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# Air Drop Test of Shielded Radioactive Material Containers

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# AIR DROP TEST OF SHIELDED RADIOACTIVE MATE[illegible]L *CONTAINERS*

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## ABSTRACT

Two shielded containers were dropped from 2000 feet onto hard prairie. *Neither of the* containers would have released their contents under this impact environment.



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## Summary

Two lead-shielded containers were dropped from 2000 feet onto hard prairie as a visible and easily understood demonstration of the ability of such containers to retain integrity under extremely adverse environments. The OD-1 cask, which weighs 16,300 lb (7410 kg), was used to ship and store spent fuel elements from an Oak Ridge research reactor. The B of E 83 container, which weighs 6,720 lb (3054 kg), was used in handling irradiated test capsules. Both are considered obsolete since they were not designed to survive the current fire requirements.

The casks were dropped from a Skycrane helicopter at the Edgewood, New Mexico, test site. The B of E 83, which is a simple cylinder, penetrated 8 ft (2.44 m) into the hard prairie after impacting at 246 mph (110 m/s). The OD-1 has a large rectangular plate as a tie-down structure which caused the impact velocity and penetration depth to be less than for the B of E 83. This cask penetrated 4.2 ft (1.28 m) after impacting at 230 mph (103 m/s).

The B of E 83 incurred no measurable deformation, but the OD-1 experienced superficial deformation which would not have resulted in release of the contents. The tie-down base plate was deformed and the superstructure crushed at the point of impact. The lead shielding inside the outer shell slumped 0.8 in. (20 mm) with respect to the outer shell as a result of deceleration forces during impact.

## Introduction

Shielded containers for radioactive materials such as spent fuel and other irradiated materials have been extensively evaluated to verify the capability to maintain their integrity under extreme accident environments. Since much of the analysis and testing utilized in such evaluations is not readily understood by the "man on the street," the Division of Waste Management and Transportation in ERDA requested that Sandia conduct the air drop test to demonstrate vividly the ruggedness and survivability of shielded containers. Accordingly, these tests were conducted to subject the containers to an obviously more severe environment than might be expected to be encountered in "normal" serious transportation accidents.

## Container Descriptions

The two containers tested are obsolete because they do not qualify for transportation use under the current safety standards. The lead thickness is adequate for shielding, but the containers were not designed to survive the current fire requirements and still retain adequate shielding. The welding one (B of E 83) is not adequate, based on current safety standards, and the outer shell may be only marginally acceptable. Even though these casks are not as rugged as those currently licensed, they were readily available at essentially no cost.

The containers selected for this test were restricted to less than 20,000 pounds (9072 kg) due to the payload capacity of the military version of the CH-54 Skycrane helicopter.

The Pratt and Whitney I container (also known as DOT Specification Number B of E 83) is a mild-steel clad and lined pot-type container. It weighs 6720 pounds (3054 kg) and was at one time authorized to transport irradiated test capsules. The interior cavity is a 4-in. (102 mm) ID by 17.5-in. (445 mm) high cylinder and the external dimensions are 24.5 in. (622 mm) OD by 40 in. (965 mm) high. The lead thickness is about 10 in. (250 mm) and the outer clad is 0.4 in. (10 mm) thick.

The OD-1 ORR (Oak Ridge Research Reactor) Spent Fuel Carrier (also known as DOT Special Permit No. 5660) was approved by the DOT to hold and ship ORR-type irradiated fuel elements. It was recently removed from service, primarily because of difficulty in meeting the fire requirements. It is a stainless steel-clad container weighing 16,300 lb (7410 kg) with an OD of 31.5 in. (800 mm) and a height of 48 in. (1.2 m). The inner cavity, 12.25 in. (311 mm) in diameter and 27.5 in. (699 mm) high, contained a removable basket capable of accommodating seven fuel elements. The cylindrical container is welded to a 2-in. (51 mm) thick rectangular tie-down base plate which is 53 in. (1.35 m) by 48 in. (1.2 m). The outer clad is 0.3-in. (7.6 mm) thick and the lead shielding varies from 9 to 11.5 in. (229 to 292 mm) thick.

