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A Laboratory-Scale Shielded Cell for ^{252}Cf

by

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ABSTRACT

A shielded-cell facility for storing and handling remotely up to 2 milligram quantities of unencapsulated ^{252}Cf has been built in a radiochemistry laboratory at the Test Reactor Area of the Idaho National Engineering Laboratory. Unique features of this facility are its compact bulk radiation shield of borated gypsum and transfer lines which permit the transport of fission product activity from ^{252}Cf fission sources within the cell to a mass separator and to a fast radiochemistry system in nearby rooms.

INTRODUCTION

Two systems for studying the decay properties of short-lived fission products are in various stages of development and use at the Idaho National Engineering Laboratory (INEL). One system utilizes an electromagnetic mass separator to produce mass-separated fission-product sources and the second utilizes fast radiochemistry systems (high pressure liquid chromatograph, solvent-solvent centrifugal contactors) to provide chemically pure sources for nuclear radiation measurements. Both systems utilize a gas-jet technique to transport fission products from "open" ^{252}Cf fission sources to the remote experimental locations. To provide for containment of and the capability for handling remotely the sources and "in-cell" experimental apparatus, a shielded cell facility has been constructed in an existing radiochemistry laboratory at the Test Reactor Area (TRA) of the INEL. This paper describes the facility we have built to handle the unique problems associated with our utilization of milligram quantities of unencapsulated ^{252}Cf.

The general design criteria for this facility follow from an understanding of the gas-jet technique and our use of ^{252}Cf as a source of fission products. For a typical experiment an "open" ^{252}Cf source (oxide form of Cf electrodeposited on a platinum disc) is transferred from an in-cell storage location to an in-cell source chamber. The chamber is pressurized to approximately 2 atmospheres with He gas to which aerosols have been added. Fission fragments from the source are thermalized by collisions with gas molecules, become attached to the aerosols, and are entrained in the gas stream as it is pumped from the source chamber through a 1 mm diameter capillary to a remote location. The aerosols with attached fission products are collected at the remote locations for subsequent processing.

Our facility is designed, therefore, with the following basic features:

(1) radiation shielding and contamination control suitable for containment of 2 mg of unencapsulated ^{252}Cf (4×10^{10} α/s, 4.5×10^{9} n/s, 2.5×10^{10} γ/s),

(2) shield structure compact enough to fit into existing radiochemistry lab (6 m deep, 6.5 m wide, 3.0 m ceiling height),

(3) capability for transfer of californium sources and experimental apparatus to and from the cell,

(4) capability for transport of fission products from within the cell to remote locations,

(5) in-cell remote handling capability.

FACILITY DESCRIPTION

Illustrated in Figure 1 is a partial floor plan of the TRA laboratory wing in which are located the californium cell, the mass separator, the fast radiochemistry system and radiation measurement systems. The cell facility consists of a stainless steel alpha containment box lining the inside walls of a completely enclosed shield structure with penetrations in which are installed a viewing window, two master-slave manipulators, and an airlock shield plug. Also included are service access penetrations, connecting pipelines to other laboratories, internal cell lighting and an independent ventilation system. Exterior dimensions of the cell are 2.9 m deep, 3.2 m wide and 3.0 m high with a minimum wall thickness of 84 cm and a ceiling thickness of 56 cm. Dimensions of the alpha containment box are 1.2 m deep, 1.2 m wide and 1.5 m high. A photograph of the west and north faces of the cell is shown as Figure 2.

