3.5 Run2e - Corner

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 3.5.1. The maximum effective plastic strain in the lid studs is in the stud at the impact with the rigid plane (0°) and is 0.5197 in/in as shown in Figure 3.5.2. It can be seen from the insert in Figure 3.5.2, 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 (stud "digging in") could also significantly effect this stud and cause failure. The maximum effective plastic strain of other components for this impact are listed in Table 3.5.1.

Table 3.5.1 - Run2e, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0142
CV Lid	0.0024
CV Nut Ring	0.0000
Angle	0.0393
Drum	0.3238
Drum Bottom Head	0.0000
Liner	0.3797
Lid	0.2968
Lid Stiffener	0.0271
Lid Stud Nuts	0.2252
Lid Stud Washers	0.0907
Plug Liner	0.1131

Figure 3.5.3 shows the final configuration for the crush impact. In Figure 3.5.4 the maximum effective plastic strain in the CV lid is shown to remain at 0.0024 in/in. Figure 3.5.5 shows the effective plastic strain in the liner to be a maximum of 0.5507 in/in. The maximum effective plastic strain in the drum is in the crimping as shown in Figure 3.5.6 and is a maximum of 0.3787 in/in. The maximum effective plastic strain in the drum studs

is shown to be 0.5578 in/in in Figure 3.5.7. As explained in the 30-foot impact results, slight variances in the length/configuration in this vicinity could prove significant in the test due to the relatively high level of strain through the thickness of the stud. There is a crimping of the lid and the drum roll in this local region, hence, even if the stud did shear, the lid would be held captive by the drum roll.

Table 3.5.2 - Run2e, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0364
CV Nut Ring	0.0000
Angle	0.0464
Drum Bottom Head	0.0731
Lid	0.3579
Lid Stiffener	0.0272
Lid Stud Nuts	0.2258
Lid Stud Washers	0.1111
Plug Liner	0.1170

The lid separation time history is given in Figure 3.5.8. A spike separation occurs in the crush impact with a maximum gap of about 0.010 inches. The run2e was extended to about 0.06 seconds so that the ringing associated with the gap at 0.05 seconds could relax. From the figure it is seen that an average value of gap would be 0.002 inches, or less due to the oscillatory nature of the gap response.

Figure 3.5.9 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 3.5.10 for the bottom kaolite. A minimum thickness of about 1.8 inches is shown.

Figure 3.5.11 shows the location of the nodes used to obtain the minimum kaolite thickness in the plug. Figure 3.5.12 shows the distance time history with the minimum being about 2.8 inches.

Figure 3.5.13 shows the nodes used to obtain overall drum dimensions for the impacts. The final lengths from the bottom head to the lid are used to describe the deformations. Curve A in Figure 3.5.14 gives the length response of the crush corner to the lid. It has a

final length of about 38.2 inches. Curve B in Figure 3.5.14 gives the length response from the initial 30-foot impact corner on the rigid surface to the bottom of the drum. This length has a final value of about 38.75 inches.

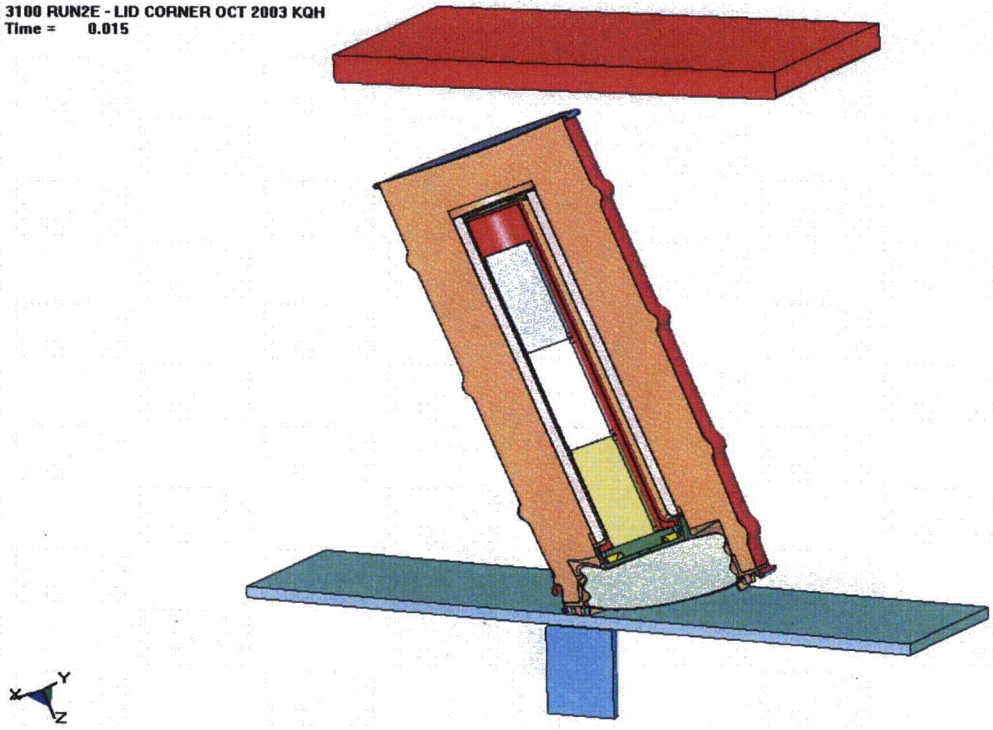

Figure 3.5.1 - Run2e, 30-Foot Impact, Final Configuration

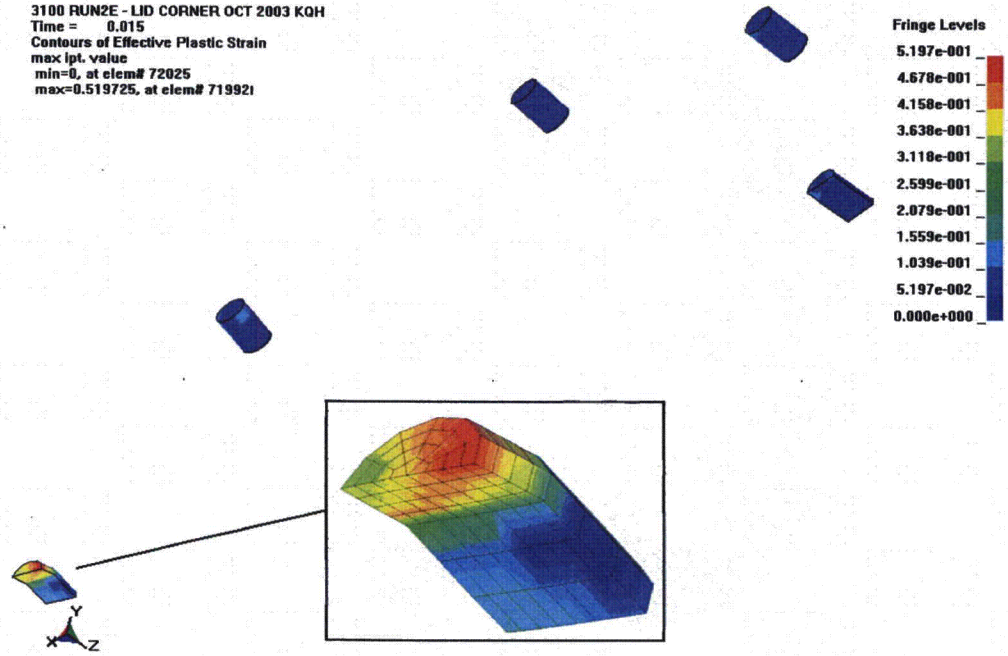

Figure 3.5.2 - Run2e, 30-Foot Impact, Effective Plastic Strain in the Drum Studs

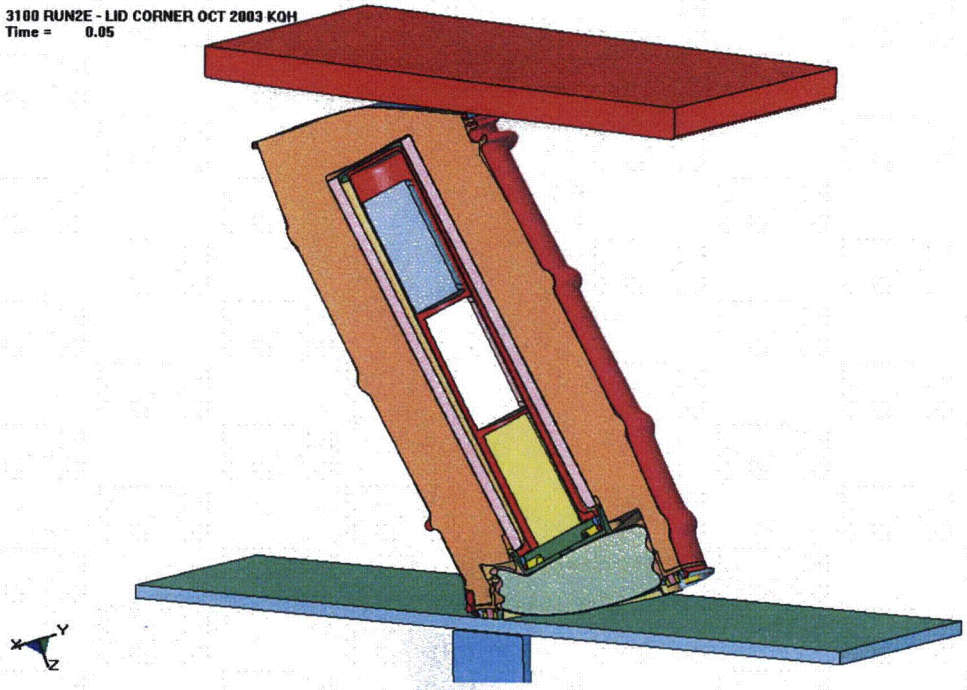

Figure 3.5.3 - Run2e, Crush Impact, Final Configuration

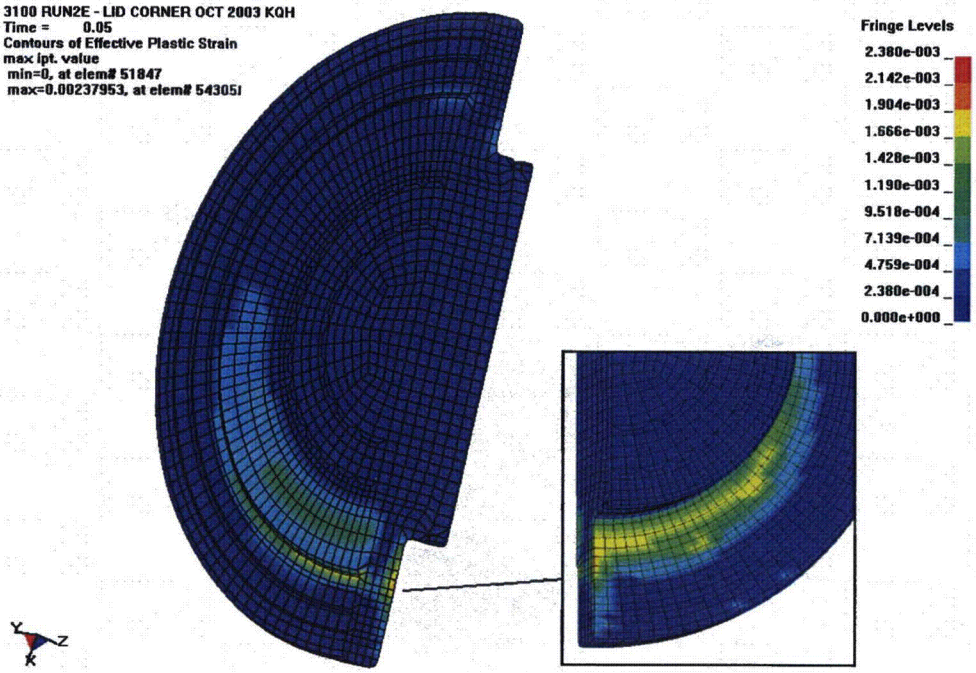

Figure 3.5.4 - Run2e, Crush Impact, Effective Plastic Strain in the CV Lid

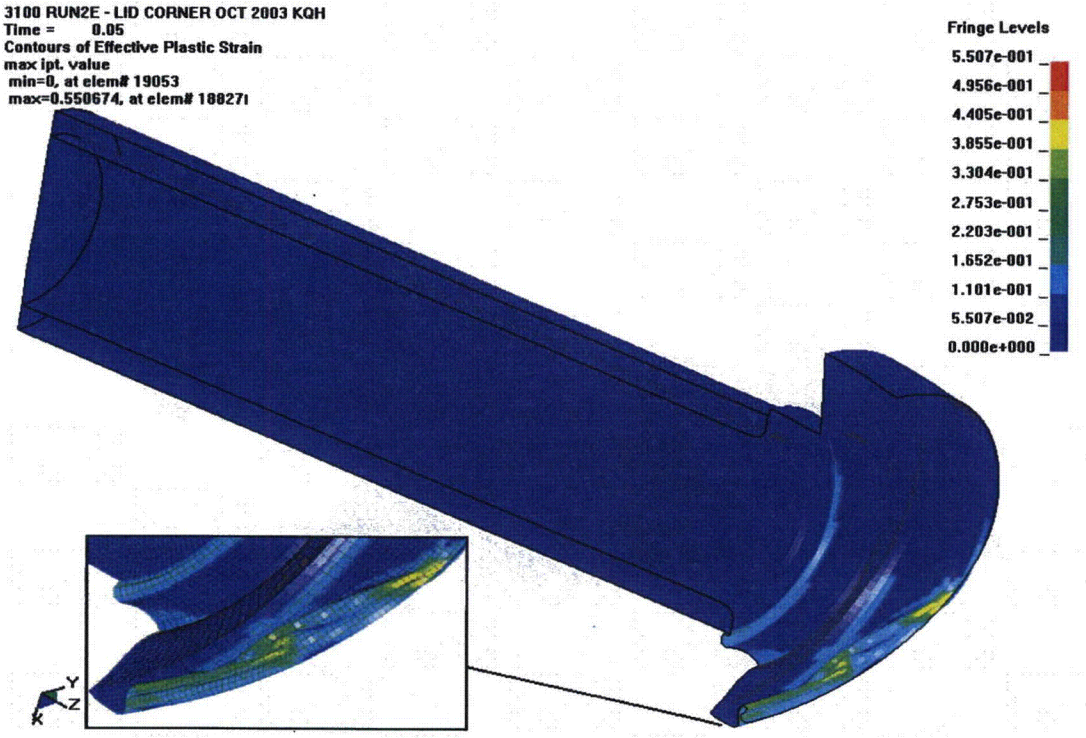

Figure 3.5.5 - Run2e, Crush Impact, Effective Plastic Strain in the Liner

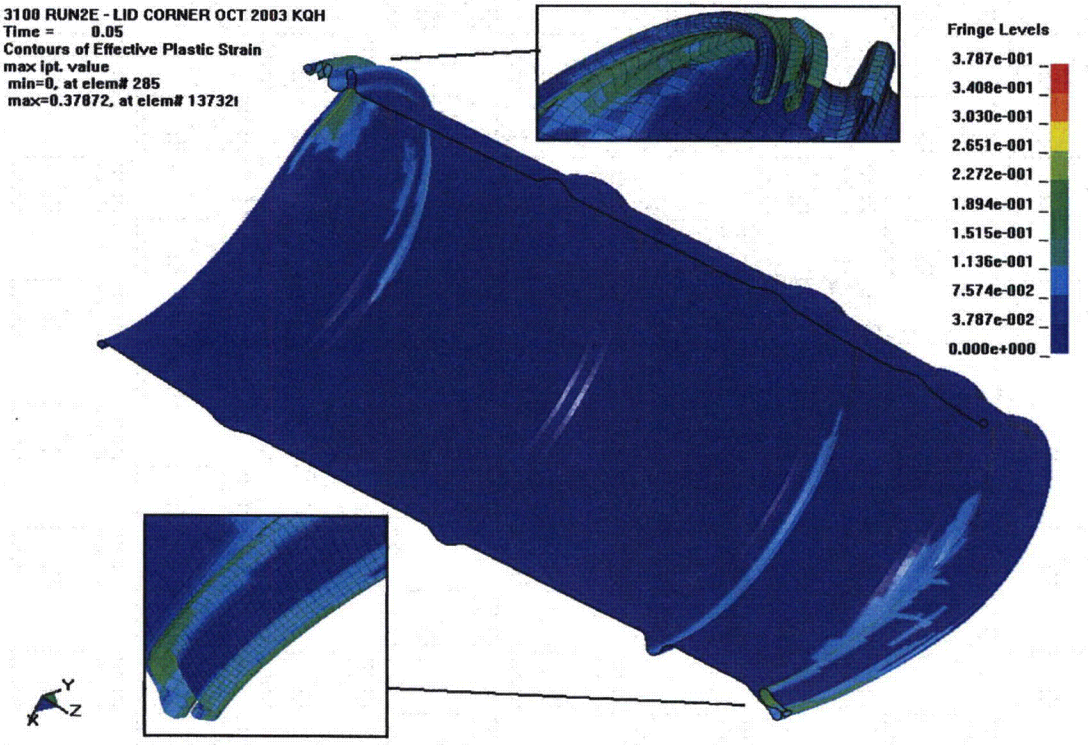

Figure 3.5.6 - Run2e, Crush Impact, Effective Plastic Strain in the Drum

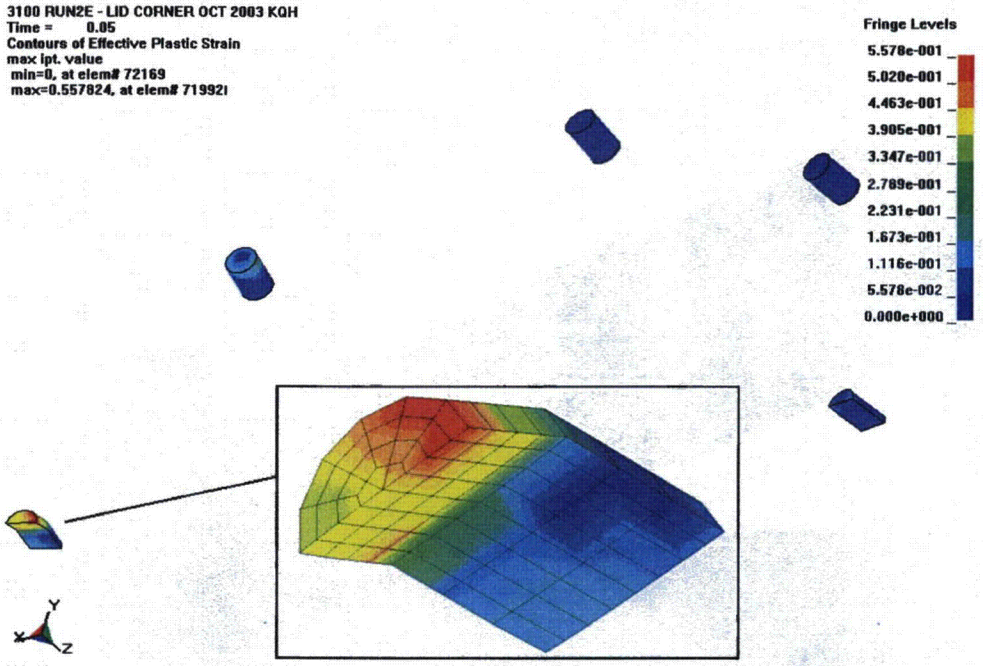

Figure 3.5.7 - Run2e, Crush Impact, Effective Plastic Strain in the Drum Studs

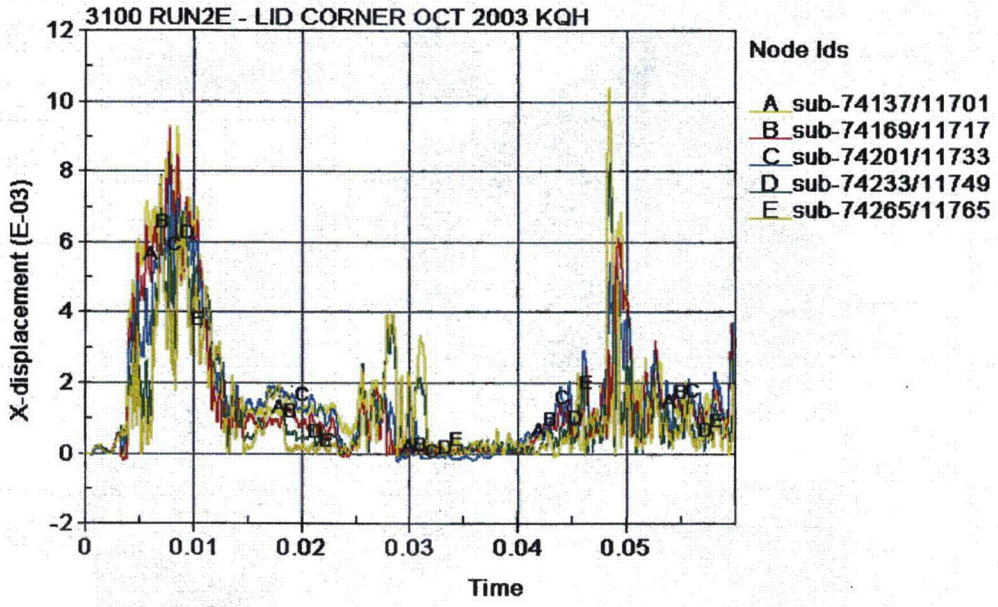

Figure 3.5.8 - Run2e, CV Lid/Body Separation Time History

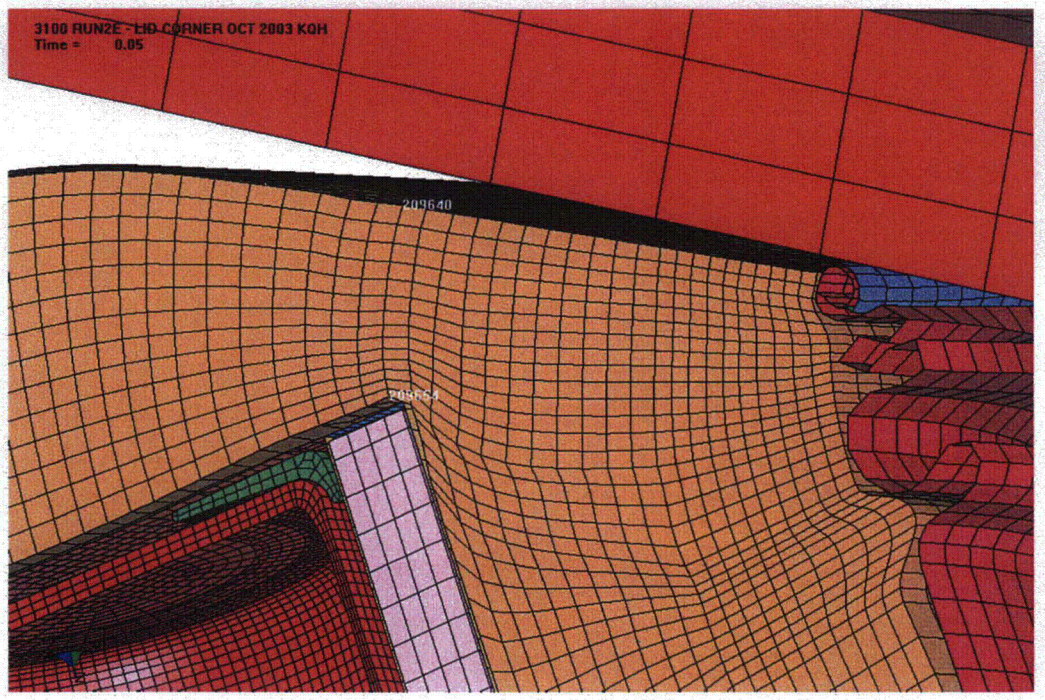

Figure 3.5.9 - Run2e, Location of Kaolite Nodes at the Bottom for Thickness Evaluation

