THE MOUND 1 KW PACKAGE - A NEW PACKAGE FOR THE SHIPMENT OF RADIOACTIVE MATERIALS

Paul Bales, Andy Langston, and Corwin Robinson
H&R Technical Associates, Inc.

ABSTRACT

Under the sponsorship of the DOE Office of Special Applications, EG&G Mound Applied Technologies, with safety analysis support provided by H&R Technical Associates, has developed a new package certified to transport Type B quantities of Fissile Class I plutonium heat source material. The package has been designed to provide a containment system that can withstand the normal conditions of transport, as well as those conditions associated with the hypothetical accident conditions, as defined in 10 CFR 71.

This package consists of a personnel shield (cage) that completely encloses a stainless steel cask. The contents of the package are contained in welded stainless steel cans—one or more primary containment vessels inside a secondary containment vessel. These cans meet the double containment requirement in 10 CFR 71 for plutonium shipments. The maximum gross weight of the packaging plus contents is 408 kg. The overall height of the package is 89.5 cm. The overall base is 78.1 cm square. The thermal evaluation allows for shipment of material emitting up to 1000 watts of heat for the various payloads.

Analysis of the cask was based upon allowable stresses as defined by ASME Boiler and Pressure Vessel Code, Section VIII. Stresses calculated in the containment vessels were compared to stress intensities per the ASME Code, Section III. Initial use of the 1 KW package will be to ship plutonium oxide powder from Russia.

INTRODUCTION

Since the late 1980s, the market for high-grade nuclear materials has steadily increased while U.S. production has dwindled. To meet our needs for space exploration and medicine, new sources of these materials had to be found. With the fall of communism and the opening of doors in the former Soviet Republics, some of the world's largest stock piles of high-grade nuclear materials have been placed on the world market in an effort to help stabilize the weak Russian economy. To take advantage of this opportunity as well as to enable safe shipping of such materials as are available within the U.S., a new Type B shipping container was designed to transport these materials from Russia and from U.S. production facilities.

The Mound One Kilowatt (Mound 1 KW) package was designed for EG&G Mound Applied Technologies, Inc., to transport various forms of heat-source-grade plutonium oxide for space applications. The first use of the package will be to ship plutonium oxide powder from Russia. The Mound 1 KW package was designed to comply with the regulations that govern the transport of Type B quantities of Fissile Class I material.

PACKAGE DESCRIPTION

The Mound 1 KW package, identified as USA/9516/B( ), consists of a personnel shield (cage) that completely confines a stainless steel cask. Fig. 1 shows the assembled package. Within the cask, the contents of the package are contained in two completely welded, cylindrical, stainless steel cans, one inside the other (1). Owing to the double containment requirement in 10 CFR 71 for plutonium shipments, the containment boundary consists of these two stainless steel cans used as a primary containment vessels (PCV) and a secondary containment vessel (SCV). Each PCV and SCV is to be used for only one shipment. The maximum gross weight of the package plus contents is 408 kg. Fig. 2 shows the confinement boundary of the package and the two levels of containment.

The containment vessels can hold any one of three content configurations. The first configuration is a general purpose heat source (GPHS) module (Fig. 3). The second configuration is multihundred watt isotope heat source (MHW-IHS) fuel sphere assemblies (FSAs) (Fig. 4). The third configuration is a maximum of either eight plutonium dioxide powder product cans (the package is currently certified to ship only this configuration), sixteen GPHS fueled clad assemblies in welded cans, or eight GPHS graphite impact shell (GIS) assemblies in threaded product cans (Fig. 5).

Design Intent

The Mound 1 KW package is designed specifically for transportation of up to 1 kilowatt of plutonium dioxide heat source material. Guidelines used for the design include criteria regarding frequency of use and storage and handling requirements.

Handling features are based primarily on use of a forklift. For short moves, where a forklift is not practical, the shipping container may be moved using a hand pallet truck. The shipping package was not designed to be lifted with chains or cables from an overhead hoist. The shipping container is designed so that loading and unloading operations may be performed quickly and with readily available tools to avoid unnecessary radiation exposure.

Regulations do not require use of materials specifically intended for shielding; however, the cask body, containment vessels, and packing material do provide some attenuation of the radiation. The external radiation level requirements of 10 CFR 71 for a single package are met by 1) restrictions of the amount and isotopic content of the plutonium source material, 2) the distance between the source material and the external surface of the package, and, for multiple package shipments, 3) proper spacing of the packages (six total) on the transport vehicle.

