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ORNL Cask Testing Program; Tests of Radioisotope Shipping Cask - Type C

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ABSTRACT

Fire endurance tests and drop tests performed on Type C radioisotope shipping casks indicate that the casks meets fire-endurance, structural-integrity, and shielding-integrity requirements as stated in the proposed amendment to Title 10 Code of Federal Regulations, Part 72, and AEC Manual Chapter 0527.

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INTRODUCTION

An evaluation and testing program for radioisotope shipping casks has been instituted by the Isotopes Division at ORNL to insure that these casks meet or exceed requirements for structural-integrity, fire-endurance, and shielding requirements after a fire as outlined in 10 CFR 72 and AEC Manual Chapter 0527 [e.g., withstand a 15-ft free fall onto an unyielding surface and withstand a standard one-hour fire (1700°F) with the shielding remaining intact, so that the maximum radiation reading at 1 m does not exceed 1 r/hr]. This report is a discussion of the tests that have been conducted on three Type C radioisotope shipping casks.

Type C radioisotope shipping casks have type 347 stainless steel shells containing lead shielding in thicknesses from 4 in. to 7.5 in. (Figure 1). The outer stainless shell is 1/4 in. thick and the outside dimensions range from 9-3/8 in. diameter and 12-1/8 in. high to 16-3/8 in. diameter and 19-1/8 in. high.

The casks have a recessed well for the top plug shield. This plug is held in place and sealed in transport by a 4-bolt flange with an asbestos gasket.

The casks originally contained an asbestos spacer material which was formed in the bottom of the cask (Figure 1) to shape the lead shield and save on overall weight of the cask.

CASK TESTING

Non-Destructive Tests

Cask 403 was subjected to a series of non-destructive tests to ascertain the general condition of these casks. All welds and the cask body were dye-checked to locate holes or cracks. The outer weld of the top flange was found to be cracked ~ 30° around the circumference in the area where the nameplate was welded to the shell. The top flange and the bottom plate of the inner well (Figure 1) had many small cracks and holes which were repaired before further testing was conducted.

An attempt was made to radiograph the welds around the outer and inner edges of the top flange, but the photographs obtained were not clear because of the angle from which they had to be taken. Radiography of the shield revealed no appreciable void spaces. Practically no bonding of the lead to the outer shell was detected.

Chemical analyses were made on the asbestos material (Figure 1), the lead shielding, and the stainless steel outer shell. The asbestos material contained ~ 52 wt % free water and 5 wt % water of hydration. Tests for nitrates in the lead and asbestos were negative. Tests on the stainless steel outer shell indicated trace amounts of

nitrates and sulfates.

Destructive Tests

Fire Tests

Three casks--4C3, 4C5, and 4C6--have undergone fire endurance tests. Each cask was pumped dry of all water in the lead cavity and the inside of the cask with a vacuum pump and external heating to ~ 212°F prior to subjecting it to the fire test. Approximately half a liter of water was removed from the lead cavity of cask 4C3. Attempts were made to measure the volumes of water in the lead cavities of casks 4C5 and 4C6 but were unsuccessful because of leaks in the top flanges.

Each cask was also subjected to a 200 psig hydrostatic test to locate leaks in lead cavity prior to being fire-tested. The leaks were then repaired and the water removed from the cask shell. It is important to note here that 110 g of water in the cask shell, assuming no asbestos material present, and 1700°F would create sufficient pressure to rupture the cask.

Five thermocouples were installed in and on the casks to obtain the temperature gradient across the cask cross-section. Thermocouple No. 1 was located on the outside of the outer shell wall ~ 6 in. down from the top; No. 2 was located on the inside of the outer shell wall ~ 6 in. down from the top. Number 3 was located 1 in. from the outer shell wall ~ 6 in. deep into the lead shielding; No. 4 was located on the inside wall of the inner shell, and No. 5 was located at the center of the cask. Table 1 is a summation of the maximum temperatures reached in the tests and the time at which these temperatures were reached.

