11-9270

NAC INTERNATIONAL

Atlanta Corporate Headquarters

September 20, 2000

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738
Attn: Document Control Desk

Subject: Information Supplement in Response to the NRC Question on NAC-UMS® Universal Transport System Responses to RAI-1 on the Scale Model Side Drop Test (TAC No. L22452)

References: 1. Submittal of NAC-UMS® Universal Transport System Safety Analysis Report, Revision UMST-00A – Docket 71-9270

Dear Sir/Madam:

NAC International (NAC) herewith submits three copies of supplemental information in response to the U.S. NRC Question on the RAI-1 Responses on the UMS® quarter-scale model side drop test results.

This response provides: a description of the actual physical configuration of the UMS® quarter-scale model and the pertinent accelerometer data; descriptions of the rigid-body and the elastic LS-DYNA models of the UMS® scale model; justification of the accelerometer traces for the side drop test; an assessment of the potential effects of friction and a small slap-down angle on the side drop test results; an assessment of the effect of tolerances on the distribution of mass along the axis of the model; and justification of the NAC-UMS® impact limiter design as presented in Reference 1.

This submittal is considered NAC Proprietary Information. The executed Proprietary Information Affidavit is attached.

If you have any comments or questions, please contact Jim Hobbs at (770) 447-1144, ext. 305, to arrange a conference call with the appropriate NAC technical staff.

Sincerely,

Jim Hobbs for

Thomas C. Thompson
Director, Licensing
Engineering & Design Services

Attachments: Proprietary Information Affidavit
Information Supplement – UMS® Scale Model Side Drop Test Results

ED20001397

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AFFIDAVIT
IN SUPPORT OF PROPRIETARY INFORMATION
CONTAINED IN THE INFORMATION SUPPLEMENT TO THE RAI-1
RESPONSE FOR THE NAC-UMS® UNIVERSAL TRANSPORT SYSTEM
SCALE MODEL SIDE DROP TEST

State of Georgia, County of Gwinnett

Willington J. Lee (Affiant), Vice President and Chief Engineer of NAC International, hereinafter referred to as NAC, at 655 Engineering Drive, Norcross, Georgia 30092, being duly sworn, deposes and says that:

1. Affiant is personally familiar with the trade secrets and privileged information contained in the Information Supplement to the RAI-1 responses being submitted in conjunction with the request for approval of the NAC-UMS® Universal Transport System Certificate of Compliance. Affiant requests that the Nuclear Regulatory Commission, pursuant to Chapter 10 of the Code of Federal Regulations, Part 2.790 (10 CFR 2.790) "Public Inspections, Exemptions, Request for Withholding," withhold the information contained within the Information Supplement to the RAI-1 response, hereafter referred to as the Proprietary Material, from public disclosure.

2. This information has been and is held in confidence by NAC International Inc.

3. The information contained within the proprietary material is the result of a design calculation including component design details and critical dimensions that were developed by NAC and interpretation of confirmatory test data. This type of information is held in confidence based on the significant commercial investment of time and money expended in its development.

4. The Proprietary material is transmitted to the Nuclear Regulatory Commission in confidence.

5. The information that is being claimed as trade secrets and privileged information has not been and is not available in public sources.

6. NAC has invested a considerable amount of time, engineering labor, and money in the development of the information. Public disclosure of this information would cause substantial harm to the competitive position of NAC. Others seeking to develop similar analysis would have to make similar investments to develop the information on their own as long as the information is not disclosed to the public.

Willington J. Lee
Vice President and Chief Engineer
NAC International Inc.

Subscribed and sworn to before me this 20th day of September, 2000.

