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CALIFORNIUM-252 PACKAGING AND TRANSPORT

by

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DISCLAIMER

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ABSTRACT

Californium-252 is packaged at the Savannah River Laboratory for use in medicine, industry, and research. Encapsulation techniques were developed within the framework of "Special Form" packaging regulations[1] so that line and point sources could be supplied for the U. S. Atomic Energy Commission's market evaluation program and for "bulk" sales to commercial encapsulators of radioisotopes. "Special Form" capsule testing techniques and quality assurance procedures for source and package fabrication are described.

Various designs of medical and industrial sources and sales packages are shown and discussed.

Several casks for domestic and international shipments were designed and built at the Savannah River Laboratory during the past six years. Among these are:

- Curium Oxide Cask (US DOT SP-5738), previously described in the *Proceedings of the Second International Symposium on Packaging and Transportation of Radioactive Materials* was modified and licensed for ^{252}Cf shipments.
- 4.5-Ton Californium Shipping Cask (US DOT SP 6642), a steel spherical cask using water-extended polyester (WEP) as shielding.
- ^{252}Cf Transfer Cask, an octagonal US DOT 7A, Type A cask with *Benelex*† shielding.
- WEP-filled, 5-gallon pail, a US DOT 7A, Type A package designed primarily for medical source shipments.

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† Trademark of the Masonite Corporation, Chicago, Illinois.

INTRODUCTION

Californium-252 has been encapsulated at the Savannah River Laboratory (SRL) since 1968 and shipped around the world in a variety of packages for use in medicine, industry, and research. Approximately 1200 encapsulations containing in excess of 400 mg of this neutron-emitting isotope have been made for sale or for loan under the USAEC ^{252}Cf market evaluation program. All of these encapsulations satisfied criteria for Special Form Radioactive Material.[1] All shipments were made in Type A or Type B shipping casks to conform to applicable Federal regulations.[1,2]

This paper describes "Special Form" packaging, testing techniques, quality assurance procedures, and shipping casks used with ^{252}Cf encapsulation.

STANDARD SOURCE FORMS

Californium-252 is shipped from SRL in Special Form capsules or packages.[3] Currently, nine standard source forms are fabricated at SRL. Table 1 and Figures 1 through 9 provide a description of these forms and their uses.

CAPSULE INTEGRITY AND QUALITY ASSURANCE TESTS

The integrity of source construction and seal welds was successfully demonstrated by subjecting dummy and active sources, where possible, to tests simulating expected adverse service conditions as specified in the AEC Manual, Chapter 0529-05, Safety Standards for the Packaging of Radioactive and Fissile Materials, Annex 4, Tests for Special Form Materials. Each of the Source forms described in Table 1 and Figures 1 through 9 was subjected to the following tests described in Annex 4 for Special Form materials:

1. Free Drop - A free drop through a distance of 30 feet onto a flat, essentially unyielding, horizontal surface; striking the surface in such a position as to suffer maximum damage.
2. Percussion - Impact of the flat circular end of a 1-in.-dia. steel rod weighing 3 pounds, dropped through a distance of 40 inches. The capsules were placed on a sheet of lead, of hardness number 3.5 to 4.5 on the Vickers scale, and 1-in.-thick, supported by a smooth, unyielding surface.
3. Heating - Heating in air to a temperature of 1475°F (800°C) and remaining at that temperature for a period of 10 minutes.
4. Immersion - Immersion for 24 hours in water at room temperature. The water was at pH 6, with a conductivity of 10 micromhos per centimeter.

Quality assurance tests are performed for each encapsulation. Capsule components are inspected for dimensional accuracy and machining flaws. All metal components for fabricating sources are thoroughly degreased and cleaned prior to use to remove cutting oil, grease, fingerprints, and dirt. The presence of these materials could cause pressure buildup during capsule sealing, or could form undesirable products due to long-term radiation exposure.

Capsules are seal-welded with argon (or helium) shielded tungsten electrode DC arcs (TIG, tungsten-insert gas, seal-welds). Capsules are positioned or rotated under the automatically controlled arc to produce the minimum weld penetration required for that capsule configuration.[4]

Examples are shown in Figures 10 and 11.

Welded units are helium leak-tested and then decontaminated to an above background level of <9 dis/min alpha and 10 c/min beta-gamma transferable radioactive contamination as determined by a wipe test. Sealed capsules are pressurized in 300 psi helium for 30 minutes. Leak tests are performed on individual capsules in a helium leak detector whose lower detection limit is 1.0 x 10^{-8} standard cubic centimeters of helium per second. All capsules must show no detectable leak.

Leaks in encapsulated ALC-P4C seeds are detected by counting an acidic penetrant solution in an ultrasonic bath in which the seed had been immersed for 30 minutes. After each test, the bath must show less than 9 dis/min alpha, or the seed does not pass the test. An alpha count of 9 dis/min is equivalent to 4 x 10^{-6} uCi of surface contamination.

SPECIAL INTEGRITY TESTS

Integrity of SR-Cf-100 series source construction and seal welds was successfully demonstrated by subjecting dummy secondary capsules to internal and external pressure tests far in excess of pressures expected under the most adverse service conditions. Infinite decay pressure created in the primary capsule from alpha decay and fission gas buildup was calculated to be 0.789 atmosphere (11.6 psia)/mg ^{252}Cf at standard temperature, or 3.06 atmospheres (46 psia)/mg ^{252}Cf at 800°C. Special tests conducted with these capsules are described below:

1. Burst Tests of Circumferential Welds - Hydrostatic burst tests on the circumferential closure weld in the secondary capsule revealed that the average burst strength of the circumferential weld is 52,000 psi for stainless steel, and 41,000 psi for Zircaloy-2 at 25°C. At 800°C, the calculated burst strength for stainless steel is 2800 psi and greater than 10,000 psi for Zircaloy-2 (internal pressure).

