail Supports $M_{rail\_sup} := \begin{bmatrix} 1000 \\ 900 \end{bmatrix} lbf$

Weight of the MTC Rails $M_{rail} := \begin{bmatrix} 3600 \\ 2600 \end{bmatrix} lbf$

Weight of MSB with fuel, wet, with shield lid, but no structural lid $M_{MSB\_wet} := \begin{bmatrix} 74000 \\ 81000 \end{bmatrix} lbf$

The material for the rails and rail supports is A-36 Carbon Steel (Reference 3.1.3). The yield stress is based on a bounding operating temperature of 200F (Reference 3.1.2):

$S_y := 32900\ psi$ Reference 3.2.1 at 200 deg F.

$S_u := 58000\ psi$ Reference 3.2.1

(Note: A-36 is not listed in the 1986 Code or the 1988 Addenda. Values used are from the 1998 Edition, Table Y-1.)

The design dimensions for the MTC doors, rails, and rail supports are provided below

$N_{door} := 2$	Number of MTC Doors
$w_{door} := \begin{bmatrix} 42.7 \\ 39.5 \end{bmatrix} in$	Width of MTC Doors
$lg_{door} := \begin{bmatrix} 70 \\ 69.5 \end{bmatrix} in$	Length of the MTC Doors
$t_{door} := \begin{bmatrix} 9 \\ 7.13 \end{bmatrix} in$	Thickness of MTC Doors
$w_{door\_cut} := \begin{bmatrix} 17.7 \\ 20.25 \end{bmatrix} in$	Width of MTC Door Cutout
$lg_{door\_cut} := \begin{bmatrix} 15 \\ 17.25 \end{bmatrix} in$	Length of the MTC Door Cutout
$N_{rail} := 2$	Number of MTC Rails
$w_{rail} := \begin{bmatrix} 6.5 \\ 7.50 \end{bmatrix} in$	Width of MTC Rails
$s_{rail} := \begin{bmatrix} 83.3 \\ 84.8 \end{bmatrix} in$	Spacing of the outside of the rails
$w_{rail\_sup} := \begin{bmatrix} 9.25 \\ 10.25 \end{bmatrix} in$	Width of MTC Rail Supports
$t_{rail\_sup} := 1.5 \ in$	Thickness of MTC Rail Support
$t_{sup\_weld} := .625 \ in$	Groove Weld Between Rail and Rail Support
$OD_{outer} := \begin{bmatrix} 83.5 \\ 82.0 \end{bmatrix} in$	Outside Diameter of the Outer MTC Shell
$t_{rail\_weld} := 0.625 \ in$	Groove Weld between Rail and MTC Shell (Inner weld)

$t_{door\_lead} := \begin{bmatrix} 0.0 \\ 2.0 \end{bmatrix}$ in — Thickness of the Lead Shielding in the Door

$OD_{MSB} := 62.5$ in — Outside Diameter of the MSB

4.2 Design Criteria

See Section 2.1.

4.3 Calculation Assumptions

4.3.1 In determining the distributed design load in Section 6.2, the weights of the MSB, the doors, and the rail support plate are assumed to be uniformly distributed along the rail supported length of the doors.

4.3.2 Assume that each door is independent and simply supported at the edges.

4.3.3 It is assumed that the half of MSB load is concentrated at the center of each door plate.

5.0 CALCULATION METHODOLOGY

To determine whether the MTC rails meet the criteria specified in NUREG 0612, described in Section 2.1, factors of safety are calculated for the MTC support rail, support rail to rail weld, and rail to MTC shell weld. The calculated factors of safety are then compared to values specified in Section 2.1.

6.0 CALCULATION

6.1 Design Loads

The total weight on the MTC rails and MTC rail supports is calculated as follows:

Total weight on the MTC Rail Supports $$W_{rail\_sup} := \overrightarrow{(M_{door} + M_{rail\_sup} + M_{MSB\_wet})}$$

$$W_{rail\_sup} = \begin{bmatrix} 89000 \\ 92900 \end{bmatrix} \cdot lbf$$

Total weight on the MTC Rails $$W_{rail} := \overrightarrow{(W_{rail\_sup} + M_{rail})}$$

$$W_{rail} = \begin{bmatrix} 92600 \\ 95500 \end{bmatrix} \cdot lbf$$

For the design load the total weight will be increased by 10% to account for the dynamic load factor per NUREG 0612 (see section 2.1):

Design Weight for Rail Support $$P_{rail\_sup} := \overrightarrow{(W_{rail\_sup} \cdot 1.10)}$$

$$P_{rail\_sup} = \begin{bmatrix} 97900 \\ 102190 \end{bmatrix} \cdot lbf$$

Design Weight for Rail $$P_{rail} := \overrightarrow{(W_{rail} \cdot 1.10)}$$

$$P_{rail} = \begin{bmatrix} 101860 \\ 105050 \end{bmatrix} \cdot lbf$$

6.2 Equivalent Distributed Design Load

The weight of the MSB, the doors and the rail support plate (i.e., self-weight) are all supported by the rail support plate. This is shown in Figure 6.2-1. The weight is assumed to be uniformly distributed along the rail supported length of the doors.

Distributed design load $$p_{avg\_rail\_sup} := \overrightarrow{\frac{P_{rail\_sup}}{N_{rail} \cdot N_{door} \cdot (w_{door} - w_{door\_cut})}}$$

$$p_{avg\_rail\_sup} = \begin{bmatrix} 979 \\ 1327 \end{bmatrix} \cdot \frac{lbf}{in}$$

6.3 Stress Analysis of the Support Rail

The shear stress along a unit length of support rail is

Rail support shear stress $$\tau_{rail\_sup} := \overrightarrow{\frac{p_{avg\_rail\_sup}}{t_{rail\_sup}}}$$

$$\tau_{rail\_sup} = \begin{bmatrix} 653 \\ 885 \end{bmatrix} \cdot psi$$

The bending stress is based on a moment arm from the rail-to-rail-support junction to the center of the contact point between the rail and door. This is shown in Figure 6.2-1.

$$\delta_{contact} := \overrightarrow{\left(\frac{s_{rail}}{2} - w_{rail} - \frac{\frac{s_{rail}}{2} - w_{rail\_sup} + \frac{lg_{door}}{2}}{2} \right)} \qquad \delta_{contact} = \begin{bmatrix} 1.45 \\ 1.45 \end{bmatrix} \cdot in$$

The bending stress along a unit length of rail support is

The bending stress in the rail support $\sigma_{rail\_sup} := \overrightarrow{\dfrac{\delta_{contact} \cdot P_{avg\_rail\_sup}}{\dfrac{t_{rail\_sup}^2}{6}}}$

$$\sigma_{rail\_sup} = \begin{bmatrix} 3785.5 \\ 5131.6 \end{bmatrix} \cdot psi$$

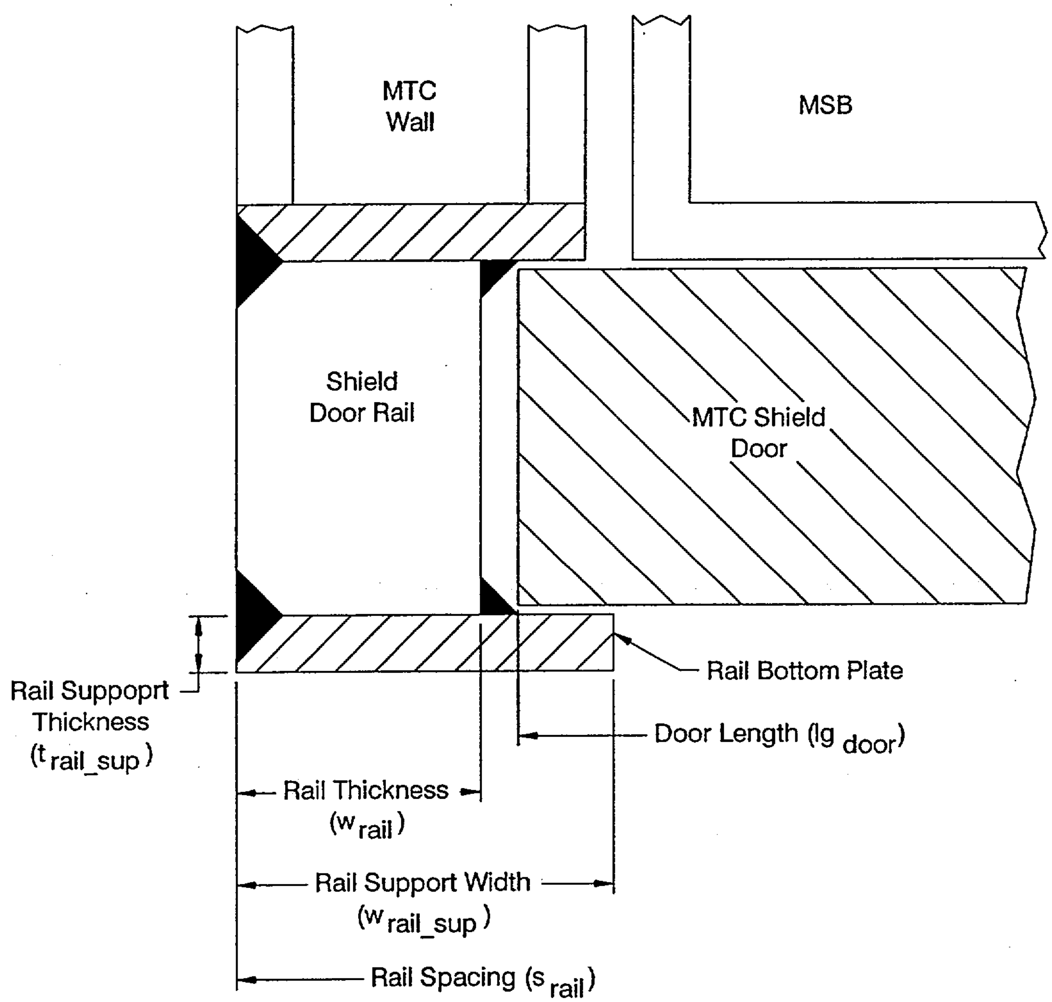


FIGURE 6.2-1: MTC RAILS DESIGN

The maximum principal stress in the rail support is

The maximum principal stress $$S1_{rail\_sup} := \overrightarrow{\left[\frac{\sigma_{rail\_sup}}{2} + \sqrt{\left(\frac{\sigma_{rail\_sup}}{2}\right)^2 + \tau_{rail\_sup}{}^2}\right]}$$

$$S1_{rail\_sup} = \begin{bmatrix} 3894.8 \\ 5279.9 \end{bmatrix} \cdot psi$$

The minimum principal stress $$S2_{rail\_sup} := \overrightarrow{\left[\frac{\sigma_{rail\_sup}}{2} - \sqrt{\left(\frac{\sigma_{rail\_sup}}{2}\right)^2 + \tau_{rail\_sup}{}^2}\right]}$$

$$S2_{rail\_sup} = \begin{bmatrix} -109.4 \\ -148.3 \end{bmatrix} \cdot psi$$

The stress intensity $$SI_{rail\_sup} := \overrightarrow{\left(S1_{rail\_sup} - S2_{rail\_sup}\right)}$$

$$SI_{rail\_sup} = \begin{bmatrix} 4004.2 \\ 5428.1 \end{bmatrix} \cdot psi$$

The factors of safety are

Factor of safety against yield

$$K1_{rail\_sup} := \overrightarrow{\frac{S_y}{SI_{rail\_sup}}}$$

$$K1_{rail\_sup} = \begin{bmatrix} 8.216 \\ 6.061 \end{bmatrix}$$

$$Comp1_{rail\_sup} = \begin{bmatrix} \text{"> 6.0 OKAY"} \\ \text{"> 6.0 OKAY"} \end{bmatrix}$$

Factor of safety against ultimate

$$K2_{rail\_sup} := \overrightarrow{\frac{S_u}{SI_{rail\_sup}}}$$

$$K2_{rail\_sup} = \begin{bmatrix} 14.485 \\ 10.685 \end{bmatrix}$$

$$Comp2_{rail\_sup} = \begin{bmatrix} \text{"> 10.0 OKAY"} \\ \text{"> 10.0 OKAY"} \end{bmatrix}$$

6.4 Support Rail to Rail Weld

The reaction load per unit length of the support rail to rail weld are

$$P_{inner\_weld} := \overrightarrow{\left(\frac{w_{rail} + \delta_{contact}}{w_{rail}} \cdot p_{avg\_rail\_sup} \cdot 1\ in\right)}$$

$$P_{inner\_weld} = \begin{bmatrix} 1197.4 \\ 1583.7 \end{bmatrix} \cdot lbf$$

$$P_{outer\_weld} := \overrightarrow{\left(\frac{\delta_{contact}}{w_{rail}} \cdot p_{avg\_rail\_sup} \cdot 1\ in\right)} \qquad P_{outer\_weld} = \begin{bmatrix} 218.4 \\ 256.6 \end{bmatrix} \cdot lbf$$

The maximum weld load is

$$P_{weld} := \left(\max(P_{inner\_weld}) \quad \max(P_{outer\_weld})\right)$$

$$P_{weld\_design} := \max(P_{weld}) \qquad P_{weld\_design} = 1583.7 \cdot lbf$$

The weld is a 5/8-in groove weld

$$\tau_{sup\_weld} := \frac{P_{weld\_design}}{(1\ in) \cdot t_{sup\_weld}} \qquad \tau_{sup\_weld} = 2534 \cdot psi$$

The factors of safety are based on a failure in shear. Therefore, the yield strength and the ultimate strength must be multiplied by 0.57.

Factor of safety against yield

$$K1_{sup\_weld} := \frac{0.57 \cdot S_y}{\tau_{sup\_weld}} \qquad K1_{sup\_weld} = 7.401$$

$Comp1_{sup\_weld}$ = "> 6.0 OKAY"

Factor of safety against ultimate

$$K2_{sup\_weld} := \overrightarrow{\frac{0.57 \cdot S_u}{\tau_{sup\_weld}}} \qquad K2_{sup\_weld} = 13.047$$

$Comp2_{sup\_weld}$ = "> 10.0 OKAY"

6.5 Rail to MTC Shell Weld

For the upper weld between the rail and the MTC shell, the evaluation is complicated by it's curved geometry. This geometry is presented in Figure 6.5-1.

The half angle of the curved weld is:

$$\phi := \overrightarrow{\mathrm{acos}\left[\frac{\frac{OD_{outer}}{2} - w_{rail}}{\frac{OD_{outer}}{2}}\right]} \qquad \phi = \begin{bmatrix} 32.4 \\ 35.2 \end{bmatrix} \circ \mathrm{deg}$$

The length of the straight weld is:

$$lg_{st\_weld} := \overrightarrow{\left(2 \cdot \sin(\phi) \cdot \frac{OD_{outer}}{2}\right)} \qquad lg_{st\_weld} = \begin{bmatrix} 44.7 \\ 47.3 \end{bmatrix} \circ \mathrm{in}$$

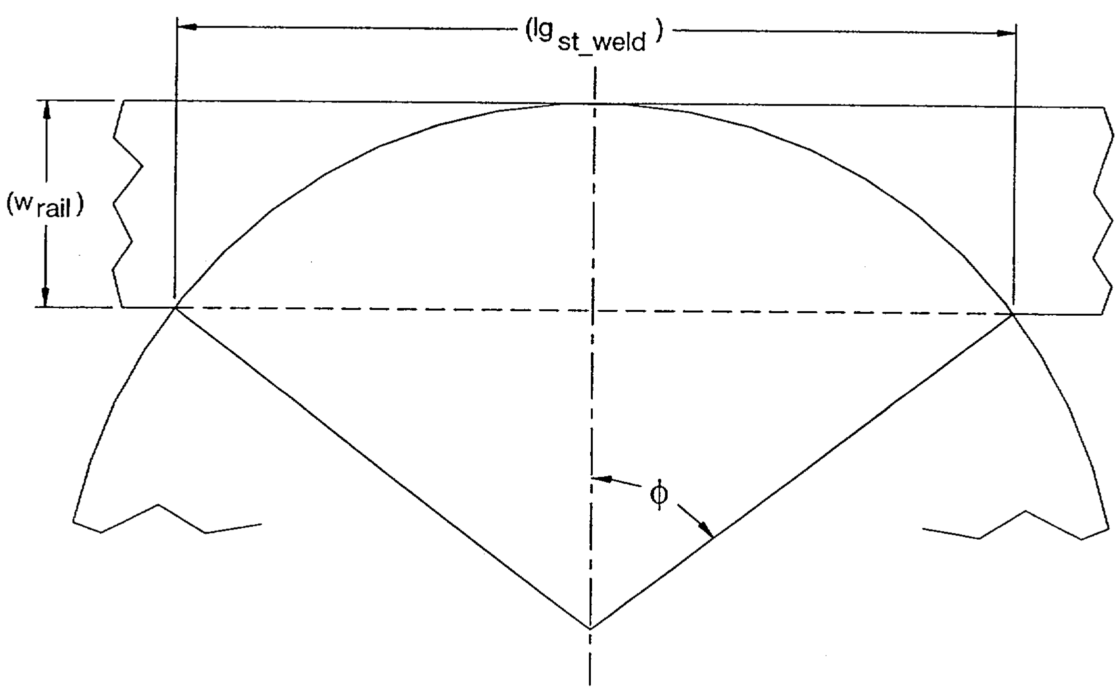


FIGURE 6.5-1: RAIL TO MTC SHELL WELD

The distance from the centerline to the inside of the rail is:

$$x_{rail\_in} := \overrightarrow{\left(\frac{OD_{outer}}{2}\cdot\cos(\phi)\right)} \qquad x_{rail\_in} = \begin{bmatrix} 35.3 \\ 33.5 \end{bmatrix}\cdot in$$

The cord length of the curved weld is:

$$lg_{cr\_weld} := \overrightarrow{\left(\pi\cdot OD_{outer}\cdot\frac{2\cdot\phi}{360\ deg}\right)} \qquad lg_{cr\_weld} = \begin{bmatrix} 47.2 \\ 50.4 \end{bmatrix}\cdot in$$

The center of gravity of the straight and curved weld relative to the centerline is:

$$cg_{weld} := \overrightarrow{\frac{\left(\frac{OD_{outer}}{2}\right)^2\cdot\int_{-\phi}^{\phi}\cos(\alpha)\,d\alpha + lg_{st\_weld}\cdot\frac{OD_{outer}}{2}\cdot\cos(\phi)}{lg_{st\_weld} + lg_{cr\_weld}}}$$

$$cg_{weld} = \begin{bmatrix} 37.5 \\ 36.1 \end{bmatrix}\cdot in$$

The moment arm for bending of the applied load on the center of gravity of the weld group

$$x_{weld} := \overrightarrow{\left(cg_{weld} - x_{rail\_in} + \delta_{contact}\right)} \qquad x_{weld} = \begin{bmatrix} 3.7 \\ 4 \end{bmatrix}\cdot in$$

The moment of inertia about the centroid is:

$j := 1..2$

$$I_{weld_j} := \int_{-\phi_j}^{\phi_j} \left(cg_{weld_j} - \frac{OD_{outer_j}}{2} \cdot \cos(\alpha) \right)^2 \cdot \frac{OD_{outer_j}}{2} \, d\alpha \; ... \\ + lg_{st\_weld_j} \cdot \left(cg_{weld_j} - x_{rail\_in_j} \right)^2$$

$$I_{weld} = \begin{bmatrix} 605.5 \\ 856.3 \end{bmatrix} \cdot in^3$$

The maximum tensile stress occurs on the inside of the weld, since the bending produces a compressive stress in the outer weld. Therefore, the maximum load per unit length is:

$$P_{max\_weld} := \overrightarrow{\left[\left[\frac{P_{rail}}{lg_{st\_weld} + lg_{cr\_weld}} + \frac{P_{rail} \cdot x_{weld} \cdot (cg_{weld} - x_{rail\_in})}{I_{weld}} \right] \cdot \frac{1 \text{ in}}{N_{rail}} \right]}$$

$$P_{max\_weld} = \begin{bmatrix} 1235.7 \\ 1168.8 \end{bmatrix} \cdot lbf$$

The weld is a 5/8-in groove weld.

$$\tau_{rail\_weld} := \overrightarrow{\frac{P_{max\_weld}}{(1 \text{ in}) \cdot t_{rail\_weld}}} \qquad \tau_{rail\_weld} = \begin{bmatrix} 1977.1 \\ 1870.1 \end{bmatrix} \cdot psi$$

The factors of safety are based on a failure in shear. Therefore, the yield strength and the ultimate strength must be multiplied by 0.57.

Factor of safety against yield

$$K1_{rail\_weld} := \overrightarrow{\frac{0.57 \cdot S_y}{\tau_{rail\_weld}}}$$

$$K1_{rail\_weld} = \begin{bmatrix} 9.485 \\ 10.028 \end{bmatrix}$$

$$Comp1_{rail\_weld} = \begin{bmatrix} \text{"> 6.0 OKAY"} \\ \text{"> 6.0 OKAY"} \end{bmatrix}$$

Factor of safety against ultimate

$$K2_{rail\_weld} := \overrightarrow{\frac{0.57 \cdot S_u}{\tau_{rail\_weld}}}$$

$$K2_{rail\_weld} = \begin{bmatrix} 16.722 \\ 17.678 \end{bmatrix}$$

$$Comp2_{rail\_weld} = \begin{bmatrix} \text{"> 10.0 OKAY"} \\ \text{"> 10.0 OKAY"} \end{bmatrix}$$

6.6 Bending Stress in the Doors

It is assumed that each door is independent and simply supported at the edges.
It is also assumed that half of the load is concentrated at the center of each plate.

$$t := t_{door} - t_{door\_lead} \qquad t = \begin{bmatrix} 9 \\ 5.13 \end{bmatrix} \cdot in$$

$$\sigma_{door} := \overrightarrow{\left[\frac{\frac{\frac{P_{rail\_sup}}{2} \cdot lg_{door}}{4}}{\left(\frac{w_{door} \cdot t^2}{6}\right)}\right]} \qquad \sigma_{door} = \begin{bmatrix} 1486 \\ 5124.2 \end{bmatrix} \cdot psi$$

The factors of safety are:

Factor of safety against yield $\quad K1_{door} := \overrightarrow{\left(\frac{S_y}{\sigma_{door}}\right)}$

$$K1_{door} = \begin{bmatrix} 22.139 \\ 6.421 \end{bmatrix}$$

$$Comp1_{door} = \begin{bmatrix} \text{"> 6.0 OKAY"} \\ \text{"> 6.0 OKAY"} \end{bmatrix}$$

Factor of safety against ultimate $\quad K2_{door} := \overrightarrow{\left(\frac{S_u}{\sigma_{door}}\right)}$

$$K2_{door} = \begin{bmatrix} 39.03 \\ 11.319 \end{bmatrix}$$

$$Comp2_{door} = \begin{bmatrix} \text{"> 10.0 OKAY"} \\ \text{"> 10.0 OKAY"} \end{bmatrix}$$

7.0 CONCLUSION

The calculation presented in Section 6.0 demonstrates that the MTC rails meet the criteria specified in NUREG 0612. The support rail, support rail to rail weld, and rail to MTC shell weld have factors of safety greater than 6.0 and 10.0 against yield and ultimate, respectively, as specified in Section 2.1.

A summary of factors of safety for the MTC Rails is provided below.

MTC Rail Support in Bending and Shear:

$$K1_{rail\_sup} = \begin{bmatrix} 8.22 \\ 6.06 \end{bmatrix}$$

$$Comp1_{rail\_sup} = \begin{bmatrix} \text{"> 6.0 OKAY"} \\ \text{"> 6.0 OKAY"} \end{bmatrix}$$

$$K2_{rail\_sup} = \begin{bmatrix} 14.5 \\ 10.7 \end{bmatrix}$$

$$Comp2_{rail\_sup} = \begin{bmatrix} \text{"> 10.0 OKAY"} \\ \text{"> 10.0 OKAY"} \end{bmatrix}$$

MTC Rail Support to Rail Weld Shear:

$$K1_{sup\_weld} = 7.4$$

$$Comp1_{sup\_weld} = \text{"> 6.0 OKAY"}$$

$$K2_{sup\_weld} = 13$$

$$Comp2_{sup\_weld} = \text{"> 10.0 OKAY"}$$

MTC Rail to MTC Shell Weld in Shear:

$$K1_{rail\_weld} = \begin{bmatrix} 9.5 \\ 10 \end{bmatrix} \qquad Comp1_{rail\_weld} = \begin{bmatrix} \text{"> 6.0 OKAY"} \\ \text{"> 6.0 OKAY"} \end{bmatrix}$$

$$K2_{rail\_weld} = \begin{bmatrix} 16.7 \\ 17.7 \end{bmatrix} \qquad Comp2_{rail\_weld} = \begin{bmatrix} \text{"> 10.0 OKAY"} \\ \text{"> 10.0 OKAY"} \end{bmatrix}$$

MTC Door Bending Stress:

$$K1_{door} = \begin{bmatrix} 22.1 \\ 6.4 \end{bmatrix} \qquad Comp1_{door} = \begin{bmatrix} \text{"> 6.0 OKAY"} \\ \text{"> 6.0 OKAY"} \end{bmatrix}$$

$$K2_{door} = \begin{bmatrix} 39 \\ 11.3 \end{bmatrix} \qquad Comp2_{door} = \begin{bmatrix} \text{"> 10.0 OKAY"} \\ \text{"> 10.0 OKAY"} \end{bmatrix}$$

Summary of Conservatisms

1. Weights of MTC doors, rail supports, and rails, and the weight of the MSB with fuel, wet, with shield lid but no structural lid, provided in Section 2.0 are conservatively higher than the weights of these components calculated in Reference 3.1.1.

2. The stress in the doors is determined assuming that the doors are simply supported and the load is concentrated in the center.

8.0 ELECTRONIC FILES

8.1 Computer Runs

None.

8.2 Other Electronic Files

None.

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.10 File No.: VSC02.6.2.3.10 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

MTC Lifting Devices.

SCOPE:

Product: ☐ FuelSolutions™ ☐ TranStor™ ☒ VSC-24 ☐ Other ______

Service: ☒ Storage ☐ Transportation ☐ Other ______

Conditions: ☒ Normal ☐ Off-Normal ☐ Accident ☐ Other ______

Component(s):

MTC trunnions and shell.

Prepared by:

Name: ROBERT KEATING

Signature: [signature]

Date: 1-31-2001

Verified by:

Name: Regina Parkerson

Signature: Regina Parkerson

Date: 1-31-2001

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: R Srinivasan

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 14 Appendix Pages A1 – A9		Replaces Calculation WEP109-002.10, Rev. 2	Robert Keating	Regina Parkerson
1	1-16		Incorporated ECN VSC02-ECN-008	Robert Keating	Regina Parkerson

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	(YES)	NO	N/A
(j) Computer codes used are under configuration control.	(YES)	NO	N/A
(k) Computer codes used are applicable to the calculation.	(YES)	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Regina Parkerson / Regina Parkerson / 1-31-2001

Name/Signature/Date

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The design of MTC lifting devices must meet the requirements of NUREG 0612, Control of Heavy Loads at Nuclear Power Plants [Reference 3.2.1]. In addition to development of the safe load paths, procedures, etc., the NUREG also requires that special lifting devices and lifting points on heavy loads qualify as "single-failure proof"; otherwise, consequences of the drop must be evaluated. The purpose of this calculation is to determine whether the MTC lifting devices support the single-failure proof design. The scope of the calculation is an analysis of the MTC trunnions and shell.

Revision 0 of this calculation was prepared to address technical issues concerning Calculation WEP109-002.10, Revision 2 discussed in CAR 98-50 (date 10/2/98) and the Design Review Record (dated 7/31/98). This calculation supercedes WEP109-002.10, Revision 2. The principal modifications in Revision 1 of this calculation are:

- The spacing between the inner and outer shells is based on the most limiting configuration, which is the ANO geometry.
- The calculation has been updated generally to bound the ANO geometry.

No calculations are known to be affected by this modified calculation.

2. REQUIREMENTS

2.1 Design Inputs

2.1.1 NUREG 0612, "Control of Heavy Loads at Nuclear Power Plants", 1980.
(Specifies the following criteria for single-failure proof devices:)

a) The ANSI N14.6 [Ref. 3.2.2] requirements must be met. For a dual load path design (i.e., a single-failure does not result in uncontrolled movement of the load), the stresses at any point shall not exceed 1/3 of material yield strength or 1/5 of its ultimate strength (safety factors of 3 on yield and 5 on ultimate). As an alternative, the double factors of safety of 6 and 10 must be provided if the lift point system does not have a load path redundancy. This alternative has been applied in this calculation.

b) On top of the ANSI N14.6 criteria above, the design shall include the dynamic load factor (this factor is not specified by NUREG 0612). Based on discussions with the NRC, the increase of 10% was selected to meet this requirement.

2.2 Regulatory Commitments

See Section 2.1.

3. REFERENCES

3.1 BFS Calculation Packages

3.1.1 BNFL Calculation VSC02.6.2.5.01, Revision 1, Weight and Center of Gravity. *(Weight of wet loaded MTC and weights of the MTC shells).*

3.1.2 BNFL Calculation VSC02.6.2.5.03, Revision 0, VSC-24 Design Parameters. *(Design Parameters)*

3.1.3 SNC Calculation WEP-109.002.10, Revision 2, MTC Lifting Devices. *(ANSYS output)*

3.2 General References

3.2.1 NUREG 0612, Control of Heavy Loads at Nuclear Power Plants, 1980.

3.2.2 ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More , 1986.

3.2.3 Deleted.

3.2.4 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda.

3.2.5 Deleted.

3.2.6 ASME Boiler and Pressure Vessel Code, Code Cases, Nuclear Components, Code Case N-71-14.

4. ASSUMPTIONS

4.1 Design Configuration

Table 4-1: Design Parameters

Item	Material	Value	Reference
Weight of loaded MTC (MSB with water)	N/A	P = 193,000 lbs	3.1.1 (Value shown is a bounding value)
Inner and Outer Shell Material	A 588, Gr. A or B (Ref. 3.1.2) at 300°F	$S_y = 45.6\ ksi$ $S_u = 70\ ksi$	3.2.6, Table 3 3.2.6, Table 5
Trunnion	A 516, Gr. 70 (Ref. 3.1.2) at 200°F (Temperature is Assumed)	Diameter = 10.75" $S_y = 34.6\ ksi$ $S_u = 70\ ksi$	3.1.2 3.2.4, Table I-2.1 3.2.4, Table I-3.1

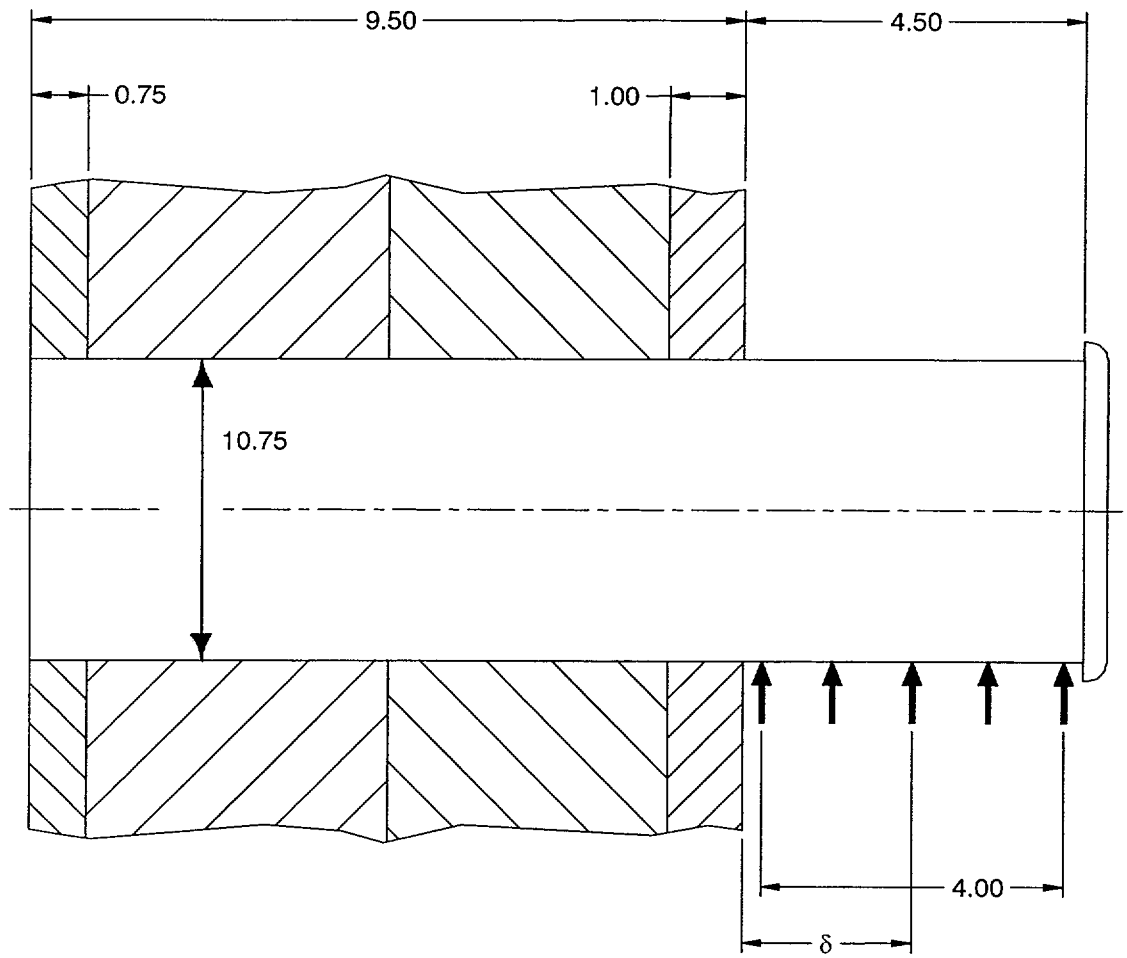
4.2 Design Criteria

None.

4.3 Calculation Assumptions

4.3.1 The MTC load application point is assumed to be at the center of yoke arm when the arm is in its center position on the trunnion. This produces the moment arm of δ=2.25" used herein. See Figure 4-1.

Figure 4-1: MTC Trunnion



Note: Dimensions are in inches and are from Reference 3.1.2. The ANO1/ANO2 dimensions are shown above and have conservatively been used in this calculation.

5. CALCULATION METHODOLOGY

To determine whether the MTC trunnion and shell are single-failure proof, as specified by criteria in NUREG 0612, factors of safety are calculated for the trunnion and shell. The calculated factors of safety are then compared to values specified in Section 2.1.

MTC trunnion stresses are calculated by hand by approximating the trunnion as a cylinder with a diameter of 10.75". The outer shell stresses are calculated using ANSYS/PC LINEAR Version 4.3 A-2. These stresses are used along with ultimate strength and yield strength of the trunnion and shell materials to calculate factors of safety.

6. CALCULATIONS

6.1 MTC Trunnion

Considering a dynamic load factor of 10%, the increased MTC design load is:

$$P = 1.1 \cdot 193{,}000\ lbs = 212{,}300\ lbs$$

A solid cylinder with an outside diameter 10.75 inches yields:

Area of section: A=90.8 in^2

Section modulus: S= 122.0 in^3

Shear stress:

$$\tau = \frac{P}{2A} = \frac{212{,}300 lbs}{2 \cdot 90.8 in^2} = 1.2\ ksi$$

Bending stress:

$$\sigma_h = \frac{P}{2}\delta\frac{1}{S} = \frac{212{,}300 lbs}{2} \cdot 2.25 in \cdot \frac{1}{122.0 in^3} = 1.96\ ksi$$

Principal stress:

$$S_1 = \frac{\sigma_h}{2} + \sqrt{\left(\frac{\sigma_h}{2}\right)^2 + \tau^2} \quad = 2.53\ ksi$$

$$S_3 = \frac{\sigma_h}{2} - \sqrt{\left(\frac{\sigma_h}{2}\right)^2 + \tau^2} \quad = -0.57\ ksi$$

$$SI = S_1 - S_3 = 3.1\ ksi$$

$$K_1 = \frac{34.6}{3.1} = 11.2 > 6.0 \qquad \text{O.K.}$$

$$K_2 = \frac{70}{3.1} = 22.6 > 10.0 \qquad \text{O.K.}$$

6.2 MTC Shell

To evaluate the MTC shell stresses, the trunnion moment was represented by a force couple on the inner and outer shells at the centerlines. The calculated reactions are then applied to the shell model using finite element analysis. Since the force distribution around the trunnion circumference is not known, the loads are applied as weights with the trunnion area supported. This allows the FEA program to achieve the correct distribution automatically. See Figure 6-1.

The reaction on the outer shell is:

$$R = \frac{P}{2}\left(1 + \frac{2.75in}{8.625in}\right) = 140.0\ kips \qquad \text{(See Figure 6-1)}$$

ANSYS/PC-LINEAR Version 4.3 A-2 code was used for the calculation of the stresses in the outer shell. 2-D STIF42 elements were used. The nodes on the trunnion were simply supported and symmetry conditions provided along x = 0. Refer to Figure 6-2 for a diagram of the finite element model.

Figure 6-1: Trunnion Force Couple on MTC Inner and Outer Shells

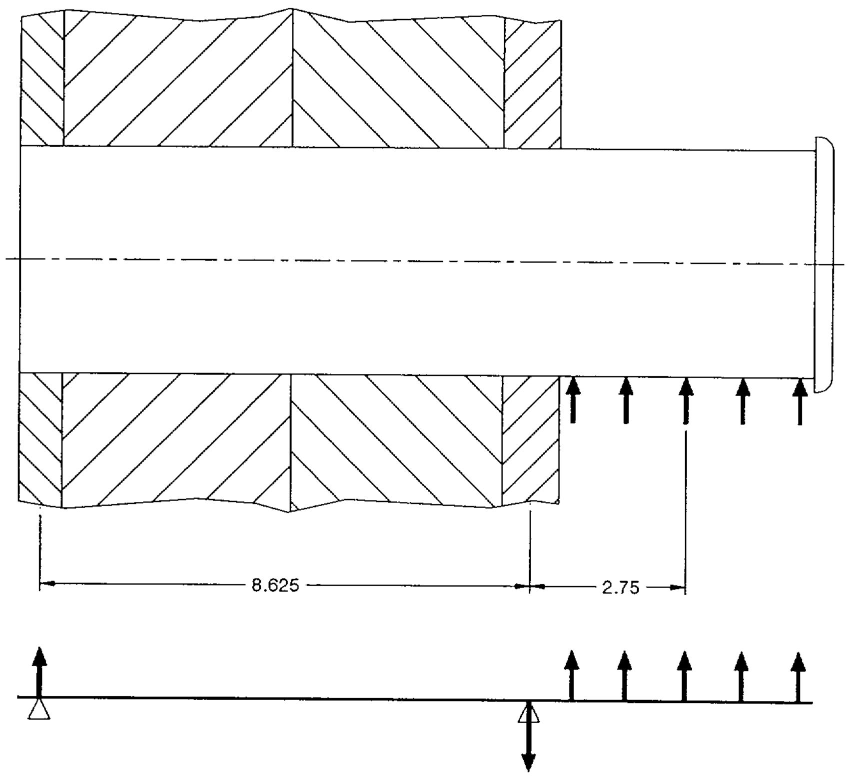
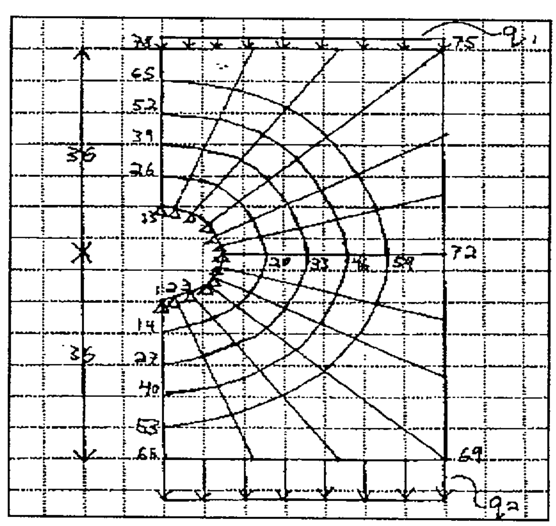


Figure 6-2: MTC Shell Finite Element Model



A 72-inch long by 36-inch wide portion of the MTC outer shell was modeled (See Figure 6-2). The plate thickness is one inch (the thickness of the MTC outer shell per Reference 3.1.2). The weight of the shell section is modeled as density, calculated using the total weight of each part of the MTC shell reduced by the ratio of the size of the model to the total size of the MTC shell. The following values from Reference 3.1.1 are used in the calculation:

$$W_{inner} := \begin{bmatrix} 6952 \\ 7644 \\ 8097 \end{bmatrix} \text{lbf}$$ Weight of the MTC inner shell

$$W_{lead} := \begin{bmatrix} 60008 \\ 66020 \\ 60262 \end{bmatrix} \text{lbf}$$ Weight of the MTC lead shield

$$W_{Rx} := \begin{bmatrix} 9695 \\ 10660 \\ 11003 \end{bmatrix} \text{lbf}$$ Weight of the MTC neutron shield

$$W_{outer} := \begin{bmatrix} 11902 \\ 13087 \\ 13717 \end{bmatrix} \text{lbf}$$ Weight of the MTC outer shell

$$L := \begin{bmatrix} 161.7 \\ 177.8 \\ 189.8 \end{bmatrix} \text{in}$$ Total length of the MTC shell

The first entry in each matrix above corresponds to the CE 15x15 fuel assembly used at Palisades, the second corresponds to the Westinghouse 14x14 fuel assembly used at Point Beach, and the last entry corresponds to the B&W 15x15 fuel assembly used at ANO1/ANO2.

Other values used in the density calculation are as follows:

$l := 72 \text{ in}$ Length of the model

$c := 36 \text{ in}$ Width of the model

$t := 1 \text{ in}$ Thickness of the model

$M := 1 + \frac{2.75\ in}{8.625\ in}$

Factor to account for trunnion moment arm (See Fig. 6-1. Note that the ANO1/ANO2 dimensions have conservatively been used to obtain the largest value of M.)

$M = 1.319$

$F := 1.1$

Dynamic load factor

The following is the weight of one-fourth of a 72-inch long portion of the MTC shell. Although the 36-inch wide model does not represent a full quarter portion of the shell, it is conservatively assumed to be one-fourth of the shell.

$$W := \overrightarrow{\left[\left(W_{inner} + W_{outer} + W_{Rx} + W_{lead} \right) \cdot \frac{1}{L} \cdot \frac{1}{4} \right]}$$

$$W = \begin{bmatrix} 9.86 \cdot 10^3 \\ 9.86 \cdot 10^3 \\ 8.83 \cdot 10^3 \end{bmatrix} \circ lbf$$

$$\rho := \frac{W}{l \cdot c \cdot t} \cdot M \cdot F$$

$$\rho = \begin{bmatrix} 5.5 \\ 5.5 \\ 4.9 \end{bmatrix} \circ \frac{lbf}{in^3}$$

The weight of the remaining portion of the loaded MTC is represented by the pressures at the top and bottom of the modeled piece. Values from Reference 3.1.1 used in the calculations are as follows:

$W_{ring} := \begin{bmatrix} 1312 \\ 1312 \\ 1229 \end{bmatrix} lbf$

Weight of the upper ring

$W_{cover} := 405\ lbf$

Weight of the MTC cover plate

$W_{MTC} := \begin{bmatrix} 180672 \\ 192203 \\ 190541 \end{bmatrix} lbf$

Weight of the loaded MTC

The pressures are calculated as follows:

q_1 - load due to the weight of the upper ring and cover plate

$$q_1 := M \cdot \left(W_{ring} + W_{cover}\right) \cdot \frac{1}{4} \cdot \frac{1}{c} \cdot \frac{1}{t} \cdot F$$

$$q_1 = \begin{bmatrix} 17.3 \\ 17.3 \\ 16.5 \end{bmatrix} \circ psi$$

q_2 - load due to the rest of the loaded MTC (not accounted for above)

$$q_2 := M \cdot \left(W_{MTC} - 4 \cdot W - W_{ring} - W_{cover}\right) \cdot \frac{1}{4} \cdot \frac{1}{c} \cdot \frac{1}{t} \cdot F$$

$$q_2 = \begin{bmatrix} 1.41 \cdot 10^3 \\ 1.52 \cdot 10^3 \\ 1.55 \cdot 10^3 \end{bmatrix} \circ psi$$

The ANSYS input/output is attached (Attachment A). The ANSYS analysis was run using a weight W of 10.0 kips (40.2 kips / 4) and a reaction of 140.1 kips. This resulted in a q_1 of 0.017 ksi and a q_2 of 1.53 ksi. The ANSYS results are scaled up by the ratio of the largest current q_2 value to the q_2 value previously evaluated.

From the ANSYS output, the highest stress intensity, occurring at Node 2, is

$SI := 6.84\ ksi$

$SI_{current} := SI \cdot \frac{1.55}{1.53}$ $\qquad$ $SI_{current} = 6.93 \circ ksi$

$K_1 := \frac{45.6\ ksi}{SI_{current}}$ $\qquad$ $K_1 = 6.6$ $\qquad$ > 6 OK

$K_2 := \frac{70\ ksi}{SI_{current}}$ $\qquad$ $K_2 = 10.1$ $\qquad$ > 10 OK

7. CONCLUSIONS

The calculation presented in Section 6.0 shows that MTC trunnion and shell are single-failure proof as specified in NUREG 0612. Both the trunnion and shell have safety factors greater than 6 and 10 against yield and ultimate, respectively.

8. ELECTRONIC FILES

8.1 Computer Runs

Copies of computer input and output from ANSYS PC/Linear Version 4.3A-2 for outer shell calculations is provided for convenience in Attachment A. This computer input and output is taken from Reference 3.1.3.

8.2 Other Electronic Files

None.

9. ATTACHMENT A – ANSYS INPUT AND OUTPUT FOR MTC SHELL

LIST ALL SELECTED NODE DSYS= 0

NODE	X	Y	Z	THXY	THYZ	THXZ
1	0.20924E-10	-5.3700	0.00000E+00	0.00	0.00	0.00
2	1.3899	-5.1870	0.00000E+00	0.00	0.00	0.00
3	2.6850	-4.6506	0.00000E+00	0.00	0.00	0.00
4	3.7972	-3.7972	0.00000E+00	0.00	0.00	0.00
5	4.6506	-2.6850	0.00000E+00	0.00	0.00	0.00
6	5.1870	-1.3899	0.00000E+00	0.00	0.00	0.00
7	5.3700	0.00000E+00	0.00000E+00	0.00	0.00	0.00
8	5.1870	1.3899	0.00000E+00	0.00	0.00	0.00
9	4.6506	2.6850	0.00000E+00	0.00	0.00	0.00
10	3.7972	3.7972	0.00000E+00	0.00	0.00	0.00
11	2.6850	4.6506	0.00000E+00	0.00	0.00	0.00
12	1.3899	5.1870	0.00000E+00	0.00	0.00	0.00
13	0.20924E-10	5.3700	0.00000E+00	0.00	0.00	0.00
14	0.28717E-10	-7.3700	0.00000E+00	0.00	0.00	0.00
15	1.9075	-7.1189	0.00000E+00	0.00	0.00	0.00
16	3.6850	-6.3826	0.00000E+00	0.00	0.00	0.00
17	5.2114	-5.2114	0.00000E+00	0.00	0.00	0.00
18	6.3826	-3.6850	0.00000E+00	0.00	0.00	0.00
19	7.1189	-1.9075	0.00000E+00	0.00	0.00	0.00
20	7.3700	0.00000E+00	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
21	7.1189	1.9075	0.00000E+00	0.00	0.00	0.00
22	6.3826	3.6850	0.00000E+00	0.00	0.00	0.00
23	5.2114	5.2114	0.00000E+00	0.00	0.00	0.00
24	3.6850	6.3826	0.00000E+00	0.00	0.00	0.00
25	1.9075	7.1189	0.00000E+00	0.00	0.00	0.00
26	0.28717E-10	7.3700	0.00000E+00	0.00	0.00	0.00
27	0.40407E-10	-10.370	0.00000E+00	0.00	0.00	0.00
28	2.6840	-10.017	0.00000E+00	0.00	0.00	0.00
29	5.1850	-8.9807	0.00000E+00	0.00	0.00	0.00
30	7.3327	-7.3327	0.00000E+00	0.00	0.00	0.00
31	8.9807	-5.1850	0.00000E+00	0.00	0.00	0.00
32	10.017	-2.6840	0.00000E+00	0.00	0.00	0.00
33	10.370	0.00000E+00	0.00000E+00	0.00	0.00	0.00
34	10.017	2.6840	0.00000E+00	0.00	0.00	0.00
35	8.9807	5.1850	0.00000E+00	0.00	0.00	0.00
36	7.3327	7.3327	0.00000E+00	0.00	0.00	0.00
37	5.1850	8.9807	0.00000E+00	0.00	0.00	0.00
38	2.6840	10.017	0.00000E+00	0.00	0.00	0.00
39	0.40407E-10	10.370	0.00000E+00	0.00	0.00	0.00
40	0.59889E-10	-15.370	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
41	3.9780	-14.846	0.00000E+00	0.00	0.00	0.00
42	7.6850	-13.311	0.00000E+00	0.00	0.00	0.00
43	10.868	-10.868	0.00000E+00	0.00	0.00	0.00
44	13.311	-7.6850	0.00000E+00	0.00	0.00	0.00
45	14.846	-3.9780	0.00000E+00	0.00	0.00	0.00
46	15.370	0.00000E+00	0.00000E+00	0.00	0.00	0.00
47	14.846	3.9780	0.00000E+00	0.00	0.00	0.00
8	13.311	7.6850	0.00000E+00	0.00	0.00	0.00
9	10.868	10.868	0.00000E+00	0.00	0.00	0.00
50	7.6850	13.311	0.00000E+00	0.00	0.00	0.00
51	3.9780	14.846	0.00000E+00	0.00	0.00	0.00

52	0.59889E-10	15.370	0.00000E+00	0.00	0.00	0.00
53	0.91061E-10	-23.370	0.00000E+00	0.00	0.00	0.00
54	6.0486	-22.574	0.00000E+00	0.00	0.00	0.00
55	11.685	-20.239	0.00000E+00	0.00	0.00	0.00
56	16.525	-16.525	0.00000E+00	0.00	0.00	0.00
57	20.239	-11.685	0.00000E+00	0.00	0.00	0.00
58	22.574	-6.0486	0.00000E+00	0.00	0.00	0.00
59	23.370	0.00000E+00	0.00000E+00	0.00	0.00	0.00
60	22.574	6.0486	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
61	20.239	11.685	0.00000E+00	0.00	0.00	0.00
62	16.525	16.525	0.00000E+00	0.00	0.00	0.00
63	11.685	20.239	0.00000E+00	0.00	0.00	0.00
64	6.0486	22.574	0.00000E+00	0.00	0.00	0.00
65	0.91061E-10	23.370	0.00000E+00	0.00	0.00	0.00
66	0.00000E+00	-36.000	0.00000E+00	0.00	0.00	0.00
67	9.6462	-36.000	0.00000E+00	0.00	0.00	0.00
68	20.785	-36.000	0.00000E+00	0.00	0.00	0.00
69	36.000	-36.000	0.00000E+00	0.00	0.00	0.00
70	36.000	-20.785	0.00000E+00	0.00	0.00	0.00
71	36.000	-9.6462	0.00000E+00	0.00	0.00	0.00
72	36.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
73	36.000	9.6462	0.00000E+00	0.00	0.00	0.00
74	36.000	20.785	0.00000E+00	0.00	0.00	0.00
75	36.000	36.000	0.00000E+00	0.00	0.00	0.00
76	20.785	36.000	0.00000E+00	0.00	0.00	0.00
77	9.6462	36.000	0.00000E+00	0.00	0.00	0.00
78	0.00000E+00	36.000	0.00000E+00	0.00	0.00	0.00

LIST ALL SELECTED ELEMENTS. (LIST NODES)

ELEM	MAT	TYP	REL	NODES			
1	1	1	1	1	14	15	2
2	1	1	1	2	15	16	3
3	1	1	1	3	16	17	4
4	1	1	1	4	17	18	5
5	1	1	1	5	18	19	6
6	1	1	1	6	19	20	7
7	1	1	1	7	20	21	8
8	1	1	1	8	21	22	9
9	1	1	1	9	22	23	10
10	1	1	1	10	23	24	11
11	1	1	1	11	24	25	12
12	1	1	1	12	25	26	13
13	1	1	1	14	27	28	15
14	1	1	1	15	28	29	16
15	1	1	1	16	29	30	17
16	1	1	1	17	30	31	18
17	1	1	1	18	31	32	19
18	1	1	1	19	32	33	20
19	1	1	1	20	33	34	21
20	1	1	1	21	34	35	22

ELEM	MAT	TYP	REL	NODES			
21	1	1	1	22	35	36	23
22	1	1	1	23	36	37	24
23	1	1	1	24	37	38	25

24	1	1	1	25	38	39	26
25	1	1	1	27	40	41	28
26	1	1	1	28	41	42	29
27	1	1	1	29	42	43	30
28	1	1	1	30	43	44	31
29	1	1	1	31	44	45	32
30	1	1	1	32	45	46	33
31	1	1	1	33	46	47	34
32	1	1	1	34	47	48	35
33	1	1	1	35	48	49	36
34	1	1	1	36	49	50	37
35	1	1	1	37	50	51	38
36	1	1	1	38	51	52	39
37	1	1	1	40	53	54	41
38	1	1	1	41	54	55	42
39	1	1	1	42	55	56	43
40	1	1	1	43	56	57	44

ELEM	MAT	TYP	REL	NODES			
41	1	1	1	44	57	58	45
42	1	1	1	45	58	59	46
43	1	1	1	46	59	60	47
44	1	1	1	47	60	61	48
45	1	1	1	48	61	62	49
46	1	1	1	49	62	63	50
47	1	1	1	50	63	64	51
48	1	1	1	51	64	65	52
49	1	1	1	53	66	67	54
50	1	1	1	54	67	68	55
51	1	1	1	55	68	69	56
52	1	1	1	56	69	70	57
53	1	1	1	57	70	71	58
54	1	1	1	58	71	72	59
55	1	1	1	59	72	73	60
56	1	1	1	60	73	74	61
57	1	1	1	61	74	75	62
58	1	1	1	62	75	76	63
59	1	1	1	63	76	77	64
60	1	1	1	64	77	78	65

IST DISPLACEMENTS FOR ALL SELECTED NODES

NODE	LABEL	DISP	CDISP
12	UY	0.000000000E+00	0.000000000E+00
12	UX	0.000000000E+00	0.000000000E+00
2	UX	0.000000000E+00	0.000000000E+00
2	UY	0.000000000E+00	0.000000000E+00
3	UX	0.000000000E+00	0.000000000E+00
3	UY	0.000000000E+00	0.000000000E+00
4	UX	0.000000000E+00	0.000000000E+00
4	UY	0.000000000E+00	0.000000000E+00
5	UX	0.000000000E+00	0.000000000E+00
5	UY	0.000000000E+00	0.000000000E+00
6	UX	0.000000000E+00	0.000000000E+00
6	UY	0.000000000E+00	0.000000000E+00
7	UX	0.000000000E+00	0.000000000E+00
7	UY	0.000000000E+00	0.000000000E+00
8	UX	0.000000000E+00	0.000000000E+00
8	UY	0.000000000E+00	0.000000000E+00

9	UX	0.000000000E+00	0.000000000E+00
9	UY	0.000000000E+00	0.000000000E+00
10	UX	0.000000000E+00	0.000000000E+00
10	UY	0.000000000E+00	0.000000000E+00

ODE	LABEL	DISP	CDISP
11	UX	0.000000000E+00	0.000000000E+00
11	UY	0.000000000E+00	0.000000000E+00
1	UX	0.000000000E+00	0.000000000E+00
13	UX	0.000000000E+00	0.000000000E+00
14	UX	0.000000000E+00	0.000000000E+00
26	UX	0.000000000E+00	0.000000000E+00
27	UX	0.000000000E+00	0.000000000E+00
39	UX	0.000000000E+00	0.000000000E+00
40	UX	0.000000000E+00	0.000000000E+00
52	UX	0.000000000E+00	0.000000000E+00
53	UX	0.000000000E+00	0.000000000E+00
65	UX	0.000000000E+00	0.000000000E+00
66	UX	0.000000000E+00	0.000000000E+00
78	UX	0.000000000E+00	0.000000000E+00
69	UX	0.000000000E+00	0.000000000E+00
70	UX	0.000000000E+00	0.000000000E+00
71	UX	0.000000000E+00	0.000000000E+00
72	UX	0.000000000E+00	0.000000000E+00
73	UX	0.000000000E+00	0.000000000E+00
74	UX	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
75	UX	0.000000000E+00	0.000000000E+00

T ALL REAL SETS

REAL CONSTANT SET 1 ITEMS 1 TO 6

1.0000	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

LIST ALL MATERIALS PROPERTY= ALL

PROPERTY TABLE EX MAT= 1 NUM. POINTS= 2

TEMPERATURE	DATA	TEMPERATURE	DATA
0.00000E+00	29000.	2300.0	29000.

PROPERTY TABLE NUXY MAT= 1 NUM. POINTS= 2

TEMPERATURE	DATA	TEMPERATURE	DATA
0.00000E+00	0.30000	2300.0	0.30000

PROPERTY TABLE DENS MAT= 1 NUM. POINTS= 2

TEMPERATURE	DATA	TEMPERATURE	DATA
0.00000E+00	0.56000E-02	2300.0	0.56000E-02

LIST PRESSURES FOR ALL SELECTED NODES

ELEM	FACE	VALUE(S)		FACE NODES	
49	2	-1.5300	0.00000E+00	66	67
50	2	-1.5300	0.00000E+00	67	68
51	2	-1.5300	0.00000E+00	68	69
58	2	0.18000E-01	0.00000E+00	75	76
59	2	0.18000E-01	0.00000E+00	76	77
60	2	0.18000E-01	0.00000E+00	77	78

IST ALL ELEMENT TYPES

NO.	STIF	KEYOPT VALUES								INOTPR	
1	42	0	0	3	0	0	0	0	0	0	0 ISOPAR. STRESS SOLID, 2-D

Calc. Package VSC02.6.2.3.10
Rev. No: 1 Page A6 of A9

PRINT PRIN NODAL STRESSES PER NODE

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	S
1	3.3473660	0.00000000E+00	-0.64271214	3.9900782	3.710
2	6.8453732	1.2860227	0.00000000E+00	6.8453732	6.302
3	5.5715628	0.54872319	0.00000000E+00	5.5715628	5.332
4	5.1167762	0.84780321E-01	-0.46294371	5.5797199	5.337
5	4.6108287	0.00000000E+00	-1.3048075	5.9156362	5.408
6	3.9286908	0.00000000E+00	-2.1152612	6.0439520	5.340
7	3.1183928	0.00000000E+00	-2.7473579	5.8657507	5.112
8	2.2423823	0.00000000E+00	-3.1702544	5.4126367	4.739
9	1.3683977	0.00000000E+00	-3.3926991	4.7610968	4.271
10	0.54976655	0.00000000E+00	-3.4493303	3.9990968	3.775
11	0.97719115E-01	-0.25772231	-3.4793174	3.5770365	3.415
12	0.00000000E+00	-0.68442538	-4.0356456	4.0356456	3.7421
13	0.40275774	0.00000000E+00	-1.9644186	2.3671763	2.1937

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
14	2.9148414	0.22167840	-1.0177637	3.9326050	3.5821
15	5.7174623	0.11119332	-0.10688824	5.8243506	5.7213
16	4.8400640	0.00000000E+00	-0.23306014	5.0731242	4.9636
17	4.3197731	0.00000000E+00	-0.52143064	4.8412037	4.6144
18	3.7873358	0.00000000E+00	-0.95038302	4.7377189	4.3610
19	3.2065456	0.00000000E+00	-1.4067184	4.6132640	4.1181
20	2.6057631	0.00000000E+00	-1.8448343	4.4505973	3.8941
21	2.0107673	0.00000000E+00	-2.2206919	4.2314593	3.6859
22	1.4543242	0.00000000E+00	-2.5131812	3.9675054	3.4935
23	0.96468081	0.00000000E+00	-2.7243668	3.6890476	3.3256
24	0.60921995	0.00000000E+00	-2.9032346	3.5124545	3.2554
25	0.34787796	0.00000000E+00	-3.3069453	3.6548233	3.4975
26	0.69893260	0.00000000E+00	-1.5872372	2.2861698	2.1330

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
27	3.7583257	0.00000000E+00	-0.97257052E-01	3.8555828	3.8086
28	3.7394854	0.00000000E+00	-0.10446868	3.8439541	3.7933
29	3.7604706	0.00000000E+00	-0.11331048	3.8737810	3.8189
30	3.1732198	0.00000000E+00	-0.14167572	3.3148955	3.2468
31	2.5923582	0.00000000E+00	-0.21642303	2.8087812	2.7104
32	2.0211890	0.00000000E+00	-0.41054231	2.4317313	2.2629
33	1.5627681	0.00000000E+00	-0.71057501	2.2733431	2.0267
[illegible]	1.2299526	0.00000000E+00	-1.0981647	2.3281173	2.0271
[illegible]	0.96913710	0.00000000E+00	-1.4964010	2.4655381	2.1583
36	0.77085502	0.00000000E+00	-1.8142004	2.5850554	2.3032
37	0.61730963	0.00000000E+00	-2.0958388	2.7131484	2.4683

38	0.51204339	0.00000000E+00	-2.0233434	2.5353868	2.3248
39	0.47553410	0.00000000E+00	-2.0134938	2.4890279	2.2910

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
40	3.0468203	0.39178471E-01	-0.71706691E-01	3.1185270	3.0648
41	2.9640688	0.46446972E-01	-0.57876753E-01	3.0219455	2.9712
42	2.7287900	0.80002060E-01	-0.22451331E-01	2.7512414	2.7016
43	2.3886742	0.10356107	0.00000000E+00	2.3886742	2.3387
44	1.8522461	0.13564379	0.00000000E+00	1.8522461	1.7915
45	1.3746748	0.12525912	-0.20508359E-01	1.3951831	1.3339
46	1.0407459	0.34426880E-01	-0.16014997	1.2008958	1.1210
47	0.83628919	0.00000000E+00	-0.46665531	1.3029445	1.1536
48	0.72996233	0.00000000E+00	-0.81909363	1.5490560	1.3515
49	0.62438246	0.00000000E+00	-1.1422495	1.7666320	1.5589
50	0.51283663	0.00000000E+00	-1.2744969	1.7873336	1.6021
51	0.46630661	0.00000000E+00	-1.3616556	1.8279622	1.6526
52	0.44827564	0.00000000E+00	-1.3949995	1.8432751	1.6718

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
53	2.4295669	0.11523352	0.00000000E+00	2.4295669	2.37
54	2.2910060	0.16067299	0.00000000E+00	2.2910060	2.21[illegible]
55	1.9684818	0.25388314	0.00000000E+00	1.9684818	1.8592
56	1.6706429	0.42112942	0.00000000E+00	1.6706429	1.5235
57	1.2988938	0.51716444	0.00000000E+00	1.2988938	1.1512
58	0.99749249	0.41696246	0.00000000E+00	0.99749249	0.88348
59	0.80246290	0.14284715	0.00000000E+00	0.80246290	0.74565
60	0.66301445	0.00000000E+00	-0.17540891	0.83842336	0.76928
61	0.49031091	0.00000000E+00	-0.37674294	0.86705386	0.76371
62	0.37777399	0.00000000E+00	-0.51242585	0.89019983	0.80088
63	0.32567447	0.00000000E+00	-0.56722586	0.89290033	0.79217
64	0.30693449	0.00000000E+00	-0.75306710	1.0600016	0.95032
65	0.31898511	0.00000000E+00	-0.84809555	1.1670807	1.0496

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
66	2.2205576	0.29449263	0.00000000E+00	2.2205576	2.0889
67	2.0371177	0.41784524	0.00000000E+00	2.0371177	1.8670
68	1.6266459	0.65625868	0.00000000E+00	1.6266459	1.4250
69	1.2369702	0.68679011	0.00000000E+00	1.2369702	1.0736
70	1.0760286	0.63012472	0.00000000E+00	1.0760286	0.93784
71	0.85053623	0.52456663	0.00000000E+00	0.85053623	0.74365
72	0.74318393	0.20874145	0.00000000E+00	0.74318393	0.66425
[illegible]	0.66165790	0.00000000E+00	-0.12285001	0.78450791	0.73086
[illegible]	0.50137409	0.00000000E+00	-0.27094964	0.77232374	0.67889
75	0.29332373	0.00000000E+00	-0.26275665	0.55608037	0.48652
76	0.42881620E-01	-0.20297801E-01	-0.32851353	0.37139515	0.34421

77	0.71676836E-01	-0.74004593E-02	-0.52055376	0.59223060	0.55941
78	0.15015510	0.00000000E+00	-0.65766729	0.80782239	0.74419

MAXIMUMS

NODE	2	2	12	2	2
LUE	6.8453732	1.2860227	-4.0356456	6.8453732	6.302

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.12 File No.: VSC02.6.2.3.12 Revision: 1

PROJECT/CUSTOMER:

TITLE:

MTC Cover Plate.

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ______
Service:	☐ Storage	☒ Transportation		☐ Other ______
Conditions:	☐ Normal	☐ Off-Normal	☒ Accident	☐ Other ______

Component(s):

MTC cover plate and cover plate bolts.

Prepared by:

Name: ROBERT KEATING

Signature: [signature]

Date: 1-31-2001

Verified by:

Name: Regina Parkerson

Signature: Regina Parkerson

Date: 1-31-2001

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: R Srinivasan

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 12		Replaces Calculation WEP109-002.12, Rev. 3	Robert Keating	Regina Parkerson
1	1 – 12		Replaces Calculation ANO-109.002.304, Revision 2 Incorporated ECN VSC02-ECN-008	Robert Keating	Regina Parkerson

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Regina Parkerson / Regina Parkerson / 1-31-2001
Name/Signature/Date

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The cover plate of the MTC is designed to prevent inadvertent lifting of the MSB while the loaded MTC is on the concrete cask. It is desirable to ensure against undue radiation exposure to nearby workers. The lifting could be caused by crane malfunction or by mistake of a crane operator. The entire weight of the empty MTC would be taken by the cover plate, thus the adequate strength of the cover plate and the bolts must be provided.

The purpose/objective of this calculation is to compare MTC cover plate and MTC cover plate bolt stresses and loads to AISC code allowable values. This comparison ensures the entire weight of the empty MTC can be safely supported during an inadvertent lifting event. Because this is a very unlikely accident condition, NUREG-0612 safety factors do not have to be met.

Revision 0 of this calculation was prepared to address technical issues concerning Calculation WEP109-002.12, Revision 3 discussed in CAR 98-50 (date 10/2/98) and the Design Review Record (dated 7/31/98). This calculation supercedes WEP109-002.12, Revision 3 and replaces Calculation ANO-109.002.304, Revision 2. Therefore, this calculation covers all of the MTC configurations. The principal modification of Revision 1 of this calculation is:

- The calculation has been updated to bound the ANO configurations.

No calculations are known to be affected by this modified calculation.

2. REQUIREMENTS

2.1 Design Inputs

2.1.1 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda. *(Material Properties)*

2.1.2 AISC Manual, Edition 9 *(Material Properties)*

2.2 Regulatory Commitments

None.

2.2 Regulatory Commitments

None.

3. REFERENCES

3.1 BFS Calculation Packages

3.1.1 VSC02.6.2.5.01, Rev. 1, Weight and Center of Gravity.
(Bounding weight of empty MTC)

3.1.2 WEP-109.003.18, Rev.2, VSC-24 Transfer Cask Thermal Analysis.
(Temperature at cover plate)

3.1.3 VSC02.6.2.5.03, Rev. 0, VSC-24 Design Parameters.

3.2 General References

3.2.1 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda.

3.2.2 AISC Manual, Edition 9.

3.2.3 Deleted.

3.2.4 Deleted.

3.2.5 Deleted.

3.2.6 Roark, Formulas for Stress and Strain , Edition 4.

4. ASSUMPTIONS

4.1 Design Configuration

TABLE 4.1-1: DESIGN PARAMETERS

Item	Material	Value	Reference
Weight of empty MTC	N/A	P = 120 kips	Bounds value from Ref. 3.1.1
MTC Cover Plate	A-516, Grade 70 (Ref. 3.1.3)	D_{outer} = 74" Thickness = 1" D_{inner} = 60.5" S_y = 34.6 ksi	3.1.3 3.2.1, Table I-2.1
MTC Cover Plate Bolts	1"-8UNC A-325 (Ref. 3.1.3)	Number of bolts = 16 $Radius_{bolt\ circle}$ = 35.5" S_{allow} = 44.0 ksi	3.1.3 3.2.2, Table I-A
MSB		Diameter = 62.5"	3.1.3

The cover plate loading is shown in Figure 4.1-1. The cover plate model is shown in Figure 4.1-2.

FIGURE 4.1-1: MTC COVER PLATE LOADING

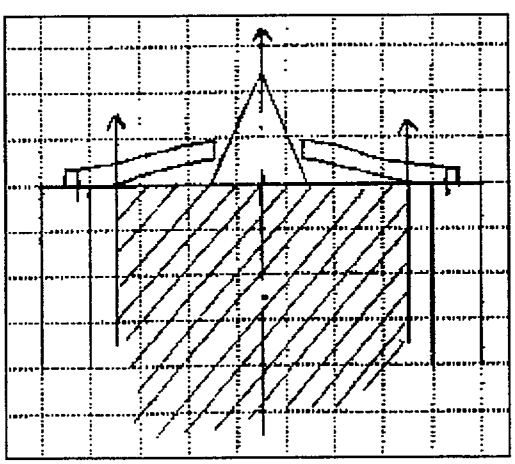
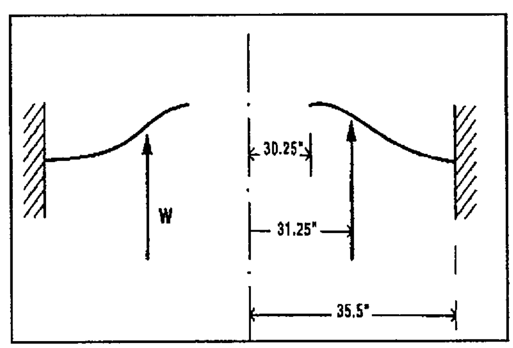


FIGURE 4.1-2: COVER PLATE MODEL



4.2 Design Criteria

None.

4.3 Calculation Assumptions

4.3.1 According to Reference 3.1.2, the MSB/MTC temperature at cover plate is a maximum temperature of 130°F. However, a bounding temperature of 200°F is conservatively assumed for this analysis.

5. CALCULATION METHODOLOGY

To determine whether the MTC cover plate and cover plate bolts can adequately support the weight of the empty MTC during an inadvertent lifting event, cover plate stresses are compared to allowable values, and the bolt tension load is compared to the allowable value specified in the AISC Code.

6. CALCULATIONS

6.1 Cover Plate Stresses

From Roark [Reference 3.2.6] p. 232, #60, the stresses on the inner edge are:

$$S_i = S_t = -\frac{3W}{4\pi m t^2}\left[(m+1)\left(2\ln\frac{a}{r_0}+\frac{r_0^2}{a^2}-1\right)\right]\frac{6M}{t^2}\left[\frac{a^2(m-1)-b^2(m+1)}{a^2(m-1)+b^2(m+1)}\right]$$

and the stresses on the outer edge are:

$$S_o = S_r = \frac{3W}{2\pi t^2}\left[1-\frac{r_o^2}{a^2}\right]+\frac{6mM}{t^2}\left[\frac{2b^2}{a^2(m-1)+b^2(m+1)}\right]$$

Where $M = \frac{W}{8\,\pi\, m}\left((m+1)\left(2\ln\frac{a}{r_o}+\frac{r_o^2}{a^2}-1\right)\right)$

For our case: $r_0 = 31.25"$; $a = 35.5"$; $b = 30.25"$; $W = 120 kips$; $m = \frac{1}{\nu} = 3.33$

$$M = \frac{120}{8\pi 3.33}\cdot(3.33+1)\cdot\left(2\ln\frac{35.5}{31.25}+\frac{31.25^2}{35.5^2}-1\right) = 0.186\ kips$$

Inside edge:

$$S_i = -\frac{3\cdot 120}{4\pi(3.33)\cdot 1^2}\left[(3.33+1)(2\ln\frac{35.5}{31.25}+\frac{31.25^2}{35.5^2}-1)\right]-$$

$$\frac{6\cdot 0.186}{1^2}\left[\frac{35.5^2(3.33-1)-30.25^2(3.33+1)}{35.5^2\cdot(3.33-1)+30.25^2\cdot(3.33+1)}\right]=-0.95ksi$$

Outside edge:

$$S_o = \frac{3\cdot 120}{2\ \pi\ 1^2}\left[1-\frac{31.25^2}{35.5^2}\right]+\frac{6\cdot 3.33\cdot 0.186}{1^2}\left[\frac{2\cdot 30.25^2}{35.5^2\cdot 2.33+30.25^2\cdot 4.33}\right]=13.9ksi$$

$$S \le 0.75S_y = 0.75(34.6ksi) = 26.0ksi$$

Shear stress on the outer edge:

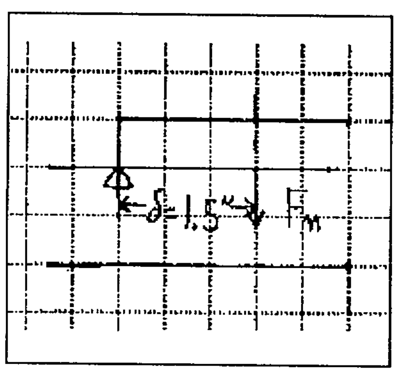
$$\tau = \frac{W}{2\pi at} = \frac{120}{2\pi\cdot 35.5\cdot 1} = 0.5ksi \le 0.4S_y = 0.4(34.6ksi) = 13.8ksi$$

6.2 MTC Cover Plate Bolts

Load on one bolt due to the reaction force:

$$F_F = \frac{W}{h} = \frac{120}{16} = 7.5kips$$

FIGURE 6.2-1: MTC COVER PLATE BOLT PRYING LOAD



Prying load on the bolt due to bending of the plate:

$$F_m = \frac{M_r 2\pi a}{16 \cdot \delta} = \frac{t^2 S_r \cdot 2\pi a}{6 \cdot 16 \cdot 1.5} = \frac{1^2 13.9 \cdot 2\pi \cdot 35.5}{6 \cdot 16 \cdot 1.5} = 21.5 kips$$

Total load on the bolt:

$$F = F_F + F_M = 7.5 + 21.5 = 29.0 \ \ kips$$

The allowable tension for A-325 bolt per AISC Code:

$$F_{all} = \frac{\pi d^2 S_{allow}}{4} = \frac{\pi (1inch)^2 \cdot 44.0}{4} = 34.6 kips > F = 29.0 kips \quad \text{OK}$$

7. CONCLUSIONS

Because the calculated stresses for the MTC cover plate and the calculated tension load for the MTC cover plate bolts are less than specified allowable values, the MTC cover plate and cover plate bolts are adequate to support the MTC load. Should the inadvertent attempt to lift the MSB out of the MTC occur, the MTC will be lifted with the MSB so that workers will not be subjected to increased radiation doses.

8. ELECTRONIC FILES

8.1 Computer Runs

None.

8.2 Other Electronic Files

None.

BNFL Fuel Solutions	CALCULATION PACKAGE	Calc. Pkg No. VSC02.6.2.3.15 File No.: VSC02.6.2.3.15 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

VSC-24 Hypothetical Tip-Over and 5-foot Drop Analyses

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ______
Service:	☒ Storage	☐ Transportation		☐ Other ______
Conditions:	☒ Normal	☒ Off-Normal	☒ Accident	☐ Other ______

Component(s):

VSC-24 concrete cask.

Prepared by:	Verified by:
Name: ROBERT KEATING	*Name:* Regina Parkerson
Signature: [signature]	*Signature:* Regina Parkerson
Date: 1-31-2001	*Date:* 1-31-2001

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: [signature]

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 22 Attachment A p. A1-A9 Attachment A.1 p. A.1.1-A.1.26		Replaces Calculation WEP109-002.15, Rev. 3	J.Hibbard	M.Heinz
1	1 – 22 Attachment A p. A1-A9 Attachment A.1 p. A.1.1-A.1.26		Replaces ANO-109.002.011, R3. Incorporated ECN VSC02-ECN-008	Robert Keating	Regina Parkerson

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION			
	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	(YES)	NO	N/A
(j) Computer codes used are under configuration control.	(YES)	NO	N/A
(k) Computer codes used are applicable to the calculation.	(YES)	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Regina Parkerson/Regina Parkerson/ 1-31-2001

Name/Signature/Date

1.0 INTRODUCTION

Although it has been shown that no credible event could tip over the VCC, the tipover accident is postulated and analyzed per the NRC request. In addition, a hypothetical 5-foot drop of the VCC is also considered despite the fact that the cask is never lifted that high.

This calculation replaces Calculation WEP109-002.15, Rev. 3. There are no deficiencies identified in CAR 98-50 for this calculation. The principal modification in Revision 1 of this calculation is:

- The calculation was updated to bound the ANO configurations.

This analysis evaluates impact energy and concrete crushing. For this condition, tall, heavy casks are bounding. The first entry in each matrix of this calculation corresponds to this condition.

The analysis also evaluates target impact acceleration stresses. For this condition, short light casks are bounding. The second entry in each matrix of this calculation corresponds to this condition.

2.0 DESIGN INPUT AND ASSUMPTIONS

The geometry below is obtained from Reference 15.

$D_{VCC} := 132 \cdot in$	VCC OD
$h_{VSC} := \begin{bmatrix} 225.1 \\ 196.5 \end{bmatrix} \cdot in$	Bounding value for height of VCC
$od_{liner} := 74 \cdot in$	VCC liner OD
$t_{liner} := 1.75 \cdot in$	VCC liner wall thickness
$od_{MSB} := 62.5 \cdot in$	MSB OD
$w_{bevel} := 3.0 \, in$	Width of the 45 deg bevel

The following mass and CG data bound the values in Reference 2:

$P_{VSC} := \begin{bmatrix} 288000 \\ 252700 \end{bmatrix} \cdot lb$ Weight of loaded VCC (bounding)

$h_{cg} := \begin{bmatrix} 116 \\ 101 \end{bmatrix} \cdot in$ Loaded VCC center of gravity (bounding)

$P_{MSB} := \begin{bmatrix} 69000 \\ 56000 \end{bmatrix} \cdot lb$ Weight of loaded MSB (bounding)

$P_{VCC} := \begin{bmatrix} 217000 \\ 189000 \end{bmatrix} \cdot lb$ Weight of empty VCC (bounding)

$P_{cover} := 1125 \cdot lb$ Weight of VCC cover

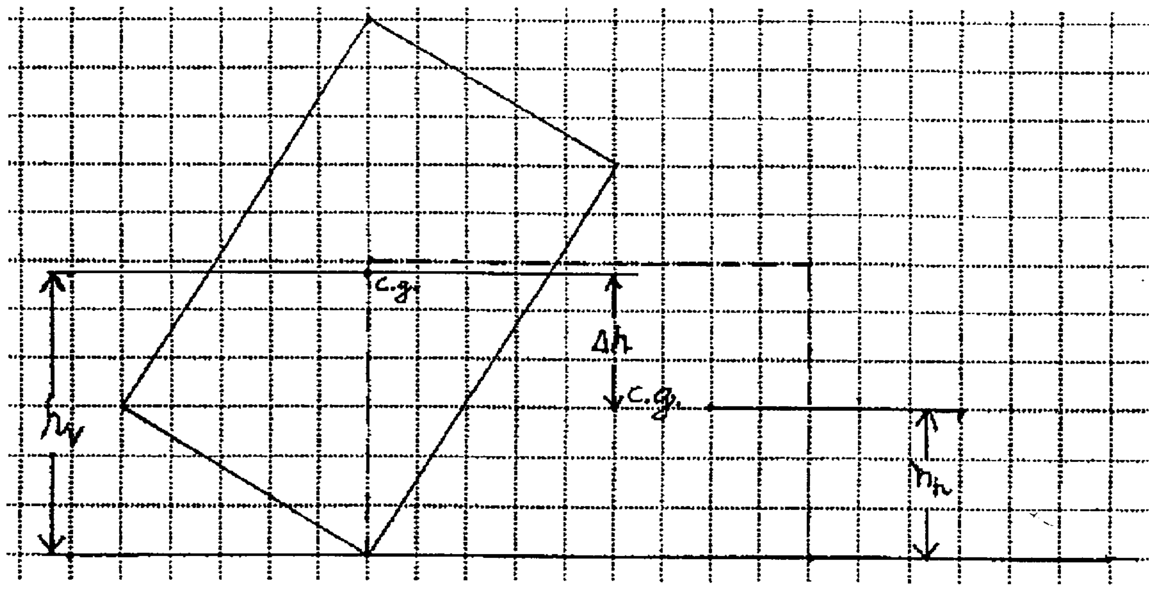
Other assumptions are stated in Section 3.0.

3.0 CALCULATIONS

3.1 Tip-Over Analysis

Two parameters are important as tip-over consequences: VSC concrete crush depth, and MSB deceleration level.

The geometry of the VSC tip-over is shown below.



The height of the cask cg above ground when the cask is balanced on its corner is calculated below. The calculation assumes that the MSB is at the cask centerline. The mass of the MSB is small compared to the mass of the VCC, so a shift in the MSB centerline is assumed to have a negligible effect on this calculation.

$$h_v := \sqrt{h_{cg}^2 + \left(\frac{D_{VCC} - 2 \cdot w_{bevel}}{2}\right)^2}$$

$$h_v = \begin{bmatrix} 132.00 \\ 119.04 \end{bmatrix} \cdot in$$

The thickness of the concrete cask wall is

$$t_{VCC} := \frac{D_{VCC} - od_{liner}}{2}$$

$$t_{VCC} = 29.00 \cdot in$$

The height of the cask cg above ground when the cask is horizontal is calculated below. It is assumed that the MSB has slid inside the VCC such that the MSB OD is contacting the liner ID.

$$h_h := \overrightarrow{\frac{P_{MSB}\cdot\left(\frac{od_{MSB}}{2} + t_{VCC} + t_{liner}\right) + (P_{VCC} + P_{cover})\cdot\frac{D_{VCC}}{2}}{P_{VSC}}}$$

$$h_h = \begin{bmatrix} 64.84 \\ 63.40 \end{bmatrix} \cdot in$$

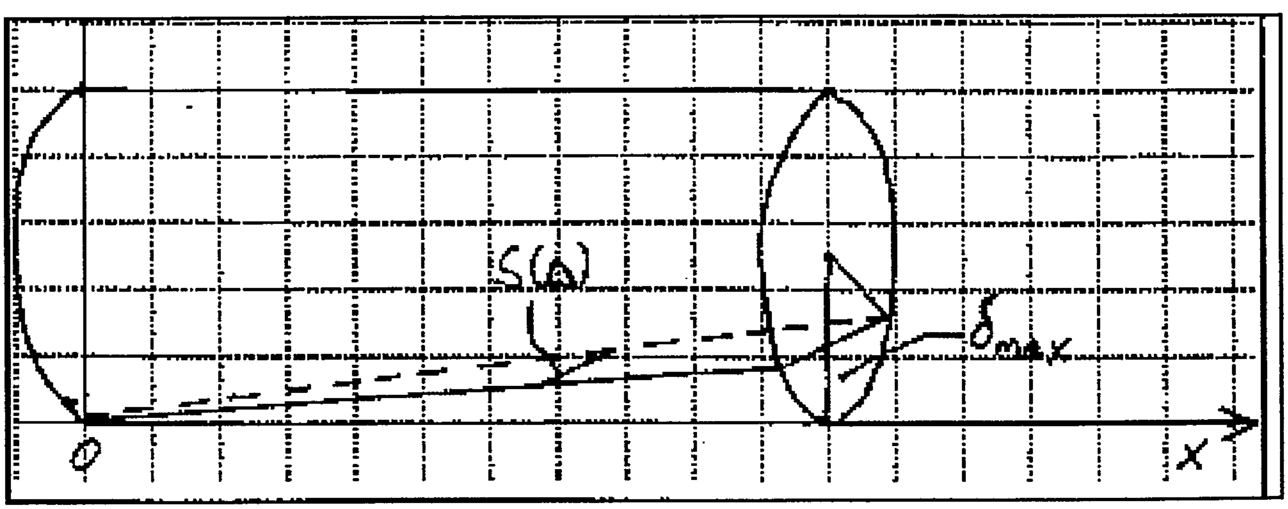
Then, the potential energy is

$$\Delta E := \overrightarrow{(P_{VSC}\cdot(h_v - h_h)\cdot 1\cdot g)}$$

$$\Delta E = \begin{bmatrix} 1.93\cdot 10^7 \\ 1.41\cdot 10^7 \end{bmatrix} \cdot in\cdot lbf$$

VSC Concrete Crush Depth

It was conservatively assumed for this calculation that the VSC hits a rigid surface so that all impact energy is absorbed by the cask. Since the motion is rotational and the rotational velocity at impact is linearly distributed along the VSC length, a linear distribution was assumed for the crush depth. The governing equation and geometry are shown below.



Parameters for the calculation are as follows:

$L := h_{VSC}$

$L = \begin{bmatrix} 225.10 \\ 196.50 \end{bmatrix} \cdot in$ — Length of cask

$r_{VSC} := \frac{D_{VCC}}{2}$

$r_{VSC} = 66.00 \cdot in$ — Radius of cask

$\sigma_u := 4000 \cdot psi$ — Compressive strength of the VCC concrete, Ref. 15

Δ — Distance from ground into cask wall

$S(\Delta)$ — Width of contact area as a function of the depth D

δ_{max} — Maximum crush depth

ΔE — Potential energy loss due to cask tip-over

The energy of the impact is set equal to the energy absorbed by the crushed concrete:

$$\Delta E = \int_0^L \int_0^{\frac{x}{L} \cdot \delta_{max}} \sigma_u \cdot S(\Delta) \, d\Delta \, dx$$

The width of the contact area as a function of the depth is:

$$S(\Delta) = 2 \cdot \sqrt{r_{VSC}^2 - (r_{VSC} - \Delta)^2} = 2 \cdot \sqrt{2 \cdot r_{VSC} \cdot \Delta - \Delta^2}$$

which is approximately equal to

$$S(\Delta) = 2 \cdot \sqrt{2 \cdot r_{VSC} \cdot \Delta}$$

Substituting gives

$$\Delta E = \sigma_u \cdot \int_0^L \int_0^{\frac{x}{L}\cdot\delta_{max}} 2\cdot\sqrt{2\cdot r_{VSC}\cdot\Delta}\, d\Delta\, dx$$

Integrating gives

$$\Delta E = \sigma_u \cdot \int_0^L 2\cdot\sqrt{2\cdot r_{VSC}}\cdot\frac{2}{3}\cdot\left(\frac{x}{L}\cdot\delta_{max}\right)^{\frac{3}{2}} dx$$

$$\Delta E = \frac{4}{3}\cdot\sqrt{2\cdot r_{VSC}}\cdot\sigma_u\cdot\frac{1}{L^{\frac{3}{2}}}\cdot\delta_{max}^{\frac{3}{2}}\cdot\frac{2}{5}\cdot L^{\frac{5}{2}}$$

Simplifying

$$\Delta E = \frac{8}{15}\cdot L\cdot\sqrt{2\cdot r_{VSC}}\cdot\sigma_u\cdot\delta_{max}^{\frac{3}{2}}$$

Solving for δ_{max} gives

$$\delta_{max} := \overrightarrow{\left(\frac{\Delta E}{\sigma_u\cdot L\cdot\sqrt{2\cdot r_{VSC}}}\cdot\frac{15}{8}\right)^{\frac{2}{3}}}$$

$$\delta_{max} = \begin{bmatrix} 2.31 \\ 2.04 \end{bmatrix} \cdot in$$

This depth of crushed concrete was obtained using the very conservative assumption that the target surface is rigid and all the energy is absorbed by crushing the VCC concrete. In reality, the crushing strength of the storage pad or road asphalt is lower than the crushing strength of the cask concrete, and therefore, the impacted surface would be crushed instead of the VSC concrete.

Deceleration Resulting from the Postulated Tip-over

For this calculation the crushing assumption is reversed: the cask is assumed to be rigid, and the target absorbs the energy. As calculated above, the potential energy of impact is:

$$\Delta E = \begin{bmatrix} 1.93 \cdot 10^{7} \\ 1.41 \cdot 10^{7} \end{bmatrix} \circ in \cdot lbf$$

This energy is assumed to be absorbed by the target.

Find the equivalent height of the horizontal drop.

$$\Delta E = P_{VSC} \cdot g \cdot h_{eq}$$

$$h_{eq} := \overrightarrow{\frac{\Delta E}{P_{VSC} \cdot g}} \qquad h_{eq} = \begin{bmatrix} 67.2 \\ 55.6 \end{bmatrix} \circ in$$

The methodology presented in EPRI report NP-4830, "The Effects of Target Hardness on the Structural Design of Concrete Storage Pads for Spent-Fuel Casks" [Ref. 3] was used for these calculations.

The following conservative assumptions were made about a typical ISFSI storage pad:

Slab Thickness:	$d := 36 \cdot in$ #11 @ 12 top and bottom two-way, under 2 inch cover	
Reinforcement	$E_{steel} := 28 \cdot 10^{6}$ $S_y := 60000 \cdot psi$	
Concrete Pad	$f_c := 3000 \cdot psi$ $v_c := .17$	
	$E_c := 57000 \cdot psi \cdot \sqrt{\frac{f_c}{psi}}$	ACI 349, Reference 4, Paragraph 8.5.1
	$E_c = 3.12 \cdot 10^{6} \circ psi$	
Soil	$E_s := 60000 \cdot psi$ $v_s := .45$	

These assumptions are conservative. (It is noted that a typical pad is only 2' thick and has #6@ 18" reinforcement; thus, the typical pad is not as rigid as assumed above and would produce lower acceleration values.)

Find the slab moment capacity (Reference 9, Eq. 12.3.5):

$A_{11} := 1.56 \cdot in^2$ — No. 11 rebar cross section area, Ref. 9, Table 12.3.1

$a := \overrightarrow{\frac{A_{11} \cdot S_y}{0.85 \cdot L \cdot f_c}}$ — Compression block depth

$$a = \begin{bmatrix} 0.1631 \\ 0.1868 \end{bmatrix} \circ in$$

$\phi := 0.9$ — Strength reduction factor for bending from Ref. 9, p. 12-49

$M_u := \overrightarrow{\left[\phi \cdot A_{11} \cdot S_y \cdot \left(d - \frac{a}{2}\right)\right]}$ — Moment capacity

$$M_u = \begin{bmatrix} 3.03 \cdot 10^6 \\ 3.02 \cdot 10^6 \end{bmatrix} \circ in \cdot lbf$$

The slab moment of inertia is

$$I_c := \overrightarrow{\frac{L \cdot d^3}{12}}$$

$$I_c = \begin{bmatrix} 875189 \\ 763992 \end{bmatrix} \circ in^4$$

The parameter β is (Ref. 3):

$$\beta := \overrightarrow{\left(\frac{E_s}{4 \cdot E_c \cdot I_c}\right)^{\frac{1}{4}}} \qquad \beta = \begin{bmatrix} 0.00861 \\ 0.00891 \end{bmatrix} \circ \frac{1}{in}$$

The recommended value for D from Reference 3 is

$D := 10 \cdot in$

The area is

$$A := \overrightarrow{(D \cdot L)}$$

$$A = \begin{bmatrix} 2251 \\ 1965 \end{bmatrix} \cdot in^2$$

Now the target hardness number can be calculated (Ref. 3):

$$S := \overrightarrow{\frac{2 \cdot A \cdot E_s \cdot M_u \cdot f_c}{(P_{VSC} \cdot g)^3 \cdot \beta}}$$

$$S = \begin{bmatrix} 11925 \\ 14890 \end{bmatrix}$$

Conservatively using the curve for 70" drop from Ref. 3, p. 2-40, the bounding deceleration using the above target hardness numbers is

$$a := 22 \cdot g$$

3.2 FIVE-FOOT DROP ANALYSIS

The assumptions and notations used for this analysis are the same as for the tip-over calculations. The potential energy from a 5 foot drop impact is

$$h := 60\ in$$

$$\Delta E := \overrightarrow{(P_{VSC} \cdot g \cdot h)}$$

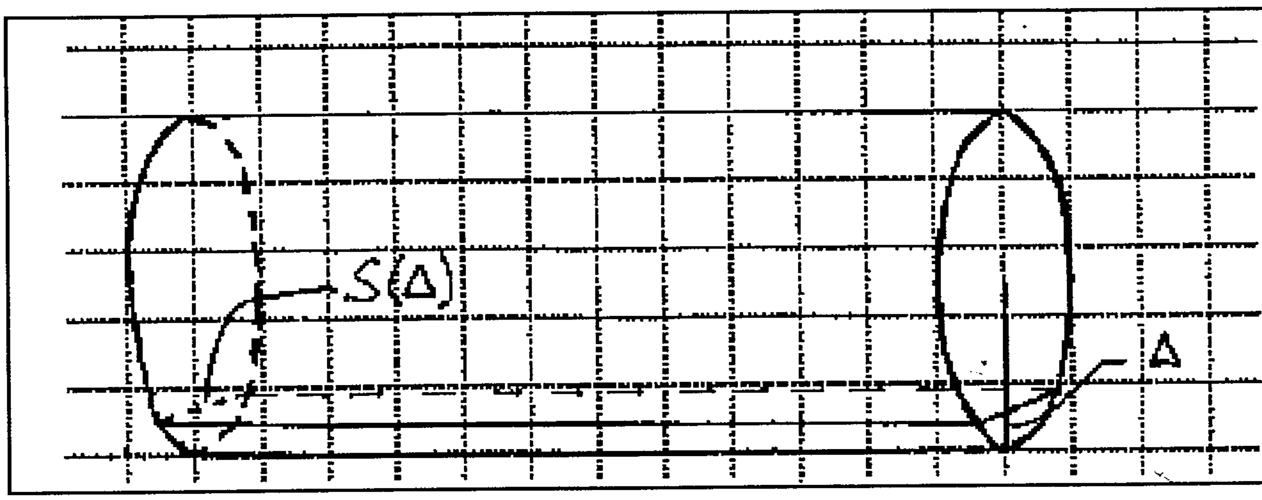
$$\Delta E = \begin{bmatrix} 1.73 \cdot 10^7 \\ 1.52 \cdot 10^7 \end{bmatrix} \cdot in \cdot lbf$$

3.2.1 Horizontal Drop

VSC Concrete Crush Depth

Again, it is conservatively assumed that all energy is absorbed by crushing of the cask concrete.

$$\Delta E = \int_0^L \int_0^{\frac{x}{L}\cdot\delta_{max2}} S(\Delta)\, d\Delta\, dx$$



$$S(\Delta) = 2\cdot\sqrt{r_{VSC}^{2} - \left(r_{VSC} - \Delta\right)^{2}} = 2\cdot\sqrt{2\cdot r_{VSC}\cdot\Delta - \Delta^{2}}$$

which is approximately equal to

$$S(\Delta) = 2\cdot\sqrt{2\cdot r_{VSC}\cdot\Delta}$$

For the horizontal drop, all points have the same velocity, so the crush depth is assumed to be constant along the cask length. Therefore, D is not a function of x.

Thus,

$$\Delta E = L\cdot\sigma_u\cdot 2\cdot\int_0^{\delta_{max2}} \sqrt{2\cdot r_{VSC}\cdot\Delta}\, d\Delta$$

$$\Delta E = 2\cdot L\cdot\sigma_u\cdot\sqrt{2\cdot r_{VSC}}\cdot\frac{2}{3}\cdot\delta_{max2}^{\frac{3}{2}}$$

Solving for δ_{max} gives

$$\delta_{max2} := \overrightarrow{\left(\frac{3}{4} \cdot \frac{\Delta E}{\sqrt{2 \cdot r_{VSC} \cdot L \cdot \sigma_u}}\right)^{\frac{2}{3}}}$$

$$\delta_{max2} = \begin{bmatrix} 1.16 \\ 1.17 \end{bmatrix} \cdot in$$

This depth of crushed concrete was obtained using the very conservative assumption that the target surface is rigid and all the energy is absorbed by crushing the VCC concrete. In reality, the crushing strength of the storage pad or road asphalt is lower than the crushing strength of the cask concrete, and therefore, the impacted surface would be crushed instead of the VSC concrete.

Deceleration

The target hardness number was calculated above for the tipover case. Using a hardness number of

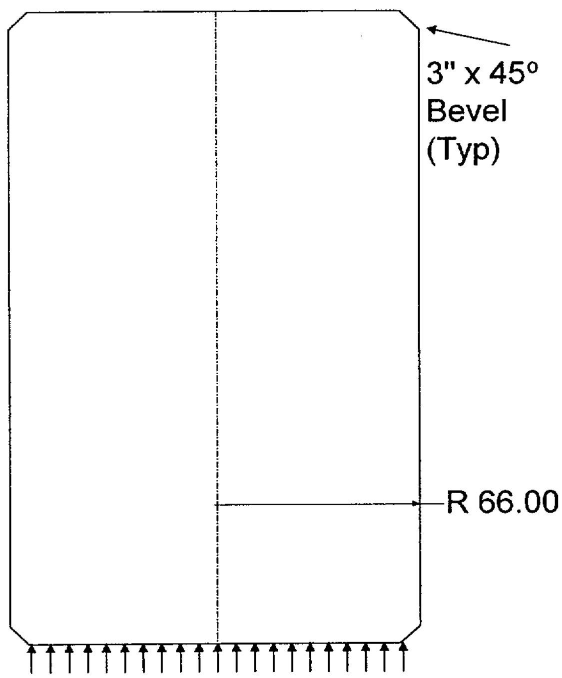
$$S = \begin{bmatrix} 11925 \\ 14890 \end{bmatrix}$$

and using the curve for a 60" drop height from Ref. 3, the bounding deceleration using the above target hardness numbers is:

$$a_h := 22 \cdot g$$

3.2.2 Vertical Drop

VSC Concrete Crush Depth



Again,

$$\Delta E = \sigma_u \cdot Area \cdot \delta_{max3} = \sigma_u \cdot \pi \cdot (r_{VSC} - w_{bevel})^2 \cdot \delta_{max3}$$

Solving for δ_{max3} gives

$$\delta_{max3} := \frac{\Delta E}{\sigma_u \cdot \pi \cdot (r_{VSC} - w_{bevel})^2}$$

$$\delta_{max3} = \begin{bmatrix} 0.346 \\ 0.304 \end{bmatrix} \cdot in$$

Using the EPRI methodology (Ref. 3)

$$S = \frac{2 \cdot r \cdot A \cdot k \cdot M_u \cdot f_c}{(P_{VSC} \cdot g)^3 \cdot (1 - e^{-\beta \cdot r} \cdot cos(\beta \cdot r))}$$

where

$r := r_{VSC} - w_{bevel}$ — Radius of the footprint accounting for the corner bevel at the bottom of the cask, Ref. 15

$r = 63.00 \cdot in$

$A := \pi \cdot r^2$ — Cask footprint area

$A = 12469 \cdot in^2$

$M_u = \begin{bmatrix} 3.03 \cdot 10^6 \\ 3.02 \cdot 10^6 \end{bmatrix} \cdot in \cdot lbf$ — Target moment capacity calculated above

$k := \frac{\pi \cdot E_s}{1 - \nu_s^2}$ — Foundation modulus, Ref. 3

$k = 236358 \cdot psi$

$D_c := \frac{E_c \cdot d^3}{12 \cdot \left(1 - \nu_c^2\right)}$ — Slab rigidity, Ref. 3

$D_c = 1.25 \cdot 10^{10} \cdot in \cdot lbf$

$\beta := \left(\frac{E_s}{4 \cdot in \cdot D_c}\right)^{\frac{1}{4}}$

$\beta = 0.0331 \cdot \frac{1}{in}$

$f_c = 3000 \cdot psi$ — Assumption about storage pad concrete strength

Then,

$$S1 := \overrightarrow{\frac{2 \cdot r \cdot A \cdot k \cdot M_u \cdot f_c}{\left(P_{VSC} \cdot g\right)^3 \cdot \left(1 - e^{-\beta \cdot r} \cdot \cos(\beta \cdot r)\right)}} \qquad S1 = \begin{bmatrix} 132978 \\ 196787 \end{bmatrix}$$

Using the curve for a 60" drop from Ref. 3, the deceleration using the above target hardness values is:

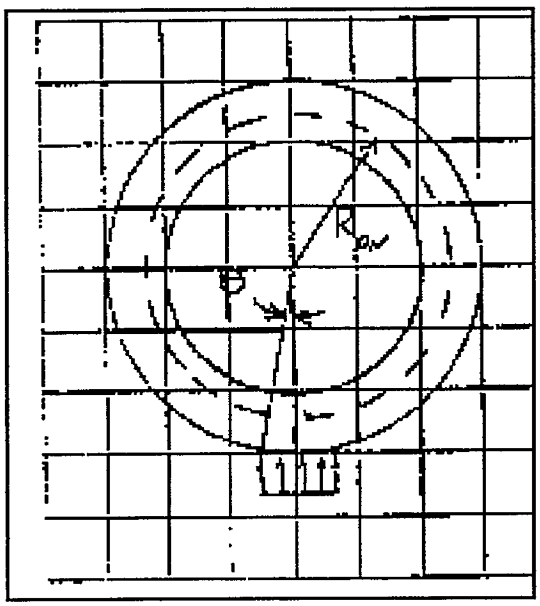
$a_v := 60 \cdot g$

3.3 Concrete Cask Evaluation

Shear and moment in the cask section for the horizontal drop are calculated below. It is assumed that the horizontal drop is the drop orientation that has the most potential to damage the cask.

The methodology is based on allowable ductility ratios (ACI-349 [Ref. 4], Appendix C), dynamic response curves from Biggs' "Structural Dynamics" [Ref. 6] and formulas from Timoshenko [Ref. 7].

The model is presented below. Since the concept is based on crushing of concrete, the maximum force will occur at the maximum crush depth.



The cask is treated as a shell. The average radius is (Ref. 15)

$$R_{av} := \frac{66 + 37}{2} \cdot in$$

$$R_{av} = 51.50 \cdot in$$

Angle θ can be calculated using results from above.

$$\delta_{max2} = \begin{bmatrix} 1.162 \\ 1.166 \end{bmatrix} \cdot in$$

$$\theta = \frac{S(\theta)}{2 \cdot r_{VSC}}$$

$$\theta := \frac{\overrightarrow{\sqrt{2 \cdot r_{VSC} \cdot \delta_{max2}}}}{r_{VSC}}$$

$$\theta = \begin{bmatrix} 0.188 \\ 0.188 \end{bmatrix}$$

The deceleration was calculated above to be $a_h = 22 \cdot g$. Impact time can be found using conservation of momentum.

$$mass \cdot velocity = force \cdot time$$

$$P_{VCC} \cdot \sqrt{2 \cdot g \cdot h} = a_h \cdot P_{VCC} \cdot t_i$$

Solving for the time gives

$$t_i := \frac{1}{a_h} \cdot \sqrt{2 \cdot g \cdot h}$$

$$t_i = 0.0253 \cdot sec$$

The natural frequency of the shell is calculated using a formula from Timoshenko "Vibration Problems in Engineering," Equation 202 (Ref. 7).

$$f = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{E_{VSC} \cdot I \cdot i^2 \cdot (1 - i^2)^2}{\rho_{VSC} \cdot A \cdot R_{av}^{\,4} \cdot (1 + i^2)}}$$

where

$i := 2$ — Fundamental mode of flexural vibration

I is the section moment of inertia (calculation is based on a one foot length of the cask). Use of the gross section moment of inertia is conservative because it produces a higher natural frequency.

$b := 1 \cdot ft$ — Cask basis length of one foot

$h := (66 - 37) \cdot in$ — Cask concrete wall thickness, Ref. 15

$h = 29.00 \cdot in$

$I := \frac{b \cdot h^3}{12}$ — $I = 24389 \cdot in^4$

The section area is

$$A := h \cdot b$$

$$A = 348.00 \cdot in^2$$

The density of the VCC concrete from Reference 15 is

$$\rho_{VSC} := 144 \cdot \frac{lb}{ft^3}$$

The modulus of elasticity for the VSC concrete is calculated from Reference 4, Paragraph 8.5.1.

$$E_{VSC} := 33 \cdot psi \cdot \left[\frac{\rho_{VSC}}{\frac{lb}{ft^3}} \right]^{1.5} \cdot \sqrt{\frac{\sigma_u}{psi}}$$

$$E_{VSC} = 3.61 \cdot 10^6 \cdot psi$$

The natural frequency and period are

$$f := \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{E_{VSC} \cdot I \cdot i^2 \cdot \left(1 - i^2\right)^2}{\rho_{VSC} \cdot A \cdot R_{av}^{\ 4} \cdot \left(1 + i^2\right)}}$$

$$f = 174 \cdot Hz$$

$$T := \frac{1}{f}$$

$$T = 0.00574 \text{ sec}$$

The ratio of the impulse time to the natural period is

$$\frac{t_i}{T} = 4.42$$

Assume that the impulse load is a triangular load impulse. Using the dynamic response curve from Reference 6, Figure 2.8, the dynamic load factor is about 1.0, i.e., no dynamic amplification of the load is required.

Shear and moment in the cask wall due to the drop are calculated in Appendix A. The maximu shear and moment per foot of cask length are:

$V_{max} := 6177 \cdot \frac{lbf}{in} \cdot \frac{a_h}{20\,g}$ $\qquad V_{max} = 81.5 \frac{kip}{ft}$

$M_{max} := 99098 \cdot \frac{in \cdot lbf}{in} \cdot \frac{a_h}{20\,g}$ $\qquad M_{max} = 1308 \frac{in \cdot kip}{ft}$

The shear and moment capacities are calculated below. The shear capacity is based on the strength of the liner, and the moment capacity is based on the strength of the reinforced concrete.

Shear Capacity of Liner:

$s_y := 32.4 \cdot ksi$ — Liner yield strength at bounding temperature of 250°F (Reference 11); liner material is A-36 steel from Reference 15; yield strength from Reference 10 (Note: A-36 is not in the 1986 Code or 1988 Addenda. The value is from the 1998 Edition, Table Y-1.)

$t := 1.75 \cdot in$ — Liner thickness from Reference 15

$F := \frac{s_y}{2} \cdot t$

$F = 340 \frac{kip}{ft}$ — per foot of cask length

The shear capacity $F = 340 \frac{kip}{ft}$ is greater than the applied shear $V_{max} = 81.5 \frac{kip}{ft}$

Bending Capacity of Liner:

The strength of the concrete and reinforcing steel are increased with a Dynamic Increase Factor (DIF) from Appendix C.2 of Reference 4. The reinforcing steel yield strength for A-615, Grade 60 (Reference 15) is $s_y = 60 \, ksi$ from References 16.

$DIF_{steel} := 1.1$

$DIF_{conc\_bend} := 1.25$

$A_s := 2 \cdot (.44 \cdot in^2)$ — Area of reinforcing steel; Two No. 6 bars in one foot per Ref. 15; rebar area from Ref. 9, Table 12.3.1

$$a := \frac{A_s \cdot DIF_{steel} \cdot S_y}{.85 \cdot DIF_{conc\_bend} \cdot \sigma_u \cdot b}$$

$$a = 1.139 \cdot in$$

The moment capacity of the VSC reinforced concrete is

$$M_u := \left[\phi \cdot A_s \cdot DIF_{steel} \cdot S_y \cdot \left(h - \frac{a}{2} \right) \right] \cdot \frac{1}{ft}$$

$$M_u = 1486 \cdot \frac{in \cdot kip}{ft}$$ per foot of cask length

The moment capacity $M_u = 1486 \cdot \frac{in \cdot kip}{ft}$ is greater than the applied moment $M_{max} = 1308 \cdot \frac{in \cdot kip}{ft}$.

4.0 CONCLUSION

The postulated tip-over and 5 foot drop will not cause significant damage to the VCC concrete.

The results of this calculation are used for the structural design of the MSB components. The calculated decelerations for the horizontal drop and vertical drop are conservatively increased by the maximum dynamic amplification factor of 2 (see the dynamic load factors for different shaped impulse loadings in Ref. 6, Figures 2.6-2.9) and applied statically as follows:

$$a_{h\_dif} := 2 \cdot a_h$$

$$a_{h\_dif} = 44 \cdot g$$

$$a_{v\_dif} := 2 \cdot a_v$$

$$a_{v\_dif} = 120 \cdot g$$

5.0 REFERENCES

1. Deleted
2. BNFL Calculation No. VSC02.6.2.5.01, "Weight and Center of Gravity," Revision 1.
3. EPRI Report NP-4830, The Effect of Target Hardness on Structural Design of Storage Pads for Spent Fuel Casks, 1986.
4. ACI 349, Code Requirements for Nuclear Safety-related Concrete Structures, 1980.
5. Deleted.
6. Biggs, "Introduction to Structural Dynamics," McGraw-Hill Book Company, 1964.
7. Timoshenko, "Vibration Problems in Engineering," Van Nostrand Company, 2nd Edition.
8. Deleted.
9. Marks' Handbook for Mechanical Engineers, McGraw-Hill Inc., 9th Edition.
10. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, Table I-2.1, 1986 Edition with the 1988 Addenda.
11. BNFL Calculation No. WEP-109-003.4, "VSC-24 Thermal Hydraulic Analysis," Revision 2.
12. Deleted.
13. Deleted.
14. Deleted.
15. BNFL Calculation VSC02.6.2.5.03, Revision 0, "VSC-24 Design Parameters."
16. ASTM Standard Specification, A-615/A-615M-96A.

APPENDIX A

FINITE ELEMENT CALCULATION OF SHEAR LOAD AND MOMENT IN CASK WALL

A.1.0 PURPOSE

The purpose of this attachment is to document a finite element analysis of the Ventilated Concrete Cask (VCC). The analysis provides the bending moment and shear load in the wall of the cask due to loads applied to the cask when it is dropped on its side from a 5 foot elevation.

A.2.0 SUMMARY OF RESULTS

The maximum moment and shear loads in the concrete wall of the cask are provided below in Table A.2-1. Note that the results are provided on a per inch of cask length basis.

Table A.2-1
Calculated Loads

Result	Maximum Value
Bending	99,098 in-lbs/in
Shear Load	6,177 lbs/in

A.3.0 FINITE ELEMENT MODEL

A.3.1 Geometry

The cask is modeled using a three-dimensional finite element model. The model is a half model cut along a plane of symmetry parallel to the axis of the cask. The model includes the concrete cask and the carbon steel liner. Figure A.3-1 shows a dimensioned drawing of the cask and Figure A.3-2 shows the finite element model. The model is meshed with ANSYS SOLID45 elements (8-node bricks with 3 degrees of freedom per node).

The steel liner and concrete cask are modeled as though they were glued together (tensile loads are allowed to be carried across the interface). In reality, a small gap may exist between the concrete and the liner. This assumption will not have a significant effect on the results.