Table 1. - MAXIMUM TEMPERATURES REACHED IN FIRE TESTS

	Cask 4C3		Cask 4C5		Cask 4C6	
Thermo-Couple	Temp. (°F)	Time (min)	Temp. (°F)	Time (min)	Temp. (°F)	Time (min)
1	> 2190	20	1870	33	2050	39
2	> 2190	50	1940	33	2040	39
3	> 2190	50	1920	33	2040	39
4	> 2190	50	1850	33	2040	39
5	2150	60	1870	33	2030	39

The fire test on cask 4C3 was conducted for one hour. Approximately 10 min after beginning the test, temperature 840°F, a noise like a slight pressure release was heard. Examination of the cask after the test revealed that a copper line to a pressure gage was burned off. Examination of the cask also revealed that a 3-in. crack had

occurred along the outer edge of the top flange, the same area in which an attempt had been made to repair this carrier. During the test, molten lead expanded and flowed out of the crack that was formed. The top and bottom flanges of the cask were bowed from the heat.

The pressure of cask 4C5 increased rapidly as heat was applied and reached 250 psig in 12 min. It then dropped sharply to 100 psig in ~ 30 sec and reached 0.0 psig at the end of 18 min. Also at the end of 18 min molten lead was spraying out of pinholes in the top flange of the cask. The cask maintained its integrity throughout the test. The test was terminated at the end of 33 min since it was felt that no further useful information would be obtained.

The pressure of cask 4C6 reached 20 psig after 5 min of heating. The valve to a 2-liter evacuated-gas-sample container was open at that time. As the heating continued, the pressure in the entire system reached ~ 105 psig in 30 min and molten lead began spraying out of pinholes in the top flange. The gas-sample container was then disconnected. The cask retained its integrity during the test. The test was terminated at the end of 39 min. Table 2 shows the results of the gas analysis.

Table 2. - GAS SAMPLE ANALYSIS - CASK 4C6 TEST

Constituent	%
H_2	8
CH_4	17
H_2O	1
Other Hydrocarbons	6
N_2 + CO	22
O_2	0.3
CO_2	45

Drop Tests

Two of the casks, 4C5 and 4C6, were subjected to drop tests. Cask 4C5 was dropped twice from a height of 5 ft with no damage. A drop from 10 ft caused a 2-1/2- to 3-in. crack in the weld around the top flange. However, visual inspection showed that this was not a full-penetration weld.

Four drops were made from 15 ft. The first drop was made on a corner and caused a deflection of ~ 7/8 in. and a 1/2-in. bulge on

the bottom. There was no rupture. A second drop on the same corner caused no measurable additional deflection. The third and fourth drops were made on the opposite corner with the same results as for the first two drops.

Six drops were made from ~ 25 ft. The first three drops were on the same corner as drops 1 and 2 above and the second three on the same corner as drops 3 and 4. There was an increased deflection to a total of ~ 1-1/2 in., but no further damage and no increase in the size of the crack mentioned above.

Cask 4C6 which had been completely repaired (as far as welds and pinholes were concerned) was dropped three times from ~ 25 ft. The deflection was the same as for cask 4C5 under the same conditions. There was no apparent damage other than the deflection; there was no cracking of welds and no apparent shifting of the lead.

DISCUSSION

The approximate volume of voids and lead in the cask cavity has been calculated to determine the amount of expansion space present in the cask and to compare it to that needed. The results of the calculations for the 4-in. size cask are as follows:

Total volume of solid lead	= 471 in.^{3}
Total volume of expansion space	= 16 "
Total volume of asbestos spacer material	= 104 "
Total volume of carrier	= 591 "
Volume ratio of molten lead at 1800°F to solid lead	= 1.16
Total volume of molten lead at 1800°F	= 546 in.^{3}

By comparing the total volume of solid lead and free space (487 in.^{3}) to the total volume of lead at 1800°F (546 in.^{3}), it can be seen that sufficient expansion space has not been provided in the carrier. The type C carriers are therefore being modified to provide sufficient expansion space for the molten lead. This is being done by removing the asbestos spacer material from the bottom of the casks. Table 3 is a summary of the cask and lead volumes.