The package was designed to dissipate 1000 watts of heat during normal transport conditions and to maintain a temperature of less than 82 degrees Celsius at the external surface of the personnel shield. Therefore, the package meets the external surface temperature requirements for exclusive use shipments.

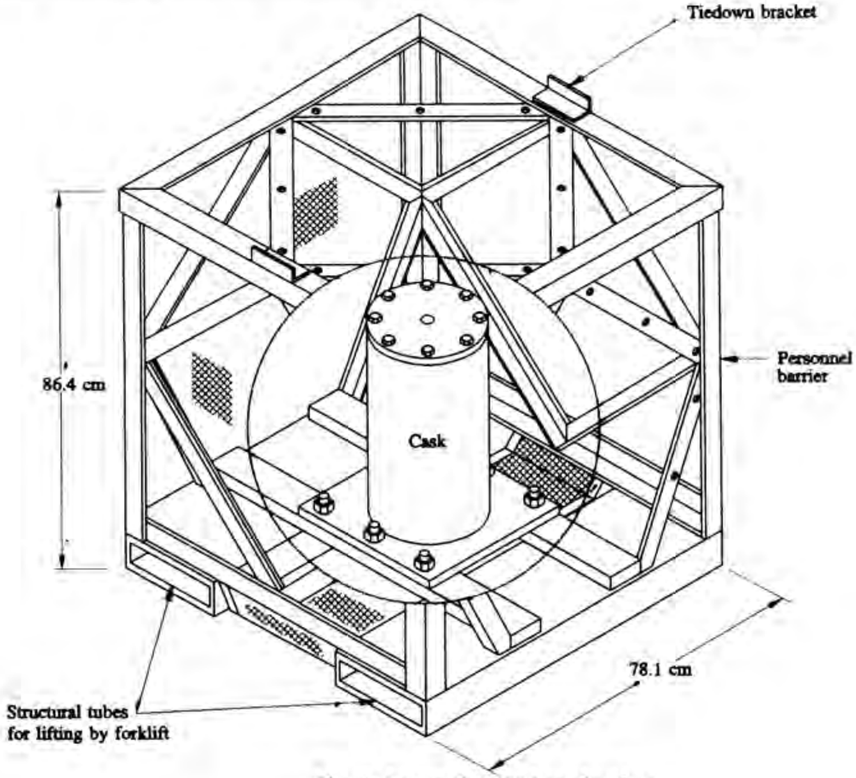

Fig. 1. Mound 1 KW packaging.

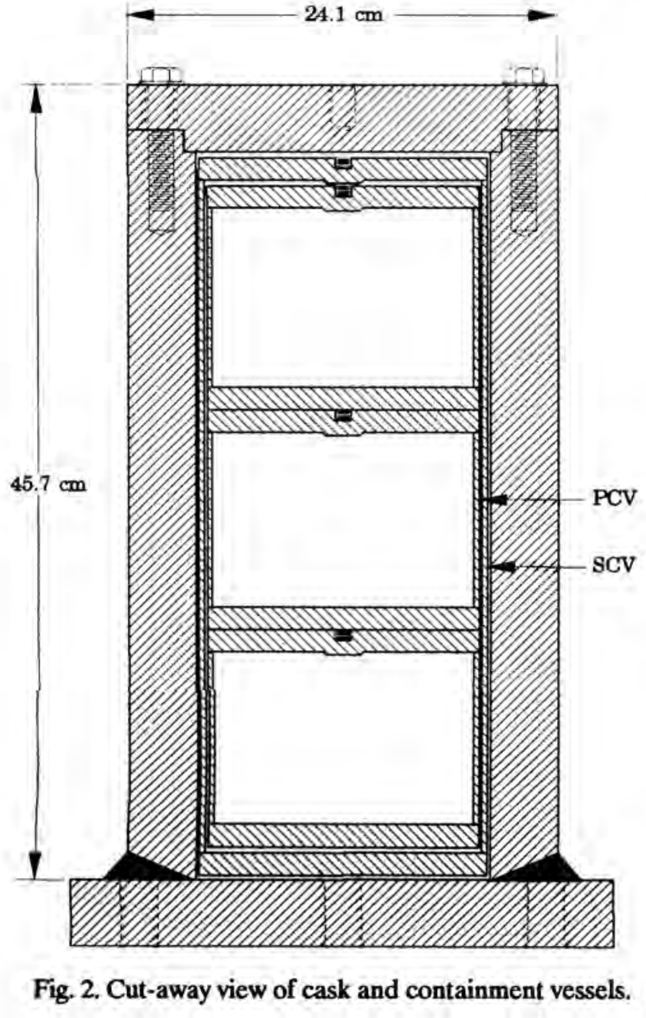

Fig. 2. Cut-away view of cask and containment vessels.

