030-04545

Control for amendment Give to John Hickey Needs device review by MCPB.

01109

MAR 19 1985

DEFENSE NUCLEAR AGENCY
ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
BETHESDA, MARYLAND 20814

DIR

SUBJECT: Amendment to NRC License #19-08330-02

Division of Fuel Cycle and Materials Safety
Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission
Washington, DC 20555

1. Request amendment to license #19-08330-02 issued to the Armed Forces Radiobiology Research Institute (AFRRI).

2. Attached is a completed copy of the Amendment Application for registration for AFRRI CALIFORNIUM-252 Irradiator.

3. The format of this amendment is based on NRC Guidelines for Applications for Registration of Devices dated March 1982, which was obtained from your office recently.

4. The attached contains all required information including shielding calculations.

5. If there questions regarding this amendment, please contact Dr. Gary Zeman at 295-1047 or Dr. Naresh Chawla at 295-1285.

Enclosures:
as stated

BOBBY R. ADCOCK
Colonel, MS, USA
Director

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AFRRI CALIFORNIUM-252 IRRADIATOR

Application for Registration

A. Summary Data

1. Date. 15 March 1985.

2. Device Type. AFRRI Californium-252 Irradiator.

3. Model. None

4. Applicant. Director
Armed Forces Radiobiology Research Institute
Naval Medical Command - National Capital Region
Bethesda Maryland 20814

Radiation Safety Officer. Naresh Chawla, Ph.D.
Chairman, Safety Department
telephone 202-295-1285

Technical contact. Gary H. Zeman, Sc.D.
Chief, Radiological Physics Division
telephone 202-295-1047

5. Companies involved. The cylindrical neutron shielding cask which forms the irradiator will be ordered from:

Reactor Experiments Inc.
963 Terminal Way
San Carlos California 94070

The sealed source of Cf-252 will be obtained on loan from:

Savannah River Operations Office
P. O. Box A
Aiken, South Carolina 29802

6. Sealed source model designation. Savannah River SR-Cf-2000.

7. Isotope and maximum activity. Californium-252, 2.6 milligrams, 1.4 Curie.

8. Leak test frequency. Semiannual.

9. Principal use. H. (General neutron source applications.)

10. Custom device. Yes. Only one AFRRI Californium-252 Irradiator will be assembled; it is for sole use by the applicant.

11. Custom user. The AFRRI Radiation Safety Officer, through the AFRRI Radionuclide and X-Ray Safety Committee (RXSC), will maintain overall responsibility for the design, construction, testing and performance evaluations of the AFRRI Californium-252 Irradiator. The Chief, Radiation Sources Division, Radiation Sciences Department, will be responsible for physical custody and all aspects of operational use of the Irradiator.

AFRRI CALIFORNIUM-252 IRRADIATOR

Application for Registration

B. Descriptive Data.

1. Summary description.

The AFRRI Californium-252 Irradiator is designed with the principal function of acting as a neutron dosimetry reference or check-source for ionization chambers and other dosimeters used in radiobiology research. This is achieved by configuring the source in a shielding cask so that dosimeters can be inserted within the cask to a position very close to the source. In this way, neutron radiation dose rates on the order of one rad per minute can be delivered to the dosimeters in the cask, with minimal radiation leakage outside the cask. This allows calibration and constancy tests of neutron dosimeters to be performed more rapidly, more reliably, and with far lower personnel radiation exposure than is possible with conventional neutron radiation fields.

A secondary function of the AFRRI Californium-252 Irradiator is to allow the direct beam of Cf-252 radiation to emanate horizontally from the shielding cask. In this mode the Irradiator would be used for exposure of personnel dosimeters, survey meters or other objects to a direct but collimated beam of Cf-252 neutrons. To use the Irradiator in this direct beam mode, a special mechanism would be required to remove and replace the source shielding plug from the cask. Such a mechanism should have the characteristics of being remotely operated, electrically interlocked, and fail-safe.

AFRRI CALIFORNIUM-252 IRRADIATOR

Application for Registration

The major components of the AFRRI Californium-252 Irradiator will be a Savannah River SR-Cf-2000 series sealed source of Cf-252 contained within a modified Reactor Experiments Inc. Catalog No. 258 neutron shielding cask. The SR-Cf-2000 series source is a doubly encapsulated cylinder 0.37" in diameter and 1.7" long; this source has been described in detail in the Savannah River sealed source registration application pending in the U.S.N.R.C. Materials Certification Branch as of 1 March 1985. The source will be held in a cylindrical source cup made of lead to attenuate primary gamma radiation. The approximately four inch diameter lead source cup will be positioned near the center of the cylindrical neutron shielding cask, which has dimensions about forty-six inches in diameter and forty-eight inches tall. The cask will have steel plate walls and will be filled with Reactor Experiment Inc.'s neutron shielding material "Poly/Cast" which contains about 10% hydrogen and 0.9% boron by weight.

Modifications to the neutron shielding cask will be made at the time of its manufacture to facilitate its use as the AFRRI Californium-252 Irradiator. First, the cask will be provided with supports so that it can be easily stored on its side rather than in the customary end-on position. Second, the cask will be provided with a special extra hole for insertion of dosimeters to be irradiated. This hole will be located just off-axis and parallel to the central hole containing the Cf-252 source. The off-axis hole will be about four inches in diameter and will extend the entire length of the cylindrical cask. The shielding material displaced from the off-axis hole will be made up by a close fitting borated polyethylene rod inserted within the hole.

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The AFRRI Californium-252 Irradiator is designed for operation in a stationary position on its side, i.e. with the axis of the cylindrical cask horizontal. Objects to be irradiated will be inserted into the cask by placing them within small indentations within the polyethylene plug in the off-axis hole. Note that it will be possible to insert and remove dosimeters from the irradiation position next to the Cf-252 source while allowing little or no leakage radiation to emanate from the irradiator. This will be accomplished by making the polyethylene plug in the off-axis hole roughly 50% longer than the shielding cask, as shown in the attached diagram. Thus the entire length of the off-axis hole will remain filled with shielding material even as the polyethylene plug is moved back and forth to insert and remove irradiated objects.

2. Labelling. Signs will be attached to the AFRRI Californium-252 Irradiator displaying the standard radiation symbol and the words "Caution - Radioactive Material" in addition to the following information: Type and amount of radioactive material, date of measurement, sealed source name, model and serial number.

3. Diagram. A diagram of the AFRRI Californium-252 Irradiator is attached.

4. Conditions of normal use. The AFRRI Californium-252 Irradiator will be used to irradiate physical, chemical or biological specimens for research and development. It will be used indoors in a shielded, radiation restricted area. Only personnel with adequate training and experience in working with ionizing radiation will be authorized access to and use of the AFRRI Californium-252 Irradiator.

AFRRI CALIFORNIUM-252 IRRADIATOR

Application for Registration

5. Supporting details. The following detailed information is submitted as enclosures to this application.

(a) Savannah River Laboratory's detailed description of the SRCF-2000 series Cf-252 source. Note that the registration application for this sealed source, submitted to the U.S.N.R.C. by the Savannah River Laboratory, was pending in the Materials Certification Branch as of 1 March 1985.

(b) Reactor Experiments Inc. product information on the catalog No. 258 shielding cask. Note that the cask to be special ordered for the AFRRI Californium-252 Irradiator will have a forty six inch diameter.

(c) A drawing of the AFRRI Californium-252 Irradiator showing the cask standing on its side and including the elongated borated polyethylene plug in the off-axis hole for dosimeter insertion.

(d) Drawings of the Standards Lab at the Armed Forces Radiobiology Research Institute showing the location in which the irradiator will be kept, the shielding materials in the walls and doors, and all adjacent areas.

(e) Shielding analysis for the walls in the Standards Lab for Cf-252 radiations.

AFRRI CALIFORNIUM-252 IRRADIATOR

Application for Registration

C. Health and Safety Data.

1. Safety analysis summary. Key safety features of the AFRRI Californium-252 Irradiator are listed below:

The shielding cask will have shielding and structural integrity sufficient for use as a shipping container for the source.

The sealed Cf-252 neutron source will remain within the neutron shielding cask at all times.

The cask containing the Cf-252 neutron source is to be stored in a radiation restricted area.

By means of the elongated borated polyethylene rod filling the off-axis hole, objects to be irradiated can be inserted and removed from a position in close proximity to the source without comprimising the integr:ty of the cask's shielding.

2. Irradiator assembly and installation. The assembly and install cion of the AFRRI Californium-252 Irradiator is planned as follows:

(a) The cask will be special ordered from Reactor Experiments Inc. complete with the modifications described above in paragraph B.1. As part of the order, the lead source cup about four inches in diameter will be constructed and threaded to accept the Cf-252 screw end.

(b) The cask will be configured with locks for the removeable shield plug and for the plug in the off-axis hole. Note that the plug in the off-axis hole will be only as long as the cask. The elongated plug described above will be installed later, at AFRRI.

(c) As part of the special order, Reactor Experiments Inc. will also complete the certification procedure for use of the cask as a shipping container for the Cf-252 source.

(d) The empty cask will be shipped to Savannah River Laboratory.

(e) The Savannah River Laboratory will screw the Cf-252 source into the lead source cup, and install the cup into the cask.

(f) The source within the cask will be shipped to AFRRI.

(g) The cask will be positioned in the Standards Lab.

(h) The borated polyethylene plug in the off-axis hole will be removed and replaced with an elongated plug for use in inserting and removing devices to be irradiated. The elongated plug(s) will have been special ordered from Reactor Experiments Inc. and pretested in the cask to give close fits to the off-axis hole.

(i) More than one interchangeable elongated plugs may be fashioned to accommodate irradiation of different types of devices. Alternately, interchangeable segments of a single elongated plug may be designed.

AFRRI CALIFORNIUM-252 IRRADIATOR

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3. Safety analysis. The AFRRI Radiation Safety Officer, through the AFRRI Radionuclide and X-Ray Safety Committee (RXSC), will maintain overall responsibility for the design, construction, testing and performance evaluations of the AFRRI Californium-252 Irradiator. The Chief, Radiation Sources Division, Radiation Sciences Department, will be responsible for physical custody and all aspects of operational use of the Irradiator. Major safety considerations are summarized below:

(a) The shielding and structural integrity of the cask will be sufficient for use of the cask as an approved shipping container for the Cf-252 source. The cask is therefore highly suitable for the long term storage of the Cf-252 source.

(b) Leakage radiation from the external surface of the cask is estimated to be approximately 80 mrem/hour, for the initial 2.3 mg source strength as of 1 August 1985. This leakage consists mostly of capture gamma radiation.

(c) Local shields of lead bricks or sheets or concrete block will be constructed around the cask to reduce the dose equivalent rate to which persons may be exposed to 10 mrem/hr.

(d) Careful radiation surveys will be conducted to determine the extent to which streaming of neutron or gamma radiation exists around the removeable shield plug or the plug in the off-axis hole. Excessive streaming would necessitate the use of portable neutron or photon shields near the front of the irradiator.

(e) From the attached shielding calculations, it is clear that routine use of the irradiator in the Standards Lab will produce only minimal radiation levels in surrounding areas.

(f) For routine use of the irradiator, the elongated borated polyethylene plug in the off-axis hole will be fitted with end cap devices which prevent removal of the plug from the cask. Also during use of the irradiator as a check source, the removeable source shielding plug which provides direct access to the source will be kept locked in place.

(g) For use in the direct beam mode, i.e. with the source shielding plug removed from the cask, the Irradiator will be equipped with a specially designed mechanism to remove and replace the shielding plug. Design of this mechanism shall include (i) remotely operated, (ii) electrically interlocked, and (iii) fail-safe.

(h) With the source shielding plug removed from the cask a direct beam of Cf-252 radiation will emerge horizontally from the cask. Initial dose equivalent rates within this beam will be on the order of 6 rem/hr at one meter from the source (30 cm from the cask opening). The attached shielding calculations show that this would cause only minimal radiation levels in unrestricted areas adjacent to the Standards Lab.

(i) If for any reason the shield should fail, and expose the ceiling and walls of the Standards Lab to direct unattenuated radiation from the Cf-252 source, the attached calculations show that a radiation area would exist in unrestricted areas adjacent to the Standards Lab. Active radiation area monitors (RAM) will be installed to provide immediate alert of such conditions.

AFRRI CALIFORNIUM-252 IRRADIATOR

Application for Registration

4. Source disposition. The Cf-252 neutron source is being obtained on loan from the Savannah River Laboratory. The source will ultimately be disposed by returning it to Savannah River Laboratory within the same shielding cask in which it will be received and stored at AFRRI. In particular, at the end of roughly eight years or whenever the source strength falls too low for use in the irradiator, the source will be returned and, hopefully, replaced. Use of an approved shipping cask as the storage shield for the irradiator makes the return and exchange of future sources a routine procedure which can be accomplished with no direct source handling by AFRRI personnel.

OSR 24-A116
(REV 10-81)
(a)

DU PONT

E. I. du Pont de Nemours & Company
INCORPORATED

ATOMIC ENERGY DIVISION
SAVANNAH RIVER LABORATORY
AIKEN, SOUTH CAROLINA 29808-0001
(TWX 810-771-26?0 TEL 803-725-6211 WU AUGUSTA GA)

February 25, 1985

Commander G. H. Zeaman
AFRRI
NMC, NCR
Bethesda, MD 20814

Dear Commander Zeaman:

In response to our recent telephone conversation I am enclosing the following:

- Description of the SRCF-2000 series source
- A dummy outer capsule (2000 series)
- Drawing of SRCF 100 series eyelet (also used on 200 series source)
- Primary and secondary capsule drawings for SRCF 100-2000-3000 series sources.

If I can be of further assistance please contact me.