The shield enclosing the alpha containment box is integrally constructed with a carbon-steel structural framework, an outer shell fabricated from 0.64 cm carbon-steel plate and penetration liners for installation of the viewing window, the manipulators and the transfer shield plug. The region between the inner stainless liner and the outer carbon-steel shell is composed of 3.8 cm of lead sheet at the stainless liner and borated gypsum. Borated gypsum, which forms the bulk of the radiation shield, is a mixture of 10 parts by weight commercial gypsum ($CaSO_4 \cdot 1/2H_2O$), 7.5 parts by weight water and 1.5 parts by weight boron frits. The boron frits include approximately 16.1% elemental boron in the chemical form B_2O_3. The as-poured mixture has a density of approximately 1.63 g/cm^3 and is approximately 78 cm thick in the north, east and west walls and 94 cm thick in the south wall. To retain moisture in the cast-in-place borated gypsum, the outer carbon-steel shell was completely sealed after pouring of the gypsum.

Several materials for use as the bulk radiation shield were evaluated in the early design stages for this facility. Included were water, limonite concrete, water-extended polyester with lead, polyethylene with lead, paraffin with lead, and borated gypsum with lead. Comparative material costs were estimated for an equivalent shielding effectiveness based on attenuation curves from Stoddard and Hootman[1]. This evaluation indicated that of these materials a shield structure composed of lead and borated gypsum was the least expensive and required the smallest wall thickness for an equivalent shielding effectiveness.

The borated gypsum shield design was optimized and estimates of the expected dose rates at the edge of the shield walls were obtained by means of calculations with the ANISN[2] transport code. These calculations were made for a 2 mg ^{252}Cf point source at the center of a spherical shield composed of the different material configurations with a 53 cm void between the source and the first layer of the shield. A 22 neutron group, 18 gamma ray group coupled cross-section library was used for the calculations[3]. The gamma source spectrum was obtained from Stoddard and Hootman[1] and restructured to fit the 18 gamma ray groups used. The neutron source spectrum was obtained from a Maxwell-Boltzman energy distribution using a neturon temperature of 1.39 MeV. Total dose rates were estimated to be less than 0.3 mrem/h at the edge of the walls and less than 1.4 mrem/h at the top of the shield structure.

Providing a view of better than 80 per cent of the cell process interior, which is lighted with mercury vapor lights, is a radiation-shielded viewing window of laminated construction. The window assembly consists of a wall liner which is welded into the shield structure and a removable window unit which matches the liner. The window unit consists of a stainless- and carbon-steel tank with framework to support lead glass components at the hot and cold sides of the tank and light mineral oil* filling the void region. Approximate dimensions and material composition along the centerline of the window from the hot to the cold side are 2.54 cm of 2.7 density cover glass, an air gap, 20.3 cm of 3.3 density lead glass, 41.2 cm of oil, 15.2 cm of 6.2 density lead glass, an air gap and 2.54 cm of 2.5 density cover glass. Based on ANISN calculations for this material composition and a 2 mg Cf point source located 53 cm from the inside surface, the estimated total dose rate at the outermost surface is less than 2.5 mrem/h.

Two Central Research Model G master-slave manipulators installed above the viewing window provide the capability for remote handling of

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*Chevron Oil Corporation, White Oil #9 UPS materials in the cell. The manipulators are fully-booted and, to minimize radiation streaming, include polyethylene and lead plates in the wall tubes.

Access to the cell interior for transfer of source material and experimental apparatus is provided by the shielded airlock passageway in the south wall. Comprising this passageway are a remotely operated inner airlock door which makes a tight seal to the alpha containment box, a shield plug of stepped design which provides radiation shielding equivalent to the shield walls, and a transfer tray which can be moved by remote operation into the alpha enclosure and back into the airlock. The shield plug is mounted on a bull-bushing shaft assembly so that it can be rolled easily without interference into the wall opening.

Access to the cell interior for experimental lines, such as tubing associated with the gas-jet apparatus, is provided by eight 2.54 cm diameter service access tubes which spiral through the north shield wall. These tubes are welded at both the cell interior and at the cell exterior and are normally capped off to maintain contamination control. Feed-thru adapters attached to the caps are used for introduction of the gas-transport inlet line to the source chamber located in the cell. Stainless steel pipelines, directly coupled to ports of two of the access tubes, are routed, above the ceilings, to a hood in a nearby chemistry laboratory and to the adjacent mass separator laboratory. Terminal ends of these pipelines are capped off when not in use and incorporate feed-thru connectors when used with the capillary tubes. The pipelines provide protection to the 0.3 mm OD X 0.1 mm ID Teflon transport capillaries and are a secondary containment of the radioactivity in the capillary tubing. In the event of a rupture of the transport capillary, fission product activity released to the pipeline interior would be exhausted through the cell filtration system.

