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The Obsolete Cask Program: Test Number 2

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Price: Printed Copy $4.00; Microfiche $2.25

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ORNL-TM-1312, Vol. 16
UC-71 — Transportation of
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Contract No. W-7405-eng-26
CHEMICAL TECHNOLOGY DIVISION

THE OBSOLETE CASK PROGRAM: TEST NUMBER 2

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APRIL 1975

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Previous reports in the obsolete cask series are: The Obsolete Cask Program: Initial Tests, ORNL-TM-1312, Vol. 14.

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THE OBSOLETE CASK PROGRAM: TEST NUMBER 2

L. B. Shappert J. H. Evans
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ABSTRACT

A cask was subjected to impact tests, which involved 30-ft drops onto a solid, essentially unyielding surface. The cask, which weighed 7100 lb, was dropped on end. Deformation of the cask and accelerations at several points were predicted before the tests; these predicted values were compared with the test results obtained from an extensive instrumentation system. Both predicted cask deformations and accelerations agreed reasonably well with the measured values.

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1. INTRODUCTION

The Obsolete Cask Program was initiated to study the behavior of large casks under specified destructive test conditions[1] and to establish the adequacy of the calculational techniques that are presently employed to predict cask damage. The test used to produce severe cask damage consists of a free fall by the cask from an elevation of 30 ft, impacting on an essentially unyielding surface in an orientation which would produce maximum damage. The 47,000-lb HWCTR cask will be the first large cask tested in the program.

The need to test equipment, instrumentation, and operating procedures by testing smaller, more readily available casks soon became apparent. The first tests in the program were conducted on a 6000-lb cask and the results reported[2] in 1974. Although it was tentatively planned to follow these tests with a series of drop tests using the 47,000-lb HWCTR cask, it was decided that another series of tests, using a smaller cask, should come first since: (1) some instrument malfunctions were experienced during the initial tests, (2) more extensive instrumentation, as planned

for the HWCTR cask, needs to be tested, and (3) additional experience was needed in the operation of instrumentation and mechanical systems.

A parallel purpose for the tests was to take additional data which would be useful in establishing the adequacy of analytical techniques for predicted cask damage and furnish performance data for cask designers and safety reviewers.

A 7100-lb, steel-clad, lead-shielded cylindrical cask, Pratt and Whitney I, was selected for this drop since it was available, not contaminated, and was similar in many ways to the HWCTR cask. For the purpose of this test it was decided to drop the cask on its base with the axis vertical because: (1) mounting of the transducers (accelerometers) was simplified, (2) the cask could be dropped several times in this attitude to resolve instrumentation problems if they were encountered, and (3) no special rigging was required.

2. TEST CASK DESCRIPTION

The test cask is identified by the common name Pratt and Whitney I and the Bureau of Explosives Permit B of E 83. The cask was obtained by ORNL from CANEL Division of Pratt and Whitney Corporation a number of years ago. Important features of the cask are illustrated in Fig. 1. There is no information available to indicate fabrication quality or details in addition to those shown in Fig. 1. The external and cavity dimensions were obtained by direct measurement. Test holes were drilled in the outer shell and top and bottom heads to determine plate thicknesses. Shell and head material are apparently low-carbon steel of an unknown type and grade. The lead appears to have been poured with the axis of the cask vertical.

The composition of the lead is also unknown. Visual inspection prior to testing indicated that the cask workmanship was of a quality typical of its fabrication era.

The cask was modified, as shown in Fig. 1, to facilitate mounting of a peak recording and two piezoelectric accelerometers directly on the lead

