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NOTICE OF DEVIATION

Client: RANOR		**Job #:** 63001-07N		**NOD #:** 001	
P. O. #: 108533	**Date of Deviation:**	20 November, 2006		**CPAR #:** N/A	
Notification Made To: *(Client Contact)*	Raul Pomares	**Notification Made By:**	Charles R. Pilotte		
Date:	20 November, 2006	**Via:**	Phone conference and E-Mail		
Test:	Heat Decay	**Test Item:**	AOS-165 Cask		
Specification:	TP63001-07N	**Model or P/N:**	AOS-165 Cask		
Revision/Date:	Revision 0 dated 03 November, 2006	**Serial Number:**	N/A		

REQUIREMENTS: *(Reference paragraph or section of specification)*

During Heat Decay test, the data logger was required to record data at one minute intervals.

DESCRIPTION OF DEVIATION

Data logger was not armed for capturing of data.

DISPOSITIONS/COMMENTS/RECOMMENDATIONS:

Repeat heat rise test to stabilization and then start Heat Decay test over again. Verify that all data is logging.

Client Test Witness (if applicable) Date	Quality Representative 12-6-06
Project Manager 20 NOV 06 Date	N/A Government QAR (if applicable) Date

NOTE: IT IS THE CLIENT'S RESPONSIBILITY TO ANALYZE AND DISPOSITION DEVIATIONS ON CLIENT TEST PROGRAMS.

FOR NTS QA US *Tracking Code 1*

1. Employee Error	2. Test Equipment Problem	3. Customer Item Problem	4. Weather	5. Power Failure	6. Equipment Limitations	7. Other

COR 16.0, REV. 4

63001

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8.3.2 Impact (Free-Drop) Test Report

CSA Engineering, Inc.

Engineering Services and Products in Structural Dynamics www.csaengineering.com

2565 Leghorn Street Mountain View, California 94043-1613 (650) 210-9000 Fax: (650) 210-9001

Test Report:
Drop Tests of the
Alpha Omega Services Shipping Cask
for Radioactive Material

Report No. 2007533 Rev 1
May 25, 2007

TABLE OF CONTENTS

This report documents the drop tests of a transport package for shipping radioactive material. The planning and the test itself were conducted by CSA Engineering in cooperation with the Nuclear Energy Division of General Electric and with Alpha Omega Services. CSA's work is conducted under Purchase Order number AOS-3301 from Alpha Omega Services who will be the end user of the transport package.

David A. Kienholz
David A. Kienholz
Vice President/Principal Engineer

Christian A. Smith
Christian A. Smith
Quality Assurance Manager

Revision History

Rev 0 19 April 2007

Initial release.

Rev 1 19 May 2007

Sequence photos for end drop, Figure 29, changed from color to black and white.

Redundancy in data types noted in introduction.

Total deceleration times estimated from video data and results included.

Conclusion added re. total deceleration time from video data.

1. Introduction and Background

This report documents the objectives, methods, results, and conclusions of drop tests of a shipping package for radioactive materials. Among other requirements imposed by the Nuclear Regulatory Commission (10 CFR 71), a shipping cask with its protective impact limiter must survive a 30-foot free fall onto an unyielding surface without loss of structural integrity by the cask. Damage to the impact limiter is allowed but the cask itself must remain capable of performing its primary functions of providing containment, shielding, and subcriticality[1] of the radioactive material.

The cask was the model AOS-165, the largest of a family of casks developed by General Electric Nuclear Energy for Alpha Omega Services. Therefore questions of testing scale models are not considered in this report.

As usual in testing of shipping packages, the test was done without radioactive material. This means that compliance with requirements must be demonstrated indirectly. In this case compliance was shown through dimensional inspections and leak rate tests of the cask before and after each drop.

In addition to verifying that the cask and impact limiter comply with their primary requirements, various instrumentation was used to obtain quantitative data during the test. This data is used both for engineering design and for verifying that the test itself meets its requirements. Measurement methods were chosen to produce some redundancy; data obtained by different methods can serve to verify each other or to fill in for each other in the event of lost data.

2. Test Overview and Objectives

The test objective is to obtain data for demonstrating the adequacy of analytical methods employed for qualifying the shipping package, both at the size tested and scaled-down versions. These analytical methods are used to show that the impact limiters are capable of limiting impact loads on the payload to an acceptable level.

The package was free-dropped three times, once in each of three orientations. The orientations, shown in Figure 1, and the reasons for choosing them are as follows.

[1] Subcriticality is always a requirement for a nuclear shipping container but is not relevant to the present test.

- End drop. The package was dropped with its axis vertical such that it struck on one end. This orientation usually tends to present the largest crushing surface and thus the largest crushing force and greatest payload acceleration.

- Side drop. The package was dropped with its axis horizontal such that the impact limiter sections on both ends struck the ground at nominally the same time. This tends to produce the largest bending and buckling loads in the cask walls.

- Slap-down drop. The package was dropped with its axis at an angle to the vertical as shown such that it lands on one side of one impact limiter section. This tends to present the smallest crush area and thus the largest inward deformation of the impact limiter. It also produces a "slap-down" effect where the cask acquires a significant angular velocity after initial impact, leading to high loads when the second impact limiter strikes the surface (slaps down).

The tests were performed in the order shown above with new impact limiters for each test. Previous tests have used the first two orientations successfully[2]. The slap-down orientation is new and is included in place of previous c.g.-over-corner drops on the basis of analysis which indicates that slap-down is a worst-case.

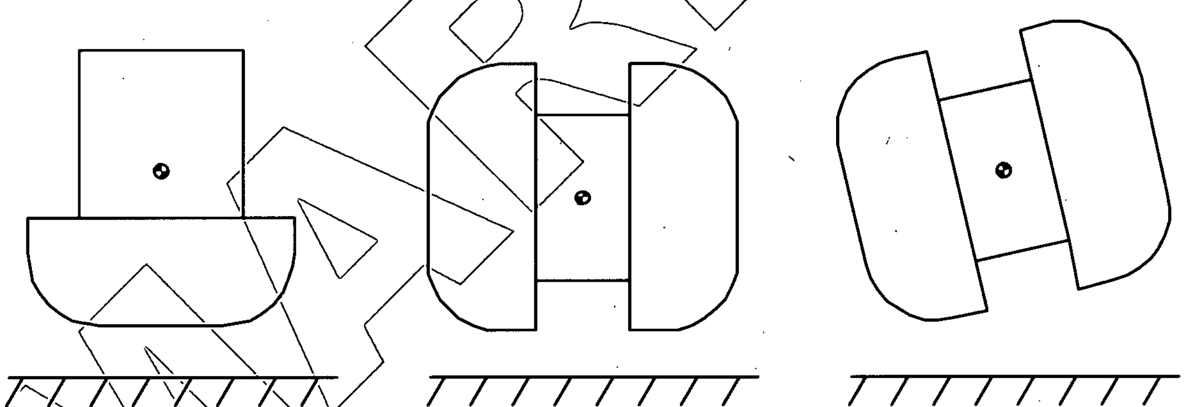


Figure 1 Package orientations for the three drop tests.

Structural integrity of the cask was determined after each of the three drops. Methods for doing so are described in the next section on acceptance criteria. In addition to this pass-fail functional testing, engineering data in the form of cask and impact limiter acceleration time histories at several location/directions were sensed and recorded. Pressure sensitive film was used to

[2] Kienholz, D.A., and Allen, Bradley, "30-ft. Free Drop Tests of a Quarter-Scale Model 2000 Transport Package," GE Nuclear Energy division Report NEDO-31581, San Jose, CA, August, 1987.

determine the pressure distribution between the cask and impact limiter. Details of the methods for obtaining these engineering data are presented later in this report.

3. Acceptance Criteria

The primary pass-fail criterion for the test is based on a helium leak rate test performed on the cask before and after the drop tests. The methodology for the leak test is detailed later in subsection 5.9 An acceptable leak rate is less than 2.96 x 10E-7 standard cubic centimeters of helium per second at a differential pressure of one atmosphere[3]. For the package to be judged acceptable, the measured leak rate must be less than this amount both before and after the drop tests.

The secondary criterion relates to external dimensions of the cask. These shall not have changed by any amount that would prevent or endanger the cask's performance of its primary functions of containment and shielding.

4. Cask Description

The test article is a full-scale prototype transport package. It is composed of two main parts: the cask and the impact limiters. The cask (
Figure 2) is cylindrical in shape with an outside diameter (excluding trunnion lugs) of 46.20 inches and an axial length of 59.40 inches. Weight of the cask with impact limiters is approximately 38,500 lbs. The cask is composed of stainless steel inner and outer shells with thick tungsten inserts between them for radiation shielding. The central payload cavity is cylindrical in shape with a diameter of 10.72 inches and axial length of 33.63 inches. The cavity is connected to atmosphere by two small ports (shown later in cross section) that are both sealed during normal transport operations.

The cask lid is secured to the cask body by 20 socket head cap screws, size 1-8 x 3.25. There is a double seal between the lid and body with a sealable port running from the volume between the seals to atmosphere. The second (outer) seal and the port allow testing the integrity of the inner seal as described in a later subsection.

The impact limiter is in the form of two "caps" that go over the ends of the cask (
Figure 2). Each cap is composed of a stainless steel shell filled with castable impact-absorbing foam. The caps are installed over the ends of the cask and secured to each other by six turnbuckles as shown.. Each cap has a recess in its outer end to produce the desired crush area and thus the desired crushing force during an end drop. The lifting rings shown at the top of

[3] Mok,G.C., Carlson,R.W., Lu, S.C., and Fischer, L.E.,"Guidelines for Conducting Impact Tests on Shipping Packages for Radioactive Material,", Lawrence Livermore National Laboratory Report No. UCRL-ID-121673, September 1995, page 19. Also ANSI N14.5.

each impact limiter are for lifting the impact limiter by itself. When assembled, the package is lifted by the side trunnions on the cask.

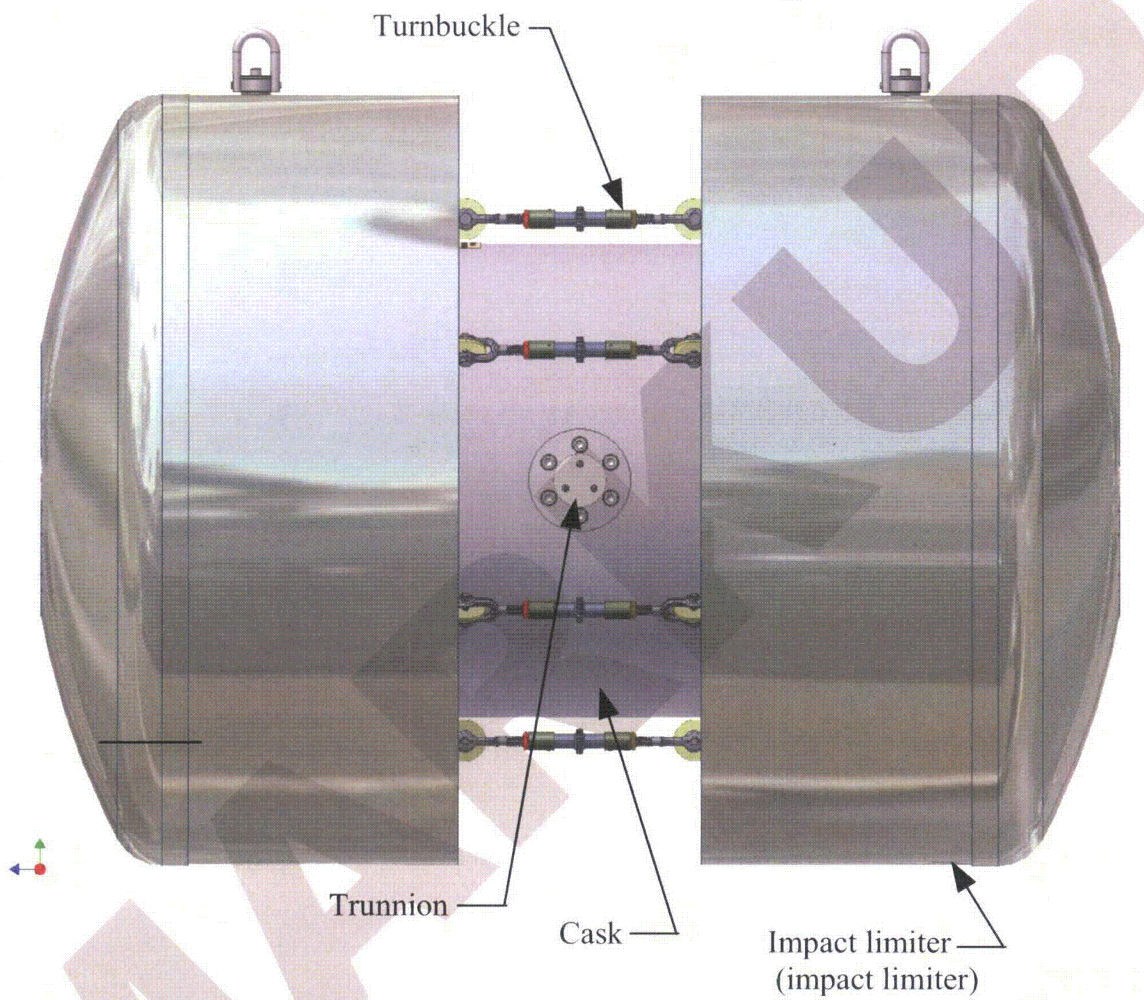


Figure 2 Shipping cask with impact limiters

5. Test Procedure and Equipment

The test procedure and instrumentation generally followed that used successfully in a 1987 test of a quarter-scale transport package[4]. Some enhancements were made in accordance with NRC

[4] Kienholz, D.A. and Allen, Bradley op cit

guidelines published since the 1987 test[5] and to take advantage of advances in photographic and instrumentation technology.

5.1 Drop target

The drop target was a large reinforced concrete block embedded in the earth at the General Electric Vallecitos CA site. Figure 3 shows a plan view of the site, including the crane for lifting the test article and the locations for two high-speed cameras. The concrete block is approximately 20' x 15'6" in plan view and six feet thick. It has a steel plate, 120" x 90" x 3", embedded in its horizontal top surface. The target block weighs approximately 290,000 lbs. The concrete has a 28-day cured strength of at least 4500 psi. The site has been used several times before for drop tests. The storage shed on the north side of the drop pad was moved to allow room for the tests. Figure 4 shows an overall view of the site.

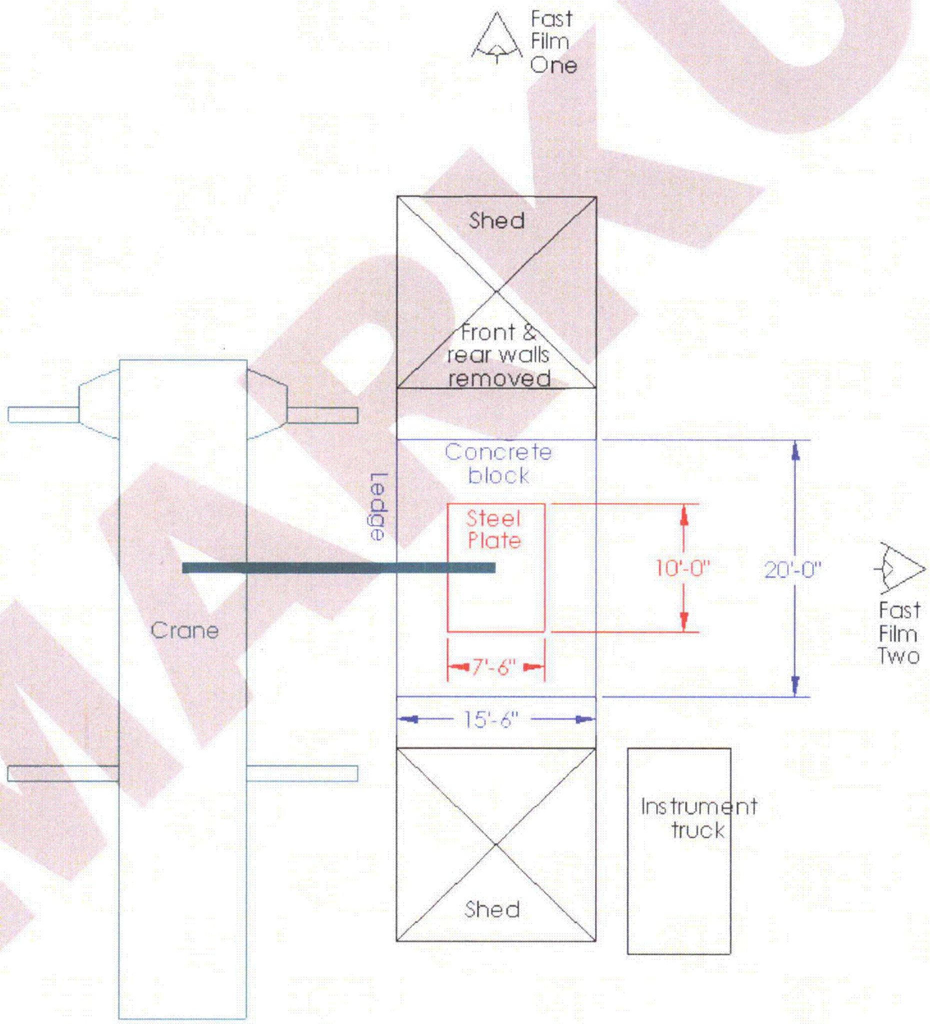


Figure 3 Plan view of drop test site.

[5] Mok, G.C. et al, op cit

Figure 4 Drop test site with crane and instrument truck in place.

5.2 Pretest and post-test dimensional inspection of cask

Dimensional inspections of the cask before and after each drop were done by East Coast Metrology, Topsfield, MA, under subcontract to GENE. The measurements were made using a laser tracker system capable of rapidly locating many points on the cask in 3-dimensional space. Figure 5 shows an impact limiter being set up for measurements. The laser tracker is the blue device on a tripod on the left

For the impact limiters, scan data was taken at the 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300 and 330 degree profiles. In order to compare each impact limiter in its pre- and post- drop condition, an alignment using the bottom perimeter (opposite the domed-end), measured as a circle, was used a reference. By measuring it as a circle, the center point and vector of the measured circle were established. The portions of this circle that were deformed due to each drop test were not used in this calculation. The vector of this axis was defined to be the primary datum in this alignment. A point was then measured at the 90 degree lifting lug to establish the second axis in the coordinate system. This process provided the only repeatable means to align each impact limiter and subsequently compare the results.

Figure 5 Measuring an impact limiter with the laser tracker.

Once the pre- and post-drop scan data was obtained for each impact limiter, the 90-270 degree profile cross-sections were overlaid in order to calculate the magnitude of deformation for each drop.

For the cask, the 0, 90, 180, and 270 degree profiles were scanned. An alignment using the axis of the cylindrical part of the cask as the controlling datum was used. This axis was then intersected with the "Lid End" of the cask and a point was constructed. Another point was measured at the 90 degree lifting lug to establish the other axis. This alignment was repeated for each measurement of the cask. Results from scans taken before any of the drop tests are shown in Figure 6 and Figure 7. The red areas represent the positive (maximum deviations) and the yellow areas represent the negative (minimum deviations) from the nominal as-designed profile.

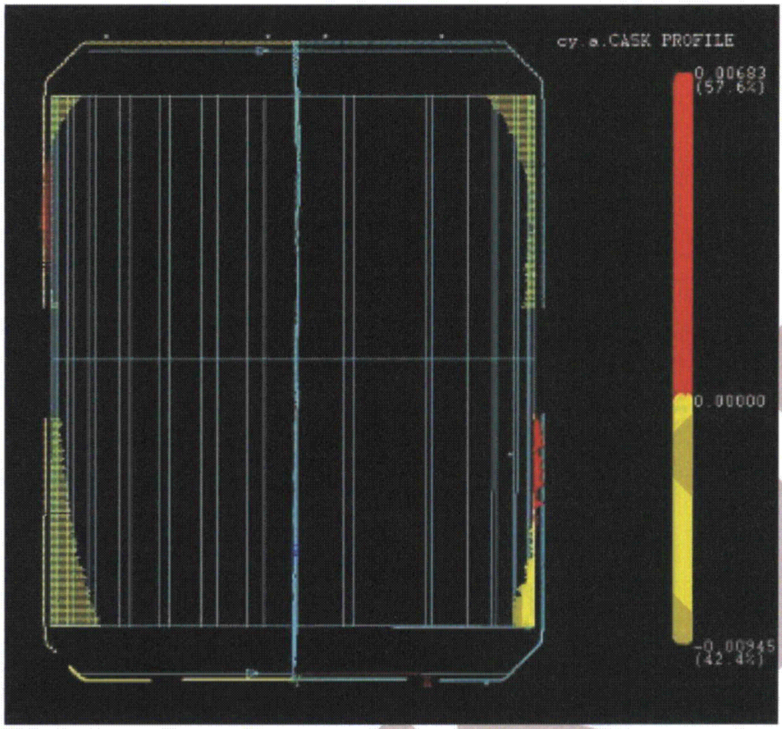


Figure 6 Scan data from cask taken before the first drop, 0-180-degree cross section

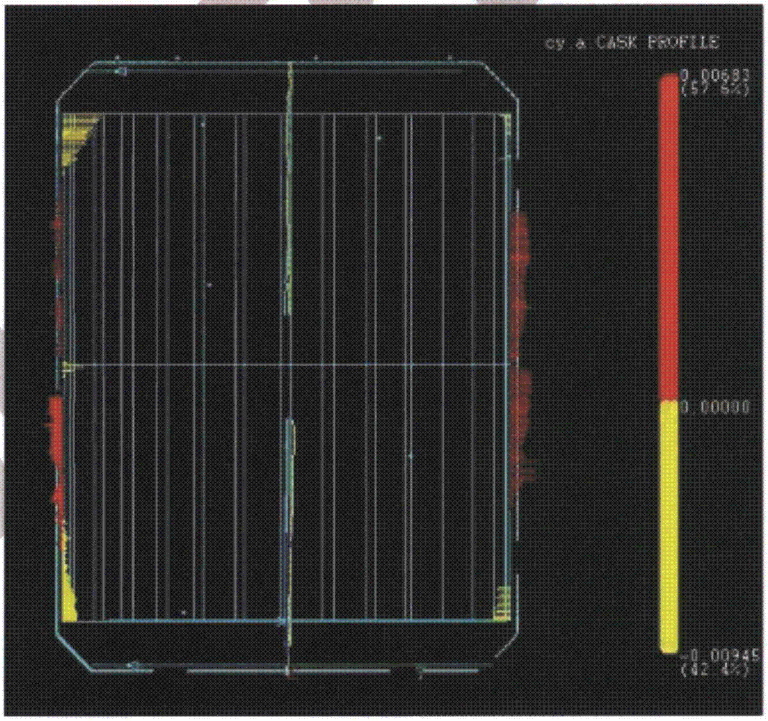


Figure 7 Scan data from cask taken before the first drop, 90-270-degree cross section.

5.3 Lifting and release methods

For each drop, the test article was lifted by a 90-ton mobile crane to a height of at least 30 feet[6] directly above the steel plate drop target. The crane was provided by Peninsula Crane Service under subcontract to GENE. GENE provided the remaining rigging equipment. Figure 8 illustrates the crane setup for the end drop. Figure 9 shows the crane and quick-release mechanism being tested by dropping a dummy weight.

Two methods were used to measure the drop height. For the first (end) drop, a graduated light chain was hung from above the package.. The chain was marked at one-foot and ten-foot intervals such that the package height above the impact point could be verified just before the drop. The chain was then pulled out of the way prior to the drop. For the second and third drop, a tape measure was secured with tape to the bottom of the package and used to adjust the height to the desired value. The tape measure was then pulled off the test article from the ground.

The use of a hydraulic crane required that the crane boom be "snubbed" with heavy wire ropes from the crane hook down to heavy weights on the ground (Figure 8). The snubbing lines restrained the crane boom when the load was released, preventing damage to the hydraulic system. Since the snubber lines were of fixed length and had to be taut at the time of release, they had some effect on the drop height. Shorter rigging as used on the end drop caused the drop height to be greater than for the side and slap-down drops. However the drop height was over 30 feet for each drop. Exact values are given later.

The package was released using the mechanism shown in the Figure 10, Figure 11, and Figure 12. The heart of the system is the mechanical release mechanism shown in Figure 10. Called a SeaCatch Model TR15Air[7], it is used in the marine industry for releasing loads while under tension, often underwater. In the photo on the right of Figure 10, the release mechanism is actuated by hand via the lever on the right side. Lifting the lever opens the jaws and allows the lower anchor shackle to fall free. The red rope tied between the shackles in the figures is only for demonstration. In the actual test, the package was hung from the lower shackle, the red rope was not present, and the lower shackle remained attached to the test article as it fell.

Because the package must strike the drop target in a known, repeatable orientation, it is essential that the release mechanism do its job quickly and cleanly, minimizing transient forces and moments imposed on the package during release. This minimizes the angular velocity imparted to the package at release and allows it to fall without rotation such that it strikes the drop target in the same orientation it had prior to release. To this end, the SeaCatch release mechanism was equipped with an integral air cylinder, an accumulator, and a fast solenoid valve for actuation. This method was used in preference to pulling the release lever via a lanyard because the required pull force of over 100 lbs would have disturbed the orientation of the test article just at the critical moment of release.

[6] 30 feet minimum from the lowest point on the test article to the upper surface of the steel plate of the drop target.
[7] McMillan Design, Inc., Gig Harbor, WA.

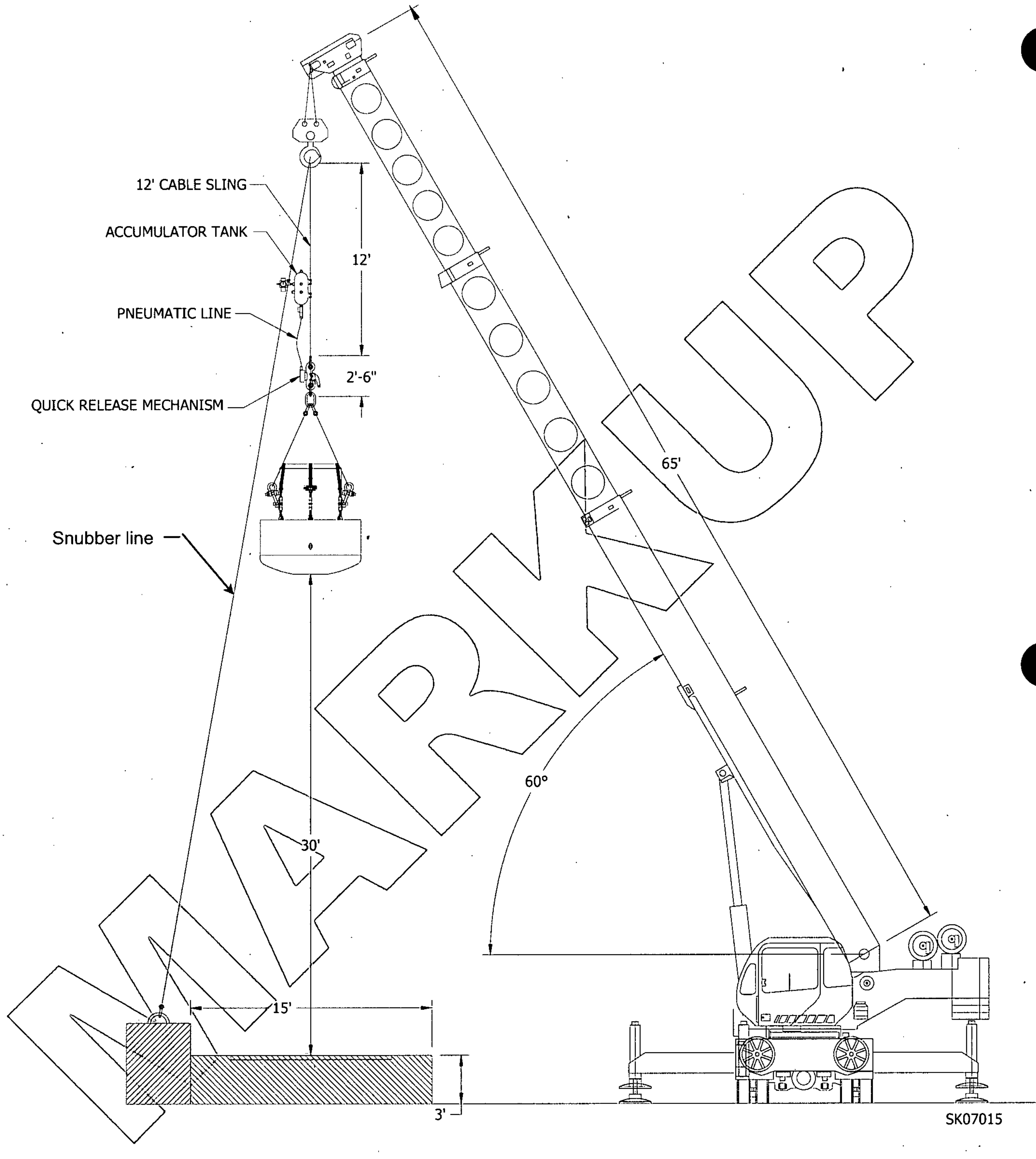


Figure 8 Crane and rigging set up for end drop.