Sincerely,

W. S. Curlee

W. S. Curlee
Laboratory Services Division

WSC:bcs

A. SCOPE

1. This report describes the manufacture, assembly, and testing of SR-CF-2000 series ^{252}Cf neutron sources. These sources are fabricated at the Savannah River Laboratory (SRL) and loaned by the U. S. Department of Energy (DOE) to organizations under contract agreement for approved use in industry. Data and information are provided to show compliance with appropriate regulations.[1-7]

B. REFERENCES

1. Code of Federal Regulations, 10 CFR, Part 20 - Standards for Protection Against Radiation (revised 1979)

2. Code of Federal regulations, 49 CFR, Transportation, Chapter I - Research and Special Programs Administration, Department of Transportation, ¶ 173.398 (revised 1979).

3. International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Materials, IAEA Safety Standards, Series 6 (revised 1973).

4. U. S. Atomic Energy Commission, Directorate of Regulatory Standards, Integrity and Test Specifications for Selected Brachytherapy Sources, Regulatory Guide 6.2, Section C.5, 1974.

5. Bureau of Explosives' Tariff, Hazardous Materials Regulations of the Department of Transportation, Specifications for Shipping Containers; ¶ 178.34, Specification 2R, 1980.

6. American National Standards Institute, Classification of Sealed Radioactive Sources, ANSI N542.1977.

7. AEC Manual Chapter 0529-05, Safety Standards for Packaging of Radioactive and Fissile Material.

C. DEFINITIONS

1. SR-CF-2000 - a doubly encapsulated neutron source containing up to 35 mg of ^{252}Cf.

2. Filter frit - a small cylindrical filter made from porous platinum used to filter the ^{252}Cf precipitate from the oxalate slurry.

3. Inner capsule - a cylindrical sleeve made from 90% platinum - 10% rhodium used as the primary container for ^{252}Cf material.

4. End plugs - Precision tapered fittings used to seal the ends of the inner and outer capsules.

D. GENERAL DESCRIPTION

The SR-CF-2000 is a neutron source that contains up to 35 mg ^{252}Cf sealed inside a platinum - 10% rhodium inner capsule which in turn is sealed in a stainless steel or Zircalloy-2 outer capsule. The source is approximately 1.7 inches long and 0.370 inches in diameter, and one end is threaded so that handling devices can be attached.

1. Idenfification

SR-CF-2000

2. Proposed Use

Applications include:

Petroleum exploration
Mineral exploration
Moisture measurements
Radiography
Process control

3. Description of Radioactive Material

The source material is ^{252}Cf oxide (Cf_2O_3) which has been precipated on a platinum filter frit inside the inner capsule. The maximum amount of material in the SR-CF-2000 series source is 35 milligrams and the maximum activity is 18.2 curies.

Radiation from ^{252}Cf includes α, β, γ, and neutrons. Alpha radiation is contained within the capsule. β, γ, and neutrons are emitted from the encapsulated source. Beta radiation is very small at distances greater than a few centimeters; the gamma emission rate is 1.3×10^7 photons/sec-microgram and the neutron emission rate is 2.3×10^6 neutrons/sec-microgram. A typical isotopic analysis of the source material is:

Isotope	Atom %
^{249}Cf	0.9
^{250}Cf	11.2
^{251}Cf	3.1
^{252}Cf	84.2
^{253}Cf	0.5
^{254}Cf	0.04
	99.94

4. ANSI Classification[6]

ANSI classification is not applicable for special form radioactive material.

5. Labeling and Instructions for Use of Sources

A ^{252}Cf Source Information Sheet is included with each shipment showing the source strength, closure test method, and test date (Figure 1). In addition, DOE requires that the user have an appropriate state and/or Nuclear Regulatory Commission (NRC) license for handling and use of radioactive material.

Standard industrial SR-CF-2000 series sources are identified by an engraved designation SR-CF-2001 through 2999. The shipping capsule assembly is non-returnable. Detailed unloading instructions accompany each shipment.

E. ADDITIONAL INFORMATION

1. Pressure Rating

The capsules and various fittings are designed to withstand pressures up to 14,500 psi at 25°C and 6,400 psi at 800°C. This

design rating exceeds the full range of internal pressures that could develop during or after the sources are assembled. The two principal sources of internal pressure are discussed below:

a. Expansion of Heated Moisture Trapped Inside Either Capsule

The most likely source of heat to generate this condition is the welding operation wherein the end fittings or plugs are welded to seal the inner or outer capsule. The manufacturing process prior to welding includes temperatures high enough (700°C) to drive off all carbon dioxide and moisture.

No problems have been experienced with weld blowouts which are an indication of trapped moisture expanding from the heat of welding. Also the sealed source is heated to 800°C for 15 minutes prior to conducting the helium leak test.

b. Pressure from Radioactive Decay Products

Radiation decay products of ^{252}Cf will produce helium gas within the capsule. A worst-case calculation for the largest amount of ^{252}Cf (50 mg) at infinite decay indicates the maximum internal pressure would be 382 psi at a capsule temperature of 0°C, and 1545 psi at 800°C. Calculated heat transfer and strength characteristics for the SR-CF-2000 source are summarized in Tables 1 and 2.

2. Corrosion Rating

Because of the excellent corrosion resistance of the 90% Pt - 10% Rh alloy, surface deterioration is insignificant. Long term (1 year) high temperature compatibility tests (800°C) revealed no chemical reaction between the Cf_2O_3 core material and the platinum inner capsule. The welds that seal the inner and outer capsules are of extremely high quality and do not corrode or deteriorate under normal conditions.

3. Source Life

The practical service life of the neutron source is determined by the rquired activity. The source strength diminishes according to the 2.6 year half life of ^{252}Cf. For example, the remaining activity after 5.2 years (2 half lives) would be 25% of the initial activity.

4. Current Use of SR-CF-2000 Sources

These sources are now being supplied to universities and industry under contract with DOE for various research projects. They are currently certified by the Department of Transportation (DOT) for not more than 18.2 curies, and an International Atomic Energy Agency (IAEA) Certificate of Competent Authority has been requested.

F. MANUFACTURING PROCESS

1. General Description of Process

A filter made of platinum is inserted in the inner capsule and rests on a shoulder as shown in Figure 2. Californium is precipitated from a solution by addition of oxalic acid. The slurry containing californium oxalate is pumped through the inner capsule and the precipitate is deposited on the filter. The subassembly is then calcined in a furnace to convert the californium oxalate to Cf_2O_3. Next, tapered end plugs are inserted and sealed by welding. The sealed assembly is shown in Figure 3.

The inner capsule is then inserted in the outer capsule which is a cylindrical member closed at one end, and open at the other, as shown in Figure 4. A tapered plug is inserted in the open end and sealed by welding. This completes the outer capsule assembly.

2. Construction

The three main parts of the source are the core, the inner capsule, and the outer capsule. A brief description of each part follows:

a. $^{252}Cf_2O_3$ for the Core is Prepared as Follows:

Californium in solution is reacted with oxalic acid to precipitate the oxalate salt. (A terbium carrier is added when necessary.)

b. Inner Capsule

The inner capsule is made from 90% Pt - 10% Rh. The ends are sealed with a tungsten arc weld. See Figure 2 for dimensions.

c. Outer Capsule

The outer capsule is made from Zircaloy-2 or 304 stainless steel. The end is sealed with a tungsten-arc weld. See Figure 4 for dimensions.

3. **Assembly**

The SR-CF-2000 series source is fabricated and assembled under carefully controlled conditions by highly trained technicians who do the following:

a. Inspect components for defects, using a 20X stereoscopic microscope.

b. Gauge components for conformance with specifications.

c. Clean and degrease to remove foreign materials.

d. Precipitate the desired amount of ^{252}Cf onto the frit.

e. Seal the inner capsule with a tungsten-arc weld.

f. Decontaminate in 4M HNO_3.

g. Perform a helium leak test.

   (1) Externally pressurize the sealed inner capsule with helium at 300 psi.

   (2) Measure helium in the system (the equipment is calibrated to detect a helium loss of less than 2.8×10^{-8} cm^3 helium per second).

h. Verify that the surface is free of contamination by smear tests. The alpha count must be less than 50 d/m, which corresponds to 0.02 nanocurries or less of removable contamination.

i. Place the inner capsule in the outer capsule and insert the end plug.

j. Seal with a tungsten-arc weld.

k. Assay for ^{252}Cf content.

l. Perform a helium leak test on the outer capsule.

   (1) Externally pressurize with helium at 300 psi.

   (2) Measure helium in the system (the equipment is calibrated to detect a helium loss of less than 2.8×10^{-8} cm^3 helium per second).

m. Verify that the surface is free of contamination by smear and leach tests. The alpha count must be less than 10 d/m, which corresponds to 0.0135 nanocuries or less of removable contamination.

G. QUALITY CONTROL OF THE SOURCE FABRICATION PROCESS

Each source is given all of the following checks during construction:

1. Components and tubing used to make the inner and outer capsules are inspected with a stereoscopic microscope. Materials containing seams or folds are rejected.

2. Components and tubing are gauged for conformance with mechanical specifications.

3. Inner and outer capsule end welds are inspected with a 20X stereoscopic microscope. Misshapen or irregular welds are rejected.

4. The inner capsule closure weld is inspected with a periscope. Misshapen or irregular welds are rejected.

5. The diameter and length of the inner and outer capsules are measured.

6. A helium leak test is performed on the inner capsule. Sources with helium leaks greater than 2.8×10^{-8} cm^3/second are rejected.

7. The outer capsule closure weld is inspected with a periscope.

8. The ^{252}Cf content is measured with a precision neutron counter.

9. A helium leak test is performed on the outer capsule. Sources with He leaks greater than 2.8×10^{-8} cm/^{3}second are rejected.

10. Acceptable surface decontamination is verified by smear test. The limit is <0.0135 nanocuries of removable surface contamination which is well below the limit of 0.5 nanocuries of removable contamination specified by Regulatory Guide 6.2.[4]

11. Quality control for the californium is performed by measurement of the neutron emission rate of an aliquot of the starting material and by analyzing for isotopic content and chemical purity. The neutron emission rate is assayed by measuring the ion current from ^{235}U fission counters surrounding the source in a polyethylene moderator. Isotopic content is measured by mass spectrometry, and chemical purity is determined by spark source mass spectrometry.

H. TESTING AND EVALUATION METHODS

1. Inner Capsule

The basic test to determine the integrity of the inner capsule is the Helium Leak Test. The sealed capsule is 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 2.8×10^{-8} standard cubic centimeters of helium per second. All capsules must show no detectable leak. Following the leak test, the capsule is decontaminated to a level of less than 50 d/m α-γ transferable radioactivity as determined by a wipe test.

2. Outer Capsule

The integrity of the outer capsule is tested with a helium detector.

I. PROTOTYPE EVALUATION

The first sources fabricated in the SR-CF-2000 series were subjected to a variety of tests to prove their integrity. The purpose was to demonstrate the adequacy of both the source design and method of manufacture. All of these tests equaled or exceeded the IAEA requirements.[3] After each test, the source was visually inspected for damage, and the integrity of the seal was determined using a helium leak test capable of detecting a loss of helium of less than 2.8×10^{-8} cm^3 per second.

1. Free Drop

The source was dropped through a distance of 30 feet onto a flat, essentially unyielding horizontal surface, so as to suffer maximum damage. No structural damage or loss of containment resulted.

2. Percussion

The capsule was placed on a one-inch thick sheet of lead, hardness number 3.5 to 4.5 on the Vickers scale, supported by a smooth, essentially unyielding surface. A one-inch diameter steel rod weighing three pounds was dropped from a height of 40 inches so that the flat end impacted the test capsule. No loss of containment resulted.

3. Heating

The source was heated in air to a temperature of 802°C and was held at that temperature for a period of 10 minutes. No damage or loss of containment resulted.

4. Immersion

The source was immersed in water at room temperature for 24 hours. The water pH was 6-8, with a maximum conductivity of 10 micromhos/cm. No damage or loss of containment resulted.

J. MECHANICAL TESTS

The integrity of the source construction and seal weld was demonstrated by successfully subjecting the secondary capsule to internal and external pressures far in excess of pressures expected under the most adverse service conditions. Infinite decay pressure created in the inner capsule from alpha decay and fission gas buildup is calculated to be 0.789 atmospheres (11.6 psia) per milligram of ^{252}Cf at standard temperature, or 3.06 atmospheres (46 psia) per milligram at 800°C.

1. Burst Tests of Circumferential Weld

Hydrostatic burst tests on the outer capsule revealed that at 25°C the circumferential weld failed at a pressure of 52,000 psi for stainless steel, and 41,000 psi for Zircaloy-2. At 800°C stainless steel outer capsules failed at 2800 psi, and Zircaloy-2 failed at 10,000 psi.

2. External Loading Tests

The two worst conditions to which the source is likely to be subjected are: a) crushing by a heavy object such as the shipping cask; and b) collapse under hydrostatic pressure, such as the capsule would experience in a deep-well or deep-sea environment.

a. Crush Test

A large shipping cask for several milligrams 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 10 tons, removed and pressurized with helium at 300 psi for 30 minutes, then tested for leaks with a helium leak detector. At a lower detection limit of 2.8×10^{-8} standard cubic centimeters of helium per second, no leaks were detected.

b. Hydrostatic Compression Test

The hydrostatic pressure at 10 miles depth in a bore hole is about 25,000 psi. Test capsules were subjected to 25,000 psi helium pressure without measurable deformation, and then tested for leaks with a helium leak detector whose lower detection limit is 2.8×10^{-8} standard cubic centimeters of helium per second. No leaks were detected.