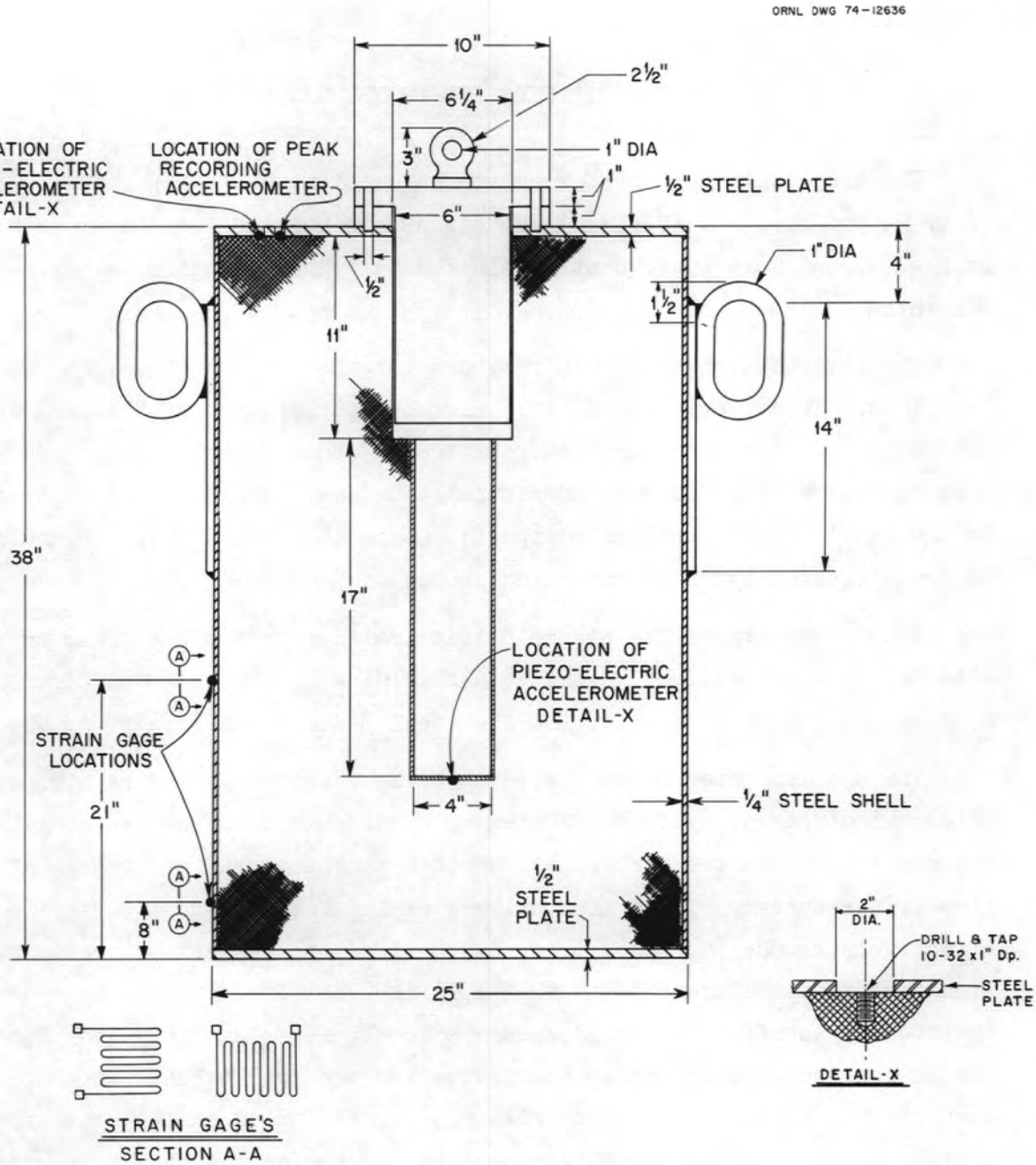

Fig. 1. Section view of the Pratt and Whitney I cask.

shielding. A series of eight 1/4-in.-diam equally spaced holes was drilled through the outer shell to allow visual determination of lead movement.

3. TEST FACILITIES AND INSTRUMENTATION

The drop tests were performed at the existing ORNL Drop Tower (Fig. 2) and Drop Pad (Fig 3). The casks were hoisted as illustrated in Fig. 4, and were subsequently released by a hydraulically actuated mechanism.

The instrumentation system provided for the cask drop test had four functions. These were to monitor: (1) the acceleration of the cask lead shielding, (2) the shock on the steel impact pad and the concrete drop tower base, and (3) the circumferential and longitudinal strain imparted to the cask's steel shell upon impact; and to (4) record output signals on two different types of recording devices.

Accelerometers of the piezoelectric transducer type were used to measure the accelerations on the lead shielding in the cask and also to measure the reaction to impact on the steel pad and concrete tower base.

The accelerometer signals were amplified, filtered, and recorded using two different systems. For example, signals from the two accelerometers mounted on the cask were connected to the amplifier through a line driver system. These line drivers employ integrated circuitry to effectively reduce the circuit impedance (i.e., the 100-ft cable connection from the accelerometer to the amplifier) to zero. Since the system operates at an effective zero impedance level, it is unaffected by loading due to interconnecting cable capacity or leakage resistance. Line drivers, connected to the accelerometers with a 3-ft section of cable, converted the charge signal from the two accelerometers mounted on the cask to current signals. These signals were then sent by coaxial cable to the amplifier, where they were converted to a voltage signal proportional to the deceleration of the cask. The amplified signals were passed through an internal low pass filter set for a 3-kHz cutoff frequency and then sent to an oscilloscope where both traces were recorded.