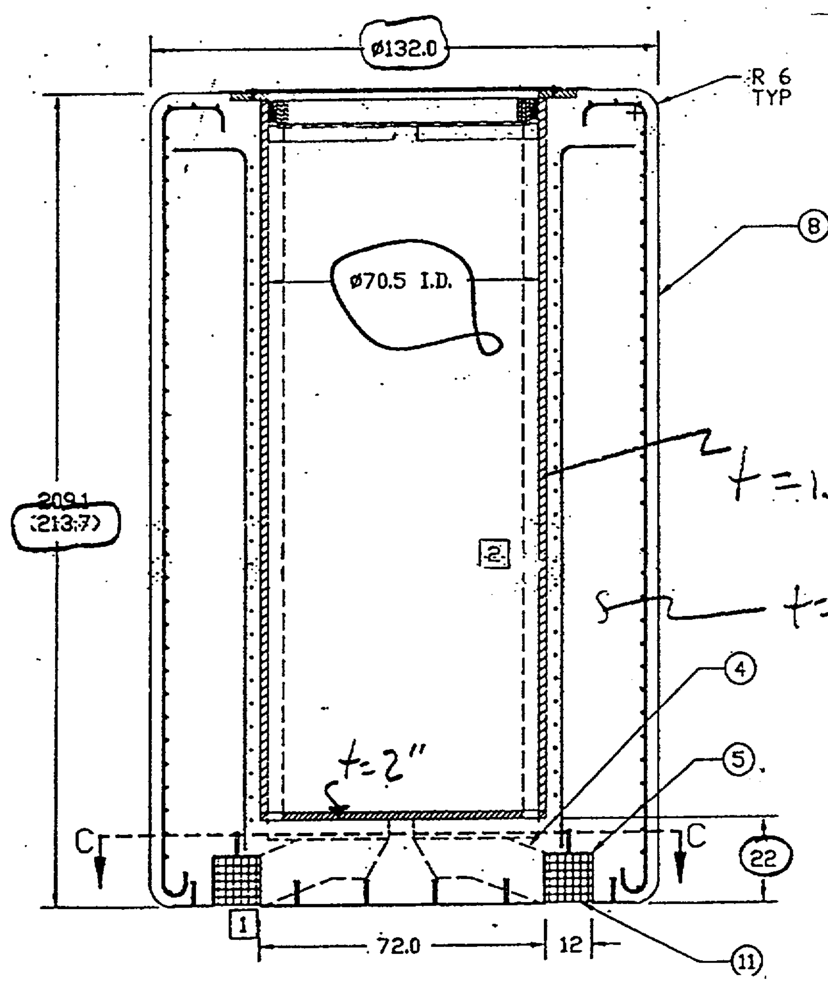


Figure A.3-1. Cask Dimensions
(Reference A.6)

Notes:

1. The cask length is long enough that local effects from the open end are not effected by the base. Therefore, this analysis is applicable for casks with a height from 196 to 226 inches.
2. Reference A.6 shows a 3"x 45° bevel on each cask corner. A 6" radius on each cask corner as shown in the above figure is used in the analysis. This difference will have little effect on analysis results.

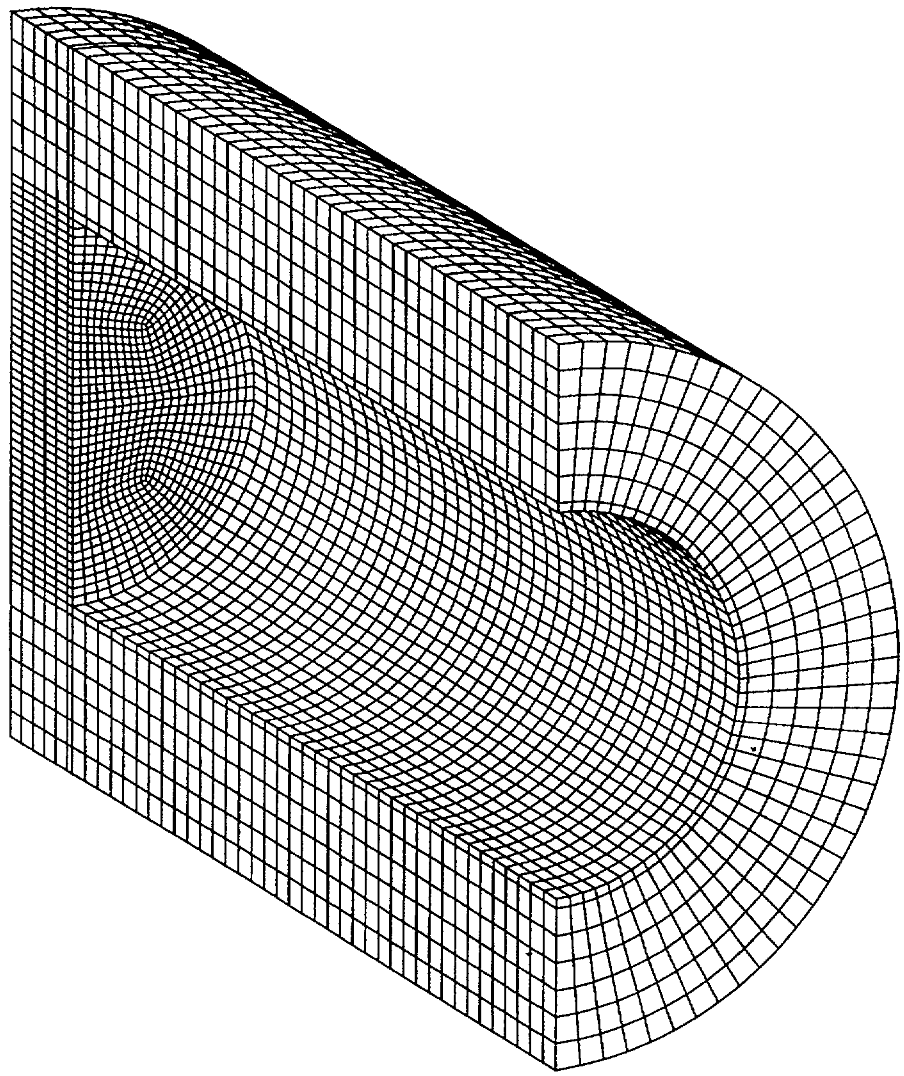


Figure A.3-2. Finite Element Model

A.3.2 Material Properties

Table A.3-1 shows the material properties used in the model. The cask is made of concrete and the liner is A36 carbon steel (Reference A.6).

Table A.3-1
Material Properties

Material	Elastic Modulus (psi)	Density (lb/in^3)	Poisson's Ratio
A36 Carbon Steel	28.6×10^6 (Reference A.3 at 250 °F)	0.29 (assumed)	0.3 (assumed)
Concrete	3.61×10^6 (see p. 19 of main calculation)	0.083 (see p. 19 of main calculation)	0.17 (assumed)

A.3.3 Boundary and Loading Conditions

The model is loaded with a 20g acceleration. The motion of the cask is restrained along the edge of the cask where it would contact the ground. The region of restraint extends the full length of the cask. The width of the modeled region is calculated based on the ½ angle over which the contact occurs (as calculated in the main calculation):

$$\text{Width} = \theta R = (0.189)(66) = 12.5 \text{ in} \qquad \text{(assuming angle is small)}$$

Where R = cask outside radius = 66 in (Reference A.6)
θ = ½ angle = 0.189 rad (See main calculation)

Nodes on the plane of symmetry are restrained in the direction normal to the plane of symmetry and a single node on the plane of symmetry is restrained in the cask's axial direction for solution purposes. Figure A.3-3 shows the loading and boundary conditions.

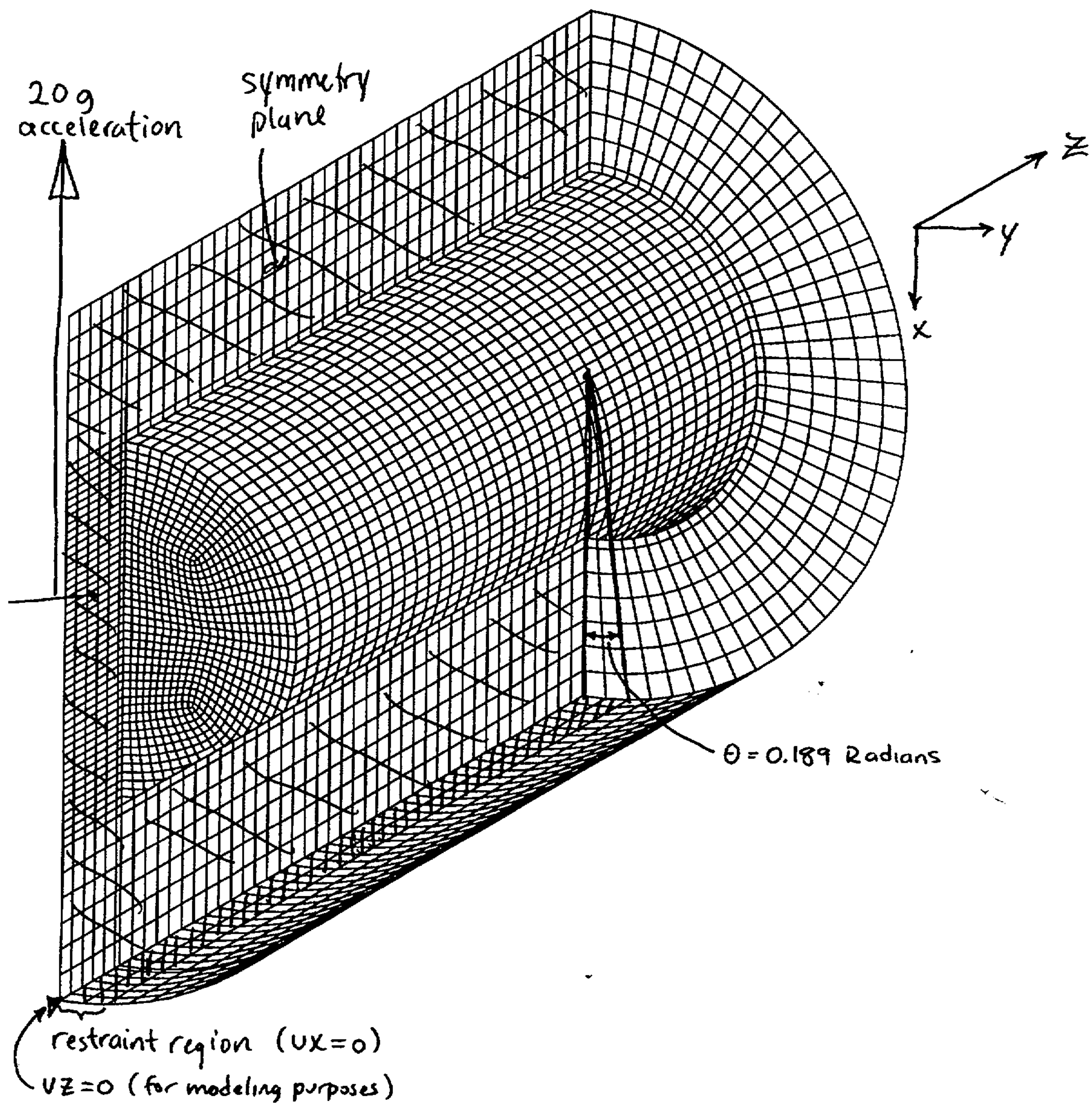


Figure A.3-3. Loading and Boundary Conditions

A.4.0 ANALYSIS RESULTS

The finite element model was analyzed using the ANSYS Computer Program version 5.5. This program is on the BFNL Fuel Solutions Computer Software List (see Reference A.5).

Filename	File Date	Computer Code	Category	Version	Platform	Machine
DROPL.OUT	1/5/00, 12:22	ANSYS	2	5.5	NT	ANSYS #4

The analysis output file is documented in Reference A.4 and portions of the output are provided as Attachment A.1 to this appendix. Bending moment and shear load are calculated using the linearized membrane plus bending stress and the shear stress in the concrete wall. Linearized stress is calculated using the ANSYS PRSECT command, which provides an analysis of the stresses along a defined path through the component thickness. Results are obtained at paths located along the edge of the region of restraint near the open end of the cask. Maximum stresses occur near the open end. Figure A.4-1 provides the displaced shape of the cask with path locations shown on the figure. From Attachment A.1, the maximum stresses are:

Membrane plus Bending = 707 psi
Shear = 213 psi

Bending moment and shear forces are calculated based on the stresses calculated using the finite element model. The moment and load are calculated on a per inch of cask length basis. For bending in the wall of the cask:

$$\sigma = \frac{6M}{t^2}, \text{ thus, } M = \frac{1}{6}\sigma \cdot t^2 = \frac{1}{6}(707)(29)^2 = 99{,}098 \text{ in-lbs/in}$$

Where: M = moment per unit length of cask,
t = wall thickness = 29 in (Reference A.6)
σ = membrane plus bending stress = 707 psi

The shear load in the wall is:

$$\tau = \frac{V}{t}, \text{ thus, } V = \tau \cdot P = (29)(213) = 6{,}177 \text{ lbs / in}$$

Where: V = shear load per unit length of cask
τ = shear stress = 213 psi

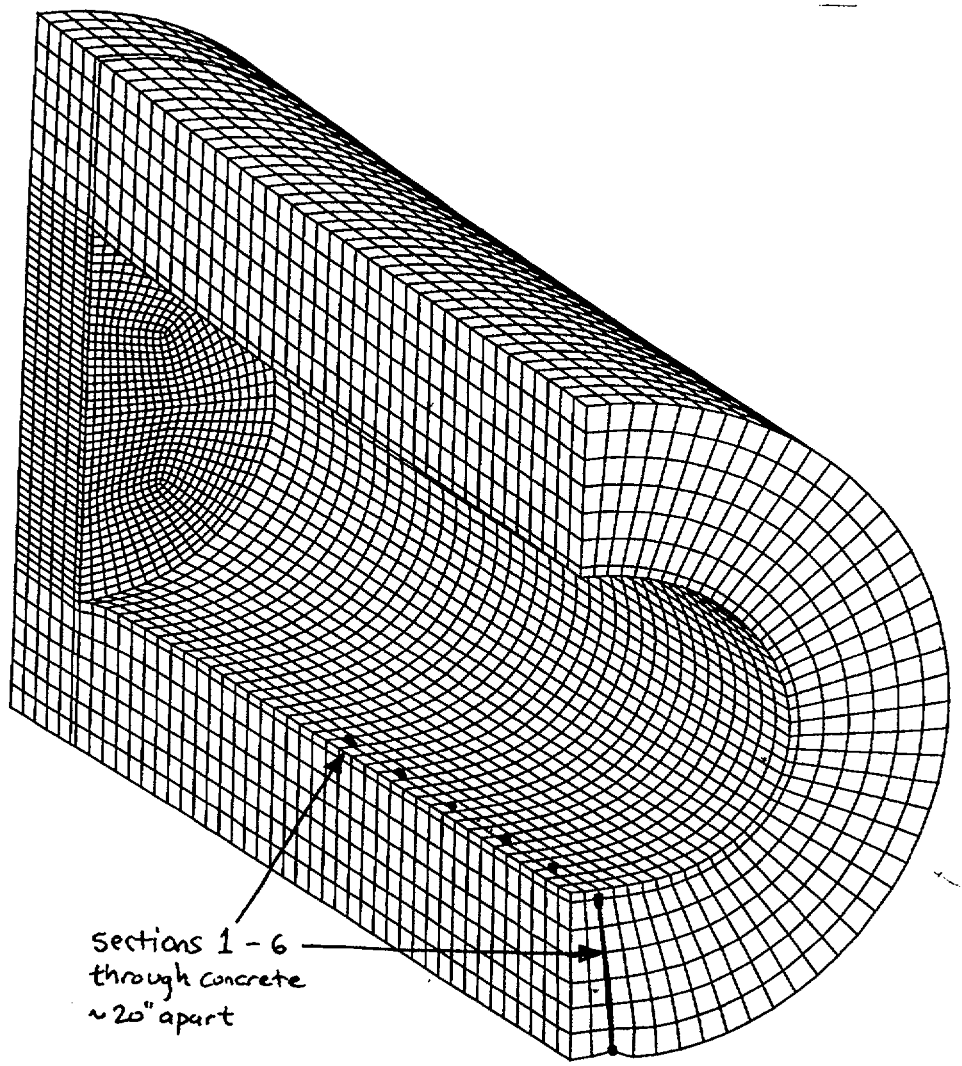


Figure A.4-1. Displaced Shape Plot

A.5.0 REFERENCES

A.1 Deleted.

A.2 Deleted.

A.3 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda.

A.4 ANSYS Output File, "DROPL.OUT", 1/5/00, 12:22.

A.5 BNFL Fuel Solutions Computer Software Listing—ANSYS Mechanical Version 5.5 (PC), File Number: Soft.001.001, Revision 0.

A.6 BNFL Calculation VSC02.6.2.5.03, Revision 0, "VSC-24 Design Parameters."

ATTACHMENT A.1

Selected Analysis Output

```
*------------------------------------------------------------------*
|                                                                  |
|   W E L C O M E   T O   T H E   A N S Y S   P R O G R A M      |
|                                                                  |
*------------------------------------------------------------------*


***************************************************************
*                      ANSYS 5.5 NOTICES                      *
***************************************************************
*                                                             *
* Copyright 1998 SAS IP, Inc.  All rights reserved.           *
* Unpublished---rights reserved under the Copyright Laws of   *
* the United States.                                          *
*                                                             *
*                                                             *
* U.S. GOVERNMENT RIGHTS                                      *
*                                                             *
* Use, duplication, or disclosure by the U.S. Government is   *
* subject to restrictions set forth in the ANSYS, Inc.        *
* license agreement and as provided in DFARS 227.7202-1(a)    *
* and 227.7202-3(a)(1995), DFARS 252.227-7013(c)(1)(ii) (OCT  *
* 1988), FAR 12.212(a)(1995), FAR 52.227-19, or FAR52.227-14  *
* (ALT III), as applicable.  ANSYS, Inc.                      *
*                                                             *
* THIS SOFTWARE CONTAINS CONFIDENTIAL INFORMATION AND TRADE   *
* SECRETS OF SAS IP, INC.  USE, DISCLOSURE, OR REPRODUCTION   *
* IS PROHIBITED WITHOUT THE PRIOR EXPRESS WRITTEN PERMISSION  *
* OF SAS IP, INC.                                             *
***************************************************************


***************************************************************
* The Program also contains the following licensed software:  *
***************************************************************
* PCGLSS: Linear Equations Solver                             *
*                                                             *
* (C) Copyright 1992-1995 Computational Applications and      *
*                              System Integration Inc.        *
*  All Rights Reserved.                                       *
*                                                             *
* CA&SI, 2004 S. Wright Street, Urbana, IL 61821              *
*  Ph         (217)244-7875                                   *
```

```
*  Fax          (217)244-7874                                  *
*                                                              *
* CA&SI DOES NOT GUARANTEE THE CORRECTNESS OR USEFULNESS OF    *
* THE RESULTS OBTAINED USING PCGLSS. CA&SI IS NOT LIABLE FOR   *
* ANY CONCLUSIONS OR ACTIONS BASED ON THE RESULTS. IT IS THE   *
* RESPONSIBILITY OF THE USER TO CONFIRM THE ACCURACY AND       *
* USEFULNESS OF THE RESULTS.                                   *
****************************************************************
* Elan License Manager: License Management portion             *
*                                                              *
* (C) Copyright 1989-1996 Elan Computer Group, Inc.            *
*     All Rights Reserved.                                     *
*     "Elan License Manager" is a trademark of                 *
*     Elan Computer Group, Inc.                                *
****************************************************************

                    Completing ANSYS Load Process.


ANSYS/Mechanical U


         *****  ANSYS COMMAND LINE ARGUMENTS  *****
 INITIAL JOBNAME              = dropl
 MEMORY REQUESTED (MB)        = 200
 BATCH MODE REQUESTED         = LIST
 START-UP FILE MODE           = READ
 STOP FILE MODE               = READ
 LANGUAGE                     = Default
 DATABASE SIZE REQUESTED (MB) = 64

*** NOTE ***                            CP=       0.030   TIME= 11:25:56
There are no parameters defined.

00107763          VERSION=INTEL NT       RELEASE= 5.5.3   UP19990405
CURRENT JOBNAME=dropl  11:25:57  JAN 05, 2000 CP=      0.030

    1  /batch,list
    2  /filnam,dropl
    3  /prep7
    4
    5  liner=1
    6
    7  r1=70.5/2
    8  r2=r1+1.75
    9  r3=132/2
   10
```

```
z1=22
z2=z1+2
z3=213.7
cylind,0,r3,0,z1,0,180
*if,liner,eq,1,then
  cylind,0,r3,z1,z2,0,180
  nummrg,kp
  vsel,none
  asel,none
  lsel,none
  ksel,none
*endif
cylind,r2,r3,0,z3,0,180
*if,liner,eq,1,then
  cylind,r1,r2,0,z3,0,180
  nummrg,kp
*endif
allsel
vovlap,all
wprota,,,90
vsbw,all
et,1,solid45
type,1
eshape,2
!csys,1
!lsel,s,loc,y,1,89
!lsel,a,loc,y,91,179
!lsel,a,loc,x,0,r1-1
!lesize,all,,,10
!lsel,s,loc,x,r2+1,r3-1
!lesize,all,,,6
esize,5
csys,1
lsel,s,loc,x,r3
lsel,a,loc,z,0
csys,0
asll,s,1
vsla
cm,concrete,volu
vatt,1
*if,liner,eq,1,then
  vsel,inve
  cm,steel,volu
  vatt,2
```

```
*endif
save,solid,db
allsel
vmesh,all
mp,ex,1,3.61e6
mp,nuxy,1,.17
mp,dens,1,144/1728
mp,ex,2,28.6e6
mp,nuxy,2,.3
mp,dens,2,.29
csys,1
nsel,s,loc,x,r3
nsel,r,loc,y,-1,90
csys,0
nsel,r,loc,y,-1,.189*r3
d,all,ux,0
d,node(r3,0,0),uz,0
nsel,s,loc,y,0
d,all,uy,0
allsel
acel,-20,0,0
fini
/solu
solve
save
fini
/post1
file,,rst
set,1
csys,1
dsys,1
rsys,1
cmsel,s,concrete
eslv
nsle
*do,ii,z3-100,z3,20
  lpath,node(r2,10,ii),node(r3,10,ii)
  prsect
*enddo
```

```
RUN SETUP PROCEDURE FROM FILE= C:\ansys55\docu\start55.ans
```

```
/INPUT FILE= C:\ansys55\docu\start55.ans  LINE=       0

CURRENT JOBNAME REDEFINED AS dropl
1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3   *****
ANSYS/Mechanical U
00107763          VERSION=INTEL NT      11:25:57  JAN 05, 2000 CP=
0.080



         ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

PARAMETER LINER    =     1.000000

PARAMETER R1       =     35.25000

PARAMETER R2       =     37.00000

PARAMETER R3       =     66.00000

PARAMETER Z1       =     22.00000

PARAMETER Z2       =     24.00000

PARAMETER Z3       =     213.7000

CREATE A CYLINDRICAL VOLUME WITH
INNER RADIUS          =      0.000000000
OUTER RADIUS          =      66.00000000
STARTING THETA ANGLE =      0.000000000
ENDING   THETA ANGLE =      180.0000000
END Z-DISTANCES FROM        0.000000000     TO      22.00000000

     OUTPUT VOLUME =     1

*IF  liner                            ( =    1.00000      )  EQ
     1                                ( =    1.00000      )  THEN

CREATE A CYLINDRICAL VOLUME WITH
INNER RADIUS          =      0.000000000
OUTER RADIUS          =      66.00000000
STARTING THETA ANGLE =      0.000000000
ENDING   THETA ANGLE =      180.0000000
```

```
END Z-DISTANCES FROM        22.00000000     TO      24.00000000

     OUTPUT VOLUME =      2

MERGE COINCIDENT KEYPOINTS WITHIN TOLERANCE OF  0.10000E-03
KEYPOINT       4 USED FOR KEYPOINT(S)        8
KEYPOINT       5 USED FOR KEYPOINT(S)        9
KEYPOINT       6 USED FOR KEYPOINT(S)        7
LINE       4 USED FOR LINE(S)      12
LINE       5 USED FOR LINE(S)      11
LINE       6 USED FOR LINE(S)      10
AREA       2 USED FOR AREA(S)       6

NONE SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE        1 TO         2 STEP         1

     0 VOLUMES (OF       2  DEFINED) SELECTED BY VSEL  COMMAND.

NONE SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE        1 TO        10 STEP         1

     0 AREAS (OF       9  DEFINED) SELECTED BY ASEL  COMMAND.

NONE SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE        1 TO        18 STEP         1

     0 LINES (OF      15  DEFINED) SELECTED BY LSEL  COMMAND.

NONE SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE        1 TO        12 STEP         1

     0 KEYPOINTS (OF      9  DEFINED) SELECTED BY KSEL  COMMAND.

*ENDIF

CREATE A CYLINDRICAL VOLUME WITH
INNER RADIUS            =      37.00000000
OUTER RADIUS            =      66.00000000
STARTING THETA ANGLE =      0.000000000
ENDING   THETA ANGLE =      180.0000000
END Z-DISTANCES FROM        0.000000000     TO      213.7000000

     OUTPUT VOLUME =      3

*IF  liner                                    ( =    1.00000       )  EQ
     1                                        ( =    1.00000       )  THEN
```

```
CREATE A CYLINDRICAL VOLUME WITH
INNER RADIUS          =     35.25000000
OUTER RADIUS          =     37.00000000
STARTING THETA ANGLE =     0.000000000
ENDING   THETA ANGLE =     180.0000000
END Z-DISTANCES FROM        0.000000000     TO      213.7000000

     OUTPUT VOLUME =      4

MERGE COINCIDENT KEYPOINTS WITHIN TOLERANCE OF  0.10000E-03
KEYPOINT       9 USED FOR KEYPOINT(S)      21
KEYPOINT       8 USED FOR KEYPOINT(S)      18
KEYPOINT      16 USED FOR KEYPOINT(S)      23
KEYPOINT      17 USED FOR KEYPOINT(S)      22
LINE     11 USED FOR LINE(S)      31
LINE     22 USED FOR LINE(S)      32
LINE     27 USED FOR LINE(S)      37
LINE     26 USED FOR LINE(S)      36
AREA     13 USED FOR AREA(S)      18

*ENDIF

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT    FOR ITEM=VOLU COMPONENT=
 IN RANGE        1 TO         4 STEP        1

    4  VOLUMES (OF      4  DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT    FOR ITEM=AREA COMPONENT=
 IN RANGE        1 TO        21 STEP        1

   20  AREAS (OF    20  DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT    FOR ITEM=LINE COMPONENT=
 IN RANGE        1 TO        39 STEP        1

   35  LINES (OF    35  DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT    FOR ITEM=KP   COMPONENT=
 IN RANGE        1 TO        25 STEP        1

    21  KEYPOINTS (OF     21  DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT    FOR ITEM=ELEM COMPONENT=
 IN RANGE        0 TO         0 STEP        1
```

```
       0  ELEMENTS (OF        0  DEFINED) SELECTED BY  ESEL  COMMAND.

 ALL SELECT   FOR ITEM=NODE COMPONENT=
  IN RANGE        0 TO         0 STEP         1

       0  NODES (OF        0  DEFINED) SELECTED BY NSEL  COMMAND.

 OVERLAP VOLUMES
      INPUT VOLUMES =     1    2    3    4
      INPUT VOLUMES WILL BE DELETED
      OUTPUT VOLUMES =     5    6    7    8    9   10   11   12

 ROTATE WORKING PLANE
      0.0000     DEGREES ABOUT WORKING PLANE'S Z AXIS (X TOWARDS Y)
      0.0000     DEGREES ABOUT WORKING PLANE'S X AXIS (Y TOWARDS Z)
      90.000     DEGREES ABOUT WORKING PLANE'S Y AXIS (Z TOWARDS X)

 SUBTRACT WORKING PLANES FROM A VOLUME
      VOLUME NUMBERS TO BE OPERATED ON =       5      6      7      8
9
      VOLUME NUMBERS TO BE OPERATED ON =      10     11     12
      VOLUMES OPERATED ON WILL BE DELETED
      OUTPUT VOLUMES =     1    2    3    4   13   14   15   16   17
18
      OUTPUT VOLUMES =    19   20   21   22   23   24

 ELEMENT TYPE       1 IS SOLID45      3-D STRUCTURAL SOLID
  KEYOPT(1-12)=    0  0  0    0  0  0    0  0  0    0  0  0

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

 ELEMENT TYPE SET TO        1

 FOR ELEMENT TYPE(S) ALLOWING MULTIPLE SHAPES:
     PRODUCE ALL QUADRILATERAL OR BRICK ELEMENTS. (MAPPED)

 DEFAULT ELEMENT DIVISIONS PER LINE BASED ON ELEMENT SIZE =   5.00

 ACTIVE COORDINATE SYSTEM SET TO      1  (CYLINDRICAL)

 SELECT       FOR ITEM=LOC  COMPONENT=X     BETWEEN  66.000     AND
66.000
   KABS=  0.  TOLERANCE= 0.330000

    17  LINES (OF    86  DEFINED) SELECTED BY LSEL  COMMAND.
```

```
 ALSO SELECT   FOR ITEM=LOC   COMPONENT=Z     BETWEEN  0.0000      AND
0.0000
   KABS=  0.  TOLERANCE= 0.100000E-05

    30  LINES (OF    86  DEFINED) SELECTED BY LSEL COMMAND.

 ACTIVE COORDINATE SYSTEM SET TO      0  (CARTESIAN)

 SELECT      ONLY AREAS COMPLETELY CONTAINED WITHIN LINE SET

     12  AREAS (OF     64  DEFINED) SELECTED FROM
     30 SELECTED LINES BY  ASLL  COMMAND.

 SELECT      ALL VOLUMES HAVING ANY AREA IN AREA SET.

     10  VOLUMES (OF     16  DEFINED) SELECTED FROM
     12 SELECTED AREAS BY  VSLA  COMMAND.

 DEFINITION OF COMPONENT = CONCRETE  ENTITY=VOLU

  SET ATTRIBUTES FOR ALL SELECTED VOLUMES
 MAT =     1   REAL =        0   TYPE =     0   ESYS =   0
 ATTRIBUTES SET FOR     10 VOLUMES (OUT OF     10 SELECTED)

 *IF  liner                              ( =   1.00000     )  EQ
     1                                   ( =   1.00000     )  THEN

 INVERT       FOR ITEM=VOLU COMPONENT=
  IN RANGE        1 TO        24 STEP        1

     6  VOLUMES (OF    16  DEFINED) SELECTED BY VSEL  COMMAND.

 DEFINITION OF COMPONENT = STEEL     ENTITY=VOLU

  SET ATTRIBUTES FOR ALL SELECTED VOLUMES
 MAT =     2   REAL =        0   TYPE =     0   ESYS =   0
 ATTRIBUTES SET FOR      6 VOLUMES (OUT OF      6 SELECTED)

 *ENDIF

 ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= solid.db
  FOR POSSIBLE RESUME FROM THIS POINT

 SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

 ALL SELECT   FOR ITEM=VOLU COMPONENT=
  IN RANGE        1 TO        24 STEP        1
```

```
    16   VOLUMES  (OF      16   DEFINED)  SELECTED BY   VSEL   COMMAND.

 ALL SELECT    FOR ITEM=AREA COMPONENT=
  IN RANGE          1 TO         84 STEP          1

    64   AREAS  (OF     64   DEFINED)  SELECTED BY ASEL COMMAND.

 ALL SELECT    FOR ITEM=LINE COMPONENT=
  IN RANGE          1 TO         98 STEP          1

    86   LINES  (OF     86   DEFINED)  SELECTED BY LSEL COMMAND.

 ALL SELECT    FOR ITEM=KP   COMPONENT=
  IN RANGE          1 TO         39 STEP          1

    39   KEYPOINTS  (OF      39   DEFINED)  SELECTED BY   KSEL   COMMAND.

 ALL SELECT    FOR ITEM=ELEM COMPONENT=
  IN RANGE          0 TO          0 STEP          1

        0   ELEMENTS  (OF          0   DEFINED)  SELECTED BY   ESEL   COMMAND.

 ALL SELECT    FOR ITEM=NODE COMPONENT=
  IN RANGE          0 TO          0 STEP          1

        0   NODES  (OF          0   DEFINED)  SELECTED BY NSEL   COMMAND.

 GENERATE NODES AND ELEMENTS    IN   ALL   SELECTED VOLUMES

 NUMBER OF VOLUMES MESHED   =        16
 MAXIMUM NODE NUMBER        =     21282
 MAXIMUM ELEMENT NUMBER     =     17908

 MATERIAL          1      EX    =   3610000.

 MATERIAL          1      NUXY =  0.1700000

 MATERIAL          1      DENS =  0.8333333E-01

 MATERIAL          2      EX    =  0.2860000E+08

 MATERIAL          2      NUXY =  0.3000000

 MATERIAL          2      DENS =  0.2900000

 ACTIVE COORDINATE SYSTEM SET TO       1   (CYLINDRICAL)
```

```
SELECT       FOR ITEM=LOC   COMPONENT=X     BETWEEN  66.000     AND
66.000
   KABS=  0.  TOLERANCE= 0.330000

     2025  NODES (OF    21282  DEFINED) SELECTED BY  NSEL  COMMAND.

RESELECT     FOR ITEM=LOC   COMPONENT=Y     BETWEEN -1.0000     AND
90.000
   KABS=  0.  TOLERANCE= 0.910000E-06

     1035  NODES (OF    21282  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO      0  (CARTESIAN)

RESELECT     FOR ITEM=LOC   COMPONENT=Y     BETWEEN -1.0000     AND
12.474
   KABS=  0.  TOLERANCE= 0.134740E-06

      135  NODES (OF    21282  DEFINED) SELECTED BY  NSEL  COMMAND.

SPECIFIED CONSTRAINT UX   FOR SELECTED NODES        1 TO   21282 BY
1
REAL=  0.00000000       IMAG=  0.00000000

SPECIFIED CONSTRAINT UZ   FOR SELECTED NODES     6518 TO    6518 BY
1
REAL=  0.00000000       IMAG=  0.00000000

SELECT       FOR ITEM=LOC   COMPONENT=Y     BETWEEN  0.0000     AND
0.0000
   KABS=  0.  TOLERANCE= 0.100000E-05

     1021  NODES (OF    21282  DEFINED) SELECTED BY  NSEL  COMMAND.

SPECIFIED CONSTRAINT UY   FOR SELECTED NODES        1 TO   21282 BY
1
REAL=  0.00000000       IMAG=  0.00000000

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE       1 TO       24 STEP       1

     16  VOLUMES (OF     16  DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
```

```
 IN RANGE         1 TO        84 STEP          1

   64  AREAS (OF    64  DEFINED) SELECTED BY ASEL COMMAND.

 ALL SELECT    FOR ITEM=LINE COMPONENT=
  IN RANGE         1 TO        98 STEP          1

   86  LINES (OF    86  DEFINED) SELECTED BY LSEL COMMAND.

 ALL SELECT    FOR ITEM=KP   COMPONENT=
  IN RANGE         1 TO        39 STEP          1

    39  KEYPOINTS (OF     39  DEFINED) SELECTED BY  KSEL  COMMAND.

 ALL SELECT    FOR ITEM=ELEM COMPONENT=
  IN RANGE         1 TO     17908 STEP          1

   17908  ELEMENTS (OF    17908  DEFINED) SELECTED BY  ESEL  COMMAND.

 ALL SELECT    FOR ITEM=NODE COMPONENT=
  IN RANGE         1 TO     21282 STEP          1

   21282  NODES (OF    21282  DEFINED) SELECTED BY NSEL  COMMAND.

 ACEL=   -20.000       0.0000       0.0000


 ***** ROUTINE COMPLETED *****  CP =         50.553



 *****  ANSYS SOLUTION ROUTINE  *****

 *****  ANSYS SOLVE    COMMAND  *****

 *** NOTE ***                            CP=      50.993   TIME= 11:26:57
 There is no title defined for this analysis.
1

 ***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3    *****
 ANSYS/Mechanical U
 00107763          VERSION=INTEL NT      11:27:00  JAN 05, 2000 CP=
53.497
```

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

   PROBLEM DIMENSIONALITY. . . . . . . . . . . . . .3-D
   DEGREES OF FREEDOM. . . . . . UX   UY   UZ
   ANALYSIS TYPE . . . . . . . . . . . . . . . . . .STATIC (STEADY-STATE)

 *** NOTE ***                           CP=      54.048   TIME= 11:27:00
 Present time 0 is less than or equal to the previous time.
  Time will default to 1.

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

   LOAD STEP NUMBER. . . . . . . . . . . . . . . .          1
   TIME AT END OF THE LOAD STEP. . . . . . . . . .     1.0000
   NUMBER OF SUBSTEPS. . . . . . . . . . . . . . .          1
   STEP CHANGE BOUNDARY CONDITIONS . . . . . . . .         NO
   INERTIA LOADS                        X            Y            Z
      ACEL . . . . . . . . . . . . -20.000       0.0000       0.0000
   PRINT OUTPUT CONTROLS . . . . . . . . . . . . .NO PRINTOUT
   DATABASE OUTPUT CONTROLS. . . . . . . . . . . .ALL DATA WRITTEN
                                                  FOR THE LAST SUBSTEP


 NONLINEAR MONITORING INFO IS WRITTEN TO FILE= dropl.mntr



          ***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA *****

  CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

  TOTAL MASS =    99587.

                             MOM. OF INERTIA          MOM. OF INERTIA
     CENTROID                 ABOUT ORIGIN             ABOUT CENTROID

  XC =   0.11684E-08     IXX =    0.1587E+10     IXX =    0.4248E+09
  YC =    31.516         IYY =    0.1587E+10     IYY =    0.5237E+09
  ZC =    103.32         IZZ =    0.2560E+09     IZZ =    0.1570E+09
                         IXY =   -0.3442E-02     IXY =    0.2251E-03
                         IYZ =   -0.3308E+09     IYZ =   -0.6510E+07
                         IZX =   -0.1474E-01     IZX =   -0.2717E-02


  *** MASS SUMMARY BY ELEMENT TYPE ***
```

```
 TYPE      MASS
    1   99587.2

Range of element maximum matrix coefficients in global coordinates
Maximum= 40162757.8 at element 17582.
Minimum= 2613078.73 at element 2652.

  *** ELEMENT MATRIX FORMULATION TIMES
 TYPE   NUMBER   ENAME       TOTAL CP  AVE CP

    1    17908   SOLID45      42.782    0.002
Time at end of element matrix formulation CP= 101.726275.

Estimated number of active DOF= 62689.
Maximum wavefront= 2126.

Time at end of matrix triangularization CP= 2136.17166.
Equation solver maximum pivot= 112636347 at node 20647 UY.
Equation solver minimum pivot= 1460212.73 at node 5573 UZ.

  *** ELEMENT RESULT CALCULATION TIMES
 TYPE   NUMBER   ENAME       TOTAL CP  AVE CP

    1    17908   SOLID45      22.613    0.001

  *** NODAL LOAD CALCULATION TIMES
 TYPE   NUMBER   ENAME       TOTAL CP  AVE CP

    1    17908   SOLID45       1.642    0.000
 *** LOAD STEP     1   SUBSTEP     1  COMPLETED.    CUM ITER =      1
 *** TIME =    1.00000          TIME INC =    1.00000      NEW TRIANG
MATRIX

 *** NOTE ***                            CP=    2187.465   TIME= 12:18:17
 Page file used.


  *** PROBLEM STATISTICS
  ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM =   62689
  R.M.S. WAVEFRONT SIZE =   1732.7


 *** ANSYS BINARY FILE STATISTICS
  BUFFER SIZE USED=  4096
      92.594 MB WRITTEN ON ELEMENT MATRIX FILE: dropl.emat
      60.938 MB WRITTEN ON ELEMENT SAVED DATA FILE: dropl.esav
     799.953 MB WRITTEN ON TRIANGULARIZED MATRIX FILE: dropl.tri
```

```
      35.609 MB WRITTEN ON RESULTS FILE: dropl.rst

 ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= dropl.db
  FOR POSSIBLE RESUME FROM THIS POINT

 FINISH SOLUTION PROCESSING


 ***** ROUTINE COMPLETED *****  CP =      2191.932


1

 ***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3    *****
 ANSYS/Mechanical U
 00107763         VERSION=INTEL NT      12:20:21  JAN 05, 2000 CP=
2191.932



         ***** ANSYS RESULTS INTERPRETATION (POST1) *****

 *** NOTE ***                            CP=   2191.932   TIME= 12:20:21
 Reading results into the database (SET command) will update the current
  displacement and force boundary conditions in the database with the
  values from the results file for that load set.  Note that any
  subsequent solutions will use these values unless action is taken to
  either SAVE the current values or not overwrite them (/EXIT,NOSAVE).

 DATA FILE CHANGED TO FILE= dropl.rst


 USE LOAD STEP     1  SUBSTEP     0  FOR LOAD CASE 0

 SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     1  CUMULATIVE ITERATION=
1
   TIME/FREQUENCY=  1.0000
 TITLE=

 ACTIVE COORDINATE SYSTEM SET TO      1  (CYLINDRICAL)

 DISPLAY COORDINATE SYSTEM SET TO      1  (CYLINDRICAL)

 RSYS KEY SET TO   1

 USE COORDINATE SYSTEM   1 FOR SOLUTION RESULTS
```

```
SELECT       COMPONENT CONCRETE

SELECT       ELEMENTS CREATED FROM SELECTED VOLUMES.

   15466  ELEMENTS (OF    17908  DEFINED) SELECTED FROM
      10 SELECTED VOLUMES BY  ESLV  COMMAND.

SELECT       ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

   18801 NODES (OF    21282  DEFINED) SELECTED FROM
   15466 SELECTED ELEMENTS BY NSLE COMMAND.

*DO LOOP ON PARAMETER= II       FROM  113.70     TO  213.70     BY
20.000

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
     15528 14502

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.
DSYS=  1
1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3    *****
ANSYS/Mechanical U
00107763           VERSION=INTEL NT      12:21:41  JAN 05, 2000 CP=
2210.038



        ***** POST1 LINEARIZED STRESS LISTING *****
       INSIDE NODE =  15528     OUTSIDE NODE =  14502

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

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

               ** MEMBRANE **
     SX           SY          SZ         SXY        SYZ        SXZ
  -393.8      -203.7      -74.09       185.6     -3.080     -6.960
     S1           S2          S3        SINT       SEQV
  -71.90      -92.35      -507.3       435.4      425.5

               ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ         SXY        SYZ        SXZ
```

```
 I    526.2        435.3        163.1        14.13        4.779        -3.707
 C    0.000        0.000        0.000        0.000        0.000         0.000
 O   -526.2       -435.3       -163.1       -14.13       -4.779         3.707
      S1           S2           S3           SINT         SEQV
 I    528.4        433.3        163.0        365.4        328.4
 C    0.000        0.000        0.000        0.000        0.000
 O   -163.0       -433.3       -528.4        365.4        328.4

            ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX           SY           SZ           SXY          SYZ          SXZ
 I    132.4        231.6        89.02        199.7        1.699        -10.67
 C   -393.8       -203.7       -74.09        185.6       -3.080        -6.960
 O   -920.0       -639.0       -237.2        171.5       -7.859        -3.253
      S1           S2           S3           SINT         SEQV
 I    387.9        89.71       -24.54        412.5        368.9
 C   -71.90       -92.35       -507.3        435.4        425.5
 O   -237.0       -558.1       -1001.        764.2        664.6

            ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX           SY           SZ           SXY          SYZ          SXZ
 I   -141.6       -71.85       -36.40       -11.38       -0.5865       1.373
 C    93.53        47.55        24.08        11.06        0.5263      -0.7521
 O   -151.6       -312.7       -79.11       -14.68       -1.568        0.1078
      S1           S2           S3           SINT         SEQV
 I   -36.36       -70.06       -143.5        107.1        94.84
 C    96.06        45.06        24.05        72.00        64.14
 O   -79.10       -150.2       -314.1        235.0        208.7

            ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX           SY           SZ           SXY          SYZ          SXZ
 I   -9.191        159.8        52.62        188.3        1.112        -9.294
 C   -300.3       -156.1       -50.01        196.6       -2.554        -7.712
 O   -1072.       -951.7       -316.3        156.8       -9.428        -3.145
      S1           S2           S3           SINT         SEQV         TEMP
 I    281.8        52.93       -131.5        413.3        358.6        0.000
 C   -17.45       -51.25       -437.7        420.2        404.4
 O   -316.1       -844.0       -1180.        863.4        753.9        0.000

 *ENDDO  INDEX= II
1

 ***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3    *****
 ANSYS/Mechanical U
 00107763          VERSION=INTEL NT       12:21:42  JAN 05, 2000 CP=
2211.049
```

```
          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =   15524     OUTSIDE NODE =   14498

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

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM    1

                ** MEMBRANE **
       SX           SY          SZ          SXY         SYZ         SXZ
   -402.6       -210.4      -70.92       190.1      -2.592      -5.804
       S1           S2          S3          SINT        SEQV
   -69.73       -94.64      -519.5       449.8       437.9

                ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
       SX           SY          SZ          SXY         SYZ         SXZ
 I   540.5        450.3       166.1       14.68       4.067      -2.861
 C   0.000        0.000       0.000       0.000       0.000       0.000
 O  -540.5       -450.3      -166.1      -14.68      -4.067       2.861
       S1           S2          S3          SINT        SEQV
 I   542.8        448.1       166.0       376.8       339.5
 C   0.000        0.000       0.000       0.000       0.000
 O  -166.0       -448.1      -542.8       376.8       339.5

                ** MEMBRANE PLUS BENDING **   I=INSIDE C=CENTER O=OUTSIDE
       SX           SY          SZ          SXY         SYZ         SXZ
 I   137.9        239.9       95.16       204.8       1.475      -8.665
 C  -402.6       -210.4      -70.92       190.1      -2.592      -5.804
 O  -943.0       -660.7      -237.0       175.4      -6.659      -2.943
       S1           S2          S3          SINT        SEQV
 I   400.0        95.61      -22.66       422.7       377.7
 C  -69.73       -94.64      -519.5       449.8       437.9
 O  -236.8       -576.9      -1027.       790.2       686.5

                ** PEAK **   I=INSIDE C=CENTER O=OUTSIDE
       SX           SY          SZ          SXY         SYZ         SXZ
 I  -145.5       -72.87      -37.47      -11.65     -0.6700      1.096
 C   96.07        48.39       24.83       11.29      0.5599    -0.6174
 O  -155.6       -320.2      -81.51      -14.91      -1.699      0.3550E-
01
       S1           S2          S3          SINT        SEQV
 I  -37.44       -71.07      -147.4       109.9       97.55
 C   98.61        45.87       24.80       73.81       65.85
 O  -81.50       -154.2      -321.6       240.1       213.2
```

```
             ** TOTAL **   I=INSIDE C=CENTER O=OUTSIDE
       SX            SY           SZ           SXY          SYZ          SXZ
 I  -7.629         167.0        57.69        193.1        0.8047       -7.570
 C  -306.5        -162.0       -46.09        201.4       -2.032        -6.421
 O  -1099.        -980.9       -318.5        160.5       -8.359        -2.907
       S1            S2           S3           SINT         SEQV         TEMP
 I   291.7         57.89       -132.5        424.2        368.0         0.000
 C  -19.23        -47.12       -448.3        429.0        415.8
 O  -318.4        -868.9       -1211.        892.4        779.8         0.000
1

 ***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3    *****
 ANSYS/Mechanical U
 00107763          VERSION=INTEL NT       12:21:43  JAN 05, 2000 CP=
2212.071



          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  15520     OUTSIDE NODE =  14494

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

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
      SX           SY           SZ           SXY          SYZ          SXZ
  -411.9       -216.9       -67.58        194.2       -2.610       -3.474
      S1           S2           S3           SINT         SEQV
  -67.03       -97.62       -531.7        464.7        450.2

             ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
       SX           SY           SZ           SXY          SYZ          SXZ
 I   554.3        463.2        167.2        14.72        3.939       -1.480
 C   0.000        0.000        0.000        0.000        0.000        0.000
 O  -554.3       -463.2       -167.2       -14.72       -3.939        1.480
       S1           S2           S3           SINT         SEQV
 I   556.6        461.0        167.1        389.5        351.6
 C   0.000        0.000        0.000        0.000        0.000
 O  -167.1       -461.0       -556.6        389.5        351.6

             ** MEMBRANE PLUS BENDING **   I=INSIDE C=CENTER O=OUTSIDE
       SX           SY           SZ           SXY          SYZ          SXZ
 I   142.4        246.4        99.60        208.9        1.329       -4.954
 C  -411.9       -216.9       -67.58        194.2       -2.610       -3.474
```

O	-966.2	-680.1	-234.8	179.5	-6.549	-1.994
	S1	S2	S3	SINT	SEQV	
I	409.7	99.77	-21.12	430.8	384.9	
C	-67.03	-97.62	-531.7	464.7	450.2	
O	-234.6	-593.8	-1053.	818.0	710.2	

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	-149.3	-74.13	-38.73	-11.82	-0.5279	0.4441
C	98.55	49.29	25.75	11.49	0.4500	-0.2159
O	-159.5	-327.6	-84.30	-15.20	-1.507	-0.2889
	S1	S2	S3	SINT	SEQV	
I	-38.72	-72.33	-151.2	112.4	99.96	
C	101.1	46.75	25.74	75.36	67.36	
O	-84.29	-158.1	-329.0	244.7	217.4	

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	-6.953	172.2	60.87	197.1	0.8007	-4.510
C	-313.4	-167.6	-41.83	205.7	-2.160	-3.690
O	-1126.	-1008.	-319.1	164.3	-8.057	-2.283
	S1	S2	S3	SINT	SEQV	TEMP
I	299.2	60.94	-134.0	433.1	375.7	0.000
C	-21.49	-42.57	-458.7	437.2	427.1	
O	-318.9	-892.3	-1241.	922.3	806.6	0.000

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 5.5.3 *****
ANSYS/Mechanical U
00107763 VERSION=INTEL NT 12:21:44 JAN 05, 2000 CP=
2213.072

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 15516 OUTSIDE NODE = 14490

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

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM 1

** MEMBRANE **

SX	SY	SZ	SXY	SYZ	SXZ
-420.6	-220.9	-61.74	197.1	-3.739	2.844
S1	S2	S3	SINT	SEQV	

```
   -61.62      -99.91      -541.8      480.2      462.2

               ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
        SX          SY          SZ          SXY         SYZ         SXZ
  I   568.4       476.0       158.7       13.78       5.593       1.860
  C   0.000       0.000       0.000       0.000       0.000       0.000
  O  -568.4      -476.0      -158.7      -13.78      -5.593      -1.860
        S1          S2          S3          SINT        SEQV
  I   570.4       474.1       158.6       411.8       373.1
  C   0.000       0.000       0.000       0.000       0.000
  O  -158.6      -474.1      -570.4       411.8       373.1

               ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
        SX          SY          SZ          SXY         SYZ         SXZ
  I   147.7       255.1       96.95       210.9       1.855       4.704
  C  -420.6      -220.9      -61.74       197.1      -3.739       2.844
  O  -989.0      -696.9      -220.4       183.3      -9.332      0.9841
        S1          S2          S3          SINT        SEQV
  I   419.1       96.95      -16.26       435.3       391.2
  C  -61.62      -99.91      -541.8       480.2       462.2
  O  -220.2      -608.8      -1077.       857.2       743.4

               ** PEAK **   I=INSIDE C=CENTER O=OUTSIDE
        SX          SY          SZ          SXY         SYZ         SXZ
  I  -153.3      -74.79      -40.89      -11.70      0.2676      -1.433
  C   101.0       49.85       27.43       11.55     -0.7728E-01   1.044
  O  -163.1      -334.2      -89.07      -15.45     -0.4237      -1.444
        S1          S2          S3          SINT        SEQV
  I  -40.87      -73.10      -155.0       114.1       101.9
  C   103.5       47.36       27.41       76.07       68.32
  O  -89.05      -161.8      -335.6       246.5       219.4

               ** TOTAL **   I=INSIDE C=CENTER O=OUTSIDE
        SX          SY          SZ          SXY         SYZ         SXZ
  I  -5.524       180.3       56.06       199.2       2.122       3.272
  C  -319.7      -171.1      -34.31       208.7      -3.816       3.888
  O  -1152.      -1031.      -309.5       167.9      -9.756     -0.4599
        S1          S2          S3          SINT        SEQV        TEMP
  I   307.2       56.02      -132.4       439.7       382.0       0.000
  C  -23.82      -34.32      -466.9       443.1       438.0
  O  -309.4      -913.3      -1270.       960.8       841.2       0.000
 1

  ***** ANSYS - ENGINEERING ANALYSIS SYSTEM  RELEASE 5.5.3    *****
  ANSYS/Mechanical U
  00107763         VERSION=INTEL NT      12:21:45  JAN 05, 2000 CP=
 2214.094
```

```
      ***** POST1 LINEARIZED STRESS LISTING *****
     INSIDE NODE =  15512     OUTSIDE NODE =  14486

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

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY          SZ          SXY         SYZ         SXZ
 -423.3      -218.5      -47.60       196.3      -8.215       19.17
     S1          S2          S3          SINT        SEQV
 -46.58      -99.72      -543.2       496.6       472.3

             ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I   578.1       488.1       116.9       12.18       13.31       9.228
C   0.000       0.000       0.000       0.000       0.000       0.000
O  -578.1      -488.1      -116.9      -12.18      -13.31      -9.228
     S1          S2          S3          SINT        SEQV
I   579.9       486.8       116.3       463.7       424.8
C   0.000       0.000       0.000       0.000       0.000
O  -116.3      -486.8      -579.9       463.7       424.8

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I   154.7       269.5       69.33       208.4       5.093       28.40
C  -423.3      -218.5      -47.60       196.3      -8.215       19.17
O  -1001.      -706.6      -164.5       184.1      -21.52       9.943
     S1          S2          S3          SINT        SEQV
I   429.6       73.00      -8.979       438.6       403.9
C  -46.58      -99.72      -543.2       496.6       472.3
O  -163.7      -618.7      -1090.       926.5       802.4

             ** PEAK **   I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  -156.1      -72.66      -45.53      -11.02       3.291      -5.751
C   102.6       49.25       30.95       11.01      -1.998       4.077
O  -165.3      -336.4      -99.11      -14.83       5.122      -3.988
     S1          S2          S3          SINT        SEQV
I  -44.68      -71.84      -157.8       113.1       102.3
C   105.0       47.52       30.32       74.64       67.70
O  -98.72      -164.3      -337.8       239.1       214.0
```

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	-1.356	196.9	23.80	197.4	8.385	22.65
C	-320.7	-169.3	-16.65	207.3	-10.21	23.25
O	-1167.	-1043.	-263.6	169.3	-16.40	5.955
	S1	S2	S3	SINT	SEQV	TEMP
I	319.9	24.08	-124.7	444.6	392.0	0.000
C	-13.10	-26.51	-467.0	454.0	447.4	
O	-263.3	-924.8	-1285.	1022.	897.8	0.000

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 5.5.3 *****
ANSYS/Mechanical U
00107763 VERSION=INTEL NT 12:21:46 JAN 05, 2000 CP=
2215.105

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 14786 OUTSIDE NODE = 13723

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

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM 1

** MEMBRANE **

SX	SY	SZ	SXY	SYZ	SXZ
-361.1	-189.8	-10.39	213.1	-6.583	20.67
S1	S2	S3	SINT	SEQV	
-8.518	-46.78	-505.9	497.4	479.4	

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	475.5	401.1	14.09	45.06	11.72	-10.45
C	0.000	0.000	0.000	0.000	0.000	0.000
O	-475.5	-401.1	-14.09	-45.06	-11.72	10.45
	S1	S2	S3	SINT	SEQV	
I	496.7	380.5	13.43	483.3	436.9	
C	0.000	0.000	0.000	0.000	0.000	
O	-13.43	-380.5	-496.7	483.3	436.9	

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	114.4	211.3	3.697	258.1	5.133	10.22

C	-361.1	-189.8	-10.39	213.1	-6.583	20.67
O	-836.5	-590.9	-24.49	168.0	-18.30	31.12
	S1	S2	S3	SINT	SEQV	
I	425.8	3.640	-99.98	525.7	482.4	
C	-8.518	-46.78	-505.9	497.4	479.4	
O	-23.03	-505.6	-923.3	900.2	780.3	

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	-122.7	-79.96	-26.88	-20.02	0.2724	7.872
C	78.77	49.52	9.892	17.47	0.6566	-6.233
O	-124.6	-317.0	-27.61	-25.52	2.453	12.56
	S1	S2	S3	SINT	SEQV	
I	-26.20	-72.20	-131.1	104.9	91.11	
C	87.30	41.68	9.197	78.10	67.96	
O	-26.01	-122.8	-320.4	294.4	259.9	

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	-8.304	131.4	-23.18	238.1	5.406	18.09
C	-282.3	-140.2	-0.5019	230.5	-5.927	14.43
O	-961.1	-907.8	-52.10	142.5	-15.85	43.68
	S1	S2	S3	SINT	SEQV	TEMP
I	310.4	-23.10	-187.4	497.7	439.3	0.000
C	30.44	-0.4711	-453.0	483.5	468.8	
O	-49.91	-789.8	-1081.	1031.	920.9	0.000

***** END OF INPUT ENCOUNTERED *****

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

***** PROBLEM TERMINATED BY INDICATED ERROR(S) OR BY END OF INPUT DATA *****

*** PAGE FILE USED ***
NUMBER OF R/W OPERATIONS= 59
MAXIMUM RECORD NUMBER = 273
RECORD SIZE (I*4 WORDS) = 16384
PAGE FILE SIZE (MB) = 17.063

```
 |
|
 |                      ANSYS RUN COMPLETED
|
 |
|
 |--------------------------------------------------------------------
-----|
 |
|
 |       RELEASE 5.5.3           UP19990405        INTEL NT
|
 |
|
 |    CP TIME      (sec) =        2215.115       TIME  =  12:21:46
|
 |    ELAPSED TIME (sec) =        3362.000       DATE  =  01/05/2000
|
 |
|
 *--------------------------------------------------------------------
-----*
```

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.16 File No.: VSC02.6.2.3.16 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

MSB Storage Sleeve Buckling Evaluation

SCOPE:

Product:	☐	FuelSolutions™	☐	TranStor™	☒	VSC-24	☐	Other ______
Service:	☒	Storage	☐	Transportation			☐	Other ______
Conditions:	☐	Normal	☐	Off-Normal	☒	Accident	☐	Other ______

Component(s):

MSB storage sleeve ☒

Prepared by:

Name: Michelle Heinz

Signature: Michelle Heinz

Date: 3/13/01

Verified by:

Name: James E. Moroney

Signature: [signature]

Date: 3/13/01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: R Srinivasan

Date: 3/26/01

Form QAP 3.2-1, Revision 1

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 11		Replaces Calculation WEP109-002.16, Rev. 3		
1	All pages in general		Updated References and revised calculation based on the updated References. Revised the sleeve width in Attachments 1 and 2 from 9 inches to 9.2 inches. (VSC02-ECN-008)	M. Heinz	J. Moroney

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

See Verification memorandum for Comments.

Verifier: James Moroney [signature] 2/16/01

Name/Signature/Date

1.0 PURPOSE AND RESULTS

Purpose

This calculation determines the minimum allowable thickness of the MSB sleeve wall based on the two sleeve design criteria: (1) deflection less than 0.5 inch so that fuel can be removed after an accident drop, and (2) stress less than ultimate strength.

This calculation supersedes WEP109.002.16, Revision 3. Revision 0 of this calculation incorporated comments from CAR 98-50.

The principal differences between Revision 0 of this calculation and WEP109.002.16, Revision 3 are:

- Calculated the sleeve assembly collapse load for the vertical drop with the approach in the AISC Code, which is conservative. (The old calculation used the Euler collapse load, which is not conservative for the sleeve slenderness ratio of about 45; a slenderness ratio of at least 120 is required to apply the Euler collapse formula).
- Corrected the temperature used for the sleeve assembly yield and ultimate strength.
- Corrected the moment of inertia calculation for the sleeve assembly.
- Updated the sleeve mass used for the calculations. Updated the 5-foot drop deceleration.

Results

The sleeve stress is the controlling parameter. The calculated minimum allowable wall thickness is 0.181 inches for a maximum stress of ultimate strength. The deflection of the sleeve with a 0.181-inch wall thickness is 0.23 inches, which is less than the allowable of 0.5 inches. It is concluded that the stress and the deflection of the sleeve are acceptable for a sleeve thickness of 0.181 inches.

Buckling was also considered for the horizontal and vertical drops in Attachment 1. For the vertical drop case, the P_u' = 174 kips (critical load) is much greater than the actual load of 42.0 kips. For the horizontal drop case, P_u' = 3.14 kips/in (critical load) is greater than the limiting actual load of 3.12 kips/in. It is concluded that the sleeve will not buckle due to the vertical or horizontal drops.

Attachment 2 evaluates the acceptable size of pockmarks in the sleeve material. The maximum allowable size pockmark is 1/4 inch x 1/4 inch, with at least a 3 inch centerline to centerline spacing between adjacent pockmarks, and a minimum allowable wall thickness in the pockmark of 1/8 inch.

2.0 DESIGN INPUT AND ASSUMPTIONS

The licensing basis sleeve stresses and sleeve geometry are:

Calculated maximum stress	57 ksi	Reference 2
Calculated maximum elastic deflection	0.12 inch	Reference 2
Used wall thickness	0.20 inch	Reference 6
A 516 Gr. 70 S_y	28.1 ksi at 600°F	Reference 5
A 516 Gr. 70 S_u	70 ksi at 600°F	Reference 5

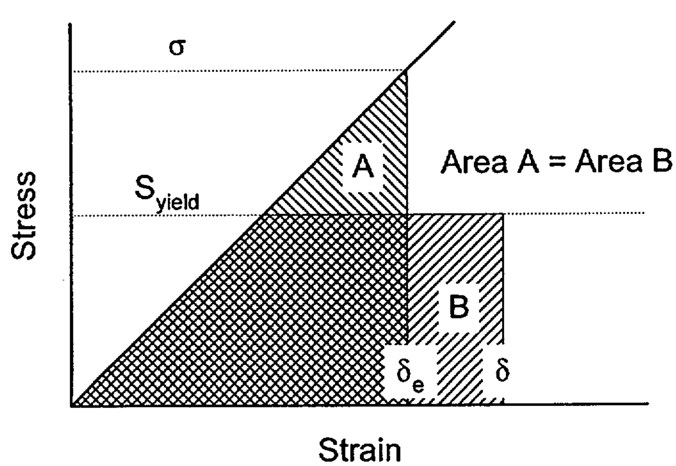
The 600°F design temperature for the sleeve bounds the temperature from Reference 7 at the location of the 57 ksi maximum stress, which occurs at the outermost wall of the outermost sleeve.

3.0 METHODOLOGY

It is noted that only the horizontal drop affects the required sleeve wall thickness. During the vertical drop, the sleeve is loaded only in compression by its self-weight; the load, therefore, is reduced together with the section area, i.e., there is no change in stresses or deflections from a reduction in the sleeve wall thickness.

For the horizontal drop, the sleeve assembly criterion is that plastic deformation of the sleeves shall not prevent removal of the fuel assembles (Reference 2). This means that the maximum stress intensity resulting from the drop should not exceed the sleeve ultimate stress (no structural failure) and the maximum deflection should be smaller than the gap between sleeve wall and fuel assembly (no interference between the sleeve and the fuel).

The original ANSYS run (presented in Reference 2) was an elastic analysis, and calculated the maximum equivalent stress of 57 ksi. This is well within the minimum ultimate strength of 70 ksi for A 516, Gr. 70 steel, but the stress is over the minimum yield strength of 28.1 ksi. Accordingly, the calculated elastic deflection of 0.12 inch was adjusted to account for plastic deformation. The absorbed energy from the elastic stress/strain curve (Area A) was balanced with the absorbed energy based on an ideal elasto-plastic material (Area B). This approach is illustrated below. The resulting formula for total deflection is derived in Reference 2.



The total plastic deformation is

$$\delta = \delta_y + \delta_{pl} = \delta_{an} \cdot \left(\frac{S_y}{\sigma_{an}} \right) + \frac{1}{2} \cdot (\delta_{an} \cdot \frac{\sigma_{an}}{S_y} - \delta_{an} \cdot \frac{S_y}{\sigma_{an}})$$

When the sleeve wall thickness is changed, it affects both the stress and deflection. The values are scaled as follows:

Stress

The stress consists of two components – membrane stress and bending stress. Membrane stress is inversely proportional to thickness, bending stress is inversely proportional to thickness squared (section modulus = $bt^2/6$). Therefore, it is conservative to scale the stress using the ratio of wall thicknesses squared.

Deflection

The total deflection also consists of two components – membrane and bending. Membrane deflection is inversely proportional to thickness, but bending deflection is inversely proportional to thickness cubed (moment of inertia = $bt^3/12$). Therefore, it is conservative to scale the elastic deflection using the cubed ratio of wall thicknesses.

4.0 CALCULATIONS

Calculate the minimum wall thickness based on a stress equal to the minimum ultimate strength:

thickness = $(57 / 70)^{1/2}$ x 0.20 = 0.181 inch

Calculated the maximum elastic deflection of a sleeve assembly with this wall thickness:

elastic deflection = 0.12 x $(.20/.181)^3$ = .162 inch

Using the formula from above, calculate the plastic deformation:

elasto-plastic deflection = .162 x (28.1/70) + 1/2 x .162 [70/28.1 – 28.1/70]

= 0.23 inch < 0.5 inch OK

5.0 REFERENCES

1. BNFL Calculation No. VSC02.6.2.3.15, "VSC-24 Hypothetical Tip-over and 5-foot Drop Analyses," Revision 1.

2. BNFL Calculation No. VSC02.6.2.3.08, "MSB-24 Drop Analysis," Revision 2.

3. AISC Manual of Steel Construction, 6th Edition.

4. Marks' Standard Handbook for Mechanical Engineers, McGraw-Hill Inc., 9th Edition.

5. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda.

6. BNFL Calculation No. VSC02.6.2.5.03, "VSC-24 Design Parameters", Revision 0.

7. SNC Calculations WEP-109-003.4, "VSC-24 Thermal Hydraulic Analysis," Revision 2, and WEP-109-003.5, "MSB-24 Thermal Hydraulic Analysis," Revision 5.

8. BNFL Calculation No. VSC02.6.2.5.01, "Weight and Center of Gravity," Revision 1.

ATTACHMENT 1

Vertical Drop

The force from deceleration of the sleeve in the vertical drop is the sleeve mass (350 lb bounds the value from Reference 8) times the acceleration (Reference 1).

Sleeve Load: W = 350 lb x 120 g = 42.0 kip

Calculate moment of inertia for the tube (dimensions from Reference 6):

$$I = \left[\frac{9.2^4}{12}\right] - \left[\frac{(9.2 - 2 \times .181)^4}{12}\right]$$

$$I = 88.6\ in^4$$

Calculate the collapse load from Reference 3, Page 5-16, Paragraph 1.5.1.3, Formula 1. The tube cross sectional area and radius of gyration are (radius of gyration from Reference 4, Table 5.2.6)

$$w_{inside} = 9.2 \cdot in - 2 \cdot .181 \cdot in = 8.84 \cdot in$$

$$Area = (9.2 \cdot in)^2 - (9.2 \cdot in - 2 \cdot .181 \cdot in)^2 = 6.53 \cdot in^2$$

$$r = \sqrt{\frac{(9.2^2 + 8.64^2)}{12}} = 3.68 in$$

The slenderness ratio is (sleeve length is the maximum value from Reference 6)

$$l/r = \frac{163.6 \cdot in}{3.68 \cdot in} = 44.5$$

The constant C_c is (the modulus of elasticity is from Reference 5 for SA 516 Gr. 70 steel at 600°F; Reference 6 for material and Reference 7 for temperature)

$$C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{S_y}} = \sqrt{\frac{2 \cdot \pi^2 \cdot 26.7 \cdot 10^6}{28{,}100}} = 137.0$$

Assuming pinned-pinned end conditions (K=1, Reference 3, Table C 1.8.1, Page 5-117) and a factor of safety equal to 1 (FS=1) gives the following collapse load:

$$P_u^1 = Area \cdot \left(1 - \frac{1}{2} \cdot \left(\frac{K \cdot L}{r \cdot C_c}\right)^2\right) \cdot \frac{S_y}{FS} = 6.53 \cdot \left(1 - \frac{1}{2} \cdot \left(\frac{1 \cdot 163.6}{3.68 \cdot 137}\right)^2\right) \cdot \frac{28{,}100}{1.0} = 174 kip$$

$P_U^1 >> W = 42.0$ kip

This approach is very conservative because the tubes are actually welded together and the moment of inertia is much higher.

Horizontal Drop

This calculation is performed using matrices. The first value in each matrix corresponds to the CE 15x15 fuel assembly, the second value to the Westinghouse 14x14 fuel assembly, and the last value corresponds to the B&W 15x15 fuel assembly w/BPRAs.

The design basis fuel assembly and fuel sleeve weights are:

$$M_{fuel} := \begin{bmatrix} 1380 \\ 1350 \\ 1585 \end{bmatrix} lbf \qquad M_{sleeve} := \begin{bmatrix} 308 \\ 342 \\ 332 \end{bmatrix} lbf$$

(values from Reference 8)

The length of the sleeve is

$$L_{sleeve} := \begin{bmatrix} 147.5 \\ 163.6 \\ 159.0 \end{bmatrix} in$$

(Reference 6)

The horizontal acceleration is

$$a_{horiz} := 44\, g$$

(Reference 1)

Load for the critical wall:

$$W := a_{horiz} \cdot \left(\frac{5}{2} + \frac{4}{2}\right) \cdot \left(M_{fuel} + M_{sleeve}\right)$$

$$W = \begin{bmatrix} 3.342 \cdot 10^5 \\ 3.35 \cdot 10^5 \\ 3.796 \cdot 10^5 \end{bmatrix} \cdot lbf$$

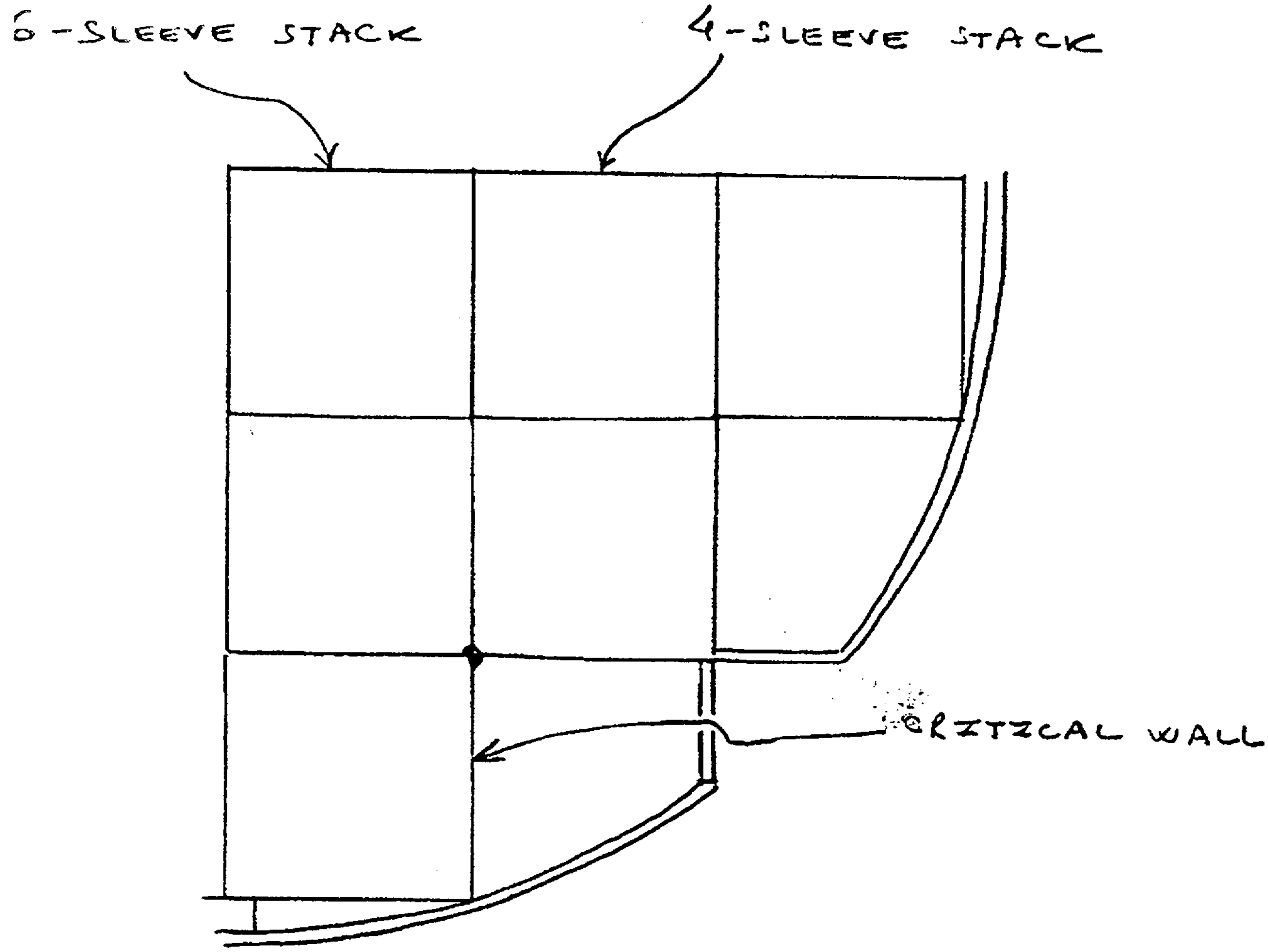


Figure A-1. Critical Wall for Buckling Evaluation

Assume the column is fixed at the top (sleeves are welded together) and simply supported at the bottom (in reality some moment resistance is provided by the horizontal wall). Use the Euler formula to calculate the collapse load. The radius of gyration is (Reference 4, Table 5.2.6):

$$r := \frac{0.181\ in}{\sqrt{12}}$$

$$r = 0.052 \cdot in$$

The length of the column is

$$l_{column} := 9.2\ in$$

Then, the l/r ratio is

$$\frac{l_{column}}{r} = 176$$

This ratio is large enough to use the Euler collapse formula for slender columns (Reference 4, p. 5-42).

Euler force per inch of length (use Roark 4th Edition, Table XV, Case 3)

$$I := \frac{1\ (0.181\ in)^3}{12} \qquad I = 4.941 \cdot 10^{-4} \cdot in^3$$

$$P_u := \frac{\pi^2 \cdot E \cdot I}{\left(0.7 \cdot l_{column}\right)^2} \qquad P_u = 3.14 \cdot 10^3 \cdot \frac{lbf}{in}$$

The top support for the wall is provided across the entire length. However, the bottom support is only provided along (per Reference 6, there are three 28" curved support plates)

$$L_{bottom} := 28\ in \cdot 3 \qquad L_{bottom} = 84 \cdot in$$

Use the average length of

$$L_{avg} := \frac{L_{sleeve} + L_{bottom}}{2} \qquad L_{avg} = \begin{bmatrix} 115.75 \\ 123.8 \\ 121.5 \end{bmatrix} \cdot in$$

Then the load per inch is:

$$P := \overrightarrow{\frac{W}{L_{avg}}} \qquad P = \begin{bmatrix} 2.887 \cdot 10^3 \\ 2.706 \cdot 10^3 \\ 3.124 \cdot 10^3 \end{bmatrix} \cdot \frac{lbf}{in}$$

For all cases, P<Pu = 3.14 lbf/in.

ATTACHMENT 2

Evaluate the acceptance size of a potential pockmark in the sleeve material.

From the review of calculation VSC02.6.2.3.08 (Reference 2), the highest stress occurs during horizontal drop in Node 225. From review of the ANSYS output, the highest stress in the neighbor node is 47.5 ksi in Node 226. The sleeve wall thickness for this calculation was 0.20 inch.

Assuming the sleeve wall thickness is 0.181 inch, the stresses can be scaled as follows. Stress is scaled as explained on Page 6 of this calculation.

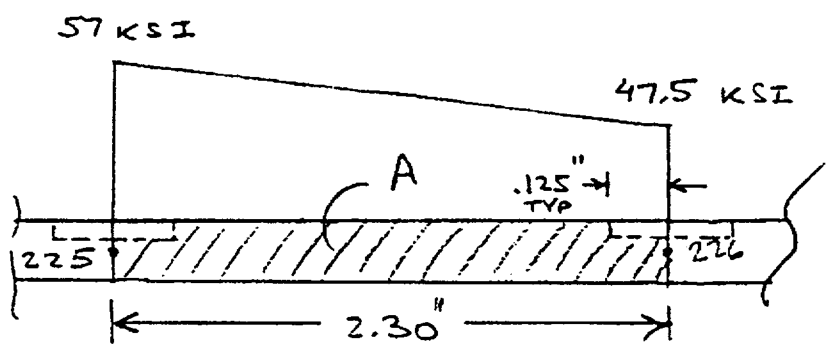
Node 225: $57 \times (.20 / .18)^2 = 70.4$ ksi

Node 226: $47.5 \times (.20 / .18)^2 = 58.6$ ksi

From the ANSYS model, the distance between Nodes 225 and 226 is 2.3 inch. The average force on the metal between these nodes is $[(70.4 + 58.6) / 2] \times 2.3 \times .181 = 26.9$ kips.

It is postulated that there are pockmarks at each of these nodes. The pockmark diameter is assumed to be 0.25 inch and the remaining wall thickness is assumed to be 0.125 inch. Then, the cross section area between Nodes 225 and 226 is:

$$A = (.125 + .125)\,(.125) + (2.30 - 2 \times 1.25)\,(.181) = .402 \text{ in}^2$$



The average stress at the section with the postulated pockmark is 26.9 kips/.402 = 66.9 ksi < 70 ksi

Based on this calculation, use the following limitation: the maximum pockmark size is 1/4 x 1/4 inch at a minimum spacing of 3 inches with a minimum remaining wall thickness of 0.125 inches.

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.18 File No.: VSC02.6.2.3.18 Revision: 2

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

VCC Thermal Stress Analysis

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ______
Service:	☒ Storage	☐ Transportation		☐ Other ______
Conditions:	☒ Normal	☐ Off-Normal	☐ Accident	☐ Other ______

Component(s):

VCC concrete, rebar, liner, bottom plate, and cover plate

Prepared by:

Name: Michelle Heinz

Signature: Michelle Heinz

Date: 1/23/01

Verified by:

Name: James E. Moroney

Signature: [signature]

Date: 1/23/01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: R Srinivasan

Date: 3/26/01

Form QAP 3.2-1, Revision 1

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 16 Appendix Pages A1 – A79		Replaces SNC Calculation WEP109-002.18, Rev. 2.		
1	1, 2, 3, 6, & 7	None.	Revised references for Design Input 2.1.2 and Reference 3.2.4 (VSC02-ECN-005).	J. Hibbard	M. Heinz
2	1, 2, 3, 7, 8, 9, 17	None.	Added WEP-109-003.04, Rev. 2 and the Design Parameter document to the list of Ref., and deleted BNFL drawings, the concrete specification, and Revisions 0 and 1 to WEP-109-003.04 on p.7. Added assumption 4.3.4 on p. 9. Revised Section 5 on p. 9 to include the results of SNC Calculation WEP-109-003.04, Rev. 2. Changed design parameter Refs. on p. 8 and 10 to the Design Parameter document. (VSC02-ECN-008)	M. Heinz	J. Moroney

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	(YES)	NO	N/A
(j) Computer codes used are under configuration control.	(YES)	NO	N/A
(k) Computer codes used are applicable to the calculation.	(YES)	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Comments documented in Verification Memorandum

Verifier: James E. Moroney [signature] 1/23/01

Name/Signature/Date

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Because the VCC is exposed to a thermal load, thermal stresses must be evaluated. The purpose/objective of this calculation is to perform an analysis to determine the thermal stresses of VCC components, and ensure these stresses are less than allowable values. These stresses are input to the VCC Load Combination Evaluation calculation to determine total loads and stresses. The scope of this calculation includes the VCC concrete, rebar, liner, bottom plate, and cover plate. This thermal analysis is performed for the case with the highest temperature gradient through the concrete wall, which bounds all other cases.

Revision 0 of this calculation was prepared to address technical issues concerning SNC Calculation WEP109-002.18, Revision 2 discussed in CAR 98-50 (date 10/2/98) and the Design Review Record (dated 7/31/98). This calculation supercedes SNC WEP109-002.18, Revision 2. The principal differences between Revision 0 of this calculation and WEP109-002.18, Revision 2 are:

- The liner thermal stress is adjusted to account for differences in the liner thickness between the old and new calculation.
- The correct yield strength for A-36 steel at 250°F is applied in this calculation.
- Notes are added to this calculation addressing the correct concrete modulus of elasticity, the linking of the liner and concrete in the ANSYS model, and the correct ID of the liner.

Changes to this calculation affect stresses used as inputs to the VCC Load Combination Evaluation Calculation.

2. REQUIREMENTS

2.1 Design Inputs

2.1.1 ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures", 1980. *(Material Properties)*

2.1.2 ASME Boiler and Pressure Vessel Code, Section III, Division I, Appendices, 1986 Edition with the 1988 Addenda. *(Material Properties)*

2.2 Regulatory Commitments

2.2.1 "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High Level Radioactive Waste", Code of Federal Regulations Title 10, Part 72.

3. REFERENCES

3.1 BFS Calculation Packages

3.1.1 Deleted.

3.1.2 Deleted.

3.1.3 SNC Calculation WEP-109.002.18, "VCC Thermal Stress Analysis", Revision 2. *(Source of ANSYS input and output included in Attachment A).*

3.1.4 SNC Calculation WEP-109.003.04, "VCC Thermal-Hydraulic Analysis", Revision 2.

3.1.5 BNFL Calculation No. VSC02.6.2.5.03, Revision 0, "VSC-24 Design Parameters."

3.2 General References

3.2.1 Deleted.

3.2.2 Deleted.

3.2.3 ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures", 1980.

3.2.4 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with the 1988 Addenda.

3.2.5 Deleted.

3.2.6 Spiegel, Leonard, and George F. Limbrunner, "Reinforced Concrete Design", Prentice-Hall, Inc., 1980.

4. ASSUMPTIONS

4.1 Design Configuration

Table 4-1 summarizes the design parameters used in this thermal analysis.

Table 4-1: Design Parameters

Item	Material	Value	Reference
Concrete		$f_c' = 4{,}000$ psi $w_c' = 144$ lb/ft^3 $\alpha = 5.5 \times 10^{-6}$/°F	3.1.5 3.1.5 3.2.3
Rebar	A-615 Grade 60 [Ref. 3.1.5]	$S_y = 60.0$ ksi	3.2.4
VCC liner	A-36 [Ref. 3.1.5]	$S_y = 32.4$ ksi $t_{liner} = 1.75$ in. $ID_{liner} = 70.5$ in.	3.2.4, Table I-2.1, at 250°F 3.1.5 3.1.5
VCC bottom plate and cover plate	A-36 [Ref. 3.1.5]	$S_y = 32.4$ ksi	3.2.4, Table I-2.1 at 250°F

4.2 Design Criteria

None.

4.3 Calculation Assumptions

4.3.1 The discrepancy between References 3.1.3 and 3.1.5 concerning the inside diameter of the VCC liner (65.75" vs. 70.5") is expected to have a minimal effect on the liner thermal stresses obtained from ANSYS runs. Because the thermal stresses obtained for the liner from Reference 3.1.3 are much less than the allowable (1.8 ksi vs. 32.4 ksi), no safety impact is expected if ANSYS is run with the correct VCC liner inside diameter.

4.3.2 The concrete modulus of elasticity used as input in the ANSYS model (3.28×10^6 psi) differs from the actual value (3.61×10^6 psi – Section 8.5, Reference 3.2.3). This difference will only impact the results by 10%. Because the stresses are small, the effect is not included in this calculation.

4.3.3 The stiffness of the gap elements in the ANSYS model is assumed to be 0.2 x 10^7 kips/in, approximately twice the maximum stiffness of concrete elements.

4.3.4 Because thermal stresses are controlled largely by thickness rather than by length, varying the height of the VCC, the height of the VCC liner, and the OD of the VCC bottom plate from the values used in the ANSYS analysis in this calculation is expected to have a minimal effect on resulting thermal stresses. The largest stress ratios calculated in this calculation for the concrete, VCC liner, and VCC bottom plate are 73%, 6%, and 19% of the allowables, respectively. Slight variations in the height of the VCC, the height of the VCC liner, and the OD of the VCC bottom plate would not cause stresses to exceed allowables.

5. CALCULATION METHODOLOGY

5.1 Temperature Gradient

ANSYS/PC – LINEAR 4.3A-2 is used in this calculation to determine the thermal stresses for the VCC components. A temperature distribution must be applied to the cask in the ANSYS model. Temperature gradients through the VCC concrete wall for several cases from Reference 3.1.4 are provided in Table 5-1. The gradients are obtained by subtracting the temperature at the VCC OD from the temperature at the VCC liner OD, where both temperatures are at the same cask elevation. Temperatures producing the maximum gradient for each case are shown. The temperature distribution of the case with the maximum temperature gradient should be used in the ANSYS model in this calculation to bound the other cases.

Table 5-1: VCC Temperature Gradients

Case	75°F normal	-40°F	100°F	125°F	75°F ½ inlets	75°F no inlets
VCC Liner OD Surface	180	40	214	248	191	206
VCC OD Surface	85	-32	136	189	86	87
ΔT	95	72	78	59	105	119

The maximum gradient of ΔT = 119°F from Reference 3.1.4 is for the case of complete inlet blockage. This temperature gradient, however, is bounded by the ΔT = 121°F maximum temperature gradient obtained from the temperature distribution used in the VCC thermal stress analysis of Reference 3.1.3. Therefore the ANSYS thermal stress analysis documented in Reference 3.1.3 is documented and used in this calculation. The maximum temperature gradient of 121°F from the analysis can be obtained from Figure 5-1 in this calculation.

5.2 Temperature Distribution

The ANSYS thermal stress analysis provided in Attachment A is from Reference 3.1.3. Figure 5-1 presents the temperature distribution used in this analysis.

5.3 Finite Element Model

ANSYS/PC – LINEAR 4.3A-2 was used to determine the thermal stresses for the VCC components. The finite element model is provided in Figure 5-2. Although the cask and its temperature distribution are axisymmetric, an 11.25° slice is used for the finite element model to include cracking of the concrete in the circumferential direction. The model includes 433 elements and 615 nodes. Air inlets and outlets were judged not to have a noticeable effect on the cask behavior and are not modeled in this analysis.

The outside rebars (both vertical and hoops) are #6 @ 6" [Reference 3.1.5]. They are bundled together at node locations and modeled using the equivalent areas: total rebar area within an element was split between two spars running along the element edges. This methodology is illustrated in Figure 5-3. The resulting areas are summarized in Figure 5-3. Each number corresponds to the appropriate real constant in ANSYS input.

Figure 5-1: VCC Temperature Distribution

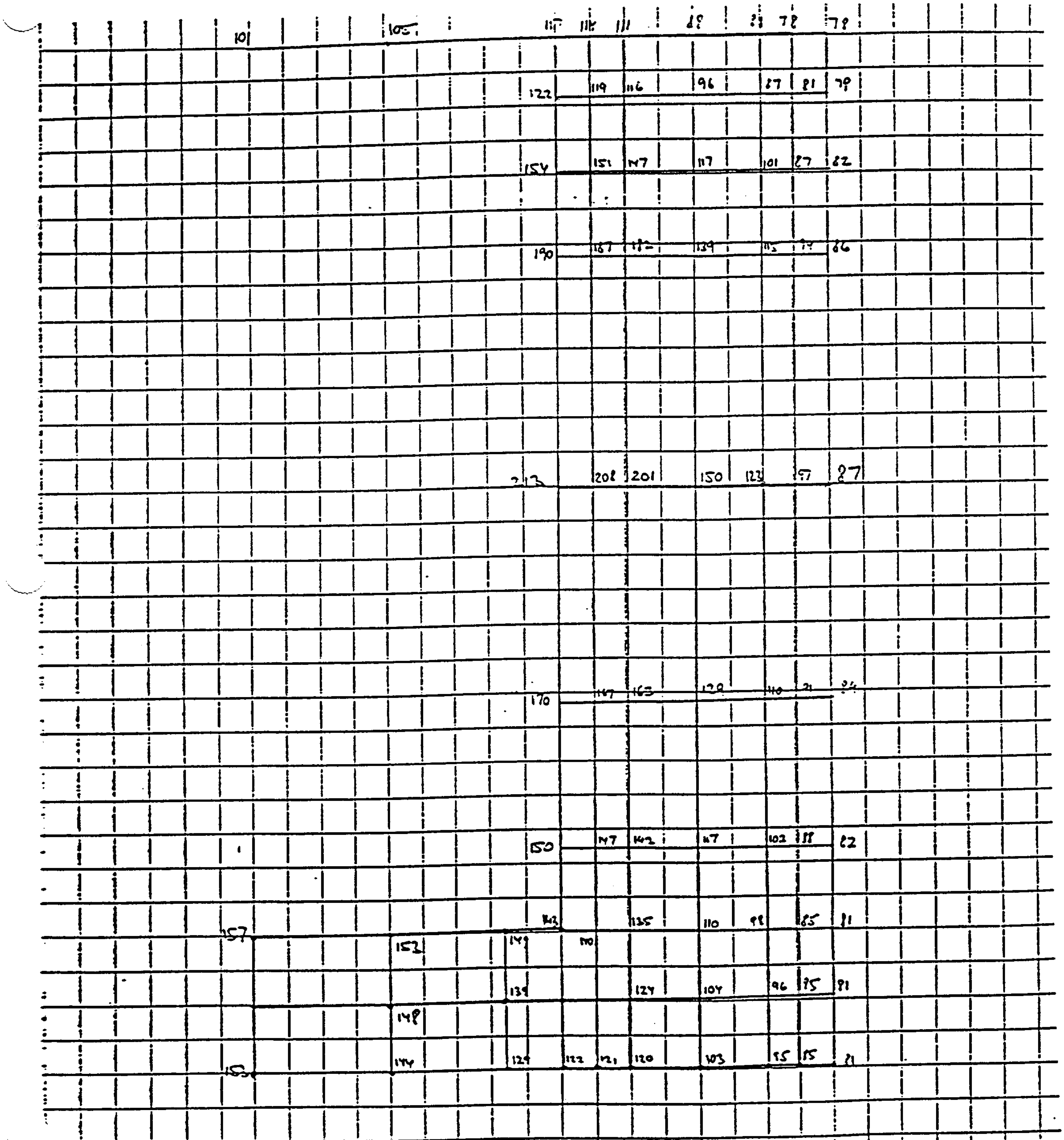


Figure 5-2: Finite Element Model

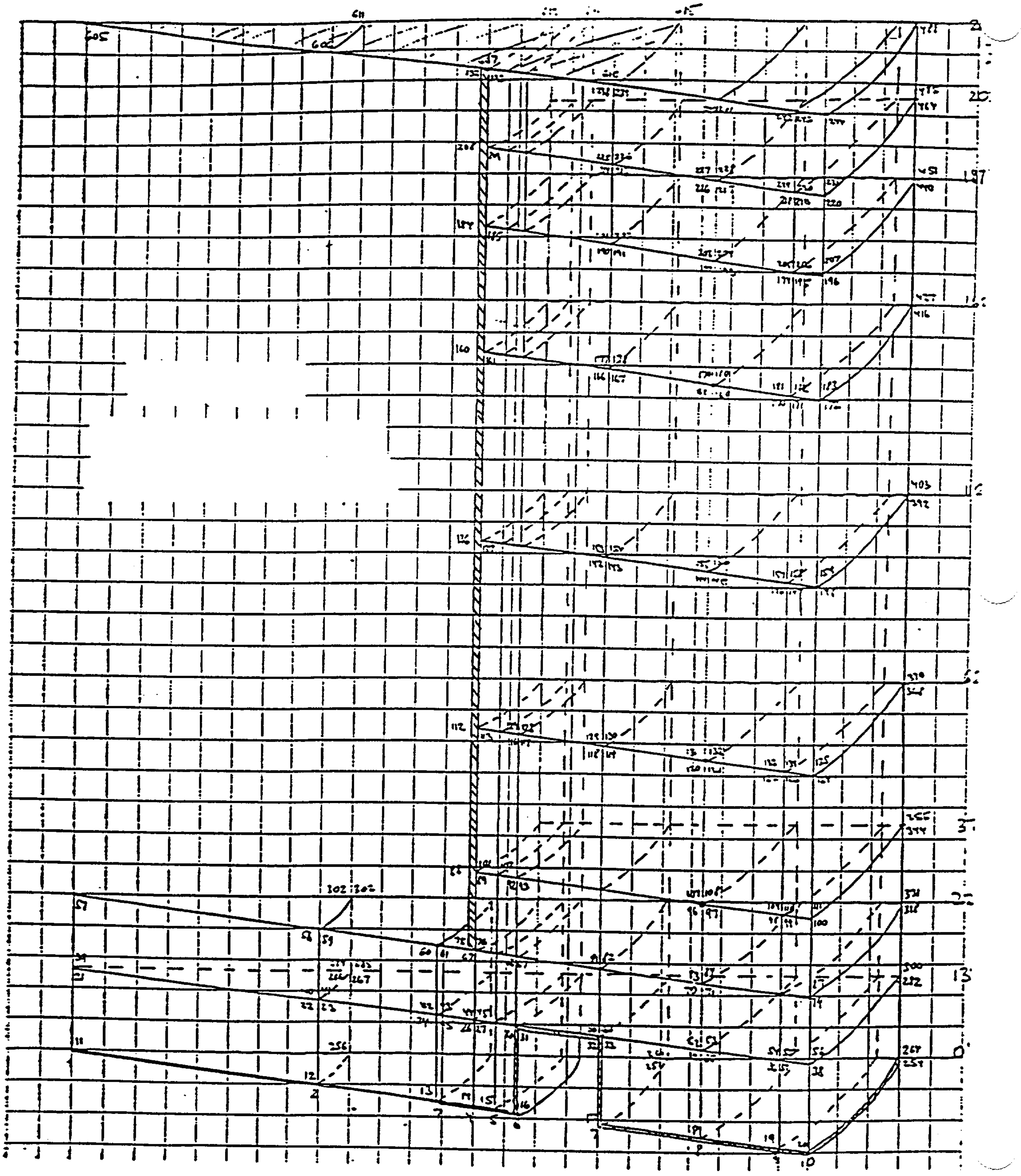
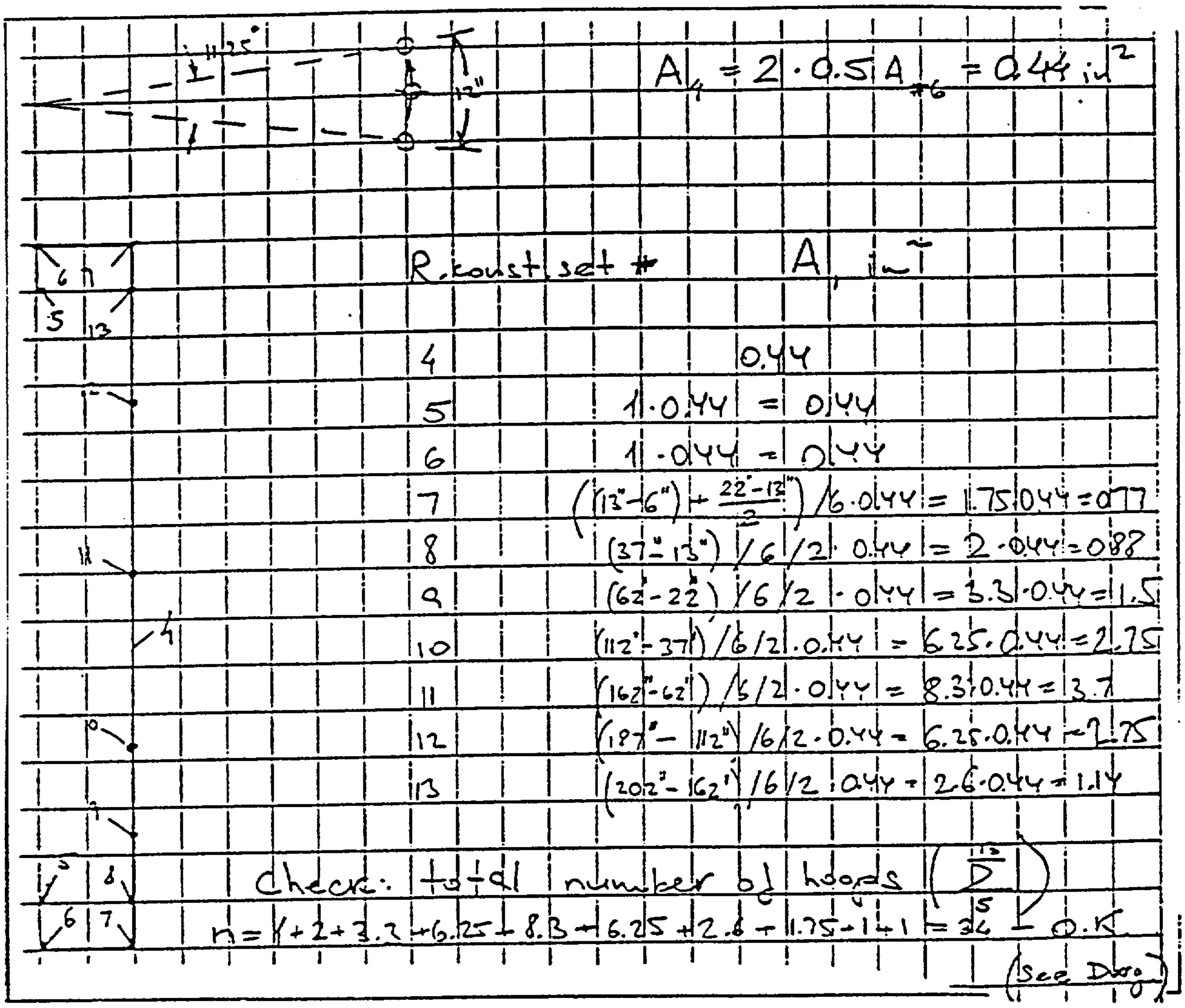
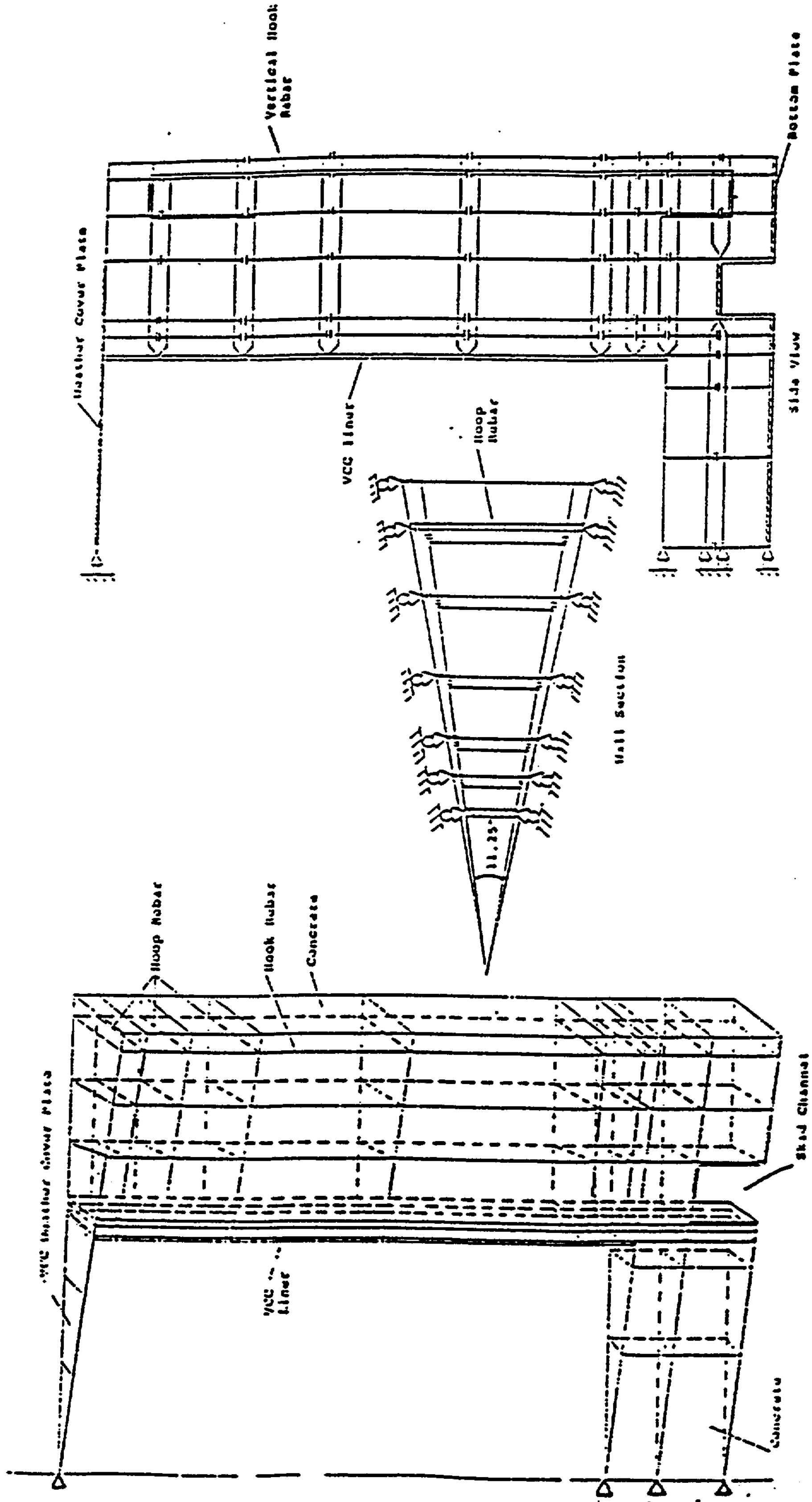


Figure 5-3: Rebar Area



Gap elements are used to model concrete ineffectiveness in tension. The elements are located in the areas where tensile stresses are expected so that cracks transfer all load to the rebars. The gap elements are not shown in Figure 5-2 due to the lack of room, but the idea is presented in Figure 5-4, and all elements are listed in ANSYS output provided in Attachment A. The gap elements' stiffness is assumed to be 0.2 x 10^7 kips/in (approximately twice the maximum stiffness of concrete elements). The element nodes are coupled in the radial direction to account for shear transfer between adjacent concrete elements.

Figure 5-4: Finite Element Model



5.4 VCC Liner Stresses

Stress results from ANSYS runs are provided in Attachment A. These runs were originally made and included in Reference 3.1.3. The thickness of the VCC liner used as an input to this analysis was 2.0". According to Reference 3.1.5, the actual thickness of the VCC liner is 1.75". As a result of the liner thickness discrepancy, thermal stresses in the liner will increase. To account for this increase, the thermal stress in the liner obtained from the ANSYS output in Attachment A is multiplied by the ratio of the old VCC liner thickness and new VCC liner thickness in Section 6.0.

6. CALCULATIONS

6.1 Concrete

The following stresses for the VCC concrete are obtained from the ANSYS output provided in Attachment A:

Maximum compressive stress (allowable from sections 9.3 and 10.2.7 of Ref. 3.2.3):

$$-0.4\ ksi < 0.7\ (0.85 f_c') = 0.7\ (0.85)\ (4\ ksi) = 2.38\ ksi \quad \text{OK}$$

Maximum shear stress (allowable from equation 11-3 and section 9.3 of Ref. 3.2.3):

$$0.08ksi < 0.85 \cdot (2 \cdot \sqrt{f_c'}) = 0.11ksi \quad \text{OK}$$

Maximum tensile stress (allowable from section 9.3 of Ref. 3.2.3 and Page 5 of Reference 3.2.6):

$$0.26ksi < 0.9 \cdot 6.7\sqrt{f_c'} = 0.38ksi \quad \text{OK}$$

6.2 Rebar

The following stresses for the rebar are obtained from ANSYS output provided in Attachment A:

Vertical stress:

$$\sigma = 28.8\ ksi < F_y = 60\ ksi \quad \text{OK}$$

Hoop stress:

$$\sigma = 14.6\ ksi < F_y = 60\ ksi \quad \text{OK}$$

6.3 Liner

The following stress intensity for the VCC liner is obtained from the ANSYS output provided in Attachment A:

Maximum Stress Intensity, multiplied by ratio of old and new liner thickness values:

$1.8\ (2.0/1.75) = 2.1 \mathit{ksi} < F_y = 32.4\ \mathit{ksi}$ OK

6.4 Bottom Plate

The following stress intensity for the VCC bottom plate is obtained from the ANSYS output provided in Attachment A:

Maximum Stress Intensity:

$6.2\ \mathit{ksi} < F_y = 32.4\ \mathit{ksi}$ OK

6.5 Cover Plate

The following stress intensity for the VCC cover plate is obtained from the ANSYS output provided in Attachment A:

Maximum Stress Intensity:

$5.3\ \mathit{ksi} < F_y = 32.4\ \mathit{ksi}$ OK

7. CONCLUSIONS

The calculation presented in Section 6.0 shows that VCC component thermal stresses are less than allowable values. These stresses will be used as input to the VCC Load Combination Evaluation.

Summary of conservatisms:

- The VCC liner and concrete are linked in the ANSYS model, adding conservatism to the calculated stresses.
- This analysis is performed for the case of a temperature gradient of $\Delta T = 121°F$. This is conservative as compared to the actual temperature gradient of $\Delta T = 119°F$ from Reference 3.1.4 (see Table 5-1).

8. ELECTRONIC FILES

8.1 Computer Runs

Copies of computer input and output from ANSYS PC/Linear Version 4.3A-2 for the thermal stress analysis is provided for convenience in Attachment A. This computer input and output is taken from Reference 3.1.3.

8.2 Other Electronic Files

None.

9. ATTACHMENT A – ANSYS INPUT AND OUTPUT FOR THERMAL ANALYSIS

ATTACHMENT

LIST ALL SELECTED NODE DSYS= 0

ODE	X	Y	Z	THXY	THYZ	THXZ
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00	0.00	0.00
2	20.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
3	30.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
4	34.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
5	36.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
6	38.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
7	48.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
8	55.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
9	63.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
10	66.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
11	0.00000E+00	0.00000E+00	0.12500	0.00	0.00	0.00
12	20.000	0.00000E+00	0.12500	0.00	0.00	0.00
13	30.000	0.00000E+00	0.12500	0.00	0.00	0.00
14	34.000	0.00000E+00	0.12500	0.00	0.00	0.00
15	36.000	0.00000E+00	0.12500	0.00	0.00	0.00
16	37.875	0.00000E+00	0.12500	0.00	0.00	0.00
17	48.125	0.00000E+00	0.12500	0.00	0.00	0.00
18	55.000	0.00000E+00	0.12500	0.00	0.00	0.00
19	63.000	0.00000E+00	0.12500	0.00	0.00	0.00
20	66.000	0.00000E+00	0.12500	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
21	0.00000E+00	0.00000E+00	13.000	0.00	0.00	0.00
22	19.875	0.00000E+00	13.000	0.00	0.00	0.00
23	20.000	0.00000E+00	13.000	0.00	0.00	0.00
24	29.875	0.00000E+00	13.000	0.00	0.00	0.00
25	30.000	0.00000E+00	13.000	0.00	0.00	0.00
26	33.875	0.00000E+00	13.000	0.00	0.00	0.00
27	34.000	0.00000E+00	13.000	0.00	0.00	0.00
28	35.875	0.00000E+00	13.000	0.00	0.00	0.00
29	36.000	0.00000E+00	13.000	0.00	0.00	0.00
30	37.875	0.00000E+00	13.000	0.00	0.00	0.00
31	38.000	0.00000E+00	13.000	0.00	0.00	0.00
32	48.000	0.00000E+00	13.000	0.00	0.00	0.00
33	48.125	0.00000E+00	13.000	0.00	0.00	0.00
34	54.875	0.00000E+00	13.000	0.00	0.00	0.00
35	55.000	0.00000E+00	13.000	0.00	0.00	0.00
36	62.875	0.00000E+00	13.000	0.00	0.00	0.00
37	63.000	0.00000E+00	13.000	0.00	0.00	0.00
38	66.000	0.00000E+00	13.000	0.00	0.00	0.00
39	0.00000E+00	0.00000E+00	13.125	0.00	0.00	0.00
40	19.875	0.00000E+00	13.125	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
41	20.000	0.00000E+00	13.125	0.00	0.00	0.00
42	29.875	0.00000E+00	13.125	0.00	0.00	0.00
43	30.000	0.00000E+00	13.125	0.00	0.00	0.00
44	33.875	0.00000E+00	13.125	0.00	0.00	0.00
45	34.000	0.00000E+00	13.125	0.00	0.00	0.00
46	35.875	0.00000E+00	13.125	0.00	0.00	0.00
47	36.000	0.00000E+00	13.125	0.00	0.00	0.00
48	37.875	0.00000E+00	13.125	0.00	0.00	0.00
49	38.000	0.00000E+00	13.125	0.00	0.00	0.00
50	48.000	0.00000E+00	13.125	0.00	0.00	0.00
51	48.125	0.00000E+00	13.125	0.00	0.00	0.00

52	54.875	0.00000E+00	13.125	0.00	0.00	0.00
53	55.000	0.00000E+00	13.125	0.00	0.00	0.00
54	62.875	0.00000E+00	13.125	0.00	0.00	0.00
55	63.000	0.00000E+00	13.125	0.00	0.00	0.00
56	66.000	0.00000E+00	13.125	0.00	0.00	0.00
57	0.00000E+00	0.00000E+00	22.000	0.00	0.00	0.00
58	19.875	0.00000E+00	22.000	0.00	0.00	0.00
59	20.000	0.00000E+00	22.000	0.00	0.00	0.00
60	29.875	0.00000E+00	22.000	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
61	30.000	0.00000E+00	22.000	0.00	0.00	0.00
62	33.875	0.00000E+00	22.000	0.00	0.00	0.00
63	34.000	0.00000E+00	22.000	0.00	0.00	0.00
64	35.875	0.00000E+00	22.000	0.00	0.00	0.00
65	36.000	0.00000E+00	22.000	0.00	0.00	0.00
66	37.875	0.00000E+00	22.000	0.00	0.00	0.00
67	38.000	0.00000E+00	22.000	0.00	0.00	0.00
68	48.000	0.00000E+00	22.000	0.00	0.00	0.00
69	48.125	0.00000E+00	22.000	0.00	0.00	0.00
70	54.875	0.00000E+00	22.000	0.00	0.00	0.00
71	55.000	0.00000E+00	22.000	0.00	0.00	0.00
72	62.875	0.00000E+00	22.000	0.00	0.00	0.00
73	63.000	0.00000E+00	22.000	0.00	0.00	0.00
74	66.000	0.00000E+00	22.000	0.00	0.00	0.00
75	33.875	0.00000E+00	22.125	0.00	0.00	0.00
76	34.000	0.00000E+00	22.125	0.00	0.00	0.00
77	35.875	0.00000E+00	22.125	0.00	0.00	0.00
78	36.000	0.00000E+00	22.125	0.00	0.00	0.00
79	37.875	0.00000E+00	22.125	0.00	0.00	0.00
80	38.000	0.00000E+00	22.125	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
81	48.000	0.00000E+00	22.125	0.00	0.00	0.00
82	48.125	0.00000E+00	22.125	0.00	0.00	0.00
83	54.875	0.00000E+00	22.125	0.00	0.00	0.00
84	55.000	0.00000E+00	22.125	0.00	0.00	0.00
85	62.875	0.00000E+00	22.125	0.00	0.00	0.00
86	63.000	0.00000E+00	22.125	0.00	0.00	0.00
87	66.000	0.00000E+00	22.125	0.00	0.00	0.00
88	33.875	0.00000E+00	22.125	0.00	0.00	0.00
89	34.000	0.00000E+00	37.125	0.00	0.00	0.00
90	35.875	0.00000E+00	37.125	0.00	0.00	0.00
91	36.000	0.00000E+00	37.125	0.00	0.00	0.00
92	37.875	0.00000E+00	37.125	0.00	0.00	0.00
93	38.000	0.00000E+00	37.125	0.00	0.00	0.00
94	48.000	0.00000E+00	37.125	0.00	0.00	0.00
95	48.125	0.00000E+00	37.125	0.00	0.00	0.00
96	54.875	0.00000E+00	37.125	0.00	0.00	0.00
97	55.000	0.00000E+00	37.125	0.00	0.00	0.00
98	62.875	0.00000E+00	37.125	0.00	0.00	0.00
99	63.000	0.00000E+00	37.125	0.00	0.00	0.00
100	66.000	0.00000E+00	37.125	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
101	35.875	0.00000E+00	37.250	0.00	0.00	0.00
102	36.000	0.00000E+00	37.250	0.00	0.00	0.00
103	37.875	0.00000E+00	37.250	0.00	0.00	0.00
104	38.000	0.00000E+00	37.250	0.00	0.00	0.00
105	48.000	0.00000E+00	37.250	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
106	48.125	0.00000E+00	37.250	0.00	0.00	0.00
107	54.875	0.00000E+00	37.250	0.00	0.00	0.00
108	55.000	0.00000E+00	37.250	0.00	0.00	0.00
109	62.875	0.00000E+00	37.250	0.00	0.00	0.00
110	63.000	0.00000E+00	37.250	0.00	0.00	0.00
111	66.000	0.00000E+00	37.250	0.00	0.00	0.00
112	33.875	0.00000E+00	62.125	0.00	0.00	0.00
113	34.000	0.00000E+00	62.125	0.00	0.00	0.00
114	35.875	0.00000E+00	62.125	0.00	0.00	0.00
115	36.000	0.00000E+00	62.125	0.00	0.00	0.00
116	37.875	0.00000E+00	62.125	0.00	0.00	0.00
117	38.000	0.00000E+00	62.125	0.00	0.00	0.00
118	48.000	0.00000E+00	62.125	0.00	0.00	0.00
119	48.125	0.00000E+00	62.125	0.00	0.00	0.00
120	54.875	0.00000E+00	62.125	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
121	55.000	0.00000E+00	62.125	0.00	0.00	0.00
122	62.875	0.00000E+00	62.125	0.00	0.00	0.00
123	63.000	0.00000E+00	62.125	0.00	0.00	0.00
124	66.000	0.00000E+00	62.125	0.00	0.00	0.00
125	35.875	0.00000E+00	62.250	0.00	0.00	0.00
126	36.000	0.00000E+00	62.250	0.00	0.00	0.00
127	37.875	0.00000E+00	62.250	0.00	0.00	0.00
128	38.000	0.00000E+00	62.250	0.00	0.00	0.00
129	48.000	0.00000E+00	62.250	0.00	0.00	0.00
130	48.125	0.00000E+00	62.250	0.00	0.00	0.00
131	54.875	0.00000E+00	62.250	0.00	0.00	0.00
132	55.000	0.00000E+00	62.250	0.00	0.00	0.00
133	62.875	0.00000E+00	62.250	0.00	0.00	0.00
134	63.000	0.00000E+00	62.250	0.00	0.00	0.00
135	66.000	0.00000E+00	62.250	0.00	0.00	0.00
136	33.875	0.00000E+00	112.12	0.00	0.00	0.00
137	34.000	0.00000E+00	112.12	0.00	0.00	0.00
138	35.875	0.00000E+00	112.12	0.00	0.00	0.00
139	36.000	0.00000E+00	112.12	0.00	0.00	0.00
140	37.875	0.00000E+00	112.12	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
141	38.000	0.00000E+00	112.12	0.00	0.00	0.00
142	48.000	0.00000E+00	112.12	0.00	0.00	0.00
143	48.125	0.00000E+00	112.12	0.00	0.00	0.00
144	54.875	0.00000E+00	112.12	0.00	0.00	0.00
145	55.000	0.00000E+00	112.12	0.00	0.00	0.00
146	62.875	0.00000E+00	112.12	0.00	0.00	0.00
147	63.000	0.00000E+00	112.12	0.00	0.00	0.00
148	66.000	0.00000E+00	112.12	0.00	0.00	0.00
149	35.875	0.00000E+00	112.25	0.00	0.00	0.00
150	36.000	0.00000E+00	112.25	0.00	0.00	0.00
151	37.875	0.00000E+00	112.25	0.00	0.00	0.00
152	38.000	0.00000E+00	112.25	0.00	0.00	0.00
153	48.000	0.00000E+00	112.25	0.00	0.00	0.00
154	48.125	0.00000E+00	112.25	0.00	0.00	0.00
155	54.875	0.00000E+00	112.25	0.00	0.00	0.00
156	55.000	0.00000E+00	112.25	0.00	0.00	0.00
157	62.875	0.00000E+00	112.25	0.00	0.00	0.00
158	63.000	0.00000E+00	112.25	0.00	0.00	0.00
159	66.000	0.00000E+00	112.25	0.00	0.00	0.00
160	33.875	0.00000E+00	162.12	0.00	0.00	0.00

liner OD

NODE	X	Y	Z	THXY	THYZ	THXZ
161	34.000	0.00000E+00	162.12	0.00	0.00	0.00
162	35.875	0.00000E+00	162.12	0.00	0.00	0.00
163	36.000	0.00000E+00	162.12	0.00	0.00	0.00
164	37.875	0.00000E+00	162.12	0.00	0.00	0.00
165	38.000	0.00000E+00	162.12	0.00	0.00	0.00
166	48.000	0.00000E+00	162.12	0.00	0.00	0.00
167	48.125	0.00000E+00	162.12	0.00	0.00	0.00
168	54.875	0.00000E+00	162.12	0.00	0.00	0.00
169	55.000	0.00000E+00	162.12	0.00	0.00	0.00
170	62.875	0.00000E+00	162.12	0.00	0.00	0.00
171	63.000	0.00000E+00	162.12	0.00	0.00	0.00
172	66.000	0.00000E+00	162.12	0.00	0.00	0.00
173	35.875	0.00000E+00	162.25	0.00	0.00	0.00
174	36.000	0.00000E+00	162.25	0.00	0.00	0.00
175	37.875	0.00000E+00	162.25	0.00	0.00	0.00
176	38.000	0.00000E+00	162.25	0.00	0.00	0.00
177	48.000	0.00000E+00	162.25	0.00	0.00	0.00
178	48.125	0.00000E+00	162.25	0.00	0.00	0.00
179	54.875	0.00000E+00	162.25	0.00	0.00	0.00
180	55.000	0.00000E+00	162.25	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
181	62.875	0.00000E+00	162.25	0.00	0.00	0.00
182	63.000	0.00000E+00	162.25	0.00	0.00	0.00
183	66.000	0.00000E+00	162.25	0.00	0.00	0.00
184	33.875	0.00000E+00	187.12	0.00	0.00	0.00
185	34.000	0.00000E+00	187.12	0.00	0.00	0.00
186	35.875	0.00000E+00	187.12	0.00	0.00	0.00
187	36.000	0.00000E+00	187.12	0.00	0.00	0.00
188	37.875	0.00000E+00	187.12	0.00	0.00	0.00
189	38.000	0.00000E+00	187.12	0.00	0.00	0.00
190	48.000	0.00000E+00	187.12	0.00	0.00	0.00
191	48.125	0.00000E+00	187.12	0.00	0.00	0.00
192	54.875	0.00000E+00	187.12	0.00	0.00	0.00
193	55.000	0.00000E+00	187.12	0.00	0.00	0.00
194	62.875	0.00000E+00	187.12	0.00	0.00	0.00
195	63.000	0.00000E+00	187.12	0.00	0.00	0.00
196	66.000	0.00000E+00	187.12	0.00	0.00	0.00
197	35.875	0.00000E+00	187.25	0.00	0.00	0.00
198	36.000	0.00000E+00	187.25	0.00	0.00	0.00
199	37.875	0.00000E+00	187.25	0.00	0.00	0.00
200	38.000	0.00000E+00	187.25	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
201	48.000	0.00000E+00	187.25	0.00	0.00	0.00
202	48.125	0.00000E+00	187.25	0.00	0.00	0.00
203	54.875	0.00000E+00	187.25	0.00	0.00	0.00
204	55.000	0.00000E+00	187.25	0.00	0.00	0.00
205	62.875	0.00000E+00	187.25	0.00	0.00	0.00
206	63.000	0.00000E+00	187.25	0.00	0.00	0.00
207	66.000	0.00000E+00	187.25	0.00	0.00	0.00
208	33.875	0.00000E+00	202.12	0.00	0.00	0.00
209	34.000	0.00000E+00	202.12	0.00	0.00	0.00
210	35.875	0.00000E+00	202.12	0.00	0.00	0.00
211	36.000	0.00000E+00	202.12	0.00	0.00	0.00
212	37.875	0.00000E+00	202.12	0.00	0.00	0.00
213	38.000	0.00000E+00	202.12	0.00	0.00	0.00
214	48.000	0.00000E+00	202.12	0.00	0.00	0.00
215	48.125	0.00000E+00	202.12	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
216	54.875	0.00000E+00	202.12	0.00	0.00	0.00
217	55.000	0.00000E+00	202.12	0.00	0.00	0.00
218	62.875	0.00000E+00	202.12	0.00	0.00	0.00
219	63.000	0.00000E+00	202.12	0.00	0.00	0.00
220	66.000	0.00000E+00	202.12	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
221	35.875	0.00000E+00	202.25	0.00	0.00	0.00
222	36.000	0.00000E+00	202.25	0.00	0.00	0.00
223	37.875	0.00000E+00	202.25	0.00	0.00	0.00
224	38.000	0.00000E+00	202.25	0.00	0.00	0.00
225	48.000	0.00000E+00	202.25	0.00	0.00	0.00
226	48.125	0.00000E+00	202.25	0.00	0.00	0.00
227	54.875	0.00000E+00	202.25	0.00	0.00	0.00
228	55.000	0.00000E+00	202.25	0.00	0.00	0.00
229	62.875	0.00000E+00	202.25	0.00	0.00	0.00
230	63.000	0.00000E+00	202.25	0.00	0.00	0.00
231	66.000	0.00000E+00	202.25	0.00	0.00	0.00
232	33.875	0.00000E+00	208.12	0.00	0.00	0.00
233	34.000	0.00000E+00	208.12	0.00	0.00	0.00
234	35.875	0.00000E+00	208.12	0.00	0.00	0.00
235	36.000	0.00000E+00	208.12	0.00	0.00	0.00
236	37.875	0.00000E+00	208.12	0.00	0.00	0.00
237	38.000	0.00000E+00	208.12	0.00	0.00	0.00
238	48.000	0.00000E+00	208.12	0.00	0.00	0.00
239	48.125	0.00000E+00	208.12	0.00	0.00	0.00
240	54.875	0.00000E+00	208.12	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
241	55.000	0.00000E+00	208.12	0.00	0.00	0.00
242	62.875	0.00000E+00	208.12	0.00	0.00	0.00
243	63.000	0.00000E+00	208.12	0.00	0.00	0.00
244	66.000	0.00000E+00	208.12	0.00	0.00	0.00
246	19.616	3.9018	0.00000E+00	11.25	0.00	0.00
247	29.424	5.8527	0.00000E+00	11.25	0.00	0.00
248	33.347	6.6331	0.00000E+00	11.25	0.00	0.00
249	35.308	7.0233	0.00000E+00	11.25	0.00	0.00
250	37.270	7.4134	0.00000E+00	11.25	0.00	0.00
251	47.078	9.3643	0.00000E+00	11.25	0.00	0.00
252	53.943	10.730	0.00000E+00	11.25	0.00	0.00
253	61.789	12.291	0.00000E+00	11.25	0.00	0.00
254	64.732	12.876	0.00000E+00	11.25	0.00	0.00
256	19.616	3.9018	0.12500	11.25	0.00	0.00
257	29.424	5.8527	0.12500	11.25	0.00	0.00
258	33.347	6.6331	0.12500	11.25	0.00	0.00
259	35.308	7.0233	0.12500	11.25	0.00	0.00
260	37.147	7.3890	0.12500	11.25	0.00	0.00
261	47.200	9.3887	0.12500	11.25	0.00	0.00
262	53.943	10.730	0.12500	11.25	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
263	61.789	12.291	0.12500	11.25	0.00	0.00
264	64.732	12.876	0.12500	11.25	0.00	0.00
266	19.493	3.8774	13.000	11.25	0.00	0.00
267	19.616	3.9018	13.000	11.25	0.00	0.00
268	29.301	5.8283	13.000	11.25	0.00	0.00
269	29.424	5.8527	13.000	11.25	0.00	0.00
270	33.224	6.6087	13.000	11.25	0.00	0.00
271	33.347	6.6331	13.000	11.25	0.00	0.00
272	35.186	6.9993	13.000	11.25	0.00	0.00

273	35.308	7.0233	13.000	11.25	0.00	0.00
274	37.147	7.3890	13.000	11.25	0.00	0.00
275	37.270	7.4134	13.000	11.25	0.00	0.00
276	47.078	9.3643	13.000	11.25	0.00	0.00
277	47.200	9.3887	13.000	11.25	0.00	0.00
278	53.821	10.706	13.000	11.25	0.00	0.00
279	53.943	10.730	13.000	11.25	0.00	0.00
280	61.667	12.266	13.000	11.25	0.00	0.00
281	61.789	12.291	13.000	11.25	0.00	0.00
282	64.732	12.876	13.000	11.25	0.00	0.00
284	19.493	3.8774	13.125	11.25	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
285	19.616	3.9018	13.125	11.25	0.00	0.00
286	29.301	5.8283	13.125	11.25	0.00	0.00
287	29.424	5.8527	13.125	11.25	0.00	0.00
288	33.224	6.6087	13.125	11.25	0.00	0.00
289	33.347	6.6331	13.125	11.25	0.00	0.00
290	35.186	6.9989	13.125	11.25	0.00	0.00
291	35.308	7.0233	13.125	11.25	0.00	0.00
292	37.147	7.3890	13.125	11.25	0.00	0.00
293	37.270	7.4134	13.125	11.25	0.00	0.00
294	47.078	9.3643	13.125	11.25	0.00	0.00
295	47.200	9.3887	13.125	11.25	0.00	0.00
296	53.821	10.706	13.125	11.25	0.00	0.00
297	53.943	10.730	13.125	11.25	0.00	0.00
298	61.667	12.266	13.125	11.25	0.00	0.00
299	61.789	12.291	13.125	11.25	0.00	0.00
300	64.732	12.876	13.125	11.25	0.00	0.00
302	19.493	3.8774	22.000	11.25	0.00	0.00
303	19.616	3.9018	22.000	11.25	0.00	0.00
304	29.301	5.8283	22.000	11.25	0.00	0.00
305	29.424	5.8527	22.000	11.25	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
306	33.224	6.6087	22.000	11.25	0.00	0.00
307	33.347	6.6331	22.000	11.25	0.00	0.00
308	35.186	6.9989	22.000	11.25	0.00	0.00
309	35.308	7.0233	22.000	11.25	0.00	0.00
310	37.147	7.3890	22.000	11.25	0.00	0.00
311	37.270	7.4134	22.000	11.25	0.00	0.00
312	47.078	9.3643	22.000	11.25	0.00	0.00
313	47.200	9.3887	22.000	11.25	0.00	0.00
314	53.821	10.706	22.000	11.25	0.00	0.00
315	53.943	10.730	22.000	11.25	0.00	0.00
316	61.667	12.266	22.000	11.25	0.00	0.00
317	61.789	12.291	22.000	11.25	0.00	0.00
318	64.732	12.876	22.000	11.25	0.00	0.00
319	33.224	6.6087	22.125	11.25	0.00	0.00
320	33.347	6.6331	22.125	11.25	0.00	0.00
321	35.186	6.9989	22.125	11.25	0.00	0.00
322	35.308	7.0233	22.125	11.25	0.00	0.00
323	37.147	7.3890	22.125	11.25	0.00	0.00
324	37.270	7.4134	22.125	11.25	0.00	0.00
325	47.078	9.3643	22.125	11.25	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
326	47.200	9.3887	22.125	11.25	0.00	0.00
327	53.821	10.706	22.125	11.25	0.00	0.00
328	53.943	10.730	22.125	11.25	0.00	0.00

329	61.667	12.266	22.125	11.25	0.00	0.00
330	61.789	12.291	22.125	11.25	0.00	0.00
331	64.732	12.876	22.125	11.25	0.00	0.00
332	33.224	6.6087	37.125	11.25	0.00	0.00
333	33.347	6.6331	37.125	11.25	0.00	0.00
334	35.186	6.9989	37.125	11.25	0.00	0.00
335	35.308	7.0233	37.125	11.25	0.00	0.00
336	37.147	7.3890	37.125	11.25	0.00	0.00
337	37.270	7.4134	37.125	11.25	0.00	0.00
338	47.078	9.3643	37.125	11.25	0.00	0.00
339	47.200	9.3887	37.125	11.25	0.00	0.00
340	53.821	10.706	37.125	11.25	0.00	0.00
341	53.943	10.730	37.125	11.25	0.00	0.00
342	61.667	12.266	37.125	11.25	0.00	0.00
343	61.789	12.291	37.125	11.25	0.00	0.00
344	64.732	12.876	37.125	11.25	0.00	0.00
345	35.186	6.9989	37.250	11.25	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
346	35.308	7.0233	37.250	11.25	0.00	0.00
347	37.147	7.3890	37.250	11.25	0.00	0.00
348	37.270	7.4134	37.250	11.25	0.00	0.00
349	47.078	9.3643	37.250	11.25	0.00	0.00
350	47.200	9.3887	37.250	11.25	0.00	0.00
351	53.821	10.706	37.250	11.25	0.00	0.00
352	53.943	10.730	37.250	11.25	0.00	0.00
353	61.667	12.266	37.250	11.25	0.00	0.00
354	61.789	12.291	37.250	11.25	0.00	0.00
355	64.732	12.876	37.250	11.25	0.00	0.00
356	33.224	6.6087	62.125	11.25	0.00	0.00
357	33.347	6.6331	62.125	11.25	0.00	0.00
358	35.186	6.9989	62.125	11.25	0.00	0.00
359	35.308	7.0233	62.125	11.25	0.00	0.00
360	37.147	7.3890	62.125	11.25	0.00	0.00
361	37.270	7.4134	62.125	11.25	0.00	0.00
362	47.078	9.3643	62.125	11.25	0.00	0.00
363	47.200	9.3887	62.125	11.25	0.00	0.00
364	53.821	10.706	62.125	11.25	0.00	0.00
365	53.943	10.730	62.125	11.25	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
366	61.667	12.266	62.125	11.25	0.00	0.00
367	61.789	12.291	62.125	11.25	0.00	0.00
368	64.732	12.876	62.125	11.25	0.00	0.00
369	35.186	6.9989	62.250	11.25	0.00	0.00
370	35.308	7.0233	62.250	11.25	0.00	0.00
371	37.147	7.3890	62.250	11.25	0.00	0.00
372	37.270	7.4134	62.250	11.25	0.00	0.00
373	47.078	9.3643	62.250	11.25	0.00	0.00
374	47.200	9.3887	62.250	11.25	0.00	0.00
375	53.821	10.706	62.250	11.25	0.00	0.00
376	53.943	10.730	62.250	11.25	0.00	0.00
377	61.667	12.266	62.250	11.25	0.00	0.00
378	61.789	12.291	62.250	11.25	0.00	0.00
379	64.732	12.876	62.250	11.25	0.00	0.00
380	33.224	6.6087	112.12	11.25	0.00	0.00
381	33.347	6.6331	112.12	11.25	0.00	0.00
382	35.186	6.9989	112.12	11.25	0.00	0.00
383	35.308	7.0233	112.12	11.25	0.00	0.00
384	37.147	7.3890	112.12	11.25	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
385	37.270	7.4134	112.12	11.25	0.00	0.00
386	47.078	9.3643	112.12	11.25	0.00	0.00
387	47.200	9.3887	112.12	11.25	0.00	0.00
388	53.821	10.706	112.12	11.25	0.00	0.00
389	53.943	10.730	112.12	11.25	0.00	0.00
390	61.667	12.266	112.12	11.25	0.00	0.00
391	61.789	12.291	112.12	11.25	0.00	0.00
392	64.732	12.876	112.12	11.25	0.00	0.00
393	35.186	6.9989	112.25	11.25	0.00	0.00
394	35.308	7.0233	112.25	11.25	0.00	0.00
395	37.147	7.3890	112.25	11.25	0.00	0.00
396	37.270	7.4134	112.25	11.25	0.00	0.00
397	47.078	9.3643	112.25	11.25	0.00	0.00
398	47.200	9.3887	112.25	11.25	0.00	0.00
399	53.821	10.706	112.25	11.25	0.00	0.00
400	53.943	10.730	112.25	11.25	0.00	0.00
401	61.667	12.266	112.25	11.25	0.00	0.00
402	61.789	12.291	112.25	11.25	0.00	0.00
403	64.732	12.876	112.25	11.25	0.00	0.00
404	33.224	6.6087	162.12	11.25	0.00	0.00
405	33.347	6.6331	162.12	11.25	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
406	35.186	6.9989	162.12	11.25	0.00	0.00
407	35.308	7.0233	162.12	11.25	0.00	0.00
408	37.147	7.3890	162.12	11.25	0.00	0.00
409	37.270	7.4134	162.12	11.25	0.00	0.00
410	47.078	9.3643	162.12	11.25	0.00	0.00
411	47.200	9.3887	162.12	11.25	0.00	0.00
412	53.821	10.706	162.12	11.25	0.00	0.00
413	53.943	10.730	162.12	11.25	0.00	0.00
414	61.667	12.266	162.12	11.25	0.00	0.00
415	61.789	12.291	162.12	11.25	0.00	0.00
416	64.732	12.876	162.12	11.25	0.00	0.00
417	35.186	6.9989	162.25	11.25	0.00	0.00
418	35.308	7.0233	162.25	11.25	0.00	0.00
419	37.147	7.3890	162.25	11.25	0.00	0.00
420	37.270	7.4134	162.25	11.25	0.00	0.00
421	47.078	9.3643	162.25	11.25	0.00	0.00
422	47.200	9.3887	162.25	11.25	0.00	0.00
423	53.821	10.706	162.25	11.25	0.00	0.00
424	53.943	10.730	162.25	11.25	0.00	0.00
425	61.667	12.266	162.25	11.25	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
426	61.789	12.291	162.25	11.25	0.00	0.00
427	64.732	12.876	162.25	11.25	0.00	0.00
428	33.224	6.6087	187.12	11.25	0.00	0.00
429	33.347	6.6331	187.12	11.25	0.00	0.00
430	35.186	6.9989	187.12	11.25	0.00	0.00
431	35.308	7.0233	187.12	11.25	0.00	0.00
432	37.147	7.3890	187.12	11.25	0.00	0.00
433	37.270	7.4134	187.12	11.25	0.00	0.00
434	47.078	9.3643	187.12	11.25	0.00	0.00
435	47.200	9.3887	187.12	11.25	0.00	0.00
436	53.821	10.706	187.12	11.25	0.00	0.00
437	53.943	10.730	187.12	11.25	0.00	0.00
433	61.667	12.266	187.12	11.25	0.00	0.00

439	61.789	12.291	187.12	11.25	0.00	0.00
440	64.732	12.876	187.12	11.25	0.00	0.00
441	35.186	6.9989	187.25	11.25	0.00	0.00
442	35.308	7.0233	187.25	11.25	0.00	0.00
443	37.147	7.3890	187.25	11.25	0.00	0.00
444	37.270	7.4134	187.25	11.25	0.00	0.00
445	47.078	9.3643	187.25	11.25	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
446	47.200	9.3887	187.25	11.25	0.00	0.00
447	53.821	10.706	187.25	11.25	0.00	0.00
448	53.943	10.730	187.25	11.25	0.00	0.00
449	61.667	12.266	187.25	11.25	0.00	0.00
450	61.789	12.291	187.25	11.25	0.00	0.00
451	64.732	12.876	187.25	11.25	0.00	0.00
452	33.224	6.6087	202.12	11.25	0.00	0.00
453	33.347	6.6331	202.12	11.25	0.00	0.00
454	35.186	6.9989	202.12	11.25	0.00	0.00
455	35.308	7.0233	202.12	11.25	0.00	0.00
456	37.147	7.3890	202.12	11.25	0.00	0.00
457	37.270	7.4134	202.12	11.25	0.00	0.00
458	47.078	9.3643	202.12	11.25	0.00	0.00
459	47.200	9.3887	202.12	11.25	0.00	0.00
460	53.821	10.706	202.12	11.25	0.00	0.00
461	53.943	10.730	202.12	11.25	0.00	0.00
462	61.667	12.266	202.12	11.25	0.00	0.00
463	61.789	12.291	202.12	11.25	0.00	0.00
464	64.732	12.876	202.12	11.25	0.00	0.00
465	35.186	6.9989	202.25	11.25	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
466	35.308	7.0233	202.25	11.25	0.00	0.00
467	37.147	7.3890	202.25	11.25	0.00	0.00
468	37.270	7.4134	202.25	11.25	0.00	0.00
469	47.078	9.3643	202.25	11.25	0.00	0.00
470	47.200	9.3887	202.25	11.25	0.00	0.00
471	53.821	10.706	202.25	11.25	0.00	0.00
472	53.943	10.730	202.25	11.25	0.00	0.00
473	61.667	12.266	202.25	11.25	0.00	0.00
474	61.789	12.291	202.25	11.25	0.00	0.00
475	64.732	12.876	202.25	11.25	0.00	0.00
476	33.224	6.6087	208.12	11.25	0.00	0.00
477	33.347	6.6331	208.12	11.25	0.00	0.00
478	35.186	6.9989	208.12	11.25	0.00	0.00
479	35.308	7.0233	208.12	11.25	0.00	0.00
480	37.147	7.3890	208.12	11.25	0.00	0.00
481	37.270	7.4134	208.12	11.25	0.00	0.00
482	47.078	9.3643	208.12	11.25	0.00	0.00
483	47.200	9.3887	208.12	11.25	0.00	0.00
484	53.821	10.706	208.12	11.25	0.00	0.00
485	53.943	10.730	208.12	11.25	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
486	61.667	12.266	208.12	11.25	0.00	0.00
487	61.789	12.291	208.12	11.25	0.00	0.00
488	64.732	12.876	208.12	11.25	0.00	0.00
489	19.999	-0.17453	13.000	-0.50	0.00	0.00
490	29.999	-0.26180	13.000	-0.50	0.00	0.00
491	33.999	-0.29670	13.000	-0.50	0.00	0.00
492	35.999	-0.31416	13.000	-0.50	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
493	54.998	-0.47996	13.000	-0.50	0.00	0.00
494	62.998	-0.54977	13.000	-0.50	0.00	0.00
495	65.997	-0.57595	13.000	-0.50	0.00	0.00
496	19.999	-0.17453	22.000	-0.50	0.00	0.00
497	29.999	-0.26180	22.000	-0.50	0.00	0.00
498	33.999	-0.29670	22.000	-0.50	0.00	0.00
499	35.999	-0.31416	22.000	-0.50	0.00	0.00
500	37.999	-0.33161	22.000	-0.50	0.00	0.00
501	47.998	-0.41887	22.000	-0.50	0.00	0.00
502	54.998	-0.47996	22.000	-0.50	0.00	0.00
503	62.998	-0.54977	22.000	-0.50	0.00	0.00
504	65.997	-0.57595	22.000	-0.50	0.00	0.00
505	35.999	-0.31416	37.125	-0.50	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
506	37.999	-0.33161	37.125	-0.50	0.00	0.00
507	47.998	-0.41887	37.125	-0.50	0.00	0.00
508	54.998	-0.47996	37.125	-0.50	0.00	0.00
509	62.998	-0.54977	37.125	-0.50	0.00	0.00
510	65.997	-0.57595	37.125	-0.50	0.00	0.00
511	35.999	-0.31416	62.125	-0.50	0.00	0.00
512	37.999	-0.33161	62.125	-0.50	0.00	0.00
513	47.998	-0.41887	62.125	-0.50	0.00	0.00
514	54.998	-0.47996	62.125	-0.50	0.00	0.00
515	62.998	-0.54977	62.125	-0.50	0.00	0.00
516	65.997	-0.57595	62.125	-0.50	0.00	0.00
517	35.999	-0.31416	112.12	-0.50	0.00	0.00
518	37.999	-0.33161	112.12	-0.50	0.00	0.00
519	47.998	-0.41887	112.12	-0.50	0.00	0.00
520	54.998	-0.47996	112.12	-0.50	0.00	0.00
521	62.998	-0.54977	112.12	-0.50	0.00	0.00
522	65.997	-0.57595	112.12	-0.50	0.00	0.00
523	35.999	-0.31416	162.12	-0.50	0.00	0.00
524	37.999	-0.33161	162.12	-0.50	0.00	0.00
525	47.998	-0.41887	162.12	-0.50	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
526	54.998	-0.47996	162.12	-0.50	0.00	0.00
527	62.998	-0.54977	162.12	-0.50	0.00	0.00
528	65.997	-0.57595	162.12	-0.50	0.00	0.00
529	35.999	-0.31416	187.12	-0.50	0.00	0.00
530	37.999	-0.33161	187.12	-0.50	0.00	0.00
531	47.998	-0.41887	187.12	-0.50	0.00	0.00
532	54.998	-0.47996	187.12	-0.50	0.00	0.00
533	62.998	-0.54977	187.12	-0.50	0.00	0.00
534	65.997	-0.57595	187.12	-0.50	0.00	0.00
535	35.999	-0.31416	202.12	-0.50	0.00	0.00
536	37.999	-0.33161	202.12	-0.50	0.00	0.00
537	47.998	-0.41887	202.12	-0.50	0.00	0.00
538	54.998	-0.47996	202.12	-0.50	0.00	0.00
539	62.998	-0.54977	202.12	-0.50	0.00	0.00
540	65.997	-0.57595	202.12	-0.50	0.00	0.00
541	35.999	-0.31416	208.12	-0.50	0.00	0.00
542	37.999	-0.33161	208.12	-0.50	0.00	0.00
543	47.998	-0.41887	208.12	-0.50	0.00	0.00
544	54.998	-0.47996	208.12	-0.50	0.00	0.00
545	62.998	-0.54977	208.12	-0.50	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
546	65.997	-0.57595	208.12	-0.50	0.00	0.00

547	19.581	4.0728	13.000	11.75	0.00	0.00
548	29.371	6.1093	13.000	11.75	0.00	0.00
549	33.288	6.9238	13.000	11.75	0.00	0.00
550	35.246	7.3311	13.000	11.75	0.00	0.00
551	53.848	11.200	13.000	11.75	0.00	0.00
552	61.680	12.829	13.000	11.75	0.00	0.00
553	64.617	13.440	13.000	11.75	0.00	0.00
554	19.581	4.0728	22.000	11.75	0.00	0.00
555	29.371	6.1093	22.000	11.75	0.00	0.00
556	33.288	6.9238	22.000	11.75	0.00	0.00
557	35.246	7.3311	22.000	11.75	0.00	0.00
558	37.204	7.7384	22.000	11.75	0.00	0.00
559	46.994	9.7748	22.000	11.75	0.00	0.00
560	53.848	11.200	22.000	11.75	0.00	0.00
561	61.680	12.829	22.000	11.75	0.00	0.00
562	64.617	13.440	22.000	11.75	0.00	0.00
563	35.246	7.3311	37.125	11.75	0.00	0.00
564	37.204	7.7384	37.125	11.75	0.00	0.00
565	46.994	9.7748	37.125	11.75	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
566	53.848	11.200	37.125	11.75	0.00	0.00
567	61.680	12.829	37.125	11.75	0.00	0.00
568	64.617	13.440	37.125	11.75	0.00	0.00
569	35.246	7.3311	62.125	11.75	0.00	0.00
570	37.204	7.7384	62.125	11.75	0.00	0.00
571	46.994	9.7748	62.125	11.75	0.00	0.00
572	53.848	11.200	62.125	11.75	0.00	0.00
573	61.680	12.829	62.125	11.75	0.00	0.00
574	64.617	13.440	62.125	11.75	0.00	0.00
575	35.246	7.3311	112.12	11.75	0.00	0.00
576	37.204	7.7384	112.12	11.75	0.00	0.00
577	46.994	9.7748	112.12	11.75	0.00	0.00
578	53.848	11.200	112.12	11.75	0.00	0.00
579	61.680	12.829	112.12	11.75	0.00	0.00
580	64.617	13.440	112.12	11.75	0.00	0.00
581	35.246	7.3311	162.12	11.75	0.00	0.00
582	37.204	7.7384	162.12	11.75	0.00	0.00
583	46.994	9.7748	162.12	11.75	0.00	0.00
584	53.848	11.200	162.12	11.75	0.00	0.00
585	61.680	12.829	162.12	11.75	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
586	64.617	13.440	162.12	11.75	0.00	0.00
587	35.246	7.3311	187.12	11.75	0.00	0.00
588	37.204	7.7384	187.12	11.75	0.00	0.00
589	46.994	9.7748	187.12	11.75	0.00	0.00
590	53.848	11.200	187.12	11.75	0.00	0.00
591	61.680	12.829	187.12	11.75	0.00	0.00
592	64.617	13.440	187.12	11.75	0.00	0.00
593	35.246	7.3311	202.12	11.75	0.00	0.00
594	37.204	7.7384	202.12	11.75	0.00	0.00
595	46.994	9.7748	202.12	11.75	0.00	0.00
596	53.848	11.200	202.12	11.75	0.00	0.00
597	61.680	12.829	202.12	11.75	0.00	0.00
598	64.617	13.440	202.12	11.75	0.00	0.00
599	35.246	7.3311	208.12	11.75	0.00	0.00
600	37.204	7.7384	208.12	11.75	0.00	0.00
601	46.994	9.7748	208.12	11.75	0.00	0.00
602	53.848	11.200	208.12	11.75	0.00	0.00

603	61.680	12.829	208.12	11.75	0.00	0.00
604	64.617	13.440	208.12	11.75	0.00	0.00
605	0.00000E+00	0.00000E+00	208.13	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
606	6.0000	0.00000E+00	208.13	0.00	0.00	0.00
607	18.000	0.00000E+00	208.13	0.00	0.00	0.00
608	36.000	0.00000E+00	208.13	0.00	0.00	0.00
609	38.000	0.00000E+00	208.13	0.00	0.00	0.00
610	48.125	0.00000E+00	208.13	0.00	0.00	0.00
611	5.8847	1.1705	208.13	11.25	0.00	0.00
612	17.654	3.5116	208.13	11.25	0.00	0.00
613	35.308	7.0233	208.13	11.25	0.00	0.00
614	37.270	7.4134	208.13	11.25	0.00	0.00
615	47.200	9.3887	208.13	11.25	0.00	0.00

LIST ALL ELEMENT TYPES

NO.	STIF	KEYOPT VALUES									INOTPR	
1	45	0	0	0	0	0	0	0	0	0	0	ISOPAR. STRESS SOLID, 3-D
2	63	0	0	0	0	0	0	0	0	0	0	QUAD. FLAT SHELL
3	8	0	0	0	0	0	0	0	0	0	0	SPAR, 3-D
4	52	0	0	1	0	0	0	0	0	0	0	INTERFACE ELEM. 3-D

LIST ALL SELECTED ELEMENTS. (LIST NODES)

ELEM	MAT	TYP	REL	NODES							
1	2	2	2	2	246	1	1				
2	2	2	2	3	247	246	2				
3	2	2	2	4	248	247	3				
4	2	2	2	5	249	248	4				
5	2	2	2	6	250	249	5				
6	2	2	2	31	275	250	6				
7	2	2	2	32	276	275	31				
8	2	2	2	7	251	276	32				
9	2	2	2	8	252	251	7				
10	2	2	2	9	253	252	8				
11	2	2	2	10	254	253	9				
12	1	1	1	12	256	11	11	22	266	21	21
13	1	1	1	13	257	256	12	24	268	267	23
14	1	1	1	14	258	257	13	26	270	269	25
15	1	1	1	15	259	258	14	28	272	271	27
16	1	1	1	16	260	259	15	30	274	273	29
17	1	1	1	18	262	261	17	34	278	277	33
18	1	1	1	19	263	262	18	36	280	279	35
19	1	1	1	20	264	263	19	38	282	281	37
20	1	1	1	40	284	39	39	58	302	57	57

ELEM	MAT	TYP	REL	NODES							
21	1	1	1	42	286	285	41	60	304	303	59
22	1	1	1	44	288	287	43	62	306	305	61
23	1	1	1	46	290	289	45	64	308	307	63
24	1	1	1	48	292	291	47	66	310	309	65
25	1	1	1	50	294	293	49	68	312	311	67
26	1	1	1	52	296	295	51	70	314	313	69
27	1	1	1	54	298	297	53	72	316	315	71
28	1	1	1	56	300	299	55	74	318	317	73
29	2	2	3	[illegible]	[illegible]	319	75				

30	2	2	3	112	356	332	88				
31	2	2	3	136	380	356	112				
32	2	2	3	160	404	380	136				
33	2	2	3	184	428	404	160				
34	2	2	3	208	452	428	184				
35	2	2	3	232	476	452	208				
36	1	1	1	77	321	320	76	90	334	333	89
37	1	1	1	79	323	322	78	92	336	335	91
38	1	1	1	81	325	324	80	94	338	337	93
39	1	1	1	83	327	326	82	96	340	339	95
40	1	1	1	85	329	328	84	98	342	341	97

ELEM	MAT	TYP	REL	NODES							
41	1	1	1	87	331	330	86	100	344	343	99
42	1	1	1	101	345	333	89	114	358	357	113
43	1	1	1	103	347	346	102	116	360	359	115
44	1	1	1	105	349	348	104	118	362	361	117
45	1	1	1	107	351	350	106	120	364	363	119
46	1	1	1	109	353	352	108	122	366	365	121
47	1	1	1	111	355	354	110	124	368	367	123
48	1	1	1	125	369	357	113	138	382	381	137
49	1	1	1	127	371	370	126	140	384	383	139
50	1	1	1	129	373	372	128	142	386	385	141
51	1	1	1	131	375	374	130	144	388	387	143
52	1	1	1	133	377	376	132	146	390	389	145
53	1	1	1	135	379	378	134	148	392	391	147
54	1	1	1	149	393	381	137	162	406	405	161
55	1	1	1	151	395	394	150	164	408	407	163
56	1	1	1	153	397	396	152	166	410	409	165
57	1	1	1	155	399	398	154	168	412	411	167
58	1	1	1	157	401	400	156	170	414	413	169
59	1	1	1	159	403	402	158	172	416	415	171
60	1	1	1	173	417	405	161	186	430	429	185

ELEM	MAT	TYP	REL	NODES							
61	1	1	1	175	419	418	174	188	432	431	187
62	1	1	1	177	421	420	176	190	434	433	189
63	1	1	1	179	423	422	178	192	436	435	191
64	1	1	1	181	425	424	180	194	438	437	193
65	1	1	1	183	427	426	182	196	440	439	195
66	1	1	1	197	441	429	185	210	454	453	209
67	1	1	1	199	443	442	198	212	456	455	211
68	1	1	1	201	445	444	200	214	458	457	213
69	1	1	1	203	447	446	202	216	460	459	215
70	1	1	1	205	449	448	204	218	462	461	217
71	1	1	1	207	451	450	206	220	464	463	219
72	1	1	1	221	465	453	209	234	478	477	233
73	1	1	1	223	467	466	222	236	480	479	235
74	1	1	1	225	469	468	224	238	482	481	237
75	1	1	1	227	471	470	226	240	484	483	239
76	1	1	1	229	473	472	228	242	486	485	241
77	1	1	1	231	475	474	230	244	488	487	243
78	2	3	4	34	83						
79	2	3	4	278	327						
80	2	3	4	34	37						

ELEM MAT TYP REL NODES

81	2	3	4	37	73
82	2	3	4	73	99
83	2	3	4	99	123
84	2	3	4	123	147
85	2	3	4	147	171
86	2	3	4	171	195
87	2	3	4	195	230
88	2	3	4	230	227
89	2	3	4	227	192
90	2	3	4	278	281
91	2	3	4	281	317
92	2	3	4	317	343
93	2	3	4	343	367
94	2	3	4	367	391
95	2	3	4	391	415
96	2	3	4	415	439
97	2	3	4	439	474
98	2	3	4	474	471
99	2	3	4	471	436
100	2	3	5	502	560

ELEM	MAT	TYP	REL	NODES	
101	2	3	5	532	590
102	2	3	6	493	551
103	2	3	6	538	596
104	2	3	7	494	552
105	2	3	7	539	597
106	2	3	8	503	561
107	2	3	9	509	567
108	2	3	10	515	573
109	2	3	11	521	579
110	2	3	12	527	585
111	2	3	13	533	591
112	3	4	14	22	23
113	3	4	14	24	25
114	3	4	14	26	27
115	3	4	14	28	29
116	3	4	14	34	35
117	3	4	14	36	37
118	3	4	14	58	59
119	3	4	14	60	61
120	3	4	14	62	63

ELEM	MAT	TYP	REL	NODES	
121	3	4	14	64	65
122	3	4	14	66	67
123	3	4	14	68	69
124	3	4	14	70	71
125	3	4	14	72	73
126	3	4	14	90	91
127	3	4	14	92	93
128	3	4	14	94	95
129	3	4	14	96	97
130	3	4	14	98	99
131	3	4	14	114	115
132	3	4	14	116	117
133	3	4	14	118	119
134	3	4	14	120	121

135	3	4	14	122	123
136	3	4	14	138	139
137	3	4	14	140	141
138	3	4	14	142	143
139	3	4	14	144	145
140	3	4	14	146	147

ELEM	MAT	TYP	REL		NODES
141	3	4	14	162	163
142	3	4	14	164	165
143	3	4	14	166	167
144	3	4	14	168	169
145	3	4	14	170	171
146	3	4	14	186	187
147	3	4	14	188	189
148	3	4	14	190	191
149	3	4	14	192	193
150	3	4	14	194	195
151	3	4	14	210	211
152	3	4	14	212	213
153	3	4	14	214	215
154	3	4	14	216	217
155	3	4	14	218	219
156	3	4	14	234	235
157	3	4	14	236	237
158	3	4	14	238	239
159	3	4	14	240	241
160	3	4	14	242	243

ELEM	MAT	TYP	REL		NODES
161	3	4	14	266	267
162	3	4	14	268	269
163	3	4	14	270	271
164	3	4	14	272	273
165	3	4	14	278	279
166	3	4	14	280	281
167	3	4	14	302	303
168	3	4	14	304	305
169	3	4	14	306	307
170	3	4	14	308	309
171	3	4	14	310	311
172	3	4	14	312	313
173	3	4	14	314	315
174	3	4	14	316	317
175	3	4	14	334	335
176	3	4	14	336	337
177	3	4	14	338	339
178	3	4	14	340	341
179	3	4	14	342	343
180	3	4	14	358	359

ELEM	MAT	TYP	REL		NODES
181	3	4	14	360	361
182	3	4	14	362	363
183	3	4	14	364	365
184	3	4	14	366	367
185	3	4	14	382	383

186	3	4	14	384	385
187	3	4	14	386	387
188	3	4	14	388	389
189	3	4	14	390	391
190	3	4	14	406	407
191	3	4	14	408	409
192	3	4	14	410	411
193	3	4	14	412	413
194	3	4	14	414	415
195	3	4	14	430	431
196	3	4	14	432	433
197	3	4	14	434	435
198	3	4	14	436	437
199	3	4	14	438	439
200	3	4	14	454	455

ELEM	MAT	TYP	REL	NODES	
201	3	4	14	456	457
202	3	4	14	458	459
203	3	4	14	460	461
204	3	4	14	462	463
205	3	4	14	478	479
206	3	4	14	480	481
207	3	4	14	482	483
208	3	4	14	484	485
209	3	4	14	486	487
210	3	4	14	489	23
211	3	4	14	490	25
212	3	4	14	491	27
213	3	4	14	492	29
214	3	4	14	493	35
215	3	4	14	494	37
216	3	4	14	495	38
217	3	4	14	496	59
218	3	4	14	497	61
219	3	4	14	498	63
220	3	4	14	499	65

ELEM	MAT	TYP	REL	NODES	
221	3	4	14	500	67
222	3	4	14	501	68
223	3	4	14	502	71
224	3	4	14	503	73
225	3	4	14	504	74
226	3	4	14	505	91
227	3	4	14	506	93
228	3	4	14	507	94
229	3	4	14	508	97
230	3	4	14	509	99
231	3	4	14	510	100
232	3	4	14	511	115
233	3	4	14	512	117
234	3	4	14	513	118
235	3	4	14	514	121
236	3	4	14	515	123
237	3	4	14	516	124
238	3	4	14	517	139
239	3	4	14	518	141

240	3	4	14	519	142

ELEM	MAT	TYP	REL	NODES	
241	3	4	14	520	145
242	3	4	14	521	147
243	3	4	14	522	148
244	3	4	14	523	163
245	3	4	14	524	165
246	3	4	14	525	166
247	3	4	14	526	169
248	3	4	14	527	171
249	3	4	14	528	172
250	3	4	14	529	187
251	3	4	14	530	189
252	3	4	14	531	190
253	3	4	14	532	193
254	3	4	14	533	195
255	3	4	14	534	196
256	3	4	14	535	211
257	3	4	14	536	213
258	3	4	14	537	214
259	3	4	14	538	217
260	3	4	14	539	219

ELEM	MAT	TYP	REL	NODES	
261	3	4	14	540	220
262	3	4	14	541	235
263	3	4	14	542	237
264	3	4	14	543	238
265	3	4	14	544	241
266	3	4	14	545	243
267	3	4	14	546	244
268	3	4	14	267	547
269	3	4	14	269	548
270	3	4	14	271	549
271	3	4	14	273	550
272	3	4	14	279	551
273	3	4	14	281	552
274	3	4	14	282	553
275	3	4	14	303	554
276	3	4	14	305	555
277	3	4	14	307	556
278	3	4	14	309	557
279	3	4	14	311	558
280	3	4	14	312	559

ELEM	MAT	TYP	REL	NODES	
281	3	4	14	315	560
282	3	4	14	317	561
283	3	4	14	318	562
284	3	4	14	335	563
285	3	4	14	337	564
286	3	4	14	338	565
287	3	4	14	341	566
288	3	4	14	343	567
289	3	4	14	344	568
290	3	4	14	359	569

291	3	4	14	361	570
292	3	4	14	362	571
293	3	4	14	365	572
294	3	4	14	367	573
295	3	4	14	368	574
296	3	4	14	383	575
297	3	4	14	385	576
298	3	4	14	386	577
299	3	4	14	389	578
300	3	4	14	391	579

ELEM	MAT	TYP	REL	NODES	
301	3	4	14	392	580
302	3	4	14	407	581
303	3	4	14	409	582
304	3	4	14	410	583
305	3	4	14	413	584
306	3	4	14	415	585
307	3	4	14	416	586
308	3	4	14	431	587
309	3	4	14	433	588
310	3	4	14	434	589
311	3	4	14	437	590
312	3	4	14	439	591
313	3	4	14	440	592
314	3	4	14	455	593
315	3	4	14	457	594
316	3	4	14	458	595
317	3	4	14	461	596
318	3	4	14	463	597
319	3	4	14	464	598
320	3	4	14	479	599

ELEM	MAT	TYP	REL	NODES	
321	3	4	14	481	600
322	3	4	14	482	601
323	3	4	14	485	602
324	3	4	14	487	603
325	3	4	14	488	604
326	3	4	14	21	39
327	3	4	14	23	41
328	3	4	14	25	43
329	3	4	14	27	45
330	3	4	14	29	47
331	3	4	14	35	53
332	3	4	14	37	55
333	3	4	14	38	56
334	3	4	14	63	76
335	3	4	14	65	78
336	3	4	14	67	80
337	3	4	14	69	82
338	3	4	14	71	84
339	3	4	14	73	86
340	3	4	14	74	87

ELEM	MAT	TYP	REL	NODES	
341	3	4	14	91	102

342	3	4	14	93	104
343	3	4	14	95	106
344	3	4	14	97	108
345	3	4	14	99	110
346	3	4	14	100	111
347	3	4	14	115	126
348	3	4	14	117	128
349	3	4	14	119	130
350	3	4	14	121	132
351	3	4	14	123	134
352	3	4	14	124	135
353	3	4	14	139	150
354	3	4	14	141	152
355	3	4	14	143	154
356	3	4	14	145	156
357	3	4	14	147	158
358	3	4	14	148	159
359	3	4	14	163	174
360	3	4	14	165	176

ELEM	MAT	TYP	REL	NODES	
361	3	4	14	167	178
362	3	4	14	169	180
363	3	4	14	171	182
364	3	4	14	172	183
365	3	4	14	187	198
366	3	4	14	189	200
367	3	4	14	191	202
368	3	4	14	193	204
369	3	4	14	195	206
370	3	4	14	196	207
371	3	4	14	211	222
372	3	4	14	213	224
373	3	4	14	215	226
374	3	4	14	217	228
375	3	4	14	219	230
376	3	4	14	220	231
378	3	4	14	267	285
379	3	4	14	269	287
380	3	4	14	271	289
381	3	4	14	273	291

ELEM	MAT	TYP	REL	NODES	
382	3	4	14	279	297
383	3	4	14	281	299
384	3	4	14	282	300
385	3	4	14	307	320
386	3	4	14	309	322
387	3	4	14	311	324
388	3	4	14	313	326
389	3	4	14	315	328
390	3	4	14	317	330
391	3	4	14	318	331
392	3	4	14	335	346
393	3	4	14	337	348
394	3	4	14	339	350
395	3	4	14	341	352
396	3	4	14	343	354

397	3	4	14	344	355		
398	3	4	14	359	370		
399	3	4	14	361	372		
400	3	4	14	363	374		
401	3	4	14	365	376		

ELEM	MAT	TYP	REL	NODES			
402	3	4	14	367	378		
403	3	4	14	368	379		
404	3	4	14	383	394		
405	3	4	14	385	396		
406	3	4	14	387	398		
407	3	4	14	389	400		
408	3	4	14	391	402		
409	3	4	14	392	403		
410	3	4	14	407	418		
411	3	4	14	409	420		
412	3	4	14	411	422		
413	3	4	14	413	424		
414	3	4	14	415	426		
415	3	4	14	416	427		
416	3	4	14	431	442		
417	3	4	14	433	444		
418	3	4	14	435	446		
419	3	4	14	437	448		
420	3	4	14	439	450		
421	3	4	14	440	451		

ELEM	MAT	TYP	REL	NODES			
422	3	4	14	455	466		
423	3	4	14	457	468		
424	3	4	14	459	470		
425	3	4	14	461	472		
426	3	4	14	463	474		
427	3	4	14	464	475		
428	2	2	15	606	611	605	605
429	2	2	15	607	612	611	606
430	2	2	15	232	476	612	607
431	2	2	15	608	613	476	232
432	2	2	15	609	614	613	608
433	2	2	15	610	615	614	609

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A21 of A79

LIST ALL REAL SETS

REAL CONSTANT SET 2 ITEMS 1 TO 6
0.25000 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

REAL CONSTANT SET 3 ITEMS 1 TO 6
2.0000 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

REAL CONSTANT SET 4 ITEMS 1 TO 6
0.44000 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

EAL CONSTANT SET 5 ITEMS 1 TO 6
0.44000 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

REAL CONSTANT SET 6 ITEMS 1 TO 6
0.44000 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