TABLE 1

Calculated Heat Transfer and Strength Characteristics of 2000 Series Capsules

Inner Capsule Material	90% Pt - 10% Rh
Source strength, mg ^{252}Cf	35
Heat generation, watts	1.4
Adiabatic temperature rise of inner capsule, °C/min	54
ΔT between capsule and air, °C	82
Gas pressure in inner capsule after infinite alpha decay	
at 0°C gas temperature, psi	382
at 25°C gas temperature, psi	418
at 800°C gas temperature, psi	1,545
Rupture pressure in inner capsule	
at 25°C capsule temperature, psi	14,500
at 800°C capsule temperature, psi	6,400

Outer Capsule Material	Zircaloy-2	304L SST
Gas pressure in outer capsule if inner capsule leaks after infinite decay		
at 0°C gas temperature, psi	180	180
at 25°C gas temperature, psi	197	197
at 800°C gas temperature, psi	749	749
Rupture pressure in outer capsule		
at 25°C capsule temperature, psi	17,900	23,800
at 800°C capsule temperature, psi	5,900	2,300

TABLE 2

Properties of Capsule Materials

Alloy	Tensile Strength, psi at Temp. 25°C	Tensile Strength, psi at Temp. 800°C	Density, g/cc	Heat Capacity, cal/g-°C
90% Pt - 10% Rh	45,000	20,000	19.97	0.034
90% Pt - 10% Ir	55,000	35,000	21.53	0.031
Zircaloy-2	60,000	20,000	6.55	0.077
304L SST	80,000	8,000	8.02	0.12

FIGURE 1. Information Sheet
"Special Form" - ^{252}Cf Source

Source Identification Number ______________________ Date: ______________

Shipped To: ____

____

Specification: Secondary Capsule Drawing ______________________

Primary Capsule Drawing ______________________

DECONTAMINATION AND CLOSURE TESTS

Method

Capsule surfaces are decontaminated after closure in an ultrasonic bath until the flush solution contains less than 200 d/m per milliliter total alpha activity. The capsule is further decontaminated, if necessary, until all exterior surfaces are free of contamination (<9 d/m alpha and 10 c/m beta-gamma) as determined by a wipe test. Each assembly is immersed in a helium atmosphere with a pressure of at least 300 pounds per square inch for a period of 30 minutes, then transferred to a helium leak detector. The leak detector has a minimum sensitivity of 1.0×10^{-8} standard cubic centimeters of helium per second.

Tests

The finished capsule was found free of detectable leaks and contamination on ______________________.

CALIFORNIUM CONTENT

Assay

The neutron emission rate of the finished assembly is determined by comparing its strength to that of a ^{252}Cf source calibrated at the National Bureau of Standards. The comparison is made by inserting the capsule assembly in an array of fission tube counters and measuring the subsequent induced electric current by a sensitive ammeter. The ^{252}Cf content given below is the effective or net californium content calculated from the neutron emission rate and is given in equivalent weight units assuming 2.311×10^6 neutrons per second per microgram of ^{252}Cf. Corrections are made when necessary for the ^{254}Cf contribution to the total neutron emission rate. The ^{252}Cf present is assumed to decay with an effective half-life of 2.646 years; the ^{254}Cf, if present, is assumed to decay with a 60.5 day half-life.

Contents

The total neutron emission rate of this source was found to be ______________ neutrons per second with a standard error of <u>+3.0%</u> on ______________________. The ^{254}Cf contribution to the total was calculated to be ______________ per second on the same date. The effective ^{252}Cf content was calculated to be ______ µg equivalent with a standard error of <u>+3.0%</u>.

The radiation intensity at three meters from a source in air at standard atmospheric conditions and without contributions from scattering media is no greater than 400 <u>mrem/hr</u> neutrons plus <u>30 mR/hr γ</u> for each milligram of ^{252}Cf in the capsule.

The fabrication and encapsulation costs excluding the value of the ^{252}Cf are ______________________.

