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STA#4

(4) ENGINEERING DATA TRANSMITTAL

Page 1 of 1

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1	SNF-6031	all	0	Simulation of Multi-Canister Overpack (MCO) Handling Machine Impact with Cask/MCO During Insertion into the Transfer Pit (FDT-137)	S	1		

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

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		Design Agent				1	1	Design Authority LH Goldmann	LH Goldmann	3/28/2000	R3-86
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1	1	Cog. Mgr. AS Daughtridge	AS Daughtridge	4/5/00	R3-86						
1	1	QA SS Moss	Stephen Scott Moss	4-5-2000	R3-11						
1	1	Safety RL Garrett	[signature]	4-3-00	R3-26						
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WW Waddel 4/5/00 Signature of EDT Originator / Date	JA Swenson 4/10/00 Authorized Representative for Receiving Organization / Date	AS Daughtridge 4/11/00 Design Authority/ Cognizant Manager / Date	Ctrl No. ______ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

BD-7400-172-2 (10/97)

BD-7400-172-1

SNF-6031
Revision 0
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Simulation of Multi-Canister Overpack (MCO) Handling Machine Impact with Cask/MCO During Insertion into the Transfer Pit (FDT-137)

C. J. Moore
Fluor Federal Services, Inc

Date Published
April 2000

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P.O. Box 1000
Richland, Washington

Total page 58

Release Approval 4/12/00 Date

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Revision 0

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Mr. A. S. Daughtridge Jr.
DE&S Hanford, Inc. R3-86
P. O. Box 350
Richland, WA 99352-0350

FLUOR DANIEL, INC.

Date: November 30, 1998

Reference: SNF Canister Storage Building
P. O. TVW-SVV-370252
Fluor Contract 4602

Dear Mr. Daughtridge

Transmittal No.: FDT-137

TRANSMITTAL

We enclose 1 copies of the items listed below. These are issued for:

[ ] Approval [X] Reference [] Review and Comment [] Other

Response due to Fluor: N/A

Responds to: EDN-094 and SNF-3328 (Draft) Section 6.2.4

Number	Rev	Date	Title
Attachment 1	0	11/03/98	Simulation of MCO Handling Machine Impact with Cask/MCO During Insertion Into the Transfer Pit

Distribution:
G. D. Bazinet, NHC, w/1
L. J. Garvin III, DESH, w/1

Very truly yours,

Stephen L. Petersen
Project Manager

SLP:MJH:tr
Attachments (1)

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Civil/Structural	ORIGINATED BY:	C. J. Moore	DATE: 10/20/98
ENG COMM NO:		CHECKED BY:	K. C. Tu	DATE: 11/3/98
AREA:	200 E	REVISED BY:		DATE:
SUBJECT:	MHM impact with Cask/MCO during insertion into CSB Transfer Pit			

SIMULATION OF MCO HANDLING MACHINE IMPACT WITH CASK/MCO DURING INSERTION INTO THE TRANSFER PIT

Gutelton J. Moore 11/3/98
ORIGINATED BY: C. J. Moore

Kuen Chin Tu 11/3/98
CHECKED BY: K. C. Tu

CALCULATIONS AND SKETCHES SHEET

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SUBJECT:	MHM impact with Cask/MCO during insertion into CSB Transfer Pit			

Executive Summary for MHM Impacting the Cask at Transfer Pit

The objective of this engineering effort is to provide independent engineering evaluations/analyses of the accidental impact of the MCO Handling Machine (MHM) with the cask/MCO (Multi-Canister Overpack) during insertion into the CSB transfer pit. The maximum MHM velocity is specified to be 40 ft/min. The total weight moving with the MHM is assumed to be 1 million pounds. The cask/MCO is assumed to be supported by a crane, hanging from the lifting fixture. The cask/MCO is assumed to be partially inserted into the 56 inch inside diameter transfer pit.

Our work scope is to define the effects of a worst case MHM impact with the cask/MCO with regard to criticality limits.

The analysis case has the MHM modeled as a large steel ring mass loaded to 1 million pounds weight with an initial velocity of 40 ft/min (8 inches per second) and applied wheel traction forces of 12,000 lb. The impact at the transfer pit has been broken into two dynamic simulations. The first being the MHM impacting a static cask/MCO hanging from a lifting fixture and crane cable. The second impact case being the MHM and cask/MCO moving side ways at 40 ft/min., impacting the transfer pit wall.

The simulation of the MHM impact with the static cask/MCO has been completed. The cask, MCO, and all six Mark 1A baskets remain linear elastic. There is no plastic damage. The baskets do not violate any criticality geometry criteria.

The simulation of the MHM and cask/MCO impacting the transfer pit wall stopped and rebounded the one million pound MHM. The maximum equivalent plastic strain was in the bottom basket with a value of approximately 0.3 per cent strain. There is no significant plastic damage. The baskets do not violate any criticality geometry criteria.

No criticality problem is identified for MCO and baskets due to the MHM impacting the outer transportation cask at a velocity of 8 inches/second.

CALCULATIONS AND SKETCHES SHEET

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Simulation of MCO Handling Machine Impact with Cask/MCO

During Insertion into the Transfer Pit

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1.0 Introduction

The K-Basin Cask and Transportation System will be used for safely packaging and transporting approximately 2,100 metric tons of unprocessed, spent nuclear fuel from the 105 K East and K West Basins to the 200 E Area Canister Storage Building (CSB). Portions of the system will also be used for drying the spent fuel under cold vacuum conditions prior to placement in interim storage.

The spent nuclear fuel is currently stored underwater in the two K-Basins. The K-Basins loadout pit is the area selected for loading spent nuclear fuel into the Multi-Canister Overpack (MCO) which in turn is located within the transportation cask. This Cask/MCO unit is secured in the pit with a pail load out structure whose primary function is to suspend and support the Cask/MCO unit at the desired elevations and to protect the unit from the contaminated K-Basin water. The fuel elements will be placed in special baskets and stacked in the MCO that have been previously placed in the cask.

The casks will be removed from the K Basin load out areas and taken to the cold vacuum drying station. Then the cask will be prepared for transportation to the CSB. The shipments will occur exclusively on the Hanford Site between K-Basins and the CSB. Travel will be by road with one cask per trailer.

At the CSB receiving area the cask will be removed from the trailer. A gantry crane will then move the cask over to the transfer pit and load the cask into the transfer pit. From the transfer pit the MCO will be removed from the cask by the MCO Handling Machine (MHM). The MHM will move the MCO from the transfer pit to a canister storage tube in the CSB. MCOs will be piled two high in each canister storage tube.

2.0 Objective

The objective of this engineering effort is to provide independent engineering evaluations/analyses of the accidental impact of the MHM with the cask/MCO during insertion into the CSB transfer pit. The maximum MHM velocity is specified to be 40 ft/min. The total weight moving with the MHM is assumed to be 1 million pounds. The cask/MCO is assumed to be supported by a crane, hanging from the lifting fixture. The cask/MCO is assumed to be partially inserted into the 56 inch inside diameter transfer pit.

The MHM is driven by two 7.5 HP electric motors coupled individually with two 3 ft diameter drive wheels. The motors are rated at 32.8 ft lb of torque at 1200 RPM. Each motor drives a separate wheel through a 271:1 ratio gear reduction transmission. Rounding up the maximum motor torque can produce a 6,000 lb with each wheel assuming zero transmission losses.

This evaluation monitors displacements, velocities, accelerations, stresses, and plastic strains in the cask, MCO, baskets, basket interface with MCO and shield plug, cask seal, and MCO seal. Also, any potential large strains and buckling will be identified. Thus, the structural numerical models must model nonlinear material behavior and large deflections, in addition to impact dynamics.

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The normal operational acceptance criteria for the K-Basins MCO packaging system are confinement of internal gases, confinement of radioactive waste, and compliance with HNF-S-0426, Rev. 3, "Performance Specification for Spent Nuclear Fuel Multi-Canister Overpack."

The accident acceptance criteria apply to the loads that are outside the performance specification design basis. The MCO must maintain radioactive waste confinement, but it does not have to be serviceable after an accident event.

3.0 Analyses and Results Summary

The transportation cask, MCO, Mark 1A baskets, lifting fixture, simplified MHM, and a rigid transfer pit were modeled with a second generation nonlinear finite element program called ABAQUS. There are two versions of ABAQUS. ABAQUS/Standard, or the implicit formulation, is best for static nonlinear solutions and ABAQUS/Explicit is best for dynamic problems. In particular, ABAQUS/Explicit 5.7 was used for this analysis effort.

An ABAQUS cask half model was created using 3D solid brick elements. The mechanical closure MCO was modeled with ABAQUS 3D solid brick elements and quadrilateral shell elements. The bricks modeled the thick MCO bottom and the top MCO cover plug. The plate MCO cylindrical wall is modeled with quadrilateral shell elements. The connection between the bricks on the bottom and top and the wall shell elements was approximated by overlapping shell and brick elements to allow moment transfer.

The half symmetry MCO model was combined with the half symmetry cask model. The MCO was free inside the cask to slide around and to bounce from side to side. Contact surfaces were included in the combined model to model the interaction between the outside of the MCO with the inside of the cask.

The Mark 1A basket bottom and center column were modeled employing half model symmetry with quadrilateral shell elements. Six Mark 1A baskets did not have the sliding inserts between each basket, but the actual connection contact and insert was modeled for the basket interface with the MCO and shield plug. The structural model of each basket was mass loaded with lumped mass elements simulating spent nuclear fuel, bringing the weight of each loaded Mark 1A basket up to 2,303 lb. The total weight of the six baskets with the spent nuclear fuel was 13,818 lb.

The cask lifting fixture was modeled as a half model using shell elements with ideal beam elements modeling the lifting pin and the cask lid trunnions. The MHM modeling was conservatively simplified as a half model of a large steel ring mass loaded to simulate a full model total weight of 1 million lb. The transfer pit half model geometry was modeled with rigid shell elements constrained to ground. The transfer pit also had inside contact surfaces defined, for reaction force interface with the impacting cask.

The impact at the transfer pit has been broken up into two dynamic simulations. The first being the MHM impacting a static cask/MCO hanging from a lifting fixture and crane cable. The second impact case being the MHM and cask/MCO moving side ways at 40 ft/min impacting the transfer pit wall.

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The simulation of the MHM impact with the static cask/MCO has been completed. The cask, MCO, and all six Mark 1A baskets remain linear elastic. There is no plastic damage. The baskets do not violate any criticality geometry criteria.

The simulation of the MHM and cask/MCO impacting the transfer pit wall stopped and rebounded the one million pound MHM. The maximum equivalent plastic strain was in the bottom basket with a value of approximately 0.3 per cent strain. There is no significant plastic damage. The baskets do not violate any criticality geometry criteria.

4.0 Recommendations

MHM 8 inches/second velocity which impacts directly or indirectly with the outer transportation cask will not cause a criticality problem for the MCO and baskets. Also the mechanical closure MCO will maintain sealing during and after the MHM impact with the cask. Although public and worker safety from radioactive contamination is maintained before, during, and after this assumed accident, we recommend that proper care be applied to the operations of the MHM and that other non-nuclear safety issues be properly addressed.

5.0 ABAQUS Modeling of Cask/MCO

The K-Basin transportation cask, MCO and baskets were modeled with a second generation nonlinear finite element program called ABAQUS. There are two versions of ABAQUS. ABAQUS/Standard or the implicit formulation is best for static nonlinear solutions and ABAQUS/Explicit is best for dynamic problems. In particular ABAQUS/Explicit 5.5 was used for this analysis effort.

An ABAQUS cask half model was created using 3D solid brick elements. Figure 5-1 shows a side view of the cask and lid half model. Figure 5-2 shows an isometric view of the cask and lid half model. The cask lid has a simplified modeling of the top lifting trunnions with mass elements located at the lift points to obtain the proper mass and mass distribution.

Figure 5-3 shows an isometric view of the lid with the idealized beam elements modeling six of the twelve hold down bolts. In Figure 5-3 the bottom of the lid shoulder and the shear lip interface groove can be seen. The contact interface between the lid and the cask shoulder and shear lip are modeled with contact surfaces. The 1.22 inch diameter bolts are modeled as beam finite elements connecting to the nodes on the lid shoulder top surface and the nodes interior to the cask cylinder. This modeling assumes the lid bolt holes are over-sized allowing free play through the lid shoulder thickness.

The mechanical closure MCO was modeled with ABAQUS 3D solid brick elements and quadrilateral shell elements. Figure 5-4 shows a side view of the mechanical closure MCO. Figure 5-5 shows an isometric view of the MCO. The bricks modeled the thick MCO bottom and the top MCO seal ledge, lifting ring, shield plug, and a short segment of the process tube. The plate MCO cylindrical wall is modeled with

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quadrilateral shell elements of 0.5 inch thickness. The connection between the bricks on the bottom and top and the wall shell elements was approximated by overlapping shell and brick elements to allow moment transfer.

Figure 5-6 shows a zoomed isometric view of the top of the MCO showing the shield plug, lifting ring, and a short segment of the process tube. Figure 5-7 shows a close zoomed isometric view of the shield plug with detail of the interface with the short segment of the process tube. The process tube is modeled with shell elements of 0.385 inch thickness.

Figure 5-8 shows the modeling of the shield plug with the compression bolts. The bolts are connected to nodes in the lifting ring solid model. These bolts interface with the shield plug with end contact nodes bearing against the top shoulder contact surface. The bolt modeling simulates 12 bolts. The Mechanical Closure MCO now has 18 bolts of 1.5 inch diameter as documented in drawing number H-2-828042, Rev. 1. The total axial area of the 18 bolts was calculated. Then the total area was divided by 12 obtaining an equivalent bolt area with a resulting bolt radius of 0.918 inch. The modeling of the 12 equivalent bolts was adjusted to be consistent with the bolt axial stresses and the existing model finite element mesh.

Figure 5-9 shows a zoomed isometric view of the MCO seal ledge and lifting ring. Figure 5-10 shows a closed zoomed view of the MCO seal ledge and lifting ring. The shield plug of Figure 5-8 interfaces with the MCO seal ledge and lifting ring with contact surfaces for force distribution.

Figure 5-11 shows the simplified modeling of the bottom modeling of the MCO. In Figure 5-11 three of the six basket support ribs of 0.5 inch thickness can be seen. Also the 0.615 inch thickness basket centering cone can be seen as a shell half model.

The half symmetry MCO model was combined with the half symmetry cask model. The MCO was free inside the cask to slide around and to bounce from side to side. Contact surfaces were included in the combined model to model the interaction between the outside of the MCO with the inside of the cask.

In Figure 5-12 six Mark 1A basket bottoms and center columns were modeled employing half model symmetry with quadrilateral shell elements. Six Mark 1A baskets did not have the sliding inserts between each basket, but the actual connection contact and insert was modeled for the basket interface with the MCO and shield plug. It is of importance to notice in Figures 5-12 and 5-13 that the top number six basket column reduces from a 6.625 inch OD pipe of 0.864 inch wall thickness to a 2.655 inch OD insert modeled with a thickness of 0.445 inch. (Note: Drawing H-2-828060 shows that the insert has an internal chamfer for the basket lifting grapple the results in a minimum thickness of 0.31 inch. The finite element mesh did not have the required detail for this feature.) The basket bottoms were approximated with shell elements of 1.058 inch thickness. The structural model of each basket was mass loaded with lumped mass elements simulating spent nuclear fuel bringing the weight of each loaded Mark 1A basket up to 2,303 lb. The total weight of the six baskets with the spent nuclear fuel was 13,818 pounds.

