Design Analysis and Calculations
Title Page

Calculation No.:	DAC-EA-801699-A002
Calculation Title:	Impact Analysis of ES3100 Design Concepts Using HABC
Preparer's Organization:	Engineering Analysis & Technology Engineering
Project/Task Name:	ES3100 Shipping Container
Rev.:	0

Comments/Purpose:

This calculation documents the computer simulation impact runs for the ES3100 (ES-3100) shipping container with high alumina borated cement (HABC) as the neutron absorber.

Assumptions that require subsequent confirmation or reconfirmation

Assumptions typical for a dynamic analysis are stated within the analysis as used.

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This D. A. C. has been reviewed by a Y-12 ADC and has been determined to be UNCLASSIFIED and contains no UCNI. This review does not constitute clearance for Public Release.
Name: S. McClanahan Date: 2/28/2005

Revision	Date	Description	Total Pages	Affected Pages
0	March 2005	Initial Issue	Frontmatter, i-ii Body, 1-133	All

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1.0 Problem Statement

This calculation documents the impact simulations made in support of the ES-3100 shipping package design with high alumina borated cement (HABC) as the neutron absorber. From the summer of 2003 through the spring of 2004 the design impact simulations were run with borobond as the neutron absorber (documented in reference 5.1). During the summer of 2004, the ES-3100 with the borobond neutron absorber was physically tested to 10CFR71 required impacts (references 5.2 and 5.3). In August 2004 a decision was made to change the neutron absorber material to a HABC. The HABC material is also known as "Catalog 277-4" or just "277-4", but the HABC notation is used in this calculation. The August 2004 absorber change also involved some minor design changes to the configuration of the package liners surrounding the HABC material. Material testing on the HABC material occurred during the Fall of 2004 (reference 5.4). The HABC simulation impacts were run in the late Fall of 2004 and are documented in this DAC.

A qualitative, cross sectional view of an ES-3100 package with the HABC neutron absorber is shown in Figure 1.1. The ES-3100 shipping package is a stainless steel drum with kaolite insulation material. The overall dimensions of the overpack are a height of about 44 inches and a diameter of about 19.4 inches. At the top of the overpack is a bolted lid restrained by eight, 5/8 inch welded studs. The lid restrains a removable plug filled with the kaolite material. The plug covers a cavity in which the stainless steel containment vessel (CV) is placed. The CV is about 32.9 inches tall with a 5.4 inch inside diameter and a body wall thickness of 0.1 inches. The CV closure is a flat plate constrained by a threaded ring. In the shipping package, and immediately surrounding the CV cavity is a layer of HABC, a neutron absorbing cast material. All the kaolite and HABC materials are wrapped by stainless steel liners.

The HABC model was derived from the initial borobond model which is documented in Reference 5.1. As such, the basic model and methodology for this calculation is based on, and is documented in reference 5.1. Reference 5.1 should be obtained and used as a constant reference supporting this calculation. Reference 5.1 documents the pre-processor, TrueGrid; the solution software, LS-Dyna; the post-processor, LS-Post; and the computers at Y12 used to simulate the impacts.

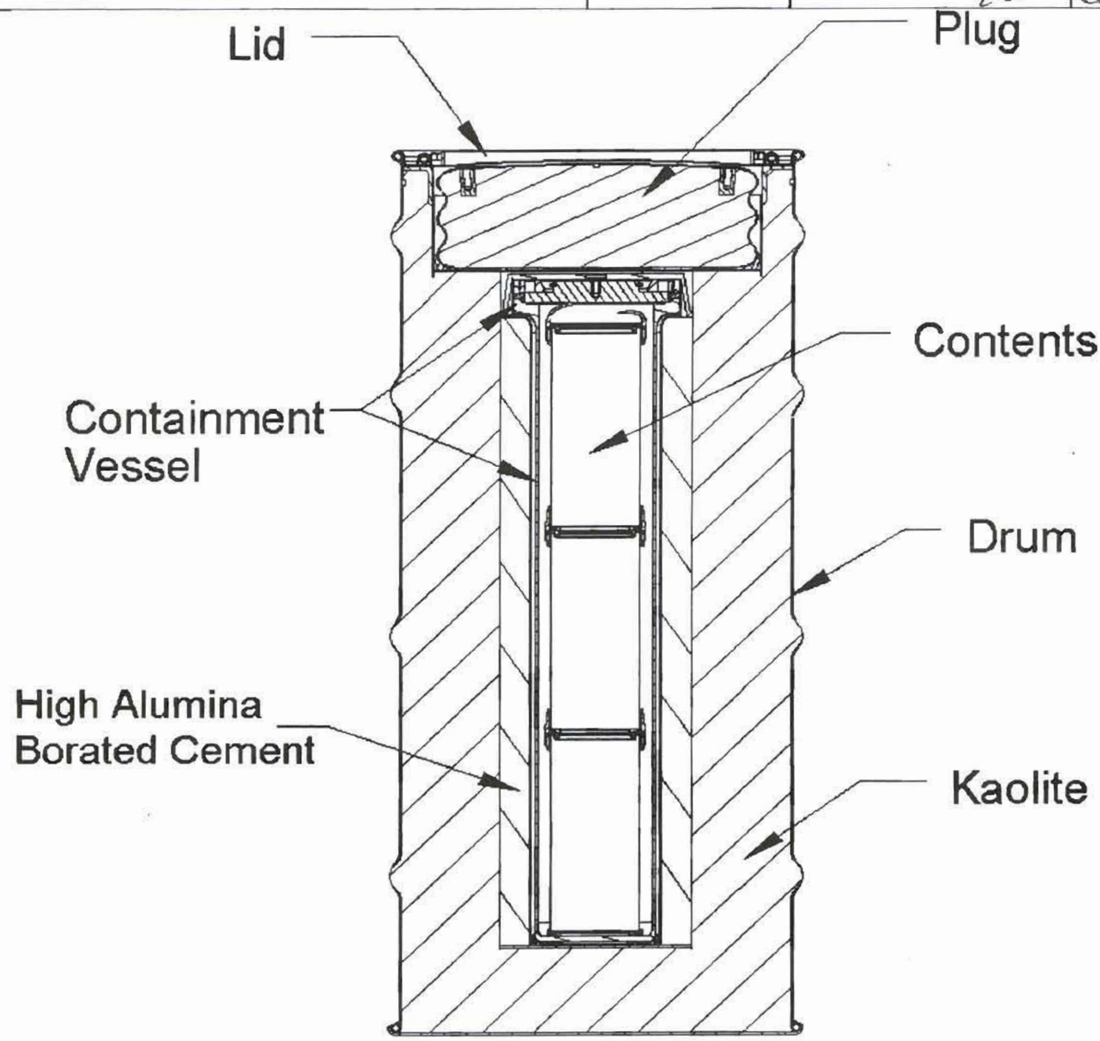

Figure 1.1 - Configuration of the Redesigned ES-3100 with the HABC as the Neutron Absorber

The impact simulations of the ES3100 package are driven by the 10CFR71, subpart F, sections 71.71 and 71.73 impact requirements. LS-Dyna allows successive restarts to be made which enables cumulative damage to be obtained in the shipping package model. Section 2.1, describes the simulations performed for the HABC design.

Section 3.7 compares the respective model results to physical test results. Reference 5.1 documents the analysis vs test comparison for the borobond absorber design. This calculation compares the HABC design analysis results to the borobond design test specimen.

2.0 Analytical Model

The differences between the ES-3100 initial, detailed borobond model (described in reference 5.1) and the redesigned HABC package are described in detail in Section 2.1. The material properties for the HABC are described in Section 2.2. Other than the geometric differences described in Section 2.1 and the material models described in Section 2.2, the detailed analytical models are the same as those presented in reference 5.1 for the initial borobond model.

2.1 Model Description

The redesign configuration details to incorporate the HABC will be described as changes to the initial model (reference 5.1). Figures 2.1.1 and 2.1.2 show the design configuration changes that were made in the analytical models. In the two figures, the black color indicates the initial design and the red (magenta) color indicates the redesign configuration. The changes to the configuration of the analytical model are noted as "Change #" in the Figures and are described below.

1. The internal radius of the liner between the neutron absorbing material and the kaolite was increased from 4.08 in to 4.30 in (Figure 2.1.1 and 2.1.2).

2. The internal radius of the liner above the neutron absorbing material and near the CV flange was decreased from 4.40 in to 4.30 in (Figure 2.1.1).

3. The radius of the CV bottom pad at its inner most part radius was increased from 0.05 in to 0.11 in. This effectively slightly thickens the pad at the footprint of the CV bottom head and therefore the CV was raised by about 0.068 in (Figure 2.1.1 and 2.1.2).

As a precipitate of the above configuration changes, some changes were made to the contact surfaces between the neutron absorber material, the kaolite and the stainless steel (SS) liners. The contact type remained the same as in the reference 5.1 computer runs (SURFACE_TO_SURFACE).

Figures 2.1.3 and 2.1.4 show the element mesh configurations near the CV flange and the

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CV bottom. These figures can be compared to the reference 5.1, Figures 2.1.3 and 2.1.4 to show the differences between the two design configurations.

The runs chosen to be made with the HABC model and compared to the initial borobond model are shown in Figure 2.1.5. To differentiate the runs, yet show similarity, the "HABC" is added to the borobond run identification to identify the redesign runs. For example, the reference 5.1, borobond "run2e" impact configuration is known as "HABC-run2e" for the HABC runs.

Table 2.1.1 describes the impact configurations for the HABC computer runs. Note that the bounding stiffness runs (1hh and 1hl) do not include the punch impact following the crush impact. The reference 5.1, 1hh and 1hl impacts and the punch study demonstrate the integrity of the drum/kaolite. The drum/kaolite remained the same for the HABC runs, therefore the punch impacts were not included in the HABC runs. Table 2.1.1 also gives the kaolite and HABC material models used in each run.

Table 2.1.2 shows the component mass/weight for the HABC models. The total weight for the fully loaded models is about 432 pounds with the 22.4 lb/ft^3 kaolite. The mass inertia about the global Y axis is 90.98 $in*lb*sec^2$ and the CG is located at Z=22.41 inches above the bottom surface of the container. This is in good agreement with the initial borobond model, such that a slapdown study is not warranted. The 12° slapdown is again representative of the worst case angle.

Appendix 6.1 lists the TrueGrid input file used to produce the HABC-run1hh LS-Dyna input file. The file is shown as changes to the TrueGrid input file presented in reference 5.1. This was done to reinforce the fact that changes to the initial borobond design are minimal. The running of TrueGrid produces the bulk of the LS-Dyna input (nodal definitions, element definitions, contact surface definitions, etc). Appendix 6.2 gives the command lines used for the HABC-run1hh. The command lines are the material definitions and the analysis control parameters. The Appendix 6.1 lines are input to TrueGrid which terminates upon writing the bulk of the LS-Dyna input file. The command lines are then edited into the beginning of the LS-Dyna input file and the complete input file is submitted to LS-Dyna.

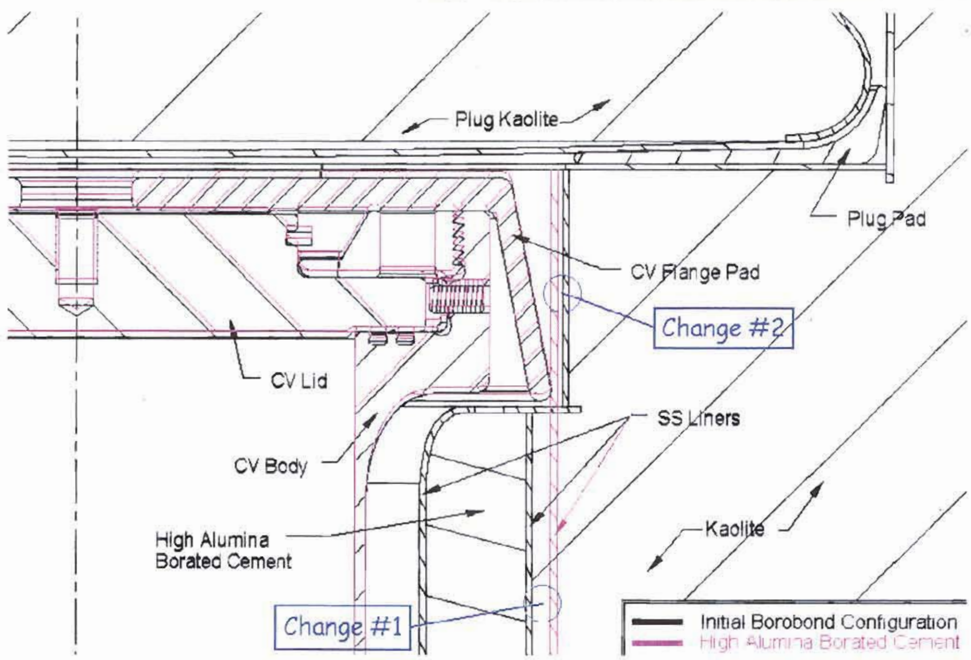

Figure 2.1.1 - Configuration Changes for the HABC, Compared to the Borobond Model Near the CV Flange

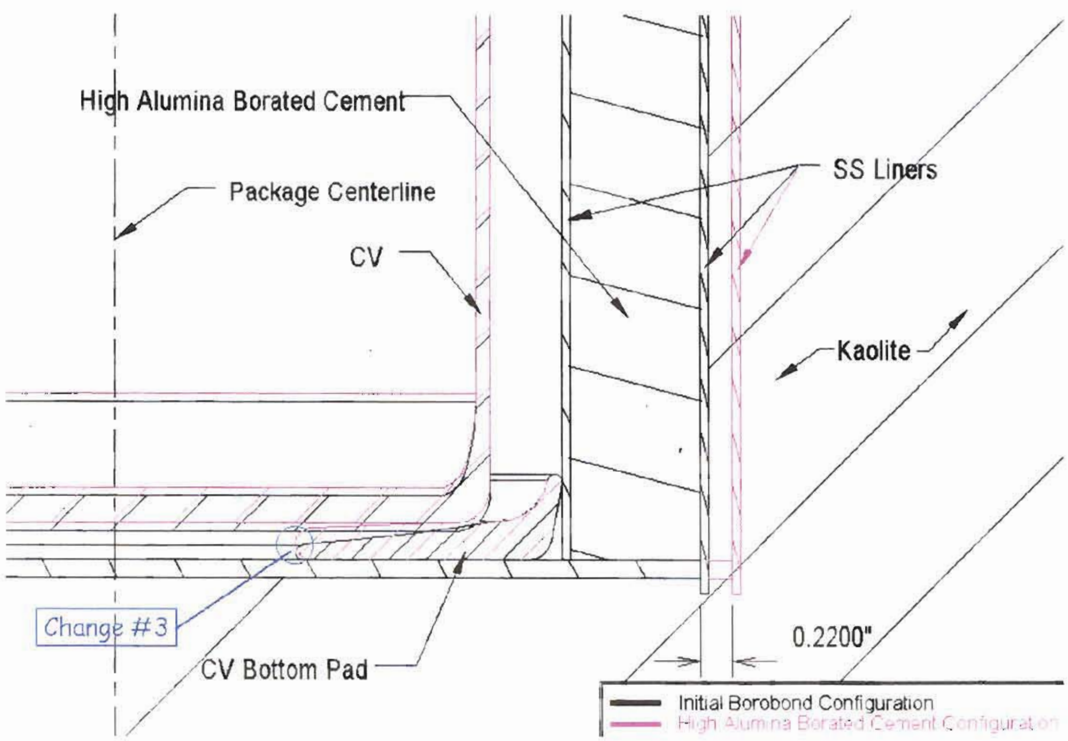

Figure 2.1.2 - Configuration Changes for the HABC, Compared to the Borobond Model Near the Bottom of the CV Body

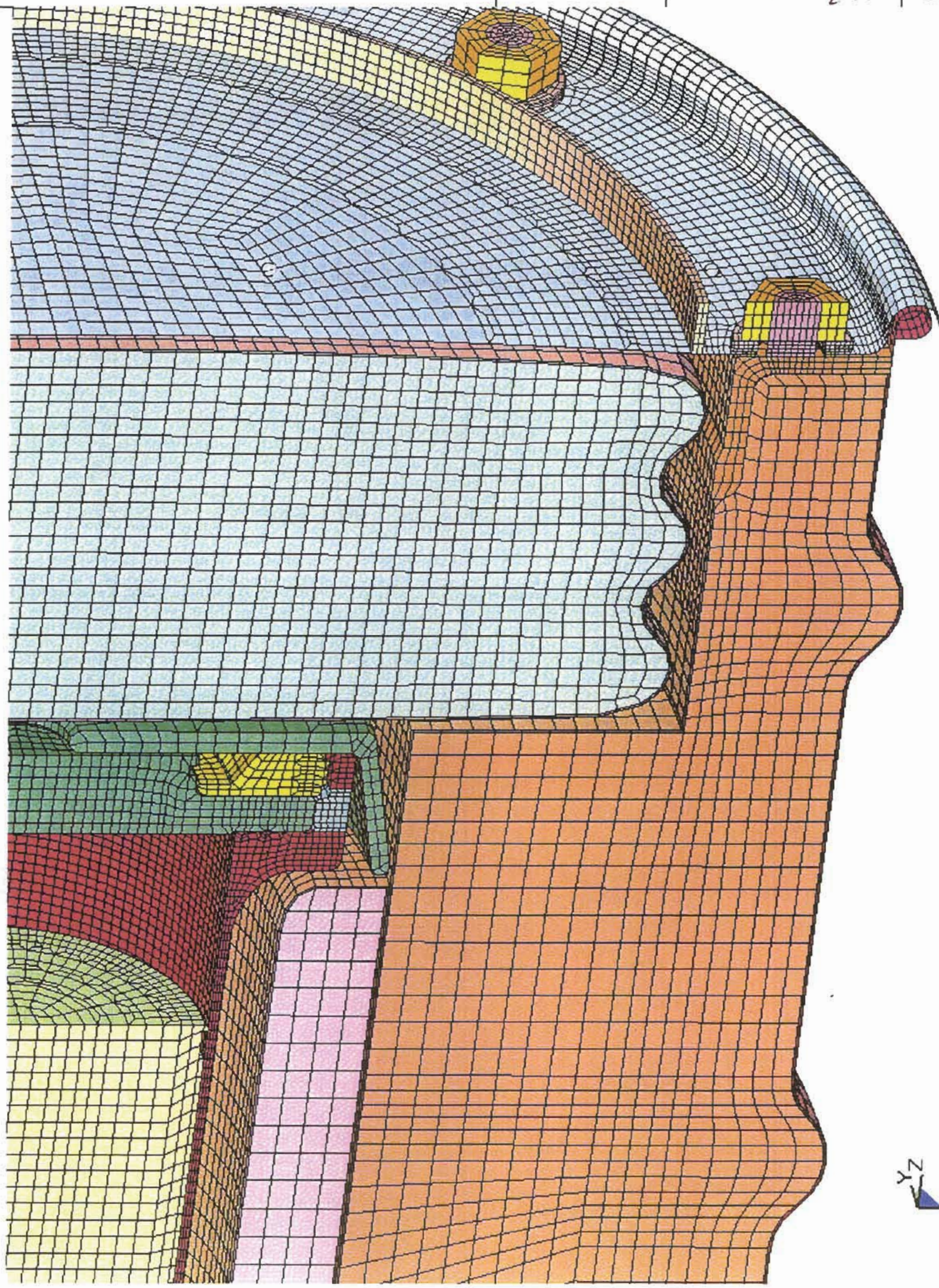

Figure 2.1.3 - Configuration of the HABC Analytical Model Near the Package Top

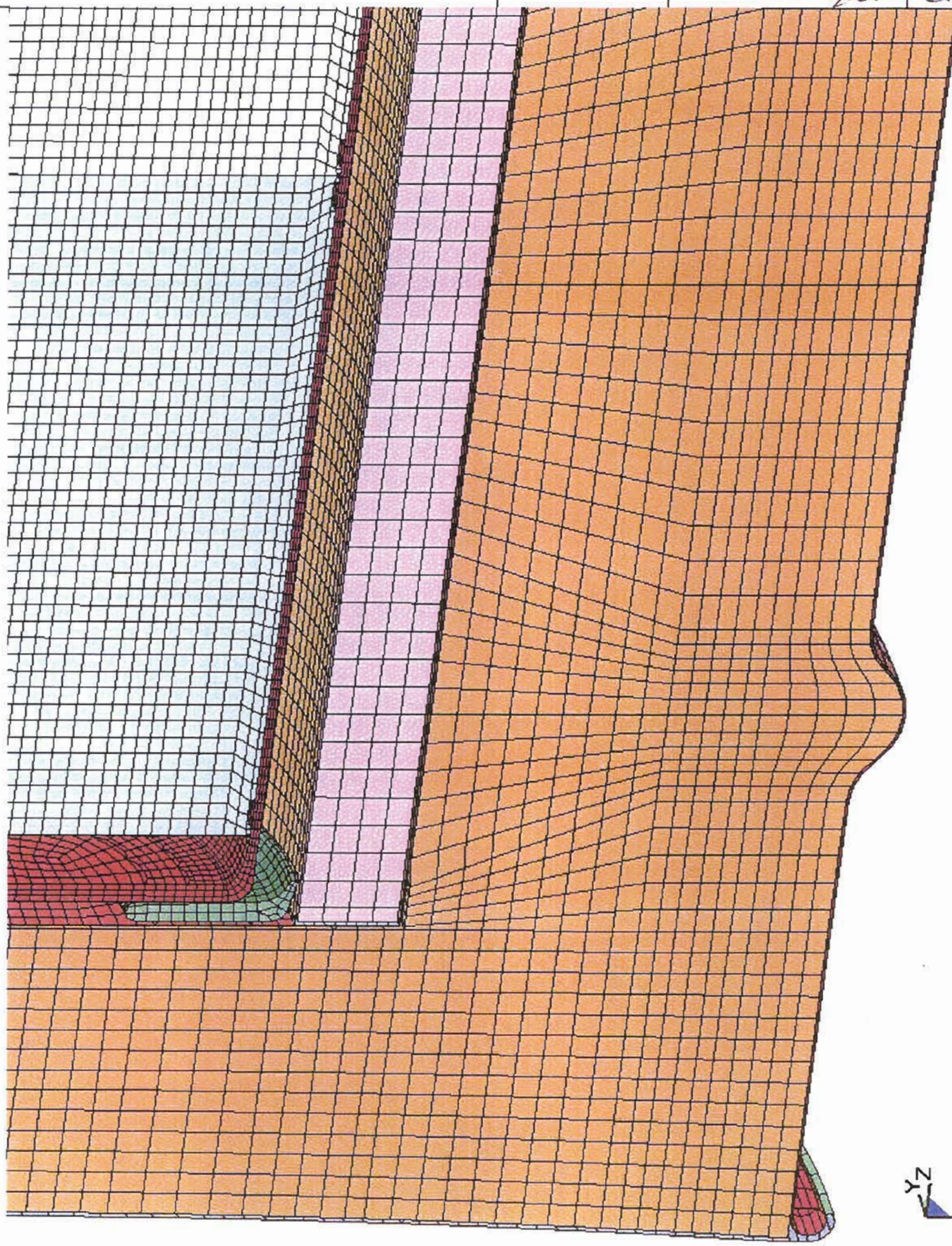

Figure 2.1.4 - Configuration of the HABC Analytical Model Near the Package Bottom

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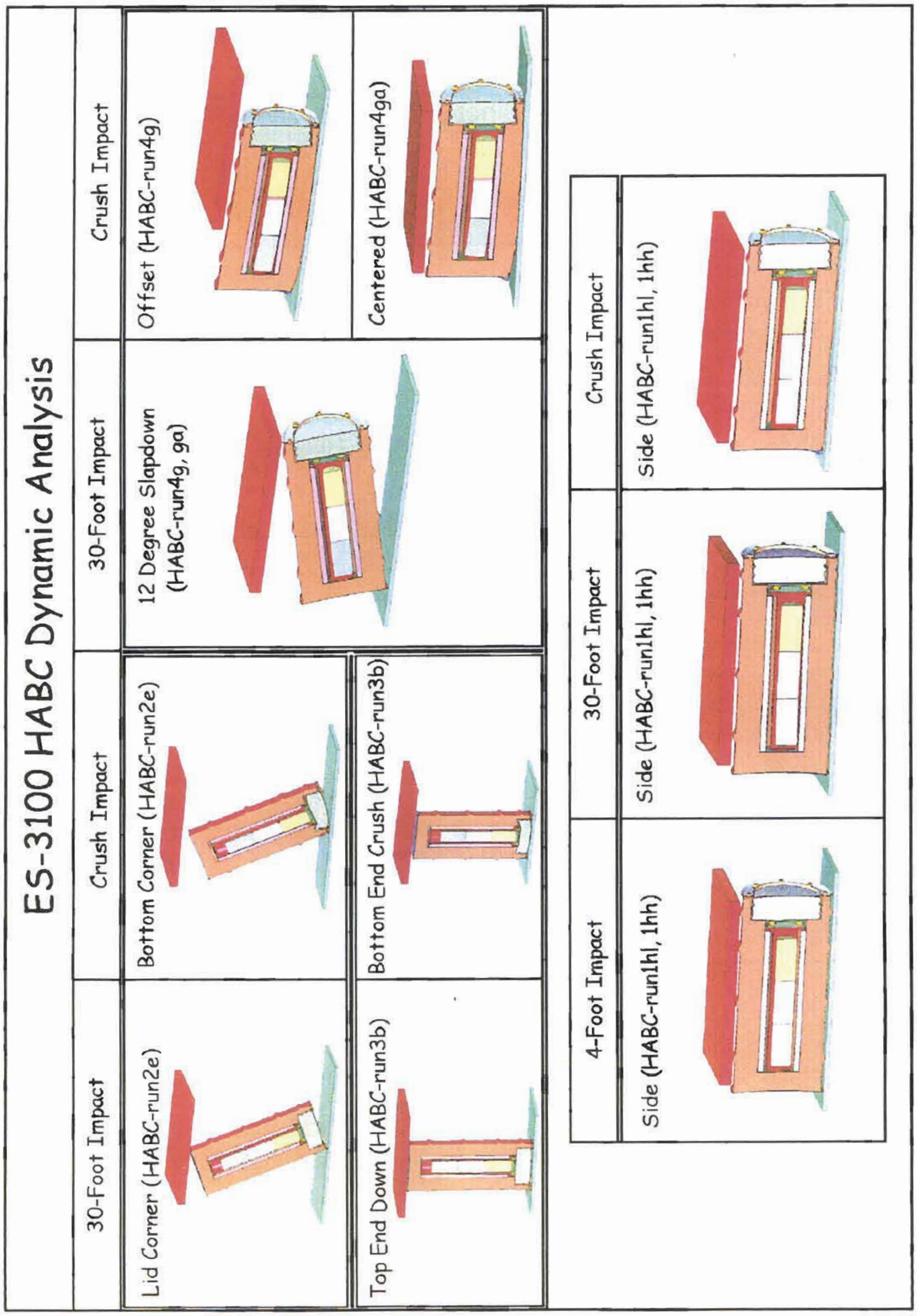

Figure 2.1.5 - LS-Dyna Impact Configurations for the HABC Model

Table 2.1.1 - Description of the ES-3100 HABC Impacts

Run ID	Impact Description	Kaolite Model	HABC Model
HABC-run1hl	4-foot side impact + 30-foot side impact + 30-foot crush impact	Lower bound stiffness, Section 3.2.5.2	100°F, Section 2.2.3
HABC-run1hh	4-foot side impact + 30-foot side impact + 30-foot crush impact	Upper bound stiffness, Section 3.2.5.3	-40°F, Section 2.2.1
HABC-run2e	30-foot CG over lid corner impact + 30-foot crush on bottom corner	Average stiffness, Section 3.2.5.1	70°F, Section 2.2.2
HABC-run3b	30-foot top end impact + 30-foot bottom end crush	Average stiffness, Section 3.2.5.1	70°F, Section 2.2.2
HABC-run4g	30-foot, 12° slapdown with lid studs on plane of symmetry + 30-foot crush with plate centered on CV flange	Average stiffness, Section 3.2.5.1	70°F, Section 2.2.2
HABC-run4ga	30-foot, 12° slapdown with lid studs on plane of symmetry + 30-foot crush with plate centered on drum	Average stiffness, Section 3.2.5.1	70°F, Section 2.2.2

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Table 2.1.2 - Analysis Weights for the ES-3100 HABC Models

Material Number	Component Description	HABC-run2e			HABC-run1hh			HABC-run1hl			HABC-run3b			HABC-run4g		
		mass *	weight **	change***	mass	weight	change***	mass	weight	change***	mass	weight	change***	mass	weight	change***
m 1	CV body	2.73E-02	21.10	0.00	2.73E-02	21.10	0.00	2.73E-02	21.10	0.00	2.73E-02	21.10	0.00	2.73E-02	21.10	0.00
m 2	CV body at flange	1.73E-03	1.34	0.00	1.73E-03	1.34	0.00	1.73E-03	1.34	0.00	1.73E-03	1.34	0.00	1.73E-03	1.34	0.00
m 3	CV lid	9.57E-03	7.39	0.00	9.57E-03	7.39	0.00	9.57E-03	7.39	0.00	9.57E-03	7.39	0.00	9.57E-03	7.39	0.00
m 4	CV screw ring	4.27E-03	3.30	0.00	4.27E-03	3.30	0.00	4.27E-03	3.30	0.00	4.27E-03	3.30	0.00	4.27E-03	3.30	0.00
m 5	angle	1.69E-02	13.02	0.00	1.69E-02	13.02	0.00	1.69E-02	13.02	0.00	1.69E-02	13.02	0.00	1.69E-02	13.02	0.00
m 6	drum	6.02E-02	46.50	0.00	6.02E-02	46.50	0.00	6.02E-02	46.50	0.00	6.02E-02	46.50	0.00	6.02E-02	46.50	0.00
m 7	drum bottom head	1.22E-02	9.42	0.00	1.22E-02	9.42	0.00	1.22E-02	9.42	0.00	1.22E-02	9.42	0.00	1.22E-02	9.42	0.00
m 8	weld drum to drum bottom head	1.18E-04	0.09	0.00	1.18E-04	0.09	0.00	1.18E-04	0.09	0.00	1.18E-04	0.09	0.00	1.18E-04	0.09	0.00
m 9	liner overlap to angle (0.03)	1.36E-04	0.11	0.00	1.36E-04	0.11	0.00	1.36E-04	0.11	0.00	1.36E-04	0.11	0.00	1.36E-04	0.11	0.00
m 10	liner (0.06)	4.05E-02	31.23	0.71	4.05E-02	31.23	0.71	4.05E-02	31.23	0.71	4.05E-02	31.23	0.71	4.05E-02	31.23	0.71
m 11	liner bottom (0.120) (see m 27 for solids)	1.40E-03	1.08	0.00	1.40E-03	1.08	0.00	1.40E-03	1.08	0.00	1.40E-03	1.08	0.00	1.40E-03	1.08	0.00
m 12	lid shells (0.06)	7.25E-03	5.59	0.00	7.25E-03	5.59	0.00	7.25E-03	5.59	0.00	7.25E-03	5.59	0.00	7.25E-03	5.59	0.00
m 13	thin lid shell at bolts	1.37E-05	0.01	0.00	1.37E-05	0.01	0.00	1.37E-05	0.01	0.00	1.37E-05	0.01	0.00	1.37E-05	0.01	0.00
m 14	lid solids at the lid bolts	5.03E-05	0.04	0.00	5.03E-05	0.04	0.00	5.03E-05	0.04	0.00	5.03E-05	0.04	0.00	5.03E-05	0.04	0.00
m 15	lid stiffener	1.39E-03	1.07	0.00	1.39E-03	1.07	0.00	1.39E-03	1.07	0.00	1.39E-03	1.07	0.00	1.39E-03	1.07	0.00
m 16	drum bolts	5.06E-04	0.39	0.00	5.06E-04	0.39	0.00	5.06E-04	0.39	0.00	5.06E-04	0.39	0.00	5.06E-04	0.39	0.00
m 17	drum bolt nuts	1.20E-03	0.93	0.00	1.20E-03	0.93	0.00	1.20E-03	0.93	0.00	1.20E-03	0.93	0.00	1.20E-03	0.93	0.00
m 18	drum bolt washers	4.71E-04	0.36	0.00	4.71E-04	0.36	0.00	4.71E-04	0.36	0.00	4.71E-04	0.36	0.00	4.71E-04	0.36	0.00
m 19	plug liner	1.29E-02	10.00	0.00	1.29E-02	10.00	0.00	1.29E-02	10.00	0.00	1.29E-02	10.00	0.00	1.29E-02	10.00	0.00
m 20	plug kaolite	1.26E-02	9.70	0.00	1.52E-02	11.70	0.00	1.52E-02	11.70	0.00	1.26E-02	9.70	0.00	1.26E-02	9.70	0.00
m 21	drum kaolite	1.40E-01	107.88	-2.20	1.69E-01	130.43	-2.60	1.69E-01	130.43	-2.60	1.40E-01	107.88	-2.20	1.40E-01	107.88	-2.20
m 22	drum HABC	6.36E-02	49.08	5.38	6.36E-02	49.08	5.38	6.36E-02	49.08	5.38	6.36E-02	49.08	5.38	6.36E-02	49.08	5.38
m 24	lower internal cv mass	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00
m 25	middle internal cv mass	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00
m 26	upper internal cv mass	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00	4.75E-02	36.69	0.00
m 27	liner bottom solids	1.25E-03	0.96	0.20	1.25E-03	0.96	0.20	1.25E-03	0.96	0.20	1.25E-03	0.96	0.20	1.25E-03	0.96	0.20
m 29	visual rigid plane	8.00E-04	0.62	-0.08	7.80E-04	0.60	0.00	7.80E-04	0.60	0.00	8.00E-04	0.62	0.00	9.00E-04	0.69	0.00
m 30	crush plate	1.42E+00	1099.99	0.00	1.42E+00	1099.99	0.00	1.42E+00	1099.99	0.00	1.42E+00	1099.99	0.00	1.42E+00	1099.99	0.00
m 31	punch	8.24E-02	63.62	0.00	8.24E-02	63.62	0.00	8.24E-02	63.62	0.00	8.24E-02	63.62	0.00	8.24E-02	63.62	0.00
m32	silicon rubber	1.74E-03	1.34	0.07	1.74E-03	1.34	0.07	1.74E-03	1.34	0.07	1.74E-03	1.34	0.07	1.74E-03	1.34	0.07
	dyna total model weight	2.07E+00	1596.23	4.09	2.10E+00	1620.77	3.77	2.10E+00	1620.77	3.77	2.07E+00	1596.23	4.16	2.07E+00	1596.31	4.16
	CV lid and nut ring		10.68			10.68			10.68			10.68			10.68	
	CV body wt		22.44			22.44			22.44			22.44			22.44	
	CV total wt		33.12			33.12			33.12			33.12			33.12	
	plug liner and kaolite		19.70			21.69			21.69			19.70			19.70	
	liner + angle		46.41			46.41			46.41			46.41			46.41	
	drum body + kaolite + borobond4		261.10			283.66			283.66			261.10			261.10	
	drum + lid + plug + kaolite + borobond4		288.81			313.36			313.36			288.81			288.81	
	internal cv masses		110.08			110.08			110.08			110.08			110.08	
	Total Package Weight		432.01			456.56			456.56			432.01			432.01	
	Crush Plate Weight		1099.99			1099.99			1099.99			1099.99			1099.99	
	Punch Weight		63.62			63.62			63.62			63.62			63.62	
	Visual Rigid Plane		0.62			0.60			0.60			0.62			0.69	
	Total Model Weight		1596.23			1620.77			1620.77			1596.23			1596.31	

* - Mass is for the 1/2 model and is the units of (pound* second^2)/inch

**- Weight is for the total package (2 * model weight) and is in units of pounds

*** - Change is the difference between the HABC run and the Table 2.1.2 results

2.2 Material Models

The material models used in the HABC runs are those described in the reference 5.1, Section 2.3 except for the Section 2.3.6 which covered the Borobond material. As in the initial borobond models the stud material was defined with a material failure at the 0.57 in/in strain level.

The borobond material was replaced with the catalog 277-4, HABC material which is described in this section and sub-sections. The LS-Dyna material model used for the HABC material is the *MAT_SOIL_AND_FOAM model (same material model used for the borobond). The material data was obtained from testing performed at Y12 in the Fall of 2004 (reference 5.4). Figure 2.2.1 shows the stress vs strain curves obtained in the test.

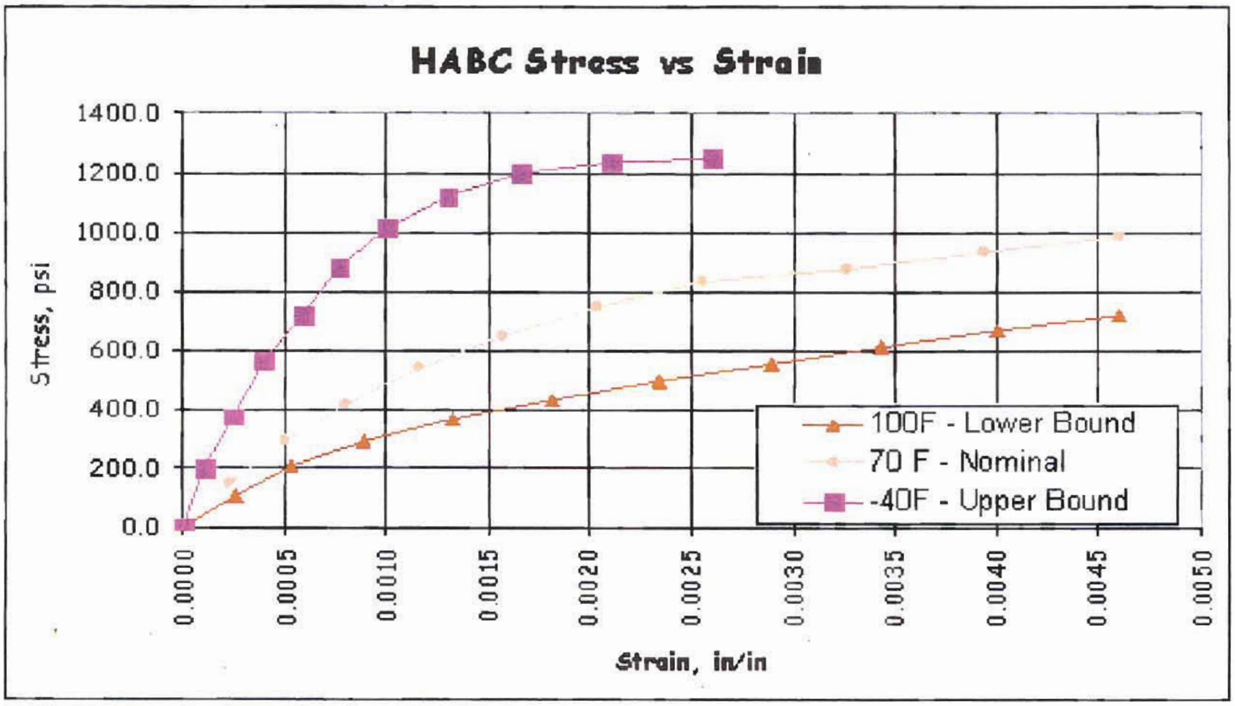

Figure 2.2.1 - HABC Stress vs Strain Curves

2.2.1 HABC at -40° F

Poisson's ratio is given as 0.33 by the testing results. The modulus of elasticity was taken to be the slope of the load deflection curve for the first data point.

$$E = \frac{\sigma}{\varepsilon} = \frac{201.3psi - 0psi}{(101.1e-6) - 0} = 1.991e6psi$$

The shear modulus is then calculated as:

$$ShearModulus = \frac{E}{2(1+\nu)} = \frac{1.991e6\ psi}{2(1+0.33)} = 7.485e5psi$$

The bulk modulus is calculated as:

$$BulkModulus = \frac{E}{3(1-2\nu)} = \frac{1.991e6\ psi}{3(1+2(0.33))} = 1.952e6\ psi$$

Volumetric response data for the HABC material is lacking. A volumetric response will be derived from the one dimensional compressive test data. The HABC material is assumed to behave as a homogeneous, isotropic material.

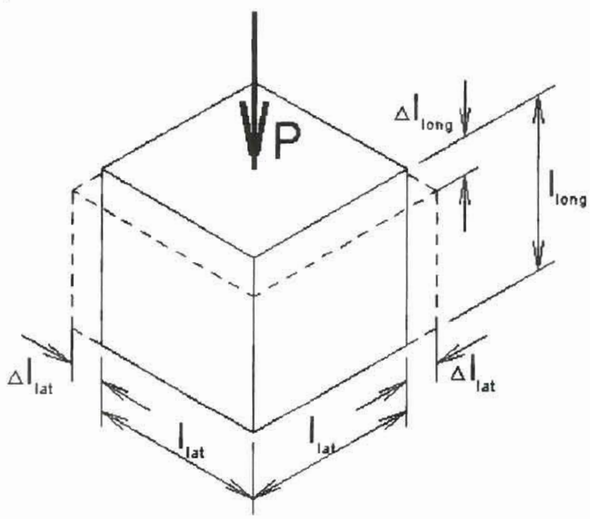

Figure 2.2.1.1 - Assumed Response of a Unit Cube

Using Figure 2.2.1.1 and noting the following definitions,

$$\varepsilon_{long} = \frac{\Delta l_{long}}{l_{long}} \quad ; \quad \varepsilon_{lat} = \frac{\Delta l_{lat}}{l_{lat}} \quad ; \quad \mu = \frac{\varepsilon_{lat}}{\varepsilon_{long}}$$

$$\varepsilon_{lat} = \mu\ \varepsilon_{long}$$

$$l_{lat} = l_{long} = l$$

The initial volume is, l^3, and the final volume is:

$$final\ volume = (l - \Delta l_{long})(l + \Delta l_{lat})(l + \Delta l_{lat})$$

Substituting the above definitions into this equation and simplifying results in the following expression for the final volume.

$$final\ volume = l^3(1 - \varepsilon_{long})(1 + \mu\varepsilon_{long})^2$$

The relative volume then is,

$$V = \frac{current\ volume}{initial\ volume} = (1 - \varepsilon_{long})(1 + \mu\varepsilon_{long})^2$$

The volumetric strain then is:

$$volumetric\ strain = \ln V$$

Using this and P = σ/3, a pressure vs volumetric strain curve is derived. The pressure cut off for tension is derived from the tensile failure of 234.7 psi. The pressure cut off for the material model is: $P = \frac{\sigma}{3} = \frac{234.7\ psi}{3} = 78.2\ psi.$

The constants a_0, a_1, and a_2 are yield function constants defined in the material model. To eliminate the pressure dependence of the yield strength, $a_1 = a_2 = 0$ and $a_0 = \sigma^2_y/3 = (1165.8\ psi)^2/3 = 4.530e5\ psi^2$. The following material model was used for the upper stiffness bound of the HABC material (-40°).

LS-Dyna Material Model	*MAT_SOIL_AND_FOAM
Density	1.5742e-4 lb-sec²/in⁴ (105 lb/ft³)
Shear Modulus	7.485e5 psi
Bulk Modulus	1.952e6 psi
A_0	4.530e5 (psi)^2
A_1	0
A_2	0
Tensile Cutoff	78.2 psi

Volumetric Strain Data vs Pressure:

Volumetric Strain, in³/in³	Pressure, psi
0	0
-3.4380E-05	67.100
-1.3300E-04	187.300
-2.5971E-04	294.367
-4.4481E-04	374.067
-8.8812E-04	416.567
-3.4612E-03†	433.333†
-1.6787E-01†	566.667†
-5.5498E-01†	1000.000†
-1.1409E+00†	100000.000†

† - assumed values to achieve numerical lock-up.

2.2.2 HABC at 70° F

Poisson's ratio is given as 0.28 by the testing. The modulus of elasticity was taken to be the slope of the load deflection curve for the first data point.

$$E = \frac{\sigma}{\varepsilon} = \frac{150.3\,psi - 0\,psi}{(219.8e-6) - 0} = 6.838e5\,psi$$

The shear modulus is then calculated as:

$$ShearModulus = \frac{E}{2(1+\nu)} = \frac{6.838e5\ psi}{2(1+0.28)} = 2.671e5 psi$$

The bulk modulus is calculated as:

$$BulkModulus = \frac{E}{3(1-2\nu)} = \frac{6.838e5\ psi}{3(1+2(0.28))} = 5.180e5\ psi$$

The pressure cut off is calculated as P=184 psi / 3 = 61.3 psi and the constants a_0 is calculated as $(983psi)^2/3 = 3.221e5\ psi^2$. The following material model was used for the 70°F runs of the HABC material.

LS-Dyna Material Model	*MAT_SOIL_AND_FOAM
Density	1.5742e-4 $lb\text{-}sec^2/in^4$ (105 lb/ft^3)
Shear Modulus	2.671e5 psi
Bulk Modulus	5.180e5 psi
A_0	3.221e5 $(psi)^2$
A_1	0
A_2	0
Tensile Cutoff	61.3 psi

Volumetric Strain Data vs Pressure:

Volumetric Strain, in^3/in^3	Pressure, psi
0.0000E+00	0.000
-9.6740E-05	50.100
-3.5131E-04	140.400
-6.9019E-04	217.100
-1.1268E-03	278.133
-2.0363E-03	329.067
-1.9536E-01†	500.000†
-6.0570E-01†	1000.000†
-8.4601E-01†	10000.000†
-1.2052E+00†	100000.000†

† - assumed values to achieve numerical lock-up.

2.2.3 HABC at 100° F

Poisson's ratio is given as 0.25. The modulus of elasticity was taken to be the slope of the load deflection curve for the first data point.

$$E = \frac{\sigma}{\varepsilon} = \frac{103.7\,psi - 0\,psi}{(257.5e-6) - 0} = 4.027e5\,psi$$

The shear modulus is then calculated as:

$$ShearModulus = \frac{E}{2(1+\nu)} = \frac{4.027e5\ psi}{2(1+0.25)} = 1.6108e5\,psi$$

The bulk modulus is calculated as:

$$BulkModulus = \frac{E}{3(1-2\nu)} = \frac{4.027e5\ psi}{3(1+2(0.25))} = 2.6847e5\ psi$$

The pressure cut off is calculated as P=209.7 psi/3 = 69.9 psi and the constants a_0 is calculated as $(833.7\ psi)^2/3 = 2.317e5\ psi^2$. The following material model was used for the lower bound, 100°F runs of the HABC material.

LS-Dyna Material Model	*MAT_SOIL_AND_FOAM
Density	1.5742e-4 lb-sec^2/in^4 (105 lb/ft^3)
Shear Modulus	1.6108e5 psi
Bulk Modulus	2.6847e5 psi
A_0	2.317e5 (psi)^2
A_1	0
A_2	0
Tensile Cutoff	69.9 psi

Volumetric Strain Data vs Pressure:

Volumetric Strain, in^3/in^3	Pressure, psi
0.0000E+00	0.0
-1.2879E-04	34.567
-6.6103E-04	123.133
-1.1769E-03	165.533
-1.7225E-03	204.967
-2.3119E-03	240.0
-5.5975E-02†	333.333†
-4.5758E-01†	500.0†
-6.3677E-01†	1000.0†
-1.2448E+00†	100000.0†

† - assumed values to achieve numerical lock-up.

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The volumetric strain vs pressure curves used by the analytical models are plotted in Figure 2.2.3.1 for the lower strain values.

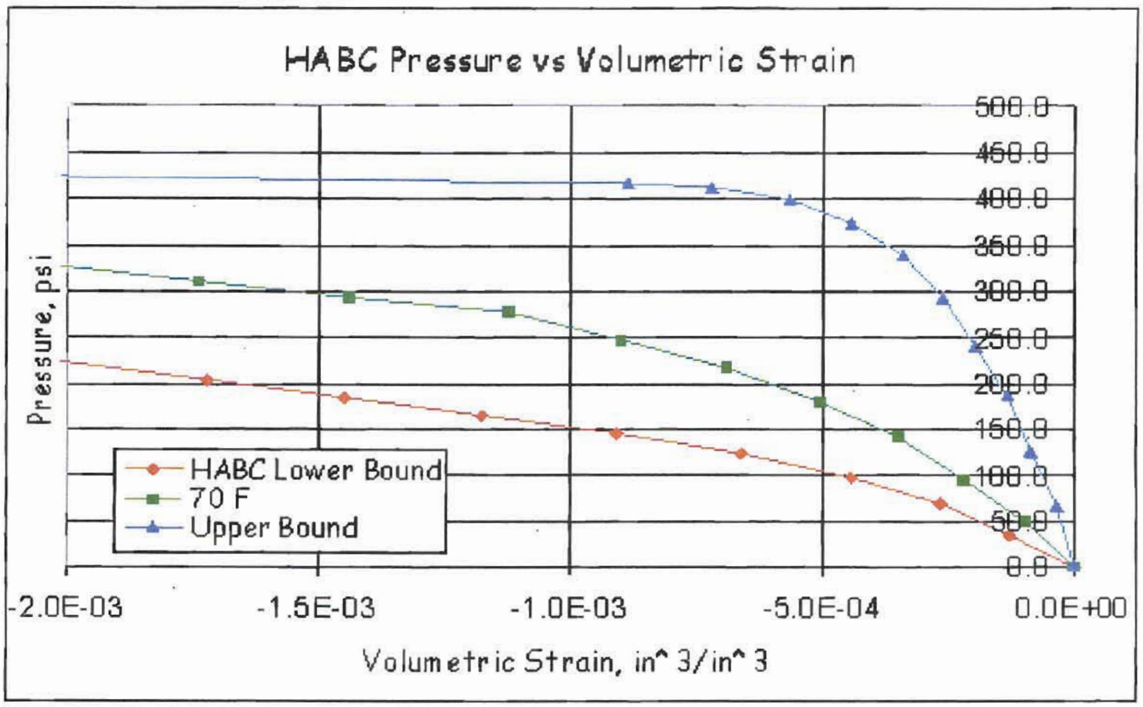

Figure 2.2.3.1 - Volumetric Strain vs Pressure Curves for the HABC Material

3.0 Analysis Results

The figures presented in Section 3 may show the punch, however, no punch impacts were made on the HABC model as discussed in Section 2.1.

3.1 HABC-run1hl - Lower Bounding Side

HABC-run1hl are the runs with the lower bounding material properties for the kaolite and the HABC materials. The 4-foot impact occurs from time = 0.0 to 0.01 seconds; the 30-foot impact occurs from 0.01 to 0.02 seconds; and the crush impact occurs from 0.02 to 0.04 seconds.

The initial configuration for HABC-run1hl is shown in Figure 3.1.1. The configuration after the 4-foot impact is shown in Figure 3.1.2. Enlargement of the lid and bottom regions after the 4-foot impact is shown in Figure 3.1.3.

The effective plastic strain in the CV body after the 4-foot impact is shown in Figure 3.1.4. The maximum is 0.0185 in/in and occurs near the bottom head of the CV body. The plastic strain in other components for the 4-foot impact are given in Table 3.1.1.

Table 3.1.1 - HABC-run1hl, 4-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0001
CV Nut Ring	0.0000
Angle	0.0055
Drum	0.1599
Drum Bottom Head	0.1033
Liner	0.1045
Lid	0.1393
Lid Stiffener	0.0004
Lid Studs	0.0000
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0194
Plug Liner	0.0022

Figure 3.1.5 shows the final configuration for the HABC-run1hl 30-foot impact. Figure

3.1.6 shows the lid and bottom regions after the 30-foot impact.

The maximum effective plastic strain due to the 30-foot impact in the CV body is 0.0195 in/in as shown in Figure 3.1.7. The maximum effective plastic strain in the drum lid is shown to be 0.5790 in/in in Figure 3.1.8. The maximum lid strain is a surface strain at the stud hole nearest the rigid surface. The membrane effective plastic strain component is 0.4416 in/in in the localized region near the stud hole. Effective plastic strain levels in other components for the 30-foot impact are given in Table 3.1.2.

Table 3.1.2 - HABC-run1hl, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0002
CV Nut Ring	0.0000
Angle	0.0780
Drum	0.2251
Drum Bottom Head	0.2126
Liner	0.1078
Lid Stiffener	0.0093
Lid Studs	0.1140
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0194
Plug Liner	0.0958

The final configuration for the crush impact is shown in Figure 3.1.9. Figure 3.1.10 shows the configuration at the bottom and lid regions after the crush impact.

Figure 3.1.11 shows the effective plastic strains in the CV body. The maximum is shown to be 0.0206 in/in and occurs below the flange region due to the upper internal weight.

The maximum effective plastic strain in the drum for the crush impact is 0.5139 in/in (surface strain) as shown in Figure 3.1.12. The maximum in the drum occurs near the angle on the crush plate side of the drum. The maximum membrane effective plastic strain at this location is 0.3551 in/in.

Figure 3.1.13 shows that the maximum effective plastic strain in the lid is 1.2580 in/in (surface strain) and occurs just below the upper stud hole (hole nearest the crush plate, 180°). The maximum membrane effective plastic strain in this region of the lid is 0.7746 in/in. A time line investigation during the crush impact shows that the lid exceeds 0.57 in/in strain in bending at about 0.0248 seconds at the 180° stud hole. The crush impact started at about 0.0200 seconds, so the lid reaches failure level near the start of the crush impact. The membrane levels in the lid reach 0.57 in/in at about 0.0264 seconds. The elevated effective plastic strain levels in the lid are localized in the region just inboard of the upper stud.

Figure 3.1.14 shows that the effective plastic strain in the drum studs is 0.5121 in/in and occurs in the upper stud at the bearing of the lid onto the stud. The elevated strains in the stud are localized on the inner surface (bearing of the lid on the stud). Effective plastic strain levels throughout the thickness of the stud are generally 0.25 in/in or less. At time 0.0264 sec, the lid has reached 0.57 in/in strain in membrane, and the maximum strain in the drum studs is about 0.2870 in/in.

Considering the strain levels in the lid and the studs, some tearing at the 180° stud hole would be expected. But the tearing would be localized to the stud hole due to the extent of the strain patterns. Failure of the stud to restrain the lid due to this tearing is not expected. The lid stiffener would limit any tearing from the stud at 180° and the large washer would be expected to restrain the lid. The effective plastic strain in other components due to the crush impact are listed in Table 3.1.3.

Table 3.1.3 - HABC-run1hl, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0002
CV Nut Ring	0.0000
Angle	0.1142
Drum Bottom Head	0.3562
Liner	0.1593
Lid Stiffener	0.0515
Lid Stud Nuts	0.0005
Lid Stud Washers	0.0693
Plug Liner	0.1220

The lid separation time history is shown in Figure 3.1.15. The nodes used in Figure 3.1.15 are shown in Figure 3.1.16. From the time history plot it can be seen that a lid separation of 0.005 in or less would be expected.

Figure 3.1.17 shows kaolite nodes used to find the kaolite thickness time history. Figure 3.1.18 shows the remaining thickness time histories for the nodal pairs shown.

Figure 3.1.19 and 3.1.20 show the diameter and radial time histories for the drum. The nodes are defined in Figure 3.1.21.

Figure 3.1.22 shows the diameter time history for nodal pairs along the length of the liner. Figure 3.1.23 shows the nodes and Table 3.1.3 gives the location of the nodes.

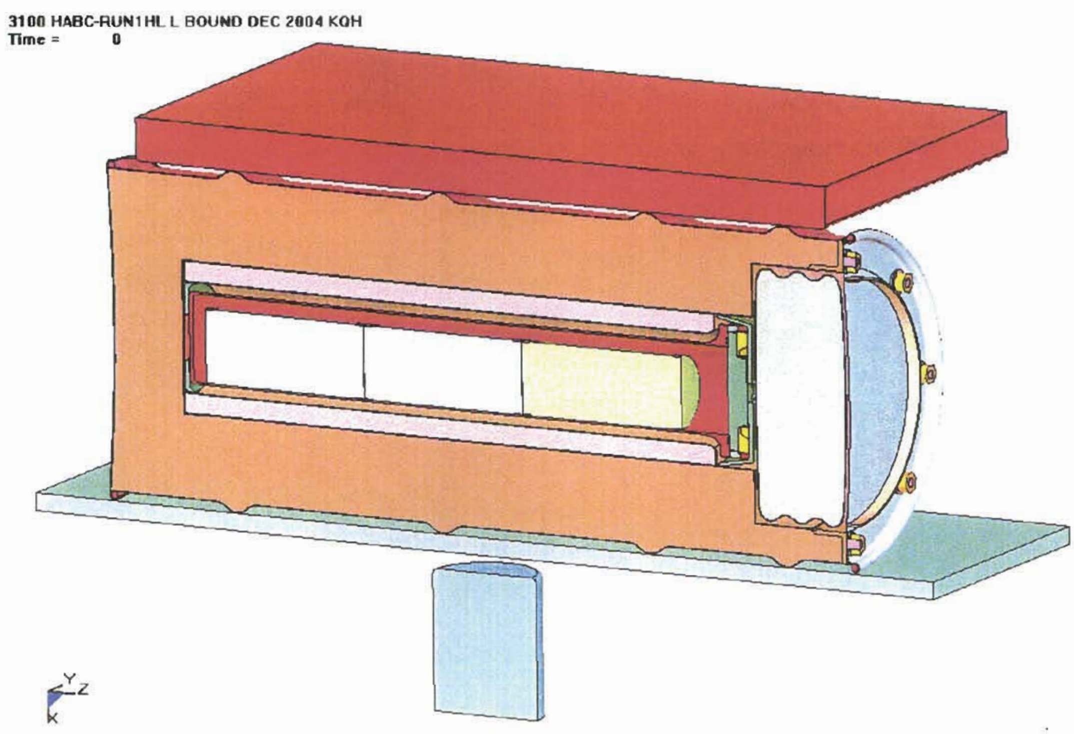

Figure 3.1.1 - HABC-run1hl, Initial Configuration

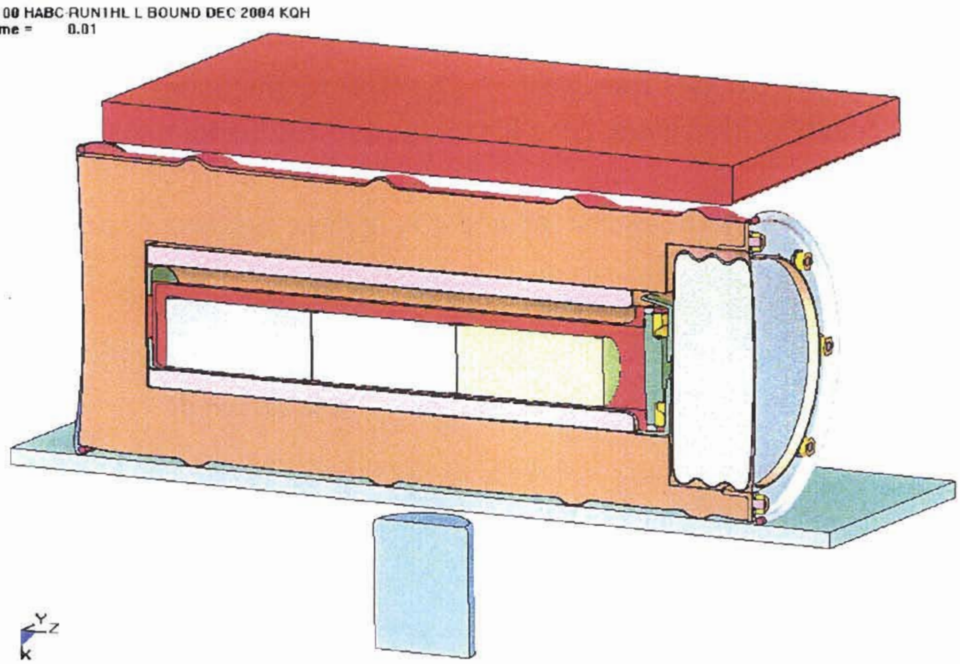

Figure 3.1.2 - HABC-run1hl, Configuration After the 4-Foot Impact

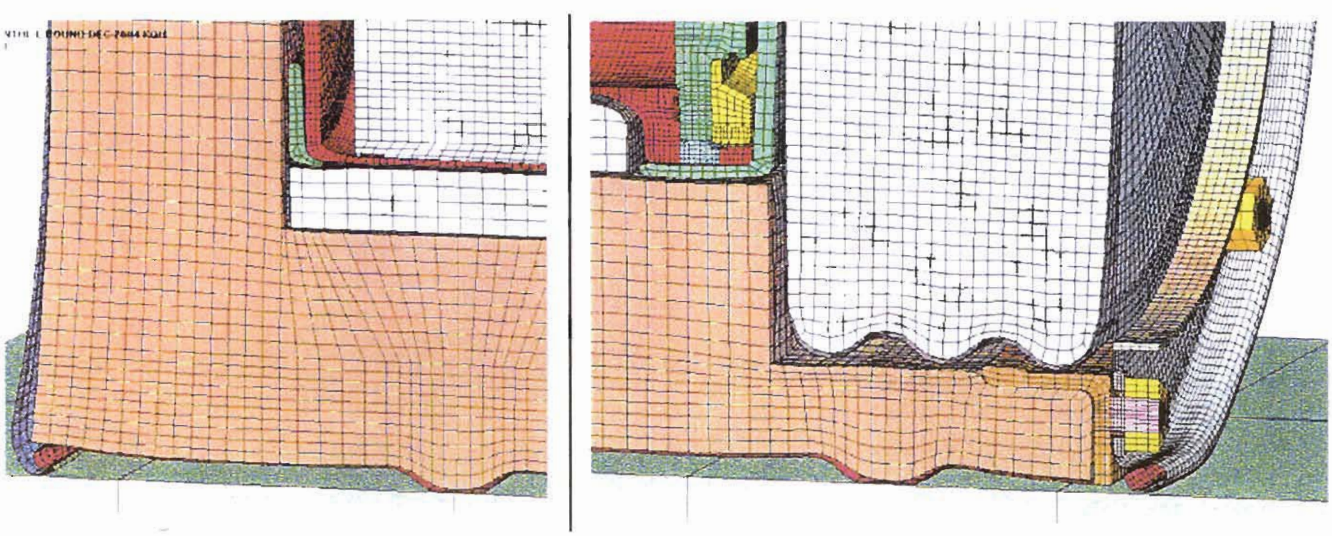

Figure 3.1.3 - HABC-run1hl, 4-Foot Impact, Configuration in the Lid and Bottom

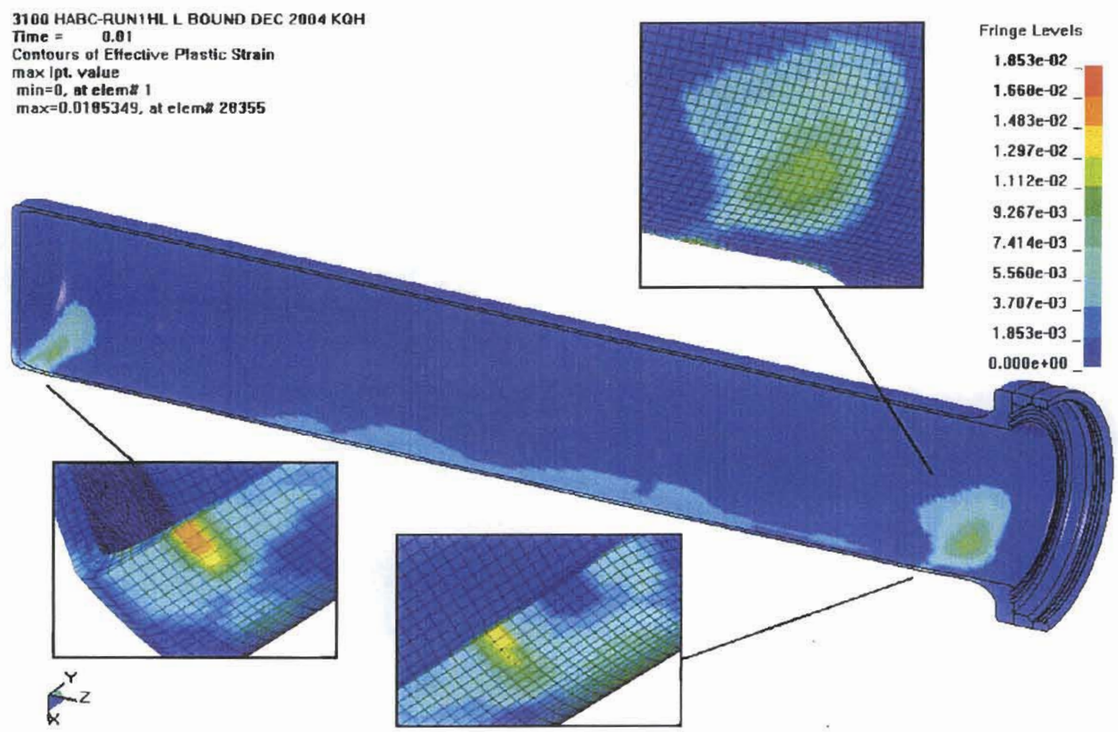

Figure 3.1.4 - HABC-run1hl, 4-Foot Impact, Effective Plastic Strain in the CV Body

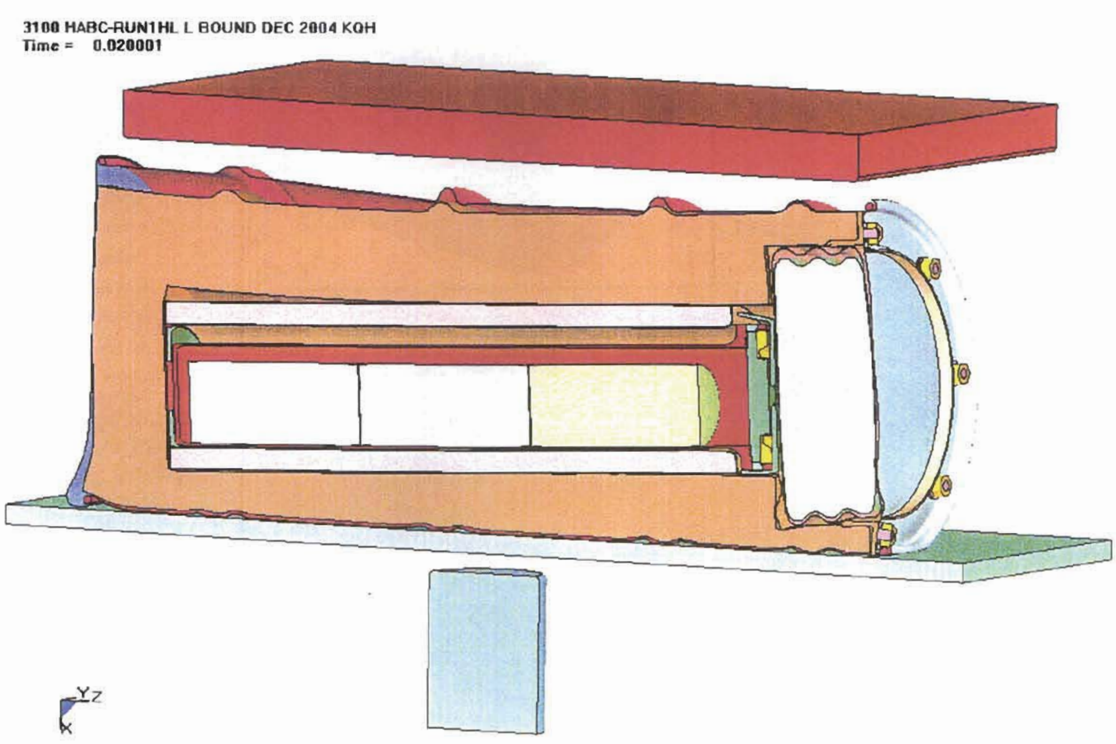

Figure 3.1.5 - HABC-run1hl, 30-Foot Impact, Final Configuration

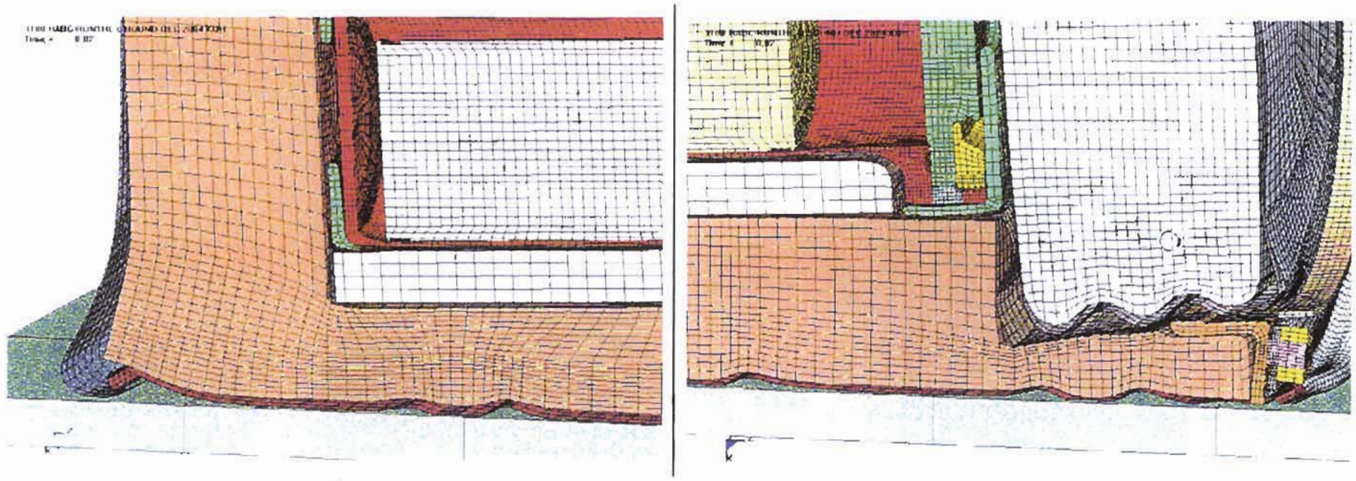

Figure 3.1.6 - HABC-run1hl, 30-Foot Impact, Configuration of the Lid and Bottom

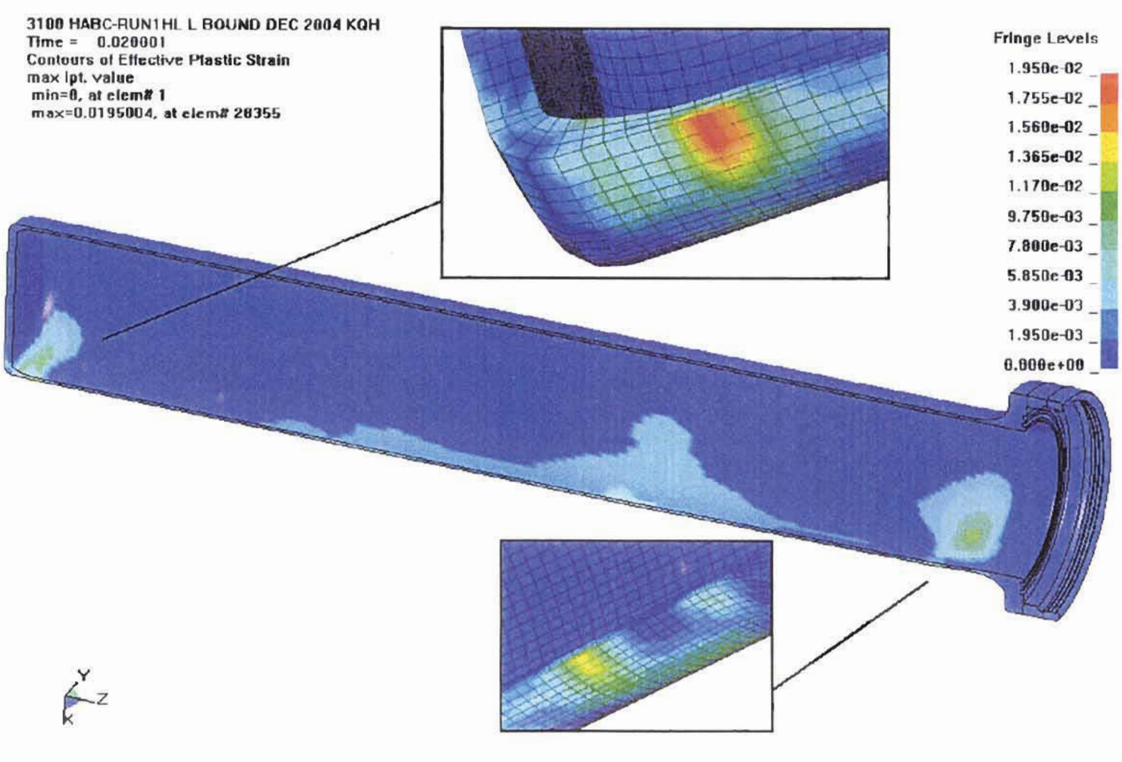

Figure 3.1.7 - HABC-run1hl, 30-Foot Impact, Effective Plastic Strain in the CV Body