____

D. Baker, Jr., Superintendent
Laboratory Services Division
Savannah River Laboratory
E. I. du Pont de Nemours and Co.

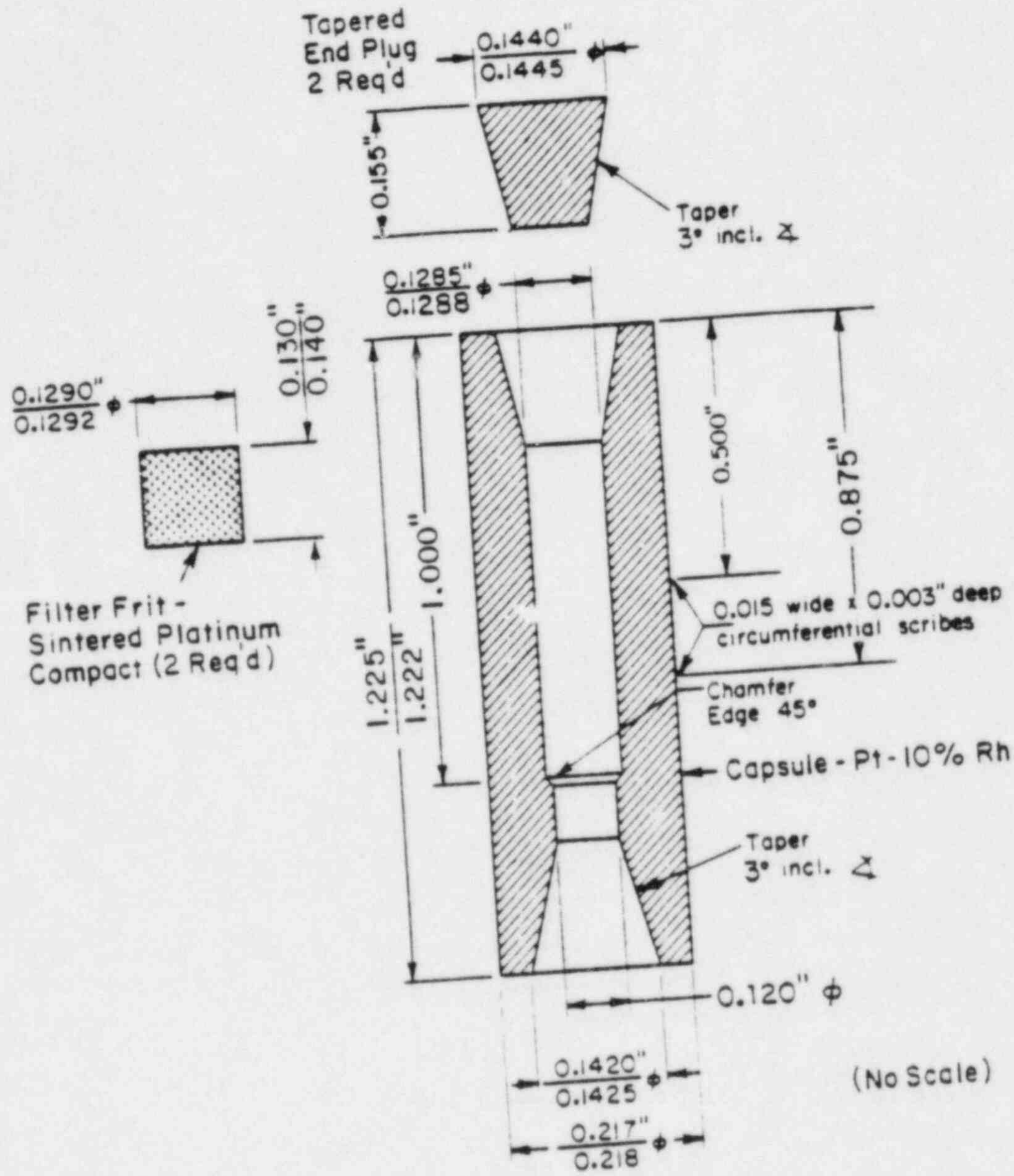


FIGURE 2. SR-CF 2000 Series - Inner Capsule Components

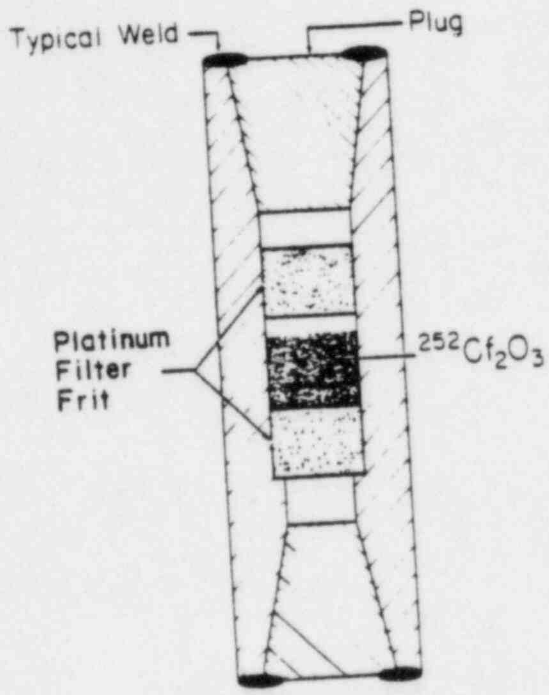


FIGURE 3. Completed Inner Capsule Assembly

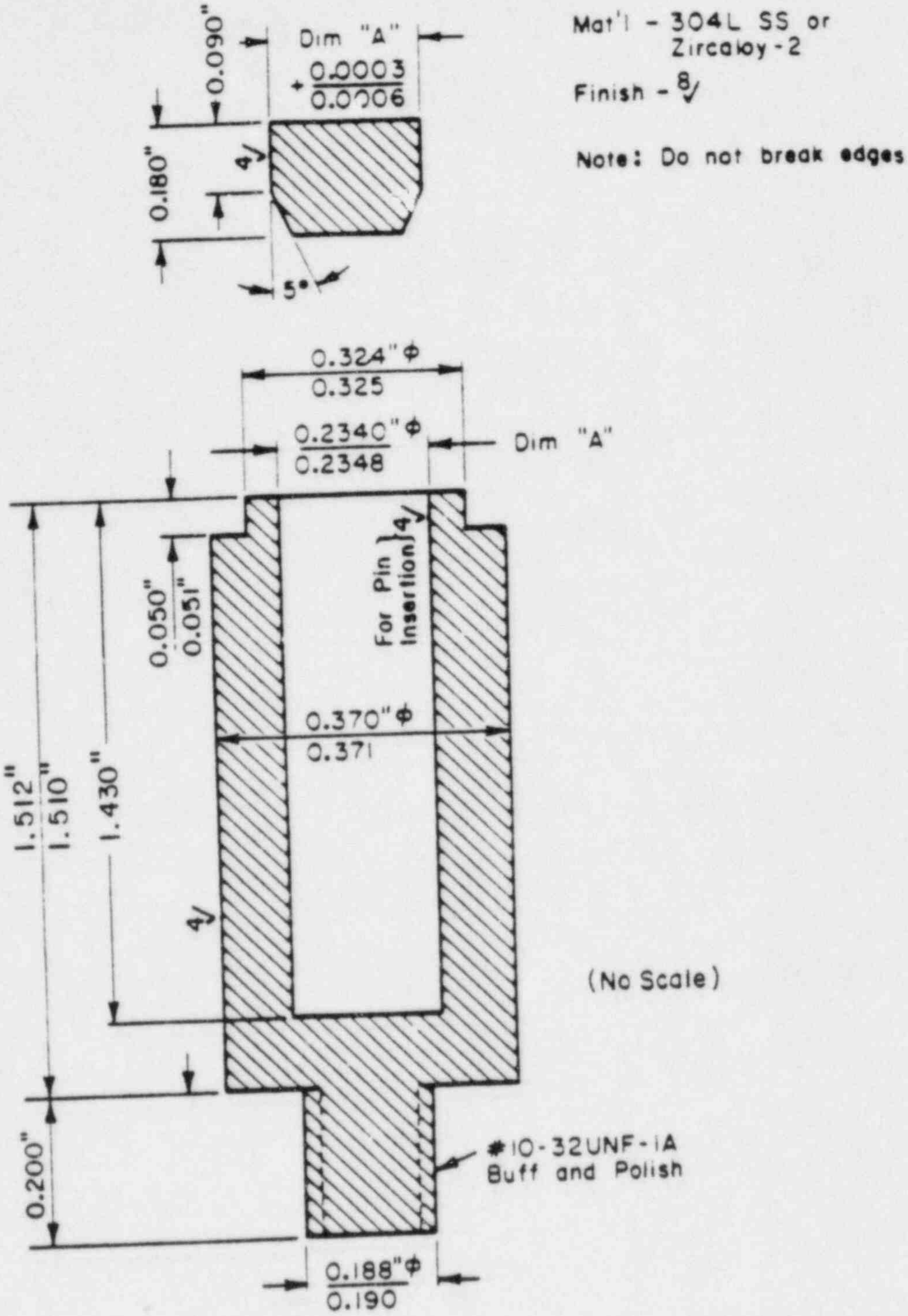


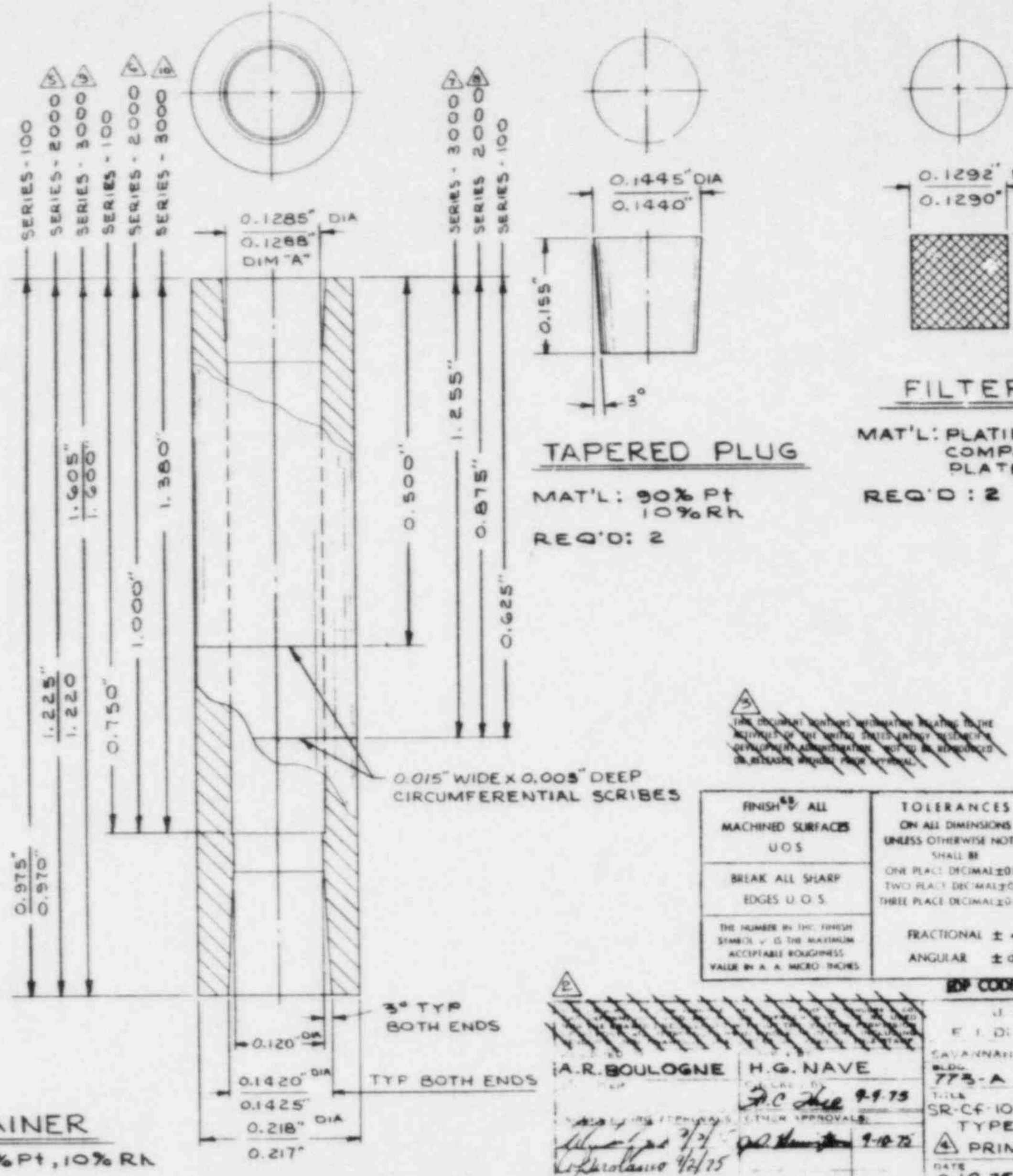
FIGURE 4. SR-CF 2000 Series - Outer Capsule

Analyze this print for
SAFETY CONSIDERATIONS

NOTES:

1. Diameter and length dimensions of filters are to be verified by the vendor after filters are sintered at 1000°C for one hour. Maximum dimensions of filter OD and container dimensions "A" may be exceeded (up to 0.008" to compensate for filter shrinkage) provided interference fit tolerances are maintained.

2. Bottom filter is to be seated by the vendor on the shoulder in each container and tested under 12 inches of water vacuum for required flow rate which is passage of 25 ml of distilled water in 2 to 3 minutes. The top filter is to be tested by the vendor in a close-fitting rubber hose or comparable tube for the same range of flow rates as the bottom filter. The top filter will be installed by the customer after the container is loaded.



CONTAINER
MAT'L: 90% Pt, 10% Rh
REQ'D: 1

TAPERED PLUG
MAT'L: 90% Pt
10% Rh
REQ'D: 2

FILTER
MAT'L: PLATINUM POROUS
COMPACT OR POROUS
PLATE 10-20 MICRON
REQ'D: 2

ST3-18570

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FINISH 63 ALL MACHINED SURFACES U O S	TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
BREAK ALL SHARP EDGES U. O. S.	ONE PLACE DECIMAL ±0.05 TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005
THE NUMBER IN THE FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A. A. MICRO-INCHES	FRACTIONAL ± ~ ANGULAR ± 0°30'

EDP CODE 20-61-13-00-00

U. S. ATOMIC ENERGY COMMISSION
E. I. DU PONT DE NEMOURS & CO., INC
SAVANNAH RIVER PLANT

A.R. BOULOGNE	H.G. NAVE
	CHECKED BY F.C. Hue 9-9-75
APPROVALS 9/2/75	OTHER APPROVALS 9-10-75

BLDG. 773-A | PROBLEM NO. | [redacted] ES-0575028 | PROJECT NO.

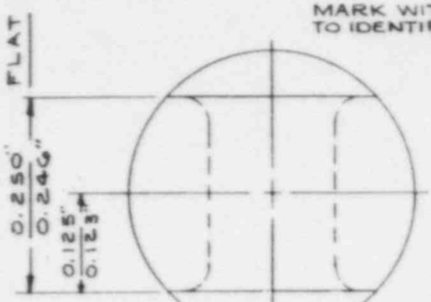
TITLE SR-Cf-100, -2000, -3000 SERIES TYPE "A-1", "A-2" AND "A-3" ⚠4 PRIMARY CAPSULES

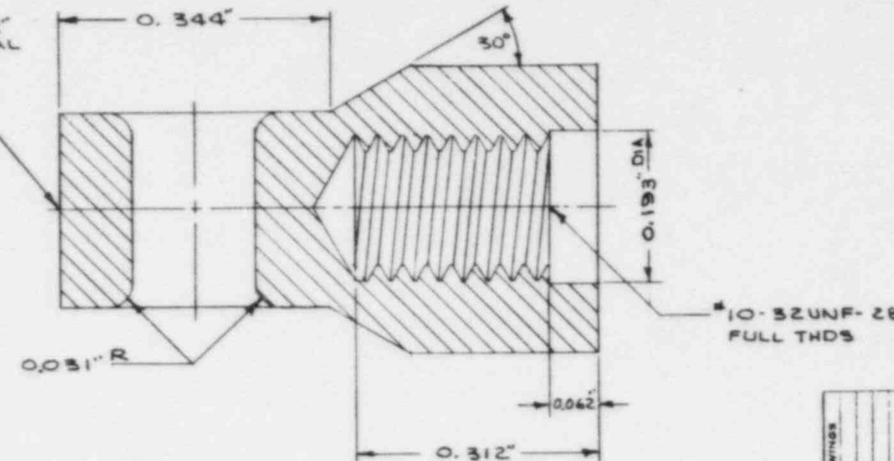
DATE 9-10-75 | SCALE 8X FULL | ST3-18570

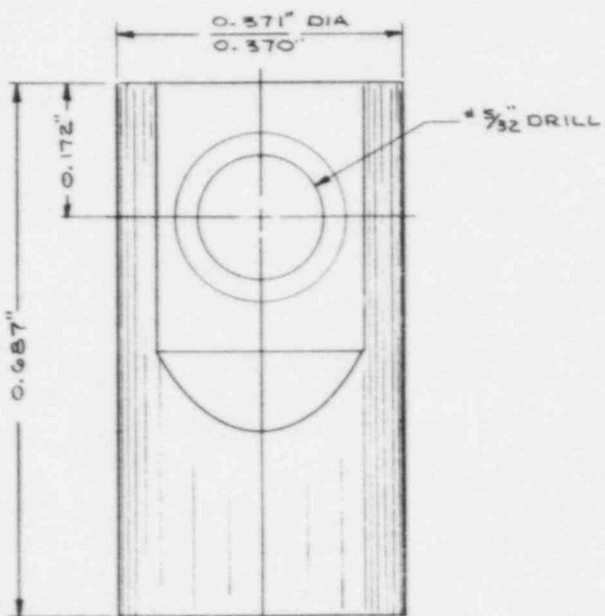
REVISIONS: ADDED NOTE; DELETED NOTES; CHANGED TITLE; ADDED DIM. FOR 3000 SERIES

LATEST REVISION ON THIS DRAWING → (10)

Analyze this print for
SAFETY CONSIDERATIONS







NOTE:

1. TORQUE EYELET TO SR-Cf 100 SERIES SOURCES TO 20 INCH/LBS

ST3-18561

△3 [illegible]

FINISH 4√ ALL MACHINED SURFACES U.O.S.	TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
BREAK ALL SHARP EDGES U.O.S.	ONE PLACE DECIMAL ±.005 TWO PLACE DECIMAL ±.010 THREE PLACE DECIMAL ±.005
THE NUMBER IN THIS FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE BY A. A. MICRO INCHES	FRACTIONAL ± ~ ANGULAR ±0°30'

EDP CODE 20-61-00-00-00

REFERENCE DRAWINGS	NO.	REVISIONS	DATE	APP'D
	1	ADDED NOTE		
	2	DELETED NOTES		

△1

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MAT'L: 17-4PH, OR
410 SST
416 SST
ZIRCALOY-2

REQ'D: 1

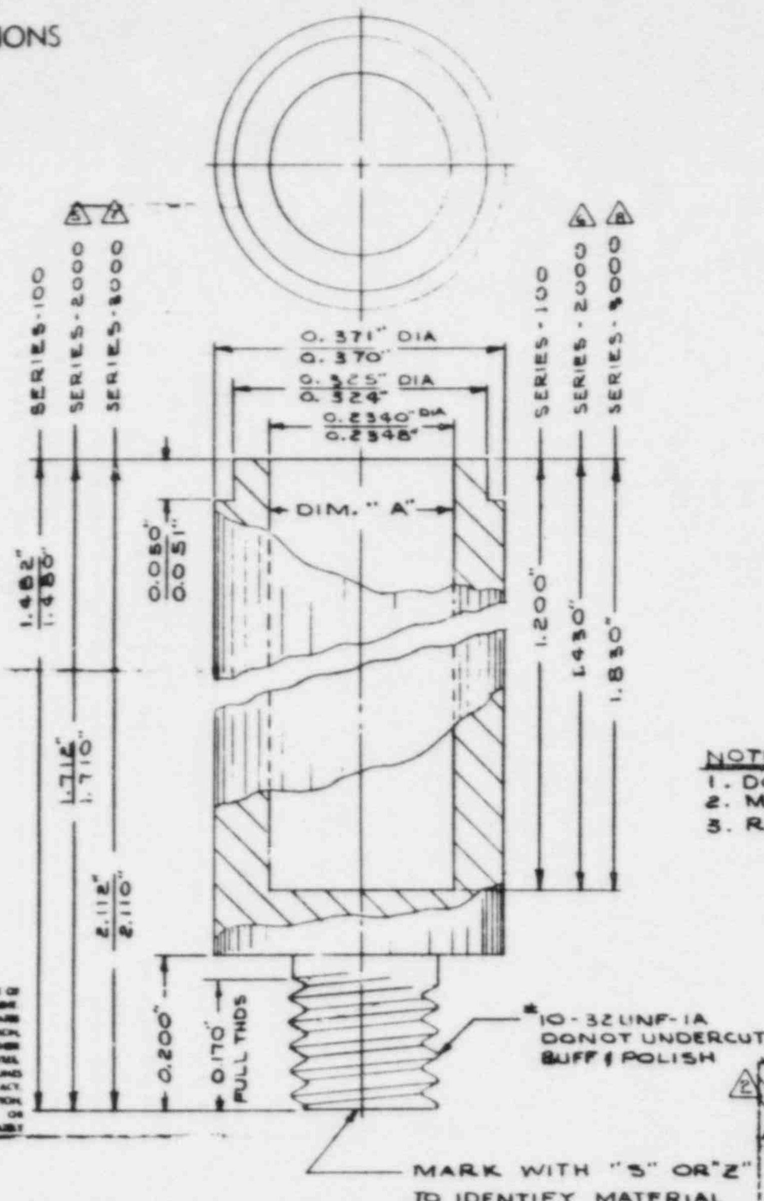
△2

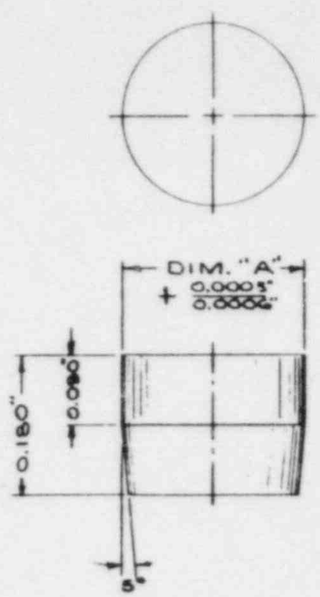
DESIGNED BY A.R. BOULOGNE ENGINEER	DRAWN BY H.G. NAVE	U.S. ATOMIC ENERGY COMMISSION E. I. DU PONT DE NEMOURS & CO., INC. SAVANNAH RIVER PLANT
	CHECKED BY P.C. Zhee 9-9-75	BLDG. 773-A PROBLEM NO. [redacted] ES-0573022 PROCESS PROJECT NO.
WORKS ENGNG APPROVALS A.R. Boulogne 9/2/75 [illegible] 9/2/75	OTHER APPROVALS J.D. Harrington 9-10-75	TITLE 200B SR-Cf 100 SERIES EYELET
		DATE 9-10-75 SCALE 8x FULL FILE ST3-18561

MF

LATEST REVISION ON THIS DRAWING → 3

Analyze this print for
SAFETY CONSIDERATIONS





ST8-18568

NOTES:
1. DO NOT BREAK EDGES.
2. MAT'L: 304L SST OR ZIRCALOY-2
3. REQ'D: 1-EACH

FINISH ✓ ALL MACHINED SURFACES U.O.S.	TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
BREAK ALL SHARP EDGES U.O.S.	ONE PLACE DECIMAL ±0.05 TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005
THE NUMBER IN THIS FINISH SYMBOL ✓ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A. A. MICRO-INCHES	FRACTIONAL ± ~ ANGULAR ±0°30'