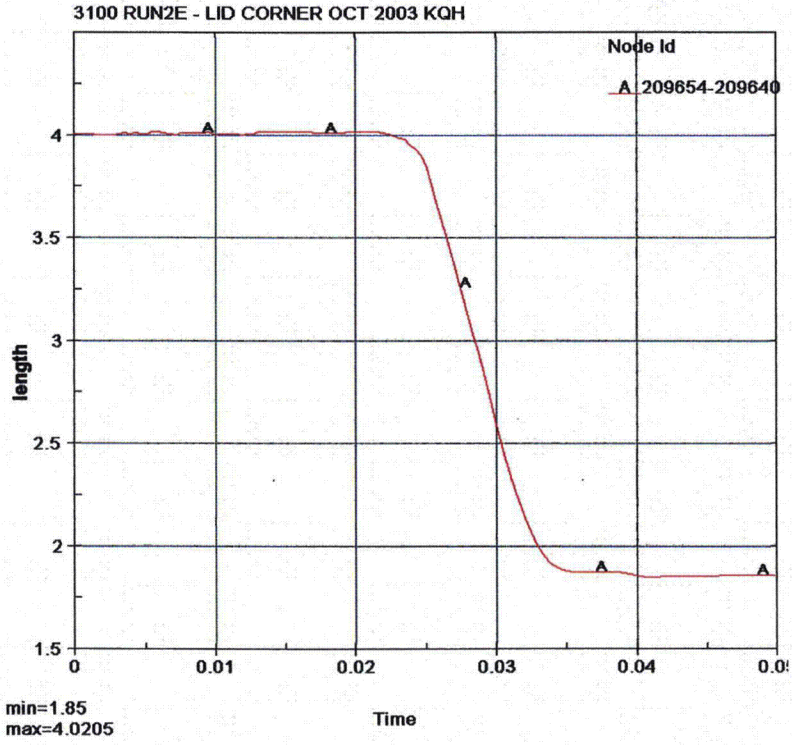

Figure 3.5.10 - Run2e, Minimum Thickness Time History for the Bottom Kaolite

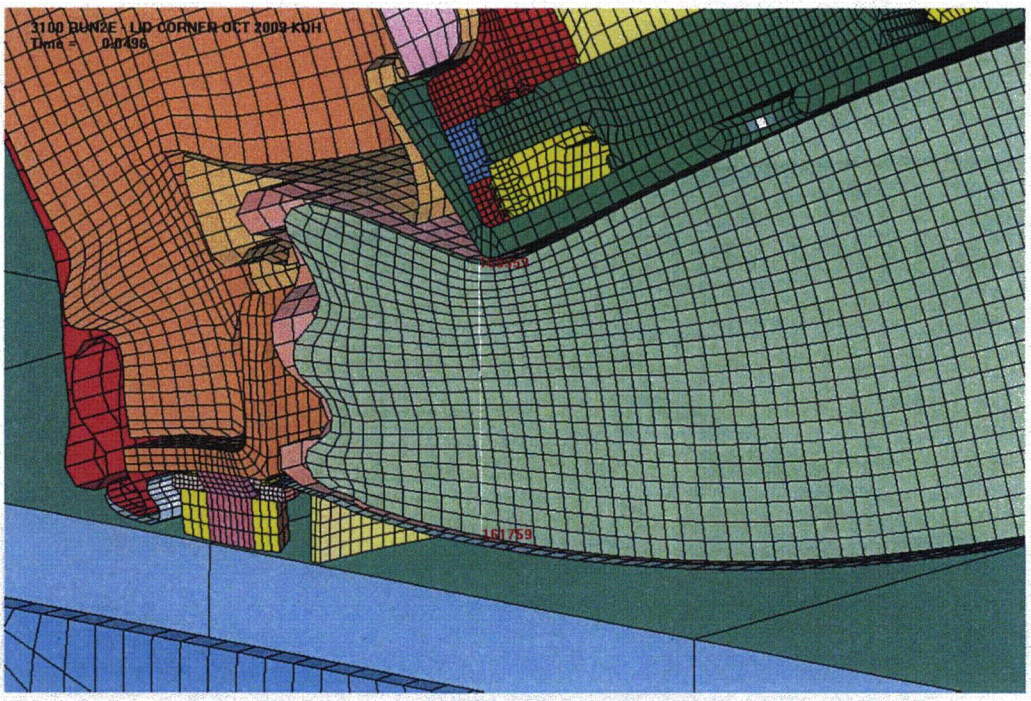

Figure 3.5.11 - Run2e, Location of Kaolite Nodes in the Plug for Thickness Evaluation

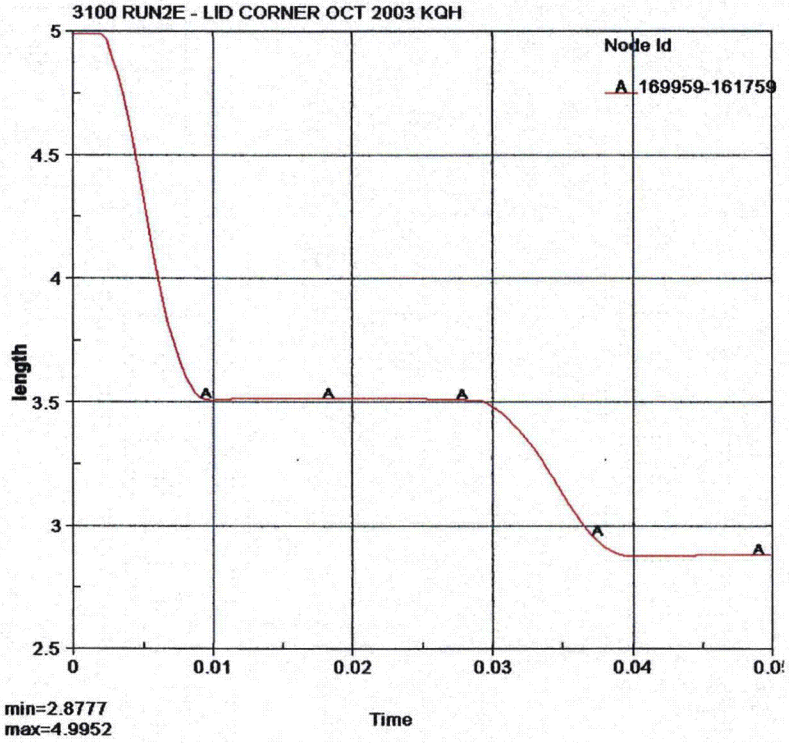

Figure 3.5.12 - Run2e, Minimum Thickness Time History for the Plug Kaolite

Figure 3.5.13 - Run2e, Length Dimensions in the Drum

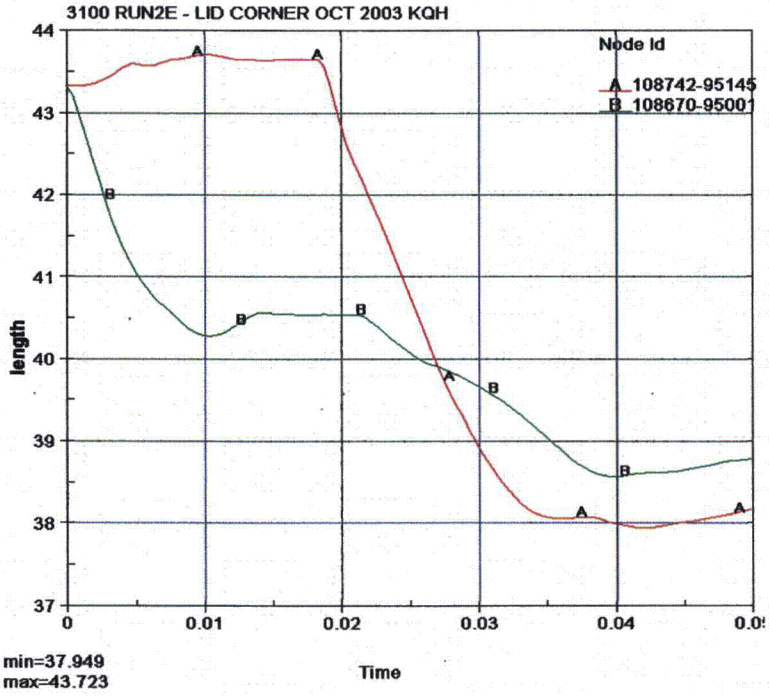

Figure 3.5.14 - Run2e, Time History of Length Dimensions in the Drum

3.6 Run3b - End

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 3.6.1 shows the final configuration for the 30-foot impact. Because of the relatively low demand placed on the components, no strain plots are presented for the 30-foot impact. Table 3.6.1 summarizes the maximum effective plastic strains in the package components.

Table 3.6.1 - Run3b, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0012
CV Lid	0.0031
CV Nut Ring	0.0000
Angle	0.0287
Drum	0.0565
Drum Bottom Head	0.0024
Liner	0.1665
Lid	0.1094
Lid Stiffener	0.0068
Lid Studs	0.0962
Lid Stud Nuts	0.0162
Lid Stud Washers	0.0510
Plug Liner	0.0636

Figure 3.6.2 shows the final configuration for the 30-foot impact and the successive crush impact. Figure 3.6.3 shows that the maximum effective plastic strain in the CV body is 0.0053 in/in. The maximum occurs in the bearing of the body flange onto the lid (at the O-ring seals). The magnitude of effective plastic strain is questioned due to the fact that the elevated strains occur at single nodes and are not symmetric (see the insert in Figure 3.6.3). The maximum effective plastic strain in the bottom region of the CV body is found to be 0.0035 in/in and does exhibit a symmetric characteristic as is shown in Figure 3.6.3.

The CV lid effective plastic strain fringes are shown from both sides in a split image in Figure 3.6.4. The maximum effective plastic strain in the lid is shown to be 0.0034 in/in in the figure. The other components are summarized in Table 3.6.2.

Table 3.6.2 - Run3b, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Nut Ring	0.0000
Angle	0.0304
Drum	0.1258
Drum Bottom Head	0.0312
Liner	0.3585
Lid	0.1415
Lid Stiffener	0.0098
Lid Studs	0.1541
Lid Stud Nuts	0.0170
Lid Stud Washers	0.0510
Plug Liner	0.0944

The CV lid separation time history is shown in Figure 3.6.5. The response during the 30-foot impact is a spike separation of about 0.012 inches, which relaxes to a maximum value of 0.003 inches for the remainder of the 30-foot impact. During the crush impact it is seen that separation is spikes to a maximum of about 0.004 inches, but the average remains at about 0.002 inches or less at the end of the impact.

Figure 3.6.6 shows the nodes chosen to obtain the drum height and kaolite thickness time history data. Figure 3.6.7 shows the drum height time history. From the figure it is seen that the overall height would be approximately 39 inches. Figure 3.6.8 shows the thickness time histories in the kaolite for the plug and the bottom. The curve A in the figure is for the bottom kaolite thickness, and it reaches about 2.2 inches as a final value. Curve B, is for the plug and it reaches about 3.4 inches for the final kaolite thickness.