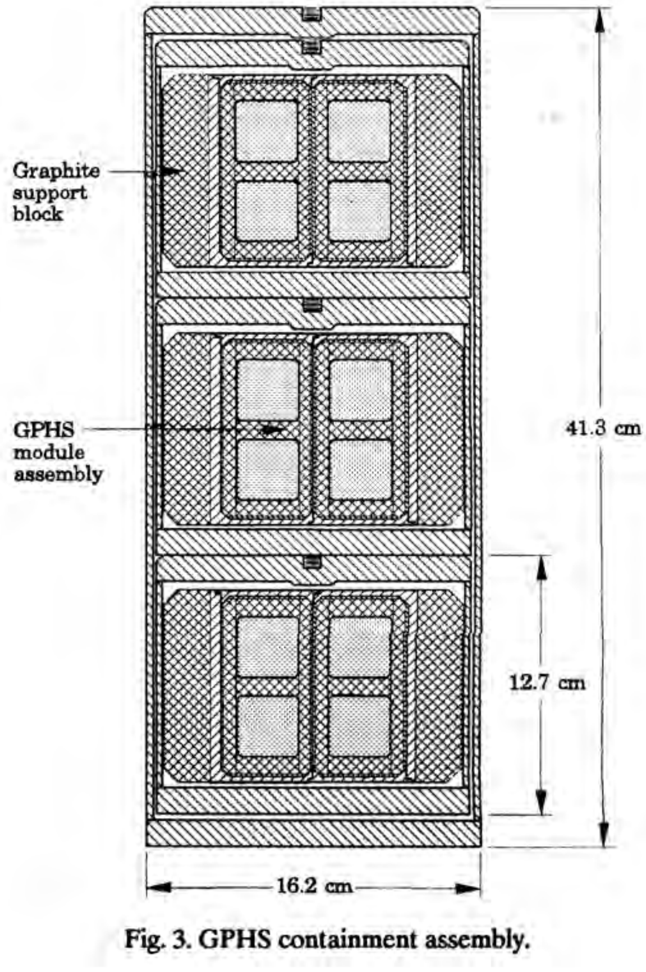

Fig. 3. GPHS containment assembly.

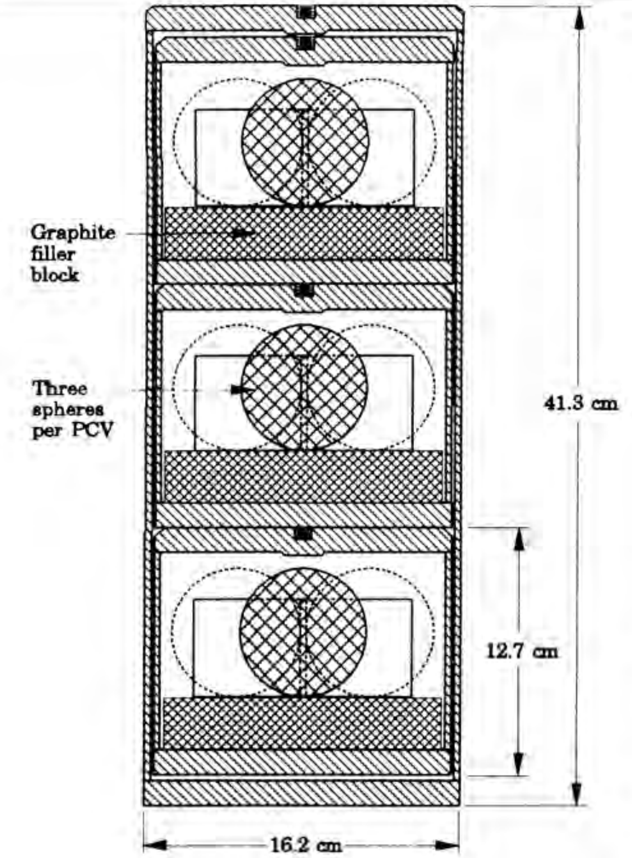

Fig. 4. MHW-IHS containment assembly.