CALCULATIONS AND SKETCHES SHEET

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Figure 5-1, Side View of Cask and Lid Half Model
(input file mhmck4.inp 10/6/98)

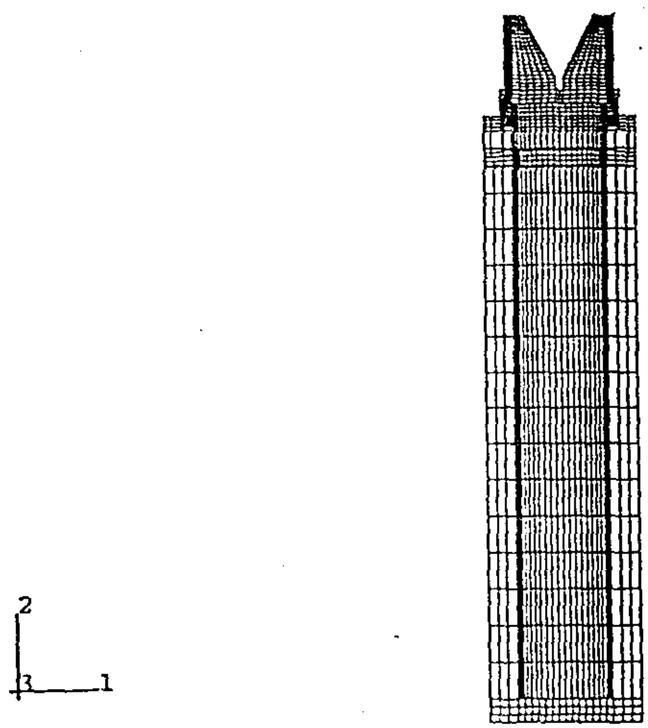

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Figure 5-2, Isometric View of Cask and Lid Half Model
(input file mhmck4.inp 10/6/98)

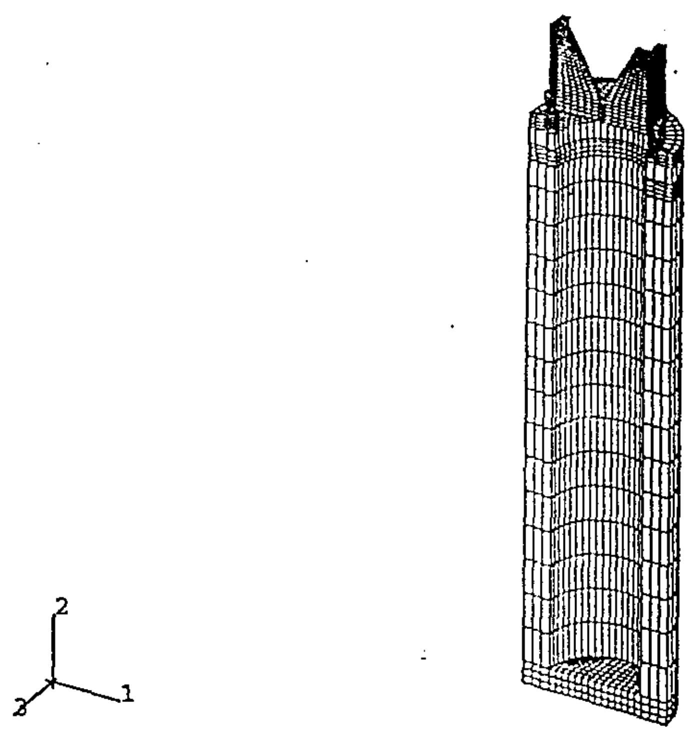

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Figure 5-3, Isometric View of Lid with Beam Modeling of Bolts
(input file mhmck4.inp 10/6/98)

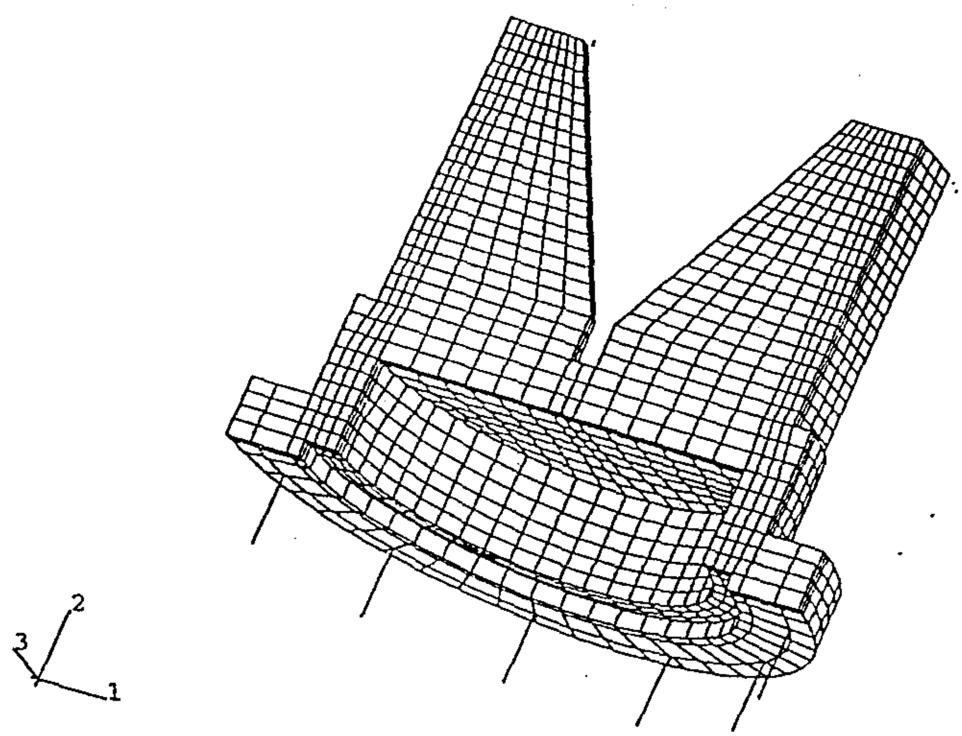

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Figure 5-4, Side View of Mechanical Closure MCO Half Model
(input file mhmck4.inp 10/6/98)

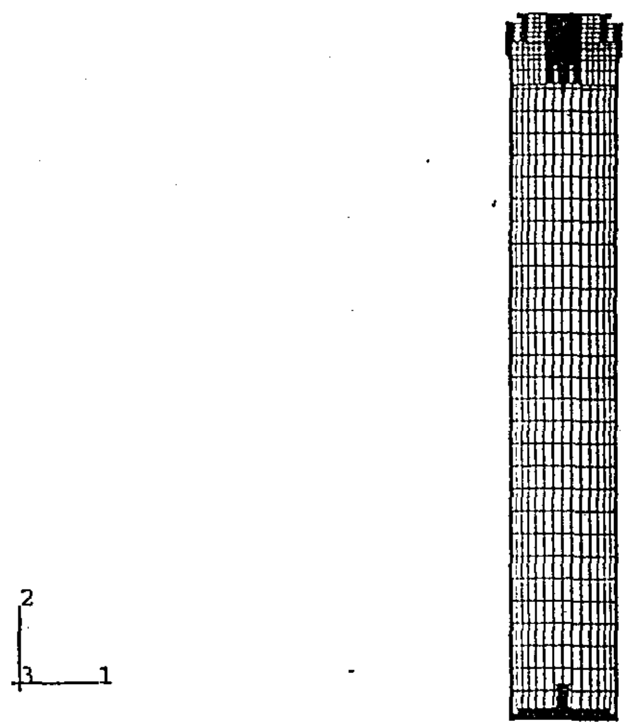

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Figure 5-5, Isometric View of Mechanical Closure MCO Half Model
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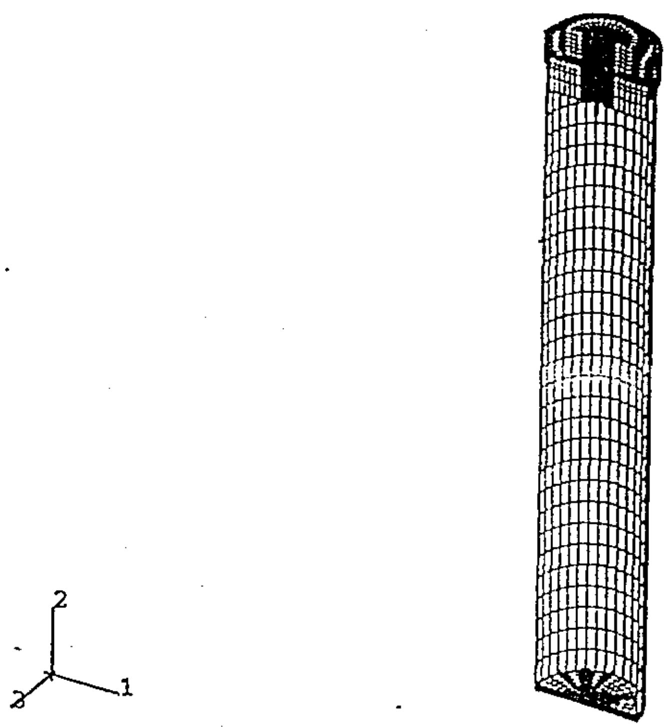

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Figure 5-6, Zoomed Isometric View of Top of MCO
Showing Shield Plug, Lifting Ring, and Short Segment of the Process Tube
(input file mhmck4.inp 10/6/98)

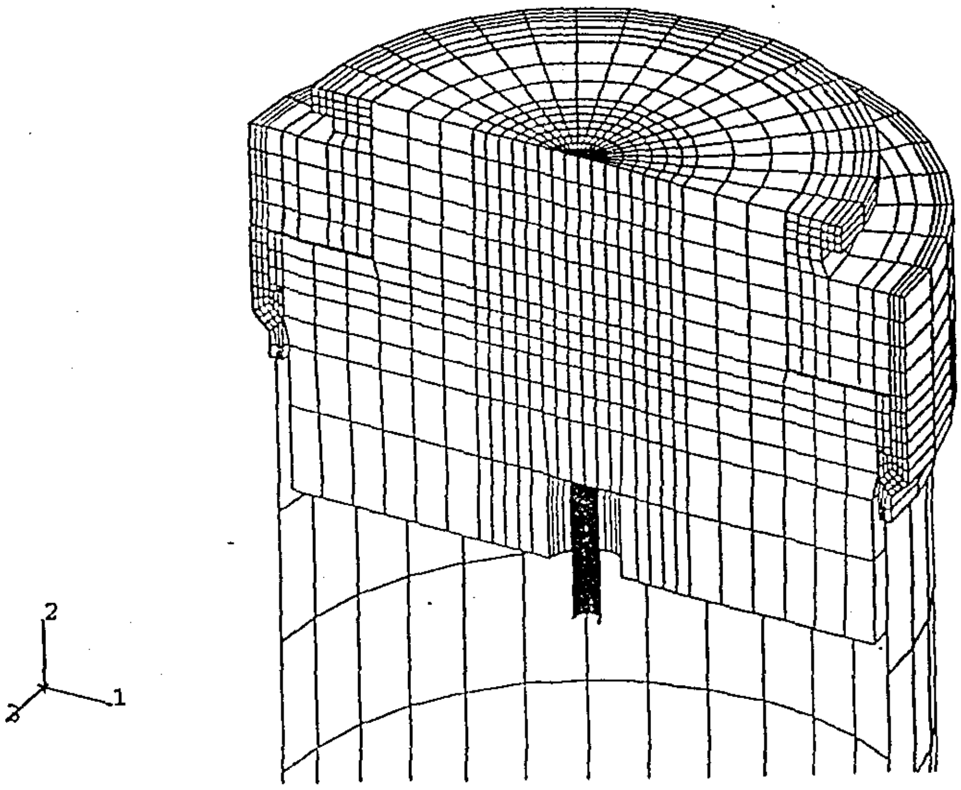

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Figure 5-7, Close Zoomed Isometric View of Shield Plug
Showing Detail of Interface with the Short Segment of Process Tube
(input file mhmck4.inp 10/6/98)

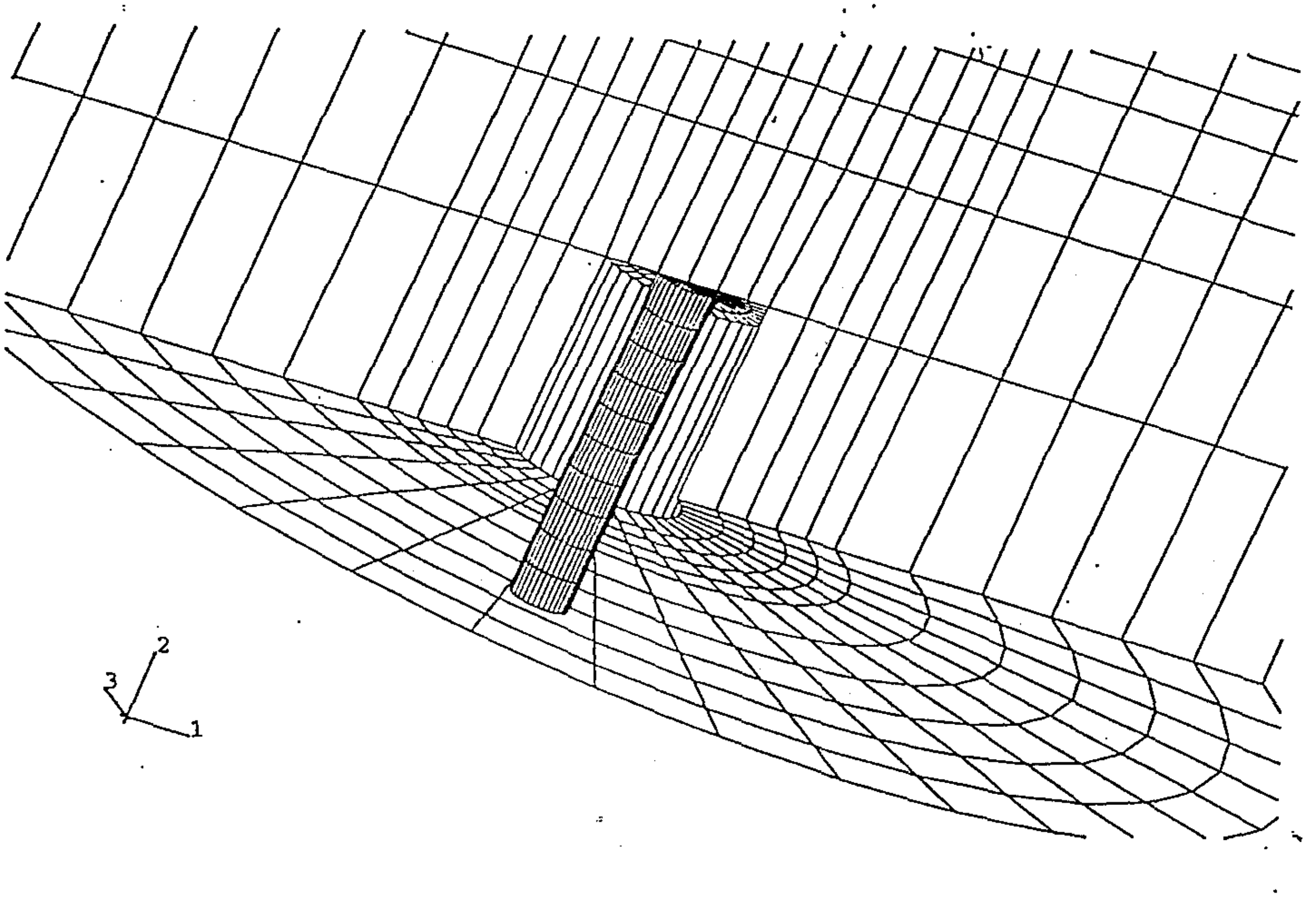

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Figure 5-8, Isometric View of Shield Plug with Compression Bolts
(input file mhmck4.inp 10/6/98)

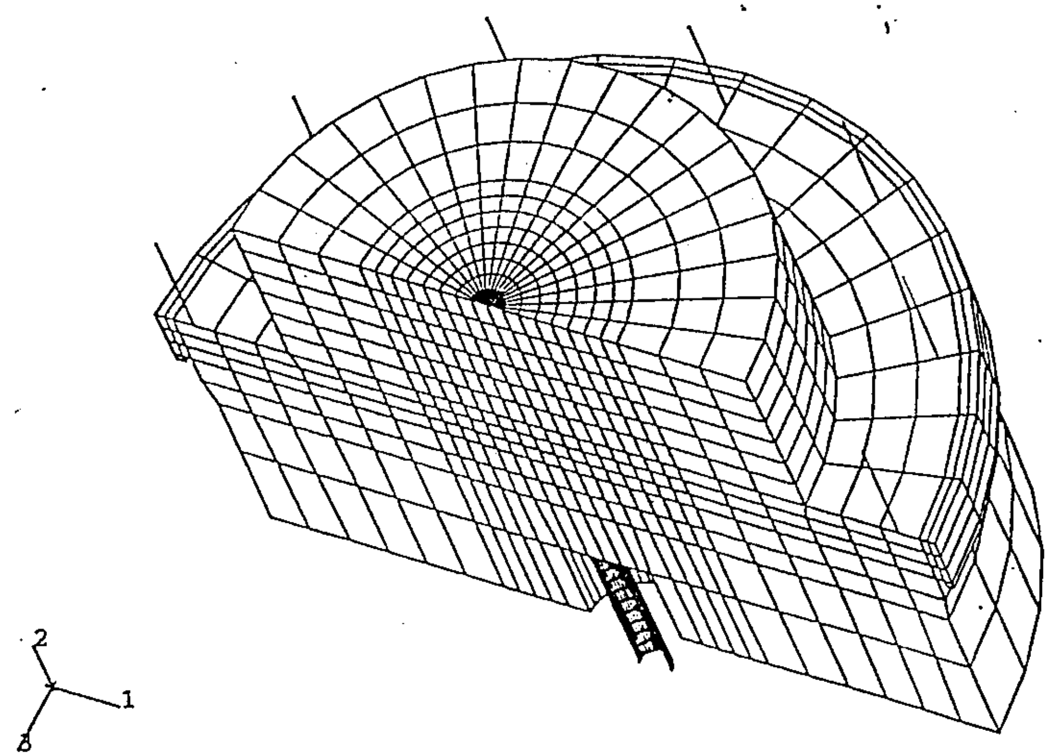

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Figure 5-9, Zoomed Isometric View of the MCO Seal Ledge and Lifting Ring
(input file mhmck4.inp 10/6/98)