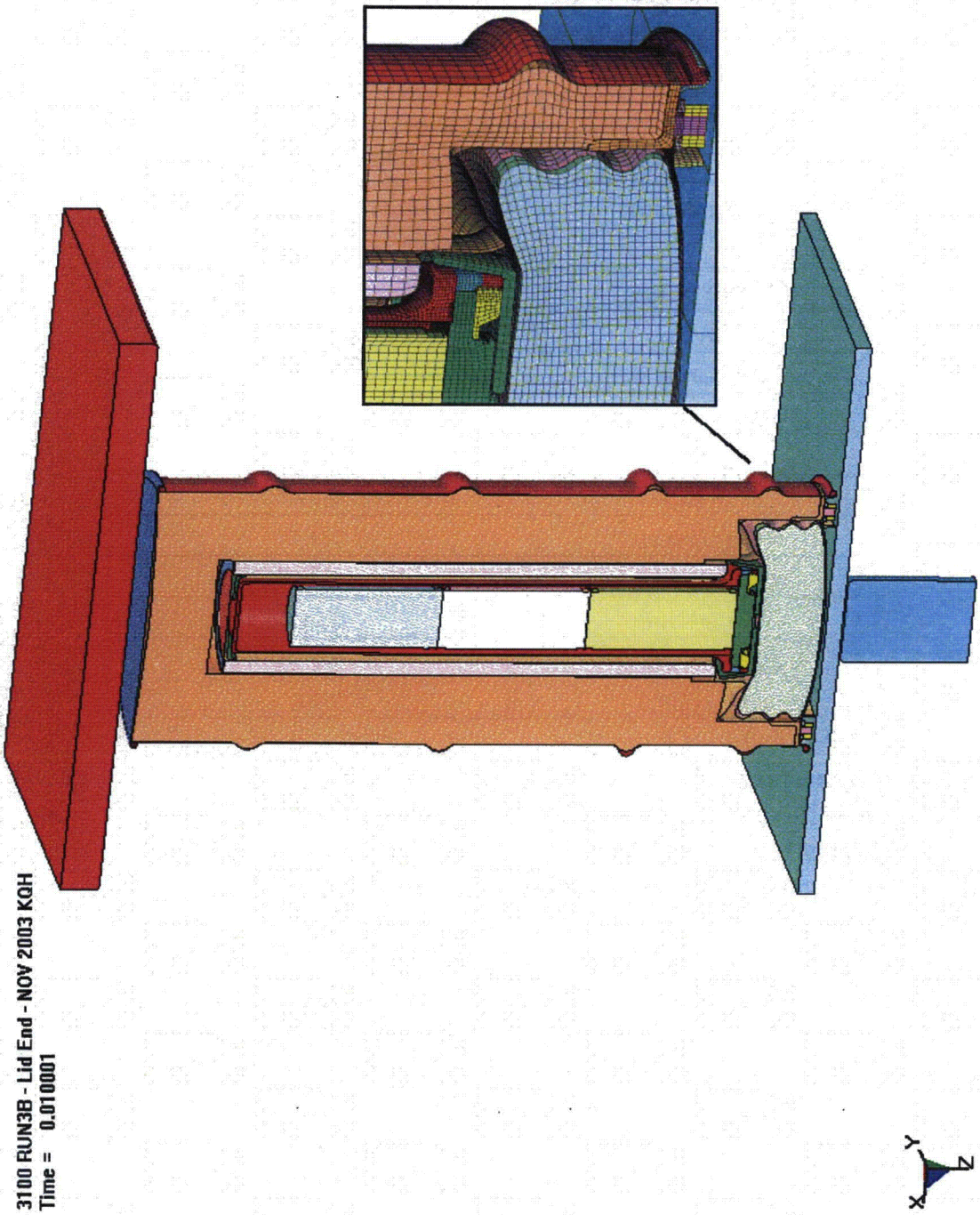

Figure 3.6.1 - Run3b, Configuration After the 30-Foot Impact

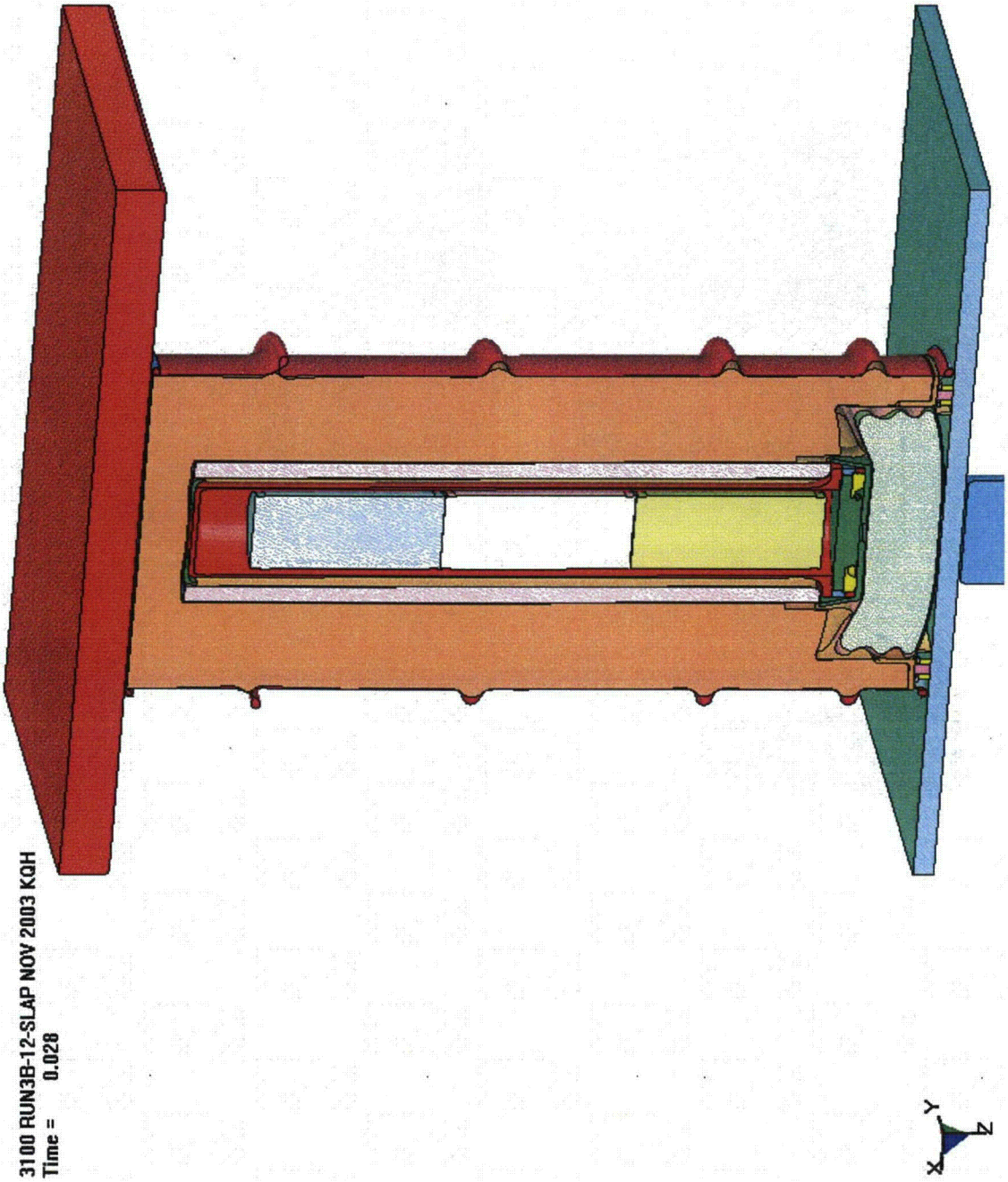

Figure 3.6.2 - Run3b, Crush Impact, Final Configuration

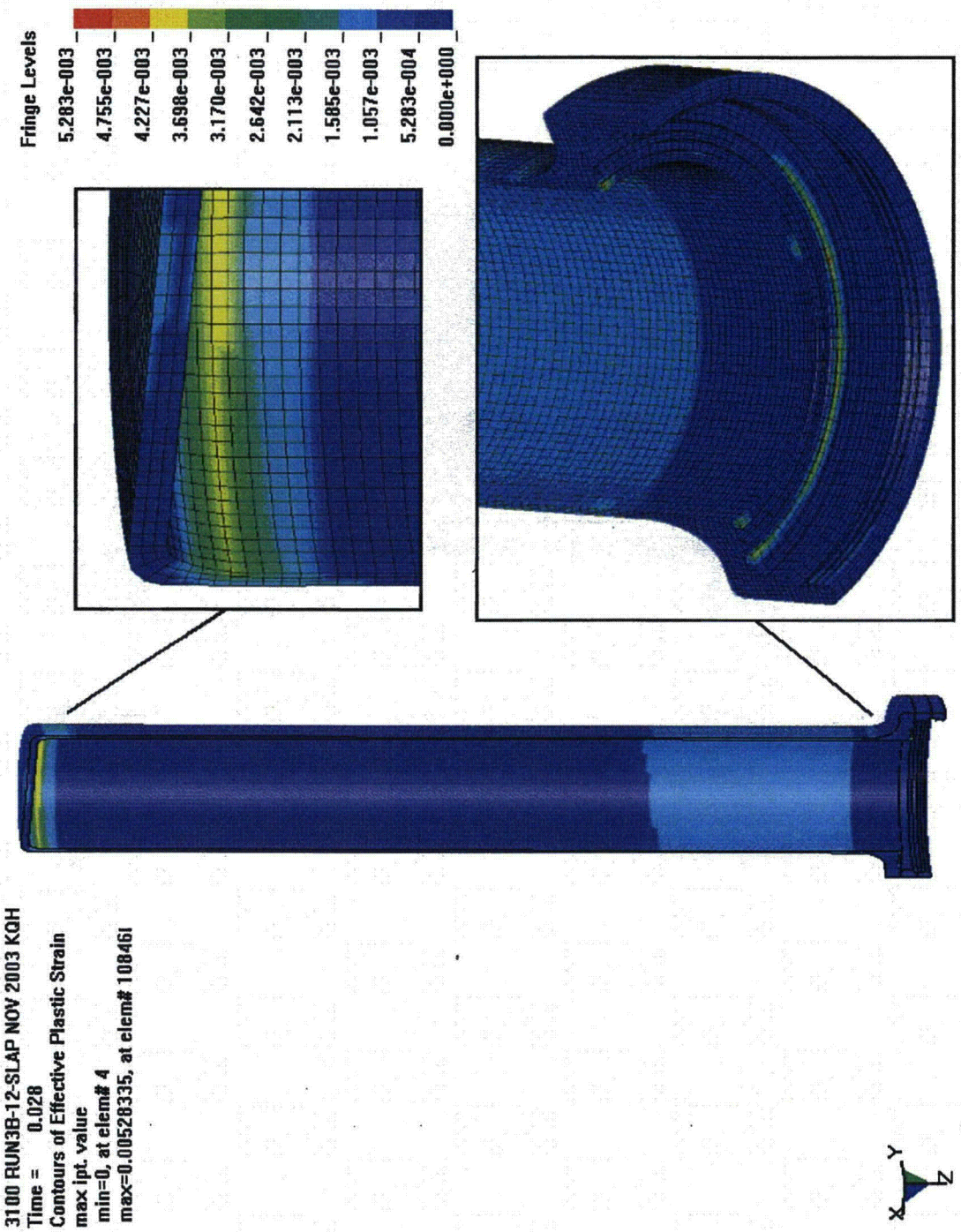

Figure 3.6.3 - Run3b, Crush Impact, Effective Plastic Strain in the CV Body

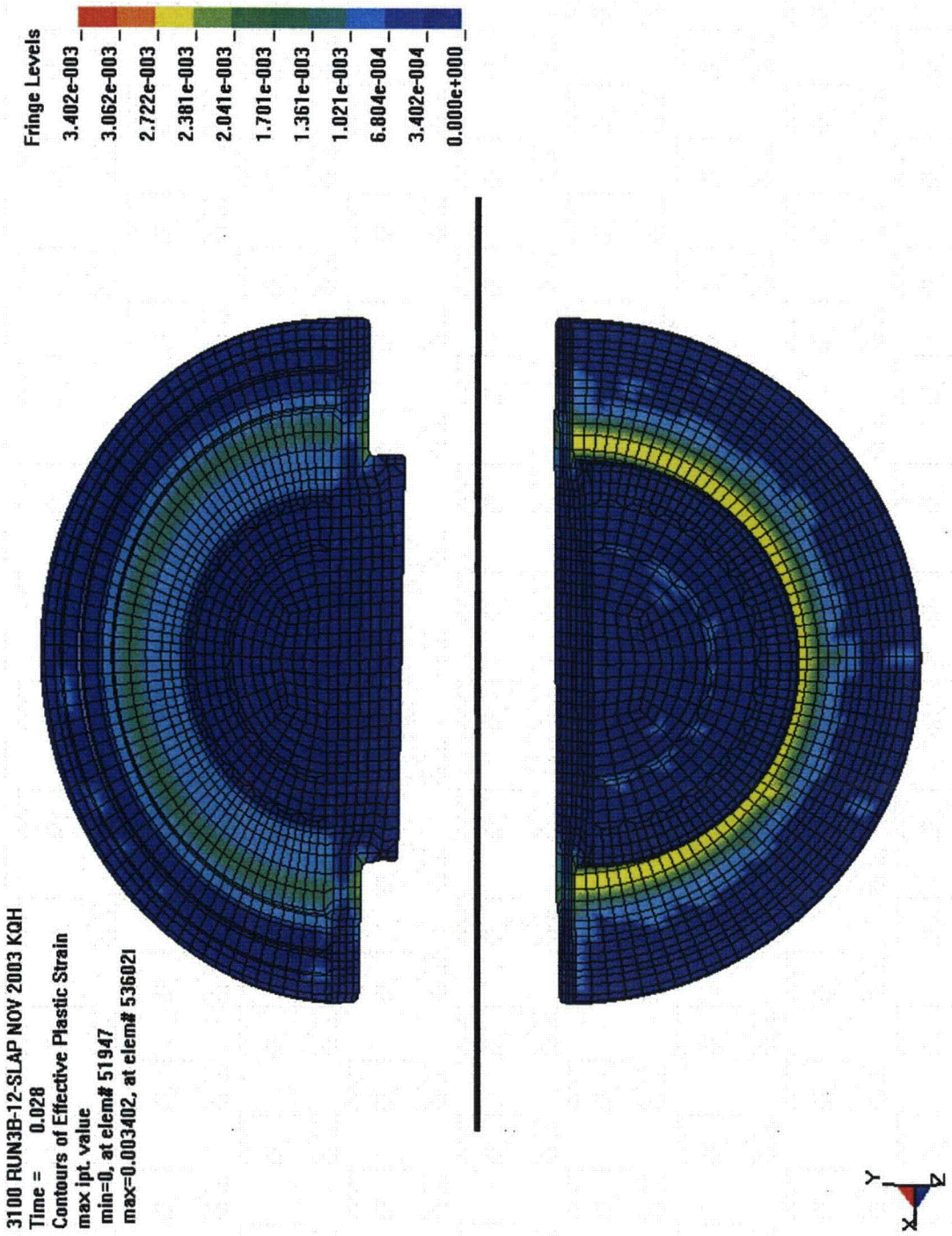

Figure 3.6.4 - Run3b, Crush Impact, Effective Plastic Strain in the CV Lid

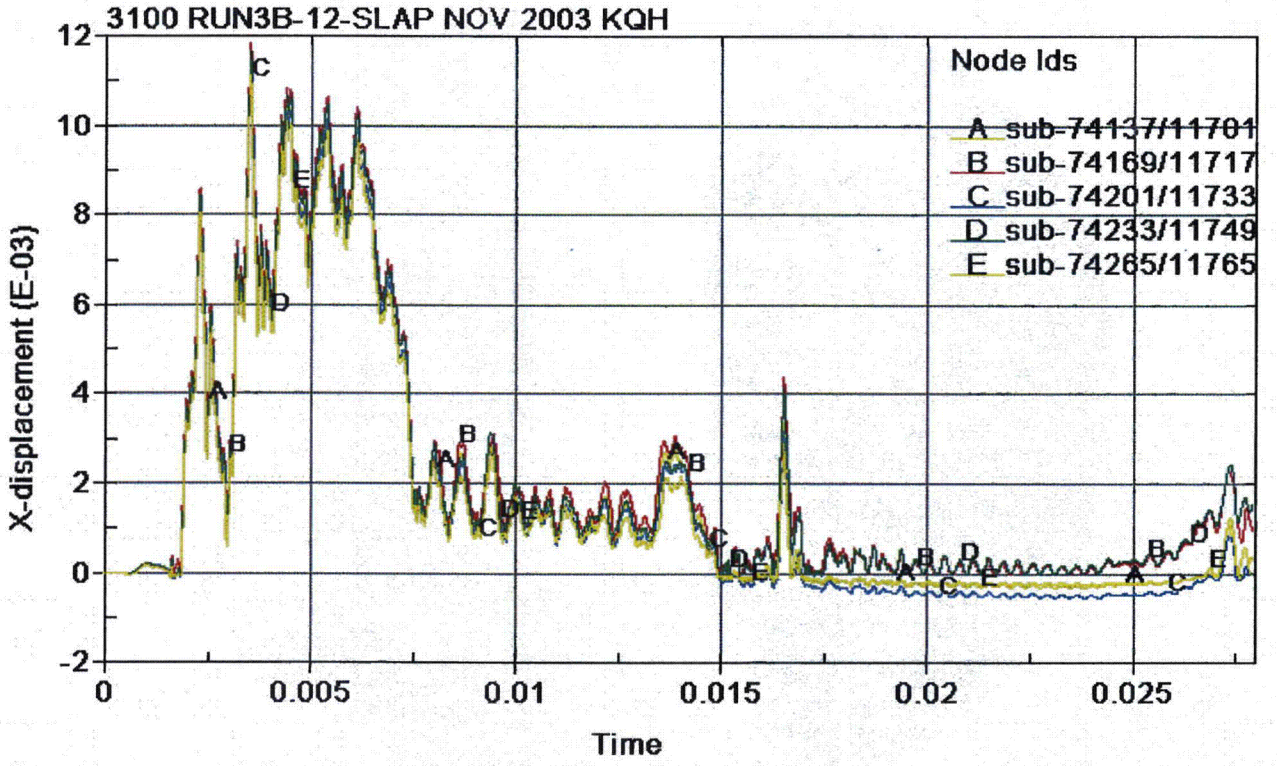

Figure 3.6.5 - Run3b, CV Lid Separation Time History

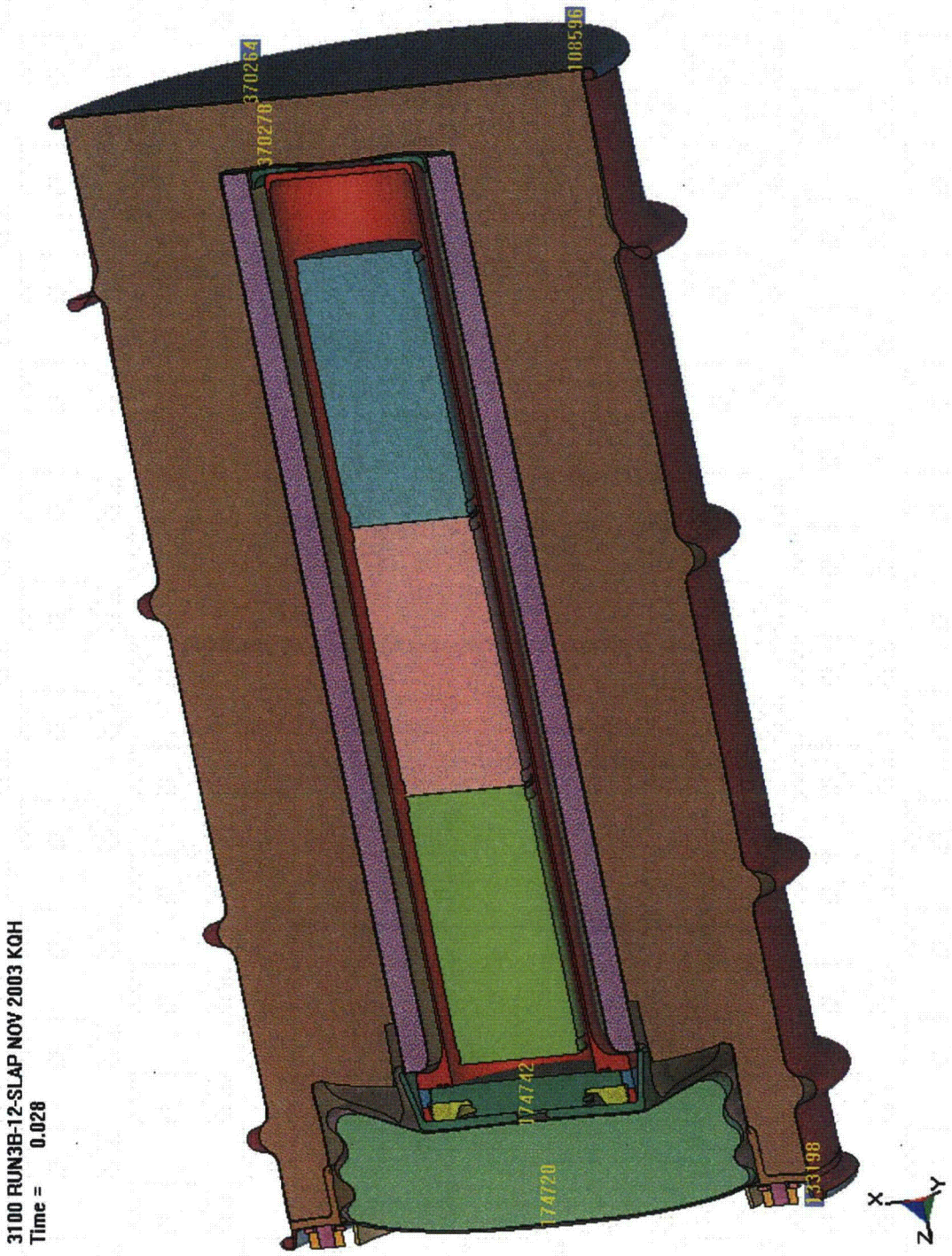

Figure 3.6.6 - Run3b, Nodes Chosen for Displacement Time Histories

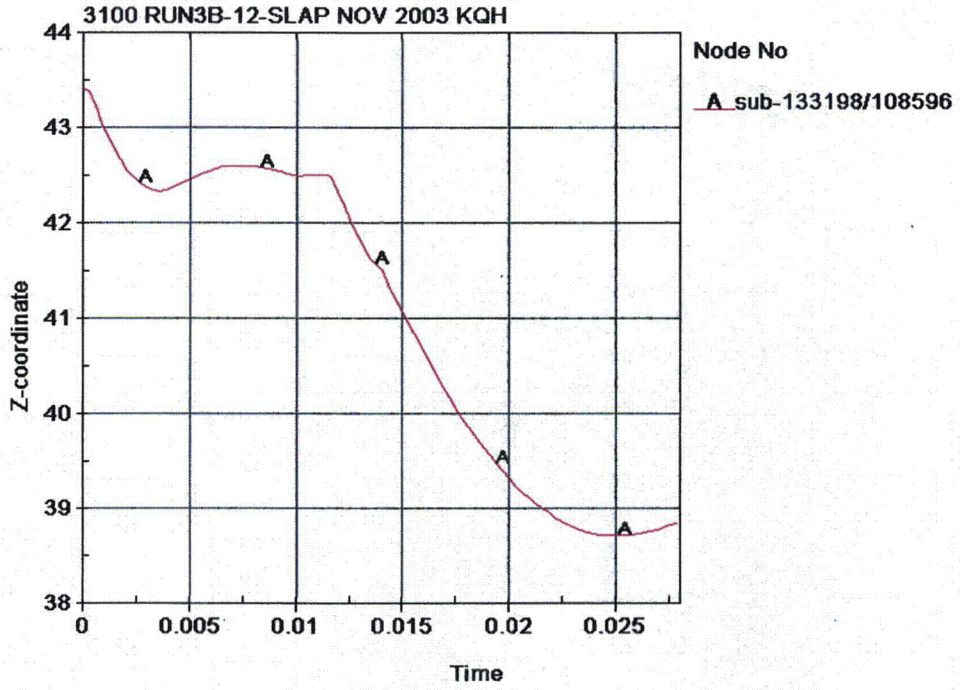

Figure 3.6.7 - Run3b, Drum Height Time History

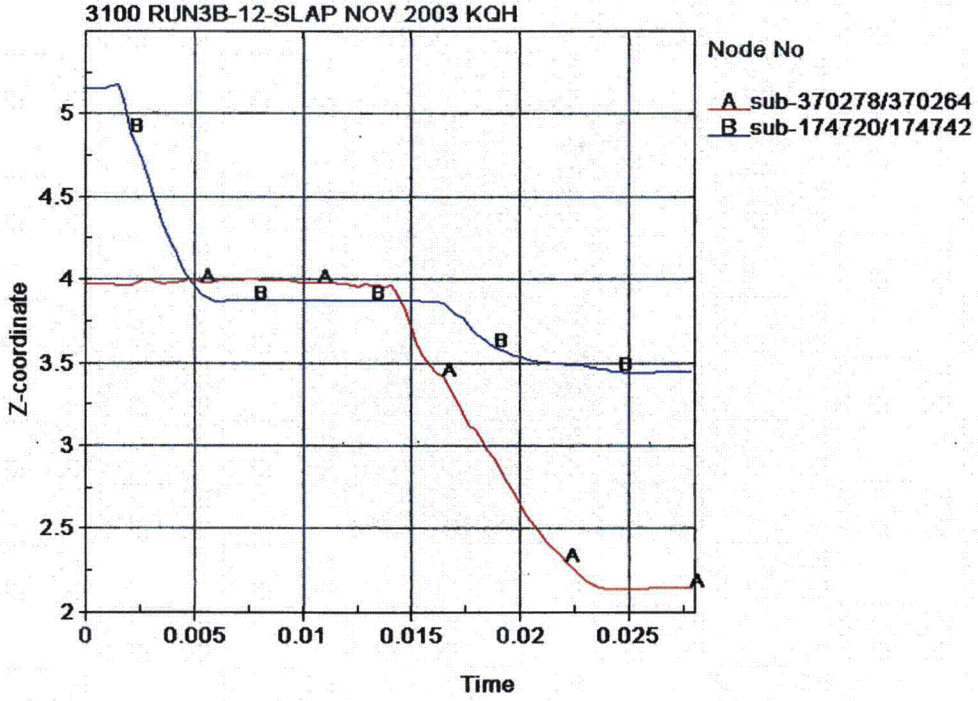

Figure 3.6.8 - Run3b, Kaolite Thickness Time History

3.7 Run4g - Slapdown

Run4g is a 12° slapdown, 30-foot impact (time 0 to 0.02 seconds) followed by a crush with the crush plate CG over the CV flange (0.02 to 0.04 seconds). A drum stud is located on the line of impact (0°) in this model.

The deflected shape of the package after the 30-foot impact is shown in Figure 3.7.1. The maximum effective plastic strain in the CV body for the 30-foot impact is 0.0445 in/in as shown in Figure 3.7.2 and occurs near the bottom head. The maximum effective plastic strain in other components for the 30-foot impact are listed in Table 3.7.1.

Table 3.7.1 - Run4g, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Lid	0.0003
CV Nut Ring	0.0000
Angle	0.0881
Drum	0.3017
Drum Bottom Head	0.2877
Liner	0.1234
Lid	0.5537
Lid Stiffener	0.0232
Lid Studs	0.1737
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0597
Plug Liner	0.1290

Figure 3.7.3 shows the final configuration for the crush impact for run4g. The maximum effective plastic strain in the CV body is 0.0457 in/in as shown in Figure 3.7.4. The maximum effective plastic strain in the drum lid is 1.0797 in/in (surface strain) as shown in Figure 3.7.5. The maximum occurs near the stud at 90°, or initially along the Y axis. This high strain is caused by lid/stud reacting the ovalization response of the package due to the crush plate impact. The fringe range has been set such that the strain levels above 0.57 in/in are colored in red in Figure 3.7.5. The maximum membrane strain in the lid at

the same location (as the surface strain) is 0.8920 in/in. The region of elevated strain is localized to the hole at 90°, therefore any tearing of the lid would be localized. The large washers would restrain the lid.

Figure 3.7.6 shows the effective plastic strain in the drum studs. At the time shown 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 reached the prescribed failure strain of 0.57 in/in and were deleted by LS-Dyna during the impact. Only one stud, the one at 90°, was shown to reach elevated strain levels and be severed for the crush impact. The plastic-kinematic model used for the studs allows a failure value to be used (0.57 in/in). The stud elements reach failure and elements begin to be deleted at about solution time = 0.0312 seconds. By 0.0332 seconds, all the elements on the cross section have been deleted by LS-Dyna.