EDP CODE- 20-61-13-00-00

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REVISIONS	NO.	REFERENCE DRAWINGS
ADDED NOTE		
DELETED NOTES		
CHANGED "TITLE"		
ADD DIM. FOR 2000 & 3000 SERIES		

U.S. ATOMIC ENERGY COMMISSION
E. I. DU PONT DE NEMOURS & CO., INC.
SAVANNAH RIVER PLANT

DESIGNED BY A.R. BOULOGNE	DRAWN BY H.G. NAVE	BLDG 773-A	PROBLEM NO.	PROJECT NO. ES-0675022
	CHECKED BY R.C. Kise 9-9-75			

TITLE
SR-CF-100, -2000, -3000 SERIES
TYPE "AA-1", "AA-2" AND "AA-3"
SECONDARY CAPSULE

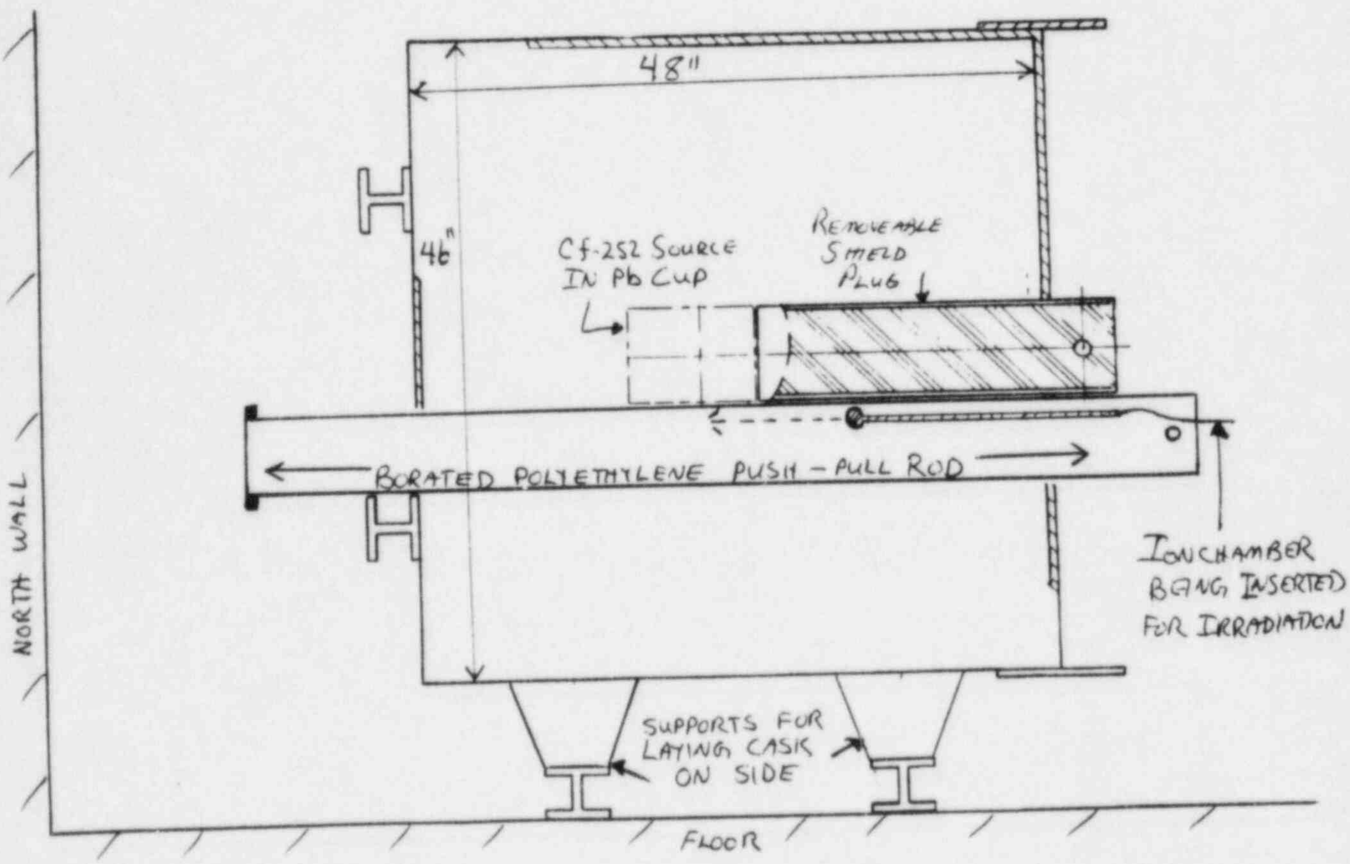
DATE	SCALE	FILE
9-10-75	8X FULL	ST8-18568

LATEST REVISION ON THIS DRAWING → 8

(C)

AFRRI CALIFORNIUM-252 IRRADIATOR

(NOT TO SCALE)



(d and E)

Shielding Calculations Californium -252 Source in the AFRRI Standard's Lab

1. Source and cask.

The Cf-252 source that AFRRI plans to obtain in August 1985 will have activity about 1.2 Ci (2.3 mg). The doubly encapsulated source is to have Pt-Rh and stainless steel casings that will be closure and leak tested to qualify as "Special Form". It is to be stored in a cylindrical poly-boron source cask with a diameter and length of about 46 inches. The exterior of the cask will be covered by a steel plate.

2. Storage and surrounding area description.

The source cask will be kept in the northeast corner of Room SB-3, AFRRI's Standards Lab Exposure Room. The Standard's Lab is comprised of the basement and first floor beneath the Directorate at AFRRI. There are three work areas adjacent to the Standard's Lab that are of radiological concern: overhead in the Director's Office, Administrative Offices beyond the north wall on the first level, and the Standard's Lab Control Room on the other side of the west interior wall. Beyond the south, east, and the basement part of the north wall is earth. Diagrams of these are attached.

3. Other sources present.

The Standards Lab is the home for other radiation sources- a Theratron 80 cobalt-60 machine, an industrial x-ray machine, and a cesium camera source. The Cf-252 source is to be located 18 feet and 10 feet from the Theratron 80 and x-ray machine exposure heads, respectively. Reference 4 has extensively addressed the radiation protection measures taken for installation of the Theratron 80 unit.

4. Dose rate calculations for a fully exposed source:

For this configuration the source position is assumed to be located in free space, 3 feet from the north and east walls and 8 feet off the ground. The neutron emission rate (NER) is 5.5 E+9 n/sec. The primary photon emission is 3.04 E+10 gamma/sec. The dose equivalent rate at one meter from the source is 5.4 Rem/hr neutron, 0.4 Rem/hr gamma, and 5.8 Rem/hr total. The following are Cf-252 shielding and distance parameters for spaces adjoining the Standard's Lab exposure room when the source is in the fully exposed position.

a. Director's Office:
The source is approximately 11 feet (335 cm) from the Directorate floor which consists of 2 feet (60 cm) of concrete.

b. Theratron Control Room:
Directly in line with the source is the control room door

which is a hollow steel door (0.16 cm thick) overlaid with 1.9 cm of lead. The distance between the source and the door is 27 feet (820 cm). The wall that separates the Control Room and the Exposure Room is constructed of 15 cm cinder blocks lined with 0.95 cm of lead and 1.91 cm of wood. Additionally a 36 cm thick wall of high-density cinder blocks loaded with lead shot was built next to the permanent wall.

c. Administrative Offices:
The Administrative Offices are behind 2 feet of concrete, and are a minimum of 5 feet (150 cm) from the source.

d. The south and east walls are not considered since both are backed by earth.

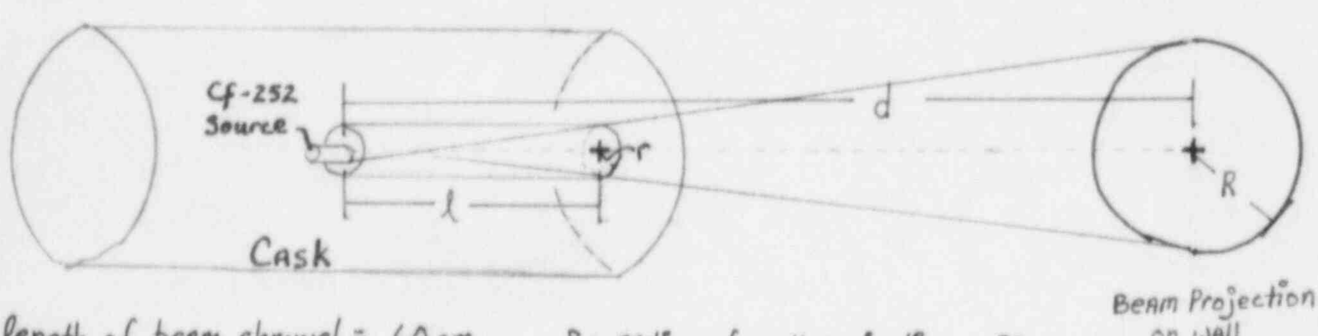
Two independent methods were used to calculate the dose equivalent rates passing through the shields. An example of these calculations is detailed in the Appendix. The final results for the areas of concern are shown below.

	Dose Equivalent Rates (mRem/hr) for Fully Exposed Source		
	Directorate	Control Room	Admin Offices
neutron	1.5	75.2	4.2
capture gamma	.6	.1	1.6
primary gamma	2.0	15.3	9.2
total	4.1	90.6	15.0

5. Dose rate calculations for a partially exposed source:

For this confuguration the source cask is assumed to be on its side in the north east corner, with the source sheilding plug removed. Radiation emerges horizontally from the cask through the 4 inch diameter beam channel toward the south wall. The beam channel is assumed to be about 2 feet (60 cm) long. The position of the source is 13 feet (396 cm) from the south wall and 4 feet off the ground.

Diagram of Cask and Beam Projection



l = length of beam channel = 60 cm
r = radius of beam channel = 5 cm
a = area of beam channel = 79 cm^2 = πr^2

R = radius of wall projection = 33 cm
d = distance between source and wall = 396 cm

If we assume that only neutrons exiting the channel without interacting are of importance then the neutron fluence rate(ϕ) at the cask opening would be the ratio of the area of the opening divided by the surface of a sphere of radius ℓ times the source neutron emission rate.

$$\phi_{\text{THROUGH OPENING}}\ (n/sec) = 5.5 \times 10^{9}\ n/sec * \frac{\pi r^2}{4\pi \ell^2}$$

$$= 5.5 \times 10^{9}\ n/sec \times \frac{79\ cm^2}{4\pi\,(60\ cm)^2}$$

$$= 9.6 \times 10^{6}\ n/sec$$

This is also the rate that neutrons are impinging on the concrete wall. The albedo effect for the wall is 0.13 (from A Handbook of Radiation Shielding Calculations: Neutron Albedo Calculations). The two foot diameter beam projection on the south wall can be considered a source of neutrons with an emission rate of 1.25 E+6 n/sec. The unattenuated beam will not be so large as to hit any other surface but the south wall.

Of primary radiological concern is the Director's Office directly overhead. The distance to the floor of the Directorate is about 14 feet (425 cm). The distances to the Admin Offices and Control Room are 19 feet (575 cm) and 32 feet (975 cm), respectively.

Dose Equivalent Rates (mRem/hr) for Partially Exposed Source

	Directorate	Control Room	Admin Offices
neutron	.0022	.0007	.0019
capture gamma	.0009	.0003	.0008
primary gamma	.0012	.0002	.0007
Total	.0043	.0012	.0034

The values above are conservative because the maximum neutron albedo factor for all neutron energies was used and the deflected neutron energy spectrum was assumed to be the same as the initial fission spectrum.

The concretes in the NCRP and Wyckoff shielding calculations have hydrogen contents of 0.015 and 0.014 grams per cubic centimeter, respectively. The values presented here are from the NCRP method. The Standard's Lab Exposure Room is constructed with high-density concrete. The hydrogen content remains unknown.

Appendix

Neutron Shielding Calculation Details for Director's Office for the Fully Exposed Source

Two methods from different references gave similar results for expected dose rates from an unshielded Cf-252 source attenuated through concrete. The first method used neutron tissue kerma per neutron fluence graphs from NCRP 38 and a Cf-252 neutron spectrum from reference 3 to estimate the dose rate delivered to tissue immediately behind an infinate concrete slab of given thickness. The dose rate due to capture gamma was graphically estimated from figure 60 of NCRP 38. Both dose rates used incremental neutron energy values from 0 - 12 MeV. The dose due to primary gamma was calculated from reference 3.

The second method from reference 2 figure 6.5 took the ratio of tissue dose equivalent at the far side of a concrete shielded wall for 60 to 0 cm of concrete. The incident fission neutron spectra was for U-235.