```
 REAL CONSTANT SET    7   ITEMS    1 TO    6
  0.77000       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET    8   ITEMS    1 TO    6
  0.88000       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET    9   ITEMS    1 TO    6
   1.5000       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET   10   ITEMS    1 TO    6
   2.7500       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET   11   ITEMS    1 TO    6
   3.7000       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET   12   ITEMS    1 TO    6
   2.7500       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET   13   ITEMS    1 TO    6
   1.1400       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET   14   ITEMS    1 TO    6
  0.20000E+07   0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

 REAL CONSTANT SET   15   ITEMS    1 TO    6
  0.75000       0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00

LIST ALL MATERIALS   PROPERTY= ALL

PROPERTY TABLE EX     MAT=    1  NUM. POINTS=  3
      TEMPERATURE        DATA          TEMPERATURE       DATA
     70.000        3640.0        100.00        3640.0
     200.00        3280.0

PROPERTY TABLE ALPX   MAT=    1  NUM. POINTS=  3
      TEMPERATURE        DATA          TEMPERATURE       DATA
     70.000      0.55000E-05   100.00      0.55000E-05
     200.00      0.55000E-05

PROPERTY TABLE EX     MAT=    2  NUM. POINTS=  3
      TEMPERATURE        DATA          TEMPERATURE       DATA
     70.000        29500.        100.00        29500.
     200.00        28800.

PROPERTY TABLE ALPX   MAT=    2  NUM. POINTS=  3
      TEMPERATURE        DATA          TEMPERATURE       DATA
     70.000      0.55300E-05   100.00      0.55300E-05
     200.00      0.58900E-05

LIST DISPLACEMENTS FOR ALL SELECTED NODES

 NODE  LABEL       DISP             CDISP
     1 UZ     0.000000000E+00 0.000000000E+00
     2 UZ     0.000000000E+00 0.000000000E+00
     3 UZ     0.000000000E+00 0.000000000E+00
     4 UZ     0.000000000E+00 0.000000000E+00
     5 UZ     0.000000000E+00 0.000000000E+00
     6 UZ     0.000000000E+00 0.000000000E+00
     7 UZ     0.000000000E+00 0.000000000E+00
```

8	UZ	0.000000000E+00	0.000000000E+00
9	UZ	0.000000000E+00	0.000000000E+00
10	UZ	0.000000000E+00	0.000000000E+00
246	UZ	0.000000000E+00	0.000000000E+00
247	UZ	0.000000000E+00	0.000000000E+00
248	UZ	0.000000000E+00	0.000000000E+00
249	UZ	0.000000000E+00	0.000000000E+00
250	UZ	0.000000000E+00	0.000000000E+00
251	UZ	0.000000000E+00	0.000000000E+00
252	UZ	0.000000000E+00	0.000000000E+00
253	UZ	0.000000000E+00	0.000000000E+00
254	UZ	0.000000000E+00	0.000000000E+00
489	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
490	UY	0.000000000E+00	0.000000000E+00
491	UY	0.000000000E+00	0.000000000E+00
492	UY	0.000000000E+00	0.000000000E+00
493	UY	0.000000000E+00	0.000000000E+00
494	UY	0.000000000E+00	0.000000000E+00
495	UY	0.000000000E+00	0.000000000E+00
496	UY	0.000000000E+00	0.000000000E+00
497	UY	0.000000000E+00	0.000000000E+00
498	UY	0.000000000E+00	0.000000000E+00
499	UY	0.000000000E+00	0.000000000E+00
500	UY	0.000000000E+00	0.000000000E+00
501	UY	0.000000000E+00	0.000000000E+00
502	UY	0.000000000E+00	0.000000000E+00
503	UY	0.000000000E+00	0.000000000E+00
504	UY	0.000000000E+00	0.000000000E+00
505	UY	0.000000000E+00	0.000000000E+00
506	UY	0.000000000E+00	0.000000000E+00
507	UY	0.000000000E+00	0.000000000E+00
508	UY	0.000000000E+00	0.000000000E+00
509	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
510	UY	0.000000000E+00	0.000000000E+00
511	UY	0.000000000E+00	0.000000000E+00
512	UY	0.000000000E+00	0.000000000E+00
513	UY	0.000000000E+00	0.000000000E+00
514	UY	0.000000000E+00	0.000000000E+00
515	UY	0.000000000E+00	0.000000000E+00
516	UY	0.000000000E+00	0.000000000E+00
517	UY	0.000000000E+00	0.000000000E+00
518	UY	0.000000000E+00	0.000000000E+00
519	UY	0.000000000E+00	0.000000000E+00
520	UY	0.000000000E+00	0.000000000E+00
521	UY	0.000000000E+00	0.000000000E+00
522	UY	0.000000000E+00	0.000000000E+00
523	UY	0.000000000E+00	0.000000000E+00
524	UY	0.000000000E+00	0.000000000E+00
525	UY	0.000000000E+00	0.000000000E+00
526	UY	0.000000000E+00	0.000000000E+00
527	UY	0.000000000E+00	0.000000000E+00
528	UY	0.000000000E+00	0.000000000E+00
529	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
530	UY	0.000000000E+00	0.000000000E+00

531	UY	0.000000000E+00	0.000000000E+00
532	UY	0.000000000E+00	0.000000000E+00
533	UY	0.000000000E+00	0.000000000E+00
534	UY	0.000000000E+00	0.000000000E+00
535	UY	0.000000000E+00	0.000000000E+00
536	UY	0.000000000E+00	0.000000000E+00
537	UY	0.000000000E+00	0.000000000E+00
538	UY	0.000000000E+00	0.000000000E+00
539	UY	0.000000000E+00	0.000000000E+00
540	UY	0.000000000E+00	0.000000000E+00
541	UY	0.000000000E+00	0.000000000E+00
542	UY	0.000000000E+00	0.000000000E+00
543	UY	0.000000000E+00	0.000000000E+00
544	UY	0.000000000E+00	0.000000000E+00
545	UY	0.000000000E+00	0.000000000E+00
546	UY	0.000000000E+00	0.000000000E+00
547	UY	0.000000000E+00	0.000000000E+00
548	UY	0.000000000E+00	0.000000000E+00
549	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
550	UY	0.000000000E+00	0.000000000E+00
551	UY	0.000000000E+00	0.000000000E+00
552	UY	0.000000000E+00	0.000000000E+00
553	UY	0.000000000E+00	0.000000000E+00
554	UY	0.000000000E+00	0.000000000E+00
555	UY	0.000000000E+00	0.000000000E+00
556	UY	0.000000000E+00	0.000000000E+00
557	UY	0.000000000E+00	0.000000000E+00
558	UY	0.000000000E+00	0.000000000E+00
559	UY	0.000000000E+00	0.000000000E+00
560	UY	0.000000000E+00	0.000000000E+00
561	UY	0.000000000E+00	0.000000000E+00
562	UY	0.000000000E+00	0.000000000E+00
563	UY	0.000000000E+00	0.000000000E+00
564	UY	0.000000000E+00	0.000000000E+00
565	UY	0.000000000E+00	0.000000000E+00
566	UY	0.000000000E+00	0.000000000E+00
567	UY	0.000000000E+00	0.000000000E+00
568	UY	0.000000000E+00	0.000000000E+00
569	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
570	UY	0.000000000E+00	0.000000000E+00
571	UY	0.000000000E+00	0.000000000E+00
572	UY	0.000000000E+00	0.000000000E+00
573	UY	0.000000000E+00	0.000000000E+00
574	UY	0.000000000E+00	0.000000000E+00
575	UY	0.000000000E+00	0.000000000E+00
576	UY	0.000000000E+00	0.000000000E+00
577	UY	0.000000000E+00	0.000000000E+00
578	UY	0.000000000E+00	0.000000000E+00
579	UY	0.000000000E+00	0.000000000E+00
580	UY	0.000000000E+00	0.000000000E+00
581	UY	0.000000000E+00	0.000000000E+00
582	UY	0.000000000E+00	0.000000000E+00
583	UY	0.000000000E+00	0.000000000E+00
584	UY	0.000000000E+00	0.000000000E+00
585	UY	0.000000000E+00	0.000000000E+00
586	UY	0.000000000E+00	0.000000000E+00

587	UY	0.000000000E+00	0.000000000E+00
588	UY	0.000000000E+00	0.000000000E+00
589	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
590	UY	0.000000000E+00	0.000000000E+00
591	UY	0.000000000E+00	0.000000000E+00
592	UY	0.000000000E+00	0.000000000E+00
593	UY	0.000000000E+00	0.000000000E+00
594	UY	0.000000000E+00	0.000000000E+00
595	UY	0.000000000E+00	0.000000000E+00
596	UY	0.000000000E+00	0.000000000E+00
597	UY	0.000000000E+00	0.000000000E+00
598	UY	0.000000000E+00	0.000000000E+00
599	UY	0.000000000E+00	0.000000000E+00
600	UY	0.000000000E+00	0.000000000E+00
601	UY	0.000000000E+00	0.000000000E+00
602	UY	0.000000000E+00	0.000000000E+00
603	UY	0.000000000E+00	0.000000000E+00
604	UY	0.000000000E+00	0.000000000E+00
75	UY	0.000000000E+00	0.000000000E+00
76	UY	0.000000000E+00	0.000000000E+00
88	UY	0.000000000E+00	0.000000000E+00
89	UY	0.000000000E+00	0.000000000E+00
112	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
113	UY	0.000000000E+00	0.000000000E+00
136	UY	0.000000000E+00	0.000000000E+00
137	UY	0.000000000E+00	0.000000000E+00
160	UY	0.000000000E+00	0.000000000E+00
161	UY	0.000000000E+00	0.000000000E+00
184	UY	0.000000000E+00	0.000000000E+00
185	UY	0.000000000E+00	0.000000000E+00
208	UY	0.000000000E+00	0.000000000E+00
209	UY	0.000000000E+00	0.000000000E+00
232	UY	0.000000000E+00	0.000000000E+00
233	UY	0.000000000E+00	0.000000000E+00
319	UY	0.000000000E+00	0.000000000E+00
320	UY	0.000000000E+00	0.000000000E+00
332	UY	0.000000000E+00	0.000000000E+00
333	UY	0.000000000E+00	0.000000000E+00
356	UY	0.000000000E+00	0.000000000E+00
357	UY	0.000000000E+00	0.000000000E+00
380	UY	0.000000000E+00	0.000000000E+00
381	UY	0.000000000E+00	0.000000000E+00
404	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
405	UY	0.000000000E+00	0.000000000E+00
428	UY	0.000000000E+00	0.000000000E+00
429	UY	0.000000000E+00	0.000000000E+00
452	UY	0.000000000E+00	0.000000000E+00
453	UY	0.000000000E+00	0.000000000E+00
476	UY	0.000000000E+00	0.000000000E+00
477	UY	0.000000000E+00	0.000000000E+00
1	UX	0.000000000E+00	0.000000000E+00
11	UX	0.000000000E+00	0.000000000E+00
21	UX	0.000000000E+00	0.000000000E+00
39	[illegible]	0.000000000E+00	0.000000000E+00

57	UX	0.000000000E+00	0.000000000E+00
57	UY	0.000000000E+00	0.000000000E+00
39	UY	0.000000000E+00	0.000000000E+00
21	UY	0.000000000E+00	0.000000000E+00
1	UY	0.000000000E+00	0.000000000E+00
2	UY	0.000000000E+00	0.000000000E+00
3	UY	0.000000000E+00	0.000000000E+00
4	UY	0.000000000E+00	0.000000000E+00
5	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
6	UY	0.000000000E+00	0.000000000E+00
7	UY	0.000000000E+00	0.000000000E+00
8	UY	0.000000000E+00	0.000000000E+00
9	UY	0.000000000E+00	0.000000000E+00
10	UY	0.000000000E+00	0.000000000E+00
11	UY	0.000000000E+00	0.000000000E+00
605	UX	0.000000000E+00	0.000000000E+00
615	UY	0.000000000E+00	0.000000000E+00
614	UY	0.000000000E+00	0.000000000E+00
613	UY	0.000000000E+00	0.000000000E+00
612	UY	0.000000000E+00	0.000000000E+00
611	UY	0.000000000E+00	0.000000000E+00
610	UY	0.000000000E+00	0.000000000E+00
609	UY	0.000000000E+00	0.000000000E+00
608	UY	0.000000000E+00	0.000000000E+00
246	UY	0.000000000E+00	0.000000000E+00
247	UY	0.000000000E+00	0.000000000E+00
248	UY	0.000000000E+00	0.000000000E+00
249	UY	0.000000000E+00	0.000000000E+00
250	UY	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
251	UY	0.000000000E+00	0.000000000E+00
252	UY	0.000000000E+00	0.000000000E+00
253	UY	0.000000000E+00	0.000000000E+00
254	UY	0.000000000E+00	0.000000000E+00
607	UY	0.000000000E+00	0.000000000E+00
606	UY	0.000000000E+00	0.000000000E+00
605	UY	0.000000000E+00	0.000000000E+00
264	UZ	0.000000000E+00	0.000000000E+00
263	UZ	0.000000000E+00	0.000000000E+00
262	UZ	0.000000000E+00	0.000000000E+00
261	UZ	0.000000000E+00	0.000000000E+00
260	UZ	0.000000000E+00	0.000000000E+00
259	UZ	0.000000000E+00	0.000000000E+00
31	UY	0.000000000E+00	0.000000000E+00
32	UY	0.000000000E+00	0.000000000E+00
276	UY	0.000000000E+00	0.000000000E+00
275	UY	0.000000000E+00	0.000000000E+00
11	UZ	0.000000000E+00	0.000000000E+00
12	UZ	0.000000000E+00	0.000000000E+00
13	UZ	0.000000000E+00	0.000000000E+00

NODE	LABEL	DISP	CDISP
14	UZ	0.000000000E+00	0.000000000E+00
15	UZ	0.000000000E+00	0.000000000E+00
16	UZ	0.000000000E+00	0.000000000E+00
17	UZ	0.000000000E+00	0.000000000E+00
18	UZ	0.000000000E+00	0.000000000E+00

```
     19 UZ     0.000000000E+00 0.000000000E+00
     20 UZ     0.000000000E+00 0.000000000E+00
    256 UZ     0.000000000E+00 0.000000000E+00
    257 UZ     0.000000000E+00 0.000000000E+00
    258 UZ     0.000000000E+00 0.000000000E+00

 LIST ALL COUPLED SETS

 COUPLED SET=       1   DIRECTION= UX     TOTAL NODES=       2
 NODES=      22      40

 COUPLED SET=       2   DIRECTION= UX     TOTAL NODES=       2
 NODES=      24      42

 COUPLED SET=       3   DIRECTION= UX     TOTAL NODES=       2
 NODES=      26      44

 COUPLED SET=       4   DIRECTION= UX     TOTAL NODES=       2
 NODES=      28      46

 COUPLED SET=       5   DIRECTION= UX     TOTAL NODES=       4
 NODES=      30      31      48      49

 COUPLED SET=       6   DIRECTION= UX     TOTAL NODES=       4
 NODES=      32      33      50      51

 COUPLED SET=       7   DIRECTION= UX     TOTAL NODES=       2
 NODES=      34      52

 COUPLED SET=       8   DIRECTION= UX     TOTAL NODES=       2
 NODES=      36      54

 COUPLED SET=       9   DIRECTION= UX     TOTAL NODES=       3
 NODES=      38      56     495

 COUPLED SET=      10   DIRECTION= UX     TOTAL NODES=       2
 NODES=      23      41

 COUPLED SET=      11   DIRECTION= UX     TOTAL NODES=       2
 NODES=      25      43

 COUPLED SET=      12   DIRECTION= UX     TOTAL NODES=       2
 NODES=      27      45

 COUPLED SET=      13   DIRECTION= UX     TOTAL NODES=       2
 NODES=      29      47

 COUPLED SET=      14   DIRECTION= UX     TOTAL NODES=       3
 NODES=      35      53     493

 COUPLED SET=      15   DIRECTION= UX     TOTAL NODES=       3
 NODES=      37      55     494

 COUPLED SET=      16   DIRECTION= UX     TOTAL NODES=       3
 NODES=      63      75      76

 COUPLED SET=      17   DIRECTION= UX     TOTAL NODES=       2
 NODES=      64      77

 COUPLED SET=      18   DIRECTION= UX     TOTAL NODES=       2
```

NODES= 66 79

COUPLED SET= 19 DIRECTION= UX TOTAL NODES= 2
NODES= 68 81

COUPLED SET= 20 DIRECTION= UX TOTAL NODES= 2
NODES= 70 83

COUPLED SET= 21 DIRECTION= UX TOTAL NODES= 2
NODES= 72 85

COUPLED SET= 22 DIRECTION= UX TOTAL NODES= 3
NODES= 74 87 504

COUPLED SET= 23 DIRECTION= UX TOTAL NODES= 2
NODES= 65 78

COUPLED SET= 24 DIRECTION= UX TOTAL NODES= 2
NODES= 67 80

COUPLED SET= 25 DIRECTION= UX TOTAL NODES= 2
NODES= 69 82

COUPLED SET= 26 DIRECTION= UX TOTAL NODES= 3
NODES= 71 84 502

COUPLED SET= 27 DIRECTION= UX TOTAL NODES= 3
NODES= 73 86 503

COUPLED SET= 28 DIRECTION= UX TOTAL NODES= 2
NODES= 90 101

COUPLED SET= 29 DIRECTION= UX TOTAL NODES= 2
NODES= 92 103

COUPLED SET= 30 DIRECTION= UX TOTAL NODES= 2
NODES= 94 105

COUPLED SET= 31 DIRECTION= UX TOTAL NODES= 2
NODES= 96 107

COUPLED SET= 32 DIRECTION= UX TOTAL NODES= 2
NODES= 98 109

COUPLED SET= 33 DIRECTION= UX TOTAL NODES= 2
NODES= 100 111

COUPLED SET= 34 DIRECTION= UX TOTAL NODES= 2
NODES= 91 102

COUPLED SET= 35 DIRECTION= UX TOTAL NODES= 2
NODES= 93 104

COUPLED SET= 36 DIRECTION= UX TOTAL NODES= 2
NODES= 95 106

COUPLED SET= 37 DIRECTION= UX TOTAL NODES= 2
NODES= 97 108

COUPLED SET= 38 DIRECTION= UX TOTAL NODES= 3

```
NODES=      99     110   509

COUPLED SET=      39   DIRECTION= UX     TOTAL NODES=        2
NODES=     114     125

COUPLED SET=      40   DIRECTION= UX     TOTAL NODES=        2
NODES=     138     149

COUPLED SET=      41   DIRECTION= UX     TOTAL NODES=        2
NODES=     162     173

COUPLED SET=      42   DIRECTION= UX     TOTAL NODES=        2
NODES=     186     197

COUPLED SET=      43   DIRECTION= UX     TOTAL NODES=        2
NODES=     210     221

COUPLED SET=      44   DIRECTION= UX     TOTAL NODES=        2
NODES=     116     127

COUPLED SET=      45   DIRECTION= UX     TOTAL NODES=        2
NODES=     140     151

COUPLED SET=      46   DIRECTION= UX     TOTAL NODES=        2
NODES=     164     175

COUPLED SET=      47   DIRECTION= UX     TOTAL NODES=        2
NODES=     188     199

COUPLED SET=      48   DIRECTION= UX     TOTAL NODES=        2
NODES=     212     223

COUPLED SET=      49   DIRECTION= UX     TOTAL NODES=        2
NODES=     118     129

COUPLED SET=      50   DIRECTION= UX     TOTAL NODES=        2
NODES=     142     153

COUPLED SET=      51   DIRECTION= UX     TOTAL NODES=        2
NODES=     166     177

COUPLED SET=      52   DIRECTION= UX     TOTAL NODES=        2
NODES=     190     201

COUPLED SET=      53   DIRECTION= UX     TOTAL NODES=        2
NODES=     214     225

COUPLED SET=      54   DIRECTION= UX     TOTAL NODES=        2
NODES=     120     131

COUPLED SET=      55   DIRECTION= UX     TOTAL NODES=        2
NODES=     144     155

COUPLED SET=      56   DIRECTION= UX     TOTAL NODES=        2
NODES=     168     179

COUPLED SET=      57   DIRECTION= UX     TOTAL NODES=        2
NODES=     192     203

COUPLED SET=      58   DIRECTION= UX     TOTAL NODES=        2
```

```
NODES=    216    227

COUPLED SET=     59  DIRECTION= UX    TOTAL NODES=      2
NODES=    122    133

COUPLED SET=     60  DIRECTION= UX    TOTAL NODES=      2
NODES=    146    157

COUPLED SET=     61  DIRECTION= UX    TOTAL NODES=      2
NODES=    170    181

COUPLED SET=     62  DIRECTION= UX    TOTAL NODES=      2
NODES=    194    205

COUPLED SET=     63  DIRECTION= UX    TOTAL NODES=      2
NODES=    218    229

COUPLED SET=     64  DIRECTION= UX    TOTAL NODES=      2
NODES=    124    135

COUPLED SET=     65  DIRECTION= UX    TOTAL NODES=      2
NODES=    148    159

COUPLED SET=     66  DIRECTION= UX    TOTAL NODES=      2
NODES=    172    183

COUPLED SET=     67  DIRECTION= UX    TOTAL NODES=      3
NODES=    196    207    553

COUPLED SET=     68  DIRECTION= UX    TOTAL NODES=      2
NODES=    220    231

COUPLED SET=     69  DIRECTION= UX    TOTAL NODES=      2
NODES=    115    126

COUPLED SET=     70  DIRECTION= UX    TOTAL NODES=      2
NODES=    139    150

COUPLED SET=     71  DIRECTION= UX    TOTAL NODES=      2
NODES=    163    174

COUPLED SET=     72  DIRECTION= UX    TOTAL NODES=      2
NODES=    187    198

COUPLED SET=     73  DIRECTION= UX    TOTAL NODES=      2
NODES=    211    222

COUPLED SET=     74  DIRECTION= UX    TOTAL NODES=      2
NODES=    117    128

COUPLED SET=     75  DIRECTION= UX    TOTAL NODES=      2
NODES=    141    152

COUPLED SET=     76  DIRECTION= UX    TOTAL NODES=      2
NODES=    165    176

COUPLED SET=     77  DIRECTION= UX    TOTAL NODES=      2
NODES=    189    200

COUPLED SET=     78  DIRECTION= UX    TOTAL NODES=      2
```

NODES= 213 224

COUPLED SET= 79 DIRECTION= UX TOTAL NODES= 2
NODES= 119 130

COUPLED SET= 80 DIRECTION= UX TOTAL NODES= 2
NODES= 143 154

COUPLED SET= 81 DIRECTION= UX TOTAL NODES= 2
NODES= 167 178

COUPLED SET= 82 DIRECTION= UX TOTAL NODES= 2
NODES= 191 202

COUPLED SET= 83 DIRECTION= UX TOTAL NODES= 2
NODES= 215 226

COUPLED SET= 84 DIRECTION= UX TOTAL NODES= 2
NODES= 121 132

COUPLED SET= 85 DIRECTION= UX TOTAL NODES= 2
NODES= 145 156

COUPLED SET= 86 DIRECTION= UX TOTAL NODES= 2
NODES= 169 180

COUPLED SET= 87 DIRECTION= UX TOTAL NODES= 3
NODES= 193 204 532

COUPLED SET= 88 DIRECTION= UX TOTAL NODES= 3
NODES= 217 228 538

COUPLED SET= 89 DIRECTION= UX TOTAL NODES= 3
NODES= 123 134 515

COUPLED SET= 90 DIRECTION= UX TOTAL NODES= 3
NODES= 147 158 521

COUPLED SET= 91 DIRECTION= UX TOTAL NODES= 3
NODES= 171 182 527

COUPLED SET= 92 DIRECTION= UX TOTAL NODES= 3
NODES= 195 206 533

COUPLED SET= 93 DIRECTION= UX TOTAL NODES= 3
NODES= 219 230 539

COUPLED SET= 94 DIRECTION= UX TOTAL NODES= 2
NODES= 266 284

COUPLED SET= 95 DIRECTION= UX TOTAL NODES= 2
NODES= 268 286

COUPLED SET= 96 DIRECTION= UX TOTAL NODES= 2
NODES= 270 288

COUPLED SET= 97 DIRECTION= UX TOTAL NODES= 2
NODES= 272 290

COUPLED SET= 98 DIRECTION= UX TOTAL NODES= 4

NODES= 274 275 292 293

COUPLED SET= 99 DIRECTION= UX TOTAL NODES= 4
NODES= 276 277 294 295

COUPLED SET= 100 DIRECTION= UX TOTAL NODES= 2
NODES= 278 296

COUPLED SET= 101 DIRECTION= UX TOTAL NODES= 2
NODES= 280 298

COUPLED SET= 102 DIRECTION= UX TOTAL NODES= 2
NODES= 282 300

COUPLED SET= 103 DIRECTION= UX TOTAL NODES= 2
NODES= 267 285

COUPLED SET= 104 DIRECTION= UX TOTAL NODES= 2
NODES= 269 287

COUPLED SET= 105 DIRECTION= UX TOTAL NODES= 2
NODES= 271 289

COUPLED SET= 106 DIRECTION= UX TOTAL NODES= 2
NODES= 273 291

COUPLED SET= 107 DIRECTION= UX TOTAL NODES= 3
NODES= 279 297 551

COUPLED SET= 108 DIRECTION= UX TOTAL NODES= 3
NODES= 281 299 552

COUPLED SET= 109 DIRECTION= UX TOTAL NODES= 3
NODES= 307 319 320

COUPLED SET= 110 DIRECTION= UX TOTAL NODES= 2
NODES= 308 321

COUPLED SET= 111 DIRECTION= UX TOTAL NODES= 2
NODES= 310 323

COUPLED SET= 112 DIRECTION= UX TOTAL NODES= 2
NODES= 312 325

COUPLED SET= 113 DIRECTION= UX TOTAL NODES= 2
NODES= 314 327

COUPLED SET= 114 DIRECTION= UX TOTAL NODES= 2
NODES= 316 329

COUPLED SET= 115 DIRECTION= UX TOTAL NODES= 3
NODES= 318 331 562

COUPLED SET= 116 DIRECTION= UX TOTAL NODES= 2
NODES= 309 322

COUPLED SET= 117 DIRECTION= UX TOTAL NODES= 2
NODES= 311 324

COUPLED SET= 118 DIRECTION= UX TOTAL NODES= 2

NODES= 313 326

COUPLED SET= 119 DIRECTION= UX TOTAL NODES= 3
NODES= 315 328 560

UPLED SET= 120 DIRECTION= UX TOTAL NODES= 3
..DDES= 317 330 561

COUPLED SET= 121 DIRECTION= UX TOTAL NODES= 2
NODES= 334 345

COUPLED SET= 122 DIRECTION= UX TOTAL NODES= 2
NODES= 336 347

COUPLED SET= 123 DIRECTION= UX TOTAL NODES= 2
NODES= 338 349

COUPLED SET= 124 DIRECTION= UX TOTAL NODES= 2
NODES= 340 351

COUPLED SET= 125 DIRECTION= UX TOTAL NODES= 2
NODES= 342 353

COUPLED SET= 126 DIRECTION= UX TOTAL NODES= 2
NODES= 344 355

COUPLED SET= 127 DIRECTION= UX TOTAL NODES= 2
NODES= 335 346

COUPLED SET= 128 DIRECTION= UX TOTAL NODES= 2
ES= 337 348

COUPLED SET= 129 DIRECTION= UX TOTAL NODES= 2
NODES= 339 350

COUPLED SET= 130 DIRECTION= UX TOTAL NODES= 2
NODES= 341 352

COUPLED SET= 131 DIRECTION= UX TOTAL NODES= 3
NODES= 343 354 567

COUPLED SET= 132 DIRECTION= UX TOTAL NODES= 2
NODES= 358 369

COUPLED SET= 133 DIRECTION= UX TOTAL NODES= 2
NODES= 382 393

COUPLED SET= 134 DIRECTION= UX TOTAL NODES= 2
NODES= 406 417

COUPLED SET= 135 DIRECTION= UX TOTAL NODES= 2
NODES= 430 441

COUPLED SET= 136 DIRECTION= UX TOTAL NODES= 2
NODES= 454 465

LED SET= 137 DIRECTION= UX TOTAL NODES= 2
NODES= 360 371

COUPLED SET= 138 DIRECTION= UX TOTAL NODES= 2

NODES= 384 395

COUPLED SET= 139 DIRECTION= UX TOTAL NODES= 2
NODES= 408 419

UPLED SET= 140 DIRECTION= UX TOTAL NODES= 2
NODES= 432 443

COUPLED SET= 141 DIRECTION= UX TOTAL NODES= 2
NODES= 456 467

COUPLED SET= 142 DIRECTION= UX TOTAL NODES= 2
NODES= 362 373

COUPLED SET= 143 DIRECTION= UX TOTAL NODES= 2
NODES= 386 397

COUPLED SET= 144 DIRECTION= UX TOTAL NODES= 2
NODES= 410 421

COUPLED SET= 145 DIRECTION= UX TOTAL NODES= 2
NODES= 434 445

COUPLED SET= 146 DIRECTION= UX TOTAL NODES= 2
NODES= 458 469

COUPLED SET= 147 DIRECTION= UX TOTAL NODES= 2
NODES= 364 375

OUPLED SET= 148 DIRECTION= UX TOTAL NODES= 2
DES= 388 399

COUPLED SET= 149 DIRECTION= UX TOTAL NODES= 2
NODES= 412 423

COUPLED SET= 150 DIRECTION= UX TOTAL NODES= 2
NODES= 436 447

COUPLED SET= 151 DIRECTION= UX TOTAL NODES= 2
NODES= 460 471

COUPLED SET= 152 DIRECTION= UX TOTAL NODES= 2
NODES= 366 377

COUPLED SET= 153 DIRECTION= UX TOTAL NODES= 2
NODES= 390 401

COUPLED SET= 154 DIRECTION= UX TOTAL NODES= 2
NODES= 414 425

COUPLED SET= 155 DIRECTION= UX TOTAL NODES= 2
NODES= 438 449

COUPLED SET= 156 DIRECTION= UX TOTAL NODES= 2
DES= 462 473

UPLED SET= 157 DIRECTION= UX TOTAL NODES= 2
NODES= 368 379

COUPLED SET= 158 DIRECTION= UX TOTAL NODES= 2

NODES= 392 403

COUPLED SET= 159 DIRECTION= UX TOTAL NODES= 2
NODES= 416 427

JPLED SET= 160 DIRECTION= UX TOTAL NODES= 2
NODES= 440 451

COUPLED SET= 161 DIRECTION= UX TOTAL NODES= 2
NODES= 464 475

COUPLED SET= 162 DIRECTION= UX TOTAL NODES= 2
NODES= 359 370

COUPLED SET= 163 DIRECTION= UX TOTAL NODES= 2
NODES= 383 394

COUPLED SET= 164 DIRECTION= UX TOTAL NODES= 2
NODES= 407 418

COUPLED SET= 165 DIRECTION= UX TOTAL NODES= 2
NODES= 431 442

COUPLED SET= 166 DIRECTION= UX TOTAL NODES= 2
NODES= 455 466

COUPLED SET= 167 DIRECTION= UX TOTAL NODES= 2
NODES= 361 372

COUPLED SET= 168 DIRECTION= UX TOTAL NODES= 2
ES= 385 396

COUPLED SET= 169 DIRECTION= UX TOTAL NODES= 2
NODES= 409 420

COUPLED SET= 170 DIRECTION= UX TOTAL NODES= 2
NODES= 433 444

COUPLED SET= 171 DIRECTION= UX TOTAL NODES= 2
NODES= 457 468

COUPLED SET= 172 DIRECTION= UX TOTAL NODES= 2
NODES= 363 374

COUPLED SET= 173 DIRECTION= UX TOTAL NODES= 2
NODES= 387 398

COUPLED SET= 174 DIRECTION= UX TOTAL NODES= 2
NODES= 411 422

COUPLED SET= 175 DIRECTION= UX TOTAL NODES= 2
NODES= 435 446

COUPLED SET= 176 DIRECTION= UX TOTAL NODES= 2
NODES= 459 470

PLED SET= 177 DIRECTION= UX TOTAL NODES= 2
NODES= 365 376

COUPLED SET= 178 DIRECTION= UX TOTAL NODES= 2

NODES= 389 400

COUPLED SET= 179 DIRECTION= UX TOTAL NODES= 2
NODES= 413 424

UPLED SET= 180 DIRECTION= UX TOTAL NODES= 3
NODES= 437 448 590

COUPLED SET= 181 DIRECTION= UX TOTAL NODES= 3
NODES= 461 472 596

COUPLED SET= 182 DIRECTION= UX TOTAL NODES= 3
NODES= 367 378 573

COUPLED SET= 183 DIRECTION= UX TOTAL NODES= 3
NODES= 391 402 579

COUPLED SET= 184 DIRECTION= UX TOTAL NODES= 3
NODES= 415 426 585

COUPLED SET= 185 DIRECTION= UX TOTAL NODES= 3
NODES= 439 450 591

COUPLED SET= 186 DIRECTION= UX TOTAL NODES= 3
NODES= 463 474 597

COUPLED SET= 187 DIRECTION= UY TOTAL NODES= 4
NODES= 22 23 40 41

UPLED SET= 188 DIRECTION= UY TOTAL NODES= 4
ES= 24 25 42 43

COUPLED SET= 189 DIRECTION= UY TOTAL NODES= 4
NODES= 26 27 44 45

COUPLED SET= 190 DIRECTION= UY TOTAL NODES= 4
NODES= 28 29 46 47

COUPLED SET= 191 DIRECTION= UY TOTAL NODES= 3
NODES= 30 48 49

COUPLED SET= 192 DIRECTION= UY TOTAL NODES= 3
NODES= 50 51 33

COUPLED SET= 193 DIRECTION= UY TOTAL NODES= 4
NODES= 34 35 52 53

COUPLED SET= 194 DIRECTION= UY TOTAL NODES= 4
NODES= 36 37 54 55

COUPLED SET= 195 DIRECTION= UY TOTAL NODES= 2
NODES= 38 56

COUPLED SET= 196 DIRECTION= UY TOTAL NODES= 2
DES= 58 59

JPLED SET= 197 DIRECTION= UY TOTAL NODES= 2
NODES= 60 61

COUPLED SET= 198 DIRECTION= UY TOTAL NODES= 2

NODES= 62 63

COUPLED SET= 199 DIRECTION= UY TOTAL NODES= 2
NODES= 75 76

UPLED SET= 200 DIRECTION= UY TOTAL NODES= 4
NODES= 64 65 77 78

COUPLED SET= 201 DIRECTION= UY TOTAL NODES= 4
NODES= 66 67 79 80

COUPLED SET= 202 DIRECTION= UY TOTAL NODES= 4
NODES= 68 69 81 82

COUPLED SET= 203 DIRECTION= UY TOTAL NODES= 4
NODES= 70 71 83 84

COUPLED SET= 204 DIRECTION= UY TOTAL NODES= 4
NODES= 72 73 85 86

COUPLED SET= 205 DIRECTION= UY TOTAL NODES= 2
NODES= 74 87

COUPLED SET= 206 DIRECTION= UY TOTAL NODES= 2
NODES= 88 89

COUPLED SET= 207 DIRECTION= UY TOTAL NODES= 4
NODES= 90 91 101 102

COUPLED SET= 208 DIRECTION= UY TOTAL NODES= 4
DES= 92 93 103 104

COUPLED SET= 209 DIRECTION= UY TOTAL NODES= 4
NODES= 94 95 105 106

COUPLED SET= 210 DIRECTION= UY TOTAL NODES= 4
NODES= 96 97 107 108

COUPLED SET= 211 DIRECTION= UY TOTAL NODES= 4
NODES= 98 99 109 110

COUPLED SET= 212 DIRECTION= UY TOTAL NODES= 2
NODES= 100 111

COUPLED SET= 213 DIRECTION= UY TOTAL NODES= 2
NODES= 112 113

COUPLED SET= 214 DIRECTION= UY TOTAL NODES= 2
NODES= 136 137

COUPLED SET= 215 DIRECTION= UY TOTAL NODES= 2
NODES= 160 161

COUPLED SET= 216 DIRECTION= UY TOTAL NODES= 2
NODES= 184 185

UPLED SET= 217 DIRECTION= UY TOTAL NODES= 2
NODES= 208 209

COUPLED SET= 218 DIRECTION= UY TOTAL NODES= 4

NODES= 114 115 125 126

COUPLED SET= 219 DIRECTION= UY TOTAL NODES= 4
NODES= 138 139 149 150

JUPLED SET= 220 DIRECTION= UY TOTAL NODES= 4
NODES= 162 163 173 174

COUPLED SET= 221 DIRECTION= UY TOTAL NODES= 4
NODES= 186 187 197 198

COUPLED SET= 222 DIRECTION= UY TOTAL NODES= 4
NODES= 210 211 221 222

COUPLED SET= 223 DIRECTION= UY TOTAL NODES= 4
NODES= 116 117 127 128

COUPLED SET= 224 DIRECTION= UY TOTAL NODES= 4
NODES= 140 141 151 152

COUPLED SET= 225 DIRECTION= UY TOTAL NODES= 4
NODES= 164 165 175 176

COUPLED SET= 226 DIRECTION= UY TOTAL NODES= 4
NODES= 188 189 199 200

COUPLED SET= 227 DIRECTION= UY TOTAL NODES= 4
NODES= 212 213 223 224

OUPLED SET= 228 DIRECTION= UY TOTAL NODES= 4
DES= 118 119 129 130

COUPLED SET= 229 DIRECTION= UY TOTAL NODES= 4
NODES= 142 143 153 154

COUPLED SET= 230 DIRECTION= UY TOTAL NODES= 4
NODES= 166 167 177 178

COUPLED SET= 231 DIRECTION= UY TOTAL NODES= 4
NODES= 190 191 201 202

COUPLED SET= 232 DIRECTION= UY TOTAL NODES= 4
NODES= 214 215 225 226

COUPLED SET= 233 DIRECTION= UY TOTAL NODES= 4
NODES= 120 121 131 132

COUPLED SET= 234 DIRECTION= UY TOTAL NODES= 4
NODES= 144 145 155 156

COUPLED SET= 235 DIRECTION= UY TOTAL NODES= 4
NODES= 168 169 179 180

COUPLED SET= 236 DIRECTION= UY TOTAL NODES= 4
ODES= 192 193 203 204

JPLED SET= 237 DIRECTION= UY TOTAL NODES= 4
NODES= 216 217 227 228

COUPLED SET= 238 DIRECTION= UY TOTAL NODES= 4

NODES= 122 123 133 134

COUPLED SET= 239 DIRECTION= UY TOTAL NODES= 4
NODES= 146 147 157 158

OUPLED SET= 240 DIRECTION= UY TOTAL NODES= 4
NODES= 170 171 181 182

COUPLED SET= 241 DIRECTION= UY TOTAL NODES= 4
NODES= 194 195 205 206

COUPLED SET= 242 DIRECTION= UY TOTAL NODES= 4
NODES= 218 219 229 230

COUPLED SET= 243 DIRECTION= UY TOTAL NODES= 2
NODES= 124 135

COUPLED SET= 244 DIRECTION= UY TOTAL NODES= 2
NODES= 148 159

COUPLED SET= 245 DIRECTION= UY TOTAL NODES= 2
NODES= 172 183

COUPLED SET= 246 DIRECTION= UY TOTAL NODES= 2
NODES= 196 207

COUPLED SET= 247 DIRECTION= UY TOTAL NODES= 2
NODES= 220 231

COUPLED SET= 248 DIRECTION= UY TOTAL NODES= 2
DES= 232 233

COUPLED SET= 249 DIRECTION= UY TOTAL NODES= 2
NODES= 234 235

COUPLED SET= 250 DIRECTION= UY TOTAL NODES= 2
NODES= 236 237

COUPLED SET= 251 DIRECTION= UY TOTAL NODES= 2
NODES= 238 239

COUPLED SET= 252 DIRECTION= UY TOTAL NODES= 2
NODES= 240 241

COUPLED SET= 253 DIRECTION= UY TOTAL NODES= 2
NODES= 242 243

COUPLED SET= 254 DIRECTION= UY TOTAL NODES= 4
NODES= 266 267 284 285

COUPLED SET= 255 DIRECTION= UY TOTAL NODES= 4
NODES= 268 269 286 287

COUPLED SET= 256 DIRECTION= UY TOTAL NODES= 4
NODES= 270 271 288 289

UPLED SET= 257 DIRECTION= UY TOTAL NODES= 4
NODES= 272 273 290 291

COUPLED SET= 258 DIRECTION= UY TOTAL NODES= 3

NODES= 274 292 293

COUPLED SET= 259 DIRECTION= UY TOTAL NODES= 3
NODES= 277 294 295

COUPLED SET= 260 DIRECTION= UY TOTAL NODES= 4
NODES= 278 279 296 297

COUPLED SET= 261 DIRECTION= UY TOTAL NODES= 4
NODES= 280 281 298 299

COUPLED SET= 262 DIRECTION= UY TOTAL NODES= 2
NODES= 282 300

COUPLED SET= 263 DIRECTION= UY TOTAL NODES= 2
NODES= 302 303

COUPLED SET= 264 DIRECTION= UY TOTAL NODES= 2
NODES= 304 305

COUPLED SET= 265 DIRECTION= UY TOTAL NODES= 2
NODES= 306 307

COUPLED SET= 266 DIRECTION= UY TOTAL NODES= 2
NODES= 319 320

COUPLED SET= 267 DIRECTION= UY TOTAL NODES= 4
NODES= 308 309 321 322

COUPLED SET= 268 DIRECTION= UY TOTAL NODES= 4
NODES= 310 311 323 324

COUPLED SET= 269 DIRECTION= UY TOTAL NODES= 4
NODES= 312 313 325 326

COUPLED SET= 270 DIRECTION= UY TOTAL NODES= 4
NODES= 314 315 327 328

COUPLED SET= 271 DIRECTION= UY TOTAL NODES= 4
NODES= 316 317 329 330

COUPLED SET= 272 DIRECTION= UY TOTAL NODES= 2
NODES= 318 331

COUPLED SET= 273 DIRECTION= UY TOTAL NODES= 2
NODES= 332 333

COUPLED SET= 274 DIRECTION= UY TOTAL NODES= 4
NODES= 334 335 345 346

COUPLED SET= 275 DIRECTION= UY TOTAL NODES= 4
NODES= 336 337 347 348

COUPLED SET= 276 DIRECTION= UY TOTAL NODES= 4
NODES= 338 339 349 350

COUPLED SET= 277 DIRECTION= UY TOTAL NODES= 4
NODES= 340 341 351 352

COUPLED SET= 278 DIRECTION= UY TOTAL NODES= 4

NODES= 342 343 353 354

COUPLED SET= 279 DIRECTION= UY TOTAL NODES= 2
NODES= 344 355

COUPLED SET= 280 DIRECTION= UY TOTAL NODES= 2
NODES= 356 357

COUPLED SET= 281 DIRECTION= UY TOTAL NODES= 2
NODES= 380 381

COUPLED SET= 282 DIRECTION= UY TOTAL NODES= 2
NODES= 404 405

COUPLED SET= 283 DIRECTION= UY TOTAL NODES= 2
NODES= 428 429

COUPLED SET= 284 DIRECTION= UY TOTAL NODES= 2
NODES= 452 453

COUPLED SET= 285 DIRECTION= UY TOTAL NODES= 4
NODES= 358 359 369 370

COUPLED SET= 286 DIRECTION= UY TOTAL NODES= 4
NODES= 382 383 393 394

COUPLED SET= 287 DIRECTION= UY TOTAL NODES= 4
NODES= 406 407 417 418

COUPLED SET= 288 DIRECTION= UY TOTAL NODES= 4
DES= 430 431 441 442

COUPLED SET= 289 DIRECTION= UY TOTAL NODES= 4
NODES= 454 455 465 466

COUPLED SET= 290 DIRECTION= UY TOTAL NODES= 4
NODES= 360 361 371 372

COUPLED SET= 291 DIRECTION= UY TOTAL NODES= 4
NODES= 384 385 395 396

COUPLED SET= 292 DIRECTION= UY TOTAL NODES= 4
NODES= 408 409 419 420

COUPLED SET= 293 DIRECTION= UY TOTAL NODES= 4
NODES= 432 433 443 444

COUPLED SET= 294 DIRECTION= UY TOTAL NODES= 4
NODES= 456 457 467 468

COUPLED SET= 295 DIRECTION= UY TOTAL NODES= 4
NODES= 362 363 373 374

COUPLED SET= 296 DIRECTION= UY TOTAL NODES= 4
NODES= 386 387 397 398

JPLED SET= 297 DIRECTION= UY TOTAL NODES= 4
NODES= 410 411 421 422

COUPLED SET= 298 DIRECTION= UY TOTAL NODES= 4

NODES= 434 435 445 446

COUPLED SET= 299 DIRECTION= UY TOTAL NODES= 4
NODES= 458 459 469 470

OUPLED SET= 300 DIRECTION= UY TOTAL NODES= 4
NODES= 364 365 375 376

COUPLED SET= 301 DIRECTION= UY TOTAL NODES= 4
NODES= 388 389 399 400

COUPLED SET= 302 DIRECTION= UY TOTAL NODES= 4
NODES= 412 413 423 424

COUPLED SET= 303 DIRECTION= UY TOTAL NODES= 4
NODES= 436 437 447 448

COUPLED SET= 304 DIRECTION= UY TOTAL NODES= 4
NODES= 460 461 471 472

COUPLED SET= 305 DIRECTION= UY TOTAL NODES= 4
NODES= 366 367 377 378

COUPLED SET= 306 DIRECTION= UY TOTAL NODES= 4
NODES= 390 391 401 402

COUPLED SET= 307 DIRECTION= UY TOTAL NODES= 4
NODES= 414 415 425 426

COUPLED SET= 308 DIRECTION= UY TOTAL NODES= 4
DES= 438 439 449 450

COUPLED SET= 309 DIRECTION= UY TOTAL NODES= 4
NODES= 462 463 473 474

COUPLED SET= 310 DIRECTION= UY TOTAL NODES= 2
NODES= 368 379

COUPLED SET= 311 DIRECTION= UY TOTAL NODES= 2
NODES= 392 403

COUPLED SET= 312 DIRECTION= UY TOTAL NODES= 2
NODES= 416 427

COUPLED SET= 313 DIRECTION= UY TOTAL NODES= 2
NODES= 440 451

COUPLED SET= 314 DIRECTION= UY TOTAL NODES= 2
NODES= 464 475

COUPLED SET= 315 DIRECTION= UY TOTAL NODES= 2
NODES= 476 477

COUPLED SET= 316 DIRECTION= UY TOTAL NODES= 2
NODES= 478 479

JPLED SET= 317 DIRECTION= UY TOTAL NODES= 2
NODES= 480 481

COUPLED SET= 318 DIRECTION= UY TOTAL NODES= 2