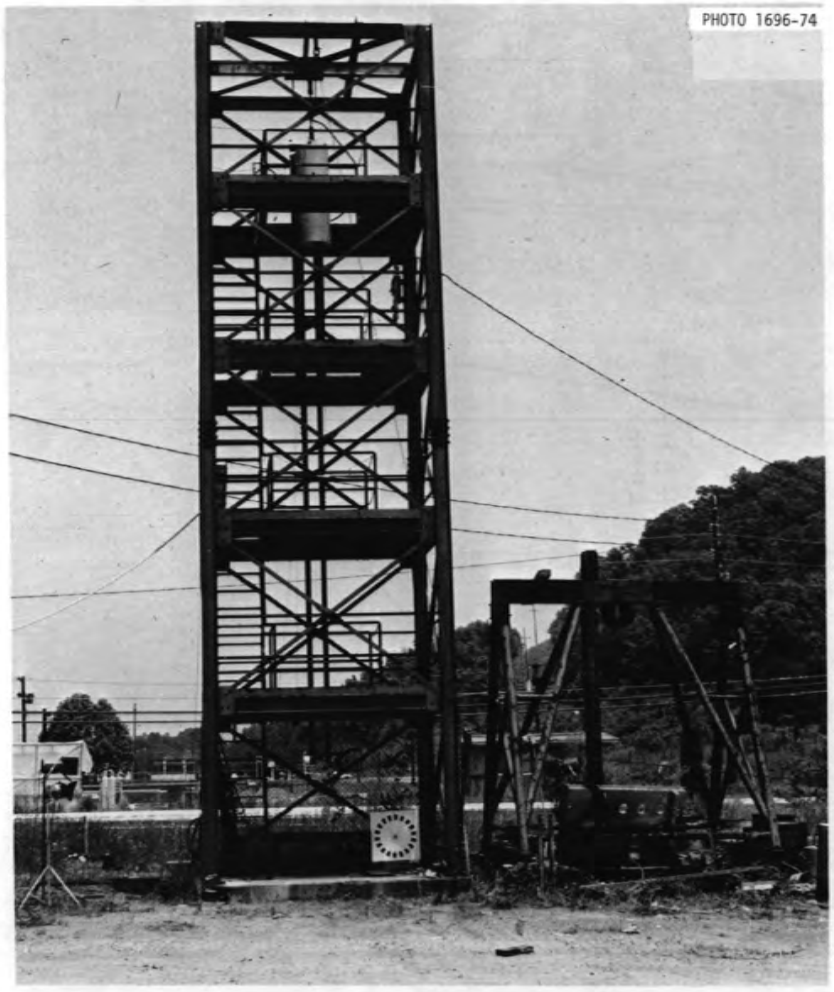

Fig. 2. ORNL Drop Tower.

ORNL-LR-DWG 74992

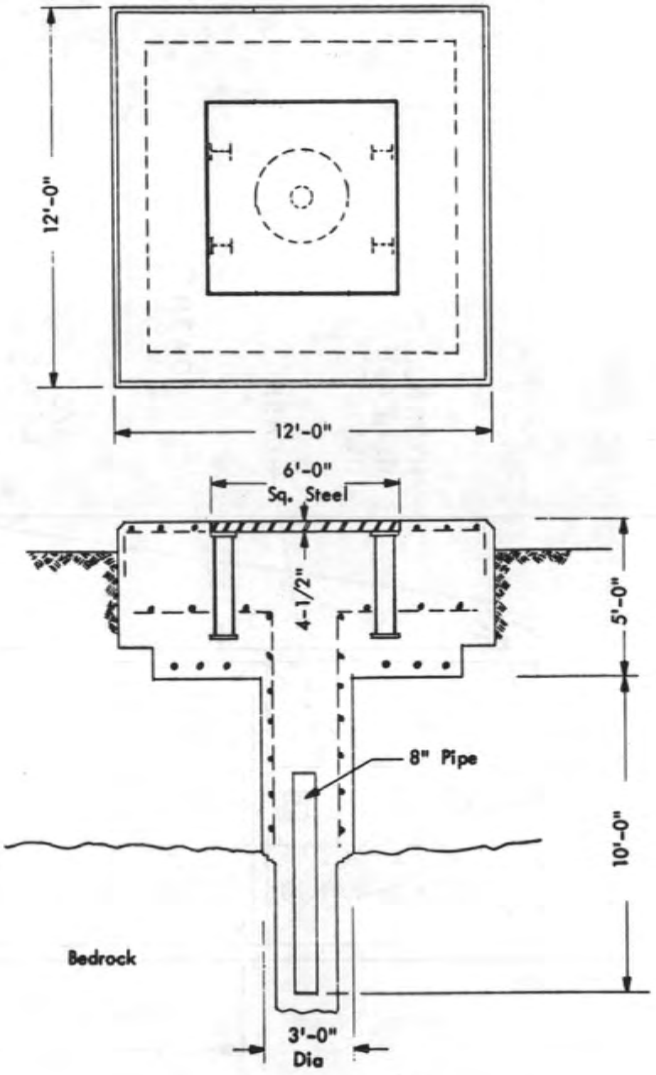

Fig. 3. ORNL Drop Pad.