The lid uses a power law model, which does not allow material failure in the model. Investigation shows that the lid reaches 0.57 in/in at about 0.0272 seconds, a time at which the stud maximum strain is about 0.28 in/in. This demonstrates that the lid reaches failure levels before the stud and at that time, 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 due to lid shear (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 3.7.2 shows the maximum effective plastic strain in the remainder of the package components for the crush impact.

Table 3.7.2 - Run4g, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0457
CV Lid	0.0005
CV Nut Ring	0.0000
Angle	0.1045
Drum	0.3972
Drum Bottom Head	0.2877
Liner	0.2702
Lid Stiffener	0.0838
Lid Stud Nuts	0.0086
Lid Stud Washers	0.1003
Plug Liner	0.2715

Figure 3.7.7 shows the lid separation time history for the nodal pairs shown in Figure 3.1.30. There are several spikes up to about 0.007 inches evident in the lid separation time history. However, most of the noise level is about 0.004 inches or less and is oscillatory in nature. Therefore, an average of 0.002 inches or less would be expected.

Figure 3.7.8 shows the drum diameter deformation in the X-direction. The nodes are those defined in Figure 3.1.34. Curve A in the figure shows that the final distance in at the lid, between the two flattened regions is about 13.5 inches. Figure 3.7.9 gives the radial deformation time history in the Y-direction.

Figure 3.7.10 gives the kaolite thickness time histories. The nodes are those defined in Figure 3.1.32.

Figure 3.7.11 shows the liner diameter time history at various locations along its length. Figure 3.1.37 and Table 3.1.3 show the locations of the nodal pairs along the liner.