Both casks were painted to enhance the photography during the test. Several holes were drilled through the outer cladding into the lead to facilitate observation of lead slump after the test. Sections of the outer clad were cross-hatched with scribed lines having punch marks at the intersections to provide a reference in the event that the cylinders were twisted or skewed by the impact. Three passive shock recorders were mounted on the OD-1 to obtain an indication of the g-levels experienced during impact. Also attached to both casks were two transmitters to be used in determining the impact velocity.

## The Test

The drop test was conducted at the Sandia Edgewood, New Mexico, test range on February 26, 1975. The soil in this area is classified as hard prairie, which is a hard dry sandy silt soil with a small amount of clay. A bar or pick is necessary to dig below the 1 - 2 in. of loose surface dirt.

Two aircraft, a CH-54 military Skycrane helicopter and a U6A Beaver fixed-wing light plane, were used for the test. The flight pattern for each aircraft is shown in Figure 1 with the helicopter at 2,000 feet (610 m) above ground level (AGL) and the Beaver at 3,000 feet (915 m) AGL. The

Beaver, flying at 60 knots true air speed (KTAS) (69 mph), turned radially in from the circular pattern at a predesignated time in the countdown such that it was directly over the impact site at the time of impact. The helicopter, flying at 20 KTAS (23 mph), was out of the impact area at the time of impact so the signals from the transmitters on the casks were received clearly by the receivers aboard the Beaver. The impact velocity is obtained by analyzing the frequency of the periodic reduction of RF signal strength ("nulls"), which is caused by the effect of the multipaths of transmission and is detected by the telemetry receiver's automatic gain control circuitry.