```
NODES=    482    483

COUPLED SET=    319   DIRECTION= UY     TOTAL NODES=     2
NODES=    484    485

 UPLED SET=     320   DIRECTION= UY     TOTAL NODES=     2
NODES=    486    487

COUPLED SET=    321   DIRECTION= UX     TOTAL NODES=     2
NODES=      2     12

COUPLED SET=    322   DIRECTION= UX     TOTAL NODES=     2
NODES=      3     13

COUPLED SET=    323   DIRECTION= UX     TOTAL NODES=     2
NODES=      4     14

COUPLED SET=    324   DIRECTION= UX     TOTAL NODES=     2
NODES=      5     15

COUPLED SET=    325   DIRECTION= UX     TOTAL NODES=     2
NODES=      6     16

COUPLED SET=    326   DIRECTION= UX     TOTAL NODES=     2
NODES=      7     17

COUPLED SET=    327   DIRECTION= UX     TOTAL NODES=     2
NODES=      8     18

COUPLED SET=    328   DIRECTION= UX     TOTAL NODES=     2
   DES=     9     19

COUPLED SET=    329   DIRECTION= UX     TOTAL NODES=     2
NODES=     10     20

COUPLED SET=    330   DIRECTION= UX     TOTAL NODES=     2
NODES=    246    256

COUPLED SET=    331   DIRECTION= UX     TOTAL NODES=     2
NODES=    247    257

COUPLED SET=    332   DIRECTION= UX     TOTAL NODES=     2
NODES=    248    258

COUPLED SET=    333   DIRECTION= UX     TOTAL NODES=     2
NODES=    249    259

COUPLED SET=    334   DIRECTION= UX     TOTAL NODES=     2
NODES=    250    260

COUPLED SET=    335   DIRECTION= UX     TOTAL NODES=     2
NODES=    251    261

COUPLED SET=    336   DIRECTION= UX     TOTAL NODES=     2
NODES=    252    262

  UPLED SET=    337   DIRECTION= UX     TOTAL NODES=     2
NODES=    253    263

COUPLED SET=    333   DIRECTION= UX     TOTAL NODES=     2
```

NODES= 254 264

COUPLED SET= 339 DIRECTION= UX TOTAL NODES= 2
NODES= 88 89

OUPLED SET= 340 DIRECTION= UX TOTAL NODES= 2
NODES= 112 113

COUPLED SET= 341 DIRECTION= UX TOTAL NODES= 2
NODES= 136 137

COUPLED SET= 342 DIRECTION= UX TOTAL NODES= 2
NODES= 160 161

COUPLED SET= 343 DIRECTION= UX TOTAL NODES= 2
NODES= 184 185

COUPLED SET= 344 DIRECTION= UX TOTAL NODES= 2
NODES= 208 209

COUPLED SET= 345 DIRECTION= UX TOTAL NODES= 2
NODES= 232 233

COUPLED SET= 346 DIRECTION= UX TOTAL NODES= 2
NODES= 332 333

COUPLED SET= 347 DIRECTION= UX TOTAL NODES= 2
NODES= 356 357

COUPLED SET= 348 DIRECTION= UX TOTAL NODES= 2
DES= 380 381

COUPLED SET= 349 DIRECTION= UX TOTAL NODES= 2
NODES= 404 405

COUPLED SET= 350 DIRECTION= UX TOTAL NODES= 2
NODES= 428 429

COUPLED SET= 351 DIRECTION= UX TOTAL NODES= 2
NODES= 452 453

COUPLED SET= 352 DIRECTION= UX TOTAL NODES= 2
NODES= 476 477

COUPLED SET= 353 DIRECTION= UZ TOTAL NODES= 2
NODES= 22 23

COUPLED SET= 354 DIRECTION= UZ TOTAL NODES= 2
NODES= 24 25

COUPLED SET= 355 DIRECTION= UZ TOTAL NODES= 2
NODES= 26 27

COUPLED SET= 356 DIRECTION= UZ TOTAL NODES= 2
NODES= 28 29

UPLED SET= 357 DIRECTION= UZ TOTAL NODES= 4
NODES= 30 31 48 49

COUPLED SET= 358 DIRECTION= UZ TOTAL NODES= 4

NODES= 32 33 50 51

COUPLED SET= 359 DIRECTION= UZ TOTAL NODES= 2
NODES= 34 35

UPLED SET= 360 DIRECTION= UZ TOTAL NODES= 2
ODES= 36 37

COUPLED SET= 361 DIRECTION= UZ TOTAL NODES= 2
NODES= 40 41

COUPLED SET= 362 DIRECTION= UZ TOTAL NODES= 2
NODES= 42 43

COUPLED SET= 363 DIRECTION= UZ TOTAL NODES= 2
NODES= 44 45

COUPLED SET= 364 DIRECTION= UZ TOTAL NODES= 2
NODES= 46 47

COUPLED SET= 365 DIRECTION= UZ TOTAL NODES= 2
NODES= 52 53

COUPLED SET= 366 DIRECTION= UZ TOTAL NODES= 2
NODES= 54 55

COUPLED SET= 367 DIRECTION= UZ TOTAL NODES= 2
NODES= 58 59

COUPLED SET= 368 DIRECTION= UZ TOTAL NODES= 2
DES= 60 61

COUPLED SET= 369 DIRECTION= UZ TOTAL NODES= 2
NODES= 62 63

COUPLED SET= 370 DIRECTION= UZ TOTAL NODES= 2
NODES= 64 65

COUPLED SET= 371 DIRECTION= UZ TOTAL NODES= 2
NODES= 66 67

COUPLED SET= 372 DIRECTION= UZ TOTAL NODES= 2
NODES= 68 69

COUPLED SET= 373 DIRECTION= UZ TOTAL NODES= 2
NODES= 70 71

COUPLED SET= 374 DIRECTION= UZ TOTAL NODES= 2
NODES= 72 73

COUPLED SET= 375 DIRECTION= UZ TOTAL NODES= 2
NODES= 75 76

COUPLED SET= 376 DIRECTION= UZ TOTAL NODES= 2
NODES= 77 78

PLED SET= 377 DIRECTION= UZ TOTAL NODES= 2
DES= 79 80

COUPLED SET= 378 DIRECTION= UZ TOTAL NODES= 2

NODES= 81 82

COUPLED SET= 379 DIRECTION= UZ TOTAL NODES= 2
NODES= 83 84

OUPLED SET= 380 DIRECTION= UZ TOTAL NODES= 2
NODES= 85 86

COUPLED SET= 381 DIRECTION= UZ TOTAL NODES= 2
NODES= 88 89

COUPLED SET= 382 DIRECTION= UZ TOTAL NODES= 2
NODES= 90 91

COUPLED SET= 383 DIRECTION= UZ TOTAL NODES= 2
NODES= 92 93

COUPLED SET= 384 DIRECTION= UZ TOTAL NODES= 2
NODES= 94 95

COUPLED SET= 385 DIRECTION= UZ TOTAL NODES= 2
NODES= 96 97

COUPLED SET= 386 DIRECTION= UZ TOTAL NODES= 2
NODES= 98 99

COUPLED SET= 387 DIRECTION= UZ TOTAL NODES= 2
NODES= 101 102

COUPLED SET= 388 DIRECTION= UZ TOTAL NODES= 2
DES= 103 104

COUPLED SET= 389 DIRECTION= UZ TOTAL NODES= 2
NODES= 105 106

COUPLED SET= 390 DIRECTION= UZ TOTAL NODES= 2
NODES= 107 108

COUPLED SET= 391 DIRECTION= UZ TOTAL NODES= 2
NODES= 109 110

COUPLED SET= 392 DIRECTION= UZ TOTAL NODES= 2
NODES= 112 113

COUPLED SET= 393 DIRECTION= UZ TOTAL NODES= 2
NODES= 136 137

COUPLED SET= 394 DIRECTION= UZ TOTAL NODES= 2
NODES= 160 161

COUPLED SET= 395 DIRECTION= UZ TOTAL NODES= 2
NODES= 184 185

COUPLED SET= 396 DIRECTION= UZ TOTAL NODES= 2
NODES= 114 115

JPLED SET= 397 DIRECTION= UZ TOTAL NODES= 2
NODES= 138 139

COUPLED SET= 398 DIRECTION= UZ TOTAL NODES= 2

NODES= 162 163

COUPLED SET= 399 DIRECTION= UZ TOTAL NODES= 2
NODES= 186 187

COUPLED SET= 400 DIRECTION= UZ TOTAL NODES= 2
NODES= 116 117

COUPLED SET= 401 DIRECTION= UZ TOTAL NODES= 2
NODES= 140 141

COUPLED SET= 402 DIRECTION= UZ TOTAL NODES= 2
NODES= 164 165

COUPLED SET= 403 DIRECTION= UZ TOTAL NODES= 2
NODES= 188 189

COUPLED SET= 404 DIRECTION= UZ TOTAL NODES= 2
NODES= 118 119

COUPLED SET= 405 DIRECTION= UZ TOTAL NODES= 2
NODES= 142 143

COUPLED SET= 406 DIRECTION= UZ TOTAL NODES= 2
NODES= 166 167

COUPLED SET= 407 DIRECTION= UZ TOTAL NODES= 2
NODES= 190 191

COUPLED SET= 408 DIRECTION= UZ TOTAL NODES= 2
NODES= 120 121

COUPLED SET= 409 DIRECTION= UZ TOTAL NODES= 2
NODES= 144 145

COUPLED SET= 410 DIRECTION= UZ TOTAL NODES= 2
NODES= 168 169

COUPLED SET= 411 DIRECTION= UZ TOTAL NODES= 2
NODES= 192 193

COUPLED SET= 412 DIRECTION= UZ TOTAL NODES= 2
NODES= 122 123

COUPLED SET= 413 DIRECTION= UZ TOTAL NODES= 2
NODES= 146 147

COUPLED SET= 414 DIRECTION= UZ TOTAL NODES= 2
NODES= 170 171

COUPLED SET= 415 DIRECTION= UZ TOTAL NODES= 2
NODES= 194 195

COUPLED SET= 416 DIRECTION= UZ TOTAL NODES= 2
NODES= 125 126

COUPLED SET= 417 DIRECTION= UZ TOTAL NODES= 2
NODES= 149 150

COUPLED SET= 418 DIRECTION= UZ TOTAL NODES= 2

NODES= 173 174

COUPLED SET= 419 DIRECTION= UZ TOTAL NODES= 2
NODES= 197 198

OUPLED SET= 420 DIRECTION= UZ TOTAL NODES= 2
NODES= 127 128

COUPLED SET= 421 DIRECTION= UZ TOTAL NODES= 2
NODES= 151 152

COUPLED SET= 422 DIRECTION= UZ TOTAL NODES= 2
NODES= 175 176

COUPLED SET= 423 DIRECTION= UZ TOTAL NODES= 2
NODES= 199 200

COUPLED SET= 424 DIRECTION= UZ TOTAL NODES= 2
NODES= 129 130

COUPLED SET= 425 DIRECTION= UZ TOTAL NODES= 2
NODES= 153 154

COUPLED SET= 426 DIRECTION= UZ TOTAL NODES= 2
NODES= 177 178

COUPLED SET= 427 DIRECTION= UZ TOTAL NODES= 2
NODES= 201 202

COUPLED SET= 428 DIRECTION= UZ TOTAL NODES= 2
DES= 131 132

COUPLED SET= 429 DIRECTION= UZ TOTAL NODES= 2
NODES= 155 156

COUPLED SET= 430 DIRECTION= UZ TOTAL NODES= 2
NODES= 179 180

COUPLED SET= 431 DIRECTION= UZ TOTAL NODES= 2
NODES= 203 204

COUPLED SET= 432 DIRECTION= UZ TOTAL NODES= 2
NODES= 133 134

COUPLED SET= 433 DIRECTION= UZ TOTAL NODES= 2
NODES= 157 158

COUPLED SET= 434 DIRECTION= UZ TOTAL NODES= 2
NODES= 181 182

COUPLED SET= 435 DIRECTION= UZ TOTAL NODES= 2
NODES= 205 206

COUPLED SET= 436 DIRECTION= UZ TOTAL NODES= 2
NODES= 208 209

JPLED SET= 437 DIRECTION= UZ TOTAL NODES= 2
NODES= 210 211

COUPLED SET= 438 DIRECTION= UZ TOTAL NODES= 2

NODES= 212 213

COUPLED SET= 439 DIRECTION= UZ TOTAL NODES= 2
NODES= 214 215

UPLED SET= 440 DIRECTION= UZ TOTAL NODES= 2
NODES= 216 217

COUPLED SET= 441 DIRECTION= UZ TOTAL NODES= 2
NODES= 218 219

COUPLED SET= 442 DIRECTION= UZ TOTAL NODES= 2
NODES= 221 222

COUPLED SET= 443 DIRECTION= UZ TOTAL NODES= 2
NODES= 223 224

COUPLED SET= 444 DIRECTION= UZ TOTAL NODES= 2
NODES= 225 226

COUPLED SET= 445 DIRECTION= UZ TOTAL NODES= 2
NODES= 227 228

COUPLED SET= 446 DIRECTION= UZ TOTAL NODES= 2
NODES= 229 230

COUPLED SET= 447 DIRECTION= UZ TOTAL NODES= 2
NODES= 266 267

COUPLED SET= 448 DIRECTION= UZ TOTAL NODES= 2
ES= 268 269

COUPLED SET= 449 DIRECTION= UZ TOTAL NODES= 2
NODES= 270 271

COUPLED SET= 450 DIRECTION= UZ TOTAL NODES= 2
NODES= 272 273

COUPLED SET= 451 DIRECTION= UZ TOTAL NODES= 4
NODES= 274 275 292 293

COUPLED SET= 452 DIRECTION= UZ TOTAL NODES= 4
NODES= 276 277 294 295

COUPLED SET= 453 DIRECTION= UZ TOTAL NODES= 2
NODES= 278 279

COUPLED SET= 454 DIRECTION= UZ TOTAL NODES= 2
NODES= 280 281

COUPLED SET= 455 DIRECTION= UZ TOTAL NODES= 2
NODES= 284 285

COUPLED SET= 456 DIRECTION= UZ TOTAL NODES= 2
NODES= 286 287

JPLED SET= 457 DIRECTION= UZ TOTAL NODES= 2
NODES= 288 289

COUPLED SET= 458 DIRECTION= UZ TOTAL NODES= 2

NODES= 290 291

COUPLED SET= 459 DIRECTION= UZ TOTAL NODES= 2
NODES= 296 297

COUPLED SET= 460 DIRECTION= UZ TOTAL NODES= 2
NODES= 298 299

COUPLED SET= 461 DIRECTION= UZ TOTAL NODES= 2
NODES= 302 303

COUPLED SET= 462 DIRECTION= UZ TOTAL NODES= 2
NODES= 304 305

COUPLED SET= 463 DIRECTION= UZ TOTAL NODES= 2
NODES= 306 307

COUPLED SET= 464 DIRECTION= UZ TOTAL NODES= 2
NODES= 308 309

COUPLED SET= 465 DIRECTION= UZ TOTAL NODES= 2
NODES= 310 311

COUPLED SET= 466 DIRECTION= UZ TOTAL NODES= 2
NODES= 312 313

COUPLED SET= 467 DIRECTION= UZ TOTAL NODES= 2
NODES= 314 315

COUPLED SET= 468 DIRECTION= UZ TOTAL NODES= 2
NODES= 316 317

COUPLED SET= 469 DIRECTION= UZ TOTAL NODES= 2
NODES= 319 320

COUPLED SET= 470 DIRECTION= UZ TOTAL NODES= 2
NODES= 321 322

COUPLED SET= 471 DIRECTION= UZ TOTAL NODES= 2
NODES= 323 324

COUPLED SET= 472 DIRECTION= UZ TOTAL NODES= 2
NODES= 325 326

COUPLED SET= 473 DIRECTION= UZ TOTAL NODES= 2
NODES= 327 328

COUPLED SET= 474 DIRECTION= UZ TOTAL NODES= 2
NODES= 329 330

COUPLED SET= 475 DIRECTION= UZ TOTAL NODES= 2
NODES= 332 333

COUPLED SET= 476 DIRECTION= UZ TOTAL NODES= 2
NODES= 334 335

COUPLED SET= 477 DIRECTION= UZ TOTAL NODES= 2
NODES= 336 337

COUPLED SET= 478 DIRECTION= UZ TOTAL NODES= 2

NODES= 338 339

COUPLED SET= 479 DIRECTION= UZ TOTAL NODES= 2
NODES= 340 341

OUPLED SET= 480 DIRECTION= UZ TOTAL NODES= 2
NODES= 342 343

COUPLED SET= 481 DIRECTION= UZ TOTAL NODES= 2
NODES= 345 346

COUPLED SET= 482 DIRECTION= UZ TOTAL NODES= 2
NODES= 347 348

COUPLED SET= 483 DIRECTION= UZ TOTAL NODES= 2
NODES= 349 350

COUPLED SET= 484 DIRECTION= UZ TOTAL NODES= 2
NODES= 351 352

COUPLED SET= 485 DIRECTION= UZ TOTAL NODES= 2
NODES= 353 354

COUPLED SET= 486 DIRECTION= UZ TOTAL NODES= 2
NODES= 356 357

COUPLED SET= 487 DIRECTION= UZ TOTAL NODES= 2
NODES= 380 381

UPLED SET= 488 DIRECTION= UZ TOTAL NODES= 2
DES= 404 405

COUPLED SET= 489 DIRECTION= UZ TOTAL NODES= 2
NODES= 428 429

COUPLED SET= 490 DIRECTION= UZ TOTAL NODES= 2
NODES= 358 359

COUPLED SET= 491 DIRECTION= UZ TOTAL NODES= 2
NODES= 382 383

COUPLED SET= 492 DIRECTION= UZ TOTAL NODES= 2
NODES= 406 407

COUPLED SET= 493 DIRECTION= UZ TOTAL NODES= 2
NODES= 430 431

COUPLED SET= 494 DIRECTION= UZ TOTAL NODES= 2
NODES= 360 361

COUPLED SET= 495 DIRECTION= UZ TOTAL NODES= 2
NODES= 384 385

COUPLED SET= 496 DIRECTION= UZ TOTAL NODES= 2
NODES= 408 409

OUPLED SET= 497 DIRECTION= UZ TOTAL NODES= 2
NODES= 432 433

COUPLED SET= 498 DIRECTION= UZ TOTAL NODES= 2

NODES= 362 363

COUPLED SET= 499 DIRECTION= UZ TOTAL NODES= 2
NODES= 386 387

COUPLED SET= 500 DIRECTION= UZ TOTAL NODES= 2
NODES= 410 411

COUPLED SET= 501 DIRECTION= UZ TOTAL NODES= 2
NODES= 434 435

COUPLED SET= 502 DIRECTION= UZ TOTAL NODES= 2
NODES= 364 365

COUPLED SET= 503 DIRECTION= UZ TOTAL NODES= 2
NODES= 388 389

COUPLED SET= 504 DIRECTION= UZ TOTAL NODES= 2
NODES= 412 413

COUPLED SET= 505 DIRECTION= UZ TOTAL NODES= 2
NODES= 436 437

COUPLED SET= 506 DIRECTION= UZ TOTAL NODES= 2
NODES= 366 367

COUPLED SET= 507 DIRECTION= UZ TOTAL NODES= 2
NODES= 390 391

COUPLED SET= 508 DIRECTION= UZ TOTAL NODES= 2
NODES= 414 415

COUPLED SET= 509 DIRECTION= UZ TOTAL NODES= 2
NODES= 438 439

COUPLED SET= 510 DIRECTION= UZ TOTAL NODES= 2
NODES= 369 370

COUPLED SET= 511 DIRECTION= UZ TOTAL NODES= 2
NODES= 393 394

COUPLED SET= 512 DIRECTION= UZ TOTAL NODES= 2
NODES= 417 418

COUPLED SET= 513 DIRECTION= UZ TOTAL NODES= 2
NODES= 441 442

COUPLED SET= 514 DIRECTION= UZ TOTAL NODES= 2
NODES= 371 372

COUPLED SET= 515 DIRECTION= UZ TOTAL NODES= 2
NODES= 395 396

COUPLED SET= 516 DIRECTION= UZ TOTAL NODES= 2
NODES= 419 420

COUPLED SET= 517 DIRECTION= UZ TOTAL NODES= 2
NODES= 443 444

COUPLED SET= 518 DIRECTION= UZ TOTAL NODES= 2

NODES= 373 374

COUPLED SET= 519 DIRECTION= UZ TOTAL NODES= 2
NODES= 397 398

COUPLED SET= 520 DIRECTION= UZ TOTAL NODES= 2
NODES= 421 422

COUPLED SET= 521 DIRECTION= UZ TOTAL NODES= 2
NODES= 445 446

COUPLED SET= 522 DIRECTION= UZ TOTAL NODES= 2
NODES= 375 376

COUPLED SET= 523 DIRECTION= UZ TOTAL NODES= 2
NODES= 399 400

COUPLED SET= 524 DIRECTION= UZ TOTAL NODES= 2
NODES= 423 424

COUPLED SET= 525 DIRECTION= UZ TOTAL NODES= 2
NODES= 447 448

COUPLED SET= 526 DIRECTION= UZ TOTAL NODES= 2
NODES= 377 378

COUPLED SET= 527 DIRECTION= UZ TOTAL NODES= 2
NODES= 401 402

COUPLED SET= 528 DIRECTION= UZ TOTAL NODES= 2
NODES= 425 426

COUPLED SET= 529 DIRECTION= UZ TOTAL NODES= 2
NODES= 449 450

COUPLED SET= 530 DIRECTION= UZ TOTAL NODES= 2
NODES= 452 453

COUPLED SET= 531 DIRECTION= UZ TOTAL NODES= 2
NODES= 454 455

COUPLED SET= 532 DIRECTION= UZ TOTAL NODES= 2
NODES= 456 457

COUPLED SET= 533 DIRECTION= UZ TOTAL NODES= 2
NODES= 458 459

COUPLED SET= 534 DIRECTION= UZ TOTAL NODES= 2
NODES= 460 461

COUPLED SET= 535 DIRECTION= UZ TOTAL NODES= 2
NODES= 462 463

COUPLED SET= 536 DIRECTION= UZ TOTAL NODES= 2
NODES= 465 466

COUPLED SET= 537 DIRECTION= UZ TOTAL NODES= 2
NODES= 467 468

COUPLED SET= 538 DIRECTION= UZ TOTAL NODES= 2

NODES= 469 470

COUPLED SET= 539 DIRECTION= UZ TOTAL NODES= 2
NODES= 471 472

COUPLED SET= 540 DIRECTION= UZ TOTAL NODES= 2
NODES= 473 474

COUPLED SET= 541 DIRECTION= UZ TOTAL NODES= 2
NODES= 232 233

COUPLED SET= 542 DIRECTION= UZ TOTAL NODES= 3
NODES= 234 235 608

COUPLED SET= 543 DIRECTION= UZ TOTAL NODES= 3
NODES= 236 237 609

COUPLED SET= 544 DIRECTION= UZ TOTAL NODES= 3
NODES= 238 239 610

COUPLED SET= 545 DIRECTION= UZ TOTAL NODES= 2
NODES= 240 241

COUPLED SET= 546 DIRECTION= UZ TOTAL NODES= 2
NODES= 242 243

COUPLED SET= 547 DIRECTION= UZ TOTAL NODES= 2
NODES= 476 477

COUPLED SET= 548 DIRECTION= UZ TOTAL NODES= 3
NODES= 478 479 613

COUPLED SET= 549 DIRECTION= UZ TOTAL NODES= 3
NODES= 480 481 614

COUPLED SET= 550 DIRECTION= UZ TOTAL NODES= 3
NODES= 482 483 615

COUPLED SET= 551 DIRECTION= UZ TOTAL NODES= 2
NODES= 484 485

COUPLED SET= 552 DIRECTION= UZ TOTAL NODES= 2
NODES= 486 487

COUPLED SET= 553 DIRECTION= UX TOTAL NODES= 2
NODES= 608 235

COUPLED SET= 554 DIRECTION= UX TOTAL NODES= 2
NODES= 609 237

COUPLED SET= 555 DIRECTION= UX TOTAL NODES= 2
NODES= 610 239

COUPLED SET= 556 DIRECTION= UX TOTAL NODES= 2
NODES= 613 479

COUPLED SET= 557 DIRECTION= UX TOTAL NODES= 2
NODES= 614 481

COUPLED SET= 558 DIRECTION= UX TOTAL NODES= 2

NODES= 615 483

MAXIMUM COUPLED SET NUMBER= 558

ST TEMPERATURES FOR ALL SELECTED NODES

NODE	TEMPERATURE	FLUENCE
1	153.00	0.00000E+00
2	144.00	0.00000E+00
3	129.00	0.00000E+00
4	122.00	0.00000E+00
5	121.00	0.00000E+00
6	120.00	0.00000E+00
7	103.00	0.00000E+00
8	95.000	0.00000E+00
9	85.000	0.00000E+00
10	81.000	0.00000E+00
11	153.00	0.00000E+00
12	144.00	0.00000E+00
13	129.00	0.00000E+00
14	122.00	0.00000E+00
15	121.00	0.00000E+00
16	120.00	0.00000E+00
17	103.00	0.00000E+00
18	95.000	0.00000E+00
19	85.000	0.00000E+00
20	81.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
21	155.00	0.00000E+00
22	148.00	0.00000E+00
23	148.00	0.00000E+00
24	139.00	0.00000E+00
25	139.00	0.00000E+00
26	131.00	0.00000E+00
27	131.00	0.00000E+00
28	129.00	0.00000E+00
29	129.00	0.00000E+00
30	124.00	0.00000E+00
31	124.00	0.00000E+00
32	104.00	0.00000E+00
33	104.00	0.00000E+00
34	96.000	0.00000E+00
35	96.000	0.00000E+00
36	85.000	0.00000E+00
37	85.000	0.00000E+00
38	81.000	0.00000E+00
39	155.00	0.00000E+00
40	148.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
41	148.00	0.00000E+00
42	139.00	0.00000E+00
43	139.00	0.00000E+00
44	131.00	0.00000E+00
45	131.00	0.00000E+00
46	129.00	0.00000E+00
47	129.00	0.00000E+00
48	124.00	0.00000E+00
49	124.00	0.00000E+00

50	104.00	0.00000E+00
51	104.00	0.00000E+00
52	96.000	0.00000E+00
53	96.000	0.00000E+00
54	85.000	0.00000E+00
55	85.000	0.00000E+00
56	81.000	0.00000E+00
57	157.00	0.00000E+00
58	153.00	0.00000E+00
59	153.00	0.00000E+00
60	149.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
61	149.00	0.00000E+00
62	143.50	0.00000E+00
63	143.50	0.00000E+00
64	140.00	0.00000E+00
65	140.00	0.00000E+00
66	135.00	0.00000E+00
67	135.00	0.00000E+00
68	110.00	0.00000E+00
69	110.00	0.00000E+00
70	98.000	0.00000E+00
71	98.000	0.00000E+00
72	85.400	0.00000E+00
73	85.400	0.00000E+00
74	81.000	0.00000E+00
75	143.50	0.00000E+00
76	143.50	0.00000E+00
77	140.00	0.00000E+00
78	140.00	0.00000E+00
79	135.00	0.00000E+00
80	135.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
81	110.00	0.00000E+00
82	110.00	0.00000E+00
83	98.000	0.00000E+00
84	98.000	0.00000E+00
85	85.400	0.00000E+00
86	85.400	0.00000E+00
87	81.000	0.00000E+00
88	150.00	0.00000E+00
89	150.00	0.00000E+00
90	147.00	0.00000E+00
91	147.00	0.00000E+00
92	142.00	0.00000E+00
93	142.00	0.00000E+00
94	117.00	0.00000E+00
95	117.00	0.00000E+00
96	103.00	0.00000E+00
97	103.00	0.00000E+00
98	88.000	0.00000E+00
99	88.000	0.00000E+00
100	82.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
101	147.00	0.00000E+00
102	147.00	0.00000E+00
103	142.00	0.00000E+00

104	142.00	0.00000E+00
105	117.00	0.00000E+00
106	117.00	0.00000E+00
107	103.00	0.00000E+00
108	103.00	0.00000E+00
109	88.000	0.00000E+00
110	88.000	0.00000E+00
111	82.000	0.00000E+00
112	170.00	0.00000E+00
113	170.00	0.00000E+00
114	167.00	0.00000E+00
115	167.00	0.00000E+00
116	163.00	0.00000E+00
117	163.00	0.00000E+00
118	128.50	0.00000E+00
119	128.50	0.00000E+00
120	110.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
121	110.00	0.00000E+00
122	91.000	0.00000E+00
123	91.000	0.00000E+00
124	84.000	0.00000E+00
125	167.00	0.00000E+00
126	167.00	0.00000E+00
127	163.00	0.00000E+00
128	163.00	0.00000E+00
129	128.50	0.00000E+00
130	128.50	0.00000E+00
131	110.00	0.00000E+00
132	110.00	0.00000E+00
133	91.000	0.00000E+00
134	91.000	0.00000E+00
135	84.000	0.00000E+00
136	213.00	0.00000E+00
137	213.00	0.00000E+00
138	208.00	0.00000E+00
139	208.00	0.00000E+00
140	201.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
141	201.00	0.00000E+00
142	150.00	0.00000E+00
143	150.00	0.00000E+00
144	123.00	0.00000E+00
145	123.00	0.00000E+00
146	97.000	0.00000E+00
147	97.000	0.00000E+00
148	87.500	0.00000E+00
149	208.00	0.00000E+00
150	208.00	0.00000E+00
151	201.00	0.00000E+00
152	201.00	0.00000E+00
153	150.00	0.00000E+00
154	150.00	0.00000E+00
155	123.00	0.00000E+00
156	123.00	0.00000E+00
157	97.000	0.00000E+00
158	97.000	0.00000E+00
159	87.500	0.00000E+00

NODE	TEMPERATURE	FLUENCE
160	190.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
161	190.00	0.00000E+00
162	187.00	0.00000E+00
163	187.00	0.00000E+00
164	182.00	0.00000E+00
165	182.00	0.00000E+00
166	139.00	0.00000E+00
167	139.00	0.00000E+00
168	115.00	0.00000E+00
169	115.00	0.00000E+00
170	94.000	0.00000E+00
171	94.000	0.00000E+00
172	86.000	0.00000E+00
173	187.00	0.00000E+00
174	187.00	0.00000E+00
175	182.00	0.00000E+00
176	182.00	0.00000E+00
177	139.00	0.00000E+00
178	139.00	0.00000E+00
179	115.00	0.00000E+00
180	115.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
181	94.000	0.00000E+00
182	94.000	0.00000E+00
183	86.000	0.00000E+00
184	154.00	0.00000E+00
185	154.00	0.00000E+00
186	151.00	0.00000E+00
187	151.00	0.00000E+00
188	147.00	0.00000E+00
189	147.00	0.00000E+00
190	117.00	0.00000E+00
191	117.00	0.00000E+00
192	101.00	0.00000E+00
193	101.00	0.00000E+00
194	87.000	0.00000E+00
195	87.000	0.00000E+00
196	82.000	0.00000E+00
197	151.00	0.00000E+00
198	151.00	0.00000E+00
199	147.00	0.00000E+00
200	147.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
201	117.00	0.00000E+00
202	117.00	0.00000E+00
203	101.00	0.00000E+00
204	101.00	0.00000E+00
205	87.000	0.00000E+00
206	87.000	0.00000E+00
207	82.000	0.00000E+00
208	122.00	0.00000E+00
209	122.00	0.00000E+00
210	119.00	0.00000E+00
211	119.00	0.00000E+00
212	116.00	0.00000E+00
213	116.00	0.00000E+00

214	96.000	0.00000E+00
215	96.000	0.00000E+00
216	87.000	0.00000E+00
217	87.000	0.00000E+00
218	81.000	0.00000E+00
219	81.000	0.00000E+00
220	79.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
221	119.00	0.00000E+00
222	119.00	0.00000E+00
223	116.00	0.00000E+00
224	116.00	0.00000E+00
225	96.000	0.00000E+00
226	96.000	0.00000E+00
227	87.000	0.00000E+00
228	87.000	0.00000E+00
229	81.000	0.00000E+00
230	81.000	0.00000E+00
231	79.000	0.00000E+00
232	117.00	0.00000E+00
233	117.00	0.00000E+00
234	114.00	0.00000E+00
235	114.00	0.00000E+00
236	111.00	0.00000E+00
237	111.00	0.00000E+00
238	88.000	0.00000E+00
239	88.000	0.00000E+00
240	81.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
241	81.000	0.00000E+00
242	78.500	0.00000E+00
243	78.500	0.00000E+00
244	78.000	0.00000E+00
246	144.00	0.00000E+00
247	129.00	0.00000E+00
248	122.00	0.00000E+00
249	121.00	0.00000E+00
250	120.00	0.00000E+00
251	103.00	0.00000E+00
252	95.000	0.00000E+00
253	85.000	0.00000E+00
254	81.000	0.00000E+00
256	144.00	0.00000E+00
257	129.00	0.00000E+00
258	122.00	0.00000E+00
259	121.00	0.00000E+00
260	120.00	0.00000E+00
261	103.00	0.00000E+00
262	95.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
263	85.000	0.00000E+00
264	81.000	0.00000E+00
266	148.00	0.00000E+00
267	148.00	0.00000E+00
268	139.00	0.00000E+00
269	139.00	0.00000E+00
270	131.00	0.00000E+00

271	131.00	0.00000E+00
272	129.00	0.00000E+00
273	129.00	0.00000E+00
274	124.00	0.00000E+00
275	124.00	0.00000E+00
276	104.00	0.00000E+00
277	104.00	0.00000E+00
278	96.000	0.00000E+00
279	96.000	0.00000E+00
280	85.000	0.00000E+00
281	85.000	0.00000E+00
282	81.000	0.00000E+00
284	148.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
285	148.00	0.00000E+00
286	139.00	0.00000E+00
287	139.00	0.00000E+00
288	131.00	0.00000E+00
289	131.00	0.00000E+00
290	129.00	0.00000E+00
291	129.00	0.00000E+00
292	124.00	0.00000E+00
293	124.00	0.00000E+00
294	104.00	0.00000E+00
295	104.00	0.00000E+00
296	96.000	0.00000E+00
297	96.000	0.00000E+00
298	85.000	0.00000E+00
299	85.000	0.00000E+00
300	81.000	0.00000E+00
302	153.00	0.00000E+00
303	153.00	0.00000E+00
304	149.00	0.00000E+00
305	149.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
306	143.50	0.00000E+00
307	143.50	0.00000E+00
308	140.00	0.00000E+00
309	140.00	0.00000E+00
310	135.00	0.00000E+00
311	135.00	0.00000E+00
312	110.00	0.00000E+00
313	110.00	0.00000E+00
314	98.000	0.00000E+00
315	98.000	0.00000E+00
316	85.400	0.00000E+00
317	85.400	0.00000E+00
318	81.000	0.00000E+00
319	143.50	0.00000E+00
320	143.50	0.00000E+00
321	140.00	0.00000E+00
322	140.00	0.00000E+00
323	135.00	0.00000E+00
324	135.00	0.00000E+00
325	110.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
326	110.00	0.00000E+00

327	98.000	0.00000E+00
328	98.000	0.00000E+00
329	85.400	0.00000E+00
330	85.400	0.00000E+00
331	81.000	0.00000E+00
332	150.00	0.00000E+00
333	150.00	0.00000E+00
334	147.00	0.00000E+00
335	147.00	0.00000E+00
336	142.00	0.00000E+00
337	142.00	0.00000E+00
338	117.00	0.00000E+00
339	117.00	0.00000E+00
340	103.00	0.00000E+00
341	103.00	0.00000E+00
342	88.000	0.00000E+00
343	88.000	0.00000E+00
344	82.000	0.00000E+00
345	147.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
346	147.00	0.00000E+00
347	142.00	0.00000E+00
348	142.00	0.00000E+00
349	117.00	0.00000E+00
350	117.00	0.00000E+00
351	103.00	0.00000E+00
352	103.00	0.00000E+00
353	88.000	0.00000E+00
354	88.000	0.00000E+00
355	82.000	0.00000E+00
356	170.00	0.00000E+00
357	170.00	0.00000E+00
358	167.00	0.00000E+00
359	167.00	0.00000E+00
360	163.00	0.00000E+00
361	163.00	0.00000E+00
362	128.50	0.00000E+00
363	128.50	0.00000E+00
364	110.00	0.00000E+00
365	110.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
366	91.000	0.00000E+00
367	91.000	0.00000E+00
368	84.000	0.00000E+00
369	167.00	0.00000E+00
370	167.00	0.00000E+00
371	163.00	0.00000E+00
372	163.00	0.00000E+00
373	128.50	0.00000E+00
374	128.50	0.00000E+00
375	110.00	0.00000E+00
376	110.00	0.00000E+00
377	91.000	0.00000E+00
378	91.000	0.00000E+00
379	84.000	0.00000E+00
380	213.00	0.00000E+00
381	213.00	0.00000E+00
382	208.00	0.00000E+00

383	208.00	0.00000E+00
384	201.00	0.00000E+00
385	201.00	0.00000E+00

DE	TEMPERATURE	FLUENCE
386	150.00	0.00000E+00
387	150.00	0.00000E+00
388	123.00	0.00000E+00
389	123.00	0.00000E+00
390	97.000	0.00000E+00
391	97.000	0.00000E+00
392	87.500	0.00000E+00
393	208.00	0.00000E+00
394	208.00	0.00000E+00
395	201.00	0.00000E+00
396	201.00	0.00000E+00
397	150.00	0.00000E+00
398	150.00	0.00000E+00
399	123.00	0.00000E+00
400	123.00	0.00000E+00
401	97.000	0.00000E+00
402	97.000	0.00000E+00
403	87.500	0.00000E+00
404	190.00	0.00000E+00
405	190.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
406	187.00	0.00000E+00
407	187.00	0.00000E+00
08	182.00	0.00000E+00
409	182.00	0.00000E+00
410	139.00	0.00000E+00
411	139.00	0.00000E+00
412	115.00	0.00000E+00
413	115.00	0.00000E+00
414	94.000	0.00000E+00
415	94.000	0.00000E+00
416	86.000	0.00000E+00
417	187.00	0.00000E+00
418	187.00	0.00000E+00
419	182.00	0.00000E+00
420	182.00	0.00000E+00
421	139.00	0.00000E+00
422	139.00	0.00000E+00
423	115.00	0.00000E+00
424	115.00	0.00000E+00
425	94.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
426	94.000	0.00000E+00
427	86.000	0.00000E+00
428	154.00	0.00000E+00
429	154.00	0.00000E+00
430	151.00	0.00000E+00
31	151.00	0.00000E+00
32	147.00	0.00000E+00
433	147.00	0.00000E+00
434	117.00	0.00000E+00
435	117.00	0.00000E+00
436	101.00	0.00000E+00

437	101.00	0.00000E+00
438	87.000	0.00000E+00
439	87.000	0.00000E+00
440	82.000	0.00000E+00
441	151.00	0.00000E+00
442	151.00	0.00000E+00
443	147.00	0.00000E+00
444	147.00	0.00000E+00
445	117.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
446	117.00	0.00000E+00
447	101.00	0.00000E+00
448	101.00	0.00000E+00
449	87.000	0.00000E+00
450	87.000	0.00000E+00
451	82.000	0.00000E+00
452	122.00	0.00000E+00
453	122.00	0.00000E+00
454	119.00	0.00000E+00
455	119.00	0.00000E+00
456	116.00	0.00000E+00
457	116.00	0.00000E+00
458	96.000	0.00000E+00
459	96.000	0.00000E+00
460	87.000	0.00000E+00
461	87.000	0.00000E+00
462	81.000	0.00000E+00
463	81.000	0.00000E+00
464	79.000	0.00000E+00
465	119.00	0.00000E+00

NODE	TEMPERATURE	FLUENCE
466	119.00	0.00000E+00
467	116.00	0.00000E+00
468	116.00	0.00000E+00
469	96.000	0.00000E+00
470	96.000	0.00000E+00
471	87.000	0.00000E+00
472	87.000	0.00000E+00
473	81.000	0.00000E+00
474	81.000	0.00000E+00
475	79.000	0.00000E+00
476	117.00	0.00000E+00
477	117.00	0.00000E+00
478	114.00	0.00000E+00
479	114.00	0.00000E+00
480	111.00	0.00000E+00
481	111.00	0.00000E+00
482	88.000	0.00000E+00
483	88.000	0.00000E+00
484	81.000	0.00000E+00
485	81.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
86	78.500	0.00000E+00
487	78.500	0.00000E+00
488	78.000	0.00000E+00
493	96.000	0.00000E+00
494	85.000	0.00000E+00

502	98.000	0.00000E+00
503	85.400	0.00000E+00
509	88.000	0.00000E+00
515	91.000	0.00000E+00
521	97.000	0.00000E+00
527	94.000	0.00000E+00
532	101.00	0.00000E+00
533	87.000	0.00000E+00
538	87.000	0.00000E+00
539	81.000	0.00000E+00
551	96.000	0.00000E+00
552	85.000	0.00000E+00
560	98.000	0.00000E+00
561	85.400	0.00000E+00
567	88.000	0.00000E+00

NODE	TEMPERATURE	FLUENCE
573	91.000	0.00000E+00
579	97.000	0.00000E+00
585	94.000	0.00000E+00
590	101.00	0.00000E+00
591	87.000	0.00000E+00
596	87.000	0.00000E+00
597	81.000	0.00000E+00
605	101.00	0.00000E+00
606	105.00	0.00000E+00
607	114.00	0.00000E+00
608	114.00	0.00000E+00
609	111.00	0.00000E+00
610	88.000	0.00000E+00
611	105.00	0.00000E+00
612	114.00	0.00000E+00
613	114.00	0.00000E+00
614	111.00	0.00000E+00
615	88.000	0.00000E+00

PRINT PRIN NODAL STRESSES PER NODE

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
11	-0.49969945E-01	-0.13814871	-0.31858959	0.26861964	0.23716
12	0.66613128E-01	-0.19376230E-01	-0.94825473E-01	0.16143860	0.14239
13	-0.11947303E-01	-0.37265571E-01	-0.10727279	0.95325491E-01	0.86787
14	-0.53031508E-02	-0.97653133E-02	-0.57796446E-01	0.52493295E-01	0.50430
15	-0.10790701E-01	-0.19867322E-01	-0.67685445E-01	0.56894744E-01	0.53124
16	0.49013964E-04	-0.15465408E-01	-0.44592701E-01	0.44641715E-01	0.39255
17	0.79430031E-01	-0.79697430E-02	-0.46667070E-01	0.12609710	0.11188
18	0.64535384E-01	-0.41324532E-02	-0.58328765E-01	0.12286415	0.10701
19	-0.36474643E-02	-0.12483041E-01	-0.78135768E-01	0.74488303E-01	0.70644
20	-0.25282781E-01	-0.64453641E-01	-0.94942964E-01	0.69660183E-01	0.60483
21	-0.50651531E-01	-0.20986708	-0.36796355	0.31731202	0.27480
22	0.10967035E-01	-0.41951640E-01	-0.14649001	0.15745705	0.13878
23	0.17237465E-01	-0.17769520E-01	-0.13722075	0.15445821	0.14027

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
24	-0.40070429E-01	-0.65223028E-01	-0.15607547	0.11600504	0.10569
25	0.31457235E-01	-0.11879897E-01	-0.80004326E-01	0.11146156	0.97320
26	0.35978292E-01	-0.52622014E-02	-0.28758844E-01	0.64737136E-01	0.56761
27	0.35952740E-01	0.12645857E-01	-0.39327643E-01	0.75280383E-01	0.66751
28	0.19261884E-01	0.73932221E-03	-0.68556822E-01	0.87818706E-01	0.80178
29	0.85386734E-02	-0.53024690E-01	-0.57111398E-01	0.65650072E-01	0.63705
30	0.67876448E-02	-0.44373130E-01	-0.53664744E-01	0.60452389E-01	0.56383
33	0.86526928E-01	0.13397594E-01	-0.10769973E-01	0.97296902E-01	0.87745
34	0.80135762E-01	0.17463633E-01	-0.12896257E-01	0.93032019E-01	0.82172
35	0.64662160E-01	0.17129491E-02	-0.30720494E-02	0.67734209E-01	0.65472
36	0.27618274E-01	0.22647205E-02	-0.37436300E-01	0.65054575E-01	0.56793
37	0.14805323E-01	0.30764270E-02	-0.27305331E-01	0.42110654E-01	0.37642
38	0.11088755E-01	-0.18785157E-01	-0.85966129E-01	0.97054884E-01	0.86096

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A65 of A79

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
39	0.83122416E-02	-0.15850198	-0.33492294	0.34323518	0.29728
40	-0.19544488E-02	-0.15841428E-01	-0.16390007	0.16194562	0.15546
41	0.17269048E-02	0.28493896E-03	-0.11388169	0.11560860	0.1[illegible]9
42	0.19140163E-01	-0.51253706E-02	-0.11520877	0.13434893	0.12400
43	0.54665204E-01	0.36587991E-02	-0.15159298	0.20625819	0.18607
44	-0.15710219E-01	-0.25415890E-01	-0.30745124	0.29174102	0.28701
45	-0.28979668E-01	-0.61177020E-01	-0.24678768	0.21780802	0.20362
46	-0.27896057E-01	-0.50866616E-01	-0.10639232	0.73996267E-01	0.70380

47	-0.11389460E-01	-0.49779608E-01	-0.92076246E-01	0.80686786E-01	0.6990
48	0.26922098E-01	-0.82632409E-02	-0.55194413E-01	0.82116511E-01	0.7135
49	-0.95642187E-02	-0.15132980E-01	-0.85363769E-01	0.75799550E-01	0.7317
50	0.37694522E-01	-0.23717571E-01	-0.85184636E-01	0.12287916	0.1064
51	0.86820780E-01	0.15902609E-01	-0.30921566E-01	0.11774235	0.1026

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
52	0.24739921E-01	-0.25383828E-01	-0.72247674E-01	0.96987595E-01	0.8400
53	0.30088766E-01	-0.96823442E-02	-0.49105357E-01	0.79194123E-01	0.6858
54	0.68547432E-01	0.10061291E-01	-0.97364017E-02	0.78283833E-01	0.7050
55	0.59868786E-01	0.37852865E-01	0.31750003E-01	0.28118783E-01	0.2561
56	0.37848381E-01	0.10687460E-01	-0.29188237E-01	0.67036618E-01	0.5840
57	0.13291929E-01	-0.12365803	-0.27702784	0.29031977	0.2515
58	0.27904143E-01	-0.96057464E-02	-0.10227562	0.13017976	0.1160
59	-0.55302173E-02	-0.21284849E-01	-0.17469724	0.16916703	0.1618
60	-0.26171577E-02	-0.12971208E-01	-0.17524808	0.17263092	0.1676
61	0.74642218E-03	-0.19272537E-01	-0.30459512	0.30534154	0.2958
62	-0.48343456E-01	-0.16235320	-0.36773295	0.31938949	0.2803
63	-0.62576267E-02	-0.14123116	-0.24924098	0.24298335	0.2108
64	-0.51740335E-02	-0.84284418E-01	-0.15598193	0.15080790	0.1306

***** POST1 NODAL STRESS LISTING *****

OAD STEP 1 ITERATION= 15 SECTION= 1
IME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
65	-0.19551967E-01	-0.86658529E-01	-0.13351775	0.11396578	0.9921
66	0.18759591E-01	-0.98763603E-02	-0.13190172	0.15066131	0.1385
67	0.95092123E-02	-0.15137694E-01	-0.86137455E-01	0.95646667E-01	0.8601
68	0.37692947E-01	-0.46440000E-02	-0.85961600E-01	0.12365455	0.10884
69	0.80177242E-01	0.23282054E-01	-0.71583438E-01	0.15176068	0.1327
70	-0.52143233E-03	-0.18005245E-01	-0.94290869E-01	0.93769436E-01	0.86365
71	0.60826986E-02	-0.18970002E-01	-0.62402268E-01	0.68484967E-01	0.60017
72	0.61632649E-01	0.77370150E-03	-0.40124666E-01	0.10175732	0.88687
73	0.59868502E-01	0.78216935E-02	-0.66645048E-02	0.66533007E-01	0.60602
74	-0.66688738E-02	-0.13240860E-01	-0.29188624E-01	0.22519750E-01	0.20058
76	-0.68779254E-02	-0.12430433E-01	-0.13282831	0.12595039	0.12326
77	-0.39501260E-01	-0.53341363E-01	-0.13285821	0.93356947E-01	0.87263
78	-0.11923994E-01	-0.55005767E-01	-0.11850140	0.10657741	0.92861

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A66 of A79

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
79	0.34944792E-01	0.12407973E-01	-0.11816741	0.15311220	0.14318
80	0.89231797E-02	0.29605297E-02	-0.90114882E-01	0.99038062E-01	0.96195
81	-0.85565585E-02	-0.11696620E-01	-0.90201475E-01	0.81644917E-01	0.80121
82	0.47265349E-02	-0.34296769E-02	-0.54595503E-01	0.59322088E-01	0.55693
83	0.304[illegible]E-01	0.16454219E-02	-0.54428074E-01	0.84888194E-01	0.74768

84	0.45257235E-01	0.75571528E-02	-0.23669392E-01	0.68926627E-01	0.5977
85	0.38508626E-01	-0.46935009E-02	-0.24583885E-01	0.63092511E-01	0.5586
86	0.35036475E-01	-0.38843883E-03	-0.88293604E-02	0.43865835E-01	0.4031
87	-0.88263918E-02	-0.98017250E-02	-0.15659234E-01	0.68328425E-02	0.6401
89	0.71575925E-01	0.35557533E-01	-0.34758840E-02	0.75051809E-01	0. [illegible]
90	0.30060206E-01	0.10123554E-01	-0.53506000E-01	0.83566206E-01	0.7559
91	0.13466782E-01	-0.29187929E-01	-0.56242802E-01	0.69709584E-01	0.6087
92	0.18880056E-01	0.17680715E-01	0.60918031E-02	0.12788253E-01	0.1223

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
93	0.12786367E-01	0.36521221E-02	0.13636767E-02	0.11422690E-01	0.1046
94	0.71098119E-02	-0.78755507E-02	-0.13655577E-01	0.20765389E-01	0.1856
95	0.87910572E-02	-0.26773046E-04	-0.94965974E-02	0.18287655E-01	0.1584
96	0.30797108E-01	0.57098944E-02	-0.62632514E-02	0.37060359E-01	0.3275
97	0.46646786E-01	0.10588273E-01	-0.13950997E-01	0.60597784E-01	0.5279
98	0.40229448E-01	-0.16623828E-02	-0.15196758E-01	0.55426206E-01	0.5005
99	0.35036592E-01	0.10654368E-01	0.31083177E-02	0.31928275E-01	0.2890
100	0.31100509E-02	0.12411308E-02	-0.15657930E-01	0.18767981E-01	0.1790
101	0.27438996E-01	-0.14705577E-01	-0.28729220E-01	0.56168216E-01	0.5063
102	0.28882356E-01	-0.14056757E-01	-0.26812152E-01	0.55694508E-01	0.5053
103	0.34316664E-01	0.32357534E-01	-0.18441923E-02	0.36160857E-01	0.3522
104	0.16926529E-01	-0.54311410E-02	-0.12835657E-01	0.29762186E-01	0.2683
105	0.19843707E-01	0.39417232E-02	-0.74043000E-02	0.27248007E-01	0.2270

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
106	0.99488308E-02	0.46519893E-02	-0.17281327E-01	0.27230158E-01	0.25006
107	0.13515007E-02	-0.28796794E-02	-0.21141931E-01	0.22493432E-01	0.20704
108	-0.16755882E-02	-0.33473970E-02	-0.22585063E-01	0.20909475E-01	0.20125
109	0.38071595E-01	-0.76883557E-02	-0.15369283E-01	0.53440878E-01	0.50044
110	0.44615370E-01	0.94133014E-02	0.48817587E-02	0.39733612E-01	0.37672
111	0.59128333E-02	0.48835033E-02	-0.17386765E-01	0.23299598E-01	0.22802
113	0.11480121	0.51581138E-01	-0.12735071E-01	0.12753628	0.11077
114	0.75685513E-02	-0.24973829E-01	-0.28947211E-01	0.36515762E-01	0.34700
115	0.56799678E-02	-0.26272659E-01	-0.40193411E-01	0.45873379E-01	0.40737
116	0.20935417E-01	0.16640967E-01	-0.21545927E-01	0.42481344E-01	0.40505
117	0.52194381E-02	-0.10273284E-01	-0.23263826E-01	0.28483264E-01	0.24698
118	0.11258618E-01	-0.90045938E-03	-0.20954432E-01	0.32213050E-01	0.28175
119	0.13542376E-01	0.10619596E-01	-0.15047696E-01	0.28590072E-01	0.27246

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A67 of A79

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
ELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
120	0.60106867E-02	0.26885883E-02	-0.19574602E-01	0.25585289E-01	0.24096
121	-0.57165731E-02	-0.86109093E-02	-0.26250937E-01	0.20534364E-01	[illegible]

122	0.37889911E-01	-0.14620179E-01	-0.21226146E-01	0.59116056E-01	0.56105
123	0.44615207E-01	-0.61362980E-02	-0.81614754E-02	0.52776682E-01	0.51793
124	-0.81582245E-02	-0.96367679E-02	-0.17388433E-01	0.92302086E-02	0.85869
125	0.31221734E-01	-0.29982383E-01	-0.41456245E-01	0.72677979E-01	0.67674
126	0.19890724E-01	-0.36006256E-01	-0.51980486E-01	0.71871210E-01	0.65364
127	0.31035716E-01	0.19829149E-01	-0.36046046E-01	0.67081762E-01	0.62239
128	0.12067023E-01	-0.42764245E-03	-0.35265249E-01	0.47332272E-01	0.42485
129	0.28611691E-01	-0.76956539E-02	-0.23199059E-01	0.51810749E-01	0.46059
130	0.30294834E-01	0.12370492E-01	-0.19655462E-01	0.49950295E-01	0.43829
131	0.14348527E-02	-0.57255387E-03	-0.49377780E-01	0.50812632E-01	0.49839
132	0.34252192E-02	0.44491664E-03	-0.47325552E-01	0.50750771E-01	0.49328

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
133	0.13499415	0.68032672E-02	-0.51258825E-02	0.14012003	0.13455
134	0.14259168	0.19233725E-01	0.38754584E-02	0.13871622	0.13171
135	0.38758334E-02	-0.10847207E-01	-0.58903219E-01	0.62779052E-01	0.56865
137	0.12608629	0.47192401E-01	-0.40985277E-01	0.16707157	0.14699
138	0.51039120E-02	-0.32083552E-01	-0.81778798E-01	0.86882710E-01	0.75502
139	0.14303940E-01	-0.25548388E-01	-0.47538479E-01	0.61842418E-01	0.54296
140	0.57467813E-01	0.14229379E-01	-0.47565281E-01	0.10503309	0.91433
141	0.20568435E-02	-0.31261344E-03	-0.47326858E-01	0.49383702E-01	0.48242
142	0.23863791E-01	-0.75800429E-02	-0.40523531E-01	0.64387322E-01	0.55766
143	0.28418114E-01	0.92037705E-02	-0.29832476E-01	0.58250590E-01	0.51410
144	-0.17319143E-02	-0.96748395E-02	-0.52329182E-01	0.50597268E-01	0.47130
145	-0.89331471E-02	-0.13543433E-01	-0.51348592E-01	0.42415445E-01	0.40308
146	0.13472315	-0.25750702E-02	-0.25846298E-01	0.16056944	0.15029

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
147	0.14259167	0.15685855E-01	-0.19092006E-02	0.14450087	0.13655
148	-0.19088010E-02	-0.14395077E-01	-0.58903249E-01	0.56994448E-01	0.51890
149	0.38465856E-01	0.34977782E-01	-0.25654388E-02	0.41031295E-01	0.39403
150	0.18604355E-01	-0.16525936E-01	-0.33153410E-01	0.51757764E-01	0.45768
151	0.53528307E-01	0.25499438E-02	-0.35809859E-01	0.89338167E-01	0.77625
152	0.19071253E-02	-0.67041455E-02	-0.37028145E-01	0.38935270E-01	0.35423
153	0.13951546E-01	-0.10231226E-01	-0.33320776E-01	0.47272322E-01	0.40942
154	0.23665317E-01	0.17469880E-01	-0.21991964E-01	0.45657281E-01	0.42896
155	-0.46345020E-02	-0.11528573E-01	-0.35338629E-01	0.30704127E-01	0.27903
156	-0.15911535E-01	-0.17392751E-01	-0.37727150E-01	0.21815615E-01	0.21114
157	0.78910402E-01	-0.94489480E-02	-0.32542883E-01	0.11145329	0.10188
158	0.91677559E-01	0.92528803E-02	-0.70903814E-02	0.98767941E-01	0.91695
159	-0.70896454E-02	-0.18541688E-01	-0.32869779E-01	0.25780134E-01	0.22372

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
161	-0.17914887E-02	-0.32724488E-01	-0.13189430	0.13010281	0.1207
162	0.17456541E-01	-0.69016619E-01	-0.13683144	0.15428798	0.1339
163	0.15691305E-01	-0.31330897E-01	-0.96235701E-01	0.11192701	0.[illegible]34
164	0.38723346E-01	-0.25887576E-02	-0.96666499E-01	0.13538985	0.[illegible]1
165	0.22390019E-02	-0.11294568E-01	-0.69732628E-01	0.71971630E-01	0.6624
166	0.12126154E-01	-0.98993443E-02	-0.68790293E-01	0.80916447E-01	0.7245
167	0.22343689E-01	0.80353343E-02	-0.58333340E-01	0.80677030E-01	0.7455
168	-0.14069061E-01	-0.23997770E-01	-0.60532422E-01	0.46463361E-01	0.4238
169	0.56769553E-02	-0.47729538E-02	-0.27506088E-01	0.33183044E-01	0.2938
170	0.79114324E-01	0.13618533E-01	-0.11384938E-01	0.90499262E-01	0.8094
171	0.91677582E-01	0.33128026E-01	0.13707162E-01	0.77970421E-01	0.7030
172	0.13707774E-01	0.53334562E-02	-0.32869631E-01	0.46577406E-01	0.4300
173	0.26242564E-01	0.16610356E-01	-0.95559231E-01	0.12180180	0.1172

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
174	0.18445110E-01	-0.15548682E-01	-0.11746618	0.13591129	0.1225
175	0.36735646E-01	0.25719562E-01	-0.11446699	0.15120264	0.1460
176	0.34012251E-01	-0.21636680E-02	-0.93631074E-01	0.12764333	0.1139
177	-0.13441345E-01	-0.17074159E-01	-0.10585852	0.92417178E-01	0.9065
178	0.20827113E-01	0.85980069E-02	-0.63004477E-01	0.83831590E-01	0.7843
179	0.14691001	0.25924195E-01	-0.38574017E-01	0.18548403	0.1630
180	0.15546267	0.65966340E-02	-0.62789964E-01	0.21825264	0.[illegible]14
181	-0.33981444E-01	-0.57669437E-01	-0.25812625	0.22414481	0.[illegible]28
182	-0.22957566E-01	-0.50930414E-01	-0.23629060	0.21333303	0.2008
183	0.12174295	0.15426926E-01	-0.22961376E-01	0.14470433	0.1298
185	0.18951375E-01	-0.88649936E-01	-0.16574261	0.18469398	0.1610
186	0.16127677E-01	-0.34536640E-01	-0.14569373	0.16182141	0.1433
187	0.24013591E-01	-0.80443502E-02	-0.94167165E-01	0.11818076	0.1058

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
188	0.41004708E-01	0.33223896E-01	-0.89868565E-01	0.13087327	0.12716
189	0.41077258E-01	0.46349860E-02	-0.60187397E-01	0.10126466	0.88838
190	0.34320510E-02	-0.10275510E-01	-0.82223232E-01	0.85655283E-01	0.79690
191	0.20856208E-01	0.92726958E-02	-0.51780249E-01	0.72636456E-01	0.67593
192	0.14793012	0.14369846E-01	-0.16111766E-01	0.16404189	0.15112
193	0.15957010	0.31594136E-01	-0.18148129E-01	0.17771823	0.15880
194	0.12209280E-01	-0.32671907E-01	-0.25556774	0.26777702	0.24839
195	0.50227081E-02	-0.18076779E-01	-0.23629055	0.24131325	0.23063
196	0.12174311	0.48280564E-01	0.50187897E-02	0.11672432	0.10220
197	0.87873169E-01	-0.53039473E-01	-0.16280053	0.25067370	0.21764
198	0.67065534E-01	-0.61201991E-02	-0.17663802	0.24370355	0.[illegible]59
199	0.83637216E-01	0.11337580E-01	-0.16681082	0.25044804	0.[illegible]25
200	0.71761933E-01	-0.36432273E-02	-0.11983739	0.19159932	0.16717

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1

TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
201	0.61209706E-01	-0.63060945E-02	-0.12762354	0.18883325	0.16573
202	0.41433124E-01	0.21477532E-01	-0.91496240E-01	0.13292936	0.12416
203	0.53958950E-01	-0.52278742E-01	-0.84078598E-01	0.13803755	0.12520
204	0.70250168E-01	0.10375233E-01	-0.34719324E-01	0.10496949	0.91206
205	0.34967952E-01	0.98575320E-02	-0.10138724	0.13635520	0.12569
206	0.26161623E-01	0.36843287E-02	-0.74168821E-01	0.10033044	0.91193
207	0.42762696E-02	-0.15612325E-02	-0.56960421E-01	0.61236690E-01	0.58536
209	0.13600617	0.87153901E-01	-0.92028700E-01	0.22803487	0.20808
210	0.11128295	0.45158380E-01	-0.13748698	0.24876993	0.22317
211	0.11594574	0.96026590E-02	-0.12740453	0.24335027	0.21130
212	0.12723214	0.27060439E-01	-0.11229205	0.23952419	0.20835
213	0.97383170E-01	0.59585840E-03	-0.91183041E-01	0.18856621	0.16332
214	0.89448454E-01	-0.20669751E-02	-0.10158673	0.19103519	0.16548

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
215	0.64097142E-01	0.41824489E-01	-0.68220110E-01	0.13231725	0.12270
216	0.73214663E-01	-0.31931789E-01	-0.57394160E-01	0.13060882	0.11992
217	0.59142477E-01	0.95406975E-03	-0.53858820E-01	0.11300130	0.97876
218	0.11199762E-01	0.43636591E-03	-0.10786624	0.11906600	0.11406
219	0.12309986E-01	-0.24341033E-02	-0.73962047E-01	0.86272033E-01	0.79926
220	0.12776924E-01	-0.30156824E-01	-0.56628778E-01	0.69405701E-01	0.60668
221	0.12106383	-0.90678096E-02	-0.57487711E-01	0.17855154	0.15993
222	0.10626410	0.10438147E-01	-0.80413274E-01	0.18667737	0.16168
223	0.11364530	0.46410454E-01	-0.70983432E-01	0.18462873	0.16184
224	0.10408537	0.14968326E-01	-0.94448090E-01	0.19853346	0.17223
225	0.79613402E-01	-0.26071212E-01	-0.12731402	0.20692742	0.17921
226	0.12421136	0.49653578E-01	-0.10882436	0.23303572	0.20613
227	0.15499279	-0.16002987E-01	-0.79544516E-01	0.23453730	0.21010

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
228	0.44247578E-01	0.41701871E-01	0.26188363E-02	0.41628742E-01	0.40416
229	0.43687108E-01	0.14978744E-01	0.25458540E-02	0.41141254E-01	0.36546
230	0.64088269E-01	0.10862298E-01	-0.89813961E-03	0.64986409E-01	0.59977
231	0.29136115E-01	-0.19532454E-01	-0.11794450	0.14708061	0.12978
233	0.11254257	0.96020117E-01	-0.70760582E-01	0.18330315	0.17562
234	0.82650394E-01	-0.61739564E-01	-0.83667886E-01	0.16631828	0.15651
235	0.10693622	-0.39318404E-01	-0.79935460E-01	0.18687168	0.17023
236	0.11426617	-0.33461227E-02	-0.70454345E-01	0.18472052	0.16195
237	0.11907674	-0.18915954E-01	-0.81556133E-01	0.20063287	0.17779
238	0.98320935E-01	-0.59952336E-01	-0.11814139	0.21646232	0.19402
239	0.24840616	0.13145998E-01	-0.57510786E-01	0.30591695	0.27742
240	0.26075538	-0.97985617E-02	-0.52510743E-01	0.31326612	0.29424
241	0.41910583E-01	0.16223981E-01	-0.30502005E-01	0.72412588E-01	0.63587

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
HELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
242	0.41308134E-01	-0.10509818E-01	-0.30522336E-01	0.71830470E-01	0.6420
243	0.52079203E-01	0.93644177E-03	-0.46110897E-01	0.98190099E-01	0.8505
244	-0.23884478E-01	-0.29458207E-01	-0.12214583	0.98261351E-01	0.9559
256	0.66612679E-01	-0.19374487E-01	-0.94822502E-01	0.16143518	0.1423
257	-0.11947183E-01	-0.37252834E-01	-0.10726734	0.95320160E-01	0.8678
258	-0.53039603E-02	-0.97666486E-02	-0.57773620E-01	0.52469660E-01	0.5040
259	-0.10783402E-01	-0.19864721E-01	-0.67676766E-01	0.56893364E-01	0.5312
260	0.64161397E-04	-0.15465397E-01	-0.44591869E-01	0.44656031E-01	0.3926
261	0.79469938E-01	-0.79697585E-02	-0.46610673E-01	0.12608061	0.1118
262	0.64589873E-01	-0.41324899E-02	-0.58259490E-01	0.12284936	0.1070
263	-0.36466888E-02	-0.12405399E-01	-0.78047844E-01	0.74401155E-01	0.7059
264	-0.25283036E-01	-0.64273326E-01	-0.94939388E-01	0.69656353E-01	0.6046
266	0.10966174E-01	-0.41953394E-01	-0.14649112	0.15745730	0.1387

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
267	0.17237326E-01	-0.17767324E-01	-0.13721053	0.15444785	0.1402
268	-0.40070602E-01	-0.65214936E-01	-0.15606505	0.11599444	0. [illegible]68
269	0.31457246E-01	-0.11864264E-01	-0.80001774E-01	0.11145902	0.[illegible]32
270	0.35978300E-01	-0.52564341E-02	-0.28744073E-01	0.64722373E-01	0.5674
271	0.35952731E-01	0.12649316E-01	-0.39310353E-01	0.75263084E-01	0.6673
272	0.19261878E-01	0.75100120E-03	-0.68546611E-01	0.87808488E-01	0.8017
273	0.85386806E-02	-0.53021735E-01	-0.57099161E-01	0.65637842E-01	0.6369
274	0.67876545E-02	-0.44377980E-01	-0.53643913E-01	0.60431567E-01	0.5637
277	0.86578001E-01	0.13397603E-01	-0.10724766E-01	0.97302768E-01	0.8776
278	0.80197407E-01	0.17463643E-01	-0.12848118E-01	0.93045525E-01	0.8219
279	0.64763383E-01	0.17139878E-02	-0.30369023E-02	0.67800285E-01	0.6555
280	0.27789254E-01	0.22650956E-02	-0.37450571E-01	0.65239825E-01	0.5694
281	0.14999444E-01	0.30761630E-02	-0.27323900E-01	0.42323344E-01	0.3779

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A71 of A79

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
282	0.11287086E-01	-0.18785405E-01	-0.85980575E-01	0.97267661E-01	0.86257
284	-0.19529482E-02	-0.15838265E-01	-0.16389836	0.16194541	0.15546
285	0.17296291E-02	0.28972884E-03	-0.11387014	0.11559977	0.11488
286	0.19139662E-01	-0.51130253E-02	-0.11519214	0.13433180	0.12399
287	0.54718505E-01	0.36588788E-02	-0.15150925	0.20622775	0.18602
288	-0.15613787E-01	-0.25416037E-01	-0.30739270	0.29177891	0.[illegible]00
289	-0.28979700E-01	-0.61097145E-01	-0.24676547	0.21778577	0.2[illegible]63
290	-0.27896112E-01	-0.50773991E-01	-0.10687721	0.78981095E-01	0.70388
291	-0.11389516E-01	-0.49714590E-01	-0.92069285E-01	0.80679769E-01	0.69899
292	0.26922035E-01	-0.82447840E-02	-0.55137137E-01	0.82059172E-01	0.71306
293	-0.95642575E-02	-0.15122095E-01	-0.85272674E-01	0.75708416E-01	0.73088

294	0.37706548E-01	-0.23717634E-01	-0.85067831E-01	0.12277438	0.1063
295	0.86838959E-01	0.15902619E-01	-0.30828263E-01	0.11766722	0.1026

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
296	0.24813568E-01	-0.25383689E-01	-0.72194333E-01	0.97007901E-01	0.8402
297	0.30139843E-01	-0.96818485E-02	-0.49020752E-01	0.79160595E-01	0.6855
298	0.68543479E-01	0.10061930E-01	-0.95774111E-02	0.78120890E-01	0.7038
299	0.59897197E-01	0.38060816E-01	0.31749915E-01	0.28147282E-01	0.2558
300	0.38065889E-01	0.10687314E-01	-0.29158072E-01	0.67223960E-01	0.5855
302	0.27905187E-01	-0.96022219E-02	-0.10227381	0.13017900	0.1160
303	-0.55252310E-02	-0.21284547E-01	-0.17468347	0.16915824	0.1618
304	-0.26182457E-02	-0.12961968E-01	-0.17522775	0.17260951	0.1676
305	0.78010535E-03	-0.19271783E-01	-0.30449244	0.30527254	0.2957
306	-0.48343354E-01	-0.16228926	-0.36764217	0.31929881	0.2802
307	-0.62576574E-02	-0.14114732	-0.24922273	0.24296507	0.2108
308	-0.51740758E-02	-0.84226864E-01	-0.15593176	0.15075768	0.1306
309	-0.19552022E-01	-0.86640975E-01	-0.13346332	0.11391130	0.9916

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

ODE	SIG1	SIG2	SIG3	SI	S
310	0.18759530E-01	-0.98639991E-02	-0.13183835	0.15059788	0.1385
311	0.95091621E-02	-0.15126837E-01	-0.86046321E-01	0.95555483E-01	0.8592
312	0.37704957E-01	-0.46440623E-02	-0.85844781E-01	0.12354974	0.1087
313	0.80187977E-01	0.23281929E-01	-0.71482558E-01	0.15167054	0.1327
314	-0.47654025E-03	-0.18005554E-01	-0.94208325E-01	0.93731785E-01	0.8631
315	0.61016745E-02	-0.18970077E-01	-0.62284992E-01	0.68386666E-01	0.5992
316	0.61624792E-01	0.77371680E-03	-0.39961147E-01	0.10158594	0.8854
317	0.59897077E-01	0.78216057E-02	-0.64567178E-02	0.66353795E-01	0.6049
318	-0.64515379E-02	-0.13241095E-01	-0.29158198E-01	0.22706660E-01	0.2018
320	-0.68779128E-02	-0.12408466E-01	-0.13278503	0.12590711	0.1232
321	-0.39501212E-01	-0.53317613E-01	-0.13281314	0.93311930E-01	0.8722
322	-0.11924036E-01	-0.54995801E-01	-0.11844754	0.10652350	0.9281
323	0.34944748E-01	0.12421920E-01	-0.11811419	0.15305894	0.1431

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A72 of A79

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
324	0.89258806E-02	0.29605334E-02	-0.90070927E-01	0.98996807E-01	0.96153
325	-0.85571614E-02	-0.11693088E-01	-0.90145466E-01	0.81588305E-01	0.80066
326	0.47266416E-02	-0.34220295E-02	-0.54552980E-01	0.59279621E-01	0.55654
327	0.30468142E-01	0.16454901E-02	-0.54378891E-01	0.84847033E-01	0.74727
328	0.45251426E-01	0.75571054E-02	-0.23644669E-01	0.68896095E-01	0.59754
329	0.38501401E-01	-0.46935502E-02	-0.24555043E-01	0.63056444E-01	0.55840
330	0.35026844E-01	-0.38842569E-03	-0.88541292E-02	0.43880974E-01	0.40320
331	-0.88525788E-02	-0.98017851E-02	-0.15669010E-01	0.68154310E-02	0.63948

333	0.71575931E-01	0.35585197E-01	-0.34729459E-02	0.75048877E-01	0.66599
334	0.30108668E-01	0.10123578E-01	-0.53485624E-01	0.83594293E-01	0.75609
335	0.13507580E-01	-0.29187971E-01	-0.56219767E-01	0.69727347E-01	0.60891
336	0.18878603E-01	0.17680754E-01	0.61603304E-02	0.12718272E-01	0.12163
337	0.12789472E-01	0.36522097E-02	0.14071442E-02	0.11382328E-01	0.1[illegible]2

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
338	0.71491559E-02	-0.78758024E-02	-0.13635730E-01	0.20784886E-01	0.18586
339	0.87911143E-02	0.32057150E-06	-0.94735205E-02	0.18264635E-01	0.15821
340	0.30806601E-01	0.57099627E-02	-0.62155401E-02	0.37022141E-01	0.32731
341	0.46640252E-01	0.10588249E-01	-0.13925572E-01	0.60565824E-01	0.52767
342	0.40221448E-01	-0.16623993E-02	-0.15167175E-01	0.55388623E-01	0.50022
343	0.35026949E-01	0.10654383E-01	0.30835611E-02	0.31943388E-01	0.28911
344	0.30839883E-02	0.12411224E-02	-0.15667882E-01	0.18751870E-01	0.17901
345	0.27445684E-01	-0.14716532E-01	-0.28729223E-01	0.56174906E-01	0.50643
346	0.28892311E-01	-0.14064715E-01	-0.26812152E-01	0.55704464E-01	0.50550
347	0.34316701E-01	0.32369394E-01	-0.18539886E-02	0.36170689E-01	0.35237
348	0.16941497E-01	-0.54311481E-02	-0.12839755E-01	0.29781251E-01	0.26854
349	0.19861907E-01	0.39417193E-02	-0.74087753E-02	0.27270682E-01	0.23727
350	0.99565581E-02	0.46519923E-02	-0.17278209E-01	0.27234767E-01	0.25008

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
351	0.13638805E-02	-0.28796717E-02	-0.21141948E-01	0.22505829E-01	0.20712
352	-0.16756406E-02	-0.33420536E-02	-0.22586613E-01	0.20910973E-01	0.20129
353	0.38072491E-01	-0.76883499E-02	-0.15365907E-01	0.53438398E-01	0.50043
354	0.44614697E-01	0.94133012E-02	0.48857658E-02	0.39728931E-01	0.37669
355	0.59128334E-02	0.48877292E-02	-0.17387498E-01	0.23300331E-01	0.22805
357	0.11480121	0.51586087E-01	-0.12741549E-01	0.12754276	0.11078
358	0.75771677E-02	-0.24986717E-01	-0.28947210E-01	0.36524378E-01	0.34713
359	0.56907547E-02	-0.26281446E-01	-0.40193414E-01	0.45884169E-01	0.40749
360	0.20935416E-01	0.16649759E-01	-0.21552617E-01	0.42488033E-01	0.40515
361	0.52311883E-02	-0.10273292E-01	-0.23264706E-01	0.28495894E-01	0.24710
362	0.11271004E-01	-0.90047138E-03	-0.20953085E-01	0.32224088E-01	0.28183
363	0.13542385E-01	0.10627997E-01	-0.15045258E-01	0.28587642E-01	0.27247
364	0.60106928E-02	0.27017433E-02	-0.19575393E-01	0.25586086E-01	0.24102

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A73 of A79

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	I
5	-0.57122207E-02	-0.86109453E-02	-0.26251512E-01	0.20539292E-01	0.19254
366	0.37890629E-01	-0.14620186E-01	-0.21222580E-01	0.59113210E-01	0.56104
367	0.44614531E-01	-0.61362981E-02	-0.81574658E-02	0.52771997E-01	0.51791
368	-0.81539745E-02	-0.96367673E-02	-0.17389191E-01	0.92352161E-02	0.85903
369	0.31233856E-01	-0.29988464E-01	-0.41456245E-01	0.72685101E-01	0.67683

370	0.19897187E-01	-0.36012106E-01	-0.51980487E-01	0.71877674E-01	0.6537
371	0.31035716E-01	0.19835951E-01	-0.36052203E-01	0.67087919E-01	0.6224
372	0.12073905E-01	-0.42764279E-03	-0.35271760E-01	0.47345665E-01	0.4249
373	0.28619598E-01	-0.76956560E-02	-0.23206497E-01	0.51826095E-01	0.4607
374	0.30301605E-01	0.12370492E-01	-0.19661871E-01	0.49963477E-01	0.4384
375	0.14348498E-02	-0.56437881E-03	-0.49385540E-01	0.50820390E-01	0.4985
376	0.34316100E-02	0.44490504E-03	-0.47330610E-01	0.50762220E-01	0.4933
377	0.13499649	0.68032634E-02	-0.51267072E-02	0.14012320	0.1345

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
378	0.14259202	0.19233724E-01	0.38777354E-02	0.13871428	0.1317
379	0.38782406E-02	-0.10847206E-01	-0.58902881E-01	0.62781122E-01	0.5686
381	0.12608629	0.47196643E-01	-0.40988256E-01	0.16707454	0.1469
382	0.51086509E-02	-0.32083552E-01	-0.81782496E-01	0.86891147E-01	0.7550
383	0.14309804E-01	-0.25548388E-01	-0.47543730E-01	0.61853533E-01	0.5430
384	0.57467813E-01	0.14235553E-01	-0.47570809E-01	0.10503862	0.9143
385	0.20633788E-02	-0.31257951E-03	-0.47333058E-01	0.49396437E-01	0.4825
386	0.23870164E-01	-0.75800408E-02	-0.40529438E-01	0.64399602E-01	0.5577
387	0.28423906E-01	0.92037722E-02	-0.29837907E-01	0.58261813E-01	0.5142
388	-0.17319205E-02	-0.96655748E-02	-0.52338029E-01	0.50606108E-01	0.4714
389	-0.89331709E-02	-0.13535377E-01	-0.51355303E-01	0.42422132E-01	0.4031
390	0.13472520	-0.25750715E-02	-0.25846840E-01	0.16057204	0.1502
391	0.14259201	0.15685855E-01	-0.19069233E-02	0.14449893	0.1365

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
392	-0.19063923E-02	-0.14395075E-01	-0.58902913E-01	0.56996521E-01	0.5189
393	0.38465864E-01	0.34983521E-01	-0.25695629E-02	0.41035427E-01	0.3940
394	0.18607692E-01	-0.16525936E-01	-0.33154007E-01	0.51761699E-01	0.4577
395	0.53528307E-01	0.25548077E-02	-0.35811841E-01	0.89340148E-01	0.7762
396	0.19071285E-02	-0.66964669E-02	-0.37029876E-01	0.38937005E-01	0.3542
397	0.13957680E-01	-0.10231237E-01	-0.33319382E-01	0.47277061E-01	0.4094
398	0.23670104E-01	0.17469885E-01	-0.21994446E-01	0.45664550E-01	0.4290
399	-0.46345076E-02	-0.11515975E-01	-0.35348588E-01	0.30714080E-01	0.2791
400	-0.15906735E-01	-0.17392896E-01	-0.37739492E-01	0.21832757E-01	0.2112
401	0.78908778E-01	-0.94489527E-02	-0.32550043E-01	0.11145882	0.1018
402	0.91671501E-01	0.92528800E-02	-0.71037983E-02	0.98775300E-01	0.9169
403	-0.71037374E-02	-0.18541682E-01	-0.32876094E-01	0.25772357E-01	0.2236
405	-0.17737702E-02	-0.32724491E-01	-0.13190540	0.13013163	0.1207

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
ELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
406	0.17457480E-01	-0.69016620E-01	-0.13683075	0.15428823	0.1339
407	0.15692860E-01	-0.31330898E-01	-0.96234517E-01	0.11192738	0.9734

408	0.38723345E-01	-0.25868267E-02	-0.96665548E-01	0.13538889	0.12018
409	0.22390001E-02	-0.11290569E-01	-0.69730675E-01	0.71969675E-01	0.66249
410	0.12130006E-01	-0.98993533E-02	-0.68786620E-01	0.80916626E-01	0.72458
411	0.22346234E-01	0.80353342E-02	-0.58333574E-01	0.80679809E-01	0.74561
412	-0.14069064E-01	-0.23990783E-01	-0.60536772E-01	0.46467709E-01	0.[illegible]36
413	0.56769312E-02	-0.47693955E-02	-0.27517311E-01	0.33194242E-01	0.2[illegible]97
414	0.79113110E-01	0.13618537E-01	-0.11392517E-01	0.90505626E-01	0.80951
415	0.91671523E-01	0.33128025E-01	0.13693747E-01	0.77977776E-01	0.70304
416	0.13693695E-01	0.53334589E-02	-0.32875955E-01	0.46569650E-01	0.43003
417	0.26273452E-01	0.16610351E-01	-0.95577777E-01	0.12185123	0.11731
418	0.18474726E-01	-0.15548700E-01	-0.11746860	0.13594333	0.12252

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
419	0.36763433E-01	0.25719545E-01	-0.11446618	0.15122961	0.14602
420	0.34032047E-01	-0.21638090E-02	-0.93601762E-01	0.12763381	0.11393
421	-0.13399594E-01	-0.17074347E-01	-0.10583823	0.92438639E-01	0.90657
422	0.20827066E-01	0.86281639E-02	-0.62947502E-01	0.83774568E-01	0.78390
423	0.14691231	0.25924110E-01	-0.38476931E-01	0.18538924	0.16302
424	0.15545164	0.65965585E-02	-0.62677999E-01	0.21812964	0.19305
425	-0.33894766E-01	-0.57669514E-01	-0.25809755	0.22420279	0.21331
426	-0.22842373E-01	-0.50930421E-01	-0.23628894	0.21344656	0.20088
427	0.12174453	0.15426922E-01	-0.22840543E-01	0.14458507	0.12975
429	0.18989794E-01	-0.88649957E-01	-0.16577068	0.18476048	0.16109
430	0.16151766E-01	-0.34536640E-01	-0.14570548	0.16185725	0.[illegible]39
431	0.24048367E-01	-0.80443870E-02	-0.94174732E-01	0.11822310	0.1[illegible]88
432	0.41037249E-01	0.33223823E-01	-0.89872445E-01	0.13090969	0.12718

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
433	0.41105145E-01	0.46348479E-02	-0.60166179E-01	0.10127132	0.88840
434	0.34885641E-02	-0.10275681E-01	-0.82217720E-01	0.85706284E-01	0.79720
435	0.20899951E-01	0.92726726E-02	-0.51736884E-01	0.72636835E-01	0.67577
436	0.14793299	0.14369774E-01	-0.16015264E-01	0.16394826	0.15106
437	0.15955864	0.31594132E-01	-0.18035809E-01	0.17759445	0.15871
438	0.12301514E-01	-0.32671920E-01	-0.25554467	0.26784618	0.24843
439	0.51379076E-02	-0.18076786E-01	-0.23628889	0.24142680	0.23069
440	0.12174466	0.48280560E-01	0.51396446E-02	0.11660502	0.10211
441	0.87921155E-01	-0.53039518E-01	-0.16283902	0.25076017	0.21772
442	0.67096544E-01	-0.61202175E-02	-0.17665194	0.24374849	0.21662
443	0.83668711E-01	0.11337559E-01	-0.16682434	0.25049305	0.22329
444	0.71820768E-01	-0.36434380E-02	-0.11985313	0.19167390	0.16723
445	0.61286863E-01	-0.63063564E-02	-0.12764626	0.18893313	0.16581

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
446	0.41500113E-01	0.21477568E-01	-0.91481233E-01	0.13298135	0.1241
447	0.54029137E-01	-0.52278703E-01	-0.84055288E-01	0.13808442	0.1252
448	0.70308325E-01	0.10375134E-01	-0.34689024E-01	0.10499735	0.9123
449	0.35060378E-01	0.98574204E-02	-0.10137855	0.13643893	0.1257
450	0.26161549E-01	0.37904728E-02	-0.74173372E-01	0.10033492	0.9123
451	0.43874751E-02	-0.15611467E-02	-0.56965358E-01	0.61352833E-01	0.5860
453	0.13602876	0.87192570E-01	-0.92060187E-01	0.22808894	0.2081
454	0.11133094	0.45158414E-01	-0.13752555	0.24885650	0.2232
455	0.11597858	0.96026522E-02	-0.12742030	0.24339888	0.2113
456	0.12726658	0.27060431E-01	-0.11230853	0.23957511	0.2084
457	0.97447637E-01	0.59572108E-03	-0.91204485E-01	0.18865212	0.1633
458	0.89531310E-01	-0.20671512E-02	-0.10161524	0.19114655	0.1655
459	0.64175015E-01	0.41824519E-01	-0.68215981E-01	0.13239100	0.1227

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
460	0.73298611E-01	-0.31931753E-01	-0.57384607E-01	0.13068322	0.11999
461	0.59190362E-01	0.95400102E-03	-0.53818277E-01	0.11300864	0.97883
462	0.11288176E-01	0.43629294E-03	-0.10785357	0.11914175	0.11410
463	0.12415984E-01	-0.24341830E-02	-0.73966446E-01	0.86382430E-01	0.79997
464	0.12888213E-01	-0.30156752E-01	-0.56633785E-01	0.69521998E-01	0.60775
465	0.12114538	-0.90677879E-02	-0.57515913E-01	0.17866130	0.16003
466	0.10638494	0.10438159E-01	-0.80479864E-01	0.18686481	0.16184
467	0.11377167	0.46410469E-01	-0.71052731E-01	0.18482440	0.16201
168	0.10417090	0.14968154E-01	-0.94498213E-01	0.19866911	0.17235
469	0.79724895E-01	-0.26071361E-01	-0.12738086	0.20710576	0.17937
470	0.12436637	0.49653780E-01	-0.10885010	0.23321647	0.20627
471	0.15515671	-0.16002756E-01	-0.79561045E-01	0.23471776	0.21027
472	0.44251854E-01	0.41698411E-01	0.25905081E-02	0.41661346E-01	0.40445

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	SI
473	0.43687943E-01	0.14978636E-01	0.25136754E-02	0.41174268E-01	0.36571
474	0.64089237E-01	0.10862317E-01	-0.94434721E-03	0.65033584E-01	0.60007
475	0.29116296E-01	-0.19532563E-01	-0.11797194	0.14708824	0.12979
477	0.11254225	0.96092246E-01	-0.70781812E-01	0.18332406	0.17567
478	0.82729558E-01	-0.61739321E-01	-0.83693923E-01	0.16642348	0.15660
479	0.10705710	-0.39318459E-01	-0.80002016E-01	0.18705911	0.17039
480	0.11439264	-0.33461509E-02	-0.70523694E-01	0.18491633	0.16212
481	0.11916399	-0.18915083E-01	-0.81609026E-01	0.20077302	0.17791
482	0.98431390E-01	-0.59951135E-01	-0.11820854	0.21663993	0.19418
483	0.24856363	0.13146118E-01	-0.57538901E-01	0.30610253	0.27759
484	0.26093818	-0.98339721E-02	-0.52510507E-01	0.31344869	0.29443
485	0.41913521E-01	0.16223713E-01	-0.30532187E-01	0.72445708E-01	0.63617
˙86	0.41311110E-01	-0.10509777E-01	-0.30556806E-01	0.71867916E-01	0.64235

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1

TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	
487	0.52076058E-01	0.93630008E-03	-0.46152831E-01	0.98228889E-01	50
488	-0.23898306E-01	-0.29458432E-01	-0.12217915	0.98280841E-01	56

MAXIMUMS

NODE	484	21	21	39	
VALUE	0.26093818	-0.20986708	-0.36796355	0.34323518	0.29

max tension max stress

ESEL FOR LABEL= TYPE FROM 2 TO 2 BY 1

24 ELEMENTS (OF 432 DEFINED) SELECTED BY ESEL COMMAND.

50 NODES (OF 610 DEFINED) SELECTED FROM 24 SELECTED ELEMENTS BY

PRINT PRIN NODAL STRESSES PER NODE

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	
1	0.00000000E+00	-3.8789619	-3.8789715	3.8789715	3.87
2	0.00000000E+00	-1.2312101	-1.5541415	1.5541415	1.46
3	0.97080359	0.00000000E+00	-0.40830314	1.3791067	1.25
4	2.0514487	0.10949885	-0.47181199E-01	2.0986299	)2
5	2.1119983	0.13134757	0.00000000E+00	2.1119983	05
6	2.1084328	0.55161145E-01	0.00000000E+00	2.1084328	2.08
7	4.3224602	1.3099720	0.00000000E+00	4.3224602	3.86
8	4.8348788	0.86811748	0.00000000E+00	4.8348788	4.46
9	5.7646625	1.0705878	0.00000000E+00	5.7646625	5.31
10	6.1674020	1.1835111	0.00000000E+00	6.1674020	5.66
31	1.8982293	0.33312611E-01	-0.28563054E-02	1.9010857	1.88
32	4.5459302	0.92069634	-0.29051317E-02	4.5488353	4.24
75	0.00000000E+00	-0.53679007	-0.54295715	0.54295715	0.539

bottom plate

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

Calc. Pckg. VSC02.6.2.3.18
Rev. 2
Pg. A77 of A79

liner

NODE	SIG1	SIG2	SIG3	SI	
88	0.30559899E-01	-0.45936070E-01	-0.60563774	0.63619764	0.601
112	0.39733066E-01	-0.19868935	-0.92022432	0.95995738	0.872
136	0.00000000E+00	-0.56818787	-1.4538588	1.4538588	1.26
160	0.00000000E+00	-1.5763491	-1.6827548	1.6827548	1.63
184	0.00000000E+00	-1.1451513	-1.6097803	1.6097803	1.45
208	0.70040191	0.00000000E+00	-0.44335733	1.1437592	1.02
232	1.7423364	1.0781777	-0.51210608E-01	1.7935470	1.62
246	0.00000000E+00	-1.2311875	-1.5541415	1.5541415	6.
247	0.97080359	0.00000000E+00	-0.40828155	1.3790851	25
248	2.0514487	0.10945444	-0.47195156E-01	2.0986439	2.02
249	2.1119983	0.13126032	0.00000000E+00	2.1119983	2.05
250	2.1084328	0.55104367E-01	0.00000000E+00	2.1084328	2.08
251	4.3224602	1.3098163	0.00000000E+00	4.3224602	3.86

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
'HELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
252	4.8348788	0.86779566	0.00000000E+00	4.8348788	4.465
253	5.7646625	1.0698432	0.00000000E+00	5.7646625	5.312
254	6.1674020	1.1823712	0.00000000E+00	6.1674020	5.669
275	1.8982293	0.33298298E-01	-0.24849872E-02	1.9007143	1.883
276	4.5459302	0.92066873	-0.24360981E-02	4.5483662	4.241
319	0.00000000E+00	-0.53674904	-0.54295715	0.54295715	0.5398
332	0.30559899E-01	-0.45936070E-01	-0.60562260	0.63618249	0.6016
356	0.39733066E-01	-0.19868935	-0.92022803	0.95996110	0.8721
380	0.00000000E+00	-0.56818787	-1.4538584	1.4538584	1.269
404	0.00000000E+00	-1.5763504	-1.6827548	1.6827548	1.632
428	0.00000000E+00	-1.1451491	-1.6097803	1.6097803	1.451
452	0.70040191	0.00000000E+00	-0.44336787	1.1437698	1.025
476	1.7424303	1.0781777	-0.51219084E-01	1.7936494	1.625

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1
SHELL STRESSES ARE AT MIDDLE

NODE	SIG1	SIG2	SIG3	SI	S
605	3.4436507	3.4434940	0.00000000E+00	3.4436507	3.443
606	2.6127054	2.5659266	0.00000000E+00	2.6127054	2.589
607	2.4196213	1.7610405	0.00000000E+00	2.4196213	2.167
608	2.0872626	1.9983592	0.00000000E+00	2.0872626	2.045
609	2.4402242	1.6192528	0.00000000E+00	2.4402242	2.162
610	5.3338550	1.3426721	0.00000000E+00	5.3338550	4.805
611	2.6127054	2.5659124	0.00000000E+00	2.6127054	2.589
612	2.4196278	1.7610405	0.00000000E+00	2.4196278	2.167
613	2.0873145	1.9983496	0.00000000E+00	2.0873145	2.045
614	2.4402242	1.6194794	0.00000000E+00	2.4402242	2.162
615	5.3338550	1.3432715	0.00000000E+00	5.3338550	4.805

cover plate

MAXIMUMS					
NODE	10	1	1	10	254
VALUE	6.1674020	-3.8789619	-3.8789715	6.1674020	5.669

ESEL FOR LABEL= TYPE FROM 3 TO 3 BY 1

34 ELEMENTS (OF 432 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

EM	SIG
78	5.0192426
79	5.0197294
30	-0.20863126

81	0.34575605
82	4.1717945
83	8.3283509
84	11.357610
85	22.260990
86	28.770849
87	11.147482
88	3.8774260
89	7.7453509
90	-0.20670294
91	0.34562934

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIG	
92	4.1720909	
93	8.3283769	
94	11.357609	
95	22.260989	
96	28.770446	— max. vertical rebars
97	11.147090	
98	3.8792454	
99	7.7452418	
100	5.4677720	
101	6.1714419	
102	4.9486159	
103	6.1672162	
104	5.9807687	
105	6.2699157	

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 15 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIG	
106	6.6394128	
107	7.7989740	
108	10.026639	
109	14.558004	— max. hoops
110	11.366707	
111	7.5203293	

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.19 File No.: VSC02.6.2.3.19 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

VSC Flood, Tornado, and Earthquake Analysis.

SCOPE:

Product: ☐ FuelSolutions™ ☐ TranStor™ ☒ VSC-24 ☐ Other ____

Service: ☒ Storage ☐ Transportation ☐ Other ____

Conditions: ☒ Normal ☒ Off-Normal ☒ Accident ☐ Other ____

Component(s):

VSC-24 Concrete cask.

Prepared by:

Name: Robert Keating

Signature: [signature]

Date: 2/2/01

Verified by:

Name: James E. Moroney

Signature: [signature]

Date: 2/2/01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: [signature]

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 29		Replaces Calculation WEP109-002.19, Rev. 2	J. Hibbard	M. Heinz
1	1 - 29		Revised to include information as needed to replace ANO calculations Incorporated ECN VSC02-ECN-008	R. Keating	J. Moroney

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION			
	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

See Verification Memorandum for comments.

Verifier: James Moroney [signature] 2/2/01

Name/Signature/Date

1.0 INTRODUCTION

In accordance with 10CFR72, Subpart E (Ref. 3.2.1) and ANS-57.9 (Ref. 3.2.2), the VSC-24 cask is designed to withstand loads associated with the most severe environmental events postulated to occur at an ISFSI site. The purpose/objective of this calculation is to demonstrate that the cask can successfully withstand the loads from tornado, flood, and earthquake events.

This calculation supersedes Revision 2 of WEP-109-002.19, Revision 0 of ANO-109-002.019, and Revision 1 of ANO-109-002.018. The principal differences between Revision 0 of this calculation and Revision 2 of WEP-109-002.19 are:

- Revised weights and centers of gravity are used.
- The rotational moment of inertia calculation calculation was corrected.
- The calculation of tornado wind loads was updated to the latest revision of ASCE 7-93.

This analysis is bounding for all configurations of the MSB/VCC. The analysis is based on lower bound estimates of the weight of the MSB and upper bound configurations with regards to height and center of gravity. This configuration is not based on a single actual MSB/VCC configuration, but instead is a combination of appropriate upper and lower bounds from all possible configurations.

Seismic stresses are calculated based on upper bound estimates of the weight.

2.0 REQUIREMENTS

2.1 Design Inputs

2.1.1 10CFR72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High Level Waste", 1987
(Specifies that the VSC-24 Cask must be designed to withstand loads associated with the most severe environmental events postulated to occur at an ISFSI site).

2.1.2 ANS-57.9, "Design Criteria for an Independent Spent Fuel Storage Installation," 1984.
(Specifies that the VSC-24 Cask must be designed to withstand loads associated with the most severe environmental events postulated to occur at an ISFSI site).

2.1.3 NUREG-0800, "Standard Review Plan for Nuclear Power Plants," 1981.
(Provides methods to convert tornado and wind loadings into forces and provides a basis for loads due to tornado generated missiles).

2.1.4 Reg Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," 1974.
(Specifies design basis tornado characteristics).

2.2 Regulatory Requirements

See Section 2.1.

3.0 REFERENCES

3.1 BFS Calculation Packages

3.1.1 Calculation VSC02.6.2.5.01, "Weight and Center of Gravity," Revision 1.
(Mass and c.g. of VCC)

3.1.2 Calculation VSC02.6.2.3.04, "MSB-24 Pressure Stress Analysis," Revision 3.
(Allowable external pressure)

3.1.3 Calculation VSC02.6.2.3.05, "Normal, Off-Normal, and Maximum Accident Pressure in the MSB," Revision 2.
(Bounding MSB internal accident pressure)

3.1.4 Calculation ANO-109-002.019, "Calculation of MSB Flood Stresses", Revision 0.

3.1.5 Calculation ANO-109-002.018, "Earthquake Stresses in MSB", Revision 1.

3.1.6 Calculation VSC02.6.2.5.03, "VSC-24 Design Parameters", Revision 0.

3.2 General References

3.2.1 10CFR72, 1987.

3.2.2 ANS-57.9, "Design Criteria for an Independent Spent Fuel Storage Installation," 1984.

3.2.3 Deleted

3.2.4 Deleted

3.2.5 Deleted.

3.2.6 Deleted.

3.2.7 Reg Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," 1974.

3.2.8 NUREG-0800, "Standard Review Plan for Nuclear Power Plants," 1981.

3.2.9 ASCE 7-93, "Minimum Design Loads for Buildings and Other Structures."

3.2.10 EPRI Report NP-440, "Full Scale Tornado Missile Impact Tests," 1977.

3.2.11 EPRI Report NP-1217, "Local Response of Reinforced Concrete to Missile Impact," 1982.

3.2.12 Bechtel Report, "Design of Structures for Missile Impact," 1974.

3.2.13 ACI-349, "Code Requirements for Nuclear Safety Related Structures", 1980.

3.2.14 Deleted.

3.2.15 Roark and Young, "Formulas for Stress and Strain", 5th Edition.

3.2.16 Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," 1973 Edition.

3.2.17 1992 ASME Code, Section II, Materials, Part D, Properties, Table Y-1.

3.2.18 "Marks' Standard Handbook for Mechanical Engineers," McGraw-Hill Inc., 9th Edition.

3.2.19 Perry & Chilton, "Chemical Engineers' Handbook," McGraw-Hill Inc., 5th edition.

3.2.20 ASTM Standard Specification, A-615/A-615M-96A.

4.0 ASSUMPTIONS

4.1 Design Configuration

4.1.1 VCC Parameters

VCC and MSB Loaded mass	$P_{VCC} := \begin{bmatrix} 250000 \\ 290000 \end{bmatrix} lb$	(Lower Bound Ref. 3.1.1) (Upper Bound Ref. 3.1.1)
VCC and MSB c.g.	$cg_{VCC} := 116\ in$	(Upper Bound Ref. 3.1.1)
Cask Outside Diameter	$OD_{VCC} := 132\ in$	(Reference 3.1.6)
Width of Bevel at Bottom	$w_{bevel} := 3\ in$	(Reference 3.1.6)
Cask Height	$h_{VCC} := 225.05\ in$	(Upper Bound Ref. 3.1.6)
VCC Liner Outside Diameter	$OD_{liner} := 74\ in$	(Reference 3.1.6)
VCC Liner Inside Diameter	$ID_{liner} := 70.5\ in$	(Reference 3.1.6)
Height of the Liner	$h_{liner} := 200\ in$	(Upper Bound Ref. 3.1.6)
VCC Lid Thickness	$t_{VCC\_lid} := 0.75\ in$	(Reference 3.1.6)
Concrete Strength	$f_c := 4000\ psi$	(Reference 3.1.6)
Number of Bars in Air Outlet Cross Section	$N_{bars} := 32$	(Reference 3.1.6)
Diameter of Bars in Air Outlet Cross Section	$d_{bars} := 0.75\ in$	(Reference 3.1.6)
Bar Material	A-615, Gr. 60	(Reference 3.1.6)
Bar Yield Strength	$f_y := 60000\ psi$	(Reference 3.2.20)

4.1.2 Wind and Tornado Loads

Tornado design parameters used to evaluate the suitability of the cask include tornado winds, wind generated pressure differentials and tornado generated missiles. The design basis tornado characteristics have been selected to be consistent with Regulatory Guide 1.76 (Reference 3.2.7).

The methods used to convert the tornado and wind loadings into forces on the cask are based on NUREG-0800 (Reference 3.2.8), Section 3.3.1, "Wind Loadings" and Section 3.3.2, "Tornado Loadings". Loads due to tornado generated missiles are based on NUREG-0800, Section 3.5.3, "Barrier Design Procedures". All missiles are assumed to impact in a manner that produces the maximum damage to the cask. The tornado properties are as follows.

Maximum Wind Speed	$Wind_{max} := 360\ mph$
Missile Velocity	$V_{missile} := 126\ mph$
Automobile Missile	$M_{auto} := 3960\ lb$
Armor Piercing Shell	$M_{shell} := 275\ lb$
	$d_{shell} := 8\ in$
Steel Sphere (1 in dia)	$M_{sphere} := 0.22\ lb$

Local damage of the cask body has been estimated using the National Defense Research Committee methodology presented in References 3.2.10 and 3.2.11. For the overall damage assessment, cask stability and stresses were evaluated. The tornado missile analysis is conservative in that the direction of the impact is assumed to be in-line with the cask axis.

4.1.3 Seismic Acceleration

The seismic acceleration was selected to bound the applicable accelerations at all sites East of the Rocky Mountains. All accelerations are assumed to act simultaneously with the worst possible sign combination. The assumed accelerations are as follows:

Horizontal Acceleration	$a_h := 0.25\ g$
Vertical Acceleration	$a_v := 0.17\ g$

4.2 Design Criteria

None.

4.3 Calculation Assumptions

4.3.1 The friction coefficient for steel on concrete is assumed to be a typical value of $\mu := 0.2$.

4.3.2 The effective velocity pressure for the wind loads in the Tornado Accident Analysis is assumed constant with the height of the cask, and is assumed uniform over the projected area of the cask.

5.0 CALCULATIONS

5.1 Tornado Accident Analysis

5.1.1 Wind Loads

The tornado wind velocity is transformed into an effective pressure applied to the cask using procedures outlined in Reference 3.2.9. The maximum velocity pressure is determined from the maximum wind speed as follows:

$C_p := 0.00256 \dfrac{lbf}{ft^2 \cdot mph^2}$ Reference 3.2.9, Eq. 3

$K_z := 1.2$ Reference 3.2.9, Table 6, Exposure D, assume 0 to 15 feet above ground

$Pressure := C_p \cdot K_z \cdot Wind_{max}^2$ Reference 3.2.9, Eq. 3

$Pressure = 398 \cdot psf$

The above effective velocity pressure is assumed constant with height and, since the cask is small in relation to the radius of the tornado, is assumed to be uniform over the projected area of the cask. Gust factors are taken as unity in evaluating effects of velocity pressures on cask surfaces.

The total tornado wind loading on the projected area of the cask is computed as follows:

$A_{proj} := OD_{VCC} \cdot h_{VCC}$ $A_{proj} = 206 \cdot ft^2$

$\dfrac{OD_{VCC}}{ft} \cdot \sqrt{\dfrac{Pressure}{psf}} = 219$ Parameters required for Table 12 in Reference 3.2.9.

$\dfrac{h_{VCC}}{OD_{VCC}} = 1.7$

$C_v := linterp\left[\begin{bmatrix}1\\7\end{bmatrix}, \begin{bmatrix}.5\\.6\end{bmatrix}, \dfrac{h_{VCC}}{OD_{VCC}}\right]$ Pressure coefficient, Ref. 3.2.9, Table 12, round and moderately smooth.

$C_v = 0.51$

$$P_{tornado} := Pressure \cdot C_v \cdot A_{proj}$$

$$P_{tornado} = 42031 \cdot lbf$$

The sliding of the cask is resisted by friction between the steel bottom and the concrete pad. The resisting force is:

$$P_{friction} := \mu \cdot P_{VCC_1} \cdot g \qquad P_{friction} = 50000 \cdot lbf$$

Criterion1 = "FRICTION FORCE EXCEEDS TORNADO FORCE—ACCEPTABLE"

The overturning moment applied by the tornado wind load is the c.g. times the applied load. The potential for the cask to tip over is resisted by the mass of the cask times the moment arm from the c.g. to the cask corner.

$$M_{overturn} := P_{tornado} \cdot cg_{VCC} \qquad M_{overturn} = 4.88 \cdot 10^{6} \cdot in \cdot lbf$$

$$M_{resist} := P_{VCC_1} \cdot g \cdot \left(\frac{OD_{VCC} - 2 \cdot w_{bevel}}{2} \right) \qquad M_{resist} = 1.57 \cdot 10^{7} \cdot in \cdot lbf$$

Criterion1a = "CASK DOES NOT TIP OVER DUE TO TORNADO FORCE -- ACCEPTABLE"

The shear force in the concrete between the cylindrical portion of the VCC and the VCC bottom is:

$$f_v := \frac{P_{tornado}}{\frac{\pi}{4} \cdot \left(OD_{VCC}^{2} - OD_{liner}^{2} \right)}$$

$$f_v = 4.5 \cdot psi$$

This shear stress is negligible.

5.1.2 Tornado Missiles

Local Damage Prediction -- VCC Body

The armor piercing shell is considered to be the most critical for the local damage of the cask components. Local damage of the cask body has been assessed using the National Defense Research Committee (NDRC) formula. This formula has been selected as the basis for predicting depth of penetration and minimum thickness of concrete to prevent spalling and scabbing. Penetration depths computed by this method have been shown to provide reasonable correlation with test results. (Reference: EPRI Reports NP-440 and NP-1217; References 3.2.10 and 3.2.11). The depth of penetration (X) as predicted using this approach is computed as follows.

$d_{shell} = 8 \cdot in$	Diameter of the missile
$M_{shell} = 275 \cdot lb$	Mass of the missile
$V_{missile} = 126 \cdot mph$	Velocity of the missile
$K_c := \frac{180 \cdot psi^{.5}}{f_c^{.5}}$	Factor depending on concrete strength
$K_c = 2.85$	
$N_{missile} := 1.14$	Missile Shape Factor 1.14 for Sharp nosed missiles (EPRI NP-1217 (Ref 3.2.11))

The depth of penetration is calculated as:

$$X_{missile} := \left[4 \cdot K_c \cdot N_{missile} \cdot \frac{M_{shell}}{lb} \cdot \left(\frac{d_{shell}}{in} \right)^{-0.8} \cdot \left(\frac{V_{missile}}{1000 \frac{ft}{sec}} \right)^{1.8} \right]^{.5} \cdot in$$

$X_{missile} = 5.69 \cdot in$

The minimum depth to prevent spalling is selected as three times the value calculated above or:

$X_{spall} := 3 \cdot X_{missile}$ $\qquad X_{spall} = 17.1 \cdot in$

The minimum thickness of the concrete body of the VCC is:

$$t_{VCC} := \frac{OD_{VCC} - OD_{liner}}{2}$$

$t_{VCC} = 29.0 \cdot in$

Criterion2 = "ACTUAL THICKNESS EXCEEDS REQUIRED THICKNESS -- ACCEPTABLE"

Local Damage Prediction - Cask Closure Plate

The VCC is closed with a steel cover plate which is bolted in place. The perforation thickness in a steel plate is given in Reference 3.2.12.

$$T_{perf} := \frac{\left[0.5 \cdot \left(\frac{M_{shell}}{slug}\right) \cdot \left(\frac{V_{missile}}{\frac{ft}{sec}}\right)^2\right]^{\frac{2}{3}} \cdot in^2}{672 \cdot d_{shell}}$$

$T_{perf} = 0.52 \cdot in$

The VCC lid thickness is

$t_{VCC\_lid} = 0.75 \cdot in$

Criterion3 = "ACTUAL THICKNESS EXCEEDS REQUIRED THICKNESS -- ACCEPTABLE"

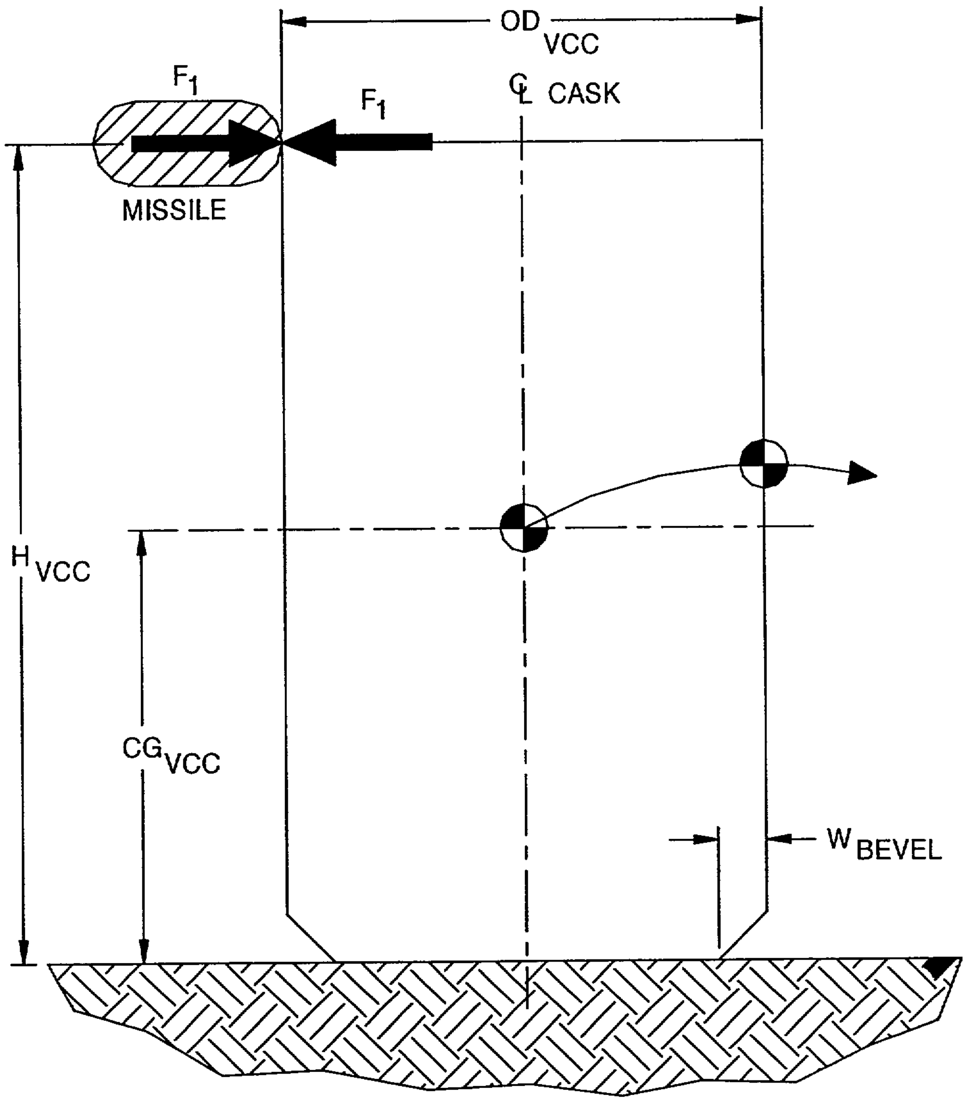


Figure 1

Sketch of Missile Cask Impact Geometry

Overall Damage Prediction

For the overall damage evaluation, the most critical missile is an automobile because it has the greatest mass. Since the cask is a freestanding structure, the tip-over analysis has been conducted using the principle of conservation of momentum during the impact event.

From the principle of conservation of momentum, the impulse force from the missile impact on the cask must equal the change in angular momentum of the cask. The impulse force due to the impact of the missile must equal the change in linear momentum of the missile. See Figure 1 for the cask geometry.

During the initial impact phase, the momentum of the missile is:

$$Momentum_{initial} := M_{auto} \cdot V_{missile}$$

$$Momentum_{initial} = 731808 \cdot ft \cdot \frac{lb}{sec}$$

The moment of inertia of the cask about it's center of gravity is (Reference 3.2.18, p. 3-10):

$$Io := P_{VCC_1} \cdot \left(\frac{OD_{VCC}^2}{16} + \frac{h_{VCC}^2}{12} \right)$$

$$Io = 1.33 \cdot 10^9 \cdot lb \cdot in^2$$

The distance from the corner of the cask to the center of gravity, R, is:

$$R := \sqrt{cg_{VCC}^2 + \left(\frac{OD_{VCC} - 2 \cdot w_{bevel}}{2} \right)^2} \qquad R = 132 \cdot in$$

The moment of inertia of the cask about the corner is (Reference 3.2.18, p. 3-10):

$$I_{cask} := Io + P_{VCC_1} \cdot R^2$$

$$I_{cask} = 5.68 \cdot 10^9 \cdot lb \cdot in^2$$

It is assumed that the velocity of the missile after impact is zero and that there is a perfectly elastic collision between the missile and the cask, i.e., there is no energy loss due to deformation of the missile or spalling of the concrete. The angular momentum of the cask is:

$$\text{Momentum}_{\text{angular}} := \text{Momentum}_{\text{initial}} \cdot h_{\text{VCC}}$$

$$\text{Momentum}_{\text{angular}} = 1.3724 \cdot 10^{7} \cdot \text{ft}^{2} \cdot \frac{\text{lb}}{\text{sec}}$$

Therefore the angular velocity is:

$$\omega := \frac{\text{Momentum}_{\text{angular}}}{I_{\text{cask}}}$$

$$\omega = 0.348 \cdot \frac{\text{rad}}{\text{sec}}$$

The kinetic energy of the cask is:

$$E_{\text{cask}} := I_{\text{cask}} \cdot \frac{\omega^{2}}{2}$$

$$E_{\text{cask}} = 74163 \cdot \text{ft} \cdot \text{lbf}$$

The energy required to overturn the cask is equal to the potential energy when the cask is balanced on it's edge minus the potential energy of the cask sitting flat on its bottom. This energy is given as:

$$R = 132 \cdot \text{in}$$

$$E_{\text{tip\_over}} := P_{\text{VCC}_1} \cdot g \cdot (R - cg_{\text{VCC}})$$

$$E_{\text{tip\_over}} = 333412 \cdot \text{ft} \cdot \text{lbf}$$

Criterion4 = "ENERGY OF IMPACT LESS THAN ENERGY TO TIP OVER -- ACCEPTABLE"

Stress in the VCC During Impact

The overall VCC stresses are evaluated at the corresponding critical sections of the concrete cask. The most critical missile for this evaluation is the automobile because it has the most mass.

The force developed by the missile has been calculated using the methodology presented in Bechtel Report "Design of Structures for Missile Impact" (Ref 3.2.12). The maximum force is:

$$F_{impact} := 0.625 \cdot \frac{V_{missile}}{\left(\frac{ft}{sec}\right)} \cdot \frac{M_{auto}}{lb} \cdot lbf$$

$$F_{impact} = 457380 \cdot lbf$$

For shear, the critical cask section is the one in the plane of the air outlets. The section capacity is calculated using the shear-friction formula per ACI-349, Section 11.7 (Ref 3.2.13).

$\phi_s := 0.85$	Shear Strength Reduction Factor (Ref. 3.2.13, Paragraph 9.3.2)
$A_v := N_{bars} \cdot \frac{\pi}{4} \cdot d_{bars}^2$	$A_v = 14.14 \cdot in^2$
$\mu_c := 1.4$	Monolithic Concrete (Ref. 3.2.13, Paragraph 11.7.5)
$U_{shear} := \phi_s \cdot A_v \cdot (1.1 \cdot f_y) \cdot \mu_c$	Ultimate shear capacity of the section (Note: use 1.1 f_y per Ref. 3.2.13, Appendix C.2)
$U_{shear} = 1.11 \cdot 10^6 \cdot lbf$	

Criterion5 = "SHEAR CAPACITY EXCEEDS FORCE OF IMPACT -- ACCEPTABLE"

The maximum moment due to the impact of the cask exists in the cask section adjacent to the bottom of the cask. The maximum moment is given as:

$$M_{impact} := F_{impact} \cdot h_{liner}$$

$$M_{impact} = 9.1476 \cdot 10^{7} \cdot in \cdot lbf$$

The moment of inertia of the cask liner at this section is:

$$I_{bottom} := \frac{\pi}{64} \cdot \left(OD_{liner}^{\ 4} - ID_{liner}^{\ 4} \right)$$

$$I_{bottom} = 259338 \cdot in^{4}$$

The strength of the liner is calculated conservatively ignoring the strength of the concrete. The yield strength of the SA-36 carbon steel liner is (Reference 3.1.6 for material; Reference 3.2.17 for yield strength at 300°F):

$$\sigma_{y} := 31900 \cdot psi$$

$$U_{bending} := \left[\sigma_{y} \cdot \frac{I_{bottom}}{\left(\frac{OD_{liner}}{2} \right)} \right]$$

Bending capacity of the liner, assuming that the outer fiber of the liner is at yield strength.

$$U_{bending} = 2.236 \cdot 10^{8} \cdot in \cdot lbf$$

Criterion6 = "BENDING CAPACITY EXCEEDS MOMENT DUE TO IMPACT -- ACCEPTABLE"

Combined Tornado Wind and Missile

The effects of tornado winds and missiles have been considered both separately and combined in accordance with NUREG-0800, Section 3.3.2.II.3.d (Reference 3.2.8). Calculate the maximum possible rotation of the cask for the case of tornado wind plus impact. The increase in the cask c.g. due to rotation is

$$\delta_{cask} := \frac{E_{cask}}{P_{VCC_1} \cdot g} \qquad \delta_{cask} = 3.56 \cdot in$$

The rotation of the cask (α_{cask}) is

$$R = 132 \cdot in$$

$$\theta_1 := \operatorname{asin}\left(\frac{cg_{VCC}}{R}\right) \qquad \theta_1 = 61.5 \cdot deg$$

$$\alpha_{cask} := \operatorname{asin}\left(\frac{\delta_{cask} + cg_{VCC}}{R}\right) - \theta_1 \qquad \alpha_{cask} = 3.43 \cdot deg$$

Applying the total tornado wind load to the cask in this configuration results in a net restoring moment of:

$$M_{restoring} := P_{VCC_1} \cdot g \cdot \left(R \cdot \cos\left(\alpha_{cask} + \theta_1\right)\right) - P_{tornado} \cdot \left(cg_{VCC} + \delta_{cask}\right)$$

$$M_{restoring} = 8.96 \cdot 10^6 \cdot in \cdot lbf$$

Criterion7 = "NO OVERTURING—NET RESTORING MOMENT POSITIVE—ACCEPTABLE"

MSB Under Tornado Missiles

Since the postulated tornado loading is not capable of overturning the cask, the tornado events have no effect on the MSB.

5.2 Flood

Immersing Flood Analysis

The buoyancy force on the cask, assuming full immersion of the cask is computed from the weight of the displaced water.

$\rho_w := 62.4 \frac{lb}{ft^3}$ Density of water

$V_{cask} := \frac{\pi}{4} \cdot (OD_{VCC})^2 \cdot h_{VCC}$

$V_{cask} = 1782 \, ft^3$

$F_b := (V_{cask} \cdot \rho_w) \cdot 1 \cdot g$

$F_b = 111214 \, lbf$ Buoyancy force for the loaded VCC

The drag force required to topple the cask is calculated by equating the overturning moment created by the drag force and the restoring moment:

$$F_{tip\_over} := \frac{(P_{VCC_1} \cdot g - F_b) \cdot \left(\frac{OD_{VCC} - 2 \cdot w_{bevel}}{2} \right)}{cg_{VCC}}$$

$F_{tip\_over} = 75375 \, lbf$

Assuming the cask is fully immersed in a steady state flow condition, the stream velocity required to overturn the cask is:

$C_d := 1.2$ Drag coefficient for an infinite cylinder, which depends on the Reynolds Number. The value of 1.2 is bounding for Re>10^3 (Reference 3.2.19, Figure 5-78).

$\mu_w := 20.92 \cdot 10^{-6} \cdot \frac{lbf \cdot sec}{ft^2}$ Viscosity of water at 68°F, Ref. 3.2.18, Table 3.3.3

$OD_{VCC} = 132 \cdot in$ Outside Diameter of the VCC

$A_{proj} = 206 \cdot ft^2$ Projected Area of the Cask

$$V_{stream} := \sqrt{\frac{F_{tip\_over} \cdot 2}{C_d \cdot \rho_w \cdot A_{proj}}}$$

Velocity required to tip over the cask based on rearrangement of the drag equation.

$$V_{stream} = 17.72 \cdot \frac{ft}{sec}$$

Check the Reynolds Number.

$$Re := \frac{\rho_w \cdot V_{stream} \cdot OD_{VCC}}{\mu_w}$$

$$Re = 1.8 \cdot 10^7$$

The Reynolds Number is greater than 1,000 and the drag coefficient of 1.2 is bounding.

The calculated stream velocity is considered to bound the site flood velocity, and therefore, the VCC is acceptable for flood conditions

MSB Flood Analysis

Reference 3.1.2 presents an analysis of the MSB under an accident internal pressure of 60 psig (bounds the value from Reference 3.1.3). This pressure ensures that stresses due to both internal and external pressures on the MSB lids do not exceed allowables. Using a minimum internal pressure of -8.0 psig (bounds the value from Reference 3.1.3), the allowable external accident pressure is to ensure stresses do not exceed allowables is 52 psig.

The ASME code allowable external pressure to preclude buckling of the MSB shell is 210 psig from Reference 3.1.2. Again using a minimum internal pressure of -8.0 psig, the allowable external pressure is 202 psig.

The limiting pressure to ensure that both buckling and stress conditions are met is 52 psig. The flood height required to achieve the 52 psig limiting pressure is:

$P_{limiting} := 52\ psi$ MSB Shell Limiting Pressure

$$d_{flood} := \frac{P_{limiting}}{\rho_w \cdot g}$$ Flood Depth to Reach Limiting Pressure

$$d_{flood} = 120 \cdot ft$$

Reference 3.1.4 calculates stresses in the MSB occurring under 35 feet of water. The flood depth calculated above is bounding and hence Reference 3.1.4 is superceded by this calculation. The MSB is acceptable for flood conditions.

5.3 Earthquake Events

5.3.1 Earthquake Event

The VSC is a very stiff structure. Although free-standing, it has been analyzed as a cantilever fixed at the base. (Ref 3.2.15, Table 36, Case 3b).

The fundamental natural frequency of vibration of the cask is:

$$K_n := 3.52$$ First Modal Frequency

$$E_c := 57000\ psi \cdot \sqrt{\frac{f_c}{psi}}$$ Elasticity of the concrete; Ref. 3.2.13, Paragraph 8.5.1

$$E_c = 3.605 \cdot 10^6 \cdot psi$$

$$I_{VSC} := \frac{\pi}{64} \cdot \left(OD_{VCC}{}^4 - OD_{liner}{}^4\right)$$

$$I_{VSC} = 1.34 \cdot 10^7 \cdot in^4$$ Moment of inertia of the cask

$$w_{dist} := \frac{P_{VCC_2}}{h_{VCC}}$$ Distributed weight of the cask

$$w_{dist} = 1289 \cdot \frac{lb}{in}$$

$$f_{natural} := \frac{K_n}{2 \cdot \pi} \cdot \sqrt{\frac{E_c \cdot I_{VSC}}{w_{dist} \cdot h_{VCC}{}^4}}$$

$$f_{natural} = 42.1 \cdot Hz$$

As shown in Reg. Guide 1.60 (Reference 3.2.16), the dynamic amplification is 1.0.

The VSC is evaluated for overturning by conservatively applying equivalent static loads to the cask in each of two orthogonal horizontal directions simultaneous with an upward vertical lift component.

$$P_{horizontal} := P_{VCC} \cdot \sqrt{a_h^2 + a_h^2}$$

$$P_{horizontal} = \begin{bmatrix} 88388 \\ 102530 \end{bmatrix} \circ lbf$$

$$P_{vertical} := P_{VCC} \cdot a_v$$

$$P_{vertical} = \begin{bmatrix} 42500 \\ 49300 \end{bmatrix} \circ lbf$$

The margin of safety against overturning is:

$$Margin_{tip\_over} := \frac{\left(P_{VCC_1} \cdot g - P_{vertical_1}\right) \cdot \left(\frac{OD_{VCC} - 2 \cdot w_{bevel}}{2}\right)}{P_{horizontal_1} \cdot cg_{VCC}}$$

$$Margin_{tip\_over} = 1.275$$

Criterion8 = "NO OVERTURING BECAUSE MARGIN IS GREATER THAN 1.0 -- ACCEPTABLE"

The maximum kinetic energy that can possibly be imparted to the cask from seismic motion is computed to compare with the energy required to tip over the cask.

The maximum relative horizontal and vertical velocities are obtained from Figures 1 and 2 of Reg. Guide 1.60 respectively, based on 0.5% damping (Reference 3.2.16). Since the figures are based on a 1 g acceleration, the velocities are scaled to $a_h = 0.25 \cdot g$ and $a_v = 0.17 \cdot g$.

$$V_{hor\_rel} := \left(180 \frac{in}{sec}\right) \cdot \frac{a_h}{1\ g}$$

$$V_{hor\_rel} = 45 \cdot \frac{in}{sec}$$

$$V_{vert\_rel} := \left(125 \frac{in}{sec}\right) \cdot \frac{a_v}{1\ g}$$

$$V_{vert\_rel} = 21 \cdot \frac{in}{sec}$$

Since the maximum ground velocities are bounded by any amplified velocity spectrum, the maximum vertical ground velocities are taken from Figures 1 and 2, respectively, based on 10% damping (Reference 3.2.16).

$$V_{hor\_abs} := \left(90 \frac{in}{sec}\right) \cdot \frac{a_h}{1\ g}$$

$$V_{hor\_abs} = 23 \cdot \frac{in}{sec}$$

$$V_{vert\_abs} := \left(65 \frac{in}{sec}\right) \cdot \frac{a_v}{1\ g}$$

$$V_{vert\_abs} = 11 \cdot \frac{in}{sec}$$

The maximum horizontal velocity (in two directions) is:

$$V_{hor} := \sqrt{V_{hor\_rel}^2 + V_{hor\_abs}^2} \qquad V_{hor} = 50.3 \cdot \frac{in}{sec}$$

$$V_{hor\_max} := \sqrt{V_{hor}^2 + V_{hor}^2} \qquad V_{hor\_max} = 71.2 \cdot \frac{in}{sec}$$

The maximum angular velocity is:

$$V_{angular} := \frac{V_{hor\_max}}{cg_{VCC}} \qquad V_{angular} = 0.613 \frac{rad}{sec}$$

The maximum rotational energy is:

$$E_{rot\_max} := \frac{I_{cask} \cdot V_{angular}^2}{2} \qquad E_{rot\_max} = 2.77 \cdot 10^6 \, in \cdot lbf$$

The maximum vertical velocity is:

$$V_{vert\_max} := \sqrt{V_{vert\_rel}^2 + V_{vert\_abs}^2} \qquad V_{vert\_max} = 24 \frac{in}{sec}$$

The maximum translational energy is:

$$E_{tran\_max} := \frac{P_{VCC_1}}{2} \cdot V_{vert\_max}^2 \qquad E_{tran\_max} = 185730 \, in \cdot lbf$$

The maximum total kinetic energy is:

$$E_{max} := E_{tran\_max} + E_{rot\_max} \qquad E_{max} = 2.955 \cdot 10^6 \, in \cdot lbf$$

The energy required to tip over the cask is

$$E_{tip\_over} = 333412 \, ft \cdot lbf$$

Criterion9 = "ENERGY OF IMPACT LESS THAN ENERGY TO TIP OVER -- ACCEPTABLE"

Therefore, the worst possible combination of natural frequency, vibration mode, damping ratio, and loading combination will not impart sufficient kinetic energy to topple the cask. The cask is concluded to be stable under seismic loads and the MSB stresses, therefore, are negligible, as shown in Reference 3.1.5. The largest MSB seismic stress calculated in Reference 3.1.5 is 0.6 ksi. The MSB seismic stresses are bounded by the vertical and horizontal drop stresses. Reference 3.1.5 is superceded by this calculation (VSC02.6.2.3.19).

VCC Seismic Stresses

The internal stresses due to the seismic loading are calculated below:

$$\tau_{seismic} := \frac{P_{horizontal_2}}{\frac{\pi}{4}\cdot\left(OD_{VCC}^2 - OD_{liner}^2\right)} \qquad \tau_{seismic} = 10.9 \cdot psi$$

Shear Stress

$$\sigma_{seismic} := \frac{P_{horizontal_2}\cdot\left(cg_{VCC} - \left(h_{VCC} - h_{liner}\right)\right)\cdot\left(\frac{OD_{VCC}}{2}\right)}{I_{VSC}}$$

Bending Stress

$$\sigma_{seismic} = 45.8 \cdot psi$$

Theses stresses are negligible and the VCC is acceptable for seismic loads.

Relative Ground Motion

Figure 2 shows the vertical ground displacement required to topple the cask:

$$\theta_{ground} := atan\left[\frac{cg_{VCC}}{\left(\frac{OD_{VCC} - 2\cdot w_{bevel}}{2}\right)}\right] \qquad \theta_{ground} = 61.5 \cdot deg$$

$$\alpha_{ground} := \left(OD_{VCC} - 2\cdot w_{bevel}\right)\cdot \sin\left(90\ deg - \theta_{ground}\right)$$

$$\alpha_{ground} = 5.01 \cdot ft$$

The type of ground motion and the required vertical ground displacement to tip over the cask are considered unrealistic. It is concluded that the cask will not topple due to permanent failure and vertical movement of the foundation.

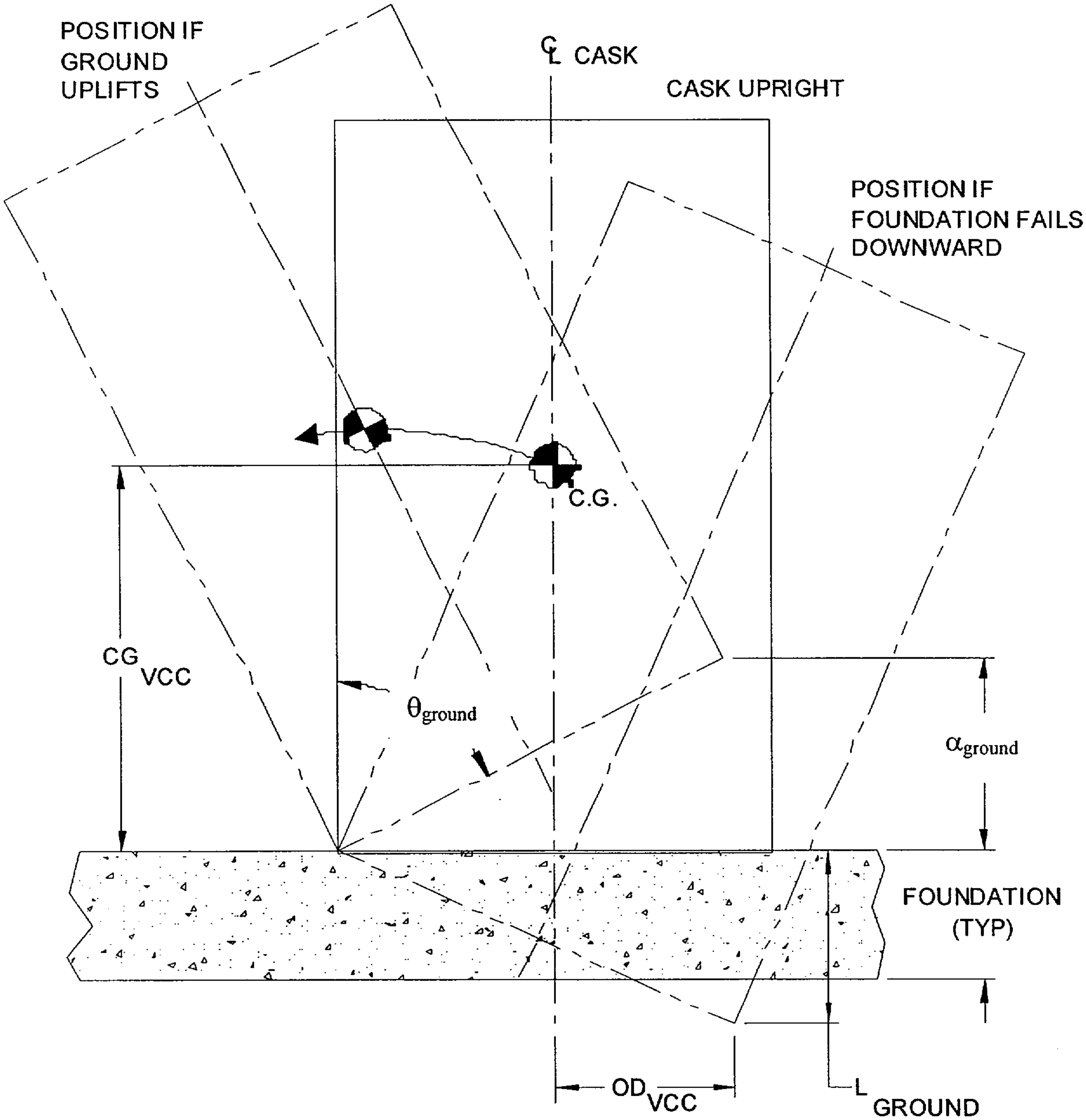


Figure 2

Cask Tip-Over Requirements

7.0 CONCLUSIONS

The analyses indicate that the cask will remain upright following all postulated natural phenomena. In addition, the loads associated with these events do not compromise the overall structural integrity of the cask (minor local damage to the concrete surface may occur but could be easily repaired). The VSC-24 cask can successfully withstand tornado, flood, and earthquakes that may occur at the ISFSI site.

8.0 ELECTRONIC FILES

8.1 Computer Runs

None.

8.2 Other Electronic Files

None.

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.20 File No.: VSC02.6.2.3.20 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

Brittle Fracture Evaluation

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ______
Service:	☒ Storage	☐ Transportation		☐ Other ______
Conditions:	☐ Normal	☐ Off-Normal	☒ Accident	☐ Other ______

Component(s):

MSB shell, bottom, and structural lid.

Prepared by:

Name: Michelle Heinz

Signature: [signature]

Date: 2/16/01

Verified by:

Name: James Morency

Signature: [signature]

Date: 2/16/01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: [signature]

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 - 8 Attachment A1-A11		Replaces Calculation WEP-109-002.20, Rev. 1	J. Hibbard	M. Heinz
1	1-6	None.	Updated the Reference list on p. 6. Provided a more detailed description of the calculation procedure on p. 4-6 and used values from the updated references. Added a detailed calculation for the structural lid. (VSC02-ECN-008)	M. Heinz	J. Moroney

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	(YES)	NO	N/A
(j) Computer codes used are under configuration control.	(YES)	NO	N/A
(k) Computer codes used are applicable to the calculation.	(YES)	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

See Verification memo

Verifier: James Moroney [signature] 2/1/01

Name/Signature/Date

1.0 INTRODUCTION

This calculation package has been generated to resolve the NRC staff concern regarding a possibility of MSB brittle fracture. In general, since the MSB is loaded with fuel, its temperature is such that brittle fracture cannot occur. However, the worst combination of conditions is investigated herein (combination of lowest ambient temperature, coolest fuel, and the highest stress due to the drop accident).

2.0 ASSUMPTIONS AND INPUT

The ANSYS Finite Element Analysis program was used in Reference 5 to calculate the MSB shell lowest temperature. The computer input – output from Reference 5 is provided for convenience in Attachment I. Figure 1 shows the finite element model node and element numbers. No new finite element analysis was performed as part of the present calculation.

The lowest ambient temperature at which the drop has to be considered is -20°F (Reference 2). The drop accident is assumed to happen at the end of cask life, after 20 years of storage. The thermal finite element analysis in Reference 5 was performed with a heat load at 20 years of:

$$Q = 9.6\ KW\mathit{t}$$

The methodology of NUREG 1815 [Reference 3] is used to determine the ductility requirements for the MSB pressure boundary material.

3.0 RESULTS

Using the methodology of NUREG 1815, σ/σ_{yd} is first calculated, where σ is the maximum principal tensile stress at a point in the absence of a flaw, and σ_{yd} is the dynamic yield strength equal to σ_y + 30 ksi for steels with $\sigma_y \leq 60$ ksi.

The maximum stresses in the MSB shell and bottom plate occur for the Horizontal Drop Accident and Vertical Drop Accident load combinations, respectively (Reference 4). Stresses bounding the maximum stresses from Reference 4 for the MSB shell and bottom plate are 55 ksi and 65 ksi respectively. These stresses bound the sum of the load case maximum principal tensile stresses for the applicable load combination.

The maximum stress in the MSB structural lid occurs for the Horizontal Drop Accident load combination (Reference 4). The stress in the MSB structural lid for this load combination from Reference 4 is approximately 50 ksi, which is the sum of the horizontal drop and pressure stresses. The majority of this stress is from the horizontal drop accident presented in Reference 9. An ANSYS analysis is used in Reference 9 to calculate the horizontal drop stresses. The ANSYS analysis uses a tapered element thickness around the periphery of the MSB structural lid, where the outer nodes of the elements on the periphery have a thickness of 0.75" and the inner nodes (closest to the lid center) have a thickness of 3". The 3" value represents the thickness of the structural lid, while the 0.75" thickness represents the thickness of the MSB shell. Because the actual configuration of the structural lid in this section is thin, brittle fracture is not of concern in this area

and stresses on the outer nodes of the structural lid from Reference 9 will not be considered in this calculation.

The maximum principal tensile stress in the structural lid from Reference 9 excluding the periphery nodes is 5.24 ksi at node 126. Using the correction factor developed in Reference 9, the scaled stress is (5.24 ksi)*1.104 = 5.78 ksi. Adding this stress to the pressure stress of 1.19 ksi from the Horizontal Drop Accident load combination in Reference 4 (bounds the maximum principal tensile stress), the value of σ for the structural lid is 6.97 ksi for the Horizontal Drop Accident load combination. The more limiting structural lid stress of 9.97 ksi for the Service Level C Stress load combination of Reference 4 will be used in this calculation.

The MSB shell, bottom plate, and structural lid material is SA-516 Gr. 70, per Reference 7. From Reference 8, the yield strength of SA-516 Gr. 70 material at temperatures between -20°F and 100°F is 38 ksi. Values of σ/σ_{yd} for the MSB shell, bottom plate, and structural lid are calculated below.

MSB Shell:
$$\frac{\sigma}{\sigma_{yd}} = \frac{55ksi}{(38ksi + 30ksi)} = 0.81$$

MSB Bottom Plate:
$$\frac{\sigma}{\sigma_{yd}} = \frac{65ksi}{(38ksi + 30ksi)} = 0.96$$

MSB Structural Lid:
$$\frac{\sigma}{\sigma_{yd}} = \frac{9.97ksi}{(38ksi + 30ksi)} = 0.15$$

The values of A in Table 1 below are determined using Figure 3 from Reference 3 (provided in Figure 2 of this calculation) along with σ/σ_{yd} and the thickness of each component. From Reference 7, the thicknesses of the MSB shell, bottom plate, and structural lid are 1.0", 0.75", and 3.0", respectively. The maximum allowable NDT is calculated using the formula

$$\text{NDT} = \text{LST} - \text{A}$$

where the LST is the lowest service temperature of 2.6°F at node 196 obtained from the ANSYS output provided in Attachment I. Assume that the Charpy V-notch test is done at –30°F. K_{ID} is obtained from Figure 2 of Reference 3 (provided in Figure 3 of this calculation). The formula

$$C_V = \frac{K_{ID}^{\;2}}{5 \cdot E}$$

is used to calculate the Charpy value, where C_v is in ft-lb, K_{ID} is in psi*in$^{1/2}$, and E is the modulus of steel in psi. A conservative value of 28.8x10^6 psi from Reference 8 is used for E (corresponding to a temperature of 200°F). A summary of the values is provided in Table 1.

Table 1

Component	A (°F)	Max Allowed NDT (°F)	Test Temp. Relative to NDT (°F)	Min Expected K_{ID} (ksi/in$^{1/2}$)	C_v ft-lb
MSB Shell	38°F	-35.5°F	5.5°F	42	12.3
MSB Bottom Plate	38°F	-35.5°F	5.5°F	42	12.3
MSB Structural Lid	45°F	-42.4°F	12.4°F	44	13.4

4.0 CONCLUSIONS

To prevent brittle fracture of the MSB pressure boundary, the shell, bottom plate, and structural lid materials must have minimum Charpy V-Notch energy absorptions of 12.3 ft-lbs, 12.3 ft-lbs, and 13.4 ft-lbs, respectively, at -30°F.

The NRC staff, during their review, imposed a stricter requirement of 15 ft-lbs at -50°F. This requirement was incorporated into the MSB fabrication specification.

5.0 REFERENCES

1. Deleted.
2. "Packaging and Transportation of Radioactive Material," Code of Federal Regulations, Title 10, Part 71, 1999 Edition.
3. NUREG 1815, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers up to Four Inches Thick," 1981.
4. BNFL Calculation No. VSC02.6.2.3.02, Revision 3, "MSB-24 Load Combination Evaluation."
5. BNFL Calculation No. WEP-109-002.20, Revision 1, "Brittle Fracture Evaluation."
6. Deleted.
7. BNFL Calculation No. VSC02.6.2.5.03, Revision 0, "VSC-24 Design Parameters."
8. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1986 Edition with 1988 Addenda.
9. BNFL Calculation No. VSC02.6.2.3.08, Revision 2, "MSB-24 Drop Analysis".

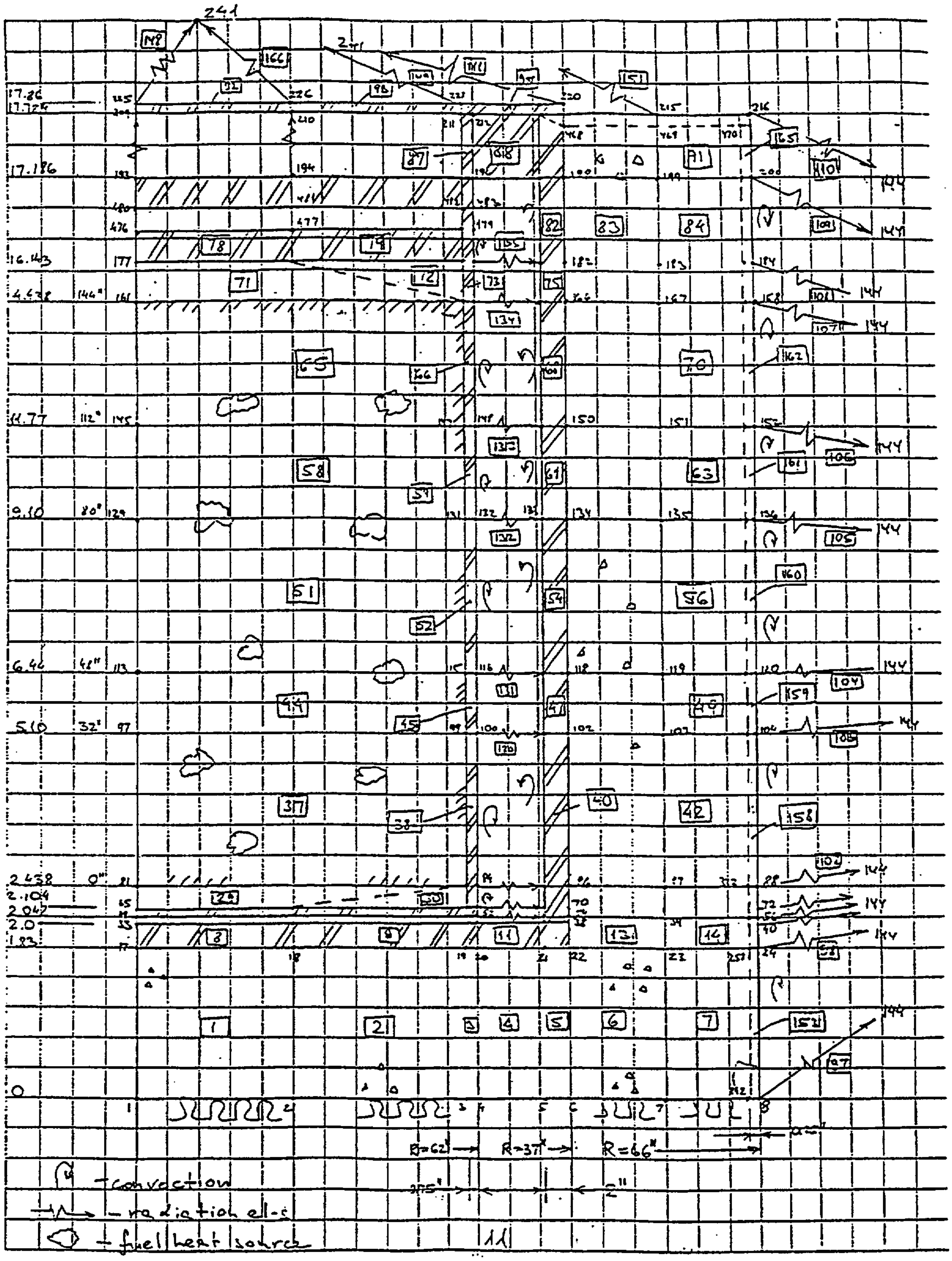


Figure 1. Finite Element Model

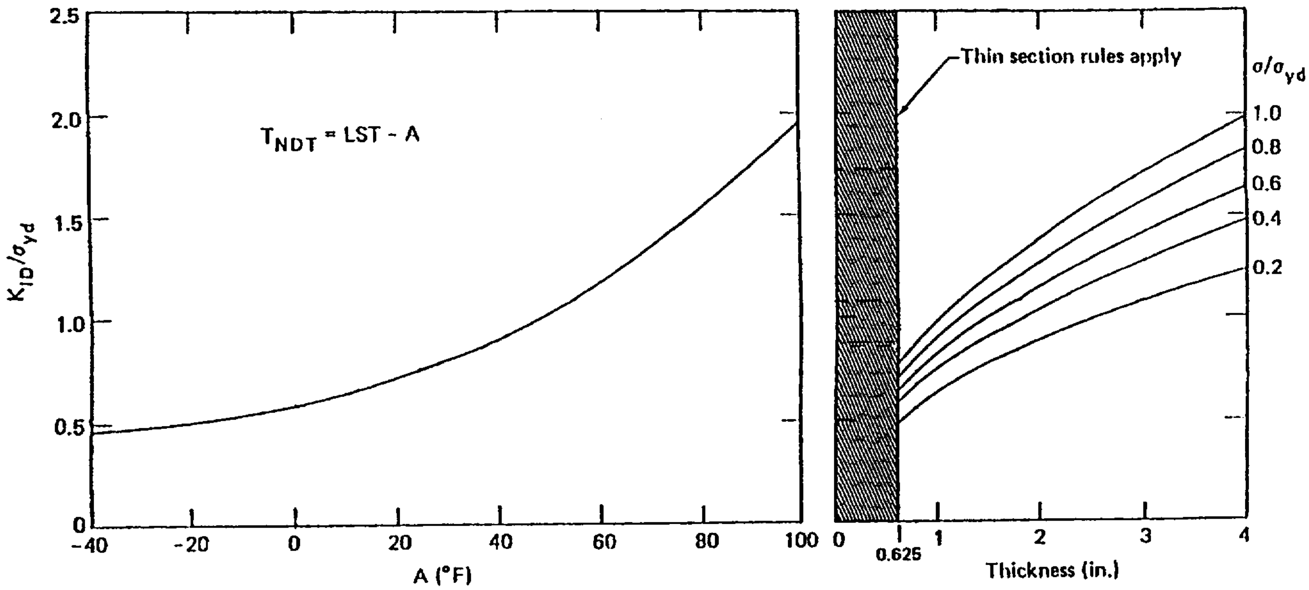


Figure 2. Design Chart for Category I Fracture Critical Components (Reference 3)

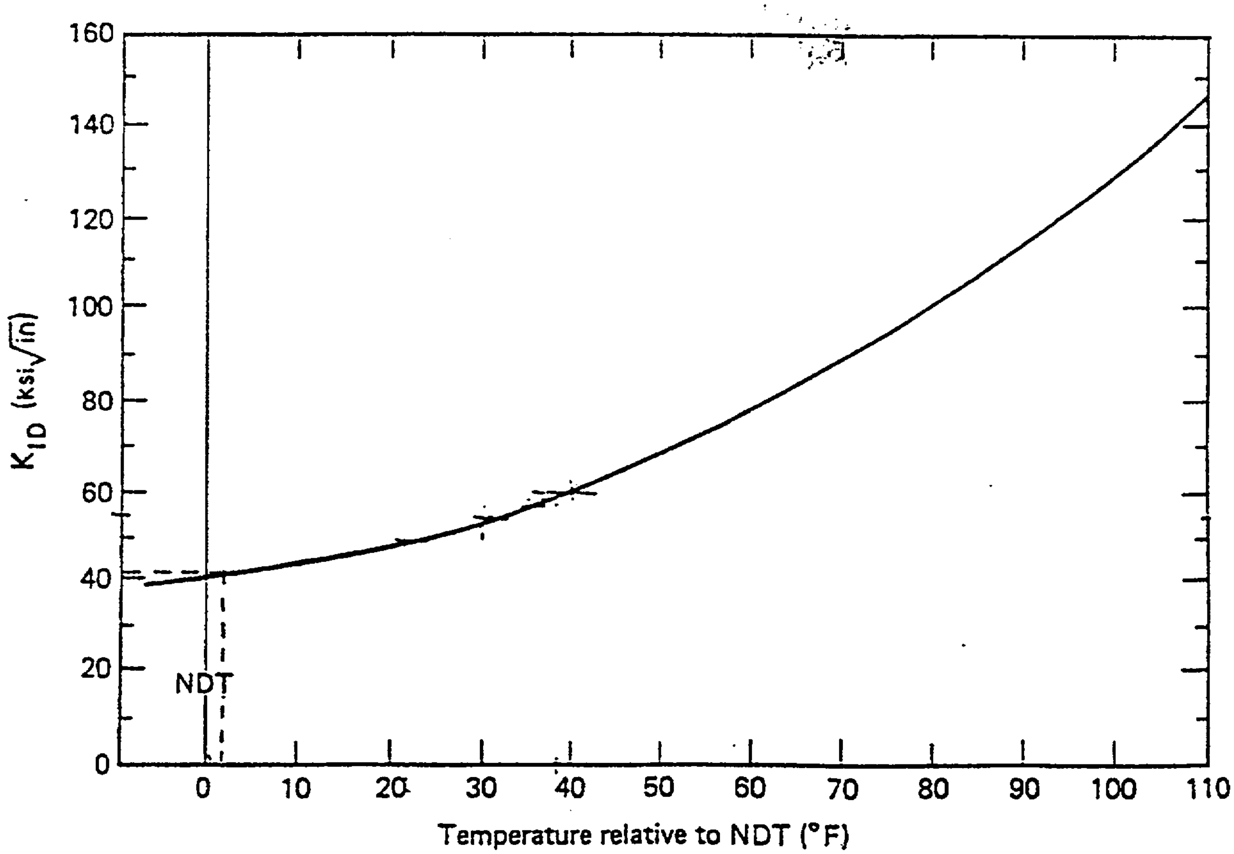


Figure 3. Design-reference Curve Relating K_{ID} and the Temperature Relative to NDT (Reference 3)

Attachment A

Finite Element Analysis Output

Attachment A

Finite Element Analysis Output

NORMAL FLOW PATH	D(H)	A	L	F	K	A**2	K/A**2	VEL	Re
NLET SNOW SKIRT with screens	-	11.87000	-	-	0.77000	140.90	0.00546	0.97	-
NLET SECTION DOWN OUTSIDE	0.66700	11.87000	3.00000	0.04000	0.17991	140.90	0.00128	0.97	4.48E+03
END & ENTER. SKID CHANNELS	-	4.68000	-	-	1.38000	21.90	0.06301	2.46	-
KID CHANNELS	1.08000	4.68000	5.11833	0.03000	0.14218	21.90	0.00649	2.46	1.84E+04
END INTO 12 IN SQ TUBE	-	4.00000	-	-	2.16000	16.00	0.13500	2.88	-
ENDS AT CHANNEL AND INLET ASSY	-	4.00000	-	-	0.38700	16.00	0.02419	2.88	-
TRAIGHT SECTION	1.00000	4.00000	1.33333	0.02600	0.03467	16.00	0.00217	2.88	1.99E+04
NLET ASSEMBLY AND BEND INTO ANN.	-	4.47200	-	-	1.38400	20.00	0.06920	2.57	-
UDDEN EXPANSION INTO ANNULUS	-	5.76000	-	-	0.05000	33.18	0.00151	2.00	-
FLOW UP ANNULUS	0.66600	5.76000	14.16667	0.03300	0.70195	33.18	0.02116	2.00	9.21E+03
BEND*CNTRCT INTO 3" by 52" SLIT	-	4.33333	-	-	1.20000	18.78	0.06391	2.65	-
ND	-	4.33333	-	-	2.78000	18.78	0.14805	2.65	-
D. T STRAIGHT SECTION	1.89000	4.33333	2.66667	0.02600	0.03668	18.78	0.00195	2.65	3.48E+04
DISCHARGE with screens	-	4.33333	-	-	1.14000	18.78	0.06071	2.65	-

K/A**2	0.60408
T TEMP	-20.00000
ET TEMP	17.90000
TEMP	-1.05000
T HEIGHT	15.00000
S DT=	37.90000
=	32755.20
	0.24100
EAT BAL)	0.99614
DENSITY	0.08662
.OW=	0.10746
TACK=	0.10729
ALC	37.90000
) FLOW)	0.99614
3/IN	227.46667

X POSITION	f REL POWER	Q(x) POWER/IN	QX	AIR TEMP	DT TEMP
0	-	-	-	-20.00	-
0-16	0.69000000	156.95200	2511.23	-17.08	2.92
16-32	1.08000000	245.66400	3930.62	-12.52	4.57
32-48	1.20000000	272.96000	4367.36	-7.44	5.07
48-64	1.19000000	270.68533	4330.97	-2.41	5.03
64-80	1.17000000	266.13600	4258.18	2.54	4.95
80-96	1.12000000	254.76267	4076.20	7.27	4.74
96-112	1.05000000	238.84000	3821.44	11.71	4.44
112-128	0.90000000	204.72000	3275.52	15.52	3.81
128-144	0.60000000	136.48000	2183.68	18.06	2.54

LIST ELEMENT CONVECTIONS FOR ALL SELECTED ELEMENTS

ELEM	FACE	VALUE(S)		FACE NODES			
17	3	2.00000000	-20.0000000	43	36	52	59
24	3	2.00000000	-20.0000000	59	52	68	75
31	3	2.00000000	-20.0000000	75	68	84	91
38	3	2.00000000	-15.0000000	91	84	100	107
45	3	2.00000000	-7.00000000	107	100	116	123
52	3	2.00000000	0.000000000E+00	123	116	132	139
59	3	2.00000000	9.00000000	139	132	148	155
66	3	2.00000000	16.5000000	155	148	164	171
73	3	2.00000000	18.0000000	171	164	180	187
80	3	2.00000000	18.0000000	187	180	479	486
19	5	2.00000000	-20.0000000	37	44	60	53
26	5	2.00000000	-20.0000000	53	60	76	69