Figure 9 Testing the quick-release mechanism by dropping a dummy weight.

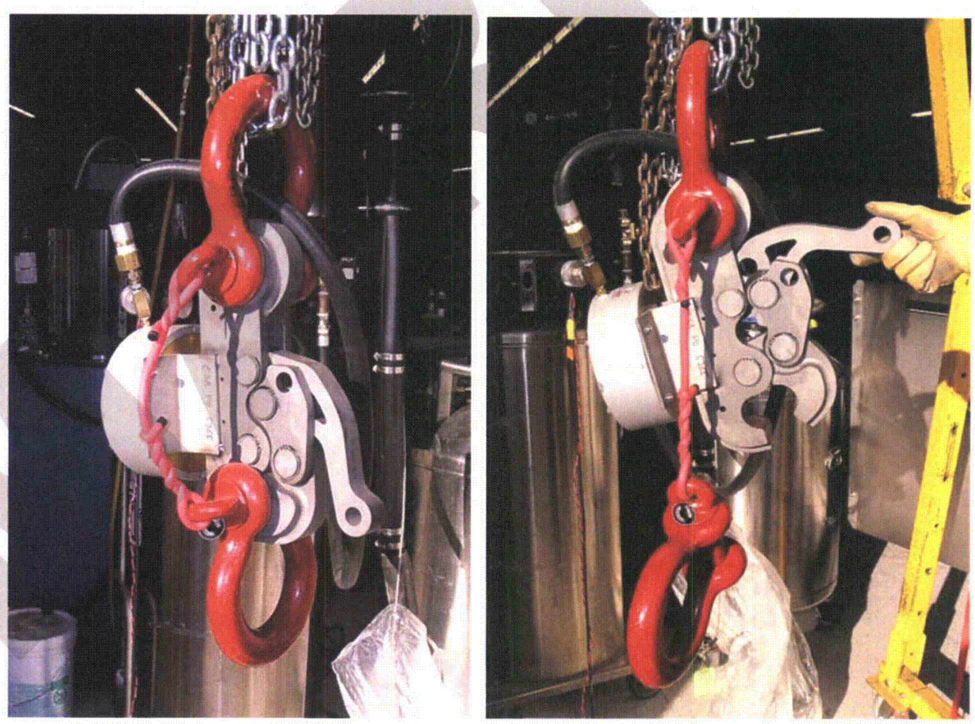


Figure 10 SeaCatch release mechanism before release (left) and after release (right).

A quick release was obtained by using a 3-gallon local air accumulator tank and a fast-acting, two-stage, electrically triggered diaphragm valve mounted close to the release mechanism . Calculated release time is on the order of 0.2 seconds. Figure 11 shows the accumulator tank and valve. Figure 12 shows the accumulator and valve mounted on a short section of heavy wire rope with the SeaCatch hanging from the loop at the lower end of the wire rope. In operation, a compressed air line for charging the accumulator and electrical trigger line were run up the crane boom and over to the accumulator tank.

The SeaCatch is a model TR15AIR and is rated at 50,200 lbs working load with a safety factor of five. It was proof tested to twice the working load by the manufacturer prior to delivery to CSA. Likewise the wire rope, which is rated for 42,000 lbs, was proof tested to 84,000 lbs.

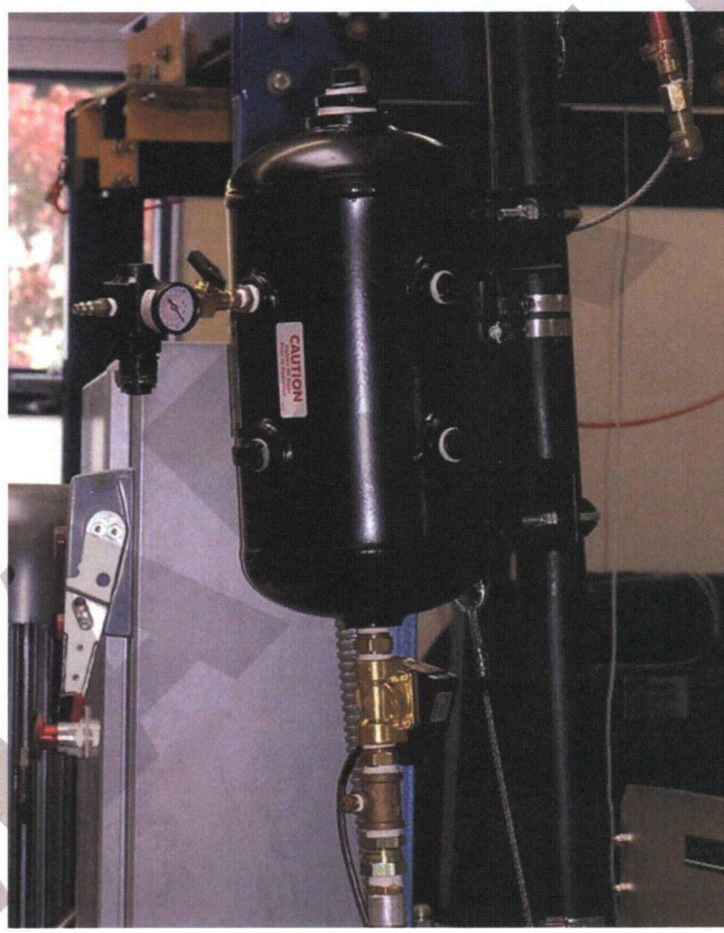


Figure 11 Accumulator tank and fast-acting valve for operating the SeaCatch air piston (left). Entire release system (right).

Figure 12 Cask being assembled with impact limiter for the end drop. The quick-release mechanism is visible at the top of the picture. Pressure-sensing paper has been taped to the part of the cask that goes inside the impact limiter.

5.4 Acceleration sensing

Acceleration time history data was recorded using accelerometers inside the cask and on the impact limiter. A total of nine uniaxial sensors was used, configured as three triaxial groups. One triaxial group was mounted on the flat surface of the impact limiter (Figure 13). The mounting block is fastened to the impact limiter by two ¼-20 cap screws threaded into tapped mounting bosses welded to the impact limiter. A cable breakout bracket for mating the main umbilical cable to individual accelerometer cables is likewise mounted to tapped bosses on the impact limiter as shown.

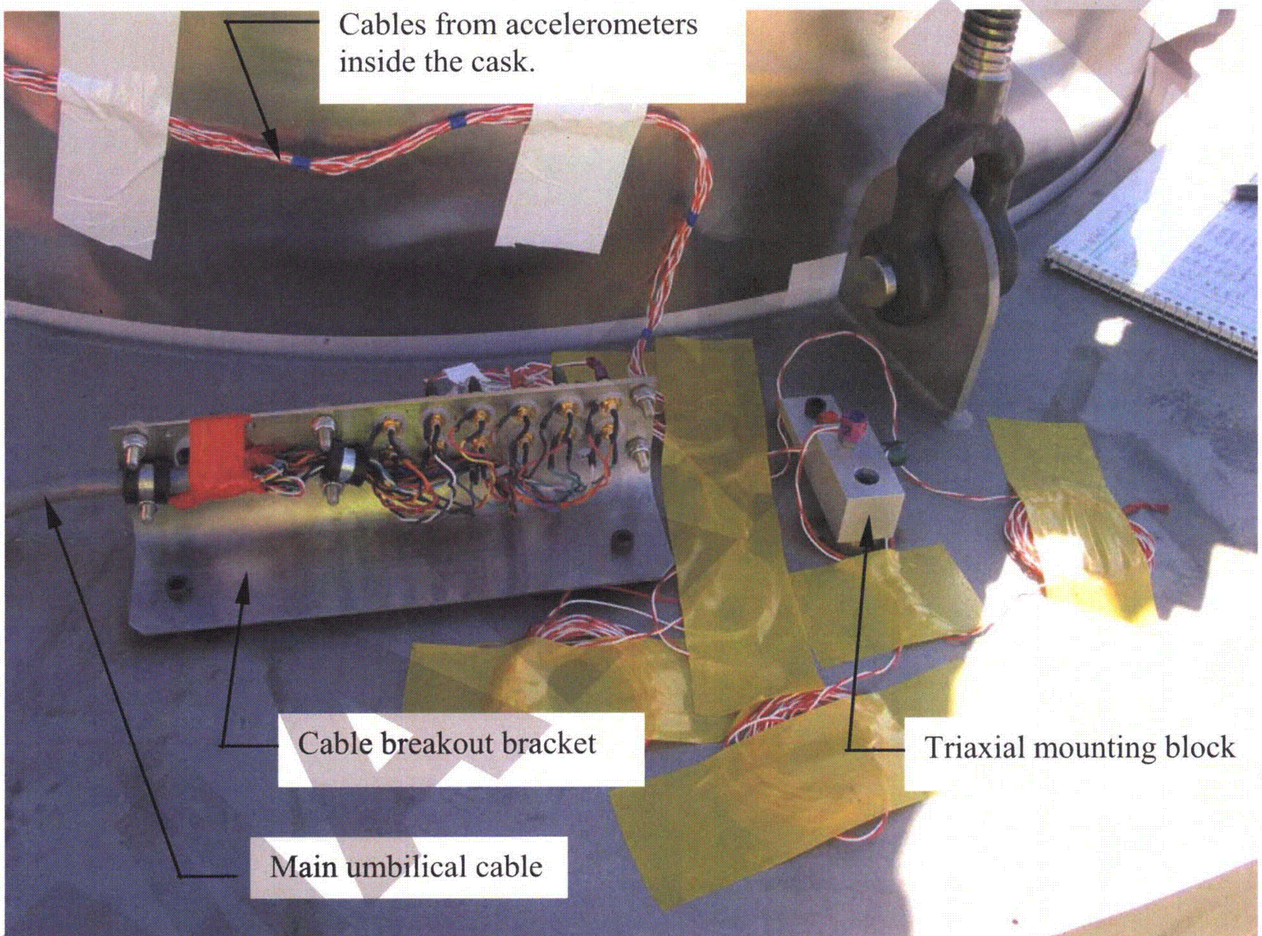


Figure 13 Triaxial accelerometer group mounted on impact limiter. The sheet metal part is a bracket for connecting the 20-conductor umbilical cable to the two-conductor cables of the individual accelerometers.

Two triaxial groups were mounted inside the cask on the wall of the payload cavity (Figure 14). They were mounted on machined aluminum blocks bonded to the cavity wall with Lord 906-16 acrylic structural adhesive. The triaxes were at nominally the same axial location and 180 degrees apart, at the 90-degree and 270-degree lines on the cask. Each triaxial set sensed in nominally the cask radial, tangential, and axial directions. The cask was oriented for the side drop and slap-down drop such that a plane containing the cask axis and the accelerometer locations was vertical and the accelerometers on the 90-degree line were on the upward-facing side of the cask. In the photos, the radial accelerometers are marked with red tape, the axials with purple tape, and the tangentials with green tape.

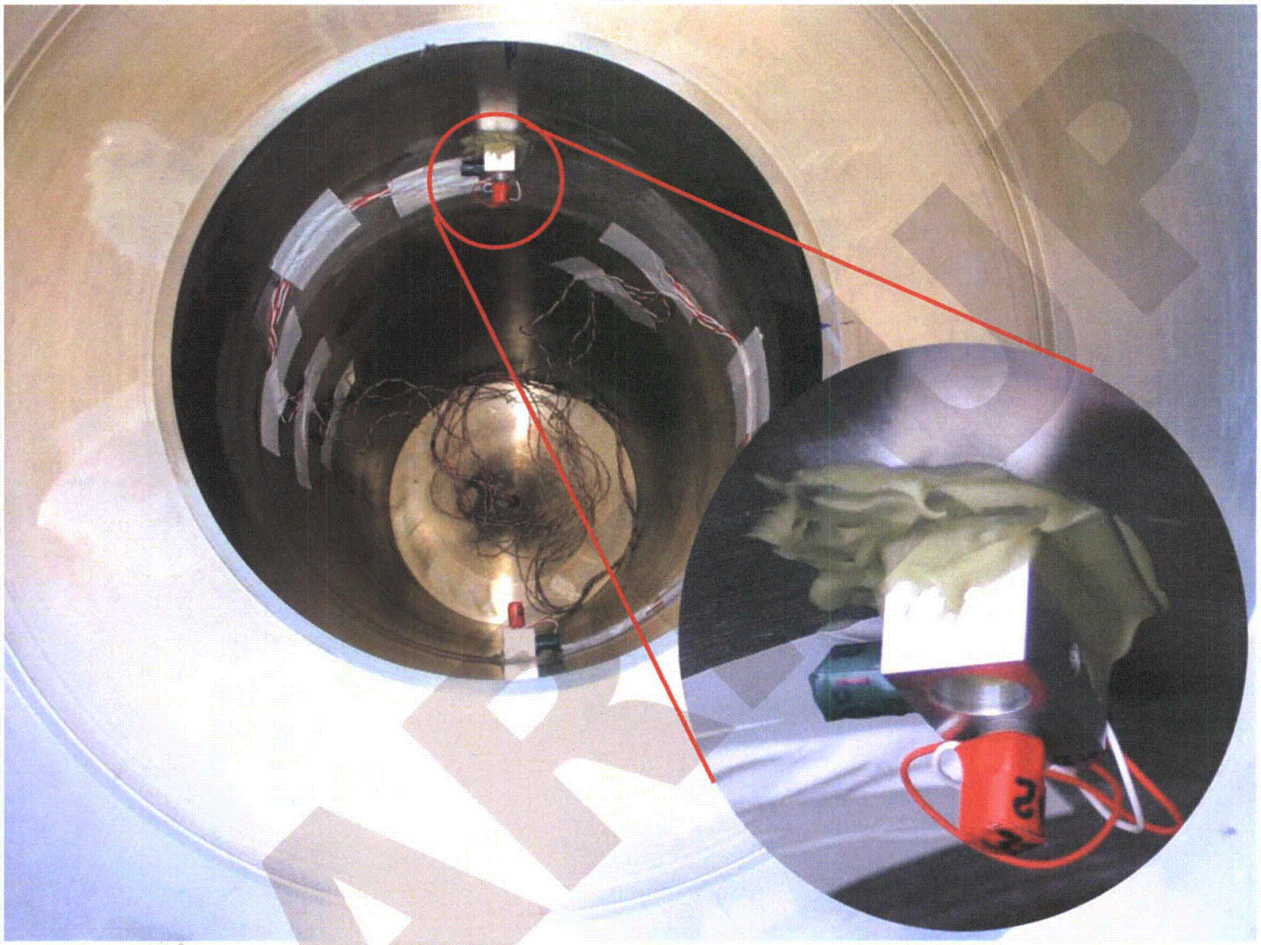


Figure 14 Accelerometers mounted inside the cask. The cables can be seen exiting via the drain port at the bottom of the cask payload cavity.

Cables for the accelerometers inside the cask were routed out through the drain port which exited near the cask bottom along the 90-degree azimuth. For the end drop, only a single impact limiter was used and it was on the lid end of the cask, with the cask being dropped upside-down (Figure 17). For this drop, there was no interference between the accelerometer cables and the impact limiter. For the other two drops, impact limiters were mounted on both ends of the cask and the cables had to come out through the 1/8th-inch radial gap between the cask OD and the impact limiter ID (Figure 16). 1/8-inch-diameter stainless steel rods were welded to the impact limiter ID running in the axial direction on either side of the cable routing to prevent the cables from being crushed between the cask and impact limiter. As described later, this was only partially successful although acceleration data was obtained for the important initial impact on each of the three drops.

All accelerometers were of the piezoelectric, integrated amplifier (ICP) type. The accelerometers mounted on the impact limiter were PCB model 350B23 having a nominal range of +/-10,000 g's (0.5 mV/g sensitivity, 0.5 g resolution, range/resolution = 20,000) and a 1-dB bandwidth of 0.4 to 10,000 Hz. The triaxial accelerometers inside the cask were PCB model 353B13 having a nominal range of +/-1000 g's (5 mV/g sensitivity, 0.05 g resolution, range/resolution = 20,000) and a 1-dB bandwidth of 0.7 to 20,000 Hz. All were powered and AC coupled to the recording system by a Kistler model 5124A power supply/coupler. Figure 15 shows the accelerometers and their power supply / signal coupler. There is no pass-fail criterion based on cask acceleration. However the data obtained will be of use in understanding the package behavior during impact and for estimating loads on the cask.

Figure 15 Accelerometers (1,000 g on lower left, 10,000 g on lower right) and power supply / signal coupler.

Piezoelectric accelerometers were used in preference to bridge-type, DC-coupled accelerometers because the former tend to be better suited to the high acceleration levels found in drop testing. Also, they use simpler electronics integrated directly into the sensor which is of great value in eliminating noise pickup in the signal cabling. Their only disadvantage is that they cannot capture the part of the signal at very low frequency, below about 1 Hz for the present case. This is considered acceptable because the very short-duration impact events have only a very small part of their signal energy in this missing band. Peak accelerations during such short impacts can be measured with AC-coupled accelerometers with negligible loss of accuracy.

The polarity for all accelerometers follows the industry convention: acceleration into the mounting surface of the sensor gives a positive output voltage. Thus the axial accelerometers inside the cask (Figure 14) give a positive voltage when the acceleration is towards the bottom end of the cask (as opposed to the top or lid end), as was the case for the end drop.

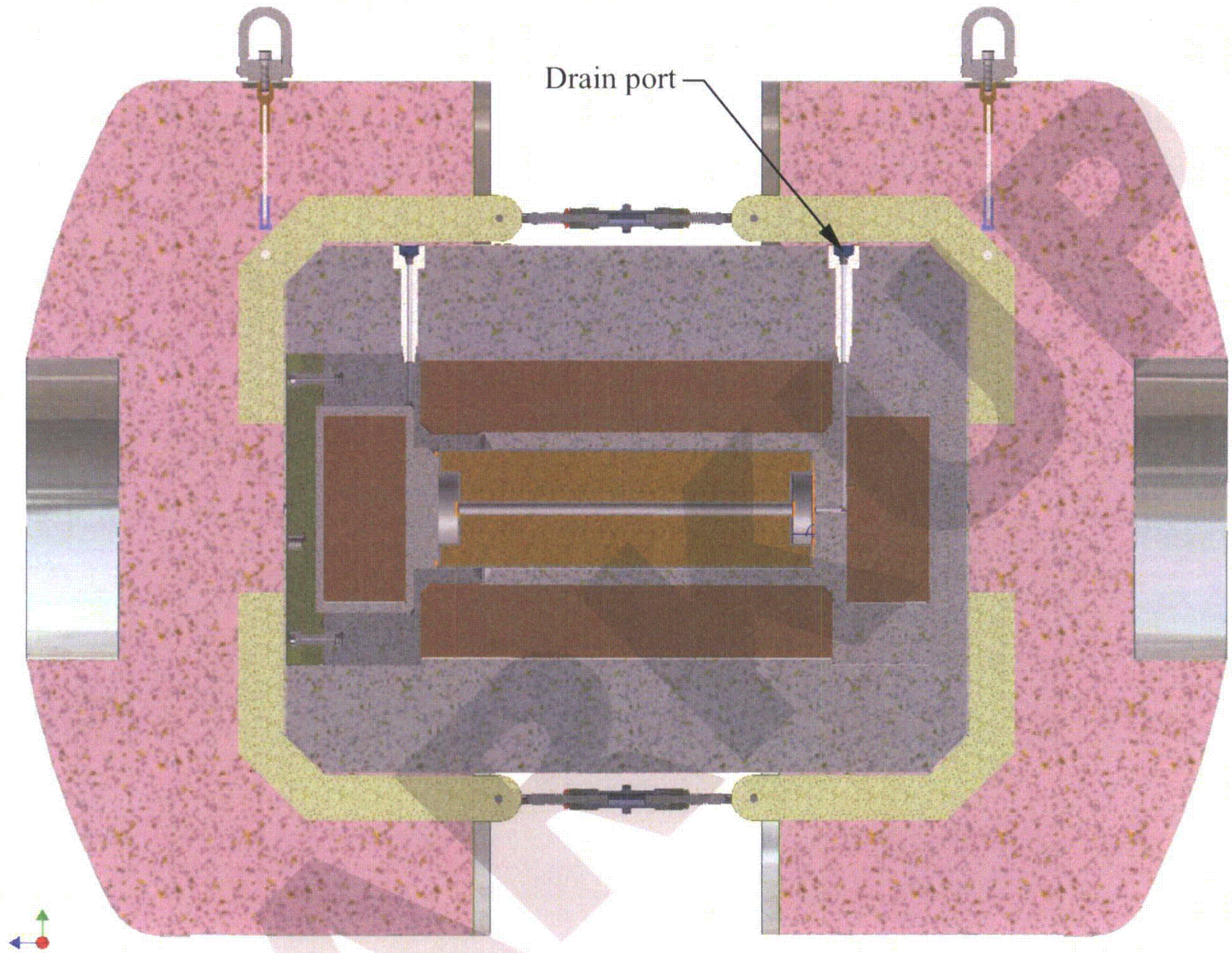


Figure 16 Cross section of cask showing drain port to be used for accelerometer cable routing.

Cables for the accelerometers inside the cask were routed through the water drain port (Figure 16) such that no special feedthroughs or modifications to the cask were needed. During the leak test, the cables were disconnected from the external breakout bracket and pushed back into the drain port so the port can be plugged.

A multi-channel umbilical cord with one shielded, twisted pair for each accelerometer was used to route the signals to a breakout box with BNC connectors on the output side. BNC cables then carried the signals to the Kistler power supply/coupler and from there to the data acquisition system located in the instrumentation truck. The total cable length of approximately 150 feet presented no significant limitation for the relatively low-frequency signals of interest in this test.

Figure 17 Cables from accelerometers inside the cask were routed through the drain port to the breakout bracket. Configuration shown is for the end drop with only one impact limiter used.

5.5 Acceleration signal recording

Acceleration signals during the impact were digitized and recorded directly to disk using a VXI data system from VXI Technology with a 16-channel front end card (model VT1432A). A/D conversion was done at 25,600 samples per second per channel with 16-bit resolution. Anti-aliasing filters were set for a cutoff frequency of 10 kHz.

Real time data acquisition was performed using I-DEAs TEST software to control the VXI front end. Immediately following each drop tests, acceleration time history data was translated to MatLab .mat format. MatLab was used for all display, plotting, filtering, spectrum analysis, and other post-processing work.

It was planned originally to use a digital tape recorder in parallel with the VXI system for redundancy. However problems were encountered with the tape recorder during test preparation so the VXI system was used alone. It performed satisfactorily so no backup was needed.

During the 1987 test, each acceleration signal was recorded to two channels of an FM instrumentation tape recorder. This allowed two different full-scale settings to be used for each signal in order to obtain the best possible signal/noise ratio within the limited (50 dB) dynamic range of the recorder. Modern 16-bit digital recording systems such as the VXI system have rendered this unnecessary since they typically have well over 72 dB of dynamic range.

5.6 Data processing

Data acquired with the VXI system was initially in I-DEAs .ati format. It was converted immediately on-site to MatLab standard double precision (8 bytes per sample) using the I-DEAs IMAT translator. Simple plotting and processing routines were created using basic MatLab commands and the MatLab Signal Processing Toolbox. All raw time history files were permanently archived.

Processing tasks include

- locating, isolating, and plotting the relevant time sections containing the impact
- digital low-pass filtering of acceleration time histories to accentuate the rigid-body component over the resonant flexible-body components
- computing the energy spectral density of the acceleration transient to determine how much is rigid-body response and how much is flexural.

5.7 Contact pressure sensing

Pressure sensitive film was installed between the cask and impact limiters prior to each drop. The film (Fuji Prescale P/N M S R270 M10 1) changes color in response to pressure. The single-sheet type contains embedded microcapsules of a chemical that reacts with another chemical impregnated into the film to produce a red color. Higher pressure breaks more capsules and produces a more intense color. The size and density of the microcapsules can be tailored to make the color change occur over various pressure ranges. The film used is for the pressure range from 10 to 50 MPa (1450 to 7250 psi). Pressure can be inferred by comparing the exposed film to a color chart (Figure 18). However for the present application, the intent is simply to use the pressure paper to indicate areas of contact between the cask and impact limiters.

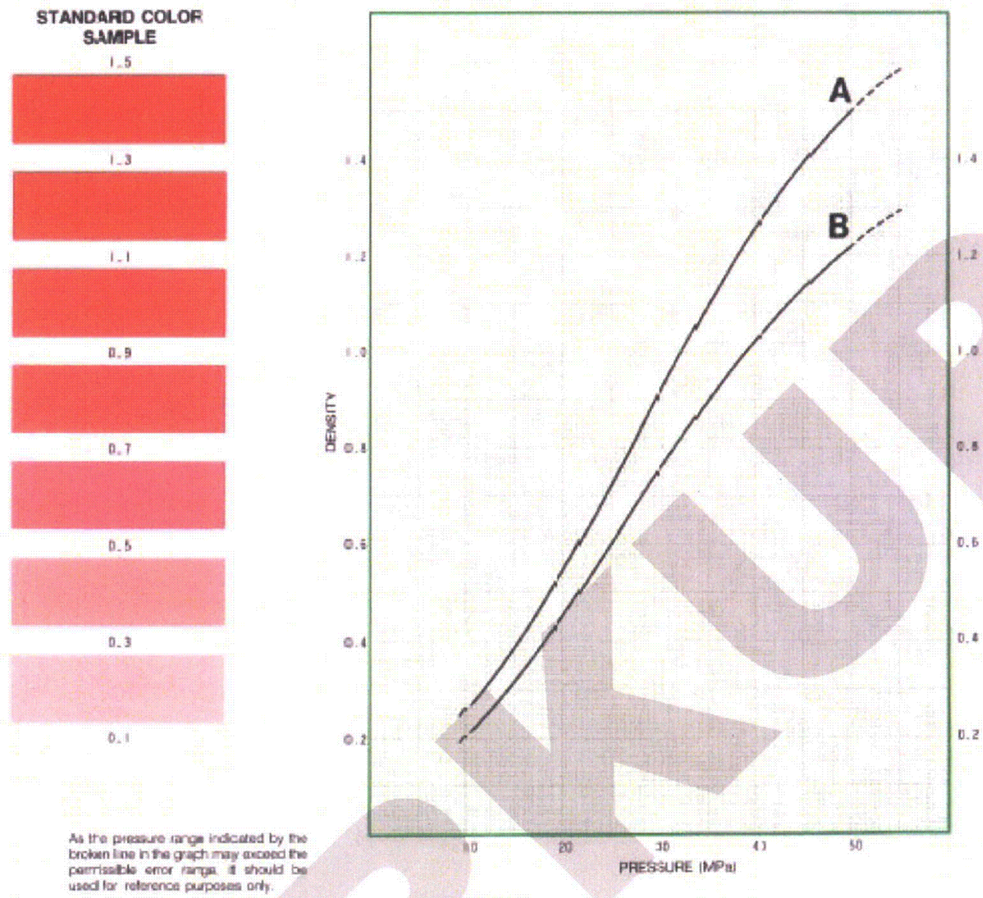


Figure 18 Chart for correlating color to pressure for Fuji medium-range Prescale film.