Notary Public in and for the
County of Cobb
State of Georgia

My commission expires the 4th day of November 2002

Notary Public, Cobb County, Georgia
My Commission Expires Nov. 4, 2002

Information Supplement
UMS Scale Model Side Drop Test Results

Discussion topics:

- Discussion of the actual physical scale model configuration and test
- LS-DYNA model description – rigid body model
- LS-DYNA model of the elastic scale model side drop test
- Justification of the Accelerometer traces from the 1999 Oak Ridge Drop Tests
- Assessment of the slap down angle in conjunction with friction
- Assessment of tolerances of the mass distribution in the axial direction
- Justification of the currently submitted impact limiter design (impact limiter trunnion modification)

Discussion of the actual physical scale model configuration and test

The quarter scale model is represented by drawings 790-301 (model body), 790-302 (bottom impact limiter) and 790-303 (top impact limiter). The scale model cask body and weights were fabricated within tolerance and specifications as noted on the drawings. Concentrated weights are axially spaced as internals to represent the total package weight, center of gravity and package moment of inertia. The concentrated weights and spacers were designed to be free standing and an adjustable component part of the total package permitting changes to the center of gravity and total package weight without major fabrication changes. These concentrated weights and spacers are neither axially linked together, nor attached to the body of the model.

In the actual UMS transport cask, the canister is full length and the fuel basket is the structural unit responsible for maintaining the configuration of the fuel. The UMS basket has six or eight (depending on PWR or BWR basket) tie rods on the exterior of the basket. These tie rods are continuous the entire length of the basket and secure the support disks and heat transfer fins. In the side drop orientation the support disks evenly distributed load over the length of the canister. In the actual cask and canister, the shield and structural lids are the only concentrated loads of the package contents and are welded to the canister. The top two weights of the scaled model comprise a concentrated load of 500 pounds. This load is representative of a full scale loading of nearly 32,000 pounds, or the weight of the distributed fuel contents. Therefore, the side drop scale model weight distribution in combination with the elastic response of the scaled system was not an identical match for the full scale package.

Performance verification of the impact limiter was captured in the test with correct distribution of the total cask weight onto the impact limiter. However, accelerometer data recorded during the drop test has displayed model response representative of the elastic scale mode and model concentrated weight distribution that has lead to the need for further explanation of test results. The evaluation discussions presented in the following sections provide the analytical study validating system performance.

LS-DYNA model description – rigid body model

To examine the effect of removing the elastic response from the quarter scale model during the 30 foot side drop, an LS-DYNA model was constructed as shown in Figure 1. This model includes the top and bottom limiter as well as the body. Due to symmetry of the cask, only one half of the cask is modeled for this analytical evaluation. Symmetry boundary conditions were applied at the plane of symmetry. In this analysis, the body was made rigid by selecting the LS-DYNA rigid body option for the cask materials. Since the cask body was made rigid, further simplification of the model was permitted by distributing the concentrated weights of the scale model internals onto the body shell, while still maintaining the total weight and CG. The cask body used in this analysis also contains a trunnion, in which the model trunnion dimensions corresponds to the actual trunnion dimensions for the scaled model (Figure 1, detail). The trunnion in the model was represented by rigid shell elements. This modeling simplification did not affect the crushing of the redwood material and resultant cask response.

The significant feature of the actual limiter is the section of the impact limiter that experiences crush and decelerates the cask model. For this reason, without any degradation of the ability to model the impact limiter crushing, the detailed models of the limiters did not contain the upper half section of the limiter as shown in Figure 2. The dimensions used in the model correspond to those contained in the above referenced drawings for the quarter scale model. The top limiter (in Figure 2) shows that the cut out for the trunnion was modeled to accurately represent the redwood under the trunnion. The bottom impact limiter design and finite element model do not contain this type of cut out. Redwood parallel to grain properties are defined for the impact limiter material. The properties are taken at ambient temperature condition, representing actual test conditions. The impact plane is modeled as an unyielding surface. The analysis condition for this model included the following:

1) the cask is in the horizontal position,
2) an initial velocity of 527.5 inches/second,
3) the friction between the impact limiter and the rigid plane is 0.5, and
4) gravitational acceleration of 1g.

Two acceleration time histories were extracted at positions corresponding to the top and bottom accelerometers used in the drop tests. The acceleration traces are shown in Figure 3. These traces do not exhibit any positive peaks at the end of the drop test. The maximum accelerations were reported to be 219 g's and 180 g's for the top and bottom locations respectively.

These analytical results are representative of actual scale model drop test results presented in the UMS SAR.

LS-DYNA model of the elastic scale model side drop test

To examine the effect of the concentrated weight and the elastic response of the system, the LS-DYNA model used in the first analysis was modified to include elastic properties and concentrated mass. Elastic properties for the main part of the body were used and the lump masses for the disks were also used. The detailed portion of the model for the trunnion and its attachment to the body remained rigid components. This would not affect the elastic response of the system. The same conditions used for the rigid model were also used in this evaluation. The acceleration traces for the top and bottom locations are shown in Figure 4. The maximum accelerations are shown below.