ORNL DWG 74-8426

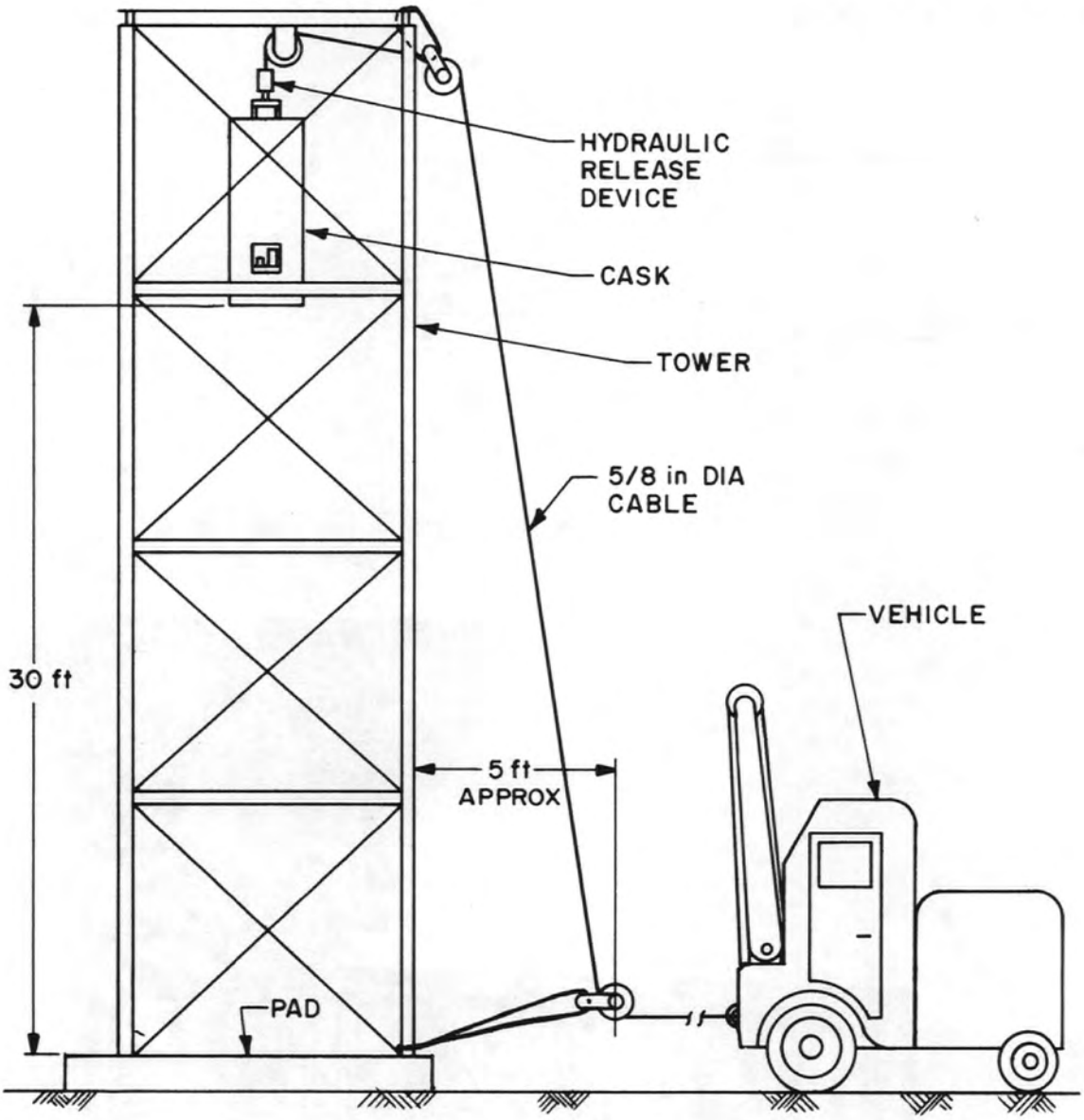

Fig. 4. Hoisting diagram.

The other amplifier and filter system was connected to the two accelerometers mounted on the impact pad. Signals from these accelerometers were sent to charge amplifiers that produced an output voltage proportional to the accelerometer crystal charge. The signals were then filtered by a discrete solid-state low pass filter with a 3-kHz cutoff frequency.

The 3-kHz cutoff frequency was chosen for both filtering networks to eliminate high-frequency ringing effects above 3 kHz that frequently make the data difficult to interpret.

The four filtered accelerometer signals were split, enabling each to be recorded by an oscillograph and an oscilloscope. Both recording instruments have their own advantages and disadvantages, and this technique permits the comparison of the same signal on the different devices.

In the case of the oscilloscopes, the signals were displayed at the instant of impact. The oscilloscopes were set in the single sweep mode and were triggered externally. The external trigger mechanism employed a laser beam focused on a photo-FET detector. When the laser beam was interrupted by the falling cask, the FET amplifier system would send a pulse to the oscilloscopes for triggering. Since the laser beam was elevated several feet off the pad surface, a 5-msec time delay was set into the trigger system so that the oscilloscope traces would sweep at the instant of impact. The traces were recorded on film by time-exposure techniques using a Polaroid Land Camera mounted on the oscilloscopes. Vertical deflections on the two oscilloscopes were set so that 60 g/cm would be displayed for the cask and 10 g/cm would be displayed for the accelerometers mounted on the pad. The time base (the horizontal sweep speed) was 5 msec/div. for the cask accelerometer traces and 10 msec/div. for the pad accelerometer traces.

In the case of the accelerometer signals which were recorded on an oscillograph, the amplified and filtered signals were sent to the galvanometer driver amplifiers. A light beam, reflecting from a mirror attached to the galvanometer, was recorded on light-sensitive paper. Movement of this recording paper through the oscillograph was started well before the

cask impact occurred, ensuring that the entire output signal of the accelerometers, generated by the impact, was recorded. One inch of galvanometer deflection represented 300 g for the cask accelerometers and 30 g for the pad accelerometers.

Four strain gages were also mounted on the cask's outer surface in pairs at 8 and 21 in., respectively, from the cask bottom. One gage of each pair was mounted parallel to the bottom of the cask to measure circumferential strains, and the other gage was mounted perpendicular to the cask bottom to measure longitudinal strains. Each strain gage formed one arm of a full bridge circuit. Four gage control units were used to regulate the bridge excitation voltage and to amplify the bridge error signal generated upon the impact of the cask. The signals recorded on the oscillograph were such that 1 in. of galvanometer deflection represented 0.0206 in./in. strain.