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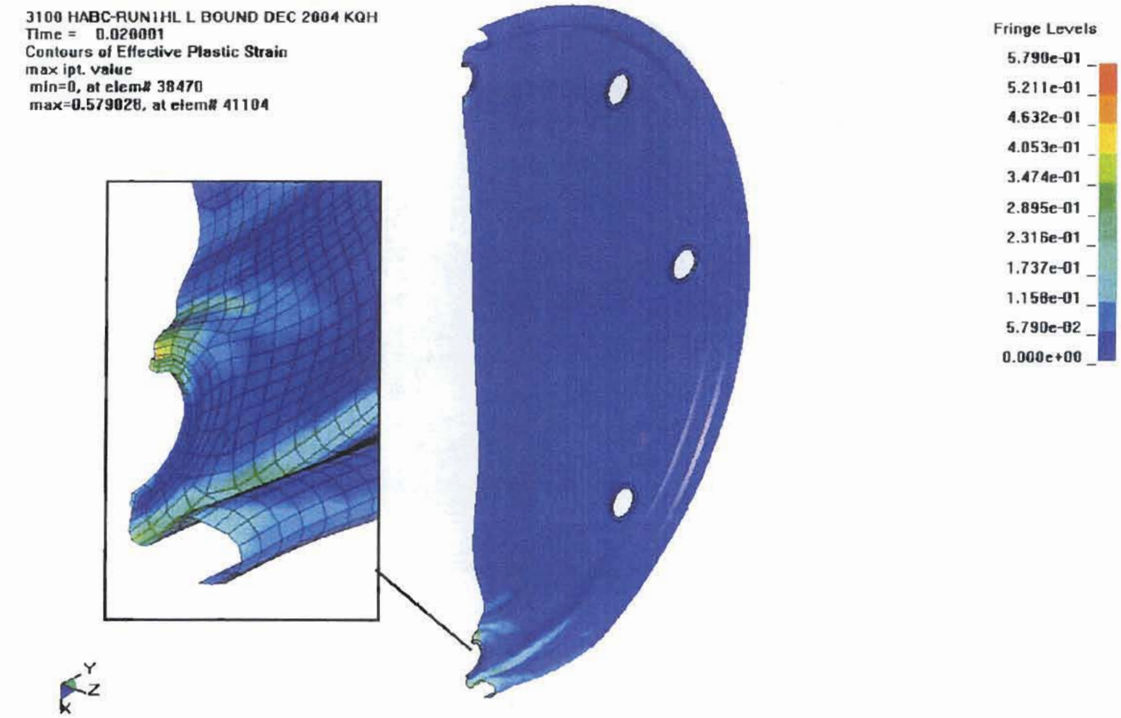

Figure 3.1.8 - HABC-run1hl, 30-Foot Impact, Effective Plastic Strain in the Lid

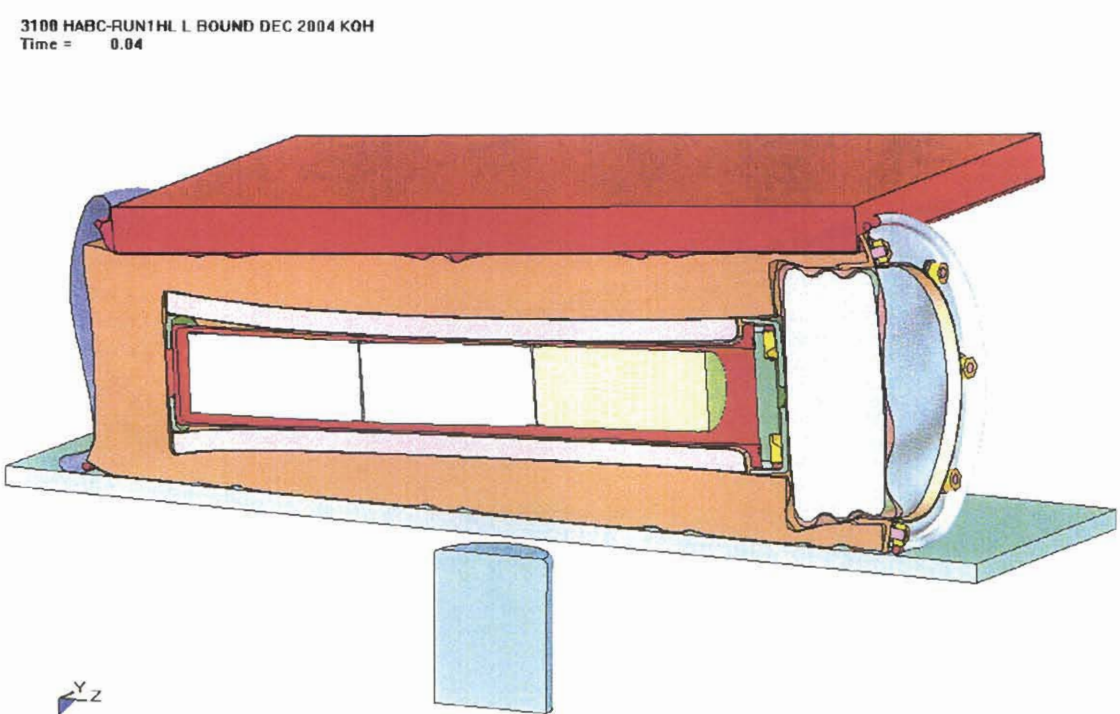

Figure 3.1.9 - HABC-run1hl, Crush Impact, Final Configuration

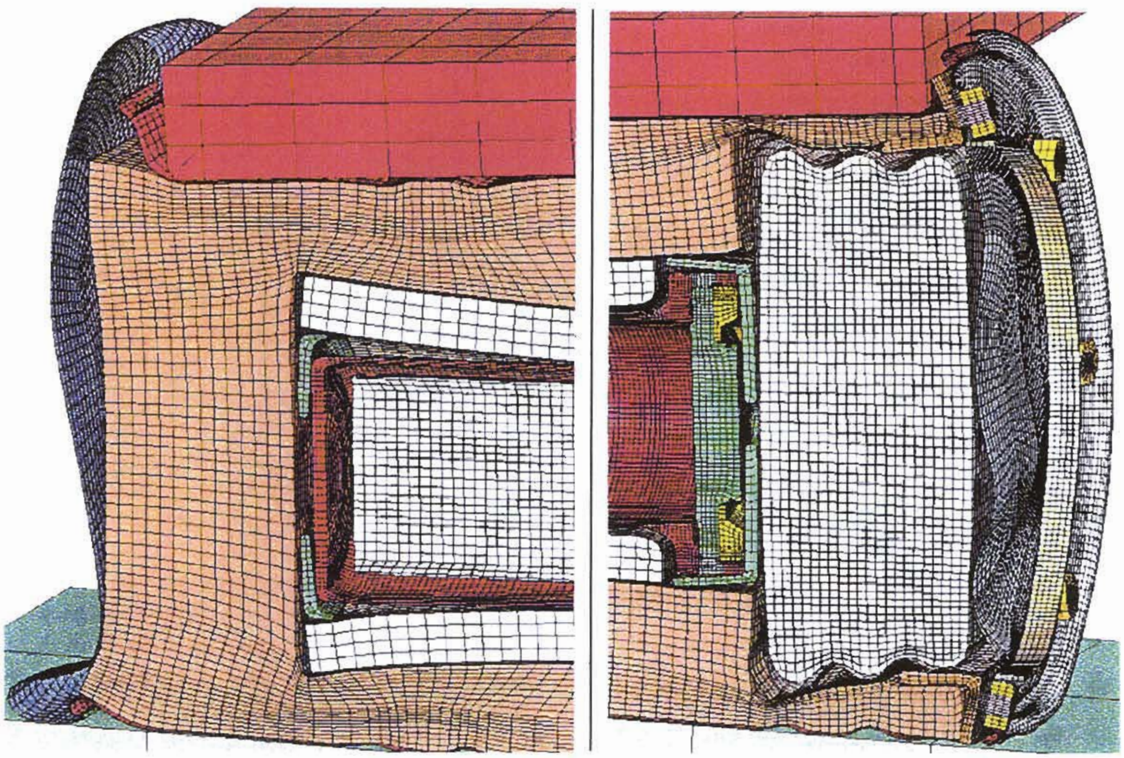

Figure 3.1.10 - HABC-run1hl, Crush Impact, Configuration of the Lid and Bottom

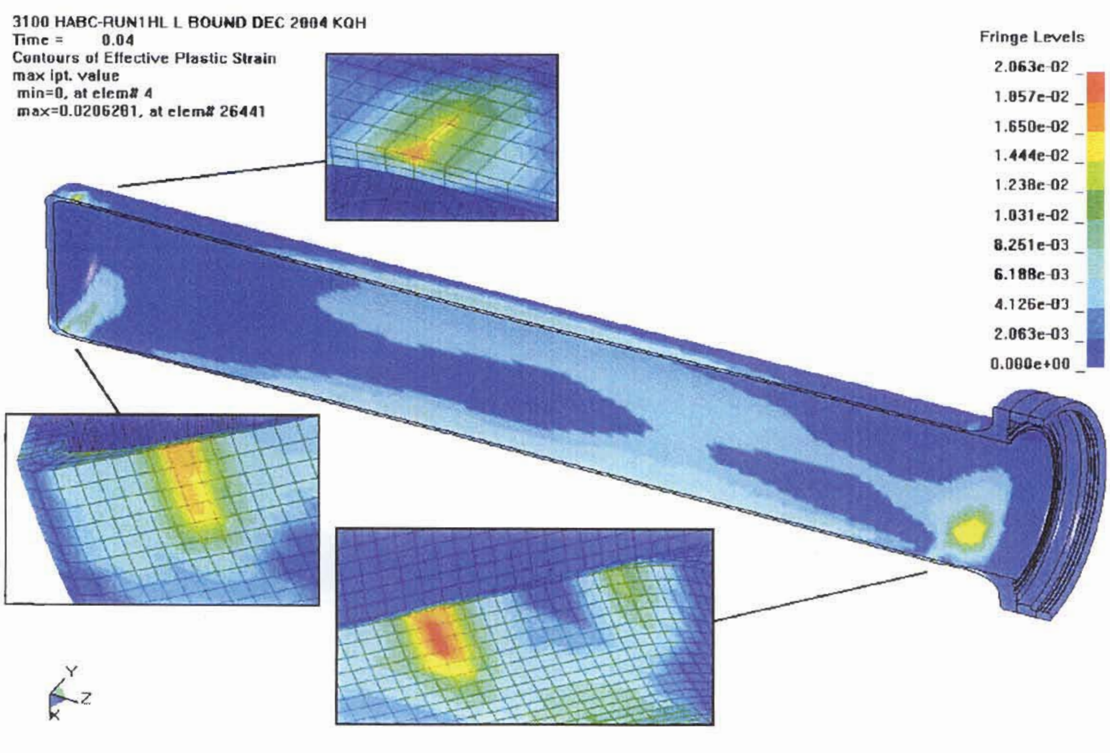

Figure 3.1.11 - HABC-run1hl, Crush Impact, Effective Plastic Strain in the CV Body

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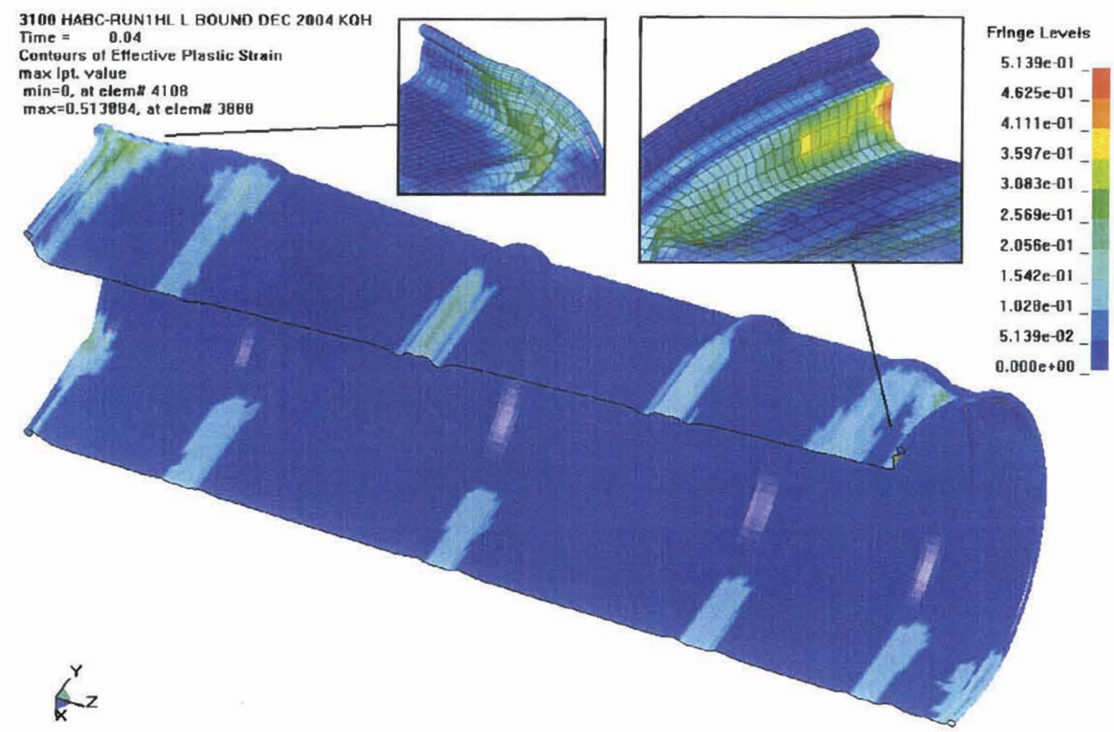

Figure 3.1.12 - HABC-run1hl, Crush Impact, Effective Plastic Strain in the Drum

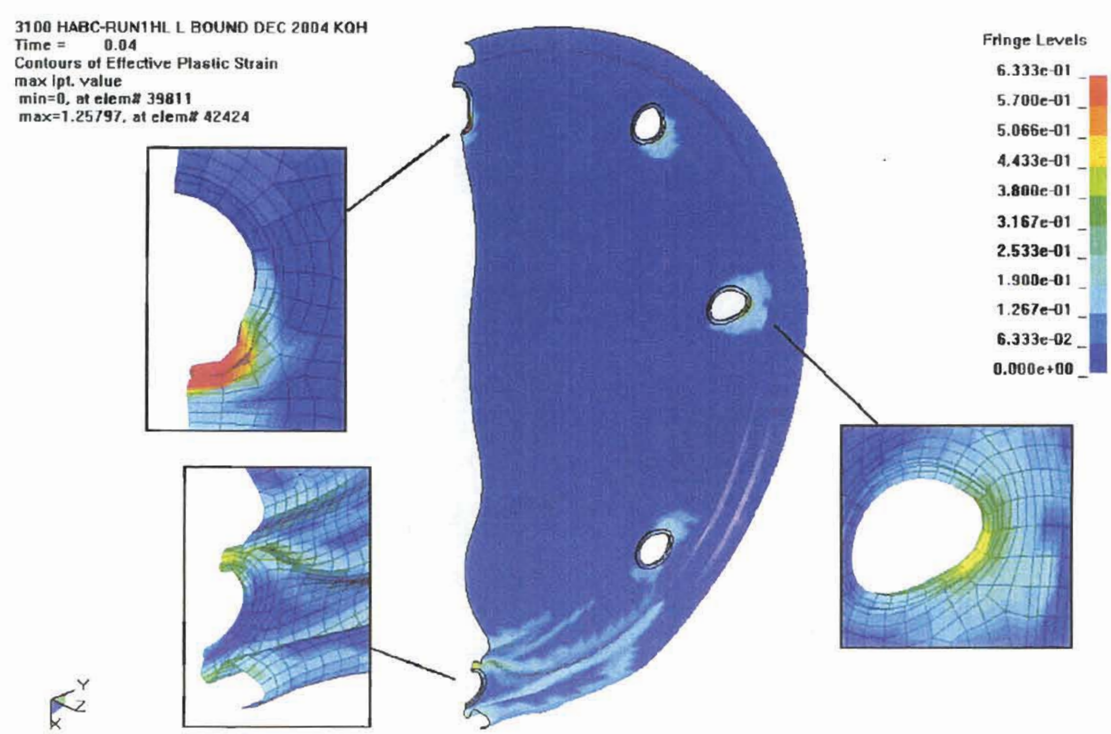

Figure 3.1.13 - HABC-run1hl, Crush Impact, Effective Plastic Strain in the Lid

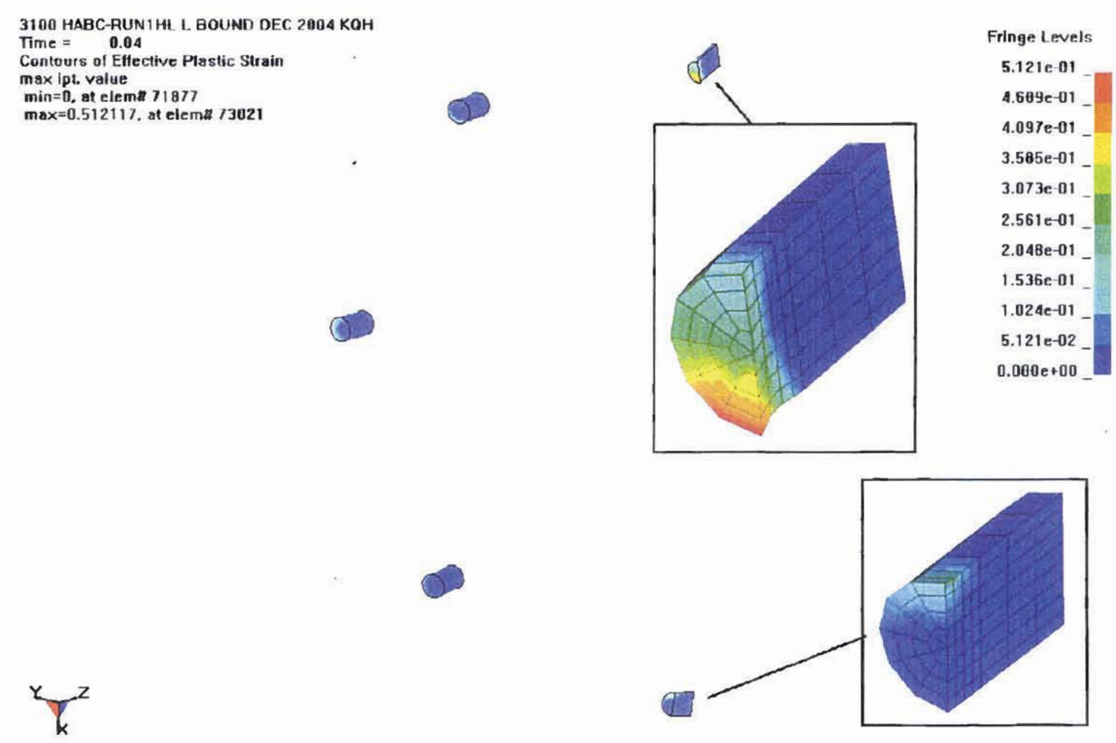

Figure 3.1.14 - HABC-run1hl, Crush Impact, Effective Plastic Strain in the Studs

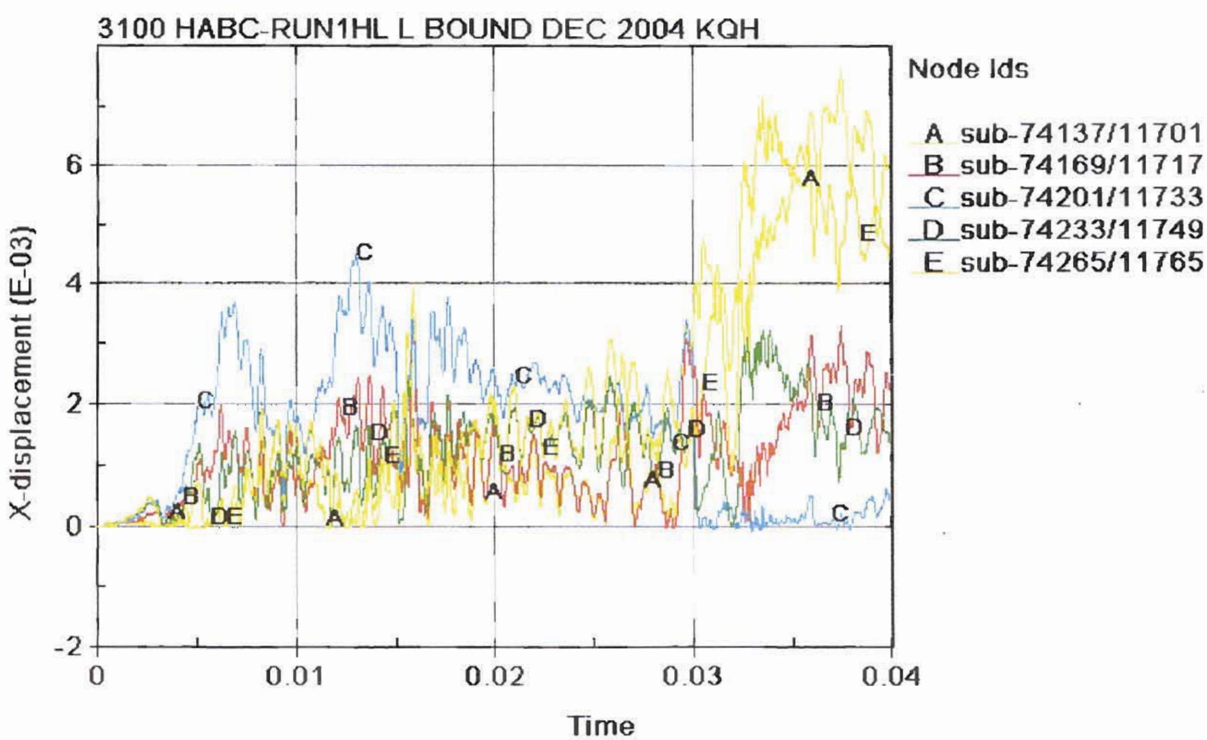

Figure 3.1.15 - HABC-run1hl, CV Lid Separation Time History

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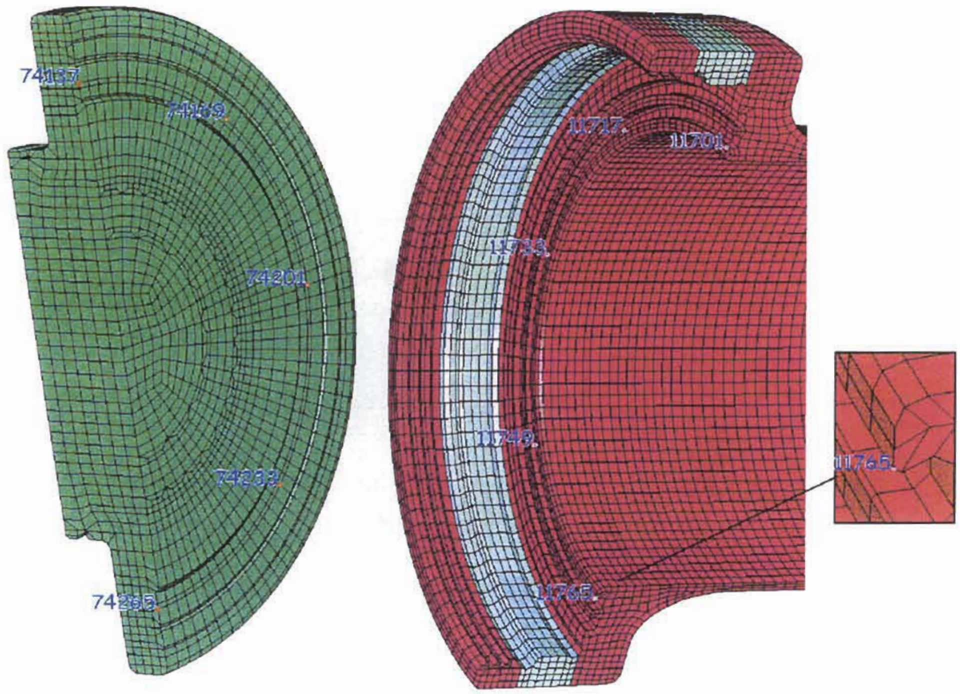

Figure 3.1.16 - HABC - run1hl, CV Separation Nodes

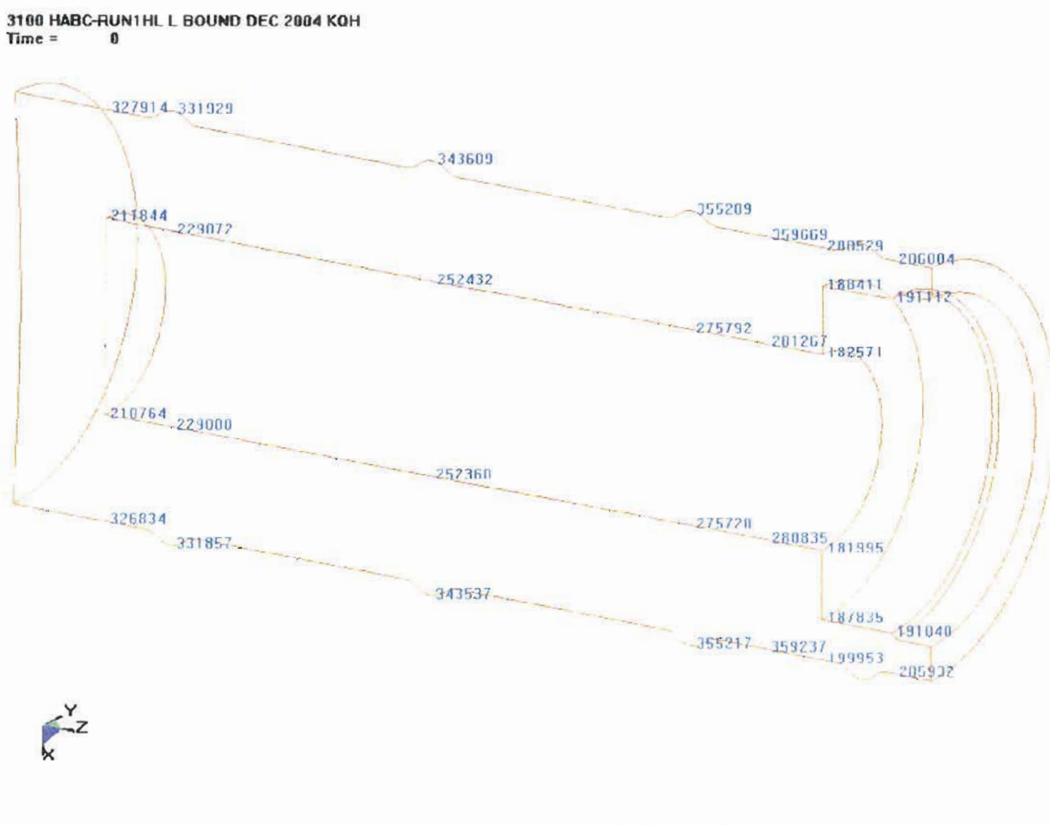

Figure 3.1.17 - HABC-run1hl, Kaolite Nodes

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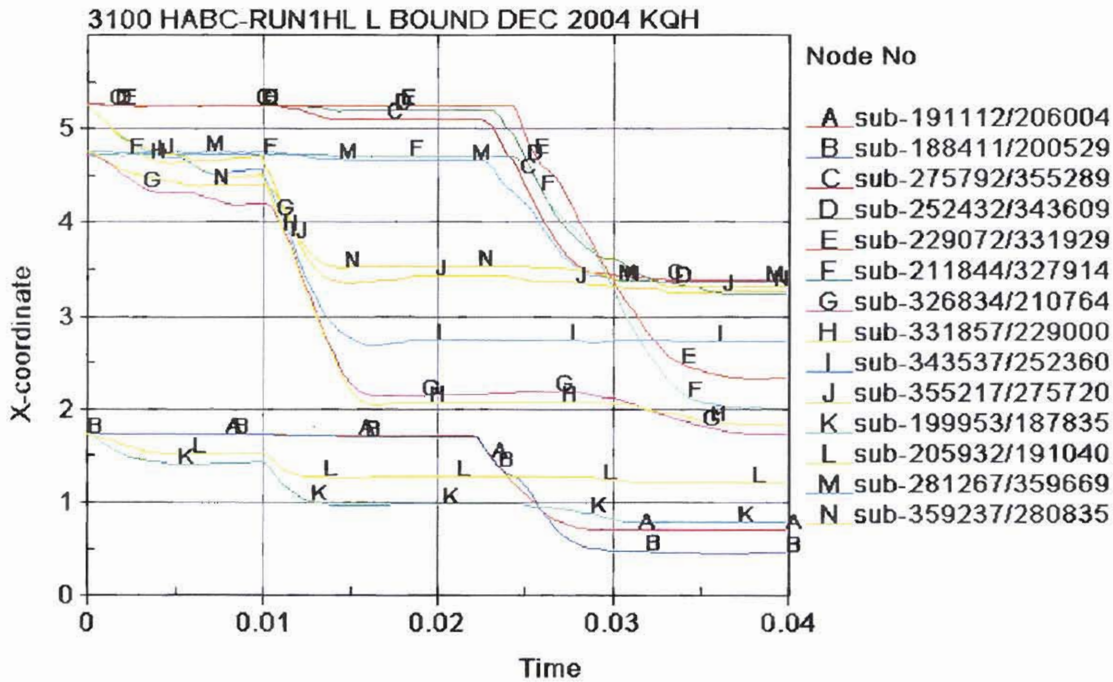

Figure 3.1.18 - HABC-run1hl, Kaolite Thickness Time History

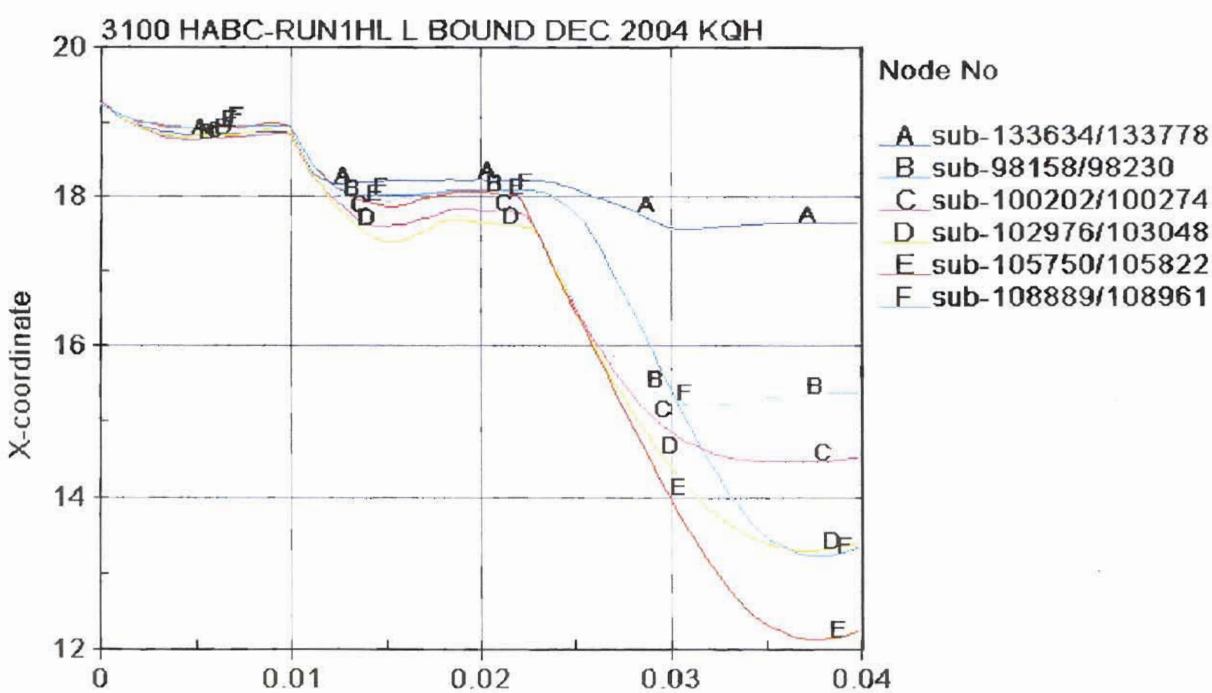

Figure 3.1.19 - HABC-run1hl, Drum Diameter Time History in the X Direction

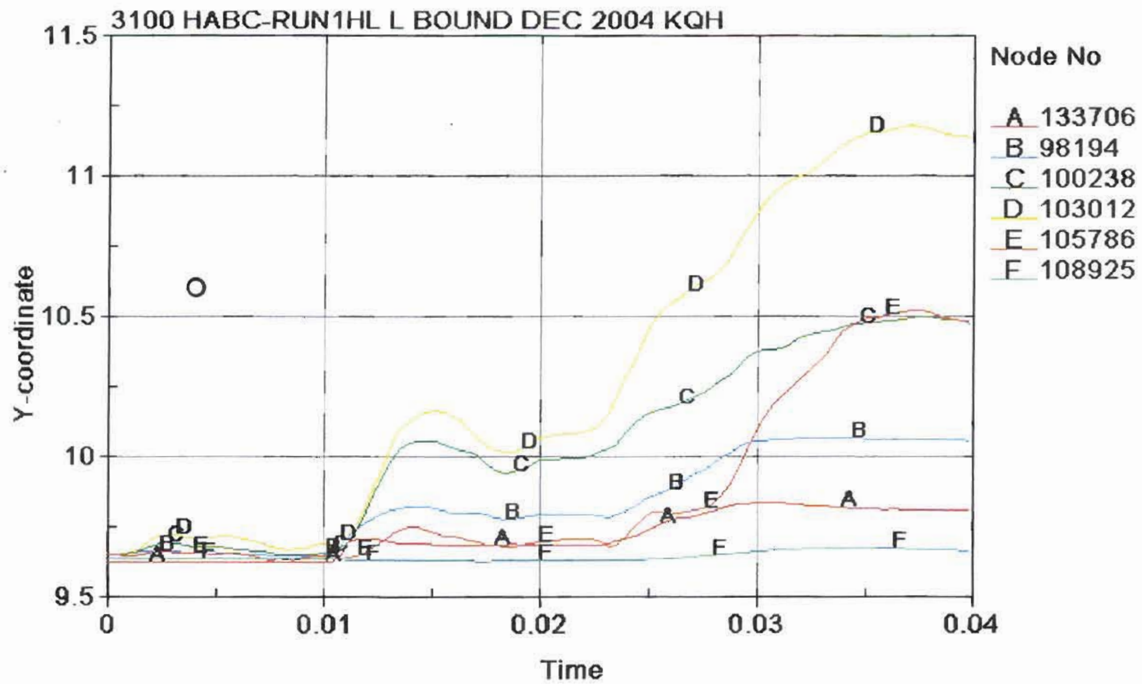

Figure 3.1.20 - HABC-run1hl, Drum Diameter Time History in the Y Direction

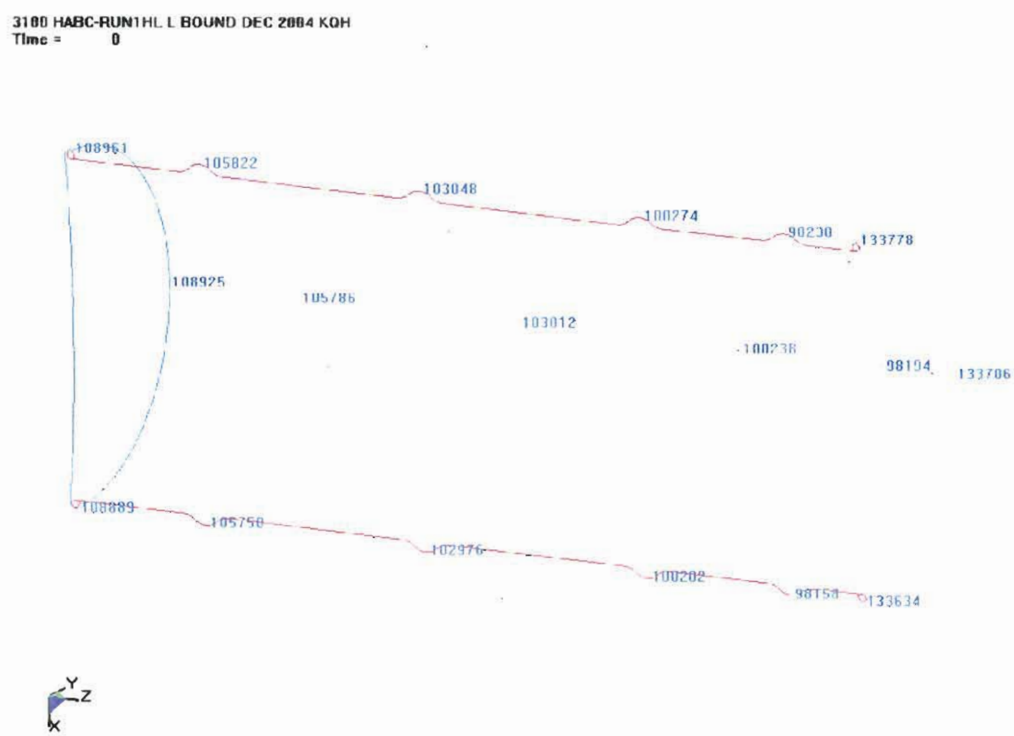

Figure 3.1.21 - HABC-run1hl, Drum Nodes Used to Measure Deformation Time Histories

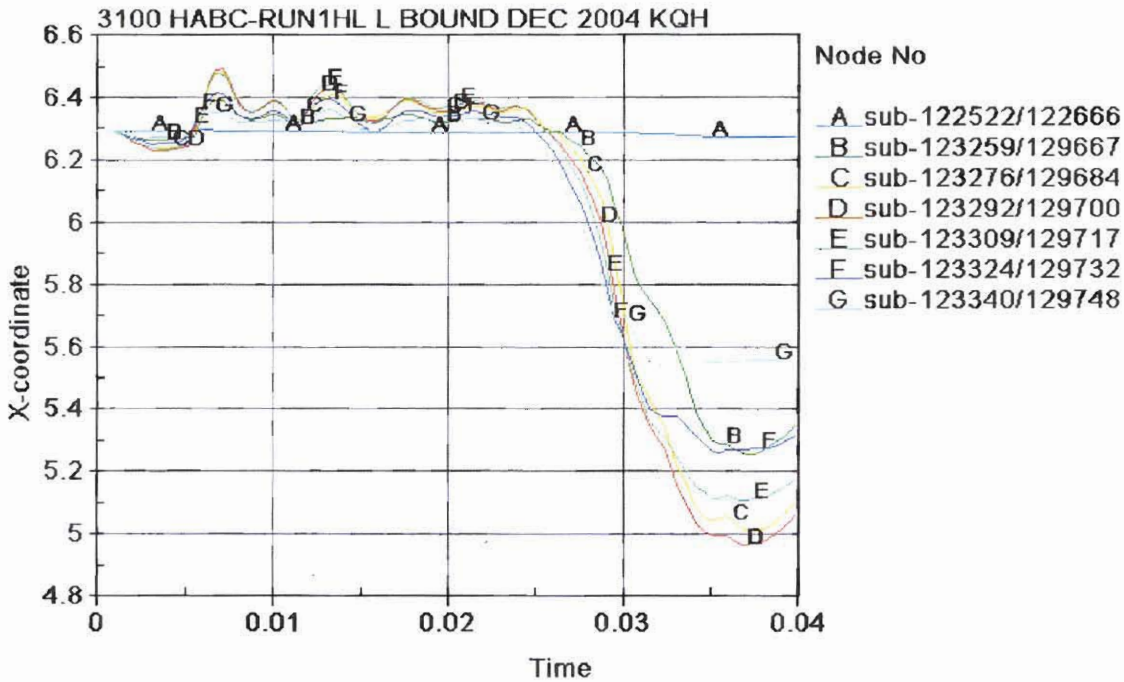

Figure 3.1.20 - HABC-run1hl, Diameter Changes in the Inner Liner

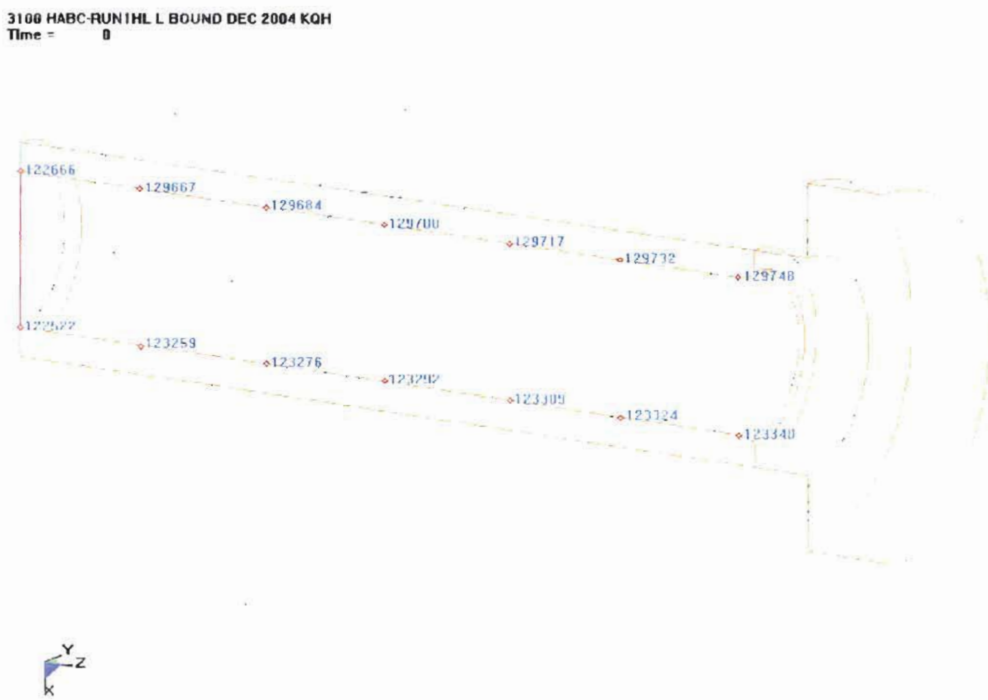

Figure 3.1.21 - HABC-run1hl, Liner Nodes Used to Obtain Diameter Time Histories

3.2 HABC-run1hh - Upper Bounding Side

HABC-run1hh are the runs with the lower bounding material properties for the kaolite and the HABC materials. The 4-foot impact occurs from time = 0.0 to 0.01 seconds; the 30-foot impact occurs from 0.01 to 0.0188 seconds; and the crush impact occurs from 0.0188 to 0.04 seconds.

The final configuration for the 4-foot impact is shown in Figure 3.2.1. The configuration at the ends of the package are shown in Figure 3.2.2. The effective plastic strain in the CV body for the 4-foot impact is shown in Figure 3.2.3 to be a maximum of 0.0238 in/in. The effective plastic strains in other package components for the 4-foot impact are listed in Table 3.2.1.

Table 3.2.1 - Run1hh, 4-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0000
CV Nut Ring	0.0000
Angle	0.0061
Drum	0.1207
Drum Bottom Head	0.1252
Liner	0.0991
Lid	0.1604
Lid Stiffener	0.0006
Lid Studs	0.0000
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0411
Plug Liner	0.0045

The final configuration for the 30-foot impact is shown in Figure 3.2.4. The configuration at the ends of the package are shown in Figure 3.2.5. The maximum effective plastic strain for the 30-foot impact in the CV Body is 0.0347 in/in near the bottom head (Figure

3.2.6). The maximum effective plastic strain in the drum lid is 0.4063 in/in at the stud near the rigid plane as shown in Figure 3.2.7. The effective plastic strain in other components for the 30-foot impact are given in Table 3.2.2.

Table 3.2.2 - HABC-run1hh, 30-Foot Impact, Effective Plastic Strain Levels in Some Components	
Component	Effective Plastic Strain, in/in
CV Lid	0.0001
CV Nut Ring	0.0000
Angle	0.0632
Drum	0.2296
Drum Bottom Head	0.2517
Liner	0.1184
Lid Stiffener	0.0076
Lid Studs	0.1306
Lid Stud Nuts	0.0004
Lid Stud Washers	0.0424
Plug Liner	0.1072

The configuration after the crush impact is shown in Figure 3.2.8. The configuration at the ends of the package are shown in Figure 3.2.9. The maximum effective plastic strain for the crush impact in the CV body is 0.0525 in/in, on the crush plate side near the lid end of the top inner weight (Figure 3.2.10). The maximum effective plastic strain in the drum is 0.2814 in/in near the angle and the rigid plane (Figure 3.2.11). The maximum effective plastic strain in the drum lid is 0.6413 in/in (surface strain) a shown in Figure 3.2.12. The maximum occurs at the lid hole for the stud closest to the crush plate (180°). The membrane effective plastic strain is 0.4907 in/in at this location in the lid. Figure 3.2.13 shows that the maximum effective plastic strain in the studs is 0.2364 in/in. The effective plastic strain in other components are listed in Table 3.2.3 for the crush impact.

Table 3.2.3 - Run1hh, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0004
CV Nut Ring	0.0005
Angle	0.0845
Drum Bottom Head	0.2827
Liner	0.2022
Lid Stiffener	0.0171
Lid Stud Nuts	0.0018
Lid Stud Washers	0.0439
Plug Liner	0.1286

The lid separation time history is shown in Figure 3.2.14. The nodes are shown in Figure 3.1.16. The response is oscillatory with peak gap separation on the order of 0.010 in. At the end of the impact, the peaks are on the order of 0.006 in with an average gap on the order of 0.003 in or less.

The kaolite thickness time history is shown in Figure 3.2.15. The nodal pairs are shown in Figure 3.1.17.

Figure 3.2.16 and 3.2.17 show the drum diameter and radial time histories. The nodes are defined in Figure 3.1.21.

Figure 3.2.18 shows the diameter response of the liner. Figure 3.1.23 define the liner nodes used in Figure 3.2.18.

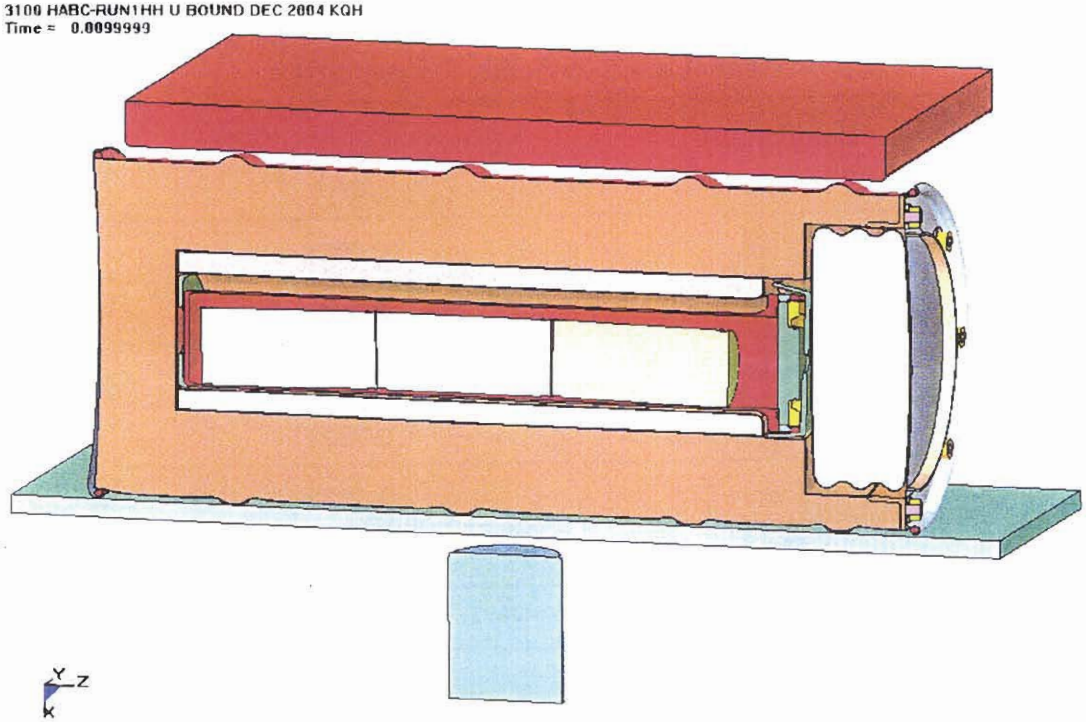

Figure 3.2.1 - HABC-run1hh, Configuration After the 4-Foot Impact

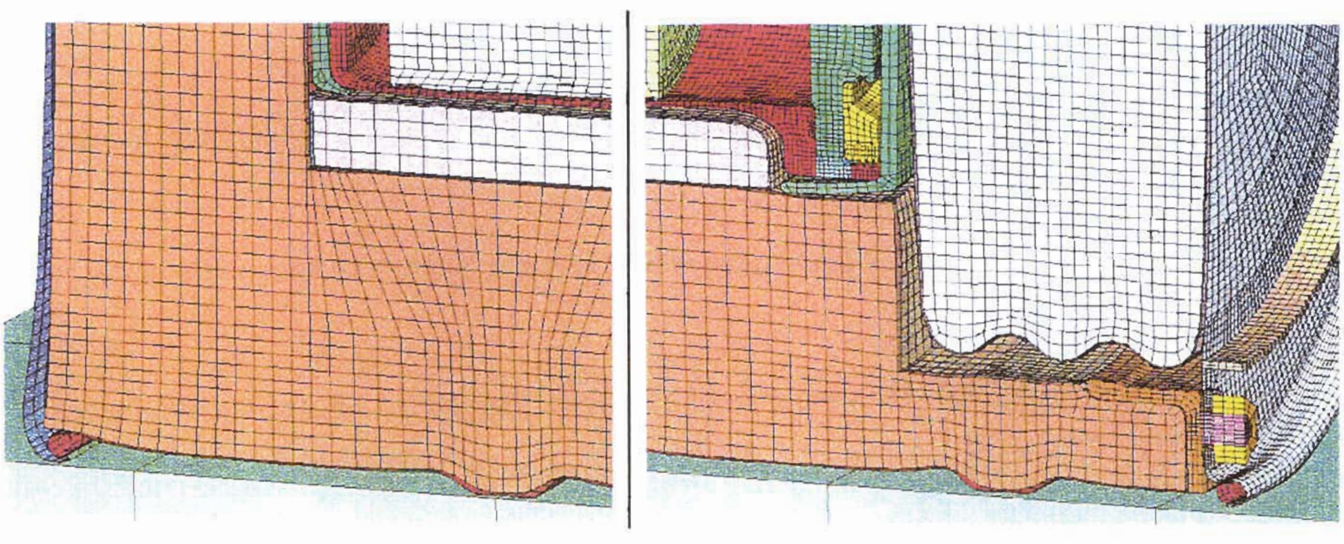

Figure 3.2.2 - HABC-run1hh, 4-Foot Impact, Configuration of the Lid and Bottom

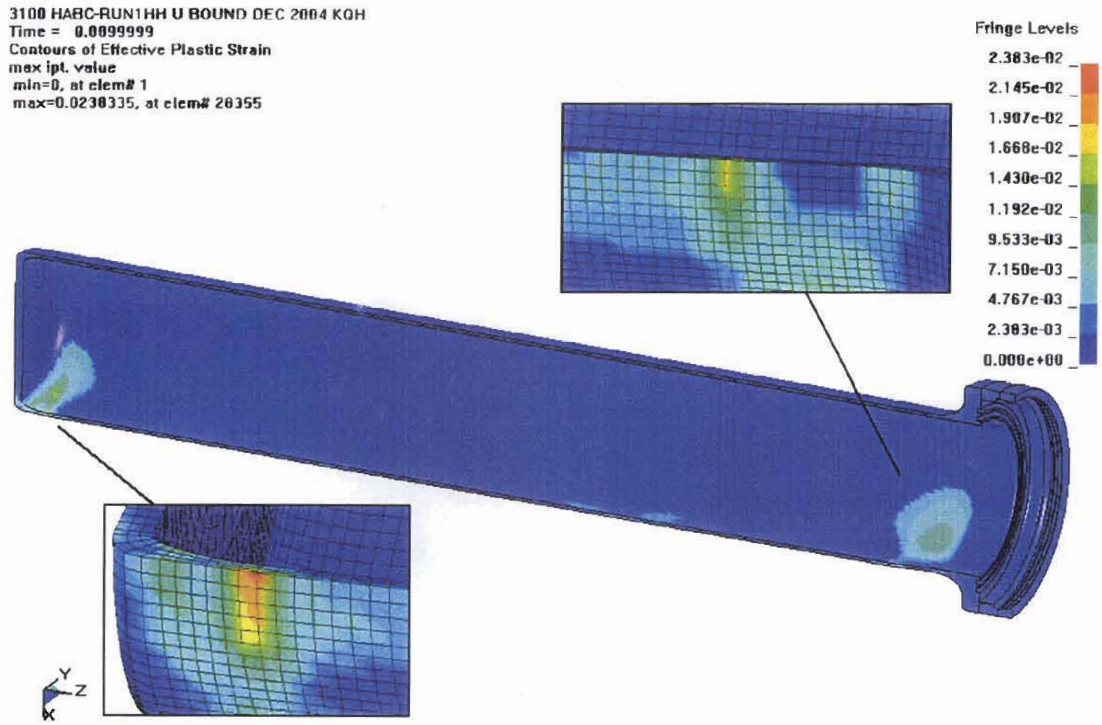

Figure 3.2.3 - HABC-run1hh, 4-Foot Impact, Effective Plastic Strain in the CV Body

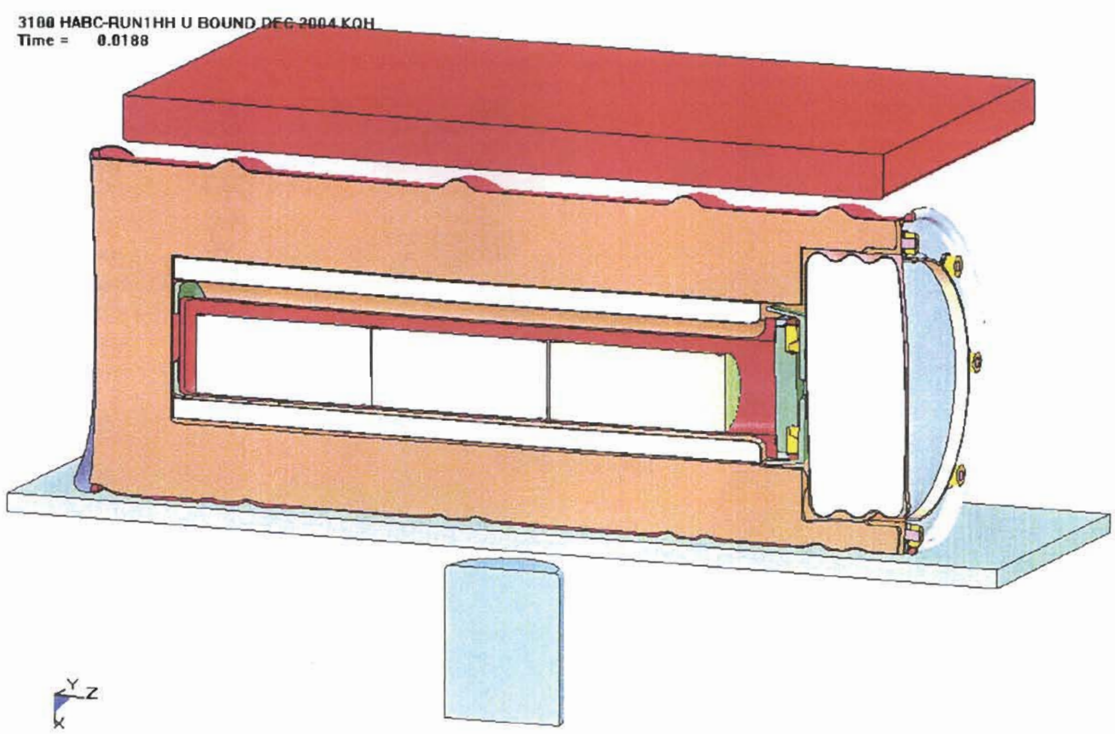

Figure 3.2.4 - HABC-run1hh, Configuration After the 30-Foot Impact

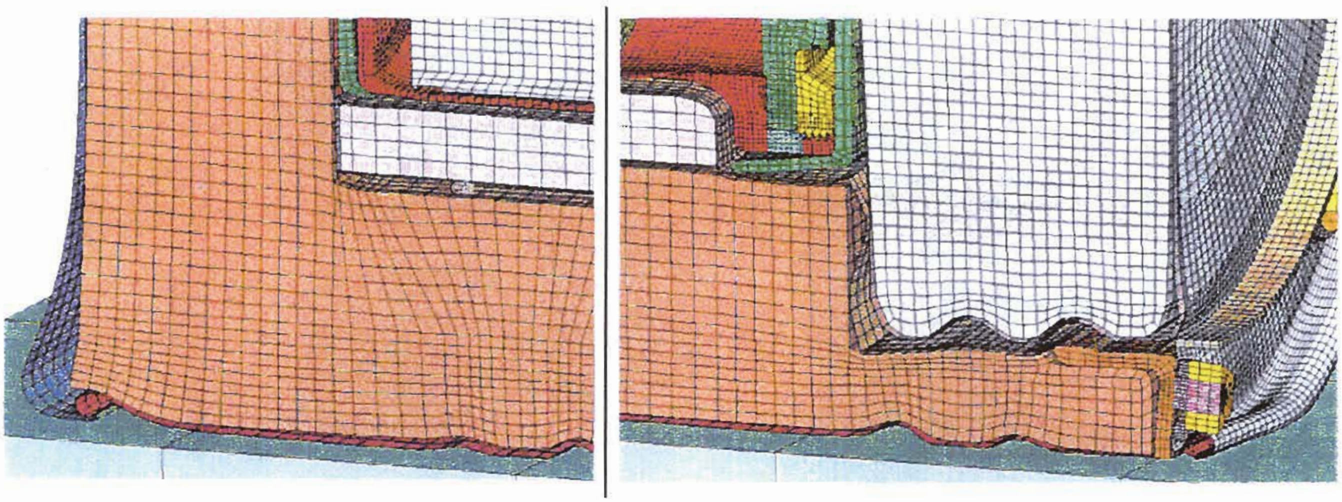

Figure 3.2.5 - HABC-run1hh, 30-Foot Impact, Configuration of the Lid and Bottom

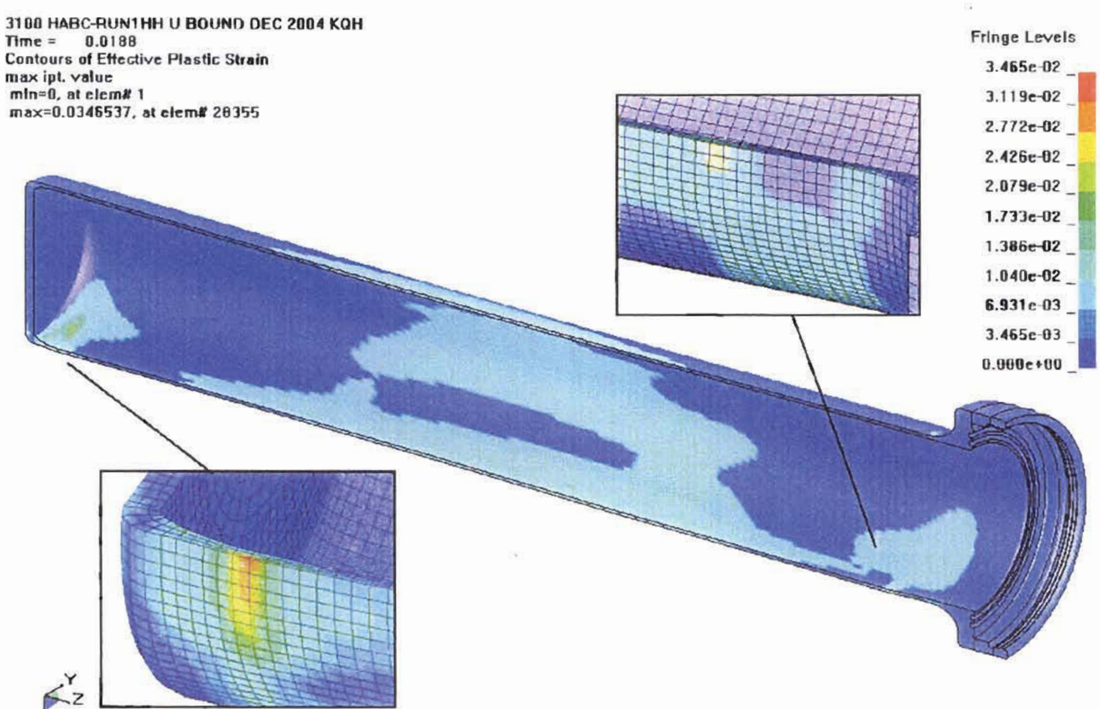

Figure 3.2.6 - HABC-run1hh,30-Foot Impact, Effective Plastic Strain in the CV Body

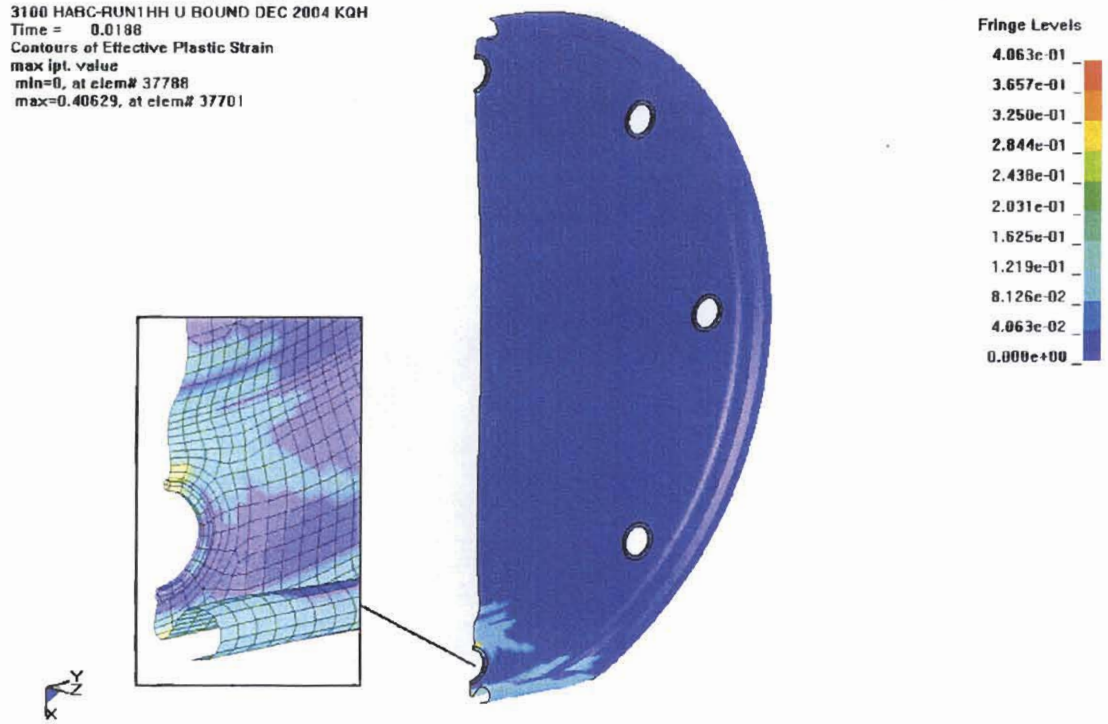

Figure 3.2.7 - HABC-run1hh, 30-Foot Impact, Effective Plastic Strain in the Lid

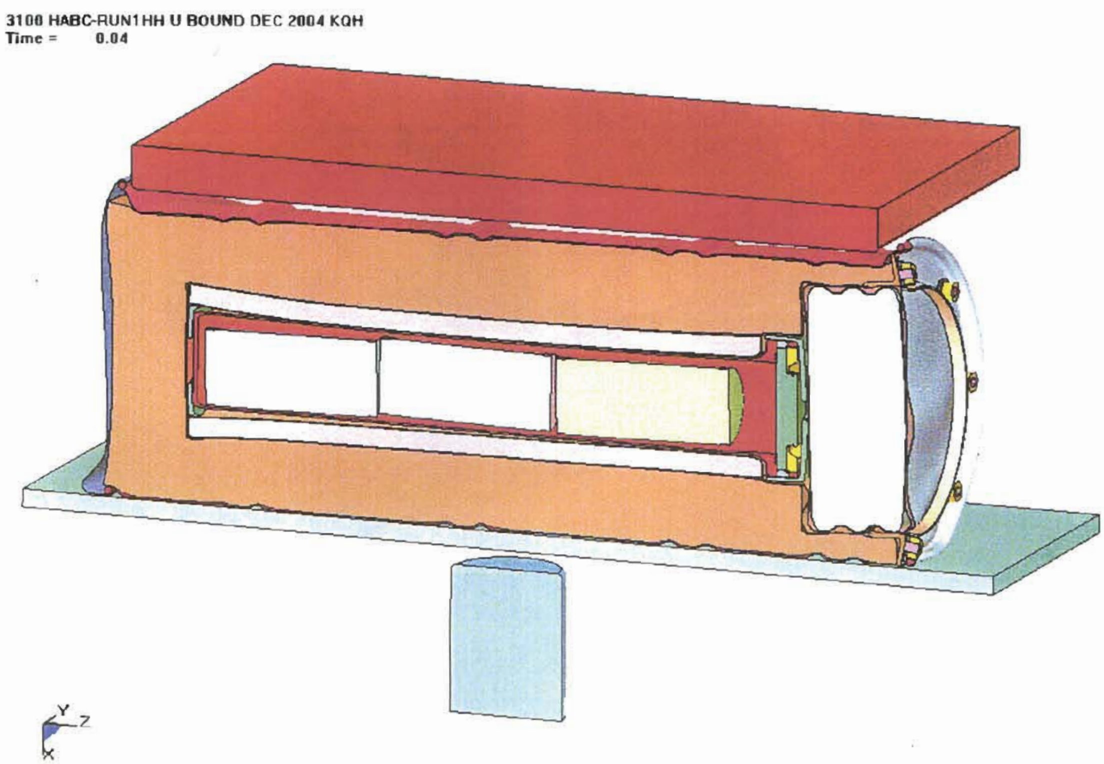

Figure 3.2.8 - HABC-run1hh, Configuration After the Crush Impact

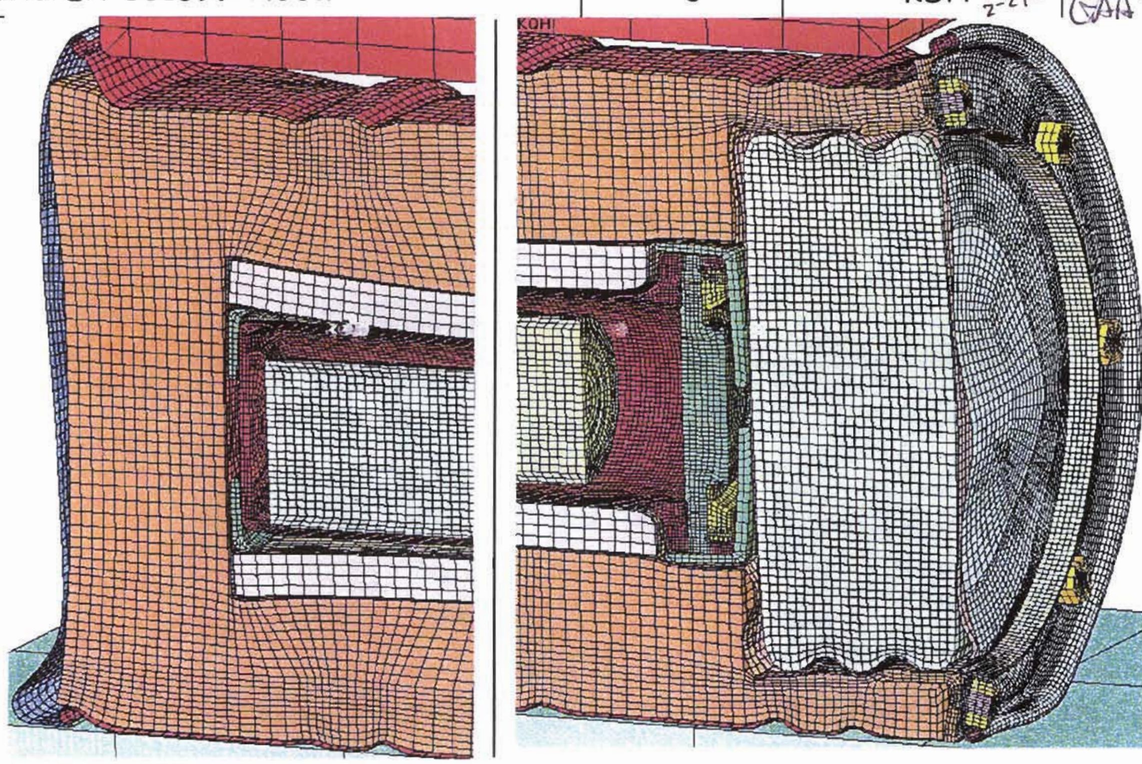

Figure 3.2.9 - HABC-run1hh, Crush Impact, Configuration of the Lid and Bottom

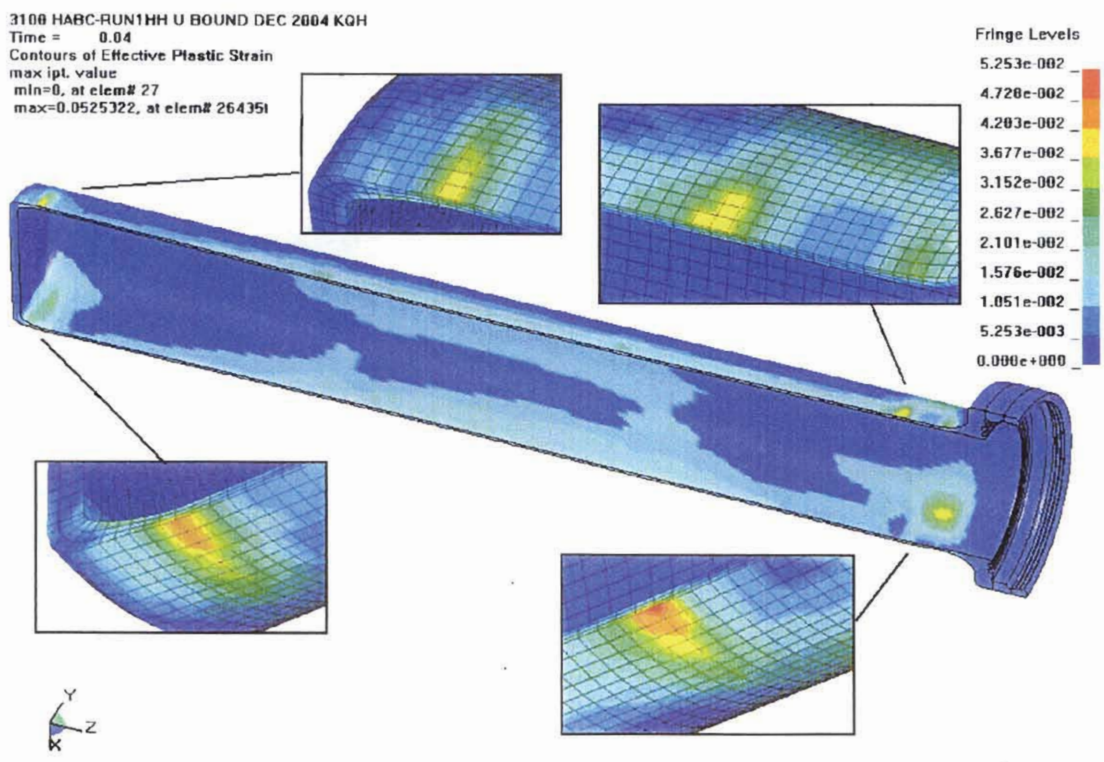

Figure 3.2.10 - HABC-run1hh, Crush Impact, Effective Plastic Strain in the CV Body