33	5	2.00000000	-20.0000000	69	76	92	85
40	5	2.00000000	-15.0000000	85	92	108	101
47	5	2.00000000	-7.00000000	101	108	124	117
54	5	2.00000000	0.000000000E+00	117	124	140	133
61	5	2.00000000	9.00000000	133	140	156	149
68	5	2.00000000	16.5000000	149	156	172	165
75	5	2.00000000	18.0000000	165	172	188	181
82	5	2.00000000	18.0000000	181	188	204	197

ELEM	FACE	VALUE(S)		FACE NODES			
171	6	2.00000000	-20.0000000	215	214	221	222
172	6	2.00000000	-20.0000000	450	215	222	451
164	3	2.00000000	-20.0000000	191	184	200	207
96	6	2.00000000	-20.0000000	230	229	236	237
95	6	2.00000000	-20.0000000	229	228	235	236
94	6	2.00000000	-20.0000000	228	227	234	235
93	6	2.00000000	-20.0000000	227	226	233	234
92	6	2.00000000	-20.0000000	226	225	233	233
153	3	2.00000000	-20.0000000	15	8	24	31
154	3	2.00000000	-20.0000000	31	24	40	47
155	3	2.00000000	-20.0000000	47	40	56	63
156	3	2.00000000	-20.0000000	63	56	72	79
157	3	2.00000000	-20.0000000	79	72	88	95
158	3	2.00000000	-20.0000000	95	88	104	111
159	3	2.00000000	-20.0000000	111	104	120	127
160	3	2.00000000	-20.0000000	127	120	136	143
161	3	2.00000000	-20.0000000	143	136	152	159
162	3	2.00000000	-20.0000000	159	152	168	175
163	3	2.00000000	-20.0000000	175	168	184	191
165	3	2.00000000	-20.0000000	207	200	216	223

LEM	FACE	VALUE(S)		FACE NODES			
173	3	2.00000000	-20.0000000	475	471	216	223
173	6	2.00000000	-20.0000000	216	450	451	223
179	3	2.00000000	18.0000000	489	483	196	203
176	3	2.00000000	18.0000000	486	479	483	489

ST TEMPERATURES FOR ALL SELECTED NODES

	LABEL	TEMPR	
1[illegible]	TEMP	-20.0000000	0.000000000E+00
241	TEMP	-20.0000000	0.000000000E+00

Calc. VSC02.6.2.3.20
Rev. 1

ST ELEM HEAT GENERATIONS FOR ALL SELECTED ELEMENTS

EMENT	HEAT GENERATIONS
37	130.500000
44	161.400000
51	157.400000
3	148.000000
5	103.600000

'INT NODAL TEMPERATURES

***** POST1 NODAL TEMPERATURE LISTING *****

.. .D STEP 1 ITERATION= 12 SECTION= 1
'IME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
1	10.528862
2	8.0809758
3	1.1418336
4	0.91076857
5	-0.67504239
6	-2.0284315
7	-9.3777614
8	-17.849450
9	8.0809794
10	1.1417585
11	0.91069905
12	-0.67505895
13	-2.0284210
14	-9.3777639

***** POST1 NODAL TEMPERATURE LISTING *****

)AD STEP 1 ITERATION= 12 SECTION= 1
:ME= 0.00000E+00 LOAD CASE= 1

DE	TEMP
.5	-17.849450
17	18.201884
18	15.934369
19	11.415625
20	10.628605
21	6.5473116
22	5.3964418
23	-9.1953469
24	-17.816159
25	15.934362
26	11.415780
27	10.628749
28	6.5473465
29	5.3964202

***** POST1 NODAL TEMPERATURE LISTING *****

AD STEP 1 ITERATION= 12 SECTION= 1
ME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
30	-9.1953419
31	-17.816159
[illegible]	18.456847
[illegible]	15.883332
[illegible]	11.807938
36	11.429526
37	5.8019143
38	4.9572026
39	-9.1589570

40	-17.790365
41	15.883283
42	11.808403
43	11.430089
4	5.8018472

***** POST1 NODAL TEMPERATURE LISTING *****

LOAD STEP 1 ITERATION= 12 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
45	4.9571346
46	-9.1589424
47	-17.790365
49	20.651208
50	16.768760
51	13.474562
52	12.530077
53	5.0478368
54	4.7604405
55	-9.1436192
56	-17.787874
57	16.769147
58	13.477594
59	12.530521

***** POST1 NODAL TEMPERATURE LISTING *****

STEP 1 ITERATION= 12 SECTION= 1
I= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
60	5.0477899
61	4.7603212
62	-9.1435927
63	-17.787876
65	20.875863
66	16.700852
67	13.787143
68	14.159950
69	4.2228388
70	4.2749708
71	-9.0824172
72	-17.782689
73	16.701022
74	13.792190

***** POST1 NODAL TEMPERATURE LISTING *****

AD STEP 1 ITERATION= 12 SECTION= 1
ME= 0.00000E+00 LOAD CASE= 1

DE	TEMP
	14.148697
5	4.2228830
77	4.2746976
78	-9.0823535
79	-17.782695
81	156.01884

83	30.666108
84	30.354084
85	1.5062096
86	1.5835151
87	-8.8290696
88	-17.740354
90	30.288404
91	30.017918

***** POST1 NODAL TEMPERATURE LISTING *****

LOAD STEP 1 ITERATION= 12 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
92	1.5036572
93	1.5821389
94	-8.8287409
95	-17.740388
97	197.23205
99	56.223279
100	55.762471
101	2.7361548
102	2.6870989
103	-8.1387875
104	-17.575323
106	55.750676
107	55.338339
08	2.7306738

***** POST1 NODAL TEMPERATURE LISTING *****

LOAD STEP 1 ITERATION= 12 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
109	2.6839771
110	-8.1380451
111	-17.575377
113	216.16313
115	67.426759
116	66.931016
117	8.0064575
118	7.9209098
119	-6.3720040
120	-17.174813
122	66.893302
123	66.454968
124	8.0003327
125	7.9174537

***** POST1 NODAL TEMPERATURE LISTING *****

STEP 1 ITERATION= 12 SECTION= 1
= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
126	-6.3711816
127	-17.174877
129	222.75685

131	73.248163
132	72.901349
133	14.799039
134	14.713771
5	-3.0223393
6	-16.659352
138	72.762469
139	72.462912
140	14.793674
141	14.710729
142	-3.0216153

***** POST1 NODAL TEMPERATURE LISTING *****

OAD STEP 1 ITERATION= 12 SECTION= 1
IME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
143	-16.659412
144	-20.000000
145	188.26758
147	70.361933
148	69.531398
149	18.691338
150	18.574070
151	-1.4339053
152	-16.398790
154	69.854315
155	69.088245
	18.685185
	18.570591
158	-1.4330777

***** POST1 NODAL TEMPERATURE LISTING *****

AD STEP 1 ITERATION= 12 SECTION= 1
ME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
159	-16.398851
161	156.68978
163	45.817749
164	45.002709
165	15.363814
66	15.264143
67	-3.1856065
68	-16.709285
70	45.465394
71	44.703787
72	15.360532
73	15.262304
74	-3.1851687
75	-16.709320

***** POST1 NODAL TEMPERATURE LISTING *****

) STEP 1 ITERATION= 12 SECTION= 1
E= 0.00000E+00 LOAD CASE= 1

DE TEMP

177	9.9938229
178	9.7747063
179	11.396873
80	11.817315
1	8.5027849
2	8.3624418
183	-7.2436905
184	-17.549803
185	9.7694540
186	11.442326
187	11.847753
188	8.5042530
189	8.3632204
190	-7.2438757

***** POST1 NODAL TEMPERATURE LISTING *****

OAD STEP 1 ITERATION= 12 SECTION= 1
IME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
191	-17.549796
193	3.3689431
194	3.9923754
195	3.1684856
196	2.6271948
197	1.5838838
198	1.6503074
9	-12.398635
[illegible]	-18.604150
[illegible]	3.9923719
202	3.1684683
203	2.6273861
204	1.5835925
205	1.6501971

***** POST1 NODAL TEMPERATURE LISTING *****

AD STEP 1 ITERATION= 12 SECTION= 1
ME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
206	-12.398609
207	-18.604150
209	-12.625305
210	-10.185625
211	-1.7947644
212	-1.3215028
213	-0.96864665
214	-1.7587605
215	-17.576772
216	-19.142915
217	-10.185627
[illegible]	-1.7947541
[illegible]	-1.3215723
[illegible]	-0.96856954

***** POST1 NODAL TEMPERATURE LISTING *****

AD STEP 1 ITERATION= 12 SECTION= 1

TIME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
221	-1.7587585
222	-17.576772
223	-19.142916
225	-12.692814
226	-10.191472
227	-1.9412206
228	-1.4703840
229	-1.1203322
230	-1.7434968
233	-10.191472
234	-1.9412174
235	-1.4704210
236	-1.1202809
237	-1.7434767

***** POST1 NODAL TEMPERATURE LISTING *****

LOAD STEP 1 ITERATION= 12 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
241	-20.000000
242	-17.078291
243	-17.078291
258	-17.014775
259	-17.014773
[illegible]	-16.980666
[illegible]5	-16.980659
290	-16.972530
291	-16.972524
306	-16.974876
307	-16.974879
322	-16.950658
323	-16.950724
338	-16.681453

***** POST1 NODAL TEMPERATURE LISTING *****

LOAD STEP 1 ITERATION= 12 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
339	-16.681581
354	-16.196217
355	-16.196363
370	-15.420412
371	-15.420541
386	-15.046945
387	-15.047089
402	-15.498147
[illegible]	-15.498226
[illegible]	-16.663369
4[illegible]	-16.663335
434	-18.189751
435	-18.189758
450	-18.832282

***** POST1 NODAL TEMPERATURE LISTING *****

LOAD STEP 1 ITERATION= 12 SECTION= 1
E= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
451	-18.832281
468	-1.5325281
469	-17.352319
470	-18.789446
471	-19.161712
472	-1.5325296
473	-17.352319
474	-18.789445
475	-19.161713
476	9.3625431
477	10.236637
478	9.5283540
479	9.2010530
480	4.0916090

***** POST1 NODAL TEMPERATURE LISTING *****

OAD STEP 1 ITERATION= 12 SECTION= 1
IME= 0.00000E+00 LOAD CASE= 1

NODE	TEMP
481	3.5355492
2	4.9548205
3	5.4696433
484	10.238468
485	9.5153883
486	9.1947453
487	3.5356008
488	4.9544814
489	5.4680363

KIMUMS
DE 129
LUE 222.75685

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.21 File No.: VSC02.6.2.3.21 Revision: 2

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

Normal and Off-normal Handling Analysis

SCOPE:

Product: ☐ FuelSolutions™ ☐ TranStor™ ☒ VSC-24 ☐ Other ______

Service: ☒ Storage ☐ Transportation ☐ Other ______

Conditions: ☒ Normal ☒ Off-Normal ☐ Accident ☐ Other ______

Component(s):

MSB Components.

Prepared by:

Name: Michelle Heinz

Signature: [signature]

Date: 2/15/01

Verified by:

Name: James Moroney

Signature: [signature]

Date: 2/15/01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: [signature]

Date: 3/26/01

Form QAP 3.2-1, Revision 1

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 - 13	None	Replaces Calculation WEP109-002.21, Rev. 1. Per ECN No. WEP01-C-018	J Hibbard	M Heinz
1	All	None	Incorporated changes due to alternative support of MSB by ceramic tiles, as per ECN No. VSC02-ECN-003 Editorial re-write	W. Price	G. Mukhim
2	All	None	Updated references and revised calculations based on the updated references. On p. 11, stated that the unit g vertical stresses are from the summary table in Reference 3.1.1 rather than from both References 3.1.1 and 3.1.3. (VSC02-ECN-008)	M. Heinz	J. Moroney

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION			
	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

See Verification memorandum for comments

Verifier: James Moroney [signature] 2/15/01

Name/Signature/Date

1. INTRODUCTION

The purpose/objective of this calculation is to determine stresses in the MSB-24 for normal and off-normal handling loads while the MSB is being stored. A separate calculation combines stresses for different loading conditions and compares stresses to ASME Code allowable stresses. Revision 1 of this calculation incorporated the analysis results of the alternative ceramic tile support configuration performed in Ref. 3.1.1 and 3.1.3.

This calculation supersedes WEP109-002.21, Revision 1. Revision 0 of this calculation addressed comments in CAR 98-50. The principal differences between Revision 0 of this calculation and WEP109-002.21 are:

- Updated the calculation for revised inputs from the references.
- Revised the calculation of the deceleration for the off-normal handling impact.
- Applied a dynamic load factor to stresses calculated for the off-normal handling impact.
- Considered off normal handling for case of MSB in transfer cask, and MSB being lowered into storage cask.

2. REQUIREMENTS

2.1. Design Inputs

None.

2.2. Regulatory Commitments

2.2.1. "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High Level Radioactive Waste", Code of Federal Regulations Title 10, Part 72.

3. REFERENCES

3.1. BFS Calculation Packages

3.1.1. BFS Calculation VSC02.6.2.3.08, "MSB-24 Drop Analysis," Revision 2. (Stress results).

3.1.2. BFS Calculation VSC02.6.2.3.15, "VSC-24 Hypothetical Tip-Over and 5-foot Drop Analyses," Revision 1. (Five-foot drop deceleration, target hardness number).

3.1.3. BFS Calculation VSC02.6.2.3.25, "MSB Dead Weight and Vertical Drop Bottom Plate Bending Stress Analysis," Revision 2 (Stress Results)

3.2. General References

3.2.1. R. J. Roark, "Formulas for Stress and Strain," McGraw Hill, Fourth Edition.

3.2.2. John N. Biggs, "Introduction to Structural Dynamics," McGraw Hill, 1964.

3.2.3. EPRI Report NP-4830, "The Effect of Target Hardness on Structural Design of Storage Pads for Spent Fuel Casks," 1986.

4. ASSUMPTIONS

4.1. Design Configuration

No assumptions are made with regard to the design configuration.

4.2. Design Criteria

No assumptions are made regarding the design criteria.

4.3. Calculations

4.3.1. The normal operation acceleration is assumed to be 0.5 g, acting in the vertical and the two horizontal directions simultaneously (per the NRC staff suggestion).

4.3.2. The off-normal acceleration for MSB transported inside the transfer cask results from an assumed impact of 2 ft/sec crane speed. The off-normal acceleration for the MSB being lowered into the storage cask is assumed to result from an impact at a lowering speed of 0.75 ft/sec.

4.3.3. Stresses due to simultaneous vertical and horizontal decelerations are conservatively assumed to add. (A less conservative but still accurate approach is to SRSS the stress components.)

4.3.4. Assume that the target hardness for the off-normal impact is 197,000. This value bounds the maximum target hardness values calculated for the horizontal and vertical cask drops in Reference 3.1.2.

4.3.5. Assume that the dynamic load factor (DLF) for normal and off-normal handling is 2.0. This is conservative, since 2.0 bounds DLFs for typical impulse loads as shown in Figures 2.6 through 2.9 of Reference 3.2.2.

5. CALCULATION METHODOLOGY

The MSB stresses due to handling loads are calculated by scaling the results from the drop analysis in Reference 3.1.1 as follows:

$$SI_{handling} = SI_{drop} \frac{a_{handling}}{a_{drop}} * DLF$$

Where,

$SI_{handling}$	=	Stress Intensity for acceleration due to handling
SI_{drop}	=	Stress Intensity for acceleration load due to drop
$a_{handling}$	=	Acceleration due to handling
a_{drop}	=	Acceleration due to drop
DLF	=	Dynamic Load Factor

6. CALCULATIONS

6.1. Normal Handling

The acceleration for normal handling is assumed to be 0.5 g acting simultaneously in the vertical and two horizontal directions.

$$a_{handling\_vert} = 0.5g$$

$$a_{handling\_horiz} = 0.5g\sqrt{2}$$

$$a_{handling\_horiz} = 0.71g$$

The accelerations for the dead weight and horizontal drop are as follows:

$$a_{deadweight} = 1g$$

$$a_{drop\_horiz} = 44g \qquad \text{(Reference 3.1.2)}$$

The stresses from the vertical and horizontal accelerations are assumed to add. A function for calculating the handling stress is as follows:

$$HandlingStress = \left[\left(\frac{a_{handling\_vert}}{a_{deadweight}}\right)SI_{vert} + \left(\frac{a_{handling\_horiz}}{a_{drop\_horiz}}\right)SI_{horiz}\right] * DLF$$

Where,

SI_{vert} = Stress Intensity due to 1g dead weight analysis. (Ref 3.1.1 and Ref 3.1.3)

SI_{horiz} = Stress Intensity due to 44g horizontal drop analysis. (Ref 3.1.1)

DLF = 2 (Dynamic Load Factor, Assumption 4.3.5)

Using the above calculation to combine vertical and horizontal normal handling, the final normal handling stresses are summarized in Table 6-1.

Horizontal stress intensity above is derived from the horizontal side drop analysis of Ref 3.1.1.

Since a dead weight analysis has been completed for two support configurations (MSB uniformly supported in the transfer cask, and MSB supported on ceramic tiles), the stresses of Table 6-1 are the bounding values of the two analyses. Dead weight stresses taken from Ref 3.1.3 are already unit g stresses and are used directly in this calculation, while stresses taken from Ref 3.1.1 are scaled by a factor of 1/120 since this is a vertical drop analysis, with a drop acceleration of 120g.

Table 6-1 Summary of Normal Handling Stresses

Location	Stress Category	Stress (ksi)				
		Dead Weight	Horiz Drop	Vert Handling	Horiz Handling	Total Handling
MSB Shell	P_m	0.50	21.40	0.50	0.69	1.19
	$P_L + P_b$	1.50	50.00	1.50	1.61	3.11
Bottom Plate	P_m	0.35	32.60	0.35	1.05	1.40
	$P_L + P_b$	12.20	43.60	12.20	1.41	13.61
Structural Lid	P_m	0.01	22.10	0.01	0.71	0.72
	$P_L + P_b$	0.04	47.40	0.04	1.53	1.57
Sleeve Assembly	P_m	0.06	60.69	0.06	1.96	2.02
	$P_L + P_b$	0.06	63.00	0.06	2.03	2.09
Support Ring Weld	P_m	0.18	0.00	0.18	0.00	0.18
	$P_L + P_b$	0.18	0.00	0.18	0.00	0.18
Structural Lid Weld	P_m	0.04	10.40	0.04	0.34	0.38
	$P_L + P_b$	0.08	47.40	0.08	1.53	1.61
Bottom Plate Weld	P_m	0.50	28.70	0.50	0.93	1.43
	$P_L + P_b$	12.20	43.60	12.20	1.41	13.61
Shield Lid	P_m	0.03	14.20	0.03	0.46	0.49
	$P_L + P_b$	0.31	21.30	0.31	0.69	1.00
Shield Lid Weld	P_m	0.27	10.20	0.27	0.33	0.60
	$P_L + P_b$	0.27	22.70	0.27	0.73	1.00

Note:
The sleeve assembly membrane and membrane plus bending stresses for the horizontal drop are from Reference 3.1.1, Attachment A. The sleeve assembly membrane stress is the average of the Node 225 shell top and shell bottom stress intensities: (53.38 ksi + 63.00 ksi)/2 = 60.69 ksi. This estimate of the membrane stress has significant margin since it includes the bending stress. The membrane plus bending stress is the maximum stress intensity, which is occurs at Node 225, shell bottom (63.00 ksi).

6.2. Off-Normal Handling

Off normal handling is considered for two scenarios.

1. The MSB is being moved via the transfer cask at an off normal crane velocity of 2 ft/sec.
2. The MSB is being lowered into the storage cask at an off normal lowering velocity of 0.75 ft/sec

Consider the off-normal load as impacts at handling velocities of 2 ft/sec, and 0.75 ft/sec. This is equivalent to a vertical drop from:

$$h = \frac{v^2}{2g}$$

For v = 2 ft/sec

$$h = 0.75 \quad in.$$

and for v = 0.75 ft/sec

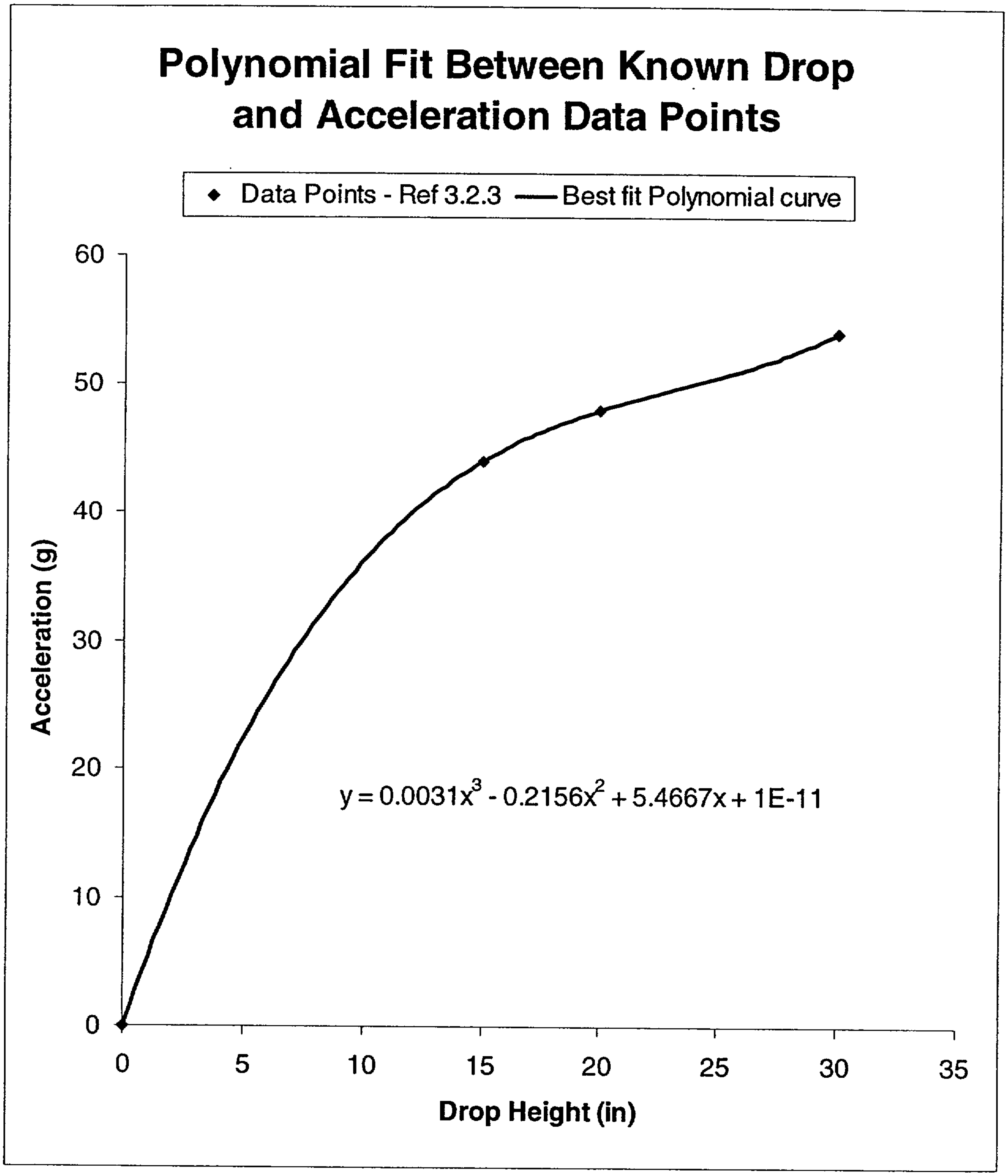
$$h = 0.1 \quad in.$$

Calculate the deceleration from the above impact velocities using the approach and the results in Reference 3.1.2, where the deceleration was calculated for vertical and horizontal drops from five feet. A target hardness of 197,000 bounds the maximum target hardness calculated in Reference 3.1.2 for a vertical drop onto a 36" thick concrete storage pad. Assume that the target hardness for the off-normal impact is also 197,000. Reference 3.2.3, Figure 19 gives the deceleration for drop heights from 15 inches to 80 inches. Use the data to determine the deceleration for the drop heights of $h = 0.75$ *in, and* $h = 0.1$ *in.* Data from Reference 3.2.3, Figure 19 is as follows:

$$x = \begin{bmatrix} 0 \\ 15 \\ 20 \\ 30 \\ 40 \\ 50 \\ 60 \end{bmatrix} \qquad a = \begin{bmatrix} 0 \\ 44 \\ 48 \\ 54 \\ 57 \\ 59 \\ 61 \end{bmatrix}$$

A fourth order polynomial curve fit was applied to the above data points using an Excel spreadsheet. Clearly, the drop heights of 0.75 and 0.1 inches are very small. For this reason the curve fit was restricted to the first 30 inches of drop height data. The equation of the polynomial was determined and the appropriate value of drop height (x) substituted into the equation (shown below), to yield the equivalent drop acceleration.

$$a = 0.0031x^3 - 0.2156x^2 + 5.4667x + 1e-11$$



It is noted that the curve fit is an approximation. For small drop heights such as those being dealt with in this analysis, it is very accurate up to a drop height of 20 inches, which easily bounds the drop heights considered of 0.1 and 0.75 inches. A higher order polynomial or different curve fitting technique would be needed if interpolation at higher drop heights was being performed.

Using the polynomial equation for the curve, and substituting the value of the off-normal impact drop from h = 0.75 in, the drop accleleration is;

$$a_{0.75} = 3.980g \quad \text{conservatively use } 4.0g$$

and for a drop height of 0.1 in

$$a_{0.1} = 0.545g \quad \text{conservatively use } 0.6g$$

Assume that the DLF for calculation of stress due to off-normal handling loads is 2.0. The off-normal decelerations including the DLF are 8.0g and 1.2g for MSB off-normal handling in the transfer cask and storage cask respectively.

Stress for the off-normal impact is calculated by scaling either the horizontal drop stress or the dead weight stress. The stress to use for scaling is based on comparing the unit acceleration stress, i.e., the horizontal drop stress divided by the horizontal drop acceleration, and the dead weight stress - which already represents unit vertical acceleration. The maximum of the unit acceleration stresses provides the stress intensity to be scaled to give the off-normal handling stress. The calculations are performed separately for transfer cask and storage cask conditions due to different off-normal handling accelerations.

Hence, for the condition of MSB in the transfer cask;

$$\text{Stress Intensity} = (\text{Max unit g Stress})_{\text{transfer cask}} \times 4.0g \times \text{DLF}$$

$$\text{With DLF} = 2, \text{Stress Intensity} = (\text{Max unit g Stress})_{\text{transfer cask}} \times 8.0$$

And for the condition of MSB lowered onto the ceramic tiles;

$$\text{Stress Intensity} = (\text{Max unit g Stress})_{\text{tiles}} \times 0.6g \times \text{DLF}$$

$$\text{With DLF} = 2, \text{Stress Intensity} = (\text{Max unit g Stress})_{\text{tiles}} \times 1.2$$

A noted previously, two separate calculations for the off-normal handling stress are completed i.e. the MSB being moved via the transfer cask at a crane velocity of 2 ft/sec, and the MSB is being lowered into the storage cask at a lowering velocity of 0.75 ft/sec.

For the calculation with the MSB in the transfer cask the unit g vertical stress is based on factoring the vertical drop stresses summarized in Reference 3.1.1 by 1/120. The off-normal handling stresses for the MSB inside the transfer cask are summarized in Table 6-2.

For the calculation with the MSB lowered into the storage cask the unit g vertical stress is taken from Ref 3.1.3 for the MSB shell, MSB base, and MSB base weld. Since these components are analyzed for a dead weight analysis, no scaling is applied. The remaining components are taken from the summary table in Reference 3.1.1, with a scaling factor of 1/120 applied. The off-normal handling stresses for the MSB inside the storage cask are summarized in Table 6-3.

The unit g acceleration stress for the horizontal orientation applies to both off-normal conditions, and is calculated based on the horizontal side drop analysis of Ref 3.1.1 and scaled by 1/44.

Table 6-2 Summary of Off Normal Handling Stresses – MSB Inside Transfer Cask, Impact at 2 ft/sec

Location	Stress Category	Stress (ksi)					
		Dead Weight (Vert)	Horiz Drop	Unit g Stress Vertical	Unit g Stress Horizontal	Max Unit g Stress	Off Normal Handling Stress
MSB Shell	P_m	0.08	21.40	0.08	0.49	0.49	3.89
	$P_L + P_b$	0.13	50.00	0.13	1.14	1.14	9.09
Bottom Plate	P_m	0.01	32.60	0.01	0.74	0.74	5.93
	$P_L + P_b$	0.24	43.60	0.24	0.99	0.99	7.93
Structural Lid	P_m	0.01	22.10	0.01	0.50	0.50	4.02
	$P_L + P_b$	0.04	47.40	0.04	1.08	1.08	8.62
Sleeve Assembly	P_m	0.06	60.69	0.06	1.38	1.38	11.03
	$P_L + P_b$	0.06	63.00	0.06	1.43	1.43	11.45
Support Ring Weld	P_m	0.18	0.00	0.18	0.00	0.18	1.44
	$P_L + P_b$	0.18	0.00	0.18	0.00	0.18	1.44
Structural Lid Weld	P_m	0.04	10.40	0.04	0.24	0.24	1.89
	$P_L + P_b$	0.08	47.40	0.08	1.08	1.08	8.62
Bottom Plate Weld	P_m	0.08	28.70	0.08	0.65	0.65	5.22
	$P_L + P_b$	0.24	43.60	0.24	0.99	0.99	7.93
Shield Lid	P_m	0.03	14.20	0.03	0.32	0.32	2.58
	$P_L + P_b$	0.31	21.30	0.31	0.48	0.48	3.87
Shield Lid Weld	P_m	0.27	10.20	0.27	0.23	0.27	2.16
	$P_L + P_b$	0.27	22.70	0.27	0.52	0.52	4.13

Note:
The sleeve assembly membrane and membrane plus bending stresses for the horizontal drop are from Reference 3.1.1, Attachment A. The sleeve assembly membrane stress is the average of the Node 225 shell top and shell bottom stress intensities: (58.38 ksi + 63.00 ksi)/2 = 60.69 ksi. This estimate of the membrane stress has significant margin since it includes the bending stress. The membrane plus bending stress is the maximum stress intensity, which occurs at Node 225, shell bottom (63.00 ksi).

Table 6-3 Summary of Off Normal Handling Stresses – MSB Lowered onto Ceramic Tiles, Impact at 0.75 ft/sec

Location	Stress Category	Stress (ksi)					
		Dead Weight (Vert)	Horiz Drop	Unit g Stress Vertical	Unit g Stress Horizontal	Max Unit g Stress	Off Normal Handling Stress
MSB Shell	P_m	0.50	21.40	0.50	0.49	0.50	0.60
	$P_L + P_b$	1.50	50.00	1.50	1.14	1.50	1.80
Bottom Plate	P_m	0.35	32.60	0.35	0.74	0.74	0.89
	$P_L + P_b$	12.20	43.60	12.20	0.99	12.20	14.64
Structural Lid	P_m	0.01	22.10	0.01	0.50	0.50	0.60
	$P_L + P_b$	0.04	47.40	0.04	1.08	1.08	1.29
Sleeve Assembly	P_m	0.06	60.69	0.06	1.38	1.38	1.66
	$P_L + P_b$	0.06	63.00	0.06	1.43	1.43	1.72
Support Ring Weld	P_m	0.18	0.00	0.18	0.00	0.18	0.22
	$P_L + P_b$	0.18	0.00	0.18	0.00	0.18	0.22
Structural Lid Weld	P_m	0.04	10.40	0.04	0.24	0.24	0.28
	$P_L + P_b$	0.08	47.40	0.08	1.08	1.08	1.29
Bottom Plate Weld	P_m	0.50	28.70	0.50	0.65	0.65	0.78
	$P_L + P_b$	12.20	43.60	12.20	0.99	12.20	14.64
Shield Lid	P_m	0.03	14.20	0.03	0.32	0.32	0.39
	$P_L + P_b$	0.31	21.30	0.31	0.48	0.48	0.58
Shield Lid Weld	P_m	0.27	10.20	0.27	0.23	0.27	0.32
	$P_L + P_b$	0.27	22.70	0.27	0.52	0.52	0.62

Note:
The sleeve assembly membrane and membrane plus bending stresses for the horizontal drop are from Reference 3.1.1, Attachment A. The sleeve assembly membrane stress is the average of the Node 225 shell top and shell bottom stress intensities: (58.38 ksi + 63.00 ksi)/2 = 60.69 ksi. This estimate of the membrane stress has significant margin since it includes the bending stress. The membrane plus bending stress is the maximum stress intensity, which occurs at Node 225, shell bottom (63.00 ksi).

7. CONCLUSIONS

The calculated stresses are combined with stresses due to other loads in a separate calculation.

8. ELECTRONIC FILES

8.1. Computer Runs

None.

BNFL Fuel Solutions	CALCULATION PACKAGE	Calc. Pkg No. VSC02.6.2.3.25 File No.: VSC02.6.2.3.25 Revision: 2

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

MSB Dead Weight and Vertical Drop Bottom Plate Bending Stress Analysis

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other
Service:	☒ Storage	☐ Transportation		☐ Other
Conditions:	☒ Normal	☐ Off-Normal	☒ Accident	☐ Other

Component(s):

MSB structural lid and bottom plate, and ceramic tile supporting MSB bottom plate.

Prepared by:

Name: Robert Keating

Signature: [signature]

Date: 2-6-01

Verified by:

Name: Michelle Heinz

Signature: Michelle Heinz

Date: 2-6-01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: RSrinivasan

Date: 3/26/01

Form QAP 3.2-1, Revision 1

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 – 18 Appendix Pages A1-A33, B1-B5, & C1-C5		Updates Calculation WEP109-002.25, Rev. 1	J.L. Hibbard	Michelle Heinz
1	All		Editorial re-write. Incorporated changes due to alternative support of MSB by ceramic tiles, as per ECN No. VSC02-ECN-003	Warren Price	Soo Bee Kok
2	All		Update calculation with changes in the reference dimensions and weights. Updated all 1's in the 'Cat' column on p. 46 to 2's per ECN VSC02-ECN-007. Incorporated ECN No. VSC02-ECN-008	Robert Keating	Michelle Heinz

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION			
	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	YES	NO	(N/A)
(i) Computer calculations are properly identified.	(YES)	NO	N/A
(j) Computer codes used are under configuration control.	(YES)	NO	N/A
(k) Computer codes used are applicable to the calculation.	(YES)	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Michelle Heinz Michelle Heinz 2/6/01
Name/Signature/Date

Form QAP 3.2-1, Revision 1

TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

1. INTRODUCTION

The objective/purpose of this calculation is to calculate the stresses in the vicinity of the MSB top and bottom regions for both normal operating and vertical drop conditions. This calculation was generated at the request of the NRC. The calculation scope includes an analysis of the MSB top and bottom regions for end drop onto base and end drop onto shield lid. In addition, the calculation evaluates the ceramic tile that supports the MSB bottom plate for normal operating conditions. Revision 1 of this calculation incorporated the analysis results of an alternative tile support configuration at the MSB bottom plate.

This calculation supersedes WEP109.002.25, Revision 1. Revision 0 of this calculation incorporated comments from CAR 98-50 and the Design Review Record (dated 8/21/98) for Calculation WEP109-002.25, Revision 1.

CAR 98-50 indicates there is a discrepancy in the temperature used to establish the allowable stress for the sleeve. It appears that this comment is an error, since this calculation only models the MSB shell and does not include the sleeve. This comment in the CAR was not addressed in this calculation.

The principal differences between Rev 0 of this calculation and WEP109.002.25, Revision 1 are:

- Dimensions for the MSB changed slightly. The ANSYS results were scaled to account for the dimensional changes.
- Calculations were revised for the revised deceleration from the five foot drop calculation in Ref 3.1.2.
- An evaluation was added to calculate the stresses in the bottom plate when the MSB is supported by ceramic tiles. The evaluation considers both normal operating and five foot drop conditions.
- An evaluation was added to calculate the bearing stress in the ceramic tile for normal operating loads (1 g acceleration).

2. REQUIREMENTS

2.1. Design Inputs

2.1.1. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, *Rules for Construction of Nuclear Power Plant Components*, Section III, Division 1, Appendix F, "*Rules for Evaluation of Service Loadings with Level D Service Limits*", 1986 Edition, 1988 Addenda.

2.1.2. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section II, "*Materials Part D – Properties*", 1986 Edition, 1988 Addenda.

2.1.3. ASME American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, *Rules for Construction of Nuclear Power Plant Components*," Section III, Division 1, Subsection NC, "*Class 2 Components*," 1986 Edition, 1988 Addenda.

2.2. Regulatory Commitments

None.

3. REFERENCES

3.1. BFS Calculation Packages

3.1.1. VSC02.6.2.5.01, Rev. 1, "Weight and Center of Gravity". (Mass of shield lid, structural lid, and support lid)

3.1.2. VSC02.6.2.3.15, Rev. 1, "VSC-24 Hypothetical Tipover and Five-foot Drop Analyses." (Vertical deceleration from 5 foot drop)

3.1.3. WEP-109-002.25, Rev. 2, "MSB Vertical Drop Bending Analysis." (ANSYS results provided in Attachment A of this calculation)

3.1.4. WEP-109-003.4, "VSC-24 Thermal Hydraulic Analysis," Revision 2, and WEP-109-003.5, "MSB-24 Thermal Hydraulic Analysis," Revision 5. (MSB design temperature of 300°F)

3.1.5. VSC02.6.2.3.05, Rev 2, "Normal, Off-Normal, and Maximum Accident Pressure in the MSB".

3.1.6 VSC02.6.2.5.03, Rev. 0, "VSC-24 Design Parameters."

3.2. General References

3.2.1. Deleted.

3.2.2. Deleted.

3.2.3. Roark & Young, "Roarks Formulas for Stress and Strain", 6th Edition, McGraw-Hill Book Company.

3.2.4. Deleted.

3.2.5. BFS Computer Software Listing, File SOFT.001.001, Rev 0, ANSYS 5.5 (PC)

4. ASSUMPTIONS

4.1. Design Configuration

The main structural members of the MSB (basket) consists of the shell, structural lid, shield lid, and base plate and all associated seam welds and closure welds. Fuel is stored inside the basket, within the storage sleeve assembly. Once inside the concrete cask, the basket sits on a ring of ceramic tiles located around the periphery of the MSB base. The purpose of the ceramic tiles is to prevent contact between the MSB base and the cask liner during normal storage conditions.

Original calculations considered the MSB base to be in direct contact with the cask liner, i.e the MSB base was uniformly supported by the cask.

Two support configurations for the MSB have been considered. These are;

- Uniform support on MSB base for the end drop. This is in line with the original design configuration noted above.

- Support to the MSB base for both normal operating and end drop onto base, is provided by ceramic tiles placed around the periphery of the MSB base.

For the end drop condition where the MSB is uniformly supported, the original ANSYS results from Ref 3.1.3 are scaled to account for some slight changes made to the MSB wall thickness.

For the support configuration with the MSB supported on ceramic tiles, additional ANSYS analyses have been completed. These additional analyses cover both the deadweight of the MSB, deadweight plus internal pressure, and five foot end drop onto the MSB base.

In addition, end drop of the MSB onto its structural lid has been considered, the resulting stresses in the MSB base being reported.

The design parameters for the analyses are listed on the following page.

The design parameters for the MSB used in this analysis are as follows;

$m_{shield} := 6449 \cdot lb$	Shield lid mass without support, Ref. 3.1.1
$m_{shield} := 6500 \cdot lb$	Bounding shield lid mass used in calculation
$m_{struct} := 2409 \cdot lb$	Structural lid mass, Ref. 3.1.1
$m_{struct} := 2500 \cdot lb$	Bounding structural lid mass used in calculation
$m_{msb\_e} := 21686 \cdot lb$	Limiting Mass of MSB, empty. Ref 3.1.1
$m_{MSB} := 70000 \cdot lb$	Bounding mass of loaded MSB with shield lid and structural lid, Ref. 3.1.1
$t_{stl} := 7.5 \cdot in$	Thickness of steel in shield lid, Ref. 3.1.6
$t_{277} := 2.0 \cdot in$	Thickness of RX-277 in shield lid, Ref. 3.1.6
$od_{msb} := 62.5 \cdot in$	OD of msb, Ref. 3.1.6
$id_{msb} := 60.5 \cdot in$	ID of msb, Ref. 3.1.6
$t_{msb} := 1 \cdot in$	Shell wall thickness of msb, Ref. 3.1.6
$L_{msb} := 192.3 \cdot in$	Limiting Length of msb, Ref. 3.1.6
$t_{bot} := .75 \cdot in$	Thickness of bottom plate, Ref. 3.1.6
$w_{cer} := 1.70\ in$	Width of ceramic tile, Ref 3.1.6
$\rho_{277} := 0.0607 \cdot \frac{lb}{in^3}$	Density of RX-277, Ref. 3.1.6
$t_{cer} := 0.3\ in$	Thickness of ceramic tiles, Ref. 3.1.6
$no_{cer} := 24$	Number of ceramic tiles, Ref. 3.1.6
$r_{cer} := 30\ in$	Ceramic tile centerline radius, Ref. 3.1.6

4.2. Design Criteria

4.2.1. Allowable Stresses

The MSB basket shell is designed to the allowable stress design criteria of the ASME Code. Stresses resulting from the deadweight loading condition are evaluated against Subsection NC (Ref 2.1.3). Stresses resulting from the end drop condition are evaluated against the ASME service level D limits. In accordance with Table NC 3217-1, Note 4, the stress limits of Appendix F of the ASME code may be applied for Service Level D conditions when a complete analysis is performed.

For a bounding temperature of 300°F (Ref 3.1.4), the following properties of material SA-516 Gr.70 apply (Ref 2.1.2 and Ref 3.1.6)

S_m = 22.5 ksi

S_y = 33.7 ksi

S_u = 70.0 ksi

4.2.1.1. Normal Operating

Stresses resulting from the deadweight loading condition are evaluated against Subsection NC (Ref 2.1.3) allowables. Hence,

$P_m \leq S_m$ = 22.5 ksi

$P_L + P_b \leq 1.5\ S_m$ = 33.75 ksi

4.2.1.2. End Drop

In accordance with Appendix F (Reference 2.1.1), when elastic system analysis is used to determine loads on components, the stress acceptance criteria for general primary membrane (P_m), local primary membrane (P_L), and primary membrane plus bending stress intensity ($P_L + P_b$) is as follows:

$P_m \leq 0.7S_u$ [Ref 2.1.1, F-1331.1(a)]

$P_L \leq$ 150% of P_m Allowable [Ref 2.1.1, F-1331.1(b)]

$P_L + P_b \leq$ 150% of P_m Allowable [Ref 2.1.1, F-1331.1(c)(1)]

Hence,

Allowable Primary Membrane, P_m = 49.0 ksi

Allowable Local Primary Membrane plus bending, $P_L + P_b$ = 73.5 ksi

In accordance with Appendix F (Ref 2.1.1), when plastic system analysis is used to determine loads on components, certain stress acceptance criteria for general primary membrane (P_m), Maximum Primary stress intensity, and Primary Shear must be satisfied. Since Appendix F does not specify the nomenclature for plastic system analysis Maximum Primary stress intensity or Primary Shear, the following symbols will be used in this calculation.

Maximum Primary Stress Intensity: (P_{max})

Maximum Primary Shear: (P_{shear})

Code allowables for the above are as follows

P_m	$\leq 0.7\ S_u$	= 0.7 * 70	= 49.0 ksi	[Ref 2.1.1F-1341.2(a)]
P_{max}	$\leq 0.9\ S_u$	= 0.9 * 70	= 63.0 ksi	[Ref 2.1.1 F-1341.2(b)]
P_{shear}	$\leq 0.42\ S_u$	= 0.42 * 70	= 29.4 ksi	[Ref 2.1.1 F-1341.2(c)]

4.3. Calculation Assumptions

4.3.1. End Drops, Uniform Support

4.3.1.1. ANSYS results are scaled where appropriate to account for a decrease in the applied deceleration, and an increase in the MSB wall thickness. Membrane stress is assumed to be proportional to the applied load and inversely proportional to the wall thickness. Bending stress is assumed to be proportional to the applied load and inversely proportional to the wall thickness squared. These assumptions are consistent with classical hand stress analysis methods.

4.3.2. Dead Weight and End Drop, Ceramic Tile Support

4.3.2.1. For the purpose of this analysis the inner surface of the storage cask impacted by the MSB is considered to be infinitely rigid. Similarly, the ceramic tiles are considered to be infinitely rigid in providing support to the MSB. This simplification is considered to be conservative since both the concrete cask base and the media that the cask is postulated to drop onto contain finite stiffness. The predicted loads will therefore be higher than those experienced by the MSB in a real drop situation.

4.3.2.2. Due to symmetry of MSB geometry as well as loading, a one eighth segment accurately simulates the behavior of the MSB under vertical drop loading.

4.3.2.3. A temperature of 300°F is assumed in the calculation of material properties and allowables.

4.3.2.4. For the elasto-plastic end drop analysis only, the following additional assumption is made:

Calculation of the material hardenability modulus due to plastic analysis is based on the conservative assumption that necking of a test specimen occurs at 2/3 elongation. This allows for inclusion of "true stress" and "true strain" to the hardenability calculation.

5. CALCULATION METHODOLOGY

The basket is analyzed using a combination of finite element analysis and hand calculations. The analytical approach is discussed below.

6. CALCULATIONS

6.1. MSB Top Region Analysis

The finite element model used for this analysis is shown in Figure 6-1. The bottom nodes of the structural lid have been coupled with the top nodes of the shield lid in the vertical direction to model support provided by the shield lid. Node 306 of the shield lid has been coupled with Node 450 of the shield lid support ring.

The shield lid is modeled as a 9.5" thick solid plate. In reality, it is 7.5" of steel plate and 2" of RX-277 (Ref 3.1.6). The equivalent density calculated below has been used to correctly represent the weight of the shield lid.

$$\rho_{stl} := .284 \cdot \frac{lb}{in^3}$$ Density per Reference 3.1.6

$$\rho_{avg} := \frac{\rho_{stl} \cdot t_{stl} + \rho_{277} \cdot t_{277}}{t_{stl} + t_{277}}$$

$$\rho_{avg} = 0.237 \cdot \frac{lb}{in^3}$$

The ANSYS input/output from Reference 3.1.3 is in Attachment A. The maximum stress intensity in the MSB shell is 12.614 ksi at Node 431. The membrane stress at this section though the MSB wall is approximately the average of the stress intensities at Nodes 426 through 431.

$$\sigma_{m\_old} := \frac{(7.072 + 7.790 + 8.613 + 9.692 + 11.127 + 12.614) \cdot ksi}{6}$$

$$\sigma_{m\_old} = 9.48 \cdot ksi$$

The approximate bending stress at the section is

$$\sigma_{b\_old} := 12.614 \cdot ksi - \sigma_{m\_old}$$

$$\sigma_{b\_old} = 3.13 \cdot ksi$$

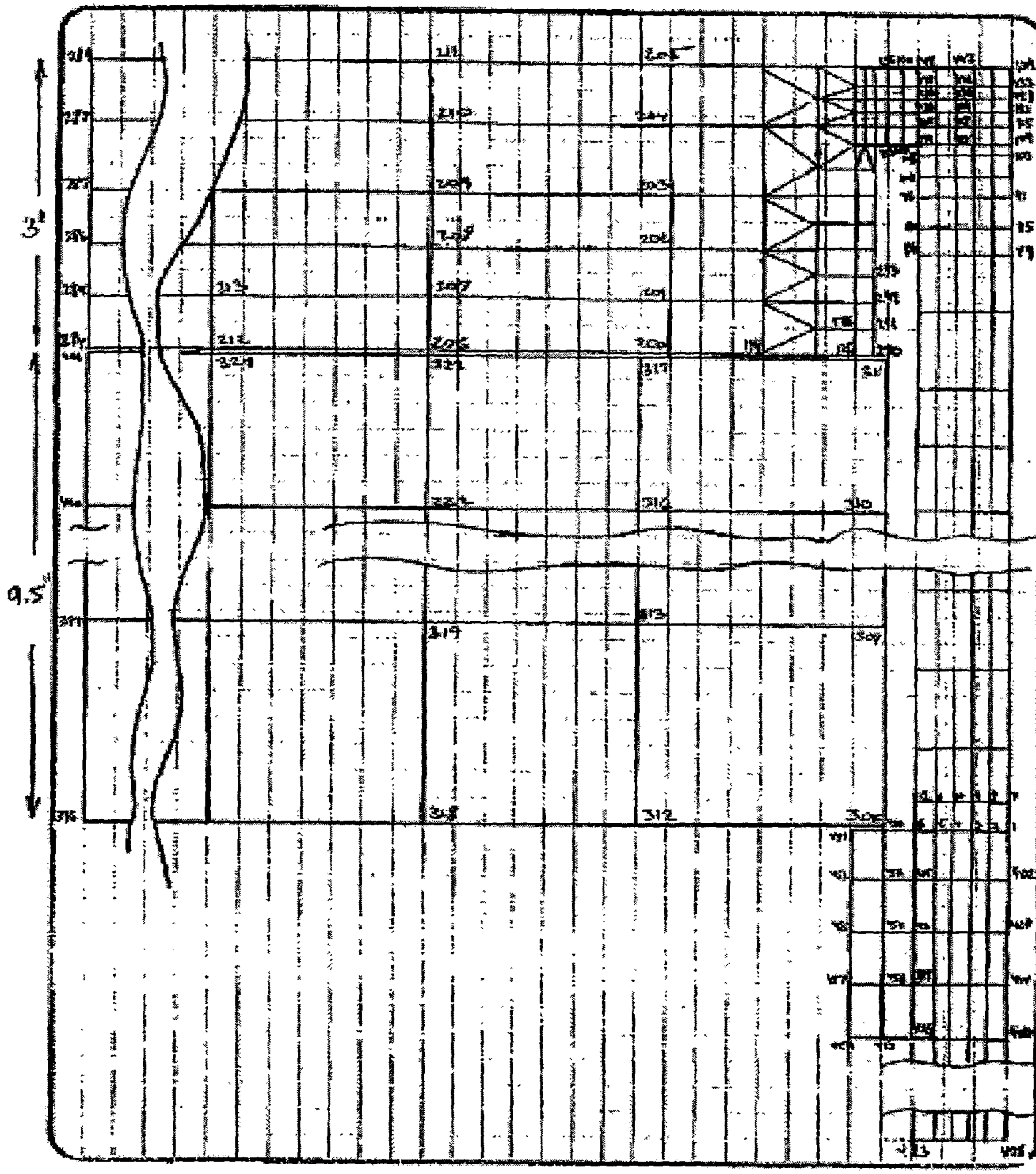


Figure 6-1 Finite Element Model for MSB Top

The revised membrane stress is calculated assuming that stress scales linearly with load and is inversely proportional to wall thickness. The MSB wall thickness for the Ref. 3.1.3 ANSYS analysis was

$$t_{msb\_old} := 0.75 \cdot in$$

The acceleration used for the analysis in Ref. 3.1.3 was

$$a_{v\_old} := 124 \cdot g$$

The deceleration from the 5' vertical drop is (Reference 3.1.2)

$$a_v := 120 \cdot g$$ Vertical acceleration, Five-foot Drop Analysis, Ref. 3.1.2

The revised membrane stress is

$$\sigma_{m\_shell1} := \sigma_{m\_old} \cdot \frac{a_v}{a_{v\_old}} \cdot \frac{t_{msb\_old}}{t_{msb}}$$

$$\sigma_{m\_shell1} = 6.9 \circ ksi$$

The revised bending stress is calculated assuming that stress scales linearly with load and is inversely proportional to the square of the wall thickness.

$$\sigma_{b\_shell1} := \sigma_{b\_old} \cdot \frac{a_v}{a_{v\_old}} \cdot \left(\frac{t_{msb\_old}}{t_{msb}}\right)^2$$

$$\sigma_{b\_shell1} = 1.7 \circ ksi$$

The maximum stress intensity in the structural lid is 5.1 ksi at Node 157 (note that this is a local stress intensity and not a true membrane or membrane plus bending stress; it is conservative, however, to use this as a membrane plus bending stress). Scaling the stress for the new deceleration gives

$$\sigma_{struct} := 5.1 \cdot ksi \cdot \frac{a_v}{a_{v\_old}}$$

$$\sigma_{struct} = 4.9 \circ ksi$$

The maximum stress in the structural lid weld is 9.4 ksi at Node 145. Scaling the stress for the new deceleration gives

$$\sigma_{struct\_weld} := 9.4 \cdot ksi \cdot \frac{a_v}{a_{v\_old}}$$

$$\sigma_{struct\_weld} = 9.1 \circ ksi$$

6.2. MSB Bottom Region Analysis, Uniform Support on Base

The shield lid load is;

$$F_{shield} := a_v \cdot m_{shield}$$

$$F_{shield} = 780 \circ kip$$

The structural lid load is;

$$F_{struct} := a_v \cdot m_{struct}$$

$$F_{struct} = 300 \circ kip$$

The finite element model of the bottom-to-shell junction is shown on Figure 6-2. Axisymmetric shell element STIF 51 has been used.

A uniform support condition is used for the MSB bottom plate. The MSB bottom plate is supported by ceramic tiles that are spaced intermittently, and thus the uniform support condition is approximate. Stress in the MSB bottom plate as it is supported by the ceramic tiles is evaluated in the following section.

Since all local effects die down away from the junction, only the lower 20" of the shell have been modeled. The load to represent the upper part of the MSB is:

$$L_{modeled} := 20 \cdot in$$

$$F_{top} := \frac{1}{2 \cdot \pi} \cdot \left[F_{shield} + F_{struct} + \frac{\pi}{4} \cdot \left(od_{msb}^{\ 2} - id_{msb}^{\ 2} \right) \cdot \left(L_{msb} - L_{modeled} \right) \cdot \rho_{stl} \cdot a_v \right]$$

$$F_{top} = 352.5 \circ \frac{kip}{rad}$$

The load applied in the ANSYS analysis of Reference 3.1.3 to represent the upper part of the MSB was:

$$F_{top\_old} := 355 \cdot \frac{kip}{rad}$$

The ANSYS input/output from Reference 3.1.3 is in Attachment B. The maximum stress intensity in the MSB shell is 17.0 ksi at Element 10. The membrane stress in the element is:

$$\sigma_{m\_old} := 12.89\ ksi$$

The approximate bending stress at the element is:

$$\sigma_{b\_old} := 17.03 \cdot ksi - \sigma_{m\_old}$$

$$\sigma_{b\_old} = 4.14 \circ ksi$$

The revised membrane stress is calculated assuming that stress scales linearly with load and is inversely proportional to wall thickness. The revised membrane stress is:

$$\sigma_{m\_shell2} := \sigma_{m\_old} \cdot \frac{F_{top}}{F_{top\_old}} \cdot \frac{t_{msb\_old}}{t_{msb}}$$

$$\sigma_{m\_shell2} = 9.6 \circ ksi$$

The revised bending stress is calculated assuming that stress scales linearly with load and is inversely proportional to the wall thickness squared. The revised bending stress is:

$$\sigma_{b\_shell2} := \sigma_{b\_old} \cdot \frac{F_{top}}{F_{top\_old}} \cdot \left(\frac{t_{msb\_old}}{t_{msb}}\right)^2$$

$$\sigma_{b\_shell2} = 2.3 \circ ksi$$

The maximum membrane and bending stresses in the shell from the top and bottom models are:

$$\sigma_{m\_shell} := \max\left(\left[\sigma_{m\_shell1} \quad \sigma_{m\_shell2}\right]\right)$$

$$\sigma_{m\_shell} = 9.6 \cdot ksi$$

$$\sigma_{b\_shell} := \max\left(\left[\sigma_{b\_shell1} \quad \sigma_{b\_shell2}\right]\right)$$

$$\sigma_{b\_shell} = 2.3 \cdot ksi$$

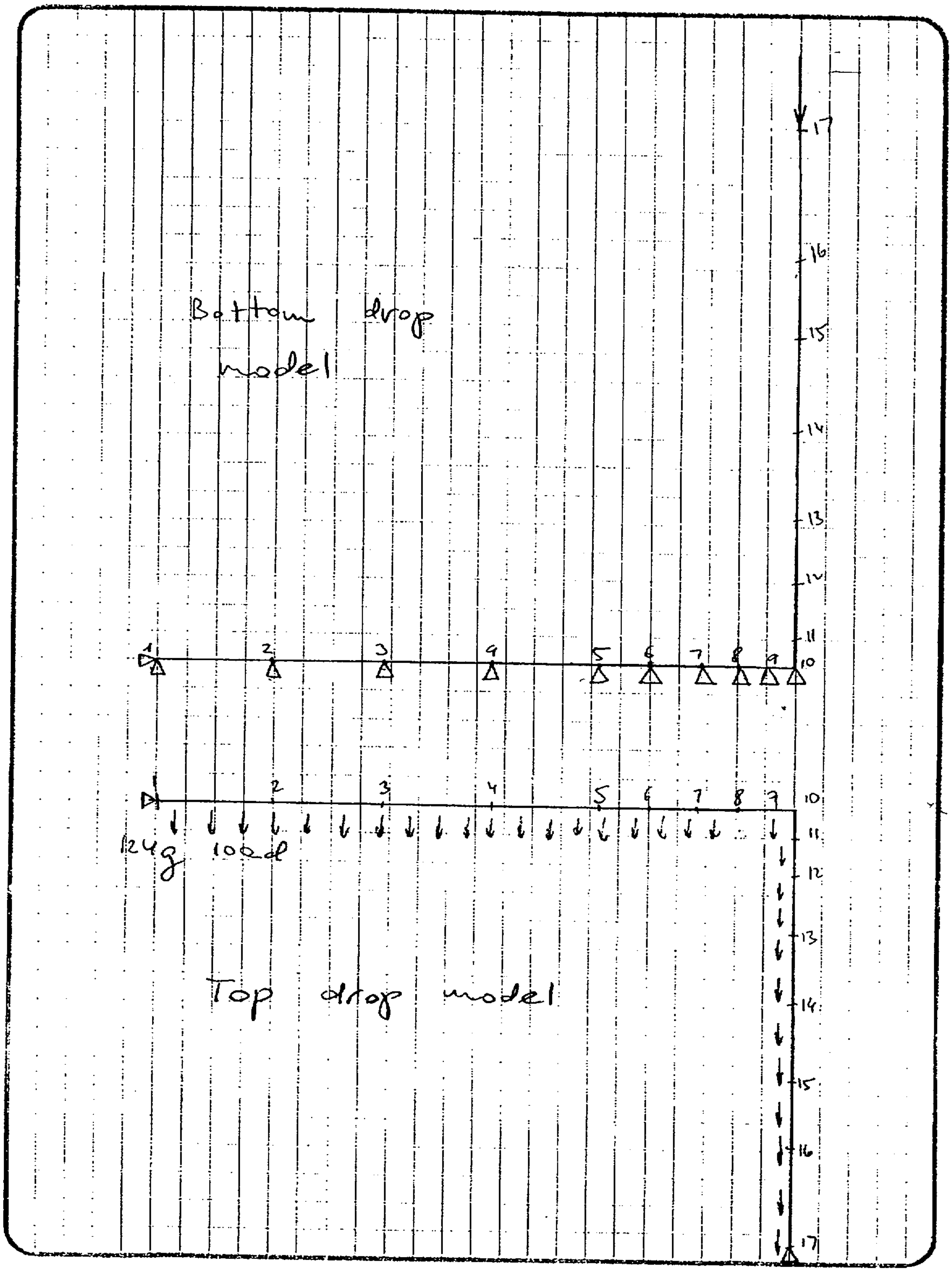


Figure 6-2 Finite Element Models for MSB Top and Bottom Drop.

(The Bottom Drop Model Covers the Uniform Support Condition)

6.3. MSB Bottom Plate Supported by Ceramic Tiles

A further support configuration is where the MSB is supported by ceramic tiles resting on the liner of the concrete cask. The purpose of the ceramic tiles is to prevent contact between the MSB base and the cask liner during normal storage conditions. In this configuration, 24 ceramic tiles are placed equi-spaced around the periphery of the MSB base. In addition to determining the stresses in the MSB base due to normal operating dead weight loading it is also necessary to demonstrate that stresses in the MSB base as a result of a five foot end drop will still be within ASME design code allowables. The normal operating condition and the end drop analyses were completed using similar finite element models and assumptions.

6.3.1. Finite Element Models

A one eighth segment of the MSB has been modeled using the ANSYS finite element computer modeling code. Due to the geometric symmetry of the MSB and the symmetry of loading, a one eighth segment with appropriate symmetry boundary conditions is preferred to a larger and computationally more intensive full model. For the end drop analysis, ANSYS plastic shell element SHELL143 was used to model the MSB. Large deformation effects were included in the analysis. For the 1g deadweight case, the plastic shell elements were replaced with elastic shell element SHELL63. In addition to the base plate, a section of the MSB wall has been included in the model, to ensure that any interaction effects between MSB base and shell wall are simulated. The length of shell wall included in both models is sufficient to ensure that the general pattern of stress is accurately modeled. This length needs to be sufficient to ensure that local effects at the shell to base interface dissipate. The ASME Code (Ref 2.1.3) uses the length $L = 2.5\sqrt{R*t}$ (R = Radius and t = wall thickness), as that within which local effects are present - beyond this length local effects are diminished. For conservatism, this length has been doubled. Hence, the vertical length of MSB shell modeled is;

$$L = 5.0\sqrt{R*t}$$

$$L = 5.0\sqrt{31.25*1.0}$$

$$L = 27.95 \text{ in.}$$

The actual modeled length was rounded up to 30 in. The stress contour plots confirm the acceptability of this modeled length of MSB shell.

The gap between the underside of the MSB base plate and the inner surface of the storage cask liner plate was modeled using the ANSYS 3D point to point contact element CONTAC52. Contact elements were modeled on all nodes of the MSB base, with the exception of those coincident with the ceramic tiles -these nodes were constrained vertically. All gaps were set initially open, with a physical gap size of 0.3 in – this representing the actual thickness of ceramic tile. The contact stiffness was set at an arbitrarily high value of 1E6 lb/in, in accordance with the ANSYS users manuals.

The finite element model is shown in Figure 6-3.

6.3.2. Boundary Conditions

The MSB is restrained from moving vertically at the location of the ceramic tiles. In addition, the contact elements are fixed at the surface simulating the cask boundary. Symmetric boundary conditions are imposed on the nodes positioned on "cut" edges of the MSB base and wall.

6.3.3. Applied Loading

The load due to the internal components within the MSB is modeled in the finite element analysis as a pressure load. The pressure load is calculated as follows;

Weight of the MSB (empty)	= 21,686 lb	[Ref 3.1.1]
Weight of the structural lid	= 2,409 lb	[Ref 3.1.1]
Weight of the shield lid	= 6,449 lb	[Ref 3.1.1]
Weight of the MSB and its contents	= 68,685 lb.	[Ref 3.1.1]
The analyses conservatively use	= 70,000 lb.	

Weight of contents $= 70{,}000 - (21{,}686 + 2{,}409 + 6{,}449) = 39{,}456$ lb
(assume a bounding weight of 40,209 lbs)

For Finite Element model using shell Centerlines,

Pressure load on base plate due to contents $$= \frac{40209}{\frac{\pi}{4}61.5^2} = 13.536 \text{ psi.}$$

Since only a portion of the MSB shell has been modeled, a force must be added to the top nodes of this section to account for weight missing in the model. For the F.E model based on a one eighth symmetrical section, the following calculations apply;

Weight of MSB modeled (30 inch vertical section) $$= \frac{1}{8}\left(\frac{\pi}{4}(62.5^2 - 60.5^2)30.0 \quad x \quad 0.284\right)$$
$$= 205.6 \text{ lb.}$$

Weight of MSB base plate modeled $\doteq 606 / 8 = 75.8$ lb.

Note: The weight from Ref 3.1.1 is 612 lbs, however the small difference in weight will not significantly affect calculation results.

Weight of contents modeled as pressure load $= 40{,}209 / 8 = 5026.1$ lbs.

Weight "missing" from F.E model = 70,000 / 8 – (205.6 + 75.8 + 5,026.1)

= 3,442.5 lbs.

This above "missing" weight is evenly applied to the model as forces on the top nodes of the MSB shell.

Finally, a body load of 1g is applied to the deadweight loading.

For the end drop analysis, the body load is increased to 120g. Note that the finite element analysis was for an acceleration of 108g. Hence stresses resulting from this model are factored by 120g/108g.

Reaction checks confirmed that the required weight was modeled. For the deadweight 1g acceleration, the required model vertical (F_Z) reaction would be expected to be,

Required F_Z Reaction = 70000 / 8 = 8750 lb.

While the 108g (as modeled) end drop vertical (F_Z) reaction would be expected to be,

Required F_Z Reaction = (70000 x 108) / 8 = 0.945 E6 lb.

The finite element model reactions were found to be 8725.8 and 0.94196 E6 lb, for the 1g deadweight and 108g end drop analyses respectively. In each case this accounts for 99.7 % of the required total. This close agreement gives confidence in the accuracy of the finite element model results.

6.3.4. Elastic-Plastic Stress Strain Curve – End Drop Analysis

Due to the high drop acceleration and consequent high stresses in the MSB, the elastic limits of stress will be exceeded in small local regions. Bending in the unsupported regions of the baseplate gives rise to high bending stresses and it is these that force the development of limited plasticity in certain regions. An elasto-plastic analysis has therefore been performed to demonstrate that such limited plasticity still falls within the allowables set by the ASME code for such conditions.

The following values were used in representing the non-linear stress-strain curve.

Young's Modulus	= 28.3E6 psi	[Ref 2.1.2]
Yield Stress	= 33.7E3 psi	[Ref 2.1.2]
Tensile Strength	= 70.0E3 psi	[Ref 2.1.2]
Elongation	= 21%	[Ref 2.1.2]

The Tangent modulus is calculated in accordance with the ANSYS theory manual. This takes into account the effect of true stress and true strain, with "necking" occurring at 2/3 elongation.

Strain at yield $$\varepsilon_{yield} = \frac{\sigma_{yield}}{E}$$

$$\varepsilon_{yield} = \frac{33.7E3}{28.3E6}$$

$$\varepsilon_{yield} = 0.00119 \text{ strain}$$

True Strain, $$\varepsilon = \ln(1 + \varepsilon_o)$$ [Ref 3.2.3]

Where ε_o is the engineering strain.

Using the assumption that necking occurs at 2/3 elongation, calculate the true strain.

$$\varepsilon = \ln(1 + \{2/3 * 0.21\})$$

$$\varepsilon = \ln(1.14)$$

$$\varepsilon = 0.131 \text{ strain}$$

True stress (Cauchy stress) is calculated by converting engineering stress, using the assumption that plastic flow occurs at constant volume.

Hence,

$$A_o L_o = AL$$ *Equation 6.3.4-1*

Where

A_o	Is the original cross sectional area.
L_o	Is the original length.
A	Is the deformed cross sectional area.
L	Is the deformed length.

Re-arranging the above formula,

$$A = \frac{A_o L_o}{L}$$ *Equation 6.3.4-2*

Also,

Engineering Strain = Change in length / Original length

i.e $$\varepsilon_o = \frac{L - L_o}{L_o}$$

or $$\frac{L}{L_o} = 1 + \varepsilon_o$$ *Equation 6.3.4-3*

Engineering Stress $\sigma = \frac{P}{A}$.

Substitute the value of A from Equation 6.3.4-2

$$\sigma = \frac{PL}{A_o L_o}$$

Finally, substituting equation 6.3.4-3 into the above, the relationship between engineering stress and true stress is obtained.

$$\sigma_T = \frac{P}{A_o}(1 + \varepsilon_o)$$

or

$$\sigma_T = \sigma_E(1 + \varepsilon_o)$$

Hence, True Max Tensile Strength σ_{max},

$$\sigma_{Max} = 70\text{ ksi} * 1.14 = 79.8\text{ ksi}$$

Tangent Modulus $$\sigma_T = \frac{\sigma_{Max} - \sigma_{Yield}}{\varepsilon - \varepsilon_{yield}}$$

$$\sigma_T = 355.1ksi$$

The resulting stress strain curve is shown in Figure 6-4.

ANSYS input for the dead weight analysis and the end drop analysis is contained in Attachments D and E respectively.

6.3.5. Results for 1g deadweight Analysis

6.3.5.1. Displaced Shape

It is a design requirement that the MSB base and the cask liner do not come into contact during the normal storage condition. To check the maximum displacement, 8.9 psig (pressure bounding the

maximum internal pressure under normal conditions from 3.1.5) was added to the pressure (13.536 psi) simulating the presence of the MSB internals. The displaced shape of the MSB model is shown in Figure 6-5. This figure arbitrarily amplifies the actual displacement, allowing the displaced shape to be more readily observed. The maximum displacement is 0.254 inches at the MSB base center. This figure is conservative due to the assumptions made in the MSB loading, and the calculation of the operating pressure. Since the tile thickness is 0.3 inches, it can be concluded that the MSB base and the cask liner will not come into contact under the normal operating condition.

6.3.5.2. Stress Intensity

Stress intensities have been derived from the finite element model. Figure 6-6, Figure 6-7, and Figure 6-8 plot the contours of stress intensity for the shell top, middle, and bottom locations of the MSB model. Values of each of the above stress intensities for the MSB base are recorded in Table 6-1. The presence of the ceramic tiles supporting the base of the MSB is a structural discontinuity and causes high stresses local to the tiles. These local stresses are discounted and hence are not listed in the above tables, although the maximum values are listed for completeness. This is in line with the ASME code definition of primary stress which discounts those stresses occurring at local discontinuities and concentrations. Code allowables are therefore compared with the appropriate primary stress, and not a local stress. The top ten values of stress intensity for the MSB shell is recorded separately in Table 6-2. Since the stresses at the location of the bottom plate weld were found to be lower than those derived for the base plate, the weld stresses have conservatively been taken to be the highest of those used to evaluate the base and the shell.

Table 6-6 compares calculated stresses with allowable stress in the form of Design Margins (DM). The design margins are calculated based on the formula;

$$DM = \left(\frac{Allowable \quad Stress}{Calculated \quad Stress} \right) - 1$$

6.3.6. Results for 120g Five Feet End Drop Analysis

As discussed above, the end drop calculation is a non-linear analysis so scaling to a higher acceleration is not always possible. However, as discussed below, the MSB base bottoms out on the VCC during loading so no additional displacement is possible. Also, in other regions the stresses are in linear portions of the stress-strain curve and during scaling the stresses do not cross a cusp in the curve. Therefore, it is considered valid and conservative to scale from the as-analyzed 108g case to the actual 120g applied case.

6.3.6.1. Displaced Shape

The displaced shape of the MSB model is shown in Figure 6-9. As with the normal loading displacement plot, this figure arbitrarily amplifies the actual displacement, allowing the displaced shape to be more readily observed. It is noticed that, as expected, the central portion of the MSB base "bottoms out" due to its contact with the cask. The vertical displacement of the MSB base is equal to the gap between base and cask liner. The base remains undisplaced in the region where support is provided by the ceramic tiles.

6.3.6.2. Stress Intensity

Stress intensities have been derived from the finite element model. Figure 6-10, Figure 6-11, and Figure 6-12 plot the contours of stress intensity for the shell top, middle, and bottom locations of the MSB model respectively. The top ten values of each of the above stress intensities for the MSB base is recorded in Table 6-3, while the top ten values of stress intensity for the MSB shell is recorded separately in Table 6-4. The stress in the base plate weld is taken as the highest of the base plate and shell stresses. Table 6-7 compares calculated stresses with allowable stress in the form of Design Margins (DM). The design margins are calculated as noted in section 6.3.5.2.

Section F1341.2(c) of (Ref 2.1.1), requires a comparison of calculated *pure* shear with a given allowable value. Strictly speaking, neither the MSB base plate nor the MSB shell experience pure shear, rather, they experience a *combination* of bending and shear loading. The value for maximum shear stress, P_{shear} is therefore compared with ASME code allowables for completeness. P_{shear} is calculated as half the maximum stress intensity i.e P_{max} / 2.

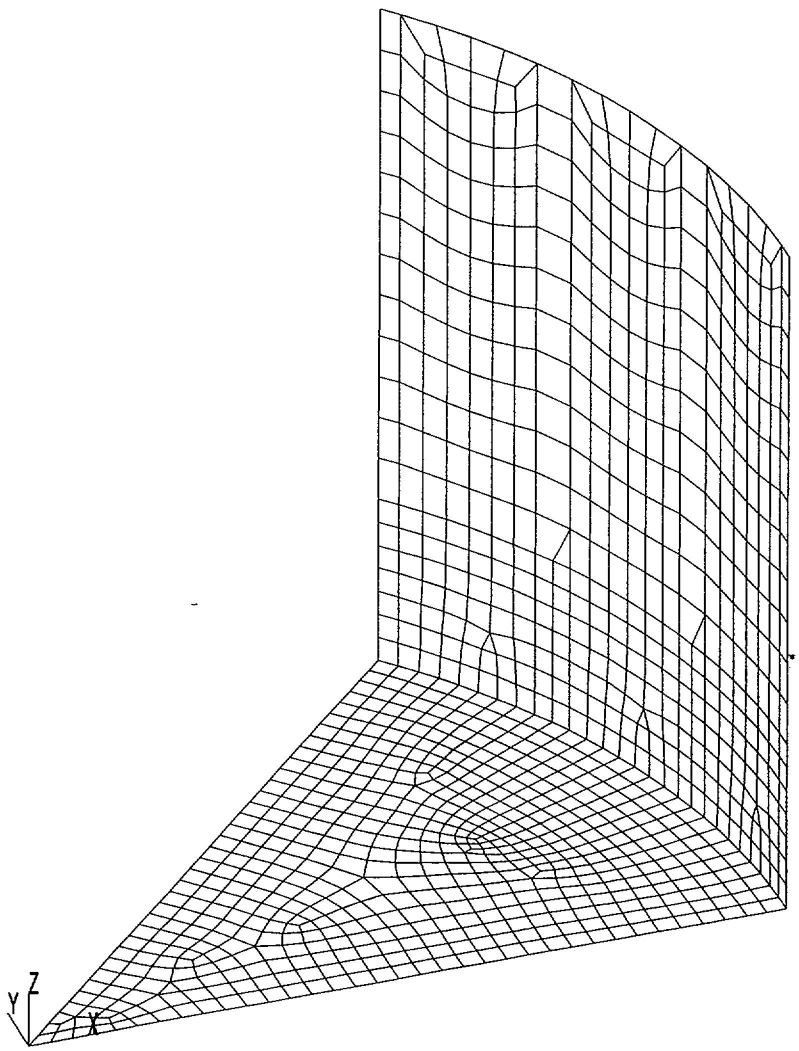


Figure 6-3 Plot of Finite Element Model.

(Gap elements removed for Clarity)

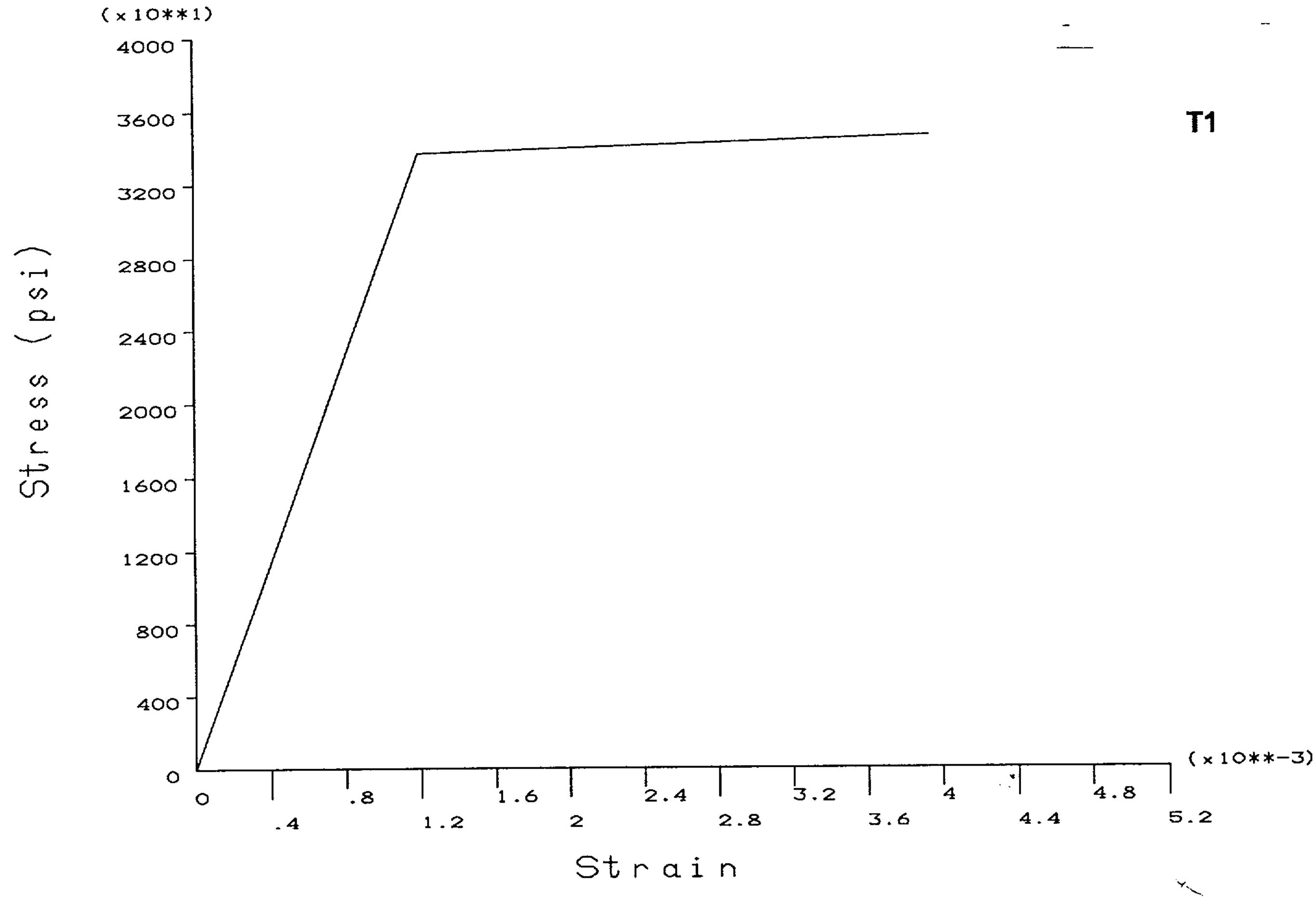


Figure 6-4 Elasto-Plastic Stress Strain Curve

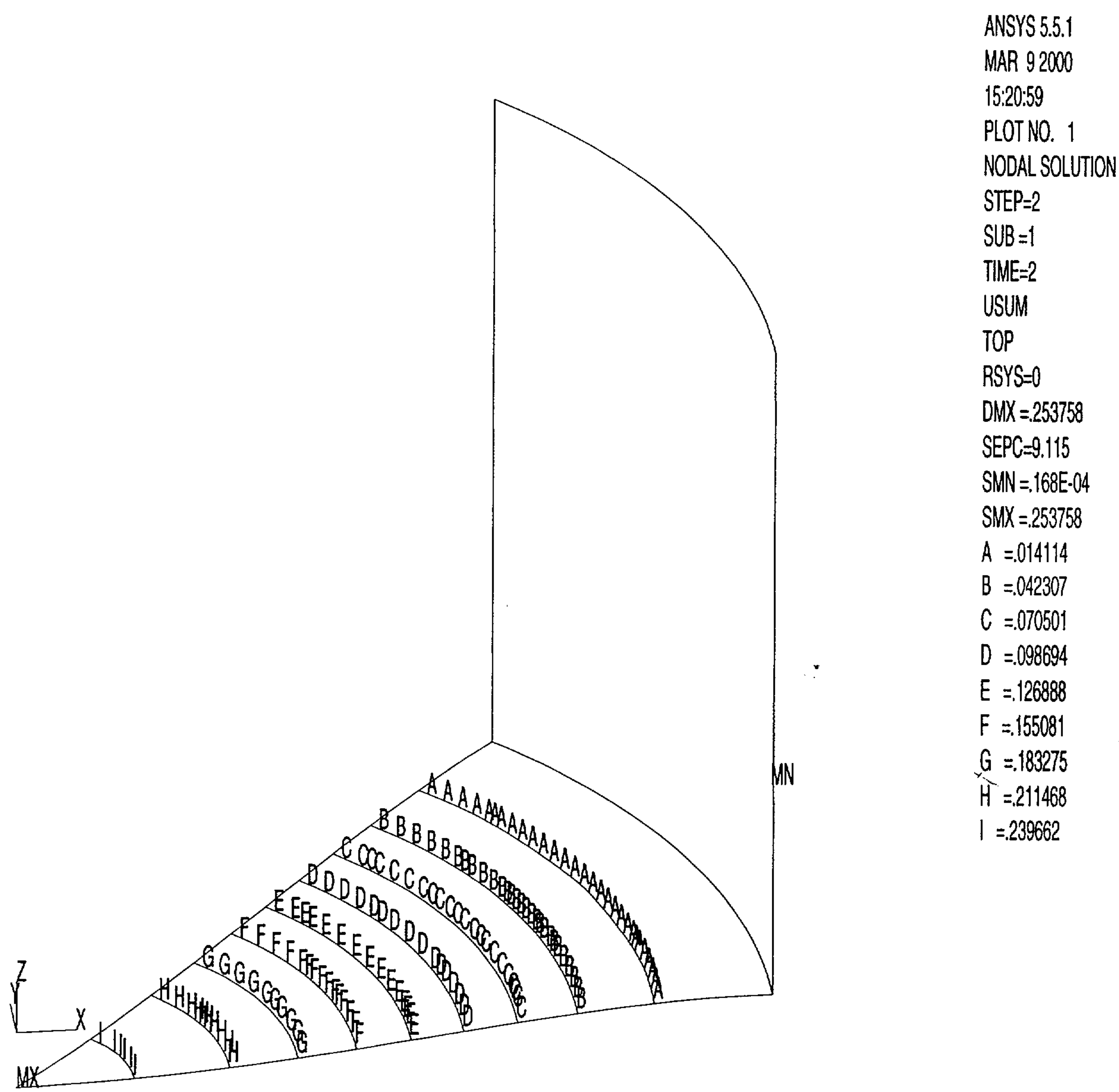


Figure 6-5 Plot of Displaced Shape of the MSB Under Dead Weight + Pressure Loading

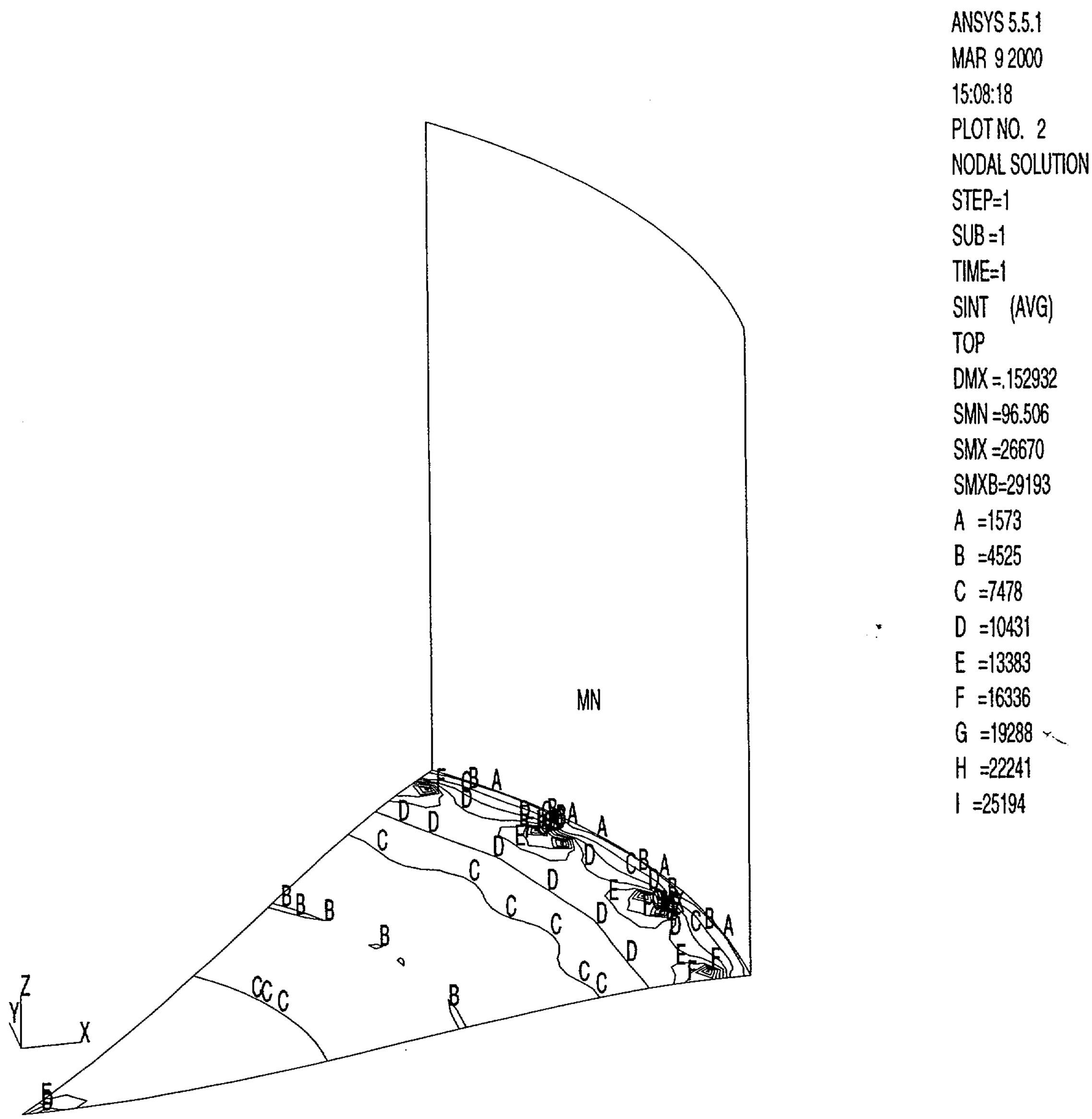


Figure 6-6 Contour Plot of Stress Intensity – Shell Top. Dead Weight Loading

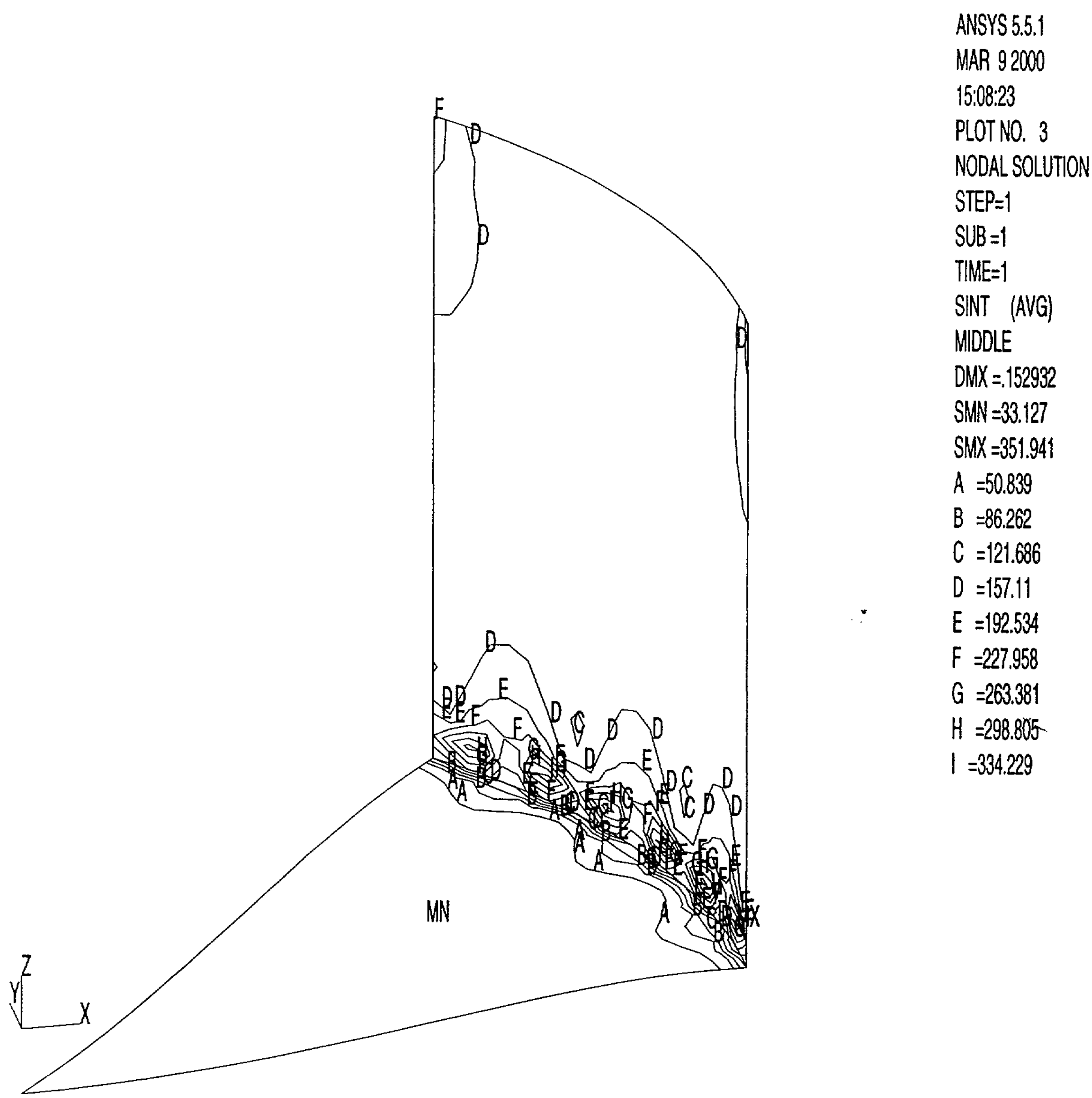


Figure 6-7 Contour Plot of Stress Intensity – Shell Middle. Dead Weight Loading

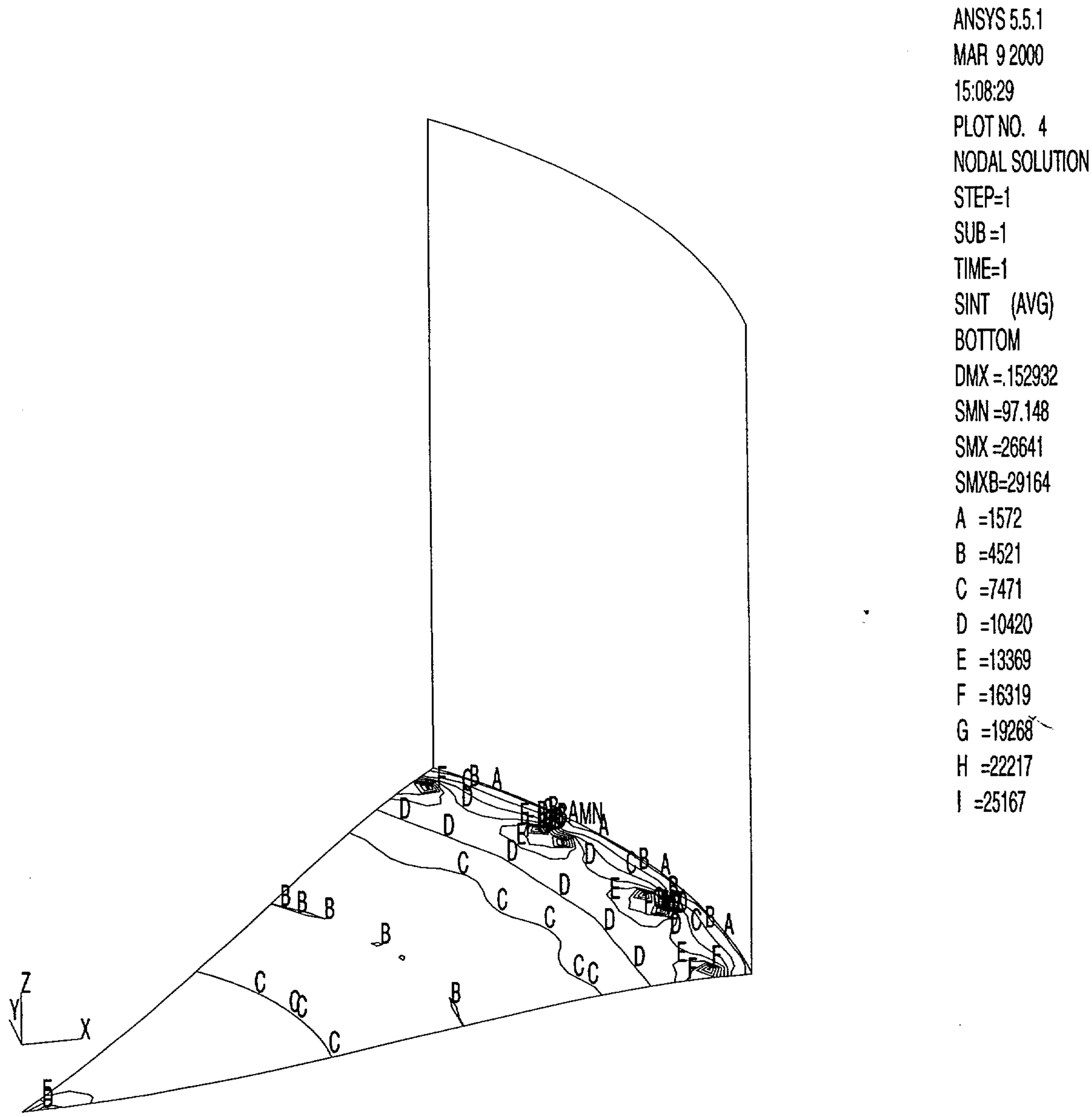


Figure 6-8 Contour Plot of Stress Intensity – Shell Bottom. Dead Weight Loading

Table 6-1 - MSB Base Plate - Stress Intensities at Top, Middle, and Bottom Locations – Dead Weight (1g)

Shell TOP

NODE	S1	S2	S3	SINT	SEQV
7	26656.	15345.	-13.536	26670.	23185.
16	26639.	15336.	-13.536	26653.	23171.
12	26633.	15329.	-13.536	26647.	23165.
.					
.					
.					
263	12153.	1157.9	-13.536	12167.	11625.
271	12138.	1110.8	-13.536	12152.	11630.
276	12120.	1054.4	-13.536	12134.	11636.
268	12098.	1025.1	-13.536	12112.	11627.
279	12048.	985.39	-13.536	12061.	11594.

Shell MIDDLE

NODE	S1	S2	S3	SINT	SEQV
623	9.5408	-0.12302E-01	-342.40	351.94	347.26
681	9.2592	-0.12634E-01	-342.16	351.42	346.88
739	9.2584	-0.12675E-01	-342.07	351.33	346.79
753	6.2894	-0.14272E-01	-340.87	347.16	344.06
695	6.0382	-0.14753E-01	-340.82	346.85	343.87
637	6.0309	-0.14857E-01	-340.80	346.83	343.85
757	0.54954E-02	-29.174	-329.42	329.43	315.85
699	0.54210E-02	-29.341	-329.37	329.37	315.72
641	0.56052E-02	-29.087	-329.26	329.26	315.72
638	0.44508E-02	-33.997	-327.81	327.82	312.21

Shell BOTTOM

NODE	S1	S2	S3	SINT	SEQV
7	0.0000	-15265.	-26641.	26641.	23154.
16	0.0000	-15257.	-26624.	26624.	23139.
12	0.0000	-15250.	-26618.	26618.	23134.
.					
.					
.					
263	0.0000	-1111.7	-12092.	12092.	11576.
271	0.0000	-1065.1	-12077.	12077.	11581.
276	0.0000	-1009.1	-12058.	12058.	11587.
268	0.0000	-980.02	-12036.	12036.	11577.
279	0.0000	-940.57	-11986.	11986.	11544.

Table 6-2 - MSB Shell - Stress Intensities at Top, Middle, and Bottom Locations – Dead Weight (1g)

Shell TOP

NODE	S1	S2	S3	SINT	SEQV
562	1164.7	236.89	0.55782E-01	1164.6	1066.1
574	1164.3	236.24	0.55689E-01	1164.3	1066.0
586	1163.8	236.08	0.55694E-01	1163.7	1065.5
575	1156.1	245.16	0.55858E-01	1156.1	1055.1
563	1155.9	245.01	0.55894E-01	1155.8	1054.9
587	1155.3	245.33	0.55872E-01	1155.2	1054.2
564	569.46	0.37271E-01	-157.04	726.49	662.08
588	569.68	0.37483E-01	-155.99	725.66	661.60
576	569.36	0.37424E-01	-156.12	725.48	661.37
585	563.61	0.32936E-01	-160.16	723.77	658.45

Shell MIDDLE

NODE	S1	S2	S3	SINT	SEQV
589	0.30434E-01	-58.410	-462.47	462.50	436.22
565	0.30230E-01	-58.618	-462.34	462.37	436.02
577	0.30225E-01	-58.600	-462.30	462.33	435.98
560	0.33952E-01	-56.340	-461.90	461.94	436.49
572	0.33695E-01	-56.539	-461.47	461.51	435.98
584	0.33745E-01	-56.496	-461.40	461.44	435.93
564	-0.27225E-01	-145.28	-370.02	369.99	322.88
576	-0.27252E-01	-145.37	-369.82	369.80	322.69
588	-0.27191E-01	-145.10	-369.61	369.59	322.53
585	-0.26725E-01	-146.94	-369.23	369.20	321.95

Shell BOTTOM

NODE	S1	S2	S3	SINT	SEQV
562	-0.77529E-01	-385.21	-1523.8	1523.7	1372.3
574	-0.77588E-01	-385.49	-1523.7	1523.6	1372.1
586	-0.77534E-01	-385.18	-1523.3	1523.2	1371.8
575	-0.76161E-01	-385.68	-1516.6	1516.5	1365.2
563	-0.76068E-01	-385.32	-1516.3	1516.3	1365.0
587	-0.76094E-01	-385.37	-1516.1	1516.0	1364.8
576	-0.44233E-01	-243.70	-1200.0	1199.9	1098.5
564	-0.44125E-01	-243.23	-1199.8	1199.8	1098.6
588	-0.44092E-01	-243.35	-1199.8	1199.8	1098.5
561	-0.51038E-01	-241.07	-1195.5	1195.5	1095.0

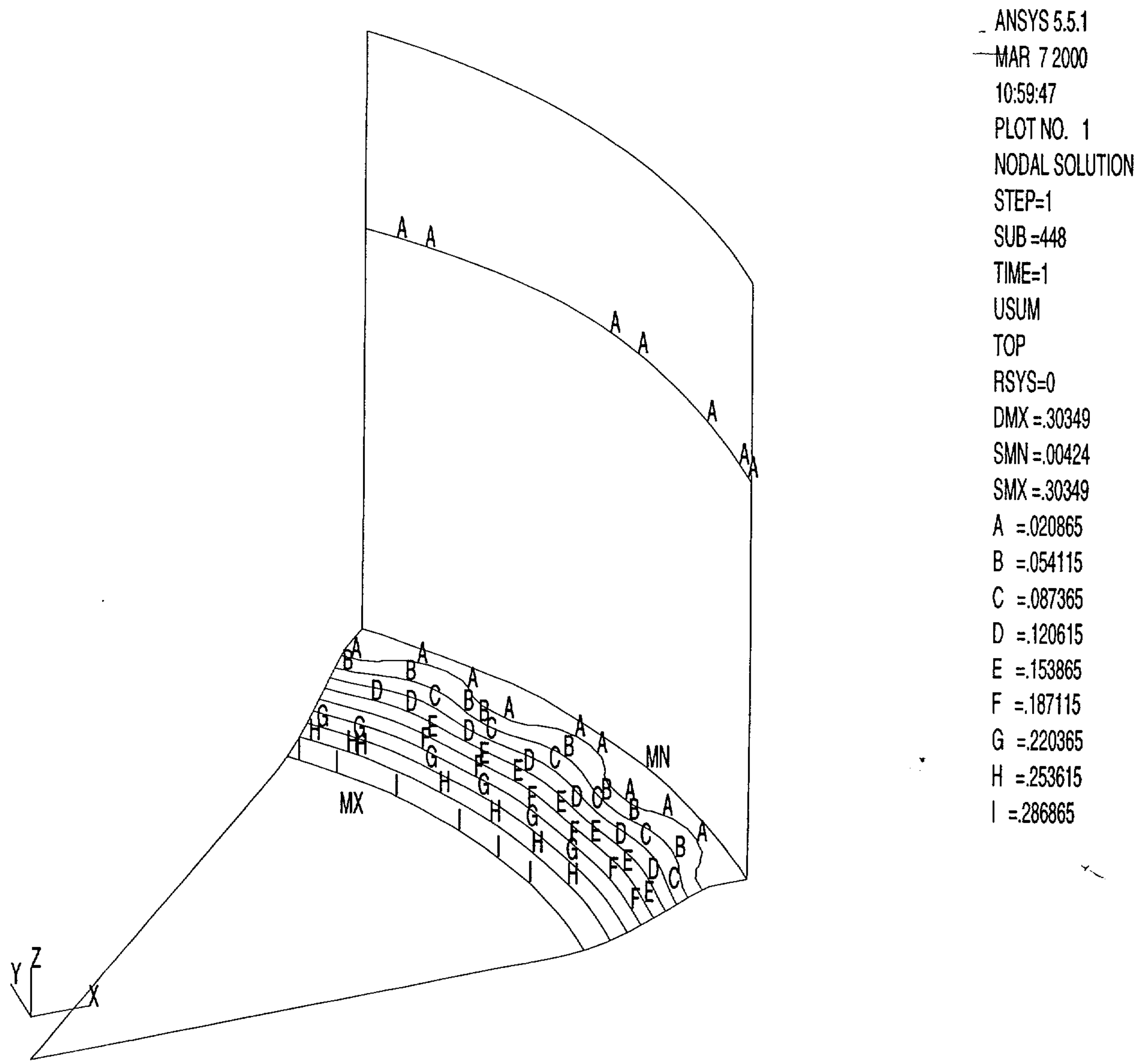


Figure 6-9 Plot of Displaced Shape of the MSB Under End Drop Loading

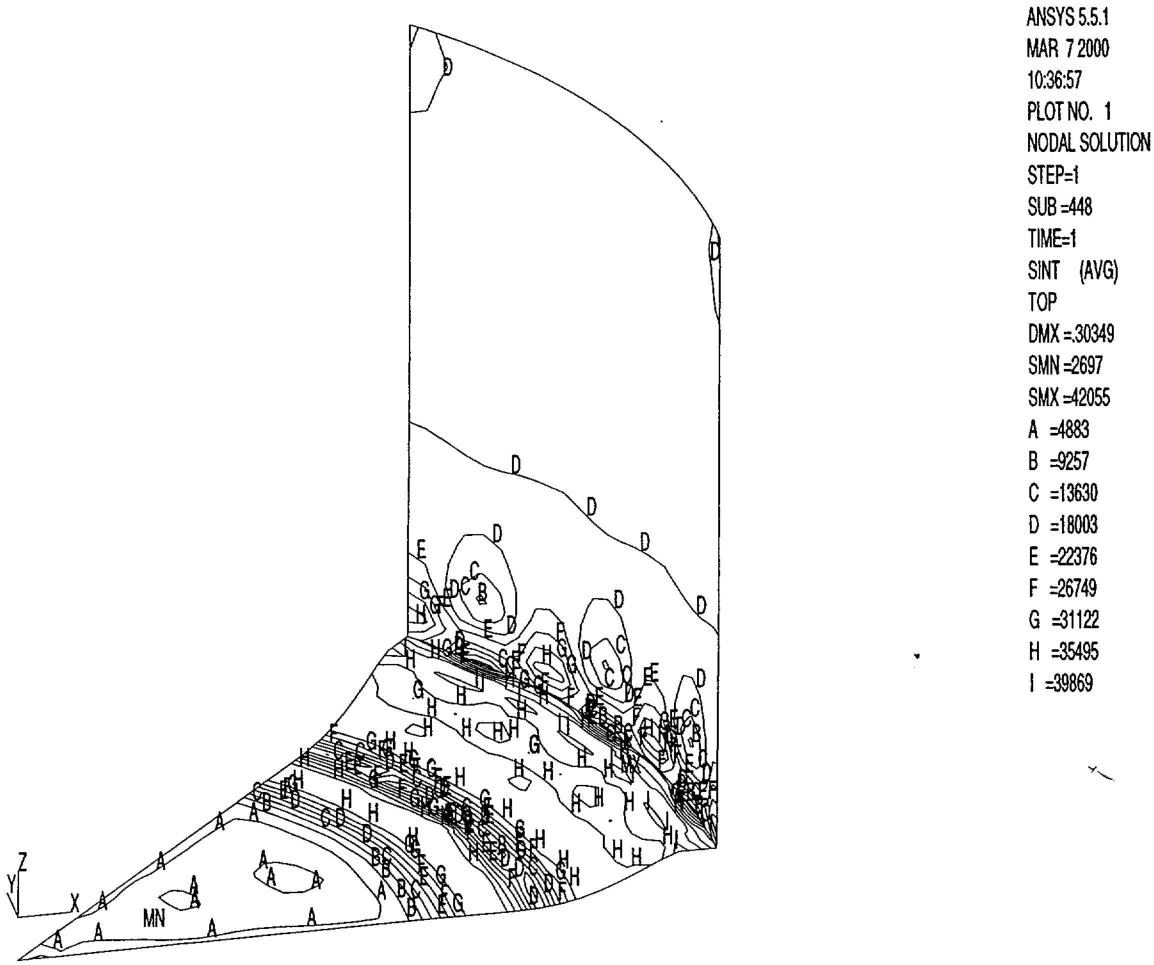


Figure 6-10 Contour Plot of Stress Intensity – Shell Top. End Drop Loading

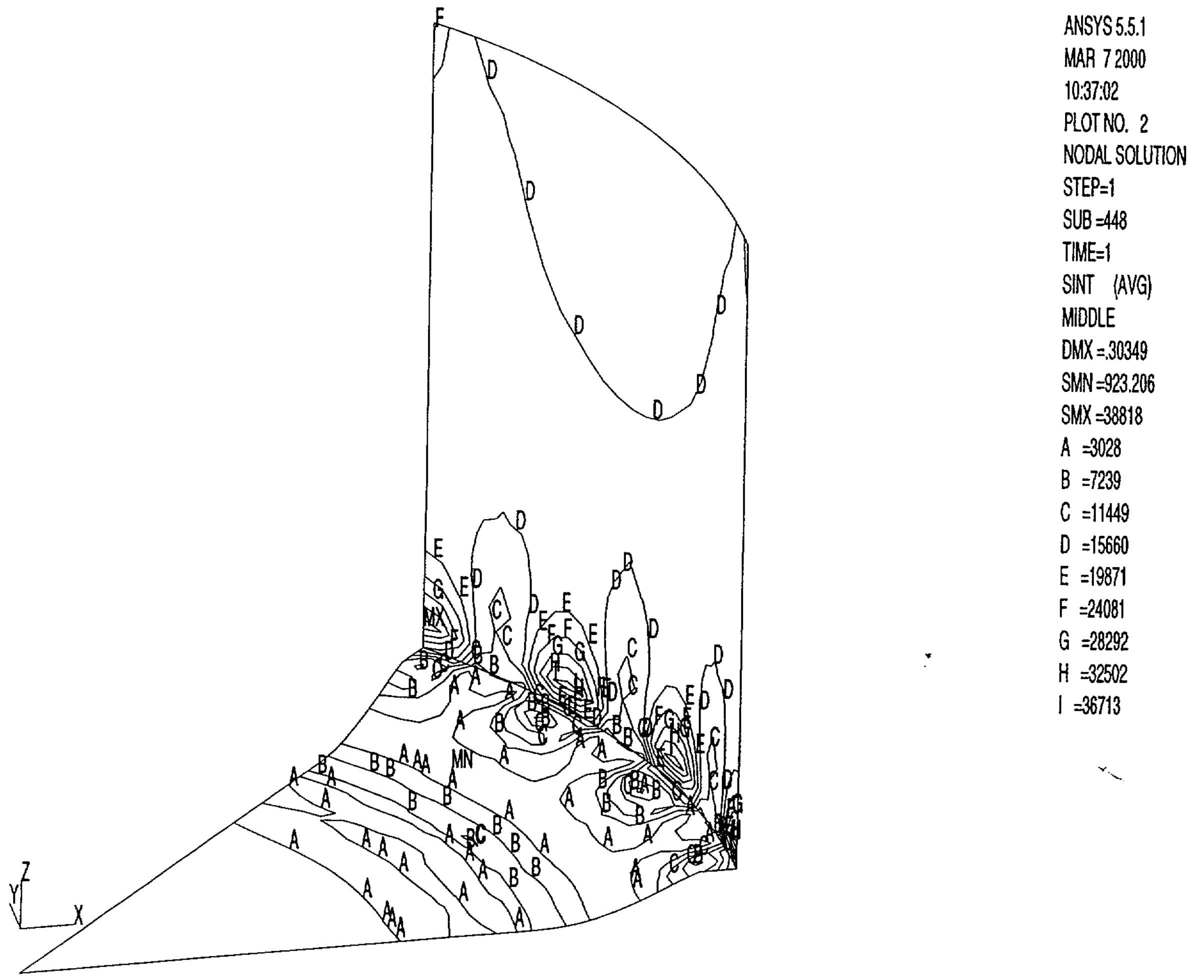


Figure 6-11 Contour Plot of Stress Intensity – Shell Middle. End Drop Loading

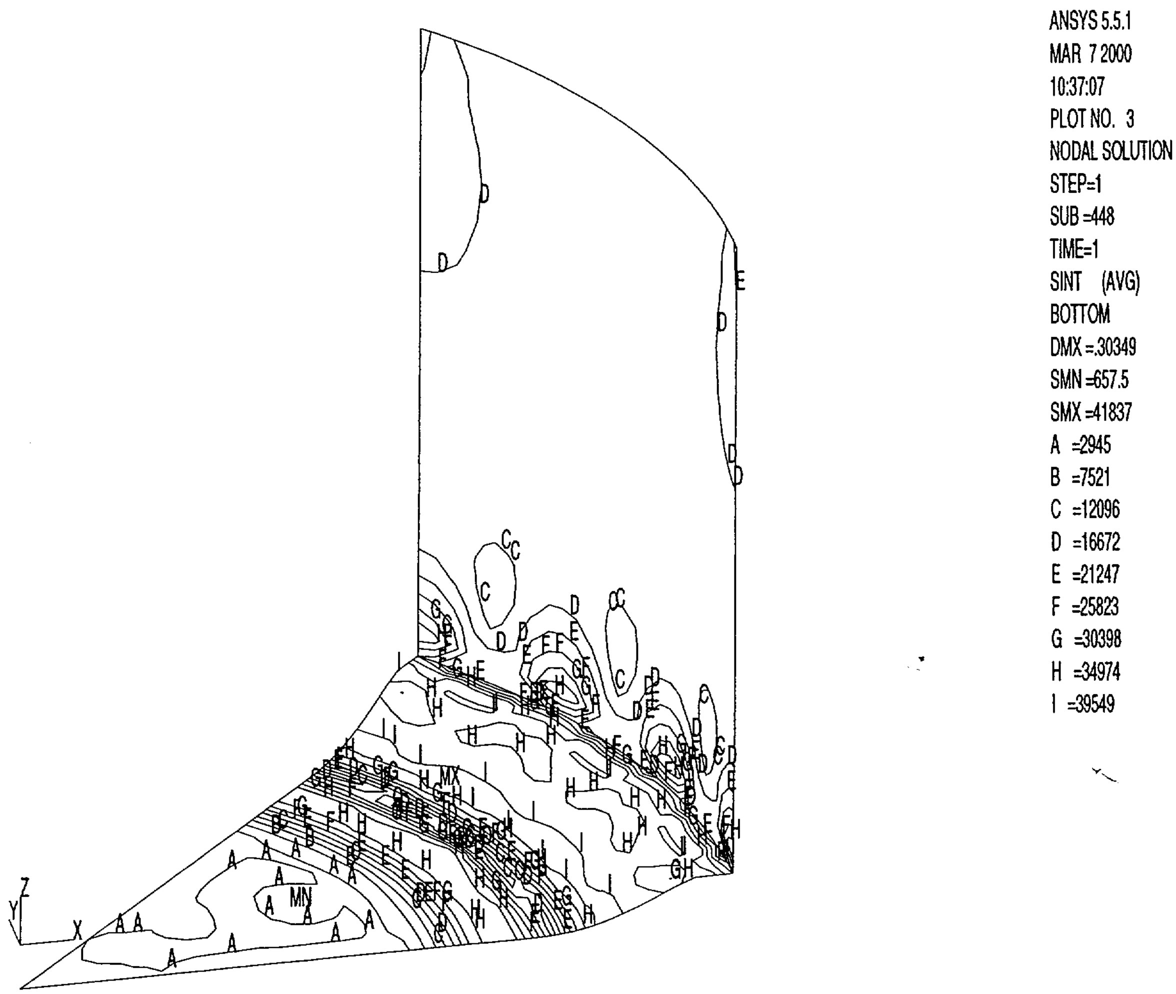


Figure 6-12 Contour Plot of Stress Intensity – Shell Bottom. End Drop Loading

Table 6-3 MSB Base Plate - Top Ten Stress Intensities at Top, Middle, and Bottom Locations– End Drop (108g)

Shell TOP

NODE	S1	S2	S3	SINT	SEQV
563	41855.	16858.	-1619.4	43475.	37791.
586	41856.	16863.	-1618.9	43474.	37790.
587	41845.	16824.	-1620.8	43466.	37786.
562	41841.	16833.	-1619.5	43460.	37780.
575	41838.	16867.	-1620.2	43458.	37775.
574	41837.	16876.	-1619.2	43456.	37772.
14	40591.	36625.	-1463.9	42055.	40219.
1	40011.	37054.	-2041.1	42052.	40655.
29	39990.	37079.	-2041.9	42031.	40654.
23	40544.	36644.	-1463.8	42008.	40200.

Shell MIDDLE

NODE	S1	S2	S3	SINT	SEQV
2	9083.0	650.83	-11666.	20749.	18074.
28	9096.4	682.40	-11648.	20744.	18072.
560	7916.9	194.78	-8681.7	16599.	14386.
577	7898.4	123.67	-8695.4	16594.	14380.
572	7913.3	200.06	-8673.9	16587.	14377.
589	7895.2	136.33	-8689.4	16585.	14373.
584	7903.1	197.37	-8670.0	16573.	14364.
565	7883.8	123.17	-8688.7	16573.	14362.
30	7545.2	907.84	-8426.3	15972.	13897.
3	7541.2	922.81	-8417.0	15958.	13887.

Shell BOTTOM

NODE	S1	S2	S3	SINT	SEQV
528	41833.	19719.	-3.8650	41837.	36251.
419	41405.	20005.	-2.5186	41407.	35866.
420	41377.	20363.	-8.3210	41385.	35842.
408	41368.	19483.	-0.32218	41369.	35846.
409	41357.	19413.	-1.0322	41358.	35839.
418	41349.	19711.	-0.57776	41350.	35823.
417	41296.	19575.	-0.64121E-01	41296.	35779.
521	41283.	21211.	-7.2713	41290.	35763.
410	41273.	19814.	-1.6575	41275.	35755.
520	41256.	21000.	-1.7699	41257.	35732.

Table 6-4 MSB Shell - Top Ten Stress Intensities at Top, Middle, and Bottom Locations – End Drop (108g)

Shell TOP

NODE	S1	S2	S3	SINT	SEQV
2	11.001	-20518.	-41294.	41305.	35771.
28	10.815	-20480.	-41279.	41290.	35758.
11	6.4605	-20505.	-41281.	41288.	35757.
20	6.4747	-20503.	-41280.	41286.	35755.
4	7.2946	-18366.	-40091.	40098.	34766.
10	7.6790	-18357.	-40076.	40084.	34754.
19	7.6391	-18350.	-40075.	40083.	34753.
8	7.5400	-18371.	-40059.	40066.	34738.
26	7.3142	-18362.	-40059.	40066.	34738.
17	7.6109	-18380.	-40058.	40066.	34737.

Shell MIDDLE

NODE	S1	S2	S3	SINT	SEQV
2	9.3288	-20944.	-41805.	41814.	36212.
11	4.7090	-20942.	-41801.	41806.	36205.
20	4.7226	-20940.	-41799.	41804.	36203.
28	9.1434	-20913.	-41792.	41801.	36200.
4	6.2332	-18509.	-40434.	40440.	35063.
10	6.5628	-18509.	-40429.	40435.	35059.
19	6.5180	-18510.	-40429.	40435.	35059.
8	6.4145	-18533.	-40414.	40421.	35045.
17	6.4942	-18529.	-40411.	40418.	35043.
26	6.2292	-18513.	-40406.	40412.	35038.

Shell BOTTOM

NODE	S1	S2	S3	SINT	SEQV
2	7.8136	-21368.	-42317.	42325.	36655.
11	3.1120	-21379.	-42320.	42324.	36654.
20	3.1249	-21377.	-42318.	42321.	36652.
28	7.6311	-21344.	-42306.	42313.	36645.
19	5.4559	-18665.	-40788.	40793.	35370.
10	5.5051	-18655.	-40787.	40792.	35370.
4	5.2261	-18647.	-40782.	40787.	35366.
8	5.3488	-18689.	-40775.	40780.	35357.
17	5.4363	-18674.	-40769.	40775.	35353.
26	5.2009	-18658.	-40758.	40763.	35343.

6.4. Ceramic Tile

This section calculates the bearing stress on the ceramic tile for normal operation. An evaluation of the ceramic tile for a vertical drop is not included because it is not important for the ceramic tile to remain intact for this accident.

$$\sigma_{bearing} = \frac{m_{MSB}}{A_{cer}}$$

Where A_{cer} is the total area of the ceramic tiles in contact with the MSB.

$$\sigma_{bearing} = \frac{70000}{24 \cdot 1.7^2} \quad = \quad 1.0 \text{ ksi}$$

The bearing stress on the tile is negligible.

6.5. MSB Drop Onto Shield Lid

Even though this analysis is not required for Part 72 license (upside down drop is not possible), the analysis has been performed for the future licensing under Part 71.

The same model was used as in Section 6.2, however, the loading was modified as shown on Figure 6-2. The ANSYS input/output from Reference 3.1.3 is in Attachment C. The maximum membrane stress in the bottom plate is 0.98 ksi at Element 1. The revised membrane stress is calculated assuming that stress scales linearly with load. The revised membrane stress is

$$\sigma_{m\_old} := 0.98 \cdot \text{ksi}$$

$$\sigma_{m\_down} := \sigma_{m\_old} \cdot \frac{a_v}{a_{v\_old}}$$

$$\sigma_{m\_down} = 0.9 \,\text{ksi}$$

The maximum stress intensity at Element 1 is 30.03 ksi. The approximate bending stress in the bottom plate at Element 1 is:

$$\sigma_{b\_old} := 30.03\ ksi - \sigma_{m\_old}$$

$$\sigma_{b\_old} = 29.1 \cdot ksi$$

The revised bending stress is calculated assuming that stress scales linearly with load. The revised bending stress is:

$$\sigma_{b\_down} := \sigma_{b\_old} \cdot \frac{a_v}{a_{v\_old}}$$

$$\sigma_{b\_down} = 28.1 \cdot ksi$$

The maximum membrane stress in the shell is 5.89 ksi at Element 12. The revised membrane stress is calculated assuming that stress scales linearly with load and is inversely proportional to MSB wall thickness. The revised membrane stress is:

$$\sigma_{m\_shell\_old} := 5.88 \cdot ksi$$

$$\sigma_{m\_shell\_down} := \sigma_{m\_shell\_old} \cdot \frac{a_v}{a_{v\_old}} \cdot \frac{t_{msb\_old}}{t_{msb}}$$

$$\sigma_{m\ shell\ down} = 4.3 \cdot ksi$$

The maximum stress intensity in the shell is 27.59 ksi at Element 10. The approximate bending stress in the shell at Element 10 is:

$$\sigma_{b\_shell\_old} := 27.59 \cdot ksi - 1.87\ ksi$$

$$\sigma_{b\_shell\_old} = 25.7 \cdot ksi$$

The revised bending stress is calculated assuming that stress scales linearly with load and is inversely proportional to MSB wall thickness squared. The revised bending stress is:

$$\sigma_{b\_shell\_down} := \sigma_{b\_shell\_old} \cdot \frac{a_{v}}{a_{v\_old}} \cdot \left(\frac{t_{msb\_old}}{t_{msb}} \right)^{2}$$

$$\sigma_{b\_shell\_down} = 14.0 \cdot ksi$$

The membrane stress in the shell at Element 10 is 1.87 ksi. The revised membrane stress in the shell at this element is:

$$\sigma_{m\_shell\_rev} := (1.87\ ksi) \cdot \frac{a_{v}}{a_{v\_old}} \cdot \frac{t_{msb\_old}}{t_{msb}}$$

$$\sigma_{m\_shell\_rev} = 1.4 \cdot ksi$$

6.6. Summary of Stress Results, Allowables, and Design Margins

Table 6-5 MSB With Uniform Support to Base, End Drop Loading. Summary of Stresses, Allowables, and Design Margins.

COMPONENT	PRIMARY MEMBRANE (ksi)			PRIMARY MEMBRANE + BENDING (ksi)		
	P_m	Allowable P_m	D.M.	$P_L + P_b$	Allowable $P_L + P_b$	D.M.
Shell [(1)]	9.6	49.0	4.1	14.0 + 1.4 = 15.4	73.5	3.8
Structural Lid	N.A	N.A	N.A	4.9	73.5	14.0
Structural Lid Weld	N.A	N.A	N.A	9.1	73.5	7.1
Bottom Plate[(1)]	0.9	49.0	53.4	0.9 + 28.1 = 29.0	73.5	1.53

Note: [1] Values tabulated are worst case for load cases considered.
The stresses summarized above are also used in combination with other load cases in a separate calculation.

Table 6-6 MSB Supported on Ceramic Tiles With Deadwt loading (1g). Summary of Stresses, Allowables, and Design Margins.

MSB SHELL (ksi)					
Primary Membrane Stress Intensity (P_m)			Primary Membrane Plus Bending Stress Intensity (P_L+P_b)		
P_m	Allowable P_m	D.M.	P_L+P_b	Allowable P_L+P_b	D.M.
0.5	22.5	Large	1.5	33.75	Large

MSB BASE (ksi)					
Primary Membrane Stress Intensity (P_m)			Primary Membrane Plus Bending Stress Intensity (P_L+P_b)		
P_m	Allowable P_m	D.M.	P_L+P_b	Allowable P_L+P_b	D.M.
0.35	22.5	Large	12.2	33.75	1.77

Note: The stresses summarized above are also used in combination with other load cases in a separate calculation.
The bottom weld stress for both P_m and P_L + P_b is conservatively taken as the worst of both the shell and base stresses.

Table 6-7 MSB Supported on Ceramic Tiles. End Drop Loading (120g). Summary of Stresses (scaled from ANSYS), Allowables, and Design Margins.

MSB SHELL (ksi)								
Primary Membrane Stress Intensity (P_m)			Maximum Primary Stress Intensity (P_{max})			Maximum Primary Shear (P_{shear})		
P_m	Allowable P_m	D.M.	P_{max}	Allowable P_{max}	D.M.	P_{shear}	Allowable P_{shear}	D.M.
46.5	49.0	0.054	47.0	63.0	0.34	23.5	29.4	0.25
MSB BASE (ksi)								
Primary Membrane Stress Intensity (P_m)			Maximum Primary Stress Intensity (P_{max})			Maximum Primary Shear (P_{shear})		
P_m	Allowable P_m	D.M.	P_{max}	Allowable P_{max}	D.M.	P_{shear}	Allowable P_{shear}	D.M.
23.1	49.0	1.12	48.3	63.0	0.30	24.2	29.4	0.21

Note: The stresses summarized above are also used in combination with other load cases in a separate calculation.
The bottom weld stress for both P_m and $P_L + P_b$ is conservatively taken as the worst of both the shell and base stresses.

7. CONCLUSION

The MSB components have been assessed for end drop loading for the uniform support condition. In this support configuration, the calculated stresses are within ASME code service level D allowables.

In addition, MSB components have been assessed for the both the dead weight and end drop conditions, while supported on a ring of ceramic tiles around the periphery of the MSB base. For the end drop condition, some local yielding occurs in regions where the ceramic tiles provide support to the MSB. The analysis has demonstrated that the calculated stresses are within ASME code allowables for acceptance criteria using plastic system analysis. Stresses due to deadweight analysis have also been shown to be acceptable.

It can be seen from the results that, as expected, the support condition of the MSB supported on the ceramic tiles has the smaller design margins, and therefore governs.

8. ELECTRONIC FILES

Filename	File Date	Code	CT	Version	Platform	Machine
Vscnorm.inp	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm.out	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm.db	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm.rst	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm-pp.inp	3/29/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm-pp.out	3/29/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm+press.inp	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm+press.out	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm+press.db	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscnorm+press.rst	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscedge.inp	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscedge.out	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscedge.db	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscedge.rst	3/6/00	ANSYS	2	5.5	NT	8834BW323307
Vscedge-pp.inp	3/27/00	ANSYS	2	5.5	NT	8834BW323307
Vscedge-pp.out	3/27/00	ANSYS	2	5.5	NT	8834BW323307

File Description

Vscnorm.inp	ANSYS input data file. Deadweight (1g).
Vscnorm.out	ANSYS output data file. Deadweight (1g).
Vscnorm.db	ANSYS database file. Deadweight (1g).
Vscnorm.rst	ANSYS results file. Deadweight (1g).

Vscnorm-pp.inp	ANSYS post processing input file. Deadweight (1g).
Vscnorm-pp.out	ANSYS post processing output file. Deadweight (1g).
Vscnorm+press.inp	ANSYS input data file. Deadweight (1g) + pressure (8.9 psig).
Vscnorm+press.out	ANSYS output data file. Deadweight (1g) + pressure (8.9 psig).
Vscnorm+press.db	ANSYS database file. Deadweight (1g) + pressure (8.9 psig).
Vscnorm+press.rst	ANSYS results file. Deadweight (1g) + pressure (8.9 psig).
Vscedge.inp	ANSYS input data file. End Drop (108g).
Vscedge.out	ANSYS output data file. End Drop (108g).
Vscedge.db	ANSYS database file. End Drop (108g).
Vscedge.rst	ANSYS results file. End Drop (108g).
Vscedge-pp.inp	ANSYS post processing input file. End Drop (108g).
Vscedge-pp.out	ANSYS post processing output file. End Drop (108g).

ATTACHMENT A

FINITE ELEMENT ANALYSIS INPUT AND OUTPUT

MSB TOP REGION

Bottom drop. lop

ATTACHMENT 1

LIST ALL SELECTED NODE DSYS= 0

NODE	X	Y	Z	THXY	THYZ	THXZ
1	31.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
2	30.850	0.00000E+00	0.00000E+00	0.00	0.00	0.00
3	30.700	0.00000E+00	0.00000E+00	0.00	0.00	0.00
4	30.550	0.00000E+00	0.00000E+00	0.00	0.00	0.00
5	30.400	0.00000E+00	0.00000E+00	0.00	0.00	0.00
6	30.250	0.00000E+00	0.00000E+00	0.00	0.00	0.00
7	31.000	0.75000	0.00000E+00	0.00	0.00	0.00
8	30.850	0.75000	0.00000E+00	0.00	0.00	0.00
9	30.700	0.75000	0.00000E+00	0.00	0.00	0.00
10	30.550	0.75000	0.00000E+00	0.00	0.00	0.00
11	30.400	0.75000	0.00000E+00	0.00	0.00	0.00
12	30.250	0.75000	0.00000E+00	0.00	0.00	0.00
13	31.000	1.5000	0.00000E+00	0.00	0.00	0.00
14	30.850	1.5000	0.00000E+00	0.00	0.00	0.00
15	30.700	1.5000	0.00000E+00	0.00	0.00	0.00
16	30.550	1.5000	0.00000E+00	0.00	0.00	0.00
17	30.400	1.5000	0.00000E+00	0.00	0.00	0.00
18	30.250	1.5000	0.00000E+00	0.00	0.00	0.00
19	31.000	2.2500	0.00000E+00	0.00	0.00	0.00
20	30.850	2.2500	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
21	30.700	2.2500	0.00000E+00	0.00	0.00	0.00
22	30.550	2.2500	0.00000E+00	0.00	0.00	0.00
23	30.400	2.2500	0.00000E+00	0.00	0.00	0.00
24	30.250	2.2500	0.00000E+00	0.00	0.00	0.00
25	31.000	3.0000	0.00000E+00	0.00	0.00	0.00
26	30.850	3.0000	0.00000E+00	0.00	0.00	0.00
27	30.700	3.0000	0.00000E+00	0.00	0.00	0.00
28	30.550	3.0000	0.00000E+00	0.00	0.00	0.00
29	30.400	3.0000	0.00000E+00	0.00	0.00	0.00
30	30.250	3.0000	0.00000E+00	0.00	0.00	0.00
31	31.000	3.7500	0.00000E+00	0.00	0.00	0.00
32	30.850	3.7500	0.00000E+00	0.00	0.00	0.00
33	30.700	3.7500	0.00000E+00	0.00	0.00	0.00
34	30.550	3.7500	0.00000E+00	0.00	0.00	0.00
35	30.400	3.7500	0.00000E+00	0.00	0.00	0.00
36	30.250	3.7500	0.00000E+00	0.00	0.00	0.00
37	31.000	4.5000	0.00000E+00	0.00	0.00	0.00
38	30.850	4.5000	0.00000E+00	0.00	0.00	0.00
39	30.700	4.5000	0.00000E+00	0.00	0.00	0.00
40	30.550	4.5000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
41	30.400	4.5000	0.00000E+00	0.00	0.00	0.00
42	30.250	4.5000	0.00000E+00	0.00	0.00	0.00
43	31.000	5.2500	0.00000E+00	0.00	0.00	0.00
44	30.850	5.2500	0.00000E+00	0.00	0.00	0.00
45	30.700	5.2500	0.00000E+00	0.00	0.00	0.00
46	30.550	5.2500	0.00000E+00	0.00	0.00	0.00
47	30.400	5.2500	0.00000E+00	0.00	0.00	0.00
48	30.250	5.2500	0.00000E+00	0.00	0.00	0.00
49	31.000	6.0000	0.00000E+00	0.00	0.00	0.00
50	30.850	6.0000	0.00000E+00	0.00	0.00	0.00
51	30.700	6.0000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
52	30.550	6.0000	0.00000E+00	0.00	0.00	0.00
53	30.400	6.0000	0.00000E+00	0.00	0.00	0.00
54	30.250	6.0000	0.00000E+00	0.00	0.00	0.00
55	31.000	6.7500	0.00000E+00	0.00	0.00	0.00
56	30.850	6.7500	0.00000E+00	0.00	0.00	0.00
57	30.700	6.7500	0.00000E+00	0.00	0.00	0.00
58	30.550	6.7500	0.00000E+00	0.00	0.00	0.00
59	30.400	6.7500	0.00000E+00	0.00	0.00	0.00
60	30.250	6.7500	0.00000E+00	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
61	31.000	7.5000	0.00000E+00	0.00	0.00	0.00
62	30.850	7.5000	0.00000E+00	0.00	0.00	0.00
63	30.700	7.5000	0.00000E+00	0.00	0.00	0.00
64	30.550	7.5000	0.00000E+00	0.00	0.00	0.00
65	30.400	7.5000	0.00000E+00	0.00	0.00	0.00
66	30.250	7.5000	0.00000E+00	0.00	0.00	0.00
67	31.000	8.2500	0.00000E+00	0.00	0.00	0.00
68	30.850	8.2500	0.00000E+00	0.00	0.00	0.00
69	30.700	8.2500	0.00000E+00	0.00	0.00	0.00
70	30.550	8.2500	0.00000E+00	0.00	0.00	0.00
71	30.400	8.2500	0.00000E+00	0.00	0.00	0.00
72	30.250	8.2500	0.00000E+00	0.00	0.00	0.00
73	31.000	9.0000	0.00000E+00	0.00	0.00	0.00
74	30.850	9.0000	0.00000E+00	0.00	0.00	0.00
75	30.700	9.0000	0.00000E+00	0.00	0.00	0.00
76	30.550	9.0000	0.00000E+00	0.00	0.00	0.00
77	30.400	9.0000	0.00000E+00	0.00	0.00	0.00
78	30.250	9.0000	0.00000E+00	0.00	0.00	0.00
79	31.000	9.7500	0.00000E+00	0.00	0.00	0.00
80	30.850	9.7500	0.00000E+00	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
81	30.700	9.7500	0.00000E+00	0.00	0.00	0.00
82	30.550	9.7500	0.00000E+00	0.00	0.00	0.00
83	30.400	9.7500	0.00000E+00	0.00	0.00	0.00
84	30.250	9.7500	0.00000E+00	0.00	0.00	0.00
85	31.000	10.500	0.00000E+00	0.00	0.00	0.00
86	30.850	10.500	0.00000E+00	0.00	0.00	0.00
87	30.700	10.500	0.00000E+00	0.00	0.00	0.00
88	30.550	10.500	0.00000E+00	0.00	0.00	0.00
89	30.400	10.500	0.00000E+00	0.00	0.00	0.00
90	30.250	10.500	0.00000E+00	0.00	0.00	0.00
91	31.000	11.000	0.00000E+00	0.00	0.00	0.00
92	30.850	11.000	0.00000E+00	0.00	0.00	0.00
93	30.700	11.000	0.00000E+00	0.00	0.00	0.00
94	30.550	11.000	0.00000E+00	0.00	0.00	0.00
95	30.400	11.000	0.00000E+00	0.00	0.00	0.00
96	30.250	11.000	0.00000E+00	0.00	0.00	0.00
97	31.000	11.500	0.00000E+00	0.00	0.00	0.00
98	30.850	11.500	0.00000E+00	0.00	0.00	0.00
99	30.700	11.500	0.00000E+00	0.00	0.00	0.00
100	30.550	11.500	0.00000E+00	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
101	30.400	11.500	0.00000E+00	0.00	0.00	0.00
102	30.250	11.500	0.00000E+00	0.00	0.00	0.00
103	31.000	11.800	0.00000E+00	0.00	0.00	0.00
104	30.850	11.800	0.00000E+00	0.00	0.00	0.00
105	30.700	11.800	0.00000E+00	0.00	0.00	0.00

106	30.550	11.800	0.00000E+00	0.00	0.00	0.00
107	30.400	11.800	0.00000E+00	0.00	0.00	0.00
108	30.250	11.800	0.00000E+00	0.00	0.00	0.00
109	31.000	11.950	0.00000E+00	0.00	0.00	0.00
110	30.850	11.950	0.00000E+00	0.00	0.00	0.00
111	30.700	11.950	0.00000E+00	0.00	0.00	0.00
112	30.550	11.950	0.00000E+00	0.00	0.00	0.00
113	30.400	11.950	0.00000E+00	0.00	0.00	0.00
114	30.250	11.950	0.00000E+00	0.00	0.00	0.00
115	31.000	12.100	0.00000E+00	0.00	0.00	0.00
116	30.850	12.100	0.00000E+00	0.00	0.00	0.00
117	30.700	12.100	0.00000E+00	0.00	0.00	0.00
118	30.550	12.100	0.00000E+00	0.00	0.00	0.00
119	30.400	12.100	0.00000E+00	0.00	0.00	0.00
120	30.250	12.100	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
121	31.000	12.250	0.00000E+00	0.00	0.00	0.00
122	30.850	12.250	0.00000E+00	0.00	0.00	0.00
123	30.700	12.250	0.00000E+00	0.00	0.00	0.00
124	30.550	12.250	0.00000E+00	0.00	0.00	0.00
125	30.400	12.250	0.00000E+00	0.00	0.00	0.00
126	30.250	12.250	0.00000E+00	0.00	0.00	0.00
127	31.000	12.400	0.00000E+00	0.00	0.00	0.00
128	30.850	12.400	0.00000E+00	0.00	0.00	0.00
129	30.700	12.400	0.00000E+00	0.00	0.00	0.00
130	30.550	12.400	0.00000E+00	0.00	0.00	0.00
131	30.400	12.400	0.00000E+00	0.00	0.00	0.00
132	30.250	12.400	0.00000E+00	0.00	0.00	0.00
133	31.000	12.550	0.00000E+00	0.00	0.00	0.00
134	30.850	12.550	0.00000E+00	0.00	0.00	0.00
135	30.700	12.550	0.00000E+00	0.00	0.00	0.00
136	30.550	12.550	0.00000E+00	0.00	0.00	0.00
137	30.400	12.550	0.00000E+00	0.00	0.00	0.00
138	30.250	12.550	0.00000E+00	0.00	0.00	0.00
139	31.000	12.700	0.00000E+00	0.00	0.00	0.00
140	30.850	12.700	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
141	30.700	12.700	0.00000E+00	0.00	0.00	0.00
142	30.550	12.700	0.00000E+00	0.00	0.00	0.00
143	30.400	12.700	0.00000E+00	0.00	0.00	0.00
144	30.250	12.700	0.00000E+00	0.00	0.00	0.00
145	30.100	11.950	0.00000E+00	0.00	0.00	0.00
146	30.100	12.100	0.00000E+00	0.00	0.00	0.00
147	30.100	12.250	0.00000E+00	0.00	0.00	0.00
148	30.100	12.400	0.00000E+00	0.00	0.00	0.00
149	30.100	12.550	0.00000E+00	0.00	0.00	0.00
150	30.100	12.700	0.00000E+00	0.00	0.00	0.00
151	29.950	11.950	0.00000E+00	0.00	0.00	0.00
152	29.950	12.100	0.00000E+00	0.00	0.00	0.00
153	29.950	12.250	0.00000E+00	0.00	0.00	0.00
154	29.950	12.400	0.00000E+00	0.00	0.00	0.00
155	29.950	12.550	0.00000E+00	0.00	0.00	0.00
156	29.950	12.700	0.00000E+00	0.00	0.00	0.00
57	29.800	11.950	0.00000E+00	0.00	0.00	0.00
58	29.800	12.100	0.00000E+00	0.00	0.00	0.00
159	29.800	12.250	0.00000E+00	0.00	0.00	0.00
160	29.800	12.400	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
161	29.800	12.550	0.00000E+00	0.00	0.00	0.00
162	29.800	12.700	0.00000E+00	0.00	0.00	0.00
163	29.650	11.950	0.00000E+00	0.00	0.00	0.00
164	29.650	12.100	0.00000E+00	0.00	0.00	0.00
165	29.650	12.250	0.00000E+00	0.00	0.00	0.00
166	29.650	12.400	0.00000E+00	0.00	0.00	0.00
167	29.650	12.550	0.00000E+00	0.00	0.00	0.00
168	29.650	12.700	0.00000E+00	0.00	0.00	0.00
169	29.500	11.950	0.00000E+00	0.00	0.00	0.00
170	29.500	12.100	0.00000E+00	0.00	0.00	0.00
171	29.500	12.250	0.00000E+00	0.00	0.00	0.00
172	29.500	12.400	0.00000E+00	0.00	0.00	0.00
173	29.500	12.550	0.00000E+00	0.00	0.00	0.00
174	29.500	12.700	0.00000E+00	0.00	0.00	0.00
175	29.500	9.7000	0.00000E+00	0.00	0.00	0.00
176	29.500	10.000	0.00000E+00	0.00	0.00	0.00
177	29.500	10.300	0.00000E+00	0.00	0.00	0.00
178	29.500	10.600	0.00000E+00	0.00	0.00	0.00
179	29.500	10.900	0.00000E+00	0.00	0.00	0.00
180	29.500	11.200	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
181	29.500	11.500	0.00000E+00	0.00	0.00	0.00
182	29.500	11.800	0.00000E+00	0.00	0.00	0.00
183	29.200	9.7000	0.00000E+00	0.00	0.00	0.00
184	29.200	10.000	0.00000E+00	0.00	0.00	0.00
185	29.200	10.300	0.00000E+00	0.00	0.00	0.00
186	29.200	10.600	0.00000E+00	0.00	0.00	0.00
187	29.200	10.900	0.00000E+00	0.00	0.00	0.00
188	29.200	11.200	0.00000E+00	0.00	0.00	0.00
189	29.200	11.500	0.00000E+00	0.00	0.00	0.00
190	29.200	11.800	0.00000E+00	0.00	0.00	0.00
191	29.200	12.100	0.00000E+00	0.00	0.00	0.00
192	29.200	12.400	0.00000E+00	0.00	0.00	0.00
193	29.200	12.700	0.00000E+00	0.00	0.00	0.00
194	28.600	9.7000	0.00000E+00	0.00	0.00	0.00
195	28.600	10.300	0.00000E+00	0.00	0.00	0.00
196	28.600	10.900	0.00000E+00	0.00	0.00	0.00
197	28.600	11.500	0.00000E+00	0.00	0.00	0.00
198	28.600	12.100	0.00000E+00	0.00	0.00	0.00
199	28.600	12.700	0.00000E+00	0.00	0.00	0.00
200	27.600	9.7000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
201	27.600	10.300	0.00000E+00	0.00	0.00	0.00
202	27.600	10.900	0.00000E+00	0.00	0.00	0.00
203	27.600	11.500	0.00000E+00	0.00	0.00	0.00
204	27.600	12.100	0.00000E+00	0.00	0.00	0.00
205	27.600	12.700	0.00000E+00	0.00	0.00	0.00
206	26.000	9.7000	0.00000E+00	0.00	0.00	0.00
207	26.000	10.300	0.00000E+00	0.00	0.00	0.00
208	26.000	10.900	0.00000E+00	0.00	0.00	0.00
209	26.000	11.500	0.00000E+00	0.00	0.00	0.00
210	26.000	12.100	0.00000E+00	0.00	0.00	0.00
211	26.000	12.700	0.00000E+00	0.00	0.00	0.00
212	24.000	9.7000	0.00000E+00	0.00	0.00	0.00
213	24.000	10.300	0.00000E+00	0.00	0.00	0.00
214	24.000	10.900	0.00000E+00	0.00	0.00	0.00
215	24.000	11.500	0.00000E+00	0.00	0.00	0.00

216	24.000	12.100	0.00000E+00	0.00	0.00	0.00
217	24.000	12.700	0.00000E+00	0.00	0.00	0.00
218	22.000	9.7000	0.00000E+00	0.00	0.00	0.00
219	22.000	10.300	0.00000E+00	0.00	0.00	0.00
220	22.000	10.900	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
221	22.000	11.500	0.00000E+00	0.00	0.00	0.00
222	22.000	12.100	0.00000E+00	0.00	0.00	0.00
223	22.000	12.700	0.00000E+00	0.00	0.00	0.00
224	20.000	9.7000	0.00000E+00	0.00	0.00	0.00
225	20.000	10.300	0.00000E+00	0.00	0.00	0.00
226	20.000	10.900	0.00000E+00	0.00	0.00	0.00
227	20.000	11.500	0.00000E+00	0.00	0.00	0.00
228	20.000	12.100	0.00000E+00	0.00	0.00	0.00
229	20.000	12.700	0.00000E+00	0.00	0.00	0.00
230	18.000	9.7000	0.00000E+00	0.00	0.00	0.00
231	18.000	10.300	0.00000E+00	0.00	0.00	0.00
232	18.000	10.900	0.00000E+00	0.00	0.00	0.00
233	18.000	11.500	0.00000E+00	0.00	0.00	0.00
234	18.000	12.100	0.00000E+00	0.00	0.00	0.00
235	18.000	12.700	0.00000E+00	0.00	0.00	0.00
236	16.000	9.7000	0.00000E+00	0.00	0.00	0.00
237	16.000	10.300	0.00000E+00	0.00	0.00	0.00
238	16.000	10.900	0.00000E+00	0.00	0.00	0.00
239	16.000	11.500	0.00000E+00	0.00	0.00	0.00
240	16.000	12.100	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
241	16.000	12.700	0.00000E+00	0.00	0.00	0.00
242	14.000	9.7000	0.00000E+00	0.00	0.00	0.00
243	14.000	10.300	0.00000E+00	0.00	0.00	0.00
244	14.000	10.900	0.00000E+00	0.00	0.00	0.00
245	14.000	11.500	0.00000E+00	0.00	0.00	0.00
246	14.000	12.100	0.00000E+00	0.00	0.00	0.00
247	14.000	12.700	0.00000E+00	0.00	0.00	0.00
248	12.000	9.7000	0.00000E+00	0.00	0.00	0.00
249	12.000	10.300	0.00000E+00	0.00	0.00	0.00
250	12.000	10.900	0.00000E+00	0.00	0.00	0.00
251	12.000	11.500	0.00000E+00	0.00	0.00	0.00
252	12.000	12.100	0.00000E+00	0.00	0.00	0.00
253	12.000	12.700	0.00000E+00	0.00	0.00	0.00
254	10.000	9.7000	0.00000E+00	0.00	0.00	0.00
255	10.000	10.300	0.00000E+00	0.00	0.00	0.00
256	10.000	10.900	0.00000E+00	0.00	0.00	0.00
257	10.000	11.500	0.00000E+00	0.00	0.00	0.00
258	10.000	12.100	0.00000E+00	0.00	0.00	0.00
259	10.000	12.700	0.00000E+00	0.00	0.00	0.00
260	8.0000	9.7000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
261	8.0000	10.300	0.00000E+00	0.00	0.00	0.00
262	8.0000	10.900	0.00000E+00	0.00	0.00	0.00
263	8.0000	11.500	0.00000E+00	0.00	0.00	0.00
264	8.0000	12.100	0.00000E+00	0.00	0.00	0.00
65	8.0000	12.700	0.00000E+00	0.00	0.00	0.00
266	6.0000	9.7000	0.00000E+00	0.00	0.00	0.00
267	6.0000	10.300	0.00000E+00	0.00	0.00	0.00
268	6.0000	10.900	0.00000E+00	0.00	0.00	0.00
269	6.0000	11.500	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
270	6.0000	12.100	0.00000E+00	0.00	0.00	0.00
271	6.0000	12.700	0.00000E+00	0.00	0.00	0.00
272	4.0000	9.7000	0.00000E+00	0.00	0.00	0.00
273	4.0000	10.300	0.00000E+00	0.00	0.00	0.00
274	4.0000	10.900	0.00000E+00	0.00	0.00	0.00
275	4.0000	11.500	0.00000E+00	0.00	0.00	0.00
276	4.0000	12.100	0.00000E+00	0.00	0.00	0.00
277	4.0000	12.700	0.00000E+00	0.00	0.00	0.00
278	2.0000	9.7000	0.00000E+00	0.00	0.00	0.00
279	2.0000	10.300	0.00000E+00	0.00	0.00	0.00
280	2.0000	10.900	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
281	2.0000	11.500	0.00000E+00	0.00	0.00	0.00
282	2.0000	12.100	0.00000E+00	0.00	0.00	0.00
283	2.0000	12.700	0.00000E+00	0.00	0.00	0.00
284	0.00000E+00	9.7000	0.00000E+00	0.00	0.00	0.00
285	0.00000E+00	10.300	0.00000E+00	0.00	0.00	0.00
286	0.00000E+00	10.900	0.00000E+00	0.00	0.00	0.00
287	0.00000E+00	11.500	0.00000E+00	0.00	0.00	0.00
288	0.00000E+00	12.100	0.00000E+00	0.00	0.00	0.00
289	0.00000E+00	12.700	0.00000E+00	0.00	0.00	0.00
290	29.800	9.7000	0.00000E+00	0.00	0.00	0.00
291	29.800	10.000	0.00000E+00	0.00	0.00	0.00
292	29.800	10.300	0.00000E+00	0.00	0.00	0.00
293	29.800	10.600	0.00000E+00	0.00	0.00	0.00
294	29.800	10.900	0.00000E+00	0.00	0.00	0.00
295	29.800	11.200	0.00000E+00	0.00	0.00	0.00
296	29.800	11.500	0.00000E+00	0.00	0.00	0.00
297	29.800	11.800	0.00000E+00	0.00	0.00	0.00
298	30.100	9.7000	0.00000E+00	0.00	0.00	0.00
299	30.100	10.000	0.00000E+00	0.00	0.00	0.00
300	30.100	10.300	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
301	30.100	10.600	0.00000E+00	0.00	0.00	0.00
302	30.100	10.900	0.00000E+00	0.00	0.00	0.00
303	30.100	11.200	0.00000E+00	0.00	0.00	0.00
304	30.100	11.500	0.00000E+00	0.00	0.00	0.00
305	30.100	11.800	0.00000E+00	0.00	0.00	0.00
306	30.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
307	30.000	1.9000	0.00000E+00	0.00	0.00	0.00
308	30.000	3.8000	0.00000E+00	0.00	0.00	0.00
309	30.000	5.7000	0.00000E+00	0.00	0.00	0.00
310	30.000	7.6000	0.00000E+00	0.00	0.00	0.00
311	30.000	9.5000	0.00000E+00	0.00	0.00	0.00
312	28.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
313	28.000	1.9000	0.00000E+00	0.00	0.00	0.00
314	28.000	3.8000	0.00000E+00	0.00	0.00	0.00
315	28.000	5.7000	0.00000E+00	0.00	0.00	0.00
316	28.000	7.6000	0.00000E+00	0.00	0.00	0.00
317	28.000	9.5000	0.00000E+00	0.00	0.00	0.00
318	26.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
319	26.000	1.9000	0.00000E+00	0.00	0.00	0.00
320	26.000	3.8000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
321	26.000	5.7000	0.00000E+00	0.00	0.00	0.00
322	26.000	7.6000	0.00000E+00	0.00	0.00	0.00
323	26.000	9.5000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
324	24.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
325	24.000	1.9000	0.00000E+00	0.00	0.00	0.00
326	24.000	3.8000	0.00000E+00	0.00	0.00	0.00
327	24.000	5.7000	0.00000E+00	0.00	0.00	0.00
328	24.000	7.6000	0.00000E+00	0.00	0.00	0.00
329	24.000	9.5000	0.00000E+00	0.00	0.00	0.00
330	22.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
331	22.000	1.9000	0.00000E+00	0.00	0.00	0.00
332	22.000	3.8000	0.00000E+00	0.00	0.00	0.00
333	22.000	5.7000	0.00000E+00	0.00	0.00	0.00
334	22.000	7.6000	0.00000E+00	0.00	0.00	0.00
335	22.000	9.5000	0.00000E+00	0.00	0.00	0.00
336	20.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
337	20.000	1.9000	0.00000E+00	0.00	0.00	0.00
338	20.000	3.8000	0.00000E+00	0.00	0.00	0.00
339	20.000	5.7000	0.00000E+00	0.00	0.00	0.00
340	20.000	7.6000	0.00000E+00	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
341	20.000	9.5000	0.00000E+00	0.00	0.00	0.00
342	18.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
343	18.000	1.9000	0.00000E+00	0.00	0.00	0.00
344	18.000	3.8000	0.00000E+00	0.00	0.00	0.00
345	18.000	5.7000	0.00000E+00	0.00	0.00	0.00
346	18.000	7.6000	0.00000E+00	0.00	0.00	0.00
347	18.000	9.5000	0.00000E+00	0.00	0.00	0.00
348	16.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
349	16.000	1.9000	0.00000E+00	0.00	0.00	0.00
350	16.000	3.8000	0.00000E+00	0.00	0.00	0.00
351	16.000	5.7000	0.00000E+00	0.00	0.00	0.00
352	16.000	7.6000	0.00000E+00	0.00	0.00	0.00
353	16.000	9.5000	0.00000E+00	0.00	0.00	0.00
354	14.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
355	14.000	1.9000	0.00000E+00	0.00	0.00	0.00
356	14.000	3.8000	0.00000E+00	0.00	0.00	0.00
357	14.000	5.7000	0.00000E+00	0.00	0.00	0.00
358	14.000	7.6000	0.00000E+00	0.00	0.00	0.00
359	14.000	9.5000	0.00000E+00	0.00	0.00	0.00
360	12.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
NODE	X	Y	Z	THXY	THYZ	THXZ
361	12.000	1.9000	0.00000E+00	0.00	0.00	0.00
362	12.000	3.8000	0.00000E+00	0.00	0.00	0.00
363	12.000	5.7000	0.00000E+00	0.00	0.00	0.00
364	12.000	7.6000	0.00000E+00	0.00	0.00	0.00
365	12.000	9.5000	0.00000E+00	0.00	0.00	0.00
366	10.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
367	10.000	1.9000	0.00000E+00	0.00	0.00	0.00
368	10.000	3.8000	0.00000E+00	0.00	0.00	0.00
369	10.000	5.7000	0.00000E+00	0.00	0.00	0.00
370	10.000	7.6000	0.00000E+00	0.00	0.00	0.00
371	10.000	9.5000	0.00000E+00	0.00	0.00	0.00
372	8.0000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
373	8.0000	1.9000	0.00000E+00	0.00	0.00	0.00
374	8.0000	3.8000	0.00000E+00	0.00	0.00	0.00
375	8.0000	5.7000	0.00000E+00	0.00	0.00	0.00
376	8.0000	7.6000	0.00000E+00	0.00	0.00	0.00
377	8.0000	9.5000	0.00000E+00	0.00	0.00	0.00
378	6.0000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
379	6.0000	1.9000	0.00000E+00	0.00	0.00	0.00

380	6.0000	3.8000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
381	6.0000	5.7000	0.00000E+00	0.00	0.00	0.00
82	6.0000	7.6000	0.00000E+00	0.00	0.00	0.00
383	6.0000	9.5000	0.00000E+00	0.00	0.00	0.00
384	4.0000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
385	4.0000	1.9000	0.00000E+00	0.00	0.00	0.00
386	4.0000	3.8000	0.00000E+00	0.00	0.00	0.00
387	4.0000	5.7000	0.00000E+00	0.00	0.00	0.00
388	4.0000	7.6000	0.00000E+00	0.00	0.00	0.00
389	4.0000	9.5000	0.00000E+00	0.00	0.00	0.00
390	2.0000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
391	2.0000	1.9000	0.00000E+00	0.00	0.00	0.00
392	2.0000	3.8000	0.00000E+00	0.00	0.00	0.00
393	2.0000	5.7000	0.00000E+00	0.00	0.00	0.00
394	2.0000	7.6000	0.00000E+00	0.00	0.00	0.00
395	2.0000	9.5000	0.00000E+00	0.00	0.00	0.00
396	0.00000E+00	0.00000E+00	0.00000E+00	0.00	0.00	0.00
397	0.00000E+00	1.9000	0.00000E+00	0.00	0.00	0.00
398	0.00000E+00	3.8000	0.00000E+00	0.00	0.00	0.00
399	0.00000E+00	5.7000	0.00000E+00	0.00	0.00	0.00
400	0.00000E+00	7.6000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
401	0.00000E+00	9.5000	0.00000E+00	0.00	0.00	0.00
402	31.000	-0.50000	0.00000E+00	0.00	0.00	0.00
403	30.850	-0.50000	0.00000E+00	0.00	0.00	0.00
404	30.700	-0.50000	0.00000E+00	0.00	0.00	0.00
05	30.550	-0.50000	0.00000E+00	0.00	0.00	0.00
06	30.400	-0.50000	0.00000E+00	0.00	0.00	0.00
407	30.250	-0.50000	0.00000E+00	0.00	0.00	0.00
408	31.000	-1.0000	0.00000E+00	0.00	0.00	0.00
409	30.850	-1.0000	0.00000E+00	0.00	0.00	0.00
410	30.700	-1.0000	0.00000E+00	0.00	0.00	0.00
411	30.550	-1.0000	0.00000E+00	0.00	0.00	0.00
412	30.400	-1.0000	0.00000E+00	0.00	0.00	0.00
413	30.250	-1.0000	0.00000E+00	0.00	0.00	0.00
414	31.000	-1.5000	0.00000E+00	0.00	0.00	0.00
415	30.850	-1.5000	0.00000E+00	0.00	0.00	0.00
416	30.700	-1.5000	0.00000E+00	0.00	0.00	0.00
417	30.550	-1.5000	0.00000E+00	0.00	0.00	0.00
418	30.400	-1.5000	0.00000E+00	0.00	0.00	0.00
419	30.250	-1.5000	0.00000E+00	0.00	0.00	0.00
420	31.000	-2.0000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
421	30.850	-2.0000	0.00000E+00	0.00	0.00	0.00
422	30.700	-2.0000	0.00000E+00	0.00	0.00	0.00
423	30.550	-2.0000	0.00000E+00	0.00	0.00	0.00
424	30.400	-2.0000	0.00000E+00	0.00	0.00	0.00
425	30.250	-2.0000	0.00000E+00	0.00	0.00	0.00
426	31.000	-3.0000	0.00000E+00	0.00	0.00	0.00
427	30.850	-3.0000	0.00000E+00	0.00	0.00	0.00
428	30.700	-3.0000	0.00000E+00	0.00	0.00	0.00
29	30.550	-3.0000	0.00000E+00	0.00	0.00	0.00
30	30.400	-3.0000	0.00000E+00	0.00	0.00	0.00
431	30.250	-3.0000	0.00000E+00	0.00	0.00	0.00
432	31.000	-5.0000	0.00000E+00	0.00	0.00	0.00
433	30.850	-5.0000	0.00000E+00	0.00	0.00	0.00

434	30.700	-5.0000	0.00000E+00	0.00	0.00	0.00
435	30.550	-5.0000	0.00000E+00	0.00	0.00	0.00
436	30.400	-5.0000	0.00000E+00	0.00	0.00	0.00
437	30.250	-5.0000	0.00000E+00	0.00	0.00	0.00
438	31.000	-7.0000	0.00000E+00	0.00	0.00	0.00
439	30.850	-7.0000	0.00000E+00	0.00	0.00	0.00
440	30.700	-7.0000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
441	30.550	-7.0000	0.00000E+00	0.00	0.00	0.00
442	30.400	-7.0000	0.00000E+00	0.00	0.00	0.00
443	30.250	-7.0000	0.00000E+00	0.00	0.00	0.00
444	31.000	-9.0000	0.00000E+00	0.00	0.00	0.00
445	30.850	-9.0000	0.00000E+00	0.00	0.00	0.00
446	30.700	-9.0000	0.00000E+00	0.00	0.00	0.00
447	30.550	-9.0000	0.00000E+00	0.00	0.00	0.00
448	30.400	-9.0000	0.00000E+00	0.00	0.00	0.00
449	30.250	-9.0000	0.00000E+00	0.00	0.00	0.00
450	30.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
451	29.750	0.00000E+00	0.00000E+00	0.00	0.00	0.00
452	30.000	-0.50000	0.00000E+00	0.00	0.00	0.00
453	29.750	-0.50000	0.00000E+00	0.00	0.00	0.00
454	30.000	-1.0000	0.00000E+00	0.00	0.00	0.00
455	29.750	-1.0000	0.00000E+00	0.00	0.00	0.00
456	30.000	-1.5000	0.00000E+00	0.00	0.00	0.00
457	29.750	-1.5000	0.00000E+00	0.00	0.00	0.00
458	30.000	-2.0000	0.00000E+00	0.00	0.00	0.00
459	29.750	-2.0000	0.00000E+00	0.00	0.00	0.00
460	31.000	-13.000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
461	30.850	-13.000	0.00000E+00	0.00	0.00	0.00
462	30.700	-13.000	0.00000E+00	0.00	0.00	0.00
463	30.550	-13.000	0.00000E+00	0.00	0.00	0.00
464	30.400	-13.000	0.00000E+00	0.00	0.00	0.00
465	30.250	-13.000	0.00000E+00	0.00	0.00	0.00
466	31.000	-18.000	0.00000E+00	0.00	0.00	0.00
467	30.850	-18.000	0.00000E+00	0.00	0.00	0.00
468	30.700	-18.000	0.00000E+00	0.00	0.00	0.00
469	30.550	-18.000	0.00000E+00	0.00	0.00	0.00
470	30.400	-18.000	0.00000E+00	0.00	0.00	0.00
471	30.250	-18.000	0.00000E+00	0.00	0.00	0.00
472	31.000	-23.000	0.00000E+00	0.00	0.00	0.00
473	30.850	-23.000	0.00000E+00	0.00	0.00	0.00
474	30.700	-23.000	0.00000E+00	0.00	0.00	0.00
475	30.550	-23.000	0.00000E+00	0.00	0.00	0.00
476	30.400	-23.000	0.00000E+00	0.00	0.00	0.00
477	30.250	-23.000	0.00000E+00	0.00	0.00	0.00
478	31.000	-30.000	0.00000E+00	0.00	0.00	0.00
479	30.850	-30.000	0.00000E+00	0.00	0.00	0.00
480	30.700	-30.000	0.00000E+00	0.00	0.00	0.00

NODE	X	Y	Z	THXY	THYZ	THXZ
481	30.550	-30.000	0.00000E+00	0.00	0.00	0.00
482	30.400	-30.000	0.00000E+00	0.00	0.00	0.00
483	30.250	-30.000	0.00000E+00	0.00	0.00	0.00

LIST ALL ELEMENT TYPES

NO. STIF KEYOPT VALUES INOTPR

1 42 0 1 1 0 0 0 0 0 0 0 ISOPAR. STRESS SOLID, 2-D

LIST ALL SELECTED ELEMENTS. (LIST NODES)

ELEM	MAT	TYP	REL	NODES			
1	1	1	1	2	1	7	8
2	1	1	1	3	2	8	9
3	1	1	1	4	3	9	10
4	1	1	1	5	4	10	11
5	1	1	1	6	5	11	12
6	1	1	1	8	7	13	14
7	1	1	1	9	8	14	15
8	1	1	1	10	9	15	16
9	1	1	1	11	10	16	17
10	1	1	1	12	11	17	18
11	1	1	1	14	13	19	20
12	1	1	1	15	14	20	21
13	1	1	1	16	15	21	22
14	1	1	1	17	16	22	23
15	1	1	1	18	17	23	24
16	1	1	1	20	19	25	26
17	1	1	1	21	20	26	27
18	1	1	1	22	21	27	28
19	1	1	1	23	22	28	29
20	1	1	1	24	23	29	30

ELEM	MAT	TYP	REL	NODES			
21	1	1	1	26	25	31	32
22	1	1	1	27	26	32	33
23	1	1	1	28	27	33	34
24	1	1	1	29	28	34	35
25	1	1	1	30	29	35	36
26	1	1	1	32	31	37	38
27	1	1	1	33	32	38	39
28	1	1	1	34	33	39	40
29	1	1	1	35	34	40	41
30	1	1	1	36	35	41	42
31	1	1	1	38	37	43	44
32	1	1	1	39	38	44	45
33	1	1	1	40	39	45	46
34	1	1	1	41	40	46	47
35	1	1	1	42	41	47	48
36	1	1	1	44	43	49	50
37	1	1	1	45	44	50	51
38	1	1	1	46	45	51	52
39	1	1	1	47	46	52	53
40	1	1	1	48	47	53	54

ELEM	MAT	TYP	REL	NODES			
41	1	1	1	50	49	55	56
42	1	1	1	51	50	56	57
43	1	1	1	52	51	57	58
44	1	1	1	53	52	58	59
45	1	1	1	54	53	59	60
46	1	1	1	56	55	61	62
47	1	1	1	57	56	62	63
48	1	1	1	58	57	63	64

49	1	1	1	59	58	64	65
50	1	1	1	60	59	65	66
51	1	1	1	62	61	67	68
52	1	1	1	63	62	68	69
53	1	1	1	64	63	69	70
54	1	1	1	65	64	70	71
55	1	1	1	66	65	71	72
56	1	1	1	68	67	73	74
57	1	1	1	69	68	74	75
58	1	1	1	70	69	75	76
59	1	1	1	71	70	76	77
60	1	1	1	72	71	77	78

ELEM	MAT	TYP	REL	NODES			
61	1	1	1	74	73	79	80
62	1	1	1	75	74	80	81
63	1	1	1	76	75	81	82
64	1	1	1	77	76	82	83
65	1	1	1	78	77	83	84
66	1	1	1	80	79	85	86
67	1	1	1	81	80	86	87
68	1	1	1	82	81	87	88
69	1	1	1	83	82	88	89
70	1	1	1	84	83	89	90
71	1	1	1	86	85	91	92
72	1	1	1	87	86	92	93
73	1	1	1	88	87	93	94
74	1	1	1	89	88	94	95
75	1	1	1	90	89	95	96
76	1	1	1	92	91	97	98
77	1	1	1	93	92	98	99
78	1	1	1	94	93	99	100
79	1	1	1	95	94	100	101
80	1	1	1	96	95	101	102

ELEM	MAT	TYP	REL	NODES			
81	1	1	1	98	97	103	104
82	1	1	1	99	98	104	105
83	1	1	1	100	99	105	106
84	1	1	1	101	100	106	107
85	1	1	1	102	101	107	108
86	1	1	1	104	103	109	110
87	1	1	1	105	104	110	111
88	1	1	1	106	105	111	112
89	1	1	1	107	106	112	113
90	1	1	1	108	107	113	114
91	1	1	1	110	109	115	116
92	1	1	1	111	110	116	117
93	1	1	1	112	111	117	118
94	1	1	1	113	112	118	119
95	1	1	1	114	113	119	120
96	1	1	1	116	115	121	122
97	1	1	1	117	116	122	123
98	1	1	1	118	117	123	124
99	1	1	1	119	118	124	125
100	1	1	1	120	119	125	126

ELEM MAT TYP REL NODES

101	1	1	1	122	121	127	128
102	1	1	1	123	122	128	129
103	1	1	1	124	123	129	130
104	1	1	1	125	124	130	131
105	1	1	1	126	125	131	132
106	1	1	1	128	127	133	134
107	1	1	1	129	128	134	135
108	1	1	1	130	129	135	136
109	1	1	1	131	130	136	137
110	1	1	1	132	131	137	138
111	1	1	1	134	133	139	140
112	1	1	1	135	134	140	141
113	1	1	1	136	135	141	142
114	1	1	1	137	136	142	143
115	1	1	1	138	137	143	144
116	1	1	1	145	114	120	146
117	1	1	1	146	120	126	147
118	1	1	1	147	126	132	148
119	1	1	1	148	132	138	149
120	1	1	1	149	138	144	150

ELEM	MAT	TYP	REL	NODES			
121	1	1	1	151	145	146	152
122	1	1	1	152	146	147	153
123	1	1	1	153	147	148	154
124	1	1	1	154	148	149	155
125	1	1	1	155	149	150	156
126	1	1	1	157	151	152	158
127	1	1	1	158	152	153	159
128	1	1	1	159	153	154	160
129	1	1	1	160	154	155	161
130	1	1	1	161	155	156	162
131	1	1	1	163	157	158	164
132	1	1	1	164	158	159	165
133	1	1	1	165	159	160	166
134	1	1	1	166	160	161	167
135	1	1	1	167	161	162	168
136	1	1	1	169	163	164	170
137	1	1	1	170	164	165	171
138	1	1	1	171	165	166	172
139	1	1	1	172	166	167	173
140	1	1	1	173	167	168	174

ELEM	MAT	TYP	REL	NODES			
141	1	1	1	174	193	173	173
142	1	1	1	193	192	173	173
143	1	1	1	173	192	172	172
144	1	1	1	172	192	171	171
145	1	1	1	171	192	191	191
146	1	1	1	171	191	170	170
147	1	1	1	170	191	169	169
148	1	1	1	169	191	190	190
149	1	1	1	169	190	182	182
150	1	1	1	183	175	176	184
151	1	1	1	184	176	177	185
152	1	1	1	185	177	178	186
153	1	1	1	186	178	179	187

154	1	1	1	187	179	180	188
155	1	1	1	188	180	181	189
156	1	1	1	189	181	182	190
157	1	1	1	194	183	184	184
158	1	1	1	195	184	185	185
159	1	1	1	194	184	195	195
160	1	1	1	195	185	186	186

ELEM	MAT	TYP	REL	NODES			
161	1	1	1	195	186	196	196
162	1	1	1	186	187	196	196
163	1	1	1	196	187	188	188
164	1	1	1	196	188	197	197
165	1	1	1	188	189	197	197
166	1	1	1	189	190	197	197
167	1	1	1	197	190	198	198
168	1	1	1	190	191	198	198
169	1	1	1	198	191	192	192
170	1	1	1	198	192	199	199
171	1	1	1	192	193	199	199
172	1	1	1	200	194	195	201
173	1	1	1	201	195	196	202
174	1	1	1	202	196	197	203
175	1	1	1	203	197	198	204
176	1	1	1	204	198	199	205
177	1	1	1	206	200	201	207
178	1	1	1	207	201	202	208
179	1	1	1	208	202	203	209
180	1	1	1	209	203	204	210

ELEM	MAT	TYP	REL	NODES			
181	1	1	1	210	204	205	211
182	1	1	1	212	206	207	213
183	1	1	1	213	207	208	214
184	1	1	1	214	208	209	215
185	1	1	1	215	209	210	216
186	1	1	1	216	210	211	217
187	1	1	1	218	212	213	219
188	1	1	1	219	213	214	220
189	1	1	1	220	214	215	221
190	1	1	1	221	215	216	222
191	1	1	1	222	216	217	223
192	1	1	1	224	218	219	225
193	1	1	1	225	219	220	226
194	1	1	1	226	220	221	227
195	1	1	1	227	221	222	228
196	1	1	1	228	222	223	229
197	1	1	1	230	224	225	231
198	1	1	1	231	225	226	232
199	1	1	1	232	226	227	233
200	1	1	1	233	227	228	234

ELEM	MAT	TYP	REL	NODES			
201	1	1	1	234	228	229	235
202	1	1	1	236	230	231	237
203	1	1	1	237	231	232	238
204	1	1	1	238	232	233	239

205	1	1	1	239	233	234	240
206	1	1	1	240	234	235	241
207	1	1	1	242	236	237	243
208	1	1	1	243	237	238	244
209	1	1	1	244	238	239	245
210	1	1	1	245	239	240	246
211	1	1	1	246	240	241	247
212	1	1	1	248	242	243	249
213	1	1	1	249	243	244	250
214	1	1	1	250	244	245	251
215	1	1	1	251	245	246	252
216	1	1	1	252	246	247	253
217	1	1	1	254	248	249	255
218	1	1	1	255	249	250	256
219	1	1	1	256	250	251	257
220	1	1	1	257	251	252	258

ELEM	MAT	TYP	REL	NODES			
221	1	1	1	258	252	253	259
222	1	1	1	260	254	255	261
223	1	1	1	261	255	256	262
224	1	1	1	262	256	257	263
225	1	1	1	263	257	258	264
226	1	1	1	264	258	259	265
227	1	1	1	266	260	261	267
228	1	1	1	267	261	262	268
229	1	1	1	268	262	263	269
230	1	1	1	269	263	264	270
231	1	1	1	270	264	265	271
232	1	1	1	272	266	267	273
233	1	1	1	273	267	268	274
234	1	1	1	274	268	269	275
235	1	1	1	275	269	270	276
236	1	1	1	276	270	271	277
237	1	1	1	278	272	273	279
238	1	1	1	279	273	274	280
239	1	1	1	280	274	275	281
240	1	1	1	281	275	276	282

ELEM	MAT	TYP	REL	NODES			
241	1	1	1	282	276	277	283
242	1	1	1	284	278	279	285
243	1	1	1	285	279	280	286
244	1	1	1	286	280	281	287
245	1	1	1	287	281	282	288
246	1	1	1	288	282	283	289
247	1	1	1	175	290	291	176
248	1	1	1	176	291	292	177
249	1	1	1	177	292	293	178
250	1	1	1	178	293	294	179
251	1	1	1	179	294	295	180
252	1	1	1	180	295	296	181
253	1	1	1	181	296	297	182
254	1	1	1	182	163	169	169
255	1	1	1	182	297	163	163
256	1	1	1	297	157	163	163
259	2	1	1	312	306	307	313
260	2	1	1	313	307	308	314

261	2	1	1	314	308	309	315
262	2	1	1	315	309	310	316

ELEM	MAT	TYP	REL	NODES			
263	2	1	1	316	310	311	317
264	2	1	1	318	312	313	319
265	2	1	1	319	313	314	320
266	2	1	1	320	314	315	321
267	2	1	1	321	315	316	322
268	2	1	1	322	316	317	323
269	2	1	1	324	318	319	325
270	2	1	1	325	319	320	326
271	2	1	1	326	320	321	327
272	2	1	1	327	321	322	328
273	2	1	1	328	322	323	329
274	2	1	1	330	324	325	331
275	2	1	1	331	325	326	332
276	2	1	1	332	326	327	333
277	2	1	1	333	327	328	334
278	2	1	1	334	328	329	335
279	2	1	1	336	330	331	337
280	2	1	1	337	331	332	338
281	2	1	1	338	332	333	339
282	2	1	1	339	333	334	340

ELEM	MAT	TYP	REL	NODES			
283	2	1	1	340	334	335	341
284	2	1	1	342	336	337	343
285	2	1	1	343	337	338	344
286	2	1	1	344	338	339	345
287	2	1	1	345	339	340	346
288	2	1	1	346	340	341	347
289	2	1	1	348	342	343	349
290	2	1	1	349	343	344	350
291	2	1	1	350	344	345	351
292	2	1	1	351	345	346	352
293	2	1	1	352	346	347	353
294	2	1	1	354	348	349	355
295	2	1	1	355	349	350	356
296	2	1	1	356	350	351	357
297	2	1	1	357	351	352	358
298	2	1	1	358	352	353	359
299	2	1	1	360	354	355	361
300	2	1	1	361	355	356	362
301	2	1	1	362	356	357	363
302	2	1	1	363	357	358	364

ELEM	MAT	TYP	REL	NODES			
303	2	1	1	364	358	359	365
304	2	1	1	366	360	361	367
305	2	1	1	367	361	362	368
306	2	1	1	368	362	363	369
307	2	1	1	369	363	364	370
308	2	1	1	370	364	365	371
309	2	1	1	372	366	367	373
310	2	1	1	373	367	368	374
311	2	1	1	374	368	369	375

312	2	1	1	375	369	370	376
313	2	1	1	376	370	371	377
314	2	1	1	378	372	373	379
315	2	1	1	379	373	374	380
316	2	1	1	380	374	375	381
317	2	1	1	381	375	376	382
318	2	1	1	382	376	377	383
319	2	1	1	384	378	379	385
320	2	1	1	385	379	380	386
321	2	1	1	386	380	381	387
322	2	1	1	387	381	382	388

ELEM	MAT	TYP	REL	NODES			
323	2	1	1	388	382	383	389
324	2	1	1	390	384	385	391
325	2	1	1	391	385	386	392
326	2	1	1	392	386	387	393
327	2	1	1	393	387	388	394
328	2	1	1	394	388	389	395
329	2	1	1	396	390	391	397
330	2	1	1	397	391	392	398
331	2	1	1	398	392	393	399
332	2	1	1	399	393	394	400
333	2	1	1	400	394	395	401
334	1	1	1	403	402	1	2
335	1	1	1	404	403	2	3
336	1	1	1	405	404	3	4
337	1	1	1	406	405	4	5
338	1	1	1	407	406	5	6
339	1	1	1	409	408	402	403
340	1	1	1	410	409	403	404
341	1	1	1	411	410	404	405
342	1	1	1	412	411	405	406

ELEM	MAT	TYP	REL	NODES			
343	1	1	1	413	412	406	407
344	1	1	1	415	414	408	409
345	1	1	1	416	415	409	410
346	1	1	1	417	416	410	411
347	1	1	1	418	417	411	412
348	1	1	1	419	418	412	413
349	1	1	1	421	420	414	415
350	1	1	1	422	421	415	416
351	1	1	1	423	422	416	417
352	1	1	1	424	423	417	418
353	1	1	1	425	424	418	419
354	1	1	1	427	426	420	421
355	1	1	1	428	427	421	422
356	1	1	1	429	428	422	423
357	1	1	1	430	429	423	424
358	1	1	1	431	430	424	425
359	1	1	1	433	432	426	427
360	1	1	1	434	433	427	428
361	1	1	1	435	434	428	429
362	1	1	1	436	435	429	430

ELEM	MAT	TYP	REL	NODES

363	1	1	1	437	436	430	431
364	1	1	1	439	438	432	433
365	1	1	1	440	439	433	434
366	1	1	1	441	440	434	435
367	1	1	1	442	441	435	436
368	1	1	1	443	442	436	437
369	1	1	1	445	444	438	439
370	1	1	1	446	445	439	440
371	1	1	1	447	446	440	441
372	1	1	1	448	447	441	442
373	1	1	1	449	448	442	443
374	1	1	1	453	452	450	451
375	1	1	1	455	454	452	453
376	1	1	1	457	456	454	455
377	1	1	1	459	458	456	457
378	1	1	1	452	407	6	450
379	1	1	1	454	413	407	452
380	1	1	1	456	419	413	454
381	1	1	1	458	425	419	456
382	1	1	1	461	460	444	445

ELEM	MAT	TYP	REL	NODES			
383	1	1	1	462	461	445	446
384	1	1	1	463	462	446	447
385	1	1	1	464	463	447	448
386	1	1	1	465	464	448	449
387	1	1	1	467	466	460	461
388	1	1	1	468	467	461	462
389	1	1	1	469	468	462	463
390	1	1	1	470	469	463	464
391	1	1	1	471	470	464	465
392	1	1	1	473	472	466	467
393	1	1	1	474	473	467	468
394	1	1	1	475	474	468	469
395	1	1	1	476	475	469	470
396	1	1	1	477	476	470	471
397	1	1	1	479	478	472	473
398	1	1	1	480	479	473	474
399	1	1	1	481	480	474	475
400	1	1	1	482	481	475	476
401	1	1	1	483	482	476	477

LIST ALL COUPLED SETS

COUPLED SET= 1 DIRECTION= UY TOTAL NODES= 2
NODES= 306 450

COUPLED SET= 2 DIRECTION= UY TOTAL NODES= 2
NODES= 401 284

COUPLED SET= 3 DIRECTION= UY TOTAL NODES= 2
NODES= 278 395

COUPLED SET= 4 DIRECTION= UY TOTAL NODES= 2
NODES= 272 389

COUPLED SET= 5 DIRECTION= UY TOTAL NODES= 2
NODES= 266 383