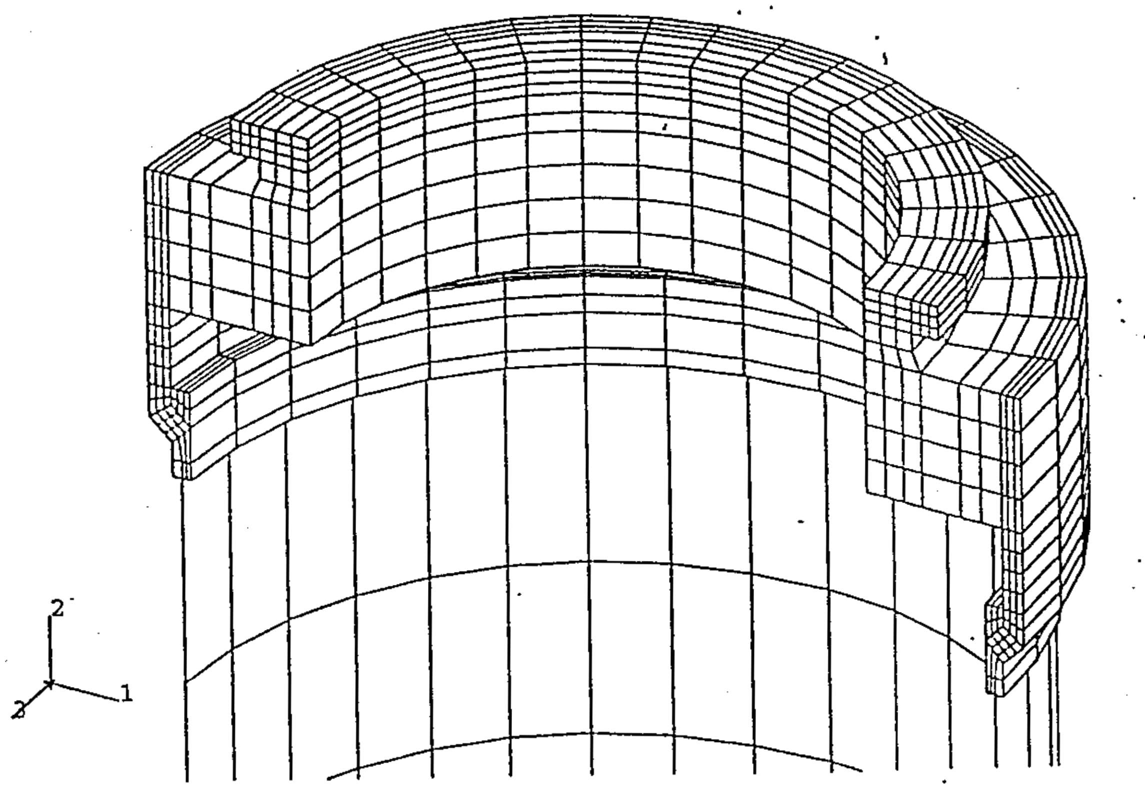

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Figure 5-10, Close Zoomed Isometric View of the MCO Seal Ledge and Lifting Ring
(input file mhmck4.inp 10/6/98)

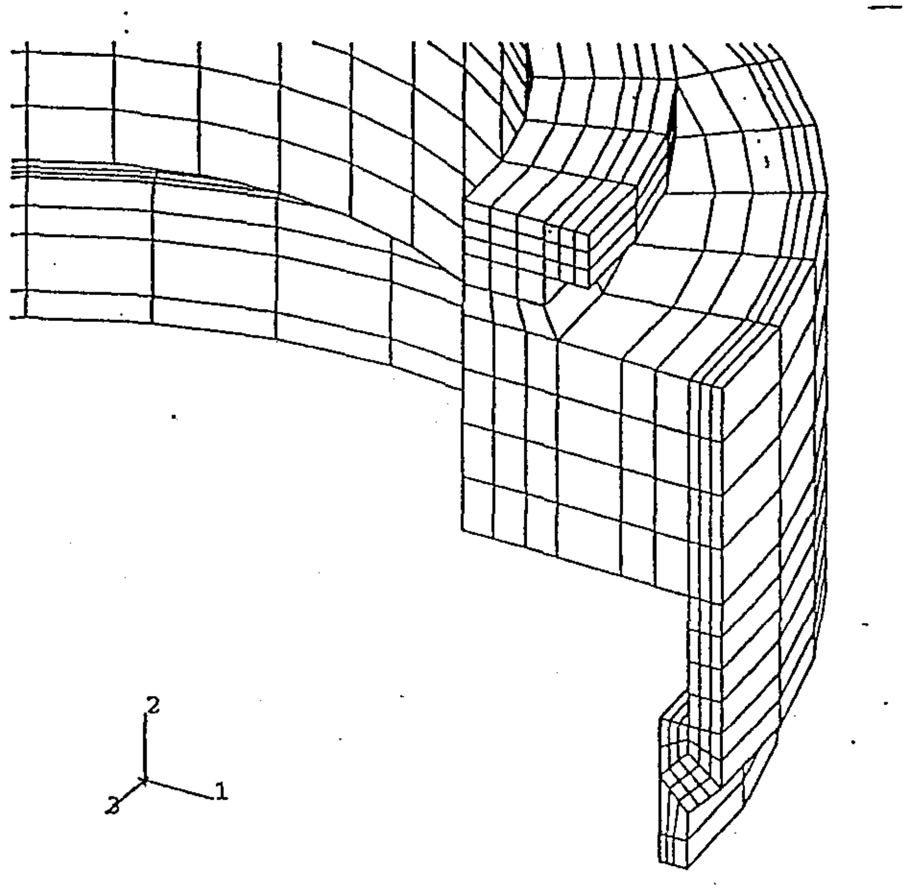

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Figure 5-11, Zoomed Isometric View of the Bottom MCO
(input file mhmck4.inp 10/6/98)

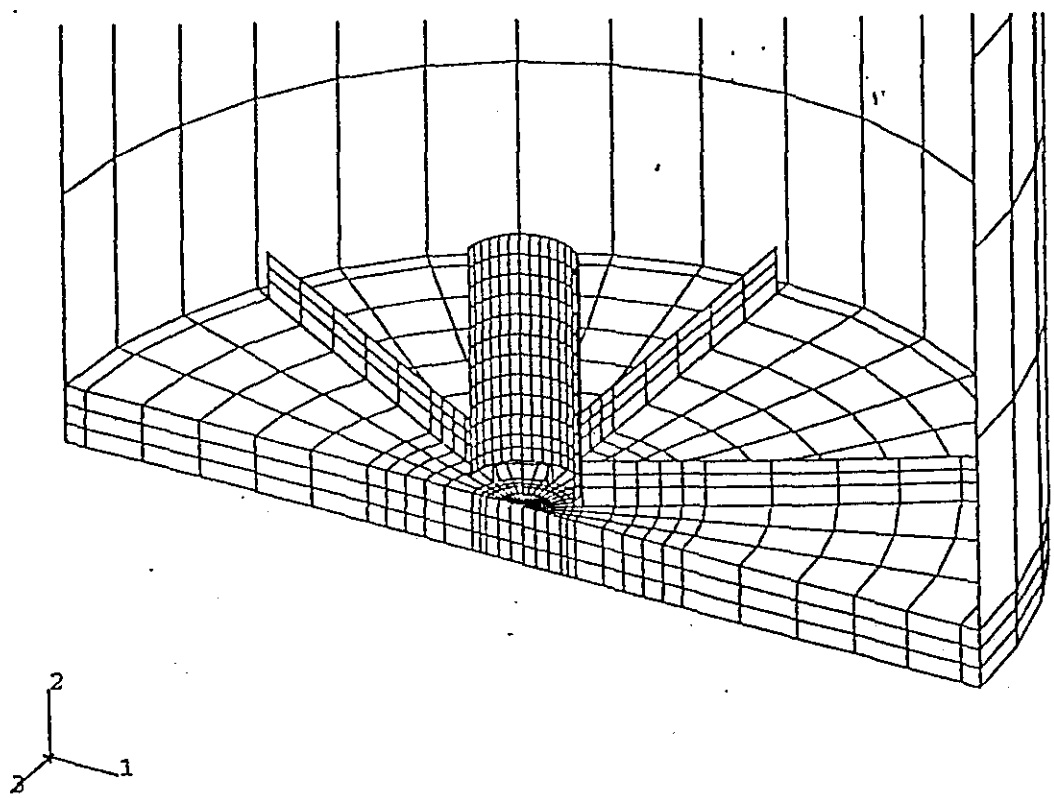

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Figure 5-12, Isometric View of Half Model of Six Mark 1A Baskets
(input file mhmck4.inp 10/6/98)

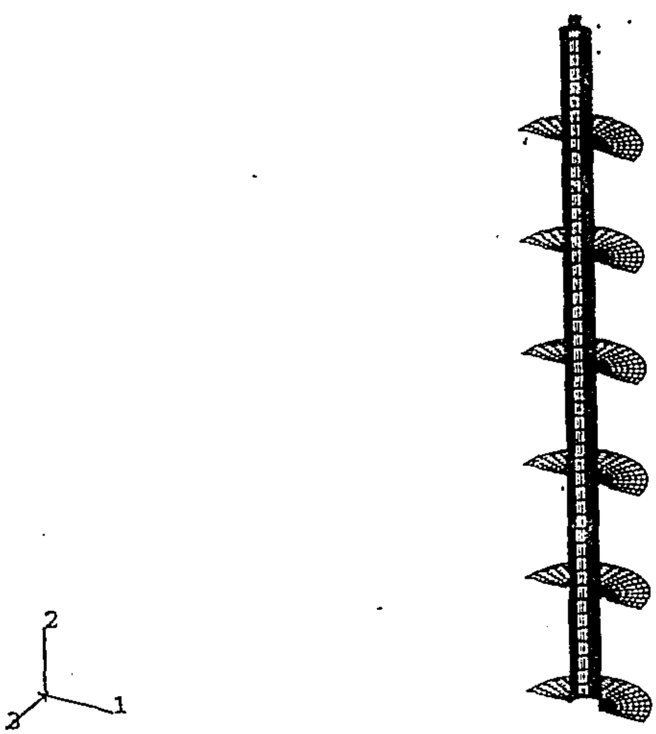

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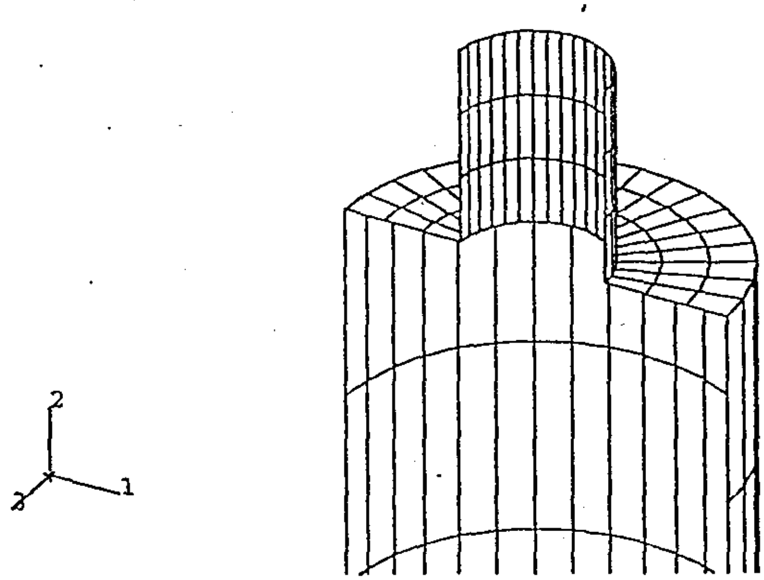
Figure 5-13, Zoomed Isometric View of Modeling of the Top Insert
(input file mhmck4.inp 10/6/98)



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6.0 Modeling of the Cask Lifting Fixture, MHM, and Transfer Pit

The cask lifting fixture was modeled as a half model using geometry from drawing number H-2-828973, Rev. 1. The fixture was modeled shell elements with thicknesses of 1 inch and 2.25 inches as specified by the drawing. The fixture lifting pin was modeled as an idealized beam element of circular cross section with a 2 inch radius. The fixture was connected to the cask lid by idealized beam elements of 3.5 inch radius circular cross section. The fixture lifting pin was connected to an idealized truss element simulating the lifting cable.

Figure 6-1 shows a side view of the lifting fixture half model. Figure 6-2 shows an isometric view of the lifting fixture half model.

The simplified MHM was modeled as half model of a steel ring mass loaded with lumped mass elements to simulate total MHM weight of 1 million pounds. Figure 6-3 shows an isometric view of the simplified half model of the MHM.

The transfer pit geometry was modeled with rigid shell elements constrained to ground. The inside diameter of the transfer pit is 56 inches as shown in drawing number H-2-120902, Rev. 1. Figure 6-4 shows an isometric view of the transfer pit modeling.

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Figure 6-1, Side View of Lifting Fixture Half Model
(input file mhmck4.inp 10/6/98)

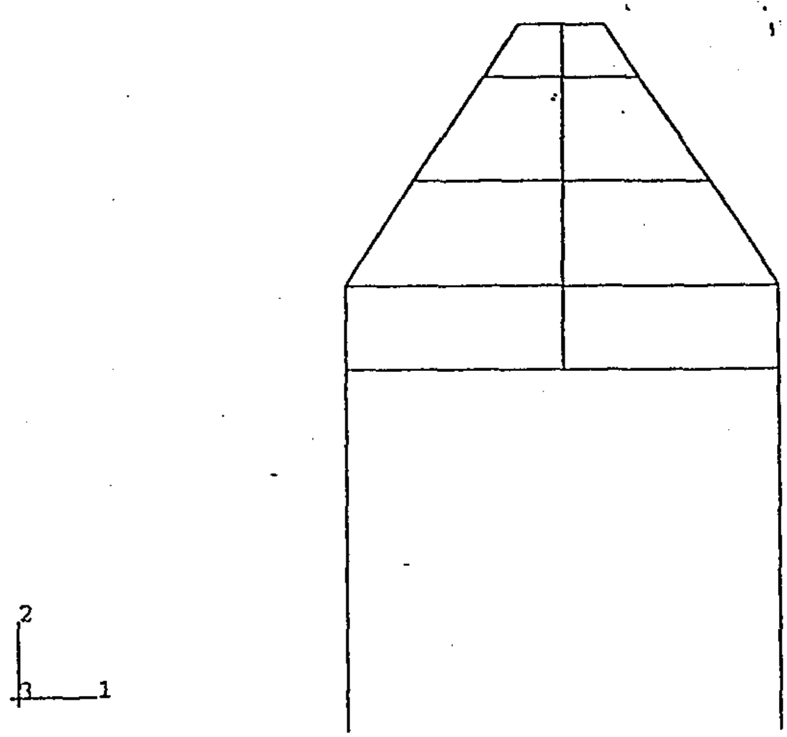

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Figure 6-2, Isometric View of Lifting Fixture Half Model
(input file mhmck4.inp 10/6/98)

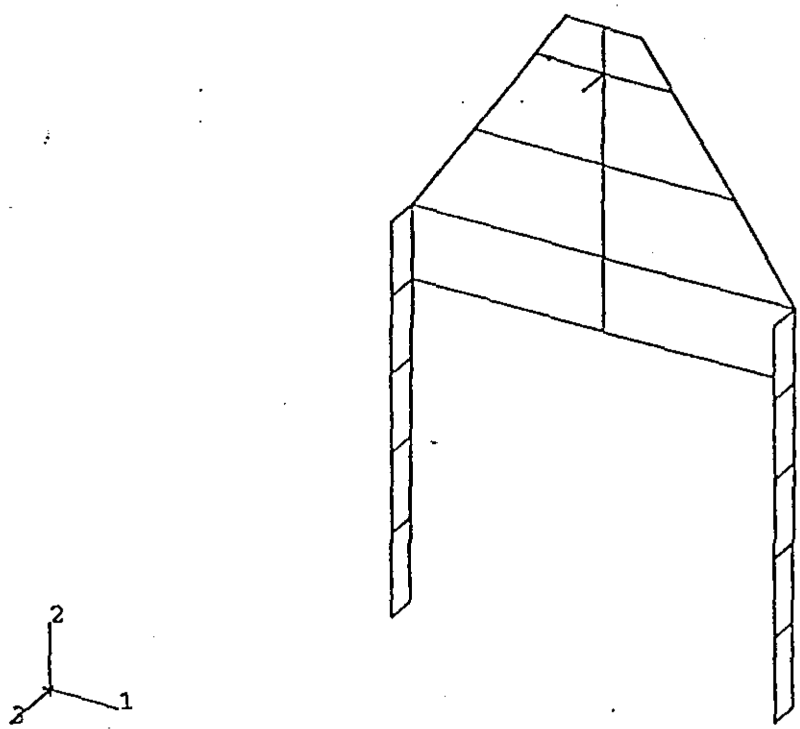

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Figure 6-3, Isometric View of Simplified MHM Half Model
(input file mhmck4.inp 10/6/98)