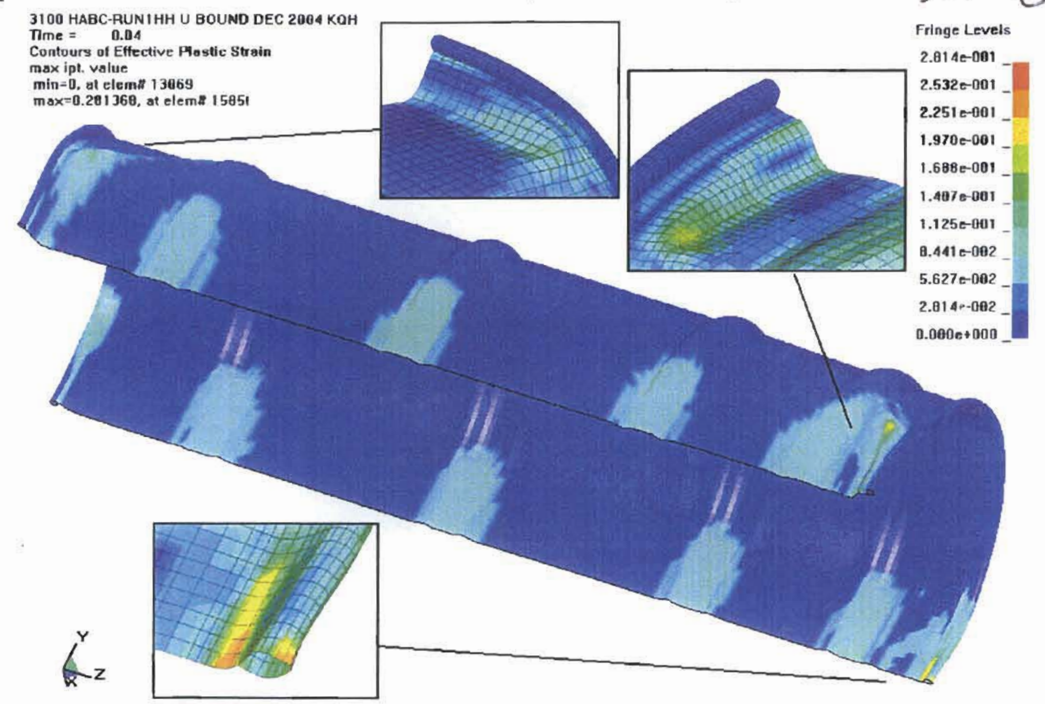

Figure 3.2.11 - HABC-run1hh, Crush Impact, Effective Plastic Strain in the Drum

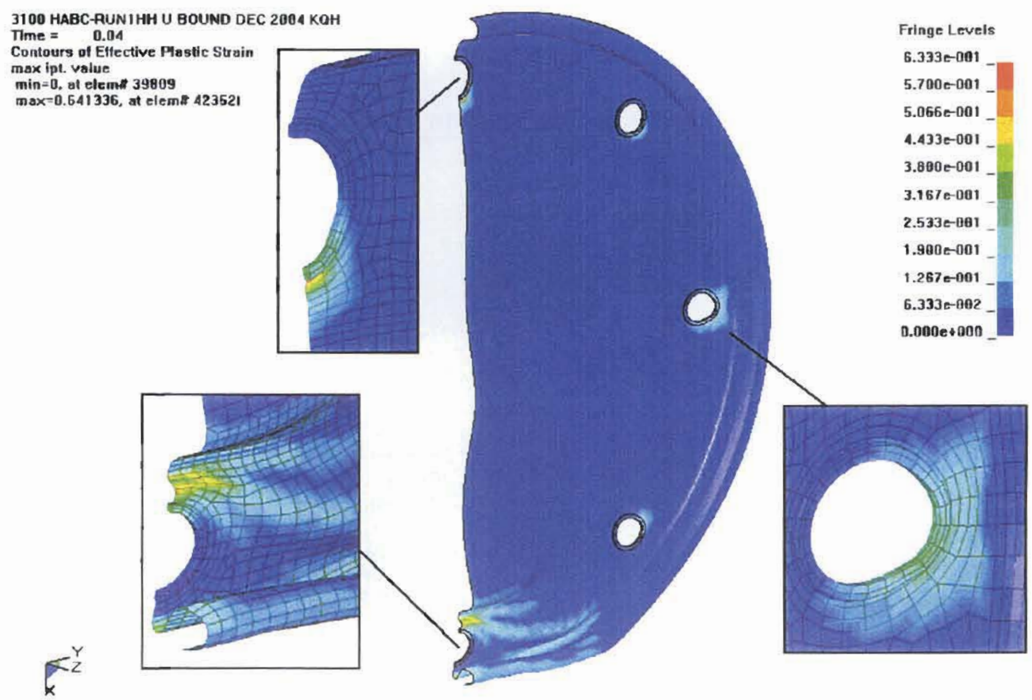

Figure 3.2.12 - HABC-run1hh, Crush Impact, Effective Plastic Strain in the Lid

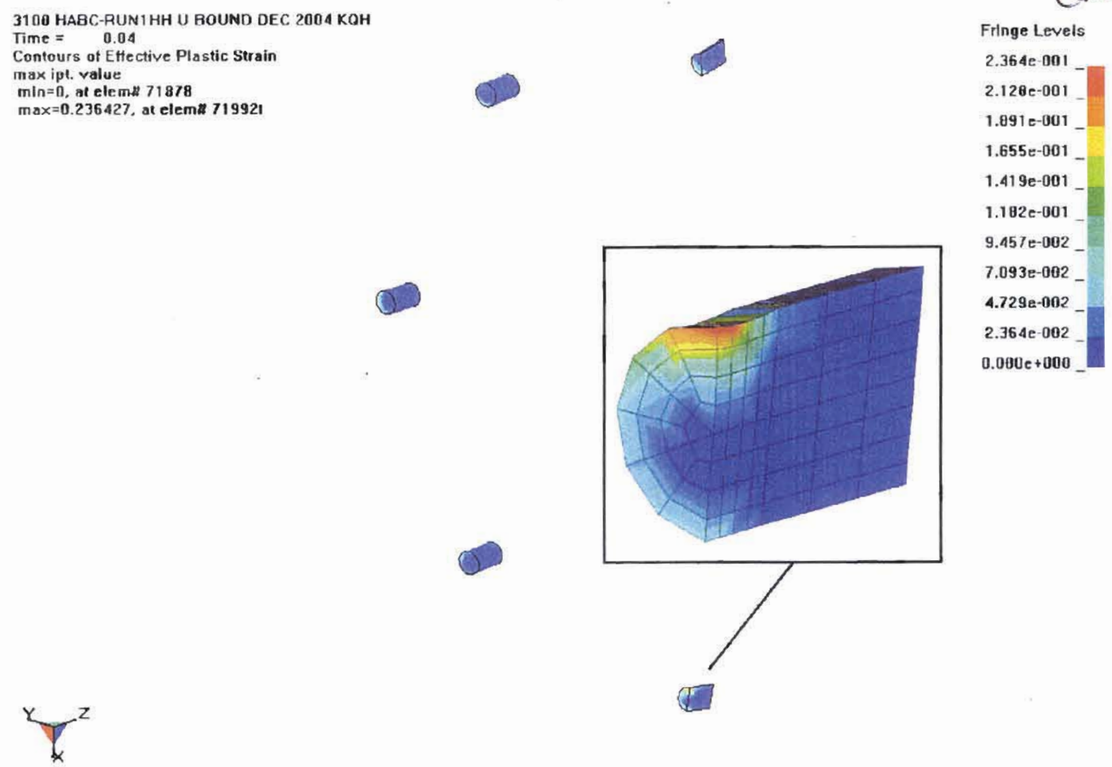

Figure 3.2.13 - HABC-run1hh, Crush Impact, Effective Plastic Strain in the Studs

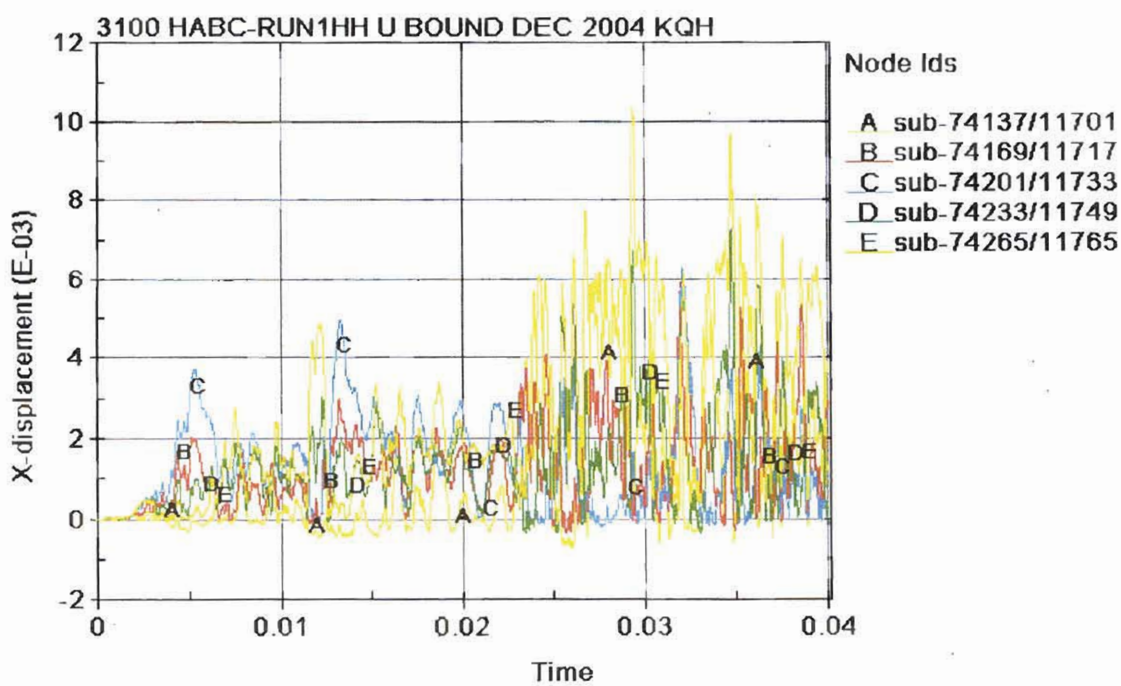

Figure 3.2.14 - HABC-run1hh, CV Lid Separation Time History

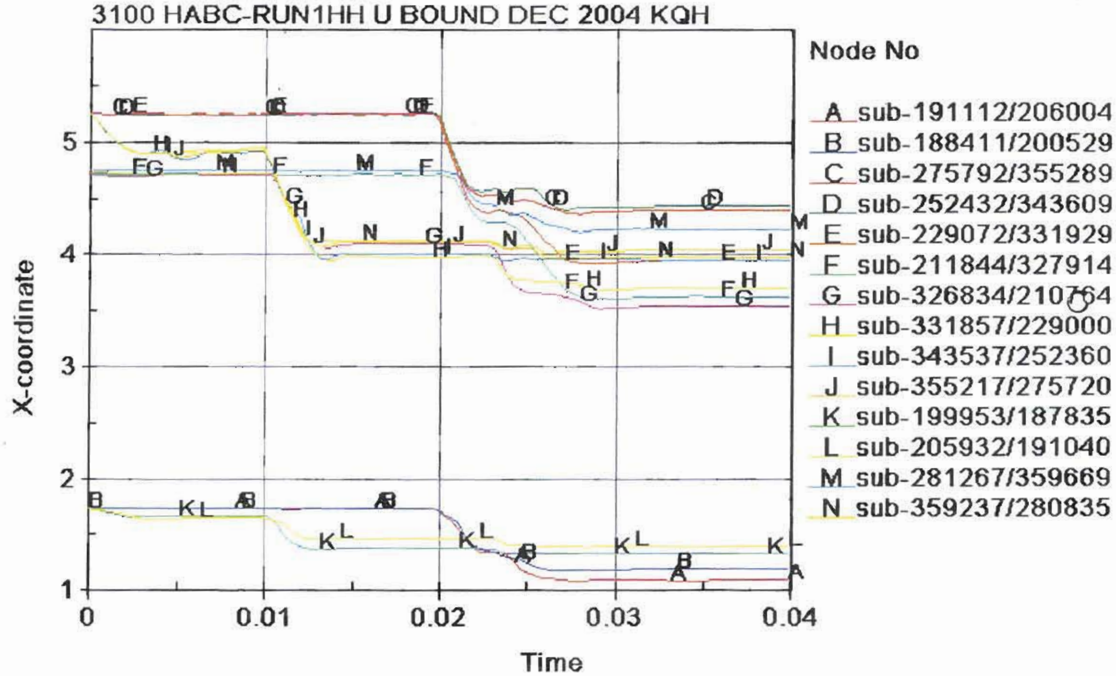

Figure 3.2.15 - HABC-run1hh, Kaolite Thickness Time History

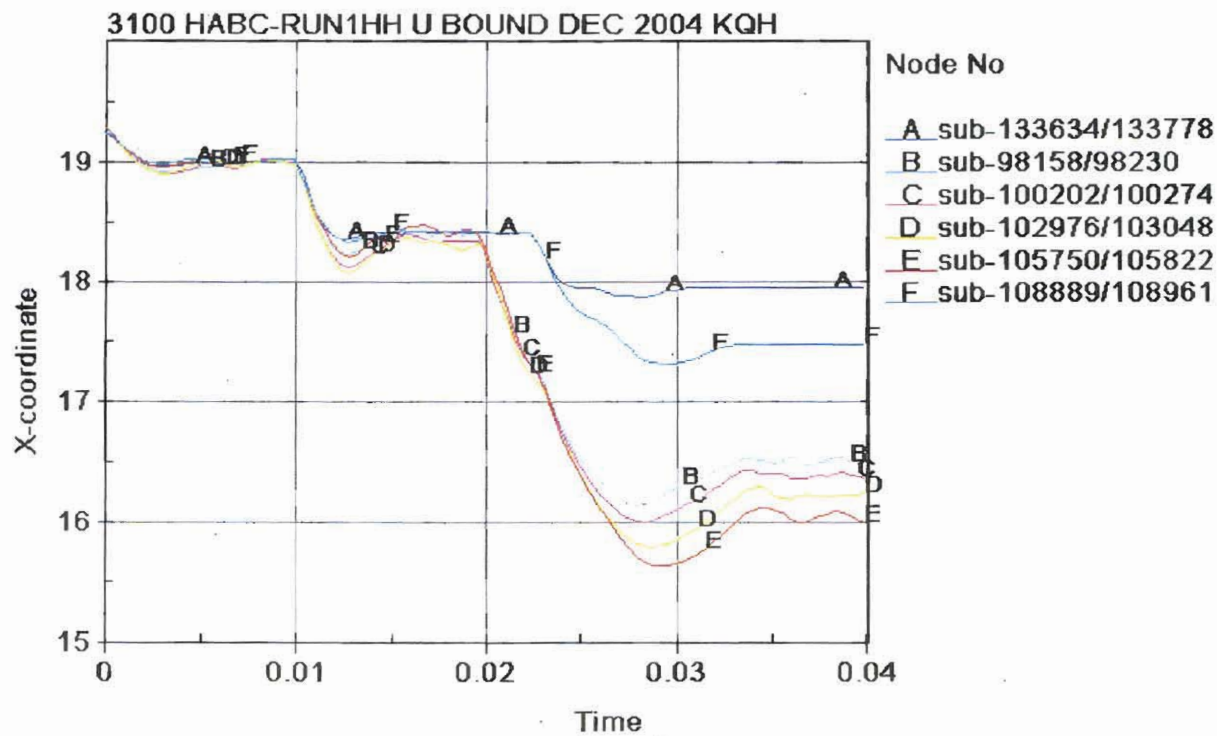

Figure 3.2.16 - HABC-run1hh, Drum Diameter Time History in the X Direction

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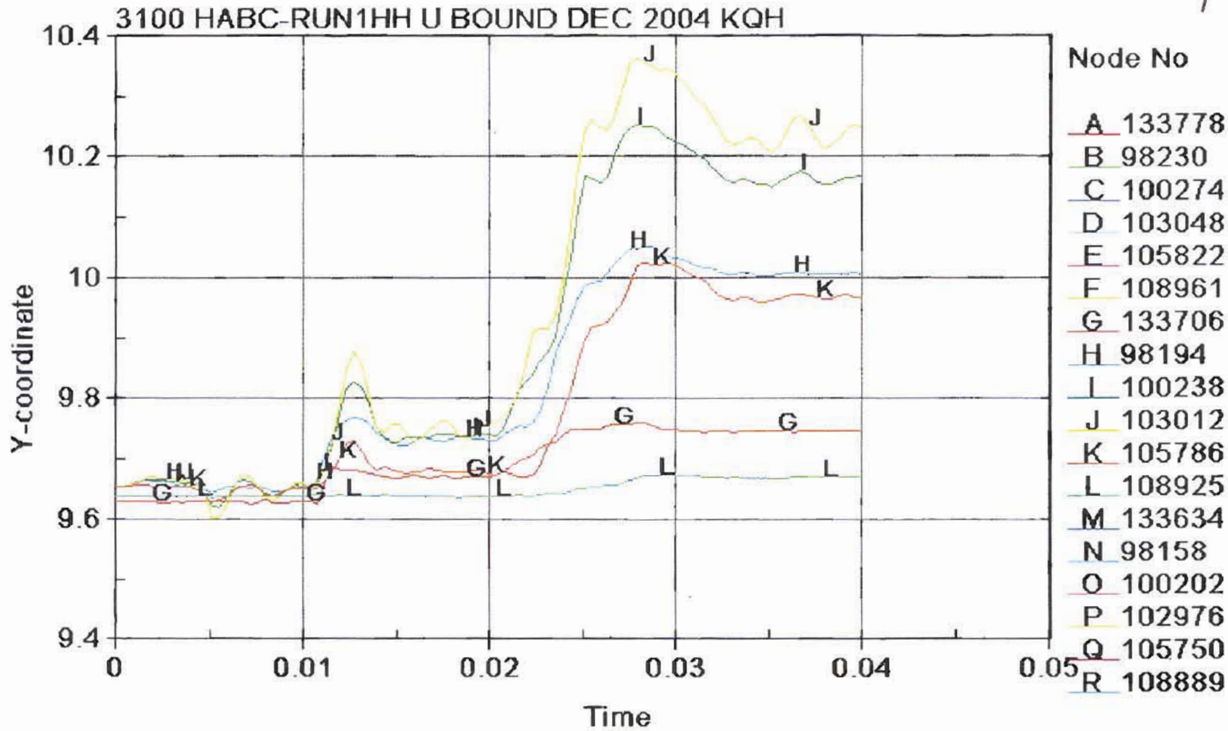

Figure 3.2.17 - HABC-run1hh, Drum Diameter Time History in the Y Direction

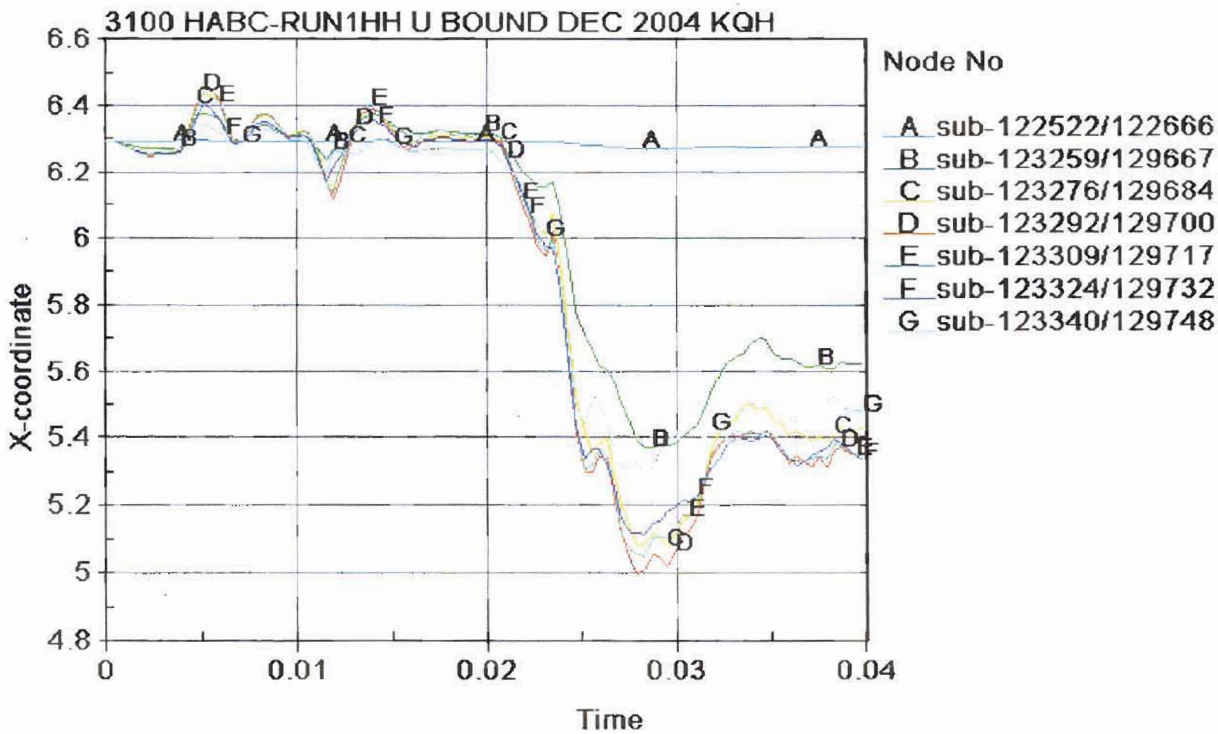

Figure 3.2.18 - HABC-run1hh, Diameter Changes in the Inner Liner

3.3 HABC-run2e - Corner

HABC-run2e is a package CG over corner impact with a 30-foot impact (time = 0 to 0.015 seconds)followed by a crush impact (0.015 to 0.05 seconds).

The configuration after the 30-foot impact is shown in Figure 3.3.1. The maximum effective plastic strain in the CV body is 0.0371 in/in as shown in Figure 3.3.2. Figure 3.3.3 shows that the maximum effective plastic strain in the CV lid is 0.0051 in/in near the outer radius of the center boss.

The maximum effective plastic strain in the lid studs is in the stud at the impact with the rigid plane (0° position) and is 0.5233 in/in. It can be seen from the insert in Figure 3.3.4, that strains near the maximum exist across the thickness of the stud. Therefore, it should be noted that slight differences between the modeled length and actual length of the stud could be significant relative to possible failure of the stud. Other differences such as friction and local flexibility in the test pad armored plate could also significantly effect this stud and cause failure. The maximum effective plastic strains of other components for this impact are listed in Table 3.3.1.

Table 3.3.1 - HABC-run2e, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Nut Ring	0.0002
Angle	0.0394
Drum	0.3247
Drum Bottom Head	0.0000
Liner	0.3983
Lid	0.2791
Lid Stiffener	0.0272
Lid Stud Nuts	0.2260
Lid Stud Washers	0.1528
Plug Liner	0.1152

Figure 3.3.5 shows the final configuration for the crush impact. Figure 3.3.6 shows that

the maximum effective plastic strain in the CV body due to the crush impact is 0.0371 in/in. Figure 3.3.7 shows the effective plastic strain in the CV lid maximum to be 0.0051 in/in. The maximum occurs near the outer radius of the center boss, nearest the impact.

The maximum effective plastic strain in the drum studs is shown to be 0.5598 in/in in Figure 3.3.8. The elevated values of plastic strain occur through out the cross section of the stud. As explained in the 30-foot impact results, slight variances in the length/configuration in this vicinity could prove detrimental for the stud in the test due to the relatively high level of strain through the thickness of the stud.

The maximum effective plastic strain in the liner is 0.5254 in/in as shown in Figure 3.3.9. The maximum is a surface strain and occurs in the folding at about the 80° position at the attachment of the liner to the angle. Investigation shows that the membrane maximum strain is 0.2205 in/in and occurs at the same location.

Table 3.3.2 - HABC-run2e, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Nut Ring	0.0002
Angle	0.0462
Drum	0.3830
Drum Bottom Head	0.0761
Liner	0.5254
Lid	0.3622
Lid Stiffener	0.0272
Lid Stud Nuts	0.2266
Lid Stud Washers	0.1528
Plug Liner	0.1166

The CV lid separation time histories for the nodes shown in Figure 3.1.16 are given in Figure 3.3.10 for the HABC-run2e. Spike separation occurs (about 0.013 in) during the 30-foot impact with the general separation of about 0.008 in. The general separation lasts about 0.01 seconds, then settles to 0.003 in or less. The general separation due to the crush impact is 0.005 in or less, with some spiking to about 0.010 in noted. Nominal

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0.003 in or less would be expected.

Figure 3.3.11 shows the location of the nodes used to obtain the minimum kaolite thickness in the plug. Figure 3.3.12 shows the minimum plug thickness time history. A minimum thickness of about 3.5 inches is reached in the 30-foot impact, and about 3.0 inches is reached in the successive crush impact.

Figure 3.3.13 shows the location of the nodes used to obtain the minimum koalite thickness in the package bottom. The time history thickness is shown in Figure 3.3.14 for the bottom kaolite. A minimum thickness of about 1.75 inches is shown.

Figure 3.3.15 shows the nodes used to obtain overall drum heights for the impacts. The final lengths from the bottom head to the lid are used to describe the deformations. Curve A in Figure 3.3.16 gives the length response of the 30-foot impacted lid corner to the drum bottom. The length after the 30-foot lid impact is about 40.5 in and goes to about 39 in after the crush impact. The Curve B in Figure 3.3.16 shows that the length from the crushed corner of the bottom to the lid reaches about 38 in in length.

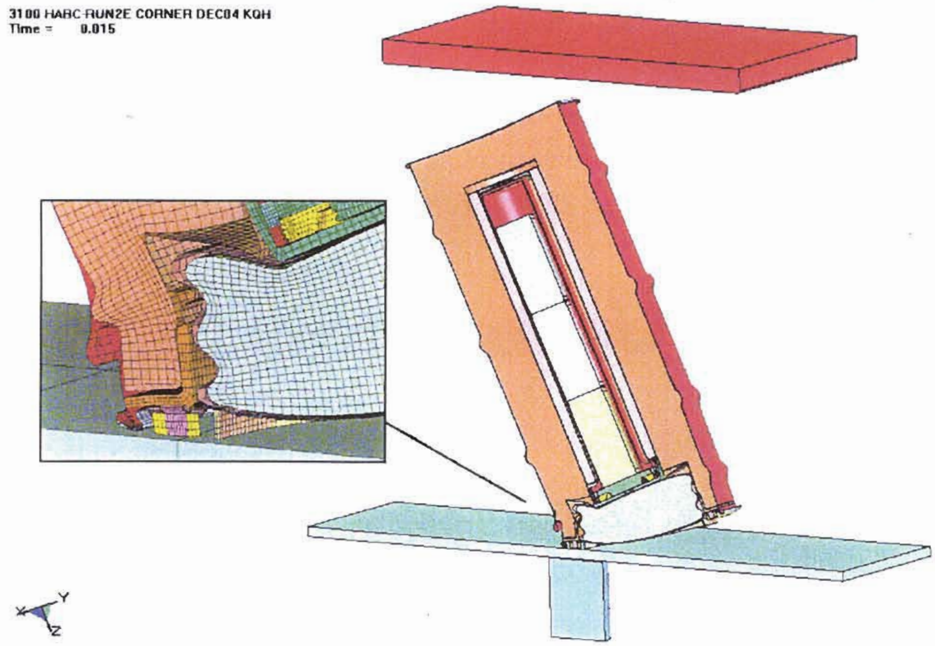

Figure 3.3.1 - HABC-run2e, Configuration of the ES-3100 After the 30-Foot Impact

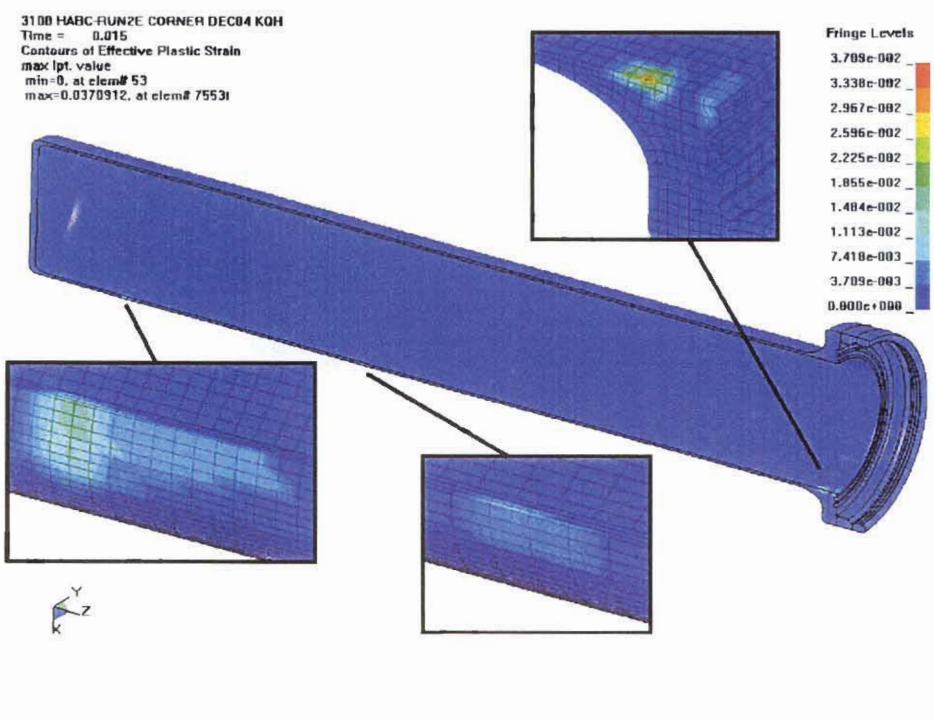

Figure3.3.2 - HABC-run2e, 30-Foot Impact, Effective Plastic Strains in the CV Body

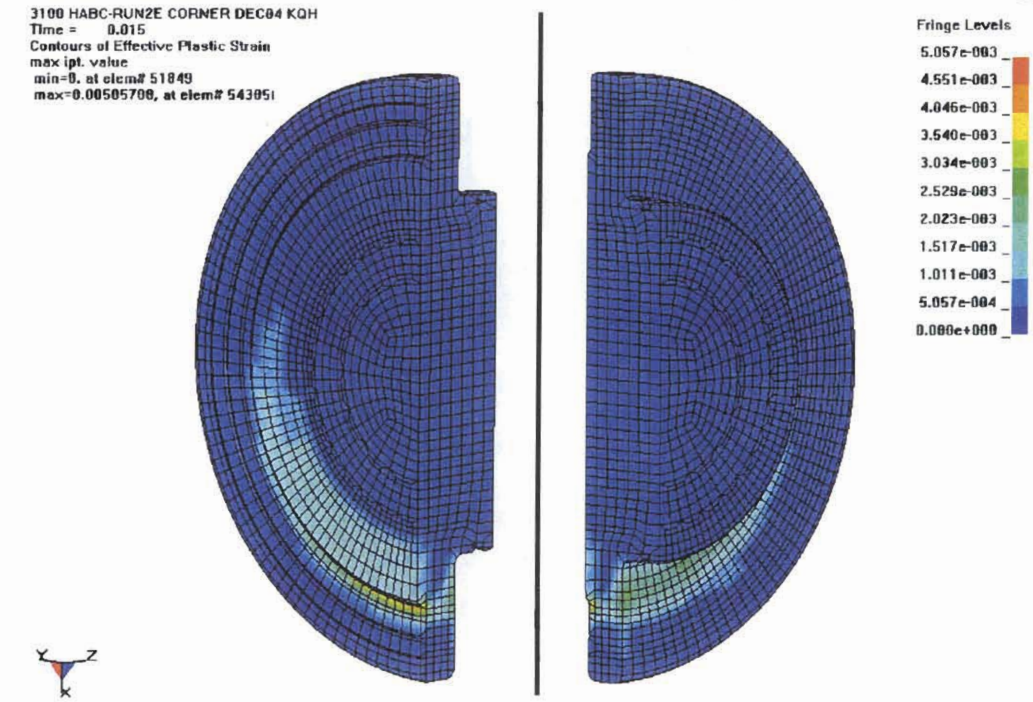

Figure 3.3.3 - HABC-run2e, 30-Foot Impact, Effective Plastic Strain in the CV Body

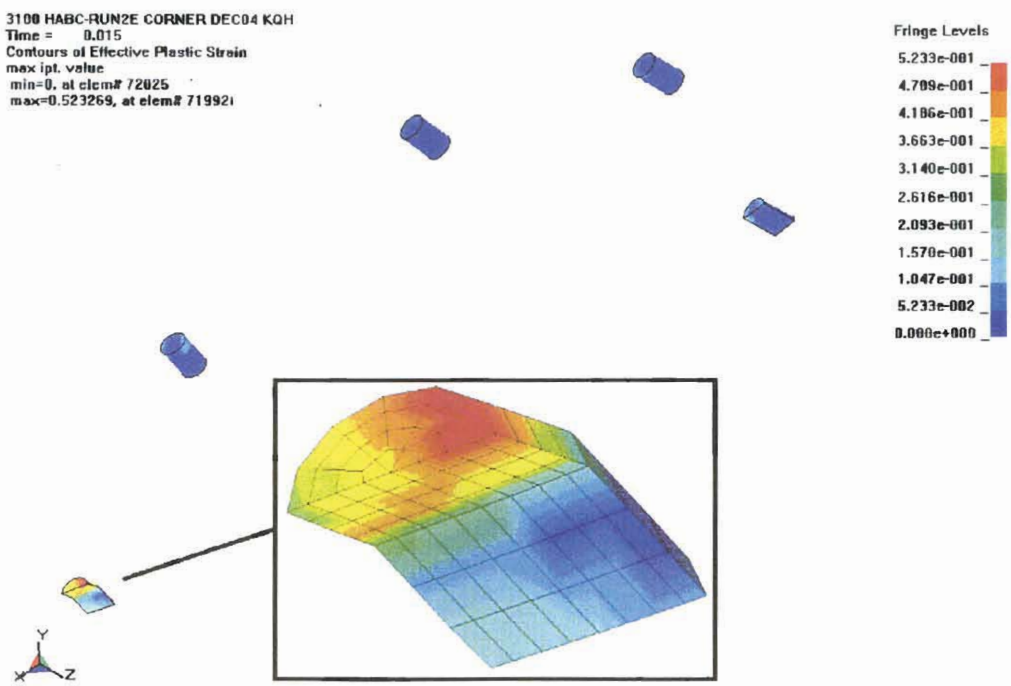

Figure 3.3.4 - HABC-run2e, 30-Foot Impact, Effective Plastic Strain in the Studs

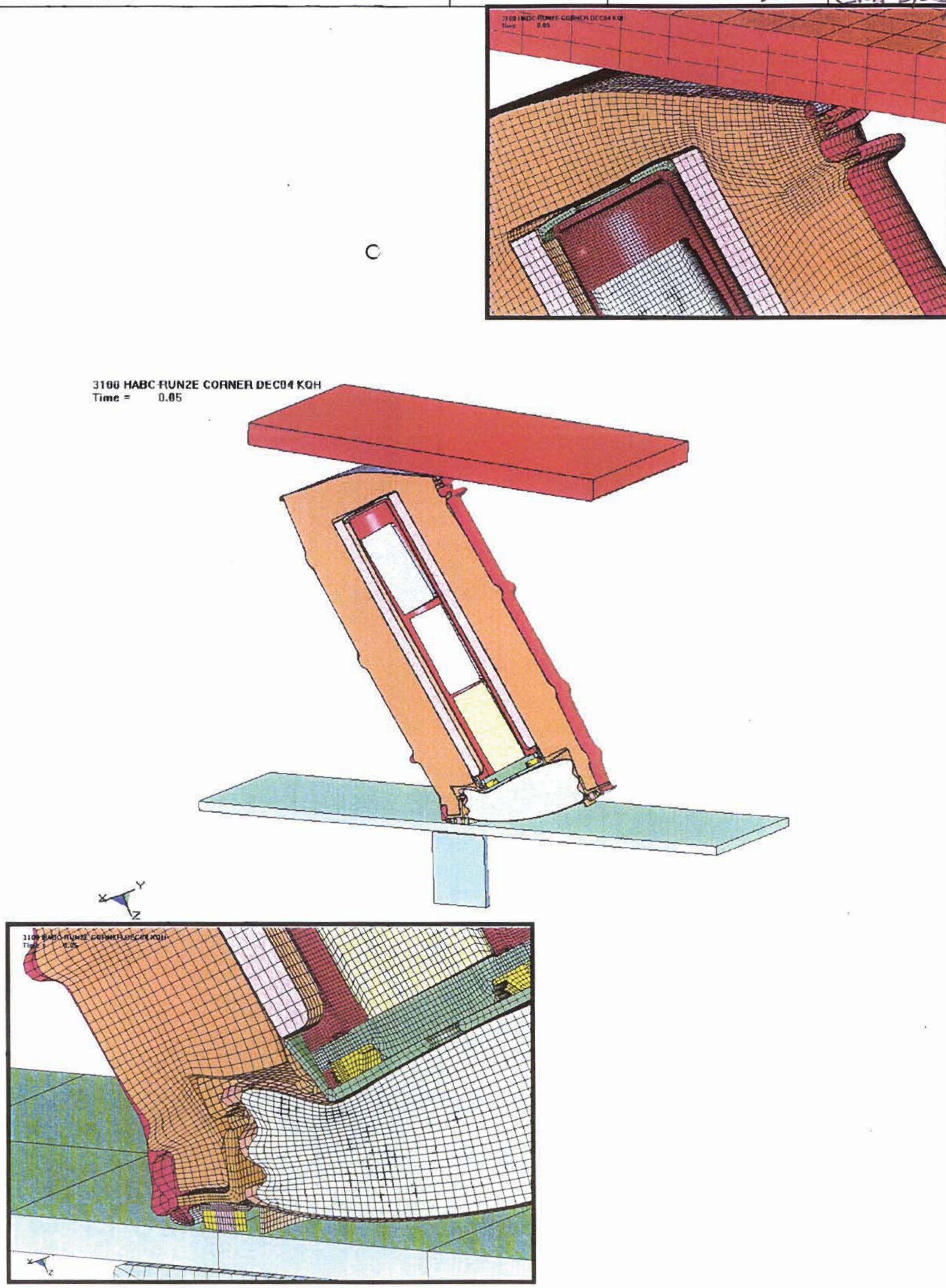

Figure 3.3.5 - HABC-run2e, Configuration After the Crush Impact

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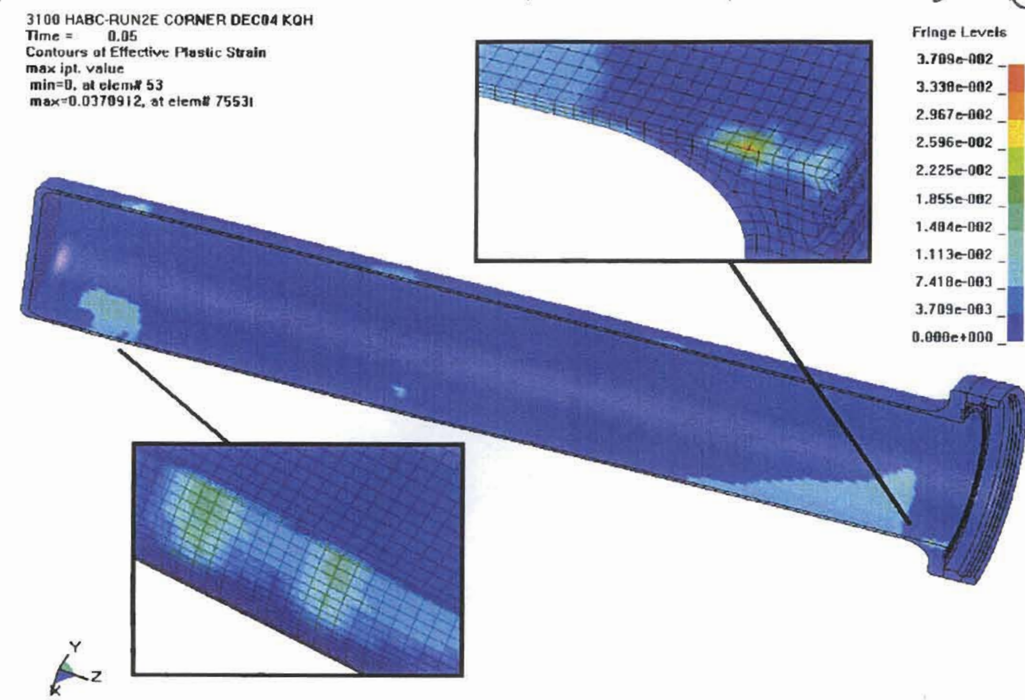

Figure 3.3.6 - HABC-run2e, Crush Impact, Effective Plastic Strain in the CV Body

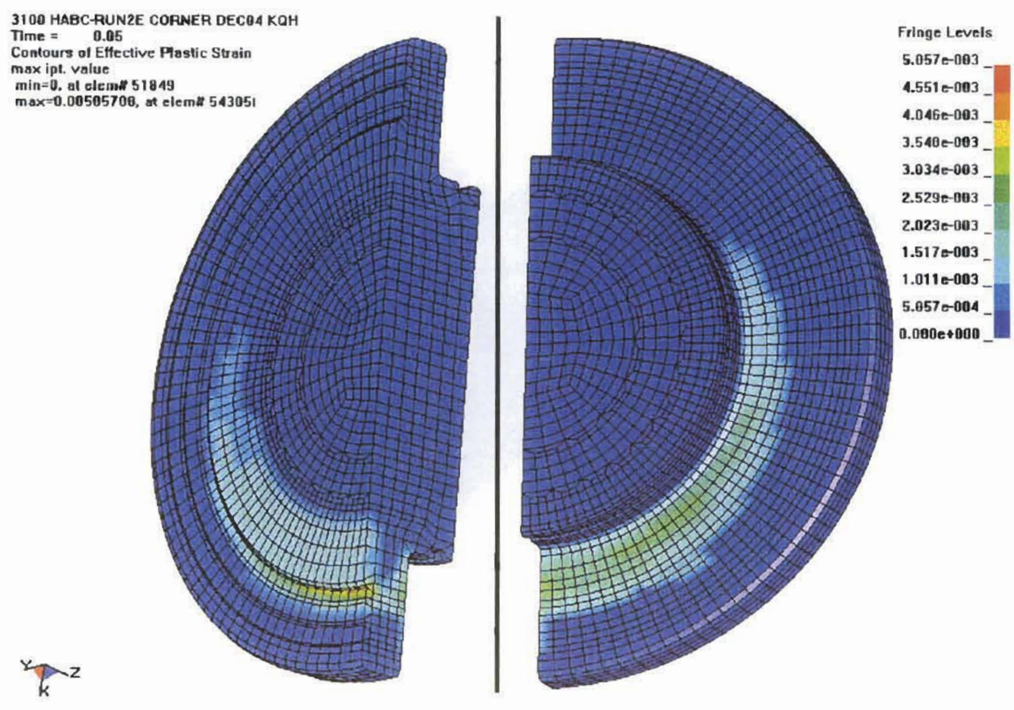

Figure 3.3.7 - HABC-run2e, Crush Impact, Effective Plastic Strain in the CV Lid

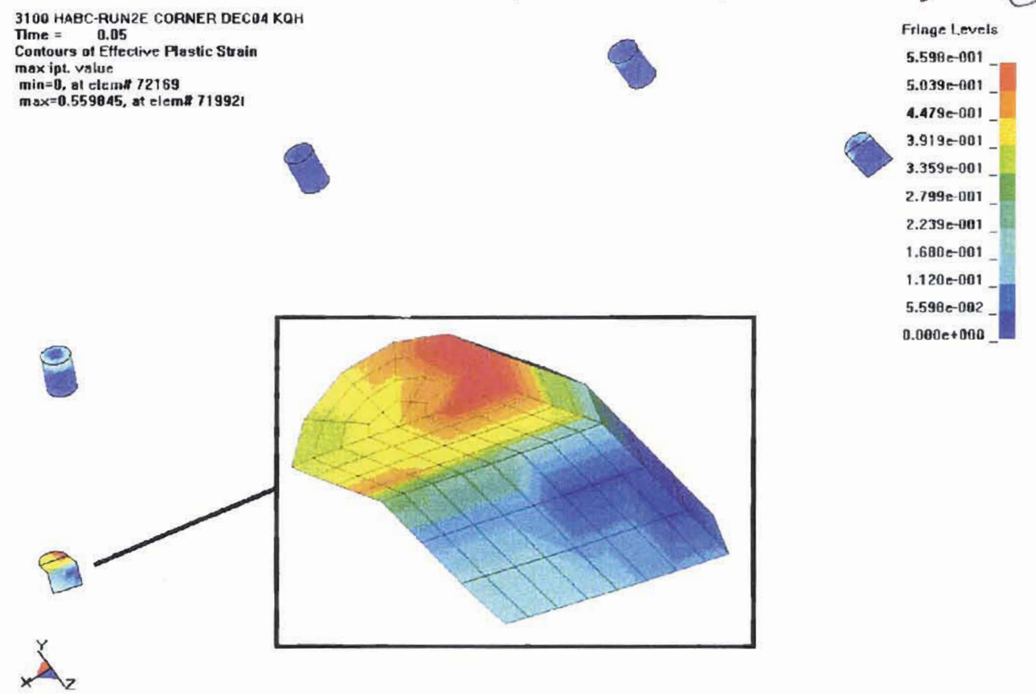

Figure 3.3.8 - HABC-run2e, Crush Impact, Effective Plastic Strain in the Studs

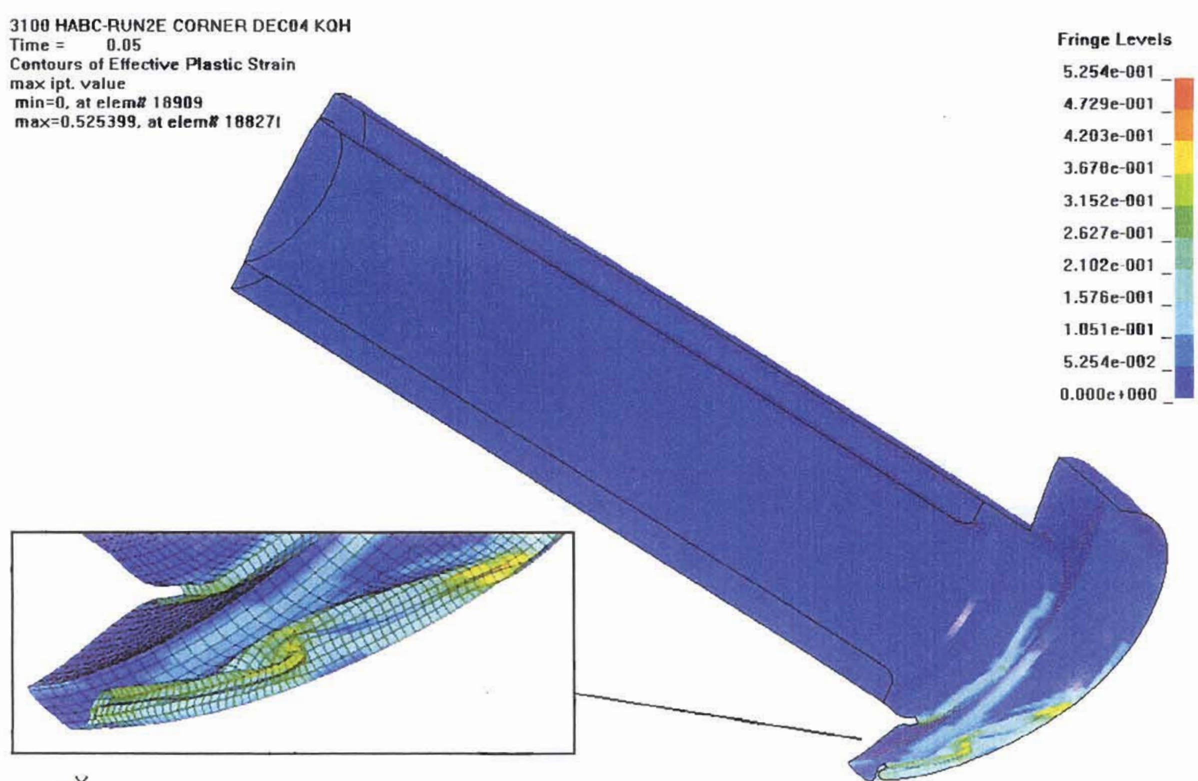

Figure 3.3.9 - HABC-run2e, Crush Impact, Effective Plastic Strain in the Liner

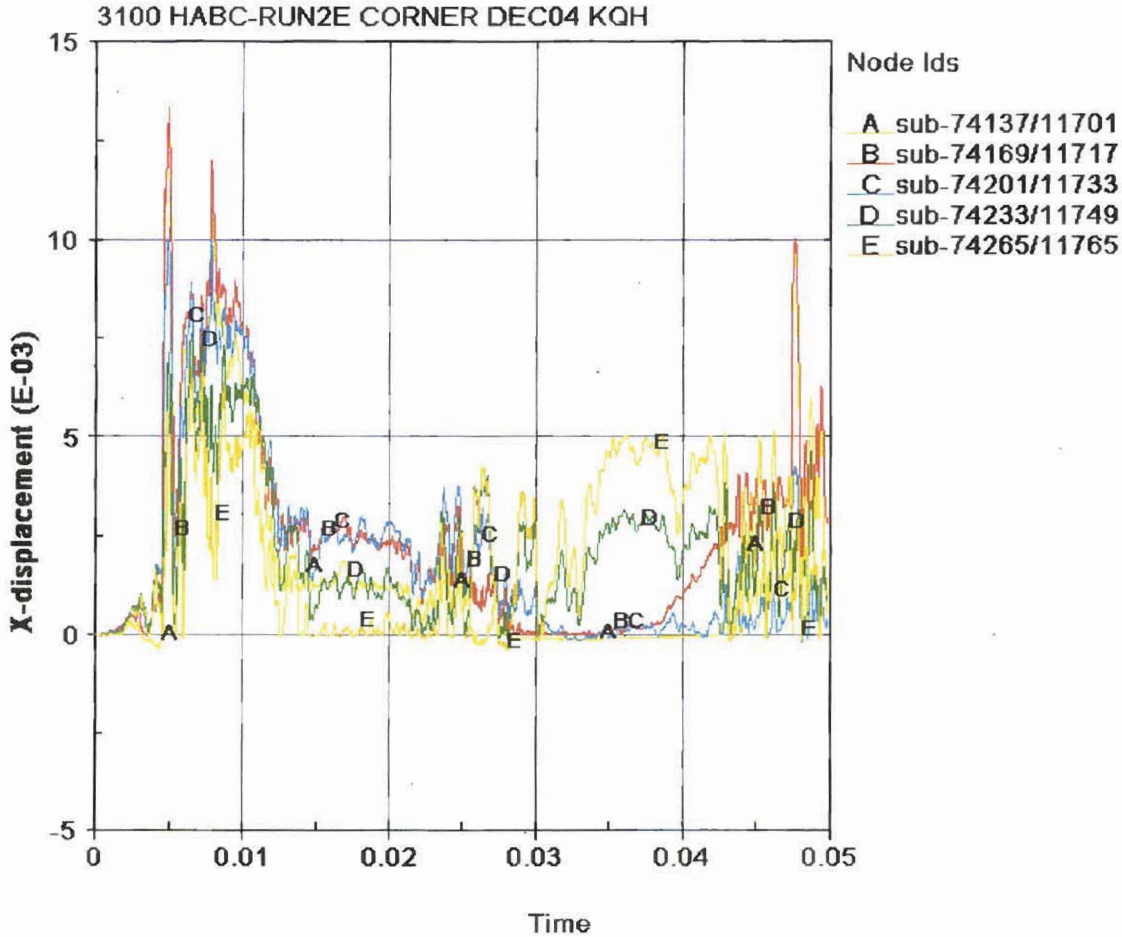

Figure 3.3.10 - HABC-run2e, Crush Impact, CV Lid/Body Separation Time History

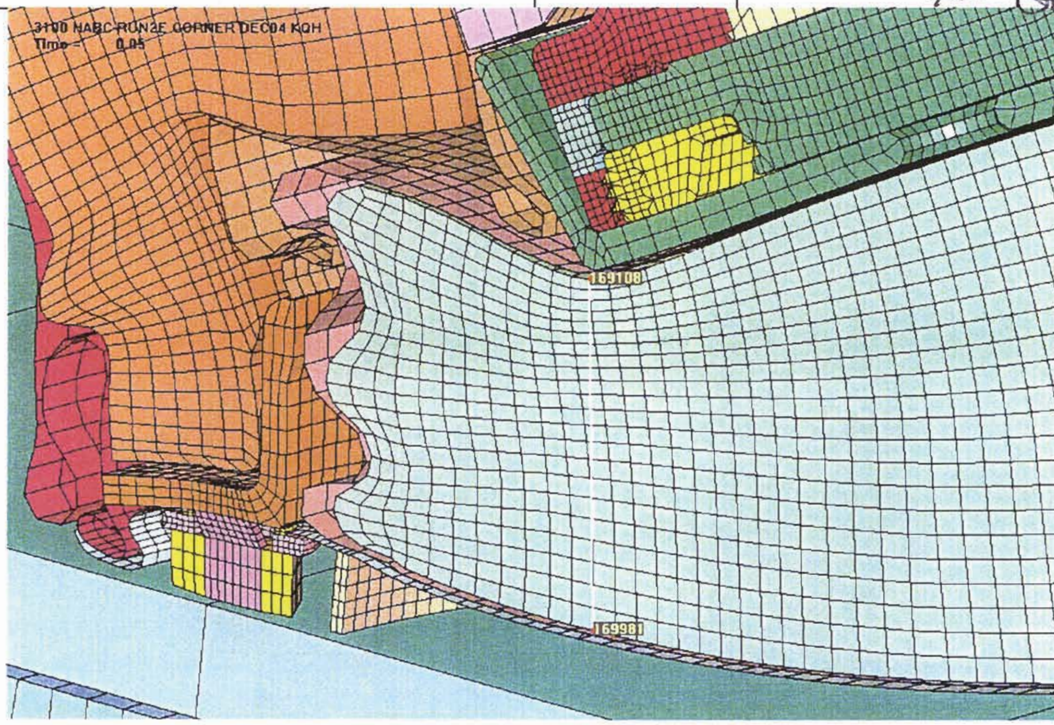

Figure 3.3.11 - HABC-run2e, Plug Thickness After the Crush Impact

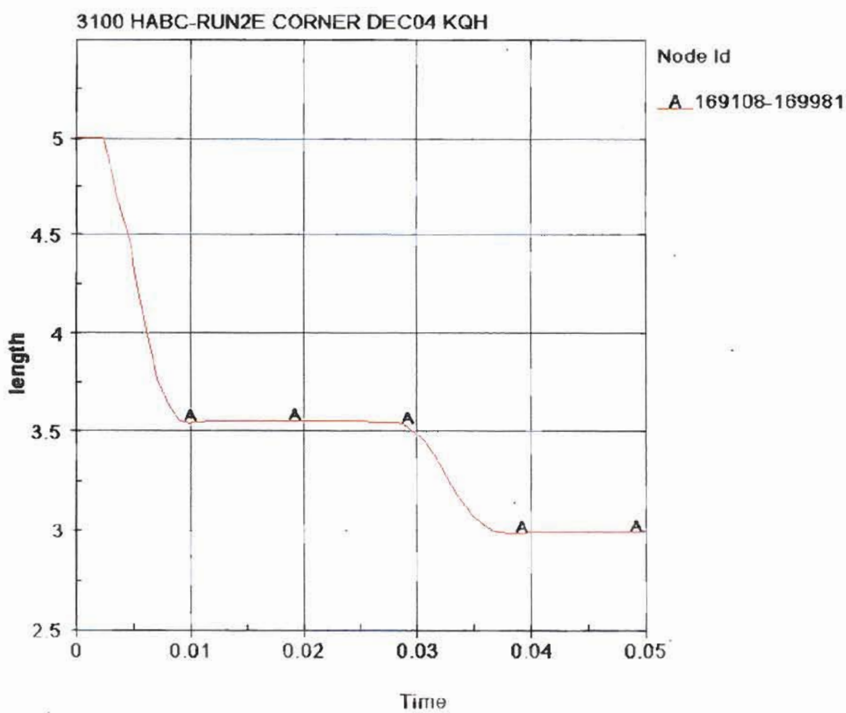

Figure 3.3.12 - HABC-run2e, Plug Thickness Time History

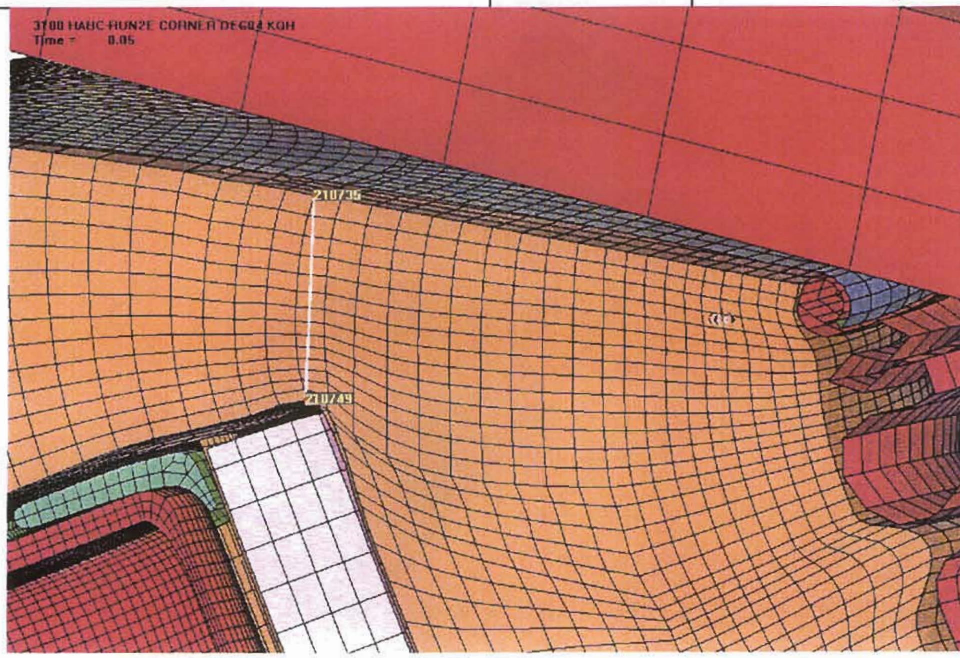

Figure 3.3.13 - HABC-run2e, Bottom Kaolite Thickness After the Crush Impact

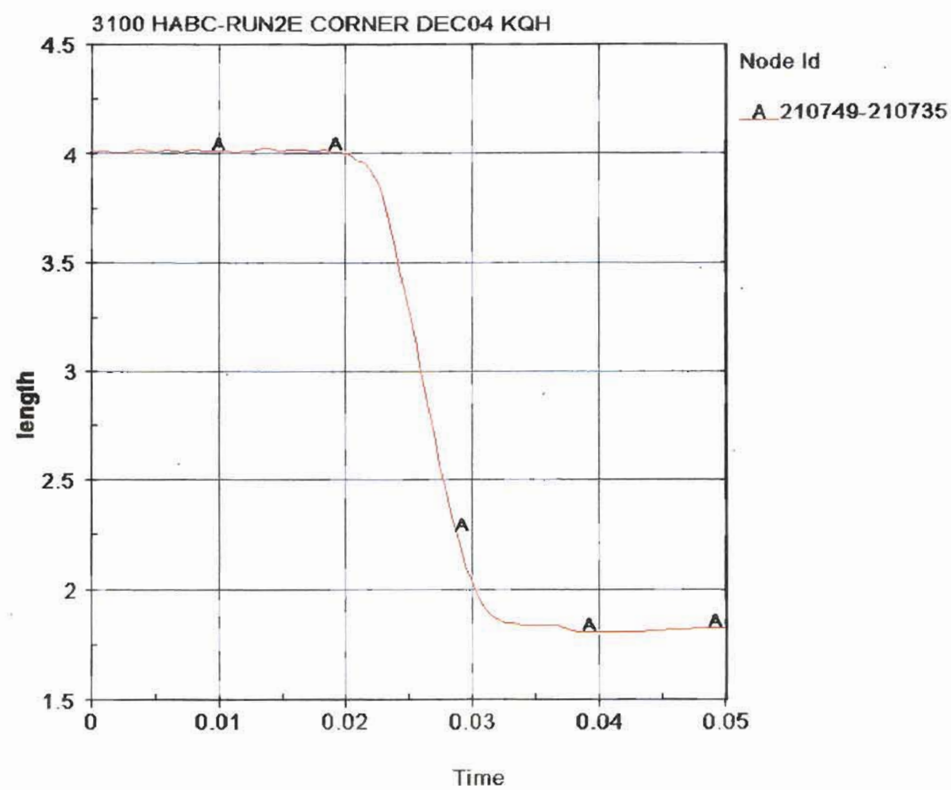

Figure 3.3.14 - HABC-run2e, Bottom Kaolite Thickness Time History

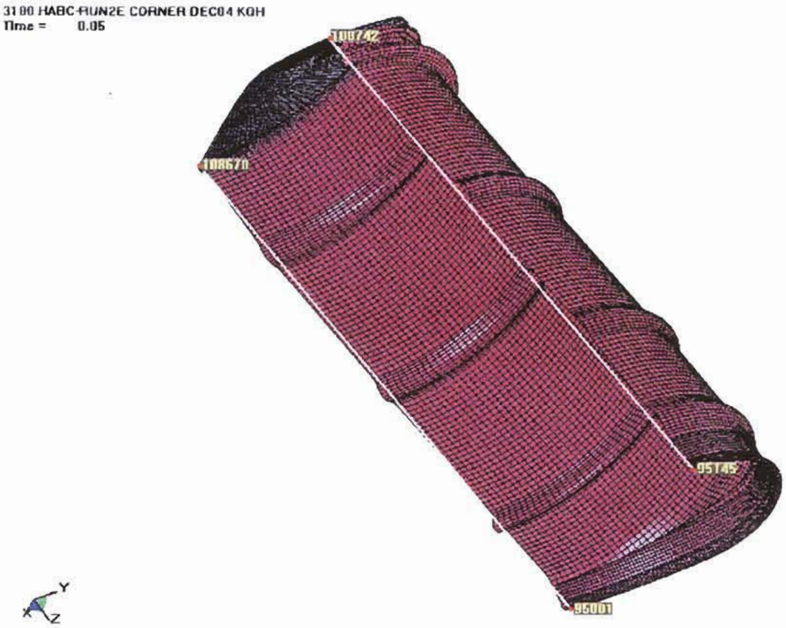

Figure 3.3.15 - HABC-run2e, Length Dimensions in the Drum

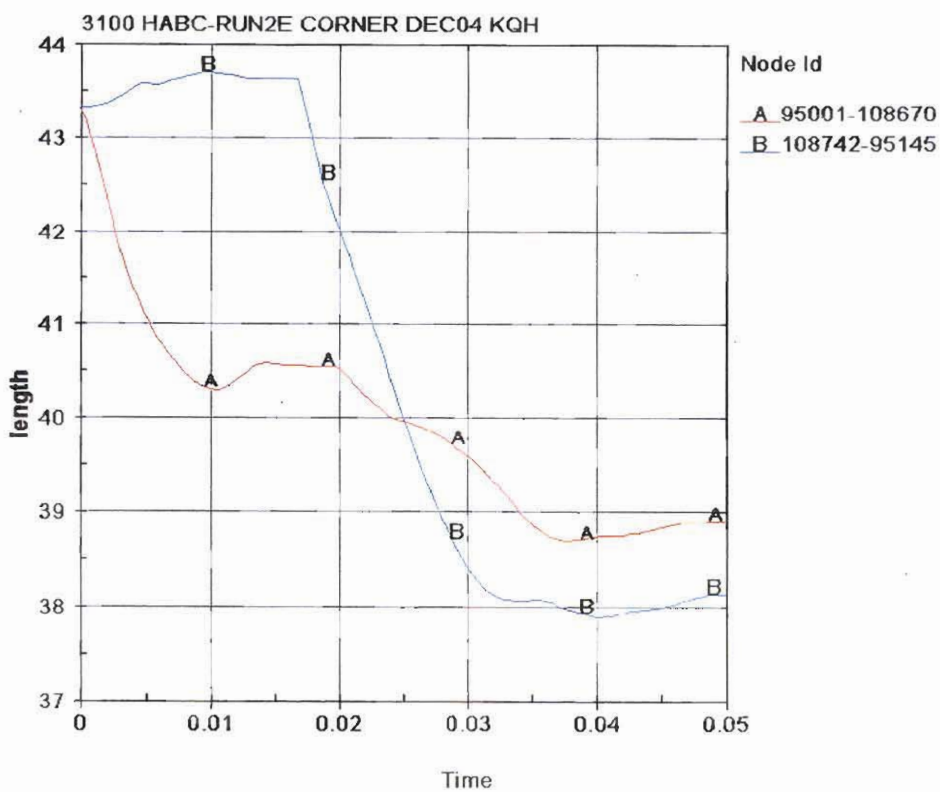

Figure 3.3.16 - HABC-run2e, Drum Length Time History

3.4 HABC-run3b - End

HABC-run3b is a 30-foot lid end impact (time = 0 to 0.010 seconds) followed by a crush impact onto the package bottom (0.010 to 0.028 seconds). Figure 3.4.1 shows the configuration of the container at the end of the 30-foot impact. Figure 3.4.2 shows that the maximum effective plastic strain in the CV body is 0.0028 in/in. The maximum plastic strain occurs in the bottom head. Figure 3.4.3 shows the CV lid. The maximum effective plastic strain is found to be 0.0072 in/in and occurs just outboard of the center boss on the outer surface.