A. NCRP 38 Method

Assume Tissue Kerma (erg/g) = Tissue Dose (erg/g).

$$\dot{D}n(\text{mRem/hr}) = \frac{K_{nt}}{\Phi_n}\left(\frac{\text{erg}\cdot\text{cm}^2}{\text{g}}\right) \phi_{ns}\left(\frac{n}{\text{sec}\cdot\text{cm}^2}\right) \frac{1\ \text{Rad}}{100\ \text{erg/g}} * \frac{10\ \text{Rem}}{\text{Rad}} * \frac{1000\ \text{mRem}}{\text{Rem}} * \frac{3600\ \text{sec}}{\text{hr}}$$

where Knt = neutron tissue kerma at far side of concrete slab

Φn = neutron fluence on irradiated side of concrete surface

ϕns = neutron fluence rate extrapolated to irradiated side of concrete surface

$$\dot{D}_{\substack{\text{CAPTURE}\\ \text{GAMMA}}}(\text{mRem/hr}) = \frac{K_{nt}}{\Phi_n}\ \frac{K_{\gamma t}}{K_{nt}}\ \phi_{ns}\ \frac{1\ \text{Rad}}{100\ \text{erg/g}} * \frac{1\ \text{Rem}}{\text{Rad}} * \frac{1000\ \text{mRem}}{\text{Rem}} * \frac{3600\ \text{sec}}{\text{hr}}$$

where Kγt/Knt = ratio of capture gamma tissue kerma to neutron tissue kerma

ϕns = (2.3mg Cf)(NER)/($4\pi d^2$)

where NER = neutron emission rate as a function of ΔE

d = distance in cm from source to the irradiated concrete surface

Using figure 6.5 of reference 2:

$\dot{D}$neutron @ 0 cm of concrete = 4 E- 8 Rem-sqcm/n
$\dot{D}$neutron @60 cm of concrete = 3 E-10 Rem-sqcm/n

The Concrete Attenuation Factor = 0.0075

The dose equivalent rate in the Director's Office:
neutron= 478 x .0075 = 3.6 mRem/hr
capture gamma = 1.4 mRem/hr
primary gamma = 2.0 mRem/hr
Total = 7.0 mrem/hr

C. Both methods give consistent results with the Wyckoff Method about 70% higher.

References:

(a) National Council on Radiation Protection.NCRP Report 38, Protection Against Neutron Radiation, NCRP Publications, Washington, DC, 1971
(b) Wyckoff JM, Dose Due to Practical Neutron Energy Distributions Incident on Concrete Shielding Walls, Handbook of Radiation Shielding Data, ANS/SD-76/14, 1973
(c) Stoddard DH, Hootman HE, Shielding Data for Cf-252 Sources, Handbook of Radiation Shielding Data, ANS/SD-76/14, 1971
(d) Ferlic KP, Radiation Survey for Installation of the Cobalt-60 Theratron 80 at Armed Forces Radiobiology Research Institute, AFRRI Report TR83-4
(e) Kamphouse J, Removal Cross sections for Iron and Lead as a Function of Hydrogenous Materials, Handbook of Radiation Shielding Data, ANS/SD-76/14, 1975

Dose Equivalent Rate in Director's Office
d=335 cm

NEUTRON ENERGY (MeV)	k_{nt}/Φ_n ($erg \cdot cm^2/g$)	ϕ_{ns} ($n/sec \cdot cm^2$)	$\dot{D}_n$ (mRem/hr)	$K_{\gamma t}/K_{nt}$	$\dot{D}_{capture\ \gamma}$ (mRem/hr)	$\dot{D}_{TOTAL}$ (mRem/hr)
.07	1.8E-12	6.4E+8	.001	100	0.01	0.011
1.3	1.8E-11	6.7E+8	.01	50	0.05	0.06
2	6 E-10	5.3E+8	.28	12	0.33	0.61
3	4 E- 9	3.2E+8	1.11	3	0.33	1.44
4	3 E- 9	1.9E+8	.48	2	0.097	0.58
6	9 E- 9	4.4E+7	.34	0.8	0.028	0.37
8	9 E- 9	9.7E+6	.076	0.7	0.005	0.08
12	8 E- 9	4.4E+5	.003	0.8	0.0002	0.003

The primary gamma dose equivalent rates are calculated from reference 3. The attenuation factor for 60 cm of concrete is 0.01.

neutron	=	1.5 mRem/hr
capture gamma	=	.6 mRem/hr
primary gamma	=	2.0 mrem/hr
Total	=	4.1 mRem/hr

The dose equivalent rate in the Control Room:

	Through the lead door (mRem/hr)	Through the wall (mRem/hr)
neutron	75	0.2
capture gamma	-	0.1
primary gamma	15	0.3
Total	90	0.6

The total dose rate in the control room is about 91 mrem/hr.

The dose equivalent rate in the Admin Offices:

neutron	=	4.2 mRem/hr
capture gamma	=	1.6 mRem/hr
primary gamma	=	9.2 mRem/hr
Total	=	15.0 mRem/hr

The ability of 60 cm of concrete to attenuate neutrons by the NCRP 38 Method is:
Concrete Attenuation Factor = $\dot{D}$(60 cm)/$\dot{D}$(0 cm)= 1.5/478 = 0.0031

B. Wyckoff Method

Tp(g/sqcm of concrete) = 60 cm x2.35 g/cm^3
=140 g/sqcm

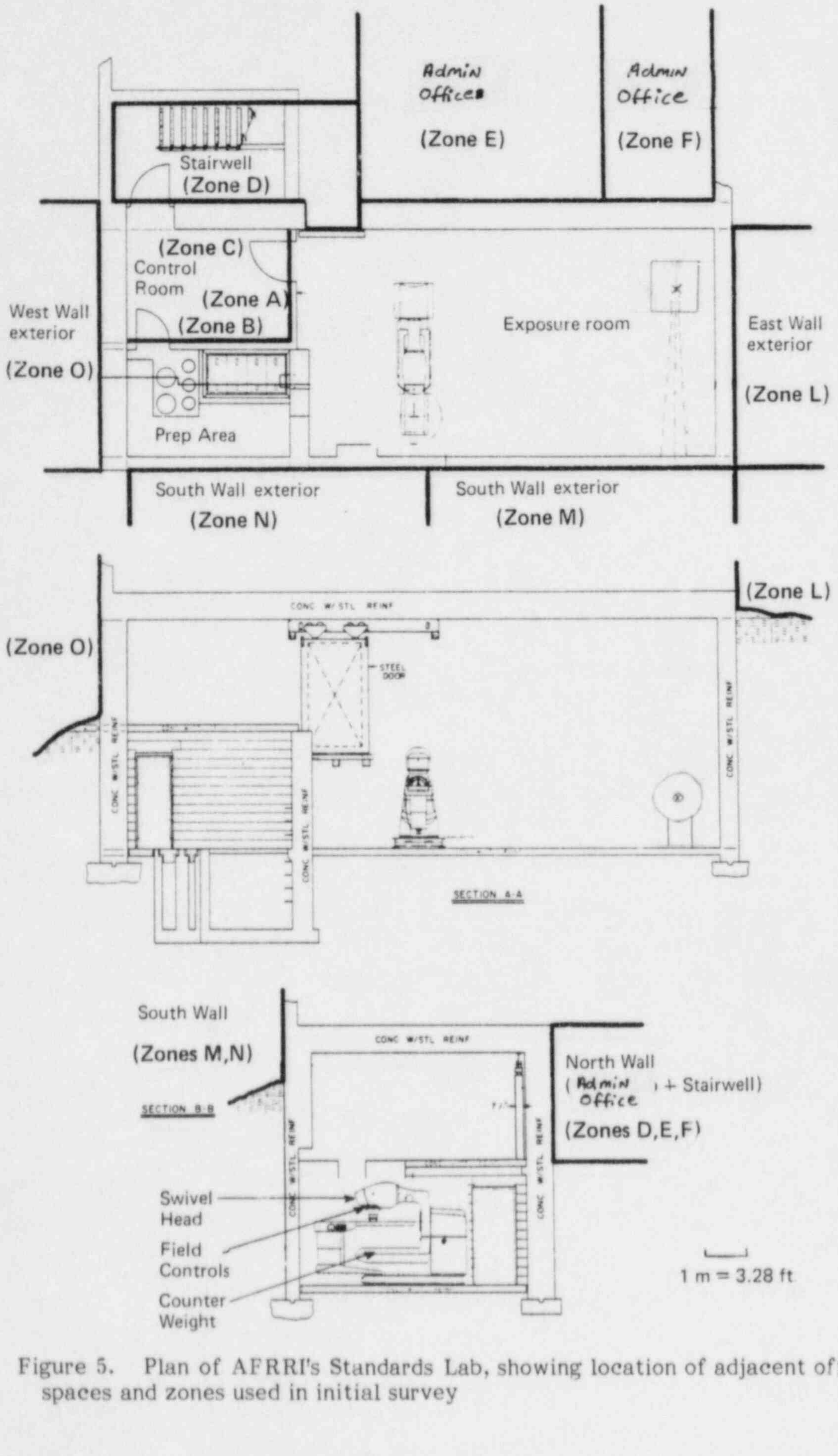


Figure 5. Plan of AFRRI's Standards Lab, showing location of adjacent office spaces and zones used in initial survey