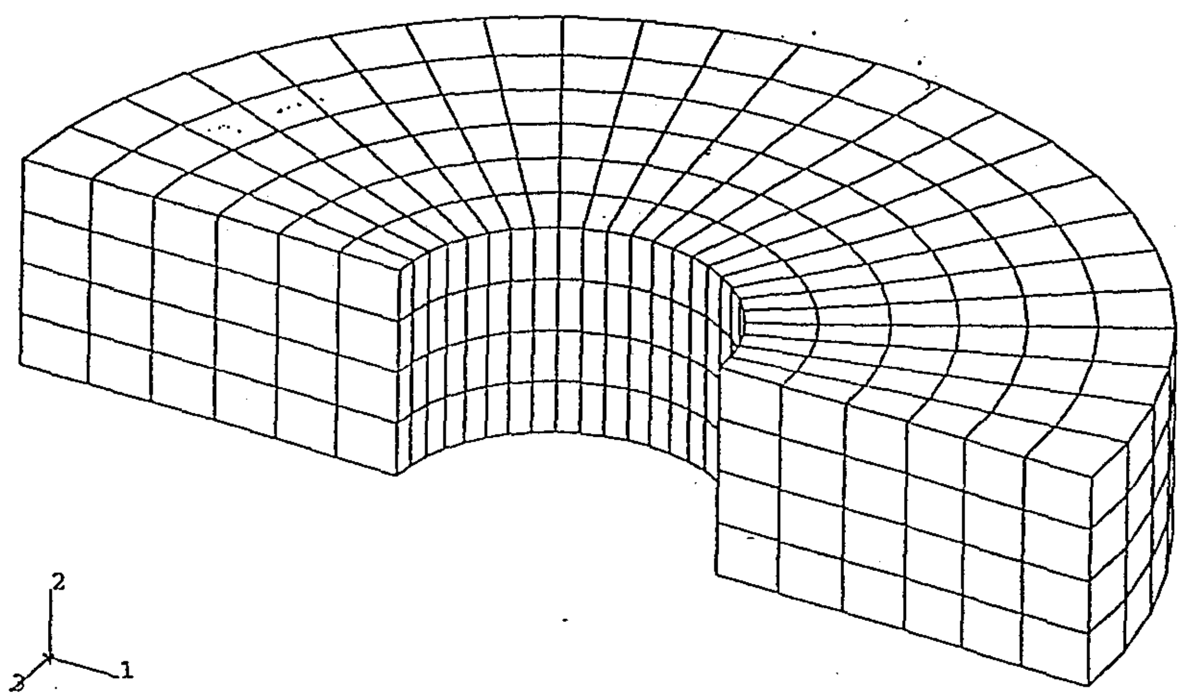

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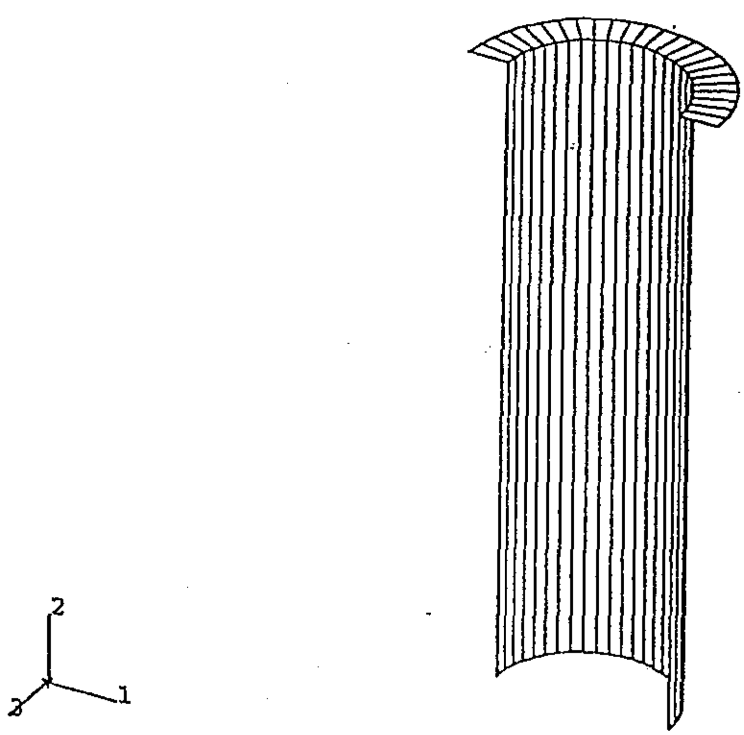
Figure 6-4, Isometric View of Transfer Pit Half Model
(input file mhmck4.inp 10/6/98)



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7.0 Analysis Results for MHM Impacting Cask

The dynamic simulation of the MHM impacting the cask/MCO during insertion into the CSB transfer pit was simplified into two separate impact problems. The first simulation evaluated the MHM moving at 8 inches per second impacting a static cask/MCO hanging from the lifting fixture and crane cable. The second simulation evaluated a MHM and cask/MCO combination moving at 8 inches per second impacting the side of the CSB transfer pit (see Section 8.0). These two separate analyses were necessary to comply with the required project schedule. The estimated real time for completion of a single simulation with both impacts was 200 days.

Figure 7-1 shows an isometric view of the initial conditions for the simulation of the MHM impacting the static cask/MCO hanging from the lifting fixture and the crane cable. In Figure 7-1 the model can be seen to be a half model. The simplified MHM is modeled as a large steel ring moving in the positive x or 1 axis direction at 8 inches/second. Figure 7-2 shows a close zoomed isometric view of the initial conditions of the MHM impacting the cask/MCO. In Figure 7-2 some details of the basket modeling can be observed. It should be noted that the MHM is positioned 0.024 inch from the cask/MCO to allow the gravity and pressure loads to be applied before the actual impact.

Figure 7-3 shows the horizontal x direction displacement time history of the bottom center of the cask and the top center of the cask lid. In Figure 7-3 the cask displacements can be seen to slowly increase and then to approach a constant slope indicating a relatively constant velocity. Figure 7-4 shows the horizontal x direction velocity time history of the bottom center of the cask and the top center of the cask lid. In Figure 7-4 dynamic oscillation of the velocity of the top and bottom of the cask can be observed with the velocity approaching a positive value between 5 and 8 inches/second.

Figure 7-5 shows the horizontal x direction displacement time history of the bottom center of the MCO, middle of MCO shell, and the bottom center of the shield plug. In Figure 7-5 the MCO displacements can be seen to begin increasing at approximately 13 milliseconds, as compared to the cask displacements beginning at approximately 4 milliseconds. The MCO takes approximately 9 milliseconds to slide over to the impact side of the cask. Figure 7-6 shows the horizontal x direction velocity time history of the bottom center of the MCO, middle of the MCO shell, and the bottom center of the shield plug. In Figure 7-6 dynamic oscillation of the velocity of the top and bottom of the MCO can be observed with the velocity approaching a positive value between 5 and 8 inches/second.

Figure 7-7 shows the horizontal x direction displacement time history of the six Mark 1A baskets with #1 being the bottom basket and #6 the top basket. In Figure 7-7 the basket displacements can be seen to begin increasing at approximately 20 milliseconds as compared to the cask displacements beginning at approximately 4 milliseconds with the MCO following at approximately 13 milliseconds. The baskets take approximately 7 milliseconds to slide over to the impact side of the MCO. Figure 7-8 shows the horizontal x direction velocity time history of the six Mark 1A baskets. In Figure 7-8 dynamic oscillation of the velocity of the six Mark 1A baskets of the MCO can be observed with the velocity approaching a positive value between 5 and 8 inches/second.

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Figure 7-9 shows at 77 milliseconds the equivalent plastic strain of the cask, cask lid, MCO, shield plug, and baskets due to the 8 inches/second impact of the MHM with the static cask/MCO. In Figure 7-9 the maximum plastic strain can be seen to be less than 0.0833 per cent strain (less than 1/10 of 1 per cent strain). The 8 inches/second impact of the MHM with the cask/MCO suspended from the lifting fixture and crane cable does not do any damage to the MCO or the six Mark 1A baskets. The local deformations are linear elastic. The MCO circumference retains the original dimensions. The MCO and baskets maintain all geometry requirements; basket criticality specifications are not violated for this impact.

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Figure 7-1, Isometric View of the Initial Conditions for the MHM Impacting the Static Cask/MCO Hanging from the Lifting Fixture and the Crane Cable. (input file mhmck4.inp 10/6/98)

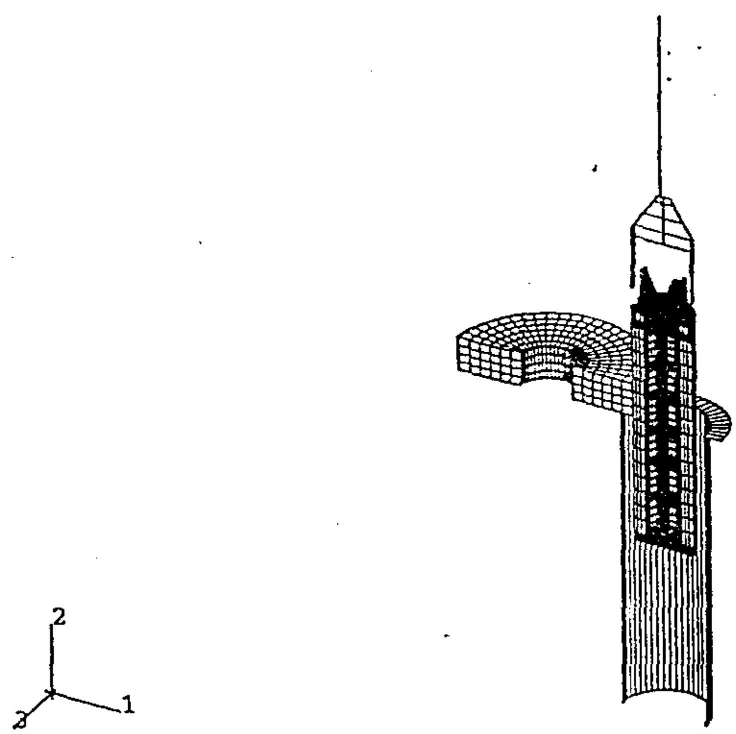

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Figure 7-2, Close Zoomed Isometric View of the Initial Conditions for the MHM *Impacting the Static Cask/MCO.*
(input file mhmck4.inp 10/6/98)

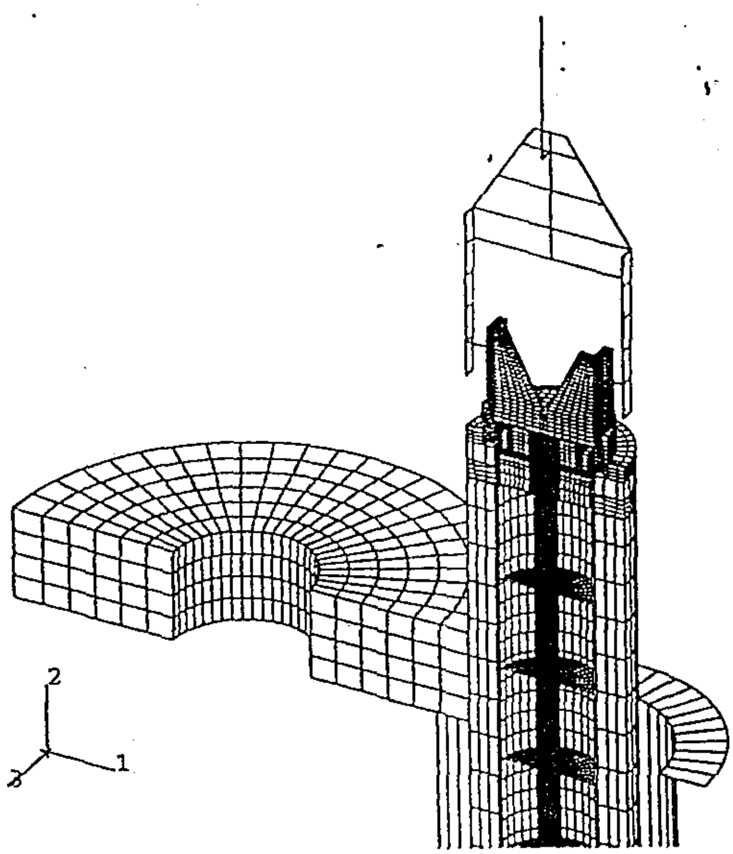

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Figure 7-3, The Horizontal X Direction Displacement Time History of the Bottom Center of the Cask and the Top Center of the Cask Lid.
(input file mhmck4.inp 10/6/98)

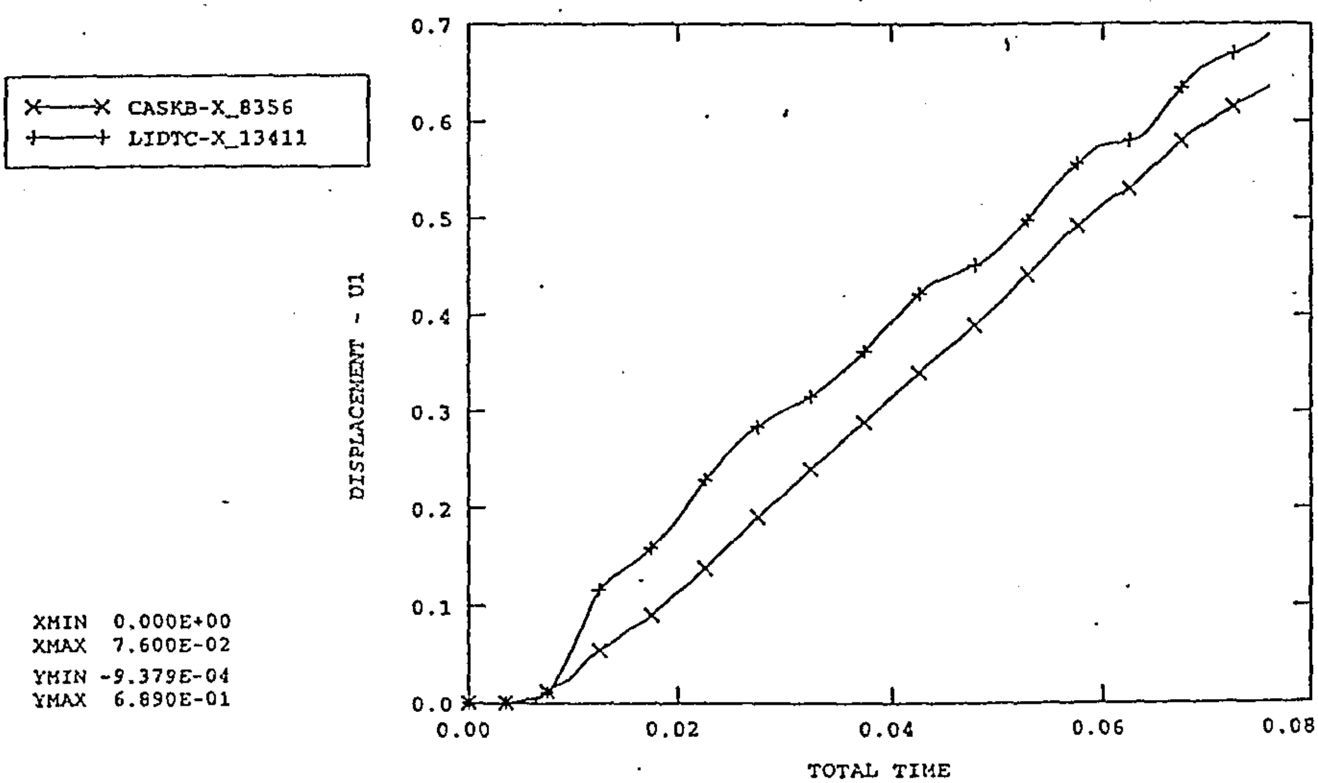

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Figure 7-4, The Horizontal X Direction Velocity Time History of the Bottom Center of the Cask and the Top Center of the Cask Lid.
(input file mhmck4.inp 10/6/98)