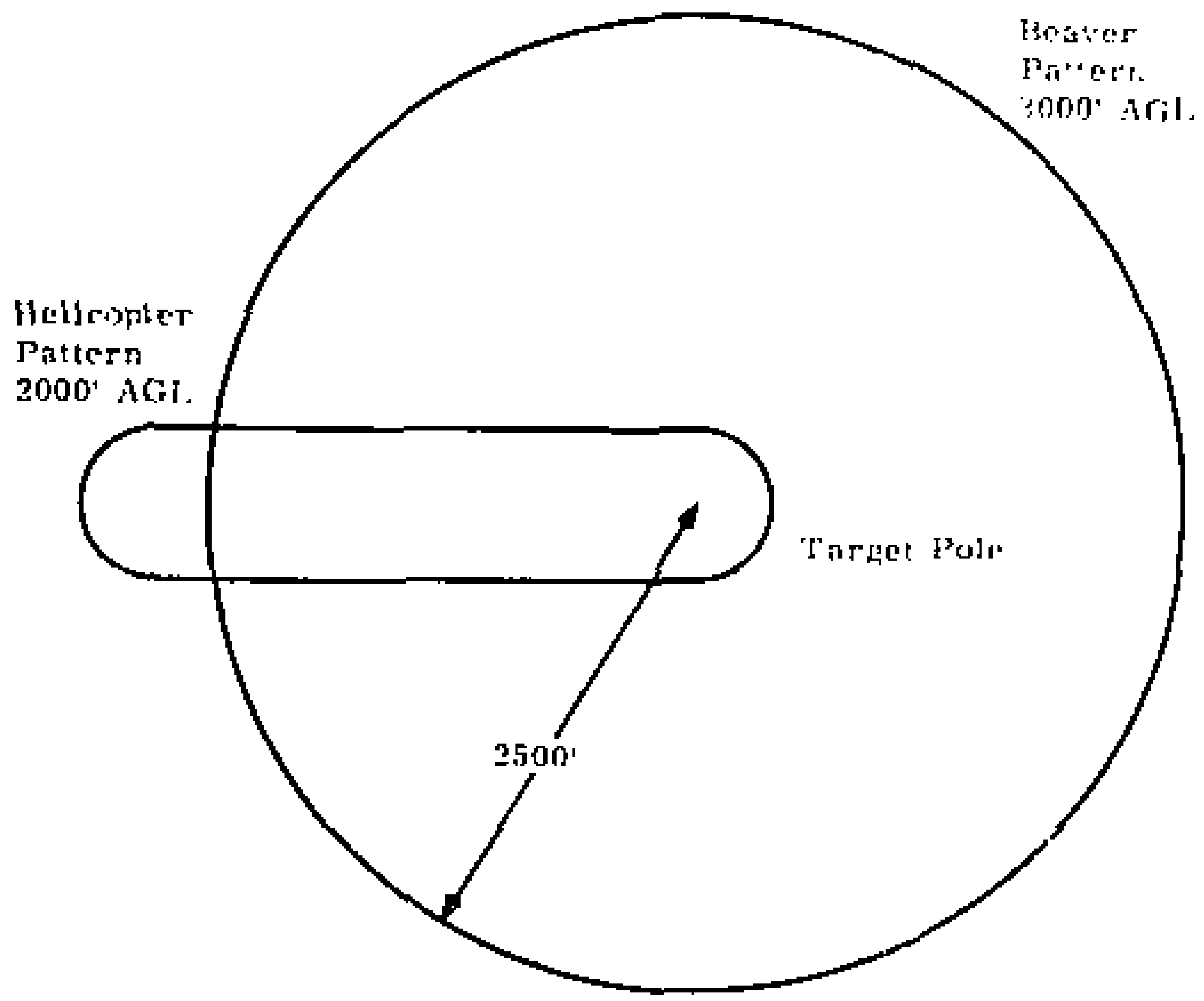



Figure 1. Helicopter and Beaver Flight Patterns for the Drop Test

The B of E 83, shown ready for takeoff in Figure 2, was dropped first, since it was considered to have the greatest chance of survival. The cylindrical axis was vertical at the time of release, but the cask rotated approximately 100 degrees, resulting in a side-on impact with the closure end slightly lower than the other end. The cask was completely buried in the crater shown in Figure 3, and it was decided to uncover it for external examination prior to dropping the OD-1. Using a backhoe, the closure end of the cask was exposed, and it was concluded that no significant external deformation had occurred.

The OD-1 was dropped under the same conditions as the first cask. Slight (approximately 30 degrees) rotation of the cask occurred during descent, but the tie-down base was the first part of the cask to contact the earth. An upper corner of the cylindrical section of the cask was visible after impact as shown in Figure 4.