```
COUPLED SET=      6   DIRECTION= UY     TOTAL NODES=       2
NODES=     260    377

COUPLED SET=     28   DIRECTION= UY     TOTAL NODES=       2
NODES=     254    371

COUPLED SET=     29   DIRECTION= UY     TOTAL NODES=       2
NODES=     248    365

COUPLED SET=     30   DIRECTION= UY     TOTAL NODES=       2
NODES=     242    359

COUPLED SET=     31   DIRECTION= UY     TOTAL NODES=       2
NODES=     236    353

COUPLED SET=     32   DIRECTION= UY     TOTAL NODES=       2
NODES=     230    347

COUPLED SET=     33   DIRECTION= UY     TOTAL NODES=       2
NODES=     224    341

COUPLED SET=     34   DIRECTION= UY     TOTAL NODES=       2
NODES=     218    335

COUPLED SET=     35   DIRECTION= UY     TOTAL NODES=       2
NODES=     212    329

COUPLED SET=     36   DIRECTION= UY     TOTAL NODES=       2
NODES=     206    323

COUPLED SET=     37   DIRECTION= UY     TOTAL NODES=       2
NODES=     200    317

COUPLED SET=     38   DIRECTION= UY     TOTAL NODES=       3
NODES=     290    311     84

COUPLED SET=     40   DIRECTION= UX     TOTAL NODES=       2
NODES=     311     84

MAXIMUM COUPLED SET NUMBER=   40

LIST DISPLACEMENTS FOR ALL SELECTED NODES

 NODE  LABEL        DISP              CDISP
  284  UX     0.000000000E+00  0.000000000E+00
  285  UX     0.000000000E+00  0.000000000E+00
  286  UX     0.000000000E+00  0.000000000E+00
  287  UX     0.000000000E+00  0.000000000E+00
  288  UX     0.000000000E+00  0.000000000E+00
  289  UX     0.000000000E+00  0.000000000E+00
  396  UX     0.000000000E+00  0.000000000E+00
  397  UX     0.000000000E+00  0.000000000E+00
  398  UX     0.000000000E+00  0.000000000E+00
  399  UX     0.000000000E+00  0.000000000E+00
  400  UX     0.000000000E+00  0.000000000E+00
  401  UX     0.000000000E+00  0.000000000E+00
  478  UY     0.000000000E+00  0.000000000E+00
  479  UY     0.000000000E+00  0.000000000E+00
  480  UY     0.000000000E+00  0.000000000E+00
  481  UY     0.000000000E+00  0.000000000E+00
```

```
 482 UY     0.000000000E+00 0.000000000E+00
 483 UY     0.000000000E+00 0.000000000E+00

 'IST ALL MATERIALS   PROPERTY= ALL

 -ROPERTY TABLE EX     MAT=    1  NUM. POINTS=  2
       TEMPERATURE      DATA         TEMPERATURE      DATA
      0.00000E+00 0.28000E+08   2300.0      0.28000E+08

 PROPERTY TABLE NUXY   MAT=    1  NUM. POINTS=  2
       TEMPERATURE      DATA         TEMPERATURE      DATA
      0.00000E+00 0.30000       2300.0      0.30000

 PROPERTY TABLE DENS   MAT=    1  NUM. POINTS=  2
       TEMPERATURE      DATA         TEMPERATURE      DATA
      0.00000E+00 0.28000       2300.0      0.28000

 PROPERTY TABLE NUXY   MAT=    2  NUM. POINTS=  2
       TEMPERATURE      DATA         TEMPERATURE      DATA
      0.00000E+00 0.30000       2300.0      0.30000

 PROPERTY TABLE EX     MAT=    2  NUM. POINTS=  2
       TEMPERATURE      DATA         TEMPERATURE      DATA
      0.00000E+00 0.28000E+08   2300.0      0.28000E+08