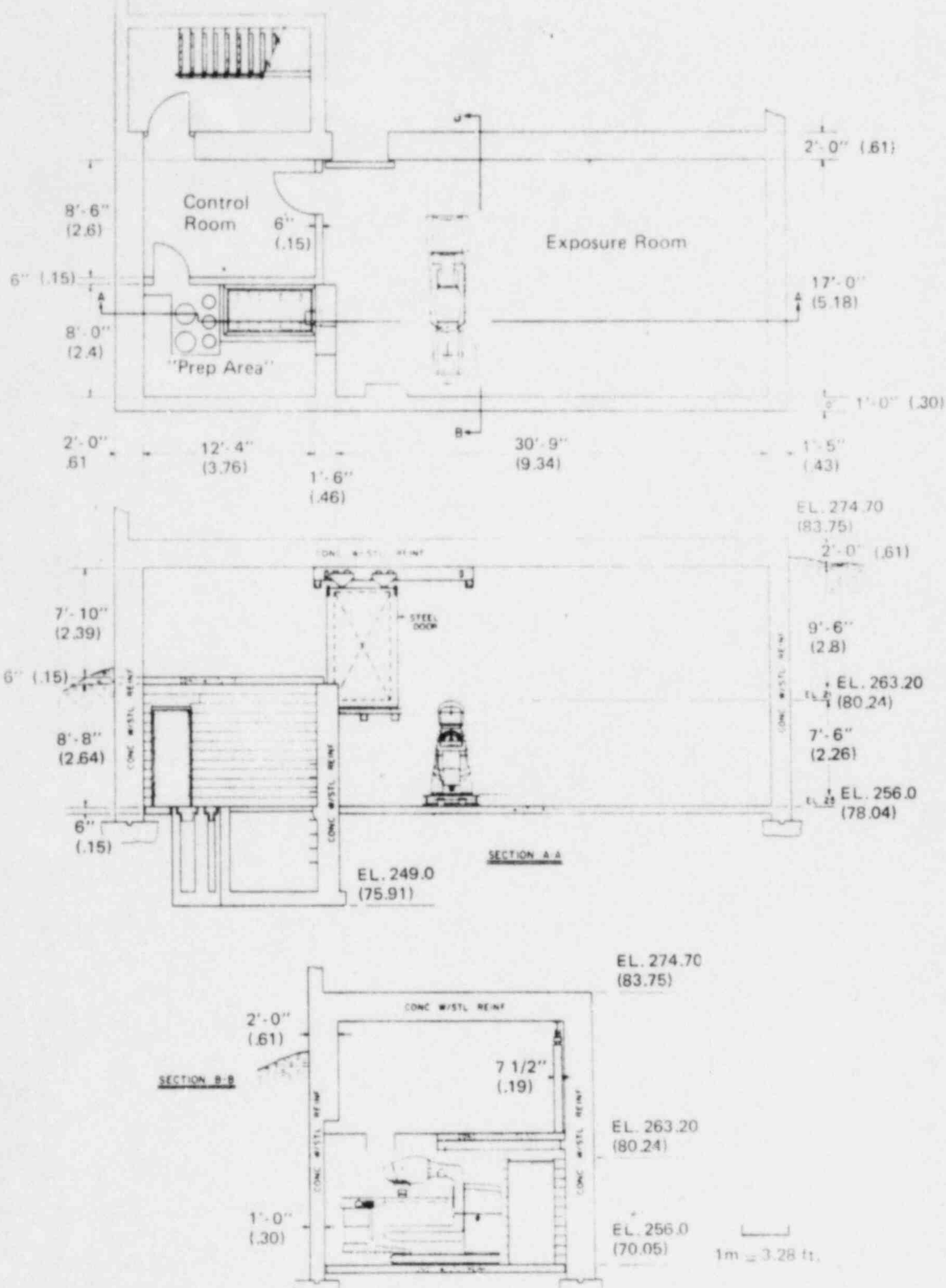


Figure 3. Dimensions of Standards Lab and approximate location of Theratron

18799

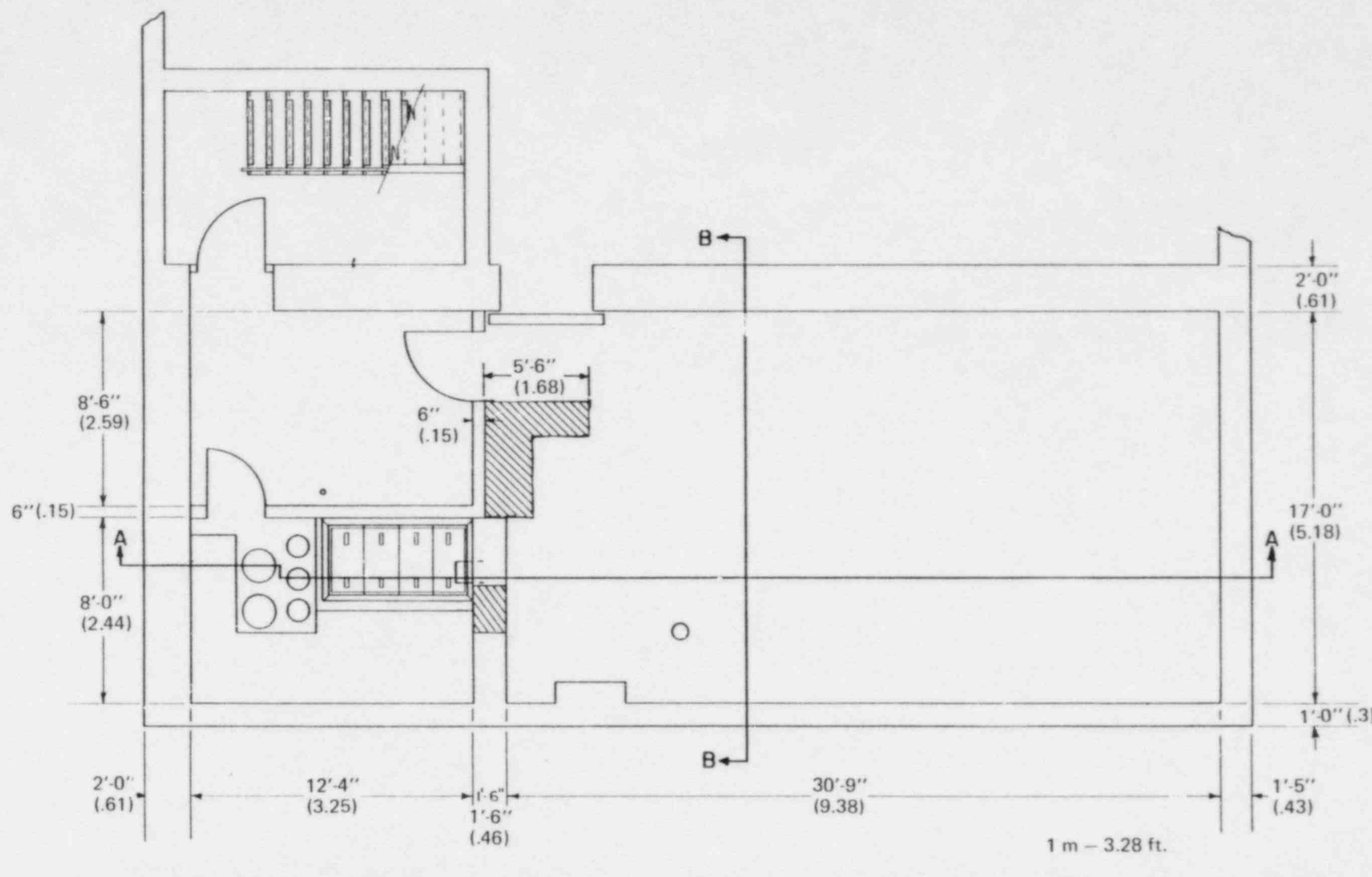
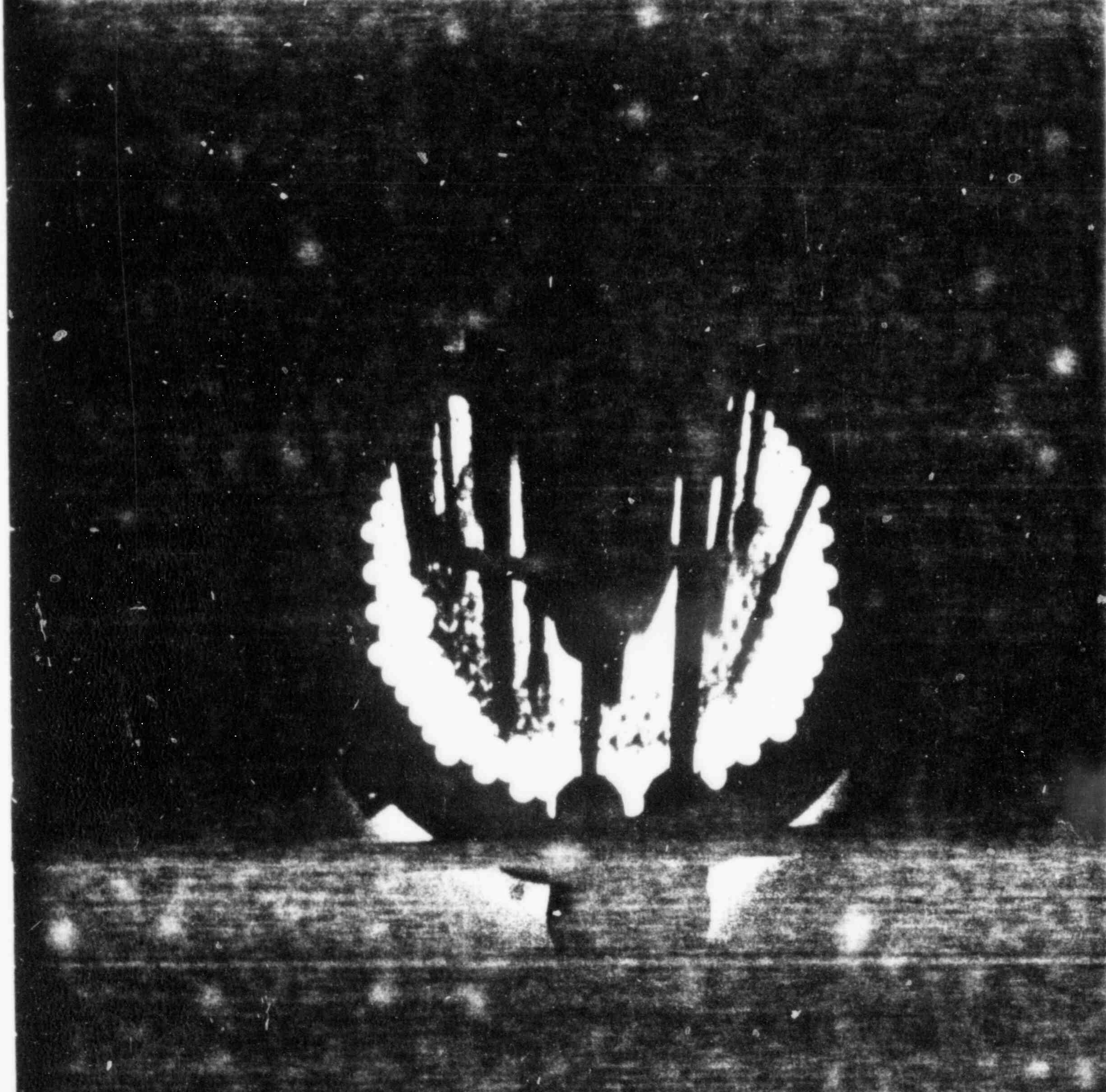


Figure 4. Dimensions of Standards Lab floor and walls, and location of shot-loaded block wall for additional shielding

REACTOR EXPERIMENTS, Inc.

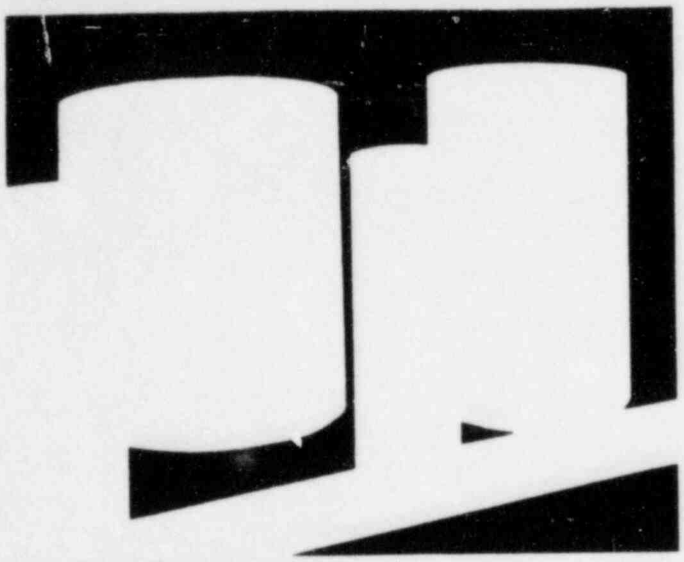
Shielding & Foils

Catalog 20



CYLINDRICAL POLYETHYLENE-BASE RODS

Many of the polyethylene-base shielding materials are available in the form of solid cylindrical rods in addition to slabs and bricks. The rod diameters are approximately 1/4" (6mm) oversize to permit the user to machine them to the exact size, where required. The rods are available in 12" (305mm) lengths: longer or shorter lengths are available on request.



Cylindrical Polyethylene Rods up to 10" in diameter

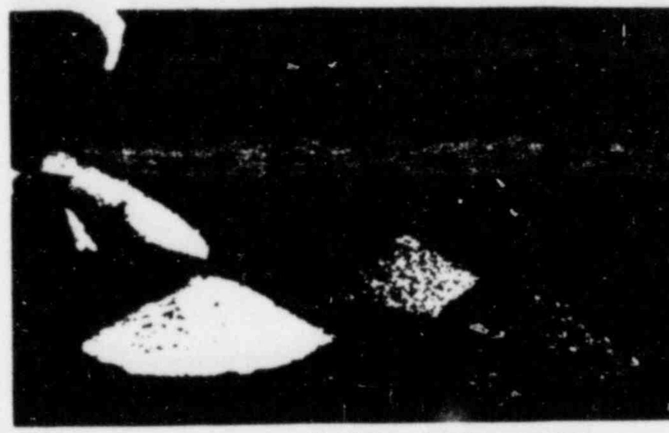
NOMINAL DIAMETERS OF RODS

mm	102	127	152	178	203	229	254

Rods are available in the following compositions: Catalog Nos. 201, 202, 205, 207, 209, 210 and 213.

SHIELDING PELLETS

In addition to the standard forms of shielding, certain types can be supplied as pellets. These pellets generally are about 1/8" (3mm) in size. They can be transported by air pressure or vacuum to fill irregular volumes. They can also be removed at a later time, if desired.



Shielding Pellets (left to right): 5% Boron, Self-Extinguishing, Boro-Silicone

The following types of pellets can be supplied: Catalog Nos. 201, 202, 207, 210 and 213. Catalog No. 237 (Boro-Silicone) is supplied as a powder. We also supply lead in the form of shot.

SHIELDING CASKS AND FILLERS

NEUTRON SHIELDING CASKS

(Catalog No. 258)

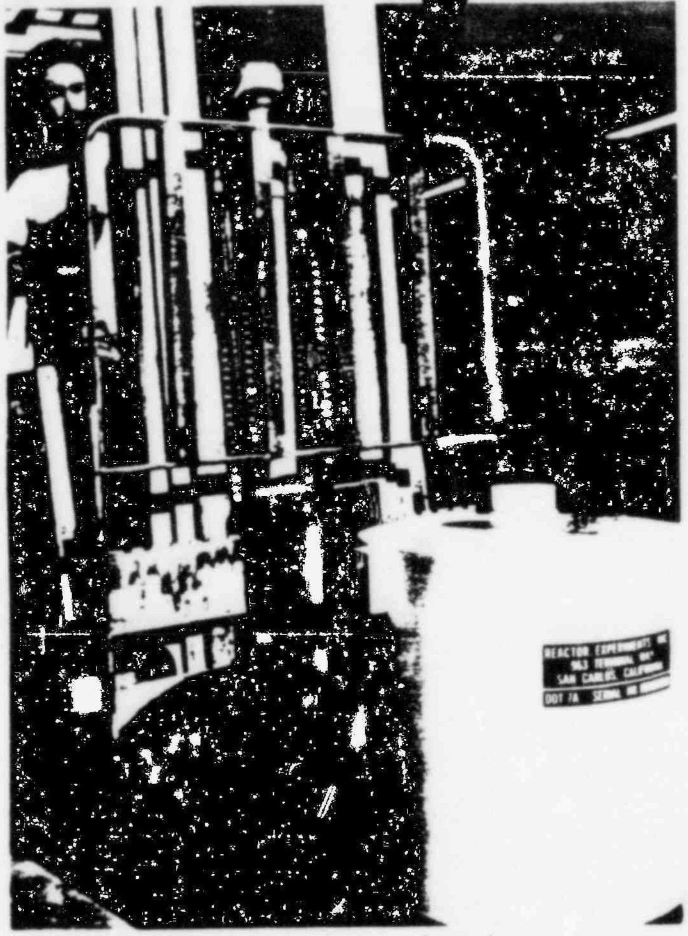
These shielding casks are designed as shipping and storage containers for neutron emitters such as Cf-252, Am-Be, and Pu-Be. The filler material has an exceptionally high hydrogen content (6% more hydrogen than water). In addition, it has a density of 1.15 g/cc (72 lbs/cu ft) which aids in gamma shielding.

Catalog No. 258 shielding containers are ruggedly constructed of heavy gauge steel and are designed to be moved by a fork-lift or overhead lifting device. The casks can be qualified as "Type A" shipping containers. They are also convenient for storage purposes. Each cask is supplied with a shielded access plug and a lock to prevent unauthorized source removal.

There is 0.9% boron present in the shielding material in order to suppress dosage from secondary gamma rays. There is a lead cup in the center of the cask for holding the source and shielding primary gamma rays. This cup is fabricated to fit your source. Request Bulletin No. S-99 for a listing of source information that will be needed to tailor a cask to your specific needs.

The filler material used in these casks is available separately as a dry mix for casting into closed containers. See the next section on POLY/CAST Castable Shielding Material (Catalog No. 259).

In addition to neutron shielding casks, we also offer a line of unique lead casks fitted with wheels for safe, convenient transport of gamma sources of any type. These PORTA-PIGS are described in detail on page 9.



18" Diameter Neutron Shielding Cask with Shield Plug and Lock

18	46	280	125	30	13
22.5	57	500	225	75	20
27	69	700	320	150	**
33	84	1350	600	375	**
40	102	3000	1350	1000	**
48	122	5000	2300	2500	**

*Shipping limit is based on 10 mR/h at 3 feet or 200 mR/h at cask surface. Storage capacity can be estimated by relating desired dose rate to 10 mR/h at 3 feet. Special cask designs and sizes are available on request.

**U.S. regulations limit Am-Be and Pu-Be sources to 20 Ci for shipment in a "Type A" container. Overseas, this limit is 8 Ci.