Fuji publishes two different color charts, one for film exposed to continuous pressure and another for film exposed to momentary pressure. However the two charts are virtually identical to the eye. Also, tests conducted with Prescale film prior to the 1987 drop tests[8] showed that the color change is virtually instantaneous upon exposure to pressure.

Figure 19 shows the cask with pressure-sensing paper attached being assembled into the impact limiter. The paper can also be seen in Figure 17 protruding out slightly beyond the impact limiter.

[8] Kienholz, D.A. and Allen, Bradley op cit

Figure 19 Cask with pressure paper attached being lowered into the impact limiter for the end drop.

5.8 High speed photography

High-speed digital video photography was used to record each of the three drops. All cameras were furnished and operated by Speedvision Technologies of San Diego under subcontract to CSA Engineering.. Two high-resolution black-and-white cameras were used with their sight lines at right angles to each other as shown in Figure 3 For the first (end) drop, lower resolution color cameras were located next to each black-and-white camera. Following review of the end drop videos from all four cameras, it was decided that only one color camera would be used for the second and third drops and it would be located at an oblique angle, about midway between the two black-and-white cameras. Figure 20 shows the cameras set up for the end drop.

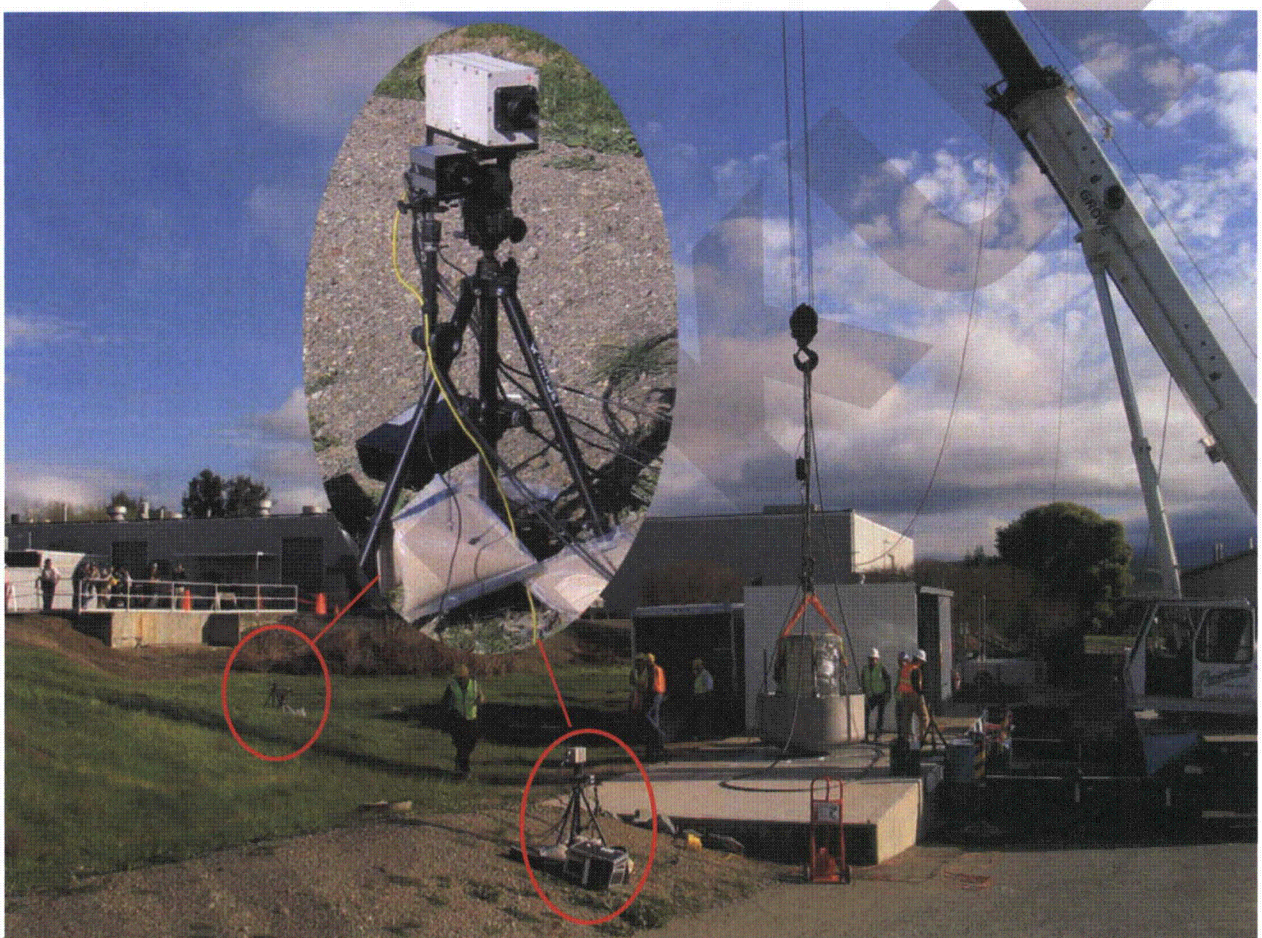


Figure 20 High-speed cameras set up for end drop

Frame rates for the first drop were 1000 frames/second for the black-and-white cameras and 500 frames/second for color. After review of the videos, it was determined that the higher frame rate offered no real advantage so all cameras were operated at 500 frames/second for the second and third drops.

Following each drop, the raw files from the camera were converted to .avi format. The raw files remain available but examination of the compressed .avi files showed that they had adequate resolution for most purposes. SpeedVision furnished software for extracting individual frames as jpeg or tiff files. This software was used to produce the frame-by-frame presentation given in later sections for each of the three drops.

A time scale and a length scale were included in the field of view of the each black-and-white camera. The length scales are dark-colored poles mounted vertically with light-colored graduations marked on them at one-inch (yellow marks) and one-foot (white marks) intervals. The poles are placed as close as possible to the vertical drop path and at the same distance from the camera as the drop path in order to minimize parallax and foreshortening error. Time scales, Figure 21, are rotating disks with a light-colored radial line. The background behind the disk has fixed, radial witness lines painted at 30-degree intervals as shown. The disk is rotated by a two-pole induction motor at a constant speed of approximately 3575 RPM or approximately 43 degrees per camera frame at 500 frames per second. The exact rotational speed was determined prior to the test using a digital optical tachometer. Table 1 shows the recent time scale calibration results and those from just before the 1987 test.

Table 1 Calibration results for time scales.

Clock	Speed (RPM) 1987	Speed (RPM) 2005	Percent Change	Degrees per 0.002 seconds
#1	3579.00	3579.00	0.00	42.95
#2	3575.40	3572.30	-0.09	42.87

The use of time scales was a hold-over from earlier tests where high-speed film photography was used and frame rates could vary significantly from their nominal value. Modern digital video cameras have very accurate frame rate control (a few parts per million) so the time scales are not strictly necessary and are actually less accurate then the cameras themselves.

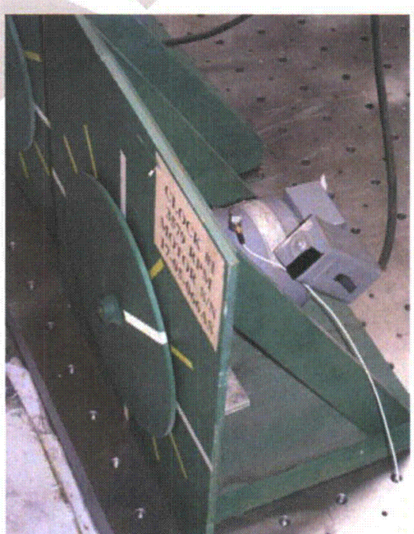


Figure 21 Time scale

At the suggestion of SpeedVision, a simple impact trigger signal generator was constructed and used to provide a time reference signal indicating when the test article first impacted the ground. The trigger was simply a sheet of cardboard approximately two feet square with a grid of 2-inch-square holes cut in it and sandwiched between two sheets of heavy-duty aluminum foil (Figure 22). The sandwich was taped to the impact surface at the location where the test article would first strike the surface. When the impact limiter hit the sandwich, it pressed the two sheets of aluminum foil together and closed a circuit. The resulting voltage signal placed a reference time marker on the stream of video frames to indicate first contact. It also cued the cameras to continue recording for another two seconds and then stop. Finally, it produced a step voltage signal that was recorded on one channel of the VXI data system as a time reference for interpreting the acceleration time histories. The impact trigger was used on the second and third drops and found to work very well.

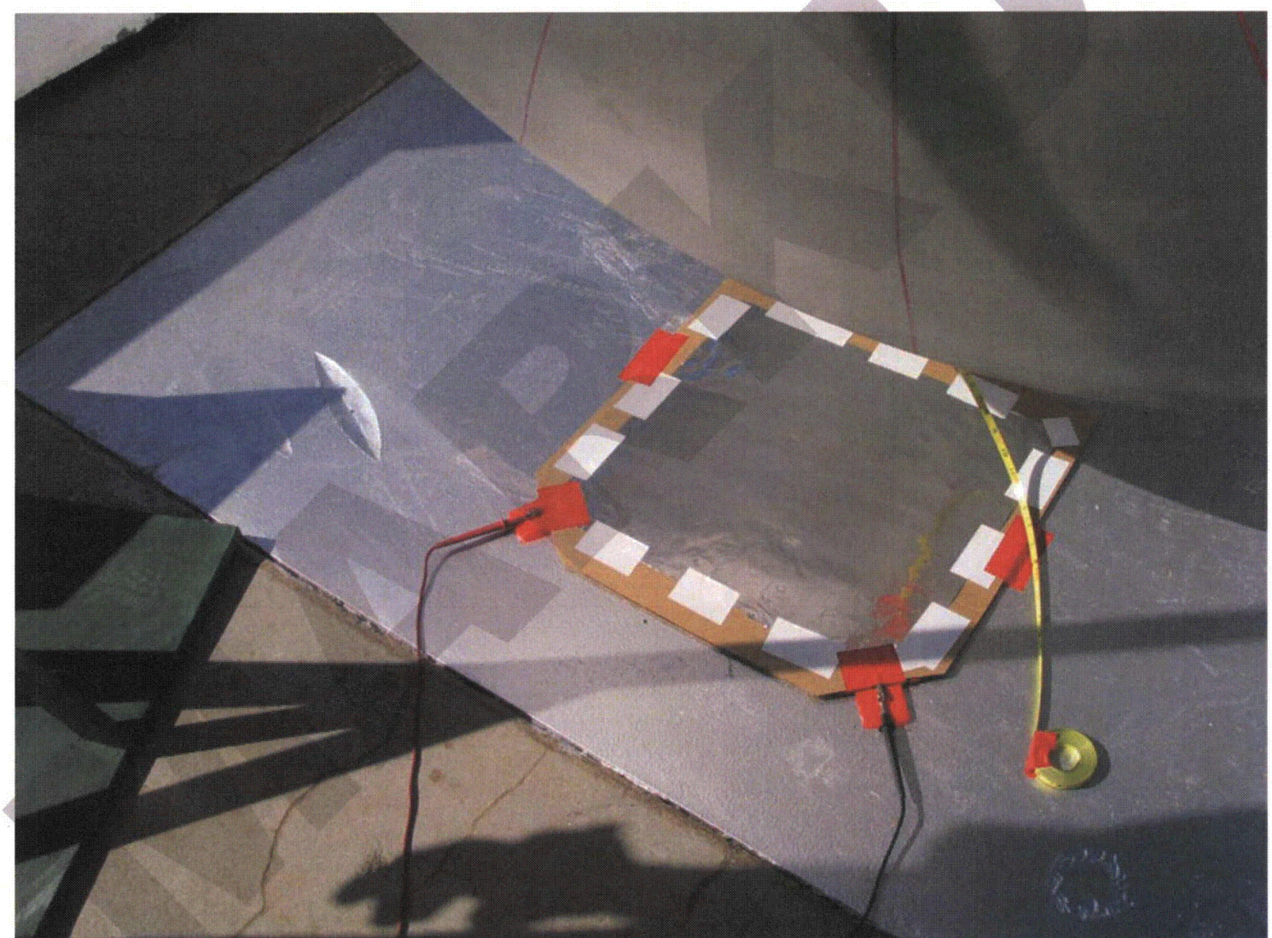


Figure 22 Impact trigger in position for side drop.

5.9 Leak rate tests

Integrity of the cask body and its lid seal was tested before and after each drop test by measuring the leak rate. The lid was bolted in place in the normal operating configuration. A helium pressure bottle was connected to one of the ports leading to the payload cavity and the cavity was purged with helium and then maintained at a pressure of 17.0 psia. The vacuum pump of a helium leak detector was connected to the port leading to the volume between the double seals of the lid. The volume between the seals was pumped down to an absolute pressure of less than 1 Torr and the leak rate of helium was measured by the leak. A leak rate of less than 2.96 x 10E-7 standard cubic centimeters of helium per second at this pressure differential was considered leak-tight. Leak detection equipment was furnished and operated by GENE personnel.

During the leak test, the cables from the accelerometers inside the cavity were disconnected from the break-out panel on the outside of the cask and pushed back into the port from which they exited the cask. The port was then plugged such that the cavity could be pressurized. Figure 23 shows the cask undergoing its initial leak test.

Figure 23 Leak testing the cask.

5.10 Test operations

GENE prepared a detailed check list of all the activities to be performed during preparation and execution of the tests. It was maintained by the GENE QA manager assigned to the project and included the designation of the individual responsible for each item. Items were checked off as they were performed.

5.11 Drop heights

Table 2 gives the free-fall distances for each of the drops. These are the measured vertical distances from the drop target to the lowest point on the impact limiter. They were different for the three drops for reasons given earlier related to the crane and rigging.

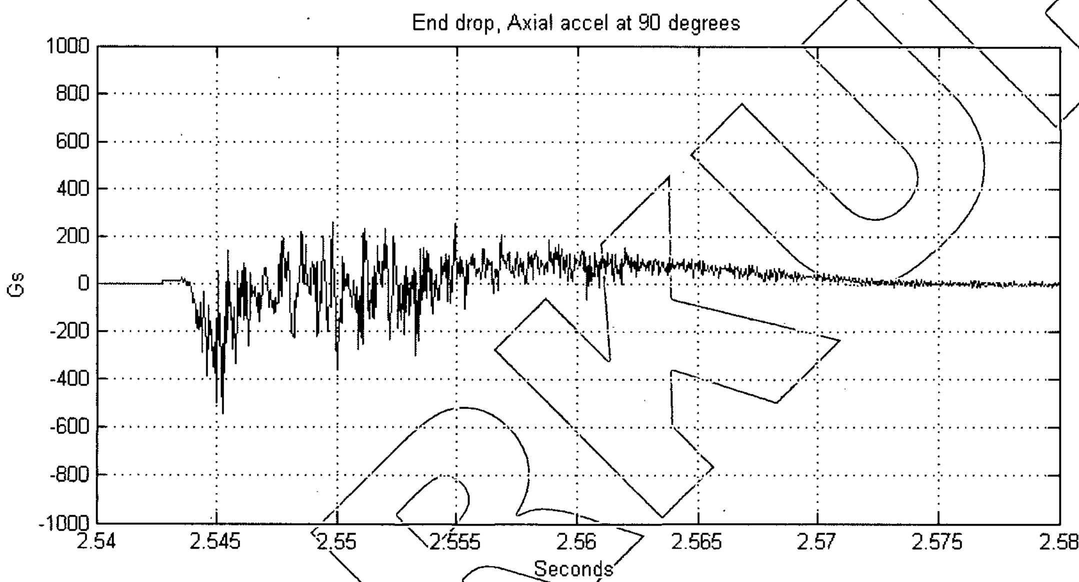
Table 2 Drop heights

Drop configuration	Drop height (feet and inches)
End	34'-3"
Side	31'-0"
Slap-down	31'-2"

6. Results: End Drop

6.1 Acceleration measurements

This section gives the time history plots of accelerations measured inside the cask and on the impact limiter for the end drop. Only the most important data are shown in this section. A full set of plots has been furnished to GENE. This organization will also be followed for presenting acceleration data from the side drop and the slap-down drop.



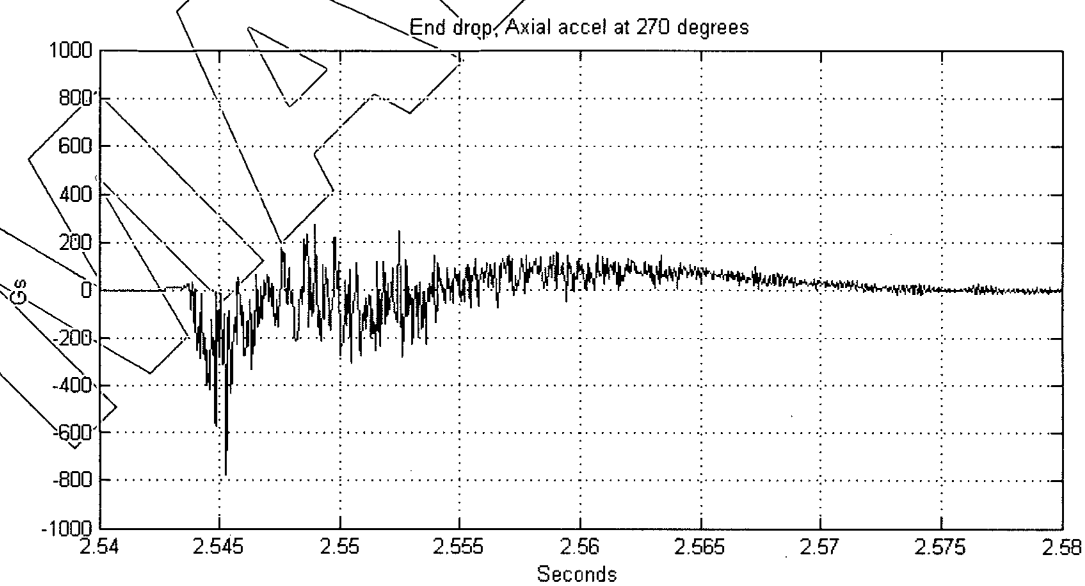


Figure 24 Accelerations measured at impact inside the cask for the end drop.

Figure 24 shows the signals from the two axial accelerometers inside the cask (Figure 14). These two were sensing in the vertical direction for this drop. A positive signal denotes upward acceleration at the accelerometer location.

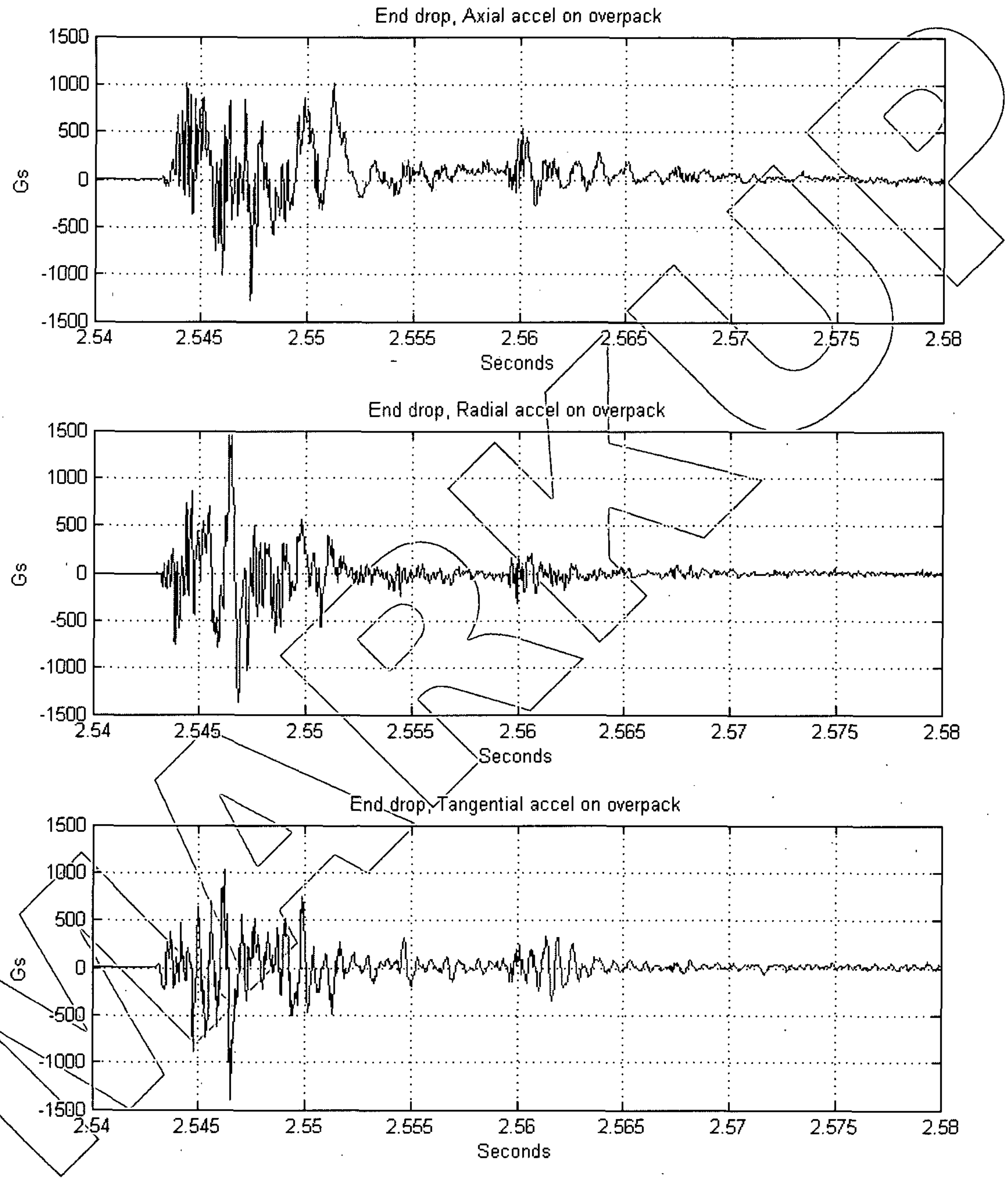


Figure 25 Accelerations measured on the impact limiter during the end drop.

Figure 25 shows data from the accelerometers on the impact limiter (Figure 13). Signals from all accelerometers showed a large amount of "ringing" or resonant response from the cask and impact limiter. This was not surprising considering the sharp blow applied to the package when it struck the steel plate of the target block. However the ringing makes it difficult to estimate the true deceleration of the cask mass center. To this end, the signals were digitally low-pass filtered to reduce the resonant response and make the rigid-body component of the cask deceleration more evident. The filter was a 4-pole phaseless Butterworth[9] with a cutoff frequency of 900 Hz. Results are shown in Figure 26, Figure 27, and Figure 28.

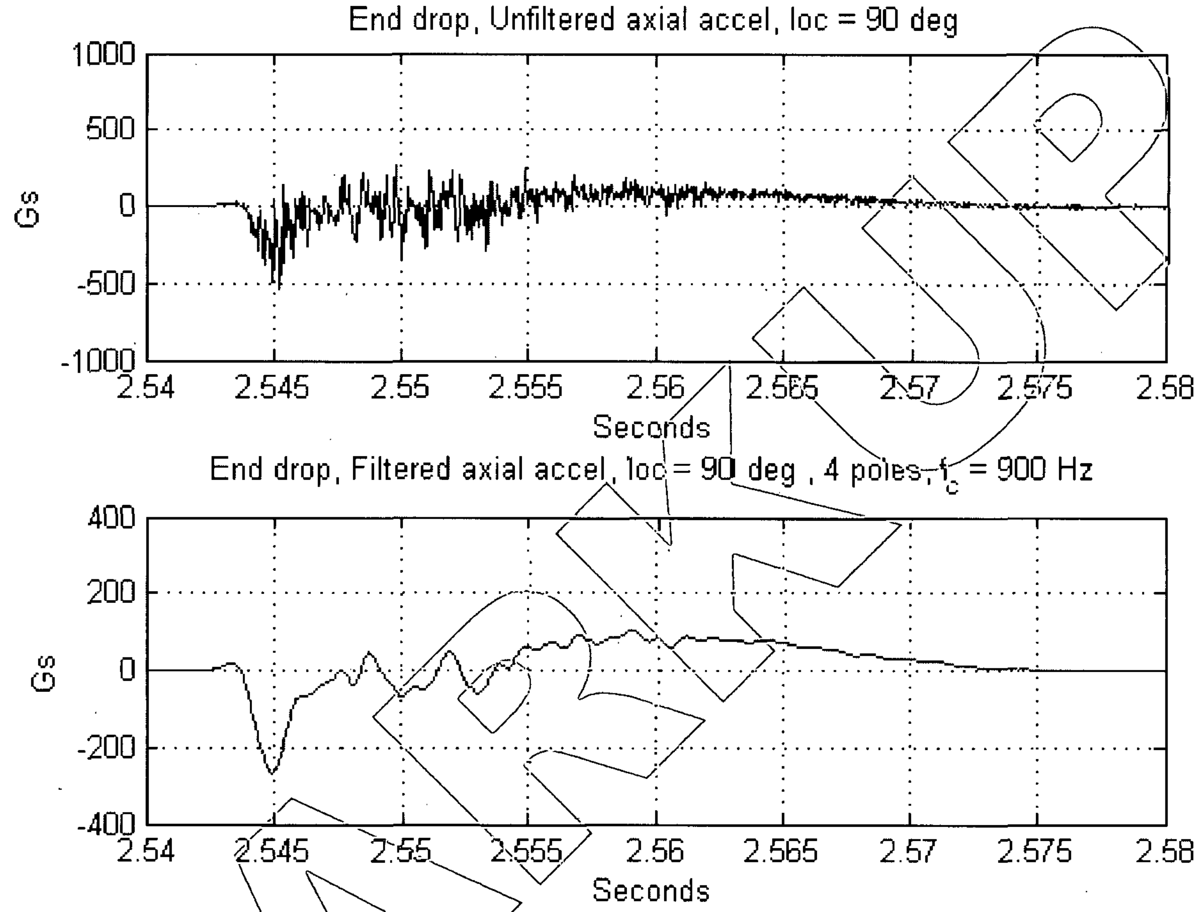


Figure 26. Signal from the axial accelerometer inside the cask on the 90-degree aximuth before (top) and after (bottom) low-pass filtering.

The vertical acceleration signals in Figure 26 and Figure 27 may seem confusing at first. It appears that the big spike in acceleration is in the downward direction. However the signals make sense when one considers the way the cask is constructed. Referring to Figure 16, the brown areas represent voids between the thick stainless steel walls of the cask. These voids are filled with heavy, tungsten "bricks" which are held in place only by steel wool packing. When the cask first strikes the hard surface, there is in fact a small pulse of upward acceleration

[9] A phaseless filter is created by running the digitized signal twice through the filter, first forward and then backwards. Thus a four-pole phaseless filter gives the same frequency rolloff as an eight-pole conventional filter and does so with no phase distortion.