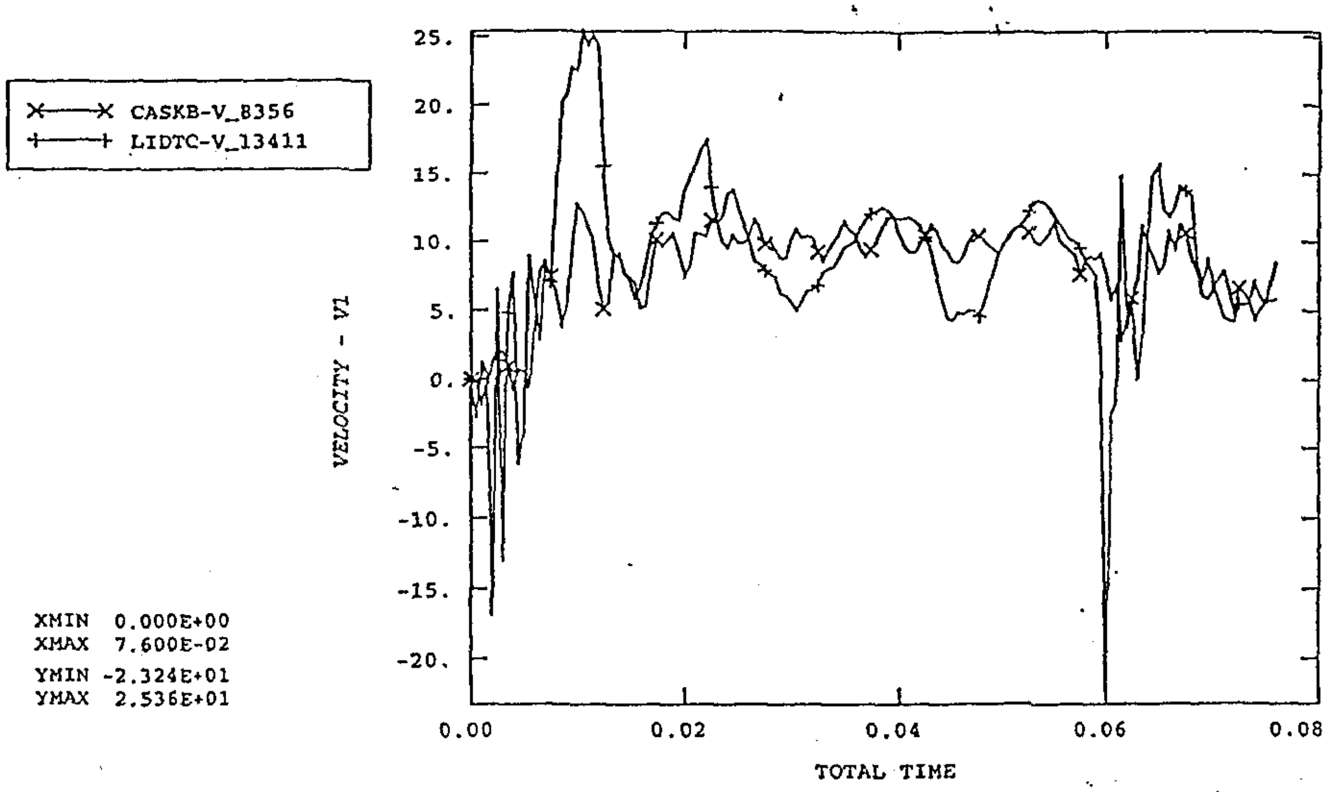

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Figure 7-5, The Horizontal X Direction Displacement Time History of the Bottom Center of the MCO, Middle of MCO Shell, and the Bottom Center of the Shield Plug.
(input file mhmck4.inp 10/6/98)

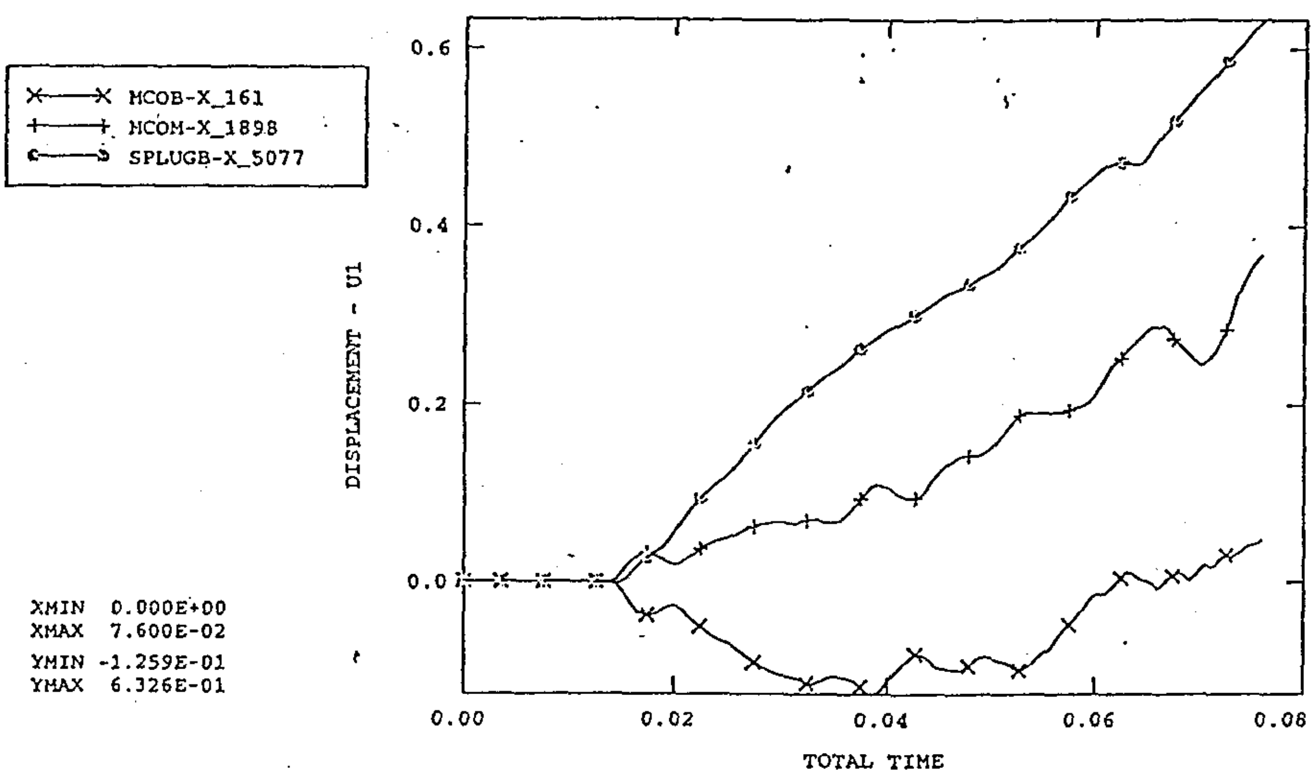

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Figure 7-6, The Horizontal X Direction Displacement Time History of the Bottom Center of the MCO, *Middle of MCO Shell, and the Bottom Center of the Shield Plug.*
(input file mhmck4.inp 10/6/98)

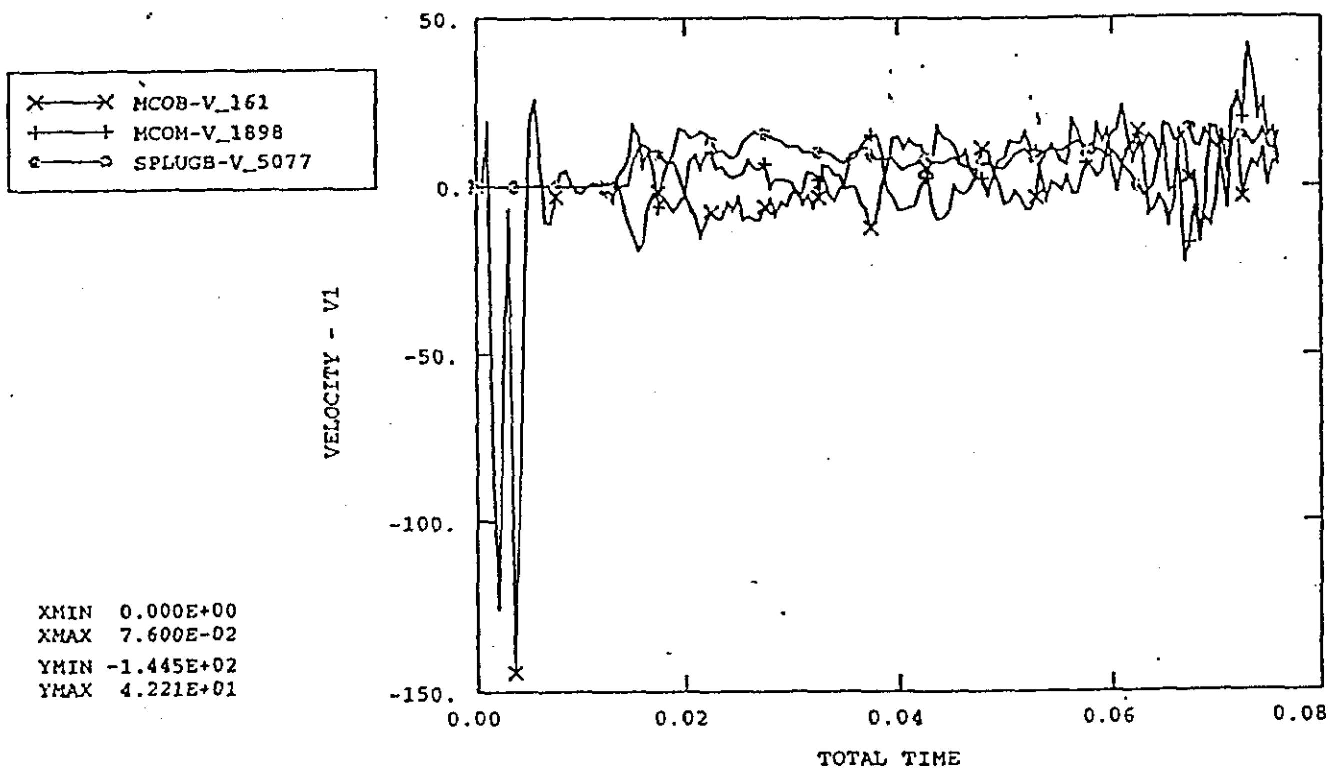

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Figure 7-7, The Horizontal X Direction Displacement Time History of the Six Mark 1A Baskets with #1 being the Bottom Basket and #6 the Top Basket.
(input file mhmck4.inp 10/6/98)

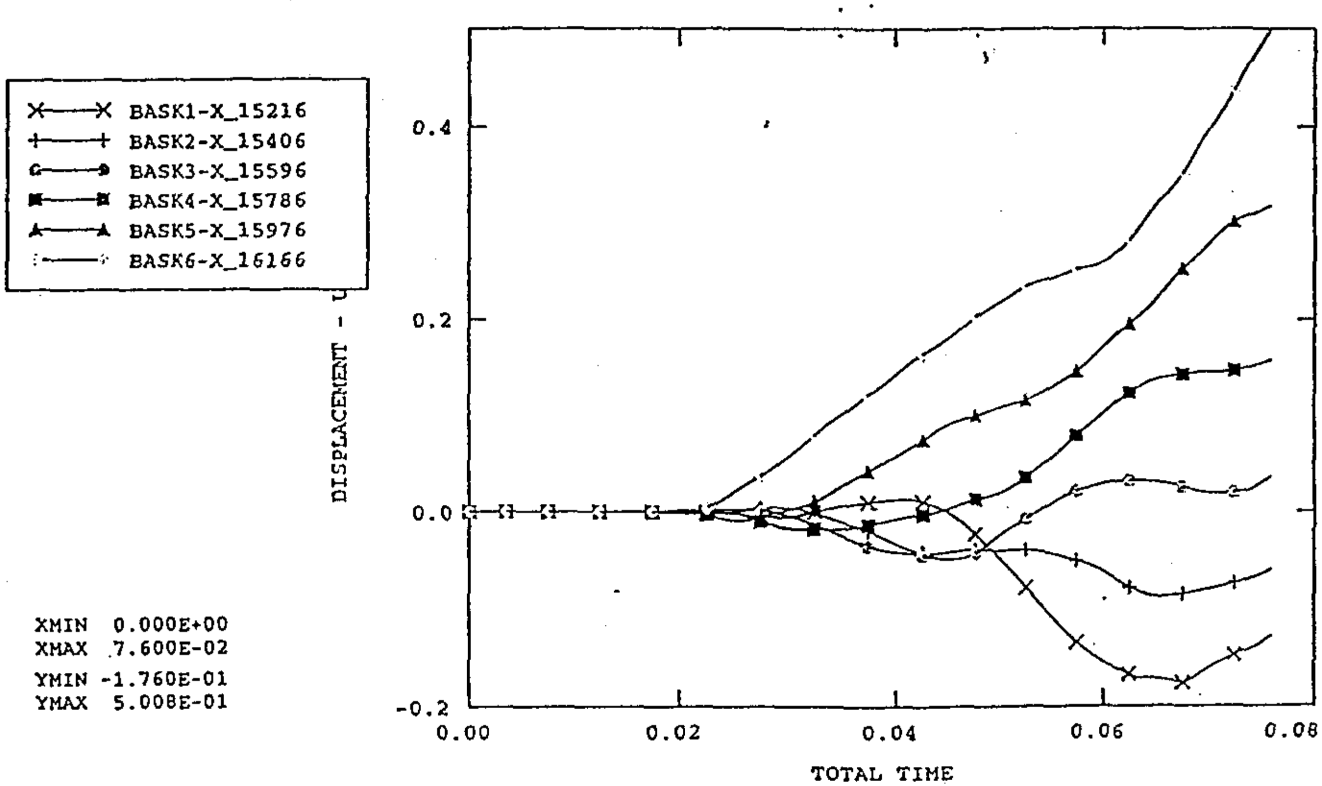

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Figure 7-8, The Horizontal X Direction Velocity Time History of the Six Mark 1A Baskets with #1 being the Bottom Basket and #6 the Top Basket.
(input file mhmck4.inp 10/6/98)