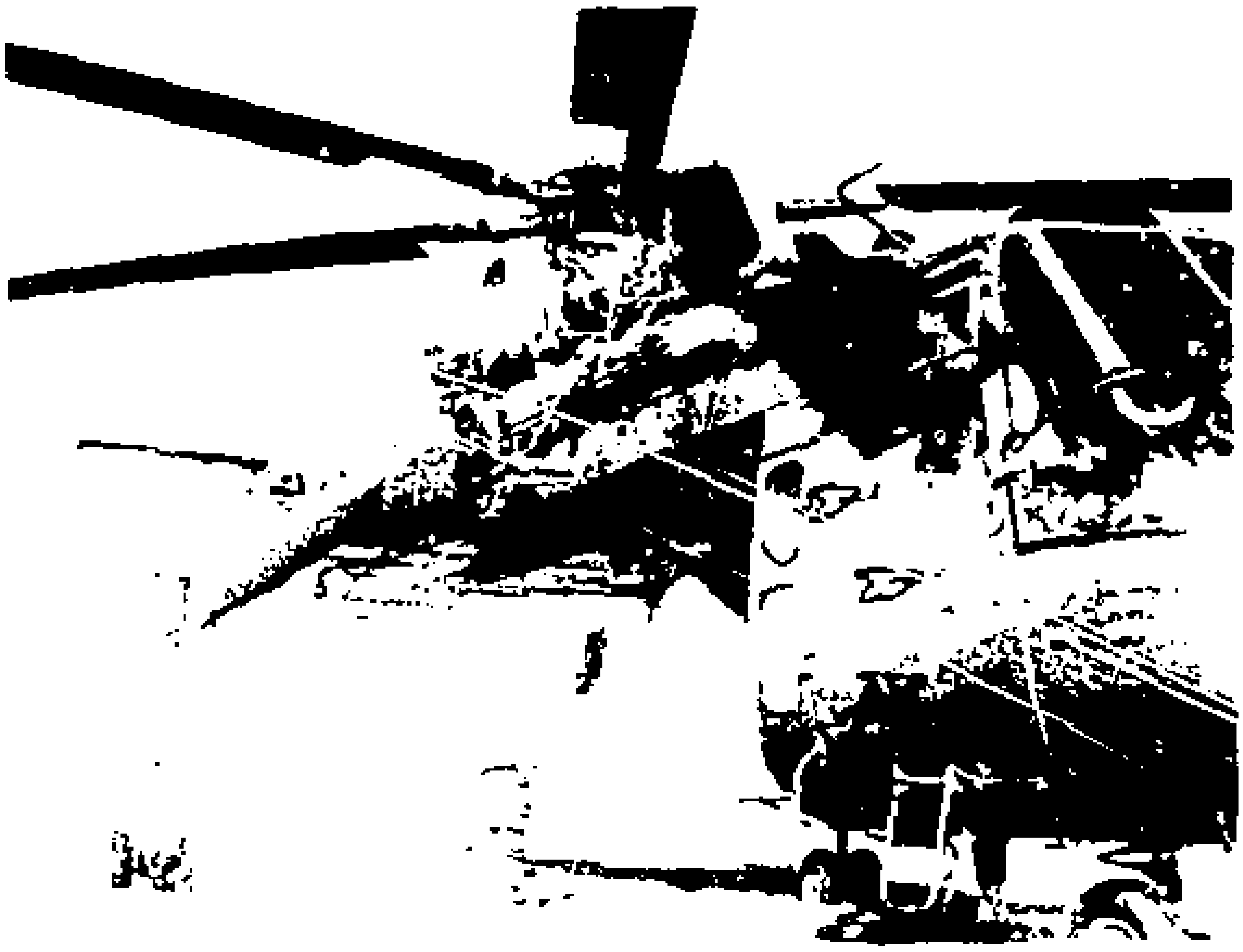


Figure 2. 6,720 Pound B of E-83 Cask Under the CH-53 Before Takeoff

Figure 3. Crater Resulting from the Impact of the 6,720 Pound B of E-83 Cask

Figure 4. Crater Resulting from the Impact of the 16,300 Pound OD-1 Cask

A summary of the results observed at the test site is given in Table 1. The burial depth is the distance from the earth surface to the deepest portion of the cask.

As an add-on to the cask drops, two polyethylene bottles used in the [illegible] Pu nitrate shipping container were filled to the bottom of the neck with water and dropped. The bottle dropped from the helicopter cockpit during the B of E 83 drop was recovered intact and subsequently attached to the inner side of one of the tie-down posts on the OD-1. This bottle accompanied the OD-1 on its drop test, and a second bottle was dropped from the cockpit during the OD-1 test.