2. Crush Test - An external load test was devised to simulate crushing of the capsule by a heavy object such as a shipping cask. A large shipping cask for several mg of ^{252}Cf may weigh as much as 20 tons. Assuming half the weight of the cask might come to rest on the capsule, prototype sources were placed between stainless steel anvils loaded with a total of ten tons. The load was removed and the sources were pressurized with helium at 300 psi for 30 minutes, then tested for leaks with a helium leak detector. No leaks were detected with a helium leak detector whose lower detection limit was 1×10^{-8} standard cubic centimeters of helium per second.
3. Hydrostatic Compression Test - A hydrostatic compression test was devised to simulate the hydrostatic pressure at 10 miles depth in a bore hole because some of these sources were to be used in well logging and mineral exploration. Pressure at this depth is approximately 25,000 psi. Helium at this pressure was used to pressurize test capsules without measureable deformation. Standard helium leak tests revealed no leaks after the hydrostatic compression tests.

Additional tests not specified in the AEC Manual were conducted to demonstrate the integrity of the ^{252}Cf seed assemblies (ALC-P4C) under conditions that might conceivably be expected during service. These tests are described below:

1. Sterilization - Individual seeds and seed assemblies were sterilized by heating for 20 minutes in a steam autoclave at 132°C.
2. Pinching - Seeds and assemblies were pinched with the maximum pressure produced by a small hemostat with serrated grips.
3. Crushing - The seed assemblies are transported in a cask composed of a 55-gallon drum filled with water-extended polyester neutron shielding. A crush test was devised to simulate the load applied by the chime of such a cask. A load of 230 kg was applied over one seed in the assembly by a steel bar 5 mm wide while the assembly rested on asphalt tile supported by an unyielding concrete surface.

4. Bending - Individual seeds were bent to a 90° angle in one direction followed by bending through 180° to a 90° bend angle in the opposite direction.

After each of these tests, the seed capsule and assembly were visually inspected and tested for leaks by immersing the assembly in an acidic penetrant solution (0.1M nitric acid) followed by checking the acid for alpha contamination. The units passed the leak tests as no alpha contamination was detected in the penetrant solution above normal background.

SHIPPING CASKS

During the last six years, four casks for domestic and international shipments were designed and built at SRL for transport of the industrial and medical ^{252}Cf sources described above. These neutron shielding devices were tested to demonstrate compliance with 49 CFR 173.3981 Special Tests, and AEC Manual, Chapter 0529, Safety Standards for the Packaging of Radioactive and Fissile Materials. In addition, quality assurance procedures were established to maintain original design standards during the useful lifetime of the cask.

Cask Descriptions

Curium Oxide Cask[5] (DOT SP 5738)

This top-loading cask is fabricated of stainless steel, has a recessed lid, is filled with a mixture of water and ethylene glycol, and weighs 13,000 pounds. The cask is 5 ft in OD (excluding 4-in.-wide fins) and 6 ft tall.

The central cavity is 4 in. in diameter and 4 in. long. An insert providing two inches of lead adjacent to the californium source(s) replaced the original spire assembly used to position curium oxide capsules within the cask body (Figure 12).

The shielding consists of 1 in. of steel, 24-1/2 in. of a water - 50% ethylene glycol mixture, and 2 in. of lead. The shielding is cast in concentric stainless steel pipes. Fusible alloy plugs in 16 vents near the top of the cask wall provide for release of pressure, but retain water in case of exposure to fire in transit.

Up to 40 mg of ^{252}Cf can be shipped in "Special Form." For domestic shipments, the cask is mounted and tied down to a specially modified flatbed trailer. For export shipments of californium, the cask is overpacked with, and secured inside of, a commercial 20-ft sealed freight container.

<u>Savannah River 4.5 Ton Californium Shipping Cask</u> (DOT 6642)

This cask is a 60-in.-diameter spherical cask with a 3/4-in.-thick outer steel shell filled with water-extended polyester. Shipping weight is 9000 pounds including lifting and tie-down lugs. The central cavity is 4 in. in diameter by 4 in. long. The shielding consists of 3/4-in.-thick steel, 25-1/2 in. of water-extended polyester with boric acid and ethylene glycol, 2-in.-thick lead, and 3/8-in.-thick steel (Figure 13). The cask is authorized for not more than 85 mg of ^{252}Cf as "Special Form" for sole-use-vehicle transport. A loading of 25 mg will produce a radiation field of about 10 mrem/hr at three feet from this cask. A lead insert with the source centered will permit a loading of about 40 mg. Authorized modes of transport are vessel, cargo-only aircraft, motor vehicle, and rail.

<u>^{252}Cf Transfer Cask</u>

This cask (Figure 14) is an octagonal DOT 7A, Type A cask, 48 in. wide by 52 in. high, and weighs 5500 pounds including lifting and tie-down lugs. The cavity is 1 in. in diameter by 7 in. high. Shielding consists of 22 in. of *Benelex* 401 and 1-1/2 in. of lead. The cask is authorized for no more than 3.7 mg of ^{252}Cf as "Special Form" (49 CFR 173.3891) and for transport by vessel, cargo-only aircraft, motor vehicle, and rail.

WEP-Filled 5 Gallon Pail

This cask is a DOT 7A Type A container designed primarily for medical source shipments of up to 5 µg per container. A DOT-17-H-80 5-gallon steel bucket is filled with water-extended polyester (WEP). The WEP contains a central cavity which is 15/16 in. in diameter by 7 in. high. A polyethylene plug housing the source fits into the central cavity (Figure 15). The polyethylene plug is restrained by a metal strap should the lid be knocked from the bucket. Authorized mode of transport is vessel, cargo-aircraft, and rail.

In addition to the SRL casks described above, SRL frequently uses to DOT SP 5461 TRU Curium casks built at SRL from Oak Ridge National Laboratory (ORNL) prints. Up to 200 µg of ^{252}Cf can be shipped as "Special Form" with a hydrogenous shield inserted in the cavity of this cask. Casks designed and built at ORNL for shipment of up to 80 mg of ^{252}Cf – the ORNL TRU 10-ton californium cask[7] (DOT 5740), and the Savannah River americium-curium slug cask[8] (DOT 6323) – are also used for shipping californium sources.

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* Trademark of the Masonite Corporation, Chicago, Illinois.