The ventilation system for this facility utilizes pressure-gradient control to maintain the transportable contamination in the alpha containment box. Two 30 CFM exhaust fans, one for normal operation and one for emergency use, provide for better than 12 air changes per hour in the cell interior and maintain the cell interior at 2.54 cm water negative pressure with respect to room ambient pressure. A single HEPA filter and a prefilter are installed on the air inlet line. Two HEPA filters in each of two parallel banks, one for normal air flow and the other for standby use when the first is being serviced, provide the exhaust filtration for air from the cell interior. All filters are equipped with DOP test ports. Differential pressure gauges monitor the pressure between the cell interior and ambient, the pressure drop across the inlet filter, and the pressure drop across the outlet filter bank. The ventilation system receives supply air from the room in which the cell is located and exhausts to the building hood-exhaust ductwork.

FACILITY UTILIZATION

To date this facility has been loaded with two approximately 100 μg ^{252}Cf fission sources electrodeposited as the oxide on platinum discs. Both sources were prepared at Oak Ridge National Laboratory and shipped to us in holders designed as part of our gas-jet transport system. The in-cell apparatus required for the transport of fission products from these sources is shown in Figure 3. In the photograph are seen two source holders with mating source storage cylinders and the source chamber to which are connected the inlet helium line and outlet capillary. For use in the source chamber a 1.26×10^{-4} cm thick nickel foil is placed over the californium source. The nickel window transmits the energetic fission fragments but is a barrier to the low energy recoil californium atoms. A closeup view of the source holder with a nickel window in place is shown in Figure 4. We have found the use of this type of source holder to be reasonably effective in minimizing the spread of alpha contamination to the source chamber and to the remote fission-product collection stations. When not in use in the source chamber the californium sources are placed in the storage cylinders.

Capillary lines have been installed in the pipeline which extends to the radiochemistry laboratory. Gross fission-product activity has been transported with transmission efficiencies of approximately 80% from the cell to a collection system in the chemistry hood for studies of short half-life (<5 min) fission-product isotopes.

CONCLUSIONS

A shielded-cell facility for storing and handling remotely up to 2 milligrams of unencapsulated ^{252}Cf has been built at the TRA of the INEL. Unique features of this facility are its bulk radiation shield of borated gypsum and transfer lines which permit the transport of fission-product acitvity from within the cell to nearby laboratories. Borated gypsum was found to be an excellent shield for the neutron and gamma radiation associated with ^{252}Cf sources and its use made possible the construction of a relatively compact laboratory-scale cell. A gas-jet technique has been used successfully to transport fission-product activity from within the cell to a remote radiochemistry system for studies of the decay properties of short half-life fission-product isotopes.

ACKNOWLEDGEMENTS

The Radiation Shielding Information Center at ORNL provided the ANISN calculations. M. S. Coops provided valuable suggestions related to shield material evaluation and cell design.