The maximum effective plastic strain in the nut ring is shown to be 0.0011 in/in in Figure 3.4.4. It is believed this plastic strain is an anomaly with the contact surface because: 1) the fringes of plastic strain are not symmetrical, 2) the maximum value of plastic strain occurs at single nodes on an edge of the component and 3) the nut ring bares on the relatively soft silicone pad. Table 3.4.1 summarizes the maximum effective plastic strains in the other package components.

Table 3.4.1 - HABC-run3b, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
Angle	0.0287
Drum	0.0557
Drum Bottom Head	0.0031
Liner	0.0607
Lid	0.1082
Lid Stiffener	0.0069
Lid Studs	0.0962
Lid Stud Nuts	0.0166
Lid Stud Washers	0.0506
Plug Liner	0.0670

Figure 3.4.5 shows the final configuration for the successive crush impact. Figure 3.4.6

shows that the maximum effective plastic strain in the CV body is 0.0083 in/in. The ring of plastic deformation in the sidewall at the bottom head is due to the bending of the bottom head. The other components are summarized in Table 3.4.2.

Table 3.4.2 - HABCrun3b, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0072
CV Nut Ring	0.0011
Angle	0.0308
Drum	0.1237
Drum Bottom Head	0.0267
Liner	0.3812
Lid	0.1389
Lid Stiffener	0.0100
Lid Studs	0.1535
Lid Stud Nuts	0.0173
Lid Stud Washers	0.0506
Plug Liner	0.0960

The CV lid separation time history is shown in Figure 3.4.7. The response during the 30-foot impact are separation spikes up to about 0.018 in with a general separation of about 0.012 in. The spikes occur for about 0.001 sec, while the general separation occurs for about 0.005 sec. During the crush impact, the gap response oscillates about values of general separation. The general separation remains below a gap of about 0.005 in.

Figure 3.4.8 shows the nodes chosen to observe the plug and bottom kaolite thicknesses and the overall drum height. Figure 3.4.9 shows the time history of the drum height. After the 30-foot impact and the successive crush impact, the drum height is found to be about 39 inches. Figure 3.4.10 shows the minimum plug thickness time history with Curve B. The minimum plug thickness after the 30-foot impact is about 3.75 in. The minimum plug thickness after the successive crush impact is about 3.4 in. Curve A shows the bottom kaolite minimum thickness is about 2.2 in after the crush impact.

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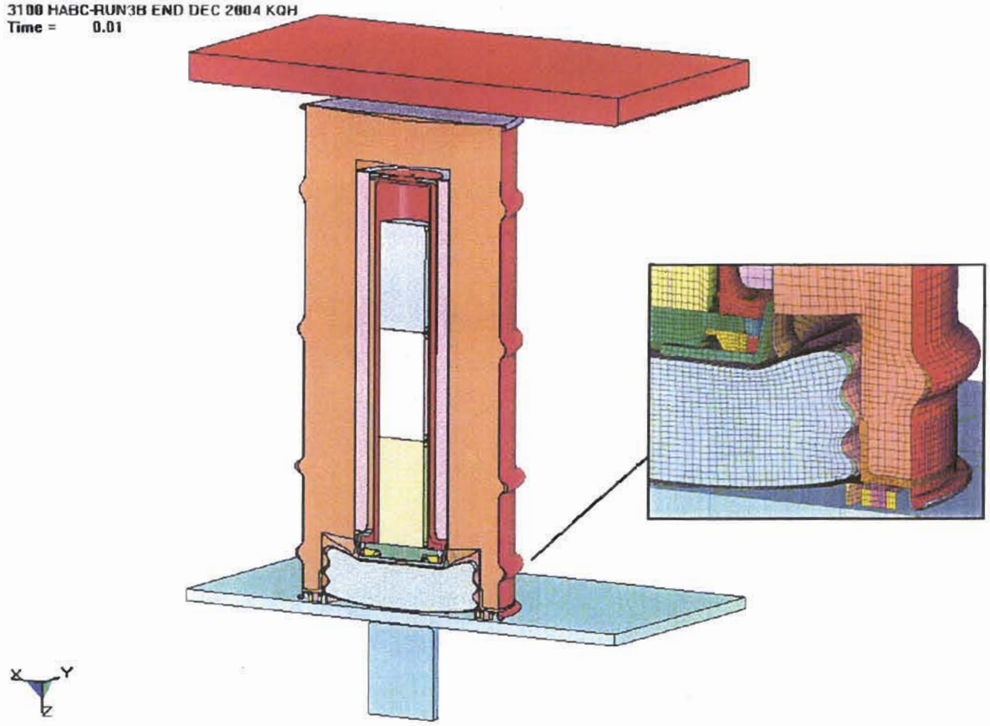


Figure 3.4.1 - HABC-run3b, Configuration After the 30-Foot Impact

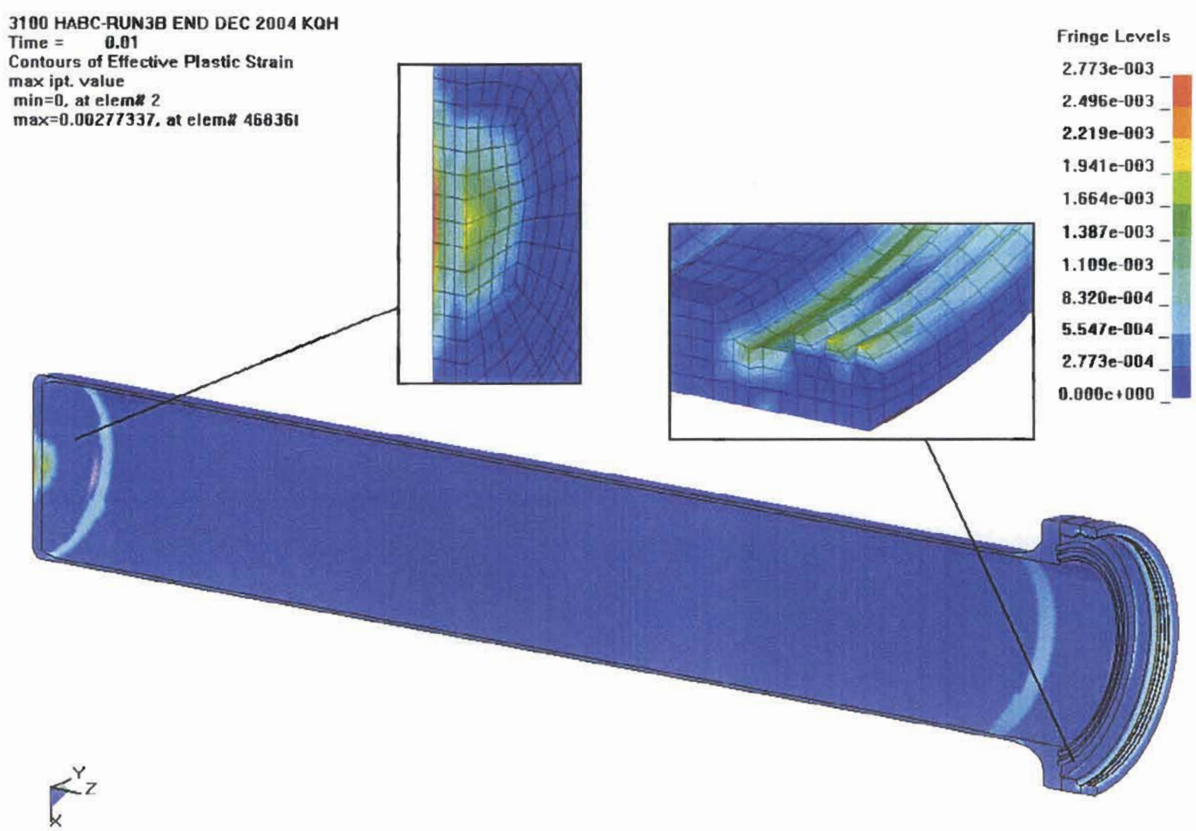


Figure 3.4.2 - HABC-run3b, 30-Foot Impact, Effective Plastic Strain in the CV Body

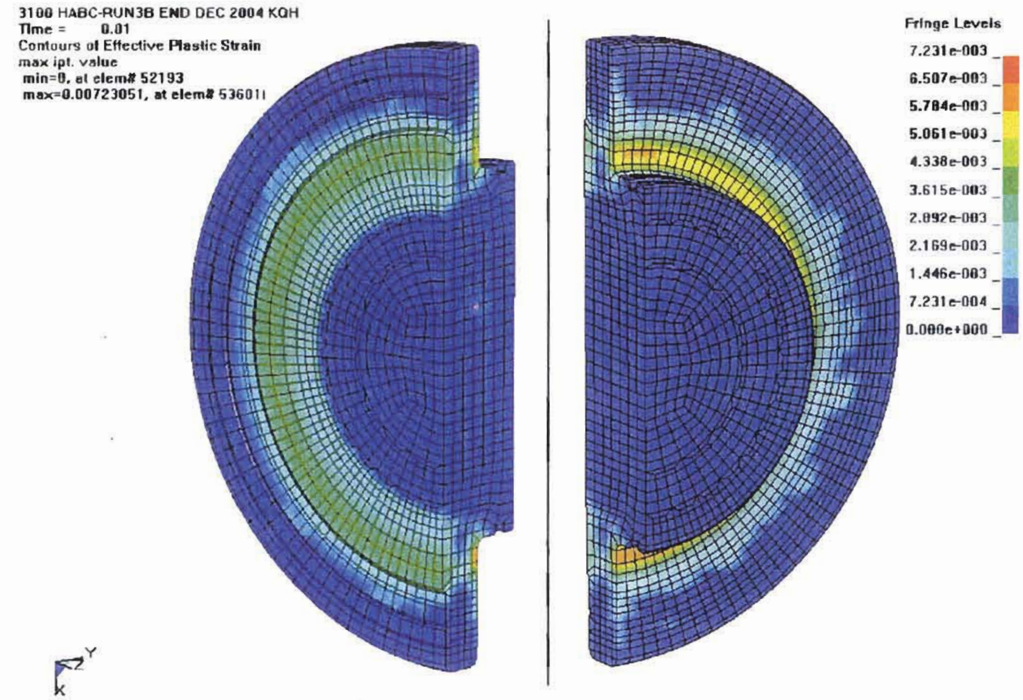


Figure 3.4.3 - HABC-run3b, 30-Foot Impact, Effective Plastic Strain in the CV Lid

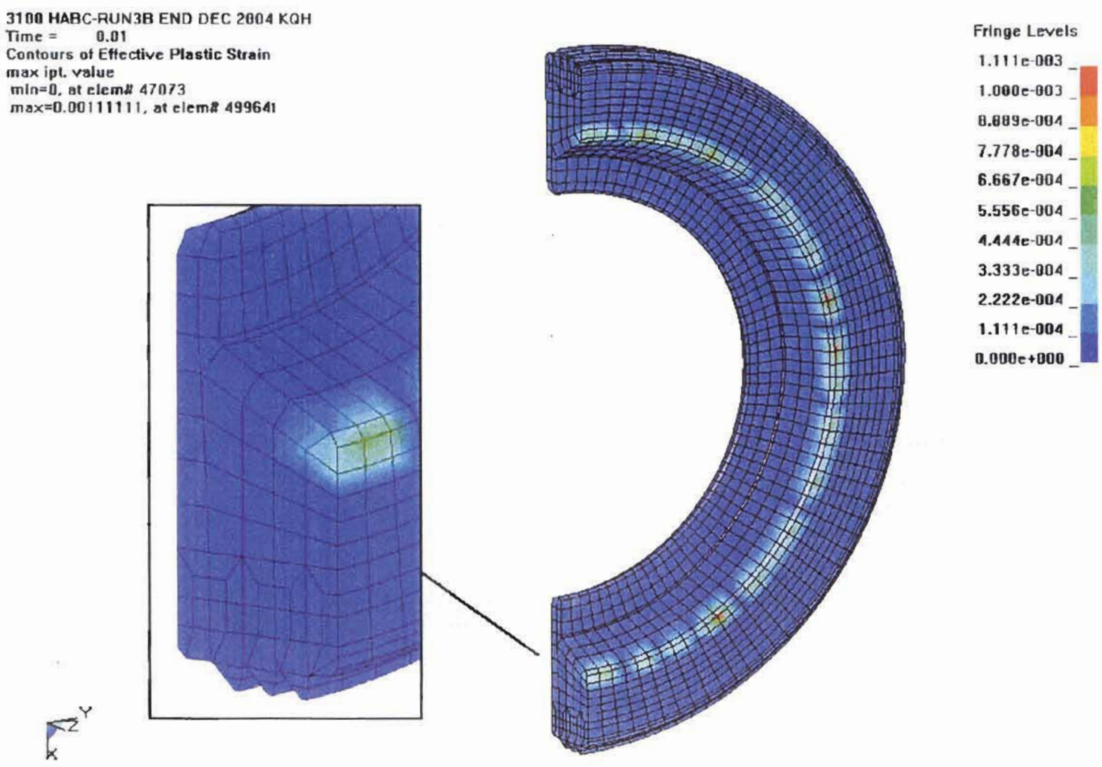


Figure 3.4.4 - HABC-run3b, 30-Foot Impact, Effective Plastic Strain in the CV Nut Ring

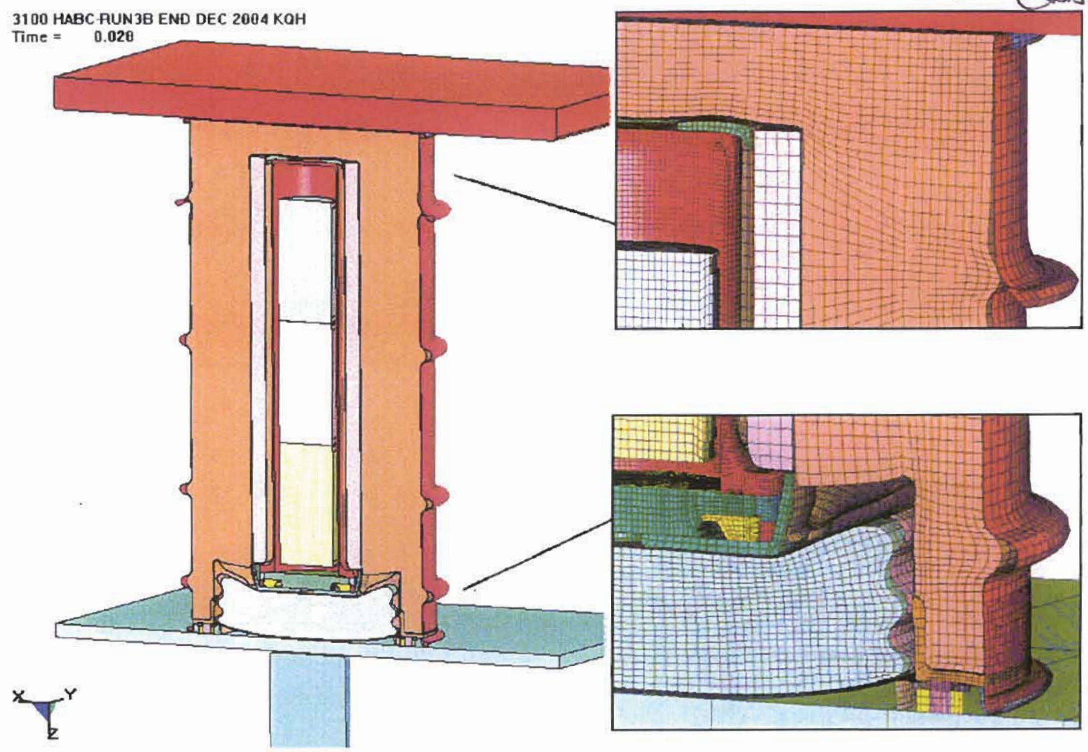


Figure 3.4.5 - HABC-run3b, Configuration After the Crush Impact

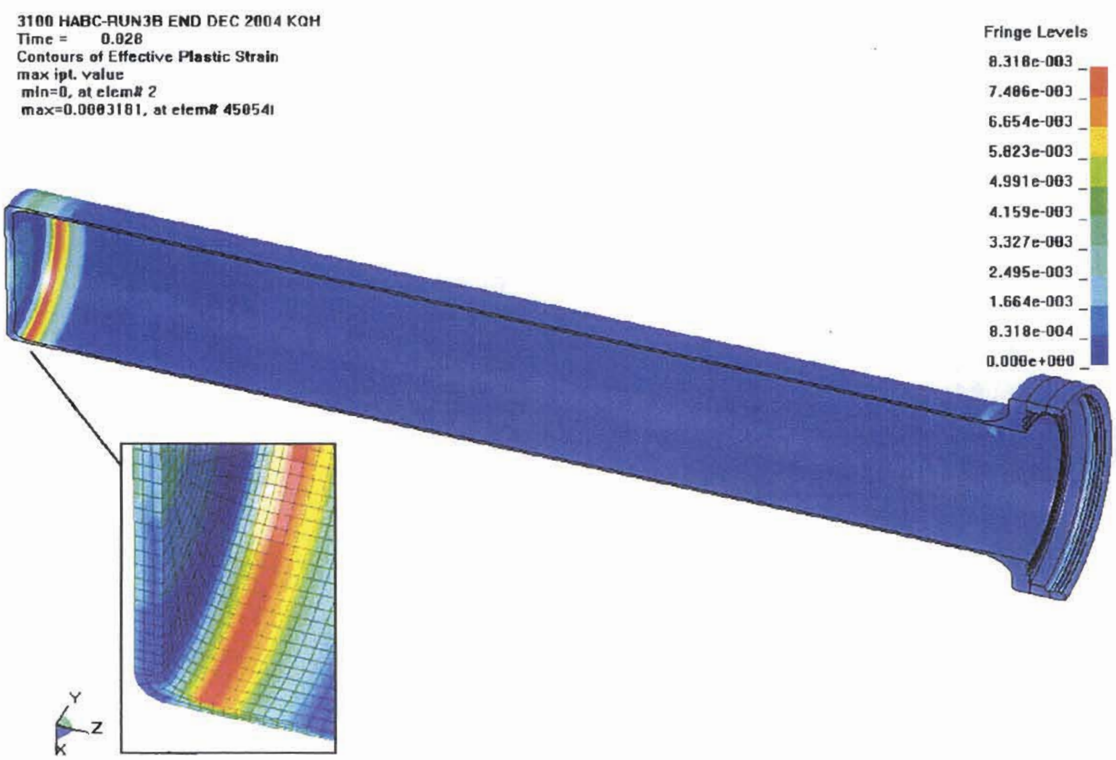


Figure 3.4.6 - HABC-run3b, Crush Impact, Effective Plastic Strain in the CV Body

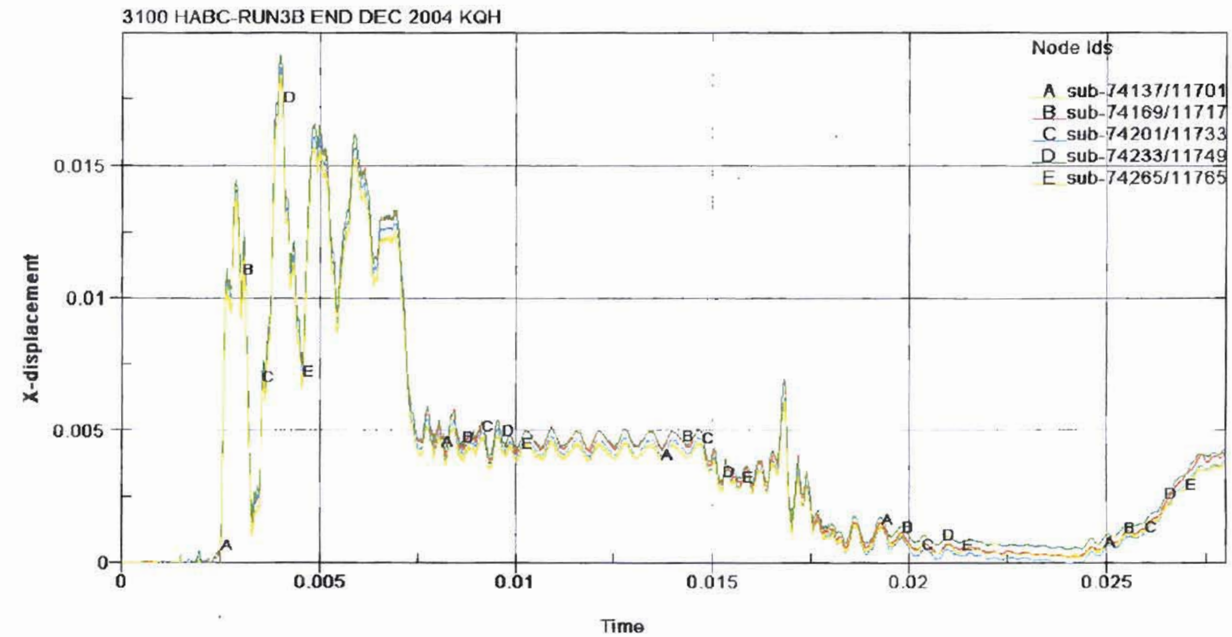


Figure 3.4.7 - HABC-run3b, CV Lid Separation Time History

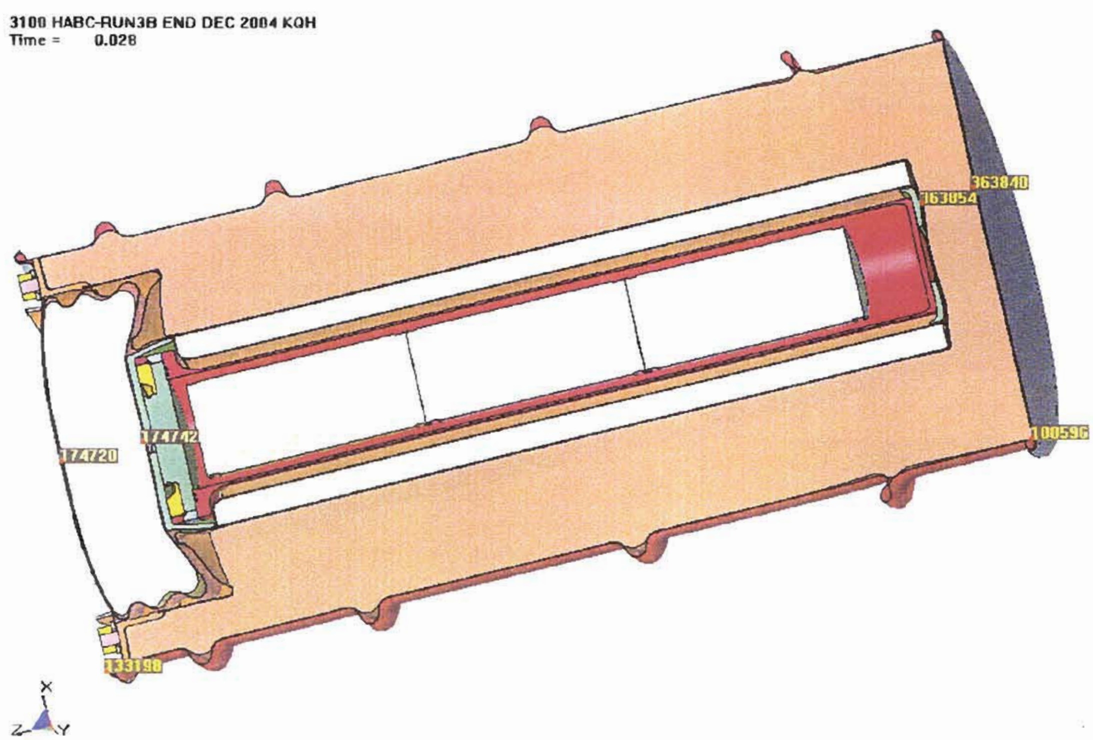


Figure 3.4.8 - HABC-run3b, Nodes to Determine Drum/Kaolite Heights

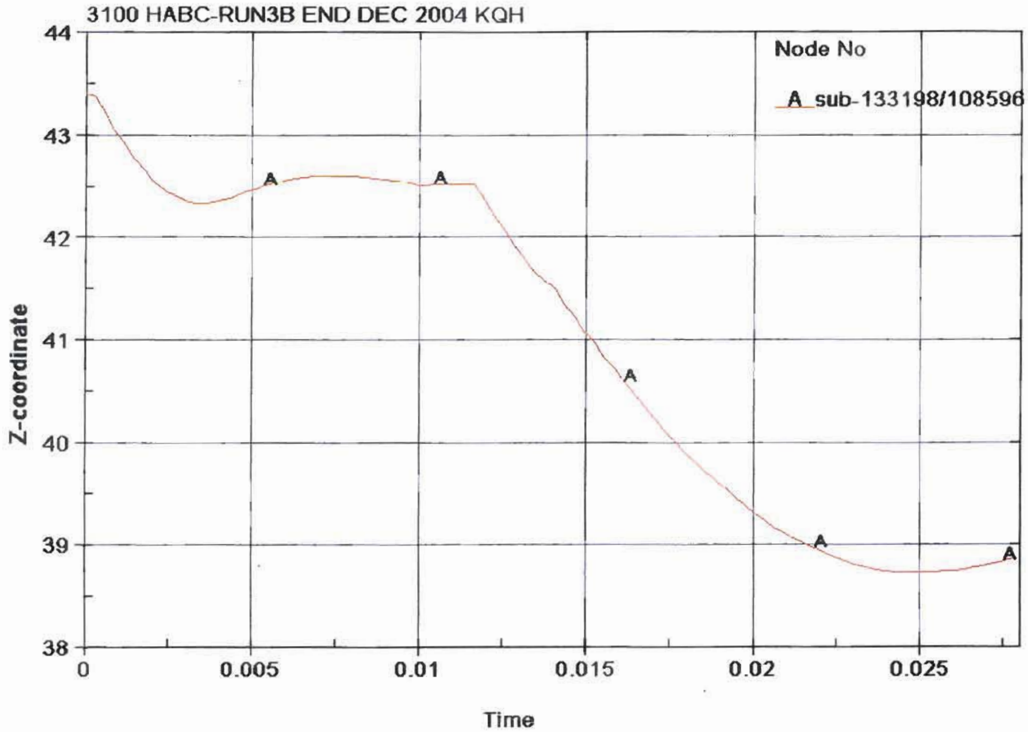


Figure 3.4.9 - HABC-run3b, Drum Height Time History

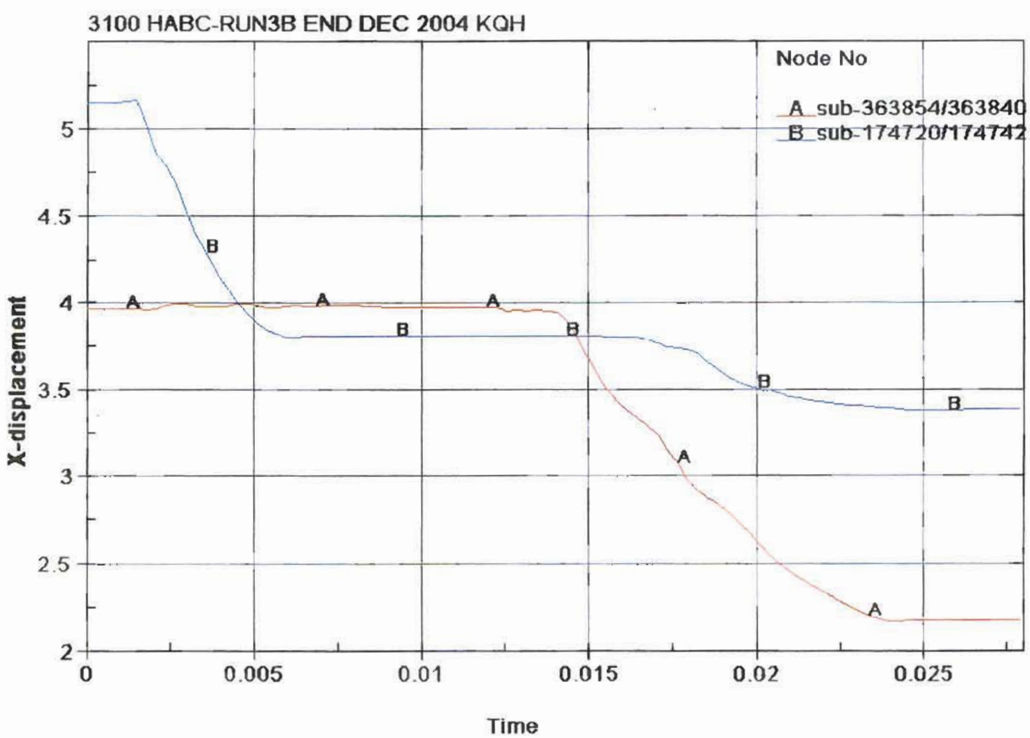


Figure 3.4.10 - HABC-run3b, Kaolite Thickness Time Histories

3.5 HABC-run4g - Slapdown

HABC-run4g is a 12° slapdown, 30-foot impact (time 0 to 0.02 seconds) followed by an offset crush with the crush plate CG over the CV flange (0.0202 to 0.04 seconds). From 0.0200 to 0.0202 sec, the crush plate is moved (via nodal velocities) such that its geometric center is approximately in line with the CV flange.

The initial configuration of the model is shown in Figure 3.5.1. The deflected shape of the package after the 30-foot impact is shown in Figure 3.5.2. Figure 3.5.3 shows enlargements of the corners of the package due to the 30-foot slapdown impact. The maximum effective plastic strain in the CV body for the 30-foot impact is 0.0376 in/in and occurs below the flange and nearest the impacted rigid surface as shown in Figure 3.5.4. Figure 3.5.5 shows that the maximum effective plastic strain in the drum is 0.3018 in/in. The maximum occurs at the bottom drum roll attachment to the drum, as is shown by the element number in the enlargement of the base region of the drum. Figure 3.5.5 does not show this by color fringes due to the nodal averaging of adjacent elements by the plot routine. The maximum strain is a highly localized bending strain in the bottom drum roll. The maximum effective plastic strain in the lid is 0.5278 in/in as shown in Figure 3.5.6. The maximum occurs due to the bearing of the lid onto the stud at the 0° position. The maximum effective plastic strains in other components for the 30-foot impact are listed in Table 3.5.1.

Table 3.5.1 - HABC-run4g, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0004
CV Nut Ring	0.0000
Angle	0.0900
Drum Bottom Head	0.2879
Liner	0.1458
Lid Stiffener	0.0213
Lid Studs	0.1892
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0724
Plug Liner	0.1258

Figure 3.5.7 shows the initial configuration for the offset impact. Figure 3.5.8 shows the final configuration for the crush impact for run4g. Figure 3.5.9 shows enlargements of the package corners after the crush.

The maximum effective plastic strain in the CV body is 0.0564 in/in as shown in Figure 3.5.10. Figure 3.5.11 shows the maximum effective plastic strain in the drum to be 0.3920 in/in, and it occurs on the crush plate side of the drum at the attachment of the angle. Figure 3.5.12 shows the lid after the offset crush impact. The maximum bending effective plastic strain is 0.9689 in/in and occurs at the 90° stud hole. The fringe range in Figure 3.5.12 has been defined to show all values near 0.57 in/in in the color red. The maximum membrane strain is 0.8935 in/in and also occurs at the 90° stud hole. This extremely high level of plastic strain is the lid response to the package trying to ovalize due to the crush impact. Due to the extreme level of effective plastic strain (>0.57 in/in), some localized tearing of the lid would be expected.

Figure 3.5.13 shows the effective plastic strain in the drum studs at the end of the crush impact, 0.4018 in/in. The stud at the 90° position has failed (evident by removed element row at the base of the stud). All of the elements on the cross section at the stud base attachment to the angle reached the prescribed failure strain of 0.57 in/in and were deleted by LS-Dyna. Therefore, the 0.4108 in/in is the plastic strain of the remaining elements. The stud elements reach failure and elements begin to be deleted at about time = 0.0311 seconds. By 0.0319 seconds, all the elements on the stud cross section have been deleted by LS-Dyna.

The lid uses a power law material model, which does not allow material failure in the model. Investigation shows that the lid reaches 0.57 in/in in membrane at about 0.0272 seconds, a time at which the stud strain is about 0.2451 in/in. This demonstrates that the lid reaches failure levels before the stud and at a time which the stud effective plastic strain is relatively low. Therefore, it would be expected that the lid would tear before the stud reaches failure. Due to the extent of the effective plastic strain fringe patterns in the lid plus the conservative modeling of the stud relative to lid shear (reference 5.1, Section 2.1 discussion), it is believed that the tearing would be local and that the lid (and by default the plug) would be restrained by the large washers. Table 3.5.2 shows the maximum effective plastic strain in the remainder of the package components for the crush impact.

Table 3.5.2 - HABC-run4g, Crush Impact, Effective Plastic Strain Levels in Some Components	
Component	Effective Plastic Strain, in/in
CV Lid	0.0013
CV Nut Ring	0.0001
Angle	0.1070
Drum	0.3920
Drum Bottom Head	0.2879
Liner	0.2060
Lid Stiffener	0.0894
Lid Stud Nuts	0.0028
Lid Stud Washers	0.0790
Plug Liner	0.2665

Figure 3.5.14 shows the CV lid separation time history. During the 30-foot impact, the maximum spikes reach the 0.0065 in range with a general gap of about 0.005 in reached. During the crush impact, the spikes in gap reach about 0.009 in, while the general separation is about 0.007 in. At the end of the crush impact, the separations appear oscillatory from 0.0 in to about 0.006 in, therefore if a permanent gap were to exist, the maximum separation would be about 0.003 in.

Figure 3.5.15 gives the kaolite thickness time history for chosen kaolite nodes. The nodes are given in Figure 3.1.17.

The nodes on the drum chosen to investigate the diameter/radius changes during the impact are shown in Figure 3.1.21. Figure 3.5.16 shows the drum diameter time histories in the X direction. Figure 3.5.17 shows the drum radial changes in the Y direction.

Figure 3.5.18 shows the diameter time history for the inner liner. The position of the nodes is shown in Figure 3.1.23.

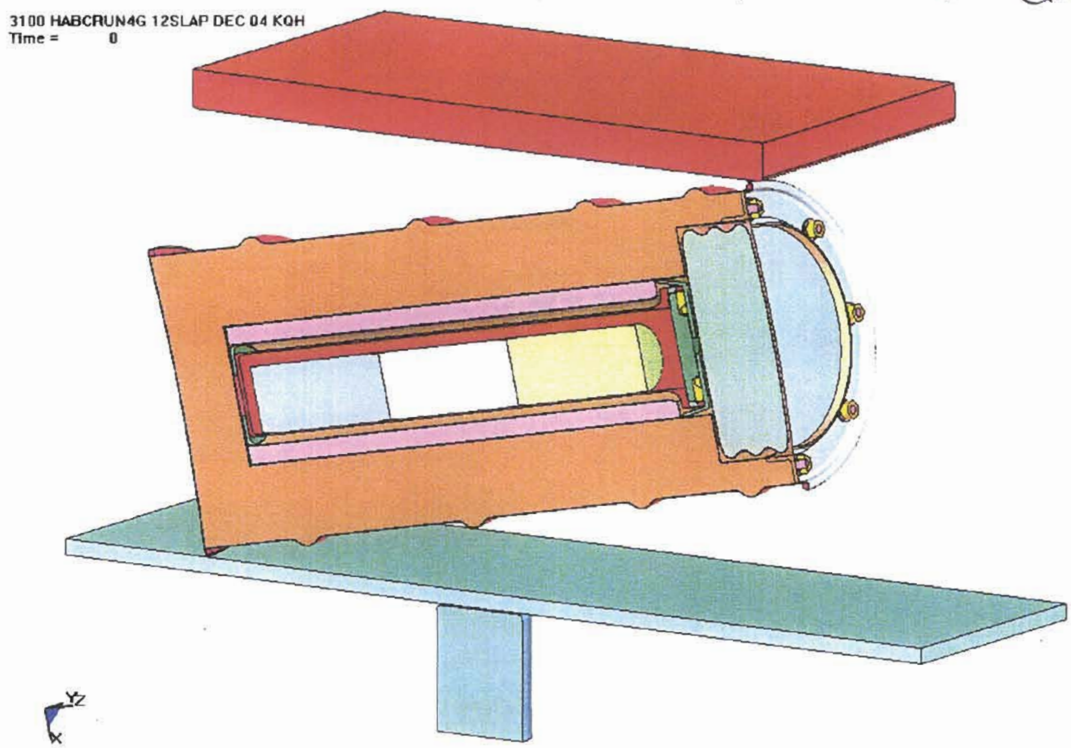
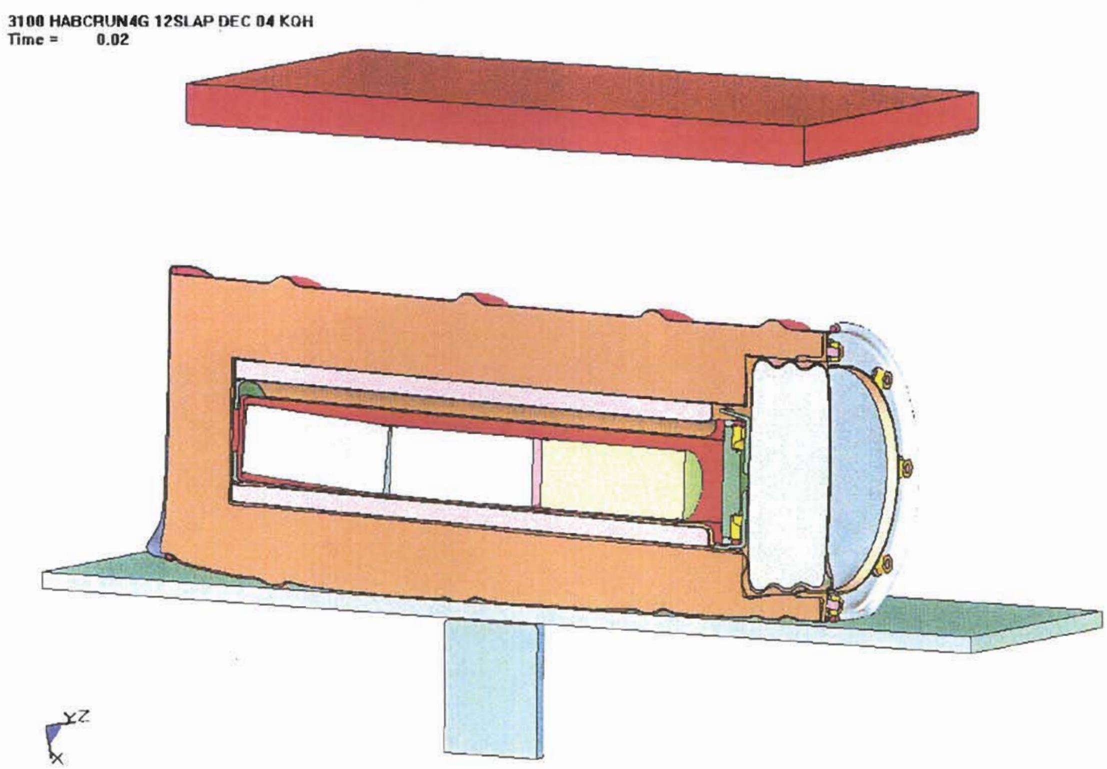


Figure 3.5.1 - HABC-run4g, 12 Degree Slapdown Initial Configuration



3.5.2 - HABC-run4g, Configuration After the 30-Foot Impact

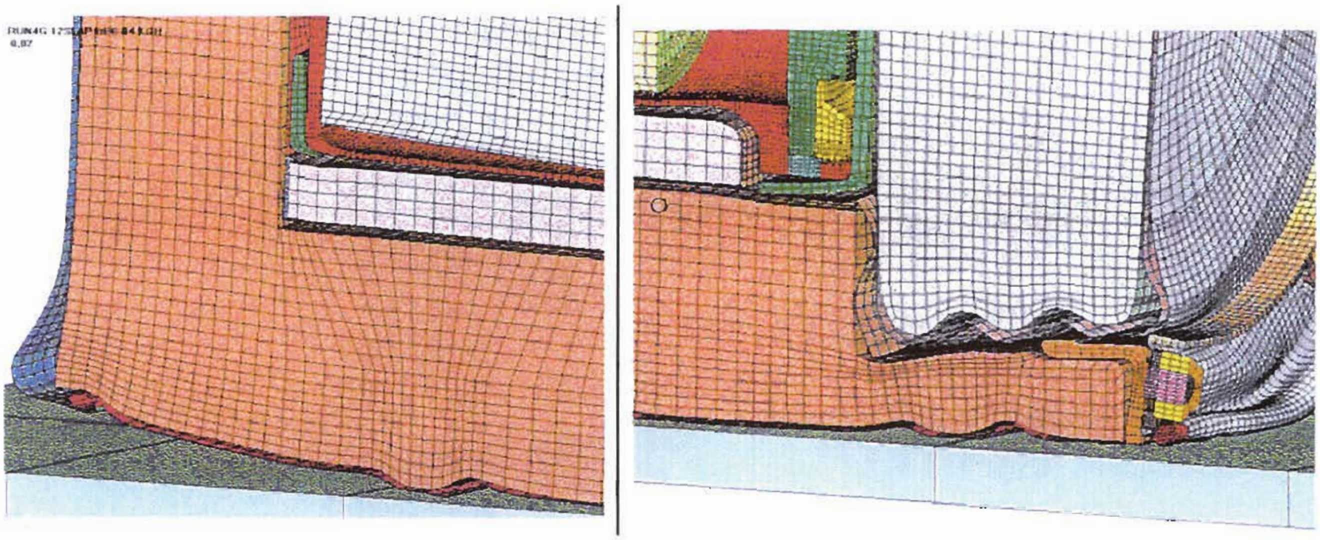


Figure 3.5.3 - HABC-run4g, 30-Foot Impact, Bottom and Lid Configurations

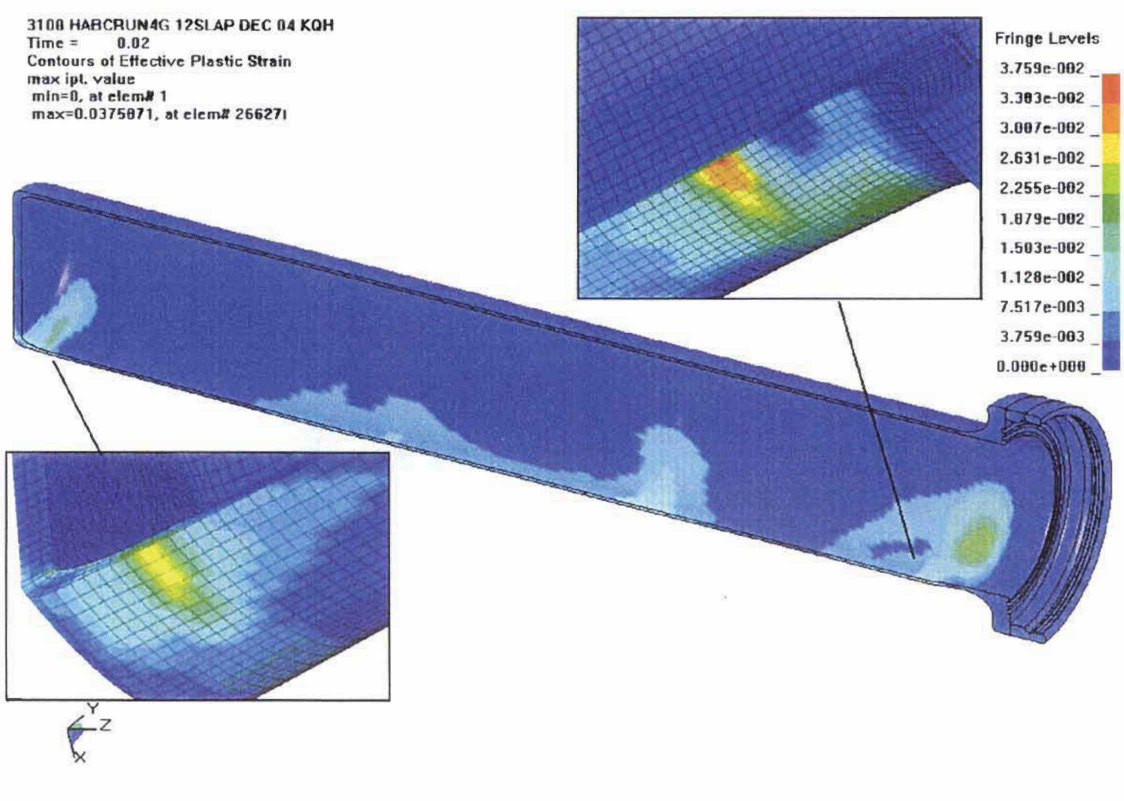


Figure 3.5.4 - HABC-run4g, 30-Foot Impact, Effective Plastic Strain in the CV Body

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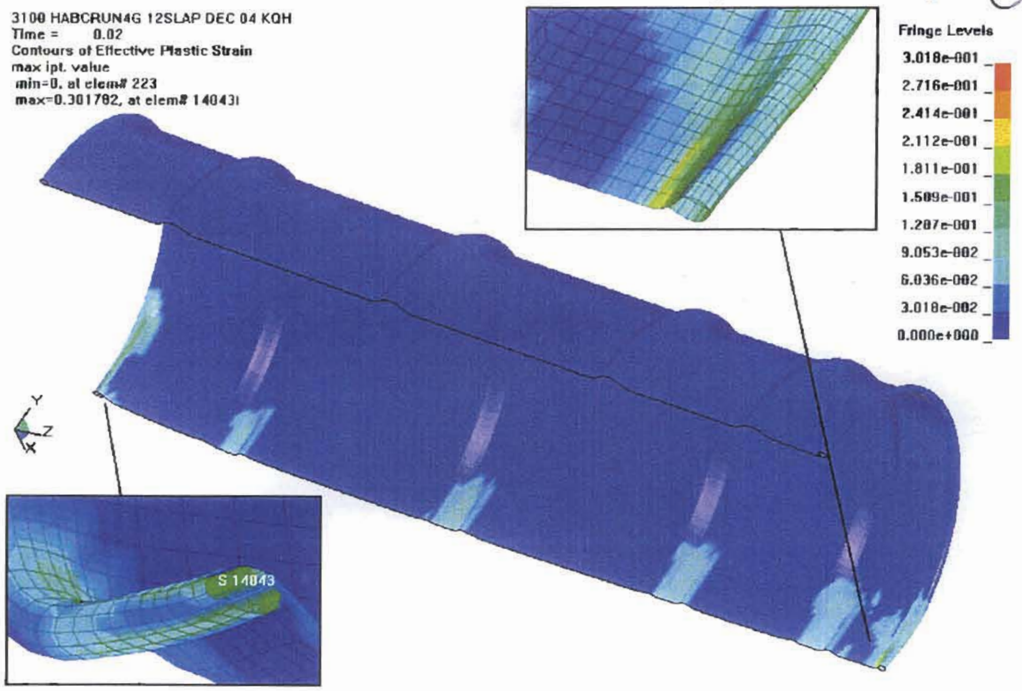

Figure 3.5.5 - HABC-run4g, 30-Foot Impact, Effective Plastic Strain in the Drum

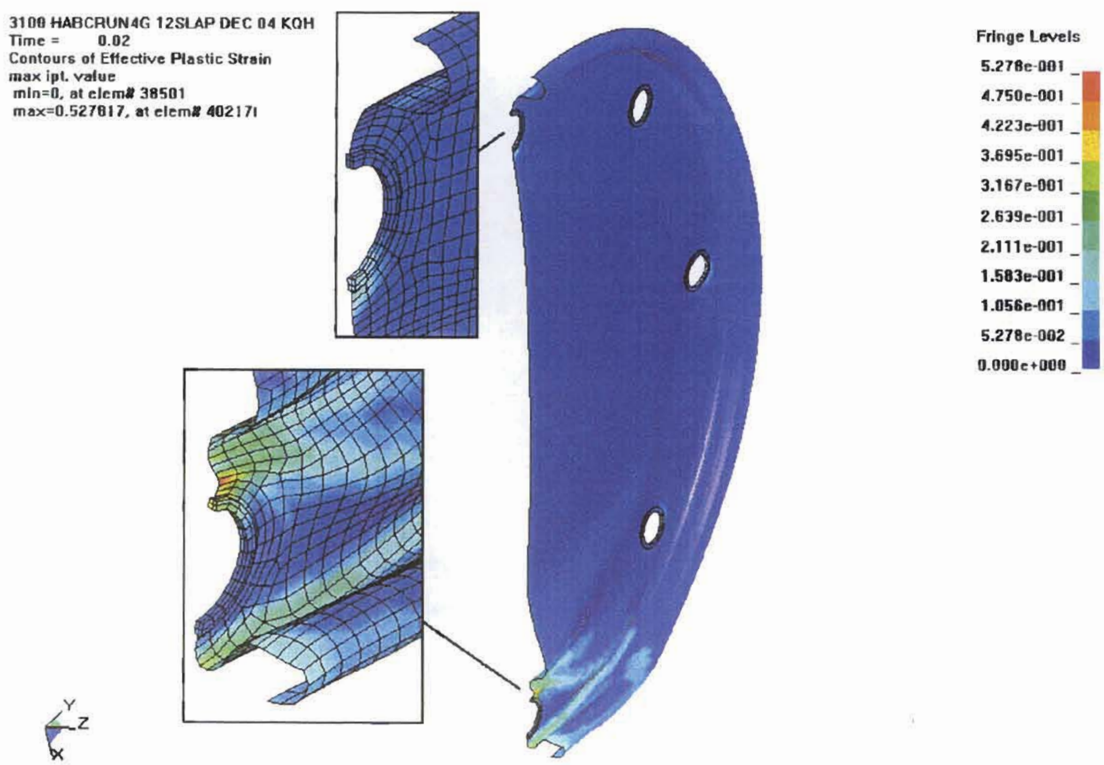

Figure 3.5.6 - HABC-run4g, 30-Foot Impact, Effective Plastic Strain in the Lid

GENERAL DESIGN AND COMPUTATION SHEET

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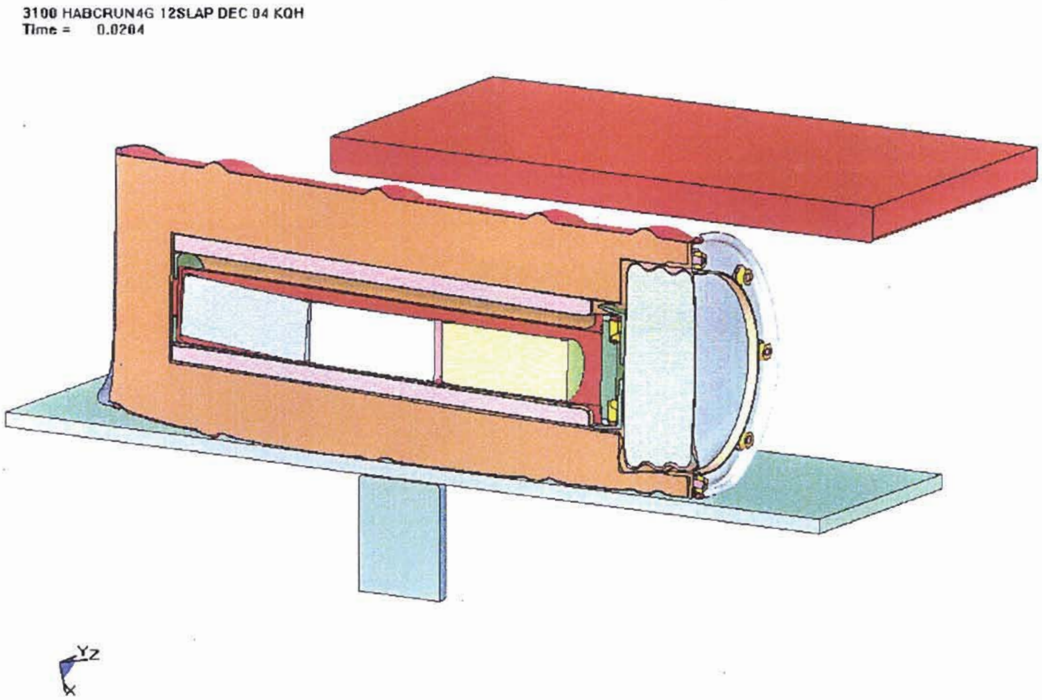

Figure 3.5.7 - HABC-run4g, Initial Configuration of the Offset Crush Impact

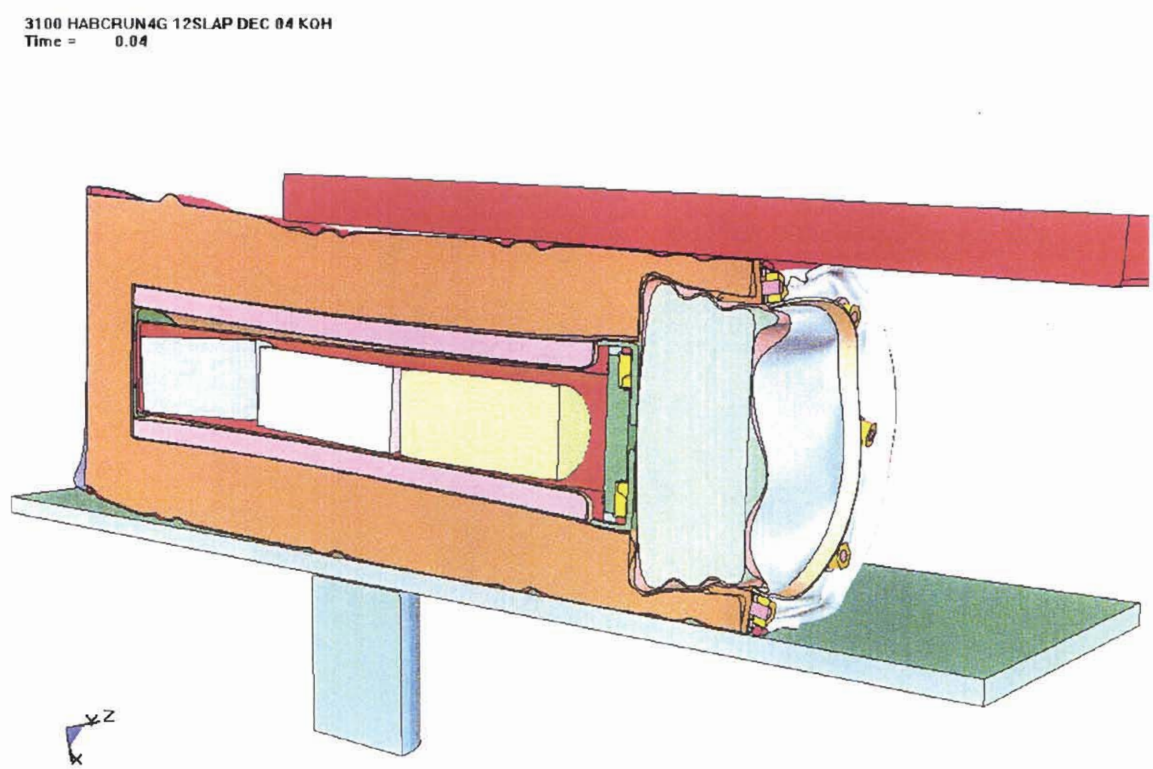

Figure 3.5.8 - HABC-run4g, Final Configuration After the Offset Crush Impact

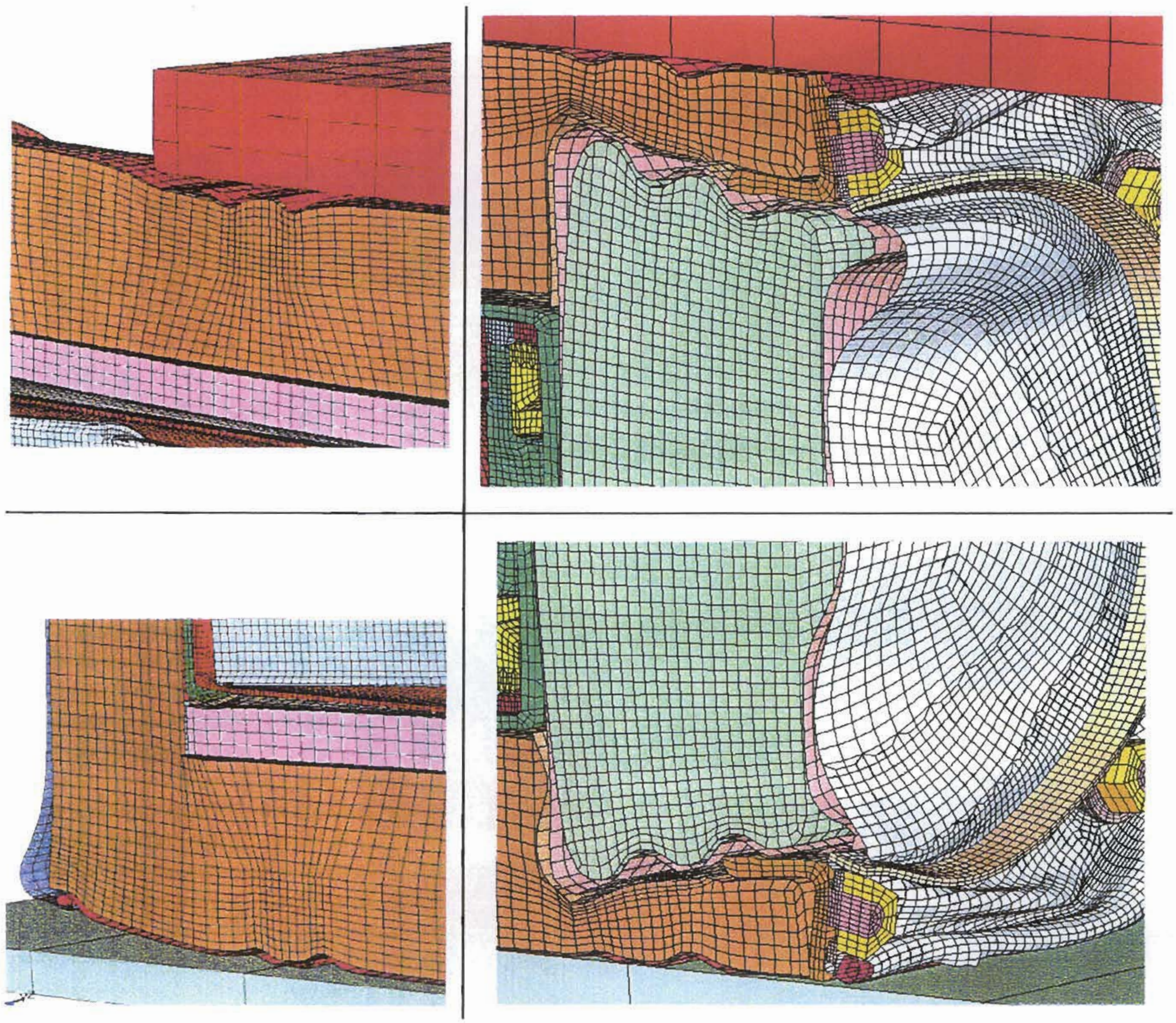

Figure 3.5.9 - HABC-run4g, Crush Impact, Enlarged Views of the Resulting Configuration

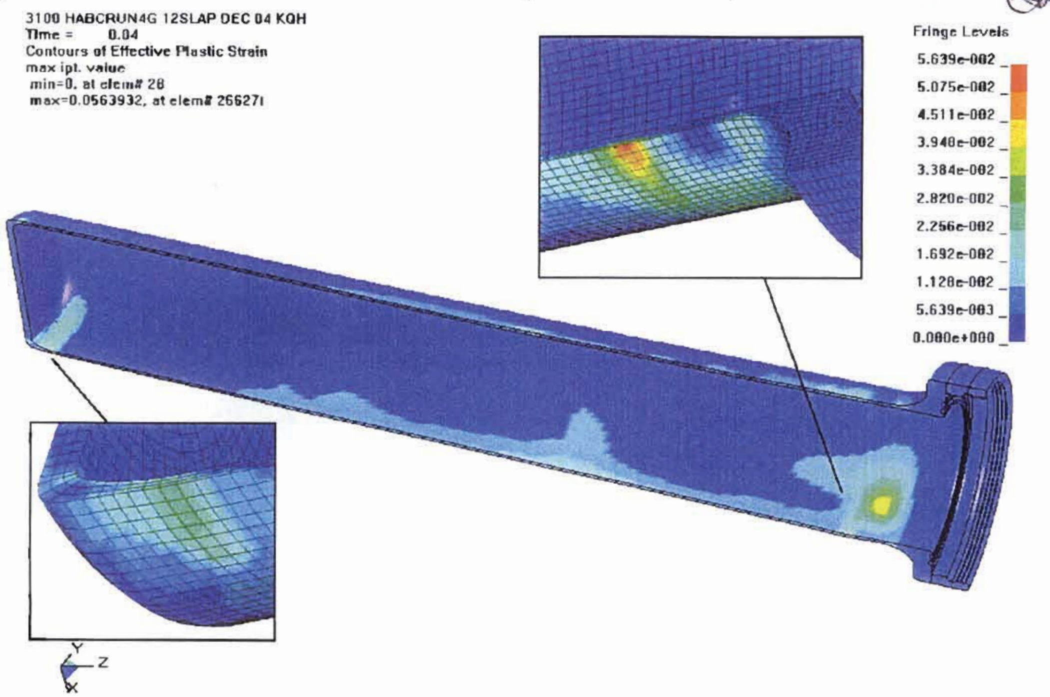

Figure 3.5.10 - HABC-run4g, Crush Impact, Effective Plastic Strain in the CV Body