REFERENCES

1. Code of Federal Regulations, Title 49, Parts 170-190.
2. Code of Federal Regulations, Title 49, Parts 173.389-173.399.
3. A. R. Boulogne, ^{252}Cf Encapsulation and Shipping at SRL, Proceedings of ANS National Topical Meeting on Applications of Californium-252, Austin, Texas, September 11-13, 1972 (to be published).
4. A. R. Boulogne and J. P. Faraci, Californium-252 Neutron Sources for Industrial Applications. Nuclear Technology 11, 75 (May 1971).
5. Proceedings of the Second International Symposium on Packaging and Transportation of Radioactive Materials. USAEC Report CONF-681001, pp. 344-353 (1968).
6. USAEC Report WASH-1279, Directory of Packagings for Transportation of Radioactive Materials, pp 53-54 (1973).
7. Ibid., USAEC Report WASH-1279, pp 127-128 (1973).
8. Ibid., USAEC Report WASH-1279, pp 243-244 (1973).

Table 1. Standard Source Forms

Series	Description	Use
SR-Cf-XX	Figure 2. Primary capsule for "point" sources of ^{252}Cf oxide or cermet pellets.	For loan in the market evaluation program.
SR-Cf-1X	Figure 1. Primary capsule for "line" sources of ^{252}Cf cermet wire or "point" sources of cermet pellets.	For loan in the market evaluation program.
SR-Cf-100	Figure 3. Doubly encapsulated neutron source. May contain either SR-Cf-1X or SR-Cf-XX primary capsule.	For loan in the market evaluation program.
SR-Cf-1000	Figure 4. ^{252}Cf shipping capsule assembly.	For all shipments of ^{252}Cf purchased by encapsulators and users. ^{252}Cf may be in the form of oxide, cermet pellets, or cermet wire.
N-X	Figure 5. Radiotherapy needle for interstitial implantation.	For loan in the medical evaluation program.
ALC-X	Figure 6. Radiotherapy afterloading cell for interstitial implantation.	For loan in the medical evaluation program.
SALC-X	Figure 7. Short afterloading cell (same as above).	For loan in the medical evaluation program.
AT-X	Figure 8. Radiotherapy applicator tube for intra-cavitary implantation.	For loan in the medical evaluation program.
SEEDS (ALC-P4C)	Figure 9. Radiotherapy seed assemblies for interstitial implantation.	For loan in the medical evaluation program.