The drop was recorded with both normal and high-speed motion pictures. An 1800-rpm timer was placed on the impact surface and photographed to facilitate interpretation of the film.

4. RESULTS

The cask was hoisted to a height of 30 ft and then released by means of the hydraulically actuated release mechanism. The bottom of the cask impacted on the pad at a slight angle, bounced once, and then came to rest on the pad without causing damage to any instrumentation. From the high-speed movies it was estimated that the cask did not impact precisely flat on the bottom, and that the angle of inclination was 3°.

Two oscilloscopes were used to record accelerations as a function of time at four points (two on the cask and two on the pad), and the traces were photographed. These photographs were of good quality, although the data were difficult to decipher. This difficulty was caused by high-frequency ringing effects (it was later determined that the electronic filters did pass frequencies up to 4000 Hz), and the fact that two channels of data were recorded on one photograph, which resulted in data crossover in some areas of the traces. The data were useful in that they provided

an approximate verification of the accelerometer data obtained from the oscillograph traces.

The four channels of accelerometer data recorded on the oscillographs provided better results than the oscilloscope traces. The accelerometer mounted on the top of the lead shielding on the cask indicated a maximum acceleration of 170 g. The accelerometer mounted on the lead at the bottom of the cask cavity floor at the bottom of the cask indicated a maximum acceleration of 210 g. The accelerometer mounted in the concrete on the drop pad indicated a maximum acceleration of 3 g. The accelerometer mounted on a steel plate on the drop pad did not provide any results since its signal passed through a defective galvanometer. The peak recording accelerometer attached to the cask was knocked loose during the hoisting sequence of the test.

The four channels of strain gage data were all recorded successfully on the oscillograph. The strain gages mounted 21 in. from the bottom of the cask produced a circumferential strain of 1.3×10^{-3} in./in. and a longitudinal strain of 6.4×10^{-4} in./in. The gages mounted 8 in. from the bottom of the cask produced a circumferential strain of 0.013 in./in. and a longitudinal strain of 0.011 in./in. The strain gage and accelerometer data are reproduced in Fig. 5.

Visual inspection of the cask after dropping revealed that the lead had moved away from the top head about 1/2 in. (see Fig. 6). The deformation of the shell was not radially symmetrical, having bulged somewhat more on the surface above the point of first impact (see Fig. 7). The top head had also dished about 1/2 in., as illustrated in Figs. 8 and 9. It is believed that lead was mechanically "bonded" to the cavity due to the thermal contraction associated with solidification. It is also possible that lead movement was restricted because of protrusions or angles welded to the steel shells. Such protrusions, if they exist, will be found only by destroying the cask which may be done, if deemed necessary, at some future time. The weld joining the head and shell failed, as indicated in Fig. 10. The crack was centered on the point of first impact. The crack was visible for 106° as shown and was wide enough to permit entry of a 3/32 thickness gage for 23°. Figures 10, 11, and 12 are photographic records of the damage to the cask.