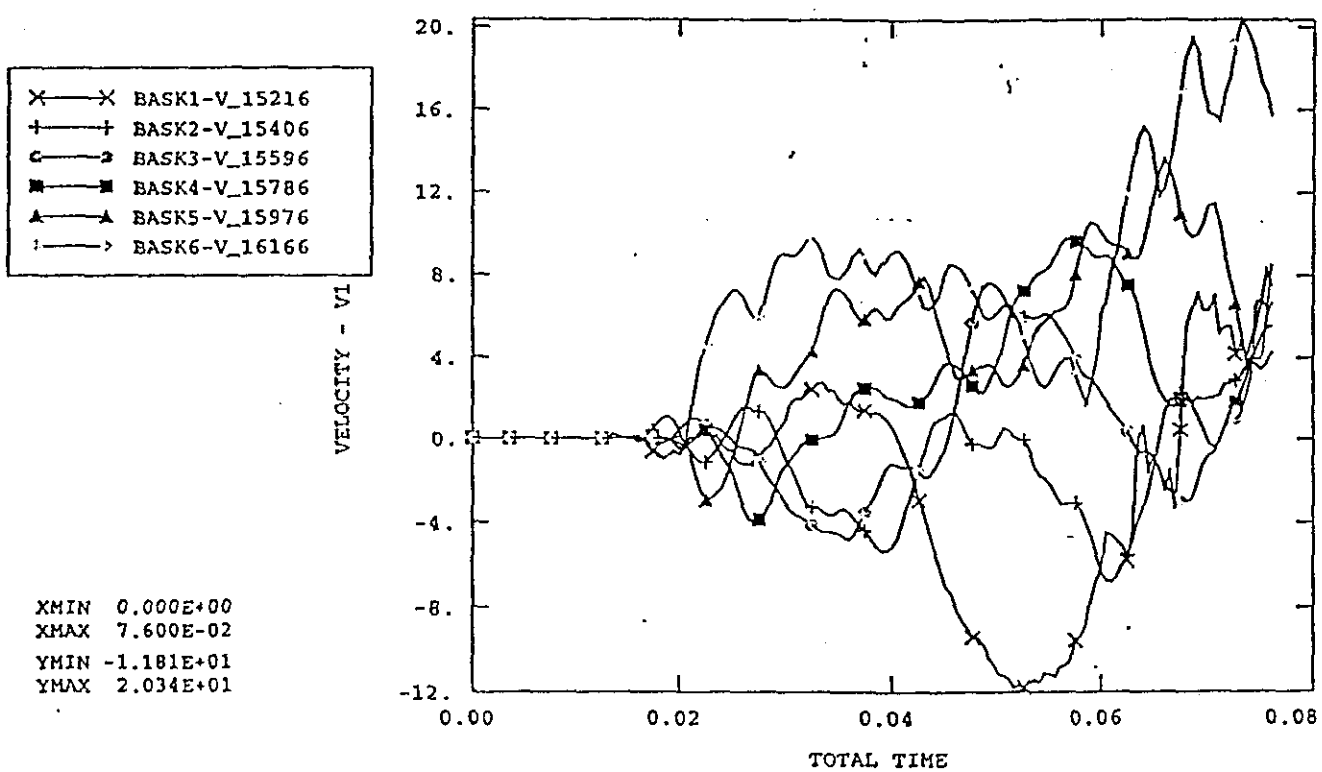

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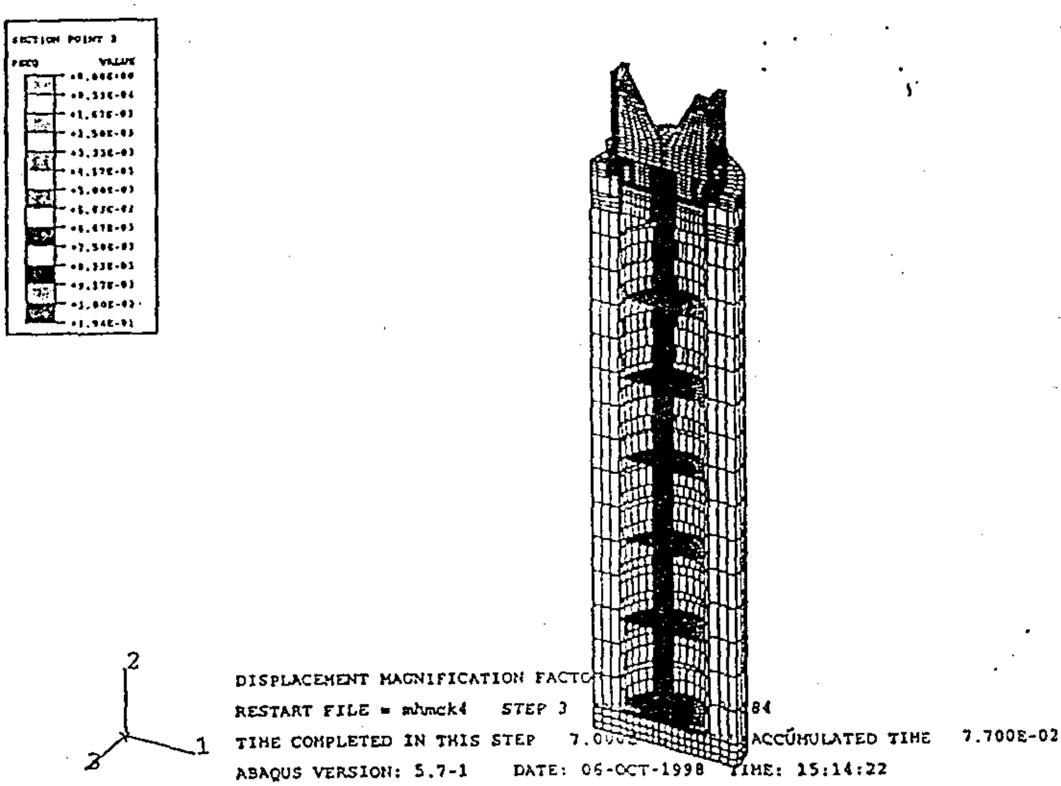
Figure 7-9, The Equivalent Plastic Strain at 77 Milliseconds of the Cask, Cask Lid, MCO, Shield Plug, and Baskets due to the 8 in/sec Impact of the MHM with the Static Cask/MCO. (input file mhmck4.inp 10/6/98)



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Section 8.0 Analysis Results for MHM and Cask/MCO Impacting the Transfer Pit Wall

The second simulation evaluated a MHM and cask/MCO combination moving at 8 inches per second impacting the side wall of the CSB transfer pit.

Figure 8-1 shows a side view of the initial conditions for the simulation of the MHM and cask/MCO impacting the CSB transfer pit wall. Figure 8-2 shows an isometric view of the initial conditions for the simulation of the MHM and cask/MCO impacting the transfer pit wall. In Figure 8-2 the model can be seen to be a half model. The simplified MHM is modeled as a large steel ring moving in the positive x or 1 axis direction at 8 inches/second. Also, in Figure 8-2 the cask/MCO is moving in the positive x or 1 axis direction at 8 inches/second. Figure 8-3 shows a zoomed isometric view of the initial conditions of the MHM and cask/MCO impacting the wall. In Figure 8-3 some details of the basket modeling can be observed. It should be noted that the MHM and cask/MCO are positioned 0.024 inch from the wall to allow the gravity and pressure loads to be applied before the actual impact. Figure 8-4 shows a zoomed isometric view of the initial conditions of the MHM and cask/MCO impacting the wall.

Figure 8-5 shows the horizontal x direction displacement time history of the MHM at a lumped mass center point. In Figure 8-5 the MHM displacements can be seen to increase and then to reverse at 25 milliseconds. Figure 8-6 shows the horizontal x direction velocity time history of the bottom center of the MHM at a lumped mass center point. In Figure 8-6 the velocity of the MHM can be seen to go to zero at 25 milliseconds.

Figure 8-7 shows the horizontal x direction displacement time history of the bottom center of the cask and the top center of the cask lid. In Figure 8-7 the cask bottom displacements can be seen to increase and then to reverse sign indicating the bottom bouncing back at 5 milliseconds. Also, in Figure 8-7 the top of the cask lid continues to increase indicating rotation of the cask. Figure 8-8 shows the horizontal x direction velocity time history of the bottom center of the cask and the top center of the cask lid. In Figure 8-8 dynamic oscillation of the velocity of the top and bottom of the cask can be observed with the velocity reversing sign between the bottom and top indicating cask rotation.

Figure 8-9 shows the horizontal x direction displacement time history of the bottom center of the MCO, middle of MCO shell, and the bottom center of the shield plug. In Figure 8-9 the MCO displacements can be seen to begin increasing at a constant rate until at approximately 15 milliseconds when the MCO impacts the inside of the cask, as compared to the cask displacements beginning at approximately 4 milliseconds. The MCO takes approximately 10 milliseconds to slide over to the impact side of the cask. Figure 8-10 shows the horizontal x direction velocity time history of the bottom center of the MCO, middle of the MCO shell, and the bottom center of the shield plug. In Figure 8-10 dynamic oscillation of the velocity of the top and bottom of the MCO can be observed with the bottom and middle velocities approaching a negative and zero value respectively.

Figure 8-11 shows the horizontal x direction displacement time history of the six Mark 1A baskets with #1 being the bottom basket and #6 the top basket. In Figure 8-11 the basket displacements can be seen to begin increasing constantly until at 21 milliseconds as compared to the cask displacements beginning at approximately 4 milliseconds with the MCO following at approximately 15 milliseconds. The baskets take approximately 6 milliseconds to slide over to the impact side of the MCO. Figure 8-12 shows the horizontal x direction velocity time history of the six Mark 1A baskets. In Figure 8-12 dynamic oscillation of

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the velocity of the six Mark 1A baskets of the MCO can be observed after basket impact at 21 milliseconds.

Figure 8-13 shows at 35 milliseconds the equivalent plastic strain of the cask, cask lid, MCO, shield plug, and baskets due to the 8 inches/second impact of the MHM and the cask/MCO with the transfer pit wall. Figure 8-14 shows at 35 milliseconds the equivalent plastic strain of the baskets. In Figure 8-14 the maximum plastic strain can be seen to be approximately 0.3 per cent strain. The 8 inches/second impact of the MHM and the cask/MCO with the transfer pit wall does not do any significant damage to the MCO or the six Mark 1A baskets. The local deformations are mainly linear elastic. The MCO circumference retains the original dimensions. The MCO and baskets maintain all geometry requirements; basket criticality specifications are not violated for this impact.

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Figure 8-1, Side View of the Initial Conditions for the MHM and Cask/MCO Impacting the CSB Transfer Pit Wall.
(input file mhmck6.inp 10/19/98)

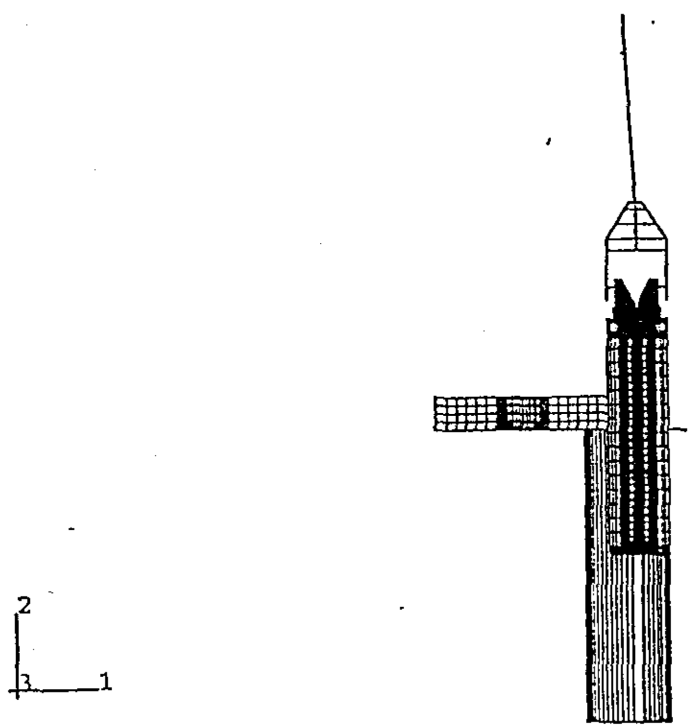

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Figure 8-2, Isometric View of the Initial Conditions for the MHM and Cask/MCO Impacting the CSB Tranfser Pit Wall.
(input file mhmck6.inp 10/19/98)

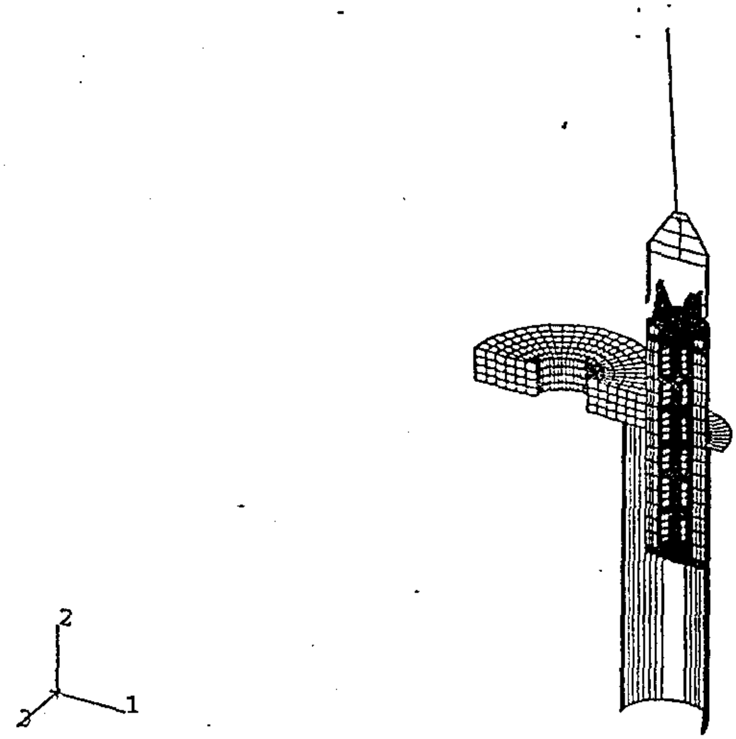

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Figure 8-3, Zoomed Isometric View of the Initial Conditions for the MHM and Cask/MCO Impacting the CSB Transfer Pit Wall.
(input file mhmck6.inp 10/19/98)

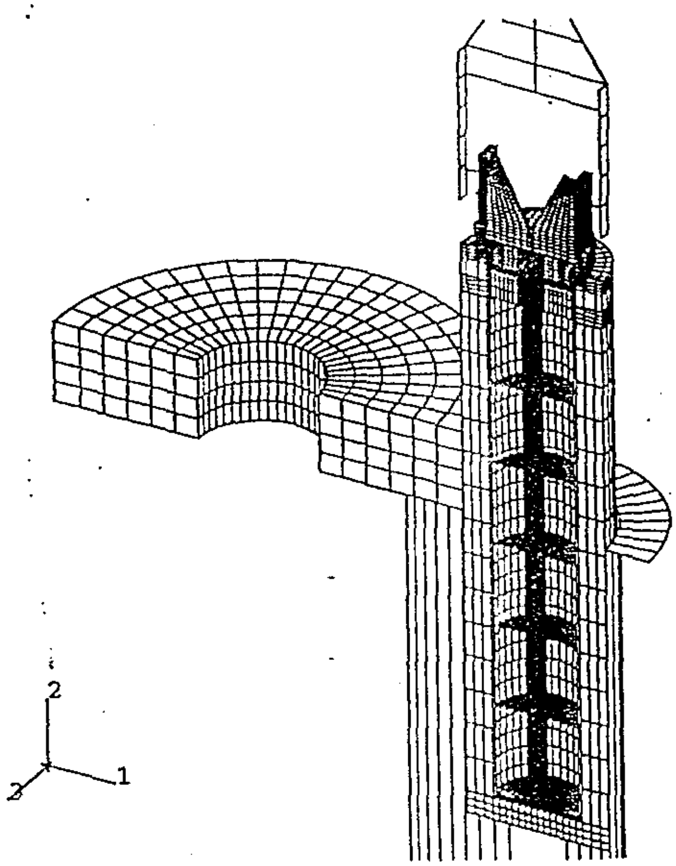

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Figure 8-4, Close Zoomed Isometric View of the Initial Conditions for the MHM and Cask/MCO impacting the CSB Transfer Pit Wall.
(input file mhmck6.inp 10/19/98)