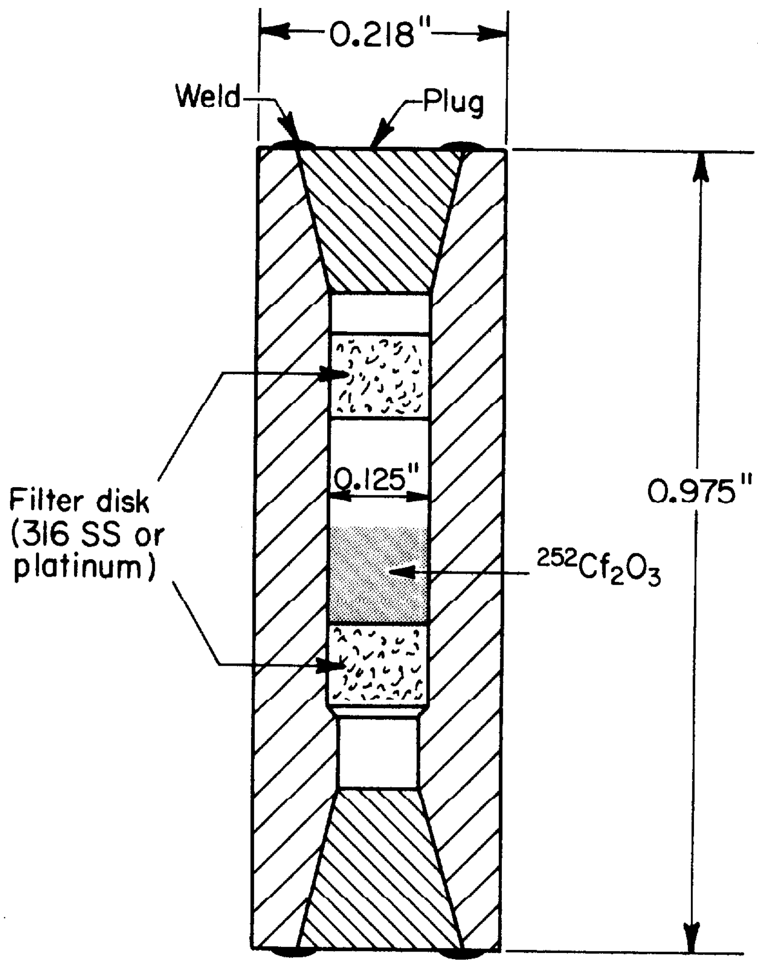


FIG. 1 SERIES SR-Cf-XX - PRIMARY CAPSULE

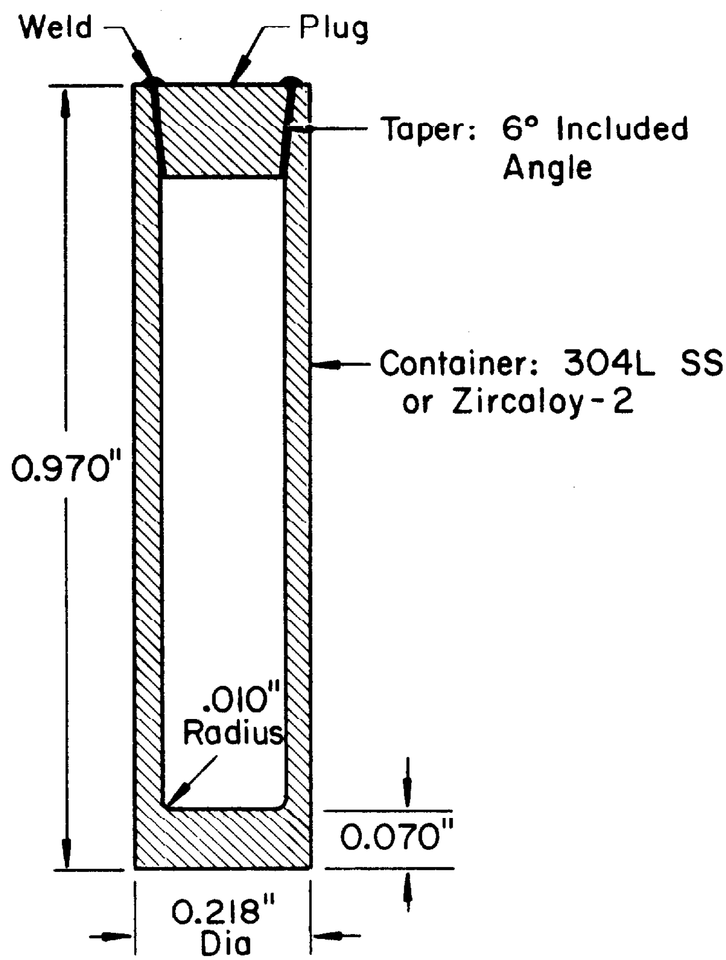


FIG. 2 SERIES SR-Cf-1X - PRIMARY CAPSULE

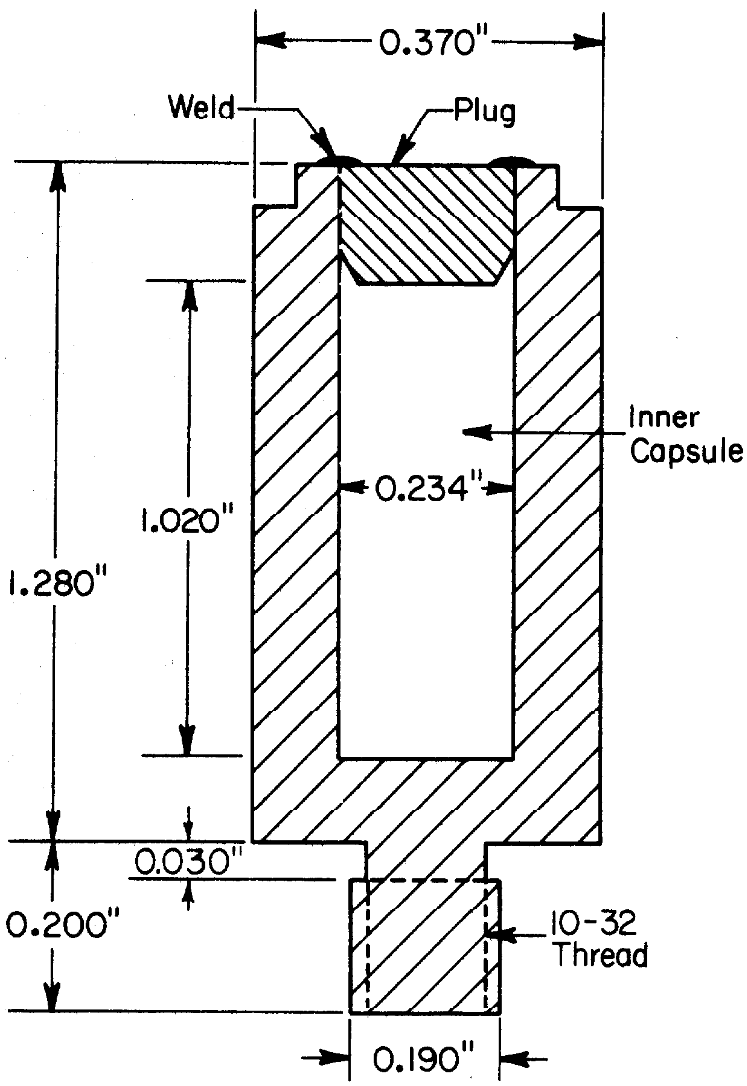


FIG. 3 SERIES SR-Cf-100 - SECONDARY CAPSULE

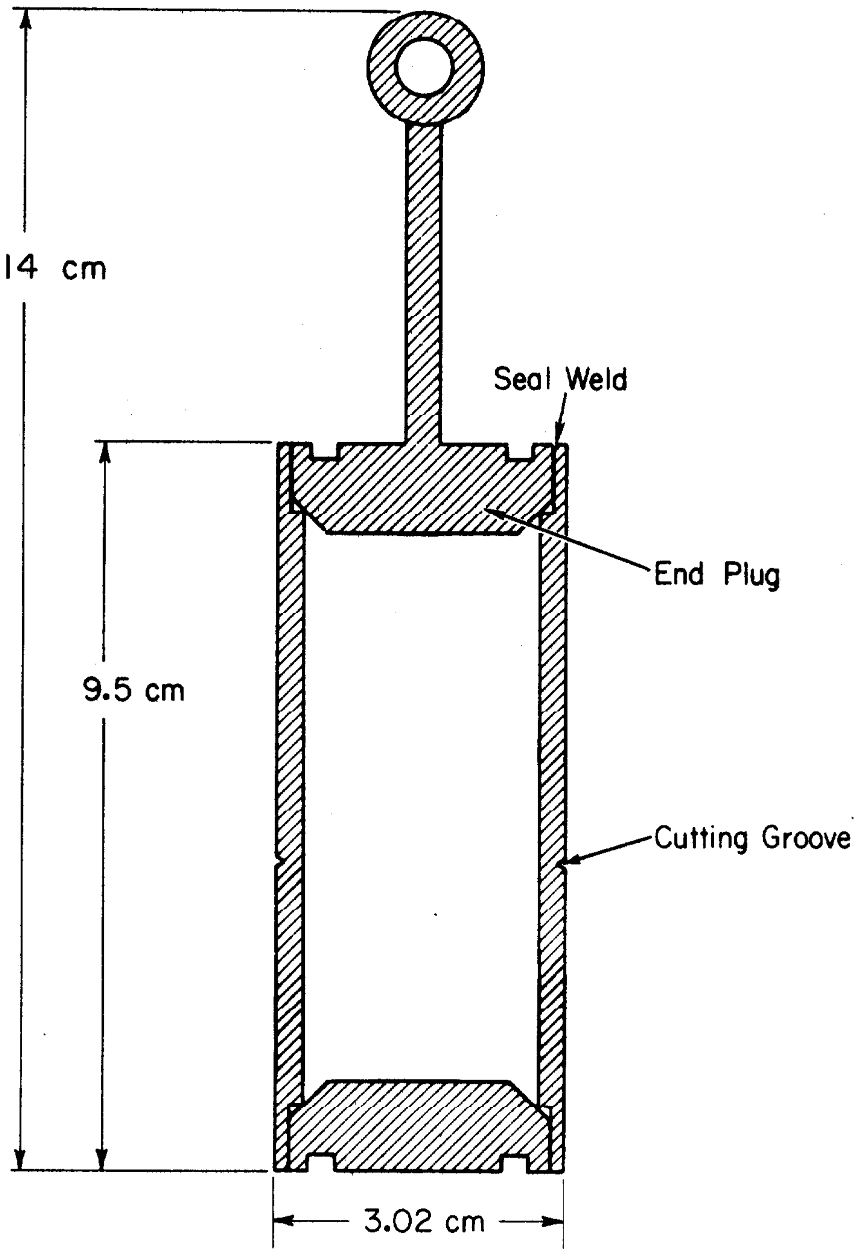


FIG. 4 SERIES SR-Cf-1000 - ^{252}Cf SHIPPING CAPSULE