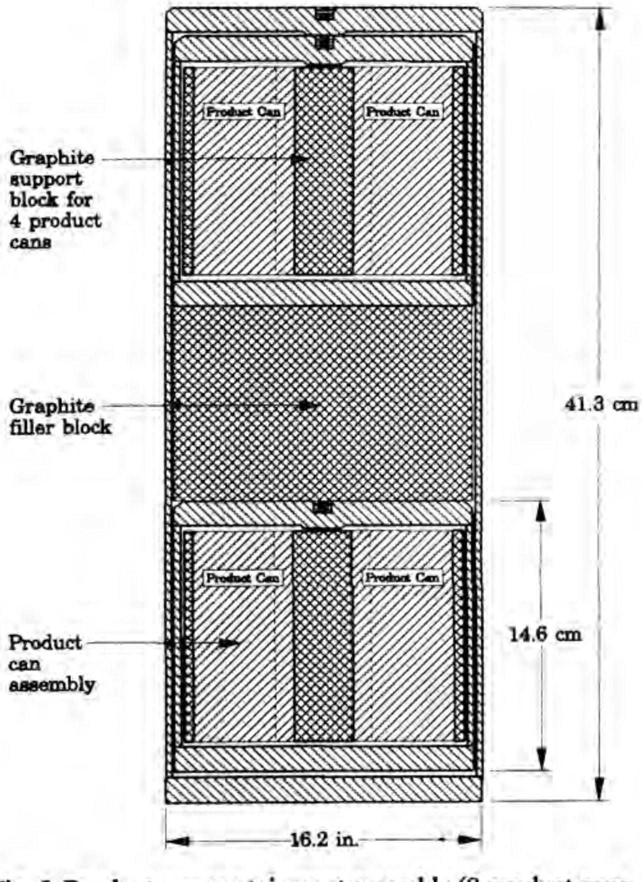

Fig. 5. Product can containment assembly (8 product cans total).

Personnel Shield

The personnel shield, which consists of a stainless steel frame and stainless steel wire mesh, is illustrated in Fig. 1. The personnel shield provides protection from heat and radiation and also serves as an impact limiter for the stainless steel cask. The base of the shield is constructed as a steel pallet that can be lifted from either of two directions. Tie-down brackets on the frame are used to secure the shipping container within the transport vehicle. The personnel shield is of welded construction and weighs approximately 227 kg. The overall height of the personnel shield is 89.5 cm, including the cage lid. The overall base is 78.1 by 78.1 cm.

The personnel shield is fabricated entirely of Type 304 stainless steel except for the structural tubes at the base, which are constructed of Type A-500 carbon steel or equivalent. The personnel shield is less than 91.4 cm high to provide easy access to the stainless steel cask. The base of the personnel shield is shown in Fig. 1. The base consists of two rectangular hollow structural tubes 20.3 cm wide, 10.2 cm inches high, and 1.27 cm thick with a total length of 76.2 cm. The structural tubes allow forklift or hand pallet access from two sides for lifting the entire package. Two 76.2-centimeter-long, 7.62 x 3.8-cm bars are welded across the structural tubes as attachment points for the baseplate of the cask. Six 2.1 cm holes are drilled in the 7.6 x 3.8-cm bars to provide attachment points for the baseplate of the cask. The framework is fabricated of 5.1 x 5.1 x 0.95-cm angle. Bracing of the framework is provided by 3.8 x 3.8 x 0.64-cm angle. Regular stainless steel wire mesh is welded to the framework so that heat can escape although the cask is completely enclosed during shipment. The top and side covers are made of 3.8 x 0.95-cm stainless steel plate bolted to the frame with 0.64 cm - 20 UNC oval head, 18-8 stainless steel, Phillips machine screws.

Cask

The cask was designed to provide confinement of the package contents during normal conditions of transport (NCT) and hypothetical accident conditions (HAC). For added safety, the cask was designed in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code (2). The cask is shown in Fig. 2.