ORNL DWG 75-2510

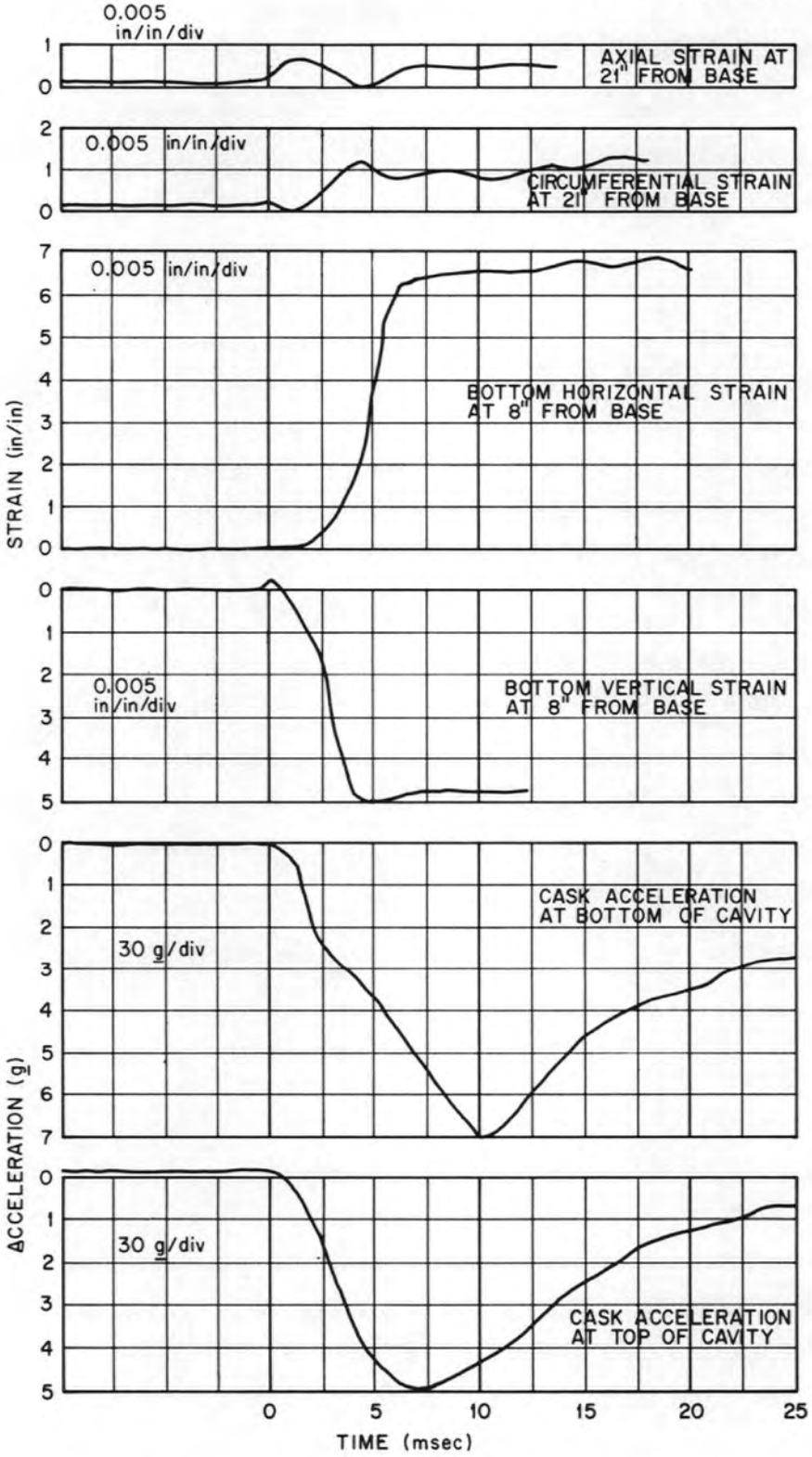

Fig. 5. Cask acceleration and strain gage data.

Fig. 6. Lead displacement from the top plate of the cask.

Fig. 7. Deformation of shell over point of first impact.

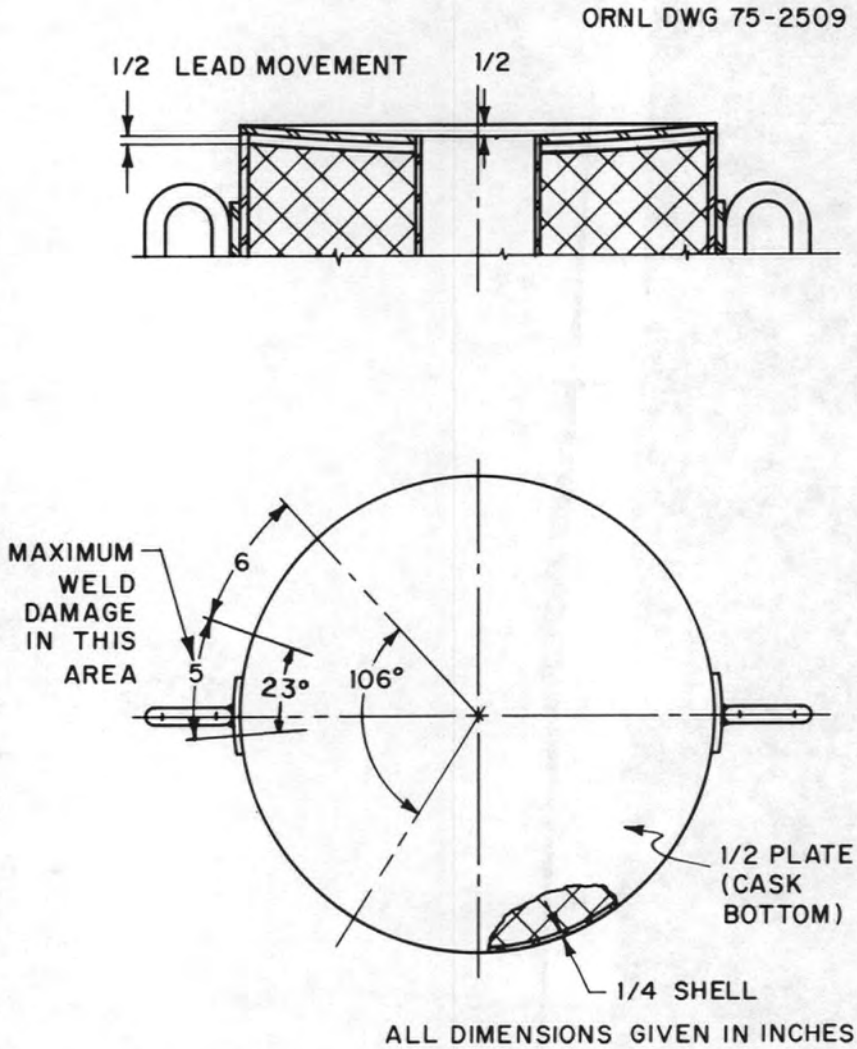

Fig. 8. Schematic of lead movement and cask damage.