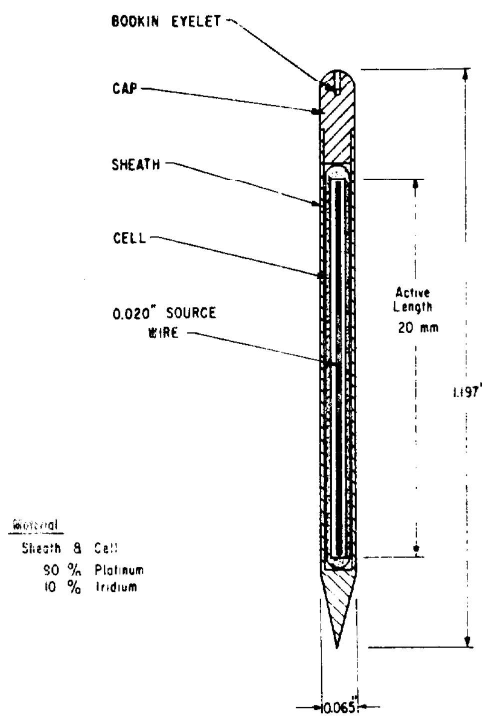


FIG. 5 ^{252}Cf NEEDLE ASSEMBLY

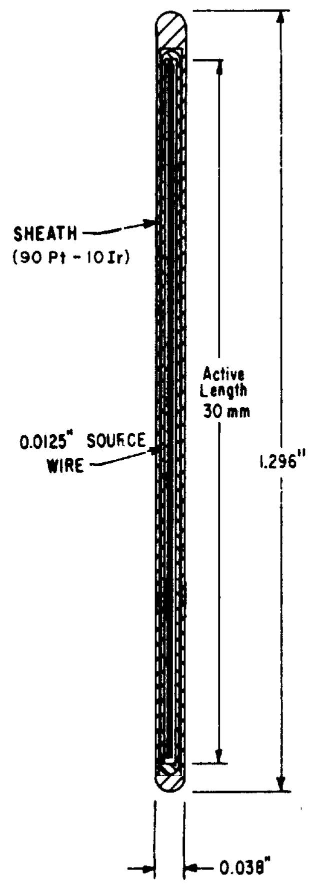


FIG. 6 ^{252}Cf AFTERLOADING CELL ASSEMBLY (ALC-X)

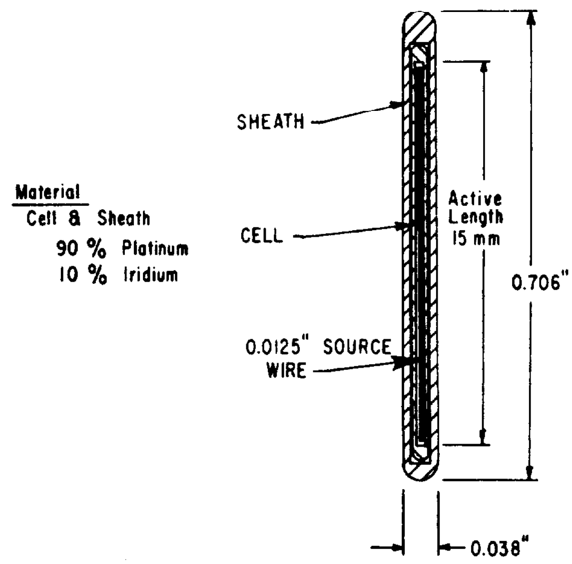


FIG. 7 ^{252}Cf SHORT AFTERLOADING CELL ASSEMBLY (SALC-X)

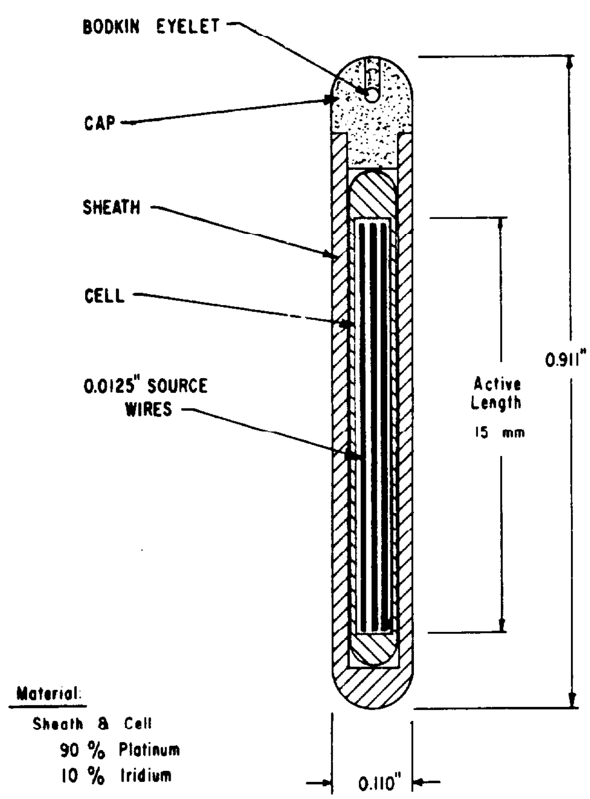
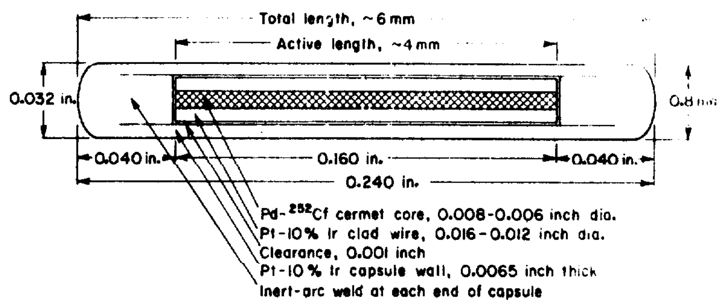