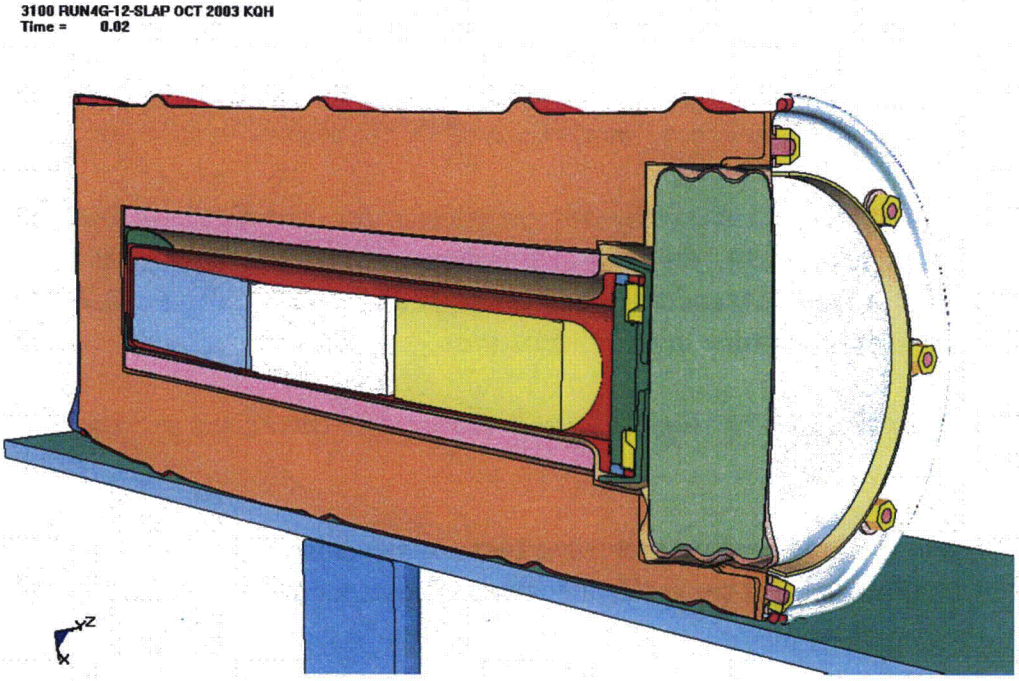

Figure 3.7.1 - Run4g, Slapdown Impact, Final Configuration

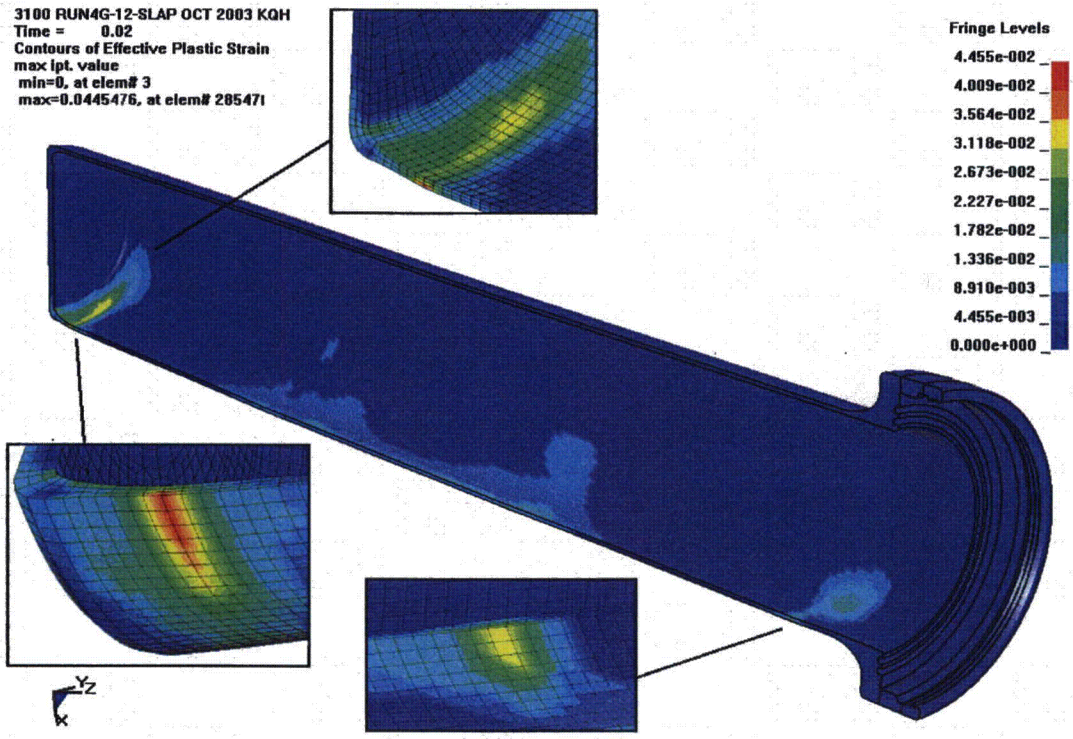

Figure 3.7.2 - Run4g, Slapdown Impact, Effective Plastic Strain in the CV Body

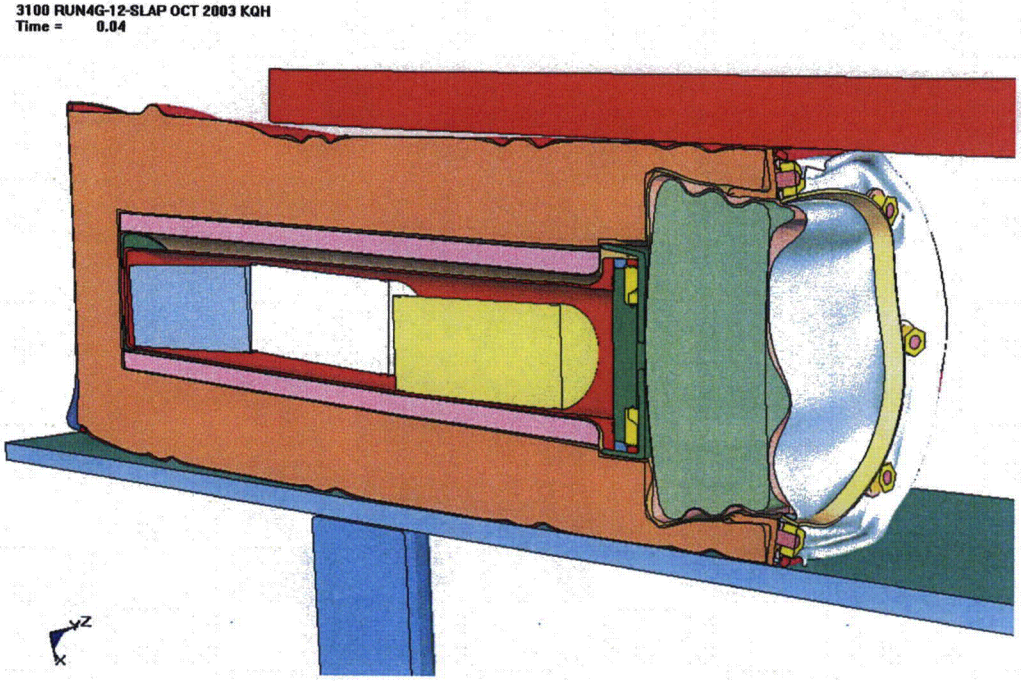

Figure 3.7.3 - Run4g, Crush Impact, Final Configuration

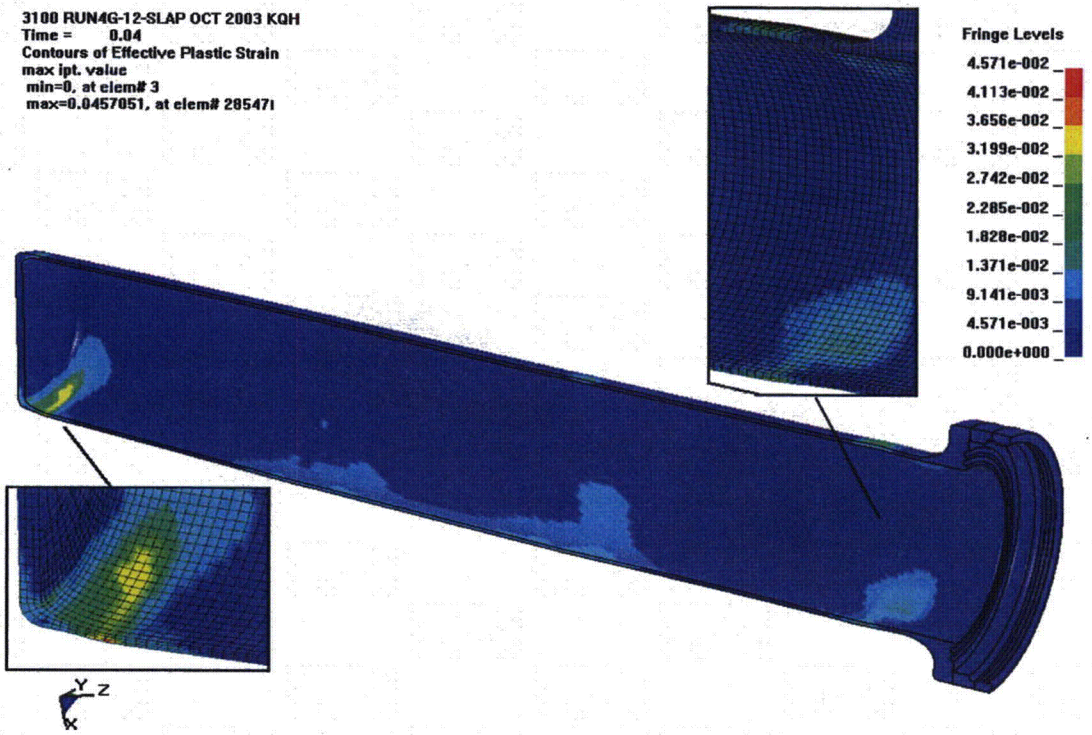

Figure 3.7.4 - Run4g, Crush Impact, Effective Plastic Strain in the CV Body

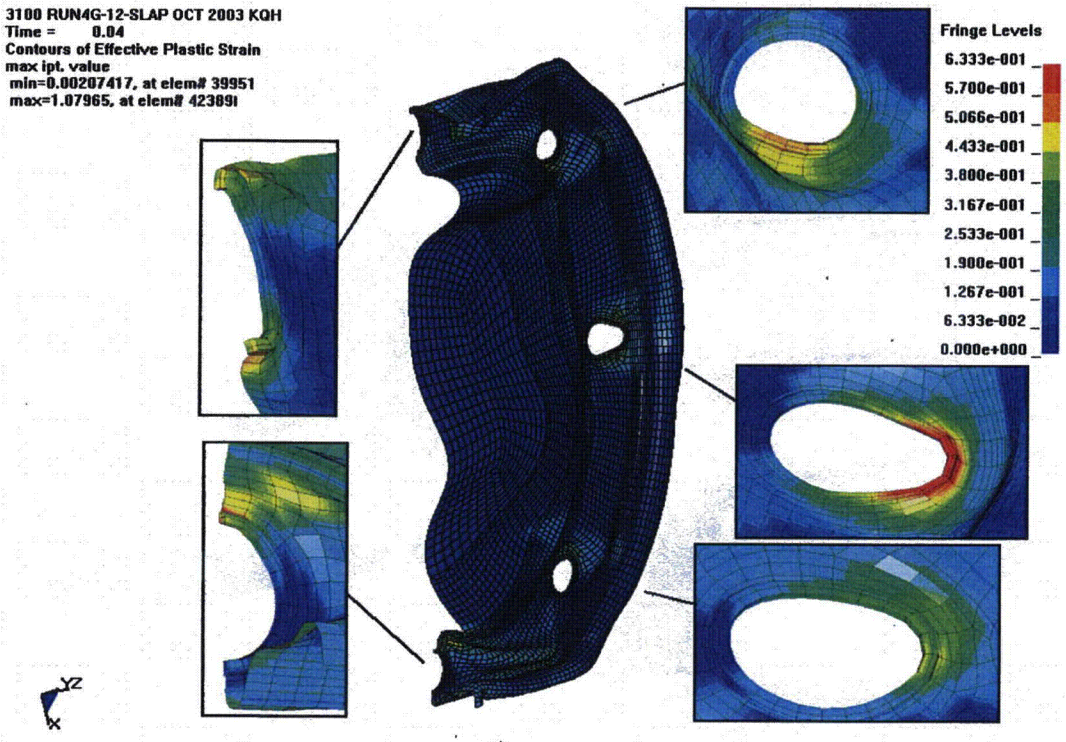

Figure 3.7.5 - Run4g, Crush Impact, Effective Plastic Strain in the Lid

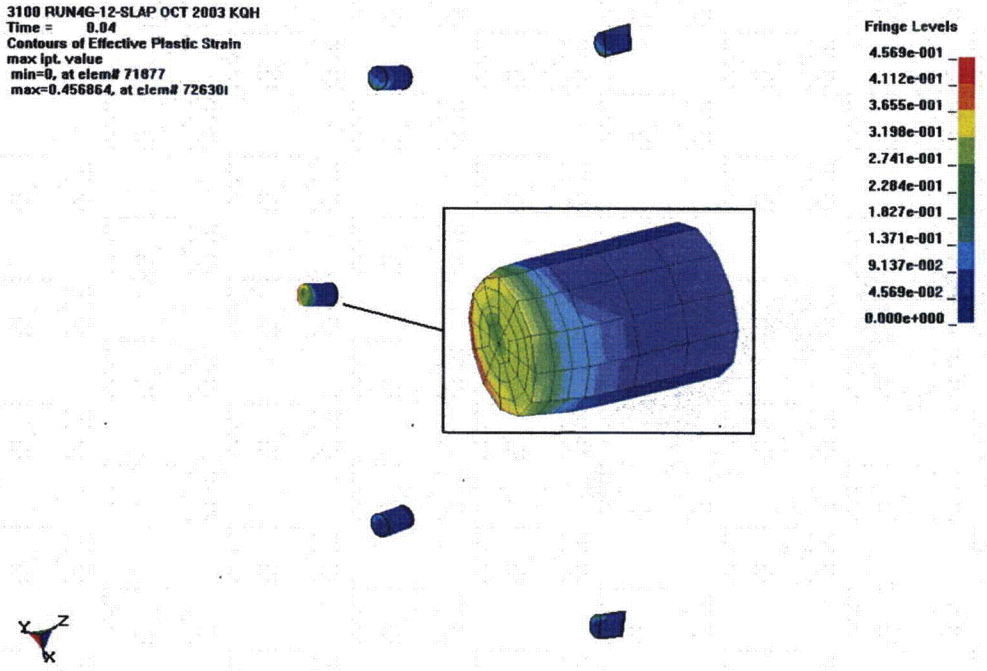

Figure 3.7.6 - Run4g, Crush Impact, Effective Plastic Strain in the Drum Studs

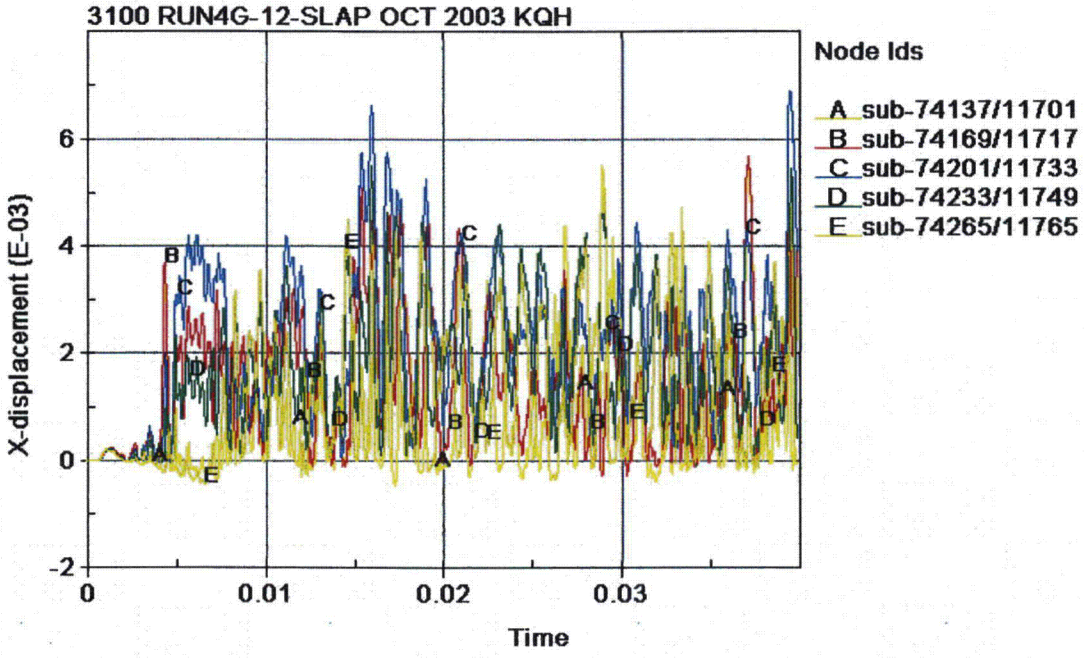

Figure 3.7.7 - Run4g, Lid Separation Time History

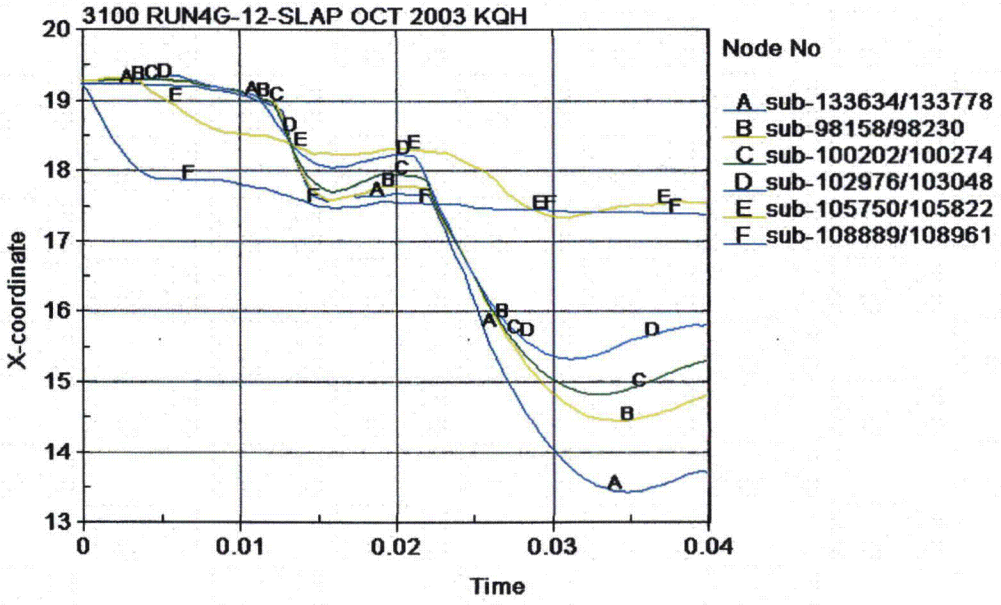

Figure 3.7.8 - Run4g, Drum Deformation in the Direction of the Impacts

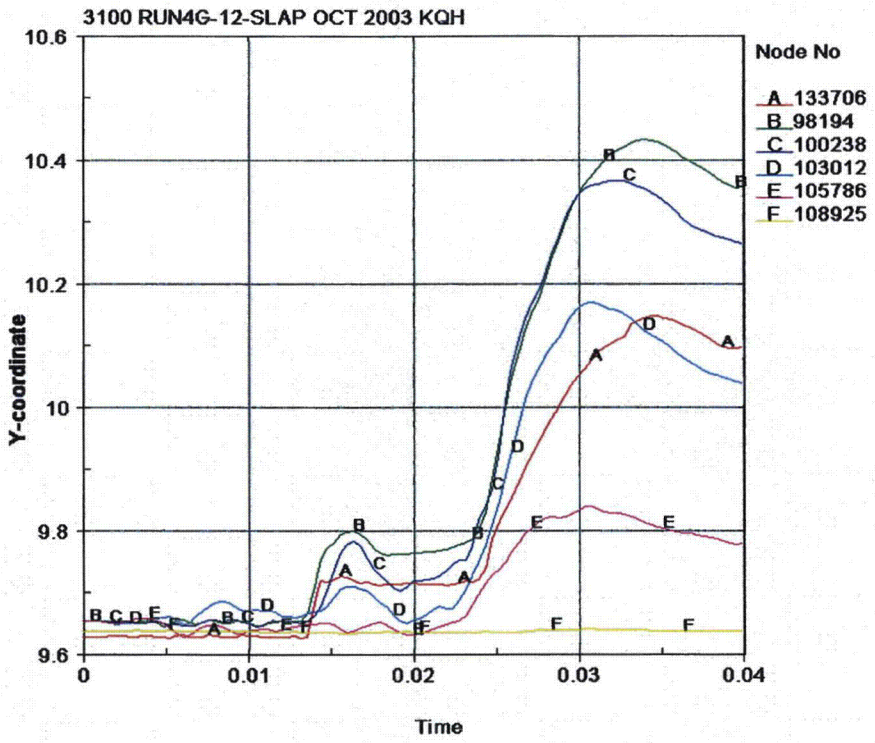

Figure 3.7.9 - Run4g, Drum Deformation Normal to the Impacts

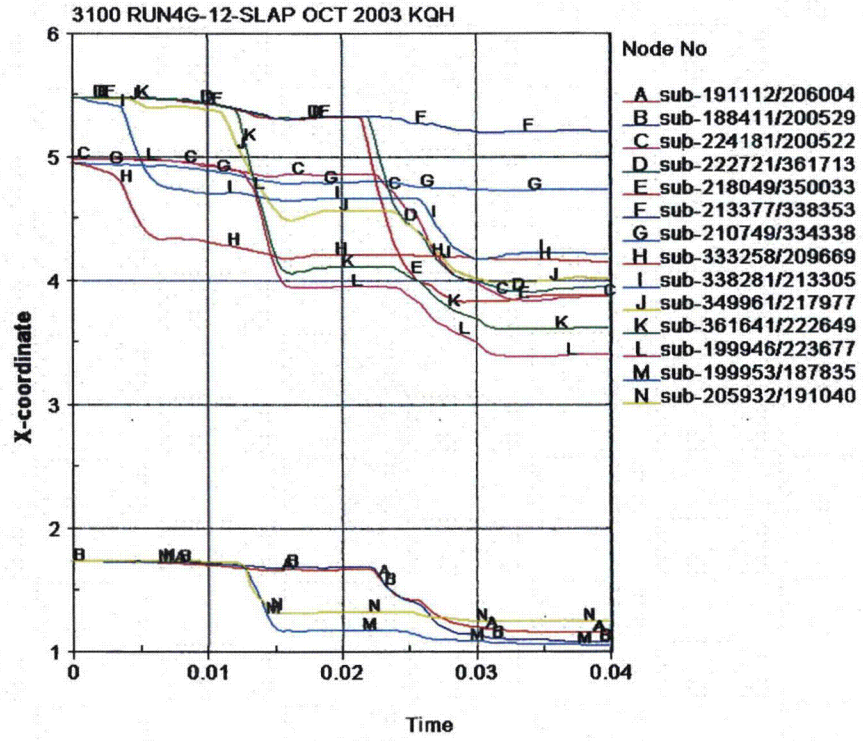

Figure 3.7.10 - Run4g, Kaolite Thickness Time Histories for the Impacts

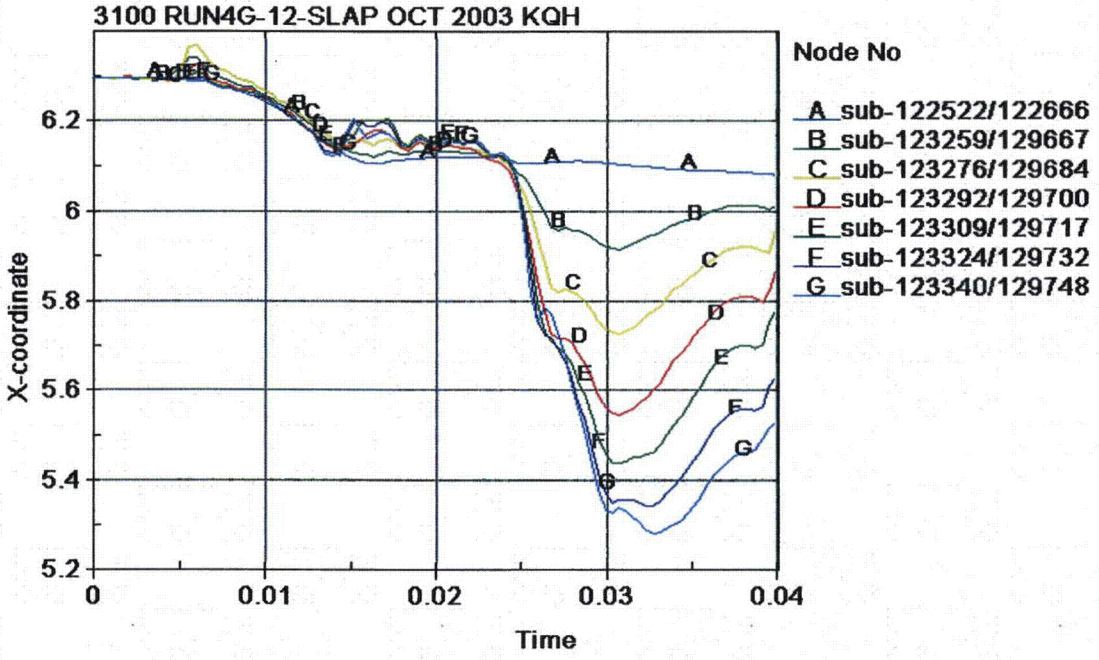

Figure 3.7.11 - Run4g, Liner Diameter Time History

3.8 Run4ga - Slapdown

Run4ga is a 30-foot, 12° slapdown impact (time - 0 to 0.02 seconds) followed by a crush impact with the crush plate centered on the drum (0.0201 to 0.04 seconds). The run4g 30-foot impact restart file was taken and the crush plate was moved by specifying nodal velocities so that it was centered on the drum. The translation occurred from time 0.02 to 0.0201 sec. Once the crush plate was centered, the run was halted and the crush impact was initiated. Therefore, the run4ga 30-foot impact is the run4g 30-foot impact. The 30-foot impact results for run1ga are presented in section 3.7 for run4g. The run4ga crush results are presented in this section.

The final configuration for the run4ga crush impact is shown in Figure 3.8.1. The maximum effective plastic strain in the CV body is 0.0741 in/in in the upper wall near the bottom head as shown in Figure 3.8.2.

The maximum effective plastic strain in the drum lid is 1.0795 in/in as shown in Figure 3.8.3. The regions of elevated strain are quite localized at the upper and lower stud holes in the lid. The value of 1.0795 in/in is a surface strain. The value of membrane strain is 0.6005 in/in. Due to the relatively localized regions of high effective plastic strain, some localized tearing may occur. Extended tearing or failure of the lid is not predicted due to the localized elevated fringe ranges of effective plastic strain. The large washers would provide restraint of the lid. Table 3.8.1 presents the maximum effective plastic strain in other shipping package components for the run4ga crush impact.

Table 3.8.1 - Run4ga, Crush Impact, Effective Plastic Strain Levels in Some Components	
Component	Effective Plastic Strain, in/in
CV Lid	0.0006
CV Nut Ring	0.0003
Angle	0.0917
Drum	0.3537
Drum Bottom Head	0.2919
Liner	0.2363
Lid Stiffener	0.0303
Lid Studs	0.3174
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0597
Plug Liner	0.1636

The CV lid separation time history is shown in Figure 3.8.4. A maximum spike of about 0.009 inches is shown for the nodal pairs shown in Figure 3.1.30. The average value at the end of the impact is about 0.002 inches or less.

The time history of the drum diameter in the direction of the impacts is shown in Figure 3.8.5. Figure 3.8.6 shows the radial changes in the direction normal to the impacts. The location of the nodes is shown in Figure 3.1.34.

Figure 3.8.7 shows the kaolite thickness time histories for the run4ga crush impact. The nodes are shown in Figure 3.1.32.

Figure 3.8.8 shows the diameter time history at various locations along the liner. Figure 3.1.37 and Table 3.1.3 show the locations of the nodal pairs.