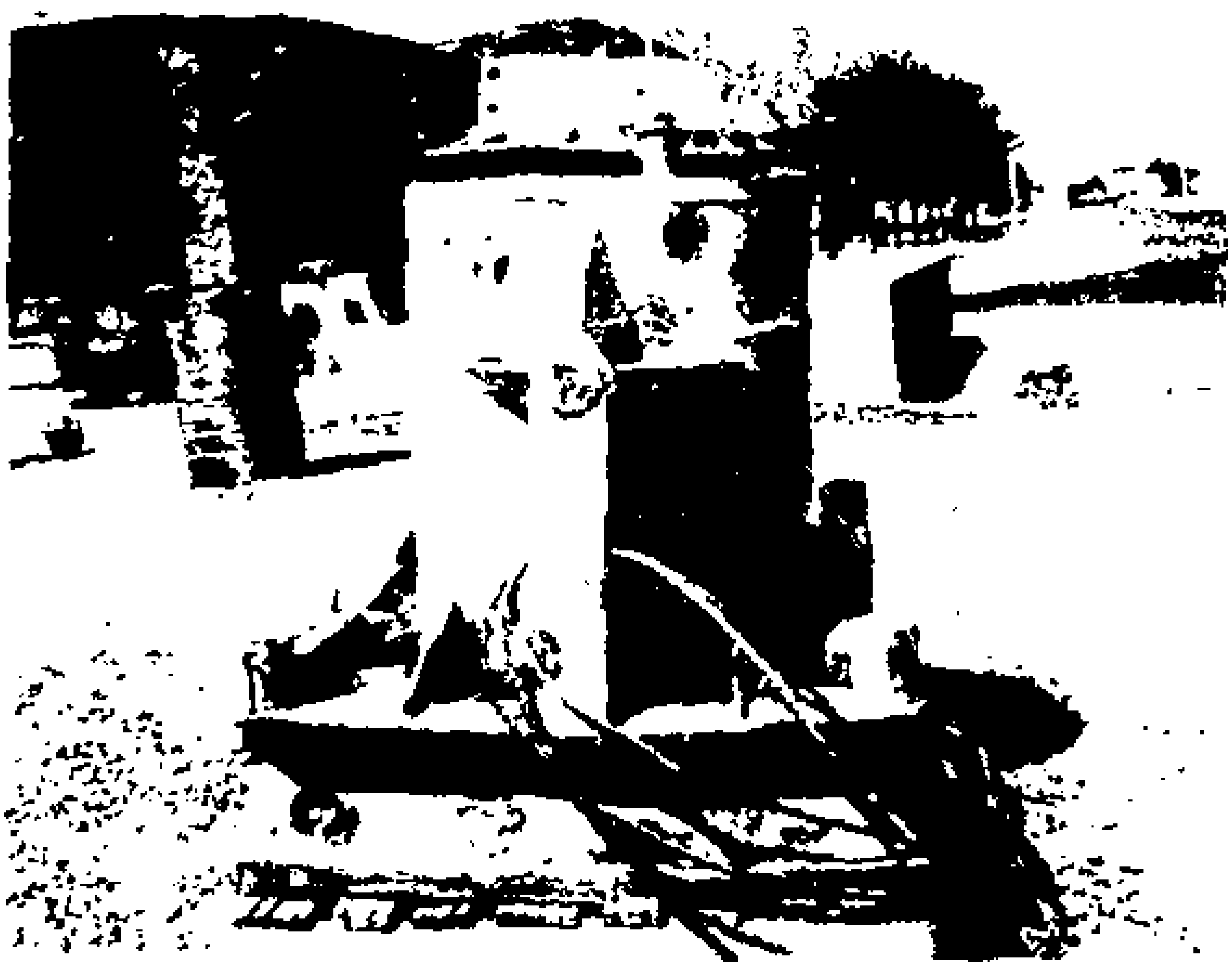
## Posttest Observations

### B of E 83

No observable deformation of this [illegible] were sheared off as a result of the combined impact and recovery effects. N[illegible] of the six holes drilled for this purpose.

### OD-1

Figure 5 shows the extent of the external [illegible] in the tie-down base plate structure. Internal [illegible] small [illegible] indicate that no solid or liquid material inside the [illegible] conditions.



Prior to testing activities, six holes were drilled through the outer shell into the lead. The relative position of five of these holes in the lead and the holes in the shell are listed in Table II. The sixth hole was inaccessible because of superstructure crushing. Hole A can be seen in the upper left of Figure 5. The lifting trunnion, shown in Figure 5, is the reference point for the angular location of the holes with the angle being measured in a clockwise direction on the top view. The minimum dimension listed for the lead holes is a measure of the resultant oval hole as compared to the original nominal 0.25-in. (6.35 mm) diameter hole.