FIG. 8 ^{252}Cf APPLICATOR TUBE ASSEMBLY



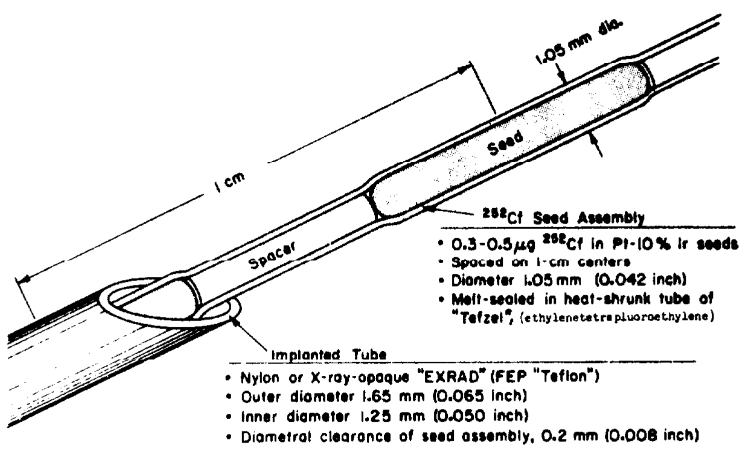
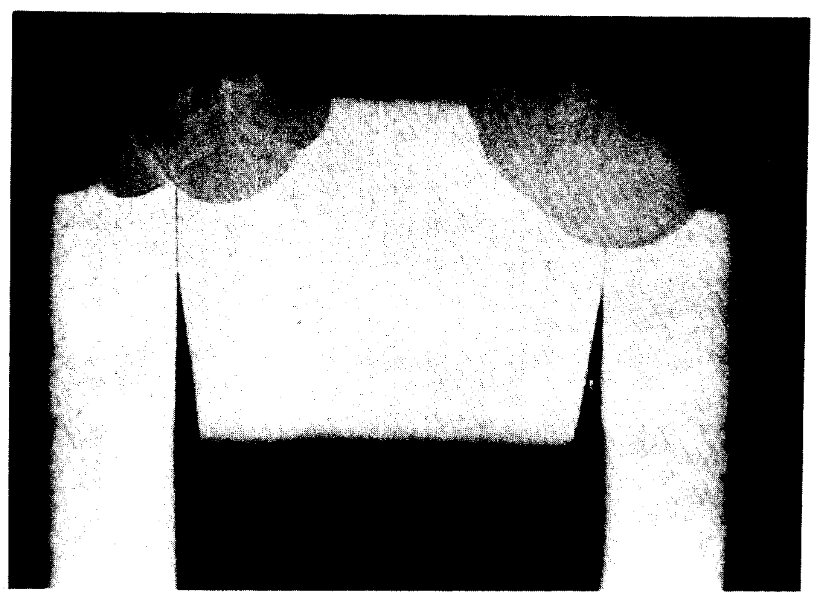


FIG. 9 ^{252}Cf SEED ASSEMBLIES

|← 1/8 inch →|

FIG. 10 MODEL SR-Cf-XX SERIES CAPSULE WELD



|← 0.370 inch →|

FIG. 11 MODEL SR-Cf-100 SERIES OUTER CAPSULE WELD
(Type 304L Stainless Steel)