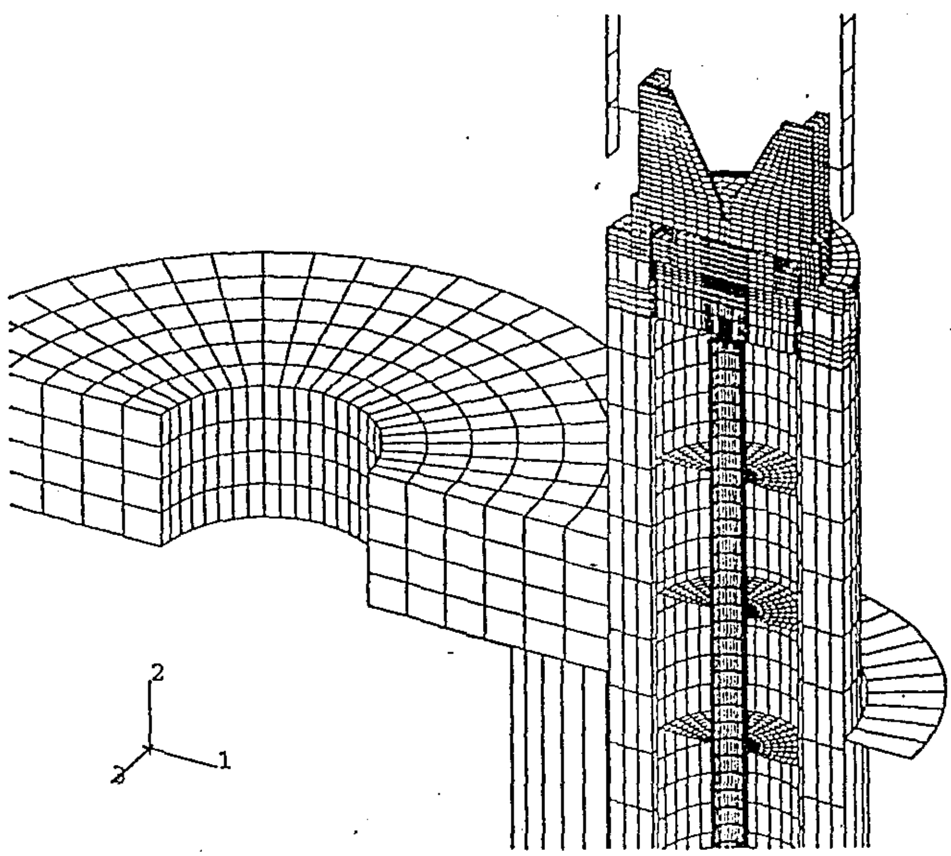

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Figure 8-5, The Horizontal X Direction Displacement Time History of the MHM Center Lumped Mass Point.
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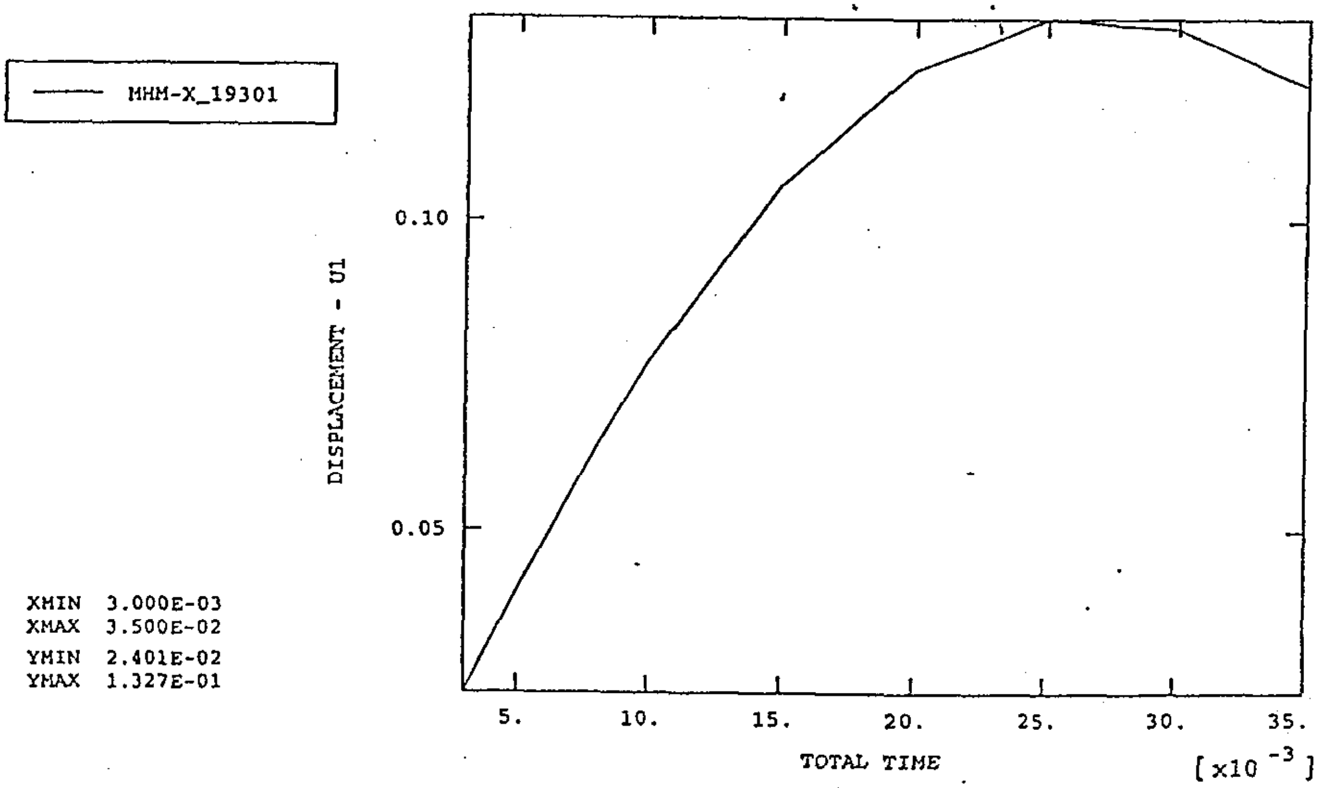

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Figure 8-6, The Horizontal X Direction Velocity Time History of the MHM Center Lumped Mass Point.
(input file mhmck6.inp 10/19/98)

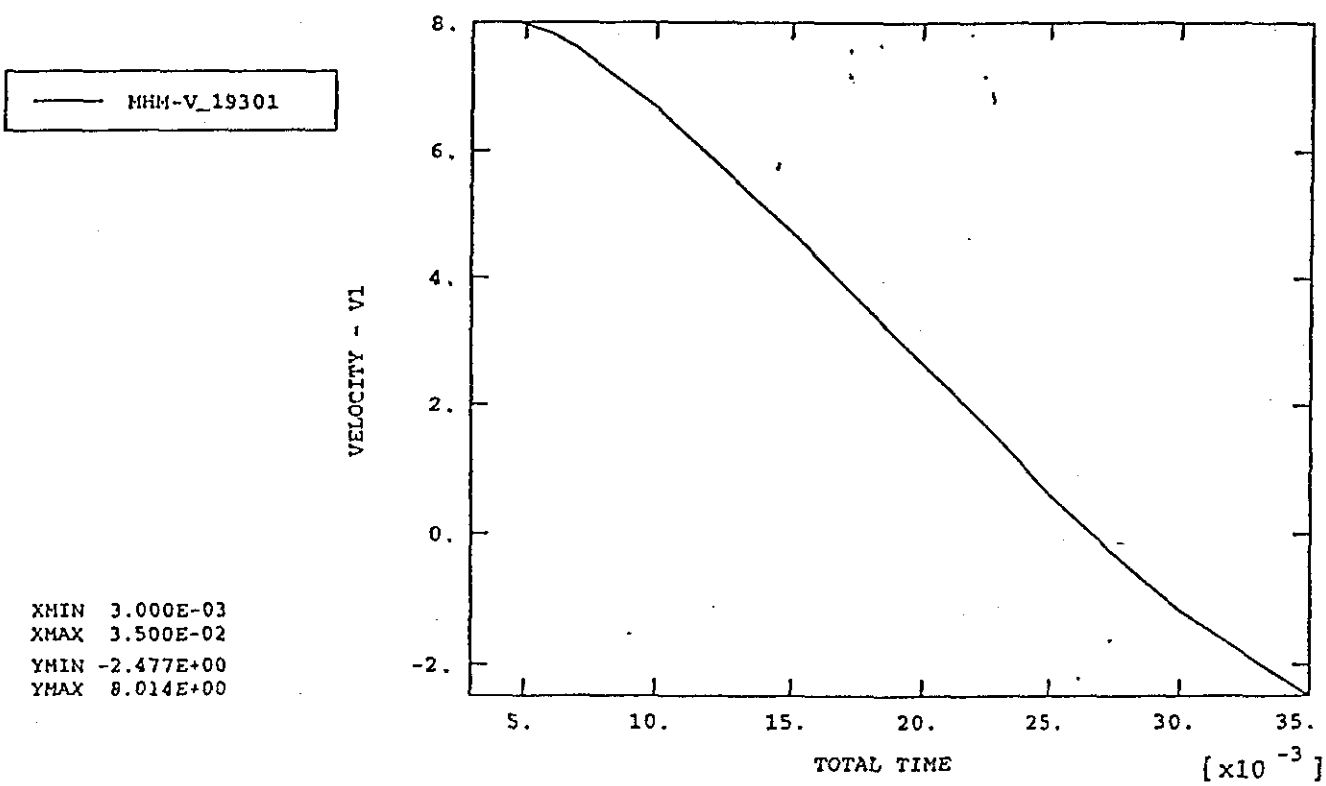

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Figure 8-7, The Horizontal X Direction Displacement Time History of the Bottom Center of the Cask and the Top Center of the Cask Lid.
(input file mhmck6.inp 10/19/98)

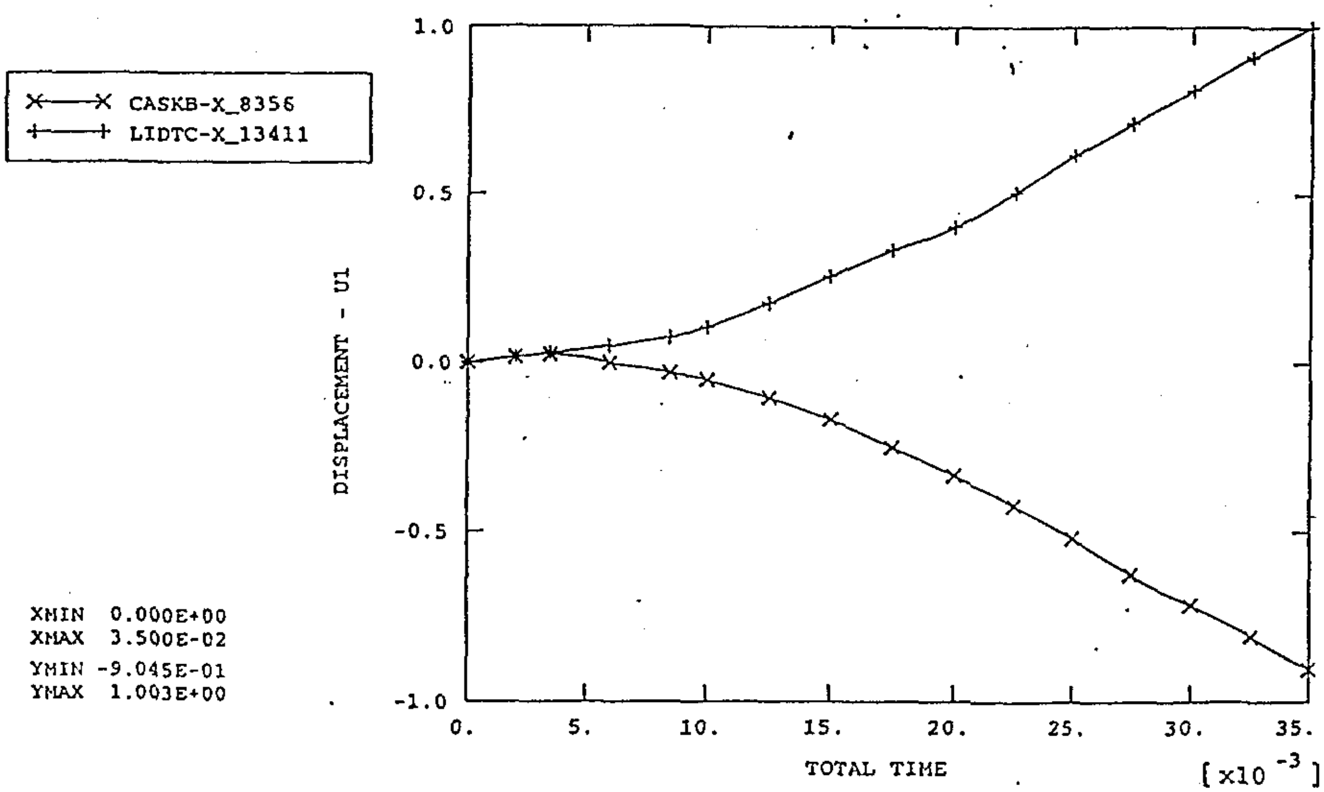

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Figure 8-8, The Horizontal X Direction Velocity Time History of the Bottom Center of the Cask and the Top Center of the Cask Lid.
(input file mhmck6.inp 10/19/98)

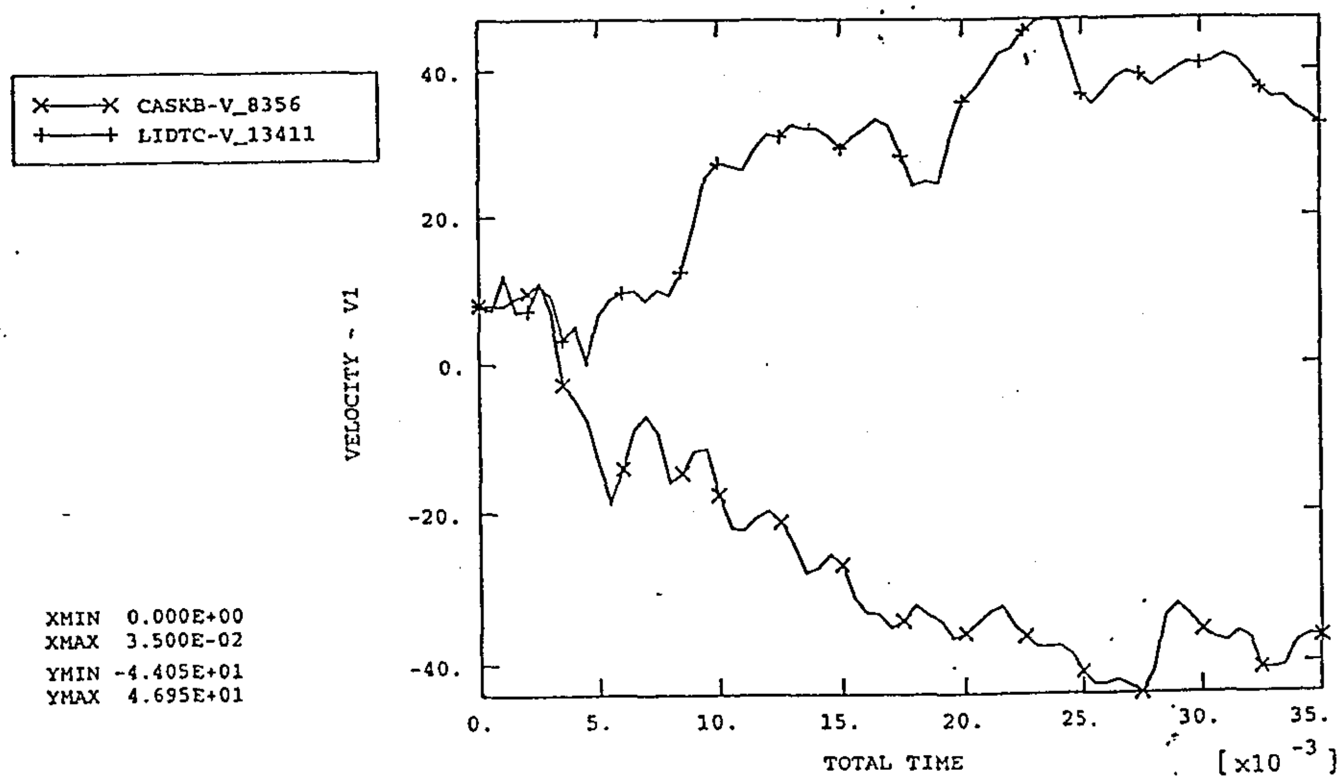

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Figure 8-9, The Horizontal X Direction Displacement Time History of the Bottom Center of the MCO, Middle of MCO Shell, and the Bottom Center of the Shield Plug.
(input file mhmck6.inp 10/19/98)

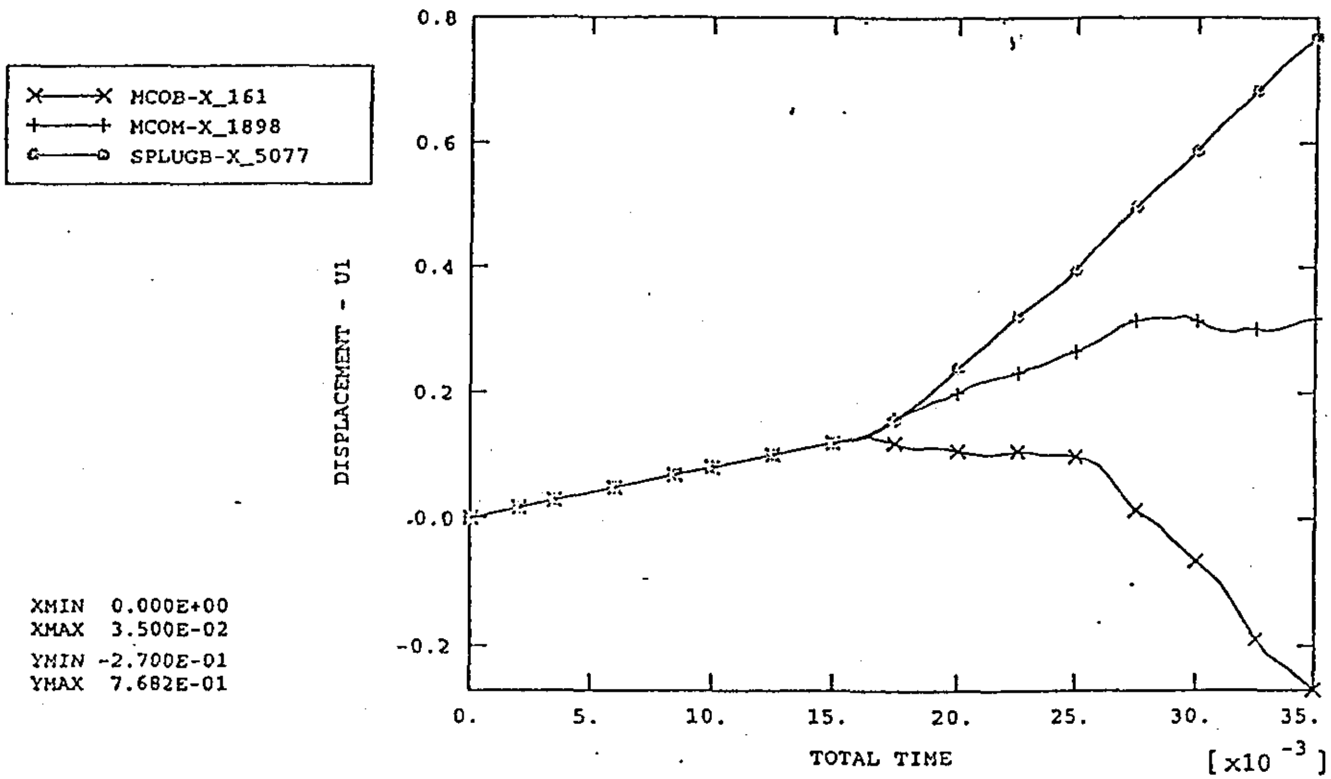

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Figure 8-10, The Horizontal X Direction Displacement Time History of the Bottom Center of the MCO, Middle of MCO Shell, and the Bottom Center of the Shield Plug.
(input file mhmck6.inp 10/19/98)