TABLE II

Lead Slump

| Hole Identification | Location on Outer Shell* | | Hole in Lead | |
|---|---|---|---|---|
| | in. (mm) from top | Angle from Trunnion | in. (mm) below Shell Hole | Min. Dimension - in. (mm) |
| A | 3.0 (76) | 28° | 0.76 (19.3) | 0.234 (5.94) |
| B | 21.2 (538) | 77° | 0.82 (20.8) | -- |
| C | 31.8 (806) | 121° | 0.84 (21.3) | 0.173 (4.39) |
| D | 2.8 (70) | 209° | 0.93 (23.6) | 0.221 (5.61) |
| E | 18.5 (470) | 267° | 0.75 (19.0) | -- |
| F | 33.1 (851) | 300° | Not Examined | |

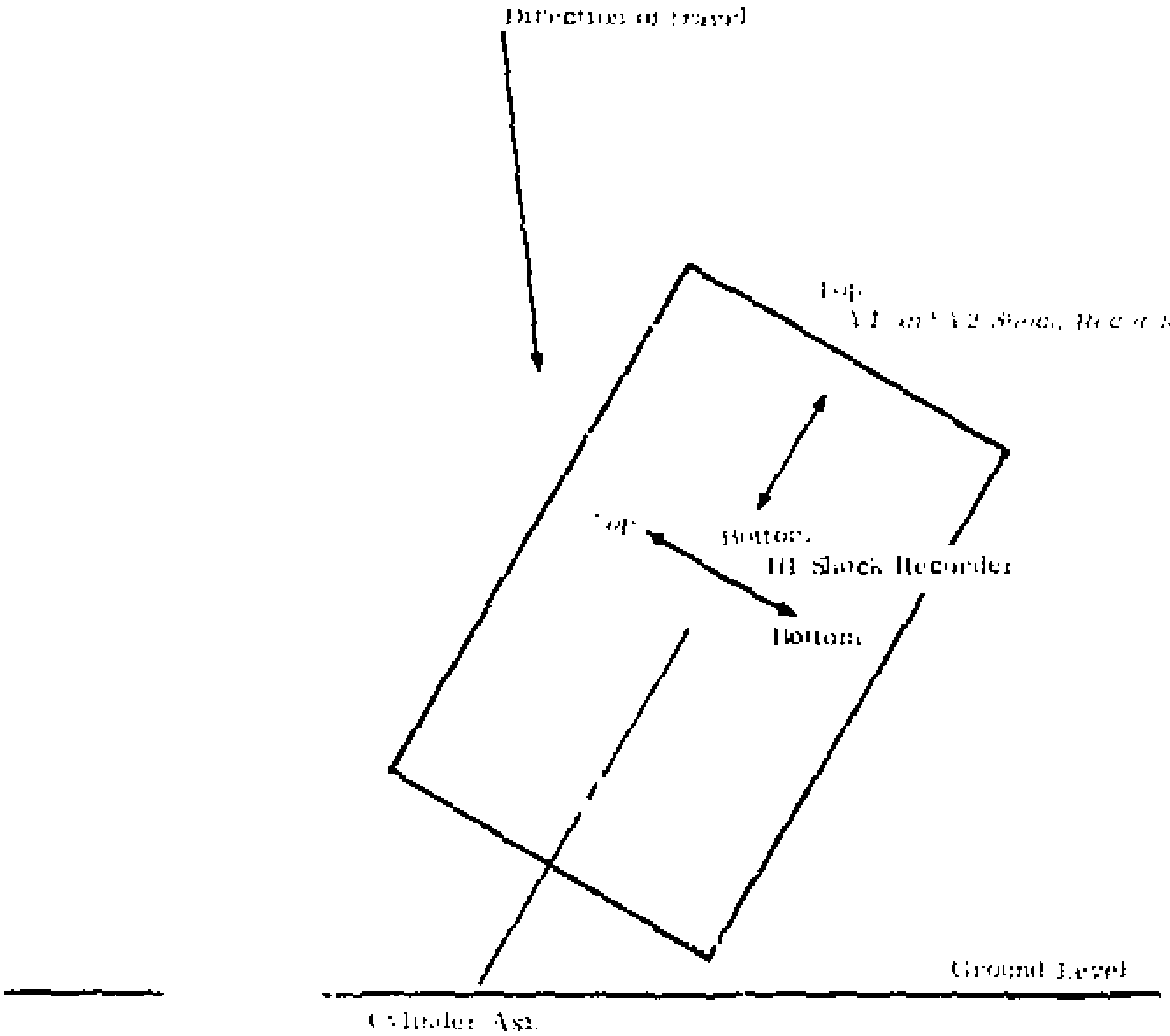
*Before the drop, the hole in the lead matched the hole in the outer shell.