LS-DYNA Elastic Body Case Accelerations

Acceleration Location	Negative Acceleration (g)	Positive Acceleration (g)
Top	229	16
Bottom	193	37

30 Foot Side Drop Test Accelerations

Acceleration Location	Negative Acceleration (g)	Positive Acceleration (g)
Top(1)	182 (3)	198
Bottom(2)	150	76

(1) This is from accelerometer designated as Side 2
(2) This is the average of the two accelerometers at the bottom end of the cask.
(3) The average of the negative peak acceleration for the two top accelerometers is 204 g's.

The elastic condition shows a positive peak, or the indication of the elastic response of the model resulting in a rocking condition. This behavior does not appear in the rigid case. This elastic and concentrated mass LS-DYNA model yields approximately 12% larger negative acceleration than the average (204g) for the top location. The top and bottom results indicate that the LS-DYNA values are conservative for the controlling negative values, which occur in decelerating the model. While the positive peaks from the analysis are not as large as those observed in the test, the analysis does show that an elastic effect does result in a rocking motion. Since the rigid model would not contain the effect of a concentrated mass, it would be concluded that the rocking motion is due to the concentration of the masses in conjunction with the elastic body. It is noted that such concentration of the weights is not representative of the package design.

The analyses indicate that the calculation methodology using LS-DYNA provides a conservative methodology to evaluate accelerations developed by the impact limiters during a 30 foot drop.

Justification of the Accelerometer traces from the 1999 Oak Ridge Drop Tests

In comparing the accelerometer data from the side drop test, it is observed that the positive peaks for the bottom accelerometers are within approximately 15% of the average value for the bottom negative peak accelerometers. It is noted that this positive peak occurs near the end of the event. This degree of comparison does not exist for the top accelerometers. The positive peak acceleration for the top accelerometers for Side 1 was greater than 100% of the positive peak from the accelerometer of Side 2. It is noted that the negative peaks (of the top accelerometers), which occur in the initial impact differ by only 15% (of the average), which is in the same range of difference as the bottom accelerometers for the positive peak. With three of the four accelerometers showing positive peaks less than or equal to the negative peak, the positive peak for accelerometer Side 1 is significantly inconsistent with the other three accelerometers. The positive peak for the Side 1 accelerometer is nearly double that of the maximum negative acceleration for Side 1.

The accelerometers are mounted on blocks, which are welded to the model body. The model body is sufficiently rigid to ensure that the relative motion from one side of the model body to the other side of the model body is insignificant. While accelerometers are known to be sensitive to mechanical noise, the extent of the inconsistency of the Side 1 and Side 2 positive accelerations are considered to be sufficiently large to require a significant level of deformation of the body to occur to permit this difference. In such a case, the bottom accelerometers would have also shown evidence of a large discrepancy. The accelerometer was tested after the 30 foot side drop test and was shown to be operational. However, the accelerometer is mechanically attached to the block, not welded, to permit it to be removed. The "after test" is important, but it is not sufficient to indicate that a problem did not develop during the impact. The observation of the good agreement in trend of the three accelerometers is sufficient to indicate that the top accelerometer for Side 1 encountered a mechanical response problem during the later portion of the impact. If the accelerometer limits had been exceeded for Side 1, then due to the stiffness of the body, Side 2 would have experienced a similar problem, but it did not. For this reason the acceleration data for the accelerometer for Side 1 is not considered to be valid in this evaluation.

Assessment of the slap down angle in conjunction with friction

LS-DYNA was also used to evaluate the maximum accelerations for shallow angle (near side drop for 75°, 80° and 85°) drop orientations (90° is a side drop). The body was converted to be a rigid body to assess the effect of the shallow angle slapdown. To represent the maximum friction between the impact limiter and the impact plane, a coefficient of friction of 1.0 was used. This is considered to be significant to determine if friction in conjunction with a shallow angle drop would result in an increased acceleration due to slap down. The initial velocity used in each evaluation was 527.5 inches/second, which would correspond to the lowest part of the model being 30 feet above the impact plane. The maximum accelerations are presented below.