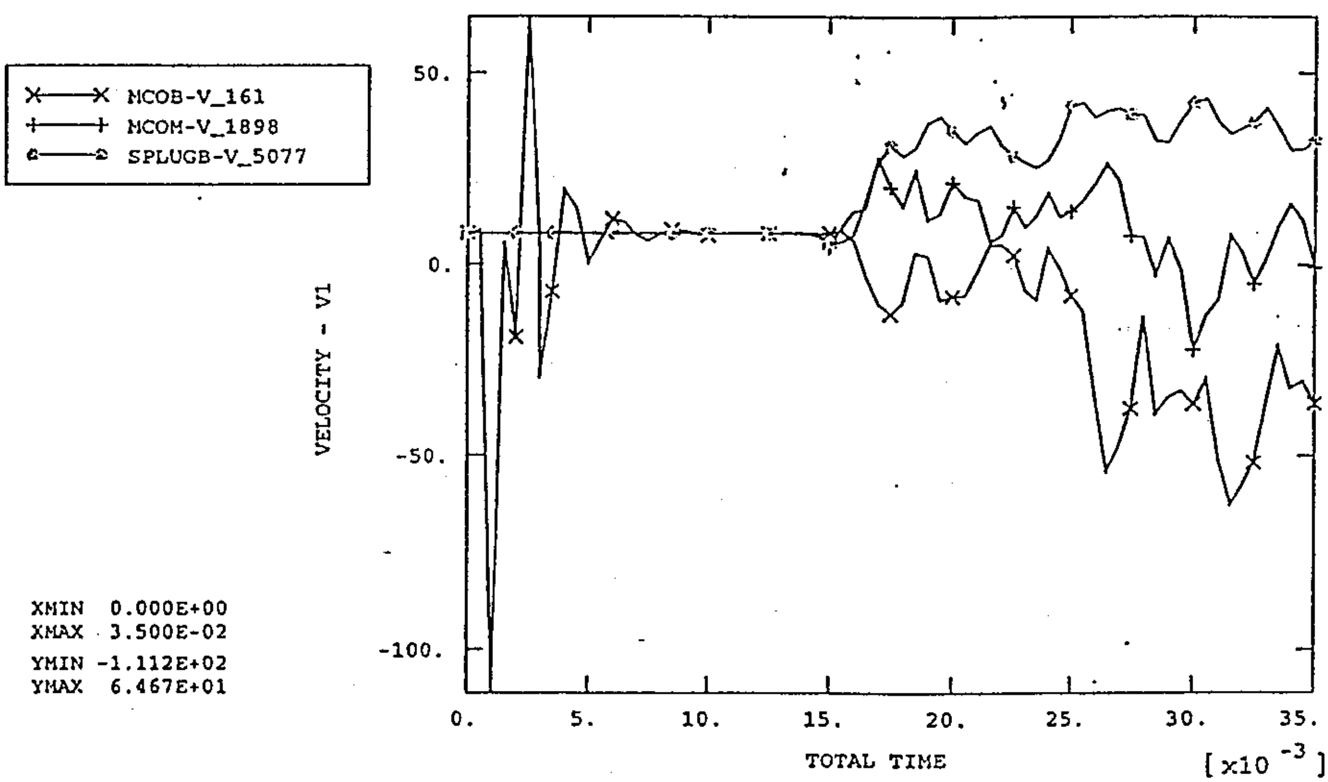

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Figure 8-11, The Horizontal X Direction Displacement Time History of the Six Mark 1A Baskets with #1 being the Bottom Basket and #6 the Top Basket.
(input file mhmck6.inp 10/19/98)

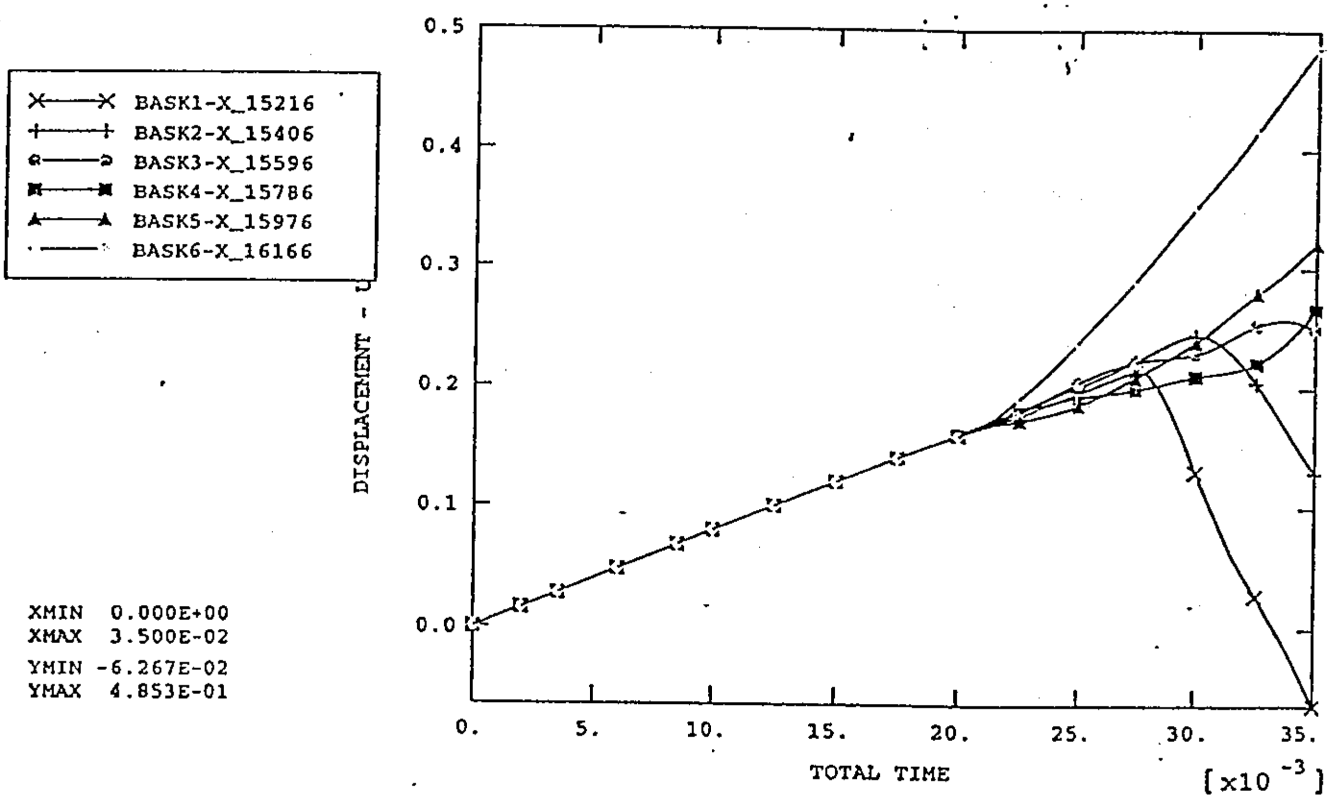

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Figure 8-12, The Horizontal X Direction Velocity Time History of the Six Mark 1A Baskets *with #1 being the Bottom Basket and #6 the Top Basket.* (input file mhmck6.inp 10/19/98)

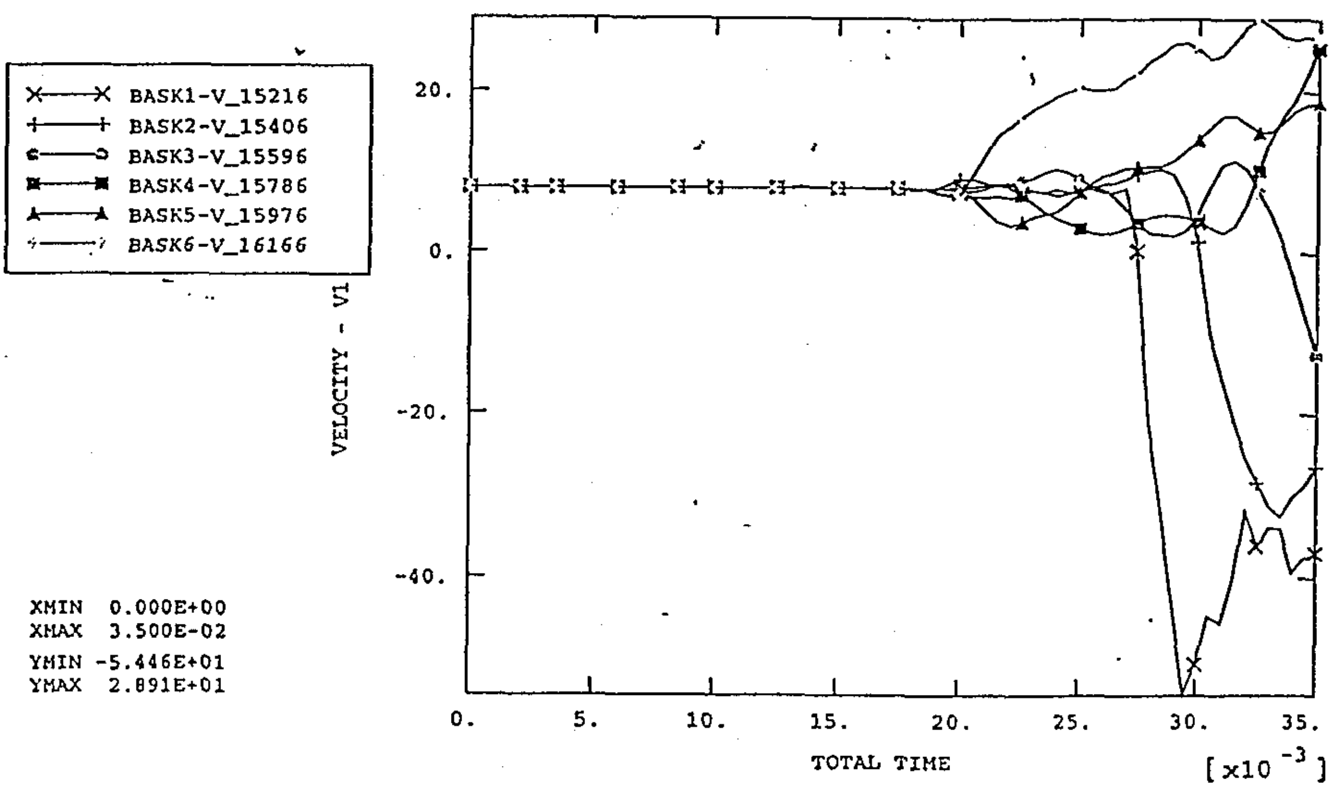

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Figure 8-13, The Equivalent Plastic Strain at 35 Milliseconds of the Cask, Cask Lid, MCO, Shield Plug, and Baskets due to the 8 in/sec Impact of the MHM and Cask/MCO with the CSB Transfer Pit Wall. (input file mhmck6.inp 10/19/98)

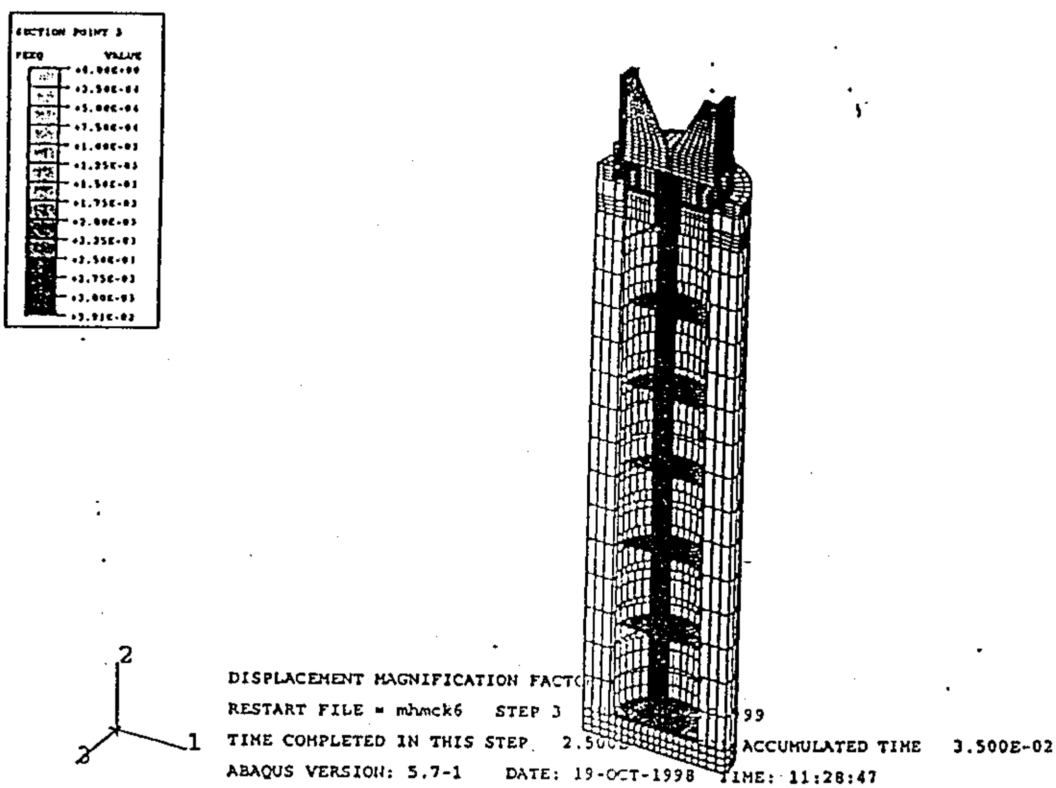

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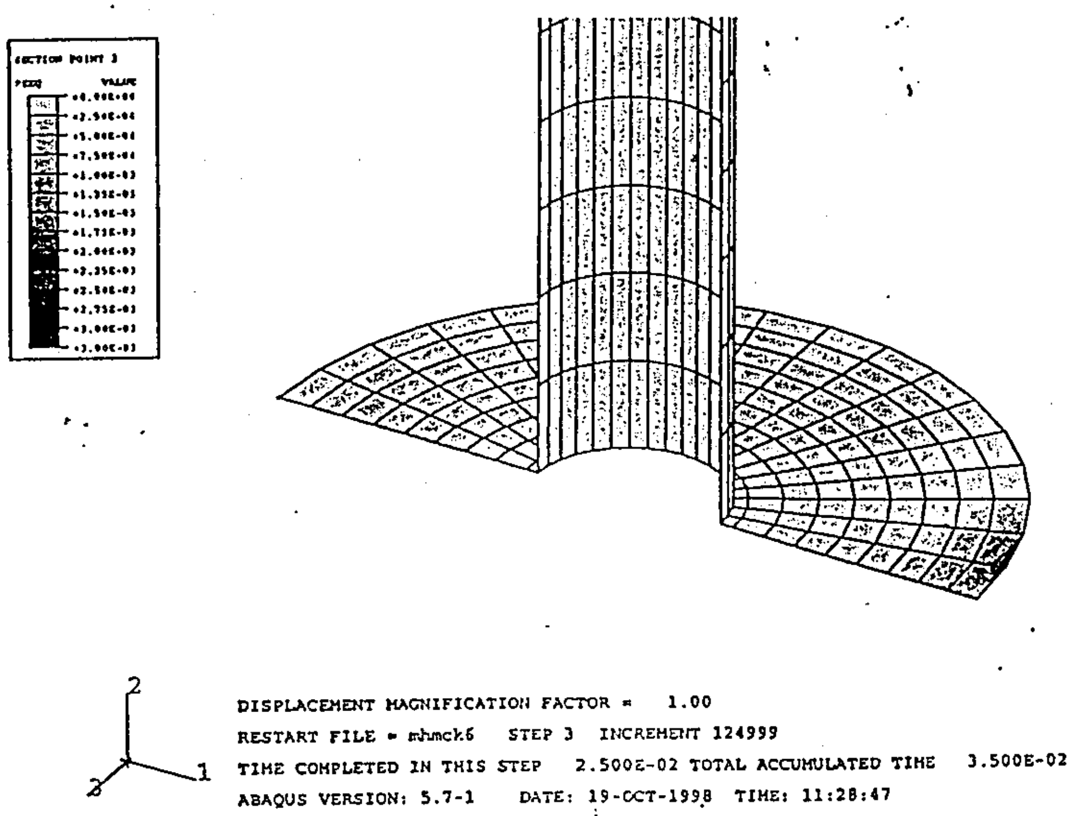
Figure 8-14, The Equivalent Plastic Strain at 35 Milliseconds of the Bottom Basket due to the 8 in/sec Impact of the MHM and Cask/MCO with the CSB Transfer Pit Wall.
(input file mhmck6.inp 10/19/98)



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SNF-6031, Simulation of Multi-Canister Overpack (MCO) Handling Machine Impact with Cask/MCO during Insertion into the Transfer Pit		ECN No. N/A

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