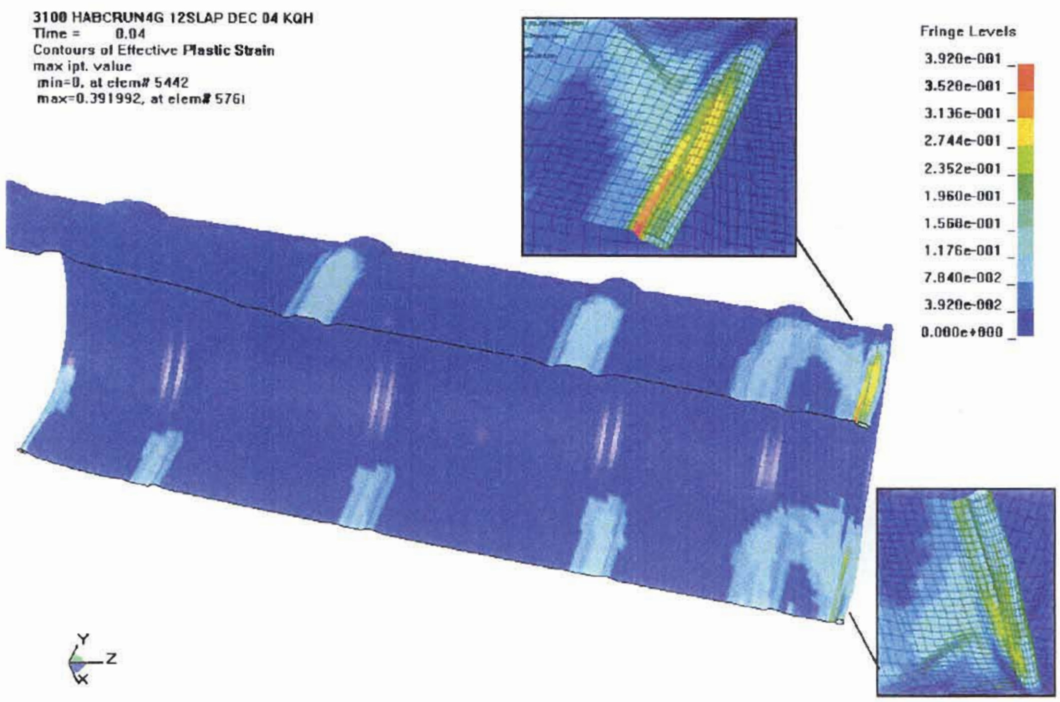

Figure 3.5.11 - HABC-run4g, Crush Impact, Effective Plastic Strain in the Drum

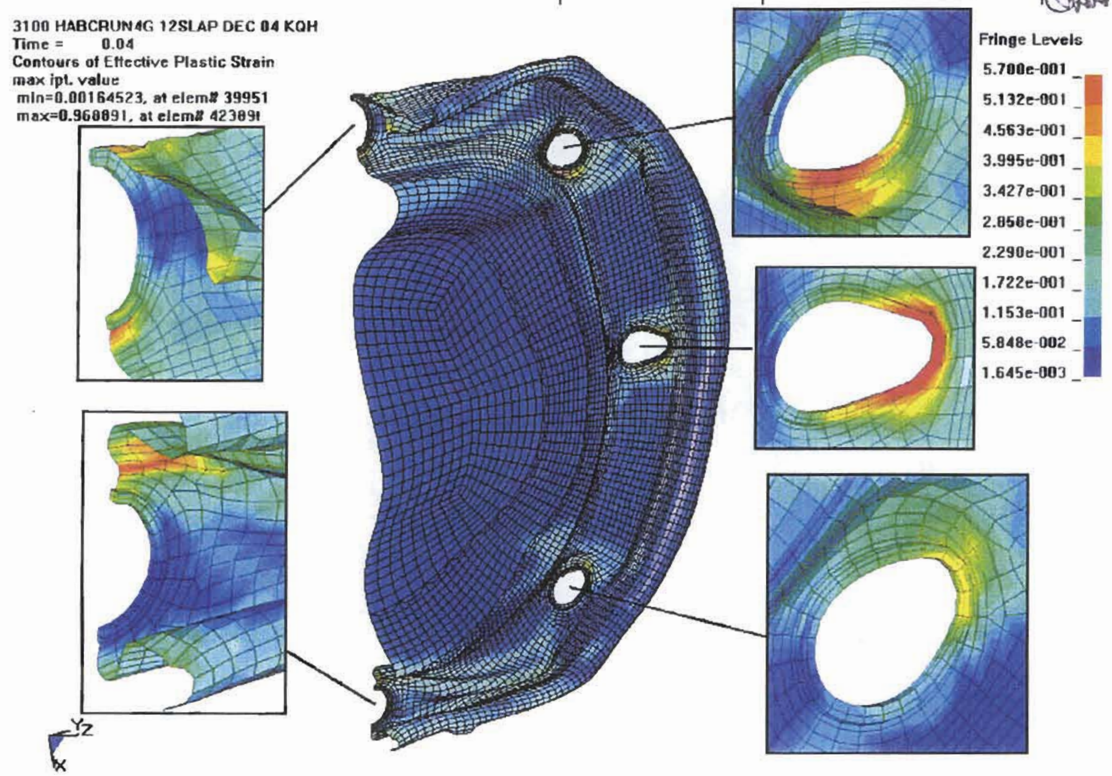

Figure 3.5.12 - HABC-run4g, Crush Impact, Effective Plastic Strain in the Lid

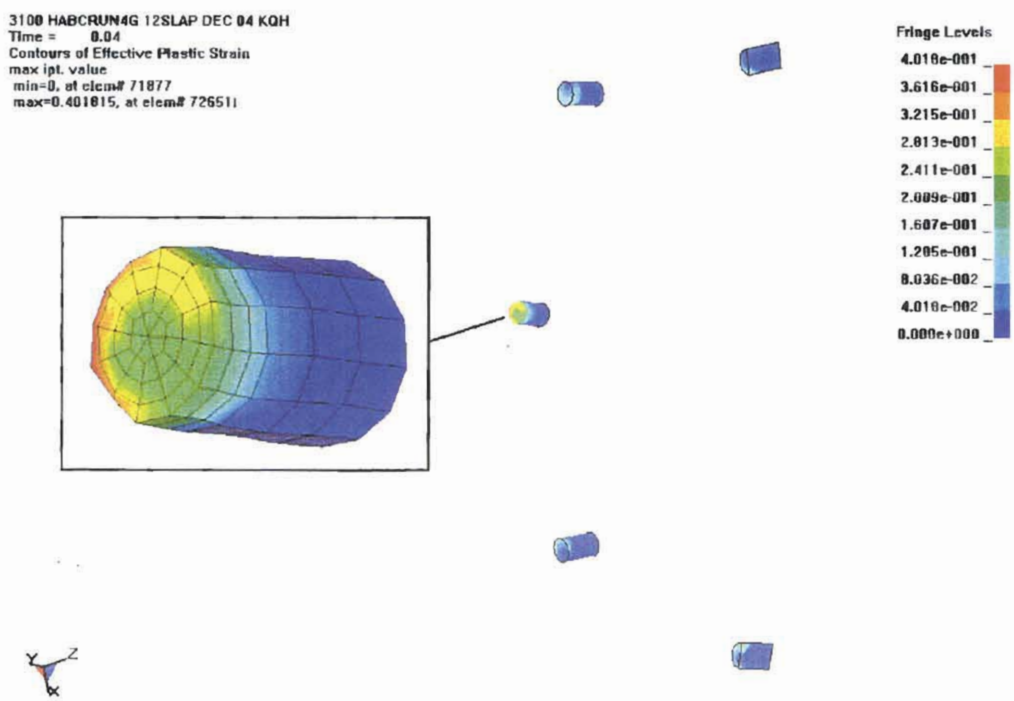

Figure 3.5.13 - HABC-run4g, Crush Impact, Effective Plastic Strain in the Studs

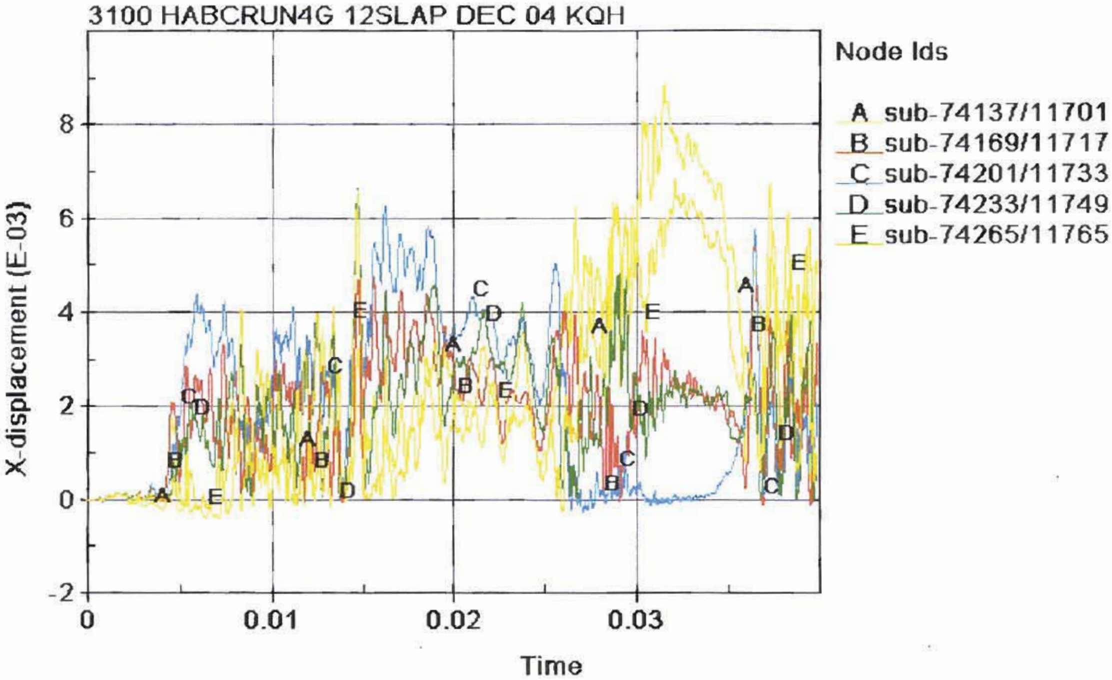

Figure 3.5.14 - HABC-run4g, CV Lid/Body Separation Time History

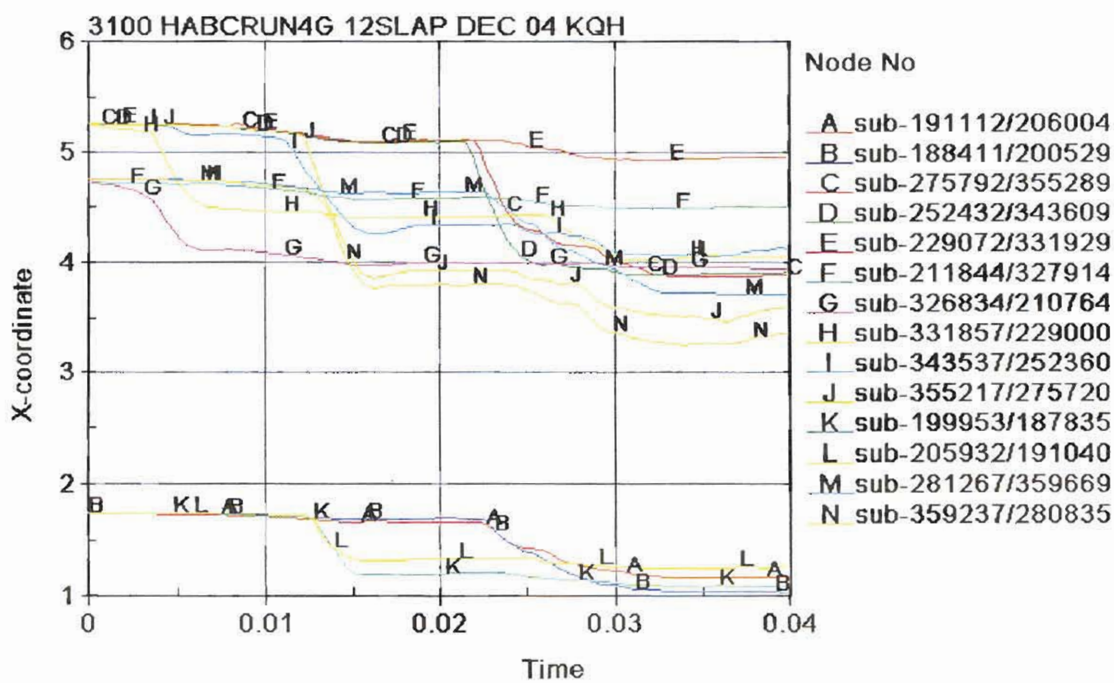

Figure 3.5.15 - HABC-run4g, Kaolite Thickness Time History

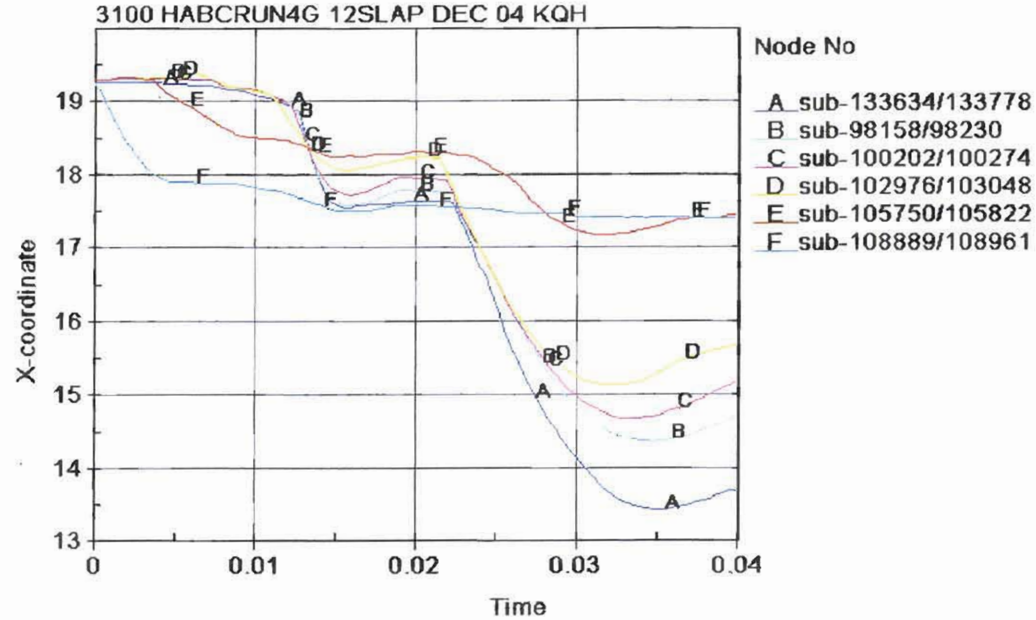

Figure 3.5.16 - HABC-run4g, Diameter Time History for the Drum in the X Direction

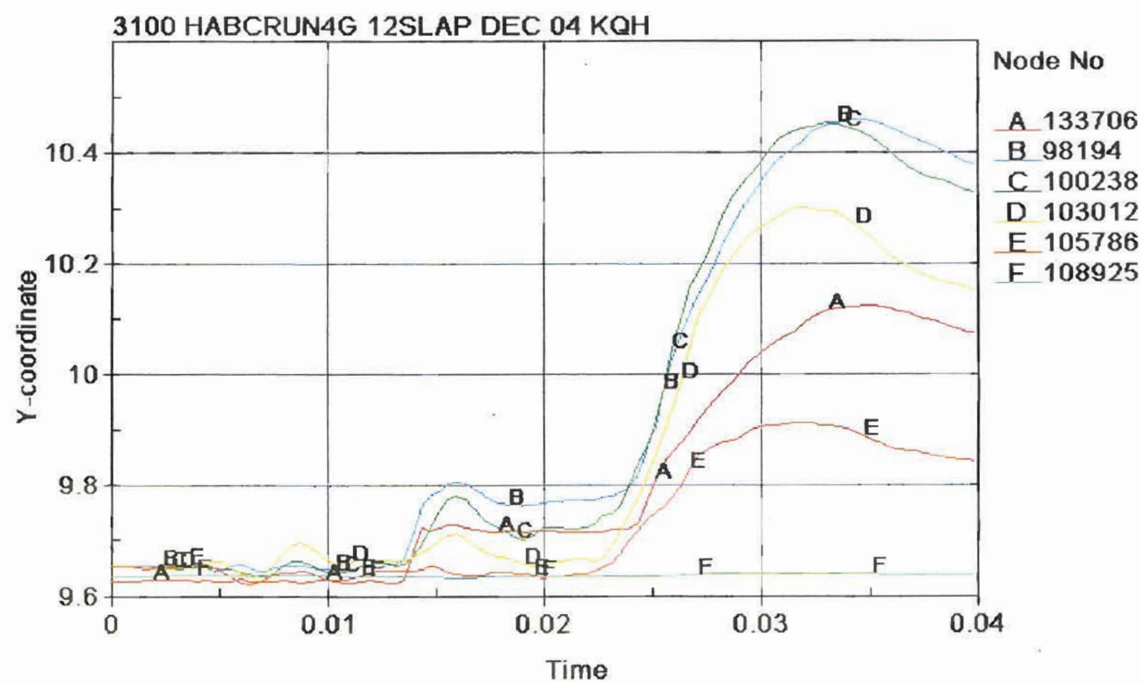

Figure 3.5.17 - HABC-run4g, Radius Time History for the Drum in the Y Direction

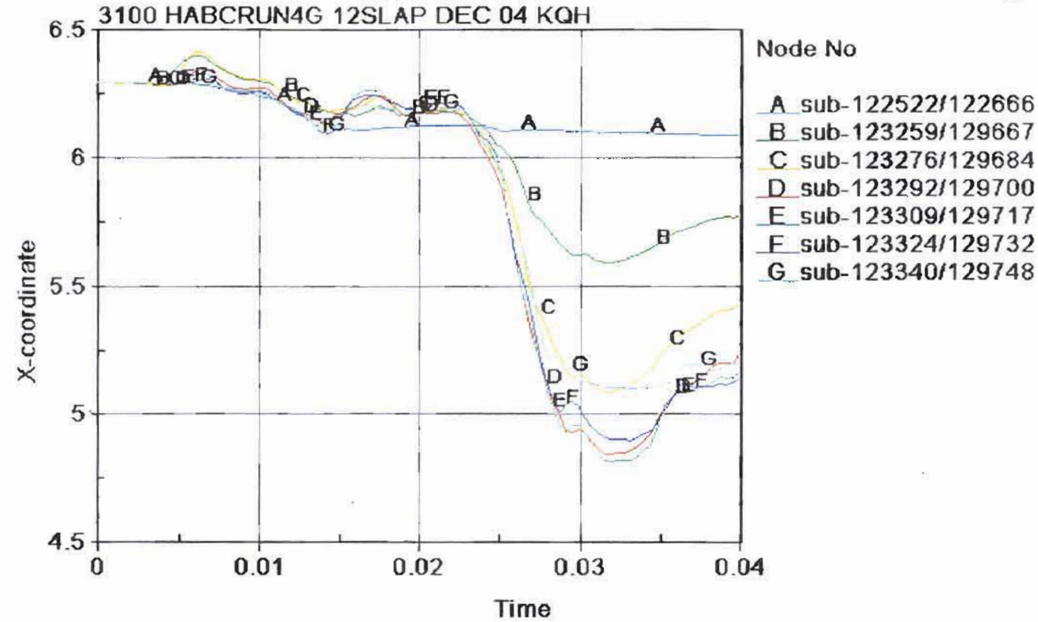

Figure 3.5.18 - HABC-run4g, Diameter Time History for the Inner Liner

3.6 HABC-run4ga - Slapdown

HABC-run4ga is a 30-foot, 12° slapdown impact (time - 0 to 0.02 sec) followed by a crush impact with the crush plate centered on the drum (0.0201 to 0.0400 sec). The HABC-run4g, 30-foot impact is the 30-foot impact for both the HABC-run4g offset crush and this HABC-run4ga centered crush. The difference between the 4g and 4ga impacts is the location to which the crush plate is moved by way of specifying velocities for specific times. In HABC-run4ga, the translation of the crush plate occurs from 0.02 to 0.0201 sec. Therefore, the 30-foot impact results are presented in Section 3.5 and the centered crush results are presented in this section (3.6).

The initial configuration for the start of the centered crush is shown in Figure 3.6.1. The final configuration for the HABC-run4ga crush impact is shown in Figure 3.6.2. Figure 3.6.3 shows the configuration at each end of the package following the centered crush impact.

The maximum effective plastic strain in the CV body is shown to be 0.0643 in/in in Figure 3.6.4. The maximum occurs in the body side wall, on the side nearest the crush plate. Figure 3.6.5 shows the fringes of effective plastic strain in the drum. The maximum strain in the drum is 0.3443 in/in and occurs near the lid in the crimped region shown in the enlarged view. Figure 3.6.6 shows that the maximum effective plastic strain in the lid is 0.5828 in/in. The maximum occurs at the 180° stud hole, and is localized. This value is a surface, or bending strain, the membrane strain is 0.4736 in/in. Therefore, the bending strain is above the failure limit of 0.57 in/in, however the membrane strain is below the limit. Some cracking may occur, but tearing of the lid is not expected. The large washers would provide restraint of the lid.

Table 3.6.1 presents the maximum effective plastic strain in other shipping package components for the run4ga crush impact.

Table 3.6.1 - Run4ga, Crush Impact, Effective Plastic Strain Levels in Some Components	
Component	Effective Plastic Strain, in/in
CV Lid	0.0018
CV Nut Ring	0.0000
Angle	0.0944
Drum Bottom Head	0.3000
Liner	0.2846
Lid Stiffener	0.0288
Lid Studs	0.2390
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0775
Plug Liner	0.1644

The CV lid separation time history is shown in Figure 3.6.7. For the crush impact (0.0201 to 0.0400 sec) the spikes in the gap reach just over 0.01 in. The general gap during the impact reaches about 0.009 in. At the time the impact was halted, the maximum separation was on the order of 0.006 in.

Figure 3.6.8 shows the kaolite thickness time history. The nodes chosen are shown in Figure 3.1.17

Figure 3.6.9 shows the X direction diameter changes in the drum. Figure 3.6.10 shows the Y direction radial changes in the drum. Figure 3.1.21 shows the location of the nodes in the Figure 3.6.9 and 3.6.10 time histories.

Figure 3.6.11 shows the diameter time history for the inner liner. The position of the nodes are shown in Figure 3.1.23.

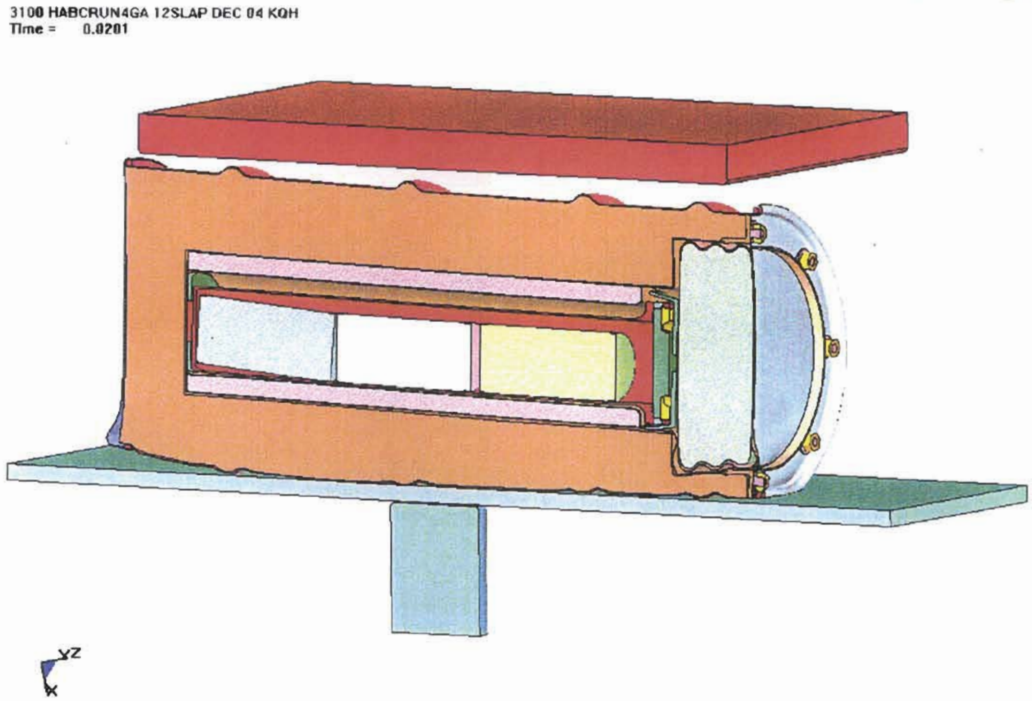

Figure 3.6.1 - HABC-run4ga, Initial Configuration for the Centered Crush Impact

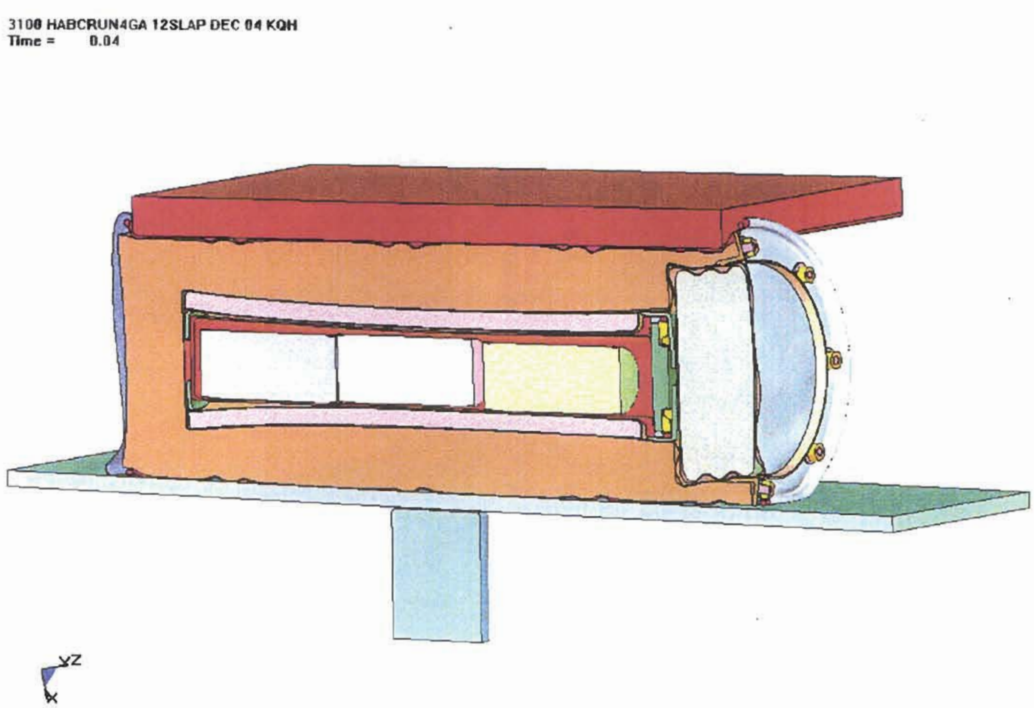

Figure 3.6.2 - HABC-run4ga, Final Configuration of the Centered Crush Impact

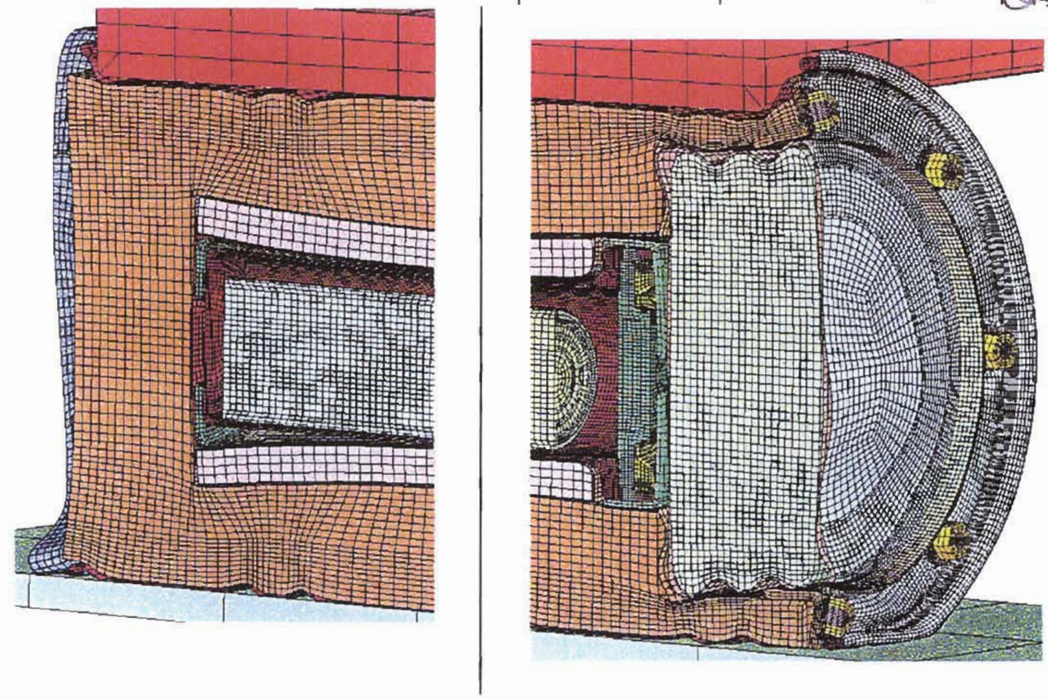

Figure 3.6.3 - HABC-run4ga, Crush Impact, Configurations at the Package Ends

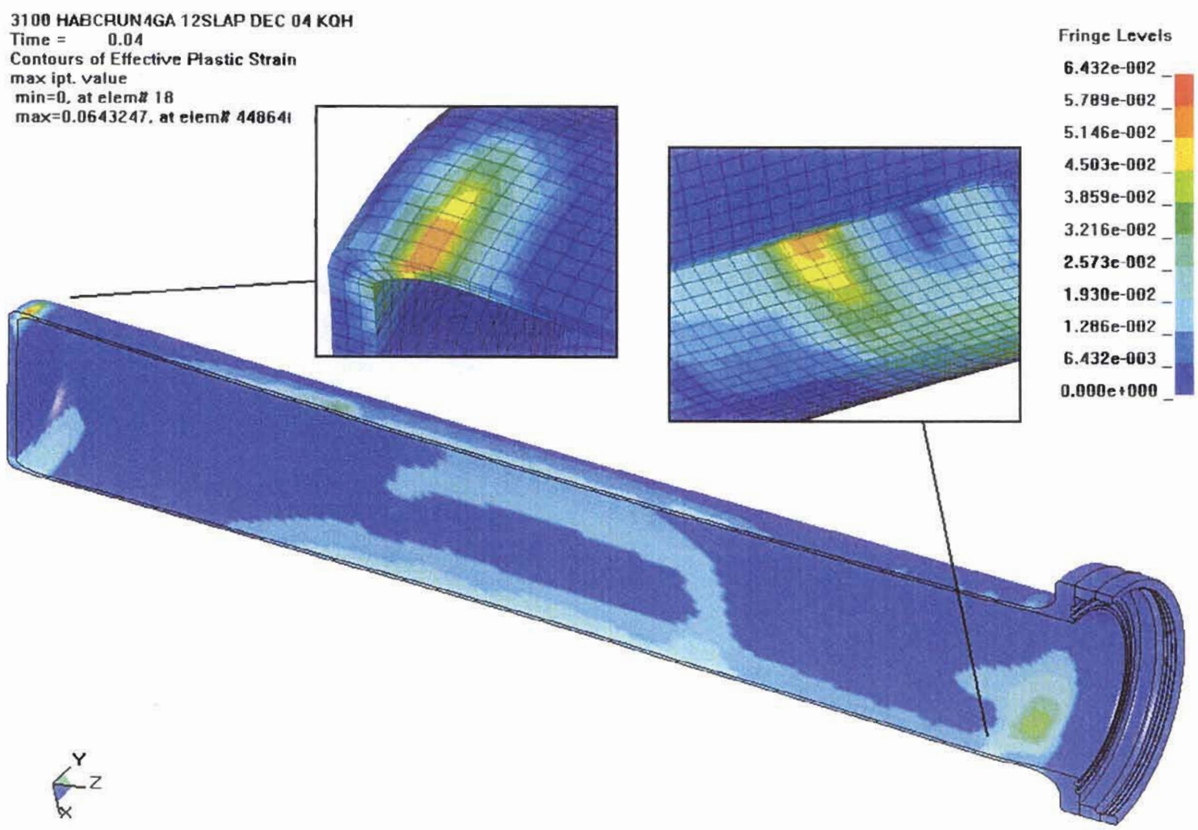

Figure 3.6.4 - HABC-run4ga, Crush Impact, Effective Plastic Strain in the CV Body

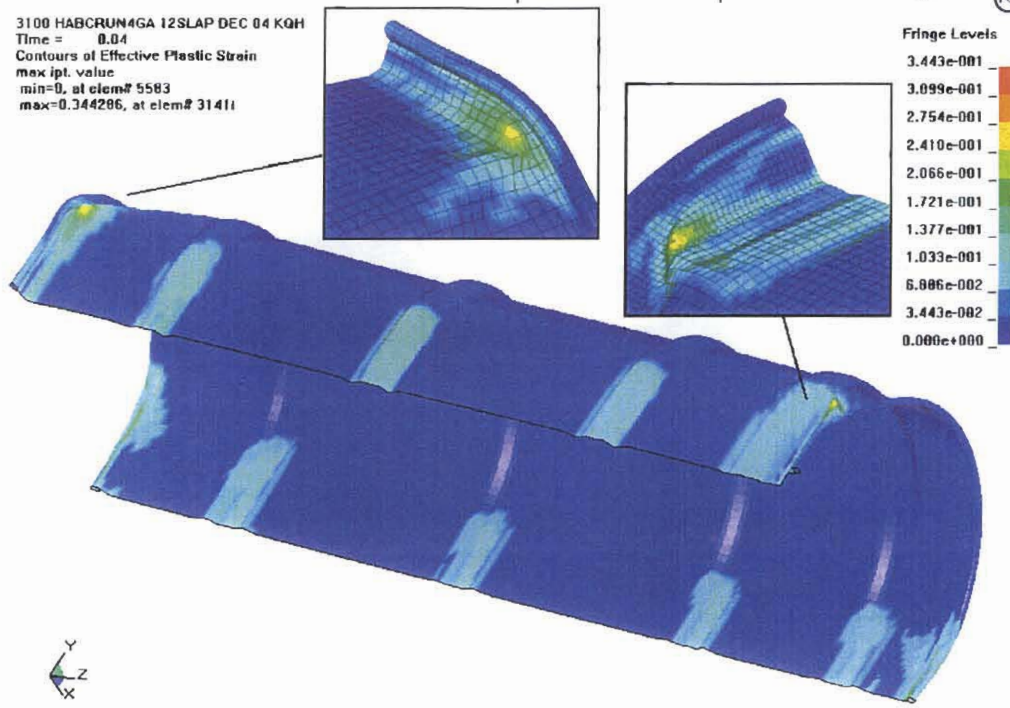

Figure 3.6.5 - HABC-run4ga, Crush Impact, Effective Plastic Strain in the Drum

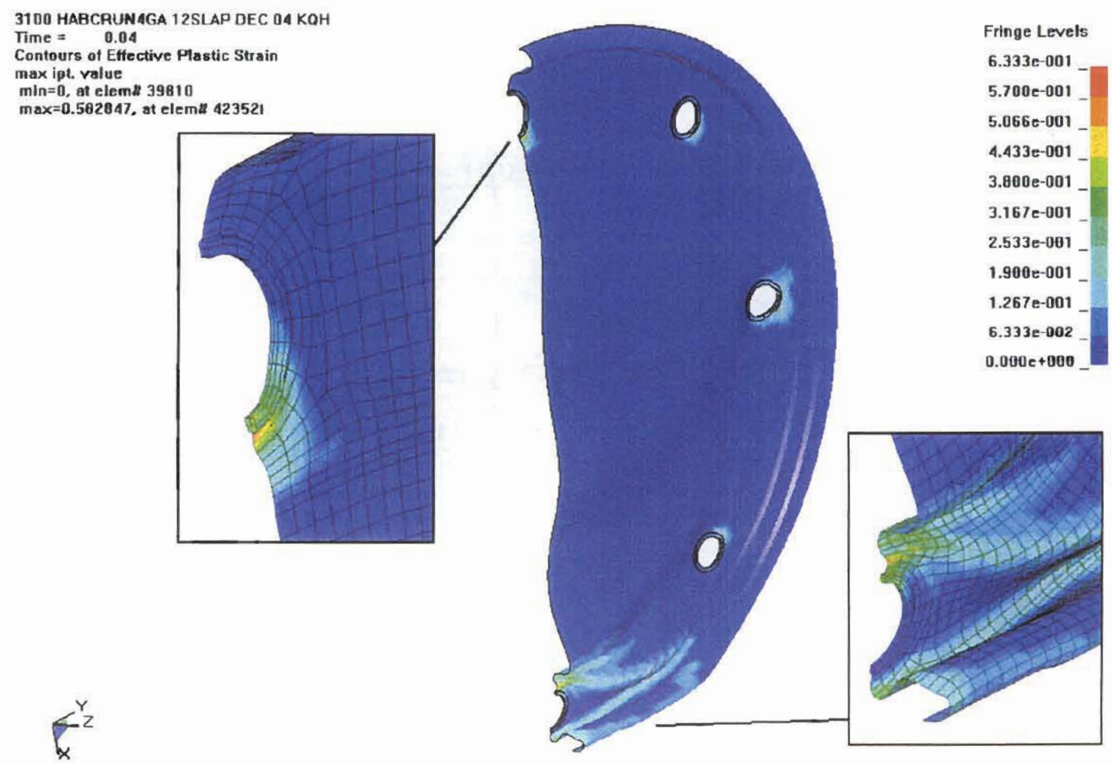

Figure 3.6.6 - HABC-run4ga, Crush Impact, Effective Plastic Strain in the Lid

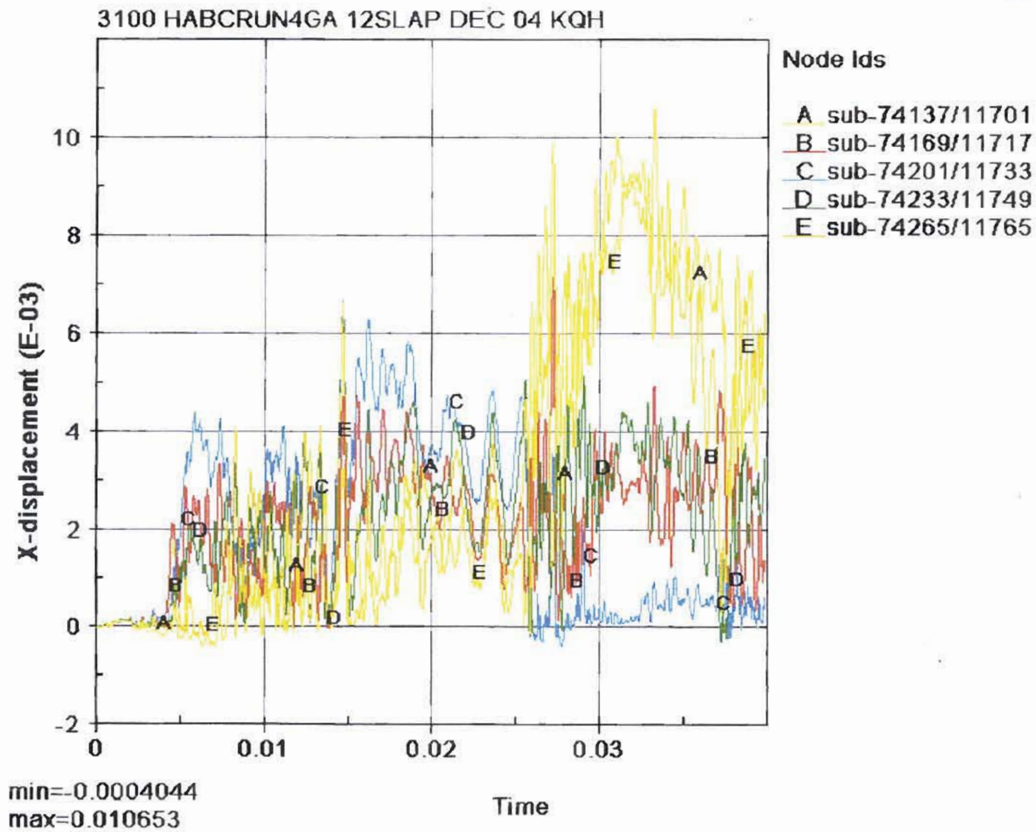

Figure 3.6.7 - HABC-run4ga, CV Lid Separation Time History

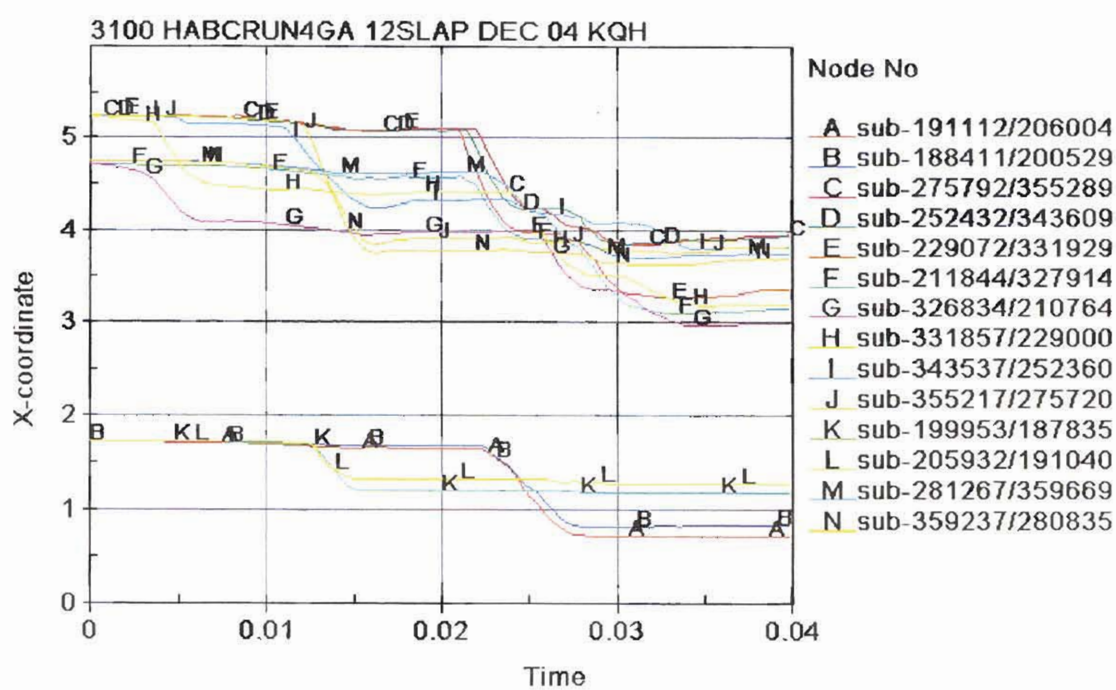

Figure 3.6.8 - HABC-run4ga, Kaolite Thickness Time History

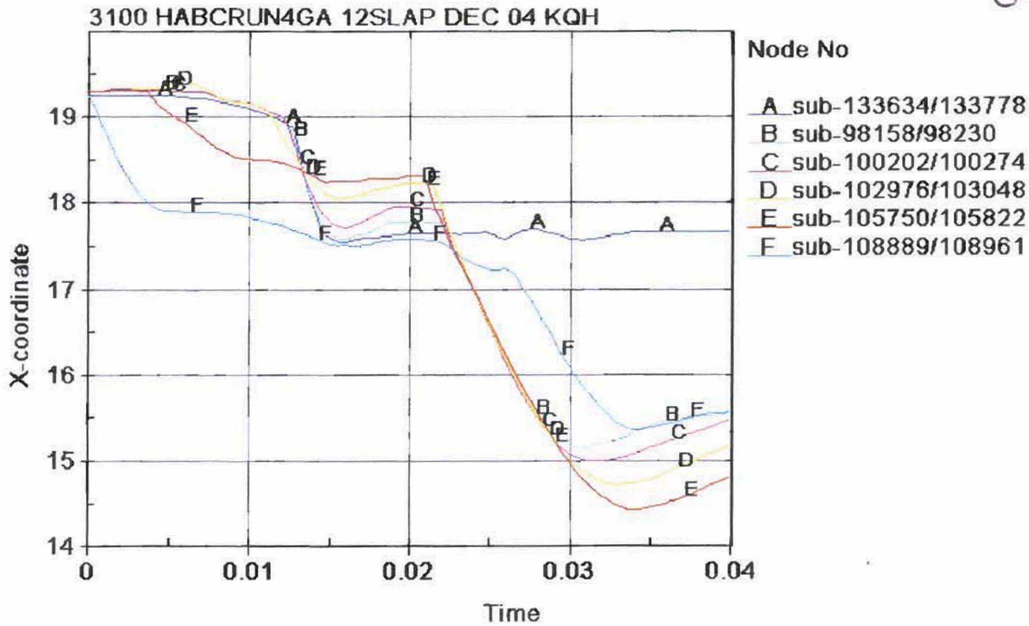

Figure 3.6.9 - HABC-run4ga, Diameter Time History for the Drum in the X Direction

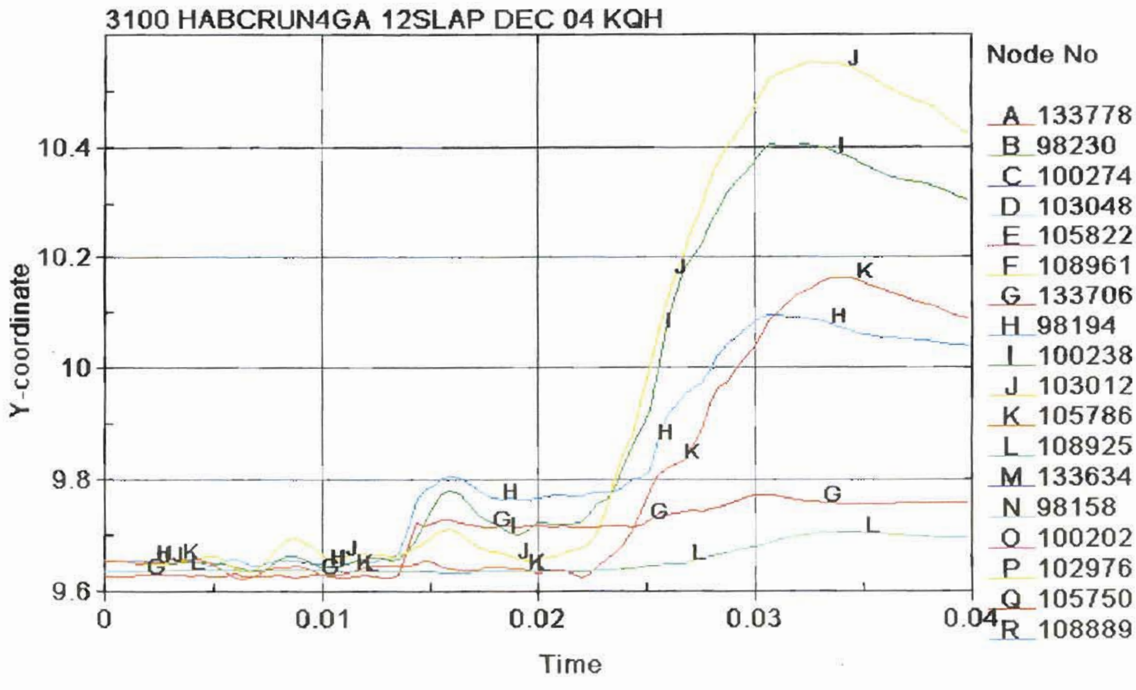

Figure 3.6.10 - HABC-run4ga, Radius Time History for the Drum in the Y Direction

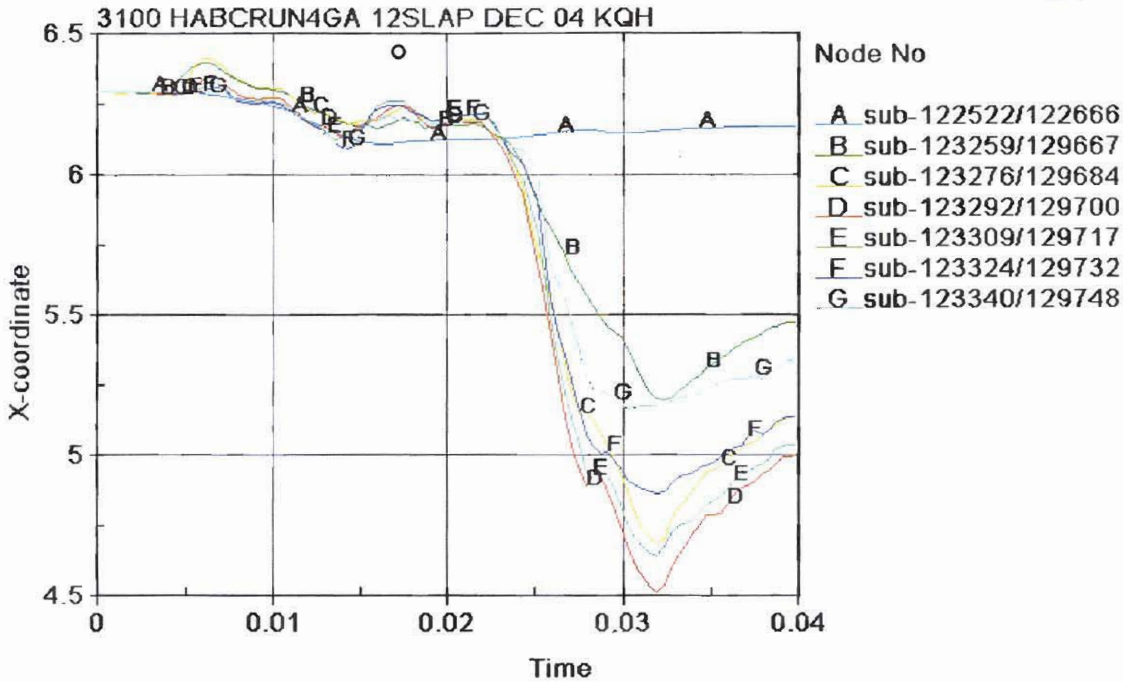

Figure 3.6.11 - HABC-run4ga, Diameter Time History for the Inner Liner

3.7 Comparison of Test vs Analysis

The HABC analysis runs are compared to the test results similar to that performed in Reference 5.1, Section 3.12 for the initial design using borobond. It should be noted that the testing was with specimen of the borobond neutron absorber design, whereas the analysis models in this section are of the HABC design. The Figure 3.7.1 sketch shows the locations at which test measurements was made.

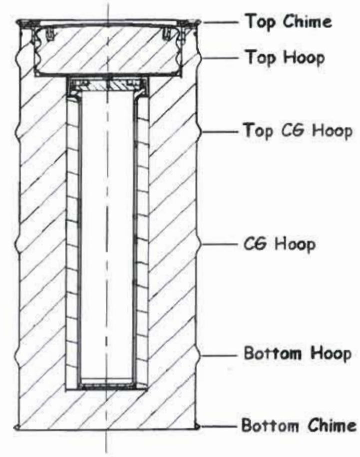

Figure 3.7.1 - Test Measurement Locations

3.7.1 Comparison of HABC Run4g to TU1

The HABC-run4g is a 30-foot, 12° slapdown impact followed by an offset crush (crush plate centered over the CV flange). TU1 is a 12° slapdown with a 4-foot impact, 30-foot impact, offset crush, and punch test specimen. The following Table 3.7.1.1 shows the initial diameter comparisons (pre-impact) using the test data compared to the analysis results.

Table 3.7.1.1 - HABC-run4g vs TU1, Comparison of Initial Diameters (Pre-Impact)

Location	0°- 180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	19.25	19.32	19.25	19.32
Top Hoop	19.25	19.37	19.25	19.37
Top CG Hoop	19.25	19.37	19.25	19.37
CG Hoop	19.25	19.37	19.25	19.37
Bottom Hoop	19.25	19.37	19.25	19.37
Bottom Chime	19.25	19.38	19.25	19.38

The Table 3.7.1.2 shows the results of the 30-foot test and analysis impacts. The test diameters are for 4 and 30-foot impacts, while the analysis is after the 30-foot impact.

Table 3.7.1.2 - HABC-run4g vs TU1, Diameter Results After the 30-Foot Impact

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	18-1/2	18.1	19-3/8	19.5
Top Hoop	18-1/2	18.2	19-3/8	19.6
Top CG Hoop	18-1/2	18.4	19-3/8	19.5
CG Hoop	18-5/8	18.8	19-3/8	19.4
Bottom Hoop	18-5/8	18.9	19-1/4	19.3
Bottom Chime	17-13/16	18.1	19-3/8	19.4

Figure 3.7.1.1 shows the final configuration of the test specimen after the 4-foot and 30-foot impacts. Figure 3.7.1.2 shows the analytical model configuration after the 30-foot impact.

Figure 3.7.1.1 - TU1, Results of 30-Foot Impact

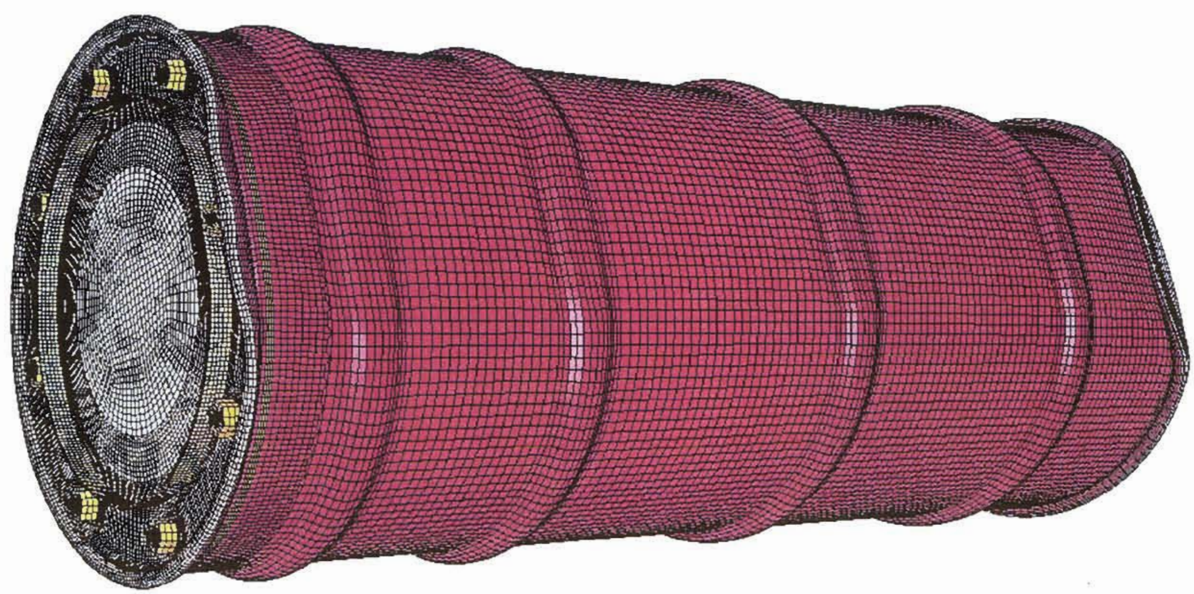

Figure 3.7.1.2 - HABC-run4g, Results of the 30-Foot Impact

Table 3.7.1.3 shows the comparison of the results of the crush impacts. The test data is for the cumulative effects of a 4-foot, 30-foot, and crush impact. The analysis data is for a cumulative 30-foot impact and crush impact.

Table 3.7.1.3 - Run4g vs TU1, Diameter Results After the Crush Impact

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	15-5/8	14.9	20-5/8	20.7
Top Hoop	16	15.1	20-7/16	20.8
Top CG Hoop	16-1/4	15.7	20-1/4	20.7
CG Hoop	16-1/2	16.2	19-7/8	20.4
Bottom Hoop	18-1/4	18.1	19-1/2	19.8
Bottom Chime	17-13/16	18.0	19-1/4	19.4

Figure 3.7.1.3 shows an isometric view of the test specimen with the crush side up. Figure 3.7.1.4 shows a similar view for the analysis results.

Figure 3.7.1.3 - TU1, View of Crush Damage with the Crush Side Up

Figure 3.7.1.4 - HABC-run4g, View of the Crush Damage, Crush Side Up

Table 3.7.1.4 shows the results of a comparison of the "flats" measurements from the test after the 30-foot impacts and Table 3.12.1.5 compares the crush impact results.

Table 3.7.1.4 - HABC-run4g vs TU1, Comparison of Flats for the 30-Foot Impact

	Test	Analysis
Top Chime	8	8.8
Top Hoop	7-3/8	8.4
Top CG Hoop	7-1/8	7.6
CG Hoop	6-3/8	5.9
Bottom Hoop	6-3/4	5.9
Bottom Chime	10	10.1

Table 3.7.1.5 - HABC-run4g vs TU1, Comparison of Flats for the Crush Impact

Location	Rigid Surface Side		Crush Plate Side	
	Test	Analysis	Test	Analysis
Top Chime	9	10.5	8-1/2	10.9
Top Hoop	10	11.0	10	11.0
Top CG Hoop	10	10.1	10-1/8	10.1
CG Hoop	9	8.4	10-5/8	10.1
Bottom Hoop	8-1/4	7.6	---	0.0
Bottom Chime	9-7/8	10.1	---	0.0

3.7.2 Comparison of HABC Run2e vs TU3

The HABC-run2e is a CG over lid corner 30-foot impact, followed by a bottom corner crush. TU3 is a similar test impact configuration with a 4-foot impact, 30-foot impact on the lid corner, then a crush impact on the bottom corner followed by a punch.

The test results show that there is 1.125 inches between the top chime and the top hoop in the test. Similar measurements in the analysis show that the distance is about 1.7 inches. This would be a somewhat judgmental comparison due to points chosen for measurement on the test specimen might not be the same as those chosen in the analysis. The analysis measurement is from the top of the crimped drum roll to the center of the flattened region in the lid roll, on the plane of symmetry.

Table 3.7.2.1 shows the comparison of the TU3 test unit and the computer run2e drum diameter changes after the 30-foot impact.

Table 3.7.2.1 - Run2e vs TU3, Diameter Results After the 30-Foot Impact

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	19-1/4	19.0	19-3/16	19.2
Top Hoop	18-5/8	19.1	19-7/8	20.0
Top CG Hoop	19-1/8	19.3	19-3/8	19.5
CG Hoop	19-1/8	19.4	19-3/8	19.4
Bottom Hoop	19-1/8	19.4	19-1/4	19.4
Bottom Chime	19-1/8	19.4	19-3/8	19.4

Figure 3.7.2.1 is an image of the damage after the 30-foot impact of TU3. The test photo shows the cumulative damage from the 4-foot and 30-foot impacts. Figure 3.7.2.2 shows a similar view after the 30-foot impact in run2e. The analysis image is the damage from only the 30-foot impact.

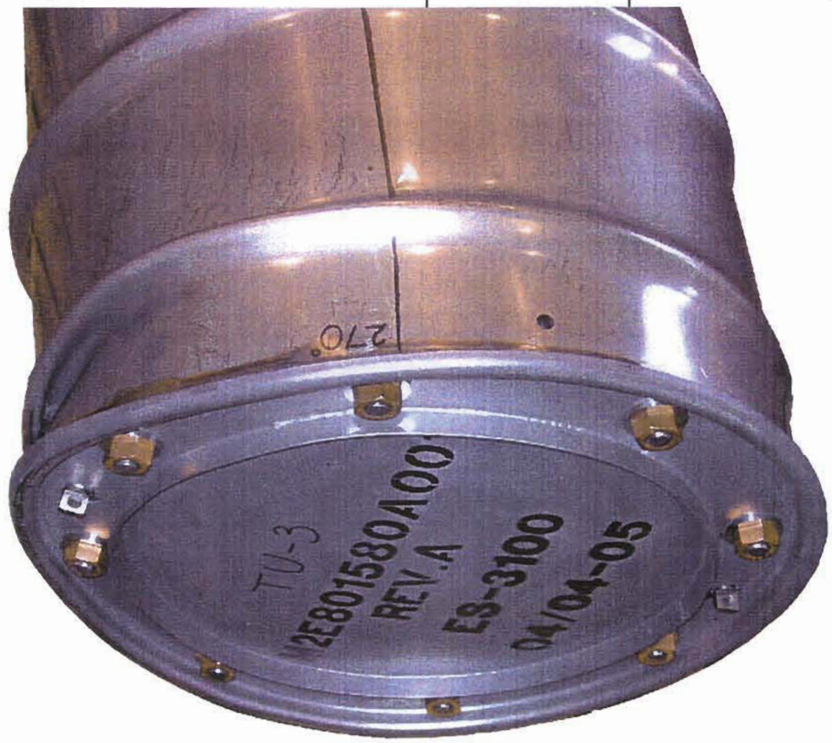

Figure 3.7.2.1 - TU3, Deformed Shape After the 30-Foot Impact

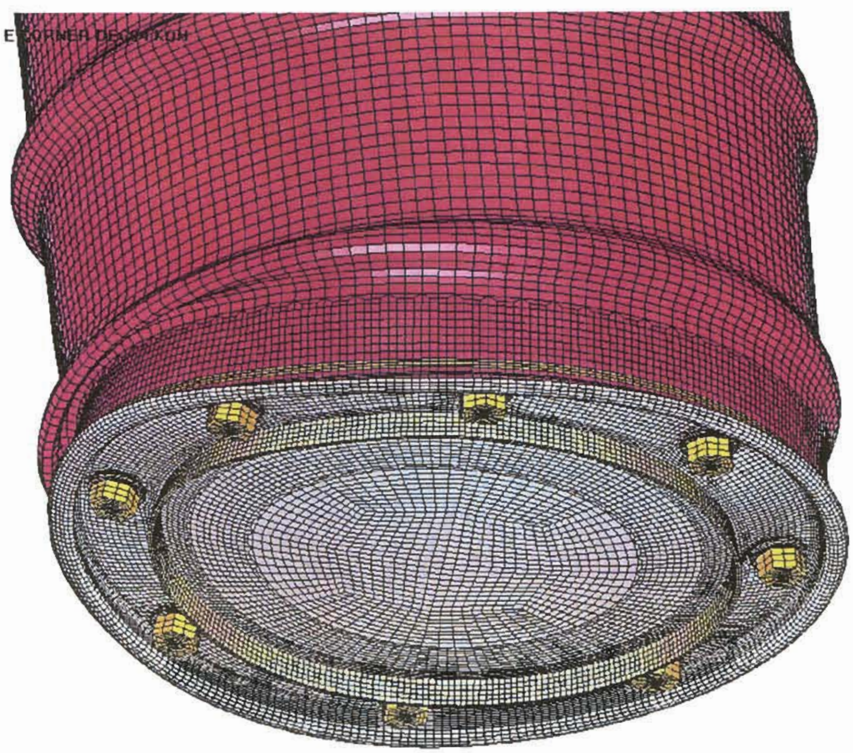

Figure 3.7.2.2 - HABC-run2e, Deformed Shape After the 30-foot Impact

The package drum diameters after the crush impact are compared in Table 3.7.2.2.

Table 3.7.2.2 - Run2e vs TU3, Diameter Results After the Crush Impact

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	19-1/4	19.0	19-1/16	19.0
Top Hoop	18-3/4	18.9	20-1/4	20.6
Top CG Hoop	19-1/4	19.4	19-3/4	19.8
CG Hoop	19-1/8	19.3	19-1/4	19.4
Bottom Hoop	19-1/8	19.3	19-3/4	20.4
Bottom Chime	18	18.6	19-3/8	19.4

The final images after the crush impact are shown for the test and the analysis. Figure 3.7.2.3 shows the final shape of the crushed bottom on the test specimen (4ft + 30ft + crush) and Figure 3.7.2.4 shows a similar view of the analysis (30ft + crush).

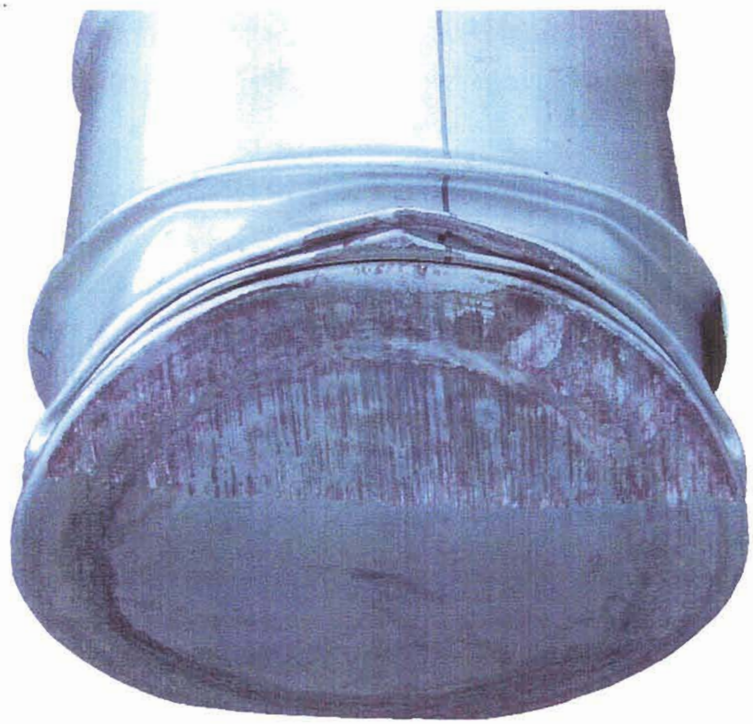

Figure 3.7.2.3 - TU3, Damage to the Bottom Head in the Crush Impact

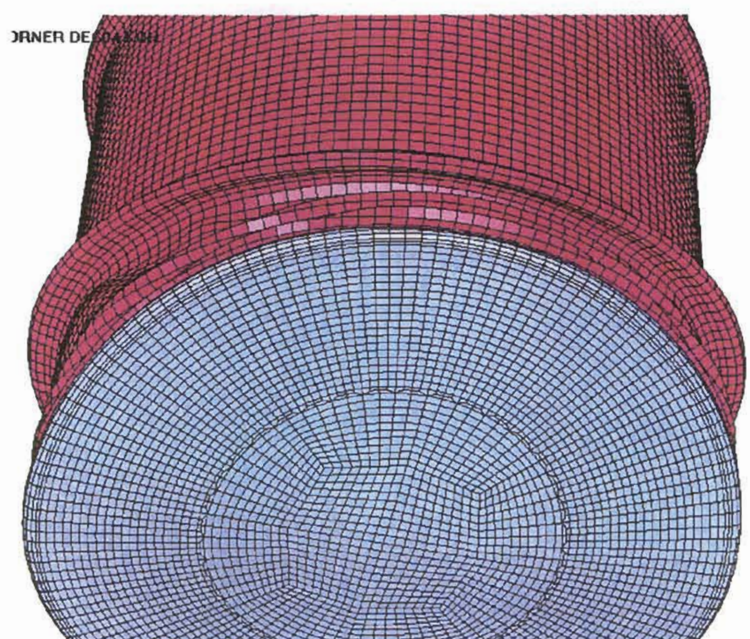

Figure 3.7.2.4 - HABC-run2e, Damage to the Bottom Head in the Crush Impact

The damage to the lid region at the end of the crush impact is shown in Figure 3.7.2.5 for the TU3. The damage to the lid region in the analysis run2e is shown in Figure 3.7.2.6.

Figure 3.7.2.5 - TU3, Lid Damage from the Crush Impact

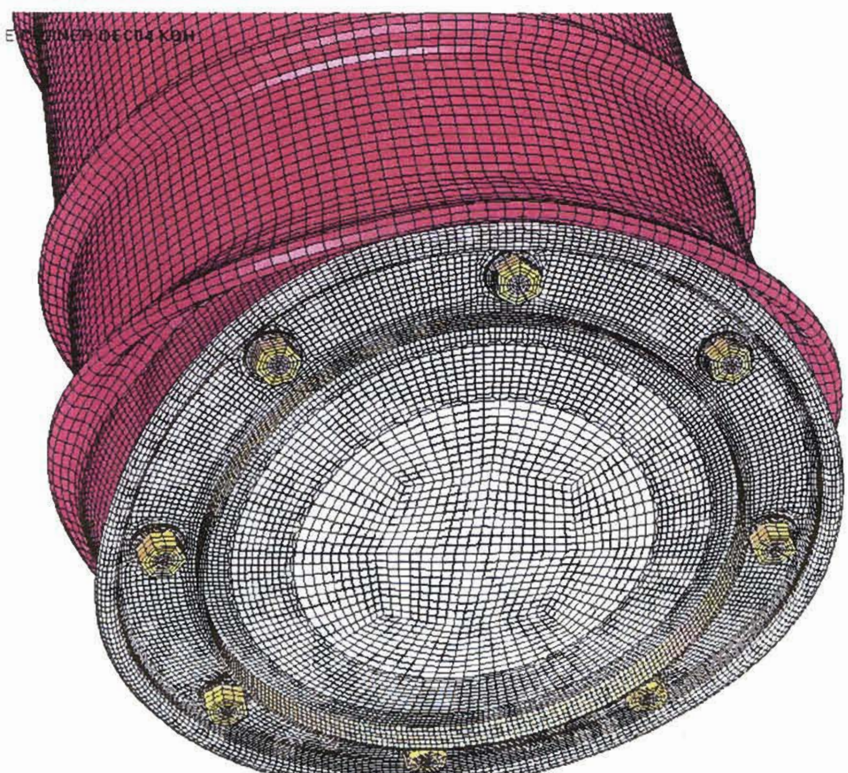

Figure 3.7.2.6 - HABC-run2e, Damage to the Bottom Head from the Crush Impact

3.7.3 Comparison of HABC-Run3b vs TU4

The HABC-run3b is a 30-foot lid down impact onto the rigid surface, followed by a crush impact onto the container bottom. The diameter measurements after the 30-foot impact are given in Table 3.7.3.1.

Table 3.7.3.1 - HABC Run3b vs TU4, Diameter Results After the 30-Foot Impact

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	19-1/4	19.3	19-3/8	19.3
Top Hoop	19-1/8	19.7	19-7/8	19.7
Top CG Hoop	19-13/16	20.0	19-3/8	20.0
CG Hoop	19-1/8	19.5	19-1/4	19.5
Bottom Hoop	19-1/4	19.4	19-1/4	19.4
Bottom Chime	19-1/4	19.4	19-1/4	19.4

The overall height measurements were compared between the test and the analysis. For the 30-foot impact, the test results vary around the circumference: 43.0 inches at 0°, 43.125 inches at 90°, 42.875 inches at 180° and 42.625 inches at 270°. The analysis is symmetrical, and the height from the top of the lid drum roll to the bottom head surface after the 30-foot impact is about 42.6 inches.

Figure 3.7.3.1 shows the configuration of the TU4 after the 30-foot impact (4ft + 30ft). Figure 3.7.3.2 shows the analysis model configuration after the 30-foot impact in a similar orientation to the test unit.

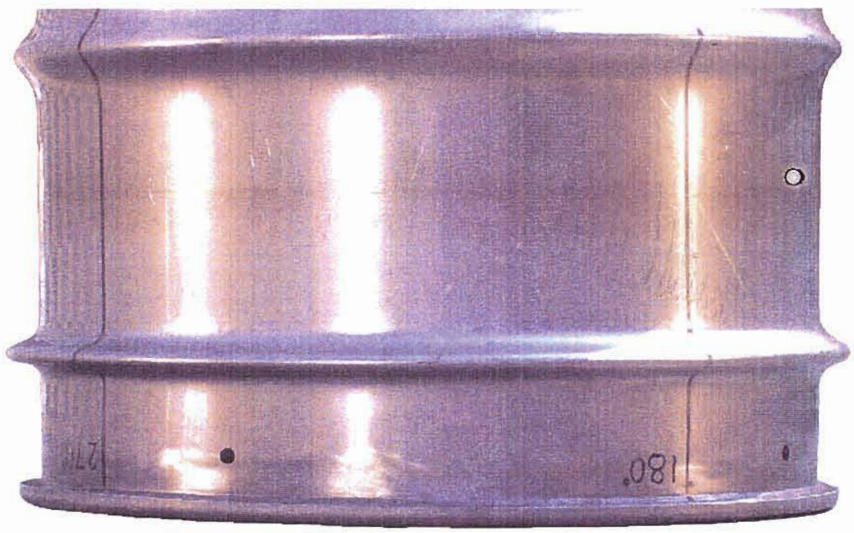

Figure 3.7.3.1 - TU4, 4-Foot + 30-Foot Impact Damage

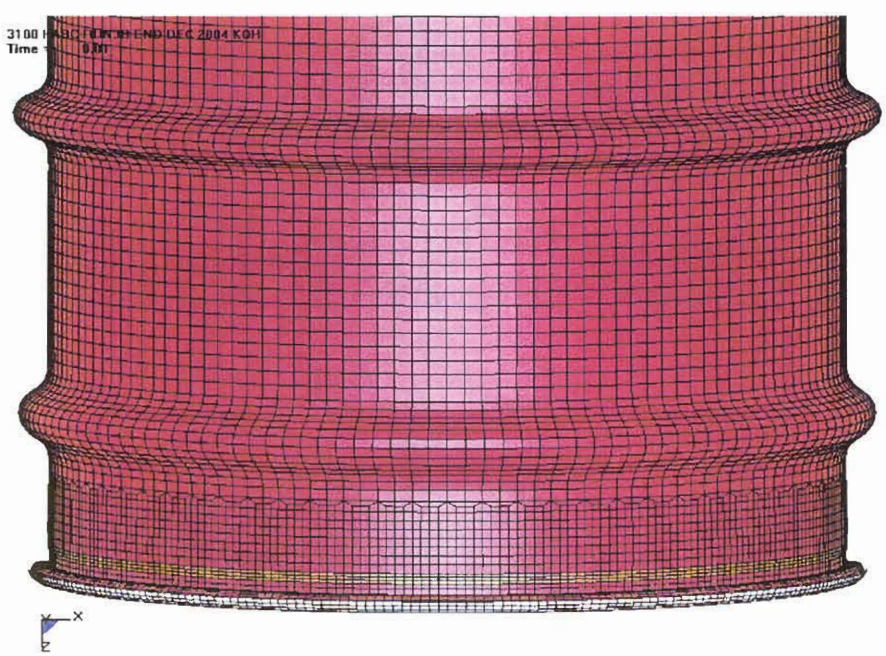

Figure 3.7.3.2 - HABC-Run3b, 30-Foot Impact Damage

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The drum height measurement after the test crush impact is 39-3/8 inches at 0°, 40-3/8 inches at 90°, 40-5/8 inches at 180°, and 39-3/4 inches at-270°. The analytical value for the height is about 39.0 inches.

The drum diameters after the crush impact are compared in Table 3.7.3.2.

Table 3.7.3.2 - HABC Run3b vs TU4, Diameter Results After the Crush Impact

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	19-1/4	19.3	19-3/8	19.3
Top Hoop	20	20.1	20-1/8	20.1
Top CG Hoop	20	20.2	20-1/16	20.2
CG Hoop	19-7/16	20.1	19-1/2	20.1
Bottom Hoop	19-15/16	20.5	20	20.5
Bottom Chime	19-1/4	19.4	19-1/4	19.4

Figure 3.7.3.3 shows the TU4 at the end of the crush impact (4ft + 30ft + crush), while Figure 3.7.3.4 shows the configuration of the HABC-run3b model (30ft + crush).