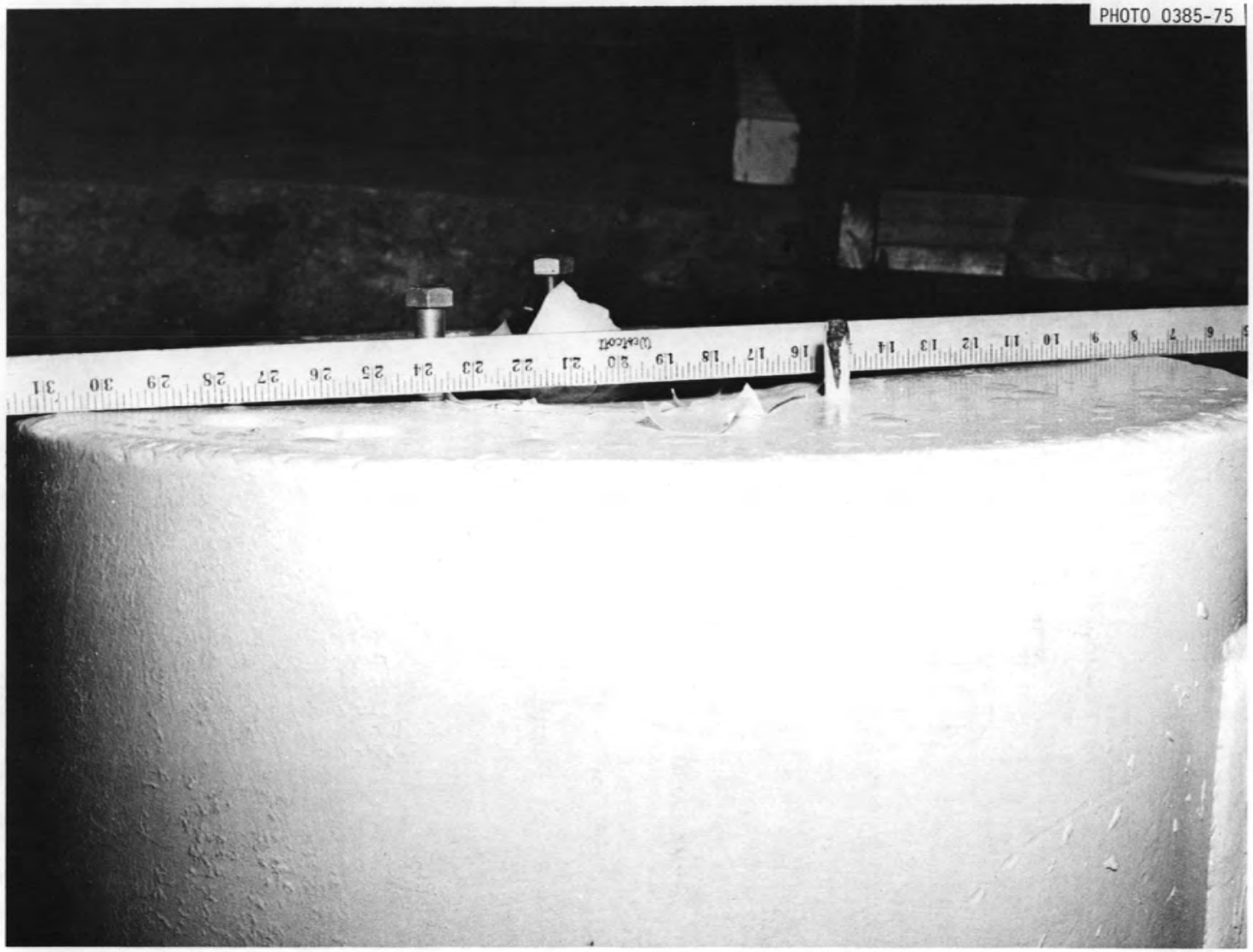

Fig. 9. Deformation of the top head due to impact on the bottom.