Table 3. - SUMMARY OF MODIFIED CASK AND LEAD VOLUMES

Cask Size (in. Pb Shielding)	Lead Volume 60°F (in.^{3})	Lead Volume 1800°C (in.^{3})	Total Volume Cask (in.^{3})
4	471	546	591
5	980	1136	1213
6	1405	1630	1782
7.5	2620	3080	3301

Shielding calculations for minimum thickness of lead were made under the condition that the lead was completely melted. The lead shielding thickness was calculated for the cask while resting on its side, top, and bottom. Since the shielding thickness is least for the cask on its side, the radiation reading was calculated at 1 m from the cask in this position. (10 CFR 72 and AEC Manual Chapter 0527 require 1 r/hr at 1 m.) Table 4 is a summary of the results of these calculations.

Table 4. - MAXIMUM RADIATION READINGS AT ONE METER AFTER FIRE

Cask Size (in. Pb Shielding)	Max. Amt. Co^{60} Allowable in Cask (curies)	Radiation Reading at 1 m (mr/hr)
4	1.5	70
5	5	90
6	25	400
7.5	175	800

ROUTINE TESTING PROGRAM

The routine test program for radioisotope shipping containers is as follows:

1. Leak-test each cask every 6 months by pressurizing with air at 200 psig under water and checking for leaks.

2. Repair leaks, if any, and repeat leak tests.

3. Check cask once every 6 months for water inside the lead cavity. Remove water with a vacuum system through P_2O_5 trap and record weight of water removed.

4. Visually inspect all casks upon return to the Laboratory from off-site shipments. Note any suspected crack, dent, or other imperfection and investigate by submitting the cask to the above-mentioned tests.

5. Decontaminate off-site shipping casks with the least corrosive decontamination agents; i.e., soap or scouring powder and water. Use nitric acid sparingly to reduce the possibility of getting nitrates into the cask since they may react with the lead to form possible explosive compounds. Chlorides or other halide compounds will not be used.

CONCLUSIONS

Type C radioisotope shipping containers will meet the requirements for structural integrity, shielding integrity after fire, and fire-endurance tests as proposed by 10 CFR, Part 72, and AEC Manual Chapter 0527 after the following minor modifications are made:

1. Providing of sufficient expansion space for molten lead by removing asbestos spacer material;

2. Repairing of all welds in cask body;

3. Removing all water from cask shell and providing routine testing to insure that cask shell remains dry.

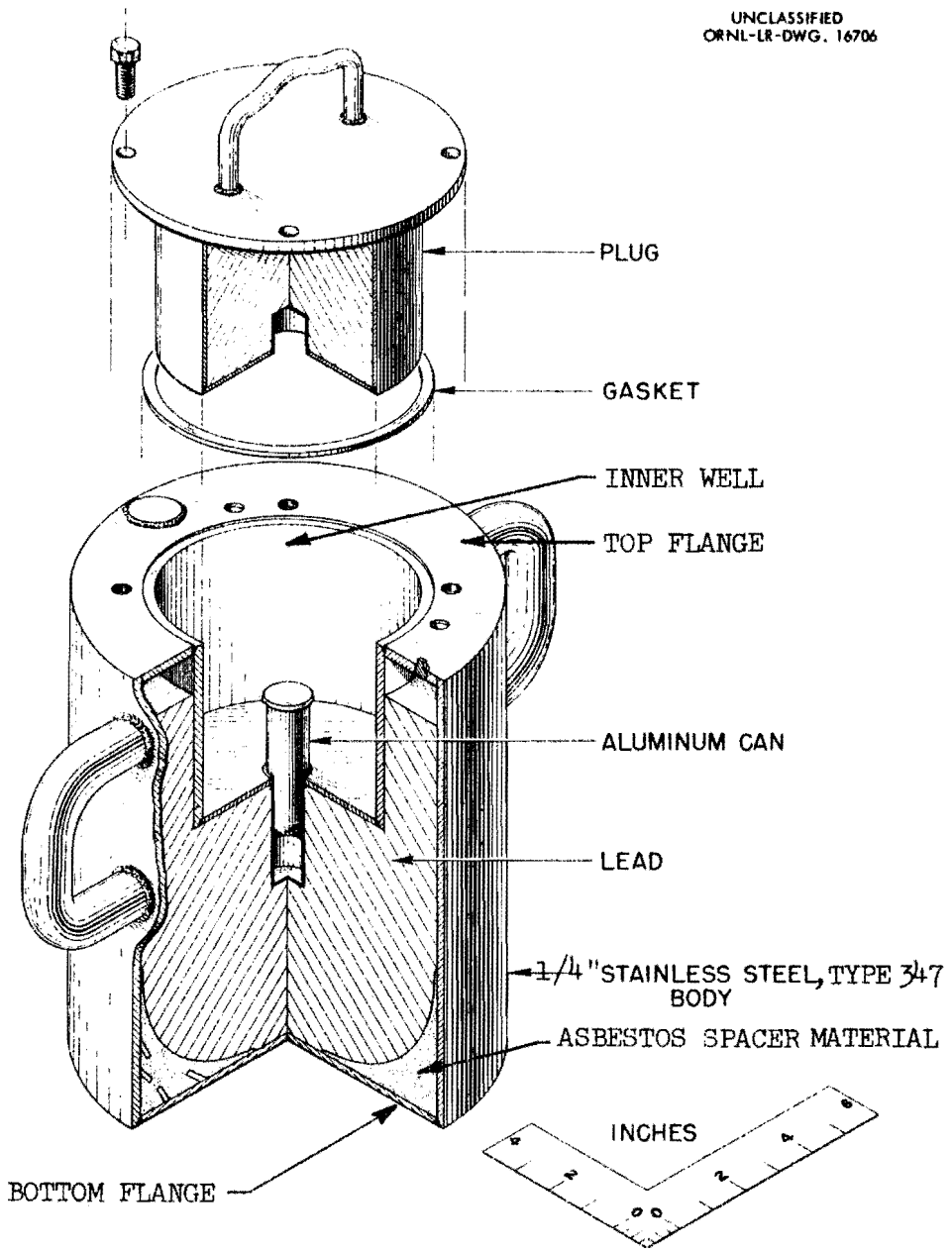

Fig. 1. Returnable Container for Solid Materials (Lead Shielding, 4 to 7 ½ in.).

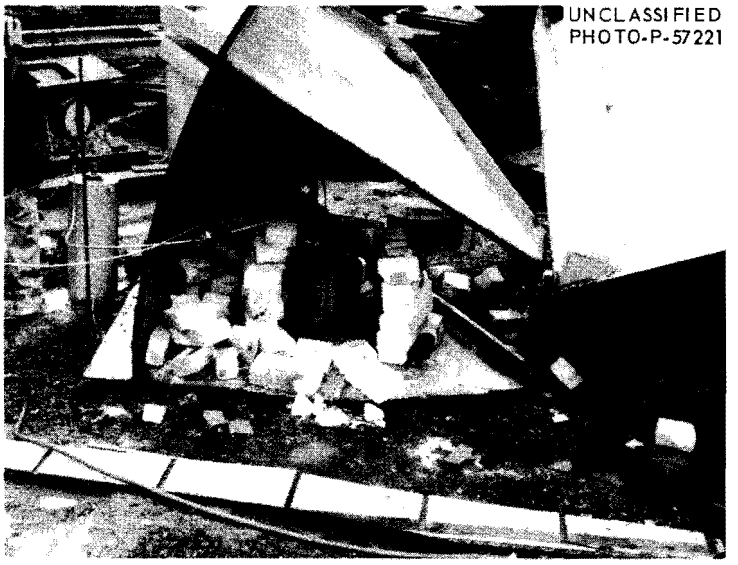

Fig. 2. Cask 4C6 – Pressure Readout Gage, Gas Sampling Cylinder, Before Fire. Steel safety shield with firebrick partially removed.