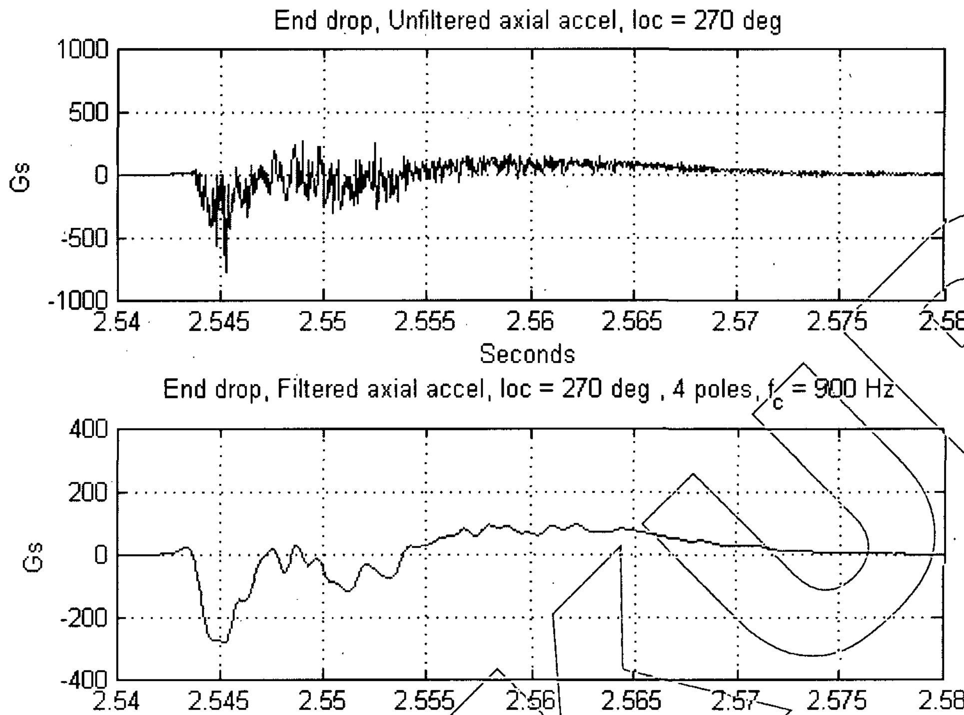


Figure 27 Signal from the axial accelerometer inside the cask on the 270-degree aximuth before (top) and after (bottom) low-pass filtering.

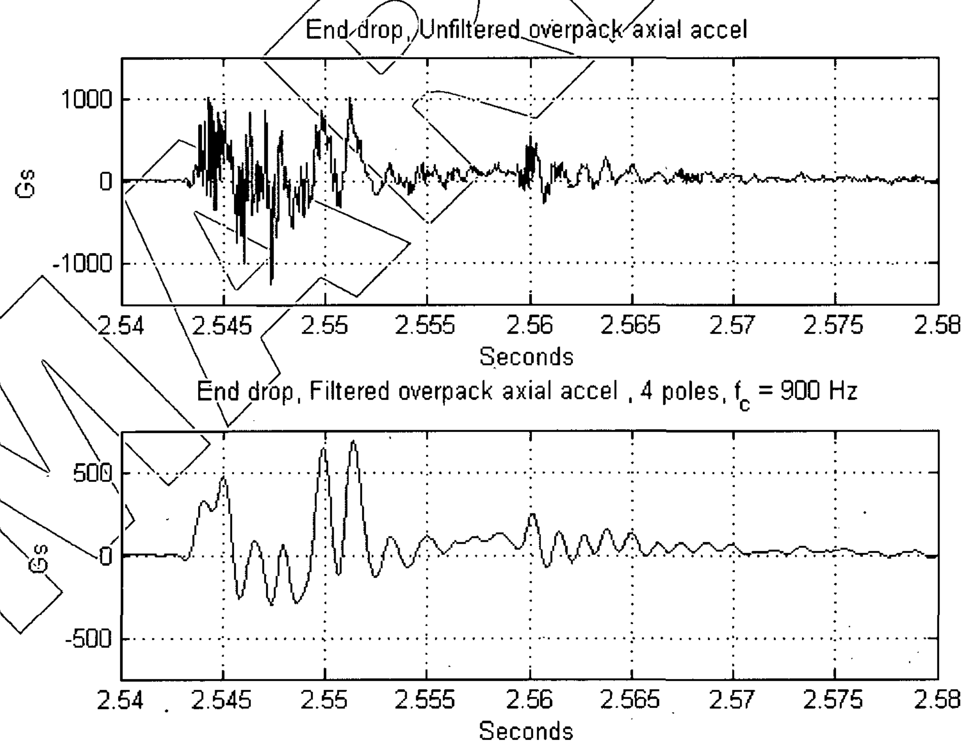


Figure 28 Signal from the axial accelerometer on the impact limiter before (top) and after (bottom) low-pass filtering.

corresponding to the initial deflection of the impact limiter and compression of the steel wool packing. However a millisecond later a secondary collision occurs as the packing goes solid and the tungsten bricks strike the lid end of the cask (recall that the cask is upside down) driving it downwards into the ground. The phenomenon is similar to a car accident where the occupants don't have their seat belts buckled, except that in this case the "occupants" are the heavy tungsten bricks. The secondary collision causes the large negative spike. Following that, a much longer period of upward acceleration occurs, which corresponds to the decay in the initial downward impact velocity. The signal corresponding to this latter positive acceleration is slightly attenuated by the AC coupling of the accelerometers themselves and also by the AC coupling of the signal to the data acquisition system.

The effect of secondary collisions is even more pronounced in the side and slap-down drops presented later, probably because the tungsten bricks are restrained less in the tangential and radial directions than they are in the axial direction.

An important feature of the peak acceleration due to the secondary collision is that it is not heavily dependent on the characteristics of the impact limiter. The spike is caused by several heavy, rigid bodies (the tungsten bricks) striking another (the stainless steel body of the cask) with the accelerometer rigidly mounted to the latter. This factor should be kept in mind in attempting to compare measured peak accelerations to analytical predictions, where the latter assume that all energy absorption is done by the impact limiter.

The effect of the secondary collisions is much less pronounced in the axial acceleration measured on the impact limiter (Figure 28), probably because the surface of the impact limiter mounting the accelerometer is only loosely coupled to the cask body. At this surface, the initial pulse of acceleration is quite large and is in the upward direction, as one would expect.

6.2 High-speed video

Figure 29 shows frames from one of the four high speed video cameras. Because the impact trigger was a last-minute addition after this first test, there is no accurate way to time-align the end-drop acceleration time history to the video frames. However based on that alignment for the side and slap-down drops, the initial impact is estimated to occur at t = 2.542 seconds in the traces of the last five figures.

Using the video and the length scales, it was determined that the cask bounced to a height of about 43 inches, indicating that about 90% of the kinetic energy was dissipated upon initial impact. After the first bounce, the cask teetered on one corner and then fell over on its side, crushing the umbilical cable from the accelerometers. Fortunately, the important acceleration event was over by this time and had been recorded.

A video editing program[10] was used to estimate the elapsed time from first impact to the point where the vertical velocity of the cask c.g. dropped to zero. It was 0.021 +/-0.004 seconds. Time resolution (time between frames) was 0.001 seconds in the video used for this estimate.

[10] Imaging Studio version 2.4.0, AOS Technologies AG

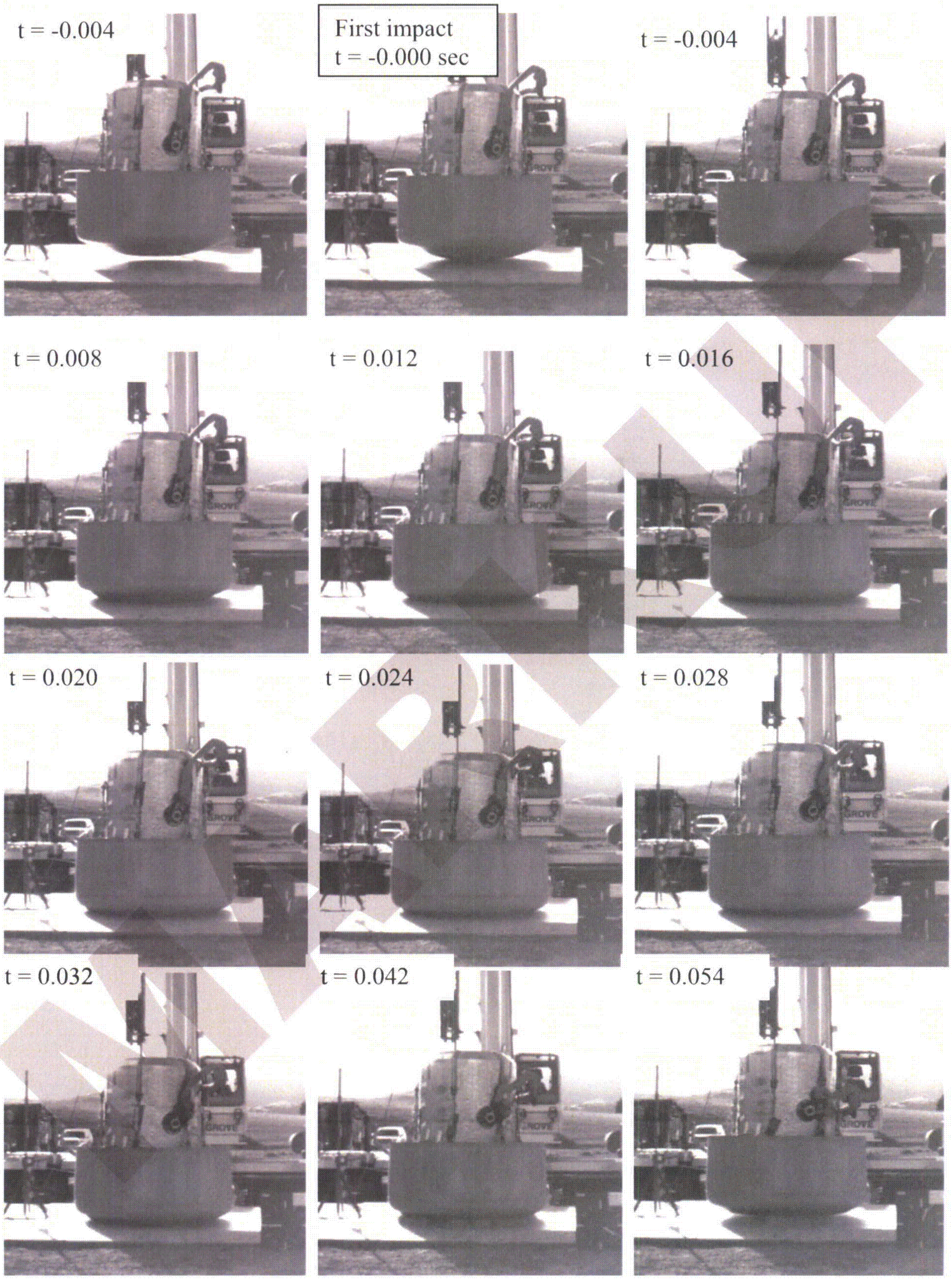


Figure 29 Frames from high-speed video of end drop.

6.3 Pressure sensing film

Figure 30 shows the pressure sensing film from the end drop. The band of film that was taped to the cylindrical surface of the cask (Figure 19) has been cut into four equal pieces which are placed in their respective azimuthal locations in Figure 30. In Figure 30 and in the similar photographs from the side and slap-down drops, the surface of the film which faced away from the cask is towards the camera.

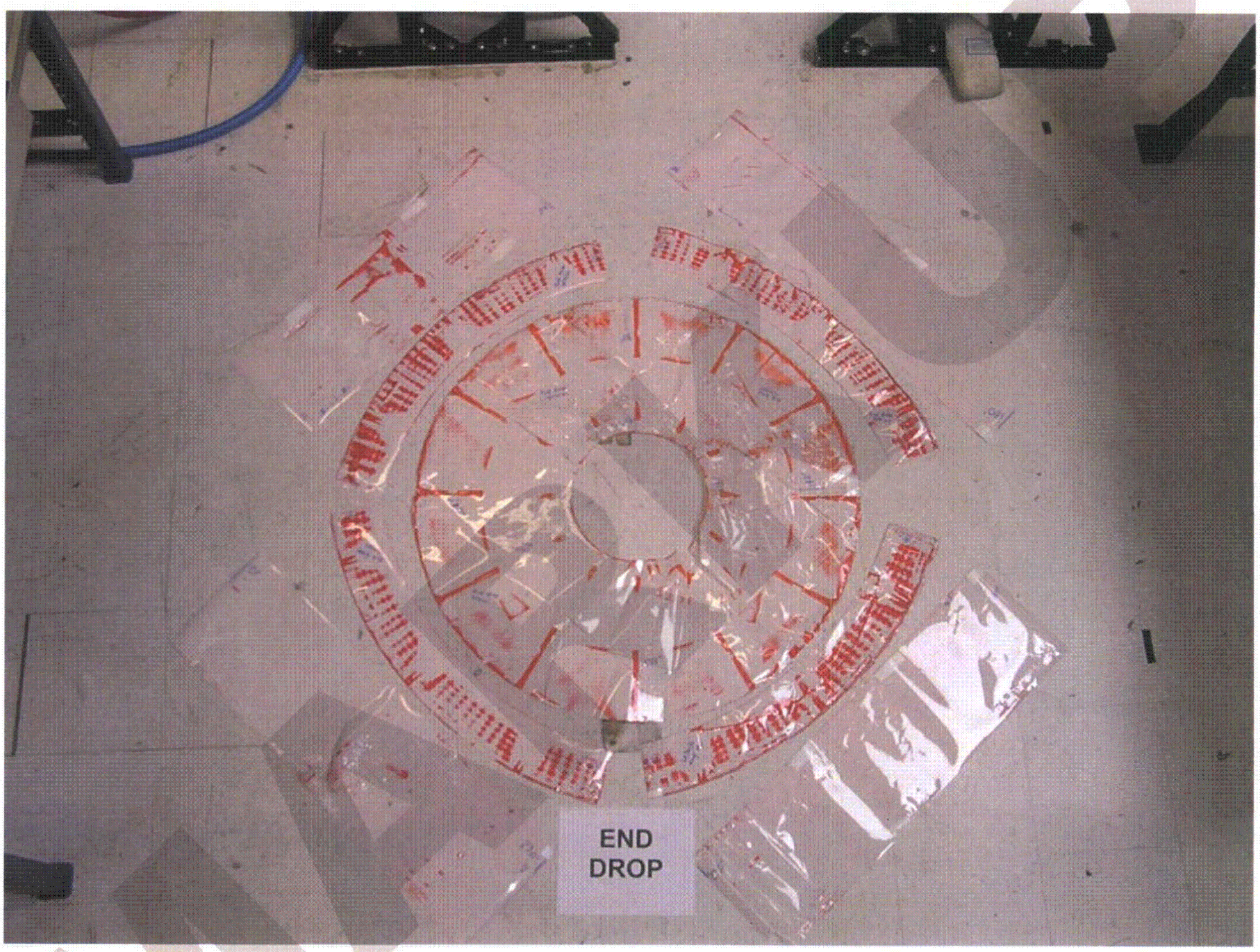


Figure 30 Pressure sensing film removed from the cask after the end drop.

The red areas on the film indicate where contact occurred between the cask and impact limiter. The radial "spoke" impressions made by the 12 strengthening ribs inside the impact limiter are clearly visible on the circular piece of film from the flat end surface of the cask. The picture also shows that significant forces between the cask and impact limiter occurred on the conical surface produced by the chamfer on the end of the cask. The package struck with its axis nearly vertical which accounts for the fact that there was relatively little contact between the cask cylindrical surface and the inside diameter of the impact limiter.

6.4 Deformation measurements

Table 1 shows the measured cask profile deviation from the design nominal before and after the end drop. The conclusion from these measurements was that no significant damage to the cask had occurred.

Table 3 Before and after end-drop measurements of the cask.

	Cask state at measurement	
		After end drop
Deviation	Before end drop	Before side drop
Maximum	0.0068	0.0046
Minimum	-0.0094	-0.0101

Figure 31 shows an overlay of the profile of the impact limiter before and after the end drop.

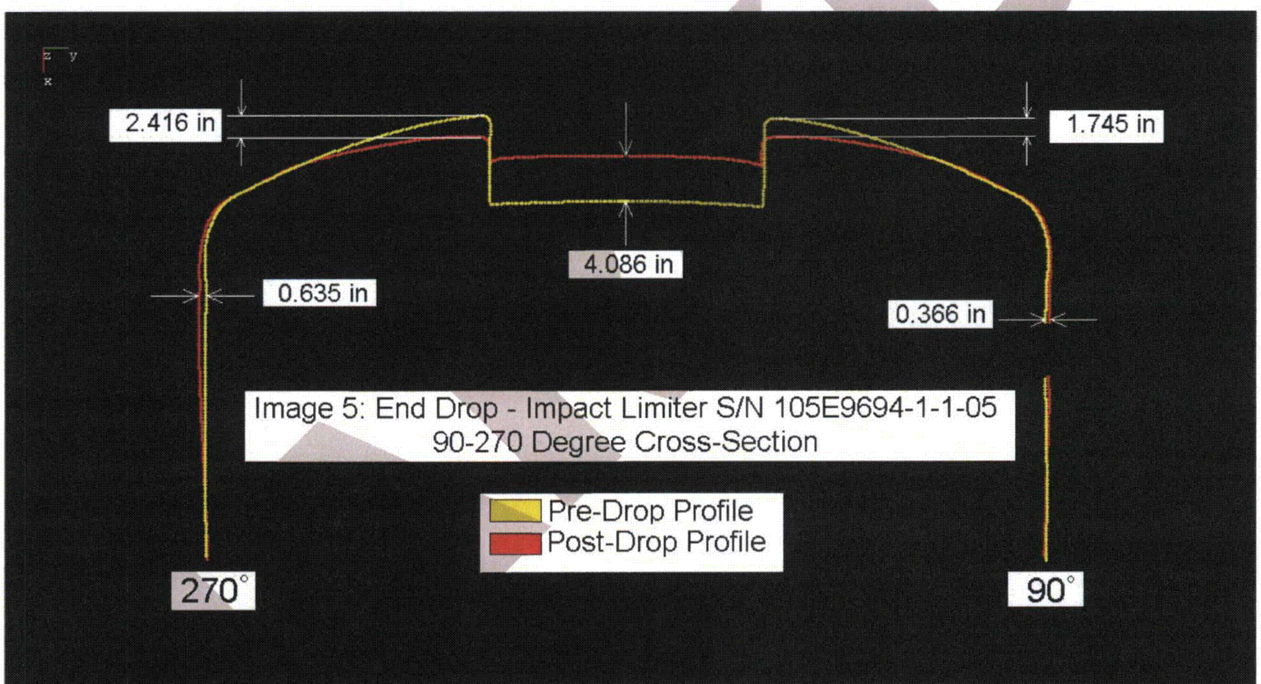


Figure 31 Profiles of the impact limiter before and after the end-drop

Figure 32 shows the impact end of the impact limiter after the end drop. The previously flat surface in the large center relief on the end of the impact limiter has been bulged out over four inches by the force from the cask transmitted through the foam. The weld around the edge of the relief has split over a small part of the circumference.

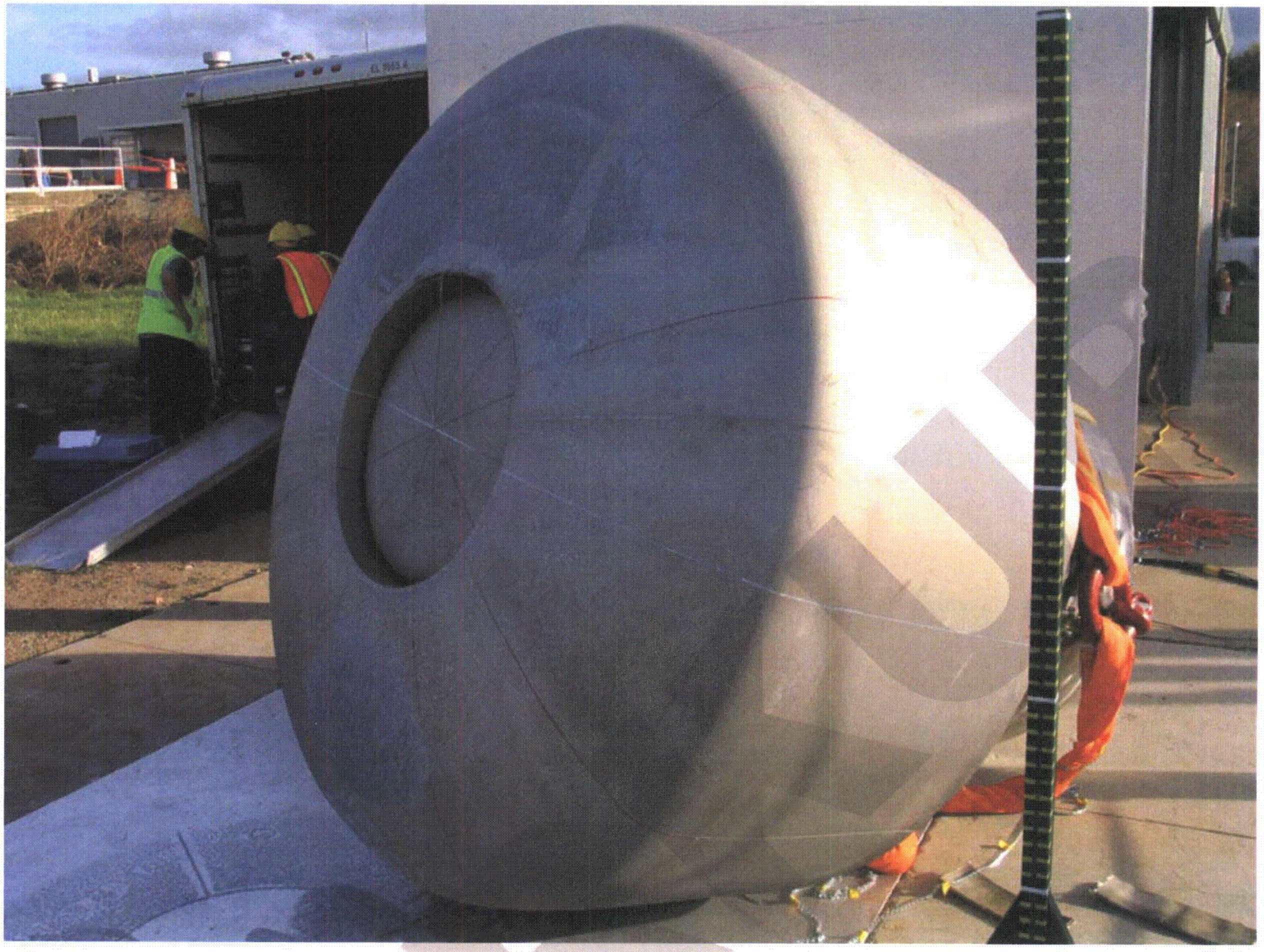


Figure 32 Cask and impact limiter immediately following the end drop.

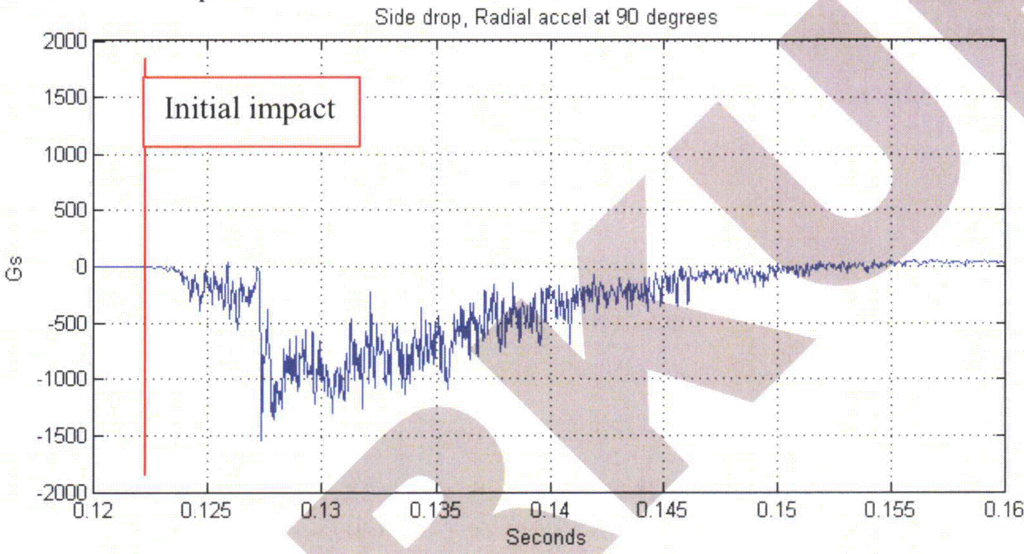
6.5 Leak rate test

The cask was leak tested following the end drop and was found to meet specification. It was concluded that no degradation had occurred in the seal integrity of the cask.

7. Results: Side drop

7.1 Acceleration measurements

For the side drop, the two radial accelerometers inside the cask were oriented in the vertical direction but facing in opposite directions. The sensor at 90 degrees azimuth faced downwards so upwards acceleration gave a negative signal. Figure 33 shows the signals from these two sensors during the initial impact.. Initial contact as sensed by the impact trigger was at time = 0.1217 seconds[11] in the plot.



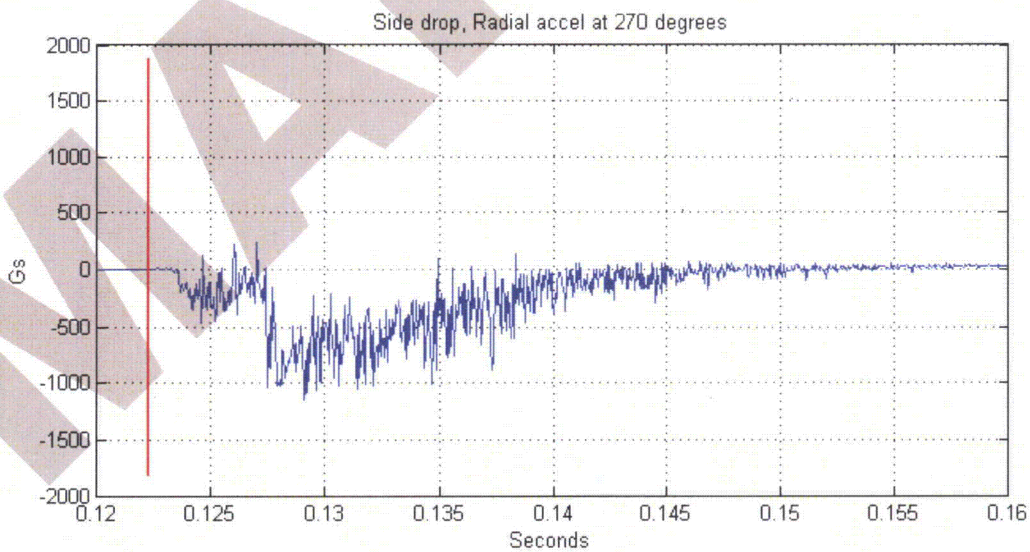


Figure 33 Vertical accelerations measured at impact inside the cask for the side drop.

[11] The t = 0 origin is arbitrary but is the same for all acceleration signals on a given drop.

Figure 34 shows the triaxial signals from the sensors on the impact limiter. The radial sensor on the impact limiter is essentially vertical and faces downward, like the in-cask accelerometer at 90 degree azimuth, so upwards acceleration gives a negative signal.