The cross-hatching on the shell revealed no sign of outer shell twisting.

Measurements indicated that the inner cavity experienced a reduction in diameter of about 1 mm. The removable basket could not be removed without destroying it but was not visibly damaged by the inner cavity deformation.

Three Celesco Model A-12 passive shock recorders were attached to the cask prior to testing to obtain an indication of the deceleration forces. These devices are rather crude and are only accurate to within +100 percent or -50 percent of the actual environment. Two recorders (V1 and V2) were positioned to measure accelerations along the cylindrical axis and the other (H) was perpendicular to both this axis and the trunnion center line, as shown in Figure 6. Table III shows the acceleration levels measured. These levels are determined by the extent of deformation occurring in two deformable plastic filaments which are located between each end of a spring-loaded seismic mass and a viewing window.

The polyethylene bottle that was attached to the tie-down post of the OD-1 ruptured at the bottom, due to hydrodynamic pressures. The other bottle, which was dropped from the cockpit at about the same time the OD-1 was released, is also shown in Figure 7. This bottle landed on its side and exhibited a slight flattening effect but no loss of contents.




6. Orientation of Shock Recorders and the OD-1 on Impact

TABLE III

*Shock Recorder Data*

| Shock Recorder | Top | Bottom |
|---|---|---|
| V1 | 400 g's | ~400 g's |
| V2 | 400 g's | ~800 g's |
| B1 | ~800 g's | ~800 g's |

Figure 7. Polyethylene Bottles After Test. Bottle on the right was attached to the OD-1. Bottle on the left was dropped directly on the ground.

The only cask testing to date which is even similar to the tests discussed in this report is the 30-foot drop tests required by the Code of Federal Regulations, Title 10, Part 71, Appendix A. The hypothetical accident condition simulated by this drop results in an impact velocity of about 30 mph (13 m/s) on the "flat essentially unyielding surface." The impact velocity for the 2000-foot drop was about eight times greater than this, but the impact surface was certainly not unyielding.

Side-on impacts with orientations similar to the B of E 83 impact have been conducted to observe the effects of the 30-foot drop test.[1] The casks demonstrated high stress concentrations in the end plate weld areas and a flattening of the impacted side.

An end-on impact 30-foot drop test was conducted on a B of E 83 as part of the obsolete cask program.[2] The lead moved away from the top head about 0.5 in. (13 mm). The weld joining the head and shell failed and the impact end was slightly bulged.

Comparing these results with the observed results of the 2000-foot drop test leads the author to the conclusion that the 30-foot drop test onto an unyielding surface is a more severe environment than the 2000-foot drop onto a hard soil.

## References


1. L. B. Shappert, *A Guide to the Design of Shipping Casks for the Transportation of Radioactive Material*, ORNL-TM-681, April 1965.

2. L. B. Shappert, W. C. Bradley, L. H. Evans, and M. C. Jurgensen, *The Obsolete Cask Program – Test No. 2*, ORNL-TM-1312, Vol. 16, April 1975.