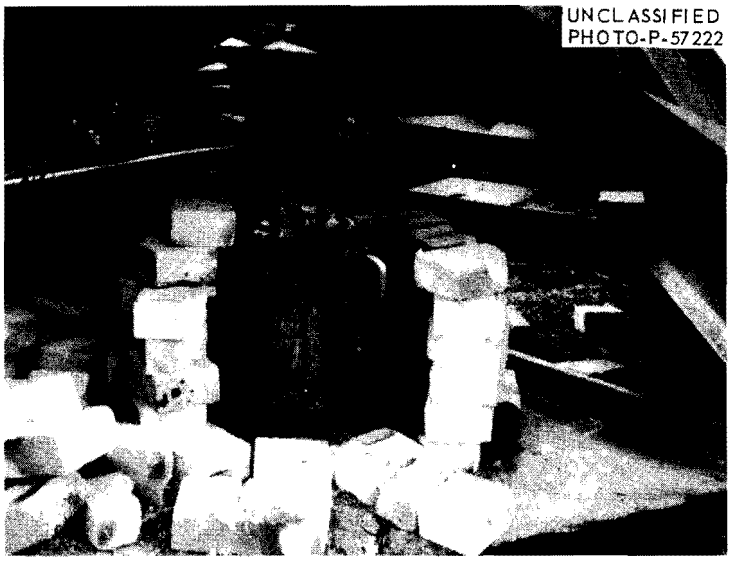

Fig. 3. Closeup of Cask 4C6 Before Fire, Note Thermocouples.

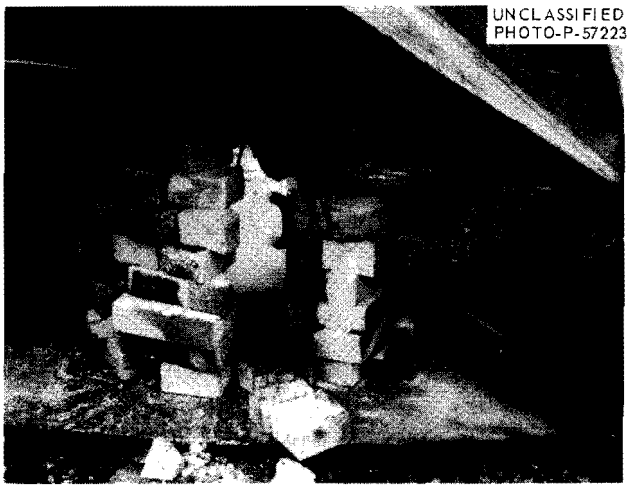

Fig. 4. Cask 4C6 – Glowing White-Hot Immediately After Torches Were Removed.

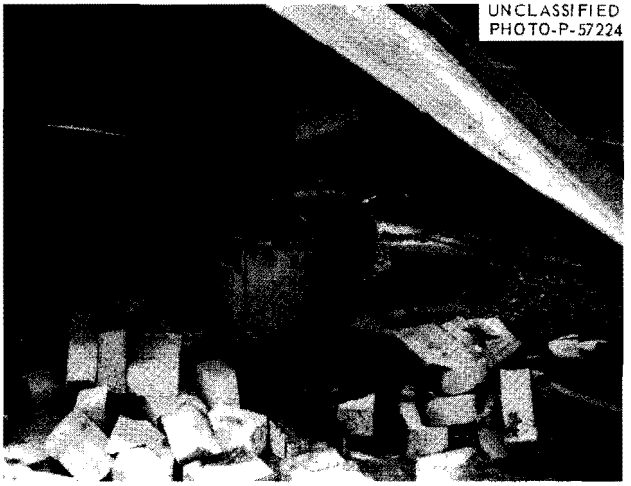

Fig. 5. Cask 4C6 – Glowing Red-Hot Approximately 5 min. After Torches Were Removed.

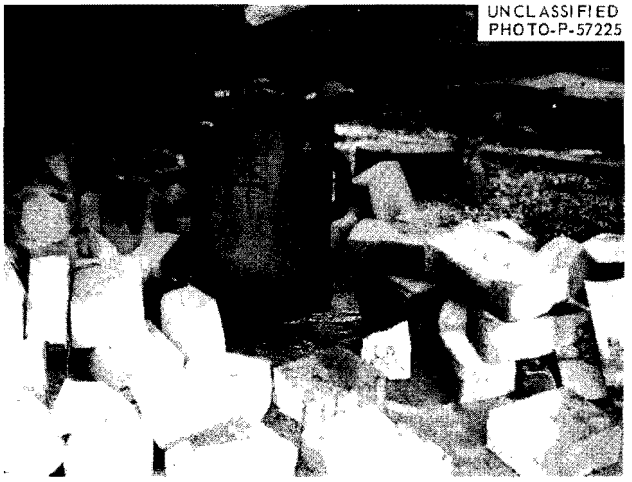

Fig. 6. Cask 4C6 – Cask Cooled.

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