Figure 3.7.3.3 - TU4, Crush Damage

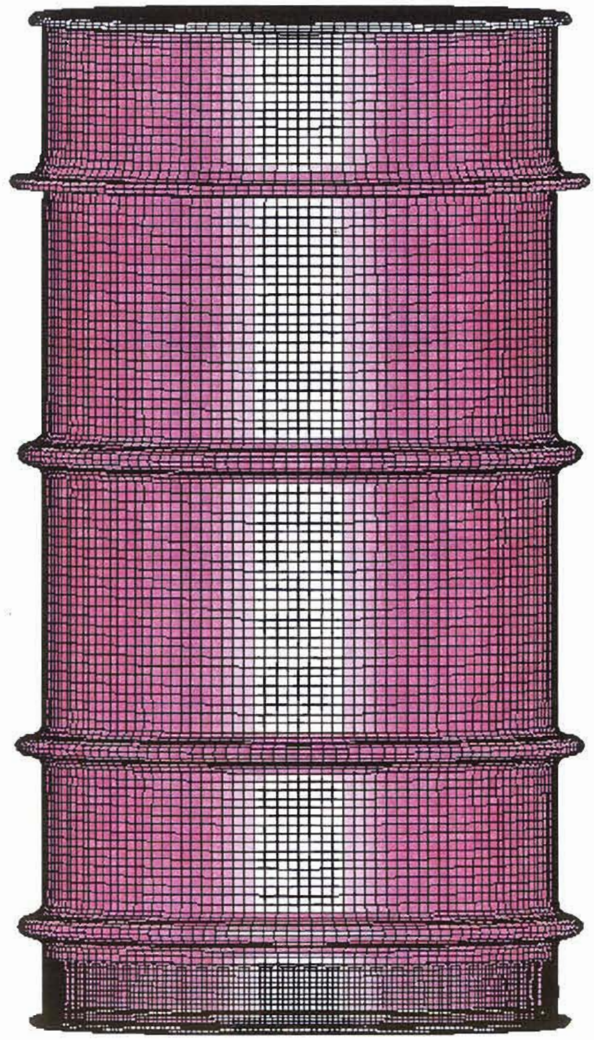

Figure 3.7.3.4 - HABC Run3b, Crush Damage

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3.7.4 Comparison of HABC Run1hh vs TU2

HABC-run1hh was the upper bounding kaolite run which included a 4-ft, 30-foot and crush impacts. The test results are for the cumulative damage from the 4-ft, 30ft, crush and punch impacts. The table 3.7.4.1 shows the results for the diameter changes due to all the impacts for the test and the analysis.

Table 3.7.4.1 - Run1hh vs TU2, Cumulative Diameter Results

	0°-180°		90°-270°	
	Test	Analysis	Test	Analysis
Top Chime	17-5/8	18.0	19-13/16	19.6
Top Hoop	17-3/8	16.6	19-3/4	20.1
Top CG Hoop	17	16.5	20	20.4
CG Hoop	16	16.3	20-1/4	20.5
Bottom Hoop	15-1/2	16.1	20-1/8	20.0
Bottom Chime	18	17.6	19-3/8	19.4

Table 3.7.4.2 shows the comparison of the "flats" dimensions for the test and the analysis.

Table 3.7.4.2 - Run1hh vs TU2, Cumulative Flats Results†

	180° - Crush Plate Side		0° - Rigid Surface Side	
	Test‡	Analysis	Test	Analysis
Top Chime	6-1/4	0	8.0	9.2
Top Hoop	8-7/8	10.1	9.0	9.3
Top CG Hoop	9-5/8	9.3	10-1/8	8.4
CG Hoop	12	9.3	9-7/8	9.3
Bottom Hoop	14-7/8	10.1	9-7/8	9.3
Bottom Chime	0	0	9-3/8	10.1

† - Note - The reported test results for the 0 and the 180 sides are reversed in the test report (evidence Figure 3.7.4.3 below).

‡ - Note - The crush plate edge was 4.75 inches from bottom of package.

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A visual comparison of the cumulative damage on the rigid surface side after the impacts is shown in Figures 3.7.4.1 (test) and Figure 3.7.4.2 (analysis).

Figure 3.7.4.1 - TU2, Cumulative Damage After the Punch Impact, Rigid Surface Side

Figure 3.7.4.2 - HABC-run1hh, Cumulative Damage, Rigid Surface Side

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A visual comparison of the cumulative damage on the crush side after the four impacts is shown in Figures 3.7.4.3 (test) and Figures 3.7.4.4 (analysis).

Figure 3.7.4.3 - TU2, Cumulative Damage After the Punch Impact, Crush Plate Side

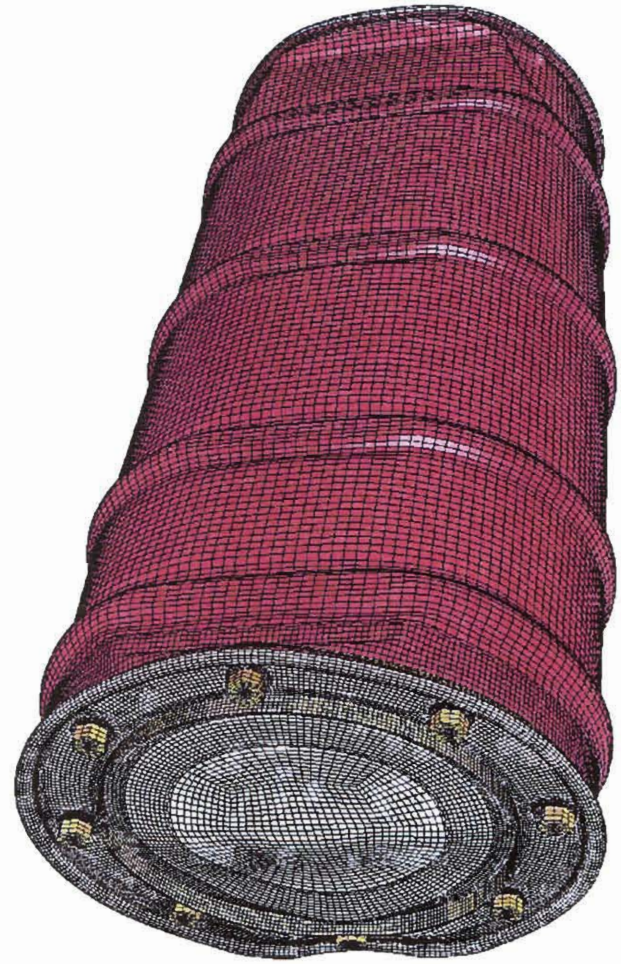

Figure 3.7.4.4 - HABC-run1hh, Cumulative Damage, Crush Plate Side

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4.0 Summary

The computer simulation impacts for the HABC re-design of the ES-3100 shipping container are presented in Sections 3.1 to 3.6. The comparison of the HABC re-design container to the physical tests is presented in Section 3.7. The effective plastic strain for the components are summarized in Table 4.0.1. The punch impact is not included in the HABC runs, due to the fact that the drum shell capability is demonstrated in the initial borobond models, and the tested specimen.

Maximum strains in excess of 0.5 in/in are near the 304L strain limit of 0.57 in/in and are highlighted in red in Table 4.0.1. The components which are highlighted included the drum , lid, studs and liner. Evidence from looking at the Table 4.0.1 summary, a high demand is placed on the lid and the studs in the side and slapdown impacts.

In runs HABC-runs1hl, 1hh, 4g and 4ga a high demand is placed on the lid/studs. In runs 1hh, 1hl, 4g and 4ga, the region of plastic strain is very localized at the stud holes. Runs 1hl and 4g also have relatively high demands placed on the studs. In runs1hl and 4g, it is shown that the times at which the lid strains become excessive in membrane, the stud strains are relatively low. Hence, it is predicted that the lid will locally tear, thereby relieving loading on the studs. The tearing associated with the lid is expected to be local due to the localized fringes of extreme strain shown in the Section 7 fringe plots. The large washers provided on the packages would restrain the lid.

In runs HABC-run1hl, 2e and 4g, the studs reach high levels of effective plastic strain. In HABC-run1hl, the lid was shown to tear before the studs reached an elevated level of plastic strain.

HABC-run2e shows that the stud at the impact reaches extreme levels of plastic strain near the 0.57 in/in failure strain in the 30-foot impact and the subsequent crush impact. The level of high strain is throughout the cross section of the stud in HABC-run2e. Due to this high level of strain and the direct load path between the shipping package and the rigid surface, any slight changes in length, friction, localized deformations (stud "digging" into the relatively rigid plate in the test) could cause the stud to fail.

In HABC-run4g, the stud reached its failure strain and the cross section row of elements failed (removed by LS-Dyna). A time study shows that the lid reaches its levels of elevated strain in membrane before the stud. Therefore, the lid is expected to tear before the stud fails, thus relieving loading on the stud. However, the model does show the shipping container response if the lid were not to tear, and the stud were to fail.

The relatively high level of plastic strain in the HABC-run2e liner is a surface strain. Investigation shows that the membrane strain is about 0.2205 in/in, or well below the expected failure level. The deformation/fringe plot shows that the region of high strain is relatively local at the attachment of the liner to the angle. The plot also shows that it is the result of crimping or folding of the liner due to the relatively stiffer angle. Any tearing that might take place would be limited, evidence the local concentration of fringe levels.

Table 8.0.1 - ES-3100 HABC Shipping Package Summary of Component Maximum Effective Plastic Strain (in/in)

Material	Description	HABC-run1hl Side - Lower Bound Kaolite (Section 7.1)			HABC-run1hh Side - Upper Bound Kaolite (Section 7.2)		
		4-foot	30-foot	Centered Crush	4-foot	30-foot	Centered Crush
1	CV Body	0.0185	0.0195	0.0206	0.0238	0.0347	0.0525
3	CV Lid	0.0001	0.0002	0.0002	0.0000	0.0001	0.0004
4	CV Nut Ring	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005
5	Angle	0.0055	0.0780	0.1142	0.0061	0.0632	0.0845
6	Drum	0.1599	0.2251	0.5139	0.1207	0.2296	0.2814
7	Drum Bottom	0.1033	0.2126	0.3562	0.1252	0.2517	0.2827
10	Liner	0.1045	0.1078	0.1593	0.0991	0.1184	0.2022
12	Lid	0.1393	0.5790	1.2580	0.1604	0.4063	0.6413
15	Lid Stiffener	0.0004	0.0093	0.0515	0.0006	0.0076	0.0171
16	Lid Studs	0.0000	0.1140	0.5121	0.0000	0.1306	0.2364
17	Lid Stud Nuts	0.0000	0.0000	0.0005	0.0000	0.0004	0.0018
18	Lid Stud Washe	0.0194	0.0194	0.0693	0.0411	0.0424	0.0439
19	Plug Liner	0.0022	0.0958	0.1220	0.0045	0.1072	0.1286

Material	Description	HABC-run2e Corner (Section 7.3)		HABC-run3b End (Section 7.4)		HABC-run4g Slapdown (Section 7.5)		HABC-run4ga Slapdown (Section 7.6)	
		Impact	Crush	Impact	Crush	Impact	Offset Crush	Impact	Centered Crush
1	CV Body	0.0371	0.0371	0.0028	0.0083	0.0376	0.0564	Same as HABC-Run4g Impact Results	0.0643
3	CV Lid	0.0051	0.0051	0.0072	0.0072	0.0004	0.0013		0.0018
4	CV Nut Ring	0.0002	0.0002	0.0011	0.0011	0.0000	0.0001		0.0000
5	Angle	0.0394	0.0462	0.0287	0.0308	0.0900	0.1070		0.0944
6	Drum	0.3247	0.3830	0.0557	0.1237	0.3018	0.3920		0.3443
7	Drum Bottom	0.0000	0.0761	0.0031	0.0267	0.2879	0.2879		0.3000
10	Liner	0.3983	0.5254	0.0607	0.3812	0.1458	0.2060		0.2846
12	Lid	0.2791	0.3622	0.1082	0.1389	0.5278	0.9689		0.5828
15	Lid Stiffener	0.0272	0.0272	0.0069	0.0100	0.0213	0.0894		0.0288
16	Lid Studs	0.5233	0.5598	0.0962	0.1535	0.1892	0.4018		0.2390
17	Lid Stud Nuts	0.2260	0.2266	0.0166	0.0173	0.0000	0.0028		0.0000
18	Lid Stud Washe	0.1528	0.1528	0.0506	0.0506	0.0724	0.0790		0.0775
19	Plug Liner	0.1152	0.1166	0.0670	0.0960	0.1258	0.2665		0.1644

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5.0 References

5.1 K. D. Handy, Impact Analysis of ES-3100 Design Concepts Using Borobond, DAC-EA-801699-A001, Revision 0, October 2004.

5.2 Code of Federal Regulations, 10CFR71, Subpart F, Section 71.71 and 71.73, 1-01 Edition.

5.3 L. S. Dickerson, M. R. Feldman and R. D. Michelhaugh, Test Report of the ES-3100 Package, Dated September 10, 2004.
Volume 1 - Main Report, ORNL/NTRC-013/V1, Rev 0.
Volume 2 - Appendices A - G, Photos of TU-1 through TU-6, ORNL/NTRC-013/V2, Rev 0.
Volume 3 - Appendices H - N, Data Forms for TU-1 through TU-6, ORNL/NTRC-013/V3, Rev 0.

5.4 B. F. Smith, Mechanical Properties of 277-4, Y/DW-1987, January 19, 2005.

5.5 CSDiff, version 4.0.201, Component Software, Inc.

6.0 Appendices

Appendix 6.1

TrueGrid Input File for HABC-run1hh

Reference 5.1 presents the TrueGrid input file for the run1g impact. The HABC models and impacts are based on the simulations performed with the initial borobond models. This appendix presents the TrueGrid input file for the HABC-run1hh. It is presented by showing changes made to the reference 5.1 borobond TrueGrid model for run1g to make it the input file used for the HABC-run1hh.

The "CSDiff" software (reference 5.5) is a PC utility software that mimics the unix based "diff" utility. The results of a comparison of the reference 5.1, run1g TrueGrid input file and the HABC-run1hh input file is reproduced below. The result is that changes to the run1g file are shown in blue and green colors. The changes made produce the TrueGrid input file for the HABC-run1hh model. The green colors show the items that existed in the run1g input file, but that do not exist in the HABC-run1hh input file. The items that exist in the HABC-run1hh input file, but do not exist in the run1g input file are given in blue color.

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```
title 3100 ~~run rg Side Nov 2003~~ HABC-runThin U Bound Dec 2004 kqh


plane 1  0 0 0  0 1 0  0.005 symm ;

~~c velocity 219.27 0 480.32~~
velocity ~~528~~196 0 0



c m  1  CV body
c m  2  CV body at flange for preload
c m  3  CV lid
c m  4  CV screw ring
c m  5  angle
c m  6  drum
c m  7  drum bottom head
c m  8  weld drum to drum bottom head
c m  9  liner overlap to angle (0.03)
c m 10  liner (0.06)
c m 11  liner bottom (0.120) (see m 27 for solids)
c m 12  lid shells (0.0598)
c m 13  thin lid shell at bolts
c m 14  lid solids at the lid bolts
c m 15  lid stiffener
c m 16  drum bolts
c m 17  drum bolt nuts
c m 18  drum bolt washers
c m 19  plug liner
c m 20  plug kaolite
c m 21  drum kaolite
c m 22  drum borobond
c m 23  lid to lid stiff weld
c m 24  lower internal cv mass
c m 25  middle internal cv mass
c m 26  upper internal cv mass
c m 27  liner bottom solids (see m 11 for shells)
c m 28  overlap of liner to solids at bottom of borobond
c m 29  visual rigid plane
c m 30  crush plate
c m 31  punch
c m 32  silicon rubber pads
c m 33  drum bolt studs


sid  1 dummy ;  c  cv bottom thread between body (s) and screw ring (m)
sid  2 dummy ;  c  cv middle thread between body (s) and screw ring (m)
sid  3 dummy ;  c  cv upper thread between body (s) and screw ring (m)
sid  4 dummy ;  c  cv body flange (s) to lid (m)
sid  5 dummy ;  c  cv lid (m) to bolt ring (s)
sid  6 dummy ;  c  cv lower mass to middle mass
sid  7 dummy ;  c  cv middle mass to upper mass
sid  8 dummy ;  c  lid solids (s) to angle solids (m)
sid  9 dummy ;  c  "changed in  run5c" lid solids (s) to lid stiff solids (m)
sid 10 dummy ;  c  "removed in run5c" lid stiff (m) to washers (s)
sid 11 dummy ;  c  "changed in  run5c" washer (m) to bolt nut (s)
sid 12 dummy ;  c  cv internal masses to CV body inner surface
sid 13 dummy ;  c  drum kaolite to ss drum and liner
sid 14 dummy ;  c  drum borobond to liner
sid 15 dummy ;  c  cv internal top mass to cv lid
sid 16 fric .3 kfric .2 decay 10 lsdsi 3 ;  c  plug kaolite to plug
sid 17 fric .3 kfric .2 decay 10 lsdsi 3 ;  c borobond to liner inner and top
sid 18 fric .3 kfric .2 decay 10 lsdsi 3 ;  c borobond to liner outer vertical side
sid 19 fric .3 kfric .2 decay 10 lsdsi 3 ;  c borobond to liner bottom

sid 20 fric .3 kfric .2 decay 10 lsdsi 3 ;  c drum kaolite to drum cylinder
sid 21 fric .3 kfric .2 decay 10 lsdsi 3 ;  c drum kaolite to angle and upper liner
sid 22 fric .3 kfric .2 decay 10 lsdsi 3 ;  c drum kaolite to liner horizontal/plug surface
sid 23 ~~fric .3 kfric .2 decay 10 lsdsi 3~~dummy ;  c drum kaolite to liner vertical by the CV flange
sid 24 ~~fric .3 kfric .2 decay 10 lsdsi 3~~dummy ;  c drum kaolite to liner short horizontal below CV
flange
sid 25 fric .3 kfric .2 decay 10 lsdsi 3 ;  c drum kaolite to liner long vertical and bottom by CV
sid 26 fric .3 kfric .2 decay 10 lsdsi 3 ;  c drum kaolite to drum bottom
sid 27 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c bottom silicon rubber to base of CV
sid 28 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c bottom silicon rubber to liner
sid 29 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c top silicon rubber to plug liner bottom
sid 30 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c top silicon rubber to liner at cv flange
sid 31 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c top silicon rubber to CV flange vertical
sid 32 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c top silicon rubber to lid ring
sid 33 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c top silicon rubber to lid center
sid 34 fric .6 kfric .5 decay 10 lsdsi 3 softc 1 ;  c bottom silicon rubber to liner side




c ****************************************
c ****** Begin CV Body  ******************
c ****************************************

c CV Body - flange region with teeth
cylinder
1 3 4 6 ; 1 65 ; 1 2 3 4 5 6 7 8 ;
3.4250 3.5001 3.5834 3.7500
0 180
36.6064 36.6787 36.7510 36.8233 36.8956 36.9679 37.0402 37.1002
dei 1 2 ; ; 1 3 0 4 5 0 6 7 ;
pb 1 0 3 1 0 3  xz 3.425016 36.739770
pb 1 0 4 1 0 4  xz 3.4250 36.7602
pb 1 0 5 1 0 5  xz 3.425016 36.864771
pb 1 0 6 1 0 6  xz 3.4250 36.8852
pb 1 0 7 1 0 7  xz 3.425016 36.989771
pb 1 0 8 1 0 8  xz 3.4250 37.0102
pb 2 0 1 2 0 1  x 3.5053
pb 2 0 2 2 0 2  xz 3.5053 36.7154
pb 2 0 3 2 0 3  xz 3.500053 36.730557
pb 2 0 4 2 0 4  xz 3.5053 36.8403
pb 2 0 5 2 0 5  xz 3.500053 36.855557
pb 2 0 6 2 0 6  xz 3.5053 36.9654
pb 2 0 7 2 0 7  xz 3.500053 36.980558
pb 2 0 8 2 0 8  xz 3.5150 37.1002
pb 4 0 8 4 0 8  x 3.6900
pb 3 0 8 3 0 8  x 3.5733
mate 1
sii 1 2 ; ; -3 ; 1 s
sii 1 2 ; ; -5 ; 2 s
```

```
sii 1 2 ; ; -7 ; 3 s
sii ; ; -8 ; 31 s
sii -4 ; ; ; 31 s
~~c~~ lct 1 ~~mx 0.4285~~mz 0.0680 ; lrep 1 ;
endpart


c CV Body
cylinder
1 2 3 6 ; 1 65 ; 1 2 3 6 7 8 9 ;
3.3765 3.4512 3.5259 3.7500
0 180
35.9972 36.0602 36.1272 36.4002 36.4880 36.5502 36.6064
dei 1 3 ; ; 5 7 ;
pb 1 0 1 1 0 1  x 3.3808
pb 2 0 1 2 0 1  x 3.4547
pb 3 0 1 3 0 1  x 3.5285
pb 1 0 2 1 0 2  x 3.4065
pb 2 0 2 2 0 2  x 3.4752
pb 3 0 2 3 0 2  x 3.5439
pb 1 0 5 1 0 5  xz 3.3939 36.4424
pb 2 0 5 2 0 5  xz 3.4359 36.4602
pb 3 0 5 3 0 5  x 3.5001
pb 3 0 6 3 0 6  x 3.5250
pb 3 0 7 3 0 7  x 3.5053
mate 2
eset 1 0 1 4 0 7  =  pstrescv
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
sii -4 ; ; ; 31 s
endpart

c CV Body
cylinder
1 2 3 4 5 6 7 8 9 ; 1 65 ; 1 2 3 4 5 6 7 8 ;
3.1513 3.2450 3.3165 3.3949 3.4733 3.5516 3.6300 3.7000 3.7500
0 180
35.4502 35.5110 35.5953 35.6761 35.7568 35.8377 35.9189 36.0002
dei 8 9 ; ; 1 2 ;
pb 1 0 1 1 0 1  xz 3.1513 35.4389
pb 2 0 1 2 0 1  xz 3.2450 35.4502
pb 3 0 1 3 0 1  xz 3.3165 35.4502
pb 4 0 1 4 0 1  xz 3.3949 35.4502
pb 5 0 1 5 0 1  xz 3.4733 35.4502
pb 6 0 1 6 0 1  xz 3.5516 35.4502
pb 7 0 1 7 0 1  xz 3.6300 35.4502
pb 8 0 1 8 0 1  xz 3.7149 35.4853
pb 9 0 2 9 0 2  xz 3.7149 35.4853
pb 1 0 2 1 0 2  xz 3.1125 35.5110
pb 1 0 3 1 0 3  xz 3.1114 35.5933
pb 1 0 4 1 0 4  xz 3.1195 35.6707
pb 1 0 5 1 0 5  xz 3.1248 35.7439
pb 1 0 6 1 0 6  xz 3.1349 35.8409
pb 1 0 7 1 0 7  xz 3.1481 35.9235
pb 1 0 8 1 0 8  xz 3.1607 36.0002
pb 2 0 8 2 0 8  xz 3.2494 36.0002
pb 3 0 8 3 0 8  xz 3.3165 35.9702
pb 4 0 8 4 0 8  xz 3.3808 35.9972
pb 5 0 8 5 0 8  xz 3.4547 35.9972
pb 6 0 8 6 0 8  xz 3.5285 35.9972
pb 7 0 8 7 0 8  xz 3.6022 35.9970
pb 8 0 8 8 0 8  xz 3.6762 35.9972
pb 9 0 8 9 0 8  xz 3.7500 35.9972
pb 8 0 2 8 0 2 xz 3.68737 35.5280
pb 2 0 2 2 0 2 xz 3.20540 35.5203
pb 3 0 2 3 0 2 xz 3.30667 35.5190
pb 4 0 2 4 0 2 xz 3.39255 35.5203
pb 5 0 2 5 0 2 xz 3.47587 35.5228
pb 6 0 2 6 0 2 xz 3.55406 35.5228
pb 7 0 2 7 0 2 xz 3.62969 35.5241
pb 2 0 3 2 0 3 xz 3.20925 35.5946
pb 3 0 3 3 0 3 xz 3.30282 35.5933
pb 4 0 3 4 0 3 xz 3.38999 35.5959
pb 5 0 3 5 0 3 xz 3.47331 35.5984
pb 2 0 4 2 0 4 xz 3.21822 35.6779
pb 2 0 5 2 0 5 xz 3.22720 35.7561
pb 2 0 6 2 0 6 xz 3.23489 35.8382
pb 2 0 7 2 0 7 xz 3.24001 35.9202
pb 3 0 4 3 0 4 xz 3.30923 35.6792
pb 3 0 5 3 0 5 xz 3.30923 35.7561
pb 3 0 4 3 0 4 xz 3.30539 35.6754
pb 3 0 6 3 0 6 xz 3.31180 35.8356
pb 4 0 7 4 0 7 xz 3.38871 35.9189
pb 5 0 7 5 0 7 xz 3.46433 35.9176
pb 5 0 6 5 0 6 xz 3.46818 35.8356
pb 6 0 7 6 0 7 xz 3.53996 35.9189
pb 6 0 6 6 0 6 xz 3.54381 35.8407
pb 6 0 6 6 0 6 xz 3.54637 35.8407
pb 7 0 7 7 0 7 xz 3.61559 35.9189
pb 7 0 6 7 0 6 xz 3.62328 35.8356
pb 7 0 5 7 0 5 xz 3.62328 35.7574
pb 7 0 5 7 0 5 xz 3.62841 35.7587
pb 8 0 7 8 0 7 xz 3.68737 35.9215
pb 8 0 6 8 0 6 xz 3.69506 35.8369
pb 8 0 5 8 0 5 xz 3.69634 35.7600
pb 8 0 4 8 0 4 xz 3.69506 35.6805
pb 8 0 3 8 0 3 xz 3.69378 35.5972
mate 1
sii -9 ; ; ; 31 s
sii ; ; -1 ; 31 s
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart


c CV Body - flange knuckle with o-rings
cylinder
1 2 3 4 5 6 7 8 9 10 ; 1 65 ; 1 2 3 4 5 6 7 8 9 10 ;
2.5200 2.5533 2.5867 2.6200 2.9071 2.9764 3.0570 3.1513 3.2 3.2
0 180
35.4031 35.55 35.60 35.65 35.7 35.75 35.8 35.9 36.0 36.1
dei 3 4 ; ; 7 10 ;
dei 6 10 ; ; 7 10 ;
dei 1 5 ; ; 1 2 ;
dei 8 10 ; ; 1 6 ;
```

```
pb 5 0 1 5 0 1 xz 2.9071 35.2914
pb 6 0 1 6 0 1 xz 2.9764 35.3531
pb 7 0 1 7 0 1 xz 3.0570 35.4038
pb 8 0 1 8 0 1 xz 3.1513 35.4389
pb 8 0 2 8 0 2 xz 3.1125 35.5110
pb 8 0 3 8 0 3 xz 3.1114 35.5933
pb 8 0 4 8 0 4 xz 3.1195 35.6707
pb 8 0 5 8 0 5 xz 3.1248 35.7439
pb 8 0 6 8 0 6 xz 3.1349 35.8409
pb 9 0 6 9 0 6 xz 3.1481 35.9235
pb 10 0 6 10 0 6 xz 3.1607 36.0002
pb 10 0 7 10 0 7 xz 3.0720 36.0002
pb 9 0 7 9 0 7 xz 3.0620 35.9902
pb 8 0 7 8 0 7 xz 3.0620 35.9162
pb 7 0 7 7 0 7 xz 3.0320 35.8862
pb 6 0 7 6 0 7 xz 2.9312 35.8862
pb 6 0 8 6 0 8 xz 2.9038 35.9284
pb 6 0 9 6 0 9 xz 2.9264 35.9791
pb 6 0 10 6 0 10 xz 2.9173 35.9932
pb 5 0 10 5 0 10 xz 2.8696 35.9932
pb 4 0 10 4 0 10 xz 2.8220 35.9932
pb 4 0 9 4 0 9 xz 2.8120 35.9832
pb 4 0 8 4 0 8 xz 2.8120 35.9162
pb 4 0 7 4 0 7 xz 2.7820 35.8862
pb 3 0 7 3 0 7 xz 2.6815 35.8862
pb 3 0 8 3 0 8 xz 2.6540 35.9284
pb 3 0 9 3 0 9 xz 2.6797 35.9861
pb 3 0 10 3 0 10 xz 2.6706 36.0002
pb 2 0 10 2 0 10 xz 2.6253 36.0002
pb 1 0 10 1 0 10 xz 2.5800 36.0002
pb 1 0 9 1 0 9 xz 2.5376 35.9826
pb 1 0 8 1 0 8 xz 2.5200 35.9402
pb 1 0 2 1 0 2 xz 2.5200 35.4031
pb 2 0 9 2 0 9 xz 2.60013 35.9679
pb 2 0 8 2 0 8 xz 2.58630 35.9177
pb 2 0 2 2 0 2 xz 2.5794 35.3944
pb 3 0 2 3 0 2 xz 2.6538 35.3835
pb 4 0 2 4 0 2 xz 2.7290 35.3726
pb 5 0 2 5 0 2 xz 2.8515 35.3514
pb 1 0 7 1 0 7 xz 2.52000 35.8682
pb 1 0 3 1 0 3 xz 2.52000 35.4824
pb 1 0 4 1 0 4 xz 2.52000 35.5773
pb 1 0 5 1 0 5 xz 2.52000 35.6735
pb 1 0 6 1 0 6 xz 2.52000 35.7661
pb 1 0 7 1 0 7 xz 2.52000 35.8516
pb 2 0 3 2 0 3 xz 2.57934 35.4812
pb 2 0 4 2 0 4 xz 2.58884 35.5750
pb 2 0 5 2 0 5 xz 2.59359 35.6759
pb 2 0 6 2 0 6 xz 2.58765 35.7685
pb 2 0 7 2 0 7 xz 2.59531 35.8412
pb 2 0 8 2 0 8 xz 2.58941 35.8860
pb 2 0 9 2 0 9 xz 2.58934 35.9354
pb 3 0 3 3 0 3 xz 2.66007 35.4776
pb 3 0 4 3 0 4 xz 2.66601 35.5714
pb 3 0 5 3 0 5 xz 2.66838 35.6759
pb 3 0 6 3 0 6 xz 2.67075 35.7791
pb 4 0 3 4 0 3 xz 2.74080 35.4740
pb 4 0 4 4 0 4 xz 2.74792 35.5666
pb 4 0 5 4 0 5 xz 2.75623 35.6735
pb 4 0 6 4 0 6 xz 2.76810 35.7827
pb 5 0 3 5 0 3 xz 2.83340 35.4705
pb 5 0 4 5 0 4 xz 2.83221 35.5833
pb 5 0 5 5 0 5 xz 2.83933 35.6854
pb 5 0 6 5 0 6 xz 2.84883 35.7756
pb 5 0 7 5 0 7 xz 2.85594 35.8450
pb 5 0 8 5 0 8 xz 2.85419 35.9001
pb 5 0 9 5 0 9 xz 2.85636 35.9368
pb 6 0 2 6 0 2 xz 2.92956 35.4301
pb 6 0 3 6 0 3 xz 2.91531 35.5192
pb 6 0 4 6 0 4 xz 2.91056 35.6106
pb 6 0 5 6 0 5 xz 2.91294 35.6949
pb 6 0 6 6 0 6 xz 2.92362 35.7815
pb 7 0 2 7 0 2 xz 3.02453 35.4895
pb 7 0 3 7 0 3 xz 3.01029 35.5607
pb 7 0 4 7 0 4 xz 3.01503 35.6379
pb 7 0 5 7 0 5 xz 3.01503 35.7079
pb 7 0 6 7 0 6 xz 3.02928 35.7946
mate 1
sii 1 6 ; ; -10 ; 4 s
sii -10 ; ; 6 7 ; 4 s
sii -1 ; ; ; 12 m
nset 3 0 10 3 0 10 + lcrd-bi
nset 10 0 7 10 0 7 + lcrd-bo
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV body
cylinder
1 2 3 4 5 6 ; 1 65 ; 1 2 3 4 5 6 7 8 9 10 ;
2.5200 2.5533 2.5867 2.5867 2.5867 2.6200
0 180
34.4502 34.5561 34.6637 34.7800 34.8962 34.9802
 35.0670 35.1436 35.2223 35.2914
dei 3 5 ; ; 1 5 ;
dei 4 5 ; ; 5 6 ;
pb 6 0 2 6 0 2 xz 2.6235 34.5561
pb 6 0 3 6 0 3 xz 2.6344 34.6637
pb 6 0 4 6 0 4 xz 2.6550 34.7800
pb 6 0 5 6 0 5 xz 2.6856 34.8962
pb 6 0 6 6 0 6 xz 2.7150 34.9802
pb 6 0 7 6 0 7 xz 2.7531 35.0670
pb 6 0 8 6 0 8 xz 2.7947 35.1436
pb 6 0 9 6 0 9 xz 2.8478 35.2223
pb 6 0 10 6 0 10 xz 2.9071 35.2914
pb 5 0 10 5 0 10 xz 2.8515 35.3514
pb 4 0 10 4 0 10 xz 2.7290 35.3726
pb 3 0 10 3 0 10 xz 2.6538 35.3835
pb 2 0 10 2 0 10 xz 2.5794 35.3944
pb 1 0 10 1 0 10 xz 2.5200 35.4031
pb 1 0 4 1 0 4 xz 2.52000 34.7702
pb 1 0 5 1 0 5 xz 2.52000 34.8752
pb 1 0 6 1 0 6 xz 2.52000 34.9692
pb 1 0 7 1 0 7 xz 2.52000 35.0727
pb 1 0 8 1 0 8 xz 2.52000 35.1746
pb 1 0 9 1 0 9 xz 2.52000 35.2906
pb 2 0 3 2 0 3 xz 2.55670 34.6647
pb 2 0 4 2 0 4 xz 2.56028 34.7733
pb 2 0 5 2 0 5 xz 2.56463 34.8761
pb 2 0 6 2 0 6 xz 2.56199 34.9725
pb 2 0 7 2 0 7 xz 2.55709 35.0727
pb 2 0 8 2 0 8 xz 2.56187 35.1714
pb 2 0 9 2 0 9 xz 2.57256 35.2844
pb 3 0 3 3 0 3 xz 2.59502 34.6633
pb 3 0 4 3 0 4 xz 2.60327 34.7781
pb 3 0 5 3 0 5 xz 2.62013 34.8814
pb 3 0 6 3 0 6 xz 2.60692 34.9778
pb 3 0 7 3 0 7 xz 2.60008 35.0711
pb 3 0 8 3 0 8 xz 2.60645 35.1682
pb 3 0 9 3 0 9 xz 2.63202 35.2738
pb 4 0 5 4 0 5 xz 2.66374 34.9765
pb 4 0 6 4 0 6 xz 2.63863 35.0016
pb 4 0 7 4 0 7 xz 2.65263 35.0759
pb 4 0 8 4 0 8 xz 2.66638 35.1681
pb 4 0 9 4 0 9 xz 2.69545 35.2619
pb 5 0 3 5 0 3 xz 2.59502 34.6633
pb 5 0 4 5 0 4 xz 2.60327 34.7781
pb 5 0 5 5 0 5 xz 2.62013 34.8814
pb 5 0 6 5 0 6 xz 2.66374 34.9765
pb 5 0 7 5 0 7 xz 2.69562 35.0711
pb 5 0 8 5 0 8 xz 2.72428 35.1618
pb 5 0 9 5 0 9 xz 2.77209 35.2527
mate 1
sii -1 ; ; ; 12 m
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart


c CV body cylinder - upper
cylinder
1 4 ; 1 65 ; 1 80 ;
2.5200 2.6200
0 180
20.0301 34.4502
res 1 1 1 2 2 2 k 0.9901 ;
mate 1
sii -1 ; ; ; 12 m
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV body cylinder - lower
cylinder
1 4 ; 1 65 ; 1 80 ;
2.5200 2.6200
0 180
5.6100 20.0301
res 1 1 1 2 2 2 k 1.01 ;
mate 1
sii -1 ; ; ; 12 m
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart


c CV Body, lower head knuckle
cylinder
1 4 ; 1 65 ; 1 2 3 4 5 6 7 8 9 10 11 ;
2.5200 2.6200
0 180
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1
pb 1 0 1 1 0 1 xz 2.3000 4.9500
pb 1 0 2 1 0 2 xz 2.3356 4.9587
pb 1 0 3 1 0 3 xz 2.3683 4.9826
pb 1 0 4 1 0 4 xz 2.3993 5.0210
pb 1 0 5 1 0 5 xz 2.4264 5.0699
pb 1 0 6 1 0 6 xz 2.4528 5.1352
pb 1 0 7 1 0 7 xz 2.4742 5.2069
pb 1 0 8 1 0 8 xz 2.4935 5.2960
pb 1 0 9 1 0 9 xz 2.5081 5.3955
pb 1 0 10 1 0 10 xz 2.5171 5.5022
pb 1 0 11 1 0 11 xz 2.5200 5.6100

pb 2 0 1 2 0 1 xz 2.3000 4.7000
pb 2 0 2 2 0 2 xz 2.3700 4.7000
pb 2 0 3 2 0 3 xz 2.4950 4.7335
pb 2 0 4 2 0 4 xz 2.5865 4.8250
pb 2 0 5 2 0 5 xz 2.6200 4.9500
pb 2 0 6 2 0 6 z 5.0750
pb 2 0 7 2 0 7 z 5.1823
pb 2 0 8 2 0 8 z 5.2876
pb 2 0 9 2 0 9 z 5.3913
pb 2 0 10 2 0 10 z 5.5011
pb 2 0 11 2 0 11 z 5.6100
mate 1
sii -1 ; ; ; 12 m
sii -2 ; ; ; 27 s
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV Body, lower head
cylinder
1 4 ; 1 65 ; 1 4 ;
2.0 2.3000
0 180
4.7000 4.9500
mate 1
sii ; ; -2 ; 12 m
sii ; ; -1 ; 27 s
bb 1 0 0 1 0 0 1;
nset 2 1 2 2 1 2 + lcrd-y
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV Body, lower head
cylinder
```

GENERAL DESIGN AND COMPUTATION SHEET


```
1 5 ; 1 33 ; 1 4 ;
1.55 2.0
0 180
4.7000 4.9500
mate 1
sii ; ; -2 ; 12 m
sii ; ; -1 ; 27 s
trbb 2 0 0 2 0 0 1 ;
bb 1 0 0 1 0 0 2 ;
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV Body, lower head
cylinder
1 3 ; 1 17 ; 1 4 ;
1.3 1.55
0 180
4.7000 4.9500
mate 1
sii ; ; -2 ; 12 m
sii ; ; -1 ; 27 s
trbb 2 0 0 2 0 0 2 ;
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV Body, lower head
block
1 5 9 13 17 ; 1 5 9 13 17 ; 1 4 ;
-0.55 -0.55 0 0.55 0.55
-0.55 -0.55 0 0.55 0.55
4.7000 4.9500
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1  1.3000
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
dei ; 1 3 ; ;
mate 1
pb 2 3 0 2 3 0  x -0.67
pb 4 3 0 4 3 0  x  0.67
pb 3 4 0 3 4 0  y  0.67
sii ; ; -2 ; 12 m
sii ; ; -1 ; 27 s
nset 3 3 2 3 3 2  +  lcrd-org
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c ****************************************
c ****** End CV Body ********************
c ****************************************


c ****************************************
c ****** Begin CV Screw ring ***************
c ****************************************

c CV screw ring
cylinder
1 2 3 5 6 ; 1 65 ; 1 2 3 4 5 6 7 8 9 10 11 ;
3.2200 3.3127 3.3 3.4 3.5
0 180
36.5002 36.5602 36.6202 36.6802 36.7402 36.8002
 36.8602 36.9202 36.9802 37.0402 37.1002
dei 3 5 ; ; 1 4 ;
dei 3 5 ; ; 5 6 ;
dei 3 5 ; ; 7 8 ;
dei 3 5 ; ; 9 10 ;
dei 3 4 ; ; 10 11 ;
dei 4 5 ; ; 1 10 ;
pb 3 0 1 3 0 1 xz 3.3835 36.5002
pb 3 0 2 3 0 2 xz 3.4141 36.5307
pb 3 0 3 3 0 3 xz 3.4141 36.6240
pb 3 0 4 3 0 4 xz 3.4167 36.6303
pb 4 0 4 4 0 4 xz 3.4970 36.7105
pb 3 0 5 3 0 5 xz 3.421915 36.740151
pb 4 0 5 4 0 5 xz 3.496984 36.730934
pb 3 0 6 3 0 6 xz 3.4169 36.7554
pb 4 0 6 4 0 6 xz 3.4970 36.8355
pb 3 0 7 3 0 7 xz 3.421915 36.865151
pb 4 0 7 4 0 7 xz 3.496966 36.855936
pb 3 0 8 3 0 8 xz 3.4169 36.8803
pb 4 0 8 4 0 8 xz 3.4970 36.9605
pb 3 0 9 3 0 9 xz 3.421915 36.990152
pb 4 0 9 4 0 9 xz 3.496984 36.980935
pb 3 0 10 3 0 10 xz 3.4141 36.9990
pb 3 0 11 3 0 11 xz 3.3481 37.1002
pb 4 0 11 4 0 11 xz 3.3481 37.1002
pb 4 0 10 4 0 10 xz 3.4141 36.9990
pb 5 0 11 5 0 11 xz 3.3835 37.1002
pb 5 0 10 5 0 10 xz 3.4141 37.0696
mate 4
sii 3 5 ; ; -5 ; 1 m
sii 3 5 ; ; -7 ; 2 m
sii 3 5 ; ; -9 ; 3 m
sii 1 3 ; ; -1 ; 5 s
sii ; ; -11 ; 32 s
sii -5 ; ; ; 32 s
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV screw ring
cylinder
1 2 3 ; 1 65 ; 1 2 3 4 5 6 7 8 9 10 11 ;
3.0700 3.15 3.2200
0 180
36.5002 36.5602 36.6202 36.6802 36.7402 36.8002
 36.8602 36.9202 36.9802 37.0402 37.1002
dei 1 2 ; ; 1 2 0 4 6 0 8 10 ;
pb 2 0 1 2 0 1 xz 3.0700 36.5002
pb 1 0 2 1 0 2 xz 3.0700 36.5002
pb 1 0 4 1 0 4 xz 3.0700 36.7402
pb 2 0 5 2 0 5 xz 3.0700 36.7402
pb 1 0 6 1 0 6 xz 3.0700 36.7402
pb 1 0 8 1 0 8 xz 3.0700 36.9802
pb 2 0 9 2 0 9 xz 3.0700 36.9802
pb 1 0 10 1 0 10 xz 3.0700 36.9802
mate 4
sii ; ; -1 ; 5 s
sii ; ; -11 ; 32 s
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart


c CV screw ring
cylinder
1 2 6 ; 1 65 ; 1 2 3 4 5 6 ;
2.4 2.5 3.0700
0 180
36.5002 36.6202 36.7402 36.8602 36.9802 37.1002
dei  1 2 ; ; 1 2 ;
pb 1 0 2 1 0 2  xz 2.4069 36.6725
pb 1 0 3 1 0 3  xz 2.4838 36.8053
pb 1 0 4 1 0 4  xz 2.5511 36.9219
pb 1 0 5 1 0 5  xz 2.6390 37.0742
pb 1 0 6 1 0 6  xz 2.6840 37.1002
pb 2 0 1 2 0 1  x 2.5046
pb 2 0 2 2 0 2  xz 2.5046 36.5897
pb 2 0 3 2 0 3  x 2.5825
pb 2 0 4 2 0 4  x 2.6447
pb 2 0 5 2 0 5  x 2.7069
pb 2 0 6 2 0 6  x 2.7691
mate 4
sii ; ; -1 ; 5 s
sii ; ; -6 ; 32 s
sii -1 ; ; ; 32 s
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c CV screw ring
cylinder
1 2 4 5 ; 1 65 ; 1 2 3 ;
2.0100 2.1300 2.3856 2.5455
0 180
36.5002 36.5802 36.6602
pb 1 0 1 1 0 1  xz 2.0452 36.5353
pb 1 0 2 1 0 2  xz 2.0100 36.6302
pb 1 0 3 1 0 3  xz 2.0400 36.6602
pb 4 0 1 4 0 1  xz 2.5046 36.5002
pb 4 0 2 4 0 2  xz 2.5046 36.5897
pb 4 0 3 4 0 3  xz 2.4069 36.6725
mate 4
sii  ; ; -1 ; 5 s
c lct 1 mx 0.4285 ; lrep 1 ;
lct 1 mz 0.0680 ; lrep 1 ;
endpart


c ****************************************
c ****** End CV Screw ring ***************
c ****************************************


c ****************************************
c ****** Begin CV Lid ********************
c ****************************************

c CV lid - outer region
cylinder
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 ;
1 65 ;
1 2 3 4 5 6 7 8 9 10 11 12 ;
1.6938 1.7963 1.9060 1.9060 2.0840 2.2353 2.3499 2.4425 2.5453
 2.6191 2.7000 2.7713 2.8720 2.9546 3.0290 3.0932 3.1700 3.2667 3.3633
0 180
34.2596 34.3972 34.5054 34.6137 34.7219 34.8096 34.8359 34.8996
 35.1096 35.2096 36 36.1
dei 1 4 ; ; 5 6 ;
dei 4 19 ; ; 6 12 ;
dei 2 3 ; ; 8 12 ;
dei 3 4 ; ; 9 12 ;
dei 3 4 ; ; 1 6 ;
pb 1 0 6 1 0 6 xz 1.6938 34.7219
pb 2 0 6 2 0 6 xz 1.7963 34.7219
pb 3 0 6 3 0 6 xz 1.9060 34.7219
pb 4 0 6 4 0 6 xz 2.0204 34.8359
pb 4 0 7 4 0 7 xz 1.9940 34.8996
pb 1 0 7 3 0 7 z  34.8996
pb 4 0 8 4 0 8 xz 1.9940 34.9846
pb 4 0 9 4 0 9 xz 1.9940 35.0696
pb 3 0 9 3 0 9 xz 1.9640 35.0996
pb 3 0 8 3 0 8 xz 1.9060 35.0996
pb 2 0 8 2 0 8 xz 1.8960 35.1096
pb 1 0 8 1 0 8 xz 1.7963 35.1096
pb 2 0 9 2 0 9 xz 1.8960 35.2096
pb 2 0 10 2 0 10 xz 1.9060 35.2196
pb 2 0 11 2 0 11 xz 1.9640 35.2196
pb 2 0 12 2 0 12 xz 1.9940 35.2496
pb 1 0 12 1 0 12 xz 1.9940 35.3396
pb 1 0 11 1 0 11 xz 1.9640 35.3696
pb 1 0 10 1 0 10 xz 1.9060 35.3696
pb 1 0 9 1 0 9 xz 1.7963 35.3696
pb 6 0 1 6 0 1 x 2.2650
pb 7 0 1 7 0 1 xz 2.4500 34.2596
pb 8 0 1 8 0 1 xz 2.4912 34.3008
pb 9 0 1 9 0 1 xz 2.5124 34.3096
pb 10 0 1 10 0 1  z 34.3096
pb 11 0 1 11 0 1 xz 2.6706 34.3096
pb 12 0 1 12 0 1 xz 2.8396 34.3096
pb 13 0 1 13 0 1 xz 2.8720 34.3296
pb 14 0 1 14 0 1 xz 2.9044 34.3096
pb 15 0 1 15 0 1 xz 3.0720 34.3096
c pb 16 0 1 16 0 1 xz 3.1100 34.3096
c pb 17 0 1 17 0 1 xz 3.1524 34.3271
c pb 17 0 2 17 0 2 xz 3.1700 34.3696
```

```
c pb 17 0 5 17 0 5 xz 3.1700 34.7496
c pb 17 0 6 17 0 6 xz 3.1524 34.7920
c pb 16 0 6 16 0 6 xz 3.1100 34.8096

pb 1 0 2 1 0 2  z 34.4069
pb 1 0 3 1 0 3  z 34.5404
pb 1 0 4 1 0 4  z 34.6835
pb 1 0 5 1 0 5  z 34.8189
pb 1 0 6 1 0 6  z 34.8189
pb 1 0 7 1 0 7  z 34.9849
pb 1 0 8 1 0 8  z 35.1394

pb 2 0 7 2 0 7  xz 1.7970 34.9278
pb 2 0 6 2 0 6  xz 1.7904 34.7562
pb 2 0 5 2 0 5  xz 1.7904 34.7562
pb 2 0 4 2 0 4  xz 1.7948 34.6330
pb 2 0 3 2 0 3  xz 1.7948 34.5163


pb 16 0 1 19 0 1  z 34.3096
pb 18 0 1 18 0 1  x 3.2733
pb 18 0 6 18 0 6  x 3.2733
pb 19 0 1 19 0 1  xz 3.3370 34.3359
pb 19 0 6 19 0 6  xz 3.3370 34.7832
pb 19 0 2 19 0 2  z 34.3996
pb 19 0 5 19 0 5  z 34.7196
mate 3
sii ; ; -1 ; 4 m
sii 4 19 ; ; -6 ; 5 m
sii 1 8 ; ; -1 ; 15 m
c lct 1 mz 1.6906 ; lrep 1 ;
c lct 1 mz 0.0680 ; lrep 1 ;
lct 1 mz 1.7586 ; lrep 1 ;
nset 11 0 1 11 0 1  + lcrd-li
nset 15 0 1 15 0 1  + lcrd-lo
c lct 1 mx 0.4285 mz 1.6906 ; lrep 1 ;
sii -1 ; ; 9 12 ; 33 s
sii ; ; -12 ; 33 s
endpart

c CV single row to begin transition
cylinder
1 2 ; 1 65 ; 1 2 3 4 5 6 7 8 ;
1.63 1.6938
0 180
34.2596 34.3972 34.5054 34.6137 34.7219 34.8996 35.1096 35.3696
pb 2 0 7 2 0 8  x 1.7963
pb 1 0 7 1 0 8  x 1.6800

pb 1 0 2 1 0 2  z 34.4182
pb 1 0 3 1 0 3  z 34.5460
pb 1 0 4 1 0 4  z 34.6916
pb 1 0 5 1 0 5  z 34.8293
pb 1 0 6 1 0 6  z 35.0000
pb 1 0 7 1 0 7  z 35.1500
pb 1 0 8 1 0 8  z 35.3696

pb 2 0 2 2 0 2  z 34.4069
pb 2 0 3 2 0 3  z 34.5404
pb 2 0 4 2 0 4  z 34.6835
pb 2 0 5 2 0 5  z 34.8189
pb 2 0 6 2 0 6  z 34.9849
pb 2 0 7 2 0 7  z 35.1394

mate 3
sii ; ; -1 ; 15 m
sii ; ; -8 ; 33 s
bb 1 0 0 1 0 0  3 ;
c lct 1 mz 1.6906 ; lrep 1 ;
c lct 1 mz 0.0680 ; lrep 1 ;
lct 1 mz 1.7586 ; lrep 1 ;
endpart

c CV transition
cylinder
1 5 ; 1 33 ; 1 2 3 4 5 6 7 8 ;
1.2 1.63
0 180
34.2596 34.4182 34.5767 34.7353 34.8939 35.0525 35.2110 35.3696
c pb 2 0 7 2 0 8  x 1.6800
pb 2 0 8 2 0 8  x 1.6800
pb 2 0 7 2 0 7  xz 1.6800 35.1500
pb 2 0 3 2 0 3 z 34.5460
pb 2 0 4 2 0 4 z 34.6916
pb 2 0 5 2 0 5 z 34.8293
pb 2 0 6 2 0 6 z 35.0000
mate 3
sii ; ; -1 ; 15 m
sii ; ; -8 ; 33 s
trbb 2 0 0 2 0 0  3 ;
bb 1 0 0 1 0 0  4 ;
c lct 1 mz 1.6906 ; lrep 1 ;
c lct 1 mz 0.0680 ; lrep 1 ;
lct 1 mz 1.7586 ; lrep 1 ;
endpart

c CV transition
cylinder
1 3 ; 1 17 ; 1 8 ;
1.0 1.2
0 180
34.2596 35.3696
mate 3
sii ; ; -1 ; 15 m
sii ; ; -2 ; 33 s
trbb 2 0 0 2 0 0  4 ;
c lct 1 mz 1.6906 ; lrep 1 ;
c lct 1 mz 0.0680 ; lrep 1 ;
lct 1 mz 1.7586 ; lrep 1 ;
endpart


c CV lid center
block
1 5 9 13 17 ; 1 5 9 13 17 ; 1 8 ;
-.45 -.45 0 .45 .45
-.45 -.45 0 .45 .45
34.2596 35.3696
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
dei ; 1 3 ; ;
sd 1 cy 0 0 0 0 0 1  1.0
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
pb 2 3 0 2 3 0  x -.55
pb 4 3 0 4 3 0  x  .55
pb 3 4 0 3 4 0  y  .55
mate 3
sii ; ; -1 ; 15 m
sii ; ; -2 ; 33 s
c lct 1 mz 1.6906 ; lrep 1 ;
c lct 1 mz 0.0680 ; lrep 1 ;
lct 1 mz 1.7586 ; lrep 1 ;
nset 3 3 1 3 3 1  +  lcrd-x
endpart


c ****************************************
c ****** End CV Lid *******************
c ****************************************

c ****************************************
c *********** Begin Angle ************
c ****************************************

c angle 0 to 22.5

c p1 angle vertical leg to upper region of fillet
cylinder
1 2 3 4 5 ; 1 2 3 10 19 ; 1 2 3 4  8 9 10 11 ;
7.3 7.4 7.5 7.6 7.7
0 1.2500 2.5000 11.2500 22.5000
40.75 40.2 40.3 41.4785 42.3122 43 43.2 43.3
dei 1 2 ; ; 1 6 ;
pb 2 0 1 2 0 1 xz 7.3250 40.7502
pb 3 0 1 3 0 1 xz 7.3550 40.7502
pb 4 0 1 4 0 1 xz 7.4673 40.7641
pb 5 0 1 5 0 1 xz 7.5849 40.8501
pb 2 0 2 2 0 2 xz 7.3250 41.0002
pb 3 0 2 3 0 2 xz 7.4284 41.0002
pb 4 0 2 4 0 2 xz 7.5317 41.0002
pb 5 0 2 5 0 2 xz 7.6350 41.0002
pb 2 0 3 2 0 3 xz 7.3250 41.2502
pb 3 0 3 3 0 3 xz 7.4284 41.2502
pb 4 0 3 4 0 3 xz 7.5317 41.2502
pb 5 0 3 5 0 3 xz 7.6350 41.2502
pb 2 0 4 2 0 4 xz 7.3850 41.4785
pb 3 0 4 3 0 4 xz 7.4684 41.4785
pb 4 0 4 4 0 4 xz 7.5517 41.4785
pb 5 0 4 5 0 4 xz 7.6350 41.4785

pb 2 0 5 2 0 5 xz 7.3850 42.3122
pb 3 0 5 3 0 5 xz 7.4684 42.3122
pb 4 0 5 4 0 5 xz 7.5517 42.3122
pb 5 0 5 5 0 5 xz 7.6350 42.3122
pb 1 0 6 1 0 6 xz 7.3850 42.7102
pb 2 0 6 2 0 6 xz 7.3850 42.5112
pb 3 0 6 3 0 6 xz 7.4747 42.4684
pb 4 0 6 4 0 6 xz 7.5622 42.4266
pb 5 0 6 5 0 6 xz 7.6496 42.3848
pb 1 0 7 1 0 7 xz 7.4050 42.7302
pb 2 0 7 2 0 7 xz 7.4763 42.6589
pb 3 0 7 3 0 7 xz 7.5476 42.5877
pb 4 0 7 4 0 7 xz 7.6188 42.5164
pb 5 0 7 5 0 7 xz 7.6901 42.4451
pb 1 0 8 1 0 8 xz 7.4250 42.7502
pb 2 0 8 2 0 8 xz 7.6299 42.7502
pb 3 0 8 3 0 8 xz 7.6717 42.6627
pb 4 0 8 4 0 8 xz 7.7135 42.5751
pb 5 0 8 5 0 8 xz 7.7553 42.4876
mate 5
sii 3 5 ; ; -1 ; 21 s
sii -5 ; ; 1 8 ; 21 s
sii 1 2 ; ; -8 ; 8 m
c gct 4 ; rz 45 ; rz 90 ; rz 135 ;
gct 8 ; rz 22.5 ; rz 45 ; rz 67.5 ; rz 90 ;
  rz 112.5 ; rz 135 ; rz 157.5 ;
grep 1 2 3 4 5 6 7 8 ;
dei ; 4 5 ; ;
endpart

c p2 angle horizontal leg from fillet to OD
cylinder
1 2 3 4 5 6 10 ; 1 2 3 4 5 10 19 ; 1 4 ;
7.6299 7.8230 8.0000 8.1650 8.3300 8.4950 9.1550
0 1.2500 2.5000 3.7500 5.0000 11.2500 22.5000
42.5002 42.7502
dei 2 4 ; 1 3 ; ;
pb 1 0 1 1 0 1  xz 7.7553 42.4876

pb 2 1 2 2 1 2  xy 7.7109 0.0000
pb 2 2 2 2 2 2  xy 7.7510 1.0686
pb 2 3 2 2 3 2  xy 7.8594 1.8255
pb 2 3 1 2 3 1  xy 7.8230 2.5000
pb 3 3 1 3 3 2  xy 8.0052 2.0696
pb 4 3 1 4 3 2  xy 8.1484 1.7607
pb 4 2 1 4 2 2  xy 8.2516 1.0037
pb 4 1 1 4 1 2  xy 8.2891 0.0000
pb 5 1 1 5 1 2  xy 8.3941 0.0000
pb 5 2 1 5 2 2  xy 8.3715 1.1656

pb 2 4 2 2 4 2 xy 7.82321 3.25812
pb 2 4 1 2 4 1 xy 7.8230 3.7500
pb 3 4 1 3 4 2 xy 8.00099 3.38257
pb 4 4 1 4 4 2 xy 8.15760 3.31756
pb 5 3 1 5 3 2 xy 8.32835 2.16898
pb 5 4 1 5 4 2 xy 8.32757 3.43898
c mod 10/02/03
sd 1 cy 8 0 0 0 0 1 0.2744
sfi -2 0 -4; 1 3; -2;sd 1
sfi 2 4; -3; -2;sd 1
```

GENERAL DESIGN AND COMPUTATION SHEET

JOB Impact Analysis of ES3100 Design Concepts Using HABC		DATE March 2004	SHEET 112 of 133
DAC NO DAC-EA-801699-A002	REVISION 0	COMPUTED KDH 2-24-05	CHECKED BY GAA 2/24/05 GAA

```
c end mod 10/02/03
mate 5
sii ; ; -1 ; 21 s
sii ; ; -2 ; 8 m
c gct 4 ; rz 45 ; rz 90 ; rz 135 ;
c grep 1 2 3 4 ;
gct 8 ; rz 22.5 ; rz 45 ; rz 67.5 ; rz 90 ;
  rz 112.5 ; rz 135 ; rz 157.5 ;
grep 1 2 3 4 5 6 7 8 ;
dei ; 6 7 ; ;
endpart

c p3 footprint in angle at 0, first 60 deg segment of bolt
block
1 2 4 6 ; 1 2 4 6 ; 1 4 ;
0 .1 .2 .3
0 .1 .2 .3
42.5002 42.7502
dei 2 4 ; 2 4 ; ;
dei 3 4 ; 1 2 ; 1 2 ;
dei 1 2 ; 3 4 ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.4265
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 43.0090 ;
sd 10 xyplan mz 43.4465 ;
sd 11 pl3  rt 0.4265 0 0
        rt 0.4265 0 1
        cy 0.4265 60 0
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; ;  sd 6
sfi -3 ; -2 ; ;  sd 3
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 11

sfi -2 ; -3 ; ;  sd 6
sfi -2 ; -3 ; ;  sd 3
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 11

sfi -1 ; -2 ; ;  sd 7
sfi -1 ; -2 ; ;  sd 1
sfi -1 ; -3 ; ;  sd 7
sfi -1 ; -3 ; ;  sd 3
sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 4

sii ; ; -1 ; 21 s
c gct 4  mx 8.0000 ; mx 8.0000  rz 45 ;
c  mx 8.0000 rz 90 ; mx 8.0000 rz 135 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 ; mx 8.0000 rz 22.5 ;
  mx 8.0000 rz 45 ; mx 8.0000 rz 67.5 ;
  mx 8.0000 rz 90 ; mx 8.0000 rz 112.5 ;
  mx 8.0000 rz 135 ; mx 8.0000 rz 157.5 ;
grep 1 2 3 4 5 6 7 8 ;
mate 5
endpart

c p4 bolt footprint in angle at 0 second 60 degree segment
block
1 2 4 6 ; 1 2 4 6 ; 1 4 ;
0 .1 .2 .3
0 .1 .2 .3
42.5002 42.7502
dei 2 4 ; 2 4 ; ;
dei 3 4 ; 1 2 ; 1 2 ;
dei 1 2 ; 3 4 ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.4265
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 43.0090 ;
sd 10 xyplan mz 43.4465 ;
sd 11 pl3  rt 0.4265 0 0
        rt 0.4265 0 1
        cy 0.4265 60 0
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; ;  sd 6
sfi -3 ; -2 ; ;  sd 3
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 11

sfi -2 ; -3 ; ;  sd 6
sfi -2 ; -3 ; ;  sd 3
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 11

sfi -1 ; -2 ; ;  sd 7
sfi -1 ; -2 ; ;  sd 1
sfi -1 ; -3 ; ;  sd 7
sfi -1 ; -3 ; ;  sd 3
sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 4

sii ; ; -1 ; 21 s
lct 1 rz 60 ;  lrep 1 ;
c gct 4  mx 8.0000 ; mx 8.0000  rz 45 ;
c  mx 8.0000 rz 90 ; mx 8.0000 rz 135 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 ; mx 8.0000 rz 22.5 ;
  mx 8.0000 rz 45 ; mx 8.0000 rz 67.5 ;
  mx 8.0000 rz 90 ; mx 8.0000 rz 112.5 ;
  mx 8.0000 rz 135 ; mx 8.0000 rz 157.5 ;
grep 1 2 3 4 5 6 7 8 ;
mate 5
endpart

c p5 bolt footprint in angle at 0 third 60 deg segment
block
1 2 4 6 ; 1 2 4 6 ; 1 4 ;
0 .1 .2 .3
0 .1 .2 .3
42.5002 42.7502
dei 2 4 ; 2 4 ; ;
dei 3 4 ; 1 2 ; 1 2 ;
dei 1 2 ; 3 4 ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.4265
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 43.0090 ;
sd 10 xyplan mz 43.4465 ;
sd 11 pl3  rt 0.4265 0 0
        rt 0.4265 0 1
        cy 0.4265 60 0
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; -2 ;  sd 6
sfi -3 ; -2 ; -2 ;  sd 3
pb 3 2 1 3 2 1  xy 0.1327 0.0766
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 11

sfi -2 ; -3 ; -2 ;  sd 6
sfi -2 ; -3 ; -2 ;  sd 3
pb 2 3 1 2 3 1  xy 0.1327 0.0766
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 11


sfi -1 ; -2 ; -2 ;  sd 7
sfi -1 ; -2 ; -2 ;  sd 1
pb 1 2 1 1 2 1  xy 0.0221 0.0383
sfi -1 ; -3 ; -2 ;  sd 7
sfi -1 ; -3 ; -2 ;  sd 3
pb 1 3 1 1 3 1  xy 0.0664 0.1149


sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 4

sii ; ; -1 ; 21 s
lct 1 rz 120 ;  lrep 1 ;
c gct 4  mx 8.0000 ; mx 8.0000  rz 45 ;
c  mx 8.0000 rz 90 ; mx 8.0000 rz 135 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 ; mx 8.0000 rz 22.5 ;
  mx 8.0000 rz 45 ; mx 8.0000 rz 67.5 ;
  mx 8.0000 rz 90 ; mx 8.0000 rz 112.5 ;
  mx 8.0000 rz 135 ; mx 8.0000 rz 157.5 ;
grep 1 2 3 4 5 6 7 8 ;
mate 5
endpart


c p6 filler around the bolt footprint at 0
block
1 2 3 4 5 6 7 ; 1 2 ; 1 4 ;
-.3 -.2 -.1 0 .1 .2 .3
.2 .3
42.5002 42.7502
sd 1 cy 0 0 0 0 0 1  0.2175
sd 2 cy 0 0 0 0 0 1  0.2744
sd 9 cy 0 0 0 0 0 1  0.2891
sd 3 zxplan ;
sd 4 zxplan rz 30 ;
sd 5 zxplan rz 60 ;
sd 6 zxplan rz 90 ;
sd 7 zxplan rz 120 ;
sd 8 zxplan rz 150 ;
sfi ; -2 ; -2 ; sd 2
sfi ; -1 ; -2 ; sd 1
sfi 4 7 ; -2 ; -1 ; sd 9
sfi 4 7 ; -1 ; -1 ; sd 1
sfi -7 ; ; ; sd 3
sfi -6 ; ; ; sd 4
sfi -5 ; ; ; sd 5
sfi -4 ; ; ; sd 6
sfi -3 ; ; -2 ; sd 7
sfi -2 ; ; -2 ; sd 8
sfi -1 ; ; -2 ; sd 3
sfi -3 ; -1 ; -1 ; sd 1
sfi -3 ; -1 ; -1 ; sd 7
```

```
pb 2 1 1 2 1 1 xy -0.1327 0.0766
pb 1 1 1 1 1 1 xy -0.1327 0.0000
pb 1 2 1 1 2 1 xy -0.1770 0.0000
pb 2 2 1 2 2 1 xy -0.1788 0.1707
pb 3 2 1 3 2 1 xy -0.1844 0.3412
mate 5
sii ; ; -1 ; 21 s
sii ; ; -2 ; 8 m
c gct 4  mx 8.0000 ; mx 8.0000  rz 45 ;
c  mx 8.0000 rz 90 ; mx 8.0000 rz 135 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 ; mx 8.0000 rz 22.5 ;
  mx 8.0000 rz 45 ; mx 8.0000 rz 67.5 ;
  mx 8.0000 rz 90 ; mx 8.0000 rz 112.5 ;
  mx 8.0000 rz 135 ; mx 8.0000 rz 157.5 ;
grep 1 2 3 4 5 6 7 8 ;
endpart


c angle 22.5 to 45

c p7 angle vertical leg to upper region of fillet
cylinder
1 2 3 4 5 ; 1 2 3 10 19 ; 1 2 3 4  8 9 10 11 ;
7.3 7.4 7.5 7.6 7.7
0 1.2500 2.5000 11.2500 22.5000
40.75 40.2 40.3 41.4785 42.3122 43 43.2 43.3
dei 1 2 ; ; 1 6 ;
pb 2 0 1 2 0 1 xz 7.3250 40.7502
pb 3 0 1 3 0 1 xz 7.3550 40.7502
pb 4 0 1 4 0 1 xz 7.4673 40.7641
pb 5 0 1 5 0 1 xz 7.5849 40.8501
pb 2 0 2 2 0 2 xz 7.3250 41.0002
pb 3 0 2 3 0 2 xz 7.4284 41.0002
pb 4 0 2 4 0 2 xz 7.5317 41.0002
pb 5 0 2 5 0 2 xz 7.6350 41.0002
pb 2 0 3 2 0 3 xz 7.3250 41.2502
pb 3 0 3 3 0 3 xz 7.4284 41.2502
pb 4 0 3 4 0 3 xz 7.5317 41.2502
pb 5 0 3 5 0 3 xz 7.6350 41.2502
pb 2 0 4 2 0 4 xz 7.3850 41.4785
pb 3 0 4 3 0 4 xz 7.4684 41.4785
pb 4 0 4 4 0 4 xz 7.5517 41.4785
pb 5 0 4 5 0 4 xz 7.6350 41.4785

pb 2 0 5 2 0 5 xz 7.3850 42.3122
pb 3 0 5 3 0 5 xz 7.4684 42.3122
pb 4 0 5 4 0 5 xz 7.5517 42.3122
pb 5 0 5 5 0 5 xz 7.6350 42.3122
pb 1 0 6 1 0 6 xz 7.3850 42.7102
pb 2 0 6 2 0 6 xz 7.3850 42.5112
pb 3 0 6 3 0 6 xz 7.4747 42.4684
pb 4 0 6 4 0 6 xz 7.5622 42.4266
pb 5 0 6 5 0 6 xz 7.6496 42.3848
pb 1 0 7 1 0 7 xz 7.4050 42.7302
pb 2 0 7 2 0 7 xz 7.4763 42.6589
pb 3 0 7 3 0 7 xz 7.5476 42.5877
pb 4 0 7 4 0 7 xz 7.6188 42.5164
pb 5 0 7 5 0 7 xz 7.6901 42.4451
pb 1 0 8 1 0 8 xz 7.4250 42.7502
pb 2 0 8 2 0 8 xz 7.6299 42.7502
pb 3 0 8 3 0 8 xz 7.6717 42.6627
pb 4 0 8 4 0 8 xz 7.7135 42.5751
pb 5 0 8 5 0 8 xz 7.7553 42.4876
mate 5
sii 3 5 ; ; -1 ; 21 s
sii -5 ; ; 1 8 ; 21 s
sii 1 2 ; ; -8 ; 8 m
c gct 4 nxz rz 45 ; nxz rz 90 ; nxz rz 135 ; nxz rz 180 ;
c grep 1 2 3 4 ;
gct 8 nxz rz 22.5 ; nxz rz 45 ; nxz rz 67.5 ; nxz rz 90 ;
  nxz rz 112.5 ; nxz rz 135 ; nxz rz 157.5 ; nxz rz 180 ;
grep 1 2 3 4 5 6 7 8 ;
dei ; 4 5 ; ;
endpart

c p8 angle horizontal leg from fillet to OD
cylinder
1 2 3 4 5 6 10 ; 1 2 3 4 5 10 19 ; 1 4 ;
7.6299 7.8230 8.0000 8.1650 8.3300 8.4950 9.1550
0 1.2500 2.5000 3.7500 5.0000 11.2500 22.5000
42.5002 42.7502
dei 2 4 ; 1 3 ; ;
pb 1 0 1 1 0 1  xz 7.7553 42.4876

pb 2 1 2 2 1 2  xy 7.7109 0.0000
pb 2 2 2 2 2 2  xy 7.7510 1.0686
pb 2 3 2 2 3 2  xy 7.8594 1.8255
pb 2 3 1 2 3 1  xy 7.8230 2.5000
pb 3 3 1 3 3 2  xy 8.0052 2.0696
pb 4 3 1 4 3 2  xy 8.1484 1.7607
pb 4 2 1 4 2 2  xy 8.2516 1.0037
pb 4 1 1 4 1 2  xy 8.2891 0.0000
pb 5 1 1 5 1 2  xy 8.3941 0.0000
pb 5 2 1 5 2 2  xy 8.3715 1.1656

pb 2 4 2 2 4 2 xy 7.82321 3.25812
pb 2 4 1 2 4 1 xy 7.8230 3.7500
pb 3 4 1 3 4 2 xy 8.00099 3.38257
pb 4 4 1 4 4 2 xy 8.15760 3.31756
pb 5 3 1 5 3 2 xy 8.32835 2.16898
pb 5 4 1 5 4 2 xy 8.32757 3.43898
mate 5
c mod 10/02/03
sd 1 cy 8 0 0 0 0 1 0.2744
sfi -2 0 -4; 1 3; -2;sd 1
sfi 2 4; -3; -2;sd 1
c end mod 10/02/03
sii ; ; -1 ; 21 s
sii ; ; -2 ; 8 m
c gct 4 nxz rz 45 ; nxz rz 90 ; nxz rz 135 ; nxz rz 180 ;
c grep 1 2 3 4 ;
gct 8 nxz rz 22.5 ; nxz rz 45 ; nxz rz 67.5 ; nxz rz 90 ;
  nxz rz 112.5 ; nxz rz 135 ; nxz rz 157.5 ; nxz rz 180 ;
grep 1 2 3 4 5 6 7 8 ;
dei ; 6 7 ; ;
endpart

c p9 bolt footprint in angle at 22.5, 4th 30 deg segment
block
1 2 4 6 ; 1 2 4 6 ; 1 4 ;
0 .1 .2 .3
0 .1 .2 .3
42.5002 42.7502
dei 2 4 ; 2 4 ; ;
dei 3 4 ; 1 2 ; 1 2 ;
dei 1 2 ; 3 4 ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.4265
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 43.0090 ;
sd 10 xyplan mz 43.4465 ;
sd 11 pl3  rt 0.4265 0 0
        rt 0.4265 0 1
        cy 0.4265 60 0
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; ;  sd 6
sfi -3 ; -2 ; ;  sd 3
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 11

sfi -2 ; -3 ; ;  sd 6
sfi -2 ; -3 ; ;  sd 3
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 11

sfi -1 ; -2 ; ;  sd 7
sfi -1 ; -2 ; ;  sd 1
sfi -1 ; -3 ; ;  sd 7
sfi -1 ; -3 ; ;  sd 3
sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 4

c sfi ; ; -1 ; sd 8
c sfi ; ; -2 ; sd 9
c sfi ; ; -3 ; sd 10
c lct 1 ; rz 60 ;  lrep 1 ;
c gct 1 mx 8.0000 ; grep 1 ;
mate 5
sii ; ; -1 ; 21 s
c gct 4  mx 8.0000 nxz rz 45 ; mx 8.0000 nxz rz 90 ;
c  mx 8.0000 nxz rz 135 ; mx 8.0000 nxz rz 180 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 nxz rz 22.5 ; mx 8.0000 nxz rz 45 ;
  mx 8.0000 nxz rz 67.5 ; mx 8.0000 nxz rz 90 ;
  mx 8.0000 nxz rz 112.5 ; mx 8.0000 nxz rz 135 ;
  mx 8.0000 nxz rz 157.5 ; mx 8.0000 nxz rz 180 ;
grep 1 2 3 4 5 6 7 8 ;
endpart

c p10 bolt footprint in angle at 22.5 5th 60 deg segment
block
1 2 4 6 ; 1 2 4 6 ; 1 4 ;
0 .1 .2 .3
0 .1 .2 .3
42.5002 42.7502
dei 2 4 ; 2 4 ; ;
dei 3 4 ; 1 2 ; 1 2 ;
dei 1 2 ; 3 4 ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.4265
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 43.0090 ;
sd 10 xyplan mz 43.4465 ;
sd 11 pl3  rt 0.4265 0 0
        rt 0.4265 0 1
        cy 0.4265 60 0
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; ;  sd 6
sfi -3 ; -2 ; ;  sd 3
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 11

sfi -2 ; -3 ; ;  sd 6
sfi -2 ; -3 ; ;  sd 3
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 11

sfi -1 ; -2 ; ;  sd 7
sfi -1 ; -2 ; ;  sd 1
sfi -1 ; -3 ; ;  sd 7
sfi -1 ; -3 ; ;  sd 3
sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 4
```

GENERAL DESIGN AND COMPUTATION SHEET

JOB Impact Analysis of ES3100 Design Concepts Using HABC		DATE March 2004	SHEET 114 of 133
DAC NO DAC-EA-801699-A002	REVISION 0	COMPUTED KDH KDH 2-24-05	CHECKED BY GAA 2/24/05 GAA