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LIST OF FIGURES

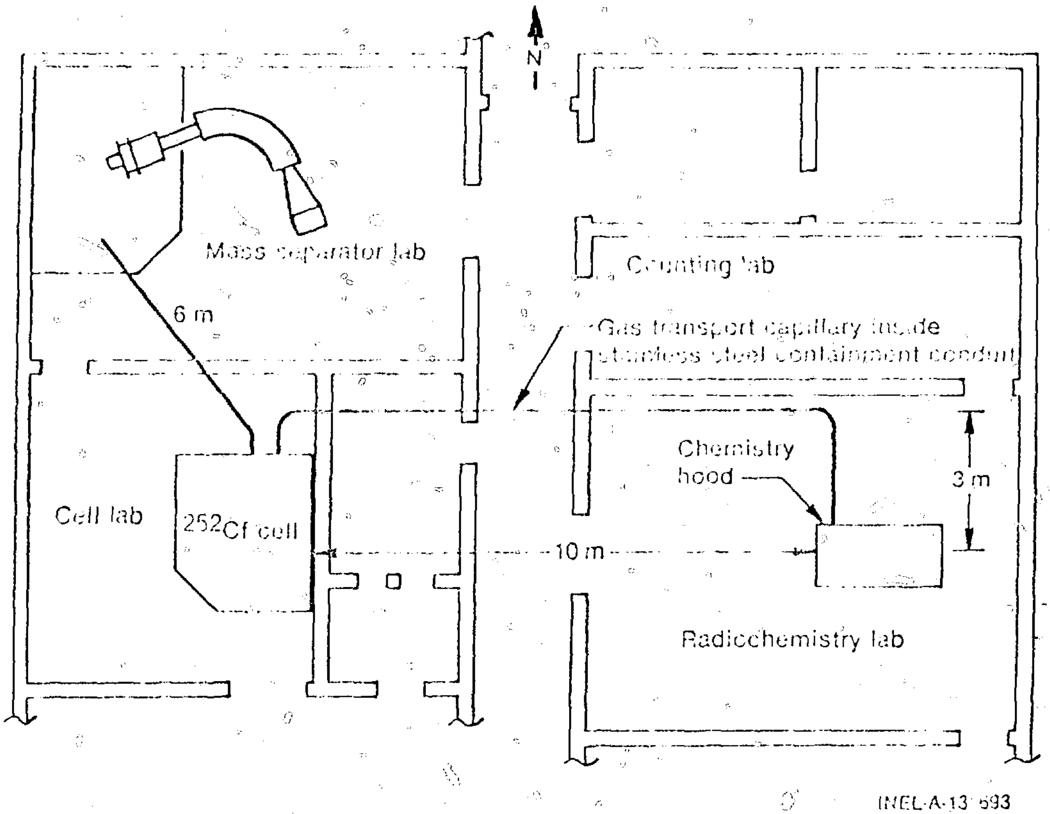

Figure 1. Floor plan of the laboratory wing which contains the californium cell and the mass separator and radiochemistry laboratories.