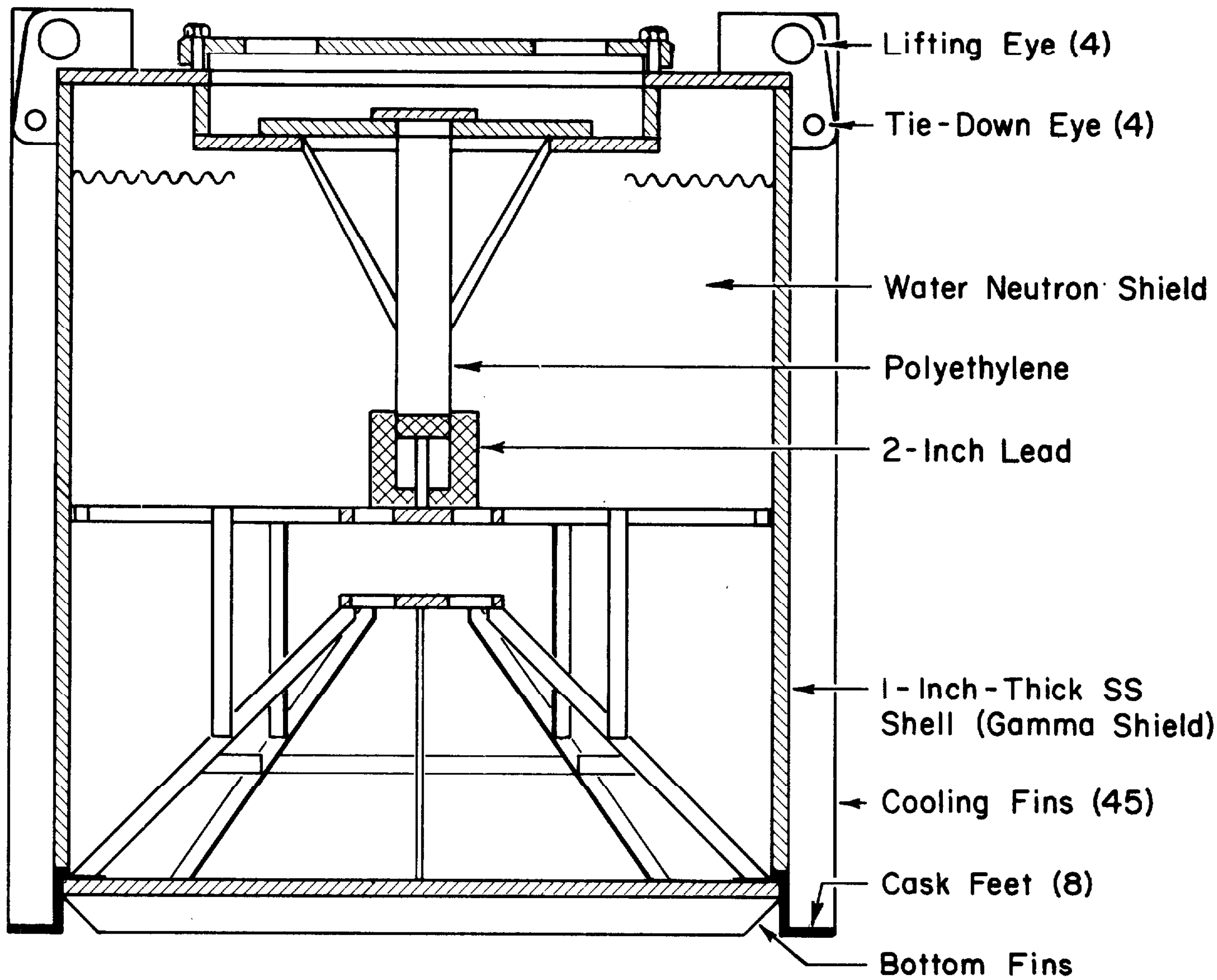


FIG. 12 CURIUM OXIDE CASK WITH ^{252}Cf INSERT

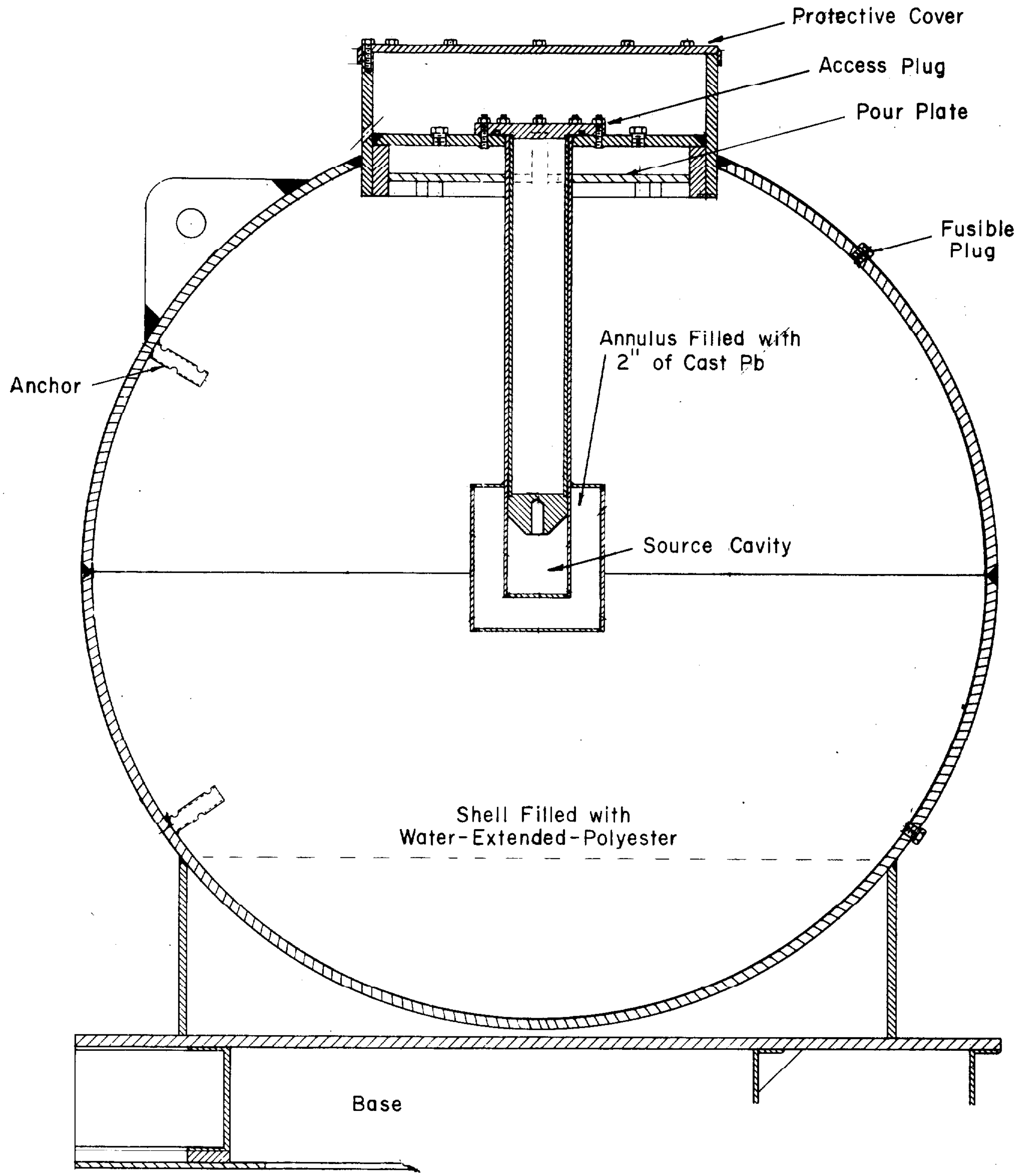
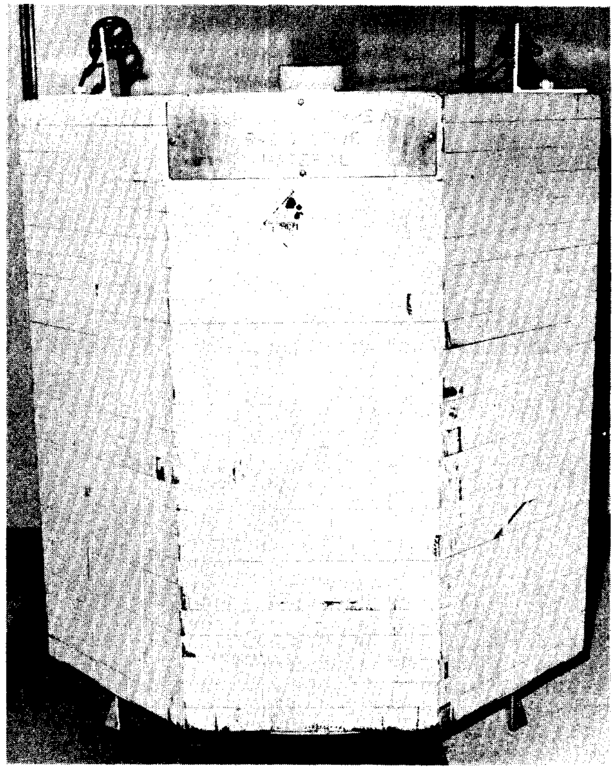