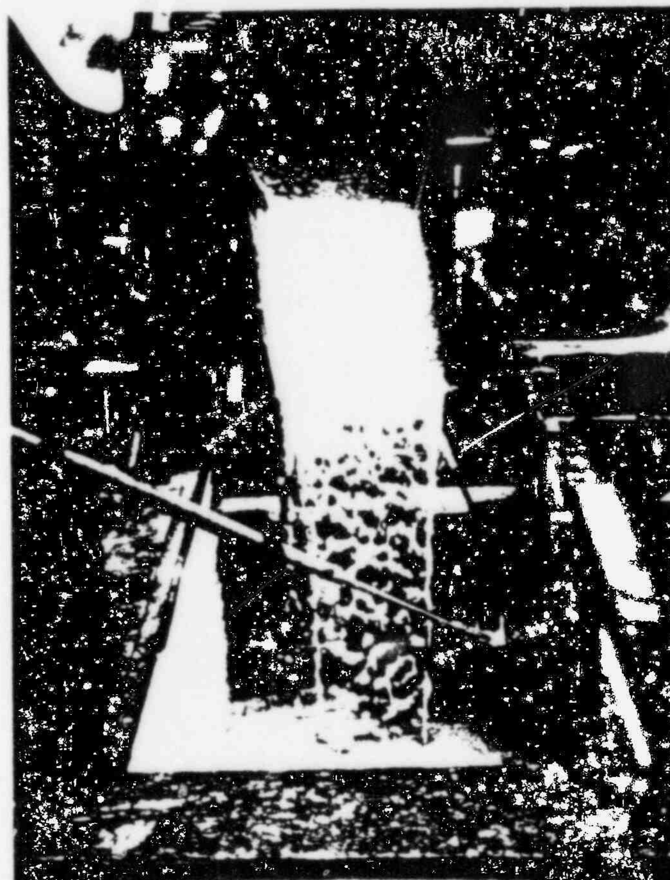
POLY/CAST™ CASTABLE SHIELDING
(Catalog No. 259)

POLY/CAST is a castable neutron shielding material designed for use in closed containers. It is the same material that is used in Reactor Experiments' shipping and storage casks. It contains a very high hydrogen loading. At the same time, its density is 15% greater than that of water, providing improved gamma shielding for such sources as Cf-252. There is 0.9% boron present in order to suppress dosage from capture gamma rays.

POLY/CAST requires only mixing with water. It sets up within 30 minutes of casting to a strong solid material. By sealing the container immediately after casting, the water (and hence, the hydrogen) content is maximized. The material can be poured in as many layers as required, since each layer bonds readily to the previous one. Aside from a mixer, no special tools are required. The weight of dry mix required to cast one cubic foot of material is 56 lbs (25.5 kg). POLY/CAST has been used to cast neutron-source casks, shielding wall barriers, and even an entire 4' (1.2m) thick roof for a cyclotron facility.

The recommended temperature limit is 150°F (66°C). When held at this temperature for extended periods, it loses only about 7% of its hydrogen content. Even at 300°F (140°C), it retains 80% of its hydrogen. POLY/CAST dry mix (Catalog No. 259) is available in multiples of 100 lbs (45.4 kg). Recommended shelf-life under dry storage conditions is 6 months.

™POLY/CAST is a trademark of Reactor Experiments, Inc.



Installation of Poly/Cast in Accelerator Room Roof

P. 1

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Bulletin S-99N
January, 1983

SOURCE HOLDER FOR NEUTRON SHIELDING CASKS

Catalog No. 258 Shielding Casks contain a lead source holder in the center of the cask for shielding primary gamma rays (see attached sketch). To assist us in determining the optimum dimensions for this holder, please supply the following information:

1) Type of Source (i.e., Cf-252, Pu^{238}-Be, Am^{241}-Be, etc.):

2) Manufacturer of Source and Catalog No. (if known):

3) Strength of Source (μg of Cf, Ci of Pu-Be, or Am-Be):

4) Outside Diameter of Source:

5) Length of Source:

(continued)

6) Diameter and Length of any protrusion on top of Source:

7) Type of protrusion (i.e., threaded rod, hook, etc.,--if threaded, give thread size):

8) Thread Size of any hole in top of Source:

9) Other features:

It would be most helpful if you can make a rough sketch of the source on the lower portion of this sheet.

Source loading and removal may be carried out in different ways depending on your application. A common way of handling the source is by means of a nylon string attached to the top of the source and run out of the cask alongside the 3" diameter shielding plug (see photo). The standard cask contains a basic source holder cup for using this technique. We can, at nominal additional cost, provide for other approaches. For example, attaching the source to the bottom of the plug. The source can be threaded to the bottom of the plug or even placed in a cut-out section of the plug. Please advise of your planned method of source handling. If you have a special holder requirement, a rough sketch of this would also be helpful.

EFFECTS OF SOURCE STRENGTH AND DISTANCE FROM CASK ON SURFACE DOSE RATES

Our Neutron Shielding Casks are frequently used to store sources, in addition to shipping them. Under storage conditions, users frequently prefer dose rates at the surface of the cask to be lower than those permittd during shipment. The following table shows the source strength that can be accommodated in different casks, while keeping the surface dose rate at 5 mR/h.

Cask Diameter (inches)	Surface Strength that will result in a Surface Dose Rate of 5 mR/h	
	Cf-252 (μg)	Pu-Be or Am-Be (Ci)
18	0.75	0.32
22.5	2	1
27	5.6	1.6
33	18.6	4.6
40	64	11.6
48	200	18

1) In order to obtain the surface dose rate for source strength different from those given in the table, the following formula may be used.

$$D = 5 \text{ mR/h} \times \frac{S}{T}$$

where: D is the surface dose rate for a source of strength, S, and T = the source strength given in the table.

Example: What will the surface dose rate be for a 7 μg Cf-252 source in an 18" diameter cask?

$$D = 5 \text{ mR/h} \times \frac{7}{0.75} = 46.7 \text{ mR/h}$$

2) In order to obtain the dose rate at various distances from the surface, the following formula may be used:

$$D_L = D \times \frac{(r)^2}{(r + L)^2}$$

where D = Dose rate at the surface of the cask
D_L = Dose rate at distance L from the surface of the cask
r = Radius (not the diameter) of the cask

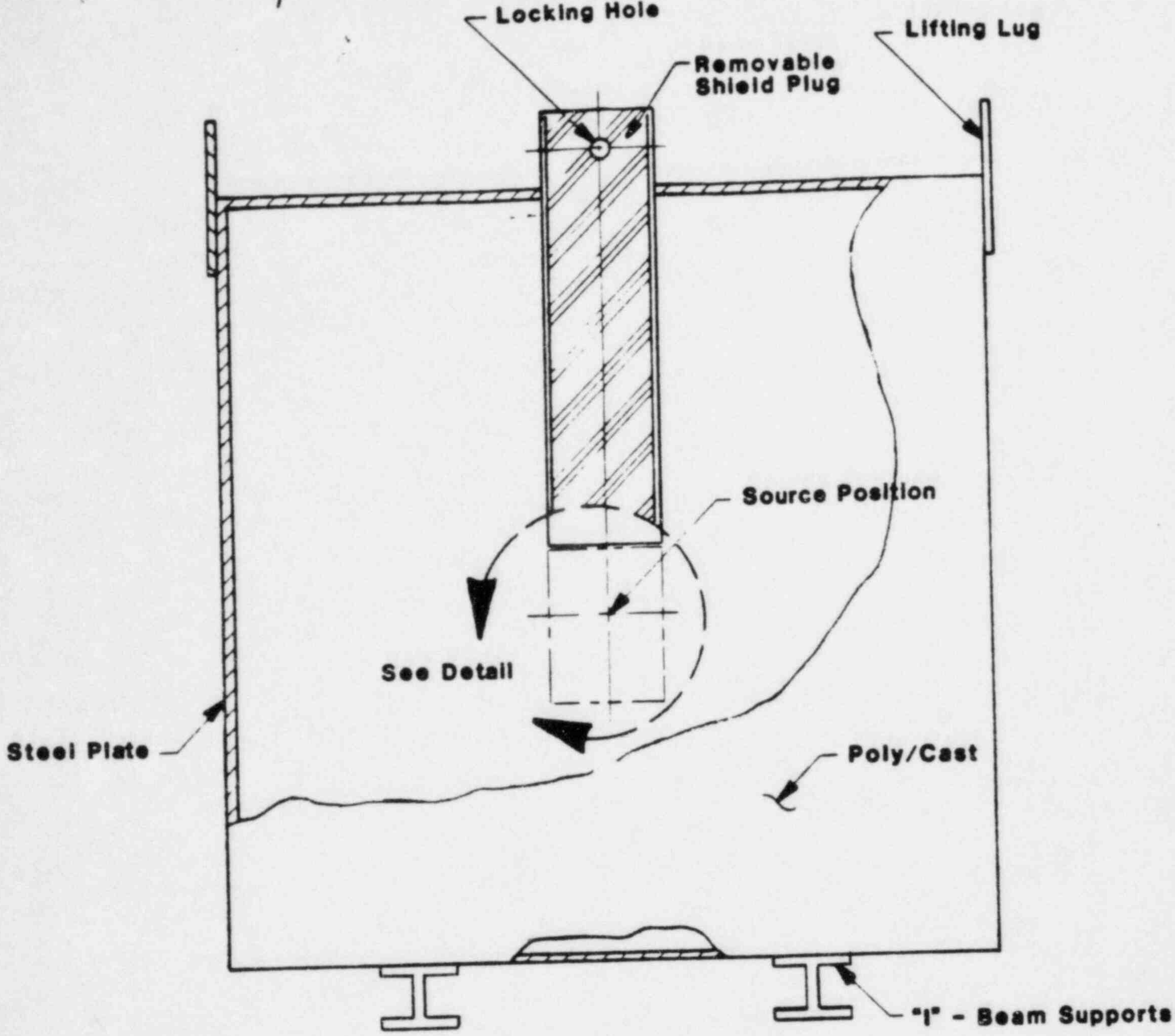
Example: What is the dose rate at 12" from the surface of a 27" diameter cask containing a 5-curie Pu-Be source?

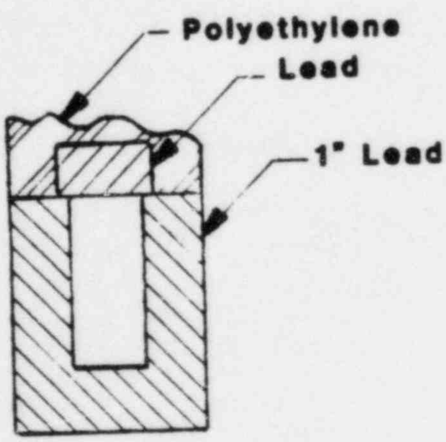
First, make the source strength correction shown in (1) above:

$$5 \text{ mR/h} \times \frac{5}{1.5} = 15.625 \text{ mR/h}$$

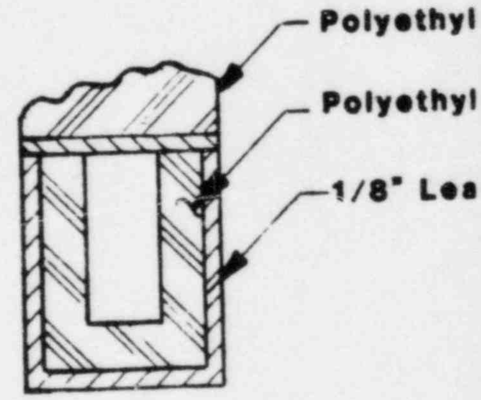
Then correct for the distance

$$D_L = 15.625 \text{ mR/h} \times \frac{(13.5)^2}{(13.5 + 12)^2} = 4.4 \text{ mR/h}$$





Source Cup For Cf-252 Source



Source Cup For Am-Be or Pu-Be Source

CATALOG NO. 258 SHIELDING CASK

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June, 1983

TYPICAL ELEMENTAL ANALYSIS

CATALOG NO. 259 - POLY/CAST *

Element	Weight Percent
H	10.46%
B	0.90
C	47.28
Al	0.03
Ca	5.49
Fe	0.05
Mn	0.03
O	31.52
S	3.83
Si	0.41
Total	100.00%

Density = 1.15 g/cc

Hydrogen Atoms/cc = 7.10×10^{22}

Boron Atoms/cc = 0.58×10^{21}

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Bulletin S-79N
January, 1983

POLY/CAST* (Catalog No. 259)

Dry Mix for Filling Shielding Containers

POLY/CAST is a castable neutron shielding material designed for use in closed containers. It is the same material that is used in Reactor Experiments' shipping and storage casks. It is also useful for casting a variety of shielding barriers.

POLY/CAST contains a very high hydrogen loading (5% more hydrogen than water). At the same time, its density is 15% greater than that of water, providing improved gamma shielding against such sources as Cf-252. There is 0.9% boron present in order to suppress dosage from capture gamma rays.

POLY/CAST requires mixing only with water. It sets up within 30 minutes of casting to a strong solid material. By sealing the container immediately after casting, the water (and hence, the hydrogen) content is maximized.

This material can be poured in as many layers as required since each layer bonds readily to the previous one. Aside from a mixer, no special tools are required. The weight of dry mix required to cast 1 cubic foot of material is 56 lbs (25.5 kg).

The recommended temperature limit is 150°F (66°C). When held at this temperature for extended periods, it loses only about 7% of its hydrogen content. Even at 300°F (149°C), it retains 80% of its hydrogen.

POLY/CAST Specifications

Hydrogen Atoms per cc: 7.1×10^{22}

Boron Atoms per cc: 0.58×10^{21}

Percent Boron: 0.9%

$\Sigma_{thermal}$: $0.42 cm^{-1}$

Density: 1.15 g/cc (72 lbs/cu ft)

*POLY/CAST is a trademark of Reactor Experiments, Inc.