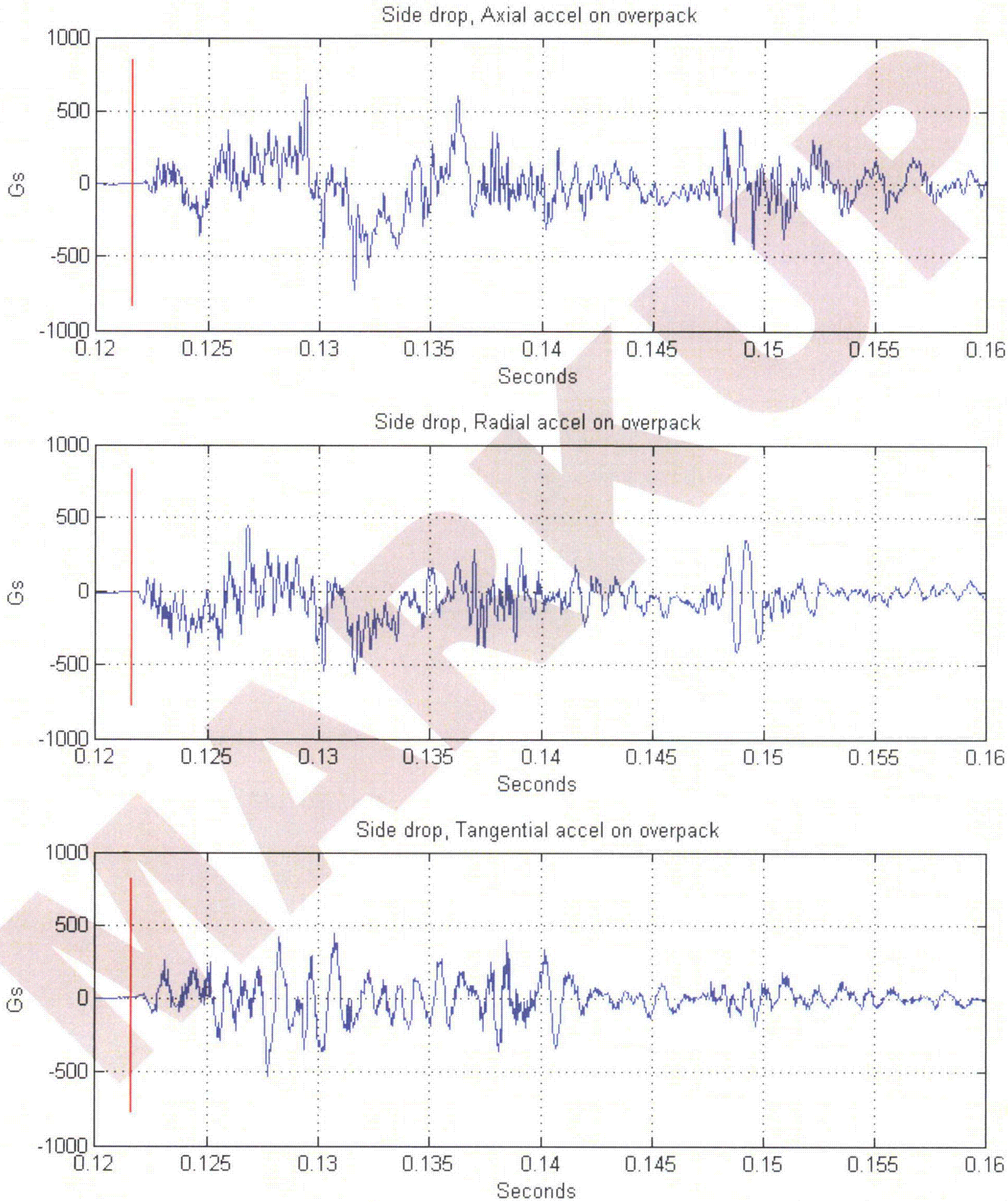


Figure 34 Accelerations measured on the impact limiter during the side drop.

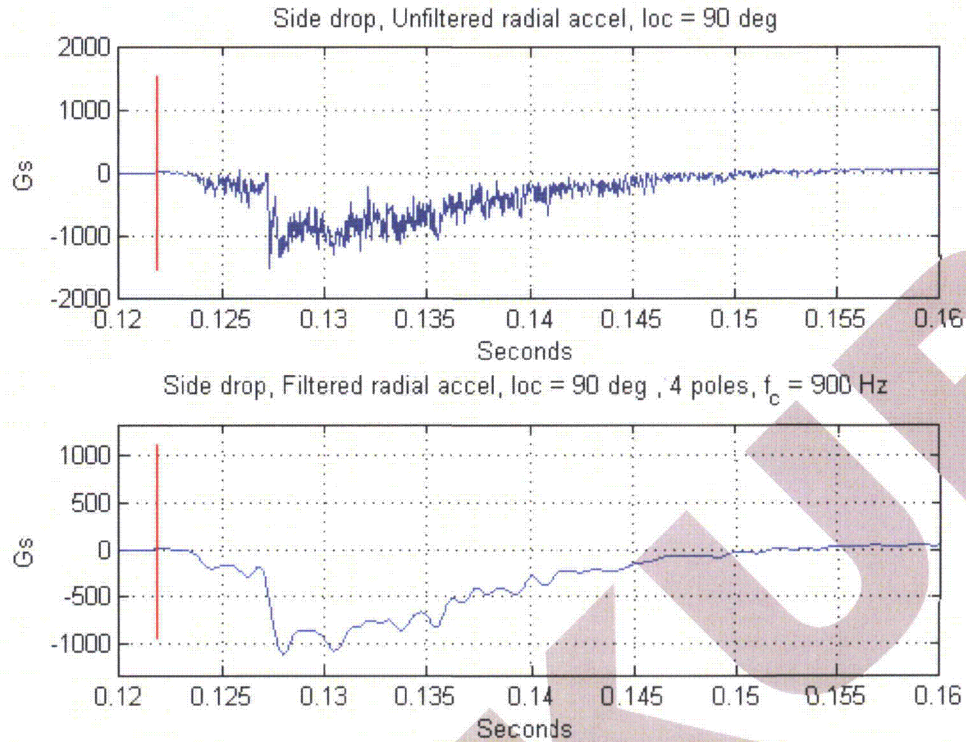


Figure 35 Signal from the radial in-cask accelerometer at 90-degree azimuth for the side drop, unfiltered (top) and low-pass filtered (bottom).

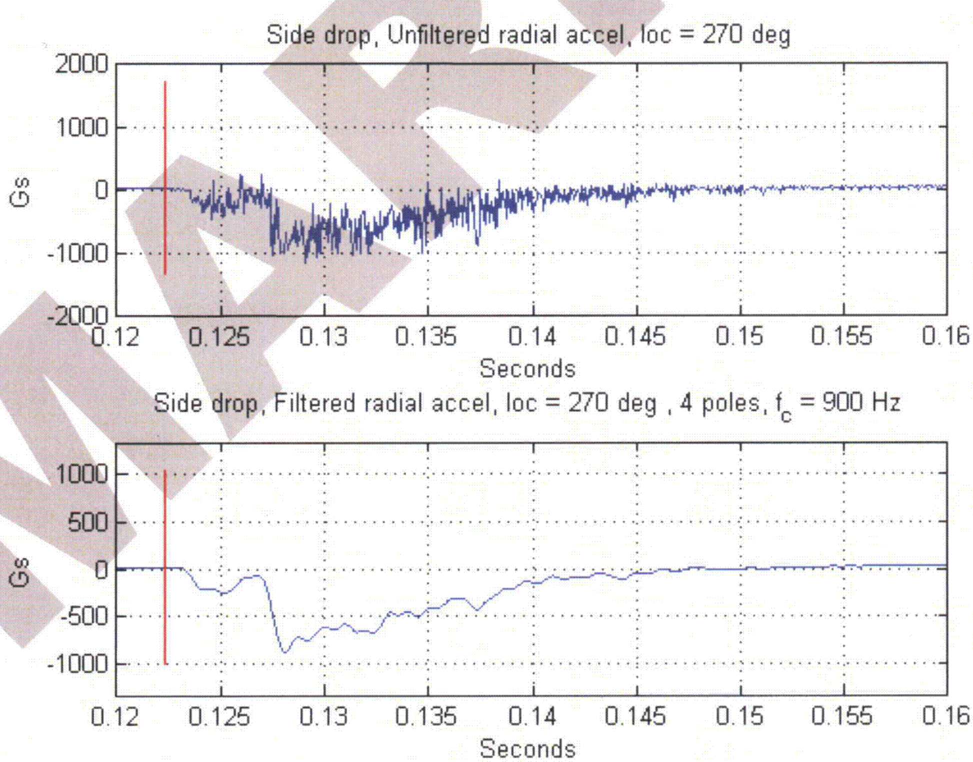


Figure 36 Signal from the radial in-cask accelerometer at 270-degree azimuth for the side drop, unfiltered (top) and low-pass filtered (bottom).

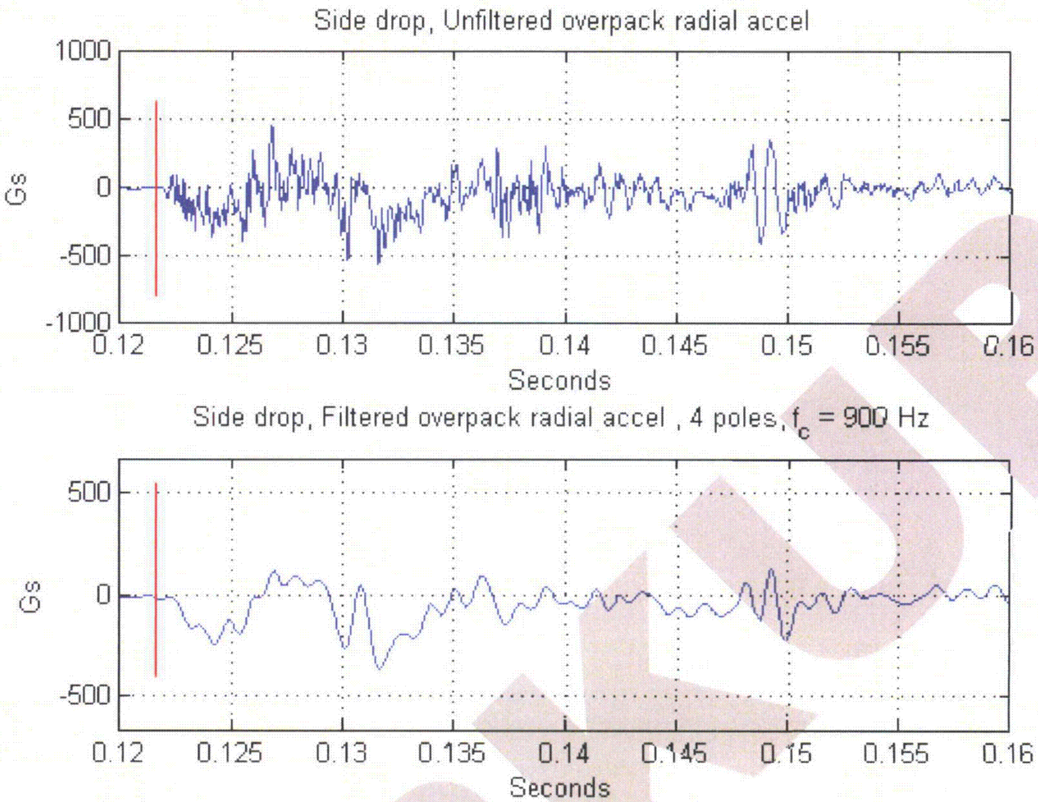


Figure 37 Signal from the radial accelerometer on the impact limiter, unfiltered (top) and low-pass filtered (bottom).

Figure 35, Figure 36, and Figure 37 show unfiltered and filtered signals from the three vertical accelerometers. The most important feature of these signals is that the in-cask accelerometers all over-ranged. They hit their 1000-g limit at time equal to approximately 0.127 seconds when a sudden negative step occurred in the acceleration. Typically with ICP accelerometers, the signal following such an over-range is not valid for a few tenths of a second. Thus, the only thing that can be said with certainty regarding cask acceleration is that it exceeded 1000 g's at the sensor location. This high level was probably caused by the secondary collisions between the heavy tungsten bricks of the shielding layer and the steel body of the cask. It's likely that the steel wool packing did not restrain the tungsten bricks as well in the radial and tangential directions as it did in the axial direction. This would account for the higher peak levels seen in the side drop compared to the end drop.

Referring to Figure 35 and Figure 36, the initial and secondary impacts are clear. The initial impact gives a peak acceleration of about 250 g's and the secondary impact gives over 1000 g's (over-range). However there is one unresolved anomaly in the data. Both radial signals go negative at both initial and secondary impacts. However the two sensors face in opposite directions and thus have signals of opposite polarities relative to upwards. One would expect their signals to be approximately the negatives of each other, at least during the initial smaller impact. At present there is no explanation for this pattern, which also occurred in the slap-down drop.

Figure 38 Cask and impact limiters following the side drop.

Figure 38 shows the cask with impact limiters after the drop. Three of the six heavy steel turnbuckles holding the impact limiters against the cask failed when their clevis pins sheared. This allowed the lower parts of the two impact limiters to move away from each other. This may have caused another secondary impact effect when the impact limiters rotated outwards as far as they could and jammed against the cask outer diameter, thus suddenly stopping the descent of the heavy cask.

7.2 High-speed video

Figure 39 shows frames from one of the three high-speed video cameras. The impact time denoted as t = 0.000 seconds in the video frames corresponds to t = 0.1217 seconds in the acceleration time histories. The video sequence shows clearly how the lower sides of the two impact limiters pulled away from each other at impact, causing the lower turnbuckles to fail. This may have been due to a wedging action of the chamfered ends of the cask against the conical section of the mating recess in the impact limiters. It might also have been caused by the centroid of the impact force against the lowest surface of each impact limiter being outboard of the cask ends, causing a rotational moment on the impact limiters.

Since there is only about ¼ inch of diametral clearance between the cask OD and the impact limiter ID, the outward rotation of the impact limiters would come up against a hard limit, which may have contributed to the secondary impact.

Following the initial impact, the package bounced to a height of about 17 inches, indicating that over 95% of the kinetic energy had been dissipated.

Using the video editing program, the elapsed time was estimated between initial impact and the instant when the cask c.g. reached zero vertical velocity. That time was 0.022 +/-0.004 seconds. The resolution of this measurement (i.e. the time between frames) was 0.002 seconds.

Figure 39 Frames from high-speed video of side drop

7.3 Pressure sensing film

Figure 40 shows the pressure sensing film from the side drop. Most of the impact was taken on the downward-facing part of the cask cylindrical surface (on the right in the photos), and on the

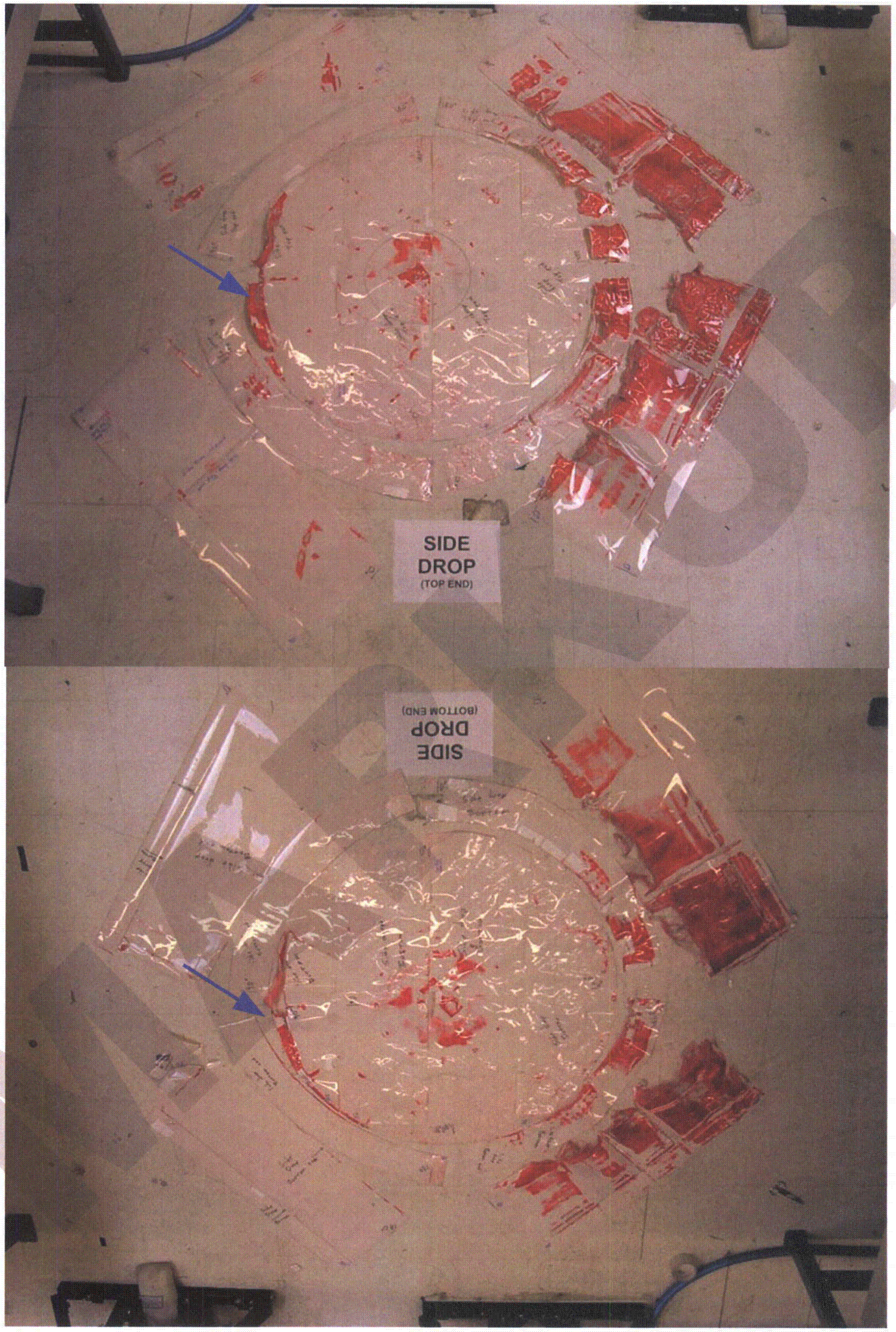


Figure 40 Pressure sensing film removed from the cask after the side drop.

downward facing part of the conical surface, as would be expected. However, there is also a significant amount of red on the paper that was on the uppermost part of the flat, circular end surfaces of the cask (blue arrows in the figure). Pressure against these areas is further evidence of secondary impact after the turnbuckles failed, the impact limiters rotated outwards, and their lower parts moved away from each other.

7.4 Deformation measurements

Table 4 shows the measured cask profile deviation from the design nominal before and after the side drop. The conclusion from these was that no significant damage to the cask had occurred.

Table 4 Measurements of the cask before and after side-drop.

	Cask state at measurement	
	After end drop	After side drop
Deviation	Before side drop	Before slap-down drop
Maximum	0.0046	0.0053
Minimum	-0.0101	-0.0109

Figure 41 shows one of the impact limiters after removal from the cask. One of the welds between the conical and cylindrical sections has split open, revealing the energy absorbing foam within. Figure 42 shows an overlay of the measured impact limiter profiles before and after the side drop.

Figure 41 Damage to impact limiter from side drop.

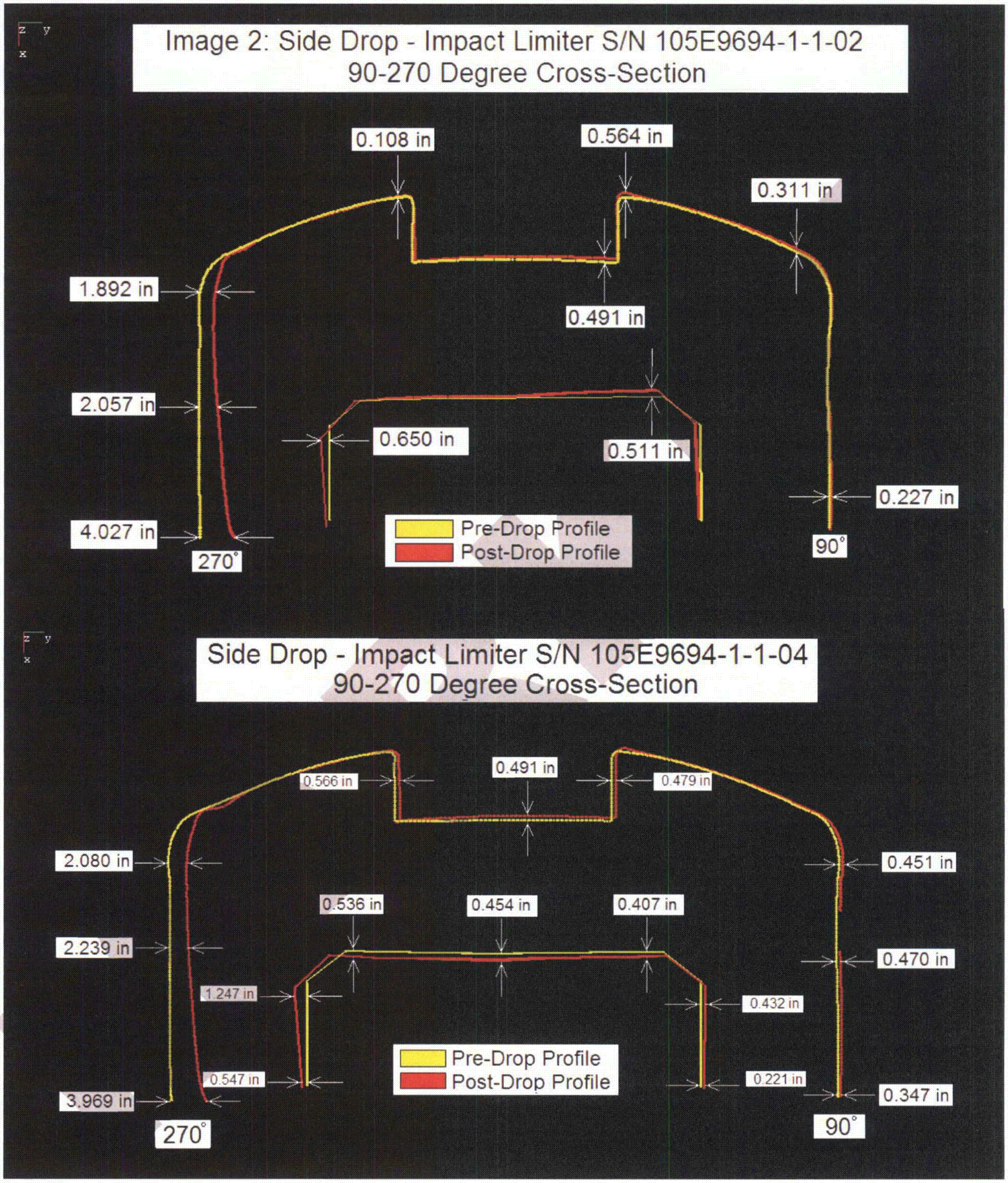


Figure 42 Profiles of the impact limiters before and after the side drop.

7.5 Leak rate test

The cask was leak tested following the side drop and was found to meet specification. It was concluded that no degradation had occurred in the seal integrity of the cask.

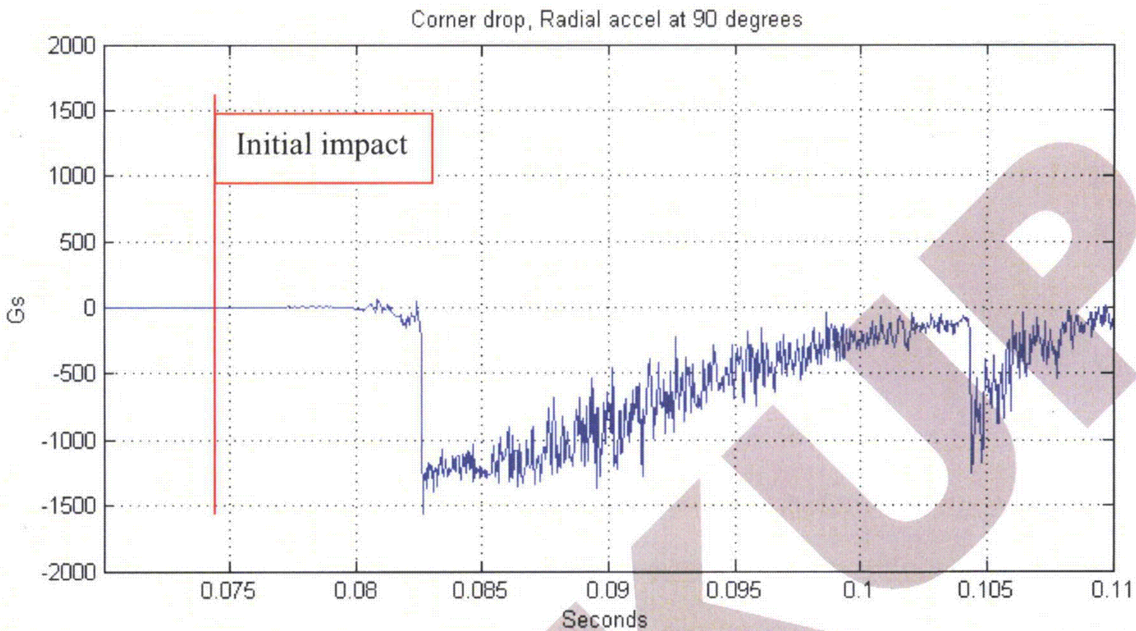
8. Results: Slap-down drop

Figure 43 Package rigged for the slap-down drop.

Figure 43 shows the package rigged for the slap-down drop. The weight of the package is held by the brown rigging straps which lift at the cask trunnions. The yellow straps on either side were adjusted to hold the package such that its left end was about 10 inches higher than its right end. This had been determined by analysis to be the worst case. The lid end of the cask is on the left in the photo. The impact limiters on the left and right will be referred to as the "lower" and "higher" respectively.

8.1 Acceleration measurements

For the slap-down drop, the two radial accelerometers inside the cask were oriented 7.7 degrees off the vertical direction, facing in opposite directions. The sensor at 90 degrees azimuth faced downwards so upwards acceleration gave a negative signal from this sensor. Figure 44 shows the signals from these two sensors.. Initial impact was at time = 0.0746 seconds



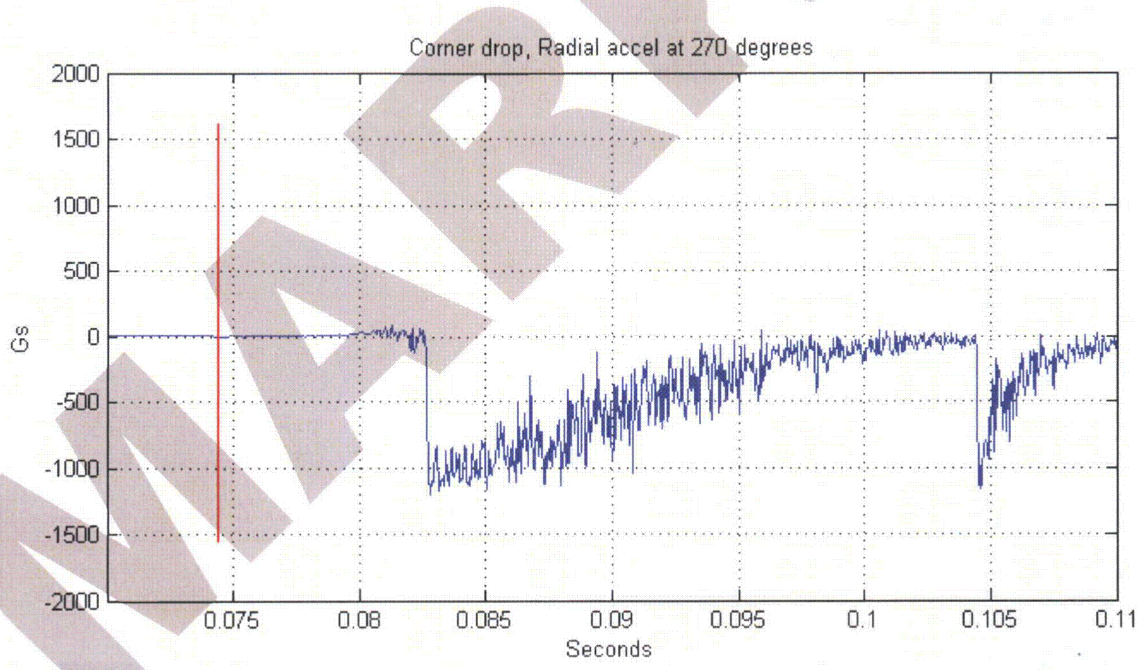


Figure 44 Near-vertical accelerations measured nside the cask for the slap-down drop.