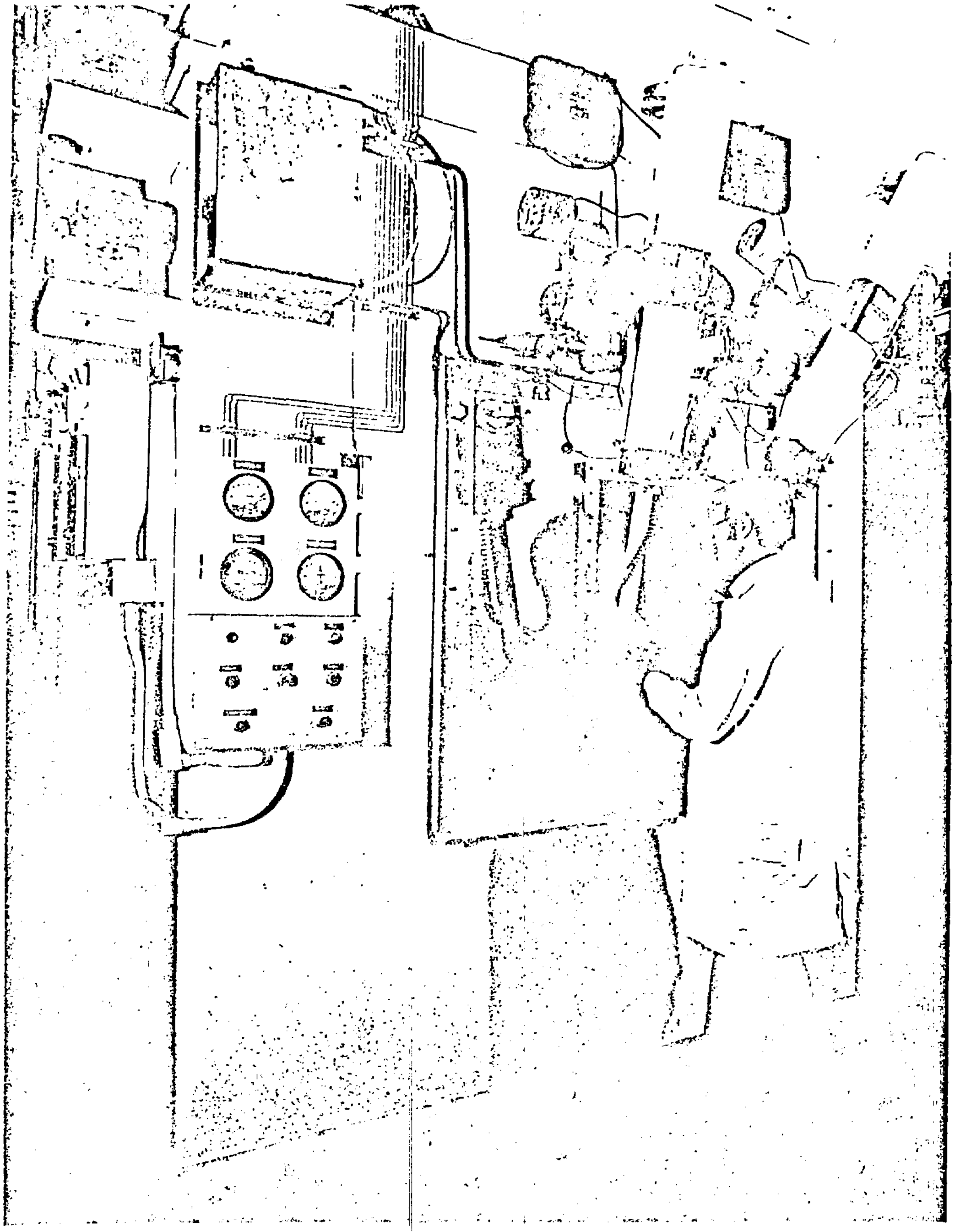

Figure 2. Photograph of the west and north faces of the californium cell.

Figure 3. View of the cell interior and the "in-cell" gas-jet hardware.

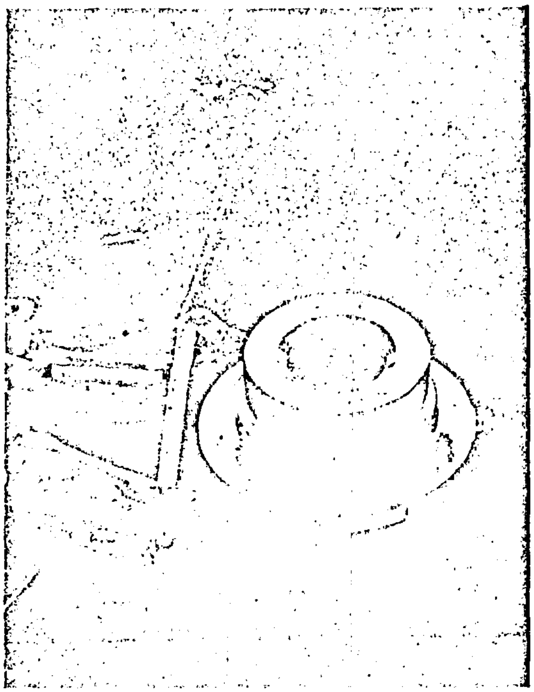

Figure 4. Photograph of the californium source holder with attached nickel window.