The cask is a 3.8-cm-thick welded stainless steel vessel that has an overall height of 49.5 cm and an outside diameter of 24.1 cm. The interior of the cask has been machined to produce a 41.9-cm-deep cavity with a diameter of 16.5 cm. The containment vessels (PCV and SCV) are inserted into this cavity. A 3.8-cm-thick lid is attached to the cask body by eight 1.27 -13 UNC x 5.08-cm grade B6(410) bolts. All eight closure bolts have a hole drilled through the bolt-head for the placement of a wire-type security seal. The security seal is placed on any two bolts to prevent inadvertent opening of the cask. The lid is sealed with an Inconel X750 aluminum-jacketed seal (O-ring) that has a cross-sectional diameter of 0.33 cm. A 1.59 x 2.54-cm, stainless steel, shoulder-style eye bolt is used to lift the lid and place the cask into the personnel shield. The baseplate of the cask is a 35.6 x 30.5 x 3.8-cm plate welded to the cask body. To provide attachment points to the personnel shield, six 2.1-cm holes are drilled in the baseplate of the cask. Six 1.91-10 UNC x 11.4-cm grade B6(410) bolts, heavy hex nuts, and stainless steel lock washers secure the cask to the personnel shield. The weight of the empty cask is approximately 129.3 kg.

Containment Vessels

During shipment, the contents will be contained inside stainless steel cans that function as primary and secondary containment vessels (PCV and SCV). The stainless steel cans are designed to remain leaktight during NCT and HAC in accordance with the standard for leaktightness in the American National Standard ANSI N14.5 (3). For added safety, the stainless steel cans were designed in accordance with Section III, Subsection NB of the ASME Boiler and Pressure Vessel Code (4).

The containment vessels are constructed of Type 304L stainless steel tubing that has a minimum wall thickness of 0.30 cm. The 304L stainless steel base plate and cover plate of the vessels are 1.27 cm thick. Two different can sizes are used as the PCVs: 15.2 cm outside diameter by 12.7 cm tall and 15.2 cm outside diameter by 14.6 cm tall. The SCV is 16.2 cm outside diameter by 14.3 cm tall. To assist in loading and unloading of the containment vessels, a 0.95-16 threaded hole is tapped into the cover. A 0.15-cm groove is provided on both the PCV and SCV to assist in opening with a pipe cutter or by other means.

The PCVs and SCVs are sealed with full penetration welds using Type ER 308L welding wire. Welding wire is added to prevent solidification cracking of the weld. All welds of the PCVs and SCVs are radiographed and helium leak checked to determine their acceptability.

The GPHS module will be shipped in 12.7-cm-tall PCVs (Fig. 3) . The GPHS module is held in position by a graphite support block. The graphite support block is designed to fit snugly inside the PCV to keep the contents in a fixed position during shipment. The block is machined to form a recess for the GPHS module. Once assembled, three of the 12.7-cm-tall PCVs can be placed into the SCV.

MHW-IHS FSAs will be shipped in 12.7-cm-tall PCVs (Fig. 4). Three or fewer MHW-IHS FSAs are shipped in a single PCV. A sphere separator is used to space the spheres equally. The clearance between the spheres and the separator is small enough to prevent any unnecessary lateral movement of the spheres. However, since the FSAs are being shipped for recovery, damage that may result from lateral movement is not a concern. A graphite filler block is used to fill excess void space. Three of the 12.7-cm-tall PCVs can be loaded into a single SCV.

The threaded and/or welded product cans are shipped in 14.6-cm-tall PCV's (Fig. 5). Two 14.6-cm PCVs separated by a graphite support block are placed in a single SCV. Four or fewer product cans are shipped in a single PCV. A graphite filler block spaces the upper and lower PCVs and prevent movement. Three content configurations will be shipped in the 14.6-cm PCV. The three configurations are 1) threaded and/or welded plutonium dioxide powder can in a threaded and/or welded product can, 2) GPHS fueled clad assemblies in a welded product can, and 3) GPHS graphite impact shells (GIS) in a threaded product can.

Operational Features

As noted previously, the Mound 1 KW package is designed to be lifted by two structural tubes (Fig. 1) that are attached to the base of the personnel shield. These tubes are compatible with a forklift. Other operational features include the personnel shield, which serves as a physical barrier to prevent unnecessary contact with the cask.

The stainless steel cask serves as the confinement boundary of the package. The lid of the cask is secured by eight 1.27-cm closure bolts and lock washers. An aluminum jacketed Inconel X750 seal (O-ring) aluminum jacket is used to maintain a tight seal. The cask is lifted by a 1.59-cm shoulder bolt. The shoulder bolt is used to lift the cask or aid in the removal of the cask lid. The shoulder bolt is removed during shipment to prevent use as a lifting device for the package.

Contents of Packaging

The total decay heat of the contents of the package can not exceed one kilowatt. Administrative controls will be placed on the loading arrangements to ensure that the maximum wattage is not exceeded.