Drop angle	Max Secondary-slapdown (top acceleration) (g)
75	143
80	167
85	214
90	229

This indicates that for the UMS design, the ratio of length to radius of gyration is sufficiently low to negate an increased acceleration due to a shallow angle drop in conjunction with friction.

Assessment of tolerances of the mass distribution in the axial direction

The analyses using the elastic body with the concentrated weights indicate that an elastic response, nontypical of a side drop, can be developed. The concentrated mass distribution of a full scale 32,000 pound weight located on the shell is not realistic. The size of the gap between the weights and the shell is not considered to be significant when compared to the effect of the concentrated weight. The cask contents are actually distributed over the full length of the cask cavity. Therefore, further considerations of tolerances for mass distribution and gaps are not considered to be significant.

Justification of the currently submitted impact limiter design (impact limiter trunnion modification)

Upon completion of the drop testing, a review of the design of the limiter was performed. It was determined that the gap between the trunnion cut out of the limiter and the trunnion would be minimized. This modification is considered to be an enhancement to the performance of the top impact limiter since it would reduce the level of crush of the redwood. From this evaluation, it is concluded that the current analysis effort envelopes the current design of the top impact limiter.

Figure 1. Overall Model Plot for the UMS Quarter Scale Model

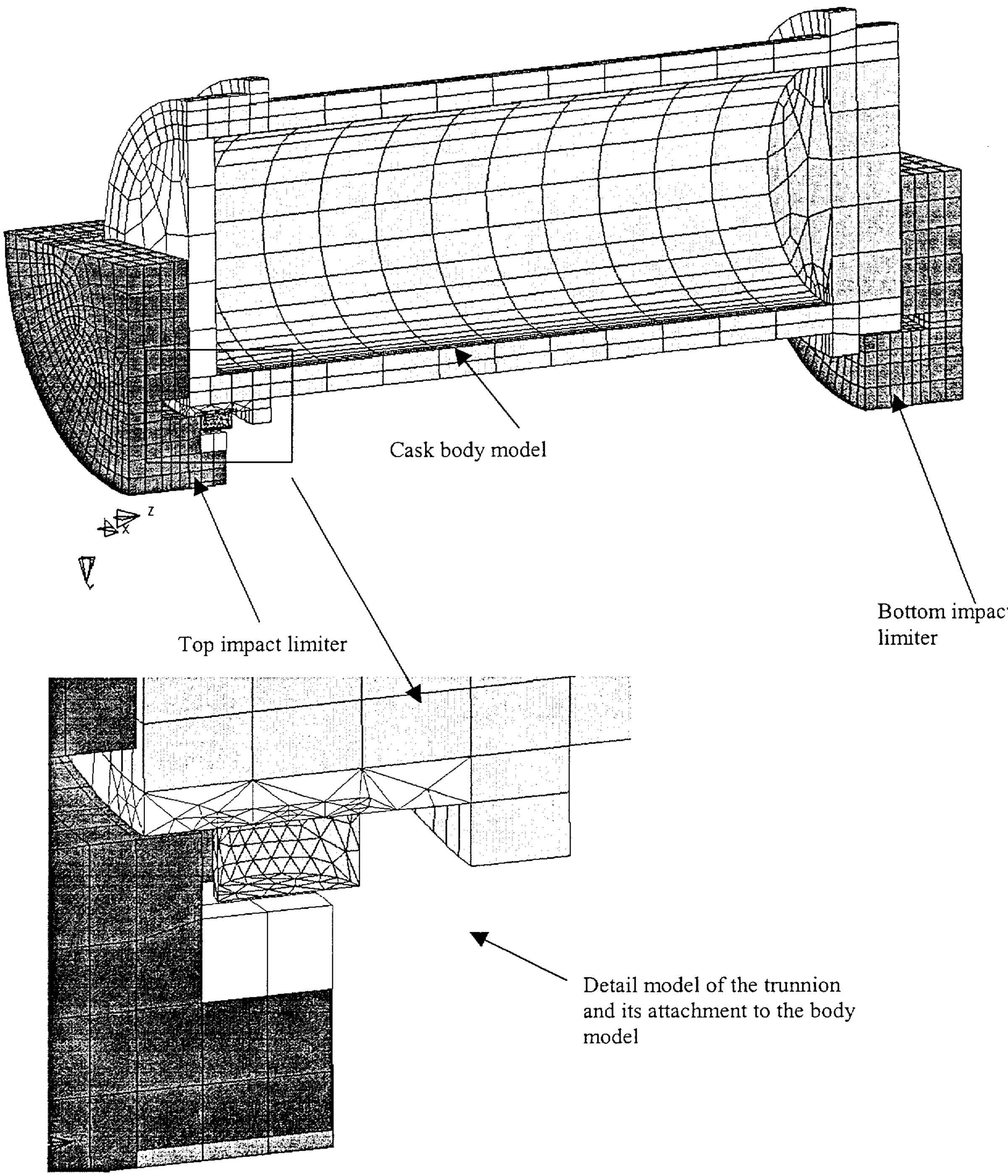

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Figure 2. Model Plots for the Top Impact Limiter and Bottom Impact Limiters for the UMS Quarter Scale Model