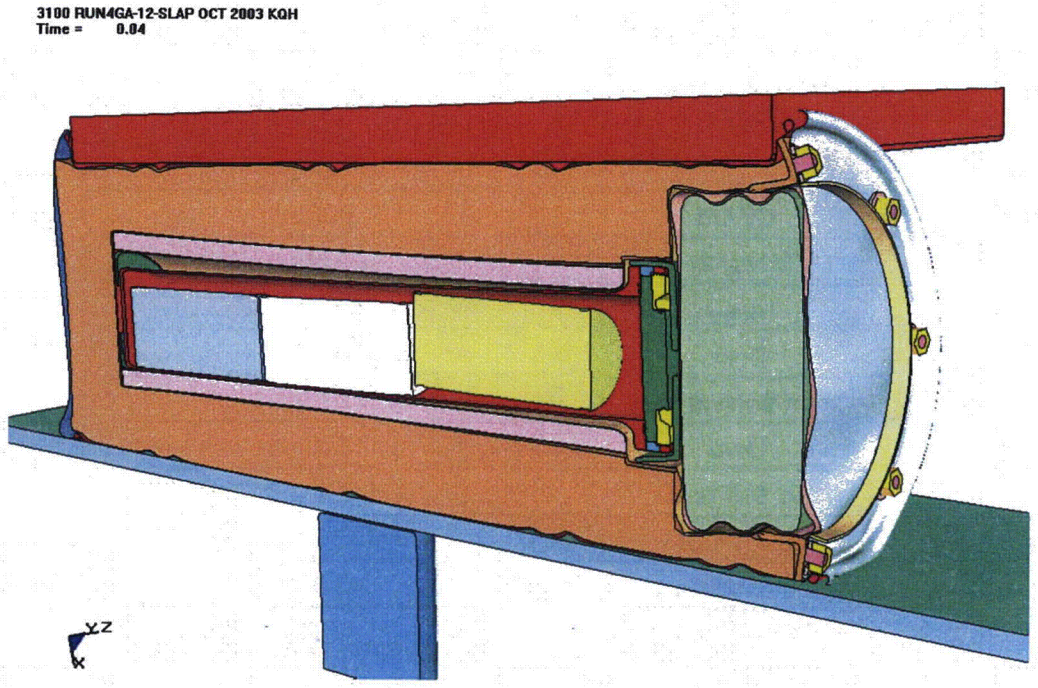

Figure 3.8.1 - Run4ga, Crush Impact, Final Configuration

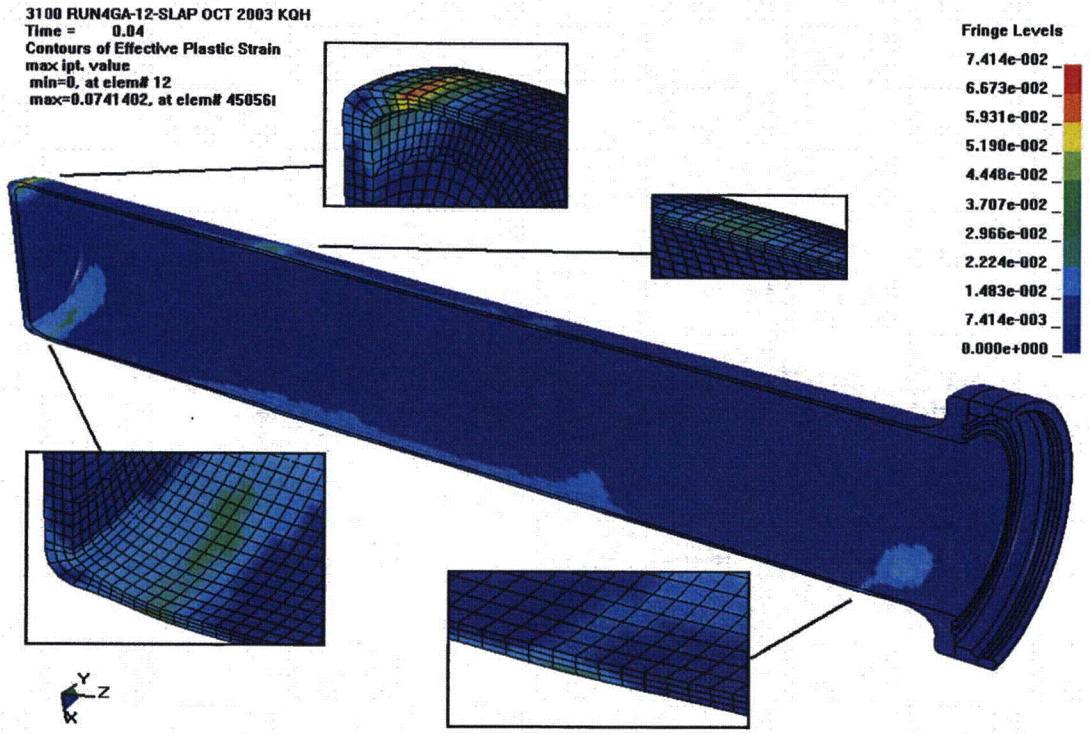

Figure 3.8.2 - Run4ga, Crush Impact, Effective Plastic Strain in the CV Body

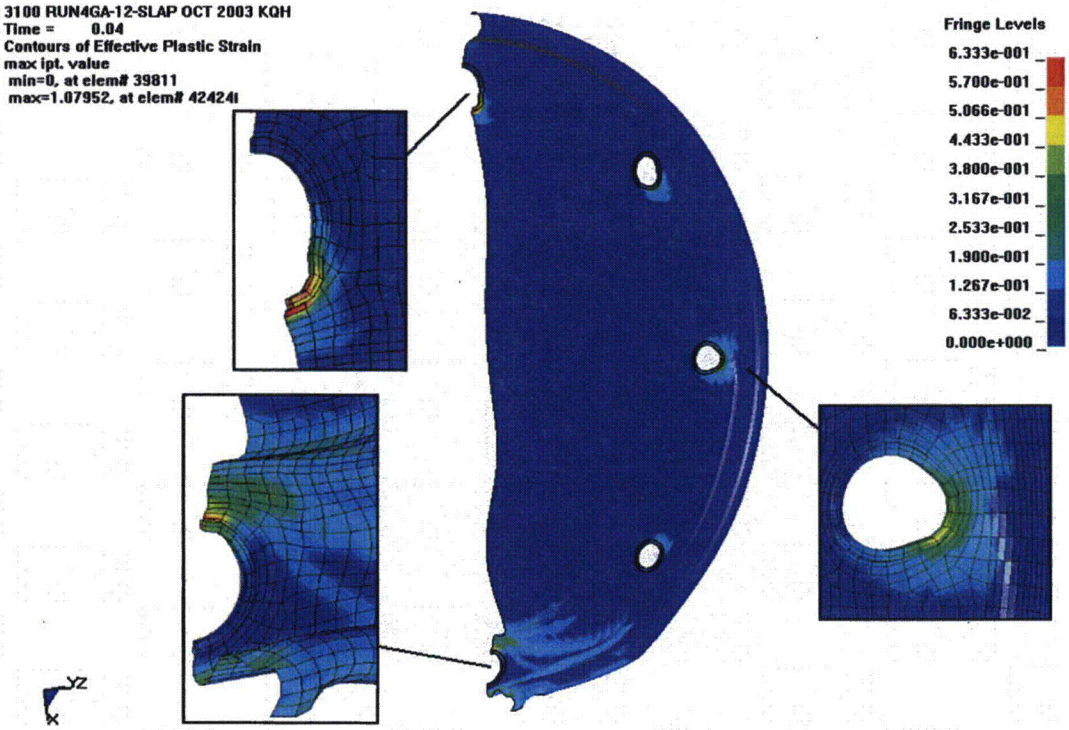

Figure 3.8.3 - Run4ga, Crush Impact, Effective Plastic Strain in the Lid

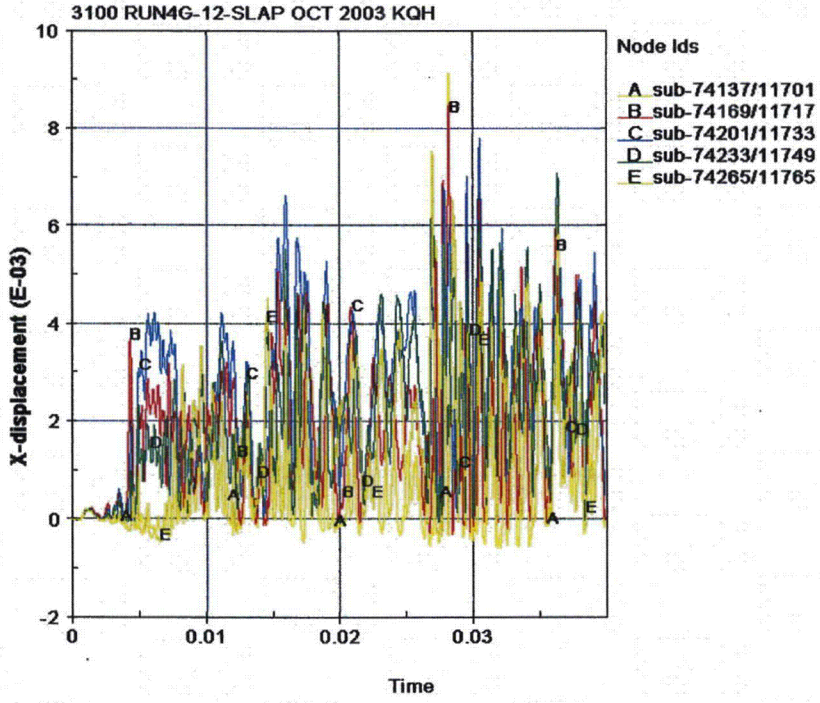

Figure 3.8.4 - Run4ga, Crush Impact, Lid Separation Time History

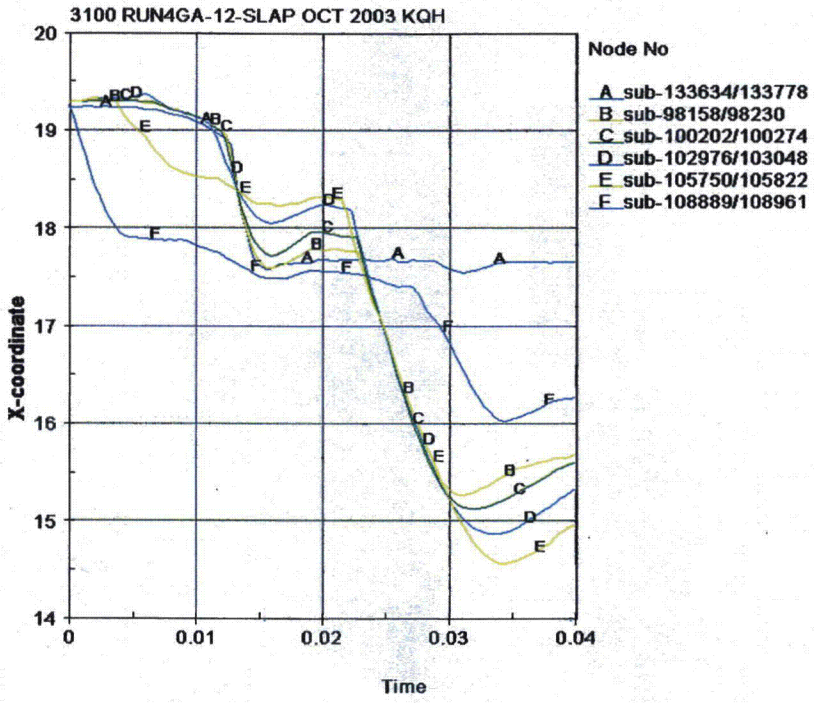

Figure 3.8.5 - Run4ga, Drum Deformation in the Direction of the Impacts

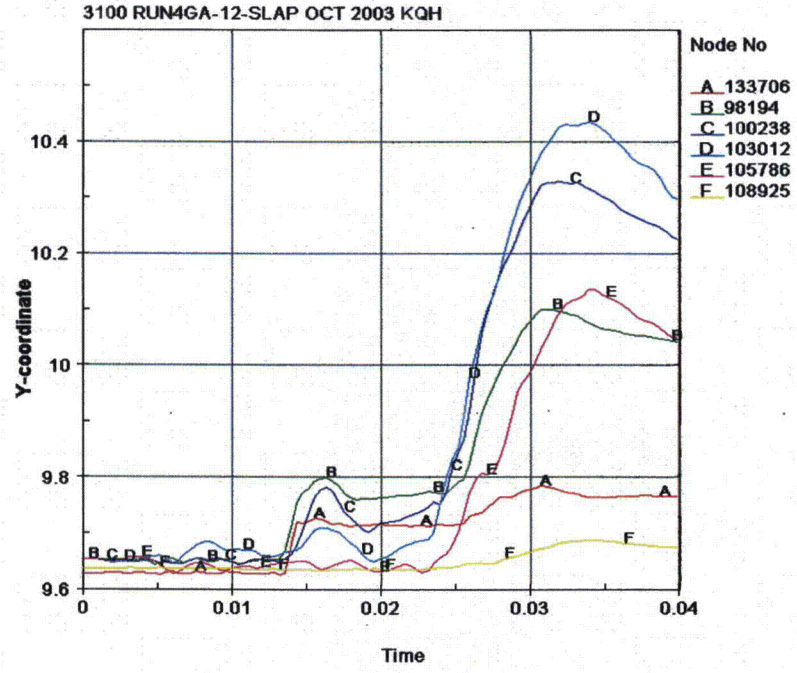

Figure 3.8.6 - Run4ga, Drum Deformation Time History in the Y-Direction

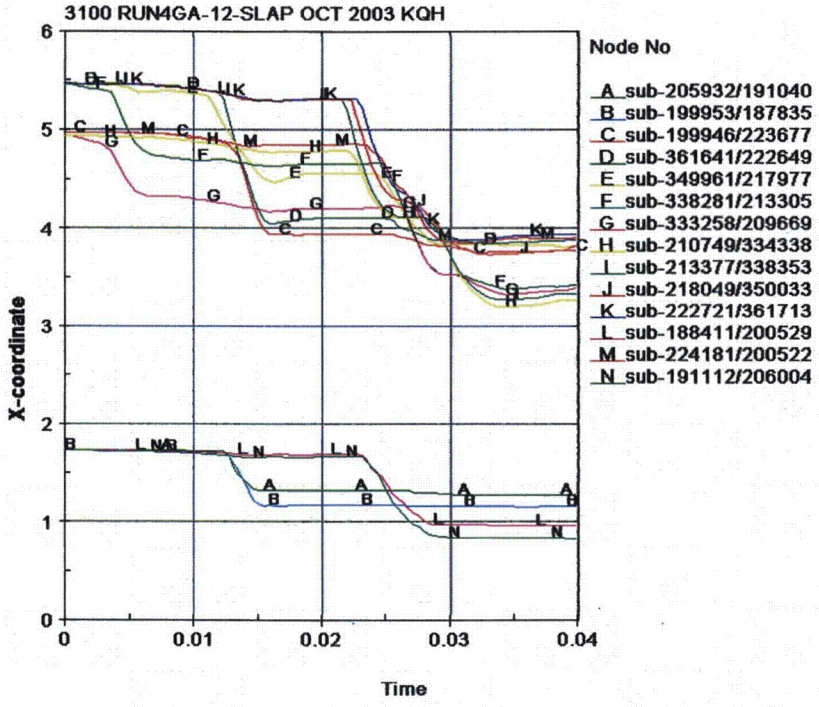

Figure 3.8.7 - Run4ga, Thickness in the Drum Kaolite in the Direction of the Impacts

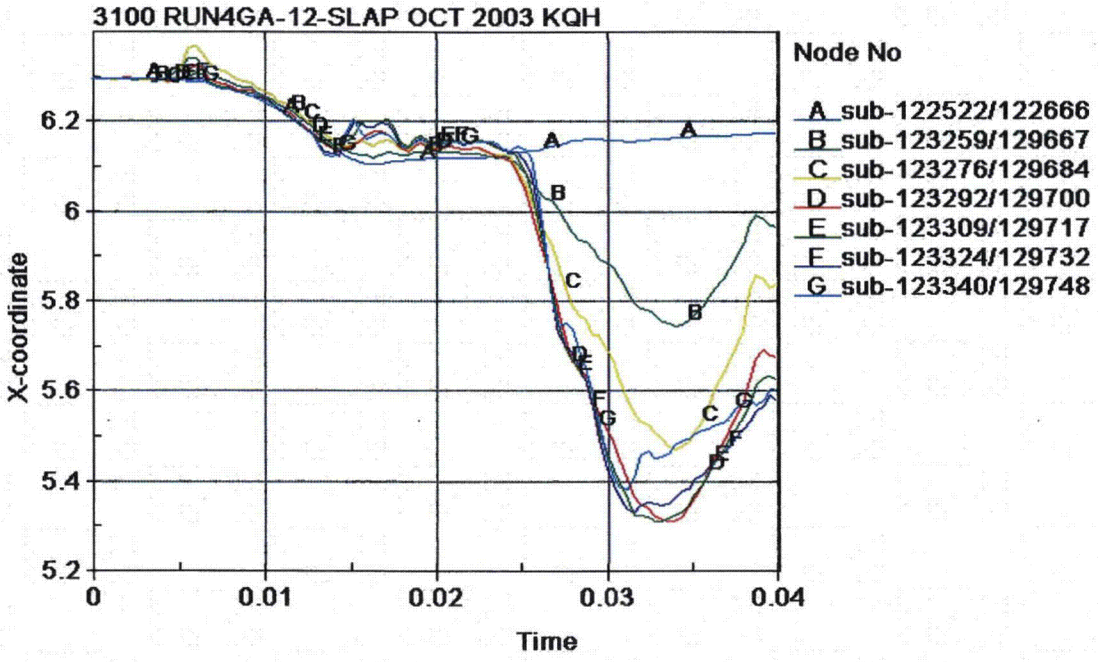

Figure 3.8.8 - Run1ga, Liner Diameter Time History

3.9 Run4h - Slapdown

Due to the minimal number of studs securing the lid, a model with the impact centered between the studs is made. Run4h is similar to run4g, except that the drum studs are rotated, such that the plane of symmetry is centered between two studs. Run4h is a 30-foot, 12° slapdown impact (time = 0 to 0.02 seconds) followed by a crush impact with the crush plate centered over the CV flange (0.02 to 0.04 seconds).

Figure 3.9.1 shows the final configuration for the 30-foot impact. Figure 3.9.2 shows the configuration in the lid region near the rigid plate. The effective plastic strain contours in the package components for the 30-foot impact are similar to strain patterns already presented. Therefore, no strain contour plots are presented for the 30-foot impact and the maximum strains are listed in Table 3.9.1.

Table 3.9.1 - Run4h, 30-Foot Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0450
CV Lid	0.0000
CV Nut Ring	0.0000
Angle	0.0861
Drum	0.3017
Drum Bottom Head	0.2877
Liner	0.1181
Lid	0.3831
Lid Stiffener	0.0184
Lid Studs	0.0891
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0782
Plug Liner	0.1592

The final configuration for the run4h crush is shown in Figure 3.9.3. Figure 3.9.4 shows the lid configuration for the crush impact. The maximum effective plastic strain in the drum lid is 0.9830 in/in, which is a surface strain. The maximum membrane strain is 0.7225 in/in and is localized around the stud holes in the lid at the 67.5° and the 112.5° positions. The regions of high strain are localized at all the stud holes in the lid,

therefore extended tearing is not predicted. Some localized tearing of the lid may be experienced, but the lid will be retained by the large washers.

The maximum effective plastic strain in the studs is 0.5364 in/in and occurs at the outer radius of the stud. The nominal effective plastic strain through the stud shank is about 0.300 in/in. Therefore, the studs would not be expected to fail. The maximum effective plastic strain in other components are listed in Table 3.9.2.

Table 3.9.2 - Run4h, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0461
CV Lid	0.0004
CV Nut Ring	0.0000
Angle	0.1071
Drum	0.3881
Drum Bottom Head	0.2877
Liner	0.2475
Lid Stiffener	0.1083
Lid Stud Nuts	0.0052
Lid Stud Washers	0.0885
Plug Liner	0.2719

The lid separation time history is similar to those presented in Sections 3.7 and 3.8. A maximum lid separation spike of approximately 0.007 inches is reached during the impacts and is oscillatory in nature. An average value of 0.003 inches or less is shown at the end of the crush impact.

Figure 3.9.7 shows the X-diameter time history for drum nodes shown in Figure 3.1.34. Figure 3.9.8 shows the radial time history for nodes normal to the direction of impact.

Due to the rotation of the studs on the lid, the nodes for the kaolite changed for the run4h model. The nodes used to obtain the kaolite thickness time histories for run4h are shown in Figure 3.9.9. The time histories for the kaolite thickness on the plane of symmetry is shown in Figure 3.9.10. Figure 3.9.11 shows the liner diameter time history at location shown in Figure 3.1.37 and Table 3.1.3.