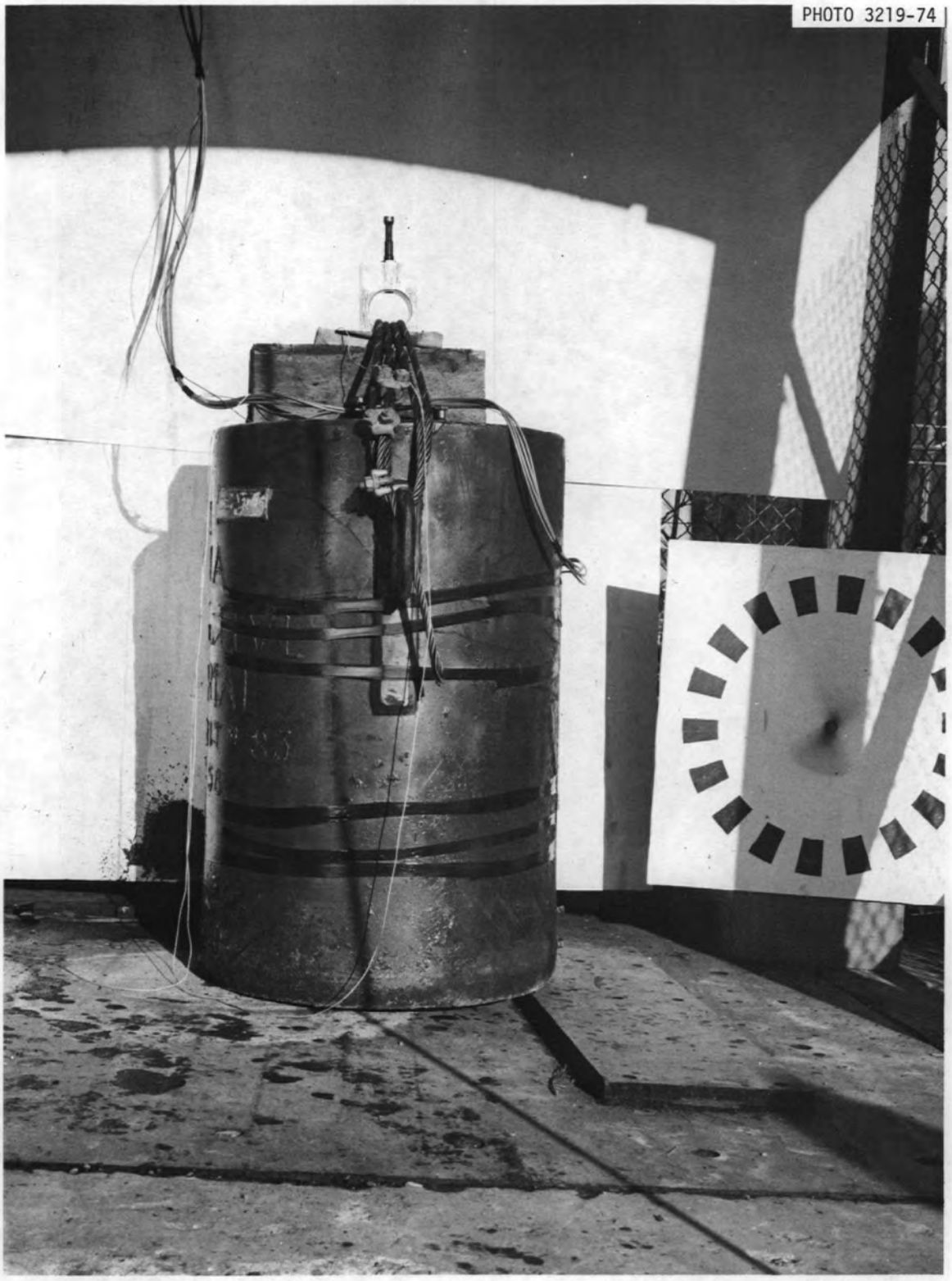

Fig. 10. Cask after impact.

Fig. 11. Cask bottom following impact.

Fig. 12. Bottom section of the cask following impact.

5. PREDICTIONS REGARDING DAMAGE

Prior to the test, an ORNL program CEIR was used to predict the deformation of a steel-jacketed, lead-shielded cask when dropped on end.[3] The calculation indicated that, for a 30-ft drop on end, onto an essentially unyielding surface, a movement or lead slump of 1.1 in. could be expected.

The measured movement relative to the top head was 0.5 in. The top head was "dished" an additional 0.5 in. as a result of the drop; hence the prediction was reasonably close.

The program, CEIR, was also utilized to predict shell strains at the point where the strain gages were located. A comparison of the predicted and measured strains is made in Table 1 below:

Table 1. Comparison of measured and calculated shell strains

Gage location from bottom of cask	Gage orientation	Measured strain (in./in.)	Calculated strain (in./in.)
8	Circumferential	0.013	0.021
8	Axial	0.011	0.010
21	Circumferential	0.010	0.001
21	Axial	0.005	0.0006

Strains measured close to the point of impact agree well with predictions, although those further away were about a factor of 10 below predictions. No reason for this behavior has been found at this time.

It was also predicted that significant weld failures would occur in the impact area, particularly the shell-to-head weld since previous tests[4] on similar welds in ASTM A 516 grade 55 low-alloy base metal and with similar casks[2] had resulted in failure. Weld failures occurred as expected.

6. CONCLUSIONS

The experimentally determined and calculated responses of the test casks were in sufficient agreement to warrant continued use of the basic calculational method employed. It was again demonstrated that welds need to be of high quality if they are to withstand, without rupture, the severe impact required by the regulations. Improvements need to be made in the data acquisition system for future tests.

7. REFERENCES

1. Code of Federal Regulations, Title 10, Part 71, "Transport of Licensed Materials."

2. L. B. Shappert and J. H. Evans, The Obsolete Cask Program: Initial Tests, ORNL-TM-1312, Vol. 14 (November 1974).

3. J. H. Evans, Structural Analysis of Shipping Casks. XIII. CEIR: A FORTRAN Program for Estimation of the Response of Cylindrical Lead-Shielded Cask to End Impacts, ORNL-TM-1312, Vol. 13 (June 1974).

4. J. H. Evans, H. A. Nelms, and W. C. Stoddart, "Experimental and Analytical Developments at Oak Ridge National Laboratory for Demonstrating Compliance with Federal Regulations," Proceedings of the Second International Symposium on Packaging and Transportation of Radioactive Material, Gatlinburg, Tenn., Oct. 14-18, 1968, CONF-681001.

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