FIG. 13 4.5- TON ^{252}Cf SHIPPING CASK



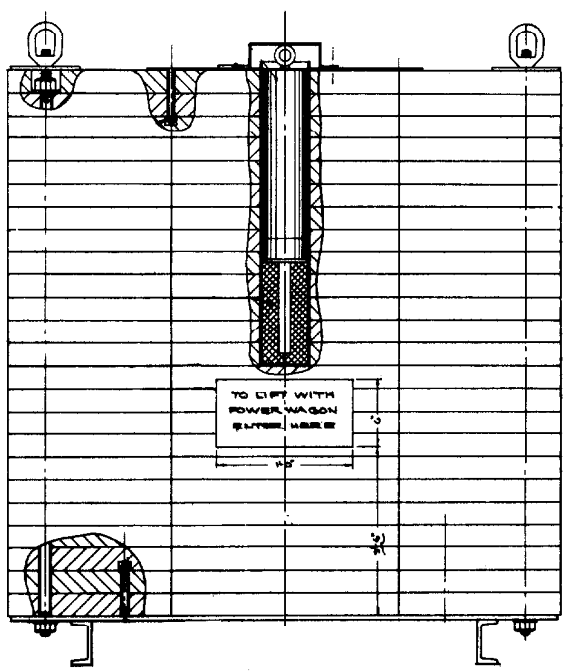


FIG. 14 OCTAGONAL ^{252}Cf TRANSFER CASK

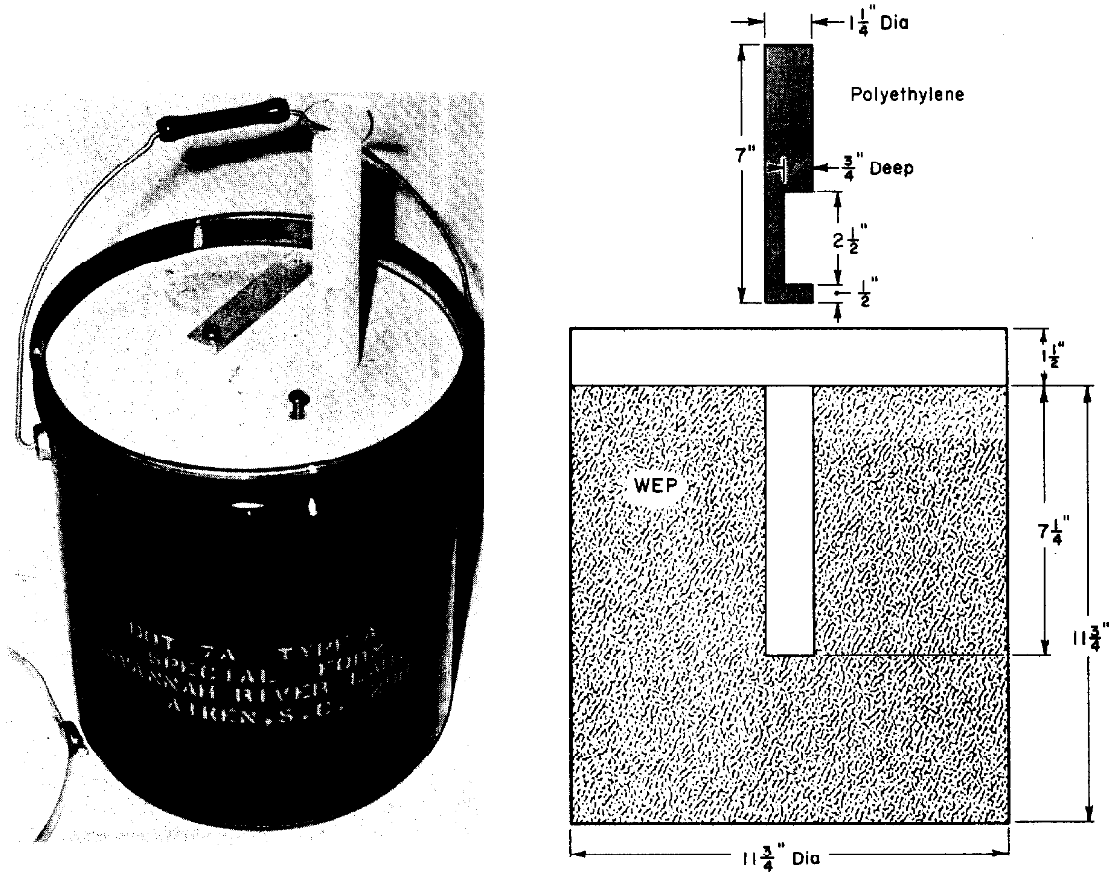


FIG. 15 CASK FOR MEDICAL SOURCE SHIPMENTS