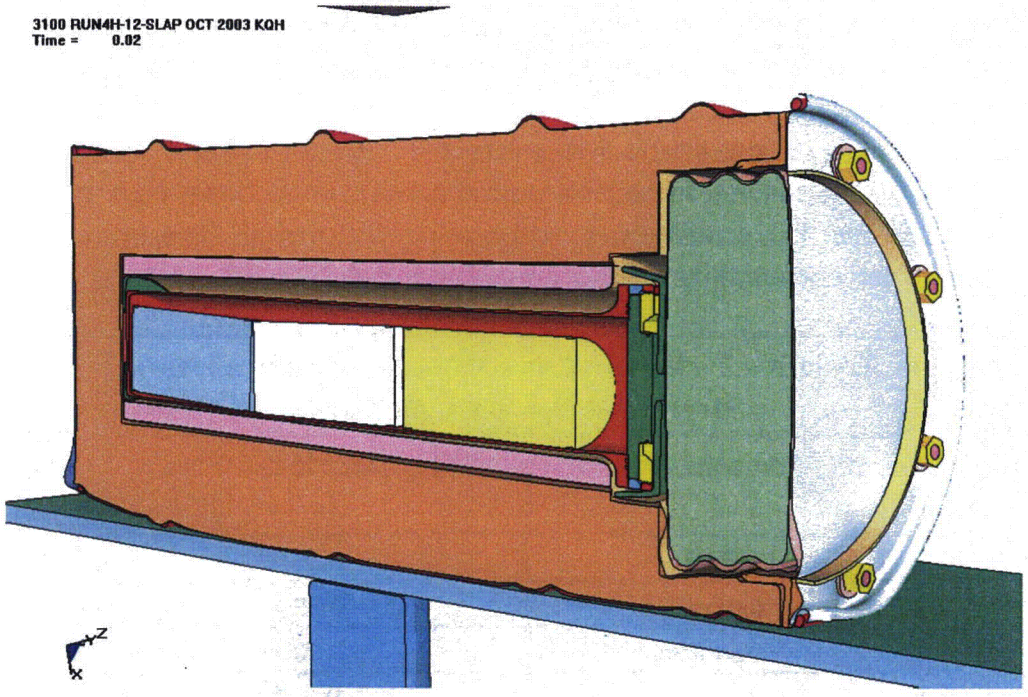

Figure 3.9.1 - Run4h, 30-Foot Impact, Final Configuration

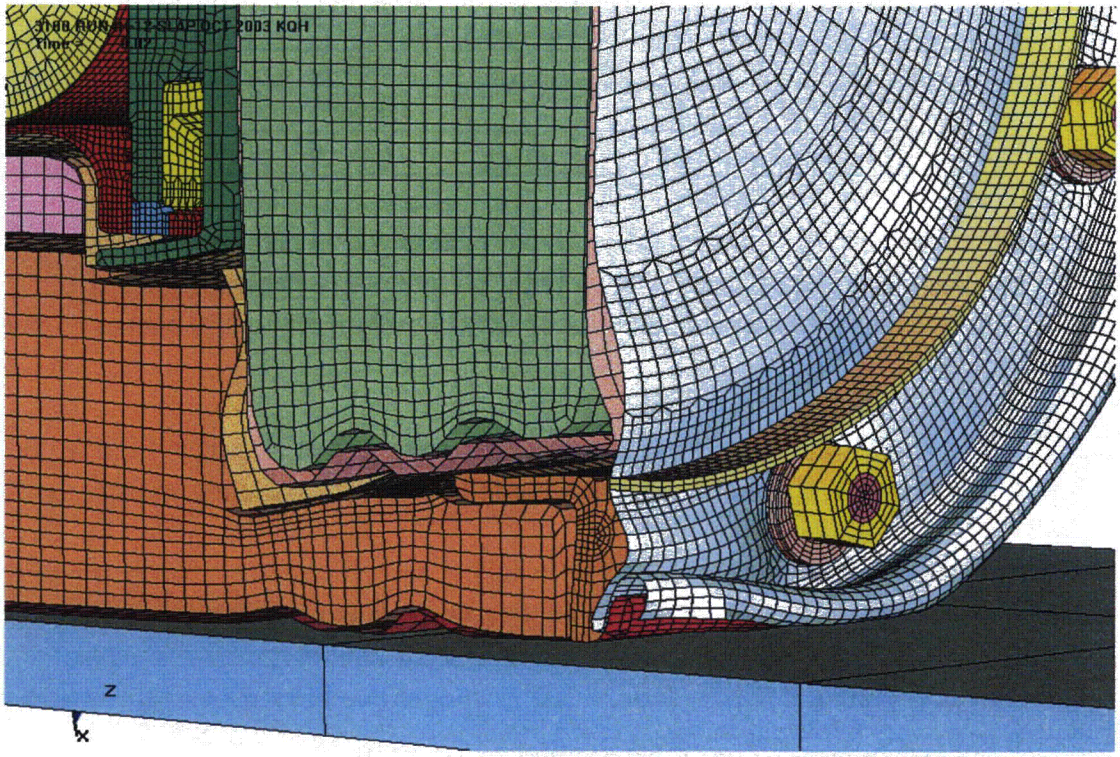

Figure 3.9.2 - Run4h, 30-Foot Impact, Configuration in the Lid

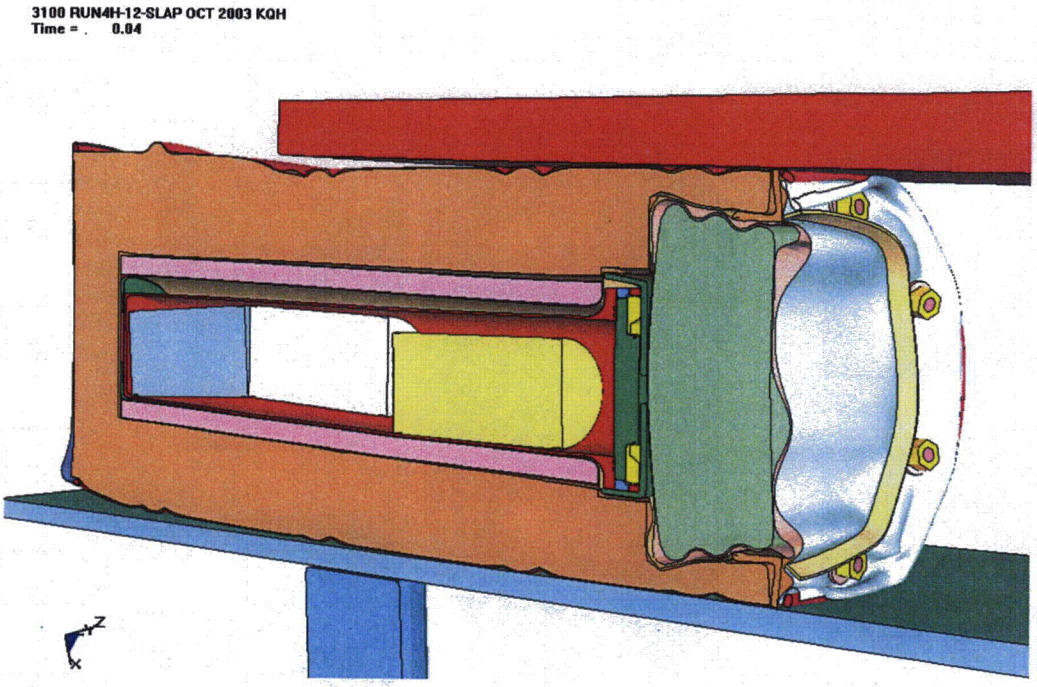

Figure 3.9.3 - Run4h, Crush Impact, Final Configuration

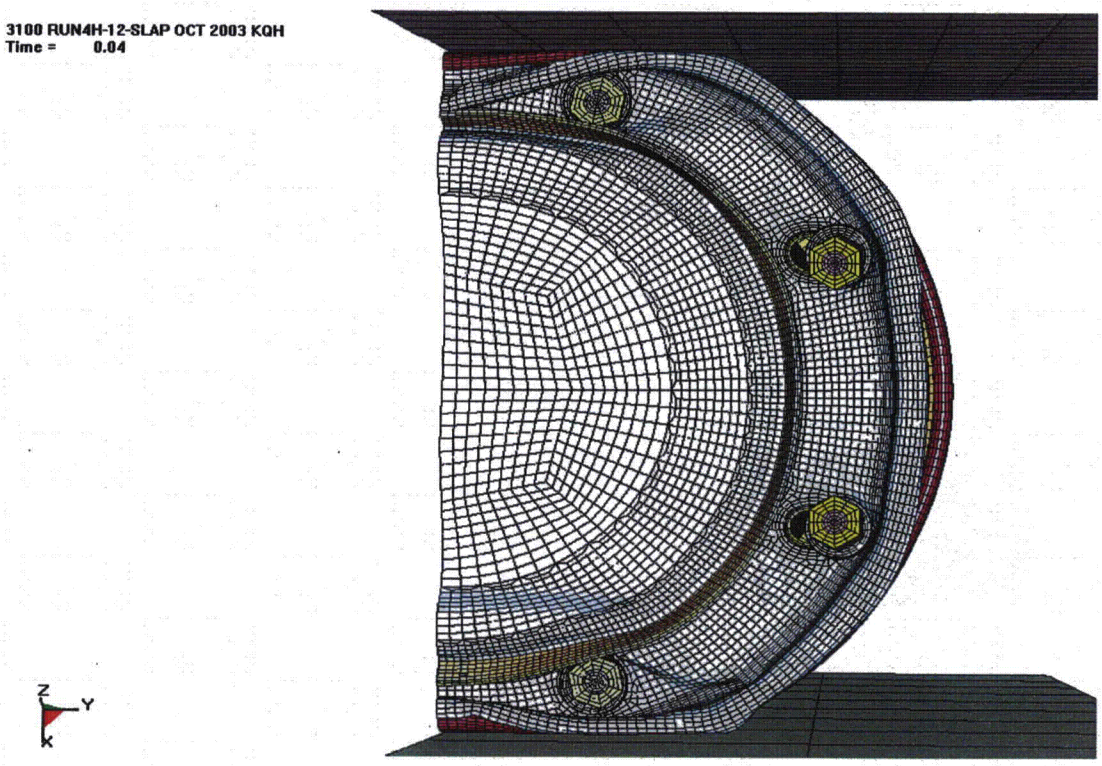

Figure 3.9.4 - Run4h, Crush Impact, Configuration of the Lid

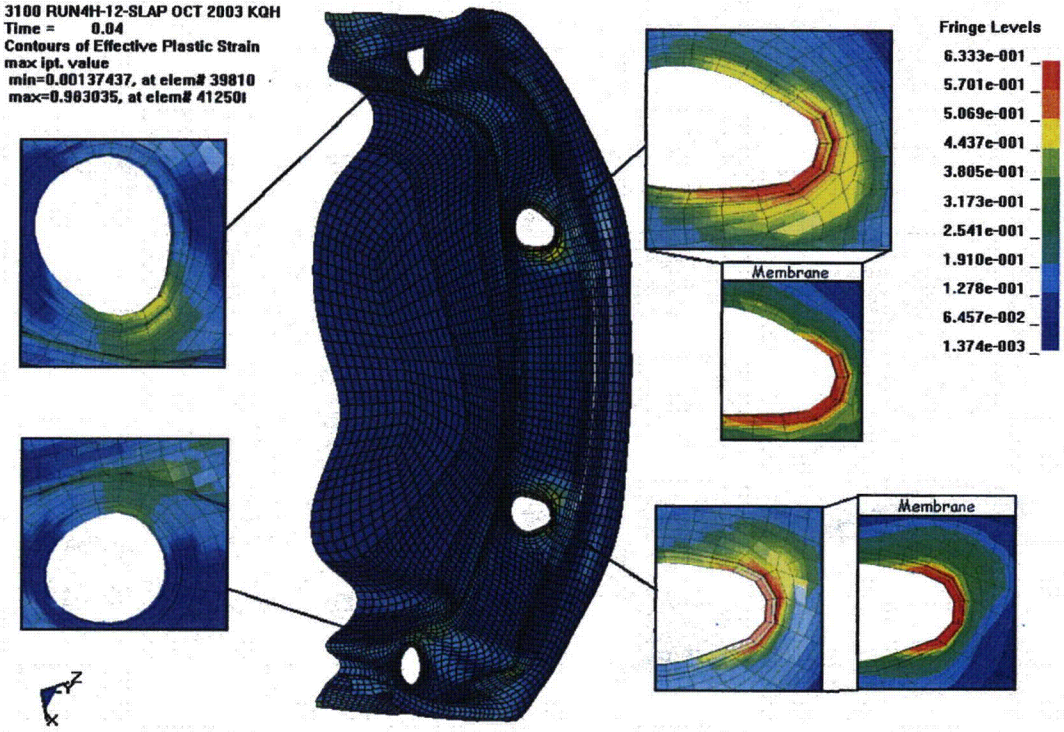

Figure 3.9.5 - Run4h, Crush Impact, Effective Plastic Strain in the Lid

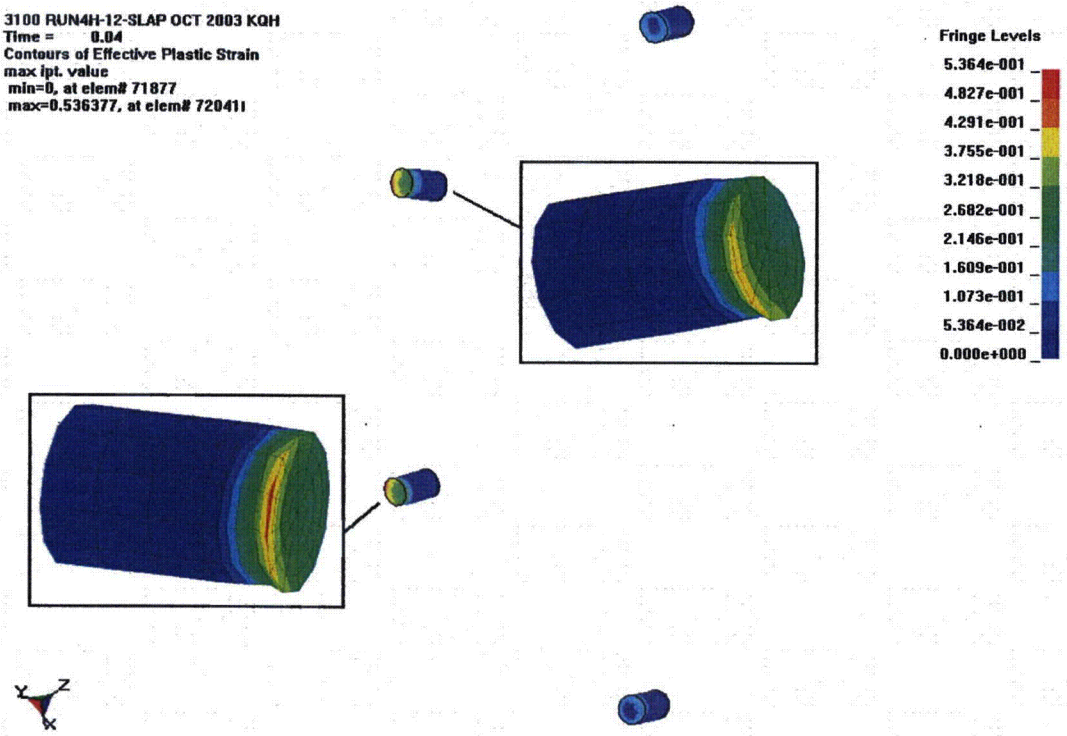

Figure 3.9.6 - Run4h, Crush Impact, Effective Plastic Strain in the Studs

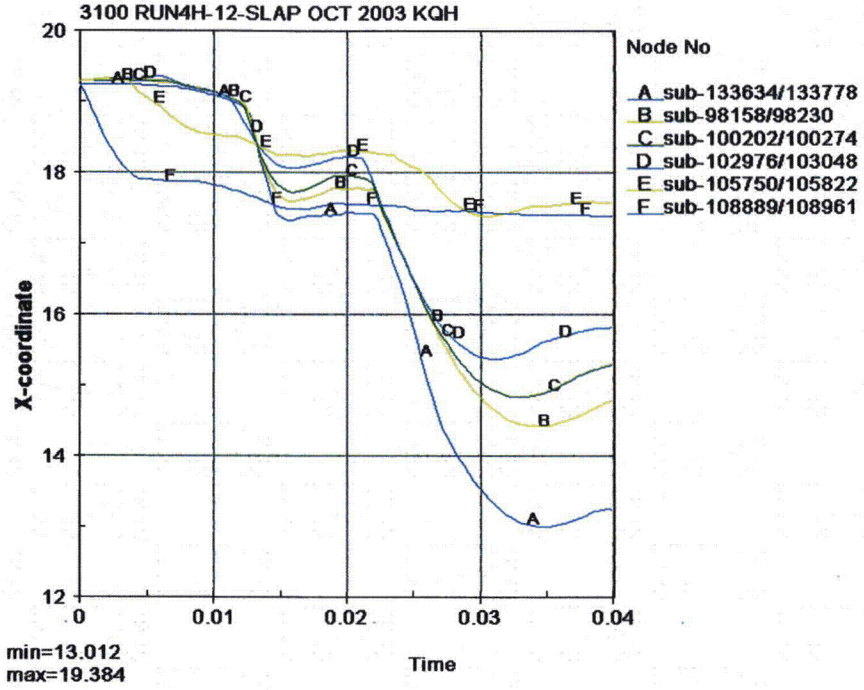

Figure 3.9.7 - Run4h, Drum Diameter in the Direction of the Impacts

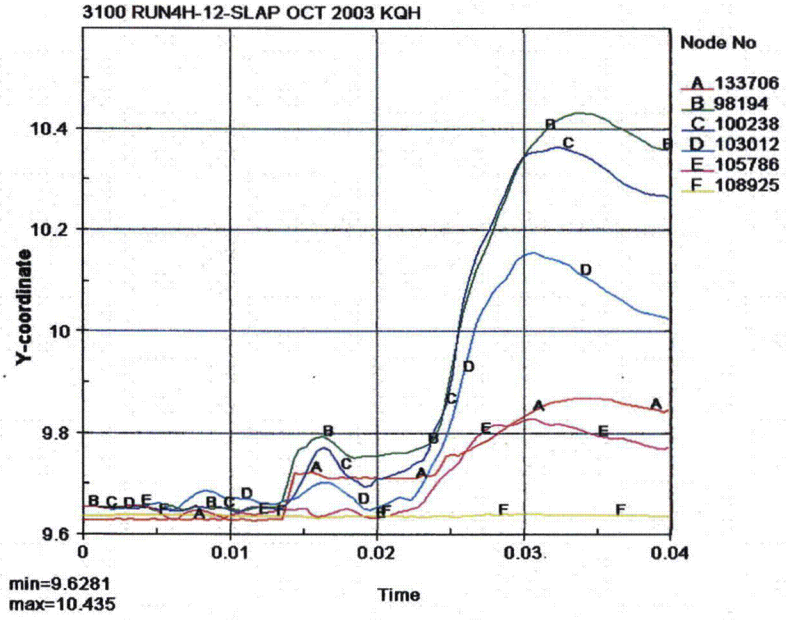

Figure 3.9.8 - Run4h, Drum Radius Normal to the Direction of the Impacts

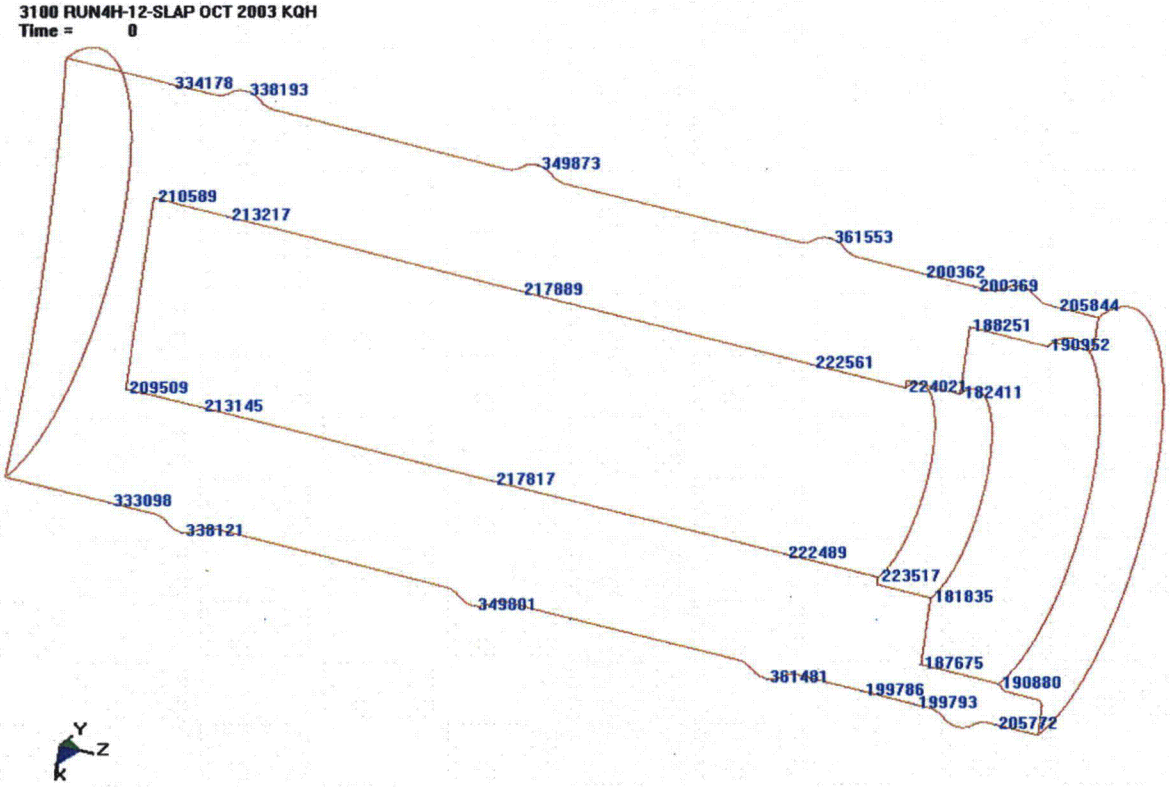

Figure 3.9.9 - Run4h, Drum Kaolite Nodes

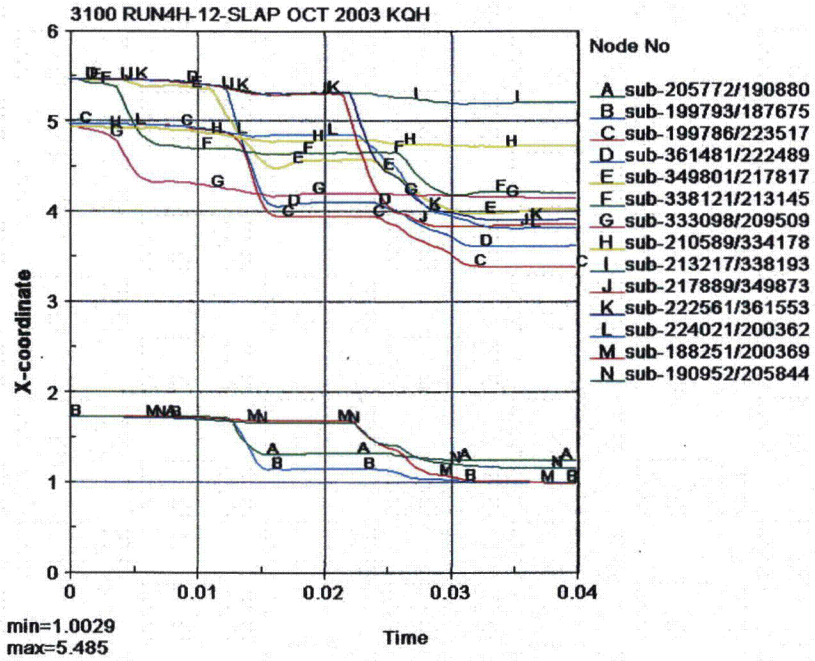

Figure 3.9.10 - Run4h, Thickness of the Drum Kaolite in the Direction of the Impacts

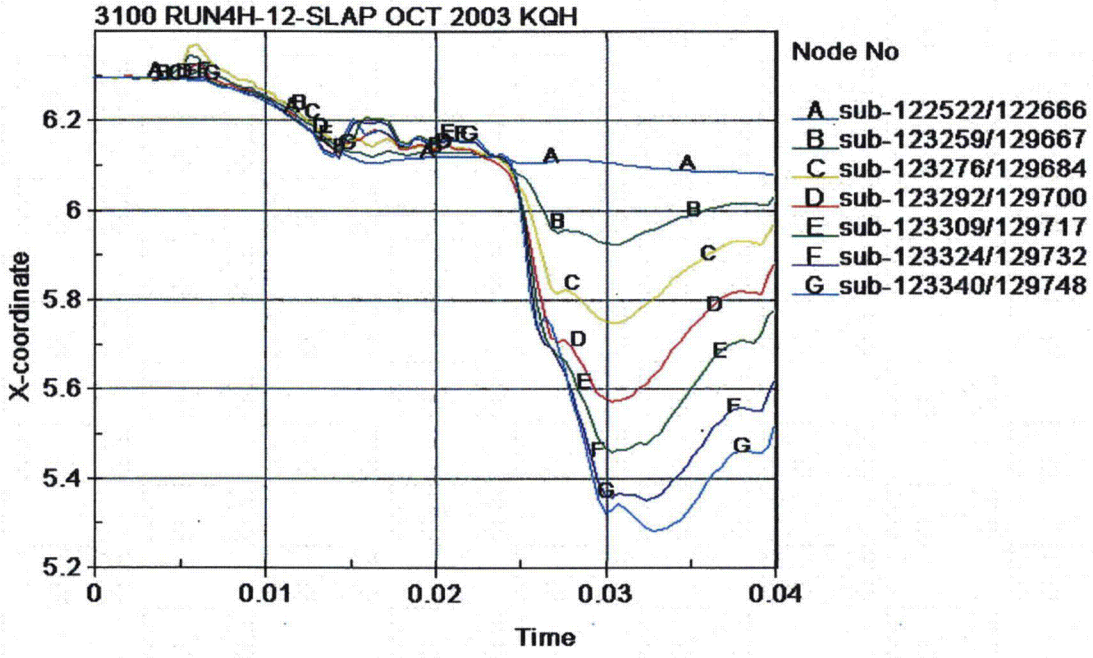

Figure 3.9.11 - Run4h, Liner Diameter Time History

3.10 Run4ha - Slapdown

Run4ha is similar to run4h except that the crush impact is with the crush plate centered on the drum. For run4ha, the restart file at the end of the run4h, 30-foot impact is used to initiate a run which moves of the crush plate such that it is centered on the drum (crush impact from 0.0201 to 0.04 seconds). The translation of the crush plate occurs at the end of the 30-foot impact, or time = 0.02 sec and lasts till 0.0201 sec. The restart file written at the end of the translation of the crush plate, becomes the restart file used to initiate the run4ha crush impact. Therefore, the 30-foot impact results from run4ha are presented in the run4h results. The results presented in this section are those of the centered crush impact for run4ha.

The final configuration for the crush impact is shown in Figure 3.10.1. The maximum effective plastic strain in the drum lid is 0.6335 in/in as shown in Figure 3.10.2. The maximum membrane strain is 0.5249 in/in and is highly localized at the stud hole nearest the crush plate (157.5°). If failure were to occur in the lid, it would be localized and the large washers would restrain the lid. The effective plastic strain in other components is shown in Table 3.10.1.

Table 3.10.1 - Run4ha, Crush Impact, Effective Plastic Strain Levels in Some Components

Component	Effective Plastic Strain, in/in
CV Body	0.0839
CV Lid	0.0013
CV Nut Ring	0.0000
Angle	0.0881
Drum	0.3848
Drum Bottom Head	0.2922
Liner	0.2633
Lid Stiffener	0.0338
Lid Studs	0.1705
Lid Stud Nuts	0.0000
Lid Stud Washers	0.0782
Plug Liner	0.1832

The lid separation time history is similar to that shown in Section 3.8. A maximum spike of 0.009 inches is shown to occur for the CV lid separation. The average separation at the end of the crush impact is 0.002 inches or less due to the oscillatory nature of the gap response.

Figure 3.10.3 gives the diameter time history in the X-direction for drum nodes shown in Figure 3.1.34. Figure 3.10.4 shows the radial time history in the Y-direction for the nodes normal to the direction of the impact.

Figure 3.9.9 shows the nodes used to obtain the kaolite thickness time history for the impact. Figure 3.10.5 shows the thickness time history for the kaolite.

Figure 3.10.6 show the liner diameter time histories in the liner. Figure 3.1.37 and Table 3.1.3 give the locations of the nodal pairs along the length of the liner.

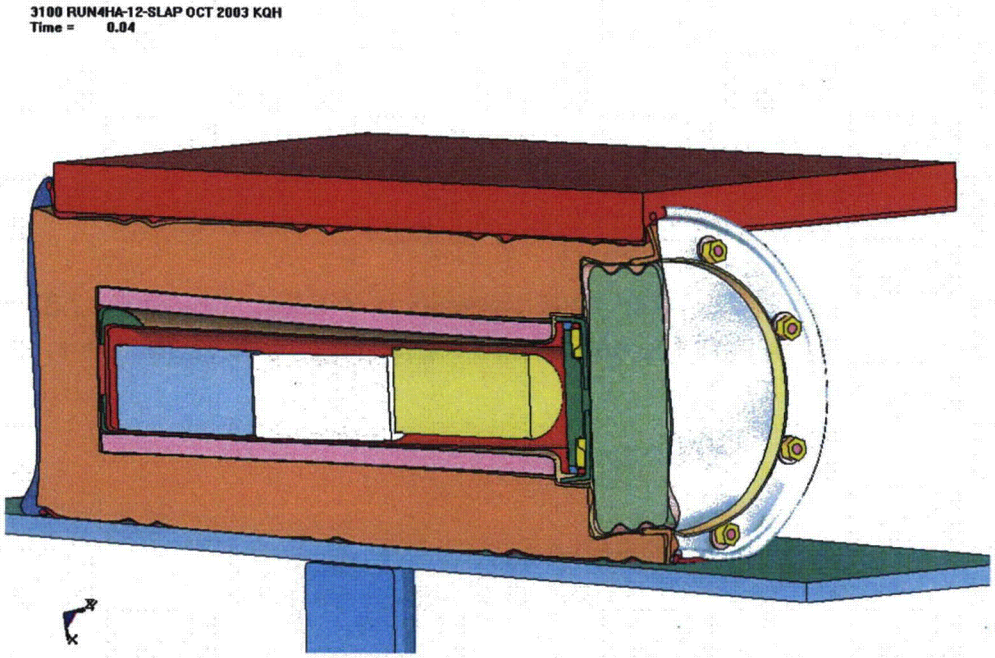

Figure 3.10.1 - Run4ha, Crush Impact, Final Configuration

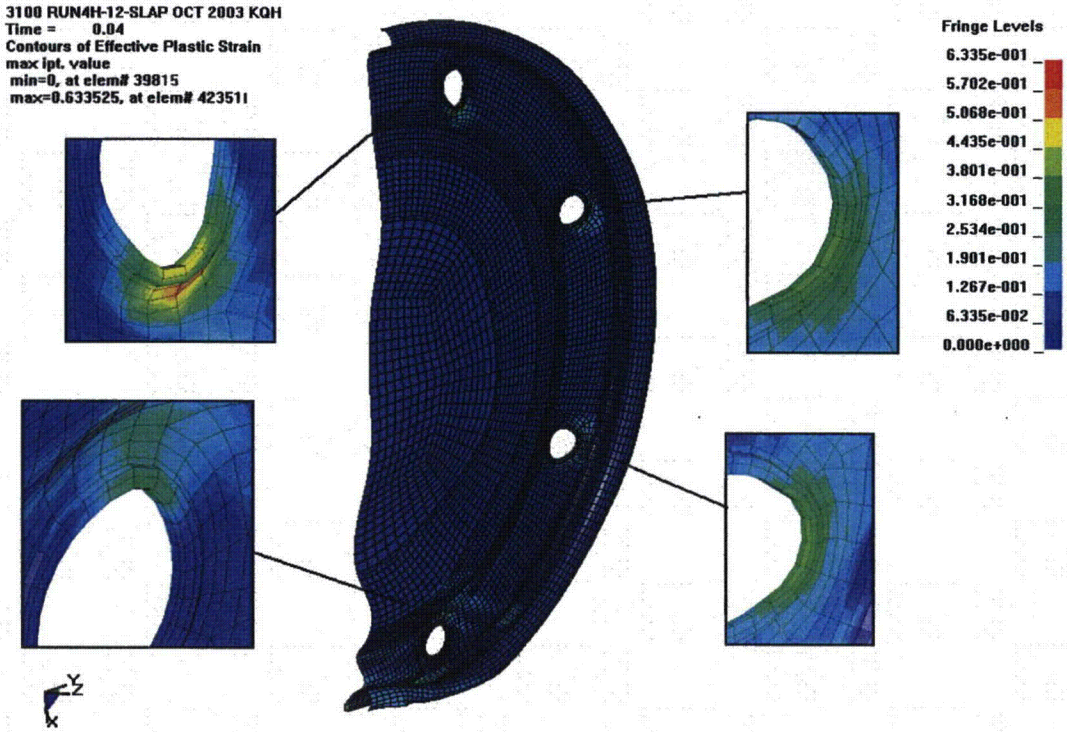

Figure 3.10.2 - Run4ha, Crush Impact, Effective Plastic Strain in the Lid

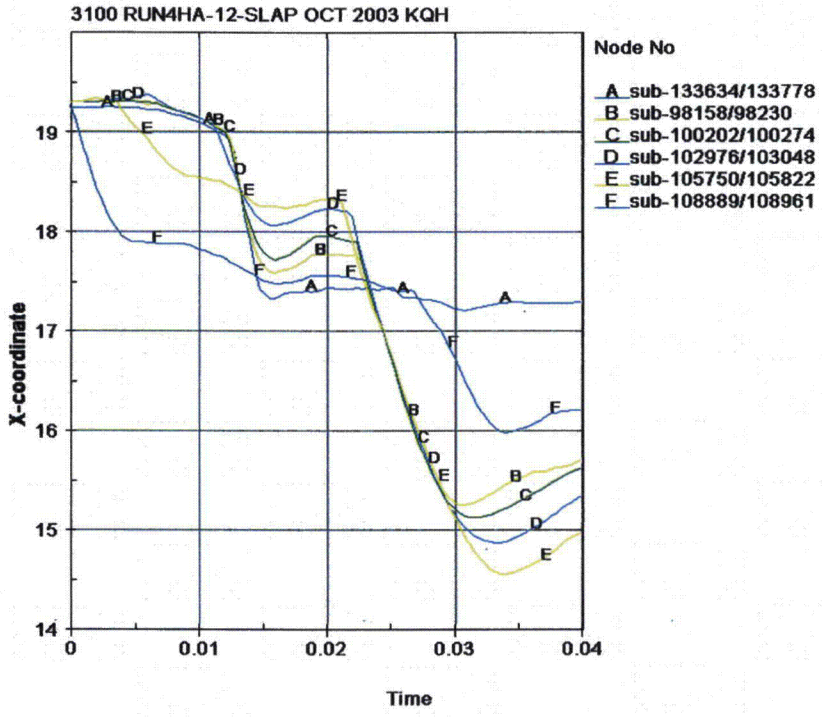

Figure 3.10.3 - Run4ha, Drum Diameter Time History in the Direction of the Impacts