Figure 45 shows the triaxial signals from the sensors on the impact limiter. The radial accelerometer on the impact limiter is again closest to vertical and faces downward. Upwards acceleration gives a negative signal from this sensor.

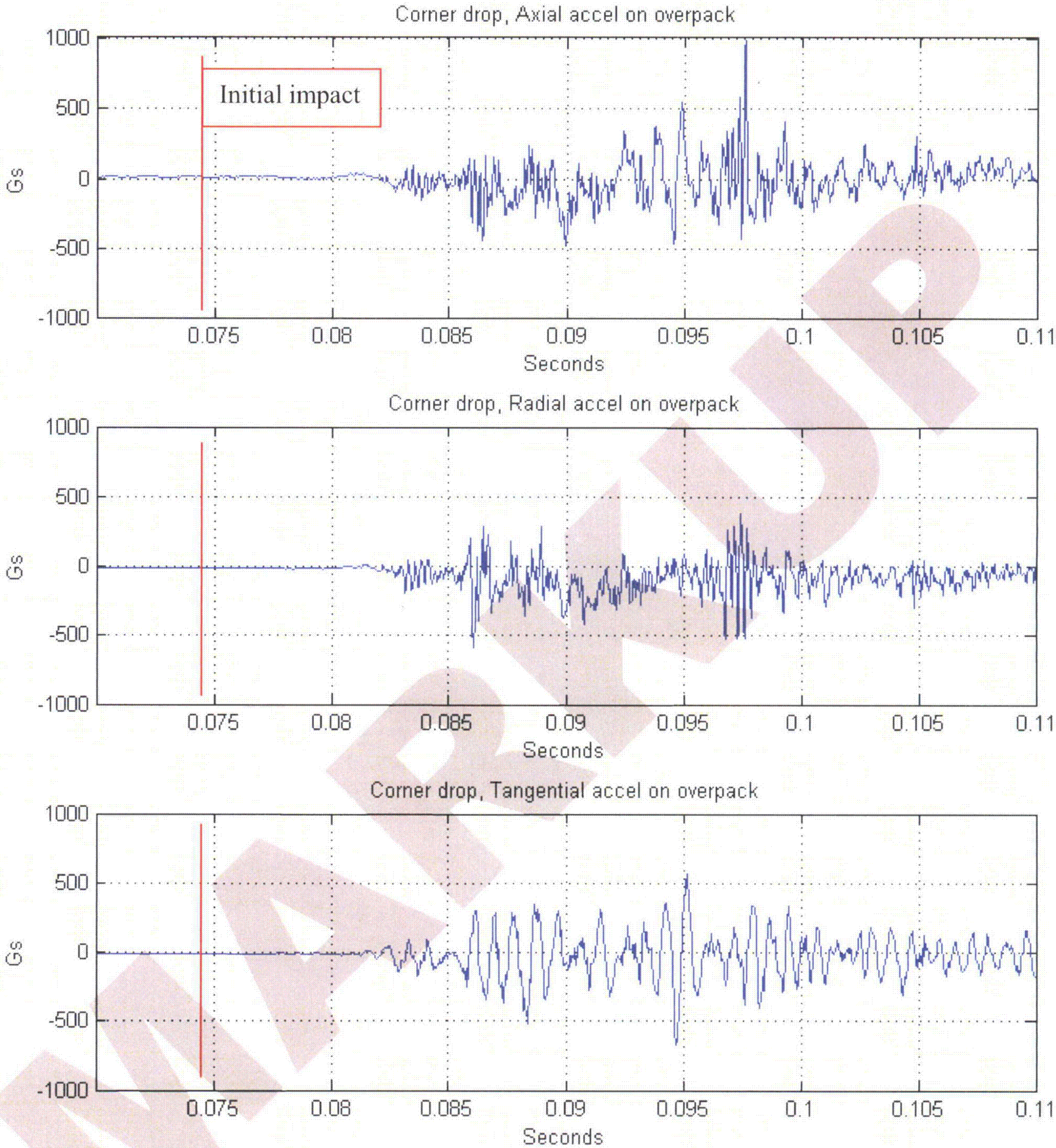


Figure 45 Accelerations measured on the impact limiter during the slap-down drop.

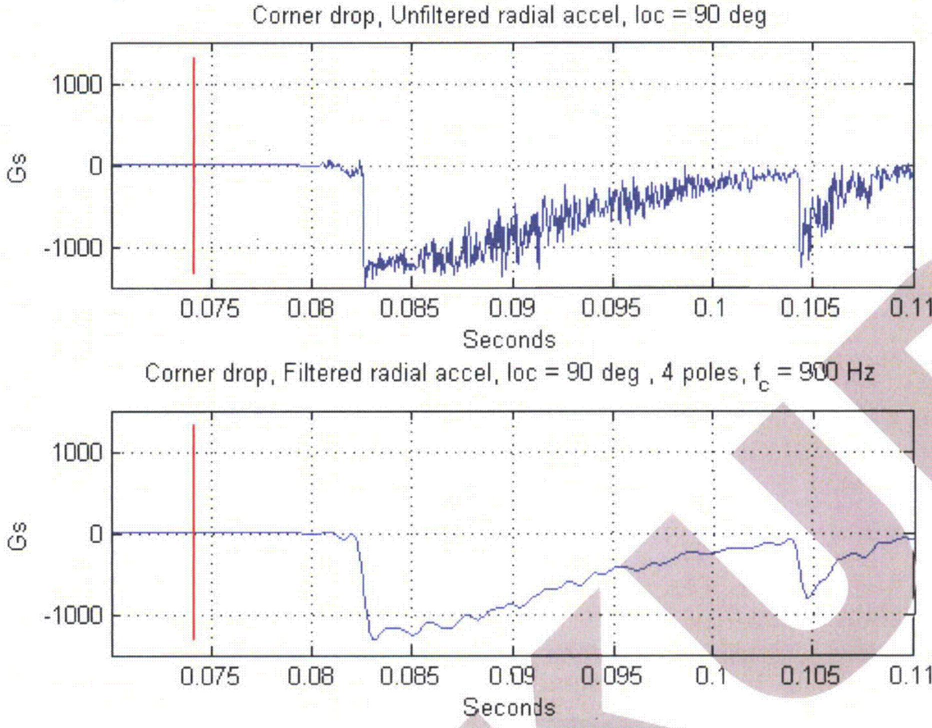


Figure 46 Signal from the radial in-cask accelerometer at 90-degree azimuth for the slap-down drop, unfiltered (top) and low-pass filtered (bottom).

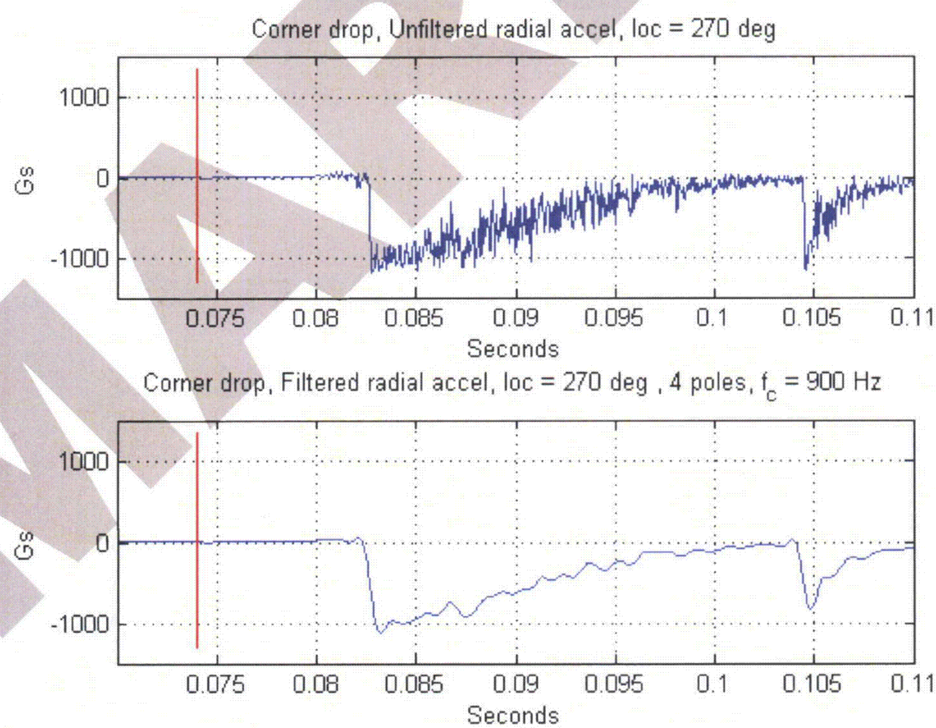


Figure 47 Signal from the radial in-cask accelerometer at 270-degree azimuth for the slap-down drop, unfiltered (top) and low-pass filtered (bottom).

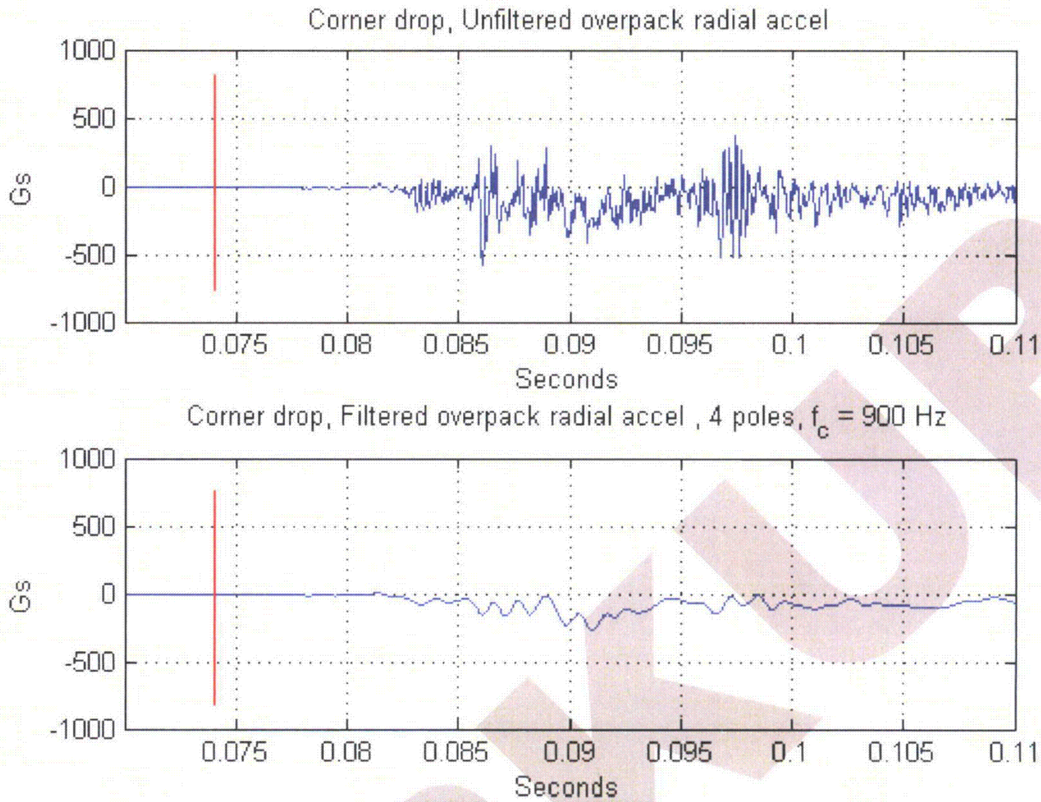


Figure 48 Signal from the radial accelerometer on the impact limiter during the slap-down drop, unfiltered (top) and low-pass filtered (bottom).

Referring to Figure 44, there are two major events, one at 0.0822 seconds and one at 0.1042. seconds. Comparing this time interval to the high-speed video (Figure 49), these two impacts are obviously due to the initial strike of the lower impact limiter (on the left in Figure 49) and the strike of the higher impact limiter (on the right in Figure 49). Like the side drop, the initial impact causes the accelerometers to over-range so the only quantitative conclusion that can be drawn is that the accelerometers saw over 1000 g's. The exact peak level in unknown.

The slap-down drop also produced the same unexplained polarity as the side drop: both in-cask radial accelerometer signals went negative at the major impact events. Taken literally, these signals would indicate that the round cross section of the cask ID was deforming suddenly into an oval, with the 90 and 270-degree azimuthal locations moving away from each other. At present, there is no satisfactory explanation for this phenomenon.

8.2 High-speed video

Figure 49 shows frames from one of the three high-speed video cameras from the slap-down drop. The impact time denoted as t = 0.000 seconds in the figure corresponds to t = 0.0746 seconds in the acceleration time histories. The turnbuckles holding the impact limiters for this

Figure 49 Frames from high-speed video of slap-down drop.

drop used heavier clevis pins which did not break on impact. However the upper turnbuckles buckled which caused them to become shorter so there was still considerable relative rotation between the two impact limiters, as evident in the video frames. Figure 50 shows the uppermost turnbuckle following the drop.

Using the video editing program, the elapsed time was estimated between initial impact and the instant when the cask c.g. reached zero vertical velocity. That time was 0.028 +/-0.004 seconds. Unlike the first two drops, the cask kinetic energy had not been completely dissipated at the zero velocity instant since there was still significant rotational velocity present. The resolution of this measurement (i.e. the time between frames) was 0.002 seconds.

Figure 50 Uppermost turnbuckle after the slap-down drop.

Figure 50 also shows how the wires from the in-cask accelerometers were crushed and cut by being pinched between the impact limiter and the cask. In this case the relative rotation between the impact limiters and the cask was sufficient to pinch the cables, in spite of the $1/8^{th}$-inch-diameter protective rods on either side of the cable. Figure 50 shows that the diametral clearance between cask and impact limiter has been increased to well over an inch by deformation of the impact limiter. In an undeformed impact limiter, this clearance is only about $1/4^{th}$ inch. Fortunately, the cable fault did not occur until about 25 milliseconds after the end of the main acceleration event so the important data was recorded.

Following the impact of the higher impact limiter against the ground, the package rotated counterclockwise (in the view of Figure 49) and its mass center rose approximately 25 inches, indicating that about 93.3 percent of the kinetic energy was dissipated. Figure 51 shows the highest point in the first bounce.

Figure 51 Highest point in the first bounce during the slap-down drop.

8.3 Pressure sensing film

Figure 52 shows the pressure sensing film removed after the slap-down drop. The pattern of pressure between the cask and impact limiter is quite similar to that from the side drop.

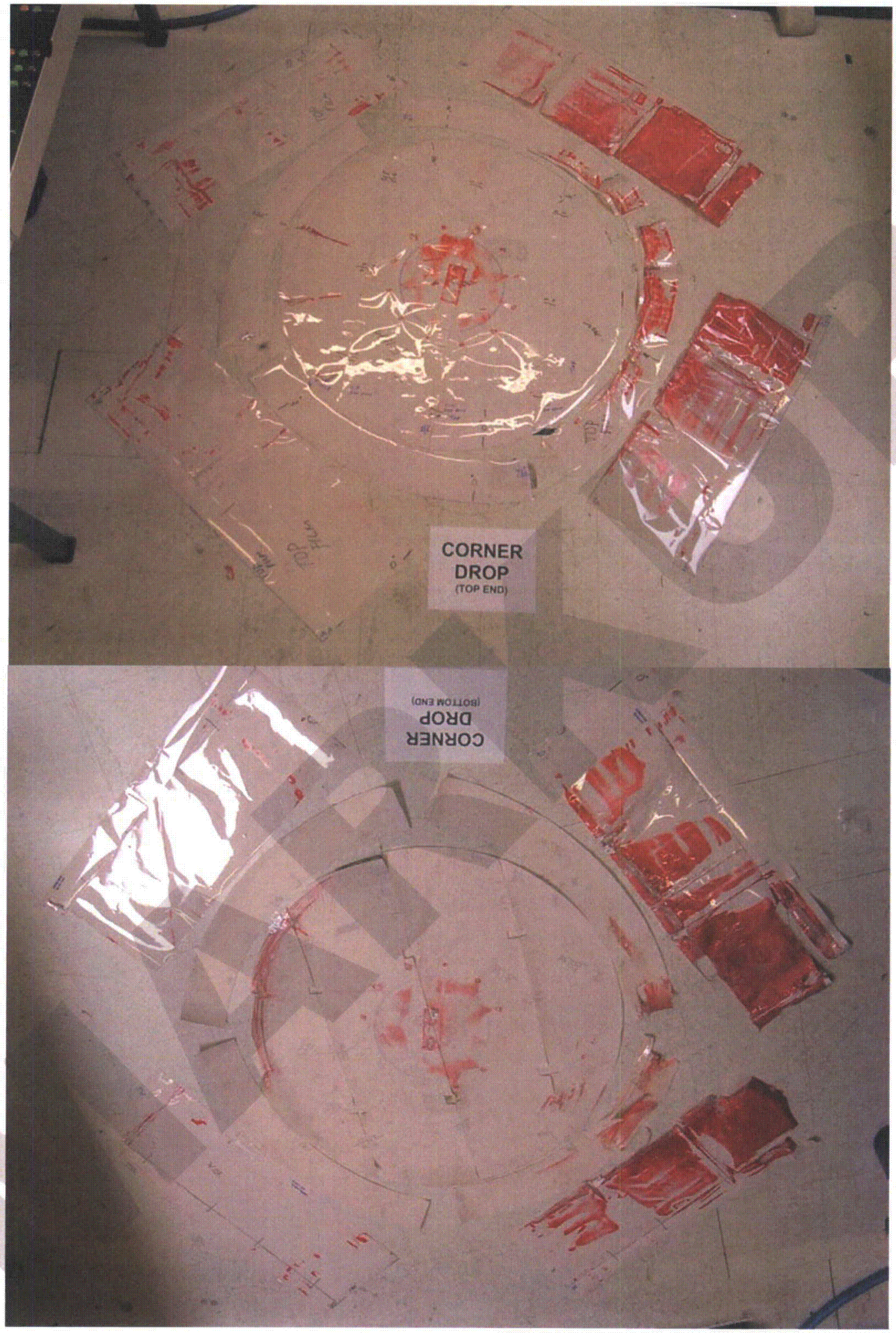


Figure 52 Pressure sensing film removed from the cask and impact limiters after the slap-down drop.

8.4 Deformation measurements

Table 5 shows the measured cask profile deviation from the design nominal before and after the slap-down drop. The conclusion from these was that no significant damage to the cask had occurred.

Table 5 Measurements of cask before and after the slap-down drop.

	Cask state at measurement	
	After side drop	After slap-down drop
Deviation	Before slap-down drop	
Maximum	0.0053	0.0047
Minimum	-0.0109	-0.0105

Figure 53 shows the deformation suffered by the impact limiter that was on the higher end of the cask. Figure 54 shows overlays of the measured impact limiter profiles before and after the slap-down drop. The lower part of the figure shows how much the inner diameter of the impact limiter was deformed when it rotated relative to the cask on impact.

Figure 53 Damage to the impact limiter from the "slap-down" end of the cask.

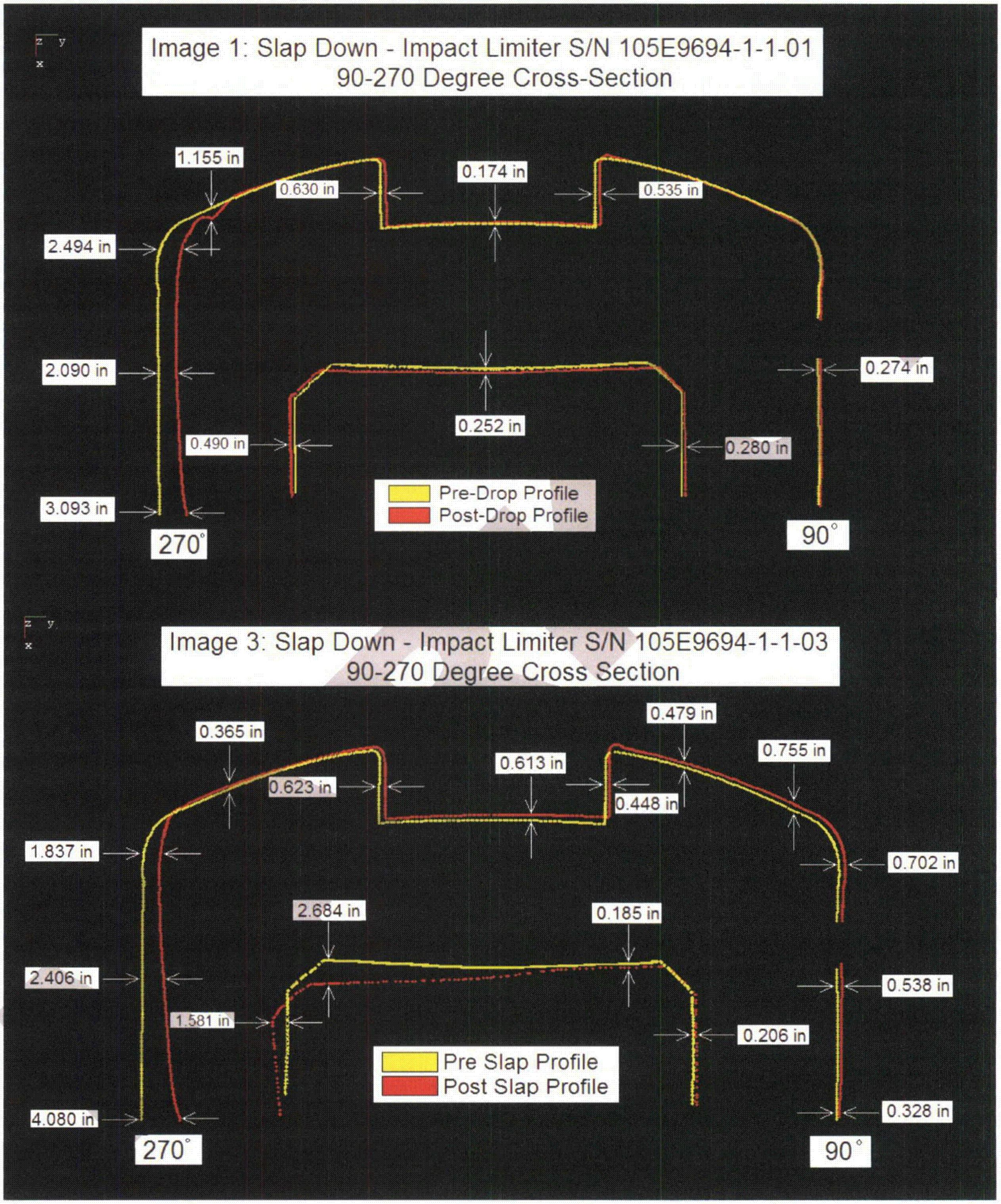


Figure 54 Profiles of the higher (top) and lower (bottom) impact limiters before and after the slap-down drop.

8.5 Leak rate test

The cask was leak tested following the slap-down drop and was found to meet specification. It was concluded that no degradation had occurred in the seal integrity of the cask.

9. Conclusions

The objectives, methods, and results of the drop test have been presented. The primary conclusions are as follows.

1. The cask and impact limiters passed the test. The cask passed its helium leak rate test before the first drop and after each of the three drops. No significant deformation of the cask was measured after any of the drops.

2. Measured peak accelerations are not usable for evaluating the accuracy of analytical predictions of cask and impact limiter behavior. Peak acceleration measured on the cask inner surface appears to be caused by secondary impacts between the internal tungsten shielding blocks and the steel cask body. The response to these impacts is not primarily dependent on impact limiter design.

3. Several measured acceleration time histories contained unexplained features. In particular, they did not exhibit a polarity consistent with the large decrease in downward velocity (i.e. upward acceleration) that had to exist at impact.

4. Two of the three drops caused accelerometers measuring in the vertical or near-vertical direction to exceed their 1000-g range. Therefore the waveform indicated by these accelerometers following the over-range is probably corrupted. The only conclusion that can be drawn from these data is that the peak acceleration exceeded 1000 g's at the sensor location. Acceleration data from the end drop is not over-ranged and should be accurate throughout the transient duration.

5. The high-speed video data allowed a reasonably accurate estimate to be made of the total elapsed time for deceleration of the cask c.g. from its impact velocity to zero. This data may be of use in evaluating the accuracy of the analytical predications.

8.3.3 Dimensional Inspection Report – Model AOS-165A

EAST COAST
METROLOGY

461 Boston Street ♦ Topsfield, Massachusetts 01983 ♦ Tel: 978-887-5781 ♦ Fax: 978-887-5782 ♦ www.EastCoastMetrology.com

RANOR / GE Energy / AOS
AOS-165 Cask Drop Test
Dimensional Summary Report No. 109699-01 (4-23-07)

RANOR Purchase Order No.: 109699

Part Names:	AOS-165 Cask Assembly and Impact Limiters
Document References:	Drawing Nos.105E9692 Rev. 2; 105E9694 Rev. 3; Specification No. 22A9418 Rev. 3
Serial Numbers:	AOS-165 105E9693-1 (RANOR S/N 050280-01) AOS-165 105E9694-1-1-01 (RANOR S/N 060452-01) AOS-165 105E9694-1-1-02 (RANOR S/N 060452-02) AOS-165 105E9694-1-1-03 (RANOR S/N 060452-03) AOS-165 105E9694-1-1-04 (RANOR S/N 060452-04) AOS-165 105E9694-1-1-05 (RANOR S/N 060452-05)
Inspection Dates:	March 16-30, 2007
Attachments:	FARO Calibration Certificate No. 4655 (10-19-2006)

Inspection Conditions:

Location:	GE Nuclear Energy Vallecitos Nuclear Center Sunol, CA 95486
Material:	Stainless Steel
Measurement Units:	Inches

East Coast Metrology was contracted by RANOR, Inc. for performance of On-Site Laser Tracker Inspection Services of the AOS-165 Cask Assembly and Impact Limiters fabricated by RANOR. The items were located at GE Nuclear Energy Vallecitos Nuclear Center 6705 Vallecitos Road Sunol, CA 95486.

East Coast Metrology utilized a FARO Laser Tracker Model X System, Serial No. X01000601930 for performing the dimensional inspections. The equipment has been calibrated by the manufacturer - FARO Technologies Kennett Square, PA 19348 on October 18, 2006, calibration due October 18, 2007 (FARO Calibration Certificate Number 4655) using standards traceable to the National Institute of Standards and Technology (NIST).

All dimensional inspection was performed under the direction and observation of GE Nuclear Energy Raul Pomares, Project Manager for the AOS-165 Cask Assembly and components.

The AOS-165 Cask Assembly and accompanying Impact Limiters were inspected by *East Coast Metrology* before and after each drop test to determine the extent of deformation due to each type of drop. Each component was scanned and compared to its corresponding CAD model using a Laser Tracker. See the following for a summary of the inspections and data.

AOS-165 Cask Assembly:

For each set of scan data for the Cask, the 0, 90, 180, and 270 degree profiles were scanned. An alignment using the axis of the cylindrical part of the cask as the controlling datum was used. This axis was then intersected with the "Lid End" of the Cask and a point was constructed. Another point was measured at the 90 degree lifting lug to establish the other axis. This alignment was repeated for each measurement of the Cask.

The table below, *Table 1*, shows the maximum and minimum deviations of the profiles of the Cask when compared to its CAD model for each drop test. The maximum (positive) deviations indicate the profile of the Cask was larger than that of the model. Similarly, the minimum (negative) deviations indicate that the profile of the Cask was smaller than that of the model.

Table 1: Cask Assembly Pre- and Post- Drop Profile Deviations from CAD Model (inches)

Cask Condition	Pre End Drop	Post End Drop	Post Side Drop	Post Slap Down
Maximum Deviation	0.0068	0.0046	0.0053	0.0047
Minimum Deviation	-0.0094	-0.0101	-0.0109	-0.0105

Over the course of all three drop tests, the maximum deviations varied by a total of 0.0022 inches, while the minimum deviations varied by a total of 0.0015 inches. This indicates that the effect of the drop tests had a negligible impact on the profile of the Cask.