 PROPERTY TABLE DENS   MAT=    2  NUM. POINTS=  2
       TEMPERATURE      DATA         TEMPERATURE      DATA
      0.00000E+00 0.23000       2300.0      0.23000
```

PRINT PRIN NODAL STRESSES PER NODE

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
1	0.26543308E-01	-1.7896177	-7.8494661	7.8760094	7.1432
2	0.58205566	-1.1370343	-6.1970223	6.7790780	6.1049
3	0.88398890	-0.64336406	-4.8259840	5.7099729	5.1215
4	1.2997939	-0.12993096	-3.5083356	4.8081295	4.2816
5	1.8182556	0.38485443	-2.2949797	4.1132352	3.6410
6	4.4396211	1.2036840	-2.1804995	6.6201206	5.7598
7	-0.79203846E-01	-2.2112266	-7.5437706	7.4645667	6.6604
8	0.34353197	-1.6337235	-6.0028549	6.3463868	5.6275
9	0.39010237	-1.2349589	-4.6896164	5.0797188	4.4970
10	0.43353036	-0.84735605	-3.4200211	3.8535515	3.4040
11	0.56292299	-0.46045808	-2.2496741	2.8125971	2.4723
12	1.5157941	0.20875427	-0.97052309	2.4863172	2.1649
13	-0.15920047	-2.2085772	-6.4138890	6.2546886	5.5246

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
14	0.14411730	-1.7722257	-5.2228038	5.3669211	4.7129
15	0.17623846	-1.4554890	-4.1657050	4.3419434	3.8004
16	0.25222183	-1.1273636	-3.1212313	3.3734532	2.9390
17	0.44264760	-0.77757696	-2.1252980	2.5679456	2.2280
18	0.95392416	-0.34274423	-1.1739861	2.1279103	1.8638
19	-0.12073204	-2.0478035	-5.2682997	5.1475677	4.5062
20	0.74249562E-01	-1.7737109	-4.5105169	4.5847665	3.9966
21	0.10667878	-1.5671540	-3.8190615	3.9257403	3.4127
22	0.13568239	-1.3621168	-3.1332138	3.2688962	2.8348
23	0.15270196	-1.1662376	-2.4701243	2.6228262	2.2734
24	0.37410439	-0.88593949	-1.7344816	2.1085860	1.8448
25	-0.81106115E-01	-1.8826296	-4.3588598	4.2777537	3.7217
26	0.17265152E-01	-1.7418710	-3.9505620	3.9678271	3.4445

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
27	0.25541720E-01	-1.6368891	-3.5733265	3.5988682	3.1200
28	0.31145307E-01	-1.5303770	-3.1903280	3.2214733	2.7904
29	0.43851526E-01	-1.4203404	-2.8047037	2.8485552	2.4683
30	0.15119894	-1.2744861	-2.3966026	2.5478016	2.2154
31	-0.37283123E-01	-1.7359786	-3.6476713	3.6103882	3.1300
32	-0.66401347E-02	-1.6989704	-3.5191000	3.5124599	3.0432
33	0.98142927E-03	-1.6687527	-3.3905361	3.3915175	2.9373
34	0.67266927E-02	-1.6378753	-3.2582603	3.2649870	2.8276
35	0.11626003E-01	-1.6081075	-3.1292151	3.1408411	2.7209
36	0.41463310E-01	-1.5706608	-2.9999822	3.0414455	2.6371
37	0.10117754E-01	-1.6380557	-3.1411255	3.1512433	2.7310

38	-0.74701713E-02	-1.6763754	-3.2164080	3.2089378	2.7802
39	-0.47294858E-03	-1.7013156	-3.2709744	3.2705015	2.8331

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
40	0.44961925E-02	-1.7261467	-3.3223449	3.3268411	2.8819
41	0.10893223E-01	-1.7514729	-3.3759719	3.3868652	2.9340
42	-0.70694463E-02	-1.7909304	-3.4515529	3.4444834	2.9842
43	0.46255244E-01	-1.6131033	-2.8378185	2.8840738	2.5075
44	-0.44293083E-03	-1.6965293	-3.0342382	3.0337953	2.6336
45	0.56077218E-02	-1.7544523	-3.1970413	3.2026490	2.7781
46	0.10780737E-01	-1.8121200	-3.3566051	3.3673858	2.9195
47	0.17767310E-01	-1.8707045	-3.5194965	3.5372639	3.0657
48	-0.29679788E-01	-1.9566191	-3.7174892	3.6878094	3.1948
49	0.58666500E-01	-1.6751170	-2.7317292	2.7903957	2.4401
50	0.34911567E-02	-1.7722625	-2.9639033	2.9673944	2.5864
51	0.10229849E-01	-1.8399379	-3.1581827	3.1684126	2.7568
52	0.14506741E-01	-1.9080030	-3.3495665	3.3640732	2.9233

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
53	0.20870259E-01	-1.9766610	-3.5432456	3.5641159	3.[illegible]1
54	-0.34854258E-01	-2.0762246	-3.7760676	3.7412133	3.2445
55	0.36251758E-01	-1.8344941	-2.8343677	2.8706195	2.5241
56	-0.47009727E-02	-1.9112892	-3.0098991	3.0051981	2.6338
57	0.40461410E-02	-1.9629725	-3.1501665	3.1542126	2.7593
58	0.13160431E-01	-2.0144287	-3.2885788	3.3017392	2.8842
59	0.20036044E-01	-2.0699205	-3.4367198	3.4567558	3.0157
60	-0.25568865E-01	-2.1515638	-3.6180338	3.5924650	3.1291
61	0.47283155E-02	-2.0791844	-3.1489207	3.1536490	2.7790
62	-0.98740168E-02	-2.1061923	-3.1804310	3.1705570	2.7932
63	-0.18113856E-01	-2.1294198	-3.2051656	3.1870517	2.8082
64	-0.25677059E-01	-2.1485452	-3.2164162	3.1907392	2.8133
65	-0.52399619E-02	-2.1534165	-3.2075177	3.2022778	2.8278

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A22 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
66	-0.64766270E-04	-2.1746477	-3.2372781	3.2372133	2.8606
67	-0.62607139E-01	-2.4026049	-3.6780346	3.6154275	3.1781
68	0.19854822E-01	-2.3331792	-3.4792135	3.4990683	3.0906
69	0.11075961	-2.2475621	-3.2350974	3.3458570	2.9775
70	0.16765180	-2.1755290	-3.0022769	3.1699287	2.8488
71	0.11964296	-2.1484168	-2.8151526	2.9347956	2.[illegible]5
72	0.15325259	-2.0607927	-2.5098018	2.6630543	2.4[illegible]1
73	-0.23582201	-2.9675336	-4.9667151	4.7308931	4.1280
74	-0.10894030	-2.6976339	-4.1376958	4.0287555	3.5394
75	-0.26204297	-2.5586732	-3.4713052	3.2092622	2.8647
76	-0.35795802	-2.4243133	-2.8829512	2.5249931	2.3380

77	-0.22873599	-2.1691022	-2.5245308	2.2957948	2.1433
78	-0.16004378	-2.2711092	-2.4848572	2.3248134	2.2257

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
79	0.43664521	-3.2295503	-6.2911456	6.7277908	5.8343
80	1.1755890	-2.5198009	-4.6006356	5.7762246	5.0676
81	1.7613544	-1.9667055	-3.2818768	5.0432312	4.5323
82	2.6149238	-1.3919056	-2.1620943	4.7770181	4.4481
83	4.1971727	-0.75119911	-1.6731249	5.8702975	5.4863
84	6.4041853	0.41846950E-01	-1.0761322	7.4803175	6.9892
85	0.19869285	-2.7564669	-5.0201220	5.2188149	4.5557
86	0.81128543	-2.1180553	-3.4528155	4.2641009	3.7921
87	1.0369430	-1.7375952	-2.3660303	3.4029733	3.1383
88	1.3481797	-1.1473132	-1.7051208	3.0533005	2.8274
89	2.1566694	-0.94397812	-1.5746305	3.7312999	3.4663
90	4.1026685	-0.36710455	-0.80071305	4.9033816	4.7016
91	-0.25300769E-01	-1.0964768	-2.2267317	2.2014309	1.9119

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
92	0.30649531	-1.1859376	-1.6156792	1.9221745	1.7644
93	0.61505777	-1.2889286	-1.3717275	1.9867853	1.9477
94	0.71291599	-0.95915495	-1.3300370	2.0429530	1.8952
95	0.90721253	-0.46509360	-1.0458633	1.9530759	1.7703
96	1.0798039	-0.15332301	-0.84772556	1.9275295	1.7191
97	2.1930791	0.37060580E-02	-0.20631793	2.3993970	2.3039
98	1.4040823	-0.36429192	-0.80277675	2.2068590	2.0253
99	1.2097176	-0.67425125	-1.1984634	2.4081810	2.1963
100	1.0106798	-0.99098790	-1.4520336	2.4627133	2.2769
101	0.31914785	-1.3967565	-2.1108984	2.4300462	2.1941
102	-0.23615644	-1.7125289	-2.6817879	2.4456314	2.2148
103	4.2235926	0.58238775	0.13035477	4.0932378	3.8884
104	2.1660982	-0.30830191	-0.78648017	2.9525784	2.7532

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A23 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
105	1.0960367	-0.82355419	-1.4355482	2.5315848	2.3131
106	0.40115539	-1.2757661	-2.2470674	2.6482228	2.3495
107	0.65026104	-1.3535866	-2.7443373	3.3945984	3.0139
108	-0.37223898	-2.8613350	-6.7232683	6.3510293	5.5649
109	4.6950112	0.81052024	0.27011885	4.4248923	4.1810
110	2.3218502	-0.18780521	-0.69411727	3.0159674	2.7981
111	0.97552290	-0.81477135	-1.4450176	2.4205405	2.1773
112	-0.31243359	-1.6313989	-2.8935539	2.5811203	2.2447
113	-1.7472755	-2.8128016	-5.4269100	3.6796344	3.2862
114	-5.1391669	-6.3737829	-12.845598	7.7064309	7.1816
115	4.0893937	0.63506199	0.18044116	3.9089525	3.7035

116	2.2589260	-0.17633646	-0.70154405	2.9604701	2.7393
117	1.2479306	-0.71038178	-1.4766298	2.7245604	2.4406

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
118	0.27768681	-1.2711894	-2.3858464	2.6635332	2.3216
119	-1.1676608	-2.0110506	-3.4224600	2.2547992	1.9762
120	-2.4481349	-3.2150638	-5.3317570	2.8836220	2.6281
121	2.9745371	0.30044700	0.10292535	2.8716117	2.7798
122	2.0243338	-0.19498296	-0.60016850	2.6245023	2.4531
123	1.6547144	-0.52101183	-1.3156874	2.9704018	2.6708
124	1.1389809	-0.84995152	-1.8930135	3.0319944	2.6768
125	0.17668416	-1.2503363	-2.2591974	2.4358816	2.1312
126	-0.86262965	-1.6967280	-2.6985115	1.8358819	1.5968
127	1.6855264	0.61108595E-01	-0.81545366E-01	1.7670718	1.7003
128	1.6271330	-0.22287344	-0.39363183	2.0207648	1.9435
129	1.8113261	-0.36073860	-0.97794242	2.7892685	2.5410
130	1.7968266	-0.47408603	-1.3226484	3.1194749	2.8008

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
131	1.4749921	-0.62863355	-1.4899475	2.9649396	2.[illegible]5
132	1.1273143	-0.73307761	-1.4581221	2.5854365	2.3151
133	0.74678827	0.12264209	-0.32814039	1.0749287	0.94798
134	1.1377072	-0.19025746E-01	-0.25703655	1.3947438	1.3115
135	1.7180562	-0.19013501	-0.35936255	2.0774187	2.0010
136	2.2710171	-0.96967399E-01	-0.56428112	2.8352982	2.6389
137	2.7056786	-0.14835117E-01	-0.67900906	3.3846877	3.1126
138	2.9947904	0.44581029E-01	-0.71316723	3.7079576	3.3971
139	0.32958823	0.74208831E-01	-0.44797305	0.77756128	0.68647
140	0.76731991	0.13164258	-0.30356911	1.0708890	0.94650
141	1.7940750	0.98535921E-01	-0.13079191E-01	1.8071542	1.7541
142	3.2886260	0.44678349	0.18291785	3.1057081	2.9848
143	4.7566653	0.89826496	0.28975618	4.4669091	4.1976

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A24 of A33

sdr. weld

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
144	5.8152777	1.2165941	0.38278467	5.4324930	5.0678
145	-1.3460278	-4.2420238	-10.777878	9.4318501	8.3705
146	-0.23471550	-1.9914855	-4.3455328	4.1108173	3.6444
147	-0.61506171	-1.4416289	-2.1339411	1.5188794	1.3325
148	1.0298966	-0.70717002	-1.2407891	2.2706857	2.0582
149	3.1263933	0.86522323E-01	-0.64190702	3.7683004	3.4[illegible]
150	6.2474054	1.3360186	0.45168050	5.7957249	5.4[illegible]
151	-1.4521574	-3.9401819	-9.7997328	8.3475754	7.4234
152	-0.26872659	-2.0502031	-4.5613688	4.2926422	3.7733
153	-0.35891870	-1.3491789	-2.0430933	1.6841746	1.4845
154	1.0508329	-0.61722053	-1.1043859	2.1552188	1.9648

155	3.0629726	0.82148120E-01	-0.52952177	3.5924944	3.3356
156	6.0253398	1.2462542	0.47975705	5.5455828	5.2050

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

str. lil

NODE	SIG1	SIG2	SIG3	SI	SI
157	-1.9689094	-3.2364653	-7.0572979	5.0883885	4.6027
158	-1.0947355	-2.2333594	-4.3960150	3.3012795	2.9065
159	-0.11904926	-1.3555696	-2.3097387	2.1906894	1.9056
160	1.1362360	-0.55752274	-1.0753807	2.2116167	2.0117
161	2.8282710	0.32745888E-01	-0.41002363	3.2382946	3.0494
162	5.2673342	0.97882442	0.44462388	4.8227103	4.5796
163	0.58664573E-01	-1.4412283	-3.1467187	3.2053833	2.7930
164	0.27396942	-1.4172177	-3.0757326	3.3497020	2.9054
165	0.66862535	-0.99272056	-1.8957410	2.5643663	2.2593
166	1.2948263	-0.53009205	-1.0069379	2.3017642	2.1137
167	2.4026533	-0.35176742E-01	-0.32782862	2.7304819	2.5986
168	4.2402894	0.63518493	0.41163169	3.8286577	3.7224
169	0.26860106	-1.0245264	-1.9988227	2.2674238	1.9856

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
170	0.50062726	-1.0323992	-2.0471483	2.5477755	2.2323
171	0.78662411	-0.80622887	-1.3991937	2.1858178	1.9651
172	1.2205109	-0.54213246	-0.78431137	2.0048223	1.8982
173	1.6905677	-0.21002854E-01	-0.31755449	2.0081221	1.8867
174	2.7265476	0.20230266	0.97982913E-01	2.6285647	2.5788
175	0.43482975	0.25968762E-01	-0.26418371	0.69901347	0.61354
176	0.39906990	0.91846731E-01	-0.20962157E-01	0.42003205	0.38036
177	0.28033114	0.12807140	-0.19337600E-01	0.29966874	0.26241
178	0.15974598	0.14287720	-0.33179167E-01	0.19292515	0.18508
179	0.13370232	0.39263164E-02	-0.64056431E-01	0.19775875	0.17424
180	0.85842570E-01	-0.15749237	-0.21738846	0.30323103	0.28093
181	0.22686848	-0.26317526	-0.45350884	0.68037731	0.61575
182	0.20285078	-0.87671892	-1.6750495	1.8779003	1.6460

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A25 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
183	0.49819594	0.25836229E-01	-0.78275951E-01	0.57647189	0.53212
184	0.40106091	0.73838400E-01	-0.12771507E-01	0.41383242	0.37960
185	0.24373653	0.42607245E-01	-0.68099736E-01	0.31183626	0.27416
186	0.96619832E-01	0.35771354E-01	-0.10876420	0.20538403	0.18578
187	0.72197735E-01	-0.39014262E-01	-0.14739674	0.21959448	0.19075
188	0.13256157	-0.19035617	-0.26898144	0.40154301	0.37183
189	0.28050472	-0.33009227	-0.40870646	0.68921117	0.65453
190	0.28530929	-0.63671809	-0.98607228	1.2713816	1.1521
191	0.59376153	-0.73637493	-1.1772644	1.7710260	1.6084
192	0.80989612	-0.45844196	-0.78358955	1.5934857	1.4670
193	1.1051775	-0.23892477	-0.54649724	1.6516747	1.5386

194	0.58037249	0.18480227	-0.13685756E-01	0.59405824	0.53154
195	0.28123547	0.10187138	-0.29195873E-01	0.31043135	0.27257

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
196	0.47665632E-01	-0.49030845E-01	-0.16016494	0.20783058	0.18364
197	0.14179261	-0.35620904	-0.45249898	0.59429160	0.55404
198	0.32804029	-0.49390440	-0.66589178	0.99393207	0.92988
199	0.20467062	-0.40058516	-0.89193576	1.0966064	0.95977
200	0.26046738	-0.73234071E-01	-0.90638125	1.1668486	1.0440
201	0.38816190E-01	-0.96196842E-01	-0.67123887	0.71005506	0.65558
202	-0.12201303	-0.18579599	-0.42774241	0.30572938	0.28249
203	-0.12803282	-0.45829403	-0.48042345	0.35239063	0.34202
204	-0.55936830E-01	-0.53655183	-0.75183777	0.69590094	0.61725
205	-0.91856382E-01	-0.60320041	-1.0671538	0.97529742	0.85461
206	1.0217391	0.98940170	0.33818712	0.68355199	0.66798
207	0.58905465	0.48634814	0.96045711E-01	0.49300893	0.45241
208	0.32655937	0.47885938E-01	-0.13969372	0.46625309	0.40657

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
209	0.17135491	-0.35432156	-0.38283526	0.55419017	0.5[illegible]4
210	0.84144035E-01	-0.60774863	-0.74813521	0.83227925	0.77[illegible]18
211	-0.89037204E-01	-0.94114806	-1.1949694	1.1059322	1.0054
212	0.75360933	0.54917944	-0.56076016E-01	0.80968534	0.72933
213	0.30418559	0.19699411	-0.19650996	0.50069555	0.45936
214	0.56113440E-01	-0.53598120E-01	-0.24186159	0.29797503	0.26626
215	0.23582608E-01	-0.42715076	-0.44680242	0.47038503	0.46111
216	0.25168617E-01	-0.71390086	-0.81048470	0.83565332	0.79181
217	-0.12125123	-1.0841598	-1.2690532	1.1478020	1.0674
218	0.80830341	0.59517407	-0.57537386E-03	0.80887878	0.72618
219	0.35217844	0.26069827	-0.14610416	0.49828260	0.45967
220	0.26528842E-01	-0.50340116E-01	-0.21391817	0.24044701	0.21734
221	-0.30359047E-01	-0.43210402	-0.44726054	0.41690149	0.40954

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
222	-0.14198588E-01	-0.72585988	-0.84032407	0.82612548	0.77532
223	-0.14971923	-1.0957093	-1.3047658	1.1550466	1.0660
224	0.86264981	0.65868297	0.18804902E-01	0.84384491	0.76269
225	0.38055944	0.29062781	-0.13651904	0.51707848	0.47863
226	0.62790605E-01	-0.31117763E-01	-0.20178716	0.26457777	0.23694
227	-0.57592668E-02	-0.43345671	-0.45021466	0.44445540	0.4[illegible]3
228	-0.50036755E-02	-0.74242282	-0.86039428	0.85539060	0.8[illegible]0
229	-0.15066645	-1.1230824	-1.3428840	1.1922176	1.0990
230	0.92752933	0.75040244	0.41801418E-01	0.88572791	0.81200
231	0.41601947	0.34475328	-0.13259388	0.54861335	0.51680
232	0.92017675E-01	-0.19951316E-01	-0.21320482	0.30522249	0.27198

233	0.12242074E-01	-0.45195373	-0.46776261	0.48000469	0.47255
234	0.70678761E-02	-0.79139770	-0.89010429	0.89717217	0.85218

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
235	-0.15315790	-1.2073166	-1.4002141	1.2470562	1.1628
236	0.99111575	0.85181345	0.53842989E-01	0.93727276	0.87621
237	0.45117575	0.40638571	-0.13580751	0.58698326	0.56602
238	0.12453492	-0.74216232E-02	-0.22340871	0.34794363	0.30863
239	0.25962279E-01	-0.46546335	-0.49446778	0.52043006	0.50701
240	0.15004134E-01	-0.85225868	-0.92380473	0.93880887	0.90521
241	-0.16012208	-1.3108735	-1.4632455	1.3031234	1.2342
242	1.0510605	0.95149796	0.63090021E-01	0.98797051	0.94234
243	0.48462469	0.46595894	-0.14070039	0.62532508	0.61629
244	0.15452117	0.37765533E-02	-0.23424937	0.38877054	0.34386
245	0.37853099E-01	-0.47586288	-0.52296326	0.56081636	0.53933
246	0.21321446E-01	-0.91182353	-0.95610568	0.97742712	0.95609
247	-0.16762518	-1.4111111	-1.5228777	1.3552525	1.3031

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
248	1.1046691	1.0409294	0.70422187E-01	1.0342469	1.0040
249	0.52454247	0.50945075	-0.14557261	0.67011508	0.66274
250	0.18087809	0.13716757E-01	-0.24403609	0.42491419	0.37514
251	0.47731752E-01	-0.48546999	-0.54880700	0.59653875	0.56812
252	0.26470568E-01	-0.96546690	-0.98527313	1.0117437	1.0020
253	-0.17455223	-1.5007261	-1.5763079	1.4017557	1.3656
254	1.1514195	1.1171426	0.76466021E-01	1.0749534	1.0583
255	0.56630704	0.53928748	-0.14990685	0.71621389	0.70327
256	0.20312369	0.22389091E-01	-0.25242820	0.45555189	0.40172
257	0.55903864E-01	-0.49387944	-0.57089784	0.62680170	0.59273
258	0.30627307E-01	-1.0068415	-1.0151716	1.0457989	1.0416
259	-0.18064482	-1.5770042	-1.6228370	1.4421922	1.4199
260	1.1918509	1.1791098	0.81380760E-01	1.1104701	1.1041

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A27 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
261	0.60341756	0.56156888	-0.15353341	0.75695097	0.73713
262	0.22070174	0.29873449E-01	-0.25923317	0.47993491	0.42297
263	0.62239647E-01	-0.50107268	-0.58875541	0.65099505	0.61261
264	0.33762179E-01	-1.0327223	-1.0484726	1.0822348	1.0744
265	-0.18597059	-1.6388919	-1.6629216	1.4769510	1.4651
266	1.2316163	1.2238182	0.84484044E-01	1.1471322	1.1432
267	0.63194967	0.58150210	-0.15675269	0.78870235	0.76495
268	0.23322120	0.36747613E-01	-0.26358630	0.49680750	0.43784
269	0.65308334E-01	-0.50772341	-0.60252589	0.66783422	0.62662
270	0.35125465E-01	-1.0524779	-1.0775760	1.1127015	1.1004
271	-0.19098915	-1.6871478	-1.6988617	1.5078725	1.5020

272	1.2676740	1.2652240	0.86211357E-01	1.1814626	1.1802
273	0.65712014	0.60267741	-0.15914002	0.81626016	0.79065

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
274	0.23948914	0.43672009E-01	-0.26508427	0.50457341	0.44523
275	0.63933239E-01	-0.51478307	-0.61276104	0.67669428	0.63426
276	0.32629011E-01	-1.0740254	-1.1046062	1.1372352	1.1222
277	-0.19869867	-1.7260983	-1.7391282	1.5404295	1.5339
278	1.3654992	1.3344601	0.10036102	1.2651382	1.2499
279	0.68931940	0.63735590	-0.16026718	0.84958658	0.82513
280	0.23359466	0.52597306E-01	-0.25611225	0.48970692	0.43417
281	0.48744423E-01	-0.52622644	-0.62001168	0.66875610	0.62844
282	0.20895846E-01	-1.1123826	-1.1447747	1.1656706	1.1498
283	-0.22942663	-1.8082365	-1.8401625	1.6107359	1.5950
284	1.3605807	1.3605807	0.10777314	1.2528076	1.2528
285	0.63115061	0.63115061	-0.12522150	0.75637211	0.75637
286	0.55982188E-01	0.50121031E-01	-0.87939189E-01	0.14392138	0.14392

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
287	-0.56762169E-01	-0.53133246	-0.53133246	0.47457029	0.4[illegible]7
288	-0.14174575E-01	-1.1141511	-1.1141511	1.0999765	1.0999
289	-0.24998730	-1.8491533	-1.8491533	1.5991659	1.5991
290	0.66757931	0.56462664	-0.96816317E-03	0.66854748	0.62347
291	0.56033365	0.49908696	0.12830646	0.43202719	0.40636
292	0.36879660	0.35853118	0.58726253E-01	0.31007035	0.30507
293	0.33473322	0.22413767	0.33218257E-01	0.30151496	0.26441
294	0.33492022	0.92128886E-01	0.30991937E-01	0.30392828	0.27844
295	0.30591639	0.85187188E-02	-0.56845137E-01	0.36276152	0.33562
296	0.19597133	-0.21445032	-0.45599349	0.65196482	0.57583
297	-0.21757307	-1.3373678	-2.7895229	2.5719498	2.2572
306	0.78860114	0.28854711	-4.1075411	4.8961423	4.6662
307	-0.23116580	-0.73261880	-3.6146554	3.3834896	3.1639

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A28 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
308	-0.10264963	-0.23713412	-1.7287871	1.6261375	1.5638
309	0.44324824	-0.23845409	-0.51887121	0.96211946	0.88219
310	1.6701878	0.19904865	-0.32315109	1.9933389	1.7909
311	3.0708593	0.45422274	-0.53420075	3.6050601	3.2264
312	2.9798340	2.4296296	0.52700053	2.4528335	2.2912
313	1.2397574	0.67558330	-0.32552148	1.5652789	1.4[illegible]
314	0.57045430	0.34252494	-0.72126451	1.2917188	1.19[illegible]9
315	0.48552817	-0.35139255	-0.74372075	1.2292489	1.0939
316	0.10843130	-0.79979676	-1.1711817	1.2796130	1.1705
317	-0.84230094E-01	-1.2588849	-2.1262150	2.0419849	1.8648
318	2.7503028	1.6580092	0.46579998	2.2845029	1.9790

319	1.3406625	0.64782350	-0.30545402	1.6461165	1.4471
320	0.76490391	0.49783819	-0.59423543	1.3591393	1.2530

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
321	0.68855161	-0.32445812	-0.76820592	1.4567575	1.2947
322	0.53510916	-0.51218803	-1.0524110	1.5875201	1.4206
323	0.11533964	-0.57503308	-2.0228690	2.1382086	1.9095
324	2.9019128	1.8159052	0.42964373	2.4722691	2.1467
325	1.5869105	0.98145070	-0.12153154	1.7084421	1.5033
326	0.75458786	0.56044260	-0.51289814	1.2674860	1.1881
327	0.62878703	-0.36032667	-0.76151520	1.3903022	1.2415
328	0.24064832	-0.87950390	-1.3348632	1.5755115	1.4157
329	-0.31536711	-1.3203303	-2.5212214	2.2058543	1.9142
330	3.1030563	2.1153043	0.39944583	2.7036104	2.3711
331	1.7469986	1.2463383	-0.11430471	1.8613034	1.6693
332	0.80823443	0.63807934	-0.41921046	1.2274449	1.1564
333	0.47101401	-0.43135503	-0.77118558	1.2421996	1.1164

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
334	0.12885368	-1.0737326	-1.5046428	1.6334965	1.4709
335	-0.46985833	-1.8373821	-2.8563315	2.3864732	2.0766
336	3.3460152	2.5081273	0.43173667	2.9142786	2.6002
337	1.8873181	1.4717811	-0.10661427	1.9939324	1.8225
338	0.84335832	0.69220907	-0.36045505	1.2038134	1.1403
339	0.37328167	-0.47484517	-0.74595756	1.1192392	1.0183
340	0.52281057E-01	-1.2716719	-1.6587243	1.7110054	1.5555
341	-0.53755105	-2.3001197	-3.1333670	2.5958160	2.2972
342	3.5820554	2.8969909	0.47514171	3.1069137	2.8285
343	2.0159242	1.6761961	-0.94214786E-01	2.1101390	1.9627
344	0.87565493	0.73308535	-0.30348725	1.1791422	1.1187
345	0.29457818	-0.51715641	-0.73752191	1.0321001	0.95002
346	0.15074623E-01	-1.4700066	-1.7937858	1.8088604	1.6713

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A29 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
347	-0.57786277	-2.6930239	-3.3690161	2.7911533	2.5232
348	3.7987588	3.2550818	0.51940549	3.2793533	3.0449
349	2.1334834	1.8631461	-0.79815254E-01	2.2132986	2.0914
350	0.89936329	0.76949686	-0.25347563	1.1528389	1.0976
351	0.23157927	-0.55072881	-0.74582060	0.97739987	0.90344
352	-0.46650769E-02	-1.6535002	-1.9122031	1.9075380	1.7926
353	-0.61525204	-3.0425065	-3.5802296	2.9649775	2.7368
354	3.9916131	3.5728394	0.55936038	3.4322527	3.2437
355	2.2385071	2.0313042	-0.67658139E-01	2.3061653	2.2100
356	0.91921951	0.80344434	-0.21161415	1.1308337	1.0817
357	0.17920809	-0.58275694	-0.75563569	0.93484378	0.86862

358	-0.17343416E-01	-1.8189118	-2.0165703	1.9992269	1.9083
359	-0.65100727	-3.3539534	-3.7694872	3.1184799	2.9334

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
360	4.1602030	3.8491135	0.59382682	3.5663762	3.4218
361	2.3305970	2.1798033	-0.58573981E-01	2.3891710	2.3175
362	0.94248002	0.82972385	-0.17806597	1.1205460	1.0721
363	0.13536839	-0.61317374	-0.76395465	0.89932304	0.84170
364	-0.26534933E-01	-1.9653052	-2.1079182	2.0813833	2.0140
365	-0.68362269	-3.6274056	-3.9365268	3.2529041	3.1102
366	4.3052998	4.0849541	0.62295652	3.6823433	3.5775
367	2.4097931	2.3080921	-0.52154426E-01	2.4619476	2.4127
368	0.96141020	0.85626894	-0.15240963	1.1138198	1.0683
369	0.10028362	-0.63713734	-0.77600465	0.87628827	0.82295
370	-0.33591927E-01	-2.0922876	-2.1866253	2.1530334	2.1075
371	-0.71221556	-3.8621242	-4.0811287	3.3689131	3.2651
372	4.4279438	4.2814768	0.64712185	3.7808220	3.7099

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	
373	2.4762876	2.4160474	-0.47821713E-01	2.5241093	2.4[illegible]
374	0.97564843	0.88282706	-0.13394571	1.1095941	1.0691
375	0.75246179E-01	-0.66098059	-0.78720148	0.86244766	0.81375
376	-0.39402858E-01	-2.1997131	-2.2528784	2.2134755	2.1874
377	-0.73687174	-4.0581120	-4.2039135	3.4670417	3.3966
378	4.5297482	4.4395613	0.66675353	3.8629946	3.8187
379	2.5301805	2.5039364	-0.45162645E-01	2.5753432	2.5623
380	0.98523429	0.90821524	-0.12177185	1.1070061	1.0734
381	0.58839894E-01	-0.68701942	-0.79445852	0.85329841	0.81215
382	-0.45273412E-01	-2.2855667	-2.3089978	2.2637244	2.2521
383	-0.75926628	-4.2168688	-4.3072015	3.5479352	3.5037
384	4.6163222	4.5628222	0.68475268	3.9315696	3.9051
385	2.5773868	2.5652950	-0.43467442E-01	2.6208542	2.6148

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A30 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
386	0.99554828	0.92354020	-0.11494113	1.1104894	1.0785
387	0.46637896E-01	-0.69986081	-0.80783231	0.85447021	0.81175
388	-0.53311734E-01	-2.3445702	-2.3590614	2.3057497	2.2985
389	-0.78507494	-4.3442272	-4.3982475	3.6131726	3.5865
390	4.7143829	4.6871427	0.71893374	3.9954492	3.981[illegible]
391	2.6137334	2.5995614	-0.39742561E-01	2.6534760	2.64[illegible]
392	0.99866547	0.93245945	-0.10269649	1.1013620	1.0714
393	0.23927346E-01	-0.70920404	-0.80885070	0.83277804	0.79274
394	-0.68542622E-01	-2.3776621	-2.3974802	2.3289376	2.3191
395	-0.83695120	-4.4791712	-4.5058798	3.6689286	3.6556
396	4.7404601	4.7404601	0.73857558	4.0018845	4.0018

397	2.5990511	2.5990511	-0.23050365E-01	2.6221015	2.6221
398	0.93539311	0.93539311	-0.30658040E-01	0.96605115	0.96605

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
399	-0.87667410E-01	-0.71459160	-0.71459160	0.62692419	0.62692
400	-0.10050938	-2.3805802	-2.3805802	2.2800708	2.2800
401	-0.87525933	-4.5403925	-4.5403925	3.6651331	3.6651
402	-0.30415531	-1.1943080	-6.9709384	6.6667831	6.2695
403	-0.14614900	-0.84797185	-5.9565801	5.8104310	5.4955
404	-0.36922643	-0.67281783	-5.1398483	4.7706218	4.6295
405	-0.47745435	-0.67112584	-4.3813809	3.9039265	3.8119
406	-0.37901650	-0.68252106	-3.8524905	3.4734740	3.3329
407	0.52220299	0.11417079	-2.9807248	3.5029278	3.3273
408	-0.17399562E-01	-0.24855312	-5.6546941	5.6372945	5.5253
409	0.49682485E-01	-0.15097194	-5.3922620	5.4419445	5.3445
410	0.47443693E-01	-0.10570121	-5.2355921	5.2830358	5.2081
411	0.87602169E-01	-0.46343115E-01	-5.0749144	5.1625166	5.0968

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
412	0.23033935	0.56055243E-01	-4.8731433	5.1034827	5.0187
413	0.98397383E-01	-0.68166505E-01	-4.9137092	5.0121066	4.9312
414	0.94999575	0.43627670	-3.7095456	4.6595414	4.4258
415	0.66400839	0.37354465	-4.6115612	5.2755696	5.1407
416	0.73470078	0.52398477	-5.3142274	6.0489281	5.9477
417	0.97596981	0.46220204	-5.8818373	6.8578071	6.6172
418	1.0210456	0.33709096	-6.3310105	7.3520562	7.0353
419	0.75723383	0.24375632	-6.3571627	7.1143965	6.8748
420	1.6262918	1.0459138	-3.6071801	5.2334718	4.9713
421	0.82838993	0.26659308	-5.5181676	6.3465576	6.0892
422	0.33123716	-0.11372129E-01	-7.0782120	7.4094492	7.2454
423	-0.39645285E-01	-0.38036364	-8.6927413	8.6530960	8.4905
424	-0.82080199E-02	-0.77735655	-10.434736	10.426528	10.075

***** POST1 NODAL STRESS LISTING *****

Calc. Pckg VSC02.6.2.3.25
Rev. No: 2
Pg. A31 of A33

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
425	-0.80239131	-1.5738543	-12.508698	11.706306	11.349
426	2.0046662	1.5422351	-5.0677719	7.0724381	6.8581
427	1.3600315	0.96953385	-6.4304433	7.7904748	7.6060
428	0.93741659	0.75153722	-7.6758214	8.6132380	8.5231
429	0.69156228	0.47283419	-9.0002523	9.6918146	9.5852
430	0.63185463	0.50631167E-01	-10.495355	11.127209	10.851
31	0.30621696E-01	-0.75746331	-12.583603	12.614225	12.239
432	1.5380430	0.50287848	-6.7534748	8.2915179	7.8257
433	1.3126120	0.32758540	-7.3566333	8.6692452	8.2216
434	1.1284963	0.27177236	-7.9387989	9.0672952	8.6713
435	0.93389177	0.20041663	-8.5374498	9.4713416	9.1272

436	0.71931686	0.73280348E-01	-9.1444088	9.8637256	9.5573
437	0.48326378	-0.13370233	-9.7376320	10.220896	9.9269

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
438	1.1670951	0.10649909	-7.5652018	8.7322969	8.2532
439	1.0793696	0.41739723E-01	-7.8156595	8.8950291	8.4243
440	1.0153501	0.30231551E-01	-8.0396606	9.0550106	8.6048
441	0.95253727	0.23623289E-01	-8.2634469	9.2159841	8.7884
442	0.89838092	0.42891674E-01	-8.4829620	9.3813429	8.9843
443	0.81176398	-0.31081191E-02	-8.7437346	9.5554986	9.1753
444	0.80535112	0.46468844E-01	-8.1201598	8.9255109	8.5713
445	0.79661463	0.31503183E-01	-8.1502132	8.9468279	8.5898
446	0.78463299	0.12123889E-01	-8.1870404	8.9716734	8.6114
447	0.77233071	-0.69081664E-02	-8.2255164	8.9978471	8.6346
448	0.75802686	-0.32083529E-01	-8.2647996	9.0228264	8.6548
449	0.74880004	-0.50241570E-01	-8.2934709	9.0422710	8.6704
450	-0.10001528	-3.3855012	-12.900456	12.800441	11.532

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	
451	3.0444762	-0.19831207E-01	-4.7971731	7.8416493	6.8[illegible]
452	-0.21422625	-1.1672212	-6.9359211	6.7216948	6.3107
453	2.0993903	0.67934673	-3.0657759	5.1651662	4.6351
454	0.14518273	-0.46918654E-01	-4.2993393	4.4445220	4.3523
455	0.29318239	0.38806532E-02	-3.8659347	4.1591171	4.0226
456	1.5933354	0.91653368	-2.7346313	4.3279667	4.0596
457	1.5801879	0.55615608	-1.7453242	3.3255122	2.9885
458	2.1300659	0.53008969	-4.2211681	6.3512340	5.8112
459	2.1739272	0.19165985	-1.1750820	3.3490093	2.9166
460	0.33906178	0.56033180E-04	-8.4639151	8.8029769	8.6384
461	0.35664364	0.89000303E-02	-8.4217722	8.7784158	8.6098
462	0.36862506	0.48108453E-02	-8.3853902	8.7540153	8.5778
463	0.38059848	0.41911956E-03	-8.3491119	8.7297104	8.5459

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
464	0.39344019	-0.23497937E-02	-8.3119390	8.7053792	8.5143
465	0.41198762	0.76762816E-02	-8.2691293	8.6811169	8.4861
466	0.39019452E-01	-0.12377073E-01	-8.6273935	8.6664130	8.6408
467	0.52959937E-01	-0.40769011E-02	-8.5908243	8.6437842	8.6154
468	0.62895704E-01	-0.50132169E-02	-8.5581886	8.6210843	8.58[illegible]
469	0.72914777E-01	-0.59675539E-02	-8.5254970	8.5984118	8.55[illegible]
470	0.82802300E-01	-0.74495127E-02	-8.4929642	8.5757665	8.5310
471	0.97008987E-01	0.58782555E-03	-8.4561894	8.5531984	8.5053
472	0.63157908E-02	-0.71257849E-01	-8.7501396	8.7564554	8.7179
473	0.10767971E-01	-0.65352818E-01	-8.7335448	8.7443127	8.7065
474	0.12058341E-01	-0.60848038E-01	-8.7182674	8.7303257	8.6941

475	0.13344410E-01	-0.56312895E-01	-8.7029455	8.7162899	8.6816
476	0.14746934E-01	-0.51694598E-01	-8.6875245	8.7022715	8.6692

***** POST1 NODAL STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

NODE	SIG1	SIG2	SIG3	SI	SI
477	0.19395979E-01	-0.45552973E-01	-8.6706400	8.6900359	8.6577
478	0.13452324E-01	-0.99749984E-01	-8.8150984	8.8285507	8.7724
479	0.15367200E-01	-0.98548518E-01	-8.8108067	8.8261739	8.7697
480	0.17635556E-01	-0.97230427E-01	-8.8062660	8.8239015	8.7670
481	0.19890225E-01	-0.95906627E-01	-8.8016609	8.8215511	8.7642
482	0.22108149E-01	-0.94600533E-01	-8.7970467	8.8191548	8.7613
483	0.24055896E-01	-0.93326401E-01	-8.7925347	8.8165906	8.7584

MAXIMUMS					
NODE	84	114	450	450	431
VALUE	6.4041853	-6.3737829	-12.900456	12.800441	12.23

ATTACHMENT B

FINITE ELEMENT ANALYSIS INPUT AND OUTPUT

MSB BOTTOM REGION

Bottom drop.
Bottom

ATTACHMENT 2

LIST ALL SELECTED NODE DSYS= 0

NODE	X	Y	Z	THXY	THYZ	THXZ
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00	0.00	0.00
2	5.0000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
3	10.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
4	15.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
5	20.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
6	24.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
7	27.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
8	29.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
9	30.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
10	31.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
11	31.000	1.0000	0.00000E+00	0.00	0.00	0.00
12	31.000	2.0000	0.00000E+00	0.00	0.00	0.00
13	31.000	4.0000	0.00000E+00	0.00	0.00	0.00
14	31.000	7.0000	0.00000E+00	0.00	0.00	0.00
15	31.000	10.000	0.00000E+00	0.00	0.00	0.00
16	31.000	15.000	0.00000E+00	0.00	0.00	0.00
17	31.000	20.000	0.00000E+00	0.00	0.00	0.00

LIST ALL ELEMENT TYPES

NO.	STIF	KEYOPT VALUES									INOTPR	
1	51	0	0	0	0	0	0	0	0	0	0	PLASTIC AXISYM. CONIC SHELL

LIST ALL MATERIALS PROPERTY= ALL

PROPERTY TABLE EX MAT= 1 NUM. POINTS= 2

TEMPERATURE	DATA	TEMPERATURE	DATA
0.00000E+00	29000.	2300.0	29000.

PROPERTY TABLE NUXY MAT= 1 NUM. POINTS= 2

TEMPERATURE	DATA	TEMPERATURE	DATA
0.00000E+00	0.30000	2300.0	0.30000

LIST ALL SELECTED ELEMENTS. (LIST NODES)

ELEM	MAT	TYP	REL	NODES	
1	1	1	1	1	2
2	1	1	1	2	3
3	1	1	1	3	4
4	1	1	1	4	5
5	1	1	1	5	6
6	1	1	1	6	7
7	1	1	1	7	8
8	1	1	1	8	9
9	1	1	1	9	10
10	1	1	1	10	11
11	1	1	1	11	12
12	1	1	1	12	13
13	1	1	1	13	14
14	1	1	1	14	15
15	1	1	1	15	16
16	1	1	1	16	17

LIST DISPLACEMENTS FOR ALL SELECTED NODES

NODE	LABEL	DISP	CDISP
1	UY	0.000000000E+00	0.000000000E+00
2	UY	0.000000000E+00	0.000000000E+00
3	UY	0.000000000E+00	0.000000000E+00
4	UY	0.000000000E+00	0.000000000E+00
5	UY	0.000000000E+00	0.000000000E+00
6	UY	0.000000000E+00	0.000000000E+00
7	UY	0.000000000E+00	0.000000000E+00
8	UY	0.000000000E+00	0.000000000E+00
9	UY	0.000000000E+00	0.000000000E+00
10	UY	0.000000000E+00	0.000000000E+00
1	UX	0.000000000E+00	0.000000000E+00

LIST FORCES FOR ALL SELECTED NODES

NODE	LABEL	FORCE	CFORCE
17	FY	-300.000000	0.000000000E+00

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT
1	0.40424401
2	0.40414484
3	0.40465998
4	0.40377912
5	0.41010978
6	0.39718216
7	0.51572185
8	0.44781680
9	2.5538332
10	8.7340985
11	11.094218
12	13.151539
13	14.185308
14	13.789877

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT
15	13.223640
16	13.001863

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIM
1	0.40418190
2	0.40418190
3	0.40418190
4	0.40418190
5	0.40418190
6	0.40418190
7	0.40418190
8	0.40418190
9	0.40418190
10	12.886482
11	12.895961
12	12.904223
13	12.908375
14	12.906787

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIM
15	13.074782
16	12.916076

INT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIB
1	0.40417422
2	0.40434388
3	0.40406065
4	0.40569903
5	0.40252948
6	0.42863345
7	0.37163288
8	1.0406025
9	1.7454694
10	17.038866
11	14.697704
12	12.656907
13	11.631442
14	12.285484

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIB
15	12.925923
16	12.847307

ATTACHMENT C

FINITE ELEMENT ANALYSIS INPUT AND OUTPUT

MSB BOTTOM—DROP ONTO SHIELD LID

Top diag. bottom

ATTACHMENT 3

LIST ALL SELECTED NODE   DSYS=   0

NODE	X	Y	Z	THXY	THYZ	THXZ
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00	0.00	0.00
2	5.0000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
3	10.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
4	15.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
5	20.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
6	24.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
7	27.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
8	29.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
9	30.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
10	31.000	0.00000E+00	0.00000E+00	0.00	0.00	0.00
11	31.000	1.0000	0.00000E+00	0.00	0.00	0.00
12	31.000	2.0000	0.00000E+00	0.00	0.00	0.00
13	31.000	4.0000	0.00000E+00	0.00	0.00	0.00
14	31.000	7.0000	0.00000E+00	0.00	0.00	0.00
15	31.000	10.000	0.00000E+00	0.00	0.00	0.00
16	31.000	15.000	0.00000E+00	0.00	0.00	0.00
17	31.000	20.000	0.00000E+00	0.00	0.00	0.00

LIST ALL ELEMENT TYPES

NO.	STIF	KEYOPT VALUES									INOTPR	
1	51	0	0	0	0	0	0	0	0	0	0	PLASTIC AXISYM. CONIC SHELL

LIST ALL SELECTED ELEMENTS.   (LIST NODES)

ELEM	MAT	TYP	REL	NODES	
1	1	1	1	1	2
2	1	1	1	2	3
3	1	1	1	3	4
4	1	1	1	4	5
5	1	1	1	5	6
6	1	1	1	6	7
7	1	1	1	7	8
8	1	1	1	8	9
9	1	1	1	9	10
10	1	1	1	10	11
11	1	1	1	11	12
12	1	1	1	12	13
13	1	1	1	13	14
14	1	1	1	14	15
15	1	1	1	15	16
16	1	1	1	16	17

LIST DISPLACEMENTS FOR ALL SELECTED NODES

NODE	LABEL	DISP	CDISP
17	UY	0.000000000E+00	0.000000000E+00
1	UX	0.000000000E+00	0.000000000E+00
1	ROTZ	0.000000000E+00	0.000000000E+00

LIST ALL MATERIALS   PROPERTY= ALL

PROPERTY TABLE EX   MAT=   1   NUM. POINTS=   2

TEMPERATURE	DATA	TEMPERATURE	DATA
0.00000E+00	29000.	2300.0	29000.

PROPERTY TABLE NUXY   MAT=   1   NUM. POINTS=   2

TEMPERATURE	DATA	TEMPERATURE	DATA

```
     0.00000E+00 0.28000      2300.0      0.28000
LIST FORCES FOR ALL SELECTED NODES

LIST ALL REAL SETS

 REAL CONSTANT SET    1   ITEMS    1 TO    6
  0.75000      0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
```

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT
1	23.039036
2	21.377540
3	18.077259
4	13.129122
5	11.811744
6	15.831018
7	21.669063
8	26.597143
9	30.034423
10	27.593383
11	20.144593
12	13.139581
13	5.6483638
14	1.9507046

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT
15	0.24222911
16	1.0460667

...NT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIM
1	0.97598052
2	0.97598052
3	0.97598052
4	0.97598052
5	0.97598052
6	0.97598052
7	0.97598052
8	0.97598052
9	0.97598052
10	1.8730923
11	4.5533461
12	5.8811868
13	4.6230067
14	2.2409505

***** POST1 ELEMENT STRESS LISTING *****

..AD STEP 1 ITERATION= 1 SECTION= 1
..IME= 0.00000E+00 LOAD CASE= 1

ELEM	SIM
15	0.96771222
16	1.1453596

```
LOAD STEP      1  ITERATION=      1  SECTION=  1
TIME=   0.00000E+00      LOAD CASE=  1

ELEM         SIB
   1      24.990997
   2      23.329501
   3      20.029220
   4      15.081083
   5      11.811744
   6      15.831018
   7      19.717102
   8      24.645182
   9      28.082462
  10      26.265171
  11      18.807050
  12      9.6850038
  13      4.3274190
  14      3.4912252

        ***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP      1  ITERATION=      1  SECTION=  1
TIME=   0.00000E+00      LOAD CASE=  1

ELEM         SIB
  15      2.0707609
  16      1.2446526
```

ATTACHMENT D

FINITE ELEMENT ANALYSIS INPUT

MSB BOTTOM SUPPORTED BY TILES ON BASE, DEADWEIGHT LOADING (1g)

```
! * 3D ANALYSIS OF BASE PLATE STRESS WITH
! * MSB BASE SUPPORTED BY CERAMIC TILES AROUND EDGE
! * NORMAL OPERATING CONDITION 1g

/filname,vscnorm

/Prep7
/Title,VSC Base Plate Stress Analysis

! Element Types
et,1,shell163              ! Elastic Shell elements
et,2,contac52              ! 3-D Point to Point Gap Elements
keyopt,2,3,1               ! Use soft spring across open gap
keyopt,2,7,1               ! Use reasonable time increment

!*** CHECK MATERIAL PROPERTIES
! Material Properties
! SA-516, Grade 70 Ferritic Carbon Steel, 300 deg.F
dens,1,0.284
nuxy,1,0.29
ex,1,28.3E6

*afun,deg                    ! Angles in degrees as default

!******************
!*** Parameters ***
!******************
OD  = 62.5                   ! Outside diameter
ID  = 60.5                   ! Inside diameter
WTH = (OD-ID)/2              ! Wall thickness
BRAD = ID/2+WTH/2            ! C/L radius of basket
BTH = 0.75                   ! Base plate thickness
LET = 1.7                    ! Length of ceramic tile
TTH = 0.30                   ! Ceramic tile thickness
TR1 = 30.0                   ! C/L radius ceramic tiles
THETA = asin((LET/2)/TR1)    ! Angle between center & edge of tiles
VLE = 30.0                   ! Length of modeled vertical portion of vessel
TOL = 0.001                  ! Select tolerance

! Real constants
r,1,BTH                      ! Thickness of base plate (non tile regions)
r,2,BTH                      ! Thickness of base plate (tiles region)
r,3,WTH                      ! Thickness of basket wall
r,4,1e6,TTH,3                ! Contact stiffness, MSB to base

!*****************
!*** Keypoints ***
!*****************
csys,1
k,1,
k,2,TR1-LET/2,0,0
k,3,BRAD,0,0
k,4,TR1-LET/2,THETA,0
k,5,BRAD,THETA,0
k,6,TR1-LET/2,15-THETA,0
```

```
k,7,BRAD,15-THETA,0
k,8,TR1-LET/2,15+THETA,0
k,9,BRAD,15+THETA,0
k,10,TR1-LET/2,30-THETA,0
k,11,BRAD,30-THETA,0
k,12,TR1-LET/2,30+THETA,0
k,13,BRAD,30+THETA,0
k,14,TR1-LET/2,45-THETA,0
k,15,BRAD,45-THETA,0
k,16,TR1-LET/2,45,0
k,17,BRAD,45,0

ksel,s,loc,x,BRAD
kgen,2,all,,,,,VLE/4,100
ksel,s,loc,z,VLE/4
kgen,2,all,,,,,VLE*3/4,100
ksel,all

! Areas
! Tile areas first
csys,1
a,2,3,5,4
a,6,7,9,8
a,10,11,13,12
a,14,15,17,16
type,1
mat,1
real,2
esize,0.9
amesh,1,4

! Rest of Base
a,1,2,4,6,8,10,12,14,16
a,4,5,7,6
a,8,9,11,10
a,12,13,15,14

lsel,s,line,,22,24
lesize,all,,,7
lsel,all
real,1
amesh,5,8

! Basket shell
numstr,area,21
a,3,103,105,5
a,5,105,107,7
a,7,107,109,9
a,9,109,111,11
a,11,111,113,13
a,13,113,115,15
a,15,115,117,17

a,103,203,205,105
a,105,205,207,107
```

```
a,107,207,209,109
a,109,209,211,111
a,111,211,213,113
a,113,213,215,115
a,115,215,217,117

esize,1.2
real,3
amesh,21,27
esize,2.0
amesh,28,34

!****************
!*** Contacts ***
!****************
! Contact between basket base & cask
! Select nodes on ceramic tile elements
esel,s,real,,1
nsle,s
! Generate coincident set of nodes
ngen,2,2000,all,,,0,0,-TTH
! Generate contact elements
esel,s,real,,1
nsle,s
*get,numnodes,node,,count
nsel,a,node,,1999,3999
*get,nextnode,node,,num,min
type,2
real,4
*do,i,1,numnodes
  *if,i,eq,1,then
     e,nextnode,nextnode+2000
     *get,nextnode,node,nextnode,nxth
  *elseif,i,ge,2,then
     e,nextnode,nextnode+2000
     *get,nextnode,node,nextnode,nxth
  *endif
*enddo

! Remove contacts on periphery of tiles
asel,s,area,,1,4
esla,s
nsle,s,ext
esln,s
esel,r,type,,2
edel,all
nall
eall

!*******************
!*** Constraints ***
!*******************
! Symmetry BC's
esel,s,type,,1
nsle,s
```

```
csys,1
nsel,s,loc,y,45
nrotat,all
dsym,symm,y,1
esel,s,type,,1
nsle,s
nsel,s,loc,y,0
dsym,symm,y

! Contacts at ground
esel,s,type,,2
nsle,s
nsel,r,,,1999,3999
d,all,all,0
nall

! Base of tiles
esel,s,real,,2
nsle
d,all,uz,0

!*********************
!*** Applied Loads ***
!*********************
! Pressure on basket base due to contents
esel,s,real,,1,2
nsle,s
sfe,all,2,pres,,13.536
nall
eall

! Force on side wall due to part of
! Basket not included in model.
! Interior nodes first
FORCE = 3442.5     ! Calculated mass missing in 1/8 model
csys,1
nsel,s,loc,x,BRAD
nsel,r,loc,z,VLE
*get,NUMNODES,node,,count
nsel,r,loc,y,1,44
NODEFORC = FORCE/(NUMNODES-1)
f,all,fz,-NODEFORC
nall
! Exterior nodes (half the load)
csys,1
nsel,s,loc,x,BRAD
nsel,r,loc,z,VLE
nsel,r,loc,y,0
f,all,fz,-NODEFORC/2
nsel,s,loc,x,BRAD
nsel,r,loc,z,VLE
nsel,r,loc,y,45
f,all,fz,-NODEFORC/2
nall
```

```
! Drop Acceleration
acel,,,1            ! 1g Body load acceleration

allsel

!****************
!*** Solution ***
!****************
/solu

solve

finish

/post1
set
prrsol
fini
/exit
```

ATTACHMENT E

FINITE ELEMENT ANALYSIS INPUT

MSB SUPPORTED BY TILES ON BASE, BOTTOM END DROP (108g)

```
!
! * 3D ANALYSIS OF BASE PLATE STRESS WITH
! * MSB BASE SUPPORTED BY CERAMIC TILES AROUND EDGE
! * END DROP ACCELERATION OF 108g

/filname,vscedge

/Prep7
/Title,VSC Base Plate Stress Analysis

! Element Types
et,1,shell143              ! Plastic Shell elements
et,2,contac52              ! 3-D Point to Point Gap Elements
keyopt,2,3,1               ! Use soft spring across open gap
keyopt,2,7,1               ! Use reasonable time increment

!*** CHECK MATERIAL PROPERTIES
! Material Properties
! SA-516, Grade 70 Ferritic Carbon Steel, 300 deg.F
dens,1,0.284
nuxy,1,0.29
ex,1,28.3E6
tb,bkin,1,1
tbdata,1,33.7E3,355.1E3    ! Yield Stress and Tangent Modulus

*afun,deg                  ! Angles in degrees as default

!******************
!*** Parameters ***
!******************
OD  = 62.5                 ! Outside diameter
ID  = 60.5                 ! Inside diameter
WTH = (OD-ID)/2            ! Wall thickness
BRAD = ID/2+WTH/2          ! C/L radius of basket
BTH = 0.75                 ! Base plate thickness
LET = 1.7                  ! Length of ceramic tile
TTH = 0.30                 ! Ceramic tile thickness
TR1 = 30.0                 ! C/L radius ceramic tiles
THETA = asin((LET/2)/TR1)  ! Angle between center & edge of tiles
VLE = 30.0                 ! Length of modeled vertical portion of vessel
ACC = 108                  ! Acceleration due to end drop
TOL = 0.001                ! Select tolerance

! Real constants
r,1,BTH                    ! Thickness of base plate (non tile regions)
r,2,BTH                    ! Thickness of base plate (tiles region)
r,3,WTH                    ! Thickness of basket wall
r,4,1e6,TTH,3              ! Contact stiffness, MSB to base

!*****************
!*** Keypoints ***
!*****************
csys,1
k,1,
k,2,TR1-LET/2,0,0
```

```
k,3,BRAD,0,0
k,4,TR1-LET/2,THETA,0
k,5,BRAD,THETA,0
k,6,TR1-LET/2,15-THETA,0
k,7,BRAD,15-THETA,0
k,8,TR1-LET/2,15+THETA,0
k,9,BRAD,15+THETA,0
k,10,TR1-LET/2,30-THETA,0
k,11,BRAD,30-THETA,0
k,12,TR1-LET/2,30+THETA,0
k,13,BRAD,30+THETA,0
k,14,TR1-LET/2,45-THETA,0
k,15,BRAD,45-THETA,0
k,16,TR1-LET/2,45,0
k,17,BRAD,45,0

ksel,s,loc,x,BRAD
kgen,2,all,,,,,VLE/4,100
ksel,s,loc,z,VLE/4
kgen,2,all,,,,,VLE*3/4,100
ksel,all

! Areas
! Tile areas first
csys,1
a,2,3,5,4
a,6,7,9,8
a,10,11,13,12
a,14,15,17,16
type,1
mat,1
real,2
esize,0.9
amesh,1,4

! Rest of Base
a,1,2,4,6,8,10,12,14,16
a,4,5,7,6
a,8,9,11,10
a,12,13,15,14

lsel,s,line,,22,24
lesize,all,,,7
lsel,all
real,1
amesh,5,8

! Basket shell
numstr,area,21
a,3,103,105,5
a,5,105,107,7
a,7,107,109,9
a,9,109,111,11
a,11,111,113,13
a,13,113,115,15
```

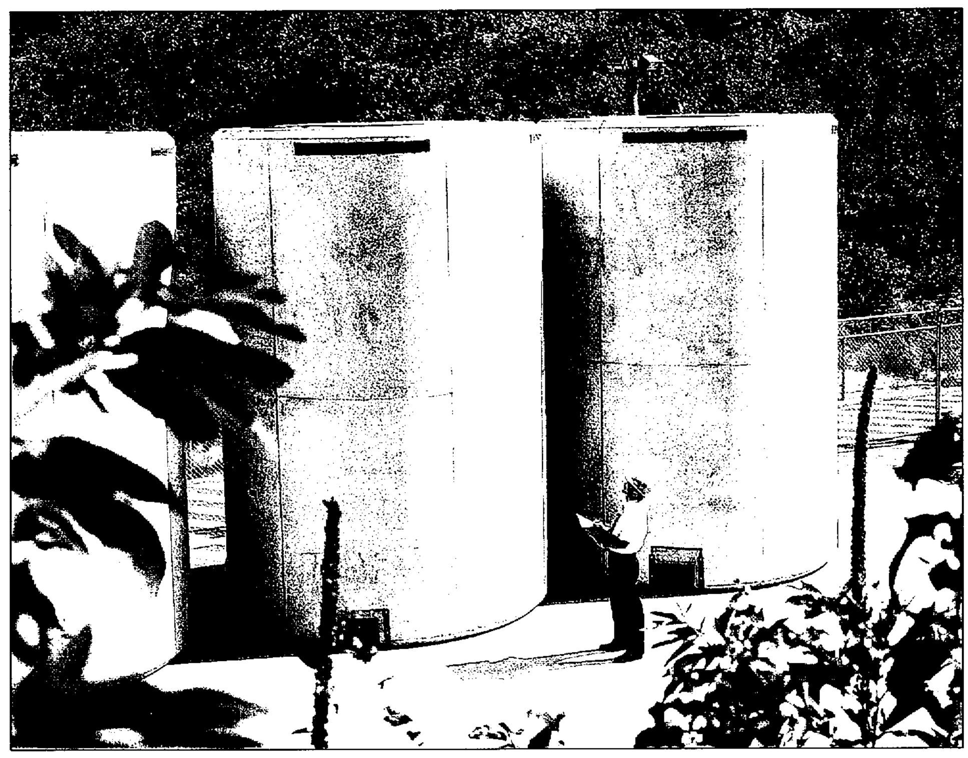
```
a,15,115,117,17

a,103,203,205,105
a,105,205,207,107
a,107,207,209,109
a,109,209,211,111
a,111,211,213,113
a,113,213,215,115
a,115,215,217,117

esize,1.2
real,3
amesh,21,27
esize,2.0
amesh,28,34

!****************
!*** Contacts ***
!****************
! Contact between basket base & cask
! Select nodes on ceramic tile elements
esel,s,real,,1
nsle,s
! Generate coincident set of nodes
ngen,2,2000,all,,,0,0,-TTH
! Generate contact elements
esel,s,real,,1
nsle,s
*get,numnodes,node,,count
nsel,a,node,,1999,3999
*get,nextnode,node,,num,min
type,2
real,4
*do,i,1,numnodes
  *if,i,eq,1,then
     e,nextnode,nextnode+2000
     *get,nextnode,node,nextnode,nxth
  *elseif,i,ge,2,then
     e,nextnode,nextnode+2000
     *get,nextnode,node,nextnode,nxth
  *endif
*enddo

! Remove contacts on periphery of tiles
asel,s,area,,1,4
esla,s
nsle,s,ext
esln,s
esel,r,type,,2
edel,all
nall
eall

!******************
!*** Constraints ***
```

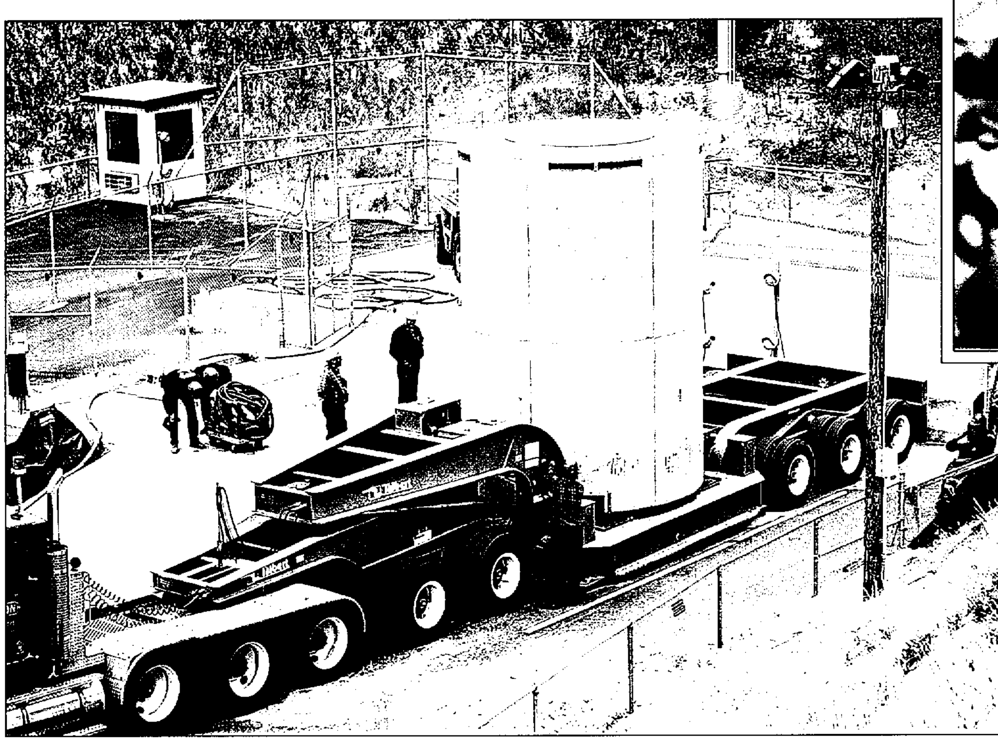
```
!*******************
! Symmetry BC's
esel,s,type,,1
nsle,s
csys,1
nsel,s,loc,y,45
nrotat,all
dsym,symm,y,1
esel,s,type,,1
nsle,s
nsel,s,loc,y,0
dsym,symm,y

! Contacts at ground
esel,s,type,,2
nsle,s
nsel,r,,,1999,3999
d,all,all,0
nall

! Base of tiles
esel,s,real,,2
nsle
d,all,uz,0

!********************
!*** Applied Loads ***
!********************
! Pressure on basket base due to contents
esel,s,real,,1,2
nsle,s
sfe,all,2,pres,,13.536*ACC
nall
eall

! Force on side wall due to part of
! Basket not included in model.
! Interior nodes first
FORCE = 3442.5*ACC   ! Calculated mass missing in 1/8 model
csys,1
nsel,s,loc,x,BRAD
nsel,r,loc,z,VLE
*get,NUMNODES,node,,count
nsel,r,loc,y,1,44
NODEFORC = FORCE/(NUMNODES-1)
f,all,fz,-NODEFORC
nall
! Exterior nodes (half the load)
csys,1
nsel,s,loc,x,BRAD
nsel,r,loc,z,VLE
nsel,r,loc,y,0
f,all,fz,-NODEFORC/2
nsel,s,loc,x,BRAD
nsel,r,loc,z,VLE
```

```
nsel,r,loc,y,45
f,all,fz,-NODEFORC/2
nall

! Drop Acceleration
acel,,,ACC            ! Body load acceleration

allsel

!****************
!*** Solution ***
!****************
/solu
nlgeom,on             ! Include large deformation effects
autots,on             ! Automatic time stepping
nsubst,50,1000,10     ! 50 substeps 1000max 10min for load step
solcon,on,on
cnvtol,f,,0.01        ! Convergence for force at 1%
cnvtol,m,,0.01        ! Convergence for moment at 1%

solve

finish

/post1
set
prrsol
fini
/exit
```

VSC-24 SAR
License Amendment Request 01-01
Fuel Specification

BNFL
Fuel Solutions





Vol. III

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.3.31 File No.: VSC02.6.2.3.31 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

Calculation for Stress on Structural Lid for a Lifting Bolt Radius of 26.5"

SCOPE:

Product: ☐ FuelSolutions™ ☐ TranStor™ ☒ VSC-24 ☐ Other ____________

Service: ☒ Storage ☐ Transportation ☐ Other ____________

Conditions: ☒ Normal ☐ Off-Normal ☐ Accident ☐ Other ____________

Component(s):

MSB Structural Lid

Prepared by:

Name: ROBERT KEATING

Signature: [signature]

Date: 1-31-2001

Verified by:

Name: Regina Parkerson

Signature: Regina Parkerson

Date: 1-31-2001

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: [signature]

Date: 3/26/01

<u>**RECORD OF REVISIONS**</u>

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 - 8		Replaces Calculation WEP109-002.31, Rev. 0	Robert Keating	Michelle Heinz
1	1 - 8		Revised calculation to ensure that the ANO configurations are included in the scope of this analysis. Incorporated ECN VSC02-ECN-008	Robert Keating	Regina Parkerson

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	YES (circled)	NO	
(b) The inputs are correctly selected and incorporated into the design.	YES (circled)	NO	N/A
(c) References are complete, accurate, and retrievable.	YES (circled)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	YES (circled)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	YES (circled)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	N/A (circled)
(g) Methods and units are clearly identified.	YES (circled)	NO	N/A
(h) Any limits of applicability are identified.	YES (circled)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	N/A (circled)
(j) Computer codes used are under configuration control.	YES	NO	N/A (circled)
(k) Computer codes used are applicable to the calculation.	YES	NO	N/A (circled)
(l) Input parameters and boundary conditions are appropriate and correct.	YES (circled)	NO	
(m) An appropriate design method is used.	YES (circled)	NO	
(n) The output is reasonable compared to the inputs.	YES (circled)	NO	
(o) Conclusions are clear and consistent with analysis results.	YES (circled)	NO	

COMMENTS:

Verifier: Regina Parkerson/Regina Parkerson/ 1-31-2001
Name/Signature/Date

1.0 INTRODUCTION

The purpose of this calculation is to determine the effect that moving the MSB Structural Lid lifting bolt holes to a radius of 26 inches (conservative compared to the actual value of 26.5") from their previously analyzed radius of 27 inches will have on the ability of the MSB lifting devices to lift a fully loaded MSB. The ANO/Palisades MSB's have a radius of 27 inches (Reference 3) and are already covered by Reference 4. The Point Beach MSB has a 26.5 inch radius (Reference 3) and this calculation evaluates the impact of the smaller radius.

This calculation supersedes SNC Calculation WEP 109-002.31, Revision 0. This calculation addresses technical issues identified in CAR 98-50. The principal difference between this calculation and the superseded calculation is the weight of the fully loaded MSB used in the calculation.

2.0 DESIGN INPUTS AND ASSUMPTIONS

2.1 Design Inputs

Radius of MSB Structural Lid	$a := 30\ in$	Reference 3
Thickness of MSB Structural Lid	$t := 3\ in$	Reference 3
Radius of Lifting Bolt Holes (Case 1)	$r_{o1} := 27\ in$	Reference 4
Radius of Lifting Bolt Holes (Case 2)	$r_{o2} := 26\ in$	Reference 3
Weight per lifting bolt of MSB used in calculation of maximum stress for case 1. (Based on 6 lifting bolts)	$w_o := 11692\ lb$	Reference 4
Number of Lifting Bolts	$n_b := 6$	Reference 3
Maximum MSB Structural Lid Stress corresponding to w_o	$s_{max} := 2.2 \cdot 10^3\ psi$	Reference 4

Material Properties (Taken at 200 degree F)

Material	SA 516-70	Reference 3
Yield Strength	$s_y := 34.6 \cdot 10^3\ psi$	Reference 5
Ultimate Tensile Strength	$s_u := 70 \cdot 10^3\ psi$	Reference 5
Poisson Ratio	$v := 0.33$	Reference 5

$$n := \frac{1}{v}$$

$$n = 3$$

2.2 Assumption

A bounding MSB weight value of 70,000 lb will be used for conservatism. (This value corresponds to a fully loaded MSB with shield and structural lids. The basis is that the weight bounds the weight calculated in Reference 7). In addition, the weight of the MSB will be increased by a factor of 1.1, in accordance with NUREG-0612 (Reference 1). The weight of the MSB (w) is taken per lifting bolt.

$$w := \frac{70000\ (lb)}{6} \cdot (1.1)$$

$$w = 12833\ lb$$

The MSB structural lid temperature is assumed to be 200F which bounds the maximum calculated temperature provided in Reference 8.

3.0 CALCULATION

The MSB structural lid and bolt holes are modeled as a uniform load on a concentric circular ring on a flat plate. Based on this, the radial stress (s_r) and tangential stress (s_t) are as follows (Reference 6, page 218). Note that the stresses are calculated at radius (r). In both cases, r is assumed to be 30 inches, the point with the highest stress.

$$r := 30\ in$$

$$s_r := \frac{(-3 \cdot w \cdot n_b)}{4 \cdot \pi \cdot n \cdot t^2} \cdot \left[(n+1) \cdot \left(2 \cdot \ln\left(\frac{a}{r}\right) + \frac{r_o^2}{a^2}\right) + (n-1) \cdot \frac{r_o^2}{r^2} - 2 \cdot n\right]$$

$$s_t := \frac{(-3 \cdot w \cdot n_b)}{4 \cdot \pi \cdot n \cdot t^2} \cdot \left[(n+1) \cdot \left(2 \cdot \ln\left(\frac{a}{r}\right) + \frac{r_o^2}{a^2}\right) - (n-1) \cdot \frac{r_o^2}{r^2} - 2\right]$$

3.1 Case 1 (r_o=27 inches)

$$s_{r1} := \frac{(-3 \cdot w \cdot n_b)}{4 \cdot \pi \cdot n \cdot t^2} \cdot \left[(n+1) \cdot \left(2 \cdot \ln\left(\frac{a}{r}\right) + \frac{r_{o1}^2}{a^2}\right) + (n-1) \cdot \frac{r_{o1}^2}{r^2} - 2 \cdot n\right]$$

$$s_{r1} = 776.1 \frac{lb}{in^2}$$

$$s_{t1} := \frac{(-3 \cdot w \cdot n_b)}{4 \cdot \pi \cdot n \cdot t^2} \cdot \left[(n+1) \cdot \left(2 \cdot \ln\left(\frac{a}{r}\right) + \frac{r_{o1}^2}{a^2} \right) - (n-1) \cdot \frac{r_{o1}^2}{r^2} - 2 \right]$$

$$s_{t1} = 256.1 \frac{lb}{in^2}$$

3.2 Case 2 (r_o=26 inches)

$$s_{r2} := \frac{(-3 \cdot w \cdot n_b)}{4 \cdot \pi \cdot n \cdot t^2} \cdot \left[(n+1) \cdot \left(2 \cdot \ln\left(\frac{a}{r}\right) + \frac{r_{o2}^2}{a^2} \right) + (n-1) \cdot \frac{r_{o2}^2}{r^2} - 2 \cdot n \right]$$

$$s_{r2} = 1016.7 \frac{lb}{in^2}$$

$$s_{t2} := \frac{(-3 \cdot w \cdot n_b)}{4 \cdot \pi \cdot n \cdot t^2} \cdot \left[(n+1) \cdot \left(2 \cdot \ln\left(\frac{a}{r}\right) + \frac{r_{o2}^2}{a^2} \right) - (n-1) \cdot \frac{r_{o2}^2}{r^2} - 2 \right]$$

$$s_{t2} = 335.5 \frac{lb}{in^2}$$

3.3 Determination of Increased Stress

The fractional increase in radial and tangential stress due to the new lifting bolt hole placement is calculated below:

$$\Delta s_r := \frac{s_{r2} - s_{r1}}{s_{r1}} \qquad \Delta s_r = 0.3099$$

$$\Delta s_t := \frac{s_{t2} - s_{t1}}{s_{t1}} \qquad \Delta s_t = 0.3099$$

Reference 4 documents a maximum principal stress of 2.2 ksi based on an evaluated load per hoist ring of 11,692 lb. Maximum stress based on the bounding weight can be calculated with the ratio of the bounding to the previously evaluated load. The stress will increase as a result of moving the lifting bolt holes in from a radius of 27 inches to a radius of 26 inches. This results in a new maximum stress of:

$$s_{new} := \left[s_{max} \cdot \left(1 + \Delta s_r\right)\right] \cdot \frac{w}{w_o}$$

$$s_{new} = 3163 \cdot psi$$

References 1 and 2 specify minimum safety factors for yield and ultimate tensile strength of 6 and 10 respectively. Based on the maximum stress calculated above (s_{new}), safety factors are:

$$\phi_y := \frac{s_y}{s_{new}} \qquad \phi_y = 10.9 \qquad \text{Minimum } \phi_y = 6$$

$$\phi_u := \frac{s_u}{s_{new}} \qquad \phi_u = 22.1 \qquad \text{Minimum } \phi_u = 10$$

4.0 CONCLUSION

The yield and ultimate tensile strength safety factors are both greater than their respective required minimums. Therefore, an MSB structural lid lifting bolt radius of 26 inches will result in acceptable safety factors with respect to yield and ultimate tensile strength.

5.0 REFERENCES

1. NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants-Resolution of Generic Technical Activity A-36", July, 1980.

2. ANSI N14.6-1993, "Special Lifting Devices for Shipping Containers Weighing 10,000 lb or more".

3. BNFL Calculation VSC02.6.2.5.03, "VSC-24 Design Parameters", Revision 0.

4. BNFL Calculation VSC02.6.2.3.03, "MSB-24 Lifting Devices", Revision 1.

5. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices 1986 Edition with the 1988 Addenda.

6. Roark, R.J., *Formulas for Stress and Strain*, Fourth Edition, McGraw-Hill, 1965.

7. BNFL Calculation VSC02.6.2.5.01, "Weight and Center of Gravity", Revision 1.

8. BNFL Calculation WEP-109.003.18, "VSC-24 Transfer Cask Thermal Analysis," Revision 2.

504258

BNFL Fuel Solutions	CALCULATION PACKAGE	Calc. Pkg No.VSC02.6.2.4.02 File No.: VSC02.6.2.4.02 Revision: 0

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

MTC TEMPERATURES FOR HELIUM BACKFILL CONDITION

SCOPE:

Product: ☐ Wesflex™ ☐ TranStor™ ☒ VSC-24 ☐ Other ______

Service: ☒ Storage ☐ Transportation ☐ Other ______

Conditions: ☒ Normal ☒ Off-Normal ☐ Accident ☐ Other ______

Component(s):

Prepared by:

Name: *Igor Shekhtman*

Signature: I Shekhtman

Date: 2-22-01

Verified by:

Name: *Kent C. Smith*

Signature: [signature]

Date: 2-22-01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: R Srinivasan

Date: 2/23/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	All	1 CD-ROM disc Rev 0	Initial Issue	Igor Shekhtman	Kent C. Smith [signature] 2-22-0[illegible]

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	YES (circled)	NO	
(b) The inputs are correctly selected and incorporated into the design.	YES (circled)	NO	N/A
(c) References are complete and accurate.	YES (circled)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	YES (circled)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	YES (circled)	NO	N/A
(f) Assumptions and references which are preliminary are noted as being preliminary.	YES	NO	N/A (circled)
(g) Methods and units are clearly identified.	YES (circled)	NO	N/A
(h) Any limits of applicability are identified.	YES (circled)	NO	N/A
(i) Computer calculations are properly identified.	YES (circled)	NO	N/A
(j) Computer codes used are under configuration control.	YES (circled)	NO	N/A
(k) Computer codes used are applicable to the calculation.	YES (circled)	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	YES (circled)	NO	
(m) An appropriate design method is used.	YES (circled)	NO	
(n) The output is reasonable compared to the inputs.	YES (circled)	NO	
(o) Conclusions are clear and consistent with analysis results.	YES (circled)	NO	

COMMENTS:

All comments are incorporated.

Verifier: [signature] / Kent Smith 2-21-01

Name/Signature/Date

Form QAP 3.2-1, Revision 1

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

No figures are used in this calculation.

1. INTRODUCTION

1.1. Objectives

The objective of this calculation package is to obtain a lower bound of the basket internal temperatures for the condition of helium backfill following vacuum drying operations.

1.2. Purpose

The lower bound estimate of the backfill temperatures will be used later on to obtain an upper bound estimate of the quantity of the basket backfill gas. The backfill gas quantity will be used in the basket internal pressure calculation.

1.3. Scope

Transient heat-up of the basket in the transfer cask under condition of vacuum drying is considered. A conservative scenario is assumed that corresponds to a conservatively low bulk backfill temperature.

2. REQUIREMENTS

2.1. Design Inputs

2.1.1. Title 10, Code of Federal Regulations, Part 72 (10 CFR 72), Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High Level Waste, United States Nuclear Regulatory Commission (USNRC), 1996.

2.2. Regulatory Commitments

2.2.1. A regulatory commitment has been made to identify any deviation from the guidance provided in Ref. 2.1.1.

3. REFERENCES

3.1. BFS Calculation Packages

3.1.1. BFS Calculation No. WEP-109.003.018, Rev. 2, VSC Transfer Cask Thermal Analysis

3.1.2. BFS Calculation No. WEP-109.003.5, Rev. 6, MSB-24 Thermal-Hydraulic Analysis

3.1.3. BFS Calculation No. WEP-109.003.4, Rev. 2, VCC-24 Thermal-Hydraulic Analysis

3.1.4. BFS Calculation No. CMPC.1705.001, Rev. 3, Materials Thermal Property Calculations

3.2. General References

3.2.1. ANSYS™ User's Manual for ANSYS™ Revision 5.5, 1999

3.2.2. M. Necati Ozisik, Heat Transfer, A Basic Approach, 1985, McGraw Hill

3.2.3. F. P. Incropera, D. P. DeWitt, Fundamentals of Heat and Mass Transfer, Fourth Edition, 1996, John Wiley & Sons

4. ASSUMPTIONS

4.1. Design Configuration

With the changes noted below, the description of the VSC-24 system basket in the transfer cask configuration for the vacuum drying case is given in Ref. 3.1.3 and 3.1.2.

4.2. Design Criteria

Unlike Ref. 3.1.3 and Ref. 3.1.2 that evaluates the upper bound temperatures for the vacuum drying condition, this calculation estimates the lower bound.

The lower bound temperatures are used to calculate the backfill gas quantities and basket internal pressure. The criteria for the gas pressure is discussed separately in the basket internal pressure calculation.

4.3. Calculation Assumptions

4.3.1. The vacuum drying and helium backfill operations are assumed to occur with the transfer cask partially submerged within the fuel pool to 1/3 of the canister's overall height. This is a conservative assumption because typical plant procedures allow for these operations to take place in a dry decontamination area, and a wetted cask exterior transfers more heat, resulting in initially cooler / denser backfill gas.

4.3.2. The MSB is assumed to be backfilled with helium instantaneously. Note: Due to operational constraints placed upon the backfill processes, backfill times are typically about 30 minutes. An assumed shorter fill time translates into initially cooler / denser backfill gas.

4.3.3. The surrounding building (air) temperature is assumed to be 32 °F. Cooler ambient conditions result in initially cooler / denser backfill gas.

4.3.4. The annulus region between the transfer cask and MSB is assumed to be filled with water. The water filled annulus aids the heat transfer between the cask / canister, and, decreases the temperature of the backfill gas.

4.3.5. The fuel pool water temperature is assumed to be a maximum of 100 °F. This is reasonably conservatively low temperature, because plant fuel pool temperatures are typically between 100 °F and 212 °F (maximum).

4.3.6. The maximum VSC-24 decay heat load of 24 kW is assumed. An assumed maximum decay heat load results in the maximum heat-up and pressurization of the MSB.

4.3.7. All MSB basket and shell coatings are intact.

4.3.8. Uniform distribution of 100 °F temperature all over the system is assumed for the initial condition. This assumption is conservative, since realistically, 100 °F is the lowest temperature in the system, and all points of the system are at the temperatures higher than 100 °F.

5. CALCULATION METHODOLOGY

In this calculation, the models developed and described in Ref. 3.1.3 and Ref. 3.1.2 are used. The thermal analysis is performed using the ANSYS version 5.5 computer program, Ref. 3.2.1. The transient thermal analysis methodology is discussed in Ref. 3.2.1.

5.1. Basket Internals Effective Conductivity

The axial thermal conductivity of 2.4 Btu/hr-ft-°F for the basket internals is calculated in Ref. 3.1.3 by the area weighted averaging of the basket internal component conductivities.

The radial conductivity of the basket internals is temperature dependent. At the higher temperatures the heat dissipation from the basket is enhanced due to the higher radiation effects. The effective radial conductivity is significantly increased with the temperature.

Ref. 3.2.2 (Pg. 52) presents the formula for the temperature distribution in a solid cylinder under a uniformly distributed heat load:

$$T(r) = \Delta T\left[1-\left(\frac{r}{a}\right)^2\right]+T_1, \qquad \Delta T = \frac{q\,a^2}{4k} \qquad (1)$$

Here T_1 is the temperature of the cylinder's exterior surface, $T_o = T_1 + \Delta T$ is the temperature at the center, q is the heat load, a is the radius and k is the thermal conductivity. The thermal conductivity can be found from the formula (1) as

$$k = \frac{q\, a^2}{4\, \Delta T} \quad (2)$$

The temperature dependence for the radial conductivity is found as follows:

1. A set of conditions is imposed on the 2-dimensional basket model (per Ref. 3.1.2). The basket shell temperature and the heat load are specified. The analysis is run to find the maximum fuel temperature, T_m. Assuming $T_o = T_m$, $\Delta T = T_o - T_1$, the average temperature T_a is calculated for the parabolic temperature distribution formula (1) as:

$$T_a = (T_o + T_1) / 2 \quad (3)$$

and the effective thermal conductivity is found by formula (2).

2. Step 1 is repeated for a number of conditions (with various shell temperatures and heat loads) to establish the dependence of the basket internals effective conductivity on the average temperature.

5.2. Radiation Heat Exchange

The radiation heat exchange in the ANSYS input is modeled using the radiation link element LINK31. This element calculates the amount of heat q transferred by radiation between two parallel surfaces by implementing the formula (per Ref. 3.2.3, p. 739):

$$q = A \varepsilon_{12} \sigma \, (T_1^4 - T_2^4) \quad (4)$$

Here A is the area, T_1 and T_2 are temperatures of the surfaces, σ is the Stefan-Boltzmann constant, and ε_{12} is the effective emissivity for the radiation heat exchange between two surfaces calculated by the formula:

$$\varepsilon_{12} = \frac{1}{(1/\varepsilon_1 + 1/\varepsilon_2 - 1)} \quad (5)$$

In formula (5), ε_1 and ε_2 are the emissivities of two surfaces exchanging the heat by radiation.

6. CALCULATIONS

6.1. Basket Internals Radial Conductivity

The basket model has been run for a set of conditions as shown in Table 6.1-1 to establish the temperature dependence for the basket internals radial conductivity. The sample ANSYS input and output (for Case 1 of Table 6.1-1) is presented in Attachment A to this calculation.

Table 6.1-1 Temperature Dependent Basket Internals Radial Conductivity

Run #	Heat Load	Heat Load per Unit of Volume	Temperatures Shell	Fuel Max	ΔT	Average	Radial Conductivity
	kW	Btu/hr-ft³	°F	°F	°F	°F	Btu/hr-ft-°F
1	2	31.34	20	142	122	81	0.408
2	4	62.68	50	257	207	154	0.481
3	4	62.68	350	460	110	405	0.905
4	4	62.68	550	631	81	591	1.229

6.2. Materials Thermal Property

The material thermal properties for steel, fuel, helium, lead and RX-277 neutron shield used in the model input file are listed in Table 6.2-1. The material properties for air are used per Ref. 3.1.3 and listed in Table 6.2-2.

The material properties for liquid water are used in accordance with Ref. 3.1.4, converted from metric units and are listed in Table 6.2-3. The effective thermal conductivity of the neutron shield material RX-277 with angles is listed in Table 6.2-1 in accordance with Ref. 3.1.1. Calculation of density and heat capacity for RX-277 with angles is done by weighted averaging and is shown in Table 6.2-4; calculated values are listed in Table 6.2-1. In Table 6.2-4, areas in the horizontal section of the neutron shield annulus are calculated as:

$A_{total} = \pi * (R_o^2 - R_i^2) = \pi * (40.75^2 - 36.5^2) = 1031\ in^2 = 7.16\ ft^2$ - total area of the neutron shield annulus, RX-277 and angles. Here R_i and R_o are inner and outer radii of the neutron shield respectively.

A_{angles} = Angle Thickness * Angle Width * Number of Angles = 0.25 in * 5.4 in * 24 = 64.8 in^2 = 0.45 ft^2 - area of angles.

$A_{steel} = A_{total} - A_{angles}$ - area of steel.

Thermal emissivity of the surfaces are used per Ref. 3.1.4 as follows: Keeler&Long (white color epoxy coating) - 0.88, uncoated carbon steel - 0.65, uncoated stainless steel (the top and the bottom if the fuel assembly) - 0.4. The effective emissivity for the radiation heat exchange between two surfaces is calculated in the ANSYS input implementing the formula (6) presented in Section 5.2.

Table 6.2-1 Thermal Properties of Materials

	Density	Thermal Conductivity	Specific Heat	Reference
	lbm/ft^3	Btu/h-ft-°F	Btu/lb-°F	
Carbon Steel	490	26	0.11	Ref. 3.1.3
Fuel [1]	176.8	2.4	0.071	Ref. 3.1.3
Helium	0.0064	0.1	1.24	Ref. 3.1.3
Lead	710	19	0.031 [2]	Ref. 3.1.1
RX-277, no angles	106	0.3	0.22	Ref. 3.1.3
RX-277 with angles	130	1.264	0.194	Ref. 3.1.1 for Kxx, Table 6.2-4 for density and specific heat

[1] Value for the axial thermal conductivity (KZZ in the model) is listed. Temperature dependent radial thermal conductivity is discussed in Section 6.1 and presented in Table 6.1-1.

[2] Value of 0.031 is slightly conservative with respect to the value of 0.03 as listed in Table 1 Ref. 3.1.1.

Table 6.2-2 Material Properties, Air

Temperature	Specific Heat	Thermal Conductivity	Density
°F	Btu/lb-°F	Btu/h-ft-°F	lbm/ft^3
-50	0.238	0.0114	0.094
0	0.239	0.013	0.086
32	0.24	0.014	0.081
100	0.24	0.0154	0.071
200	0.241	0.0174	0.06
300	0.243	0.0193	0.052
500	0.247	0.0231	0.041
700	0.253	0.0268	0.037

Table 6.2-3 Material Properties, Liquid Water

Temperature	Specific Heat	Thermal Conductivity	Density
°F	Btu/lb-°F	Btu/h-ft-°F	lbm/ft³
32	0.3288	1.0072	62.43
81	0.3543	0.9982	62.24
126	0.3727	0.9989	61.62
171	0.3860	1.0020	60.74
212	0.3930	1.0072	59.81

Table 6.2-4 Effective Density and Heat Capacity Calculation for RX-277 with Angles

	Density	C_p	Area	Density*Area	Density*C_p	Density*C_p*Area
	lbm/ft³	Btu/lb-°F	ft²	lbm/ft	Btu/ft³-°F	Btu/ft-°F
RX-277	106	0.22	6.71	711.5	23.32	156.54
Steel	490	0.11	0.45	220.5	53.9	24.26
Total	130	0.194	7.16	932.0	25.24	180.79

6.3. Computer Input and Output

The system model is described in Ref. 3.1.1. In this calculation, material properties are used as discussed in Section 6.2. The gap between the basket and the transfer cask inner wall is filled with water and air. According to the scenario presented in Section 4.3, 1/3 of the basket length is under water. In the model, the basket length is 192.25 inches and all the nodes at the level of node 69 (coordinate Z = 76.75 inches) and lower are under water. As long as 192.25 / 3 = 64 < 76.75, the modeling is conservative, since higher level of water corresponds to lower temperature of the system which is pessimistic in terms of the higher quantity of the backfill gas. The boundary nodes on the transfer cask external surface under the level of Z = 76.75 inches are held constant at 100 °F. This boundary condition is conservative with respect to the more realistic condition of natural convection to the water at the temperature of 100 °F.

The input file MTC.INP generates the model and performs a transient run for 10 hours heat-up from the initial condition of uniform 100 °F temperature distribution. Next, it post-processes the temperature

distribution in the end of 10 hour heat-up and outputs the summary in the file MTC.SUM. The computer input files are presented in Attachment B.

7. CONCLUSIONS

7.1. Results

Summary output of the basket gas temperatures in the end of the 10 hours heat-up is obtained and presented in Section 10.2 for the future use in the basket pressure analysis.

7.2. Compliance with Requirements

This calculation obtains the lower bound estimate of the basket internal temperatures.

The compliance with requirement in terms of the basket internal gas pressure is to be verified in a separate calculation.

7.3. Range of Validity

The analyses and results presented herein apply to the VSC-24 design configuration as discussed in Section 4.1. Also, the basket internal temperatures obtained in this calculation is valid as the lower bound estimate for the case discussed in Section 4.3.

7.4. Summary of Conservatism

This calculation incorporates conservative assumptions as discussed in Section 4.3.

7.5. Limitations or Special Instructions

None.

8. ELECTRONIC FILES

8.1. Computer Runs

All runs have been performed using ANSYS computer code version 5.5 on Compaq PC hardware platform, machine ID 7819BR960141. The listing of the input and output files is given in Table 8.1-1.

Table 8.1-1 Input and Output Files

Directory	Filename	File Size	Date	Time	
basket	mpbvac.inp	12Kb	1/12/01	3:21	P
	mpbvac1.sum	2Kb	1/12/01	2:43	P
	mpbvac2.sum	2Kb	1/12/01	2:12	P
	mpbvac3.sum	2Kb	1/12/01	3:19	P
	mpbvac4.sum	2Kb	1/12/01	3:22	P
transient	mtc.des	2Kb	2/14/01	1:26	P
	mtc.inp	17Kb	2/14/01	1:31	P
	mtc.sum	9Kb	2/14/01	1:40	P

8.2. Other Electronic Files

None.

9. ATTACHMENT A. INPUT AND OUTPUT FOR BASKET RUNS

9.1. Input

Sample input is presented for Case 1 of Table 6.1-1. Table 9.1-1 shows the beginning fragment of the input. The rest of the input is identical to the file presented in Ref. 3.1.2.

Table 9.1-1 Basket in the Transfer Cask, Input File MSB.INP (Fragment)

```
!   msbvac.inp
!   Design paramters and boundary condition data
!
!   Units: BTU,FT,F(K),HR
!
/title,VSC-24 BASKET THERMAL ANALYSIS,24 kW,Tamb=100F
/prep7
case='msbvac'               ! Id for this run, appears at the top
!                           of each plot and is listed in the
!                           summary file ("case".sum)
heatld=2                    ! max. heat load (kW)
tshell=20                   ! temperature at mpb shell
!
lfuel=12                    ! active fuel length (ft)
cell=8.9/12                 ! side of the cell
!
! Emissivity
e_cz=0.72
eps=1/(2/e_cz-1)

!
! sbc=(.119e-10)            ! radiation constant (btu, in, k)
sbc=(1.7136e-9)             ! radiation constant (btu, ft, k)
formf=1                     ! form (view) factor
kfuel=0.6                   ! conductivity of the fuel (btu/ft-hr-F)
ksteel=26                   ! conductivity of steel
khe=2.8                     ! He conductivity (wide area)
khenar=0.11                 ! He conductivity (narrow area)
!
qpeak=1.1                   ! peaking factor for the fuel
qtot=heatld*3412            ! total heat load  (btu/hr)
arfuel=cell*cell*24         ! area of fuel region (in**2)
qfuel=qpeak*qtot/(lfuel*arfuel)   ! heat generation for the fuel-
!                           btu/hr-in**3
gf=12                       ! conversion factor ft to inch
vc=1e-6                     ! factor for vacuum condition
! vc=1                      ! factor for Helium condition
fini
/prep7
```

```
!   material assignments
!    material 1 = steel for sleeves and shell
!    material 2 = fuel region
!    material 3 = helium (wide area)
!    material 4 = steel
!    material 5 = helium (narrow)
!
! Steel
mp,kxx,1,ksteel
!
! Fuel region
mptemp
mptemp,1,212,302,392,482
mpdata,kxx,2,1,0.0936,0.136,0.187,0.250
mptemp,5,572,662,752
mpdata,kxx,2,5,0.324,0.410,0.511
!
! Helium (wide)
mp,kxx,3,khe*vc
!
! Steel
mp,kxx,4,ksteel
!
! Helium (narrow)
mp,kxx,5,khenar*vc
!
TOFFST,460
ET,1,PLANE55,1
ET,2,LINK31
!
! Real Constants for the Radiation Links
r,101,.1938,1,eps,sbc
r,102,.3875,1,eps,sbc
r,103,.3875,1,eps,sbc
r,104,.3875,1,eps,sbc
r,105,.3875,1,eps,sbc
r,106,.3875,1,eps,sbc
r,107,.1938,1,eps,sbc
```

9.2. Output

Sample summary output is presented for Case 1 of Table 6.1-1.

Table 9.2-1 Basket in the Transfer Cask, Output Summary File MSB.SUM

```
ABBREVIATION STATUS-

 ABBREV   STRING
 SAVE_DB  SAVE
 RESUM_DB RESUME
 QUIT     Fnc_/EXIT
 POWRGRPH Fnc_/GRAPHICS
 ANSYSWEB Fnc_HomePage
 TUTORIAL Fnc_Tutorial
 WHATSNEW Fnc_Whatsnew

PARAMETER STATUS-        ( 23 PARAMETERS DEFINED)
        (INCLUDING    2 INTERNAL PARAMETERS)

 NAME        VALUE          TYPE   DIMENSIONS
 ARFUEL   13.2016667     SCALAR
 CASE      msbvac   CHARACTER
 CELL    0.741666667     SCALAR
 EPS     0.562500000     SCALAR
 E_CZ    0.720000000     SCALAR
 FORMF    1.00000000     SCALAR
 GF       12.0000000     SCALAR
 HEATLD   2.00000000     SCALAR
 KFUEL   0.600000000     SCALAR
 KHE      2.80000000     SCALAR
 KHENAR  0.110000000     SCALAR
 KSTEEL   26.0000000     SCALAR
 LFUEL    12.0000000     SCALAR
 QFUEL    47.3829062     SCALAR
 QPEAK    1.10000000     SCALAR
 QTOT     6824.00000     SCALAR
 SBC   1.713600000E-09   SCALAR
 TMXFUEL  141.761174     SCALAR
 TMXSLV   124.121698     SCALAR
 TSHELL   20.0000000     SCALAR
 VC    1.000000000E-06   SCALAR
```

10. ATTACHMENT B. INPUT AND OUTPUT FOR THE TRANSFER CASK RUN

10.1. Input

Table 10.1-1 Design Parameters Input File MTC.DES

```
!   mtc.des
!   Design paramters and boundary condition data
!     for MTC thermal analysis
!   dimensions are in FEET, F, BTU, HR
case='mtc'              ! Id for this run, appears at the top
!                         of each plot and is listed in the
!                         summary file ("case".sum)
/TITLE, VSC MTC Thermal Transient Analysis
TINT=100                ! Initial temperature
TWATER=32               ! max. time for msb with water
TVAC=100                ! max. time for vacuum drying
!
TAMB=32                 ! amb. temperature F outside of mtc
tmwater=100             ! water temperature F outside of mtc
!
RMSBO=31.25/12          ! outside radius of msb shell
RMSBI=30.25/12          ! inside radius of msb shell
RF1=RMSBI/2             ! radius for fuel element
!
RMTCI=31.75/12          ! inside radius of MTC inner shell
TINNER=0.75/12          ! thickness of MTC inner shell
TLEAD=4.0/12            ! thickness of Lead
TRX277=4.25/12          ! thickness of RX-277
TOUTER=1.0/12           ! thickness of MTC outer shell
TMTC=TINNER+TLEAD+TRX277+TOUTER   ! thickness of MTC
wall
RMTCO=RMTCI+TMTC        ! outside radius of MTC outer
shell
!
TDOOR=-9/12
Z1=TDOOR/3
Z2=TDOOR*2/3
!
!
! Heat generation rate (BTU/HR-FT**3)
!
Q1= 341.9
Q2= 376.1
Q3= 376.1
Q4= 372.7
Q5= 362.4
Q6= 307.7
```

Table 10.1-2 Main Input File MTC.INP

```
/com mtc.inp
fini
fini
/clear
! Run design parameters input file
/inp,mtc,des
!
/com
/COM THERMAL STEADY-STATE ANALYSIS FOR MTC, VSC
GEOMETRY
/COM CLIENT:
/COM PROJECT:
/COM
/COM RESPONSE TO LICENSING QUESTION
/COM
/COM UNITS: BTU,FT,HR,F,LBM
/COM
/filename,mtc
/ann,dele
/tlab,-.95,.95, Design Case: %case%
/com
/com macro for design parameters
/com
! /input,mtctran,des
/COM
/com generates the following files:
/com   mtctran.mda    listing of model data
/com   "case".sum   analysis result summary
/com   "case".plt   plot file
/com Note: "case" is defined in design parameter file
/COM
/PREP7
ANTYPE,0     ! Static Analysis
TOFFST,460
ET,1,SOLID70
ET,2,LINK31
/com
/com Material Properties
/com
/com   Material 1  = Carbon Steel
/com   Material 2 = Stainless Steel
/com   Material 4  = Fuel region
/com   Material 5  = Helium
/com   Material 6  = Air
/com   Material 7  = Water
/com   Material 9  = Lead
/com   Material 10 = RX-277 (with Angles)
/com   Material 11 = RX-277
/com
/com  Carbon Steel
mptemp
MPTEMP, 1, 0.000000000E+00, 2300.00000
MPDATA,DENS,   1, 1, 490.000000   , 490.000000
mptemp
! MPTEMP, 1,-50,32,212,572,932
! MPDATA,KXX ,   1, 1 ,26.73,26.5,26,25,22
mp,kxx,1,26
mptemp
MPTEMP, 1,0.000000000E+00, 2300.00000
MPDATA,C  ,   1, 1, 0.110000000   , 0.110000000
mptemp
MP,EMIS,1,.8
/com Stainless Steel
mp,dens,2,488
mp,kxx,2,9.4
mp,c,2,.11
/com
/com Fuel (with vacuum)
MP,DENS,4,176.8
! MP,KXX,4,1.358
! MP,KYY,4,1.358
MP,KZZ,4,2.4
MP,C,4,0.071
mptemp
mptemp,1,81,154,405,591
mpdata,kxx,4,1,0.408,0.481,0.905,1.229
/com
/com  Helium  (Vacuum)
! vc=1.0       ! Helium
vc=1.0e-6      ! Vacuum
mptemp
MPTEMP, 1, 0.000000000E+00, 2300.00000
MPDATA,DENS,    5, 1, 6.400000000E-03*vc, 6.400000000E-03*vc
! mptemp
! MPTEMP, 1,0,200,400,600,800
! MPDATA,KXX ,    5, 1,.078*vc,.097*vc,.115*vc,.129*vc,.138*vc
mp,kxx,5,.1*vc
mptemp
MPTEMP, 1, 0.000000000E+00, 2300.00000
MPDATA,C  ,    5, 1,  1.24000000   , 1.24000000
!    Air
/com  Air
mptemp
MPTEMP,     1, -50,0.000, 32, 100
MPTEMP,     5, 200, 300, 500, 700
MPDATA,DENS,6,1, 9.4E-02, 8.6E-02, 8.1E-02, 7.1E-02
MPDATA,DENS,6,5, 6.0E-02, 5.2E-02, 4.12E-02, 3.73E-02
mptemp
MPTEMP,     1, -50,0.000, 32, 100
MPTEMP,     5, 200, 300, 500, 700
MPDATA,KXX ,6,1, 1.14E-02, 1.30E-02, 1.40E-02, 1.54E-02
MPDATA,KXX ,6,5, 1.74E-02, 1.93E-02, 2.31E-02, 2.68E-02
mptemp
MPTEMP,     1, -50,0.000, 32, 100
MPTEMP,     5, 200, 300, 500, 700
MPDATA,C,   6, 1, 0.2385, 0.2390, 0.2400, 0.2400
MPDATA,C,   6, 5, 0.2410, 0.2430, 0.2470, 0.2530
/com     Water
mptemp
MPTEMP,1,32,81,126,171,212
mpdata,dens,7,62.43,62.24,61.62,60.74,59.81
mptemp
MPTEMP,1,32,81,126,171,212
mpdata,kxx,7,0.3288,0.3543,0.3727,0.3860,0.3930
mptemp
MPTEMP,1,32,81,126,171,212
mpdata,c,7,1.0072,0.9982,0.9989,1.0020,1.0072
/com  Lead
mptemp
MP,DENS,9,710
mptemp
! MPTEMP, 1,-148,32,212,392,572
! MPDATA,KXX, 9, 1,21.32,20.28,19.3,18.2,17.22
mp,kxx,9,19
mptemp
MP,C,9,.031
/com  RX-277 (Neutron shield with angles)
MP,DENS,10,130
MP,KXX,10,1.264
MP,C,10,.194
/com
/com  RX-277 (Neutron shield)
```

```
MP,DENS,11,106
MP,KXX,11,.3
MP,C,11,.22
/com
/VIEW,,,-1
!
N,1,,,TDOOR
N,2,,,Z2
N,3,,,Z1
N,4
N,5,,,(0.75/12)      ! MSB Bottom Thickness
N,6,,,(4.75/12)    ! Fuel begins
N,12,,,(148.75/12) ! Fuel ends = Previous + 144
FILL,6,12,5
N,13,,,(179.75/12)
N,14,,,(184.75/12)
N,15,,,(186.75/12)
N,16,,,(192.25/12)
NGEN,2,20,1,16,,RF1

NGEN,2,40,1,16,,RMSBI
NGEN,2,60,1,16,,RMSBO
NGEN,2,80,1,16,,RMTCI
! N,95 is commented out in SNC version
N,95,RMTCI,,(186.75/12)
N,96,RMTCI,,(190.5/12)
N,97,RMTCI,,(192.5/12)
NGEN,2,20,81,97,,TINNER
NGEN,2,40,81,97,,(TINNER+TLEAD)
NGEN,2,60,81,97,,(TINNER+TLEAD+TRX277)
NGEN,2,80,81,97,,TMTC
!
CSYS,1
NSEL,U,NODE,,1,16
NGEN,2,400,ALL,,,,10
N,300,8,5,8
N,301,(20/12),5,(230/12)
N,700,8,5,8
N,701,(20/12),5,(230/12)
NALL
!
TYPE,1
MAT,1
E,21,421,1,1,22,422,2,2
E,41,441,421,21,42,442,422,22
EGEN,5,20,2
EGEN,2,1,1,6,,8
EGEN,2,2,1,6
/COM
EGEN,2,1,17,18
EGEN,3,20,20
EGEN,13,1,19,22,3
EGEN,2,1,20,,,8
EGEN,2,1,21,,,9
EGEN,9,1,47,48
EGEN,3,1,64
EGEN,2,-20,65,66
EGEN,2,20,45
EGEN,2,20,69
EGEN,2,1,13,15
EGEN,2,1,71,72,,4
EGEN,2,1,74,75,,-1
EGEN,6,1,76,77
EGEN,2,1,86,87,,1
EGEN,2,1,88,89,,-4
EGEN,2,1,90,91,,10
EGEN,2,1,92,93,,-10
EGEN,12,1,73
NALL
/COM Modify elements for appropriate material
mat,1
EMODIF,7
EMODIF,8
EMODIF,9
EMODIF,10
EMODIF,11
EMODIF,12
mat,11
EMODIF,48
EMODIF,62
EMODIF,64
EMODIF,65
EMODIF,66
EMODIF,68
mat,9
EMODIF,67
esel,s,,,18
esel,a,,,12
esel,a,,,6
EGEN,3,20,ALL
! Filling annulus with air and water
alls
egen,11,1,16
esel,,,,113,117
emod,all,mat,7
esel,,,,118,122
emod,all,mat,6
eall
nall
! We used to have some stainless steel components
! on the control model
! csys,1
! nsel,s,loc,x,0,rmsbo+.01
! nsel,r,loc,z,0,192.6/12
! esln,,1
! esel,r,mat,,1
! type,1
! real,1
! mat,2
! emod,all
! eall
! nall
/com
! Emissivities
em11=0.88          ! Outside MTC
em12=1.0          ! Ambient
em1=1/(1/em11+1/em12-1) ! Outside MTC to Ambient
!
em21=0.88          ! MPB shell
em22=0.88          ! MTC inner shell
em2=1/(1/em21+1/em22-1) ! Gap between MPB and MTC
!
em31=0.65          ! Top MPB
em32=1.0          ! Ambient
em3=1/(1/em31+1/em32-1) ! Top MPB to Ambient
!
em41=0.88          ! Top MTC
em42=1.0          ! Ambient
em4=1/(1/em41+1/em42-1) ! Top MTC to Ambient
!
em51=0.4          ! Fuel
em52=0.65          ! Bottom Plate
em5=1/(1/em51+1/em52-1) ! Fuel to Bottom Plate
!
em61=0.4          ! Fuel
em62=0.65          ! Shield Lid
em6=1/(1/em61+1/em62-1) ! Fuel to Shield Lid
!
```

```
/com Real Numbers for Radiation Elements
/COM Outside MTC
R, 201, 0.038,1.0,em1,1.714E-9
R, 202, 0.114,1.0,em1,1.714E-9
R, 203, 0.085,1.0,em1,1.714E-9
R, 204, 0.060,1.0,em1,1.714E-9
R, 205, 0.354,1.0,em1,1.714E-9
R, 206, 0.607,1.0,em1,1.714E-9
R, 207, 0.607,1.0,em1,1.714E-9
R, 208, 0.607,1.0,em1,1.714E-9
R, 209, 0.607,1.0,em1,1.714E-9
R, 210, 0.607,1.0,em1,1.714E-9
R, 211, 0.696,1.0,em1,1.714E-9
R, 212, 0.455,1.0,em1,1.714E-9
R, 213, 0.089,1.0,em1,1.714E-9
R, 214, 0.073,1.0,em1,1.714E-9
R, 215, 0.098,1.0,em1,1.714E-9
/com Gap betw MSB and MTC
R, 301, 0.052,1.0,em2,1.714E-9
R, 302, 0.265,1.0,em2,1.714E-9
R, 303, 0.455,1.0,em2,1.714E-9
R, 304, 0.455,1.0,em2,1.714E-9
R, 305, 0.455,1.0,em2,1.714E-9
R, 306, 0.455,1.0,em2,1.714E-9
R, 307, 0.455,1.0,em2,1.714E-9
R, 308, 0.521,1.0,em2,1.714E-9
R, 309, 0.341,1.0,em2,1.714E-9
R, 310, 0.066,1.0,em2,1.714E-9
R, 311, 0.123,1.0,em2,1.714E-9
/com Top of MTC
R, 401, 0.035,1.0,em3,1.714E-9
R, 402, 0.146,1.0,em3,1.714E-9
R, 403, 0.133,1.0,em3,1.714E-9
R, 404, 0.047,1.0,em4,1.714E-9
R, 405, 0.111,1.0,em4,1.714E-9
R, 406, 0.064,1.0,em4,1.714E-9
/com Bot of Fuel region
R, 501, 0.035,1.0,em5,1.714E-9
R, 502, 0.260,1.0,em5,1.714E-9
/com Top of Fuel region
R, 601, 0.035,1.0,em6,1.714E-9
R, 602, 0.260,1.0,em6,1.714E-9
/COM
TYPE,2
MAT,3
/com
/com Radiation elem outside MTC
/com use macro: mlink.mac
/com
*creat,mlink,mac
REAL,ARG1
EN,ARG1,ARG2,ARG3
*end
!
! Nodes 161 through 169 are under water
! radiation links restored
!
MLINK,201,161,300
MLINK,202,162,300
/COM
*DO,I,164,176
E1=I+39
MLINK,E1,I,300
*ENDDO
/com
/com Rad elem betw MSB & MTC
*DO,I,65,75
E2=I+236
I2=I+20
MLINK,E2,I,I2
*ENDDO
/COM
/com Rad elem at top of MTC
MLINK,401,16,301
MLINK,402,36,301
MLINK,403,76,301
MLINK,404,97,301
MLINK,405,137,301
MLINK,406,177,301
/COM
/com Rad elem at Helium Region
MAT,5
/com bottom of fuel region
MLINK,501,5,6
MLINK,502,25,26
/com top of fuel region
MLINK,601,12,13
MLINK,602,32,33
/COM
ESEL,S,TYPE,,2
ESEL,U,ELEM,,401,601,100
EGEN,2,400,ALL
EALL
NUMMRG,NODE
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
/com
/out,%case%,mda
mplist,all
rlist,all
dsys,1
nlist,all
dsys
elist,all
/out
!
FINISH
/SOLU
D,300,TEMP,TAMB
D,301,TEMP,TAMB
/COM
BFE,76,HGEN,1,Q1
BFE,78,HGEN,1,Q2
BFE,80,HGEN,1,Q3
BFE,82,HGEN,1,Q4
BFE,84,HGEN,1,Q5
BFE,86,HGEN,1,Q6
BFE,77,HGEN,1,Q1
BFE,79,HGEN,1,Q2
BFE,81,HGEN,1,Q3
BFE,83,HGEN,1,Q4
BFE,85,HGEN,1,Q5
BFE,87,HGEN,1,Q6
/com
! Convection outside MTC
CSYS,1
tol=0.1 ! inch
alls
! MTC side
NSEL,S,LOC,X,(RMTCO-TOL/12),5.0
! 1/3 of the basket under water
! convection starts at the level Z = 76.75
nsel,u,loc,z,(-9-tol)/12,(76.75-tol)/12
! Top
NSEL,A,LOC,Z,(192.25-TOL)/12,18.0
SF,ALL,CONV,2,TAMB
NALL
!
! water temperature (100F) constraint outside mtc
```

```
alls
NSEL,S,LOC,X,(RMTCO-TOL/12),5.0
nsel,r,loc,z,(-9-tol)/12,(76.75+tol)/12
d,all,temp,tmwater
alls
/com
/com   specify initial temperature for the msb shell
/com
!
tstep1=10      ! transient run for 10 hrs
antype,transient,new
tunif,TINT
!
AUTOTS,ON
TIMINT,ON
DELTIME,0.001,0.0005,0.005
TIME,0.01
KBC,1
CNVTOL,TEMP,2,0.5
CNVTOL,FLUX,-1
OUTPR,BASI,NONE
OUTRES,ALL,all
solve
TIMINT,ON
KBC,1
DELTIME,0.3,0.3,0.3
TIME,tstep1
solve
CSYS,0
FINISH
/com
/POST1
/show,%case%,plt,0
/num,0
csys,1
nsel,s,loc,y,0
/title,Transfer Cask Thermal Analysis
plns,temp
nall
! plot temperature distribution for mtc portion
csys,1
nsel,s,loc,x,0,rmsbo
nsel,r,loc,z,0.001,20
nsel,inve
nsel,u,node,,300,301
nsel,r,loc,y,0
/ratio,,3
plns,temp
/ratio
nall
eall
csys,0
!
! DEFINITION OF PARAMETERS
!
! aside  : total area of radiation elem at mtc side
! atop   : total area of radiation elem at mtc/msb top
! agap   : total area of radiation elem from msb to mtc liner
! aftop  : total area of radiation elem at top of fuel region
! afbot  : total area of radiation elem at bottom of fuel region
! tshell : maximum temperature at msb shell (outer surface)
!
/com  Check area for radiation elements
nsel,s,,,300
esln
nsle
etable,area31,nmisc,3
ssum
*get,aside,ssum,,item,area31
!
nsel,s,,,301
esln
nsle
etable,area31,nmisc,3
ssum
*get,atop,ssum,,item,area31
!
nsel,s,node,,65,75
nsel,a,node,,465,475
esln
esel,r,type,,2
nsle
etable,area31,nmisc,3
ssum
*get,agap,ssum,,item,area31
!
nsel,s,node,,12,32,20
nsel,a,node,,432
esln
esel,r,type,,2
nsle
etable,area31,nmisc,3
ssum
*get,aftop,ssum,,item,area31
!
nsel,s,node,,6,26,20
nsel,a,node,,426
esln
esel,r,type,,2
nsle
etable,area31,nmisc,3
ssum
*get,afbot,ssum,,item,area31
eall
nall
/com
/com  max. msb shell temp (outside surface of msb shell)
/com
nsel,s,node,,65,76
nsort,temp
*get,tshell,sort,,max
nall
eall
/com
/com  temp distribution across mtc wall
lpath,68,168
pdef,temp,temp
/view,,,,1
/axlab,y,Temperature (F)
/axlab,x,Distance from basket shell (ft)
/grid,1
/title,Transfer Cask Through-Wall Temperatures (Node 68-168)
plpath,temp
lpath,69,169
pdef,temp,temp
/title,Transfer Cask Through-Wall Temperatures (Node 69-169)
plpath,temp
/com
/com
/out,%case%,sum
! Result summary from MTC thermal analysis - mtct
*stat
/com
/com  through wall temperature
nsel,s,node,,68,168,20
prns,temp
nsel,s,node,,69,169,20
prns,temp
```

```
/com
/com  temperature at center line of cask
nsel,s,node,,1,16
prns,temp
/com
/com  temperature at outside surface of msb shell
nsel,s,node,,65,76
prns,temp
/com
/com  temperature at inside surface of mtc inner shell
nsel,s,node,,85,97
prns,temp
/com
/com  temperature at outside surface of mtc outer shell
nsel,s,node,,161,177
prns,temp
! Temperature of the Basket Internals
nsel,s,node,,6,12,3
nsel,a,node,,26,32,3
nsel,a,node,,46,52,3
prns,temp
!
nall
/out
eall
nall
/title,Transfer Cask Thermal Analysis
/show,term
/num
/edge
/view,,,-1
SAVE,%case%,db
finish
```

10.2. Output

Table 10.2-1 Output Summary File MTC.SUM

```
ABBREVIATION STATUS-

ABBREV   STRING
SAVE_DB  SAVE
RESUM_DB  RESUME
QUIT    Fnc_/EXIT
POWRGRPH  Fnc_/GRAPHICS
ANSYSWEB  Fnc_HomePage
TUTORIAL  Fnc_Tutorial
WHATSNEW  Fnc_Whatsnew

PARAMETER STATUS-      ( 58 PARAMETERS DEFINED)
          (INCLUDING   2 INTERNAL PARAMETERS)

NAME      VALUE       TYPE   DIMENSIONS
AFBOT   0.555000000    SCALAR
AFTOP   0.555000000    SCALAR
AGAP    7.28600000    SCALAR
ASIDE   10.1940000    SCALAR
ATOP    1.03700000    SCALAR
CASE     mtc     CHARACTER
E1     215.000000    SCALAR
E2     311.000000    SCALAR
EM1    0.880000000    SCALAR
EM11   0.880000000    SCALAR
EM12    1.00000000    SCALAR
EM2    0.785714286    SCALAR
EM21   0.880000000    SCALAR
EM22   0.880000000    SCALAR
EM3    0.650000000    SCALAR
EM31   0.650000000    SCALAR
EM32    1.00000000    SCALAR
EM4    0.880000000    SCALAR
EM41   0.880000000    SCALAR
EM42    1.00000000    SCALAR
EM5    0.329113924    SCALAR

NAME      VALUE       TYPE   DIMENSIONS
EM51   0.400000000    SCALAR
EM52   0.650000000    SCALAR
EM6    0.329113924    SCALAR
EM61   0.400000000    SCALAR
EM62   0.650000000    SCALAR
I      75.0000000    SCALAR
I2     95.0000000    SCALAR
Q1     341.900000    SCALAR
Q2     376.100000    SCALAR
Q3     376.100000    SCALAR
Q4     372.700000    SCALAR
Q5     362.400000    SCALAR
Q6     307.700000    SCALAR
RF1    1.26041667    SCALAR
RMSBI   2.52083333    SCALAR
RMSBO   2.60416667    SCALAR
RMTCI   2.64583333    SCALAR
RMTCO   3.47916667    SCALAR
TAMB    32.0000000    SCALAR
TDOOR  -0.750000000    SCALAR
TINNER  6.250000000E-02  SCALAR