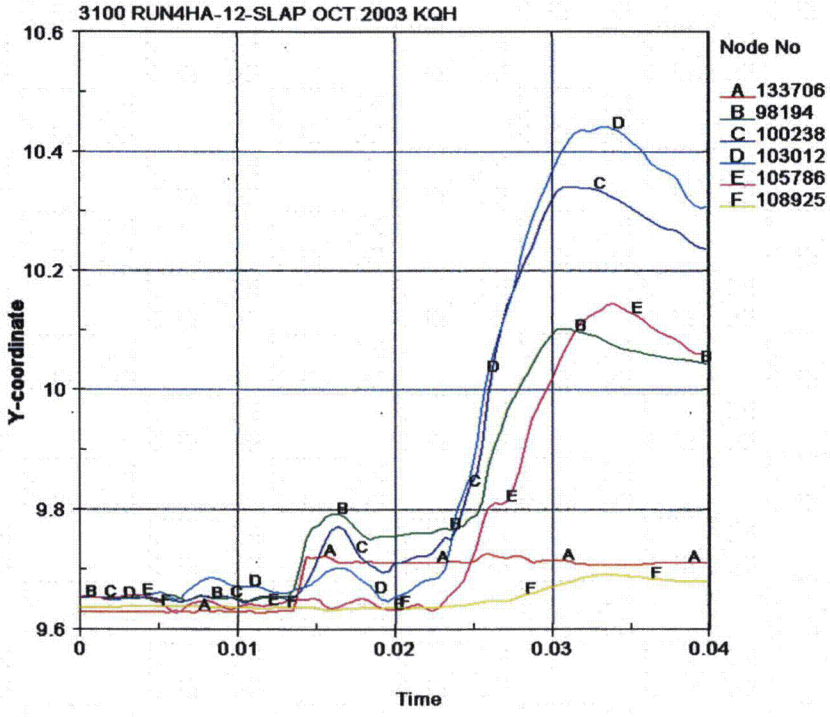

Figure 3.10.4 - Run4ha, Drum Radius Time History Normal to the Direction of the Impacts

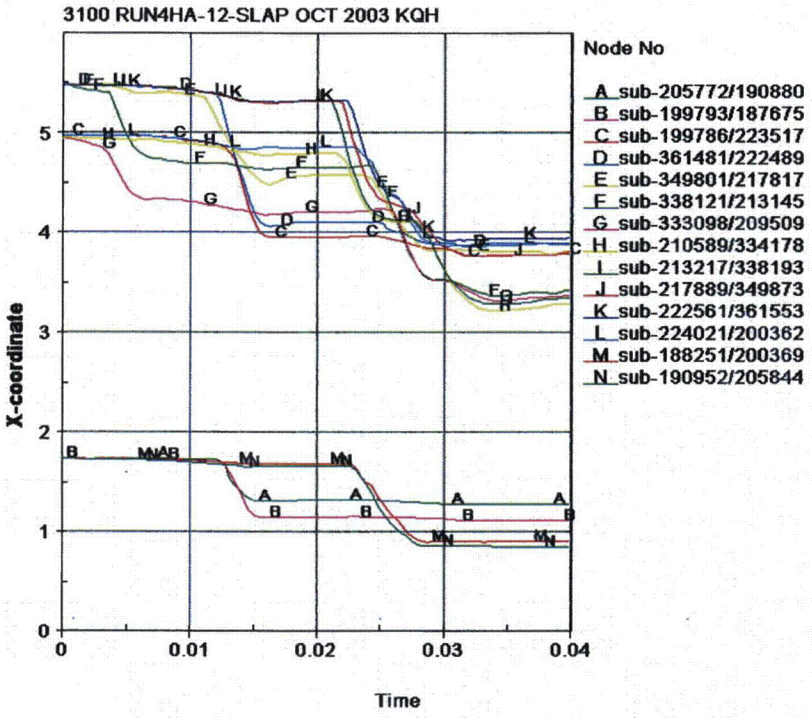

Figure 3.10.5 - Run4ha, Drum Kaolite Thickness in the Direction of the Impacts

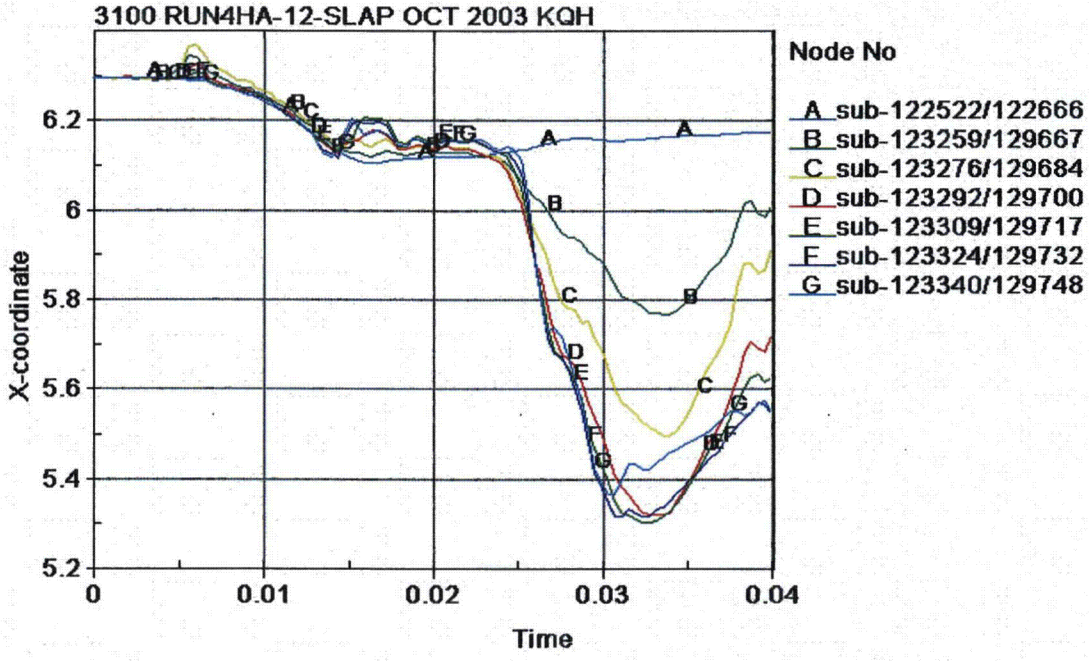

Figure 3.10.6 - Run4ha, Liner Diameter Time History

3.11 Punch Runs

The punch impacts were made with the simple model described in Section 2.2. The final configuration for the punch at 0° is shown in Figure 3.11.1. The surface effective plastic strain in the drum is shown in Figure 3.11.2 to be a maximum of 0.2030 in/in. The maximum membrane strain fringe plot is not shown, but is a maximum of 0.1385 in/in with a contour pattern similar to the surface strain.

Fringe plots of effective plastic surface strain for punch impacts at 40, 50, 60 and 63.6 are shown in Figures 3.11.3 through 3.11.6. Table 3.11.1 summarizes the maximum surface and membrane strain for all the punch impacts.

Table 3.11.1 - ES-3100 Summary of Punch Impacts

Punch Angle (degrees)	Maximum Effective Plastic Strain in the Drum (in/in)	
	Surface	Membrane
0	0.2030	0.1385
10	0.1204	0.0633
20	0.1100	0.0529
30	0.1551	0.0951
40	0.1632	0.1115
50	0.3340	0.1238
60	0.1844	0.0646
63.6	0.3895	0.1858

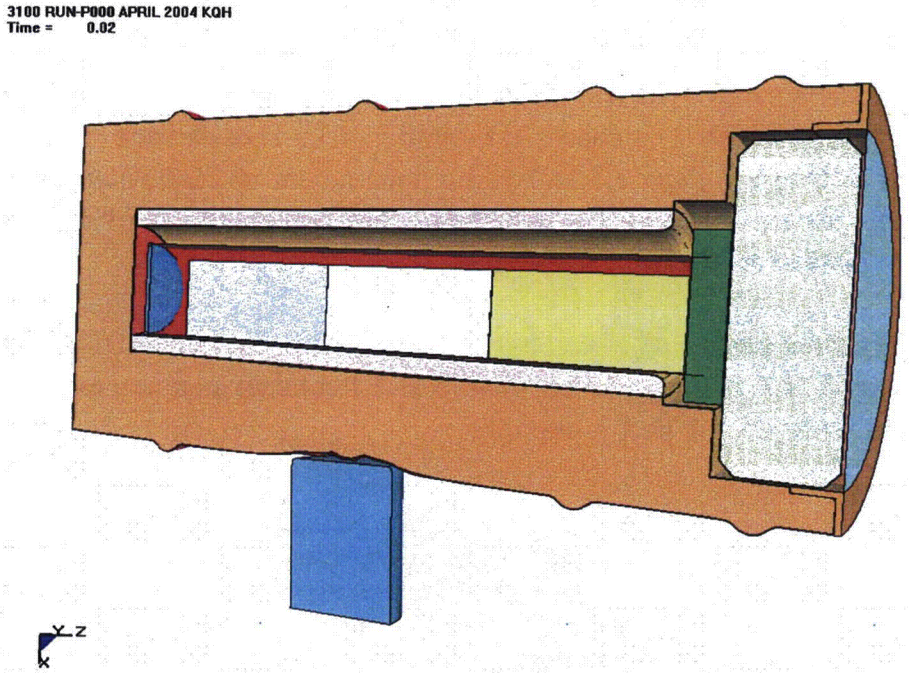

Figure 3.11.1 - Punch at 0°, Final Configuration

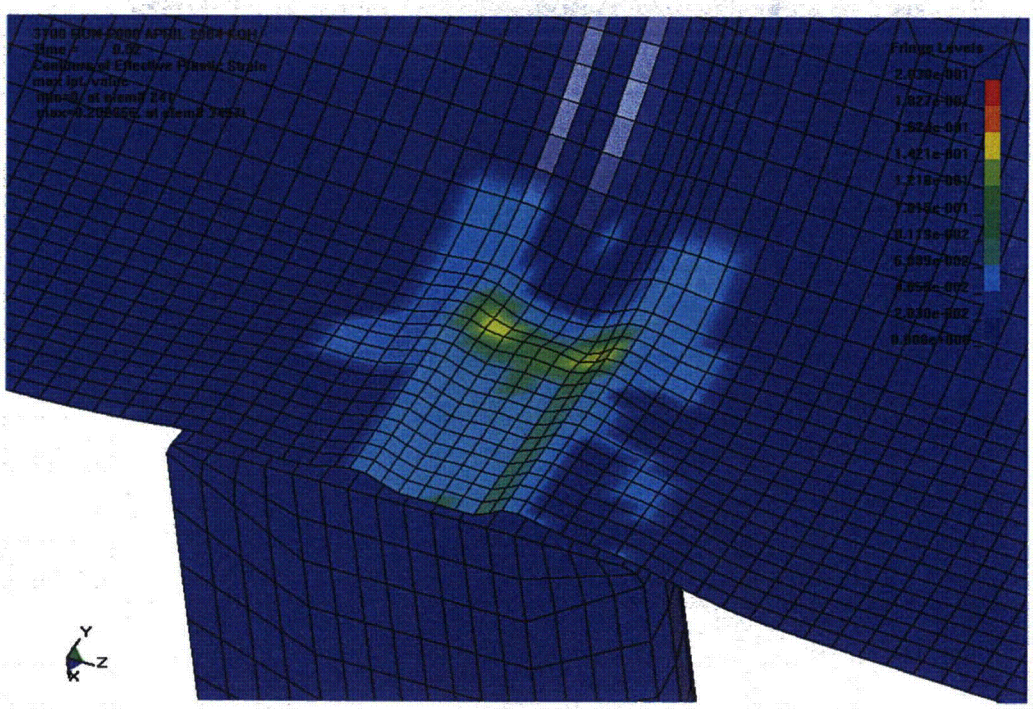

Figure 3.11.2 - Punch at 0°, Surface Strain in the Drum Liner

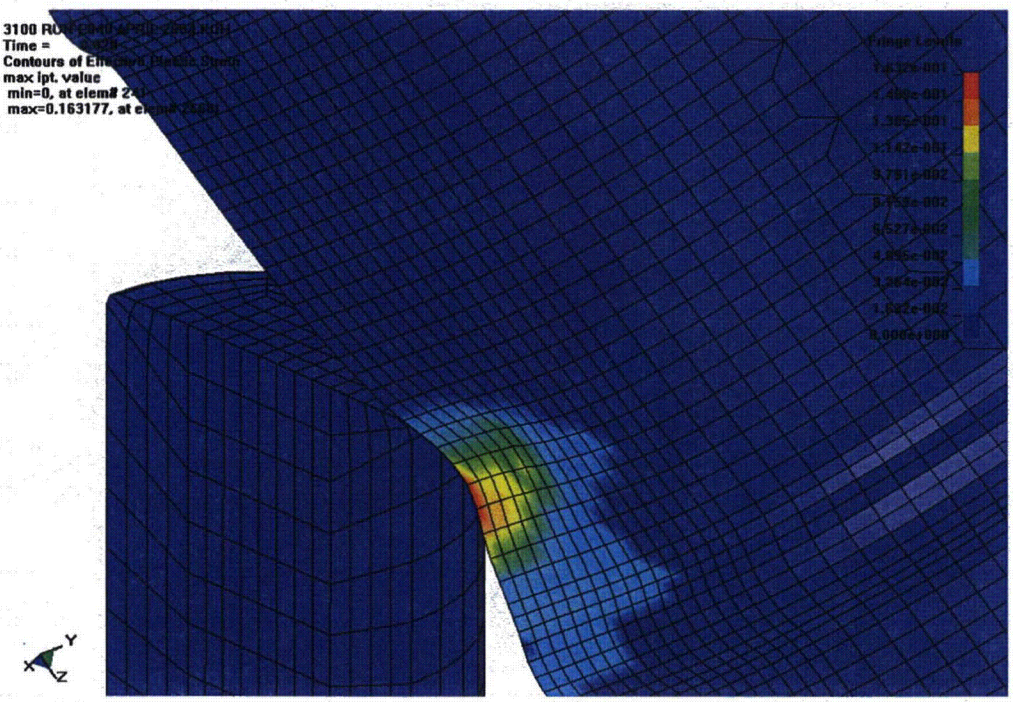

Figure 3.11.3 - Punch at 40°, Surface Strain in the Drum Liner

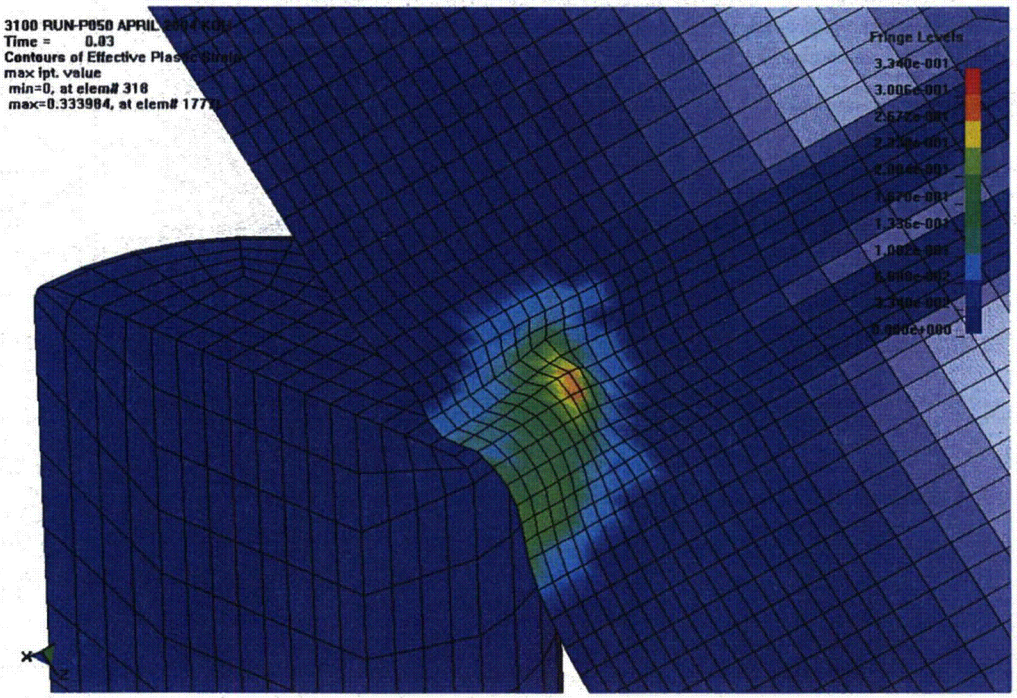

Figure 3.11.4 - Punch at 50°, Surface Strain in the Drum Liner

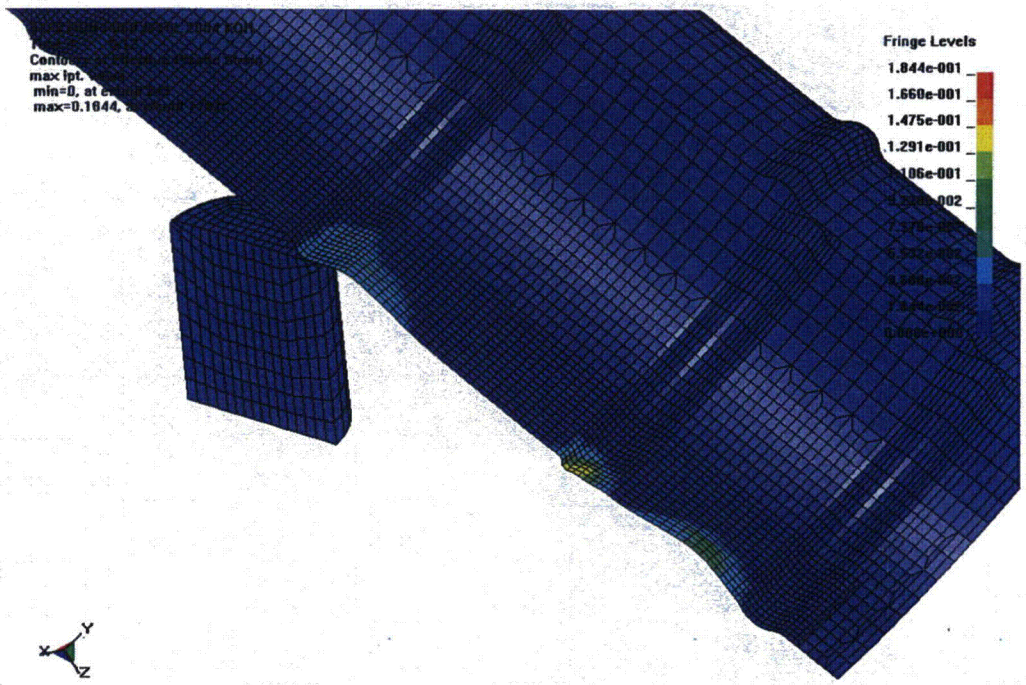

Figure 3.11.5 - Punch at 60°, Surface Strain in the Drum Liner

Figure 3.11.6 - Punch at 63.6°, Surface Strain in the Drum Liner