Below is a sample of the Cask profile from the Pre- End Drop scan. There are 2 pictures, *Image A* is the 0-180 Cross-Section of the Cask, and *Image B* is the 90-270 Cross-Section. The red areas represent the positive (maximum deviations) and the yellow areas represent the negative (minimum deviations).

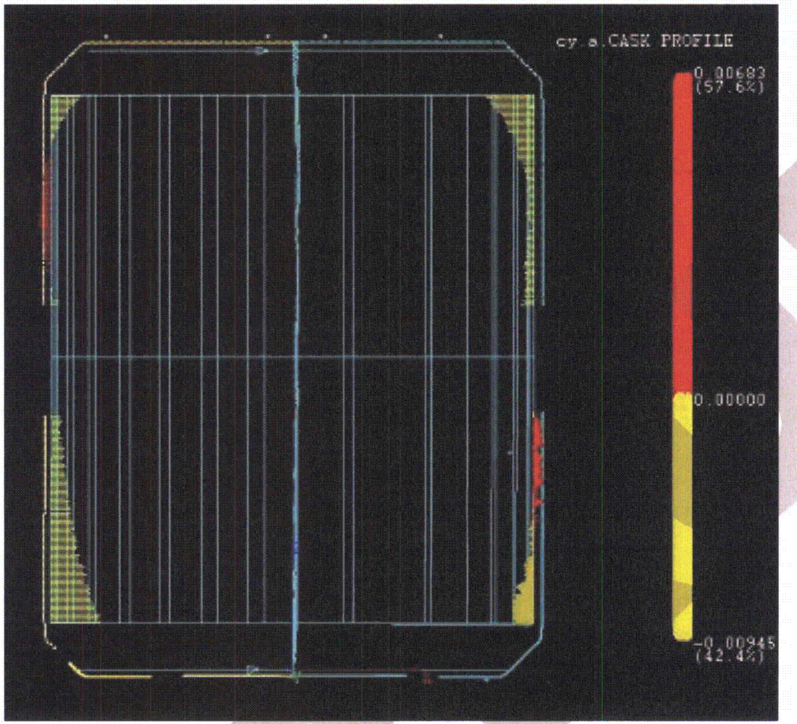


Image A: Cask Assembly Pre-End Drop Scan Data, 0-180 Degree Cross-Section

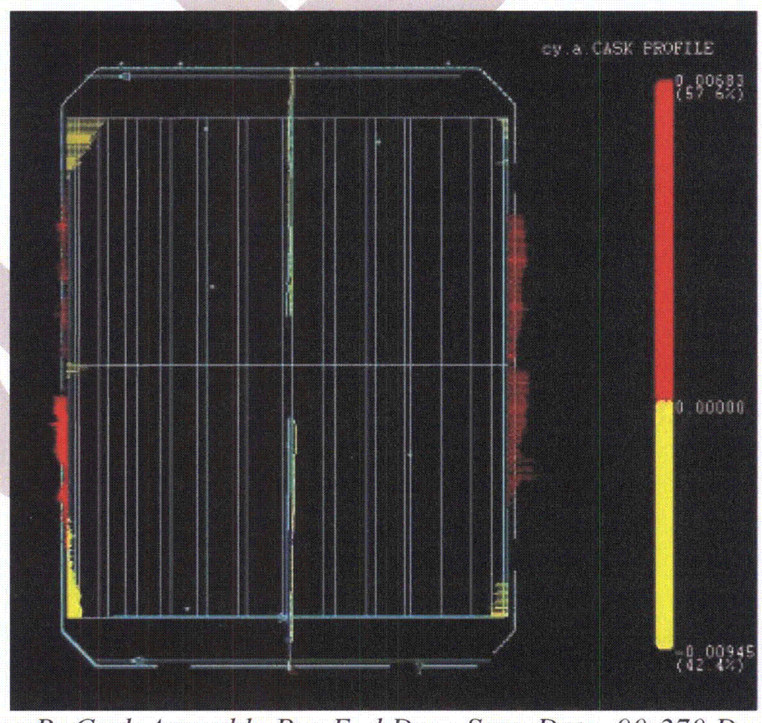


Image B: Cask Assembly Pre-End Drop Scan Data, 90-270 Degree Cross-Section

<u>AOS-165 Cask Impact Limiter Assemblies:</u>

For the Impact Limiters, scan data was taken at the 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300 and 330 degree profiles. In order to compare each impact limiter in its pre- and post- drop condition, an alignment using the bottom perimeter (opposite the domed-end), measured as a circle, was used a reference. By measuring it as a circle, the center point and vector of the measured circle were established. The portions of this circle that were deformed due to each drop test were not used in this calculation. The vector of this axis was defined to be the primary datum in this alignment. A point was then measured at the 90 degree lifting lug to establish the second axis in the coordinate system. This process provided the only repeatable means to align each impact limiter and subsequently compare the results.

Once the pre- and post-drop scan data was collected for each Impact Limiter, the 90-270 degree profile cross-sections were overlaid in order to calculate the magnitude of deformation for each drop. In the images below, each Impact Limiter has been analyzed in this manner and the deformations reported. They are listed below in the same order that the drop tests occurred: End Drop (Impact Limiter 5), Side Drop (Impact Limiters 1 & 3) and Slap Down (Impact Limiters 2 & 4).

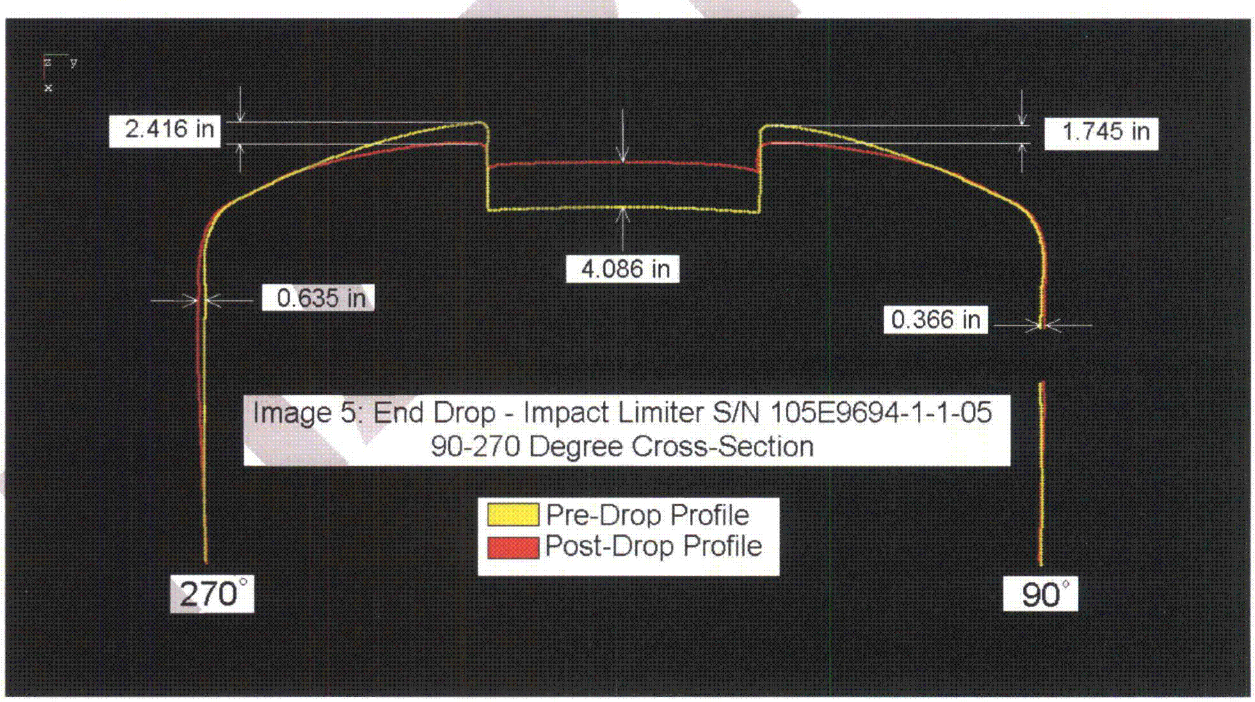


Image 5: Impact Limiter Serial No. 105E9694-1-1-05 - End Drop Cross-Section Overlay

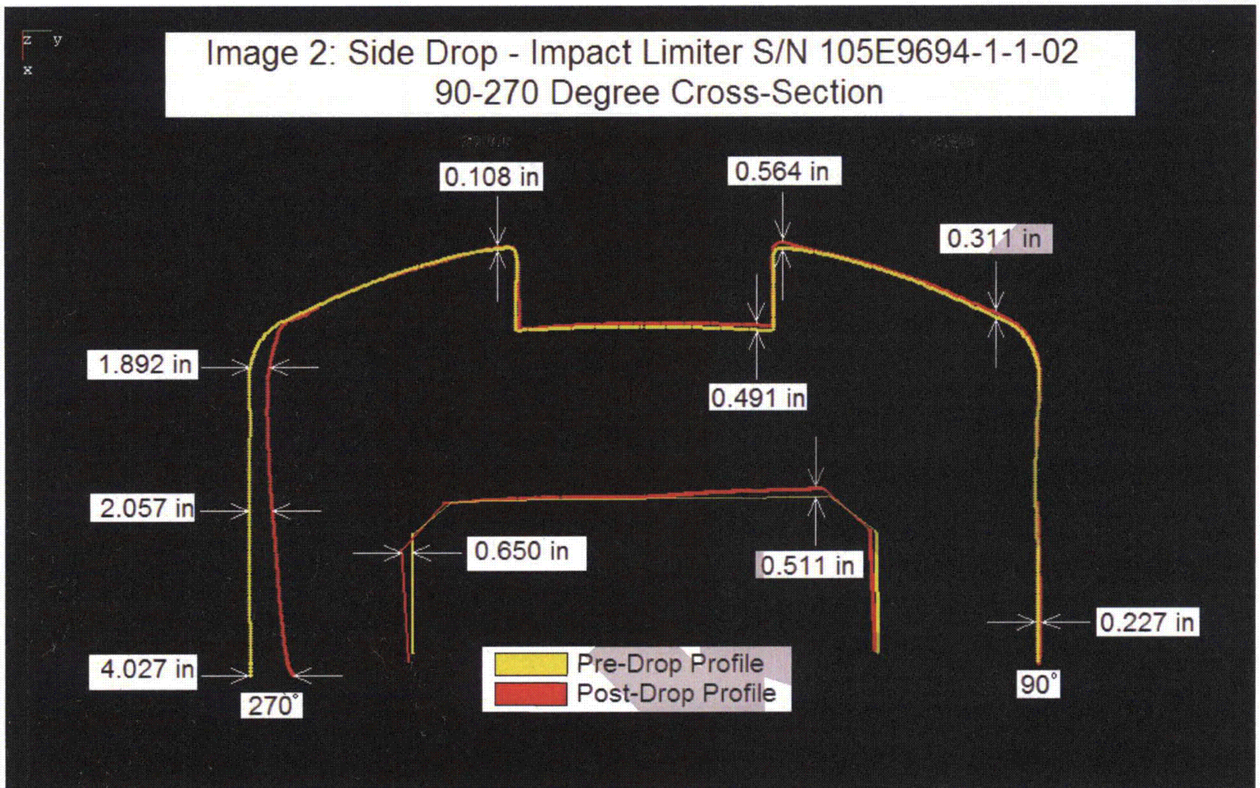


Image 2: Impact Limiter Serial No. 105E9694-1-1-02 - Side Drop Cross-Section Overlay

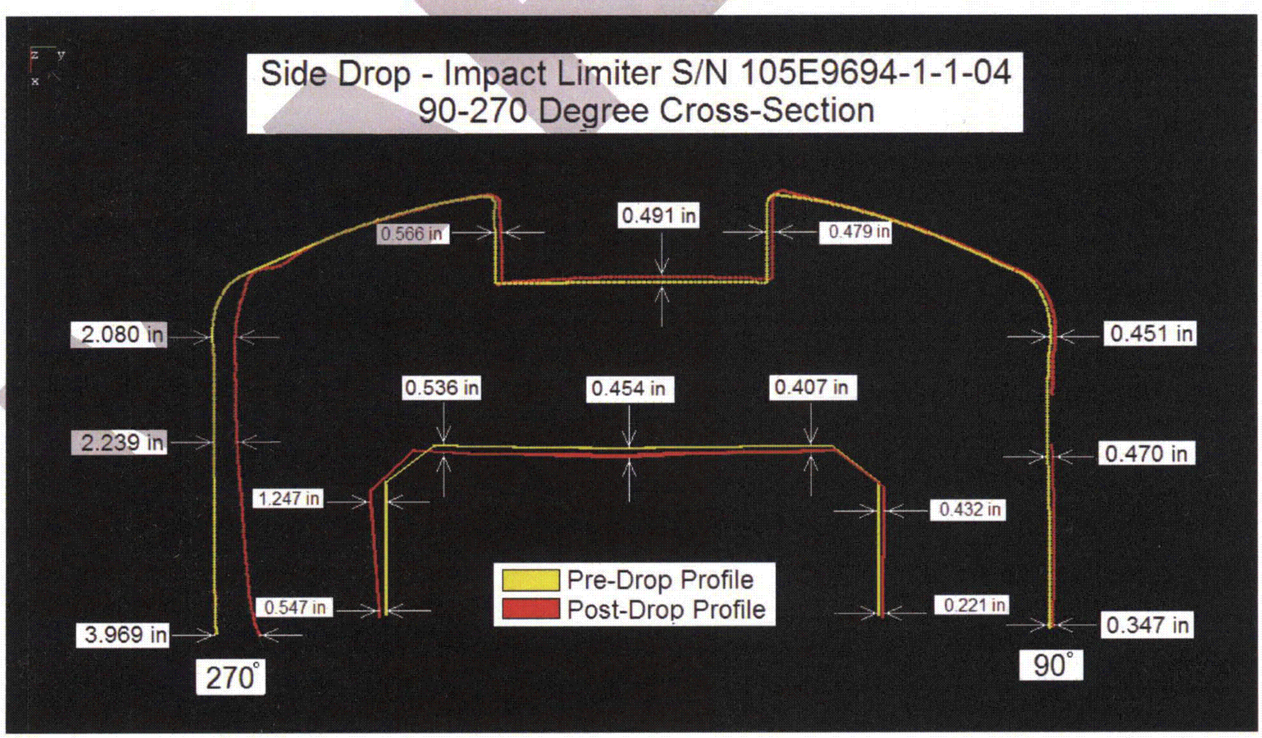


Image 4: Impact Limiter Serial No. 105E9694-1-1-04 - Side Drop Cross-Section Overlay

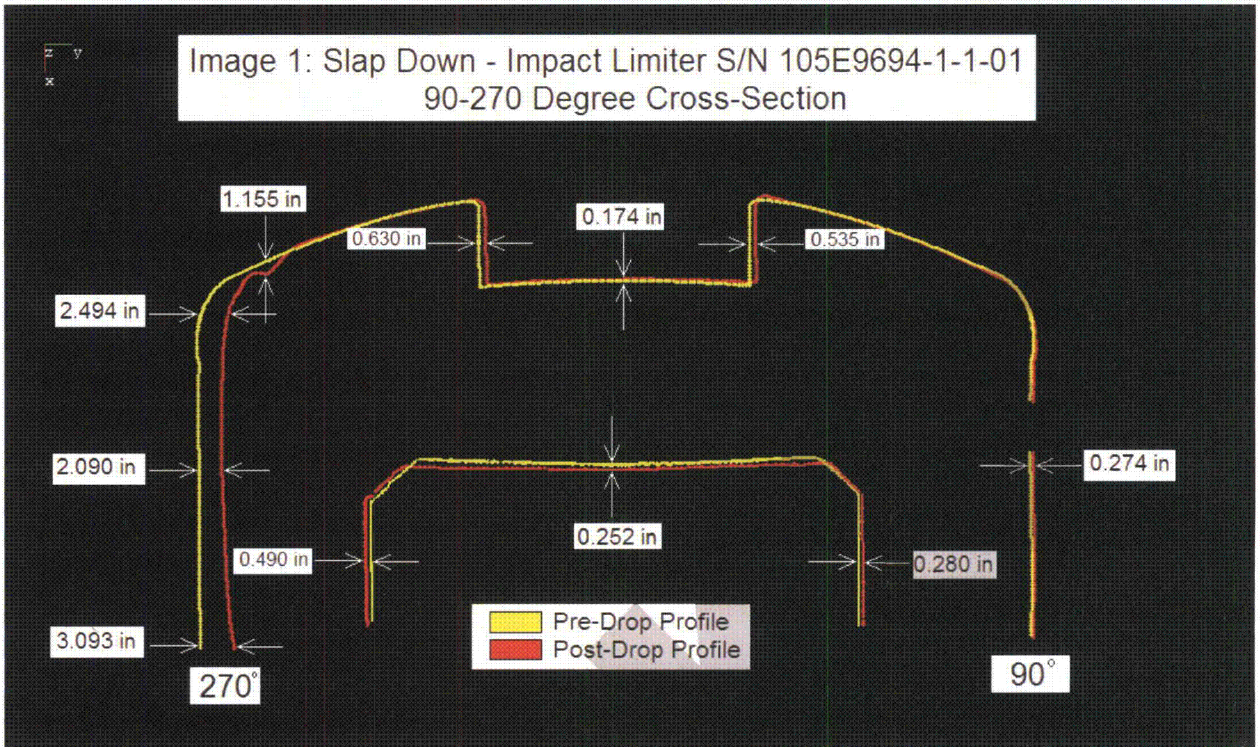


Image 1: Impact Limiter Serial No. 105E9694-1-1-01 - Slap Down Cross-Section Overlay

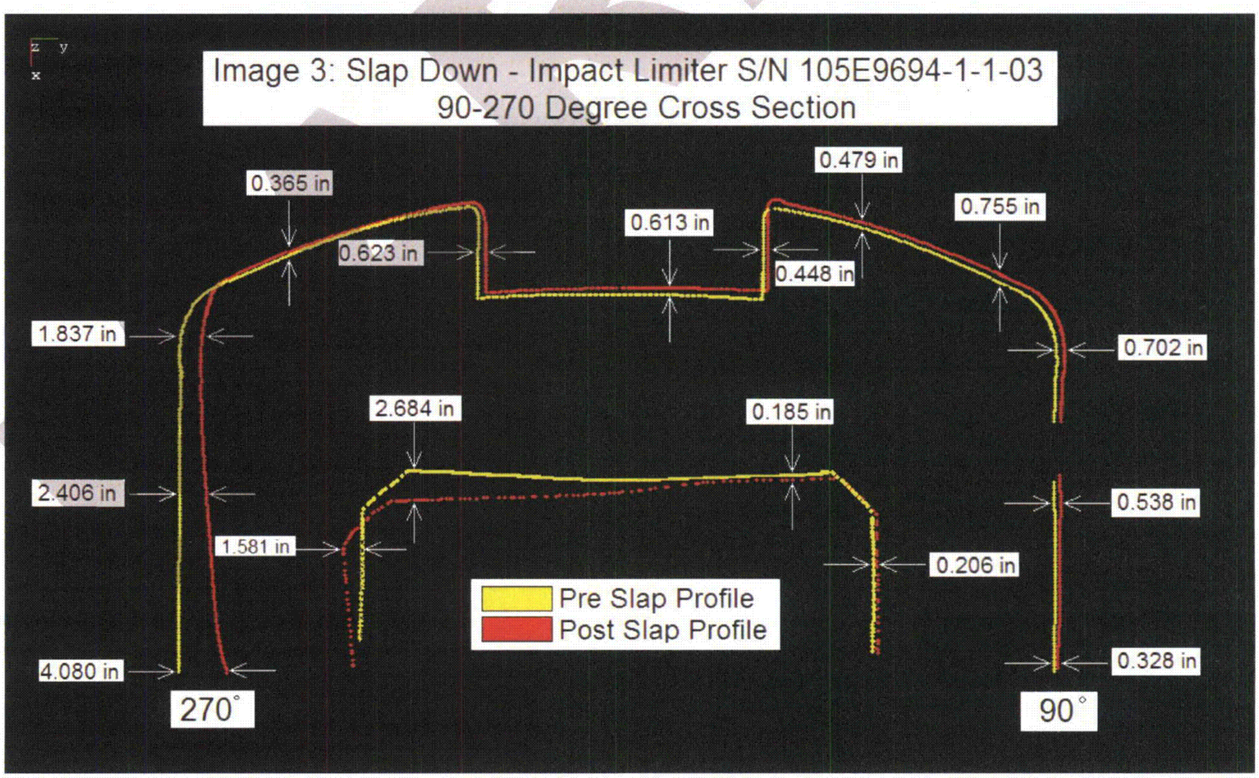


Image 3: Impact Limiter Serial No. 105E9694-1-1-03 - Slap Down Cross-Section Overlay

Contact Information

As part of this report, *East Coast Metrology* appreciates the request for any additional information, which will help our customers find solutions to their measurement problems.

We proudly consider ourselves as allied partners to our customers, and can assist in the positioning and alignment of features, along with our ability to perform high accuracy measurements.

The key to our success is to be able to provide our customers with complete solutions, and the information that is most valuable to their cause, in a clear and concise manner.

We welcome any questions you may have, and look forward to working together in the near future.

Please feel free to contact us for additional information or concerns that may arise.

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Topsfield, Massachusetts 01983
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E-mail: dkramer@eastcoastmetrology.com

Attachments:
AOS-165 Cask Assembly Impact limiter, Serial No. 105E9694-1-1-01 Pre- and Post- Slap Down Scan Data (12 pgs)
AOS-165 Cask Assembly Impact limiter, Serial No. 105E9694-1-1-02 Pre- and Post- Side Drop Scan Data (10 pgs)
AOS-165 Cask Assembly Impact limiter, Serial No. 105E9694-1-1-03 Pre- and Post- Slap Down Scan Data (14 pgs)
AOS-165 Cask Assembly Impact limiter, Serial No. 105E9694-1-1-04 Pre- and Post- Side Drop Scan Data (12 pgs)
AOS-165 Cask Assembly Impact limiter, Serial No. 105E9694-1-1-05 Pre- and Post- Head Drop Scan Data (10 pgs)

MARKUP

8.3.4 Maintenance Checksheet Sample

Oak Ridge National Laboratory Research Reactors Division Preventive Maintenance Instructions	Document No. RRDPMI-25.1 Revision 4 Page 1 of 11
Prepared by: 2/10/06 Engineer Date	Approved by: 2/10/06 Maintenance Manager Date
Reviewed by: 2/10/06 Maintenance Engineer Date	Reviewed by: Quality Assurance Date 2/10/06 Spent Fuel/Shipping Coordinator Date

Subject: GE Transport Package Periodic Maintenance - Packaging

This maintenance activity was first performed by RRD under MWP 33435. It was classified as a Type E package. It is not a safety related component as described in ORNLIRRDIINT-70. The packaging is used under NRC jurisdiction guided by 10CFR71. Program support provided by the RRD definition of safety related is consistent with 10CFR71.

LIST OF EFFECTIVE PAGES

Page	Revision
1-11, A: 1-9	4

Revision Summary: Revision 4: Updated references including lift plan, 0&IW manual, and Certificate of Compliance. Provided alternate direction to Step 2.2 for simply inspecting components with liner in horizontal configuration. Indicated proper step torque values in Step 2.6 d. Changed units of temperature from Rankin to Kelvin on Att A, page 6.Corrected fractions on Att A, Page 8. Indicated direction for determining the 'Next due date' based on annual leak testing which places the cask into service. This includes one month of grace for all other components in the annual inspection.

Revision 3: Updated lift plans (Ref. #2) and notes referring to procedure TXP-5200, Rev. 14. Incorporated previous Industrial Hygiene experience concerning entry into the cask overpack. Updated reference to Basis Document (CofC) on Attachment A, page 1.

Revision 2: Removed items not necessary to be documented in the PMI 25 such as Rigging tackle and equipment, the trailer, and auxiliary equipment. The items removed are checked individually in the transportation procedure TXP-5200 (i.e., auxiliary equipment), or documented in facility PM's. Procedure revision incorporates notes made during the last maintenance activities (WP506354 pages 109-1 11). This includes changes to confined space entry, radiological controls, and arrangement of equipment for improving diagnostic leak testing. The bases documents that exist as of January 18, 2002 were reviewed to ensure compliance and have been added to Attachment A for reference.

SCOPE/DISCUSSION

The following maintenance instruction addresses requirements for periodic maintenance on the GE-2000 transport package and a means to organize record of their completion. These items briefly include:

- Cask, basket, overpack, and trailer tiedown weld inspections (*)
- Screws for cask lid, cask lifting ears, and overpack (*)
- Cask plug port and leak test of cavity seals (*)
- Impact limiter (*)
- Spreader bar
- Trailer - dedicated (*)
- Tiedown tackle (*)
- Vacuum sensor

Items not included in this instruction are the DOT-7A accessories and tools box, and the overpack storage stand. The identification of inspection dates for items indicated above with an asterisk is crucial to the completion of this instruction as explained in the CLOSEOUT section.

PRECAUTIONS

1. Acceptable cleaning materials for steel components of the packaging are alcohol, acetone, demineralized water, and lemon fresh Joy®. Reference MMP-0815 or equivalent for VOC permitting requirements. A general list of consumable products used with the cask are included in TXP-5200, Attachment D.

2. Do not allow alcohol or acetone to come into contact with the cask lid seal.

3. Only those materials and their conditions as identified in this package may be used in surface finishing.

4. To avoid risk of asphyxiation, do not allow personnel to enter the cask cavity to clean the cask with any cleaning agent except for towels or soap and water.

5. The cask does contain radioactive contamination. Some of the work is to be conducted in a radiological controlled area (i.e., internal components of the cask will be removed from the cask while the cask is stationed in the HFIR bay or suitable controlled area).

PREREQUISITES

1. Review basis documents (Attachment A) to determine if any changes need to be made to this instruction.

2. Review JSP-268 and applicable procedures referenced in this instruction if changes have occurred in the basis documentation.

3. Review TXP-5200 to determine that this maintenance procedure is consistent with the step numbers identified. This instruction was prepared to interface with TXP-5200, Rev. 19.

4. Reference 2 allows for moving cask contained inside overpack. Lifting the cask contained in overpack is a VERY HEAVY LOAD and requires the reactor to be shutdown (ADM-0159).

5. Working inside the cask cavity (if necessary) or the cask top section overpack is performed as a non-permit confined space. Previous air sampling indicates that an initial air quality check is

not required. Air quality checks are necessary for entry after volatile cleaning solutions (i.e., acetone) are used.

DIRECTIONS

1. Packaging Receipt and Unloading

1.1 The packaging may be unloaded with the guidance given in TXP-5200 covering sections 1, 2 and 3 pausing before step 3.28 to allow for the inspections of the cask liner and completion of the required maintenance. Equivalent instructions may be generated depending on the facilities OR related maintenance work packages being used to disassemble the packaging.

1.2 As components are removed from the packaging, segregate to enable record of the identification and serial numbers where applicable.

1.3 During the following inspections identify any unusual surface conditions and when deemed significant on a scratch map of the component. This is primarily intended for the cask body, cask lid, liner, basket, and the overpack.

2. Preparations for Inspections

To prepare for periodic inspections beyond the routine receipt inspections certain components must be disassembled. The process of inspection for some of these components requires positioning horizontally instead of vertically. All lifting operations involving the Cask, Overpack, Cask liner, and cask basket which are routine in operation (all vertical lifts with no rotation of components) are covered in reference 1. Use reference 1 for such lifting. Operations which are not routine but are specific to the periodic maintenance are covered by the lift plan in reference 2. Review these plans before performing the intended lifts.

Review RWP for intended activities and verify with HP that correct RWP is used.