Plutonium 238 is the principal isotope to be transported in the Mound 1 KW package. The weight percent of plutonium that is plutonium 238 will range from 79.5% to 89.5% for different mixtures. As the weight percent of plutonium 238 is increased in a mixture of plutonium dioxide, the weight percents of the other fissile plutonium isotopes, plutonium 239 and 240, are reduced. The weight percent of plutonium that is plutonium 239 could range from 18% to 8% for different mixtures. The weight percent of plutonium that is plutonium 241 will be less than 1% for all mixtures. The fissile isotopes of uranium, uranium 235 and 233, will be present only in trace amounts.

An additional loading restriction is required to assure the maximum pressure buildup in a PCV remains below the allowable pressure. The allowable pressure is the pressure in a PCV under HAC above which localized secondary stresses can exceed the ultimate strength of the PCV material. Failure is not predicted to occur at the allowable pressure.

The pressure in a PCV results from thermal expansion of the gases, that is, the argon cover gas and helium generated from the alpha decay of the plutonium. To limit buildup of helium, a restriction of 1 year is placed on the length of time that the PCV can be welded shut. Under this condition, pressure buildup is dependent on the curie content (wattage) and the void volume in the PCV. The maximum pressure will occur at 1 year under HAC thermal conditions. Therefore, a PCV with contents shall not remain welded shut for more than 1 year.

DETAILED DESCRIPTION OF PACKAGE CONTENTS

The General-Purpose Heat Source (GPHS) Module

The General-Purpose Heat Source (GPHS) module is a component of the radioisotope thermoelectric generator (RTG) that will provide power for a number of space missions. To ensure public safety, the GPHS module was designed to contain its plutonium heat source following a severe accident. A series of tests were performed to simulate an aborted space mission with subsequent reentry and Earth impact (5). The test series included a simulation of an accident resulting in the explosion of the space shuttle and/or liquid-fueled Centaur rocket.

Product Can Assemblies

Detailed here are two typical product cans used for shipment in the Mound 1 KW package. The first type of product can has a threaded lid. The second type has a welded lid. The dimensions given are nominal values.

The threaded product can is constructed of Type 304 or 304L stainless steel. The can has a height of 10.8 cm and an outside diameter of 5.08 cm. The wall thickness is 0.30 cm and the base is 0.49 cm thick. The lid has an overall thickness of 1.59 cm inches with 0.97 cm threaded. A 0.05-cm-thick gasket provides the seal.

The welded product can is constructed of Type 304 or 304L stainless steel. The can has a height of 11.02 cm and an outside diameter of 5.08 cm. The wall thickness is 0.15 cm. The base and lid of the can have thicknesses of 0.25 and 0.89 cm, respectively. A full penetration weld seals the can. The product cans may carry several different content configurations. Some of these are one or two GPHS fueled clad assemblies in a welded product can; one GIS with two GPHS fueled clad assemblies in a threaded can; and a plutonium dioxide powder can in a threaded and/or welded product can.

Plutonium Dioxide Powder Can in Threaded Product Can

The plutonium dioxide powder can is a 8.59-cm-tall stainless steel tube that has a 4.45-cm outside diameter. The wall thickness of the can is 0.476 cm. The lid and base are 0.25 and 0.51 cm thick, respectively. The can is designed to hold 130 grams of plutonium dioxide powder. A 0.05-cm- thick copper gasket is used to seal the plutonium powder can.

REFERENCES

1. "Packaging and Transportation of Radioactive Material, Code of Federal Regulations," Title 10, Part 71, Washington, D.C.
2. "ASME Boiler and Pressure Vessel Code, Rules for Constructions of Pressure Vessels, Section VIII, Division 1," New York (1989).
3. "American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment," N14.5-1987, American National Standards Institute (1987).
4. "ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Division 1 - Subsection NB," New York (1989).
5. "General Purpose Heat Source Safety Verification Programs:" 1. "Edge-on Flyer Plate Test," LA-10872-MS (1987); 2. "SVT-1 through SVT-6," LA-10353-MS (19850; 3. "SVT-7 through SVT-10," LA-10408-MS (1985); 4. "SVT-11 through SVT-12," LA-10710-MS (1968); 5. "Bullet/Fragment Test Series," LA-10364-MS (1985); 6. "Explosion Overpressure Test Series," LA-10697-MS (1986).