NAME      VALUE       TYPE   DIMENSIONS
TINT    100.000000    SCALAR
TLEAD   0.333333333    SCALAR
TMTC    0.833333333    SCALAR
TMWATER  100.000000    SCALAR
TOL     0.100000000    SCALAR
TOUTER  8.333333333E-02  SCALAR
TRX277  0.354166667    SCALAR
TSHELL   199.229983    SCALAR
TSTEP1   10.0000000    SCALAR
TVAC    100.000000    SCALAR
TWATER   32.0000000    SCALAR
VC      1.000000000E-06  SCALAR
Z1     -0.250000000    SCALAR
Z2     -0.500000000    SCALAR

through wall temperature

SELECT      FOR ITEM=NODE COMPONENT=
IN RANGE     68 TO     168 STEP      20

     6  NODES (OF     284  DEFINED) SELECTED BY  NSEL
COMMAND.
```

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
68	158.15
88	140.29
108	139.76
128	136.65
148	100.40
168	100.00

MAXIMUM ABSOLUTE VALUES
NODE 68
VALUE 158.15

SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 69 TO 169 STEP 20

6 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
69	172.37
89	131.89
109	131.36
129	128.51
149	100.25
169	100.00

MAXIMUM ABSOLUTE VALUES
NODE 69
VALUE 172.37

temperature at center line of cask

SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 16 STEP 1

16 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
1	115.02
2	115.16
3	115.52
4	115.83
5	115.79
6	329.12
7	366.68
8	384.34
9	385.33
10	378.13
11	351.51
12	311.12
13	103.60
14	103.05
15	73.664
16	71.864

MAXIMUM ABSOLUTE VALUES
NODE 9
VALUE 385.33

temperature at outside surface of msb shell

SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 65 TO 76 STEP 1

12 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
65	111.06
66	126.34
67	153.81
68	158.15
69	172.37
70	199.23
71	186.69
72	145.86
73	89.382
74	87.012
75	81.044
76	76.811

MAXIMUM ABSOLUTE VALUES
NODE 70
VALUE 199.23

temperature at inside surface of mtc inner shell

SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 85 TO 97 STEP 1

13 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
85	109.57
86	114.50
87	134.23
88	140.29
89	131.89
90	107.14
91	95.659

92 88.165
93 74.912
94 71.747
95 69.151
96 57.056
97 55.136

MAXIMUM ABSOLUTE VALUES
NODE 88
VALUE 140.29

temperature at outside surface of mtc outer shell

SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 161 TO 177 STEP 1

17 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
161	100.00
162	100.00
163	100.00
164	100.00
165	100.00
166	100.00
167	100.00
168	100.00
169	100.00
170	70.988
171	64.858
172	54.503
173	45.559
174	46.285
175	46.901
176	48.609
177	48.739

MAXIMUM ABSOLUTE VALUES
NODE 161
VALUE 100.00

SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 6 TO 12 STEP 3

3 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

ALSO SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 26 TO 32 STEP 3

6 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

ALSO SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 46 TO 52 STEP 3

9 NODES (OF 284 DEFINED) SELECTED BY NSEL COMMAND.

PRINT TEMP NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 2 SUBSTEP= 34
TIME= 10.000 LOAD CASE= 0

NODE	TEMP
6	329.12
9	385.33
12	311.12
26	276.55
29	357.61
32	264.69
46	126.97
49	173.14
52	146.21

MAXIMUM ABSOLUTE VALUES
NODE 9
VALUE 385.33

284 NODES (OF 284 DEFINED) SELECTED BY NALL COMMAND.

BNFL Fuel Solutions	CALCULATION PACKAGE	Calc. Pkg No. VSC02.6.2.5.01 File No.: VSC02.6.2.5.01 Revision: 1

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

Weight and Center of Gravity

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ______
Service:	☒ Storage	☐ Transportation		☐ Other ______
Conditions:	☒ Normal	☐ Off-Normal	☐ Accident	☐ Other ______

Component(s):

MSB, MTC and VCC, including all components and sub components.

Prepared by:

Name: Robert KEATING

Signature: [signature]

Date: 1-31-2001

Verified by:

Name: Regina Parkerson / Michelle Heinz

Signature: Regina Parkerson / Michelle [signature]

Date: 1-31-2001

Engineering Manager Approval:

Name: R. SRINIVASAN

Signature: [signature]

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (print or type)	
				PREPARER	CHECKER
0	1 - 28		Replaces Calculation WEP109-004.1, Rev. 2	Robert Keating	Regina Parkerson
1	1-32		Revised to include information as needed to replace calculation ANO-109.002.001, Rev 5 Incorporated ECN VSC02-ECN-008	Robert Keating	Regina Parkerson Michelle Heinz

Note: This calculation has been prepared in accordance with QAP 3.2, Revision 9, except that because this calculation is a revision of an existing calculation, the format is essentially based on the superceded calculation. The title page, record of revision page, and record of verification page are per QAP 3.2, Revision 9. Other format requirements of QAP 3.2 have been included where this could be readily accomplished. This approach was approved in BFS Memorandum 00-427.

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	~~YES~~ RMP	NO	(N/A)
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Regina Parkerson / Regina Parkerson / 1-31-2001
Name/Signature/Date Michelle Heinz / Michelle Heinz

1.0 INTRODUCTION

This Calculation determines the MSB, MTC, and VCC component weights, volumes and centers of gravity. The information is required for different cask analyses as well as for handling of items when empty or loaded. This calculation also determines weights of MSB, MTC, and VCC components that are used by referencing calculations.

This analysis is bounding size (weight and height) and generic for the VSC-24 system. The calculation is a generic calculation. This generic analysis includes the resolution of discrepancies identified in Corrective Action Reports CAR 98-50 and CAR 98-51.

2.0 REQUIREMENTS

2.1 Design Inputs

None.

2.2 Regulatory Commitments

None.

3.0 REFERENCES

3.1 BFS Calculation Packages

3.1.1. Calculation No. VSC02.6.2.5.03, "VSC-24 Design Parameters Document," Revision 0.

4.0 ASSUMPTIONS

4.1 Design Configuration

All design configurations are from the Design Parameters (Reference 3.1.1). The weights and centers of gravity are calculated for six bounding configurations. These six configurations bound all of the configurations provided in the Design Parameters. These are summarized as follows:

1. A small VSC-24 assembly loaded with the lightest non-BPRA fuel and the heaviest BPRA fuel. This represents the Palisades configuration.

2. A medium size VSC-24 assembly loaded with the lightest non-BPRA fuel and the heaviest BPRA fuel. This represents the Point Beach configuration.

3. A large size VSC-24 assembly loaded with the lightest non-BPRA fuel and the heaviest BPRA fuel. The largest size is the ANO-1 and ANO-2 configuration. This case also applies to the Westinghouse 15x15 and 17x17 fuel assemblies, assuming the fuel and basket are loaded into the ANO style design of the MSB, MTC, and VCC.

All of the dimensions and material properties are from Reference 3.1.1, unless noted.

The input data for the analysis and the calculation results are provided in matrices. The first row is the short cask, the second row is the mid-size cask, and the third row is the tall cask. The first column is the lightest fuel and the second column is the heaviest fuel. Specifically,

Example 3x1 matrix

$$'' \equiv \begin{bmatrix} \text{"Short"} \\ \text{"Medium"} \\ \text{"Tall"} \end{bmatrix}$$

Example 3x2 matrix

$$' \equiv \begin{bmatrix} \text{"Short-Light"} & \text{"Short-Heavy"} \\ \text{"Medium-Light"} & \text{"Medium-Heavy"} \\ \text{"Tall-Light"} & \text{"Tall-Heavy"} \end{bmatrix}$$

4.1.1 Density of Materials

Steel $\rho_{st} := 0.284 \frac{lbf}{in^3}$

Lead $\rho_{lead} := 0.41 \frac{lbf}{in^3}$

Concrete/ Rebar $\rho_{c} := 150 \frac{lbf}{ft^3}$

Water $\rho_{w} := 62.4 \frac{lbf}{ft^3}$

Rx-277 $\rho_{Rx} := 0.0607 \frac{lbf}{in^3}$

4.1.2 Fuel Assembly

This analysis is based on an assumed bounding fuel weight with control components installed in the fuel assembly during storage.

$N_{fuel} := 24$ Number of Fuel Assemblies

$$M_{fuel} := \begin{bmatrix} 1305 & 1380 \\ 1110 & 1350 \\ 1370 & 1585 \end{bmatrix} lbf$$

Mass of Fuel per Fuel Assembly (The first row is the short cask, the second row is the mid-size cask, and the third row is the tall cask. The first column is the lightest fuel and the second column is the heaviest fuel.)

$$h_{fuel} := \begin{bmatrix} 140 \\ 152.4 \\ 153.68 \end{bmatrix} in$$

Height of Individual Fuel Pin

$$N_{pins} := \begin{bmatrix} 15 \\ 14 \\ 15 \end{bmatrix}$$

Number of Pins Along One Side of Fuel Array

$$lg_{fuel} := \begin{bmatrix} 150.6 \\ 166.3 \\ 178.6 \end{bmatrix} in$$

Total Length of Fuel Assembly

$$OD_{fuel} := \begin{bmatrix} 0.418 \\ 0.422 \\ 0.382 \end{bmatrix} in$$

Outside Diameter of Fuel Pin

4.1.3 MSB Geometry

$OD_{MSB} := 62.5\ in$	Outside Diameter of MSB-24
$t_{MSB\_shell} := 1.0\ in$	Thickness of MSB-24 Shell

$ID_{MSB} := OD_{MSB} - 2 \cdot t_{MSB\_shell}$

$ID_{MSB} = 60.5 \cdot in$	Inside Diameter of MSB-24
$h_{MSB} := \begin{bmatrix} 164.2 \\ 180.3 \\ 192.25 \end{bmatrix} in$	Overall Height of MSB-24
$t_{Mbase} := 0.75\ in$	Thickness of Base of MSB-24
$OD_{Mlid} := 60\ in$	Conservative (i.e. maximum) Outside Diameter of MSB-24 Structural Lid
$t_{Mlid} := 3\ in$	Thickness of MSB-24 Structural Lid
$N_{bar} := 12$	Number of Support Bars
$h_{bar} := 28\ in$	Height of Support Bar
$t_{bar} := 1.45\ in$	Thickness of Support Bars
$w_{bar} := 2.0\ in$	Width of Support Bars
$N_{wall} := 3$	Number of Support Wall Courses
$OD_{wall} := 59.2\ in$	Outside Diameter of Support Walls
$t_{wall} := 0.5\ in$	Thickness of Support Wall
$lg_{wall} := 28\ in$	Length of Support Wall
$M_{MSB\_hardware} := 100\ lbf$	Assumed Weight of Miscellaneous MSB Hardware

$$lg_{sleeve} := \begin{bmatrix} 147.5 \\ 163.6 \\ 159.0 \end{bmatrix} in$$ Length of Storage Sleeve

$w_{sleeve} := 9.2\ in$ Width of Storage Sleeve

$t_{sleeve} := 0.2\ in$ Thickness of Storage Sleeve

$OD_{shield} := 60.1\ in$ Outside Diameter of Shield Lid

$t_{shieldtop} := 2.5\ in$ Thickness of Shield Top Plate

$t_{neutron} := 2\ in$ Thickness of Neutron Shield in Top

$t_{ring} := 0.5\ in$ Thickness of Side Ring

$t_{support} := 5.0\ in$ Thickness of Support Plate (bottom plate of the shield lid)

$OD_{support} := 60.25\ in$ Outside Diameter of Support Plate

$t_{shield\_support} := 0.5\ in$ Thickness of the Shield Lid Support Ring

$h_{shield\_support} := 2.0\ in$ Height of the Shield Lid Support Ring

$d_{support} := 12.55\ in$ Distance from Top of MSB to Top of Shield Lid Support Ring

4.1.4 MTC Geometry

$$OD_{inner} := \begin{bmatrix} 65.0 \\ 65.0 \\ 64.5 \end{bmatrix} in$$

OD of the MTC Inner Shell

$t_{inner} := 0.75\ in$

Thickness of the MTC Inner Shell

$$ID_{inner} := \overrightarrow{\left(OD_{inner} - 2 \cdot t_{inner}\right)} \qquad ID_{inner} = \begin{bmatrix} 63.5 \\ 63.5 \\ 63 \end{bmatrix} \cdot in$$

ID of the MTC Inner Shell

$$h_{MTC} := \begin{bmatrix} 161.7 \\ 177.8 \\ 189.8 \end{bmatrix} in$$

Height of MTC Shell

$$OD_{outer} := \begin{bmatrix} 83.5 \\ 83.5 \\ 82.0 \end{bmatrix} in$$

OD of the MTC Outer Shell

$t_{outer} := 1.0\ in$

Thickness of the MTC Outer Shell

$$ID_{outer} := \overrightarrow{\left(OD_{outer} - 2\ t_{outer}\right)} \qquad ID_{outer} = \begin{bmatrix} 81.5 \\ 81.5 \\ 80 \end{bmatrix} \cdot in$$

ID of the MTC Outer Shell

$$D_{middle} := \begin{bmatrix} 73.38 \\ 73.38 \\ 72.0 \end{bmatrix} in$$

Diameter at the lead to shielding interface.

$t_{Ttop} := 2\ in$

Thickness of the Top of the MTC

$t_{Tbot} := 1\ in$

Thickness of the Bottom of the MTC

$$gap_{lead} := \begin{bmatrix} 1.0 \\ 1.0 \\ 7.0 \end{bmatrix} in$$

Gap between the top of the lead and the bottom of the MTC Top Ring. This is the height of the free space.

$OD_{Tlid} := 74\ in$	OD of the MTC Lid
$ID_{Tlid} := 60.5\ in$	ID of the MTC Lid
$t_{Tlid} := 1\ in$	Thickness of MTC Lid
$N_{trunion} := 2$	Number of Trunions
$OD_{trunion} := 10.75\ in$	OD of Trunion Cylinder
$lg_{trunion} := \begin{bmatrix} 15.0 \\ 15.0 \\ 14.5 \end{bmatrix} in$	Total Trunion Length (including end plates)
$N_{door} := 2$	Number of MTC Doors
$w_{door} := \begin{bmatrix} 42.7 \\ 42.7 \\ 39.25 \end{bmatrix} in$	Overall Width of MTC Doors
$lg_{door} := \begin{bmatrix} 70.0 \\ 70.0 \\ 69.5 \end{bmatrix} in$	Overall Length of the MTC Doors
$w_{door\_cut} := \begin{bmatrix} 17.7 \\ 17.7 \\ 20.25 \end{bmatrix} in$	Overall Width of MTC Door Cutout
$lg_{door\_cut} := \begin{bmatrix} 15 \\ 15 \\ 17.25 \end{bmatrix} in$	Overall Length of the MTC Door Cutout

$t_{door} := \begin{bmatrix} 9.0 \\ 9.0 \\ 7.13 \end{bmatrix} in$ Total Thickness of MTC Doors

$t_{door\_lead} := 2.0\ in$ Thickness of the lead in Shielded Door Assemblies. The lead is assumed to extend to the full edge of the door.

$N_{rail} := 2$ Number of MTC Rails

$lg_{rail} := \begin{bmatrix} 105 \\ 105 \\ 99 \end{bmatrix} in$ Overall Length of the MTC Rails

$h_{rail} := \begin{bmatrix} 9.125 \\ 9.125 \\ 7.25 \end{bmatrix} in$ Height of MTC Rails

$w_{rail} := \begin{bmatrix} 6.5 \\ 6.5 \\ 7.5 \end{bmatrix} in$ Width of MTC Rails

$w_{rail\_sup} := \begin{bmatrix} 9.25 \\ 9.25 \\ 10.25 \end{bmatrix} in$ Width of MTC Rail Supports

$w_{rail\_backer} := 5.50\ in$ Width of Partial Length Rail Shield Plate

$lg_{rail\_backer} := 75.5\ in$ Average Length of Rail Shield Plate

$t_{rail\_sup} := 1.5\ in$ Thickness of MTC Rail Support

$M_{hydraulics} := 500\ lbf$ Assumed Weight of MTC Hydraulic Hardware

4.1.5 VCC Geometry

$OD_{VCC} := 132\ in$	Outside Diameter of the VCC
$h_{VCC} := \begin{bmatrix} 196.7 \\ 213.0 \\ 225.05 \end{bmatrix} in$	Overall Height of the VCC (excluding cask lid)
$ID_{liner} := 70.5\ in$	Inside Diameter of the VCC Steel Liner
$t_{liner} := 1.75\ in$	Thickness of the VCC Steel Liner
$OD_{liner} := ID_{liner} + 2 \cdot t_{liner}$	$OD_{liner} = 74 \cdot in$ Outside Diameter of VCC Steel Liner
$t_{liner\_bot} := 2\ in$	Thickness of the VCC Steel Liner Bottom
$h_{liner} := \begin{bmatrix} 170.7 \\ 188.7 \\ 199.05 \end{bmatrix} in$	Overall Height of the VCC Steel Liner Assembly (excluding cask lid)
$OD_{liner\_flg} := 90\ in$	Outside Diameter of Liner Flange
$t_{liner\_flg} := 2\ in$	Thickness of the Liner Flange
$N_{skid} := 2$	Number of Skid Channels
$w_{skid} := 12\ in$	Width of the Skid Channel
$h_{skid} := 12.2\ in$	Height of the Skid Channel
$lg_{skid} := 100.3\ in$	Average Length of Skid Channels
$OD_{VCC\_bot} := 126\ in$	Outside Diameter of VCC Bottom Steel Plate
$t_{VCC\_bot} := 0.25\ in$	Thickness of VCC Bottom Steel Plate
$N_{air\_out} := 4$	Number of Air Outlets
$w_{air\_out} := 47.8\ in$	Width of the Air Outlet Channels
$lg_{air\_out} := 36.3\ in$	Length of Air Outlet Channels with 3 inches of overlap between high and low channels

$h_{air\_out} := 4\ in$	Height of Air Outlet Channels
$t_{air\_out} := 0.5\ in$	Thickness of Air Outlet Channel Liners
$e_{out} := 8\ in$	Approximate distance from top of VCC to midpoint of outlet assembly.
$N_{air\_in} := 4$	Number of Air Inlet Assemblies
$w_{in\_tube} := 12\ in$	Width of the Air Inlet Tubes
$lg_{in\_tube} := 40\ in$	Approximate Length of Air Inlet Tubes based on the average length.
$h_{in\_tube} := 12\ in$	Height of Air Inlet Tubes
$w_{in\_ch} := 4.5\ in$	Width of the Air Inlet Channels
$h_{in\_ch} := 5\ in$	Height of Air Inlet Channels
$angle_{in\_ch} := 71\ deg$	Angular Extent of Air Inlet Channel
$r_{in\_ch} := 35.25\ in$	Outer radius of Air Inlet Channels
$t_{air\_in} := 0.5\ in$	Thickness of Air Inlet Channel Liners
$OD_{VCC\_lid} := 82\ in$	Outside Diameter of VCC Lid
$t_{VCC\_lid} := 0.75\ in$	Thickness of the VCC Lid
$OD_{shield\_ring} := ID_{liner}$	Outside Diameter of the VCC Shield Ring is the same as the ID of the liner. The weight will include the fixed and removable portions of the shield rings.
$ID_{shield\_ring} := 60.0\ in$	Inside Diameter of the VCC Shield Ring Assembly
$h_{shield\_ring} := 6\ in$	Height of the VCC Shield Ring

4.2 Design Criteria

None.

4.3 Calculation Assumptions

None.

5.0 CALCULATION METHODOLOGY

The MSB, MTC, and VCC component weights and centers of gravity are determined using appropriate component dimensions and densities from section 4.1 above. The following weights and centers of gravity are calculated for each component:

- Empty (no fuel) w/o any lids
- Loaded w/ fuel and all shield lids and structural lids
- Loaded w/fuel and water w/ shield lids and w/o structural lids (MSB/MTC only)

The weight of the VCC is calculated based on the gross concrete weight and the weight of the liner. The internal concrete voids are subtracted from the gross weight. The rebars and the thin steel liners are accounted for by use of an appropriate density for the reinforced concrete.

The calculation of the three configurations is performed using a matrix with three rows. The top row is the short cask, the second row is the mid-size cask, and the third row is the tall cask. The first column is the lightest fuel and the second column is the heaviest fuel. Those dimensions that are common to all three casks are provided as a single scalar.

The results of this analysis are also presented in a three row matrix with the same configuration as the input.

Example 3x1 matrix

$$'' = \begin{bmatrix} \text{"Short"} \\ \text{"Medium"} \\ \text{"Tall"} \end{bmatrix}$$

Example 3x2 matrix

$$' = \begin{bmatrix} \text{"Short-Light"} & \text{"Short-Heavy"} \\ \text{"Medium-Light"} & \text{"Medium-Heavy"} \\ \text{"Tall-Light"} & \text{"Tall-Heavy"} \end{bmatrix}$$

6.0 CALCULATIONS

6.1 Weight of Multi-Assembly Storage Basket (MSB)

Weight of Individual Components in the MSB

$$M_{MSB\_shell} := \overrightarrow{\left[\frac{\pi}{4}\left(OD_{MSB}^{2} - ID_{MSB}^{2}\right)\cdot h_{MSB}\cdot \rho_{st}\right]} \qquad M_{MSB\_shell} = \begin{bmatrix} 9010 \\ 9893 \\ 10549 \end{bmatrix} \cdot lbf$$

$$M_{MSB\_base} := \left(\frac{\pi}{4}\cdot ID_{MSB}^{2}\cdot t_{Mbase}\right)\cdot \rho_{st} \qquad M_{MSB\_base} = 612 \cdot lbf$$

$$M_{MSB\_lid} := \frac{\pi}{4}\cdot OD_{Mlid}^{2}\cdot t_{Mlid}\cdot \rho_{st} \qquad M_{MSB\_lid} = 2409 \cdot lbf$$

$$M_{bar} := \left(N_{bar}\cdot h_{bar}\cdot t_{bar}\cdot w_{bar}\right)\cdot \rho_{st} \qquad M_{bar} = 277 \cdot lbf$$

$$M_{wall} := \left(N_{wall}\cdot \pi\cdot OD_{wall}\cdot t_{wall}\cdot lg_{wall}\right)\cdot \rho_{st} \qquad M_{wall} = 2218 \cdot lbf$$

$$M_{per\_sleeve} := \overrightarrow{\left[\left(w_{sleeve}\cdot 4\cdot lg_{sleeve}\cdot t_{sleeve}\right)\cdot \rho_{st}\right]} \qquad M_{per\_sleeve} = \begin{bmatrix} 308 \\ 342 \\ 332 \end{bmatrix} \cdot lbf$$

$$M_{sleeve} := \overrightarrow{\left[\left(N_{fuel}\cdot w_{sleeve}\cdot 4\cdot lg_{sleeve}\cdot t_{sleeve}\right)\cdot \rho_{st}\right]} \qquad M_{sleeve} = \begin{bmatrix} 7399 \\ 8207 \\ 7976 \end{bmatrix} \cdot lbf$$

$$M_{sleeve\_assy} := \overrightarrow{\left(M_{bar} + M_{wall} + M_{sleeve}\right)} \qquad M_{sleeve\_assy} = \begin{bmatrix} 9895 \\ 10702 \\ 10471 \end{bmatrix} \cdot lbf$$

$$M_{shield\_support} := \frac{\pi}{4}\cdot\left[ID_{MSB}^{2} - \left(ID_{MSB} - 2\cdot t_{shield\_support}\right)^{2}\right]\cdot h_{shield\_support}\cdot \rho_{st}$$

$$M_{shield\_support} = 54 \cdot lbf$$

$$M_{shield} := \overrightarrow{\left[\left[\frac{\pi}{4} \cdot OD_{shield}^{2} \cdot (t_{shieldtop})\right] \cdot \rho_{st} + \left[\frac{\pi}{4} \cdot (OD_{shield} - 2 \cdot t_{ring})^{2} \cdot t_{neutron}\right] \cdot \rho_{Rx} + \left(\pi \cdot OD_{shield} \cdot t_{ring} \cdot t_{neutron} + \frac{\pi}{4} \cdot OD_{support}^{2} \cdot t_{support}\right) \cdot \rho_{st}\right]}$$

$$M_{shield} = 6449 \cdot lbf$$

Weight of MSB Empty without any lids

$$P_{MSB\_empty} := \overrightarrow{\left(M_{MSB\_shell} + M_{MSB\_base} + M_{sleeve} + M_{bar} + M_{wall} + M_{shield\_support}\right)}$$

$$P_{MSB\_empty} = \begin{bmatrix} 19570 \\ 21261 \\ 21686 \end{bmatrix} \cdot lbf$$

Weight of a Fully Loaded MSB with the Shield Lid, but not the Structural Lid

$i := 1 .. 3$

$j := 1 .. 2$

$$P_{MSB\_nolid_{i,j}} := P_{MSB\_empty_{i}} + M_{shield} + N_{fuel} \cdot M_{fuel_{i,j}} + M_{MSB\_hardware}$$

$$P_{MSB\_nolid} = \begin{bmatrix} 57440 & 59240 \\ 54451 & 60211 \\ 61116 & 66276 \end{bmatrix} \cdot lbf$$

Weight of a Fully Loaded and Closed MSB

$$P_{MSB} := \overrightarrow{\left(P_{MSB\_nolid} + M_{MSB\_lid}\right)}$$

$$P_{MSB} = \begin{bmatrix} 59849 & 61649 \\ 56860 & 62620 \\ 63525 & 68685 \end{bmatrix} \cdot lbf$$

6.2 Weight of MSB Transfer Cask (MTC)

Weight of Individual Components of the MTC

$$M_{inner} := \overrightarrow{\left[\frac{\pi}{4}\cdot\left(OD_{inner}^{2} - ID_{inner}^{2}\right)\cdot h_{MTC}\cdot\rho_{st}\right]} \qquad M_{inner} = \begin{bmatrix} 6952 \\ 7644 \\ 8097 \end{bmatrix}\cdot lbf$$

$$M_{lead} := \overrightarrow{\left[\frac{\pi}{4}\cdot\left(D_{middle}^{2} - OD_{inner}^{2}\right)\cdot\left(h_{MTC} - gap_{lead}\right)\cdot\rho_{lead}\right]} \qquad M_{lead} = \begin{bmatrix} 60008 \\ 66020 \\ 60262 \end{bmatrix}\cdot lbf$$

$$M_{Rx} := \overrightarrow{\left[\frac{\pi}{4}\cdot\left(ID_{outer}^{2} - D_{middle}^{2}\right)\cdot h_{MTC}\cdot\rho_{Rx}\right]} \qquad M_{Rx} = \begin{bmatrix} 9695 \\ 10660 \\ 11003 \end{bmatrix}\cdot lbf$$

$$M_{outer} := \overrightarrow{\left[\frac{\pi}{4}\cdot\left(OD_{outer}^{2} - ID_{outer}^{2}\right)\cdot h_{MTC}\cdot\rho_{st}\right]} \qquad M_{outer} = \begin{bmatrix} 11902 \\ 13087 \\ 13717 \end{bmatrix}\cdot lbf$$

$$M_{Ttop} := \frac{\pi}{4}\cdot\left(OD_{outer}^{2} - ID_{inner}^{2}\right)\cdot t_{Ttop}\cdot\rho_{st} \qquad M_{Ttop} = \begin{bmatrix} 1312 \\ 1312 \\ 1229 \end{bmatrix}\cdot lbf$$

$$M_{Tbot} := \frac{\pi}{4}\cdot\left(OD_{outer}^{2} - ID_{inner}^{2}\right)\cdot t_{Tbot}\cdot\rho_{st} \qquad M_{Tbot} = \begin{bmatrix} 656 \\ 656 \\ 615 \end{bmatrix}\cdot lbf$$

$$M_{Ttopbot} := M_{Ttop} + M_{Tbot} \qquad M_{Ttopbot} = \begin{bmatrix} 1967 \\ 1967 \\ 1844 \end{bmatrix}\cdot lbf$$

$$M_{MTC\_lid} := \left[\frac{\pi}{4}\left(OD_{Tlid}^{2} - ID_{Tlid}^{2}\right)\cdot t_{Tlid}\right]\cdot\rho_{st} \qquad M_{MTC\_lid} = 405\cdot lbf$$

$$M_{trunion} := \overrightarrow{\left[N_{trunion}\cdot\frac{\pi}{4}\cdot\left(OD_{trunion}^{2}\right)\cdot lg_{trunion}\cdot\rho_{st}\right]} \qquad M_{trunion} = \begin{bmatrix} 773 \\ 773 \\ 748 \end{bmatrix}\cdot lbf$$

$$M_{MTC\_shell} := \overrightarrow{\left(M_{inner} + M_{lead} + M_{Rx} + M_{outer} + M_{Ttopbot} + M_{trunion}\right)}$$

$$M_{MTC\_shell} = \begin{bmatrix} 91298 \\ 100152 \\ 95669 \end{bmatrix} \cdot lbf$$

The mass of the door for each assembly depends on the type of assembly

$$M_{door\_solid} := \overrightarrow{\left[N_{door} \cdot \left(w_{door_1} \cdot lg_{door_1} - w_{door\_cut_1} \cdot lg_{door\_cut_1}\right) \cdot t_{door_1} \cdot \rho_{st}\right]}$$

$$M_{door\_solid} = 13923 \cdot lbf$$

$$M_{door\_shield} := N_{door} \cdot \left[\left(w_{door_3} \cdot lg_{door_3} - w_{door\_cut_3} \cdot lg_{door\_cut_3}\right) \cdot \left(t_{door_3} - t_{door\_lead}\right) \cdot \rho_{st} \cdots \atop + \left(w_{door_3} \cdot lg_{door_3} - w_{door\_cut_3} \cdot lg_{door\_cut_3}\right) \cdot \left(t_{door\_lead}\right) \cdot \rho_{lead}\right]$$

$$M_{door\_shield} = 10832 \cdot lbf$$

$$M_{door} := \begin{bmatrix} M_{door\_solid} \\ M_{door\_solid} \\ M_{door\_shield} \end{bmatrix} \qquad M_{door} = \begin{bmatrix} 13923 \\ 13923 \\ 10832 \end{bmatrix} \cdot lbf$$

$$M_{rail\_full} := \overrightarrow{\left(N_{rail} \cdot h_{rail} \cdot lg_{rail} \cdot w_{rail} \cdot \rho_{st}\right)} \qquad M_{rail\_full} = \begin{bmatrix} 3537 \\ 3537 \\ 3058 \end{bmatrix} \cdot lbf$$

$$M_{rail\_reduction} := N_{rail} \cdot w_{rail\_backer} \cdot h_{rail_3} \cdot \left(lg_{rail_3} - lg_{rail\_backer}\right) \cdot \rho_{st}$$

$$M_{rail\_reduction} = 532 \cdot lbf$$

$$M_{rail} := \begin{bmatrix} M_{rail\_full_1} \\ M_{rail\_full_2} \\ M_{rail\_full_3} - M_{rail\_reduction} \end{bmatrix} \qquad M_{rail} = \begin{bmatrix} 3537 \\ 3537 \\ 2525 \end{bmatrix} \cdot lbf$$

$$M_{rail\_sup\_full} := \overrightarrow{\left(N_{rail} \cdot w_{rail\_sup} \cdot lg_{rail} \cdot t_{rail\_sup} \cdot \rho_{st}\right)} \qquad M_{rail\_sup\_full} = \begin{bmatrix} 828 \\ 828 \\ 865 \end{bmatrix} \cdot lbf$$

$$M_{rail\_sup\_reduction} := N_{rail} \cdot w_{rail\_backer} \cdot t_{rail\_sup} \cdot \left(lg_{rail_3} - lg_{rail\_backer}\right) \cdot \rho_{st}$$

$$M_{rail\_sup\_reduction} = 110 \cdot lbf$$

$$M_{rail\_sup} := \begin{bmatrix} M_{rail\_sup\_full_1} \\ M_{rail\_sup\_full_2} \\ M_{rail\_sup\_full_3} - M_{rail\_sup\_reduction} \end{bmatrix} \qquad M_{rail\_sup} = \begin{bmatrix} 828 \\ 828 \\ 754 \end{bmatrix} \cdot lbf$$

Weight of Empty MTC without any lids

$$P_{MTC\_empty} := \overrightarrow{\left(M_{MTC\_shell} + M_{door} + M_{rail} + M_{rail\_sup} + M_{hydraulics}\right)}$$

$$P_{MTC\_empty} = \begin{bmatrix} 110085 \\ 118939 \\ 110281 \end{bmatrix} \cdot lbf$$

Weight of MTC loaded with an Empty MSB (Dry with no lids)

$$P_{MTC\_nolid} := \overrightarrow{\left(P_{MTC\_empty} + P_{MSB\_empty}\right)}$$

$$P_{MTC\_nolid} = \begin{bmatrix} 129655 \\ 140201 \\ 131967 \end{bmatrix} \cdot lbf$$

Weight of MTC with a Fully Loaded MSB (Dry with all lids)

$$P_{MTC_{i,j}} := P_{MTC\_empty_i} + P_{MSB_{i,j}} + M_{MTC\_lid}$$

$$P_{MTC} = \begin{bmatrix} 170339 & 172139 \\ 176204 & 181964 \\ 174210 & 179370 \end{bmatrix} \cdot lbf$$

6.3 Weight of the Ventilated Concrete Cask (VCC)

Weight of the Individual Components

$$M_{conc\_shell} := \overrightarrow{\left[\frac{\pi}{4}\cdot\left(OD_{VCC}^2 - OD_{liner}^2\right)\cdot h_{VCC}\cdot\rho_c\right]}$$

$$M_{conc\_shell} = \begin{bmatrix} 160227 \\ 173505 \\ 183321 \end{bmatrix}\cdot lbf$$

$$M_{conc\_bot} := \overrightarrow{\left[\frac{\pi}{4}\cdot OD_{liner}^2\cdot\left(h_{VCC} - h_{liner}\right)\cdot\rho_c\right]}$$

$$M_{conc\_bot} = \begin{bmatrix} 9707 \\ 9072 \\ 9707 \end{bmatrix}\cdot lbf$$

$$M_{liner\_shell} := \overrightarrow{\left[\left[\frac{\pi}{4}\cdot\left(OD_{liner}^2 - ID_{liner}^2\right)\cdot h_{liner} \cdots + \frac{\pi}{4}\cdot\left(OD_{liner\_flg}^2 - OD_{liner}^2\right)\cdot t_{liner\_flg}\right]\cdot\rho_{st}\right]}$$

$$M_{liner\_shell} = \begin{bmatrix} 20427 \\ 22458 \\ 23625 \end{bmatrix}\cdot lbf$$

$$M_{liner\_bot} := \overrightarrow{\left[\left(\frac{\pi}{4}\cdot ID_{liner}^2\cdot t_{liner\_bot}\right)\cdot\rho_{st}\right]}$$

$$M_{liner\_bot} = 2217\cdot lbf$$

$$M_{skid} := N_{skid}\cdot\left(-w_{skid}\cdot h_{skid}\cdot lg_{skid}\cdot\rho_c + 2\cdot h_{skid}\cdot lg_{skid}\cdot t_{VCC\_bot}\cdot\rho_{st}\right)$$

$$M_{skid} = -2202\cdot lbf$$

$$M_{VCC\_bot} := \frac{\pi}{4}\cdot OD_{VCC\_bot}^2\cdot t_{VCC\_bot}\cdot\rho_{st}$$

$$M_{VCC\_bot} = 885\cdot lbf$$

$$M_{air\_out} := N_{air\_out} \cdot \left[-w_{air\_out} \cdot lg_{air\_out} \cdot h_{air\_out} \cdot \rho_c \cdots + \left(2 \cdot w_{air\_out} + 2 \cdot h_{air\_out}\right) \cdot lg_{air\_out} \cdot t_{air\_out} \cdot \rho_{st} \right]$$

$M_{air\_out} = -274 \cdot lbf$

$$M_{in\_tube} := N_{air\_in} \cdot \left[-w_{in\_tube} \cdot lg_{in\_tube} \cdot h_{in\_tube} \cdot \rho_c \cdots + \left(2 \cdot w_{in\_tube} + 2 \cdot h_{in\_tube}\right) \cdot lg_{in\_tube} \cdot t_{air\_in} \cdot \rho_{st} \right]$$

$M_{in\_tube} = -909 \cdot lbf$

$$M_{in\_ch} := N_{air\_in} \cdot \left[-\pi \cdot 2 \cdot r_{in\_ch} \cdot \frac{angle_{in\_ch}}{360\ deg} \cdot w_{in\_ch} \cdot h_{in\_ch} \cdot \rho_c \cdots + \pi \cdot 2 \cdot r_{in\_ch} \cdot \frac{angle_{in\_ch}}{360\ deg} \cdot h_{in\_ch} \cdot 2 \cdot t_{air\_in} \cdot \rho_{st} \right]$$

$M_{in\_ch} = -93 \cdot lbf$

$$M_{VCC\_lid} := \frac{\pi}{4} \cdot OD_{VCC\_lid}^2 \cdot t_{VCC\_lid} \cdot \rho_{st}$$

$M_{VCC\_lid} = 1125 \cdot lbf$

$$M_{shield\_ring} := \frac{\pi}{4} \cdot \left(OD_{shield\_ring}^2 - ID_{shield\_ring}^2\right) \cdot h_{shield\_ring} \cdot \rho_{st}$$

$M_{shield\_ring} = 1834 \cdot lbf$

Weight of empty VCC without the shield ring or lid

$$P_{VCC\_empty} := \overrightarrow{\left(M_{conc\_shell} + M_{conc\_bot} + M_{liner\_shell} + M_{liner\_bot} + M_{skid} \cdots + M_{VCC\_bot} + M_{air\_out} + M_{in\_tube} + M_{in\_ch}\right)}$$

$$P_{VCC\_empty} = \begin{bmatrix} 189986 \\ 204659 \\ 216277 \end{bmatrix} \cdot lbf$$

The total weight of the empty VCC and an empty MSB without any lids on either component

$$P_{VCC\_MSB\_empty} := \overrightarrow{\left(P_{VCC\_empty} + P_{MSB\_empty}\right)}$$

$$P_{VCC\_MSB\_empty} = \begin{bmatrix} 209556 \\ 225921 \\ 237963 \end{bmatrix} \cdot lbf$$

The total weight of a VCC with a fully loaded MSB with all lids and shield rings installed

$$P_{VCC_{i,j}} := P_{VCC\_empty_i} + P_{MSB_{i,j}} + M_{shield\_ring} + M_{VCC\_lid}$$

$$P_{VCC} = \begin{bmatrix} 252793 & 254593 \\ 264477 & 270237 \\ 282760 & 287920 \end{bmatrix} \cdot lbf$$

6.4 Free Volumes

Volume in between the MTC and the MSB

$$V_{gap} := \overrightarrow{\left[\frac{\pi}{4}\cdot\left(ID_{inner}^{2} - OD_{MSB}^{2}\right)\cdot h_{MSB} \cdots + \frac{\pi}{4}\cdot ID_{inner}^{2}\cdot\left(h_{MTC} + t_{Ttop} + t_{Tbot} - h_{MSB}\right)\right]}$$

$$V_{gap} = \begin{bmatrix} 17833 \\ 19426 \\ 11189 \end{bmatrix} \cdot in^{3}$$

Volume inside of the MSB (without fuel or baskets)

$$V_{MSB\_empty} := \overrightarrow{\left(\frac{\pi}{4}\, ID_{MSB}^{2}\cdot h_{MSB}\right)}$$

$$V_{MSB\_empty} = \begin{bmatrix} 472035 \\ 518318 \\ 552671 \end{bmatrix} \cdot in^{3}$$

Volume of the Basket and Base

$$V_{basket} := \overrightarrow{\frac{M_{MSB\_base} + M_{sleeve} + M_{bar} + M_{wall}}{\rho_{st}}}$$

$$V_{basket} = \begin{bmatrix} 36996 \\ 39840 \\ 39027 \end{bmatrix} \cdot in^{3}$$

Volume of the Shield Lid and Structural Support

$$V_{shield} := \frac{\pi}{4}\cdot OD_{shield}^{2}\cdot\left(t_{shieldtop}\right) \cdots + \frac{\pi}{4}\cdot\left(OD_{shield} - 2\cdot t_{ring}\right)^{2}\cdot t_{neutron} \cdots + \pi\cdot OD_{shield}\cdot t_{ring}\cdot t_{neutron} + \frac{\pi}{4}\cdot OD_{support}^{2}\cdot t_{support}$$

$$V_{shield} = 27023 \cdot in^{3}$$

Volume of the Fuel Bundle

$$V_{fuel} := \overrightarrow{\left(\frac{\pi}{4}\cdot OD_{fuel}^{2}\cdot lg_{fuel}\cdot N_{pins}^{2}\cdot N_{fuel}\right)}$$

$$V_{fuel} = \begin{bmatrix} 111599 \\ 109414 \\ 110533 \end{bmatrix} \cdot in^{3}$$

Total Free Volume in the MTC with fully loaded MSB (without Structural Lid)

$$V_{free} := \overrightarrow{\left(V_{gap} + V_{MSB\_empty} - V_{basket} - V_{shield} - V_{fuel}\right)}$$

$$V_{free} = \begin{bmatrix} 314249 \\ 361467 \\ 387278 \end{bmatrix} \cdot in^{3}$$

6.5 Weights with Water

Weight of the water in a loaded MSB/MTC Assembly

$$P_{water} := \overrightarrow{\left(V_{free} \cdot \rho_w\right)}$$

$$P_{water} = \begin{bmatrix} 11348 \\ 13053 \\ 13985 \end{bmatrix} \cdot lbf$$

Weight of fully loaded and wet MSB (with shields but without Structural Lid)

The weight of the water in the gap between the MTC and the MSB is conservatively included

$$P_{MSB\_wet_{i,j}} := P_{MSB\_nolid_{i,j}} + P_{water_i} \qquad P_{MSB\_wet} = \begin{bmatrix} 68787 & 70587 \\ 67504 & 73264 \\ 75101 & 80261 \end{bmatrix} \cdot lbf$$

Weight of MTC (without MTC lid) and a fully loaded and wet MSB (with shields but without Structural Lid)

$$P_{MTC\_wet_{i,j}} := P_{MSB\_nolid_{i,j}} + P_{MTC\_empty_i} + P_{water_i} \qquad P_{MTC\_wet} = \begin{bmatrix} 178872 & 180672 \\ 186443 & 192203 \\ 185381 & 190541 \end{bmatrix} \cdot lbf$$

6.6 Centers of Gravity

Centers of Gravity are relative to the bottom of the item or assembly evaluated

Center of Gravity of the MSB empty with no lids installed

$$cg_{MSB\_empty} := \frac{\overrightarrow{M_{MSB\_shell}\cdot\frac{h_{MSB}}{2} + M_{MSB\_base}\cdot\frac{t_{Mbase}}{2} + \left(M_{sleeve} + M_{bar} + M_{wall}\right)\cdot\left(\frac{lg_{sleeve}}{2} + t_{Mbase}\right) + M_{shield\_support}\cdot\left(h_{MSB} - d_{support} - \overrightarrow{\frac{h_{shield\_support}}{2}}\right)}}{P_{MSB\_empty}}$$

$$cg_{MSB\_empty} = \begin{bmatrix} 75.9 \\ 83.9 \\ 86 \end{bmatrix}\cdot in$$

Center of Gravity of MSB fully loaded with all lids installed

$$cg_{MSB_{i,j}} := \frac{P_{MSB\_empty_i}\cdot cg_{MSB\_empty_i} + N_{fuel}\cdot M_{fuel_{i,j}}\cdot\left(\frac{lg_{fuel_i}}{2} + t_{Mbase}\right) + M_{MSB\_lid}\cdot\left(h_{MSB_i} - \frac{t_{Mlid}}{2}\right) + M_{shield}\cdot\left(h_{MSB_i} - d_{support} + \frac{t_{support} + t_{shieldtop} + t_{neutron}}{2}\right)}{P_{MSB_{i,j}}}$$

$$cg_{MSB} = \begin{bmatrix} 88 & 87.7 \\ 97.8 & 96.6 \\ 101.9 & 101 \end{bmatrix}\cdot in$$

Center of Gravity of an MSB fully loaded and wet with shield lid, but no structural lid

$$cg_{MSB\_wet_{i,j}} := \frac{cg_{MSB_{i,j}} \cdot P_{MSB_{i,j}} - M_{MSB\_lid} \cdot \left(h_{MSB_i} - \frac{t_{Mlid}}{2}\right) \ldots + P_{water_i} \cdot \left[\frac{\left(h_{MSB_i} - t_{Mlid} - t_{Mbase}\right)}{2} + t_{Mbase}\right]}{P_{MSB\_wet_{i,j}}}$$

$$cg_{MSB\_wet} = \begin{bmatrix} 84.2 & 84 \\ 93.2 & 92.5 \\ 97.8 & 97.3 \end{bmatrix} \cdot in$$

Center of Gravity of MTC empty with no cover

$$cg_{MTC\_empty} := \overrightarrow{\frac{M_{MTC\_shell} \cdot \left(\frac{h_{MTC} + t_{Ttop} + t_{Tbot}}{2} + t_{Tbot} + h_{rail} + t_{rail\_sup}\right) \ldots + M_{door} \cdot \left(t_{rail\_sup} + \frac{t_{door}}{2}\right) \ldots + M_{rail} \cdot \frac{\left[h_{rail} \cdot w_{rail} \cdot \left(t_{rail\_sup} + \frac{h_{rail}}{2}\right) \ldots + w_{rail\_sup} \cdot t_{rail\_sup} \cdot \frac{t_{rail\_sup}}{2}\right]}{h_{rail} \cdot w_{rail} + w_{rail\_sup} \cdot t_{rail\_sup}} + M_{hydraulics} \cdot h_{rail}}{P_{MTC\_empty}}}$$

$$cg_{MTC\_empty} = \begin{bmatrix} 78.9 \\ 86.8 \\ 92.7 \end{bmatrix} \cdot in$$

Center of Gravity of MTC with a fully loaded dry MSB with all lids installed

$$cg_{MTC_{i,j}} := \frac{P_{MTC\_empty_i} \cdot cg_{MTC\_empty_i} + P_{MSB_{i,j}} \cdot \left(cg_{MSB_{i,j}} + h_{rail_i} + t_{rail\_sup}\right) \cdots + M_{MTC\_lid} \cdot \left(h_{MTC_i} + t_{Ttop} + t_{Tbot} + h_{rail_i} + t_{rail\_sup} + \frac{t_{Tlid}}{2}\right)}{P_{MTC_{i,j}}}$$

$$cg_{MTC} = \begin{bmatrix} 86.1 & 86.1 \\ 94 & 94 \\ 99.5 & 99.5 \end{bmatrix} \cdot in$$

Center of Gravity of an MTC with a fully loaded and wet MSB with shield lid, but no structural lid

$$cg_{MTC\_wet_{i,j}} := \frac{P_{MTC\_empty_i} \cdot cg_{MTC\_empty_i} \cdots + P_{MSB\_wet_{i,j}} \cdot \left(cg_{MSB\_wet_{i,j}} + h_{rail_i} + t_{rail\_sup}\right)}{P_{MTC\_wet_{i,j}}}$$

$$cg_{MTC\_wet} = \begin{bmatrix} 85 & 85.1 \\ 93 & 93 \\ 98.3 & 98.3 \end{bmatrix} \cdot in$$

Center of Gravity of VCC empty, without shield ring or lid

$$cg_{VCC\_empty} := \frac{\overrightarrow{M_{conc\_shell}\cdot\frac{h_{VCC}}{2} + M_{skid}\cdot\frac{h_{skid}}{2} + M_{air\_out}\cdot\left(h_{VCC} - e_{out}\right) + \left(M_{conc\_bot} + M_{in\_tube} + M_{in\_ch}\right)\cdot\left(\frac{h_{VCC} - h_{liner}}{2}\right) + M_{liner\_shell}\cdot\left(h_{VCC} - \frac{h_{liner}}{2}\right) + M_{liner\_bot}\cdot\left(h_{VCC} - h_{liner} + \frac{t_{liner\_bot}}{2}\right) + M_{VCC\_bot}\cdot\frac{t_{VCC\_bot}}{2}}}{P_{VCC\_empty}}$$

$$cg_{VCC\_empty} = \begin{bmatrix} 95.5 \\ 103.7 \\ 109.6 \end{bmatrix} \cdot in$$

Center of Gravity of VCC with an empty MSB, with no cover shields or lids

$$cg_{VCC\_MSB\_empty} := \frac{\overrightarrow{P_{VCC\_empty}\cdot cg_{VCC\_empty} + P_{MSB\_empty}\cdot\left(cg_{MSB\_empty} + h_{VCC} - h_{liner} + t_{liner\_bot}\right)}}{P_{VCC\_empty} + P_{MSB\_empty}}$$

$$cg_{VCC\_MSB\_empty} = \begin{bmatrix} 96.3 \\ 104.3 \\ 110 \end{bmatrix} \cdot in$$

Center of Gravity of VCC with a fully loaded MSB (dry) with all covers and lids

$$cg_{VCC_{i,j}} := \frac{cg_{VCC\_empty_i} \cdot P_{VCC\_empty_i} + P_{MSB_{i,j}} \cdot \left(cg_{MSB_{i,j}} + h_{VCC_i} - h_{liner_i} + t_{liner\_bot}\right) + M_{VCC\_lid} \cdot \left(h_{VCC_i} + \frac{t_{VCC\_lid}}{2}\right) + M_{shield\_ring} \cdot \left(h_{VCC_i} - e_{out} + \frac{h_{shield\_ring}}{2}\right)}{P_{VCC\_empty_i} + P_{MSB_{i,j}} + M_{VCC\_lid} + M_{shield\_ring}}$$

$$cg_{VCC} = \begin{bmatrix} 101.5 & 101.5 \\ 109.3 & 109.3 \\ 115.3 & 115.4 \end{bmatrix} \cdot in$$

7.0 CONCLUSIONS

A summary of the masses and centers of gravity is provided below in arrays and matrices. The first row is the small cask, the second row is the mid-size cask, and the third row is the tall cask. The first column is the lightest fuel and the second column is the heaviest fuel.

CONDITION	COMPONENT	WEIGHT	CENTER OF GRAVITY
Empty (no fuel) w/o any lids	MSB	$P_{MSB\_empty} = \begin{bmatrix} 19570 \\ 21261 \\ 21686 \end{bmatrix} \cdot lbf$	$cg_{MSB\_empty} = \begin{bmatrix} 75.9 \\ 83.9 \\ 86 \end{bmatrix} \cdot in$
	MTC	$P_{MTC\_empty} = \begin{bmatrix} 110085 \\ 118939 \\ 110281 \end{bmatrix} \cdot lbf$	$cg_{MTC\_empty} = \begin{bmatrix} 78.9 \\ 86.8 \\ 92.7 \end{bmatrix} \cdot in$
	VCC	$P_{VCC\_empty} = \begin{bmatrix} 189986 \\ 204659 \\ 216277 \end{bmatrix} \cdot lbf$	$cg_{VCC\_empty} = \begin{bmatrix} 95.5 \\ 103.7 \\ 109.6 \end{bmatrix} \cdot in$
Loaded w/ fuel and shield lid and structural lid	MSB	$P_{MSB} = \begin{bmatrix} 59849 & 61649 \\ 56860 & 62620 \\ 63525 & 68685 \end{bmatrix} \cdot lbf$	$cg_{MSB} = \begin{bmatrix} 88 & 87.7 \\ 97.8 & 96.6 \\ 101.9 & 101 \end{bmatrix} \cdot in$
	MTC/MSB	$P_{MTC} = \begin{bmatrix} 170339 & 172139 \\ 176204 & 181964 \\ 174210 & 179370 \end{bmatrix} \cdot lbf$	$cg_{MTC} = \begin{bmatrix} 86.1 & 86.1 \\ 94 & 94 \\ 99.5 & 99.5 \end{bmatrix} \cdot in$
	VCC/MSB	$P_{VCC} = \begin{bmatrix} 252793 & 254593 \\ 264477 & 270237 \\ 282760 & 287920 \end{bmatrix} \cdot lbf$	$cg_{VCC} = \begin{bmatrix} 101.5 & 101.5 \\ 109.3 & 109.3 \\ 115.3 & 115.4 \end{bmatrix} \cdot in$
Loaded w/ fuel and water w/ shield lid w/o structural lid	MSB	$P_{MSB\_wet} = \begin{bmatrix} 68787 & 70587 \\ 67504 & 73264 \\ 75101 & 80261 \end{bmatrix} \cdot lbf$	$cg_{MSB\_wet} = \begin{bmatrix} 84.2 & 84 \\ 93.2 & 92.5 \\ 97.8 & 97.3 \end{bmatrix} \cdot in$
	MTC/MSB	$P_{MTC\_wet} = \begin{bmatrix} 178872 & 180672 \\ 186443 & 192203 \\ 185381 & 190541 \end{bmatrix} \cdot lbf$	$cg_{MTC\_wet} = \begin{bmatrix} 85 & 85.1 \\ 93 & 93 \\ 98.3 & 98.3 \end{bmatrix} \cdot in$

A summary of selected results that are used by referencing calculations is provided below, for convenience.

Weight of Shield Lid	$M_{shield} = 6449 \cdot lbf$
Weight of the MSB Structural Lid	$M_{MSB\_lid} = 2409 \cdot lbf$
Weight of a single fuel bundle	$M_{fuel} = \begin{bmatrix} 1305 & 1380 \\ 1110 & 1350 \\ 1370 & 1585 \end{bmatrix} \cdot lbf$
Weight of a single fuel sleeve	$M_{per\_sleeve} = \begin{bmatrix} 308 \\ 342 \\ 332 \end{bmatrix} \cdot lbf$
Weight of the fuel basket (i.e. all of the sleeves)	$M_{sleeve} = \begin{bmatrix} 7399 \\ 8207 \\ 7976 \end{bmatrix} \cdot lbf$
Weight of the complete sleeve assembly	$M_{sleeve\_assy} = \begin{bmatrix} 9895 \\ 10702 \\ 10471 \end{bmatrix} \cdot lbf$
Weight of the MTC rails support plates	$M_{rail\_sup} = \begin{bmatrix} 828 \\ 828 \\ 754 \end{bmatrix} \cdot lbf$
Weight of the MTC doors	$M_{door} = \begin{bmatrix} 13923 \\ 13923 \\ 10832 \end{bmatrix} \cdot lbf$
Weight of the MTC rails	$M_{rail} = \begin{bmatrix} 3537 \\ 3537 \\ 2525 \end{bmatrix} \cdot lbf$
Weight of the MTC Top Ring	$M_{Ttop} = \begin{bmatrix} 1312 \\ 1312 \\ 1229 \end{bmatrix} \cdot lbf$
Weight of the MTC Cover Plate	$M_{MTC\_lid} = 405 \cdot lbf$
Weight of the VCC Cover Plate	$M_{VCC\_lid} = 1125 \cdot lbf$
Weight of the MSB Base	$M_{MSB\_base} = 612 \cdot lbf$

BNFL Fuel Solutions	CALCULATION PACKAGE	Calc. Pkg No. VSC02.6.2.5.02 File No.: VSC02.6.2.5.02 Revision: 1

PROJECT/CUSTOMER:

Generic VSC-24

TITLE:

Helium Leakage Analysis

SCOPE:

Product:	☐ FuelSolutions™	☐ TranStor™	☒ VSC-24	☐ Other ________
Service:	☒ Storage	☐ Transportation		☐ Other ________
Conditions:	☒ Normal	☒ Off-Normal	☒ Accident	☐ Other ________

Component(s):

VSC-24 MSB

Prepared by:

Name: R.W. Swayne

Signature: RW Swayne

Date: 03/05/01

Verified by:

Name: Jim Hopf

Signature: James E. Hopf

Date: 03/12/01

Engineering Manager Approval:

Name: Ram Srinivasan

Signature: RSrinivasan

Date: 3/26/01

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (Print or Type)	
				PREPARER	CHECKER
0	All	NA	Initial Issue	R.W. Swayne	Ashok Bhatia
1	2, 3, 6, 7, 11-14	NA	Design pressures and temperatures and minimum internal volumes revised. (ECN - VSC02 - ECN - 008)	R.W. Swayne	Jim Hopf

RECORD OF VERIFICATION

	Circle:		
(a) The objective is clear and consistent with the analysis.	(YES)	NO	
(b) The inputs are correctly selected and incorporated into the design.	(YES)	NO	N/A
(c) References are complete, accurate, and retrievable.	(YES)	NO	N/A
(d) Basis for engineering judgments is adequately documented.	(YES)	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	(YES)	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	(N/A)
(g) Methods and units are clearly identified.	(YES)	NO	N/A
(h) Any limits of applicability are identified.	(YES)	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	(N/A)
(j) Computer codes used are under configuration control.	YES	NO	(N/A)
(k) Computer codes used are applicable to the calculation.	YES	NO	(N/A)
(l) Input parameters and boundary conditions are appropriate and correct.	(YES)	NO	
(m) An appropriate design method is used.	(YES)	NO	
(n) The output is reasonable compared to the inputs.	(YES)	NO	
(o) Conclusions are clear and consistent with analysis results.	(YES)	NO	

COMMENTS:

Verifier: Jim Hopf James E. Hopf 3/12/01

Name/Signature/Date

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

None.

1. INTRODUCTION

1.1 Objectives

This document determines postulated gas leakage flow rates for the confinement boundary of the VSC-24 Multi-assembly Sealed Baskets (MSBs) for normal, off-normal, and accident storage conditions for a given set of helium test conditions. It also determines the maximum fraction of helium lost from the MSB interior, over the 50-year storage life, during normal operation.

1.2 Purpose

The gas leakage characteristics determined herein are (a) to be used in support of VSC-24 storage system atmospheric release calculations and (b) to confirm the ability to maintain an adequate inert gas inventory in the MSB over its 50-year storage design life, during normal operation.

1.3 Scope

These analyses apply to VSC-24 MSBs used in dry spent fuel storage. The analyses follow NRC guidelines for normal, off-normal, and accident storage conditions, and for helium test conditions (Ref. 2.2.1, 2.2.2, and 2.2.3).

2. REQUIREMENTS

2.1 Design Inputs

2.1.1 10CFR72, *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Waste.*)

(10 CFR 72.24(l)(1) states that the applicant must estimate the quantity of radionuclides expected to be released annually to the environment.)

(10 CFR 72.122(h)(1) states that the design must adequately protect the spent fuel cladding against degradation that might otherwise lead to gross ruptures during storage. Otherwise, the fuel must be confined through other means such that fuel degradation during storage will not pose operational safety problems with respect to removal of the fuel from storage.)

(10 CFR 72.236(f) states that the cask must be designed to provide adequate heat removal capacity without active cooling systems.)

(10 CFR 72.236(g) states that the cask must be designed to store the spent fuel safely for a minimum of 20 years and permit maintenance as required.)

(10 CFR 72.236(l) and 10 CFR 72.24(d) state that the applicant must evaluate the cask and its systems important to safety. This evaluation must use appropriate tests or other means acceptable to the Commission, to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.)

2.2 Regulatory Commitments

2.2.1 U.S. Nuclear Regulatory Commission (NRC), Spent Fuel Project Office Interim Staff Guidance-5, Revision 1, Issue: Confinement Evaluation, May 21, 1999.

(This document provides NRC guidance for adequately demonstrating the confinement capabilities of a dry cask storage system.)

2.2.2 U. S. NRC NUREG-1536, *Standard Review Plan for Dry Cask Storage Systems*, January 1997, as modified by the ISG-5 Rev. 1 attachment that replaces SRP Chapter 7.

(This document provides guidance to NRC staff in the Spent Fuel Project Office for performing safety reviews of dry cask storage systems. Thus, the document also provides the applicant with guidance on performing safety evaluations of dry cask storage systems.)

2.2.3 American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment, ANSI N14.5-1997, American National Standards Institute, Inc., February 5, 1998

(This document describes a method for calculating cask leakage rates.)

3. REFERENCES

3.1 BFS Calculation Packages

3.1.1 VSC02.6.2.3.05, Rev. 2, Normal, Off-Normal, and Maximum Accident Pressure in the MSB, (Provides bounding minimum volumes and maximum operating pressures and temperatures.)

3.2 BFS Drawings

3.2.1 MSB-24-001, Sht. 2/2, Rev. 5, MSB Assembly, (Provides weld lengths.)

3.3 General References

3.3.1 B.L. Anderson, R.W. Carlson, L.E. Fischer, "Containment Analysis for Type B Packages Used to Transport Various Contents", NUREG/CR-6487, UCRL-ID-124822, LLNL, prepared for the Office of Nuclear Material Safety and Safeguards, U.S. NRC, Washington DC, November 1996

3.3.2 *American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment*, ANSI N14.5-1997, American National Standards Institute, Inc., February 5, 1998

3.3.3 Petersen, Helge, "Tables of Thermophysical Properties of Helium", Dragon Project Report 734, Danish AEC Research Establishment

4. ASSUMPTIONS

4.1 Design Configuration

4.1.1 The postulated leak path is through the confinement boundary of the MSB. The MSB is located within the Ventilated Concrete Cask (VCC) during storage conditions, and within the Multi-purpose Transfer Cask (MTC) during transfer operations. Both the depth of the shield-lid-to-shell weld and the combined depth of the welds of both lids to the shell are evaluated, because this range of weld depths envelopes the postulated leak path length. Based on the weld sizes shown in Ref. 3.2.1, the postulated leak path is thus assumed to be between 1/4 in. and 1 in. long.

4.1.2 The average gas temperatures VSC-24 MSB thermodynamic state properties for the normal, off-normal, and accident storage conditions are required for this calculation. The values are identified in Table 4-1 below. The off-normal cases use the same assumptions and method as the normal cases, except that 10% of the fuel rods and BPRA rods are assumed to fail. The accident case assumes 100% fuel rod cladding failure. The MSB gas volumes, pressures, and operating temperatures are obtained from Reference 3.1.1. The gas volumes, pressures, and operating temperatures are chosen in such a way as to provide the maximum leak rates and result in a bounding condition. The MSB gas volumes are minimum free volumes from Section 6.3, 6.4, and 6.5 of Reference 3.1.1. The maximum operating pressures are from Section 7 of Reference 3.1.1. These pressures are bounding pressures from Reference 3.1.1 and have been adjusted for the helium loading temperature and the storage temperature. The operating temperatures are the lower of the temperatures for each operating condition of those from Sections 6.3 through 6.5 of Reference 3.1.1. These pressures and temperatures are chosen to provide maximum leak rates through selection of the combination of maximum pressure and the lowest temperature at which that pressure can occur for MSBs with and without BPRAs.

Table 4-1 VSC-24 MSB Gas Volumes, Temperatures, and Pressures

Operating Condition	Volume (inch^3/cc)	Max. Pressure (psig)	At Average Gas Temperature (F/K)
Normal Conditions	269,500 / 4.42E+6	5.23	439°F / 499°K
Off-Normal Conditions	270,100 / 4.43E+6	10.0	445°F / 503°K
Accident Conditions	276,100 / 4.52E+6	55.7	460°F / 511°K

4.1.3 The following helium gas properties are from Reference 3.3.3:

Molecular Weight, M = 4.0025 gm/gmole

Specific Heat Ratio, $k = c_p/c_v$ = 5195 / 3117 = 1.6667

Dynamic Viscosity, $\mu(T)$ = 3.674 E-7 $[T(K)]^{0.7}$ kgm/m-sec

[See Ref. 3.3.3, Eq. (3a)] = 3.674 E-6 $[T(K)]^{0.7}$ gm/cm-sec

= 3.674 E-4 $[T(K)]^{0.7}$ centiPoise (cP)

Reference 3.3.3 provides accuracies for the above properties. All of the numbers are more than 100 times as accurate as the assumptions made regarding configuration of the MSB and the postulated leak path.

The helium density is obtained from the ideal gas law

$P = \rho R_u T / M$

where

P	= Gas pressure, atm
R_u	= Gas Constant = 82.057 cc-atm/gmole-°K
ρ	= Gas density, gm/cc
T	= Gas temperature, °K
M	= Molecular weight, gm/gmole

4.2 Design Criteria

4.2.1 The design life for the VSC-24 MSB is 50 years.

4.2.2 The VSC-24 MSB will be subjected to a helium leak test at a pressure of 7.3 psig of dry helium (>99% pure), at an upstream temperature of 50-260°F (283-400°K), and at a downstream pressure of 1 atm abs, with an acceptance criteria of 1.0×10^{-4} std cc/sec. (The standard condition is pressure of 1 atm abs and temperature of 298°K). This acceptance criterion is selected based on past practice and availability of measuring instruments.

4.3 Calculation Assumptions

4.3.1 Gas Leakage

(a) The radioactive gases required to be considered for release effects are tritium, iodine, krypton, and xenon. For this calculation, the leaking gas is assumed to be all helium. The presence of these possible fission gases and/or suspended fine particles in the helium gas are neglected. Because the combination of atomic mass and viscosity of these gases are higher than for helium, and because the vast majority of the gas is helium (due to the helium backfill), this provides a conservatively low gas viscosity and molecular weight, and thus a conservative flow resistance. This, in turn, provides a conservative maximum flow rate for a given leak diameter.

(b) Because the pressures involve are relatively low, the helium and gas mixtures are assumed to be calorically and thermally perfect gases. Thus, the ideal gas law (see 4.1.3) approximates the state equation for these gases.

(c) Because temperature and pressure changes in the MSB (over hours or days, rather than seconds) occur relatively slowly, the gas leakage for each operating condition is assumed to occur at a steady state flow rate.

(d) A conservatively high upstream temperature of 260°F is assumed. If a lower temperature exists upstream during the helium leak test, a correspondingly smaller diameter would be calculated for the same volumetric flow rate and upstream pressure.

5. CALCULATION METHODOLOGY

This section describes the steps and formulae used for the leakage analyses in this calculation.

5.1 Volumetric Flow Rate for Normal and Accident Storage Conditions

5.1.1 Leak Path Geometry

The methodology used for modeling gas flow through the postulated leakage path in the MSB confinement boundary is as described in Section 2.2 on page 4 of Reference 3.3.1 and Section B.3 on page 27 of Reference 3.3.2.

5.1.2 The volumetric flow rates for the normal, off-normal, and accident storage conditions are calculated, for the postulated test conditions and at reference conditions (25°C and 1 atm abs), in accordance with the following.

5.1.3 Given the reference flow rate Q_r (std-cc/sec) (see 4.2.2), the equivalent volumetric average flow rate is calculated as $(Q_r)(T_a / T_{ref}) / P_{ave}$

where
T_a =average gas temperature, °K
T_{ref} = standard temperature, °K
P_{ave} = average pressure, atm

5.1.4 Then a hole diameter, D, is determined by iteration (using the Microsoft Excel spreadsheet shown in Table 6-1), such that it will provide a volumetric leakage rate, at the average pressure of the helium leak test, equal to the above equivalent volumetric average flow rate. Equations (B.1) through (B.4) of Section B.3 of Reference 3.3.2. are used for this calculation, as follows:

$$Q_a = ((2.49 \times 10^6 D^4)/(a\,\mu) + (3.81 \times 10^3 D^3 (T/M)^{0.5})/(a\,P_a))\,(P_u - P_d) \qquad \text{(Eq. 1)}$$

where
Q_a = average volumetric leakage rate in leak path, cc/sec
D = leak path diameter, cm
a = leak path length, cm.
μ = dynamic viscosity, cP
T = temperature, °K
M = molecular weight, gm/gm-mole
P_a = average pressure, atm
P_u = upstream pressure, atm
P_d = downstream pressure, atm

5.1.5 The upstream flow rate is calculated by multiplying the calculated average volumetric leakage rate by the ratio (T_u/T_a) (P_a/P_u), and downstream flow rate is calculated by multiplying the calculated average volumetric leakage rate by the ratio (T_d/T_a) (P_a/P_d) , where T_u and T_d are the upstream and downstream temperatures, ^oK. ,

5.1.6 The upstream and downstream flow rates based on the postulated operating conditions (see 4.1.2) are then calculated using Eq. 1 and the diameter determined in accordance with 5.1.4, above, followed by applying the adjustments of 5.1.5, above.

5.1.7 The results are shown in Table 6-1 and are summarized in Table 7-1.

5.2 Long Term MSB Inert Gas Inventory

5.2.1 Based on the maximum leak rate for the Normal Storage Condition, the inert gas inventory is evaluated to ensure that it is adequate at the end of the 50-year life of the MSB.

Let:
$V_{initial}$ = Initial helium volume stored in the MSB, cc
V_{final} = Final helium volume in the MSB at end of life, defined below, cc
V_{loss} = Helium volume loss due to leakage over the 50 year life, defined below, cc
Q_{tu} = Maximum upstream helium leak rate for normal storage conditions, cc/sec
t_{loss} = Maximum time for the normal loss to occur, sec

Then:
$V_{loss} = Q_{tu} \times t_{loss}$, for either the BWR or the PWR MSB
$V_{final} = V_{initial} - V_{loss}$
Percent Inert Gas Retained = $[V_{final} / V_{initial}]$ 100%

6. CALCULATIONS

6.1 Leak Path Diameter

6.1.1 The leak path diameter is determined, by iteration, from the limiting helium test volumetric flow rate and test conditions. The helium leak rates for normal, off-normal, and accident storage conditions are tabulated for the both the 1/4-in. and 1-in. leak path length, and for both 50°F and 260°F, to show the effects of variations in path length and temperature. Table 6-1 shows the results of these calculations.

6.2 Long Term MSB Inert Gas Inventory

6.2.1 Given the maximum leak rate for normal storage conditions, this section provides a check that the inert gas inventory remains adequate throughout the 50-year life of the MSB. From the input from Sections 4.2 and 6.1, together with the method described in Section 5.2, the maximum leak rate is determined in Table 6-1. Based on the maximum leak rate of 6.2×10^{-5} cc/sec shown in Table 6-1, the gas volume lost during 50 years of normal operation is determined below.

$$\begin{aligned} V_{loss} &= Q_{tu} \text{ x } t_{loss} \\ &= [6.2 \text{ E-5 cc/sec}]\ [(3600 \text{ sec/hr})\ (24 \text{ hr/day})(365 \text{ days/yr})(50 \text{ yrs})] \\ &= [6.2 \text{ E-5 cc/sec}]\ [1.5768 \text{ E+9 sec}] \\ &= 98{,}000 \text{ cc lost} = 0.098 \text{ E+6 cc lost from the MSB.} \end{aligned}$$

$$V_{initial} = 4.42 \text{ E+6 cc}$$

$$V_{final} = V_{initial} - V_{loss} = 4.42 \text{ E+6 cc} - 0.098 \text{ E+6 cc} = 4.32 \text{ E+6 cc}$$

$$\begin{aligned} \text{Percent Inert Gas Retained} &= [V_{final} / V_{initial}]\ 100\% \\ &= [4.32 \text{ E+6 cc} / 4.42 \text{ E+6 cc}]\ 100\% = 97.8\ \% \end{aligned}$$

Table 6-1 Leak Test Temperature Sensitivity to Leak Diameter and Fill Temperature

LEAK GEOMETRY:												
Hole Length, L (in)	1/4			1			1/4			1		
Hole Length, L (cm)	0.6350			2.5400			0.6350			2.5400		
Hole Diameter, D (cm)	8.824E-04			1.266E-03			1.007E-03			1.450E-03		
GAS PROPERTIES:	He			He			He			He		
Molecular Weight, Mw(gm/gmole)	4.0025			4.0025			4.0025			4.0025		
Upstream Pressure, P_o (atm) (7.3 psig)	1.5			1.5			1.5			1.5		
Temperature (F)	50			50			260			260		
Temperature (K)	283			283			400			400		
Upstream Density, r (gm/cc)	2.584E-04			2.584E-04			1.830E-04			1.830E-04		
Downstream Pressure, P_3 (atm)	1.000E+00			1.000E+00			1.000E+00			1.000E+00		
Downstream Density, (gm/cc)	1.723E-04			1.723E-04			1.220E-04			1.220E-04		
ANSI Reference Density, (gm/cc)	1.637E-04			1.637E-04			1.637E-04			1.637E-04		
Avg Pressure, $P_a=(P_o+P_3)/2$ (atm)	1.250E+00			1.250E+00			1.250E+00			1.250E+00		
Average Density, (gm/cc)	2.153E-04			2.153E-04			1.525E-04			1.525E-04		
Dynamic Viscosity, m (cP)	1.912E-02			1.912E-02			2.435E-02			2.435E-02		
FLOW PARAMETERS DURING TEST:												
Reference Flow, Q_r (std cc/sec)	1.000E-04			1.000E-04			1.000E-04			1.000E-04		
Mass Flow Rate (gm/sec)	1.637E-08			1.637E-08			1.637E-08			1.637E-08		
Specified Average Vol. Flow, Q_a (cc/sec)	7.601E-05			7.601E-05			1.073E-04			1.073E-04		
Fc=(2.49E6)*D**4/(m*L)	1.243E-04			1.316E-04			1.657E-04			1.781E-04		
Fm=(3.81E3)*(D**3)*SQ(To/M)/(L*Pa)	2.773E-05			2.046E-05			4.900E-05			3.658E-05		
rf = Fc/Fm	4.482E+00			6.429E+00			3.381E+00			4.869E+00		
Qc = Fc*(P_o-P_3), (cc/sec)	6.215E-05			6.578E-05			8.283E-05			8.904E-05		
Qm = Fm*(P_o-P_3), (cc/sec)	1.387E-05			1.023E-05			2.450E-05			1.829E-05		
$Q_a = Q_c + Q_m$, (cc/sec)	7.601E-05			7.601E-05			1.073E-04			1.073E-04		
Flow Rate Error = [(Calc-Spec)/Spec]%	-5.170E-13			-1.248E-13			-1.263E-14			0.000E+00		
FLOW DURING STORAGE:												
Storage Condition	Normal	Off-Normal	Accident	Normal	Off-Normal	Accident	Normal	Off-Normal	Accident	Normal	Off-Normal	Accident
GAS PROPERTIES:	He	He	He	He	He	He	He	He	He	He	He	He
Upstream Pressure, P_o (psig)	5.23	10.0	55.7	5.23	10.0	55.7	5.23	10.0	55.7	5.23	10.0	55.7
Upstream Pressure, P_o (atm abs)	1.36	1.68	4.79	1.36	1.68	4.79	1.36	1.68	4.79	1.36	1.68	4.79
Temperature (K)	499	503	511	499	503	511	499	503	511	499	503	511
Upstream Density, r (gm/cc)	1.325E-04	1.629E-04	4.571E-04	1.325E-04	1.629E-04	4.571E-04	1.325E-04	1.629E-04	4.571E-04	1.325E-04	1.629E-04	4.571E-04
Downstream Pressure, P_3 (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Downstream Density, (gm/cc)	9.775E-05	9.697E-05	9.545E-05	9.775E-05	9.697E-05	9.545E-05	9.775E-05	9.697E-05	9.545E-05	9.775E-05	9.697E-05	9.545E-05
Reference Density, (gm/cc)	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04	1.637E-04
Avg Pressure, $P_a=(P_o+P_3)/2$ (atm)	1.18	1.34	2.89	1.18	1.34	2.89	1.18	1.34	2.89	1.18	1.34	2.89
Average Density, (gm/cc)	1.151E-04	1.300E-04	2.763E-04	1.151E-04	1.300E-04	2.763E-04	1.151E-04	1.300E-04	2.763E-04	1.151E-04	1.300E-04	2.763E-04
Dynamic Viscosity, m (cP)	2.843E-02	2.859E-02	2.891E-02	2.843E-02	2.859E-02	2.891E-02	2.843E-02	2.859E-02	2.891E-02	2.843E-02	2.859E-02	2.891E-02
FLOW PARAMETERS:												
Fc=(2.49E6)*D**4/(m*L)	8.360E-05	8.313E-05	8.222E-05	8.849E-05	8.799E-05	8.703E-05	1.419E-04	1.411E-04	1.395E-04	1.525E-04	1.516E-04	1.500E-04
Fm=(3.81E3)*(D^3)*SQ(To/M)/(L*Pa)	3.907E-05	3.448E-05	1.609E-05	2.883E-05	2.544E-05	1.187E-05	5.809E-05	5.126E-05	2.392E-05	4.337E-05	3.827E-05	1.786E-05
Qc = Fc*(P_o-P_3), (cc/sec)	2.974E-05	5.655E-05	3.115E-04	3.148E-05	5.986E-05	3.298E-04	5.047E-05	9.597E-05	5.287E-04	5.426E-05	1.032E-04	5.683E-04
Qm = Fm*(P_o-P_3), (cc/sec)	1.390E-05	2.345E-05	6.096E-05	1.026E-05	1.731E-05	4.499E-05	2.067E-05	3.487E-05	9.064E-05	1.543E-05	2.603E-05	6.767E-05
Qtransition-avg (cc/sec)	4.364E-05	8.001E-05	3.725E-04	4.174E-05	7.717E-05	3.747E-04	7.114E-05	1.308E-04	6.193E-04	6.969E-05	1.292E-04	6.360E-04
Mass Flow Rate (gm/sec)	5.025E-09	1.040E-08	1.029E-07	4.806E-09	1.003E-08	1.035E-07	8.191E-09	1.700E-08	1.711E-07	8.023E-09	1.679E-08	1.757E-07
Qin, Inlet Flowrate (cc/sec)	3.792E-05	6.381E-05	2.251E-04	3.626E-05	6.155E-05	2.265E-04	6.181E-05	1.044E-04	3.743E-04	6.054E-05	1.030E-04	3.844E-04
Qout, Outlet Flowrate (cc/sec)	5.14E-05	1.07E-04	1.08E-03	4.92E-05	1.03E-04	1.08E-03	8.38E-05	1.75E-04	1.79E-03	8.21E-05	1.73E-04	1.84E-03

7. CONCLUSIONS

7.1 Results

7.1.1 Based on the results documented in Table 6-1, the highest upstream helium leak test temperature of 260°F leads to the largest leak diameter. The limiting leak path geometry is a right-circular cylinder with a leak path length of 1/4 in. for the normal and off-normal conditions and 1 in. for the accident condition. The helium leak test temperature of 260°F results in the highest storage condition leak rates. For the normal and off-normal conditions, the shorter leak path provides the highest upstream flow rates, and for the accident condition, the longer leak path provides the highest upstream flow rates. Table 7-1 summarizes the basket leakage analysis results for the maximum normal, off-normal, and accident storage conditions analyzed herein.

Table 7-1: VSC-24 Multi-Assembly Sealed Basket Leakage Rates

Storage or Test Condition	Inlet / Outlet Volumetric Flow Rate (cc/sec)	He Flow Rate at Reference Conditions (std cc/sec)
Helium Leak Test	Not Applicable	1.0 E-4
Normal Storage	6.18 E-5 / 8.38 E-5	Not Applicable
Off- Normal Storage	1.04 E-4 / 1.75 E-4	Not Applicable
Accident Storage	3.84 E-4 / 1.84 E-3	Not Applicable

7.1.2 The MSB will maintain essentially all of the helium inventory over the 50 year life. The loss of up to 2.2% helium during the 50-year life has a smaller effect on the MSB thermal performance than the effect of the time-dependent reduction of the fuel heat-generation rate. It also has a negligible effect on the corrosion protection of the MSB internals, due to lack of oxygen.

7.2 Compliance with Requirements

7.2.1 This VSC-24 storage system leakage analysis has followed the guidelines in Regulatory Commitment 2.2.1. Regulatory Commitment 2.2.2 (Standard Review Plan), as modified by Regulatory Commitment 2.2.1, contains the same information as in Regulatory Commitment 2.2.1. The leak analysis methods follow the guidance in Regulatory Commitment 2.2.3 and Reference 3.3.1. Therefore, Regulatory Commitments 2.2.1 and 2.2.2 have been met by these analyses.

7.3 Range of Validity

The analyses and leakage results presented herein apply only to a VSC-24 MSB fabricated in accordance with the referenced drawings and containing 24 fuel assemblies with a maximum thermal load of 24 kW, and operated and tested in accordance with the criteria specified in Section 4.2, above.

7.4 Summary of Conservatisms

7.4.1 This calculation incorporates the following conservative assumptions.

(a) For the off-normal and accident conditions, pure helium is assumed to leak rather than a mixture of fuel rod fill gases. As stated in 4.3.1, above, the resulting mixture would have a higher combination of viscosity and molecular weight, and thus larger hydraulic losses, which would cause lower leakage flow rates for the off-normal and accident conditions.

(b) The leak path is assumed to be the more conservative of the shortest possible length and the sum of the lid-to-shell weld depths.

(c) The upstream temperature for the helium leak test is set at a conservatively high value of 260°F (400°K), which, in turn, is based on the maximum permitted thermal load of 24 kW.

(d) Conservative assumptions are inherent in the analysis of the upstream gas conditions for the normal, off-normal, and accident storage conditions. These include the following:

- Minimized gas free volume within the MSB due to conservative allowances for MSB internals and irradiation growth of 2 inches for all fuel rods
- Conservatively low helium backfill temperature (220°F), which maximizes He fill gas moles, is assumed in Ref. 3.1.1.
- 3% failed rods are assumed for maximum normal conditions, although only intact rods are loaded
- 10% failed rods are assumed for off-normal conditions
- 100% failed rods are assumed for accident conditions

7.5 Limitations or Special Instructions

None.

8. ELECTRONIC FILES

None.

BNFL Fuel Solutions	**CALCULATION PACKAGE**	Calc. Pkg No. VSC02.6.2.5.03 File No.: VSC02.6.2.5.03 Revision: 0

PROJECT/CUSTOMER:

VSC02/BNFL Fuel Solutions

TITLE:

VSC-24 Design Parameters

SCOPE:

Product: ☐ FuelSolutions™ ☐ TranStor™ ☒ VSC-24 ☐ Other ______

Service: ☒ Storage ☒ Transportation ☐ Other ______

Conditions: ☒ Normal ☒ Off-Normal ☒ Accident ☐ Other ______

Component(s):

Entire VSC-24

Prepared by:

Name: Michelle Heinz

Signature: Michelle Heinz

Date: 3-9-01

Verified by:

Name: RICK SWAYNE

Signature: R. Swayne

Date: 3/12/01

Engineering Manager Approval:

Name: RAM SRINIVASAN

Signature: R Srinivasan

Date: 3/26/01

Form QAP 3.2-1, Revision 1

RECORD OF REVISIONS

REV.	AFFECTED PAGES	AFFECTED MEDIA	DESCRIPTION	NAMES (Print or Type)	
				PREPARER	CHECKER
0	All	None	Initial issue		

TABLE OF CONTENTS

LIST OF TABLES

RECORD OF VERIFICATION			
	Circle:		
(a) The objective is clear and consistent with the analysis.	YES	NO	
(b) The inputs are correctly selected and incorporated into the design.	YES	NO	N/A
(c) References are complete, accurate, and retrievable.	YES	NO	N/A
(d) Basis for engineering judgments is adequately documented.	YES	NO	N/A
(e) The assumptions necessary to perform the design activity are adequately described and reasonable.	YES	NO	N/A
(f) Assumptions and references, which are preliminary, are noted as being preliminary.	YES	NO	N/A
(g) Methods and units are clearly identified.	YES	NO	N/A
(h) Any limits of applicability are identified.	YES	NO	N/A
(i) Computer calculations are properly identified.	YES	NO	N/A
(j) Computer codes used are under configuration control.	YES	NO	N/A
(k) Computer codes used are applicable to the calculation.	YES	NO	N/A
(l) Input parameters and boundary conditions are appropriate and correct.	YES	NO	
(m) An appropriate design method is used.	YES	NO	
(n) The output is reasonable compared to the inputs.	YES	NO	
(o) Conclusions are clear and consistent with analysis results.	YES	NO	

COMMENTS:

Verifier: ______________________________

Name/Signature/Date

1. INTRODUCTION

The objective of this calculation is to document the values of various design parameters of VSC-24 components. The design parameters will be used to develop bounding design calculations for the VSC-24. This calculation also identifies the bounding configuration evaluated in each of the design calculations.

The scope of this calculation applies to 1) the VCC, MSB, and MTC design parameters (summarized in Tables 4-1, 4-2, and 4-3 of this calculation, respectively) associated with the following fuel assembly types (facilities using these fuel assembly types are provided in parentheses):

- B&W 15x15 (used at ANO-1)
- CE 16x16 (used at ANO-2)
- CE 15x15 (used at Palisades)
- W 14x14 (used at Point Beach)

and 2) the fuel and fuel assembly design parameters (summarized in Table 4-4) associated with the following fuel assembly types (facilities using these fuel assembly types are provided in parentheses):

- B&W 15x15 (used at ANO-1)
- CE 16x16 (used at ANO-2)
- CE 15x15 (used at Palisades)
- W 14x14 (used at Point Beach)
- W 15x15
- W 17x17

2. REQUIREMENTS

2.1 Design Inputs

None.

2.2 Regulatory Commitments

None.

3. REFERENCES

3.1 BFS Calculation Packages

None.

3.2 General References

None.

4. ASSUMPTIONS

4.1 Design Configuration

The VSC-24 Design Parameters are summarized in the following tables:

Table 4-1	VCC Design Parameters
Table 4-2	MSB Design Parameters
Table 4-3	MTC Design Parameters
Table 4-4	Fuel Design Parameters

These tables are located at the end of Section 4. Parenthetical information in the tables specifies which fuel assembly type (or the facility – see Section 1 for the correlation between fuel assembly types and facilities) corresponds to each design parameter. If a fuel assembly type (or facility) is not provided with a design parameter, then the design parameter is applicable to all fuel assembly types applicable to the table (see Section 1 for correlation between tables and fuel assembly types).

The design configurations for the design calculations are identified in Table 4-5. The design calculations are bounding for all the fuel assembly types and MSB/MTC/VCC configurations. Table 4-5 indicates the configurations to analyze to assure the calculation is bounding.

4.2 Design Criteria

The design criteria applicable to this calculation are summarized below, and are also included in Tables 4-1, 4-2, 4-3, and 4-4.

- The VCC concrete density not accounting for the rebar is 144 lbf/ft^3.
- The VCC concrete density taking account for the rebar is 150 lbf/ft^3.
- The VCC concrete strength is 4,000 psi.
- The MSB shell and shield lid steel density is 0.284 lbf/ft^3.
- The MSB shield lid Rx-277 density is 0.0607 lbf/ft^3.
- The MSB shield lid lead density is 0.41 lbf/ft^3.
- The plenum spring material density is 0.3 lb/in^3.
- The fuel assembly stainless steel density is 0.29 lb/in^3.

4.3 Calculation Assumptions

All VSC-24 design parameters documented in this calculation are assumed. The parameters are used to develop bounding VSC-24 calculations.

Unless otherwise noted, the dimensions provided in Tables 4-1 through 4-4 are nominal, i.e., material and machining dimensional tolerances are not included. When the nominal dimensions vary over a finite range, the minimum or maximum value is assumed (as shown in Table 4-4), whichever yields the more conservative result in the bounding design calculations.

Table 4-1 VCC Design Parameters

Component	Design Input	Value	Referencing Calcs	Notes
VCC CASK	Concrete/rebar Density	150 lbf/ft^3	3.01, 5.01	Accounts for rebar in concrete
	Concrete Density	144 lbf/ft^3	3.15, 3.18	
	Concrete Strength	4,000 psi	3.01, 3.18, 3.19, 3.15	
	OD	132"	5.01, 3.01, 3.15, 3.19	
	Length	225.05" (ANO1, ANO2) 196.7" (Pal) 213.0 (PB) 213.6" (W15x15) 215.6 (W17x17)	5.01, 3.19, 3.15, 3.01 5.01, 3.15, 3.01 5.01, 3.01 3.01 3.01	Length excludes cover
	Corner Chamfer	3" x 45° bevel	3.15, 3.19	
VCC BOTTOM PLATE	Material	A-36	3.18	
	OD	126"	5.01	
	Thickness	0.25"	5.01	
VCC LID	OD	82"	5.01	
	Thickness	0.75"	5.01, 3.19	
VCC SHIELD RING	OD	70.5"	5.01	
	ID	60"	5.01	Includes ring attached to shield lid
	Height	6"	5.01	
VCC SKID CHANNELS	Number	2	5.01	
	Width	12"	5.01	
	Height	12.2"	5.01	
	Average Length	100.3"	5.01	
VCC COVER PLATE	Material	A-36	3.18	
VCC CASK LINER	Height	199.05" (ANO1, ANO2) 170.7" (Pal) 188.7" (PB)	5.01, 3.19 5.01, 3.19 5.01, 3.19	
	ID	70.5"	5.01, 3.01, 3.18, 3.19, 3.15, 3.08	
	Thickness	1.75"	3.01, 3.15, 3.18, 3.19, 5.01	
	Vent Hole Width	49.0"	3.01	
	Cask Liner Segment Width between Vent Holes	4.56"	3.01	
	Material	A-36	3.01, 3.15, 3.18, 3.19	
VCC CASK LINER FLANGE	OD	90"	5.01	
	Thickness	2"	5.01	
VCC CASK LINER BOTTOM	Thickness	2"	5.01	

Component	Design Input	Value	Referencing Calcs	Notes
VCC REBAR	VCC Outside Rebar	#6 @ 6"	3.18, 3.15	
	No. in Air Outlet Cross Section	32	3.19	
	Diameter in Air Outlet Cross Section	0.75"	3.19	
	Material	A-615 Gr. 60	3.01, 3.18, 3.15, 3.19	
VCC AIR OUTLET CHANNELS	Number	4	5.01	
	Width	47.8"	5.01	
	Length with 3 Inches of Overlap Between High and Low Channels	36.3"	5.01	
	Height	4"	5.01	
	Thickness	0.5"	5.01	
	Length from Top of VCC to Midpoint of Outlet Assembly	8"	5.01	No dimension on drawing, length is approximate
VCC AIR INLET ASSEMBLIES	No. of Air Inlet Assemblies	4	5.01	
VCC AIR INLET TUBES	Width	12"	5.01	
	Length	40"	5.01	No dimension on drawing, length is approximate
	Height	12"	5.01	
VCC AIR INLET CHANNELS	Width	4.5"	5.01	Mid-wall dimension
	Height	5"	5.01	
	Angular Extent	71 deg	5.01	
	Outer Radius	35.25"	5.01	
	Liner Thickness	0.5"	5.01	
CERAMIC TILE	No. of Tiles	24	3.25	
	Tile Centerline Radius	30"	3.25	
	Square Tile Thickness	0.3"	3.25	
	Square Tile Width	1.7"	3.25	

Table 4-2 MSB Design Parameters

Component	Design Input	Value	Referencing Calcs	Notes
MSB SHELL	MSB Shell Material	SA-516 Gr. 70	3.07, 3.25, 3.02, 3.06	
	Steel Density	0.284 lbf/ft^3	3.25	
	MSB Bottom Plate Material	SA-516 Gr. 70	3.02, 3.06, 3.25	
	Minimum MSB Cavity Length	178.6" (ANO1, ANO2) 150.55" (Pal) 166.65" (PB) 167.25" (W15x15) 169.25" (W17x17)	3.05 3.05 3.05 3.05 3.05	Includes effects of drawing and material tolerances.
	MSB Length	192.25" (ANO1, ANO2) 164.2" (Pal) 180.3" (PB) 180.9" (W15x15) 182.9 (W17x17)	3.25, 5.01, 3.04, 3.07 5.01, 3.04, 3.07 5.01, 3.04, 3.07 3.04, 3.07 3.04, 3.07	The ANSYS analyses in Calcs 04 and 07 use 181"
	MSB Shell Thickness	1.00"	3.07, 3.25, 3.08, 3.04, 3.06, 5.01	
	MSB Bottom Thickness	0.75"	5.01, 3.07, 3.25, 3.08, 3.04	
	MSB OD	62.5"	5.01, 3.09, 3.12, 3.07, 3.15, 3.25, 3.08, 3.04, 3.01	
	Minimum MSB Basket Inside Diameter	59.8"	3.05	Includes effects of drawing and material tolerances.
MSB STRUCTURAL LID	MSB Structural Lid-to-Shell Weld Size	0.75"	3.04	
	Material	SA-516 Gr. 70	3.03, 3.31, 3.02	
	MSB Structural Lid Thickness	3"	5.01, 3.03, 3.31, 3.07, 3.04, 3.08	
	MSB Structural Lid OD	60"	5.01, 3.07, 3.31	
	Hoist Thread Engagement Length	1.5" (PB, Pal) 2.0" (ANO1, ANO2)	3.03 3.03	
	Lid Lifting Bolt Holes Radius	27.0" (ANO1, ANO2, Pal) 26.5" (PB)	3.03, 3.31 3.31	
	No. of Lid Lifting Bolts/Hoist Rings	6	3.03, 3.31	
	MSB Hoist Thread Type	2.0-4.5 UNC (ANO1 & 2) 1.5-6 UNC (PB, Pal)	3.03 3.03	
	Hoist Ring Type	Am. Drill Bushing Co. #23202 (PB, Pal) #23200 (ANO1, ANO2)	 3.03 3.03	
MSB SHIELD LID	Material	SA-516-70	3.02	
	Rx-277 Density	0.0607 lb/in^3	5.01, 3.25	
	Steel Density	0.284 lbf/ft^3	5.01, 3.25	
	Lead Density	0.41 lbf/ft^3	5.01	
	Shield Lid Weld Type and Size	¼" partial penetration	3.08	
	Shield Lid Support Ring Weld Type & Size	½" partial penetration	3.08	

Component	Design Input	Value	Referencing Calcs	Notes
MSB SHIELD LID	Thickness	9.5" (sandwich of 2.5" plate, 2" Rx-277 neutron absorber, and 5" plate)	3.08, 3.25, 5.01	7.5" used in Calc 08 ANSYS analysis
	OD	60.1"	5.01	
	Distance from Top of MSB to Top of Support Ring	12.55"	5.01	
	Shield Lid Support Plate OD	60.25"	5.01, 3.08	
	Shield Lid Side Ring Thickness	0.5"	5.01	
	Support Ring Thickness	0.5"	5.01	
	Support Ring Height	2.0"	5.01	
MSB STORAGE SLEEVE	Material	SA-516 Gr. 70	3.07, 3.02, 3.08, 3.16	
	Outer Dimension	9.2"	3.16, 3.05, 5.01, 3.07, 3.08	
	Thickness	0.2"	5.01, 3.07, 3.16, 3.05, 3.08	
	Length	159.0" (ANO1, ANO2) 147.5" (Pal) 163.6" (PB) 163.6" (W15x15) 163.6" (W17x17)	5.01, 3.16, 3.05, 3.07 5.01, 3.16, 3.05, 3.07 5.01, 3.16, 3.05, 3.07 5.01, 3.05, 3.07 5.01, 3.05, 3.07	160" used in Calc 07 ANSYS analysis
MSB BASKET ASSEMBLY	Storage Sleeve Assembly OD	59.2"	5.01, 3.05, 3.07	
	No. of Curved Support Plates	3	5.01, 3.05, 3.16	Four plates at one elevation considered as one
	Curved Support Plate Height	28"	5.01, 3.05, 3.08, 3.16	
	Curved Support Plate Thickness	0.5"	5.01, 3.05, 3.07	
	No. of Support Wall Plates	24	3.05	
	Support Wall Plate Height	28.0"	3.05	
	Support Wall Plate Width	4.37"	3.05	
	Support Wall Plate Thickness	0.5"	3.07, 3.05	
	No. of Support Bars	12	5.01, 3.05	
	Support Bar Height	28"	5.01, 3.05	
	Support Bar Thickness	1.45"	5.01, 3.05	
	Support Bar Width	2.0"	5.01, 3.05	

Table 4-3 MTC Design Parameters

Component	Design Input	Value	Referencing Calcs	Notes
MTC SHELL	Inner Shell Material	SA-588 Gr. A or B	3.10	
	Outer Shell Material	SA-588 Gr. A or B	3.10	
	Gamma Shielding Material	Lead	5.01	
	Neutron Shielding Material	Rx-277	5.01	
	Outer Shell OD	82.0" (ANO1, ANO2) 83.5" (PB, Pal)	5.01, 3.09, 3.10 5.01, 3.09, 3.10	
	Outer Shell Thickness	1.0"	5.01, 3.10	
	Outer Shell Height	189.8"(ANO1, ANO2) 177.8"(PB) 161.7"(Pal)	5.01	
	Inner Shell OD	64.5"(ANO1, ANO2) 65.0" (PB, Pal)	5.01, 3.10 5.01, 3.10	
	Inner Shell Thickness	0.75"	5.01, 3.10	
	Diameter at Lead to Shielding Interface	72.0" (ANO1, ANO2) 73.38" (PB, Pal)	5.01 5.01	
	Top Thickness	2"	5.01	
	Bottom Thickness	1"	5.01	
	Lead Shielding Top Gap	7.0" (ANO1, ANO2) 1.0" (PB, Pal)	5.01 5.01	
MTC COVER PLATE	Cover Plate Material	SA-516, Gr. 70	3.12	
	Cover Plate OD	74"	5.01, 3.12	
	Cover Plate Thickness	1"	5.01, 3.12	
	Cover Plate ID	60.5"	5.01, 3.12	
	No. of Cover Plate Bolts	16	3.12	
	Cover Plate Bolt Type	1"-8UNC	3.12	
	Cover Plate Bolt Material	A-325	3.12	
	MTC Cover Plate Bolt Circle Radius	35.5"	3.12	
MTC TRUNNION	No.	2	5.01	
	Material	SA-516 Gr. 70	3.10	
	Diameter	10.75"	5.01, 3.10	
	Length from Outer Shell OD to End of Bearing Surface	4.5"	3.10	
	Length	14.5"(ANO1, ANO2) 15.0" (PB, Pal)	5.01 5.01	
MTC DOORS	No.	2	5.01, 3.09	
	Width	39.25" (ANO1, ANO2) 42.7" (PB, Pal)	5.01, 3.09 5.01, 3.09	
	Length	69.5" (ANO1, ANO2) 70.0" (PB, Pal)	5.01, 3.09 5.01, 3.09	
	Thickness	7.13" (ANO1, ANO2) 9.0" (PB, Pal)	5.01, 3.09 5.01, 3.09	
	Door Cutout Width	20.25" (ANO1, ANO2) 17.7" (PB, Pal)	5.01, 3.09 5.01, 3.09	

Component	Design Input	Value	Referencing Calcs	Notes
MTC DOORS	Door Cutout Length	17.25 (ANO1, ANO2) 15" (PB, Pal)	5.01, 3.09 5.01, 3.09	
	Lead Thickness in Shielded Door Assemblies	2.0" (ANO1, ANO2) 0" (PB, Pal)	5.01, 3.09 3.09	
MTC RAILS	Material	A-36	3.09	
	Number	2	5.01, 3.09	
	Height	7.25" (ANO1, ANO2) 9.125" (PB, Pal)	5.01 5.01	
	Length	99" (ANO1, ANO2) 105" (PB, Pal)	5.01 5.01	
	Width	7.5" (ANO1, ANO2) 6.5" (PB, Pal)	5.01, 3.09 5.01, 3.09	The 7.5" thickness includes the partial length rail shield plate thickness.
	Partial Length Rail Shield Plate Thickness	5.50"	5.01	
	Rail Shield Plate Average Length	75.5"	5.01	
	Spacing at Outside of Rails	84.8" (ANO1, ANO2) 83.3 (PB, Pal)	3.09 3.09	
	Rail to Shell (Inner Weld) Leg Length	0.625"	3.09	
MTC RAIL SUPPORTS	Material	A-36	3.09	
	Width	10.25" (ANO1, ANO2) 9.25" (PB, Pal)	5.01, 3.09 5.01, 3.09	The 10.25" thickness includes the partial length rail shield plate thickness.
	Thickness	1.5"	5.01, 3.09	
	Rail to Rail Support Partial Penetration Weld Size	0.625"	3.09	

Table 4-4 Fuel Design Parameters

Design Input	Value	Plant	Referencing Calcs	Notes
MAX FUEL WEIGHT WITH BPRAS (LBS)	1585	ANO1	5.01	
	1450	ANO2		
	1380	Palisades	5.01	
	1350	Point Beach	5.01	
	1500	W15x15		
	1515	W17x17		
MAX FUEL WEIGHT W/O BPRAS (LBS)	1515	ANO1	3.05	
	1430	ANO2	3.05	
	1360	Palisades	3.05	
	1330	Point Beach	3.05	
	1480	W15x15	3.05	
	1495	W17x17	3.05	
MIN FUEL WEIGHT (LBS)	1500	ANO1		
	1400	ANO2		
	1305	Palisades	5.01	
	1110	Point Beach	5.01	
	1440	W15x15		
	1370	W17x17	5.01	
PLENUM SPRING WEIGHT (LBS)	0.042	ANO1	3.05	
	0.1	ANO2	3.05	
	0.05	Palisades	3.05	
	0.07	Point Beach	3.05	
	0.044	W15x15	3.05	
	0.037	W17x17	3.05	
FUEL ROD FILL PRESSURE (PSIG)	415	ANO1	3.05	
	450	ANO2	3.05	
	450	Palisades	3.05	
	460	Point Beach	3.05	
	475	W15x15	3.05	
	500	W17x17	3.05	
MAX ROD WEIGHT (FOR MAX FUEL WT.) (LBS)	7.00	ANO1	3.05	
	5.70	ANO2	3.05	
	5.80	Palisades	3.05	
	6.68	Point Beach	3.05	
	6.85	W15x15	3.05	
	5.37	W17x17	3.05	
NO. OF FUEL RODS	208	ANO1	3.05, 5.01	
	236	ANO2	3.05	
	208	Palisades	3.05, 5.01	
	179	Point Beach	3.05, 5.01	
	204	W15x15	3.05	
	264	W17x17	3.05	
MAX FUEL ROD OD (IN)	0.430	ANO1	3.05	
	0.382	ANO2	3.05, 5.01	
	0.418	Palisades	3.05, 5.01	
	0.422	Point Beach	3.05, 5.01	
	0.422	W15x15	3.05	
	0.374	W17x17	3.05	

Design Input	Value	Plant	Referencing Calcs	Notes
MAX FUEL ROD ID (IN)	0.377	ANO1	3.05	
	0.332	ANO2	3.05	
	0.366	Palisades	3.05	
	0.377	Point Beach	3.05	
	0.3736	W15x15	3.05	
	0.329	W17x17	3.05	
MIN PELLET OD (IN)	0.368	ANO1	3.05	Minimum parameter for W standard fuel. The Calc 05 analysis with W standard fuel bounds the W OFA fuel.
	0.325	ANO2	3.05	
	0.358	Palisades	3.05	
	0.364	Point Beach	3.05	
	0.3659	W15x15	3.05	
	0.3225	W17x17	3.05	
MAX FUEL ASSEMBLY LENGTH (IRRADIATED, IN)	173.5	ANO1	3.08	
	178.6	ANO2	5.01, 3.08	
	150.6	Palisades	5.01, 3.08	
	166.3	Point Beach	5.01, 3.08	
	166.9	W15x15	3.08	
	168.9	W17x17	3.08	
MAX FUEL ROD LENGTH (UNIRRADIATED, IN)	153.68	ANO1	5.01	
	161.0	ANO2		
	140.0	Palisades	5.01	
	152.4	Point Beach	5.01	
	151.88	W15x15		
	151.64	W17x17		
MAX FUEL ROD LENGTH (IRRADIATED, IN)	155.22	ANO1	3.05	
	162.61	ANO2	3.05	
	141.40	Palisades	3.05	
	153.92	Point Beach	3.05	
	153.40	W15x15	3.05	
	153.16	W17x17	3.05	
MAX FUEL LENGTH (IN)	141.8	ANO1	3.05	
	150.0	ANO2	3.05	
	132.0	Palisades	3.05	
	145.2	Point Beach	3.05	
	144.0	W15x15	3.05	
	144.0	W17x17	3.05	
MAX PLENUM LENGTH (IN)	11.72	ANO1	3.05	
	9.53	ANO2	3.05	
	8.0	Palisades	3.05	
	6.99	Point Beach	3.05	
	8.2	W15x15	3.05	
	6.3	W17x17	3.05	
MAX URANIUM MASS (MTU/ASSY)	0.464	ANO1	3.05	
	0.413	ANO2	3.05	
	0.413	Palisades	3.05	
	0.407	Point Beach	3.05	
	0.469	W15x15	3.05	
	0.426	W17x17	3.05	
MIN GAP BETWEEN FUEL ASSEMBLY AND SLEEVE	0.264"	All	3.08	ANO1 B&W 15x15 is limiting
MAX BURNUP (MWD/MTU)	51800	All	3.05	

Design Input	Value	Plant	Referencing Calcs	Notes
PLENUM SPRING MATERIAL DENSITY	0.3 lb/in^3	All	3.05	
NO. OF FUEL ASSEMBLIES PER MSB	24	All	3.05, 5.01, 3.08	
FUEL ASSEMBLY STAINLESS STEEL DENSITY	0.29 lb/in^3	All	3.05	
NO. OF BPRA	16 0 8 16 20 24	ANO1 ANO2 Palisades Point Beach W15x15 W17x17	3.05 3.05 3.05 3.05 3.05 3.05	
BPRA BACKFILL GAS PRESSURE (PSIG)	400 0 450 460 475 500	ANO1 ANO2 Palisades Point Beach W15x15 W17x17	3.05 3.05 3.05 3.05 3.05 3.05	
BPRA FILL GAS VOLUME PER ROD (IN^3)	1.6 0 1.6 1.6 1.6 1.6	ANO1 ANO2 Palisades Point Beach W15x15 W17x17	3.05 3.05 3.05 3.05 3.05 3.05	
BPRA BORON-10 MASS PER ROD ($gm_{boron-10}$/rod)	2.61 0 2.61 2.873 2.873 2.873	ANO1 ANO2 Palisades Point Beach W15x15 W17x17	3.05 3.05 3.05 3.05 3.05 3.05	See Note for calculation of Westinghouse mass of boron 10 per rod.

Note:

Westinghouse fuel mass of boron 10 per rod:

$$0.043 \cdot \frac{gm_{boron}}{cm} \cdot \frac{mole_{boron}}{10.811 \cdot gm_{boron}} \cdot 0.199 \cdot \frac{mole_{boron-10}}{mole_{boron}} \cdot \frac{10.0129 \cdot gm_{boron-10}}{mole_{boron-10}} \cdot 142.7 \cdot \frac{in}{rod} \cdot \frac{2.54 \cdot cm}{in}$$

Table 4-5 Design Configurations for Calculations

Calculated Load/Stress	Calculation Number[1]	Analyzed Configurations[2]	Limiting Configuration[3]	Notes
Deadweight				
MSB Ceramic Tile Support	VSC02.6.2.3.25, R2 VSC02.6.2.3.02, R3	• Heaviest Loaded MSB	• Heaviest Loaded MSB	
MSB Structural Lid	VSC02.6.2.3.31, R1	• Heaviest Loaded MSB	• Heaviest Loaded MSB	
MSB Hoist Ring	VSC02.6.2.3.03, R1	(1) • ANO1 & ANO2 Hoist Ring • Heaviest Loaded MSB (2) • PB & Pal Hoist Ring • Heaviest PB/Pal Loaded MSB	Not applicable. Both configurations analyzed.	
MTC Support Rail, Support Rail to Rail Weld, Rail to MTC Shell Weld	VSC02.6.2.3.09, R1	(1) • ANO1 & ANO2 MTC Configuration • Heaviest Loaded ANO1/ANO2 MSB (2) • PB & Pal MTC Configuration • Heaviest Loaded PB/Pal MSB	Not applicable. Both configurations analyzed.	
MTC Trunnion	VSC02.6.2.3.10, R1	• ANO1 & ANO2 MTC Configuration • Heaviest Loaded MTC	(1) • ANO1 & ANO2 MTC Configuration • Heaviest Loaded ANO1/ANO2 MTC	
MTC Shell	VSC02.6.2.3.10, R1	(1) • ANO1 & ANO2 MTC Configuration • Heaviest Loaded ANO1/ANO2 MTC (2) • PB MTC Configuration • Heaviest Loaded PB MTC (3) • Pal MTC Configuration • Heaviest Loaded Pal MTC	(1) • ANO1 & ANO2 MTC Configuration • Heaviest Loaded ANO1/ANO2 MTC	
MTC Cover Plate	VSC02.6.2.3.12, R1	• Heaviest Empty MTC	• Heaviest Empty MTC	
VCC Bottom and Wall Stresses	VSC02.6.2.3.01, R1	• Heaviest Loaded VCC • Tallest VCC	• Heaviest Loaded VCC • Tallest VCC	

Calculated Load/Stress	Calculation Number[1]	Analyzed Configurations [2]	Limiting Configuration[3]	Notes
VCC Liner Stress	VSC02.6.2.3.01, R1	• Heaviest Loaded MTC	• Heaviest Loaded MTC	
Thermal				
MSB Stresses	VSC02.6.2.3.07, R2	• Medium-Length MSB • Medium-Length Storage Sleeve	• Medium-Length MSB • Medium-Length Storage Sleeve	Varying the lengths of the MSB and storage sleeve has minimal effect on stress results.
VCC Stresses	VSC02.6.2.3.18, R2	• Medium-Length VCC • Medium-Length VCC Liner	• Medium-Length VCC • Medium-Length VCC Liner	Varying the heights of the VCC and the VCC liner has minimal effect on thermal stresses.
Pressure				
MSB Normal, Off-Normal, and Accident Pressures	VSC02.6.2.3.05, R2	• Analyzes six fuel assembly and MSB configurations	• B&W 15x15 fuel assembly (ANO1)	
MSB Normal Pressure Stress	VSC02.6.2.3.02, R3	• Heaviest Loaded MSB	• Heaviest Loaded MSB	The analysis combines deadweight, handling, and pressure.
MSB Accident Pressure Stress	VSC02.6.2.3.02, R3	• Heaviest Loaded MSB	• Heaviest Loaded MSB	
MSB Normal, Off-Normal, and Accident Pressure Stresses	VSC02.6.2.3.04, R3	• Medium-Length MSB	• Medium-Length MSB	Varying the length of the MSB has minimal effect on stress results.
Normal Handling				
Vertical	VSC02.6.2.3.21, R2 VSC02.6.2.3.02, R3	• Tallest MSB • Heaviest MSB	• Tallest MSB • Heaviest MSB	
Horizontal	VSC02.6.2.3.21, R2	• Medium-Length MSB • Heaviest MSB	• Medium-Length MSB • Heaviest MSB	Varying the length of the MSB has minimal effect on stress results.
Off-Normal Handling				
Vertical	VSC02.6.2.3.21, R2	• Tallest MSB • Heaviest MSB	• Tallest MSB • Heaviest MSB	
Horizontal	VSC02.6.2.3.21, R2	• Medium-Length MSB • Heaviest MSB	• Medium-Length MSB • Heaviest MSB	Varying the length of the MSB has minimal effect on stress results.

Calculated Load/Stress	Calculation Number[1]	Analyzed Configurations[2]	Limiting Configuration[3]	Notes
Drop				
MSB Vertical Drop – Ceramic Tile Support	VSC02.6.2.3.25, R2	• Heaviest Loaded MSB	• Heaviest Loaded MSB	
MSB Vertical Drop – No Ceramic Tile	VSC02.6.2.3.25, R2	• Tallest MSB	• Tallest MSB	
	VSC02.6.2.3.08, R2	• Tallest MSB • Tallest Storage Sleeve • Heaviest Fuel	• Tallest MSB • Tallest Storage Sleeve • Heaviest Fuel	
MSB Horizontal Drop	VSC02.6.2.3.08, R2	• Medium-Length MSB • Tallest Storage Sleeve • Heaviest Fuel	• Medium-Length MSB • Tallest Storage Sleeve • Heaviest Fuel	Varying the length of the MSB has minimal effect on stress results.
Storage Sleeve Horizontal Drop	VSC02.6.2.3.08, R2	• Heaviest Fuel • Tallest Storage Sleeve	• Heaviest Fuel • Tallest Storage Sleeve	
Storage Sleeve Buckling Due to Horizontal Drop	VSC02.6.2.3.16, R1	• Tallest Storage Sleeve	• Tallest Storage Sleeve	
Storage Sleeve Buckling Due to Vertical Drop	VSC02.6.2.3.16, R1	(1) (ANO1, ANO2, W15x15, & W17x17 configurations) • Heaviest BPRA Fuel Weight • Medium-Length Storage Sleeve (2) (PB configuration) • Lightest BPRA Fuel Weight • Tallest Storage Sleeve (3) (Pal. configuration) • Medium BPRA Fuel Weight • Shortest Storage Sleeve	(1) • Heaviest BPRA Fuel Weight • Medium-Length Storage Sleeve	
VCC Shear and Moment Due to Horizontal Drop	VSC02.6.2.3.15, R1	• Medium-Length VCC	• Medium-Length VCC	Varying the length of the VCC has minimal effect on results.
VCC Tip Over – VCC Concrete Crush Depth	VSC02.6.2.3.15, R1	(1) • Tallest VCC • Heaviest Loaded VCC (2) • Shortest VCC • Lightest Loaded VCC	(1) • Tallest VCC • Heaviest Loaded VCC	

Calculated Load/Stress	Calculation Number[1]	Analyzed Configurations[2]	Limiting Configuration[3]	Notes
VCC Tip Over – MSB Deceleration	VSC02.6.2.3.15, R1	(1) • Tallest VCC • Heaviest Loaded VCC (2) • Shortest VCC • Lightest Loaded VCC	(2) • Shortest VCC • Lightest Loaded VCC	
VCC Vertical 5-Foot Drop Concrete Crush Depth	VSC02.6.2.3.15, R1	(1) • Tallest VCC • Heaviest Loaded VCC (2) • Shortest VCC • Lightest Loaded VCC	(1) • Tallest VCC • Heaviest Loaded VCC	
VCC Vertical 5-Foot Drop – MSB Deceleration	VSC02.6.2.3.15, R1	(1) • Tallest VCC • Heaviest Loaded VCC (2) • Shortest VCC • Lightest Loaded VCC	(2) • Shortest VCC • Lightest Loaded VCC	
VCC Horizontal 5-Foot Drop Concrete Crush Depth	VSC02.6.2.3.15, R1	(1) • Tallest VCC • Heaviest Loaded VCC (2) • Shortest VCC • Lightest Loaded VCC	(2) • Shortest VCC • Lightest Loaded VCC	
VCC Horizontal 5-Foot Drop – MSB Deceleration	VSC02.6.2.3.15, R1	(1) • Tallest VCC • Heaviest Loaded VCC (2) • Shortest VCC • Lightest Loaded VCC	(2) • Shortest VCC • Lightest Loaded VCC	
Seismic				
VCC Tip-Over Due to Horizontal & Vertical Acceleration	VSC02.6.2.3.19, R1	• Lightest Loaded VCC • Highest Loaded VCC Center of Gravity	• Lightest Loaded VCC • Highest Loaded VCC Center of Gravity	
VCC Tip-Over Due to Vertical Corner Lift	VSC02.6.2.3.19, R1	• Highest Loaded VCC Center of Gravity	• Highest Loaded VCC Center of Gravity	
VCC Seismic Stresses	VSC02.6.2.3.19, R1	• Heaviest Loaded VCC • Highest Loaded VCC Center of Gravity • Tallest VCC • Tallest VCC Liner	• Heaviest Loaded VCC • Highest Loaded VCC Center of Gravity • Tallest VCC • Tallest VCC Liner	
Flood				
VCC Tip-Over Due to Immersing Flood	VSC02.6.2.3.19, R1	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	

Calculated Load/Stress	Calculation Number[1]	Analyzed Configurations[2]	Limiting Configuration[3]	Notes
Tornado				
VCC Sliding Due to Tornado Wind Load	VSC02.6.2.3.19, R1	• Tallest VCC • Lightest Loaded VCC	• Tallest VCC • Lightest Loaded VCC	
VCC Tip-Over Due to Tornado Wind Load	VSC02.6.2.3.19, R1	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	
VCC Tip-Over Due to Tornado Missile	VSC02.6.2.3.19, R1	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	
VCC Tip-Over Due to Combined Tornado Wind and Missile	VSC02.6.2.3.19, R1	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	• Highest Loaded VCC Center of Gravity • Lightest Loaded VCC • Tallest VCC	
VCC Stress Due to Tornado Missile	VSC02.6.2.3.19, R1	• Tallest VCC Liner	• Tallest VCC Liner	

Notes

1. The calculation number and revision number are provided for information. The calculation approach as identified in the next two columns applies to the indicated revision number of the calculation and to any higher revision of the calculation.

2. Each calculation is bounding for all six fuel assemblies and MSB/VCC configurations. This table indicates the approach used in the calculation to assure the calculation is bounding. The third column, "Analyzed Cask Configurations," indicates the number and types of configurations analyzed to assure the calculation was bounding.

3. The fourth column, "Limiting Configuration," indicates which configuration was limiting for the specific analysis.

5. CALCULATION METHODOLOGY

None.

6. CALCULATIONS

None.

7. CONCLUSIONS

7.1 Results

The design parameters of the VSC-24 components have been documented in Tables 4-1, 4-2, 4-3, and 4-4. The design configurations for the calculations are identified in Table 4-5.

7.2 Compliance with Requirements

None.

7.3 Range of Validity

Parenthetical information in Tables 4-1, 4-2, 4-3, and 4-4 specifies which fuel assembly type (or facility – see Section 1 for the correlation between fuel assembly types and facilities) corresponds to each design parameter. If a fuel assembly type (or facility) is not provided with a design parameter, then the design parameter is applicable to all fuel assembly types associated with the table (see Section 1 for corresponding fuel assembly types and tables).

7.4 Summary of Conservatisms

The design configurations identified in Table 4-5 are conservative and provide a bounding analysis for all the fuel assembly types and MSB/MTC/VCC configurations.

7.5 Limitations or Special Instructions

The design parameters presented in this document apply only to the fuel assembly types as described in the 'Range of Validity' above.

8. COMPUTER RUNS

8.1 Computer Runs

None.

8.2 Other Electronic Files

None.