> STEP Steps 2.1 through 2.10
>
> **NOTE**
>
> Steps 2.# are not required to be sequentially conducted. Each step is related to an independent component inspection. Task Leader may also prepare several components at one time for inspections. When returning to a particular component (i.e., Step 2.#) the Task leader should include in pre-job briefings a review of completed substeps before discussion of task to be accomplished.

2.1 Inspection of Overpack components

a. Remove base section of overpack from trailer using same hardware for lifting the top section.

b. Clear area and stage the overpack storage sled.

c. Review lift plan (Reference 2) for rotating overpack.

d. Rotate top section of overpack to horizontal resting the overpack on the storage sled.

> STEP 2.1 e. through i.
>
> **CAUTION**
>
> Consult with IH for assessment of air quality after any volatile cleaning solutions are used inside or near the entrance of the overpack cavity.

e. Perform radiological surveys of interior surfaces as possible.

f. Remove the 8 screws and support angles used to retain the energy absorber and set aside screws for inspection.

g. Remove upper limiter for inspection.

h. Perform interior weld examinations per JSP-268.

i. Install QA accepted upper limiter and secure with inspected and approved screws and angles. No specific torque requirements, the RRD Maintenance torque guide would suggest 4 ft-lb.

j. Inspect bottom end of overpack base by assembling the entire overpack and placing assembly on the storage sled.

k. Once overpack transport base has been inspected and secured to trailer return overpack bottom section to the transport base and prepare overpack for cask loading by separating the top section and staging it on an appropriate storage area.

2.2 Removal, inspection, and installation of HFIR cask liner and tungsten plug.

a. Review lift plan (Reference 2) for rotating liner.

b. Lift liner for rotation and position horizontal on a platform designed to prevent rolling.

c. IF liner plug is desired to be removed then perform the following:

- Loosen but do not remove the 12 liner screws.
- Lift liner to vertical position and place on short stand.
- With liner on stand and still connected to the crane, remove the 12 liner screws and support pads.
- Perform any cleaning and inspection of the liner plug.
- Rotate liner again to the horizontal position on the platform.
- Inspections at this time should include the support pads, liner screws, and all liner threaded components (use JSP-268) and surface conditions, recording observations on scratch map as applicable.
- To assemble tungsten plug lift liner to vertical position and hover liner over tungsten plug which is resting on the short stand.
- Install liner support pads and liner screws (all dry - no lubricant) to hand tight.
- Lift assembled liner and rotate to horizontal

d. IF liner plug is not desired to be removed then remove and inspect a portion of the liner screws and support pads at one time keeping the plug supported.

e. Tighten liner screws to be installed snug-tight. No specific torque requirements, the RRD Maintenance torque guide would suggest 30 ft-lb. Typical tightening sequence is opposite sides on vertical followed by opposite sides on horizontal etc..

f. Ensure by visual inspection the uniform seating of liner plug with liner body including seating of all support pads and liner screws.

2.3 Inspection of HFIR cask basket

STEP 2.3.a
NOTE

It is beneficial to place the basket on the stand with general purpose plastic covering the basket. This plastic can then be split for access to areas where weld inspection is to be performed.

a. Remove basket from specialty tapered bag but continue to use the storage stand to support the basket and generic plastic bags to reduce the spread of contamination.

STEP 2.3.b
NOTE

Basket plug should remain in position after removing screws due to the interference fit between plug and basket tube.

b. Remove basket plug modified cap screws.

c. Inspect all screws and welds per JSP-268.

d. Install basket plug modified cap screws with no lubrication snug-tight. No specific torque requirements, the RRD Maintenance torque guide would suggest 6 ft-lb.

2.4 Inspection of cask body and cask lid.

a. Cask cavity weld inspection may be performed with aids such as a mirror or video camera.

b. Inspect weldments per JSP-268.

c. Follow procedure JSP-268 for the inspection of plug ports, lid screw holes and cask ear pad screw holes.

d. Check nameplate weldment to verify plate is welded along the entire perimeter.

e. Check name plate for legibility.

STEP 2.5

NOTE

Use only mild detergent and water to clean seals. No alcohol or acetone.

2.5 Cask Seals (seal is generically used in the following for O-rings and lid seal)

a. Inspect lid seal and port cover O-rings for signs of damage.

b. Replace any seal that has had 12 usages (12 shipments) or which has been in service 12 months, or that is defective.

c. Apply thin film of vacuum grease to all rubber surfaces of seals before installing.

STEP 2.6

NOTE

Leak test may be repeated as necessary to meet the leak test criteria. All failures of the test should be indicated along with actions required to achieve the leak test criteria.

2.6 Packaging Leak Testing

a. Ensure interior of cask and cask lid including sealing surface are clean paying special attention to wipe the sealing surfaces of any loose debris and allow to air dry.

b. After having aligned new or checked lid seal return lid to cask.

c. Ensure that lid screws OR mating threads are lubricated with Fel-Pro N-5000.

d. Tighten lid screws using the steps identified below.

- Torque lid screws in progression as stamped on the cask lid to 230 ft-lb. using the 250 ft-lb. range torque wrench.
- Continue in the same progression making 460 ft-lb. and 690 ft-lb. using the 1000 ft-lb. range torque wrench.
- Repeat 690 ft-lb. torque but in a clockwise or counter-clockwise direction (no screwing pattern progression required).

e. Connect instruments as indicated in Figure A (basket and liner are not necessary for test):

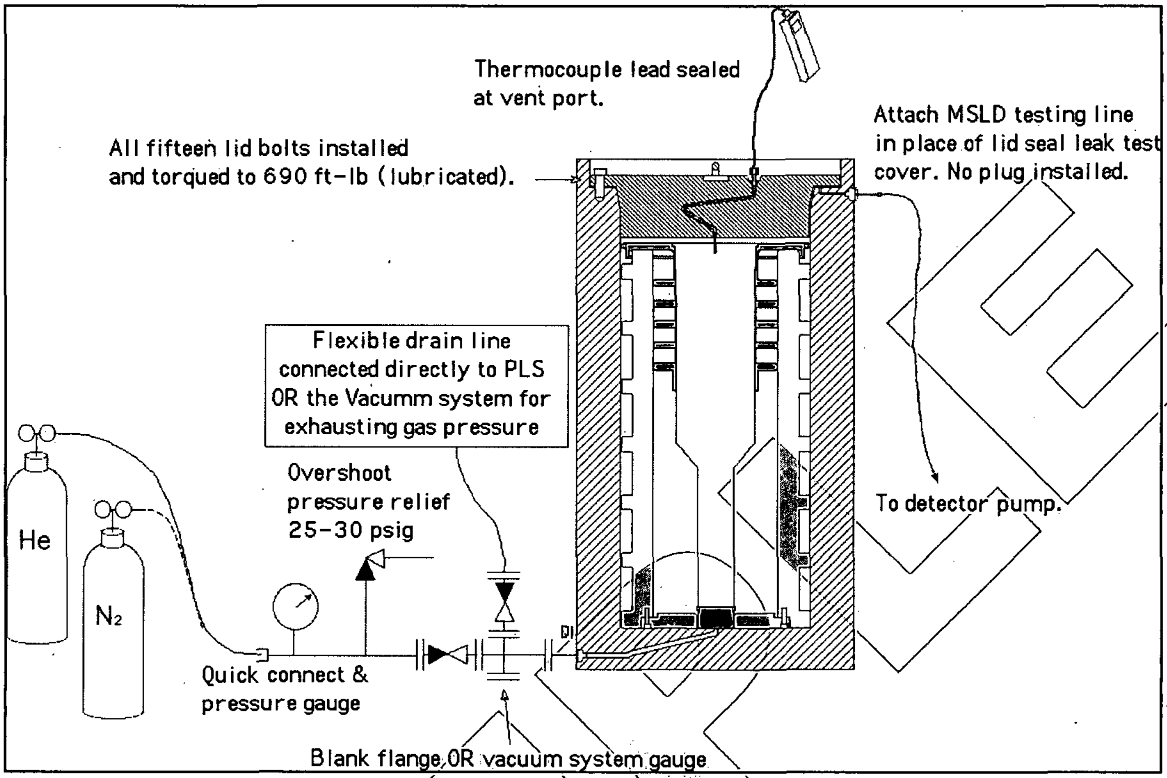

Figure A: Cask lid seal leak testing

f. Purge cask with nitrogen OR vacuum dry the cask.

> STEP 2.6 g
>
> NOTE
>
> To ensure tight connection of the leak testing apparatus a method of indicating outside leaks is to perform initial fit test without Helium in the cask cavity and then observing response upon adding the tracer gas (Helium added to cavity).

g. Perform leak test as indicated in Attachment A.

h. After testing lid seal relieve internal cask pressure.

i. Remove thermocouple assembly from lid.

j. Wrap an inspected / accepted plug with thread tape and install snug-tight in lid vent.

k. Assemble MSLD equipment to the cask vent port (on lid) as indicated in Figure B.

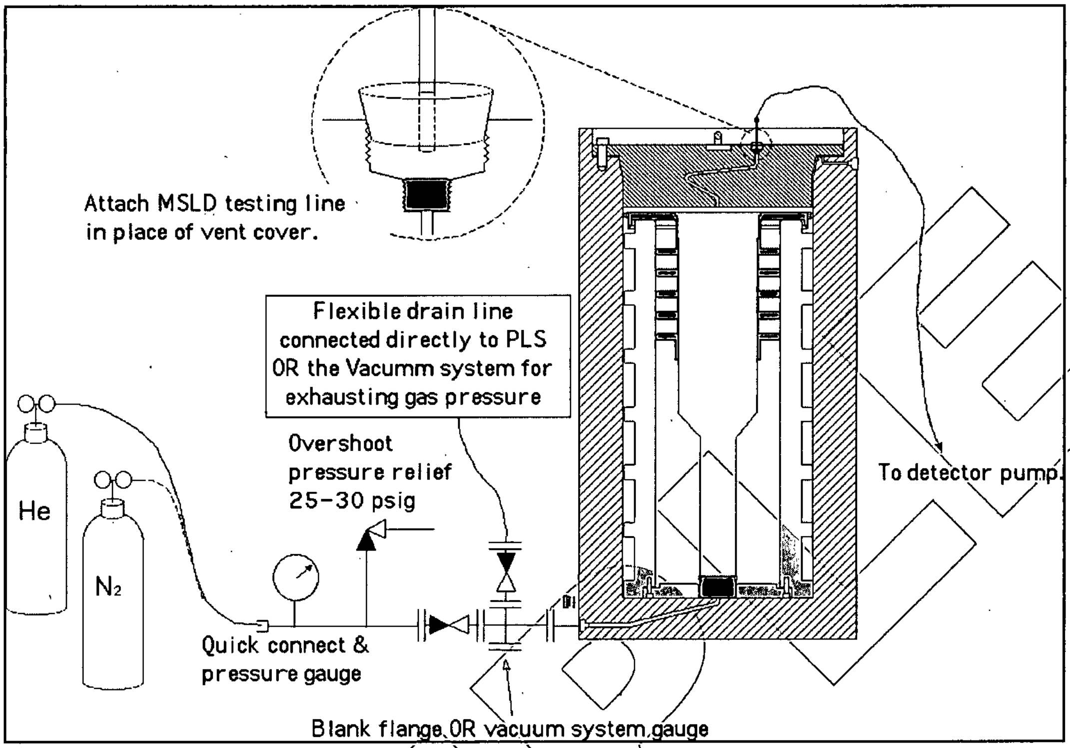

Figure B: Port plug leak testing

STEP 2.6 l

NOTE

To ensure tight connection of the leak testing apparatus a method of indicating outside leaks is to perform initial fit test without Helium in the cask cavity and then observing response upon adding the tracer gas (Helium added to cavity).

l. Perform leak test of lid vent plug (assume temperature recorded for lid seal).

m. After testing lid vent plug relieve internal cask pressure.

n. Remove gas supply line from drain port for installation to the lid vent.

o. Remove MSLD equipment from lid vent and lid vent port plug.

p. Reapply thread tape to plug and install snug-tight to drain port.

q. Install MSLD equipment to drain port and install gas supply to the lid vent (swap of port used in Figure B.

STEP 2.6 r NOTE
To ensure tight connection of the leak testing apparatus a method of indicating outside leaks is to perform initial fit test without Helium in the cask cavity and then observing response upon adding the tracer gas (Helium added to cavity).

r. Perform leak test of drain port (assume temperature recorded for lid seal).

s. After testing drain port relieve internal cask pressure.

t. After successful leak testing begin to breakdown the cask for inspection of seals.

u. Remove lid screws and any installed plug.

v. Remove cask lid using lid hook tool and temporarily store lid.

w. Inspect all seals used in leak tests for defects.

2.7 Energy Absorbing Honeycomb

a. Energy absorbing honeycombs are to be inspected as identified on Attachment A.

2.8 Tiedown Equipment

a. Once packaging has been removed from trailer, remove the tiedowns and deliver these components to F&O for inspection and pull testing.

b. Lubricate turnbuckles as necessary.

c. If lubrication is deemed necessary for tiedown shackle pins use Fel-Pro N5000.

d. Inspect transport base fasteners per JSP-268.

e. Inspect tiedown eyes and pads per JSP-268 (documentation of this activity may also be included in a Level II or trailer re-certification per ANSI N-14.30).

2.9 Rigging Equipment

a. Inspections are performed on all equipment by F&O. Additional inspection criteria are implemented for the GE designed spreader bar which include a dimensional as defined in TXP-5200 and weld examination as recorded in JSP-268.

2.10 Vacuum Sensor

a. The only vacuum sensing equipment requires specific manufacturer directions as indicated in Attachment A.

3. Prepare cask for post inspection use.

Once the periodic maintenance has been performed it is appropriate to configure the cask for use. Off-site shipment may only proceed after record review and approval.

3.1 Prepare for fuel loading.

CLOSEOUT

After completion of repairs (if required) as noted in the Scratch Reduction Repair Sheets a complete cleaning of the cask components must be performed to remove debris and inspection related chemicals. The final cleaning must be performed with approved products.

Cask and components will either be returned to the trailer as a complete unit or the cask will be staged for preparation in loading depending on the timeliness of completing this package.

Reports for inspections and all necessary attachments are included and the package has been reviewed for completeness by a single task leader and a single QA representative. Items indicated with an asterisk in Attachment A have been successfully completed and the next earliest due date and the most recently performed shipment are identified below. Shipment number and date identifies that 12 more succeeding shipments OR the date (12 months to the day of conducting the annual leak test*), which ever occurs first, should be used to determine next scheduled maintenance as indicated in TXP-5200.

Next due date ______________, Shipment number preceding this inspection _____ + 12 = ______

Task Leader: __________________ Date: ____________

QA : __________________ Date: ____________

* All other annual inspections are understood to have a frequency of one year. If completion date of an item of the annual inspection identified in the Scope (*) did not occur within the month preceding the annual leak test, or the cask was used prior to the annual THEN indicate the 'Next due date' based on the particular item.

FINAL CONDITIONS

Close out of the package is identified in the work package approval sheet. A copy of this documentation shall be forwarded to the spent fuel shipping coordinator (SFSC). The SFSC will forward a copy to General Electric.

Task Leader: __________________ Date: ____________

REFERENCES

1. "Summary of Rigging Operations for using the GE 2000 Transport Package at the High Flux Isotope Reactor", September 1995.
2. "Research Reactors Division Lifting Details for conducting Annual Maintenance on the GE-2000 Transport Package", Rev. 2, January 2003. (re-approved on 10/14/2004)
3. RRD-M-8.0, General Torque Guide.
4. ANSI N14.6-1986, Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More.

Type of Maintenance ____ periodic (specific maintenance issue) OR _____annual.
Last shipment number (include all previous shipments not just HFIR fuel) _______.

Basis Documents

- C of C 9228, Rev. 22
- Specification # 22A9380, Operations and Maintenance of Model 2000 Transport Package, Rev 8, July 24, 2003.
- NEDO-31581, SAR "Model 2000," Rev. 1, October 2000.
- NEDO-32229, SAR " HFIR Fuel Basket and Liner," Rev. 1, August 2000

_____ Review of certifying documentation and guidance given (basis documents) are current (no changes to maintenance documentation were required)

_____ Review of certifying documentation and guidance given (basis documents) are not current. List of documentation revisions and effected changes to package maintenance.

List outstanding maintenance issues to be conducted (date or shipment number, item, and brief description of maintenance issue)

Cask body and cask lid structure

	Task leader	QA rep.
Removed and identify all fasteners (see fastener section for identification of fasteners)		
Visual during receipt of package (after removal of liner from cask) - No signs of corrosion, dents (excluding scratches), punctures, signs of chemical attack, and signs of heat/fire.		
* Describe if observations are positive (NCR number if applicable)		
Cleaning performed in preparation for detailed inspection (including screw holes)		
Record of scratches and normal wear indications (attach to this form)		
Initiate inspection of Weldments, and screw holes and fasteners per JSP-268		
Visual inspection of cask ears - auxiliary (4) Ident.________________		
Visual inspection of cask ears - standard (2) Ident.________________		
Visual inspection of cask ears - optional (2) Ident.________________		
* Visual inspection of lid screw holes (not identified in JSP-268)		
* Check cask lid screw holes with go/no-go gauge (not identified in JSP-268)gauge ID________		
* Check cask ear pad inserts with go/no-go gauge (not identified in JSP-268) gauge-ID________		
Final conditions		
Scratch reduction was OR was not performed (circle one and if applicable attach report of reduction)		
Cleaning performed after completion of JSP-268 and maintenance.		

Notes:

Overpack structure

	Task leader	QA rep.
Removed and label all fasteners (see fastener section for identification of fasteners)		
Visual during receipt of package (including inside of top section) - No signs of corrosion, dents (excluding scratches), punctures, signs of chemical attack, and signs of heat/fire.		
• Describe if observations are positive (NCR number if applicable)		
Removal of impact limiter from top section of overpack (ID number recorded in limiter section)		
Cleaning performed in preparation for detailed inspection (including screw holes)		
Record of scratches and normal wear indications (attach to this form)		
Initiate inspection of Weldments, and screw holes and fasteners per JSP-268		
Final conditions		
Scratch reduction was OR was not performed (circle one and if applicable attach report of reduction)		
Cleaning performed after completion of JSP-268 and maintenance.		
• Upper impact limiter installed (ID number _______________) with eight support angles fastened each with screws tightened snug-tight (dry), suggested 4 ft-lb. Top energy absorber correctly installed with center hole visible (facing cask). Fasteners used have been inspected (see page 5).		

Notes:

Basket structure

	Task leader	QA rep.
Removed and label all fasteners (see fastener section for identification of fasteners)		
Visual during receipt of package (after removal of liner from cask) - No signs of corrosion, dents (excluding scratches), punctures, signs of chemical attack, and signs of heat/fire.		
* Describe if observations are positive (NCR number if applicable)		
Cleaning performed in preparation for detailed inspection (including screw holes)		
Record of scratches and normal wear indications		
Initiate inspection of Weldments, and screw holes and fasteners per JSP-268		
* Visual inspection of basket tungsten plug for physical damage / firmly fit to basket tube		
Snug basket plug screws to approximately 6 ft-lb dry		
Final conditions		
Scratch reduction was OR was not performed (circle one and attach report of reduction)		
Cleaning performed after completion of JSP-268 and maintenance.		

Liner structure

	Task leader	QA rep.
Removed and label all fasteners (see fastener section for identification of fasteners)		
Visual during receipt of package (after removal of liner from cask) - No signs of corrosion, dents (excluding scratches), punctures, signs of chemical attack, and signs of heat/fire.		
* Describe if observations are positive (NCR number if applicable)		
Cleaning performed in preparation for detailed inspection (including screw holes)		
Record of scratches and normal wear indications		
Initiate inspection of screw holes and fasteners per JSP-268		
* Visual inspection of liner plug for physical damage		
* Inspection of screws holes not covered in JSP-268 - visual inspection of cask liner inserts		
Snug liner screws to approximately 30 ft-lb dry		
* Uniform seating of liner and fasteners upon installation of liner plug.		
Final conditions		
Scratch reduction was OR was not performed (circle one and if applicable attach report of reduction)		
Cleaning performed after completion of JSP-268 and maintenance.		

Notes:

Fasteners (not including items associated with trailer) per JSP-268

Fasteners removed upon receipt from last package use and identified/cleaned. Use, (part number from drawing), Type, Specific identification.	Cleaned for inspection	List item removed from service (after Inspection)	List item placed into service (replacements)
* Cask lid screws Serial numbers			
* Cask ear screws Serial numbers			
* Port covers Serial numbers			
* Port plugs Serial numbers			
* Overpack screws Serial numbers			
* Upper impact limiter modified cap screws			
Liner thread inserts (3).			
* Liner plug screws and support pads			

Final Conditions	**Task leader**	**QA rep.**
* Fasteners inspected per JSP-268 and those removed from service identified. Reasons for removal (briefly):		
* Replacement fasteners identified and appropriate paper work is attached		
All screws and screws cleaned (post-inspection for those returned to service) and the following have been lubricated: Lid screws, ear screws, and shoulders ONLY on overpack screws.		
Installation of liner and basket fasteners - removed only periodically (excluding those used to install impact limiter - page 3). Routine use fasteners may be installed later as part of a shipment.		
* Liner plug screws w/ spacers installed snug tight (dry), suggested 30 ft-lb		
* Basket plug screws installed snug tight (dry), suggested 6 ft-lb		

Notes:

Seals and Leak testing

(not including items associated with trailer) Seals removed upon receipt from last package use and identified/cleaned Use, (part number from drawing), Type, Specific identification.	Cleaned for inspection	List item removed from service (after Inspection)	List item placed into service (replacements)
* Cask lid seal Serial number		a must after 12 uses	
* O-rings from vent, drain, and test port		a must after 12 uses	

Leak testing	**Task leader**	**QA rep.**
Packaging contents cleaned and dry		
Sealing surfaces of lid and cask checked for cleanliness		
Seals removed from service visually inspected		
Install lid seal with Identification ____________		
Fastening lid (torque pattern stamped on lid)		
Apply lubricant to lid screws		
Install and torque screws to 230 ft-lb., S/N ____________ Due date ________		
Repeat torque to 460 ft-lb., and 690 ft-lb. S/N ____________ Due date ________		
CCW or CW check at 690 ft-lb. (Using same wrench as indicated above)		
Install testing apparatus for lid seal test (see procedure Figure A)		
Thermocouple S/N ____________ Due date ________		
Leak source used S/N ____________ Due date ________		
MSLD equipment ID__________ and sensitivity data attached. Leak testing apparatus response time __________ ($\sim^{2}/_{3}$ source strength)		
Helium pressure gauge S/N ____________ Due date ________		
(A) Seal test initiated and leak criteria as follows:		
Helium pressure __________ psig achieved at __________(hh:mm)		
Temperature __________ and conversion to __________K		
$L_{He}\left(std.\frac{cm^3}{\sec}\right) = 1.162x10^{-8}\left(std.\frac{cm^3}{\sec\sqrt{K}}\right)\sqrt{\_\_\_\_\ K} = \_\_\_\_\_\_$		
* Leak Rate of lid seal ____________ (atm cc/sec He) As conducted on (hh:mm mm/dd/yy) ____________ ____________		
(B) Cask vent plug test (located on cask lid):		
Helium pressure __________ psig achieved at __________(hh:mm)		
* Leak Rate at vent plug ____________ (atm cc/sec He) As conducted on (hh:mm mm/dd/yy) ____________ ____________		
(C) Cask drain plug test (located near cask bottom):		
Helium pressure __________ psig achieved at __________(hh:mm)		
* Leak Rate at drain port ____________ (atm cc/sec He) As conducted on (hh:mm mm/dd/yy) ____________ ____________		
Post testing inspection:		
* Lid seal removed and visually inspected		
Section A, B, and C was performed by: ______________ date ________ witnessed by: ______________ date ________ Performers ASNT-TC-1A certification is attached to this instruction.		

Energy absorber inspection

			Dimension	Task leader	QA Rep.
Top energy absorber identification upon removal Drwg. & Serial number ______________________					
Bottom energy absorber identification upon removal Drwg. & Serial number ______________________					
* Diameter - Top energy absorber	40.00	± 0.12 inch			
* Diameter - Bottom energy absorber	41.00	± 0.12 inch			
* Thickness - Top energy absorber	6.00	± 0.12 inch			
* Thickness - Bottom energy absorber	4.00	± 0.12 inch			
* Diameter of center hole in top energy absorber	8.00	± 0.06 inch			
* Depth of center hole in top energy absorber	0.50	± 0.06 inch			
* Notes of dimple and crushed region examination for top energy absorber:					
* Notes of dimple and crushed region examination for bottom energy absorber:					
* Top energy absorber identification installed Drwg. & Serial number ______________________					
* Bottom energy absorber identification to install (Overpack section for installation) Drwg. & Serial number ______________________					

Notes:

Tiedown equipment

LIST SERIAL NUMBERS OF ITEMS INSPECTED	Task leader	QA rep.
• Load test of the following to nominally 26,000 lb. on equipment Identification ________________ Due date __________		
• 1-$^3/_8$ Shackles (8) with ID #'s		
• $^7/_8$ Slings x 37 in. (4)		
• $^7/_8$ Slings x 102 in. (4)		
• 12 inch Load binder (4)		
• 18 inch Load binder (4)		
• Welds of overpack transport base inspected per JSP-268		
• Nuts of transport base secured to transport base and torque to 420 ft-lb. Wrench S/N ___________ Due date __________		
• Lock wire installed on transport base screws.		

Rigging equipment

	Task leader	QA rep.
Spreader bar S/N 11632 inspected per JSP-268		
Dimensional measurements for spreader bar recorded in TXP-5200 had the following values representing maximum and minimum departure from base line. (1) _________/_________ in (3) _________/_________ in (2) _________/_________ in (4) _________/_________ in As recorded from shipment # __________ through shipment # ________ Permissible tolerance of ± $^1/_4$ was not exceeded.		

Notes:

Vacuum Sensor

	Task Leader	I & C Tech
Check for signs of physical damage in **gauge cable**. If it appears to be damaged then measure the Convectron gauge cable resistance (0.016 ohms/foot). Length ________ ohms _________ Line 1 ohms _________ Line 2 ohms _________ Line 3 ohms _________ Line 4 ohms _________ Line 5		
Perform a high vacuum adjustment on **controller unit** by one of the following. 1) Check battery of Zero Pressure simulator Verify Pins 1-3 voltage + 0.372 to +0.377 volts Use simulator to set VAC potentiometer to optimum 2) Apply pressure of ~0.1 mTorr to a gauge tube and adjust VAC potentiometer to optimum. S/N Due date		
Convectron Gauge tube at atmospheric pressure with a meter applying less than 10 mA ensure the following: Pin 1 to 2: 20 to 30 ohms __________ ohms Pin 2 to 3: 50 to 60 ohms __________ ohms Pin 1 to 5: 174 to 190 ohms __________ ohms Any pin to tube body checked to ensure the condition is an open circuit. Verify gauge tube response to atmospheric conditions and set ATM potentiometer to 730 Torr. Qualify gauge tube by one of the following: 1) Use redundant gauge tubes and reduce system pressure to demonstrate accuracy at 1 Torr. 2) For single gauge tube use a reference standard gauge. Acceptance criteria for gauge/controller response is +/- 0.2 Torr at a pressure of 1 Torr.		

IF gauge tube is faulty due to contaminated filament the gauge tube may need cleaning. See manufacturer's instructions on cleaning.

Notes:

8.4 REFERENCES

[8.1] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material," January 26, 2004.

[8.2] ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, 2004, No Addendums.

[8.3] ASME, *Boiler and Pressure Vessel Code*, Section III, Division 3, 2004, No Addendums.

[8.4] ASME, *Boiler and Pressure Vessel Code*, Code Case N-659, "Use of Ultrasonic Examination in Lieu of Radiography for Weld Examination, Section III, Division 1," September, 2002.

[8.5] American National Standards Institute, *ANSI N14.5-1977*, "Radioactive Materials – Leakage Tests on Packages for Shipment," January 1, 1997.