```
mate 5

sii ; ; -1 ; 21 s
lct 1 rz 60 ; lrep 1 ;
c gct 4 mx 8.0000 nxz rz 45 ; mx 8.0000 nxz rz 90 ;
c mx 8.0000 nxz rz 135 ; mx 8.0000 nxz rz 180 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 nxz rz 22.5 ; mx 8.0000 nxz rz 45 ;
  mx 8.0000 nxz rz 67.5 ; mx 8.0000 nxz rz 90 ;
  mx 8.0000 nxz rz 112.5 ; mx 8.0000 nxz rz 135 ;
  mx 8.0000 nxz rz 157.5 ; mx 8.0000 nxz rz 180 ;
grep 1 2 3 4 5 6 7 8 ;
endpart


c p11 bolt footprint in angle at 22.5 6th 60 deg segment
block
1 2 4 6 ; 1 2 4 6 ; 1 4 ;
0 .1 .2 .3
0 .1 .2 .3
42.5002 42.7502
dei 2 4 ; 2 4 ; ;
dei 3 4 ; 1 2 ; 1 2 ;
dei 1 2 ; 3 4 ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.4265
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 43.0090 ;
sd 10 xyplan mz 43.4465 ;
sd 11 pl3  rt 0.4265 0 0
       rt 0.4265 0 1
       cy 0.4265 60 0
sfi -2 ; -1 ; ; sd 5
sfi -2 ; -1 ; ; sd 1
sfi -3 ; -1 ; ; sd 5
sfi -3 ; -1 ; ; sd 3
sfi -4 ; -1 ; ; sd 5
sfi -4 ; -1 ; ; sd 4

sfi -2 ; -2 ; ; sd 6
sfi -2 ; -2 ; ; sd 2
sfi -3 ; -2 ; -2 ; sd 6
sfi -3 ; -2 ; -2 ; sd 3
pb 3 2 1 3 2 1  xy 0.1327 0.0766
sfi -4 ; -2 ; ; sd 6
sfi -4 ; -2 ; ; sd 11

sfi -2 ; -3 ; -2 ; sd 6
sfi -2 ; -3 ; -2 ; sd 3
pb 2 3 1 2 3 1  xy 0.1327 0.0766
sfi -2 ; -4 ; ; sd 6
sfi -2 ; -4 ; ; sd 11


sfi -1 ; -2 ; -2 ; sd 7
sfi -1 ; -2 ; -2 ; sd 1
pb 1 2 1 1 2 1  xy 0.0221 0.0383
sfi -1 ; -3 ; -2 ; sd 7
sfi -1 ; -3 ; -2 ; sd 3
pb 1 3 1 1 3 1  xy 0.0664 0.1149


sfi -1 ; -4 ; ; sd 7
sfi -1 ; -4 ; ; sd 4

sii ; ; -1 ; 21 s
lct 1 rz 120 ; lrep 1 ;
c gct 4  mx 8.0000 nxz rz 45 ; mx 8.0000 nxz rz 90 ;
c  mx 8.0000 nxz rz 135 ; mx 8.0000 nxz rz 180 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 nxz rz 22.5 ; mx 8.0000 nxz rz 45 ;
  mx 8.0000 nxz rz 67.5 ; mx 8.0000 nxz rz 90 ;
  mx 8.0000 nxz rz 112.5 ; mx 8.0000 nxz rz 135 ;
  mx 8.0000 nxz rz 157.5 ; mx 8.0000 nxz rz 180 ;
grep 1 2 3 4 5 6 7 8 ;
mate 5
endpart

c p12 filler around the bolt footprint at 22.5
block
1 2 3 4 5 6 7 ; 1 2 ; 1 4 ;
-.3 -.2 -.1 0 .1 .2 .3
.2 .3
42.5002 42.7502
sd 1 cy 0 0 0 0 0 1  0.2175
sd 2 cy 0 0 0 0 0 1  0.2744
sd 9 cy 0 0 0 0 0 1  0.2891
sd 3 zxplan ;
sd 4 zxplan rz 30 ;
sd 5 zxplan rz 60 ;
sd 6 zxplan rz 90 ;
sd 7 zxplan rz 120 ;
sd 8 zxplan rz 150 ;
sfi ; -2 ; -2 ; sd 2
sfi ; -1 ; -2 ; sd 1
sfi 4 7 ; -2 ; -1 ; sd 9
sfi 4 7 ; -1 ; -1 ; sd 1
sfi -7 ; ; ; sd 3
sfi -6 ; ; ; sd 4
sfi -5 ; ; ; sd 5
sfi -4 ; ; ; sd 6
sfi -3 ; ; -2 ; sd 7
sfi -2 ; ; -2 ; sd 8
sfi -1 ; ; -2 ; sd 3
sfi -3 ; -1 ; -1 ; sd 1
sfi -3 ; -1 ; -1 ; sd 7
pb 2 1 1 2 1 1  xy -0.1327 0.0766
pb 1 1 1 1 1 1  xy -0.1327 0.0000
pb 1 2 1 1 2 1  xy -0.1770 0.0000
pb 2 2 1 2 2 1  xy -0.1788 0.1707
```

```
pb 3 2 1 3 2 1  xy -0.1844 0.3412
mate 5
sii ; ; -1 ; 21 s
sii ; ; -2 ; 8 m
c gct 4 mx 8.0000 nxz rz 45 ; mx 8.0000 nxz rz 90 ;
c  mx 8.0000 nxz rz 135 ; mx 8.0000 nxz rz 180 ;
c grep 1 2 3 4 ;
gct 8 mx 8.0000 nxz rz 22.5 ; mx 8.0000 nxz rz 45 ;
  mx 8.0000 nxz rz 67.5 ; mx 8.0000 nxz rz 90 ;
  mx 8.0000 nxz rz 112.5 ; mx 8.0000 nxz rz 135 ;
  mx 8.0000 nxz rz 157.5 ; mx 8.0000 nxz rz 180 ;
grep 1 2 3 4 5 6 7 8 ;
endpart


c ******************************************
c ************ End Angle ****************
c ******************************************

c ************************************
c ******** Begin Drum  ********
c ************************************

c drum roll to angle
cylinder
-1 ; 1 145 ; 1 4 6 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 ;
9.1550
0 180
42.5002 42.7502 43.0002 43.1952
  43.2 43.3 43.4 43.5 43.6 43.7 43.8 43.9 44.0 44.1 44.2 44.3
  44.4 44.5
pb 1 0 5 1 0 5  xz 9.1699 43.2698
pb 1 0 6 1 0 6  xz 9.2122 43.3331
pb 1 0 7 1 0 7  xz 9.2754 43.3754
pb 1 0 8 1 0 8  xz 9.3500 43.3902
pb 1 0 9 1 0 9  xz 9.4247 43.3754
pb 1 0 10 1 0 10 xz 9.4879 43.3331
pb 1 0 11 1 0 11 xz 9.5302 43.2698
pb 1 0 12 1 0 12 xz 9.5450 43.1952
pb 1 0 13 1 0 13 xz 9.5302 43.1206
pb 1 0 14 1 0 14 xz 9.4879 43.0573
pb 1 0 15 1 0 15 xz 9.4247 43.0150
pb 1 0 16 1 0 16 xz 9.3500 43.0002
pb 1 0 17 1 0 17 xz 9.2525 43.0002
pb 1 0 18 1 0 18 xz 9.1550 43.0002
mate 6
thic 0.06
endpart

c drum between angle and bump
cylinder
-1 ; 1 145 ; 1 8 ;
9.1550
0 180
41.0000 42.5002
mate 6
thic 0.06
orpt + 0 0 0
sii -1 ; ; ; 20 s
bb 0 0 1 0 0 1  5 ;
endpart

c drum between the angle and bump
cylinder
-1 ; 1 73 ; 1 3 ;
9.1550
0 180
40.4743 41.0000
mate 6
thic 0.06
orpt + 0 0 0
sii -1 ; ; ; 20 s
trbb 0 0 2 0 0 2  5 ;
endpart


c drum upper bump
cylinder
-1 ; 1 73 ; 1 2 3 4 5 6 7 8 9 10 11 12 13 ;
9.1550
0 180
38.0660 38.2709 38.4618 38.6256 38.8143 39.0341 39.2702
  39.5062 39.7261 39.9148 40.0786 40.2694 40.4743
pb 1 0 2 1 0 2  x 9.1821
pb 1 0 3 1 0 3  x 9.2613
pb 1 0 4 1 0 4  x 9.3874
pb 1 0 5 1 0 5  x 9.5326
pb 1 0 6 1 0 6  x 9.6239
pb 1 0 7 1 0 7  x 9.6550
pb 1 0 8 1 0 8  x 9.6239
pb 1 0 9 1 0 9  x 9.5326
pb 1 0 10 1 0 10 x 9.3874
pb 1 0 11 1 0 11 x 9.2613
pb 1 0 12 1 0 12 x 9.1821
mate 6
thic 0.06
orpt + 0 0 39
sii -1 ; ; ; 20 s
endpart

c drum between the upper and mid-upper bumps
cylinder
-1 ; 1 73 ; 1 17 ;
9.1550
0 180
32.6243 38.0660
mate 6
thic 0.06
orpt + 0 0 35
sii -1 ; ; ; 20 s
endpart

c drum mid-upper bump
cylinder
```

```
-1 ; 1 73 ; 1 2 3 4 5 6 7 8 9 10 11 12 13 ;
9.1550
0 180
30.2160 30.4209 30.6118 30.7756 30.9642 31.1841 31.4201
 31.6562 31.8761 32.0647 32.2285 32.4194 32.6243
pb 1 0 2 1 0 2  x 9.1821
pb 1 0 3 1 0 3  x 9.2613
pb 1 0 4 1 0 4  x 9.3874
pb 1 0 5 1 0 5  x 9.5326
pb 1 0 6 1 0 6  x 9.6239
pb 1 0 7 1 0 7  x 9.6550
pb 1 0 8 1 0 8  x 9.6239
pb 1 0 9 1 0 9  x 9.5326
pb 1 0 10 1 0 10 x 9.3874
pb 1 0 11 1 0 11 x 9.2613
pb 1 0 12 1 0 12 x 9.1821
mate 6
thic 0.06
orpt + 0 0 31
sii -1 ; ; ; 20 s
endpart


c drum between the mid-upper and mid-lower bumps
cylinder
-1 ; 1 73 ; 1 27 ;
9.1550
0 180
20.6243 30.2160
mate 6
thic 0.06
orpt + 0 0 25
sii -1 ; ; ; 20 s
endpart

c drum mid-lower bump
cylinder
-1 ; 1 73 ; 1 2 3 4 5 6 7 8 9 10 11 12 13 ;
9.1550
0 180
18.2159 18.4208 18.6117 18.7755 18.9642 19.1841 19.4201
 19.6561 19.8760 20.0647 20.2285 20.4193 20.6243
pb 1 0 2 1 0 2  x 9.1821
pb 1 0 3 1 0 3  x 9.2613
pb 1 0 4 1 0 4  x 9.3874
pb 1 0 5 1 0 5  x 9.5326
pb 1 0 6 1 0 6  x 9.6239
pb 1 0 7 1 0 7  x 9.6550
pb 1 0 8 1 0 8  x 9.6239
pb 1 0 9 1 0 9  x 9.5326
pb 1 0 10 1 0 10 x 9.3874
pb 1 0 11 1 0 11 x 9.2613
pb 1 0 12 1 0 12 x 9.1821
mate 6
thic 0.06
orpt + 0 0 19
sii -1 ; ; ; 20 s
endpart

c drum between the mid-lower and lower bumps
cylinder
-1 ; 1 73 ; 1 27 ;
9.1550
0 180
8.6242 18.2159
mate 6
thic 0.06
orpt + 0 0 12
sii -1 ; ; ; 20 s
endpart

c drum lower bump
cylinder
-1 ; 1 73 ; 1 2 3 4 5 6 7 8 9 10 11 12 13 ;
9.1550
0 180
6.2159 6.4208 6.6117 6.7755 6.9641 7.1840 7.4200
 7.6561 7.8759 8.0646 8.2284 8.4193 8.6242
pb 1 0 2 1 0 2  x 9.1821
pb 1 0 3 1 0 3  x 9.2613
pb 1 0 4 1 0 4  x 9.3874
pb 1 0 5 1 0 5  x 9.5326
pb 1 0 6 1 0 6  x 9.6239
pb 1 0 7 1 0 7  x 9.6550
pb 1 0 8 1 0 8  x 9.6239
pb 1 0 9 1 0 9  x 9.5326
pb 1 0 10 1 0 10 x 9.3874
pb 1 0 11 1 0 11 x 9.2613
pb 1 0 12 1 0 12 x 9.1821
mate 6
thic 0.06
orpt + 0 0 7
sii -1 ; ; ; 20 s
endpart

c drum between the lower bump and the bottom roll
cylinder
-1 ; 1 73 ; 1 15 ;
9.1550
0 180
1.5000 6.2159
mate 6
thic 0.06
orpt + 0 0 0
sii -1 ; ; ; 20 s
endpart

c drum
cylinder
-1 ; 1 73 ; 1 6 ;
9.1550
0 180
0.5250 1.5000
mate 6
thic 0.06
res 0 0 1 0 0 2  k 1.30
orpt + 0 0 0
sii -1 ; ; ; 20 s
endpart


c drum bottom roll
cylinder
-1 ; 1 73 ; 1 2 3 4 5 6 7 8 9 10 11 12 14 ;
9.1550
0 180
.01 .02 .03 .04 .05 .06 .07 .08 .09 1.0 1.1
 0.3300 0.5250
pb 1 0 1 1 0 1  xz  9.1550 0.5250
pb 1 0 2 1 0 2  xz  9.2525 0.5250
pb 1 0 3 1 0 3  xz  9.3500 0.5250
pb 1 0 4 1 0 4  xz  9.4475 0.4989
pb 1 0 5 1 0 5  xz  9.5189 0.4275
pb 1 0 6 1 0 6  xz  9.5450 0.3300
pb 1 0 7 1 0 7  xz 9.5189 0.2325
pb 1 0 8 1 0 8  xz 9.4475 0.1611
pb 1 0 9 1 0 9  xz 9.3500 0.1350
pb 1 0 10 1 0 10 xz 9.2525 0.1611
pb 1 0 11 1 0 11 xz 9.1812 0.2325
pb 1 0 12 1 0 12 xz 9.1550 0.3300
mate 6
thic 0.06
orpt + 0 0 -10
sii -1 ; ; 10 13 ; 20 s
endpart


c ************************************
c ******** End  Drum  ********
c ************************************

c ************************************
c ******** Begin Drum Bottom  ********
c ************************************

c drum bottom at roll ring
cylinder
1 2 4 5 6 7 8 ; 1 73 ; -1 ;
8.9880 9.1691 9.3700 9.5038 9.6017 9.6375 9.7
0 180
0.0
pb 1 0 1 1 0 1  z 0.0599
pb 2 0 1 2 0 1  z 0.0527
pb 3 0 1 3 0 1  z 0.0525
pb 4 0 1 4 0 1  z 0.0883
pb 5 0 1 5 0 1  z 0.1863
pb 6 0 1 6 0 1  z 0.3200
pb 7 0 1 7 0 1  xz 9.6017 0.4538
mate 7
thic 0.1050
orpt + 0 0 100
sii 1 3 ; ; -1 ; 26 s
endpart

cylinder
1 19 ; 1 73 ; -1 ;
5.0000 8.9880
0 180
0.0000
sd 1 sp 0 0 -128.9856  129.3581
sd 2 cy 0 0 0 0 0 1  8.9880
sd 3 cy 0 0 0 0 0 1  5.0000
sfi -2 ; ; -1 ; sd 2
sfi -1 ; ; -1 ; sd 3
sfi   ; ; -1 ; sd 1
mate 7
thic 0.1050
orpt + 0 0 100
sii ; ; -1 ; 26 s
bb 1 0 0 1 0 0  6 ;
endpart

cylinder
1 3 ; 1 37 ; -1 ;
4.6000 5.0000
0 180
0.0000
sd 1 sp 0 0 -128.9856  129.3581
sd 2 cy 0 0 0 0 0 1  4.6000
sd 3 cy 0 0 0 0 0 1  5.0000
sfi -2 ; ; -1 ; sd 3
sfi -1 ; ; -1 ; sd 2
sfi ; ; -1 ; sd 1
mate 7
thic 0.1050
orpt + 0 0 100
sii ; ; -1 ; 26 s
trbb 2 0 0 2 0 0   6 ;
endpart


block
1 10 19 28 37 ; 1 10 19 28 37 ; -1 ;
-2.1 -2.1 0 2.1 2.1
-2.1 -2.1 0 2.1 2.1
0
dei ; 1 3 ; ;
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1  4.6
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
sd 2  sp 0 0 -128.9856  129.3581
sfi ; ; -1 ; sd 2
pb 2 3 0 2 3 0  x -2.6
pb 4 3 0 4 3 0  x  2.6
pb 3 4 0 3 4 0  y  2.6
mate 7
thic 0.1050
orpt + 0 0 100
sii ; ; -1 ; 26 s
```

```
endpart

c ***********************************
c ******** End Drum Bottom ********
c ***********************************

c weld of drum to drum bottom head
cylinder
1 2 ; 1 73 ; -1 ;
9.5189 9.6017
0 180
0.4275
pb 2 0 0 2 0 0 z 0.4538
mate 8
thic 0.06
endpart


c ***********************************
c ******** Begin Liner ********
c ***********************************

c liner overlap to angle
cylinder
-1 ; 1 145 ; 1 2 ;
7.3550
0 180
40.7502 41.0002
pb 0 0 2 0 0 2 xz 7.4284 41.0002
mate 9
thic .03
endpart

c liner from angle down to base of pillow - fine
c fine
cylinder
-1 ; 1 145 ; 1 11 ;
7.3550
0 180
39.0 40.7502
mate 10
thic .06
orpt - 0 0 39
sii -1 ; ; ; 21 s
bb 0 0 1 0 0 1 7 ;
endpart

c liner from angle down to base of pillow - coarse
c coarse
cylinder
-1 ; 1 73 ; 1 2 3 9 ;
7.3550
0 180
37.5002 37.5734 37.7502 39.0000
c pb 0 0 1 0 0 1 x 7.1050
c pb 0 0 2 0 0 2 x 7.2800
mate 10
thic .06
orpt - 0 0 38
sii -1 ; ; ; 21 s
trbb 0 0 4 0 0 4 7 ;
endpart

c horizontal surface below the pillow
cylinder
1 14 ; 1 73 ; -1 ;
c 4.4300 7.3550
4.3300 7.3550
0 180
37.5002
mate 10
thic .06
orpt + 0 0 0
sii ; ; -1 ; 22 s
endpart

c vertical by the CV flange
cylinder
-1 ; 1 73 ; 1 11 ;
c 4.4300
4.3300
0 180
35.3002 37.5002
mate 10
thic .06
orpt - 0 0 36
c sii -1 ; ; ; 23 s
sii -1 ; ; ; 25 s
orpt + 0 0 30
sii -1 ; ; ; 30 m
endpart

c horzontal beneath the CV flange
cylinder
1 4 7 ; 1 73 ; -1 ;
c 3.5000 4.1100 4.4300
3.5000 3.9150 4.3300
0 180
35.3002
mate 10
thic .06
orpt + 0 0 0
c sii 2 3 ; ; -1 ; 24 s
sii 1 23 ; ; -1 ; 17 s
orpt - 0 0 0
sii ; ; -1 ; 30 m
endpart



c boro / kaolite vertical
cylinder
-1 ; 1 73 ; 1 2 3 101 ;
c 4.1100
4.3300
0 180
4.4400 4.5100 4.7300 35.3002
c pb 0 0 1 0 0 1 x 3.8600
c pb 0 0 2 0 0 2 x 4.0368
mate 10
thic .06
orpt - 0 0 20
sii -1 ; ; ; 25 s
orpt + 0 0 20
sii -1 ; ; ; 18 s
endpart

c boro inner liner vertical
cylinder
-1 ; 1 73 ; 1 2 3 10 99 100 101 102 ;
3.1500
0 180
4.4400 4.5100 4.7300 7.0000 34.6302 34.9502 35.1785 35.3002
pb 0 0 6 0 0 6 x 3.1925
pb 0 0 7 0 0 7 x 3.2989
pb 0 0 8 0 0 8 x 3.5000
mate 10
thic .06
orpt - 0 0 50
sii -1 ; ; ; 17 s
orpt + 0 0 20
sii -1 ; ; 1 4 ; 34 m
endpart

c ***** liner bottom

c c liner bottom solids
c cylinder
c 1 2 10 11 12 ; 1 73 ; 1 2 3 ;
c 3.1500 3.2430 3.9870 4.1100 4.1400
c 0 180
c 4.3800 4.4400 4.5000
c mate 27
c pb 2 0 1 2 0 1 x 3.2346
c pb 3 0 1 3 0 1 x 3.9109
c pb 4 0 1 4 0 1 x 3.9955
c pb 4 0 2 4 0 2 x 4.0800
c pb 5 0 1 5 0 1 x 4.0800
c sii ; ; -1 ; 25 s
c sii -1 ; ; 1 2 ; 25 s
c sii -5 ; ; ; 25 s
c sii 4 5 ; ; -3 ; 25 s
c sii 1 4 ; ; -3 ; 19 s
c endpart

c liner bottom solid replacement
cylinder
c 1 2 10 11 ; 1 73 ; -1 ;
3.1500 3.2430 3.9870 4.1100
1 11 ; 1 73 ; -1 ;
c 3.1500 3.2430 3.9870 4.1100
3.1500 4.3300
0 180
4.4400
mate 27
thic 0.1200
orpt + 0 0 0
sii ; ; -1 ; 25 s
orpt - 0 0 0
sii ; ; -1 ; 19 s
endpart


c liner bottom
cylinder
1 3 6 ; 1 73 ; -1 ;
2.800 3.1500 3.8600
0 180
4.4400
del 2 3 ; ; ;   c to make room for solids
mate 11
thic 0.1200
orpt + 0 0 0
sii ; ; -1 ; 25 s
orpt - 0 0 0
sii 2 3 ; ; -1 ; 14 s
orpt - 0 0 0
sii ; ; -1 ; 28 m
bb 1 0 0 1 0 0 8 ;
endpart

c liner bottom
cylinder
1 8 ; 1 37 ; -1 ;
1.8 2.8
0 180
4.4400
mate 11
thic 0.1200
orpt + 0 0 0
sii ; ; -1 ; 25 s
orpt - 0 0 0
sii ; ; -1 ; 28 m
trbb 2 0 0 2 0 0 8 ;
bb 1 0 0 1 0 0 9 ;
endpart

c liner bottom
cylinder
1 2 ; 1 19 ; -1 ;
1.6 1.8
0 180
4.4400
mate 11
thic 0.1200
orpt + 0 0 0
sii ; ; -1 ; 25 s
orpt - 0 0 0
```

```
sii ; ; -1 ; 28 m
trbb 2 0 0 2 0 0 9 ;
endpart

c liner bottom
block
1 5 10 15 19 ; 1 5 9 13 17 ; -1 ;
-0.8 -0.8 0 0.8 0.8
c -0.8391 -0.8391 0 0.8391 0.8391
-0.6713 -0.6713 0 0.6713 0.6713
4.4400
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1  1.6
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
dei ; 1 3 ; ;
mate 11
thic 0.1200
orpt + 0 0 0
sii ; ; -1 ; 25 s
orpt - 0 0 0
sii ; ; -1 ; 28 m
endpart


c ************************************
c ******** End Liner ********
c ************************************




c ************************************
c ******** Begin Lid  ********
c ************************************

c p1 lid at drum roll
cylinder
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ; 1 145 ; -1 ;
8.8500 8.9070 8.9600 9.0057 9.0406 9.0625 9.0700 9.0700 9.0700
 9.0700 9.0914 9.1521 9.2429 9.3500 9.4572 9.5480 9.6086 9.6299
0 180
42.7802
pb 2 0 0 2 0 0  z 42.7877
pb 3 0 0 3 0 0  z 42.8097
pb 4 0 0 4 0 0  z 42.8446
pb 5 0 0 5 0 0  z 42.8902
pb 6 0 0 6 0 0  z 42.9433
pb 7 0 0 7 0 0  z 43.0002
pb 8 0 0 8 0 0  z 43.0635
pb 9 0 0 9 0 0  z 43.1269
pb 10 0 0 10 0 0  z 43.1902
pb 11 0 0 11 0 0  z 43.2973
pb 12 0 0 12 0 0  z 43.3881
pb 13 0 0 13 0 0  z 43.4488
pb 14 0 0 14 0 0 z 43.4701
pb 15 0 0 15 0 0 z 43.4488
pb 16 0 0 16 0 0 z 43.3881
pb 17 0 0 17 0 0 z 43.2973
pb 18 0 0 18 0 0 z 43.1902
mate 12
thic 0.060
endpart

c lid at bolts inner radius part
cylinder
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 ;
1 2 3 4 5 6 7 8 9 10 19 ;
-1 ;
7.0000 7.0817 7.1634 7.2450 7.3340 7.5161 7.6864 7.8445
 8.0000 8.1591 8.3101 8.4757 8.6250 8.7493 8.8500
0.0000 1.2500 2.5000 3.7500 5.0000 6.2500 7.5000 8.7500
 10.0000 11.2500 22.5000
42.7802
dei 6 15 ; 1 4 ; ;
dei 10 15 ; 1 6 ; ;
pb 2 1 0 2 1 0  xy 7.0624 0.0000
pb 3 1 0 3 1 0  xy 7.1247 0.0000
pb 4 1 0 4 1 0  xy 7.1870 0.0000
pb 5 1 0 5 1 0  xy 7.2494 0.0000
pb 6 1 0 6 1 0  xy 7.3117 0.0000
pb 2 2 0 2 2 0  xy 7.0750 1.3133
pb 3 2 0 3 2 0 xy 7.14178 1.35199
pb 4 2 0 4 2 0 xy 7.20930 1.41136
pb 5 2 0 5 2 0 xy 7.27161 1.46049
pb 6 2 0 6 2 0  xy 7.3373 1.3912
pb 2 3 0 2 3 0 xy 7.08265 2.65219
pb 3 3 0 3 3 0 xy 7.15611 2.80135
pb 4 3 0 4 3 0 xy 7.24364 2.91100
pb 5 3 0 5 3 0  xy 7.3226 2.8950
pb 6 3 0 6 3 0  xy 7.4119 2.6613
pb 2 4 0 2 4 0 xy 7.09042 3.92764
pb 3 4 0 3 4 0  xy 7.1696 4.0478
pb 4 4 0 4 4 0  xy 7.2697 4.1059
pb 5 4 0 5 4 0  xy 7.3834 4.0071
pb 6 4 0 6 4 0  xy 7.5290 3.7064
pb 7 4 0 7 4 0  xy 7.6790 4.4521
pb 8 4 0 8 4 0  xy 7.8501 4.8584
pb 9 4 0 9 4 0  xy 8.0296 4.9175
pb 10 4 0 10 4 0  xy 8.2051 4.6477
pb 2 5 0 2 5 0 xy 7.09444 5.13153
pb 3 5 0 3 5 0 xy 7.19113 5.17626
pb 4 5 0 4 5 0 xy 7.29170 5.10468
pb 5 5 0 5 5 0 xy 7.41940 4.66544
pb 6 5 0 6 5 0 xy 7.51439 4.95471
pb 7 5 0 7 5 0 xy 7.67215 5.28342
pb 8 5 0 8 5 0  xy 7.8381 5.5076
pb 9 5 0 9 5 0  xy 8.0221 5.5448
pb 10 5 0 10 5 0  xy 8.2238 5.3634
pb 2 6 0 2 6 0 xy 7.09530 6.25501
pb 3 6 0 3 6 0 xy 7.19537 6.24026
pb 4 6 0 4 6 0 xy 7.30547 6.03599
pb 5 6 0 5 6 0 xy 7.41977 5.94266
pb 6 6 0 6 6 0 xy 7.52148 6.02503
pb 2 7 0 2 7 0 xy 7.09437 7.41079
pb 3 7 0 3 7 0 xy 7.17962 7.37369
pb 4 7 0 4 7 0 xy 7.27488 7.29351
pb 5 7 0 5 7 0 xy 7.37622 7.19276
pb 6 7 0 6 7 0 xy 7.52090 7.24978
pb 7 7 0 7 7 0 xy 7.68411 7.38295
pb 3 8 0 3 8 0 xy 7.17028 8.67152
pb 4 8 0 4 8 0 xy 7.25993 8.63158
pb 5 8 0 5 8 0 xy 7.35961 8.66462
thic .06
mate 12
lct 4  ; rz 45 ; rz 90 ; rz 135 ;
lrep 1 2 3 4 ;
endpart

c lid at bolts outer radius
cylinder
1 2 3 4 ; 1 2 3 4 5 6 7 8 9 10 11 ; -1 ;
8 8.3 8.6 9
0 1 2 3 4 5 6 7 8 9 10
42.7802
dei 1 2 ; 4 7 ; ;
dei 2 3 ; 5 7 ; ;
dei 3 4 ; 6 7 ; ;
dei 1 2 0 3 4 ; 10 11 ; ;
pb 1 1 0 1 1 0 xy 8.6883 0.0000
pb 2 1 0 2 1 0 xy 8.7422 0.0000
pb 3 1 0 3 1 0 xy 8.7961 0.0000
pb 4 1 0 4 1 0 xy 8.8500 0.0000
pb 1 2 0 1 2 0 xy 8.6667 1.1778
pb 2 2 0 2 2 0 xy 8.7278 1.2022
pb 3 2 0 3 2 0 xy 8.7889 1.2263
pb 4 2 0 4 2 0 xy 8.8500 1.2500
pb 1 3 0 1 3 0 xy 8.6030 2.2927
pb 2 3 0 2 3 0 xy 8.6853 2.3631
pb 3 3 0 3 3 0 xy 8.7677 2.4322
pb 4 3 0 4 3 0 xy 8.8500 2.5000
pb 1 4 0 1 4 0 xy 8.5006 3.2822
pb 2 4 0 2 4 0 xy 8.6170 3.4424
pb 3 4 0 3 4 0 xy 8.7335 3.5982
pb 4 4 0 4 4 0 xy 8.8500 3.7500
pb 2 5 0 2 5 0 xy 8.5844 3.8790
pb 3 5 0 3 5 0 xy 8.7051 4.6638
pb 4 5 0 4 5 0 xy 8.8500 5.0000
pb 3 6 0 3 6 0 xy 8.7493 6.2500
pb 4 6 0 4 6 0 xy 8.8500 6.2500
pb 1 7 0 1 7 0 xy 8.6170 3.4424
pb 2 7 0 2 7 0 xy 8.5844 3.8790
pb 3 7 0 3 7 0 xy 8.7051 4.6638
pb 4 7 0 4 7 0 xy 8.7493 6.2500
pb 1 8 0 1 8 0 xy 8.5006 3.2822
pb 2 8 0 2 8 0 xy 8.5363 4.1625
pb 3 8 0 3 8 0 xy 8.5797 5.0724
pb 4 8 0 4 8 0 xy 8.6250 6.2500
pb 1 9 0 1 9 0 xy 8.3654 4.0861
pb 2 9 0 2 9 0 xy 8.4134 4.6612
pb 3 9 0 3 9 0 xy 8.4540 5.3118
pb 4 9 0 4 9 0 xy 8.4757 6.2500
pb 1 10 0 1 10 0 xy 8.2051 4.6477
pb 2 10 0 2 10 0 xy 8.2238 5.3634
pb 3 10 0 3 10 0 xy 8.3490 5.7054
pb 4 10 0 4 10 0 xy 8.3101 6.2500
pb 2 11 0 2 11 0 xy 8.1591 6.2500
pb 3 11 0 3 11 0 xy 8.3101 6.2500
thic .060
mate 12
lct 4  ; rz 45 ; rz 90 ; rz 135 ;
lrep 1 2 3 4 ;
endpart


c circular at the bolt
cylinder
1 2 3 4 ; 1 13 ; -1 ;
0.5052 0.5402 0.6143 0.6883
0 180
42.7802
thic 0.060
mate 12
lct 4  mx 8.0000 ; mx 8.0000 rz 45 ; mx 8.0000 rz 90 ;
  mx 8.0000 rz 135 ;
lrep 1 2 3 4 ;
endpart

c circular overlap at bolt
cylinder
1 2 ; 1 13 ; -1 ;
0.4542 0.5052
0 180
42.7802
thic 0.030
mate 13
lct 4  mx 8.0000 ; mx 8.0000 rz 45 ; mx 8.0000 rz 90 ;
  mx 8.0000 rz 135 ;
lrep 1 2 3 4 ;
endpart

c circular bricks at bolt
cylinder
1 2 3 ; 1 13 ; 1 2 3 ;
0.3994 0.4542 0.5052
0 180
42.7502 42.7802 42.8102
pb 3 0 1 3 0 1  x 0.4935
pb 3 0 3 3 0 3  x 0.4935
mate 14
sii ; ; -1 ; 8 s
sii ; ; -3 ; 9 s
lct 4  mx 8.0000 ; mx 8.0000 rz 45 ; mx 8.0000 rz 90 ;
  mx 8.0000 rz 135 ;
lrep 1 2 3 4 ;
endpart
```

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```
c *************************

c lid at bolts inner radius part
cylinder
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 ;
1 2 3 4 5 6 7 8 9 10 19 ;
-1 ;
7.0000 7.0817 7.1634 7.2450 7.3340 7.5161 7.6864 7.8445
  8.0000 8.1591 8.3101 8.4757 8.6250 8.7493 8.8500
0.0000 1.2500 2.5000 3.7500 5.0000 6.2500 7.5000 8.7500
 10.0000 11.2500 22.5000
42.7802
dei 6 15 ; 1 4 ; ;
dei 10 15 ; 1 6 ; ;
pb 2 1 0 2 1 0  xy 7.0624 0.0000
pb 3 1 0 3 1 0  xy 7.1247 0.0000
pb 4 1 0 4 1 0  xy 7.1870 0.0000
pb 5 1 0 5 1 0  xy 7.2494 0.0000
pb 6 1 0 6 1 0  xy 7.3117 0.0000
pb 2 2 0 2 2 0  xy 7.0750 1.3133
pb 3 2 0 3 2 0 xy 7.14178 1.35199
pb 4 2 0 4 2 0 xy 7.20930 1.41136
pb 5 2 0 5 2 0 xy 7.27161 1.46049
pb 6 2 0 6 2 0  xy 7.3373 1.3912
pb 2 3 0 2 3 0 xy 7.08265 2.65219
pb 3 3 0 3 3 0 xy 7.15611 2.80135
pb 4 3 0 4 3 0 xy 7.24364 2.91100
pb 5 3 0 5 3 0  xy 7.3226 2.8950
pb 6 3 0 6 3 0  xy 7.4119 2.6613
pb 2 4 0 2 4 0 xy 7.09042 3.92764
pb 3 4 0 3 4 0  xy 7.1696 4.0478
pb 4 4 0 4 4 0  xy 7.2697 4.1059
pb 5 4 0 5 4 0  xy 7.3834 4.0071
pb 6 4 0 6 4 0  xy 7.5290 3.7064
pb 7 4 0 7 4 0  xy 7.6790 4.4521
pb 8 4 0 8 4 0  xy 7.8501 4.8584
pb 9 4 0 9 4 0  xy 8.0296 4.9175
pb 10 4 0 10 4 0  xy 8.2051 4.6477
pb 2 5 0 2 5 0 xy 7.09444 5.13153
pb 3 5 0 3 5 0 xy 7.19113 5.17626
pb 4 5 0 4 5 0 xy 7.29170 5.10468
pb 5 5 0 5 5 0 xy 7.41940 4.66544
pb 6 5 0 6 5 0 xy 7.51439 4.95471
pb 7 5 0 7 5 0 xy 7.67215 5.28342
pb 8 5 0 8 5 0  xy 7.8381 5.5076
pb 9 5 0 9 5 0  xy 8.0221 5.5448
pb 10 5 0 10 5 0  xy 8.2238 5.3634
pb 2 6 0 2 6 0 xy 7.09530 6.25501
pb 3 6 0 3 6 0 xy 7.19537 6.24026
pb 4 6 0 4 6 0 xy 7.30547 6.03599
pb 5 6 0 5 6 0 xy 7.41977 5.94266
pb 6 6 0 6 6 0 xy 7.52148 6.02503
pb 2 7 0 2 7 0 xy 7.09437 7.41079
pb 3 7 0 3 7 0 xy 7.17962 7.37369
pb 4 7 0 4 7 0 xy 7.27488 7.29351
pb 5 7 0 5 7 0 xy 7.37622 7.19276
pb 6 7 0 6 7 0 xy 7.52090 7.24978
pb 7 7 0 7 7 0 xy 7.68411 7.38295
pb 3 8 0 3 8 0 xy 7.17028 8.67152
pb 4 8 0 4 8 0 xy 7.25993 8.63158
pb 5 8 0 5 8 0 xy 7.35961 8.66462
thic .06
mate 12
lct 4  rxz rz 45 ; rxz rz 90 ; rxz rz 135 ; rxz rz 180 ;
lrep 1 2 3 4 ;
endpart

c lid at bolts outer radius
cylinder
1 2 3 4 ; 1 2 3 4 5 6 7 8 9 10 11 ; -1 ;
8 8.3 8.6 9
0 1 2 3 4 5 6 7 8 9 10
42.7802
dei 1 2 ; 4 7 ; ;
dei 2 3 ; 5 7 ; ;
dei 3 4 ; 6 7 ; ;
dei 1 2 0 3 4 ; 10 11 ; ;
pb 1 1 0 1 1 0 xy 8.6883 0.0000
pb 2 1 0 2 1 0 xy 8.7422 0.0000
pb 3 1 0 3 1 0 xy 8.7961 0.0000
pb 4 1 0 4 1 0 xy 8.8500 0.0000
pb 1 2 0 1 2 0 xy 8.6667 1.1778
pb 2 2 0 2 2 0 xy 8.7278 1.2022
pb 3 2 0 3 2 0 xy 8.7889 1.2263
pb 4 2 0 4 2 0 xy 8.8500 1.2500
pb 1 3 0 1 3 0 xy 8.6030 2.2927
pb 2 3 0 2 3 0 xy 8.6853 2.3631
pb 3 3 0 3 3 0 xy 8.7677 2.4322
pb 4 3 0 4 3 0 xy 8.8500 2.5000
pb 1 4 0 1 4 0 xy 8.5006 3.2822
pb 2 4 0 2 4 0 xy 8.6170 3.4424
pb 3 4 0 3 4 0 xy 8.7335 3.5982
pb 4 4 0 4 4 0 xy 8.8500 3.7500
pb 2 5 0 2 5 0 xy 8.5844 3.8790
pb 3 5 0 3 5 0 xy 8.7051 4.6638
pb 4 5 0 4 5 0 xy 8.8500 5.0000
pb 3 6 0 3 6 0 xy 8.7493 6.2500
pb 4 6 0 4 6 0 xy 8.8500 6.2500
pb 1 7 0 1 7 0 xy 8.6170 3.4424
pb 2 7 0 2 7 0 xy 8.5844 3.8790
pb 3 7 0 3 7 0 xy 8.7051 4.6638
pb 4 7 0 4 7 0 xy 8.7493 6.2500
pb 1 8 0 1 8 0 xy 8.5006 3.2822
pb 2 8 0 2 8 0 xy 8.5363 4.1625
pb 3 8 0 3 8 0 xy 8.5797 5.0724
pb 4 8 0 4 8 0 xy 8.6250 6.2500
pb 1 9 0 1 9 0 xy 8.3654 4.0861
pb 2 9 0 2 9 0 xy 8.4134 4.6612
pb 3 9 0 3 9 0 xy 8.4540 5.3118
pb 4 9 0 4 9 0 xy 8.4757 6.2500
pb 1 10 0 1 10 0 xy 8.2051 4.6477
pb 2 10 0 2 10 0 xy 8.2238 5.3634
pb 3 10 0 3 10 0 xy 8.3490 5.7054
pb 4 10 0 4 10 0 xy 8.3101 6.2500
pb 2 11 0 2 11 0 xy 8.1591 6.2500
pb 3 11 0 3 11 0 xy 8.3101 6.2500
thic .060
mate 12
lct 4  rxz rz 45 ; rxz rz 90 ; rxz rz 135 ; rxz rz 180 ;
lrep 1 2 3 4 ;
endpart

c circular at the bolt
cylinder
1 2 3 4 ; 1 13 ; -1 ;
0.5052 0.5402 0.6143 0.6883
0 180
42.7802
thic 0.060
mate 12
lct 4 mx 8.0000 rxz rz 45 ; mx 8.0000 rxz rz 90 ;
  mx 8.0000 rxz rz 135 ; mx 8.0000 rxz rz 180 ;
lrep 1 2 3 4 ;
endpart

c circular overlap at bolt
cylinder
1 2 ; 1 13 ; -1 ;
0.4542 0.5052
0 180
42.7802
thic 0.030
mate 13
lct 4 mx 8.0000 rxz rz 45 ; mx 8.0000 rxz rz 90 ;
  mx 8.0000 rxz rz 135 ; mx 8.0000 rxz rz 180 ;
lrep 1 2 3 4 ;
endpart

c circular bricks at bolt
cylinder
1 2 3 ; 1 13 ; 1 2 3 ;
0.3994 0.4542 0.5052
0 180
42.7502 42.7802 42.8102
pb 3 0 1 3 0 1  x 0.4935
pb 3 0 3 3 0 3  x 0.4935
mate 14
sii ; ; -1 ; 8 s
sii ; ; -3 ; 9 s
lct 4 mx 8.0000 rxz rz 45 ; mx 8.0000 rxz rz 90 ;
  mx 8.0000 rxz rz 135 ; mx 8.0000 rxz rz 180 ;
lrep 1 2 3 4 ;
endpart

c *************************

c ****************** inboard of bolting region ****************

c lid at the lid stiff
cylinder
1 2 3 ; 1 145 ; -1 ;
6.8800 6.9400 7.0000
0 180
42.7802
pb 1 0 0 1 0 0  xz 6.8800 42.7874
pb 2 0 0 2 0 0  xz 6.9400 42.7832
mate 12
thic 0.060
endpart

c lid inside the stiff
cylinder
1 5 ; 1 145 ; -1 ;
6.3000 6.8800
0 180
42.7802
sd 1 sp  0.0000 0.0000 -54.6253  97.6553
sd 2 cy 0 0 0  0 0 1  6.3000
sd 3 cy 0 0 0  0 0 1  6.8800
sfi -1 ; ; -1 ; sd 2
sfi -2 ; ; -1 ; sd 3
sfi 1 2 ; ; -1 ; sd 1
thic 0.060
mate 12
bb 1 0 0 1 0 0  10 ;
endpart

c lid transition
cylinder
1 10 ; 1 73 ; -1 ;
4.8 6.3000
0 180
42.7802
sd 1 sp  0.0000 0.0000 -54.6253  97.6553
sd 2 cy 0 0 0  0 0 1  4.8000
sd 3 cy 0 0 0  0 0 1  6.3000
sfi -1 ; ; -1 ; sd 2
sfi -2 ; ; -1 ; sd 3
sfi 1 2 ; ; -1 ; sd 1
thic 0.060
mate 12
trbb 2 0 0 2 0 0  10 ;
bb 1 0 0 1 0 0  11 ;
endpart

c lid transition
cylinder
1 2 ; 1 37 ; -1 ;
4.6 4.8000
0 180
42.7802
sd 1 sp  0.0000 0.0000 -54.6253  97.6553
sd 2 cy 0 0 0  0 0 1  4.6000
sd 3 cy 0 0 0  0 0 1  4.8000
sfi -1 ; ; -1 ; sd 2
sfi -2 ; ; -1 ; sd 3
sfi 1 2 ; ; -1 ; sd 1
thic 0.060
mate 12
```

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```
trbb 2 0 0 2 0 0 11 ;
endpart

block
1 10 19 28 37 ; 1 10 19 28 37 ; -1 ;
-2.1 -2.1 0 2.1 2.1
-2.1 -2.1 0 2.1 2.1
42.7801
dei ; 1 3 ; ;
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1 4.6
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
sd 2 sp 0.0000 0.0000 -54.6253 97.6553
sfi ; ; -1 ; sd 2
pb 2 3 0 2 3 0 x -2.6
pb 4 3 0 4 3 0 x 2.6
pb 3 4 0 3 4 0 y 2.6
mate 12
thic 0.060
endpart

c ************************************
c ******** End Lid ********
c ************************************


c ************************************
c ******** Begin Lid Stiffener ********
c ************************************

c lid stiffening ring
cylinder
1 2 3 ; 1 145 ; 1 6 ;
6.8800 6.9400 7.0000
0 180
42.7802 43.4900
pb 1 0 1 1 0 1 xz 6.8800 42.7874
pb 2 0 1 2 0 1 xz 6.9400 42.7832
mate 15
endpart

c ************************************
c ******** End Lid Stiffener ********
c ************************************

c ************************************
c ******** Begin Drum Bolts ********
c ************************************

block
1 2 4 5 7 ; 1 2 4 5 7 ; 1 5 8 ;
0 .1 .2 .3 .4
0 .1 .2 .3 .4
0 .1 .2
dei 2 5 ; 2 5 ; ;
dei 4 5 ; ; ;
dei ; 4 5 ; ;
sd 1 cy 0 0 0 0 0 1 0.0725
sd 2 cy 0 0 0 0 0 1 0.0837
sd 3 cy 0 0 0 0 0 1 0.2175
sd 4 cy 0 0 0 0 0 1 0.5859
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 42.9662 ;
sd 10 xyplan mz 43.5131 ;
sd 11 pl3 rt 0.5859 0 0
        rt 0.5859 0 1
        cy 0.5859 60 0
sd 12 cy 0 0 0 0 0 1 0.2744
sfi -2 ; -1 ; ; sd 5
sfi -2 ; -1 ; ; sd 1
sfi -3 ; -1 ; ; sd 5
sfi -3 ; -1 ; ; sd 3
sfi -4 ; -1 ; ; sd 5
sfi -4 ; -1 ; ; sd 12
sfi -5 ; -1 ; ; sd 5
sfi -5 ; -1 ; ; sd 4

sfi -2 ; -2 ; ; sd 6
sfi -2 ; -2 ; ; sd 2
sfi -3 ; -2 ; ; sd 6
sfi -3 ; -2 ; ; sd 3
sfi -4 ; -2 ; ; sd 6
sfi -4 ; -2 ; ; sd 12
sfi -5 ; -2 ; ; sd 6
sfi -5 ; -2 ; ; sd 11

sfi -2 ; -3 ; ; sd 6
sfi -2 ; -3 ; ; sd 3
sfi -2 ; -4 ; ; sd 6
sfi -2 ; -4 ; ; sd 12
sfi -2 ; -5 ; ; sd 6
sfi -2 ; -5 ; ; sd 11

sfi -1 ; -2 ; ; sd 7
sfi -1 ; -2 ; ; sd 1
sfi -1 ; -3 ; ; sd 7
sfi -1 ; -3 ; ; sd 3
sfi -1 ; -4 ; ; sd 7
sfi -1 ; -4 ; ; sd 12
sfi -1 ; -5 ; ; sd 7
sfi -1 ; -5 ; ; sd 4

sfi ; ; -1 ; sd 8
sfi ; ; -2 ; sd 9
sfi ; ; -3 ; sd 10

lct 3 ; rz 60 ; rz 120 ;
lrep 1 2 3 ;
gct 4 mx 8.0000 ; mx 8.0000 rz 45 ; mx 8.0000 rz 90 ;
  mx 8.0000 rz 135 ;
grep 1 2 3 4 ;
mate 16
endpart

block
1 2 4 5 7 ; 1 2 4 5 7 ; 1 5 8 ;
0 .1 .2 .3 .4
0 .1 .2 .3 .4
0 .1 .2
dei 2 5 ; 2 5 ; ;
dei 4 5 ; ; ;
dei ; 4 5 ; ;
sd 1 cy 0 0 0 0 0 1 0.0725
sd 2 cy 0 0 0 0 0 1 0.0837
sd 3 cy 0 0 0 0 0 1 0.2175
sd 4 cy 0 0 0 0 0 1 0.5859
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 42.9662 ;
sd 10 xyplan mz 43.5131 ;
sd 11 pl3 rt 0.5859 0 0
        rt 0.5859 0 1
        cy 0.5859 60 0
sd 12 cy 0 0 0 0 0 1 0.2744
sfi -2 ; -1 ; ; sd 5
sfi -2 ; -1 ; ; sd 1
sfi -3 ; -1 ; ; sd 5
sfi -3 ; -1 ; ; sd 3
sfi -4 ; -1 ; ; sd 5
sfi -4 ; -1 ; ; sd 12
sfi -5 ; -1 ; ; sd 5
sfi -5 ; -1 ; ; sd 4

sfi -2 ; -2 ; ; sd 6
sfi -2 ; -2 ; ; sd 2
sfi -3 ; -2 ; ; sd 6
sfi -3 ; -2 ; ; sd 3
sfi -4 ; -2 ; ; sd 6
sfi -4 ; -2 ; ; sd 12
sfi -5 ; -2 ; ; sd 6
sfi -5 ; -2 ; ; sd 11

sfi -2 ; -3 ; ; sd 6
sfi -2 ; -3 ; ; sd 3
sfi -2 ; -4 ; ; sd 6
sfi -2 ; -4 ; ; sd 12
sfi -2 ; -5 ; ; sd 6
sfi -2 ; -5 ; ; sd 11

sfi -1 ; -2 ; ; sd 7
sfi -1 ; -2 ; ; sd 1
sfi -1 ; -3 ; ; sd 7
sfi -1 ; -3 ; ; sd 3
sfi -1 ; -4 ; ; sd 7
sfi -1 ; -4 ; ; sd 12
sfi -1 ; -5 ; ; sd 7
sfi -1 ; -5 ; ; sd 4

sfi ; ; -1 ; sd 8
sfi ; ; -2 ; sd 9
sfi ; ; -3 ; sd 10


lct 3 ; rz 60 ; rz 120 ;
lrep 1 2 3 ;
gct 4 mx 8.0000 rxz rz 45 ; mx 8.0000 rxz rz 90 ;
  mx 8.0000 rxz rz 135 ; mx 8.0000 rxz rz 180 ;
grep 1 2 3 4 ;
mate 16
endpart

c ************************************
c ******** End Drum Bolts ********
c ************************************

c ************************************
c ******** Begin Drum Bolt Studs ********
c ************************************

c no studs in this run

c ************************************
c ******** End Drum Bolt Studs ********
c ************************************

c ************************************
c ******** Begin Drum Bolt Nuts ********
c ************************************

block
1 2 4 5 8 ; 1 2 4 5 8 ; 1 5 8 ;
0 .1 .2 .3 .4
0 .1 .2 .3 .4
0 .1 .2
dei 2 5 ; 2 5 ; ;
dei 1 4 ; 1 4 ; ;
dei ; ; 1 2 ;
sd 1 cy 0 0 0 0 0 1 0.0725
sd 2 cy 0 0 0 0 0 1 0.0837
sd 3 cy 0 0 0 0 0 1 0.2175
sd 4 cy 0 0 0 0 0 1 0.5859
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 42.9662 ;
sd 10 xyplan mz 43.5131 ;
sd 11 pl3 rt 0.5859 0 0
```

```
        rt 0.5859 0 1
        cy 0.5859 60 0
sd 12 cy 0 0 0  0 0 1  0.2744
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 12
sfi -5 ; -1 ; ;  sd 5
sfi -5 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; ;  sd 6
sfi -3 ; -2 ; ;  sd 3
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 12
sfi -5 ; -2 ; ;  sd 6
sfi -5 ; -2 ; ;  sd 11

sfi -2 ; -3 ; ;  sd 6
sfi -2 ; -3 ; ;  sd 3
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 12
sfi -2 ; -5 ; ;  sd 6
sfi -2 ; -5 ; ;  sd 11

sfi -1 ; -2 ; ;  sd 7
sfi -1 ; -2 ; ;  sd 1
sfi -1 ; -3 ; ;  sd 7
sfi -1 ; -3 ; ;  sd 3
sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 12
sfi -1 ; -5 ; ;  sd 7
sfi -1 ; -5 ; ;  sd 4

sfi ; ; -1 ; sd 8
sfi ; ; -2 ; sd 9
sfi ; ; -3 ; sd 10

 lct 3 ; rz 60 ; rz 120 ;
lrep 1 2 3 ;
gct 4 mx 8.0000 ; mx 8.0000 rz 45 ; mx 8.0000 rz 90 ;
  mx 8.0000 rz 135 ;
grep 1 2 3 4 ;
mate 17
sii 4 5 ; ; -2 ; 11 s
sii ; 4 5 ; -2 ; 11 s
endpart


block
1 2 4 5 8 ; 1 2 4 5 8 ; 1 5 8 ;
0 .1 .2 .3 .4
0 .1 .2 .3 .4
0 .1 .2
dei 2 5 ; 2 5 ; ;
dei 1 4 ; 1 4 ; ;
dei ; ; 1 2 ;
sd 1 cy 0 0 0  0 0 1  0.0725
sd 2 cy 0 0 0  0 0 1  0.0837
sd 3 cy 0 0 0  0 0 1  0.2175
sd 4 cy 0 0 0  0 0 1  0.5859
sd 5 zxplan ;
sd 6 zxplan rz 30 ;
sd 7 zxplan rz 60 ;
sd 8 xyplan mz 42.7502 ;
sd 9 xyplan mz 42.9662 ;
sd 10 xyplan mz 43.5131 ;
sd 11 pl3  rt 0.5859 0 0
        rt 0.5859 0 1
        cy 0.5859 60 0
sd 12 cy 0 0 0  0 0 1  0.2744
sfi -2 ; -1 ; ;  sd 5
sfi -2 ; -1 ; ;  sd 1
sfi -3 ; -1 ; ;  sd 5
sfi -3 ; -1 ; ;  sd 3
sfi -4 ; -1 ; ;  sd 5
sfi -4 ; -1 ; ;  sd 12
sfi -5 ; -1 ; ;  sd 5
sfi -5 ; -1 ; ;  sd 4

sfi -2 ; -2 ; ;  sd 6
sfi -2 ; -2 ; ;  sd 2
sfi -3 ; -2 ; ;  sd 6
sfi -3 ; -2 ; ;  sd 3
sfi -4 ; -2 ; ;  sd 6
sfi -4 ; -2 ; ;  sd 12
sfi -5 ; -2 ; ;  sd 6
sfi -5 ; -2 ; ;  sd 11

sfi -2 ; -3 ; ;  sd 6
sfi -2 ; -3 ; ;  sd 3
sfi -2 ; -4 ; ;  sd 6
sfi -2 ; -4 ; ;  sd 12
sfi -2 ; -5 ; ;  sd 6
sfi -2 ; -5 ; ;  sd 11

sfi -1 ; -2 ; ;  sd 7
sfi -1 ; -2 ; ;  sd 1
sfi -1 ; -3 ; ;  sd 7
sfi -1 ; -3 ; ;  sd 3
sfi -1 ; -4 ; ;  sd 7
sfi -1 ; -4 ; ;  sd 12
sfi -1 ; -5 ; ;  sd 7
sfi -1 ; -5 ; ;  sd 4

sfi ; ; -1 ; sd 8
sfi ; ; -2 ; sd 9
sfi ; ; -3 ; sd 10

lct 3 ; rz 60 ; rz 120 ;
lrep 1 2 3 ;
gct 4 mx 8.0000 rxz rz 45 ; mx 8.0000 rxz rz 90 ;
 mx 8.0000 rxz rz 135 ; mx 8.0000 rxz rz 180 ;
grep 1 2 3 4 ;
mate 17
sii 4 5 ; ; -2 ; 11 s
sii ; 4 5 ; -2 ; 11 s
endpart

c ***********************************
c ******** End Drum Bolt Nuts ********
c ***********************************

c ***********************************
c ******** Begin Drum Bolt Washer ********
c ***********************************

c drum bolt washer at 0
cylinder
1 6 7 ; 1 13 25 ; 1 2 3 4 ;
0.3839 0.6475 0.6875
0 180 360
42.8102 42.8622 42.9142 42.9662
dei ; 2 3 ; ;
mate 18
pb 2 0 1 2 0 1  x 0.6725
pb 3 0 1 3 0 1  z 42.8252
pb 2 0 4 2 0 4  x 0.6725
pb 3 0 4 3 0 4  z 42.9512
sii ; ; -1 ; 9 m
sii ; ; -4 ; 11 m
lct 1 mx 8.0000 ; lrep 1 ;
endpart

c drum bolt washer at 45 to 135
cylinder
1 6 7 ; 1 13 25 ; 1 2 3 4 ;
0.3839 0.6475 0.6875
0 180 360
42.8102 42.8622 42.9142 42.9662
mate 18
pb 2 0 1 2 0 1  x 0.6725
pb 3 0 1 3 0 1  z 42.8252
pb 2 0 4 2 0 4  x 0.6725
pb 3 0 4 3 0 4  z 42.9512
sii ; ; -1 ; 9 m
sii ; ; -4 ; 11 m
lct 3 mx 8.0000 rz 45 ;
     mx 8.0000 rz 90 ;
     mx 8.0000 rz 135 ;
lrep 1 2 3 ;
endpart

c drum bolt washer at 180
cylinder
1 6 7 ; 1 13 25 ; 1 2 3 4 ;
0.3839 0.6475 0.6875
0 180 360
42.8102 42.8622 42.9142 42.9662
dei ; 1 2 ; ;
mate 18
sii ; ; -1 ; 9 m
sii ; ; -4 ; 11 m
lct 1 mx 8.0000 rz 180 ; lrep 1 ;
endpart


c ***********************************
c ******** End Drum Bolt Washer ********
c ***********************************

c ***********************************
c ******** Begin  Plug ********
c ***********************************

c liner ripples
cylinder
-1 ; 1 73 ;
1 2 3 4 5 6 7 8 9 10 11 12 13 14
 15 16 17 18 19 20 21 22 23 24 25 ;
6.0
0 180
37.6959 37.7651 37.8570 38.0706 38.3537 38.5999 38.8012 39.0028
 39.2494 39.4961 39.6977 39.8990 40.1452 40.3914 40.5927 40.7940
 41.0402 41.2864 41.4877 41.6890 41.9352 42.2302 42.4462 42.5252
 42.5922
pb 0 0 1 0 0 1  x 6.4155
pb 0 0 2 0 0 2  x 6.6062
pb 0 0 3 0 0 3  x 6.8835
pb 0 0 4 0 0 4  x 7.0827
pb 0 0 5 0 0 5  x 7.1550
pb 0 0 6 0 0 6  x 7.1012
pb 0 0 7 0 0 7  x 6.9495
pb 0 0 8 0 0 8  x 6.7976
pb 0 0 9 0 0 9  x 6.7437
pb 0 0 10 0 0 10 x 6.7976
pb 0 0 11 0 0 11 x 6.9495
pb 0 0 12 0 0 12 x 7.1012
pb 0 0 13 0 0 13 x 7.1550
pb 0 0 14 0 0 14 x 7.1012
pb 0 0 15 0 0 15 x 6.9495
pb 0 0 16 0 0 16 x 6.7979
pb 0 0 17 0 0 17 x 6.7440
pb 0 0 18 0 0 18 x 6.7979
pb 0 0 19 0 0 19 x 6.9495
pb 0 0 20 0 0 20 x 7.1012
pb 0 0 21 0 0 21 x 7.1550
pb 0 0 22 0 0 22 x 7.0760
pb 0 0 23 0 0 23 x 6.8600
pb 0 0 24 0 0 24 x 6.5650
pb 0 0 25 0 0 25 x 6.4170
mate 19
thic 0.06
orpt + 0 0 40.14
sii -1 ; ; ; 16 m
endpart
```

GENERAL DESIGN AND COMPUTATION SHEET


```
c upper surface of plug liner
block
c 1 19 37 55 73 ; 1 19 37 55 73 ; -1 ;
1 11 29 47 57 ; 1 11 29 47 57 ; -1 ;
-3.25 -3.25 0 3.25 3.25
-3.25 -3.25 0 3.25 3.25
42
sd 1 sp 0 0 -43.7865  86.6166
sd 2 cy 0 0 0 0 0 1  6.4170
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
dei ; 1 3 ; ;
sfi -1 0 -5 ; ; -1 ; sd 2
sfi ; -1 0 -5 ; -1 ; sd 2
sfi ; ; -1 ; sd 1
pb 2 3 0 2 3 0  x -4
pb 4 3 0 4 3 0  x 4
pb 3 4 0 3 4 0  y 4
mate 19
thic .06
orpt + 0 0 40.14
sii ; ; -1 ; 16 m
endpart

c lower surface of plug liner
block
1 11 29 47 57 ; 1 11 29 47 57 ; -1 ;
-3.25 -3.25 0 3.25 3.25
-3.25 -3.25 0 3.25 3.25
37
sd 1 sp 0 0 277.8264  240.2162
sd 2 cy 0 0 0 0 0 1  6.4155
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
dei ; 1 3 ; ;
sfi -1 0 -5 ; ; -1 ; sd 2
sfi ; -1 0 -5 ; -1 ; sd 2
sfi ; ; -1 ; sd 1
pb 2 3 0 2 3 0  x -4
pb 4 3 0 4 3 0  x 4
pb 3 4 0 3 4 0  y 4
mate 19
thic 0.06
orpt + 0 0 40.14
sii ; ; -1 ; 16 m
orpt + 0 0 0
sii ; ; -1 ; 29 m
endpart

c plug kaolite
cylinder
1 7 8 9 10 ; 1 73 ; 1 2 3 4 5 6 7 8 9 10 11 12
  13 14 15 16 17 18 19 20 21 22 23 ;
4.9361 6.4 6.5 6.6 6.7
0 180
37.6909 37.91674091 38.14258182 38.36842273 38.59426364 38.82010455
  39.04594545 39.27178636 39.49762727 39.72346818 39.94930909 40.17515
  40.40099091 40.62683182 40.85267273 41.07851364 41.30435454 41.53019545
  41.75603636 41.98187727 42.20771818 42.43355909 42.6594
dei 4 5 ; ; 1 2 0 22 23 ;
sd 1  sp 0 0 277.8264 240.1862
sd 2  sp 0 0 -43.7865 86.5866
sfi 1 2 ; ; -1 ; sd 1
sfi 1 2 ; ; -23 ; sd 2
pb 2 0 1 2 0 1  x 6.4099
pb 3 0 1 3 0 1  xz 6.5963 37.7934
pb 4 0 1 4 0 1  xz 6.8668 37.8831
pb 5 0 2 5 0 2  xz 6.8668 37.8831
pb 5 0 3 5 0 3  xz 7.0555 38.0855
pb 5 0 4 5 0 4  xz 7.1242 38.3542
pb 5 0 5 5 0 5  xz 7.0733 38.5871
pb 5 0 6 5 0 6  xz 6.9256 38.7831
pb 5 0 7 5 0 7  xz 6.7697 38.9900
pb 5 0 8 5 0 8  xz 6.7130 39.2494
pb 5 0 9 5 0 9  xz 6.7697 39.5089
pb 5 0 10 5 0 10  xz 6.9256 39.7157
pb 5 0 11 5 0 11  xz 7.0733 39.9118
pb 5 0 12 5 0 12  xz 7.1243 40.1452
pb 5 0 13 5 0 13  xz 7.0733 40.3786
pb 5 0 14 5 0 14  xz 6.9256 40.5746
pb 5 0 15 5 0 15  xz 6.7700 40.7812
pb 5 0 16 5 0 16  xz 6.7133 41.0402
pb 5 0 17 5 0 17  xz 6.7700 41.2992
pb 5 0 18 5 0 18  xz 6.9256 41.5057
pb 5 0 19 5 0 19  xz 7.0733 41.7018
pb 5 0 20 5 0 20  xz 7.1242 41.9345
pb 5 0 21 5 0 21  xz 7.0491 42.2147
pb 5 0 22 5 0 22  xz 6.8445 42.4193
pb 4 0 23 4 0 23  xz 6.8445 42.4193
pb 3 0 23 3 0 23  xz 6.5549 42.4969
pb 2 0 23 2 0 23  x 6.4095

pb 4 0  2 4 0  2 xz 6.78411 37.9882
pb 3 0  2 3 0  2 xz 6.57764 37.9370
pb 4 0  3 4 0  3 xz 6.82248 38.1033
pb 3 0  3 3 0  3 xz 6.59774 38.1124
pb 4 0  4 4 0  4 xz 6.87547 38.3518
pb 3 0  4 3 0  4 xz 6.62515 38.3481
pb 4 0  5 4 0  5 xz 6.82431 38.5784
pb 3 0  5 3 0  5 xz 6.59774 38.5747
pb 4 0  6 4 0  6 xz 6.75598 38.7818
pb 3 0  6 3 0  6 xz 6.58202 38.7928
pb 4 0  7 4 0  7 xz 6.66625 38.9924
pb 3 0  7 3 0  7 xz 6.54174 39.0107
pb 4 0  8 4 0  8 xz 6.60766 39.2506
pb 3 0  8 3 0  8 xz 6.49962 39.2542
pb 4 0  9 4 0  9 xz 6.62255 39.5208
pb 3 0  9 3 0  9 xz 6.51965 39.5208
pb 4 0  9 4 0  9 xz 6.64276 39.5226
pb 4 0 10 4 0 10 xz 6.71810 39.7284
pb 3 0 10 3 0 10 xz 6.55456 39.7266
pb 4 0 11 4 0 11 xz 6.84237 39.9402
pb 3 0 11 3 0 11 xz 6.59406 39.9493
pb 4 0 12 4 0 12 xz 6.86428 40.1538
pb 3 0 12 3 0 12 xz 6.62145 40.1629
pb 4 0 13 4 0 13 xz 6.85150 40.3838
pb 3 0 13 3 0 13 xz 6.61232 40.3875
```