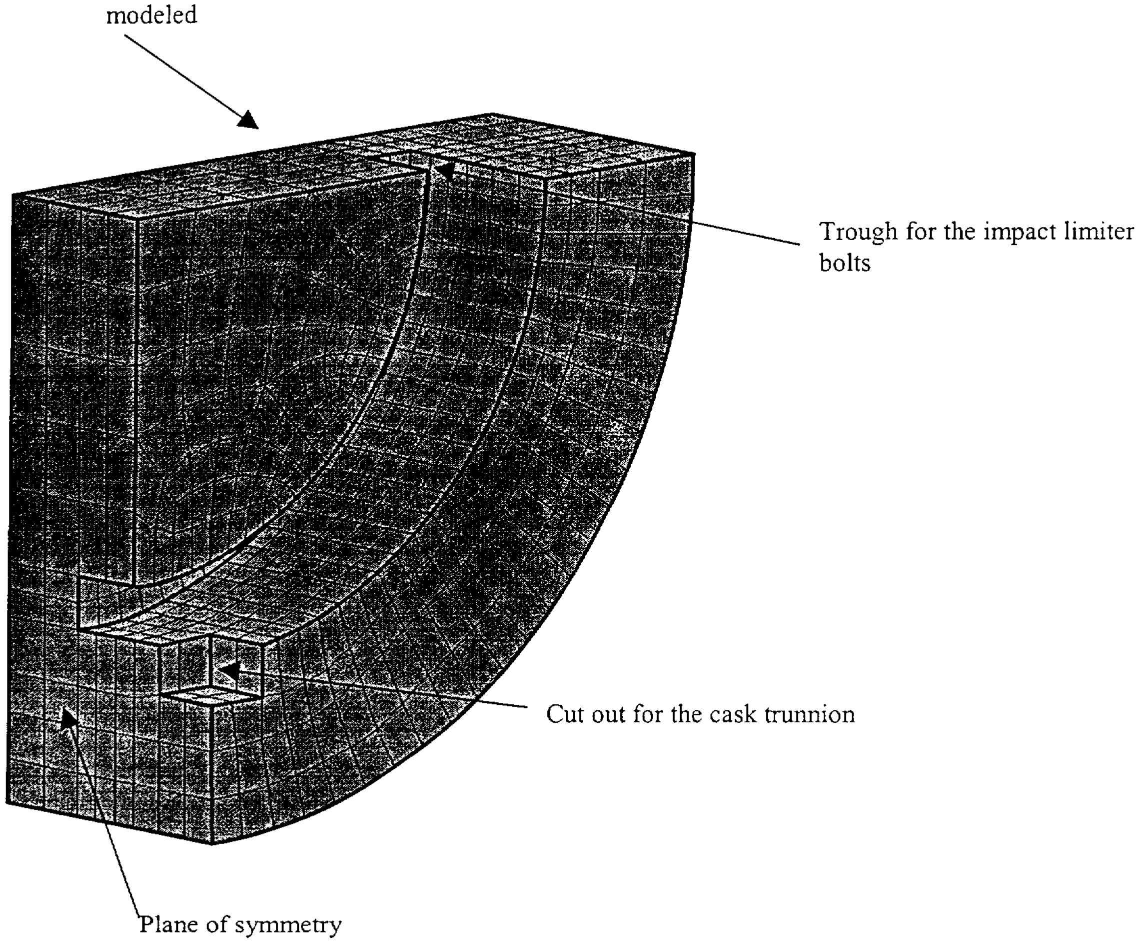

Figure 3. Acceleration Traces for the Rigid Body Model

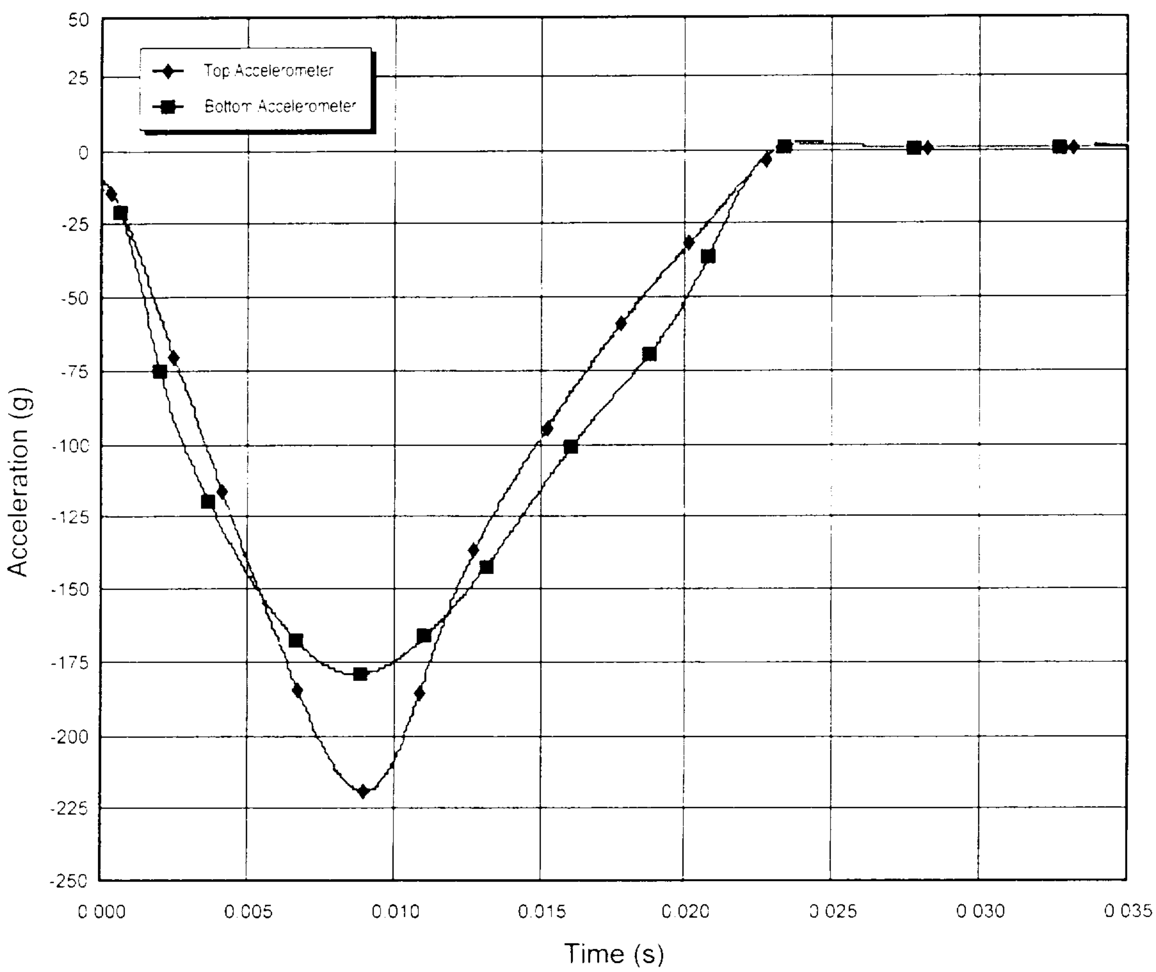

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Figure 4. Acceleration Traces for the Elastic Model of the Quarter Scale Model