```
pb 4 0 14 4 0 14 xz 6.76193 40.5655
pb 3 0 14 3 0 14 xz 6.58412 40.5839
pb 4 0 15 4 0 15 xz 6.65561 40.7782
pb 3 0 15 3 0 15 xz 6.52363 40.8038
pb 4 0 16 4 0 16 xz 6.61345 41.0531
pb 3 0 16 3 0 16 xz 6.51080 41.0623
pb 4 0 17 4 0 17 xz 6.64629 41.3225
pb 3 0 17 3 0 17 xz 6.52567 41.3243
pb 4 0 18 4 0 18 xz 6.71026 41.5473
pb 3 0 18 3 0 18 xz 6.55308 41.5546
pb 4 0 18 4 0 18 xz 6.73402 41.5473
pb 4 0 19 4 0 19 xz 6.81261 41.7556
pb 3 0 19 3 0 19 xz 6.58964 41.7739
pb 4 0 19 4 0 19 xz 6.84368 41.7538
pb 3 0 19 3 0 19 xz 6.61522 41.7739
pb 4 0 20 4 0 20 xz 6.85830 41.9622
pb 3 0 20 3 0 20 xz 6.62436 41.9841
pb 4 0 21 4 0 21 xz 6.84065 42.1685
pb 3 0 21 3 0 21 xz 6.58878 42.2032
pb 4 0 22 4 0 22 xz 6.71654 42.3401
pb 3 0 22 3 0 22 xz [illegible].54680 42.3656
pb 2 0 22 2 0 22 xz 6.39714 42.4204
pb 2 0 21 2 0 21 xz 6.39232 42.1927
pb 2 0 22 2 0 22 xz 6.40309 42.3541
pb 2 0 22 2 0 22 xz 6.40309 42.3810
pb 2 0 22 2 0 22 xz 6.39232 42.3864
pb 2 0 20 2 0 20 xz 6.39770 41.9666
pb 2 0 20 2 0 20 xz 6.39232 41.9882
pb 3 0 21 3 0 21 xz 6.59683 42.1711
pb 2 0 16 2 0 16 xz 6.31501 41.0916
pb 2 0 17 2 0 17 xz 6.36339 41.3228
pb 2 0 15 2 0 15 xz 6.36339 40.8550
pb 3 0 15 3 0 15 xz 6.50856 40.8228
pb 2 0 15 2 0 15 xz 6.37415 40.8389
pb 3 0 16 3 0 16 xz 6.47630 41.0701
pb 3 0 17 3 0 17 xz 6.49781 41.3174
pb 2 0 14 2 0 14 xz 6.37415 40.6131
pb 2 0 15 2 0 15 xz 6.35802 40.8389
pb 2 0 17 2 0 17 xz 6.34189 41.3174
pb 2 0 18 2 0 18 xz 6.36339 41.5593
pb 2 0  8 2 0  8 xz 6.27101 39.2611
pb 3 0  8 3 0  8 xz 6.41664 39.2665
pb 4 0  8 4 0  8 xz 6.57305 39.2611
pb 2 0  9 2 0  9 xz 6.31416 39.4930
pb 3 0  9 3 0  9 xz 6.45439 39.4984
pb 4 0  9 4 0  9 xz 6.61081 39.4984
pb 2 0 10 2 0 10 xz 6.35191 39.7250
pb 3 0 10 3 0 10 xz 6.50294 39.7196
pb 3 0 10 3 0 10 xz 6.53530 39.7142
pb 4 0 10 4 0 10 xz 6.70790 39.7142
pb 4 0 11 4 0 11 xz 6.83195 39.9191
pb 3 0 11 3 0 11 xz 6.58924 39.9299
pb 2 0 11 2 0 11 xz 6.37349 39.9515
pb 2 0  7 2 0  7 xz 6.32495 39.0292
pb 3 0  7 3 0  7 xz 6.49215 39.0184
pb 4 0  7 4 0  7 xz 6.63778 38.9968
pb 2 0  6 2 0  6 xz 6.34652 38.8081
pb 3 0  6 3 0  6 xz 6.54609 38.7973
pb 4 0  6 4 0  6 xz 6.71868 38.7811
pb 2 0  5 2 0  5 xz 6.37349 38.5869
pb 2 0  4 2 0  4 xz 6.36810 38.3604
pb 2 0  3 2 0  3 xz 6.36810 38.1231
pb 2 0  2 2 0  2 xz 6.37888 37.9127
pb 2 0  8 2 0  8 xz 6.30337 39.2611
mate 20
bb 1 0 0 1 0 0  12 ;
sii  ; ; -1 ; 16 s
sii  ; ; -23 ; 16 s
sii -5 ; ; ; 16 s
endpart

c plug kaolite transition
cylinder
1 4 ; 1 37 ; 1 23 ;
4.3000 4.9361
0 180
37 42
sd 1  sp 0 0 277.8264 240.1862
sd 2  sp 0 0 -43.7865 86.5866
sd 3  cy 0 0 0  0 0 1  4.3
sd 4  cy 0 0 0  0 0 1  4.9361
sfi -2 ; ; ; sd 4
sfi -1 ; ; ; sd 3
sfi ; ; -1 ; sd 1
sfi ; ; -2 ; sd 2
mate 20
sii ; ; -1 ; 16 s
sii ; ; -2 ; 16 s
trbb 2 0 0 2 0 0  12 ;
endpart

c center of plug kaolite
block
1 10 19 28 37 ; 1 10 19 28 37 ; 1 23 ;
-1.9 -1.9 0 1.9 1.9
-1.9 -1.9 0 1.9 1.9
37 42
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
dei ; 1 3 ; ;
sd 1  sp 0 0 277.8264 240.1862
sd 2  sp 0 0 -43.7865 86.5866
sd 3  cy 0 0 0  0 0 1  4.3
sfi -1 0 -5 ; ; ; sd 3
sfi ; -1 0 -5 ; ; sd 3
sfi ; ; -1 ; sd 2
sfi ; ; -2 ; sd 1
mate 20
pb 2 3 0 2 3 0  x -2.3
pb 4 3 0 4 3 0  x  2.3
pb 3 4 0 3 4 0  y  2.3
sii ; ; -1 ; 16 s
sii ; ; -2 ; 16 s
endpart

c ***********************************
```

GENERAL DESIGN AND COMPUTATION SHEET

JOB Impact Analysis of ES3100 Design Concepts Using HABC		DATE March 2004	SHEET 122 of 133
DAC NO DAC-EA-801699-A002	REVISION 0	COMPUTED KDH KDH 2-24-05	CHECKED BY GAA 2/24/05 GAA

```
c ******* End Plug *******
c ***********************************

c ***********************************
c ******* Begin Drum Kaolite *******
c ***********************************

c drum kaolite upper piece
cylinder
1 10 11 12 13 14 15 20 ;
1 73 ;
c 1 11 12  13 14 15 16 17 18 19
c  20 21 22 23 24  25  26 27 32 33 34 ;
1 8 9   10 11 12 13 14 15 16
   17 18 19 20 21  22  23 24 28 29 30 ;

c 4.4600 7.1110 7.3850 7.5362 7.6645 7.8062 8.0000 9.125
c no boro 001
4.3600 7.1110 7.3850 7.5362 7.6645 7.8062 8.0000 9.125
0 180
35.2702 37.4702 37.7442
 38.0680 38.2788 38.4770 38.6441 38.8294 39.0420 39.2702
 39.4984 39.7109 39.8965 40.0634 40.2616 40.4724 40.7502
 41.0002 42.1614 42.3334 42.5002
dei 1 3 ; ; 2 21 ;
dei 1 5 ; ; 17 21 ;
dei 5 6 ; ; 20 21 ;
c pb 3 0 2 3 0 2  xz  7.3048 37.5504
pb 3 0 2 3 0 2  xz  7.3850 37.4702

pb 5 0 20 5 0 20 xz 7.6901 42.4451
pb 7 0 21 7 0 21 xz 7.8347 42.5002

pb 4 0 17 4 0 17 xz  7.4673 40.7641
pb 5 0 17 5 0 17 xz  7.5849 40.8501
pb 5 0 18 5 0 18 xz  7.6350 41.0002
pb 5 0 19 5 0 19 xz  7.6350 42.3122
pb 5 0 20 5 0 20 xz  7.6901 42.4451
pb 6 0 21 6 0 21 xz  7.6901 42.4451
pb 6 0 20 6 0 20 xz  7.8062 42.3334

pb 8 0 4 8 0 4  xz 9.1250 38.0680
pb 8 0 5 8 0 5  xz 9.1529 38.2788
pb 8 0 6 8 0 6  xz 9.2352 38.4770
pb 8 0 7 8 0 7  xz 9.3635 38.6441
pb 8 0 8 8 0 8  xz 9.5064 38.8294
pb 8 0 9 8 0 9  xz 9.5947 39.0420
pb 8 0 10 8 0 10  xz 9.6248 39.2702
pb 8 0 11 8 0 11  xz 9.5947 39.4984
pb 8 0 12 8 0 12  xz 9.5064 39.7109
pb 8 0 13 8 0 13  xz 9.3636 39.8965
pb 8 0 14 8 0 14  xz 9.2351 40.0634
pb 8 0 15 8 0 15  xz 9.1529 40.2616
pb 8 0 16 8 0 16  xz 9.1250 40.4724


pb 4 0 16 4 0 16 xz 7.51449 40.5936
pb 6 0 16 6 0 16 xz 7.78375 40.5872
pb 5 0 16 5 0 16 xz 7.63685 40.6099
pb 3 0 16 3 0 16 xz 7.38500 40.5440
pb 3 0 15 3 0 15 xz 7.38500 40.3403
pb 5 0 15 5 0 15 xz 7.66157 40.3436
pb 6 0 15 6 0 15 xz 7.80236 40.3201
pb 4 0 15 4 0 15 xz 7.53016 40.3418
pb 7 0 15 7 0 15 xz 7.97395 40.3090
pb 7 0 14 7 0 14 xz 7.98714 40.0989
pb 6 0 14 6 0 14 xz 7.80126 40.1032
pb 5 0 14 5 0 14 xz 7.66370 40.0940
pb 4 0 14 4 0 14 xz 7.53485 40.0886
pb 3 0 14 3 0 14 xz 7.38500 40.0856
pb 7 0 16 7 0 16 xz 7.99633 40.5213
pb 2 0 1 2 0 1 xz 7.00561 35.2702
pb 3 0 1 3 0 1 xz 7.21878 35.2702
pb 4 0 1 4 0 1 xz 7.42103 35.2702
pb 5 0 1 5 0 1 xz 7.63503 35.2702
pb 6 0 1 6 0 1 xz 7.84468 35.2702
pb 7 0 1 7 0 1 xz 8.03948 35.2702

pb 4 0 2 4 0 2 xz 7.50967 37.5174
pb 5 0 2 5 0 2 xz 7.65243 37.5084
pb 6 0 2 6 0 2 xz 7.80966 37.4965
pb 4 0 3 4 0 3 xz 7.53743 37.7847
pb 5 0 3 5 0 3 xz 7.66860 37.7758
pb 6 0 3 6 0 3 xz 7.81339 37.7723
pb 7 0 3 7 0 3 xz 8.01213 37.7571

pb 4 0 2 4 0 2 xz 7.52844 37.4718
pb 5 0 2 5 0 2 xz 7.70141 37.4760
pb 6 0 2 6 0 2 xz 7.84424 37.4657
pb 3 0 3 3 0 3 z 37.6729
pb 4 0 3 4 0 3 z 37.6939
pb 5 0 3 5 0 3 z 37.7180
pb 6 0 3 6 0 3 z 37.7358
pb 3 0 4 3 0 4 z 37.8992
pb 4 0 4 4 0 4 z 37.9303
pb 5 0 4 5 0 4 z 37.9507
pb 6 0 4 6 0 4 z 37.9763
pb 7 0 4 7 0 4 z 38.0110
pb 3 0 5 3 0 5 z 38.1269
pb 4 0 5 4 0 5 z 38.1618
pb 5 0 5 5 0 5 z 38.1904
pb 6 0 5 6 0 5 z 38.2119
pb 7 0 5 7 0 5 z 38.2380
pb 3 0 6 3 0 6 z 38.3492
pb 4 0 6 4 0 6 z 38.3885
pb 5 0 6 5 0 6 z 38.4091
pb 6 0 6 6 0 6 z 38.4342
pb 7 0 6 7 0 6 z 38.4563
pb 3 0 7 3 0 7 z 38.5869
pb 4 0 7 4 0 7 z 38.6133
pb 5 0 7 5 0 7 z 38.6250
pb 3 0 8 3 0 8 z 38.8004
pb 4 0 8 4 0 8 z 38.8100
pb 5 0 8 5 0 8 z 38.8251
```

```
pb 3 0 17 3 0 17  z 40.6500

mate 21
c sii -1 ; ; 1 2 ; 13 m
c sii 1 3 ; ; -2 ; 13 m
c sii -3 ; ; 2 17 ; 13 m
c sii 3 5 ; ; -17 ; 13 m
c sii -5 ; ; 17 20 ; 13 m
c sii 6 8 ; ; -21 ; 13 m
c sii -8 ; ; ; 13 m

c sii -1 ; ; 1 2 ; 23 m
sii -1 ; ; 1 2 ; 25 m
sii 1 3 ; ; -2 ; 22 m
sii -3 ; ; 2 17 ; 21 m
sii 3 5 ; ; -17 ; 21 m
sii -5 ; ; 17 20 ; 21 m
sii 6 8 ; ; -21 ; 21 m
sii -8 ; ; ; 20 m

endpart


c drum kaolite main part
cylinder
1 2 3   12 13 14 15 16 17 22 ;
1 73 ;
1 15 16
 20 21 22 23 24 25 26 27 28 29 30 31 32
 52 53 54 55 56 57 58 59 60 61 62 63 64
 84 85 86 87 88 89 90 91 92 93 94 95 96
 103 ;


c 3.8770 4.1400 4.4600  7.00561 7.21878 7.42103 7.63503
c no boro 002
3.8770 4.1400 4.3600  7.00561 7.21878 7.42103 7.63503
  7.84468 8.03948 9.1250
0 180
0.0 4.3800 4.6841
  6.2178 6.4286 6.6268 6.7939 6.9793 7.1918 7.4200 7.6482
     7.8608 8.0463 8.2132 8.4114 8.6222
  18.2179 18.4287 18.6269 18.7940 18.9793 19.1919 19.4201
     19.6483 19.8608 20.0464 20.2133 20.4115 20.6223
  30.2179 30.4287 30.6269 30.7941 30.9794 31.1920 31.4201
     31.6483 31.8609 32.0464 32.2134 32.4116 32.6223
  35.2702
dei 1 2 ; ; 2 43 ;
sd 1 sp 0 0 -128.9856 129.4136
sfi ; ; -1 ; sd 1
sd 2 cy 0 0 0 0 0 1  3.8770
sfi -1 ; ; ; sd 2
pb 1 0 2 1 0 2  xz 3.8770 4.3800
c pb 2 0 2 2 0 2  xz 4.0500 4.4000
pb 2 0 2 2 0 2  xz 4.1700 4.3800   c bottom inside corner
pb 2 0 3 2 0 3  xz 4.1700 4.4400
c pb 3 0 3 3 0 3   z 4.5000
pb 2 0 4 2 0 4  xz 4.1700 5.0000
c pb 3 0 4 3 0 4   z 5.3000
pb 2 0 5 2 0 5   z 5.4033
pb 2 0 6 2 0 6   z 5.8067
pb 2 0 7 2 0 7   z 6.2100
pb 2 0 8 2 0 8   z 6.6133
pb 2 0 9 2 0 9   z 7.0167
c pb 3 0 5 3 0 5   z 5.6533
c pb 3 0 6 3 0 6   z 6.0067
c pb 3 0 7 3 0 7   z 6.3600
c pb 3 0 8 3 0 8   z 6.7133
c pb 3 0 9 3 0 9   z 7.0667

c no boro 003
pb 3 0 2 3 0 2   x 4.3900
pb 3 0 3 3 0 3   xz 4.3900 4.4400
pb 3 0 4 3 0 4   xz 4.3900 5.0000
pb 3 0 5 3 0 5   z 5.4033
pb 3 0 6 3 0 6   z 5.8067
pb 3 0 7 3 0 7   z 6.2100
pb 3 0 8 3 0 8   z 6.6133
pb 3 0 9 3 0 9   z 7.0167


pb 10 0 4 10 0 4  x 9.1250
pb 10 0 5 10 0 5  x 9.1529
pb 10 0 6 10 0 6  x 9.2352
pb 10 0 7 10 0 7  x 9.3636
pb 10 0 8 10 0 8  x 9.5064
pb 10 0 9 10 0 9  x 9.5947
pb 10 0 10 10 0 10  x 9.6248
pb 10 0 11 10 0 11  x 9.5947
pb 10 0 12 10 0 12  x 9.5064
pb 10 0 13 10 0 13  x 9.3636
pb 10 0 14 10 0 14  x 9.2351
pb 10 0 15 10 0 15  x 9.1529
pb 10 0 16 10 0 16  x 9.1250

pb 10 0 17 10 0 17  x 9.1250
pb 10 0 18 10 0 18  x 9.1529
pb 10 0 19 10 0 19  x 9.2352
pb 10 0 20 10 0 20  x 9.3636
pb 10 0 21 10 0 21  x 9.5064
pb 10 0 22 10 0 22  x 9.5947
pb 10 0 23 10 0 23  x 9.6248
pb 10 0 24 10 0 24  x 9.5947
pb 10 0 25 10 0 25  x 9.5064
pb 10 0 26 10 0 26  x 9.3636
pb 10 0 27 10 0 27  x 9.2351
pb 10 0 28 10 0 28  x 9.1529
pb 10 0 29 10 0 29  x 9.1250

pb 10 0 30 10 0 30  x 9.1250
pb 10 0 31 10 0 31  x 9.1529
pb 10 0 32 10 0 32  x 9.2352
pb 10 0 33 10 0 33  x 9.3636
pb 10 0 34 10 0 34  x 9.5064
pb 10 0 35 10 0 35  x 9.5947
```

GENERAL DESIGN AND COMPUTATION SHEET

JOB Impact Analysis of ES3100 Design Concepts Using HABC		DATE March 2004	SHEET 123 of 133
DAC NO DAC-EA-801699-A002	REVISION 0	COMPUTED KDH KDH 2-24-05	CHECKED BY GAA 2/24/05 GA

```
pb 10 0 36 10 0 36 x 9.6248
pb 10 0 37 10 0 37 x 9.5947
pb 10 0 38 10 0 38 x 9.5064
pb 10 0 39 10 0 39 x 9.3636
pb 10 0 40 10 0 40 x 9.2351
pb 10 0 41 10 0 41 x 9.1529
pb 10 0 42 10 0 42 x 9.1250

pb 2 0 11 3 0 11 z 7.7950
pb 2 0 12 3 0 12 z 8.1700
pb 2 0 13 3 0 13 z 8.5450
pb 2 0 14 3 0 14 z 8.9200
pb 2 0 15 3 0 15 z 9.2950
pb 2 0 16 3 0 16 z 9.6700
pb 2 0 17 3 0 17 z 17.1701
pb 2 0 18 3 0 18 z 17.5451
pb 2 0 19 3 0 19 z 17.9201
pb 2 0 20 3 0 20 z 18.2951
pb 2 0 21 3 0 21 z 18.6701
pb 2 0 22 3 0 22 z 19.0451

pb 2 0 24 3 0 24 z 19.7951
pb 2 0 25 3 0 25 z 20.1701
pb 2 0 26 3 0 26 z 20.5451
pb 2 0 27 3 0 27 z 20.9201
pb 2 0 28 3 0 28 z 21.2951
pb 2 0 29 3 0 29 z 21.6701
pb 2 0 30 3 0 30 z 29.1701
pb 2 0 31 3 0 31 z 29.5451
pb 2 0 32 3 0 32 z 29.9201
pb 2 0 33 3 0 33 z 30.2951
pb 2 0 34 3 0 34 z 30.6701
pb 2 0 35 3 0 35 z 31.0451
mate 21
c sii 1 2 ; ; 2 ; 18 m
c sii 2 ; ; 2 43 ; 18 m
c sii 10 ; ; ; 18 m
c sii ; ; 1 ; 18 m
sii -10 ; ; ; 20 m
c sii -2 ; ; 2 43 ; 25 m
sii 1 2 ; ; 2 3 ; ; 2 43 ; 25 m
c sii 1 2 ; ; -2 ; 25 m
sii 1 3 ; ; -2 ; 25 m
sii ; ; 01 ; 26 m
c sii 2 3 ; ; -43 ; 24 m
bb 1 0 1 1 0 2 13 ;
dei 2 3 ; ; 2 43 ;
endpart

cylinder
1 3 ; 1 37 ; 1 15 ;
3.3000 3.8770
0 180
0 4.3800
sd 1 sp 0 0 -128.9856 129.4136
sd 2 cy 0 0 0 0 0 1 3.3000
sd 3 cy 0 0 0 0 0 1 3.8770
sfi ; ; -1 ; sd 1
sfi -1 ; ; ; sd 2
sfi -2 ; ; ; sd 3
mate 21
sii ; ; -1 ; 26 m
sii ; ; -2 ; 25 m
trbb 2 0 0 2 0 0 13 ;
bb 1 0 0 1 0 0 14 ;
endpart

cylinder
1 2 ; 1 19 ; 1 15 ;
3.00 3.3000
0 180
0 4.3800
sd 1 sp 0 0 -128.9856 129.4136
sd 2 cy 0 0 0 0 0 1 3.0000
sd 3 cy 0 0 0 0 0 1 3.3000
sfi ; ; -1 ; sd 1
sfi -1 ; ; ; sd 2
sfi -2 ; ; ; sd 3
mate 21
sii ; ; -1 ; 26 m
sii ; ; -2 ; 25 m
trbb 2 0 0 2 0 0 14 ;
endpart

block
1 5 10 15 19 ; 1 5 9 13 17 ; 1 15 ;
-1.5 -1.5 0 1.5 1.5
-1.25865 -1.25865 0 1.25865 1.25865
0 4.3800
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
dei ; 1 3 ; ;
sd 1 sp 0 0 -128.9856 129.4136
sd 2 cy 0 0 0 0 0 1 3.0000
sfi -1 0 -5 ; ; ; sd 2
sfi ; -1 0 -5 ; ; sd 2
sfi ; ; -1 ; sd 1
sii ; ; -1 ; 26 m
sii ; ; -2 ; 25 m
mate 21
endpart

c ************************************
c ******** End Drum Kaolite ********
c ************************************


c ************************************
c ******** Begin Borobond ********
c ************************************
c borobond
cylinder
1 2 4 5 ; 1 73 ; 1 2 79 80 81 ;
c 3.1800 3.4050 3.8550 4.0800
3.1800 3.4600 4.0200 4.3000
0 180
4.5000 4.6960 34.6302 34.9422 35.2702
c pb 3 0 1 3 0 1 xz 3.8529 4.5000
c pb 4 0 1 4 0 1 xz 4.0149 4.5389
c pb 4 0 2 4 0 2 xz 4.0800 4.6900
pb 1 0 3 1 0 3 xz 3.1800 34.6302
pb 1 0 4 1 0 4 xz 3.2206 34.9422
pb 1 0 5 1 0 5 xz 3.3217 35.1616
pb 2 0 5 2 0 5 xz 3.5000 35.2702
mate 22
sii -1 ; ; ; 17 m
sii -4 ; ; ; 18 m
sii ; ; -1 ; 19 m
sii ; ; -5 ; 17 m
endpart

c ************************************
c ******** End Borobond ********
c ************************************

c lid stiffener weld removed in run5c
c c lid to lid stiff weld
c cylinder
c -1 -2 ; 1 145 ; 1 2 ;
c 7.1250 8.6250
c 0 180
c 42.7802 42.8102
c mate 23
c thic .06
c endpart


c ************************************
c ******** Begin Internal Weight ********
c ************************************

c ***** begin lower weight ********
c lower internal cv weight - 36.7 lb
cylinder
1 2 3 4 ; 1 65 ; 1 2 3 4 38 39 40 41 ;
1.8200 1.9500 2.0650 2.1250
0 180
4.9500 5.0400 5.2400 5.4400
 13.6600 13.8600 14.0600 14.1500
dei 3 4 ; ; 2 4 0 5 7 ;
pb 3 0 1 3 0 1 xz 2.0850 4.9500
pb 4 0 1 4 0 1 xz 2.1250 4.9900
pb 3 0 8 3 0 8 xz 2.0850 14.1500
pb 4 0 8 4 0 8 xz 2.1250 14.1100

pb 1 0 2 1 0 2 xz 1.8200 5.1800
pb 1 0 3 1 0 3 xz 1.8200 5.4100
pb 1 0 4 1 0 4 xz 1.8200 5.6400
pb 1 0 5 1 0 5 xz 1.8200 13.4600
pb 1 0 6 1 0 6 xz 1.8200 13.6900
pb 1 0 7 1 0 7 xz 1.8200 13.9200

pb 2 0 2 2 0 2 z 5.1000
pb 2 0 3 2 0 3 z 5.2900
pb 2 0 4 2 0 4 z 5.5266
pb 2 0 5 2 0 5 z 13.5760
pb 2 0 6 2 0 6 z 13.7934
pb 2 0 7 2 0 7 z 14.0000
mate 24
bb 1 0 0 1 0 0 20 ;
sii ; ; -1 ; 12 s
sii -4 ; ; ; 12 s
sii ; ; -8 ; 6 s
c lct 1 mx 0.3950 mz 3.4001 ; lrep 1 ;
lct 1 mx 0.3950 mz 0.76 ; lrep 1 ;
endpart

c lower internal cv weight
cylinder
1 3 ; 1 33 ; 1 41 ;
1.42 1.82
0 180
4.9500 14.1500
mate 24
trbb 2 0 0 2 0 0 20 ;
bb 1 0 0 1 0 0 21 ;
sii ; ; -1 ; 12 s
sii ; ; -2 ; 6 s
c lct 1 mx 0.3950 mz 3.4001 ; lrep 1 ;
lct 1 mx 0.3950 mz 0.76 ; lrep 1 ;
endpart

c lower internal cv weight
cylinder
1 3 ; 1 17 ; 1 41 ;
1.02 1.42
0 180
4.9500 14.1500
mate 24
trbb 2 0 0 2 0 0 21 ;
bb 1 0 0 1 0 0 22 ;
sii ; ; -1 ; 12 s
sii ; ; -2 ; 6 s
c lct 1 mx 0.3950 mz 3.4001 ; lrep 1 ;
lct 1 mx 0.3950 mz 0.76 ; lrep 1 ;
endpart

c lower internal cv weight
cylinder
1 3 ; 1 9 ; 1 41 ;
0.72 1.02
0 180
4.9500 14.1500
mate 24
```

```
trbb 2 0 0 2 0 0 22 ;
sii ; ; -1 ; 12 s
sii ; ; -2 ; 6 s
c lct 1 mx 0.3950 mz 3.4001 ; lrep 1 ;
lct 1 mx 0.3950 mz 0.76 ; lrep 1 ;
endpart

c lower internal cv weight
block
1 3 5 7 9 ; 1 3 5 7 9 ; 1 41 ;
-0.3 -0.3 0 0.3 0.3
-0.3 -0.3 0 0.3 0.3
4.9500 14.1500
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1 0.72
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
dei ; 1 3 ; ;
mate 24
pb 2 3 0 2 3 0 x -0.4
pb 4 3 0 4 3 0 x 0.4
pb 3 4 0 3 4 0 y 0.4
sii ; ; -1 ; 12 s
sii ; ; -2 ; 6 s
c lct 1 mx 0.3950 mz 3.4001 ; lrep 1 ;
lct 1 mx 0.3950 mz 0.76 ; lrep 1 ;
endpart

c ***** end lower weight ********

c ***** begin middle weight ********

c middle internal cv weight - 36.7 lb
cylinder
1 2 3 4 ; 1 65 ; 1 2 3 4 38 39 40 41 ;
1.8200 1.9500 2.0650 2.1250
0 180
4.9500 5.0400 5.2400 5.4400
 13.6600 13.8600 14.0600 14.1500
dei 3 4 ; ; 2 4 0 5 7 ;
pb 3 0 1 3 0 1 xz 2.0850 4.9500
pb 4 0 1 4 0 1 xz 2.1250 4.9900
pb 3 0 8 3 0 8 xz 2.0850 14.1500
pb 4 0 8 4 0 8 xz 2.1250 14.1100

pb 1 0 2 1 0 2 xz 1.8200 5.1800
pb 1 0 3 1 0 3 xz 1.8200 5.4100
pb 1 0 4 1 0 4 xz 1.8200 5.6400
pb 1 0 5 1 0 5 xz 1.8200 13.4600
pb 1 0 6 1 0 6 xz 1.8200 13.6900
pb 1 0 7 1 0 7 xz 1.8200 13.9200

pb 2 0 2 2 0 2 z 5.1000
pb 2 0 3 2 0 3 z 5.2900
pb 2 0 4 2 0 4 z 5.5266
pb 2 0 5 2 0 5 z 13.5760
pb 2 0 6 2 0 6 z 13.7934
pb 2 0 7 2 0 7 z 14.0000
mate 25
bb 1 0 0 1 0 0 20 ;
c lct 1 mx 0.3950 mz 12.6001 ; lrep 1 ;
lct 1 mx 0.3950 mz 9.9700 ; lrep 1 ;
sii ; ; -1 ; 6 m
sii -4 ; ; ; 12 s
sii ; ; -8 ; 7 s
endpart

c middle internal cv weight
cylinder
1 3 ; 1 33 ; 1 41 ;
1.42 1.82
0 180
4.9500 14.1500
mate 25
trbb 2 0 0 2 0 0 20 ;
bb 1 0 0 1 0 0 21 ;
sii ; ; -1 ; 6 m
sii ; ; -2 ; 7 s
c lct 1 mx 0.3950 mz 12.6001 ; lrep 1 ;
lct 1 mx 0.3950 mz 9.9700 ; lrep 1 ;
endpart

c middle internal cv weight
cylinder
1 3 ; 1 17 ; 1 41 ;
1.02 1.42
0 180
4.9500 14.1500
mate 25
trbb 2 0 0 2 0 0 21 ;
bb 1 0 0 1 0 0 22 ;
sii ; ; -1 ; 6 m
sii ; ; -2 ; 7 s
c lct 1 mx 0.3950 mz 12.6001 ; lrep 1 ;
lct 1 mx 0.3950 mz 9.9700 ; lrep 1 ;
endpart

c middle internal cv weight
cylinder
1 3 ; 1 9 ; 1 41 ;
0.72 1.02
0 180
4.9500 14.1500
mate 25
trbb 2 0 0 2 0 0 22 ;
sii ; ; -1 ; 6 m
sii ; ; -2 ; 7 s
c lct 1 mx 0.3950 mz 12.6001 ; lrep 1 ;
lct 1 mx 0.3950 mz 9.9700 ; lrep 1 ;
endpart

c middle internal cv weight
block
1 3 5 7 9 ; 1 3 5 7 9 ; 1 41 ;
-0.3 -0.3 0 0.3 0.3
-0.3 -0.3 0 0.3 0.3
4.9500 14.1500
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1 0.72
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
dei ; 1 3 ; ;
mate 25
pb 2 3 0 2 3 0 x -0.4
pb 4 3 0 4 3 0 x 0.4
pb 3 4 0 3 4 0 y 0.4
sii ; ; -1 ; 6 m
sii ; ; -2 ; 7 s
c lct 1 mx 0.3950 mz 12.6001 ; lrep 1 ;
lct 1 mx 0.3950 mz 9.9700 ; lrep 1 ;
endpart

c ***** end middle weight ********

c ***** begin upper weight ********

c upper internal cv weight - 36.7 lb
cylinder
1 2 3 4 ; 1 65 ; 1 2 3 4 38 39 40 41 ;
1.8200 1.9500 2.0650 2.1250
0 180
4.9500 5.0400 5.2400 5.4400
 13.6600 13.8600 14.0600 14.1500
dei 3 4 ; ; 2 4 0 5 7 ;
pb 3 0 1 3 0 1 xz 2.0850 4.9500
pb 4 0 1 4 0 1 xz 2.1250 4.9900
pb 3 0 8 3 0 8 xz 2.0850 14.1500
pb 4 0 8 4 0 8 xz 2.1250 14.1100

pb 1 0 2 1 0 2 xz 1.8200 5.1800
pb 1 0 3 1 0 3 xz 1.8200 5.4100
pb 1 0 4 1 0 4 xz 1.8200 5.6400
pb 1 0 5 1 0 5 xz 1.8200 13.4600
pb 1 0 6 1 0 6 xz 1.8200 13.6900
pb 1 0 7 1 0 7 xz 1.8200 13.9200

pb 2 0 2 2 0 2 z 5.1000
pb 2 0 3 2 0 3 z 5.2900
pb 2 0 4 2 0 4 z 5.5266
pb 2 0 5 2 0 5 z 13.5760
pb 2 0 6 2 0 6 z 13.7934
pb 2 0 7 2 0 7 z 14.0000
mate 26
bb 1 0 0 1 0 0 20 ;
sii ; ; -1 ; 7 m
sii -4 ; ; ; 12 s
sii ; ; -8 ; 15 s
c lct 1 mx 0.3950 mz 21.8001 ; lrep 1 ;
lct 1 mx 0.3950 mz 19.1800 ; lrep 1 ;
endpart

c upper internal cv weight
cylinder
1 3 ; 1 33 ; 1 41 ;
1.42 1.82
0 180
4.9500 14.1500
mate 26
trbb 2 0 0 2 0 0 20 ;
bb 1 0 0 1 0 0 21 ;
sii ; ; -1 ; 7 m
sii ; ; -2 ; 15 s
c lct 1 mx 0.3950 mz 21.8001 ; lrep 1 ;
lct 1 mx 0.3950 mz 19.1800 ; lrep 1 ;
endpart

c upper internal cv weight
cylinder
1 3 ; 1 17 ; 1 41 ;
1.02 1.42
0 180
4.9500 14.1500
mate 26
trbb 2 0 0 2 0 0 21 ;
bb 1 0 0 1 0 0 22 ;
sii ; ; -1 ; 7 m
sii ; ; -2 ; 15 s
c lct 1 mx 0.3950 mz 21.8001 ; lrep 1 ;
lct 1 mx 0.3950 mz 19.1800 ; lrep 1 ;
endpart

c upper internal cv weight
cylinder
1 3 ; 1 9 ; 1 41 ;
0.72 1.02
0 180
4.9500 14.1500
mate 26
trbb 2 0 0 2 0 0 22 ;
sii ; ; -1 ; 7 m
sii ; ; -2 ; 15 s
c lct 1 mx 0.3950 mz 21.8001 ; lrep 1 ;
lct 1 mx 0.3950 mz 19.1800 ; lrep 1 ;
endpart

c upper internal cv weight
block
1 3 5 7 9 ; 1 3 5 7 9 ; 1 41 ;
-0.3 -0.3 0 0.3 0.3
-0.3 -0.3 0 0.3 0.3
4.9500 14.1500
dei 1 2 0 4 5 ; 1 2 0 4 5 ; ;
sd 1 cy 0 0 0 0 0 1 0.72
sfi -1 0 -5 ; ; ; sd 1
sfi ; -1 0 -5 ; ; sd 1
dei ; 1 3 ; ;
mate 26
pb 2 3 0 2 3 0 x -0.4
```

GENERAL DESIGN AND COMPUTATION SHEET

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```
pb 4 3 0 4 3 0 x 0.4
pb 3 4 0 3 4 0 y 0.4
sii ; ; -1 ; 7 m
sii ; ; -2 ; 15 s
c lct 1 mx 0.3950 mz 21.8001 ; lrep 1 ;
lct 1 mx 0.3950 mz 19.1800 ; lrep 1 ;
endpart

c ***** end upper weight ********

c ************************************
c ******** End Internal Weight ********
c ************************************


c  c overlap of liner to solids at base of borobond
c  cylinder
c  -1 -2 -3 ; 1 73 ; 1 2 ;
c  3 3.2 4.3
c  0 180
c  4 4.2
c  c form the overlap to the thick bottom plate
c  pb 1 0 1 1 0 1  xz 3.1500 4.4400
c  pb 1 0 2 1 0 2  xz 3.2430 4.4400
c  c
c  c form the overlap to the
c  pb 2 0 1 2 0 1  xz 3.1500 4.4400
c  pb 2 0 2 2 0 2  xz 3.1500 4.5000
c  c
c  c form the overlap to the borobong/kaolite liner
c  pb 3 0 1 3 0 1  xz 4.0800 4.4400
c  pb 3 0 2 3 0 2  xz 4.1100 4.5000
c  mate 28
c  thic 0.04

c  endpart



c ****************************
c visual rigid plane
block
1 2 ; 1 3 ; 1 10 ;
0 1
0.0 15
-26 26
c b  0 1 1 0 2 2  dx 1 ry 1 dz 1 rx 1 ry 1 rz 1 ;
mate 29
velocity 0 0 0
lct 1 mx 9.6900 mz 21.7551 ; lrep 1 ;
endpart
c ****************************


c ****************************
c impacting mild steel plate
block
1 3 4 ; 1 11 ; 1 2 12 22 23 ;
-2.42449 -0.7500 0.0
0.0 20.0
-20 -19.25 0 19.25 20
mate 30
dei 2 3 ; ; 1 2 0 4 5 ;
lct 1 mx -9.6900 mz 21.7551 ; lrep 1 ;
velocity ~~5.28~~0.2 0 0
endpart

c mild steel plate
block
1 2 ;
1 11 ;
1 2 3 ;
-0.75 0.0000
0.0 20.0
-20.0 -19.25 -19.0
pb 2 0 1 2 0 1  x -0.2500
pb 2 0 2 2 0 2  xz -0.0732 -19.9268
pb 1 0 3 1 0 3  xz 0.0000 -19.250
pb 2 0 3 2 0 3  xz  0.0000 -19.7500
mate 30
lct 2 mx -9.6900 mz 21.7551 ; rxy mx -9.6900 mz 21.7551 ; lrep 1 2 ;
velocity ~~5.28~~0.2 0 0
endpart
c ****************************


c ****************************
c  PART - punch
block
1 5 9 13 17 ; 1 5 9 13 17 ; 1 9 10 11 ;
-1.4 -1.4 0 1.4 1.4
-1.4 -1.4 0 1.4 1.4
c -8.0000 -0.2500 -0.1250 0.0000
-8.0000 -1.500 -.7500 0.0000
dei 1 2 0 4 5 ; 1 2 0 4 5 ; 1 4 ;
sd 1  cy  0.0 0.0 0.0  0.0 0.0 1.0  2.7500
sd 2  cy  0.0 0.0 0.0  0.0 0.0 1.0  2.9268
sd 3  cy  0.0 0.0 0.0  0.0 0.0 1.0  3.0000
sd 4  xyplan ;
sd 5  xyplan mz -0.0732 ;
sd 6  xyplan mz -0.2500 ;
sfi -1 -5 ; -1 -5 ; 1 2 ; sd 3
sfi -1 0 -5 ; 3 4 ; -3 ; sd 2
sfi 2 4 ; -5 ; -3 ; sd 2
sfi -1 0 -5; 2 4; -4;sd 1
sfi 2 4; -5; -4;sd 1
sfi ; ; -4 ; sd 4
sfi -1 0 -5 ; 2 4 ; -3 ; sd 5
sfi 2 4 ; -1 0 -5 ; -3 ; sd 5
sfi -1 0 -5 ; 2 4 ; -2 ; sd 6
sfi 2 4 ; -1 0 -5 ; -2 ; sd 6
dei ; 1 3 ; ;
b 1 1 1 5 5 1   dx 1 dy 1 dz 1 ;
mate 31
velocity 0 0 0
```

```
lct 1 ry -90 mx 11.6900 mz 21.7551 ; lrep 1 ;
endpart
c ****************************


c ****************************
c **** begin silicon rubber ***
c ****************************

c silicon rubber bottom piece
cylinder
1 2 12 13 14 15 16 17 18 19 ; 1 65 ; 1 2 3 4 5 6 ;
1.30 1.35 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4
0 180
4.0 4.1 4.2 4.5000 4.5500 4.5998
dei 1 3;; 1 4;
dei 3 4;; 2 6;
dei 4 5;; 4 6;
dei 5 6;; 2 6;
dei 6 10;; 3 6;
pb 1 0 4 1 0 4  xz 1.~~8000 4.5000~~2812 4.5333
pb 1 0 5 1 0 5  xz 1.~~2575 4.5207~~2500 4.6100
pb 1 0 6 1 0 6  xz 1.~~2502 4.5774~~2812 4.6867
pb 2 0 4 2 0 4  xz 1.3~~214~~600 4.5000
pb 2 0 5 2 0 5  xz 1.~~8214 4.5526~~3579 4.6100
pb 2 0 6 2 0 6  xz 1.~~2058 4.5990~~3559 4.7199
pb 3 0 4 3 0 4  xz 2.7431 4.5000
pb 3 0 1 3 0 1  xz 2.7431 4.5000
pb 4 0 1 4 0 1  xz 2.8909 4.5000
pb 5 0 1 5 0 1  xz 2.9938 4.5375
pb 6 0 1 6 0 1  xz 3.0485 4.6322
pb 7 0 1 7 0 1  xz 3.0747 4.7810
pb 8 0 1 8 0 1  xz 3.0985 4.9158
pb 9 0 1 9 0 1  xz 3.1104 4.9861

pb 3 0 5 3 0 5  xz 2.~~7431 4.6182~~7229 4.6351
pb 4 0 3 4 0 3  xz 2.~~7431 4.6182~~7229 4.6351
pb 3 0 2 3 0 2  xz 2.~~7431 4.6182~~7229 4.6351
pb 4 0 2 4 0 2  xz 2.8388 4.5752

pb 3 0 6 3 0 6  xz 2.~~7431 4.7265~~7027 4.7703
pb 4 0 4 4 0 4  xz 2.~~7431 4.7265~~7027 4.7703
pb 5 0 2 5 0 2  xz 2.9414 4.6163
pb 5 0 3 5 0 3  xz 2.~~9420 4.7011~~9368 4.7151
pb 5 0 4 5 0 4  xz 2.~~8878 4.7706~~8252 4.7980

pb 6 0 2 6 0 2  xz 2.~~9420 4.7011~~9368 4.7151
pb 6 0 3 6 0 3  xz 2.~~8878 4.7706~~8252 4.7980
pb 7 0 2 7 0 2  xz 2.~~9821 4.8128~~9929 4.8163
pb 7 0 3 7 0 3  xz 2.~~9209 4.8402~~9110 4.8517
pb 8 0 2 8 0 2  xz 3.0443 4.9311
pb 8 0 3 8 0 3  xz 2.~~9801 4.9460~~9865 4.9472
pb 9 0 2 9 0 2  xz 3.~~0574 5.0120~~0613 5.0141
pb 9 0 3 9 0 3  xz 3.~~0298 5.0510~~0219 5.0364
pb 10 0 1 10 0 1  xz 3.1200 5.0423
pb 10 0 2 10 0 2  xz 3.~~0082 5.0886~~0987 5.0843
pb 10 0 3 10 0 3  xz 3.~~0486 5.0875~~0490 5.0869
mate 32
sii -1 ; ; ; 27 m
sii 1 5 ; ; -6 ; 27 m
sii 6 10 ; ; -3 ; 27 m
sii 4 5 ; ; -4 ; 27 m
sii -10 ; ; ; 27 m
sii -1 ; ; ; 28 s
sii 1 3 ; ; -4 ; 28 s
sii ; ; -1 ; 28 s
sii -10 ; ; ; 28 s
sii -1 ; ; ; 34 s
sii 1 3 ; ; -4 ; 34 s
sii ; ; -1 ; 34 s
sii -10 ; ; ; 34 s
endpart

c silicon rubber upper piece - fine mesh
cylinder
c 1 2 15 16 17 18 19 20 28 29 30 ; 1 65 ; 1 2 3 ;
1 2  9  14  15 16 17 18 19 20 28 29 30 ; 1 65 ; 1 2 3 ;
0.5000 0.6000 2.15 3.46 3.7 3.73 3.85 3.9 3.93 4.0 4.5 4.6 4.7
0 180
37.1902 37.2502 37.4002
dei 5 6 0 9 10 ; ; 1 2 ;
dei 1 4 ; ; ;
pb 1 0 1 1 0 1  xz 0.5900 37.1002
pb 2 0 1 2 0 1  xz 0.7066 37.1002
pb 5 0 1 5 0 1  xz 3.7117 37.1002
pb 6 0 1 6 0 1  xz 3.6746 37.2502
pb 7 0 1 7 0 1  xz 3.7117 37.1002
pb 8 0 1 8 0 1  xz 3.8000 37.0273
pb 9 0 1 9 0 1  xz 3.8945 37.0456
pb 10 0 1 10 0 1  xz 3.8000 37.0273
pb 11 0 1 11 0 1  xz 4.0690 35.6400
pb 12 0 1 12 0 1  xz 4.1037 35.4611
pb 13 0 1 13 0 1  xz 4.1722 35.3847

pb 1 0 2 1 0 2  xz 0.5000 37.1902
pb 2 0 2 2 0 2  xz 0.7066 37.2502
pb 5 0 2 5 0 2  xz 3.6746 37.2502
pb 6 0 2 6 0 2  xz 3.7351 37.3151
pb 7 0 2 7 0 2  xz 3.7844 37.2502
pb 8 0 2 8 0 2  xz 3.8728 37.1773
pb 9 0 2 9 0 2  xz 3.9141 37.1302
pb 10 0 2 10 0 2  xz 3.8945 37.0456
pb 11 0 2 11 0 2  xz 4.1672 35.6590
pb 12 0 2 12 0 2  xz 4.1881 35.4866
pb 13 0 2 13 0 2  xz 4.2713 35.4083

pb 1 0 3 1 0 3  xz 0.5000 37.3102
pb 2 0 3 2 0 3  xz 0.5900 37.4002
pb 5 0 3 5 0 3  xz 3.6376 37.4002
pb 6 0 3 6 0 3  xz 3.7313 37.4002
pb 7 0 3 7 0 3  xz 3.8572 37.4002
pb 8 0 3 8 0 3  xz 3.9456 37.3273
pb 9 0 3 9 0 3  xz 3.9734 37.1840
pb 10 0 3 10 0 3  xz 3.9964 37.0654
```

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```
pb 11 0 3 11 0 3  xz 4.2653 35.6780
pb 12 0 3 12 0 3  xz 4.2814 35.5951
pb 13 0 3 13 0 3  xz 4.3000 35.4992

pb 3 0 1 3 0 1  xz 2.1500 37.1002
pb 3 0 2 3 0 2  xz 2.1500 37.2502
pb 3 0 3 3 0 3  xz 2.1500 37.4002

pb 4 0 1 4 0 1  xz 3.4600 37.1002
pb 4 0 2 4 0 2  xz 3.4600 37.2502
pb 4 0 3 4 0 3  xz 3.4600 37.4002

mate 32
sii ; ; -3 ; 29 s
sii ; ; -3 ; 30 s
sii -13 ; ; ; 30 s
sii 12 13 ; ; -1 ; 30 s
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 31 m
sii -13 ; ; ; 31 m
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 32 m
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 33 m
sii -1 ; ; ; 33 m
bb 4 0 0 4 0 0 18;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c silicon rubber upper piece - medium mesh
cylinder
c 1 2 15 16 17 18 19 20 28 29 30 ; 1 65 ; 1 2 3 ;
1 2 9 14 15 16 17 18 19 20 28 29 30 ; 1 33 ; 1 2 3 ;
0.5000 0.6000 2.15 3.46 3.7 3.73 3.85 3.9 3.93 4.0 4.5 4.6 4.7
0 180
37.1902 37.2502 37.4002
dei 5 6 0 9 10 ; ; 1 2 ;
dei 1 3 0 4 13 ; ; ;
pb 1 0 1 1 0 1  xz 0.5900 37.1002
pb 2 0 1 2 0 1  xz 0.7066 37.1002
pb 5 0 1 5 0 1  xz 3.7117 37.1002
pb 6 0 1 6 0 1  xz 3.6746 37.2502
pb 7 0 1 7 0 1  xz 3.7117 37.1002
pb 8 0 1 8 0 1  xz 3.8000 37.0273
pb 9 0 1 9 0 1  xz 3.8945 37.0456
pb 10 0 1 10 0 1  xz 3.8000 37.0273
pb 11 0 1 11 0 1  xz 4.0690 35.6400
pb 12 0 1 12 0 1  xz 4.1037 35.4611
pb 13 0 1 13 0 1  xz 4.1722 35.3847

pb 1 0 2 1 0 2  xz 0.5000 37.1902
pb 2 0 2 2 0 2  xz 0.7066 37.2502
pb 5 0 2 5 0 2  xz 3.6746 37.2502
pb 6 0 2 6 0 2  xz 3.7351 37.3151
pb 7 0 2 7 0 2  xz 3.7844 37.2502
pb 8 0 2 8 0 2  xz 3.8728 37.1773
pb 9 0 2 9 0 2  xz 3.9141 37.1302
pb 10 0 2 10 0 2  xz 3.8945 37.0456
pb 11 0 2 11 0 2  xz 4.1672 35.6590
pb 12 0 2 12 0 2  xz 4.1881 35.4866
pb 13 0 2 13 0 2  xz 4.2713 35.4083

pb 1 0 3 1 0 3  xz 0.5000 37.3102
pb 2 0 3 2 0 3  xz 0.5900 37.4002
pb 5 0 3 5 0 3  xz 3.6376 37.4002
pb 6 0 3 6 0 3  xz 3.7313 37.4002
pb 7 0 3 7 0 3  xz 3.8572 37.4002
pb 8 0 3 8 0 3  xz 3.9456 37.3273
pb 9 0 3 9 0 3  xz 3.9734 37.1840
pb 10 0 3 10 0 3  xz 3.9964 37.0654
pb 11 0 3 11 0 3  xz 4.2653 35.6780
pb 12 0 3 12 0 3  xz 4.2814 35.5951
pb 13 0 3 13 0 3  xz 4.3000 35.4992

pb 3 0 1 3 0 1  xz 2.1500 37.1002
pb 3 0 2 3 0 2  xz 2.1500 37.2502
pb 3 0 3 3 0 3  xz 2.1500 37.4002

pb 4 0 1 4 0 1  xz 3.4600 37.1002
pb 4 0 2 4 0 2  xz 3.4600 37.2502
pb 4 0 3 4 0 3  xz 3.4600 37.4002

mate 32
sii ; ; -3 ; 29 s
sii ; ; -3 ; 30 s
sii -13 ; ; ; 30 s
sii 12 13 ; ; -1 ; 30 s
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 31 m
sii -13 ; ; ; 31 m
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 32 m
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 33 m
sii -1 ; ; ; 33 m
trbb 4 0 0 4 0 0 18;
bb 3 0 0 3 0 0 19;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c silicon rubber upper piece - coarse mesh
cylinder
c 1 2 15 16 17 18 19 20 28 29 30 ; 1 65 ; 1 2 3 ;
1 2 9 14 15 16 17 18 19 20 28 29 30 ; 1 17 ; 1 2 3 ;
0.5000 0.6000 2.15 3.46 3.7 3.73 3.85 3.9 3.93 4.0 4.5 4.6 4.7
0 180
37.1902 37.2502 37.4002
dei 5 6 0 9 10 ; ; 1 2 ;
dei 3 13 ; ; ;
pb 1 0 1 1 0 1  xz 0.5900 37.1002
pb 2 0 1 2 0 1  xz 0.7066 37.1002
pb 5 0 1 5 0 1  xz 3.7117 37.1002
pb 6 0 1 6 0 1  xz 3.6746 37.2502
pb 7 0 1 7 0 1  xz 3.7117 37.1002
pb 8 0 1 8 0 1  xz 3.8000 37.0273
pb 9 0 1 9 0 1  xz 3.8945 37.0456
pb 10 0 1 10 0 1  xz 3.8000 37.0273
pb 11 0 1 11 0 1  xz 4.0690 35.6400
pb 12 0 1 12 0 1  xz 4.1037 35.4611
pb 13 0 1 13 0 1  xz 4.1722 35.3847
pb 1 0 2 1 0 2  xz 0.5000 37.1902
pb 2 0 2 2 0 2  xz 0.7066 37.2502
pb 5 0 2 5 0 2  xz 3.6746 37.2502
pb 6 0 2 6 0 2  xz 3.7351 37.3151
pb 7 0 2 7 0 2  xz 3.7844 37.2502
pb 8 0 2 8 0 2  xz 3.8728 37.1773
pb 9 0 2 9 0 2  xz 3.9141 37.1302
pb 10 0 2 10 0 2  xz 3.8945 37.0456
pb 11 0 2 11 0 2  xz 4.1672 35.6590
pb 12 0 2 12 0 2  xz 4.1881 35.4866
pb 13 0 2 13 0 2  xz 4.2713 35.4083

pb 1 0 3 1 0 3  xz 0.5000 37.3102
pb 2 0 3 2 0 3  xz 0.5900 37.4002
pb 5 0 3 5 0 3  xz 3.6376 37.4002
pb 6 0 3 6 0 3  xz 3.7313 37.4002
pb 7 0 3 7 0 3  xz 3.8572 37.4002
pb 8 0 3 8 0 3  xz 3.9456 37.3273
pb 9 0 3 9 0 3  xz 3.9734 37.1840
pb 10 0 3 10 0 3  xz 3.9964 37.0654
pb 11 0 3 11 0 3  xz 4.2653 35.6780
pb 12 0 3 12 0 3  xz 4.2814 35.5951
pb 13 0 3 13 0 3  xz 4.3000 35.4992

pb 3 0 1 3 0 1  xz 2.1500 37.1002
pb 3 0 2 3 0 2  xz 2.1500 37.2502
pb 3 0 3 3 0 3  xz 2.1500 37.4002

pb 4 0 1 4 0 1  xz 3.4600 37.1002
pb 4 0 2 4 0 2  xz 3.4600 37.2502
pb 4 0 3 4 0 3  xz 3.4600 37.4002

mate 32
sii ; ; -3 ; 29 s
sii ; ; -3 ; 30 s
sii -13 ; ; ; 30 s
sii 12 13 ; ; -1 ; 30 s
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 31 m
sii -13 ; ; ; 31 m
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 32 m
sii 1 5 0 7 8 0 10 13 ; ; -1 ; 33 m
sii -1 ; ; ; 33 m
trbb 3 0 0 3 0 0 19;
lct 1 mz 0.0680 ; lrep 1 ;
endpart

c ******************************
c **** end silicon rubber ***
c ******************************


merge

tp .005
lsdyna keyword
write
```

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Appendix 6.2
Command Lines for HABC-run1hh

```
$ - Added lines
*KEYWORD
*TITLE
$ 345678901234567890123456789012345678 9
3100 HABC-run1hh U Bound Dec 2004 kqh
$
*CONTROL_CONTACT
,,,1
,
*CONTROL_PARALLEL
2,,
*CONTROL_TERMINATION
0.010,,,,
*DATABASE_BINARY_D3PLOT
0.0004,,,,
*DATABASE_BINARY_RUNRSF
2000,
*DATABASE_SLEOUT
1.e-5,
*DATABASE_MATSUM
1.e-5,
*DATABASE_GLSTAT
1.e-5,
$
*DATABASE_RWFORCE
1.e-5,
$
$ ********************************************
$
$ DEFINE GRAVITY
*LOAD_BODY_X
2,1,
*DEFINE_CURVE
2,
0.00, -386.
100.00, -386.
$
$ END DEFINE GRAVITY
$
$
*CONTACT_AUTOMATIC_SINGLE_SURFACE_TITLE
35,TrueGrid Sliding Interface #        35
1,0,2,0,,,0,0
0.300,0.200,10.00E+00,0.000E+00,0.000E+00,0,0.000E+00,0.040E+
00
0.000E+00,0.000E+00,0.000E+00,0.000E+00,0.000E+00,0.000E+00,
0.000E+00,0.000E+00
0,0.000E+00,0,0.000E+00,0.000E+00,0,0,
0.000E+00,0,0,0,1
*SET_PART_LIST
1
 1, 2, 3, 4, 5, 6, 7,10,
11,12,14,15,16,17,18,19,
24,25,26,27,29,30
$
$
$
$
*CONTACT_AUTOMATIC_SINGLE_SURFACE_TITLE
36,TrueGrid Sliding Interface #        36
2,0,2,0,,,0,0
0.300,0.200,10.00E+00,0.000E+00,0.000E+00,0,0.040E+00,1.000E+
00
0.000E+00,0.000E+00,0.000E+00,0.000E+00,0.000E+00,0.000E+00,
0.000E+00,0.000E+00
0,0.000E+00,0,0.000E+00,0.000E+00,0,0,
0.000E+00,0,0,0,1
*SET_PART_LIST
2
 1, 2, 3, 4, 5, 6, 7,10,
11,12,14,15,16,17,18,19,
24,25,26,27,31
$
$
$
$ *RIGIDWALL_GEOMETRIC_FLAT
$ ,
$ 9.6900, 0.0, 21.7551, -9.6900, 0.0, 21.7551, 0.2
$ 9.6900, 0.0, 35.6900,
$
$
$
$ ********************************************
$
$ ************************************************************
$
*SECTION_SOLID
1,1
*SECTION_SHELL
2,2,,3
,
$
$ ************************************************************
$
*HOURGLASS
1,4,
*HOURGLASS
2,4,
$
$ ************************************************************
$
$ part #1 CV body
*PART
CV body
1,1,1,,1
$ 304L
*MAT_POWER_LAW_PLASTICITY
$ 1, 7.4093E-4, 2.8000E+7, 0.29, 160455., 0.27916
1, 7.5094E-4, 2.8000E+7, 0.29, 160455., 0.27916
,
$
$ part #2 CV body at flange for preload
*PART
CV body at flange for preload
2,1,2,,1
$ 304L
*MAT_POWER_LAW_PLASTICITY
$ 2, 7.4093E-4, 2.8000E+7, 0.29, 160455., 0.27916
2, 7.5094E-4, 2.8000E+7, 0.29, 160455., 0.27916
,
$
$ part #3 CV lid
*PART
CV lid
```

```
3,1,3,,1
$ 304L
*MAT_POWER_LAW_PLASTICITY
$ 3, 7.4093E-4, 2.8000E+7, 0.29, 160455., 0.27916
3, 7.5094E-4, 2.8000E+7, 0.29, 160455., 0.27916
,
$
$
$ part #4  CV nut ring
*PART
CV nut ring
4,1,4,,1
$ ASME A-479 Nitronic-60
*MAT_PLASTIC_KINEMATIC
$ 4, 7.1347e-4, 26.2e+6, 0.298, 50000., 129000.,
4, 7.5094e-4, 26.2e+6, 0.298, 50000., 129000.,
,
$
$
$ part #5 angle
*PART
angle
5,1,5,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
5, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$
$ part #6 drum
*PART
drum
6,2,6,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
6, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #7 drum bottom head
*PART
drum bottom head
7,2,7,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
7, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #8 weld drum to drum bottom head
*PART
weld drum to drum bottom head
8,2,8,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
8, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #9 liner overlap to angle (0.03)
*PART
liner overlap to angle (0.03)
9,2,9,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
9, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #10 liner (0.06)
*PART
liner (0.06)
10,2,10,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
10, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #11 liner bottom (0.120) (see m 27 for solids)
*PART
liner bottom (0.120) (see m 27 for solids)
11,2,11,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
11, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #12 lid shells (0.0598)
*PART
lid shells (0.0598)
12,2,12,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
12, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #13 thin lid shell at bolts
*PART
thin lid shell at bolts
13,2,13,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
13, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #14 lid solids at the lid bolts
*PART
lid solids at the lid bolts
14,1,14,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
14, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #15 lid stiffener
*PART
lid stiffener
15,1,15,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
15, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$
$ part #16 drum bolts
*PART
drum bolts
16,1,16,,1
```

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DAC NO DAC-EA-801699-A002	REVISION 0	COMPUTED KDH 2-24-05	CHECKED BY GAA 2/24/05 GAA

```
$ 304
$ *MAT_POWER_LAW_PLASTICITY
$ 16, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
*MAT_PLASTIC_KINEMATIC
16, 7.3451e-4, 29e+6, 0.29, 34000., 93180.,
,,0.57
$
$
$ part #17 drum stud nuts
*PART
drum stud nuts
17,1,17,,1
$ bronze
*MAT_POWER_LAW_PLASTICITY
17, 8.2371e-4, 1.70E+7, 0.33, 70989., 0.09191
,
$
$
$ part #18 drum studs
*PART
drum studs
18,1,18,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
18, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$
$ part #19  plug liner
*PART
plug liner
19,2,19,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
$ 19, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
19, 8.1752E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$ part #20  plug kaolite
*PART
plug kaolite
20,1,20,,1
$ kaolite
*MAT_HONEYCOMB
$ 20, 4.6081E-05, 1.0E+6, 0.01, 40000., 0.20,
$ $ $  4.0479E-05 is 27.0 lb/ft^3
$  low bound $
$  low bound $20, 4.0479E-05, 1.0E+6, 0.01, 40000., 0.10,
$  low bound $1,
$  low bound $2197., 2197., 2197., 1099.0, 1099.0, 1099.0,
$  low bound $,
$  low bound $,
$  low bound $$
$  low bound $*DEFINE_CURVE  $ Lower Bound Kaolite February
2004 Curve
$  low bound $1,
$  low bound $0.0000, 29.0
$  low bound $0.0132, 29.0
$  low bound $0.0456, 48.0
$  low bound $0.0792, 56.0
$  low bound $0.1128, 64.0
$  low bound $0.1464, 75.0
$  low bound $0.1800, 83.0
$  low bound $0.2136, 93.0
$  low bound $0.2460, 105.0
$  low bound $0.2796, 109.0
$  low bound $0.3144, 117.0
$  low bound $0.3480, 127.0
$  low bound $0.3816, 148.0
$  low bound $0.4140, 174.0
$  low bound $0.4488, 202.0
$  low bound $0.4824, 237.0
$  low bound $0.5160, 281.0
$  low bound $0.5496, 330.0
$  low bound $0.5832, 381.0
$  low bound $0.6168, 443.0
$  low bound $0.6492, 520.0
$  low bound $0.6828, 619.0
$  low bound $0.7140, 744.0
$  low bound $0.7476, 896.0
$  low bound $0.7800, 1099.0
$  low bound $0.7944, 1205.0
$  low bound $0.8200, 3000.0
$  low bound $0.8700, 10000.0
$  low bound $0.9000, 40000.0
$
20, 4.0479E-05, 6.0E+5, 0.01, 40000., 0.12,
1,
29210., 29210., 29210., 14605.0, 14605.0, 14605.0,
,
,
$
*DEFINE_CURVE  $ Upper Bound Kaolite June 2004 Curve
1,
0.00,      292.1
0.01,      292.1
0.019,     313.3
0.029,     336.1
0.04,      360.5
0.051,     386.6
0.064,     414.3
0.079,     443.6
0.094,     474.5
0.111,     506.9
0.13,      540.7
0.15,      575.7
0.172,     611.6
0.197,     647.9
0.224,     684.1
0.253,     719.6
0.285,     780.0
0.32,      860.0
0.3504,    958.0
0.3696,    1086.0
0.3888,    1231.0
0.45,      2000.0
0.5,       3000.0
0.6,       6000.0
0.7,       10000.0
0.8,       16000.0
0.85,      22000.0
0.88,      40000.0
$
$ part #21  drum kaolite
```

```
*PART
drum kaolite
21,1,21,,1
$ kaolite
*MAT_HONEYCOMB
$ 21, 4.6081E-05, 1.0E+6, 0.01, 40000., 0.20,
$ $ $ 4.0479E-05 is 27.0 lb/ft^3
21, 4.0479E-05, 6.0E+5, 0.01, 40000., 0.12,
1,
29210., 29210., 29210., 14605.0, 14605.0, 14605.0,
,
,
$
$
$ part/mat 22 borobond4 - from HEU Pallet Corner (Huston)
$ *PART
$ borobond4
$ 22,1,22,,1
$ *MAT_SOIL_AND_FOAM
$ 22, 1.799E-4, 1.019E6, 2.491E6, 1.0083E7, 0.0, 0.0, -309.3,
$ ,
$ 0.0, -7.387e-4, -4.236e-2, -0.1733, -0.2699, -0.3963, -0.5650,
-0.7997
$ -1.1536,
$ 0.0,  1833.3,   1850.,  1866.,  1883.,  1900.,  10000.,  30000.
$ 100000.,
$
*PART
HABC 277-4 -40F
22,1,22,,1
*MAT_SOIL_AND_FOAM
22, 1.5742e-4, 7.485e5, 1.952e6, 4.530e5, 0., 0., -78.2
,
0.00,-3.438E-05,-1.330E-04,-2.597E-04,-4.448E-04,-8.881E-04,-3.4
61E-03,-1.679E-01,
-5.550E-01, -1.141E+00
0.00, 67.100, 187.300, 294.367, 374.067, 416.567, 433.333,
566.667,
1000.000, 100000.000
$
$ $ part #23 lid to lid stiffener weld
$ *PART
$ lid to lid stiffener weld
$ 23,2,23,,1
$ $ 304
$ *MAT_POWER_LAW_PLASTICITY
$ 23, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
$ ,
$
$ part #24 lower internal cv mass
*PART
lower internal cv mass
24,1,24,,1
$ mild steel
*MAT_PLASTIC_KINEMATIC
$ 24, 7.3451e-4, 29e+6, 0.29, 30000., 100000.,
24, 7.3242e-4, 29e+6, 0.29, 30000., 100000.,
,
$
$
$ part #25 middle internal cv mass
*PART
middle internal cv mass
25,1,25,,1
$ mild steel
*MAT_PLASTIC_KINEMATIC
$ 25, 7.3451e-4, 29e+6, 0.29, 30000., 100000.,
25, 7.3242e-4, 29e+6, 0.29, 30000., 100000.,
,
$
$
$ part #26 upper internal cv mass
*PART
upper internal cv mass
26,1,26,,1
$ mild steel
*MAT_PLASTIC_KINEMATIC
$ 26, 7.3451e-4, 29e+6, 0.29, 30000., 100000.,
26, 7.3242e-4, 29e+6, 0.29, 30000., 100000.,
,
$
$
$ part #27 liner solids
*PART
liner solids
27,2,27,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
27, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$
$ part #28 liner overlap
*PART
liner overlap
28,2,28,,1
$ 304
*MAT_POWER_LAW_PLASTICITY
28, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
,
$
$
$ part #29 visual rigid plane
*PART
visual rigid plane
29,1,29,,0,0
$ RIGID MATERIAL
*MAT_RIGID
29, 1.0E-6, 2.8E+7, 0.29,
1.0, 7, 7
,
$
$
$ part #30 mild steel - crush plate
*PART
mild steel - crush plate
30,1,30,,1
$ mild steel
*MAT_PLASTIC_KINEMATIC
$ 30, 7.3483e-4, 29e+6, 0.29, 30000., 100000.,
$ run1a - 30, 7.4327e-4, 29e+6, 0.29, 30000., 100000.,
30, 7.34905e-4, 29e+6, 0.29, 30000., 100000.,
,
$
```

GENERAL DESIGN AND COMPUTATION SHEET

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DAC NO DAC-EA-801699-A002	REVISION 0	COMPUTED KDH KDH 2-24-05	CHECKED BY GAA 2/24/05 GAA

```
$
$ part #31 punch
*PART
punch
31,1,31,,1
$ mild steel
*MAT_PLASTIC_KINEMATIC
31, 7.3451e-4, 29e+6, 0.29, 30000., 100000.,
,
$
$
$ part #32 silicon rubber
*PART
silicon rubber
32,1,32,,1
$ silicon rubber
*MAT_BLATZ-KO_RUBBER
32, 1.1554e-4, 51260., 0.0
$
$
$
$ $ part #33 drum studs
$ *PART
$ drum studs
$ 33,1,33,,1
$ $ 304
$ $ *MAT_POWER_LAW_PLASTICITY
$ $ 16, 7.5130E-4, 2.81E+7, 0.29, 162738., 0.27208
$ *MAT_PLASTIC_KINEMATIC
$ 33, 7.3451e-4, 29e+6, 0.29, 34000., 93180.,
$ ,,0.57
$
$
$
$
$
$
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@@@@@@@@@@@@@@@@@@@@@@@@
$
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@@@@@@@@@@@@@@@@@@@@@@@@
$
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@@@@@@@@@@@@@@@@@@@@@@@@
$
*DEFINE_COORDINATE_NODES
1, 62716, 80351, 58241,
$ node 62716 is N1, the origin of the local coordinate system #1 and
$       is located in the inside center of the CV bottom flat head
$ node 80351 is N2, and therefore defines the local +X direction, it
is
$       located on the centerline of the CV lid
$ node 58241 is N3, and defines the +Y local direction, it is initilly
$       located in the direction of the global X axis from N1
$
*DATABASE_NODOUT
0.00001,
*DATABASE_HISTORY_NODE_SET_LOCAL
 1, 1, 2
 2, 1, 2
 5, 1, 2
 6, 1, 2
$
$
$ node 80840 is the node on the angle at the corner,
$       mid chamfer at 0 degrees to track velocity changes
*DATABASE_HISTORY_NODE
80840,
$
$
$ - End Added Lines
```