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Radioisotope Thermoelectric Generator Licensed Hardware Package and Certification Tests

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Westinghouse
Hanford Company Richland, Washington

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Abstract

This paper presents the Licensed Hardware package and the Certification Test portions of the Radioisotope Thermoelectric Generator Transportation System. This package has been designed to meet those portions of the *Code of Federal Regulations* (10 CFR 71) relating to "Type B" shipments of radioactive materials. The licensed hardware is now in the U. S. Department of Energy licensing process that certifies the packaging's integrity under accident conditions. The detailed information for the anticipated license is presented in the safety analysis report for packaging, which is now in process and undergoing necessary reviews. As part of the licensing process, a full-size Certification Test Article unit, which has modifications slightly different than the Licensed Hardware or production shipping units, is used for testing. Dimensional checks of the Certification Test Article were made at the manufacturing facility. Leak testing and drop testing were done at the 300 Area of the U.S. Department of Energy's Hanford Site near Richland, Washington. The hardware includes independent double containments to prevent the environmental spread of ^{238}Pu, impact limiting devices to protect portions of the package from impacts, and thermal insulation to protect the seal areas from excess heat during accident conditions. The package also features electronic feed-throughs to monitor the Radioisotope Thermoelectric Generator's temperature inside the containment during the shipment cycle. This package is designed to safely dissipate the typical 4,500 thermal watts produced in the largest Radioisotope Thermoelectric Generators. The package also contains provisions to ensure leak tightness when radioactive materials, such as a Radioisotope Thermoelectric Generator for the Cassini Mission, planned for 1997 by the National Aeronautics and Space Administration, are being prepared for shipment. These provisions include test ports used in conjunction with helium mass spectrometers to determine seal leakage rates of each containment during the assembly process.

INTRODUCTION

The Radioisotope Thermoelectric Generator (RTG) Transportation System Package consists of the following: (1) two independent containment systems, (2) an impact limiter, (3) a personnel thermal barrier, and 4) a tie-down securing system. The RTG Transportation System Package is a Type B(U) packaging system that is used to transport an RTG (Alderman 1992) or similar radioactive materials. Specifically considered in the design of the package and in the safety analysis report for packaging (SARP) is the General Purpose Heat Source (GPHS) RTG payload, which is the type of RTG planned for the Cassini Mission. This RTG is classified as Fissile Class III and contains sufficient quantities of plutonium to warrant the special requirements of Title 10, *Code of Federal Regulations*, Part 71.63, "Special Requirements for Plutonium Shipments," (10 CFR 71).

The package is mounted on its own shock-resistant transportation skid to protect the RTG from shock and vibration. The entire Licensed Hardware package is secured to the transport skid by two tie-down straps that cross over the outer containment vessel (OCV) between its "fins." The package and transportation skid is transported within an exclusive-use trailer. The OCV packaging also includes two active cooling loops welded to the OCV's outer surface to ensure the RTG's maximum allowable temperatures are not exceeded, thereby maintaining the operational reliability of the RTG in outer space. These double pitch cooling loops that spiral along the OCV's outer surface are made of 6.4-mm (0.25-in.) by 31.8-mm (1.25-in.) bar and covered with 10 gauge in between the ribs forming 25.4-mm (1-in.) by 51-cm (2-in.) cooling channels. According to 10 CFR 71.51(b) these loops are not needed to satisfy 10 CFR 71.51(a) activity release limits. The packaging is shown in exploded view in Figure 1 and in the assembled partial cross section in Figure 2.

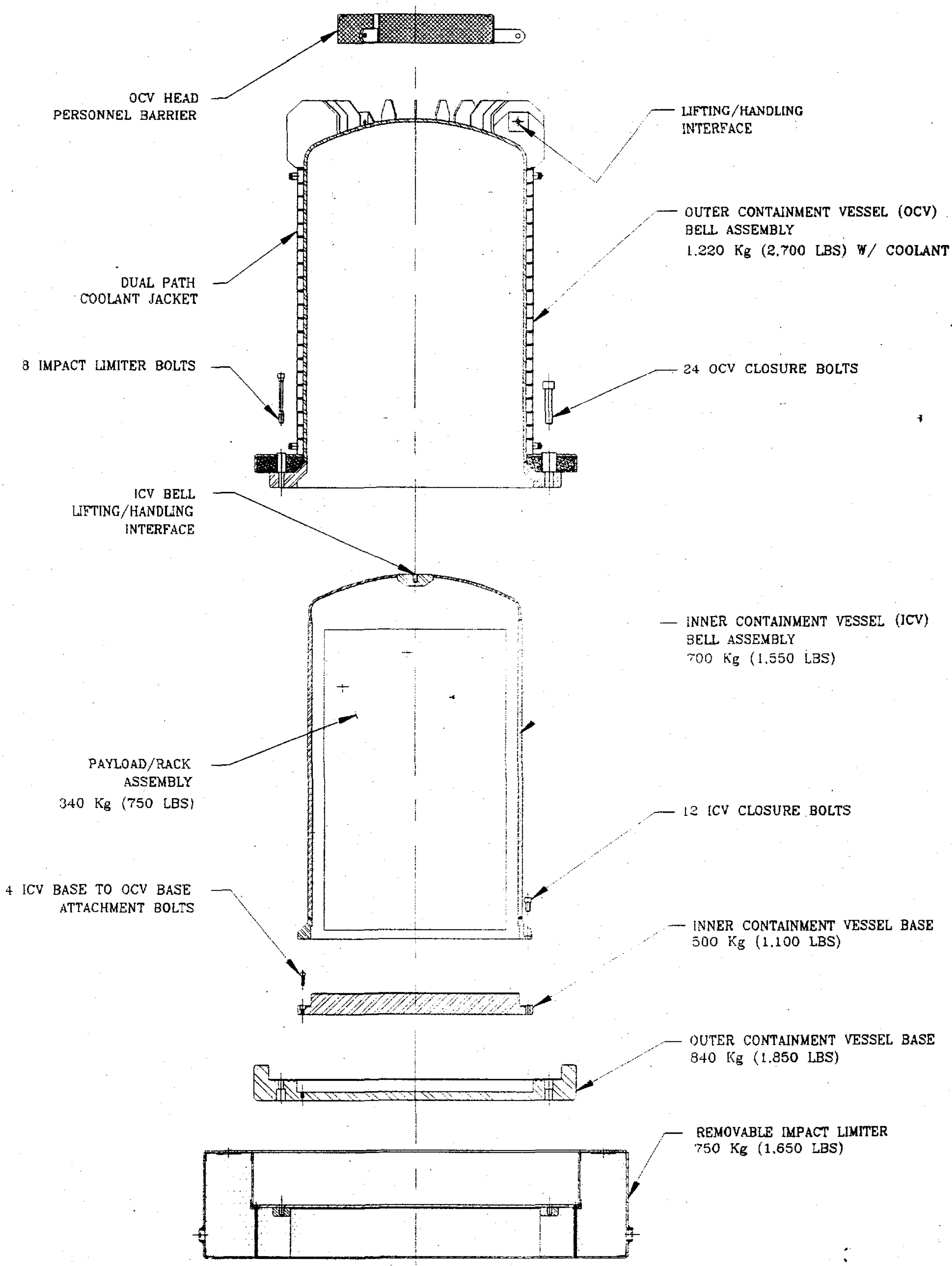

FIGURE 1. Licensed Hardware Assembly Exploded View.

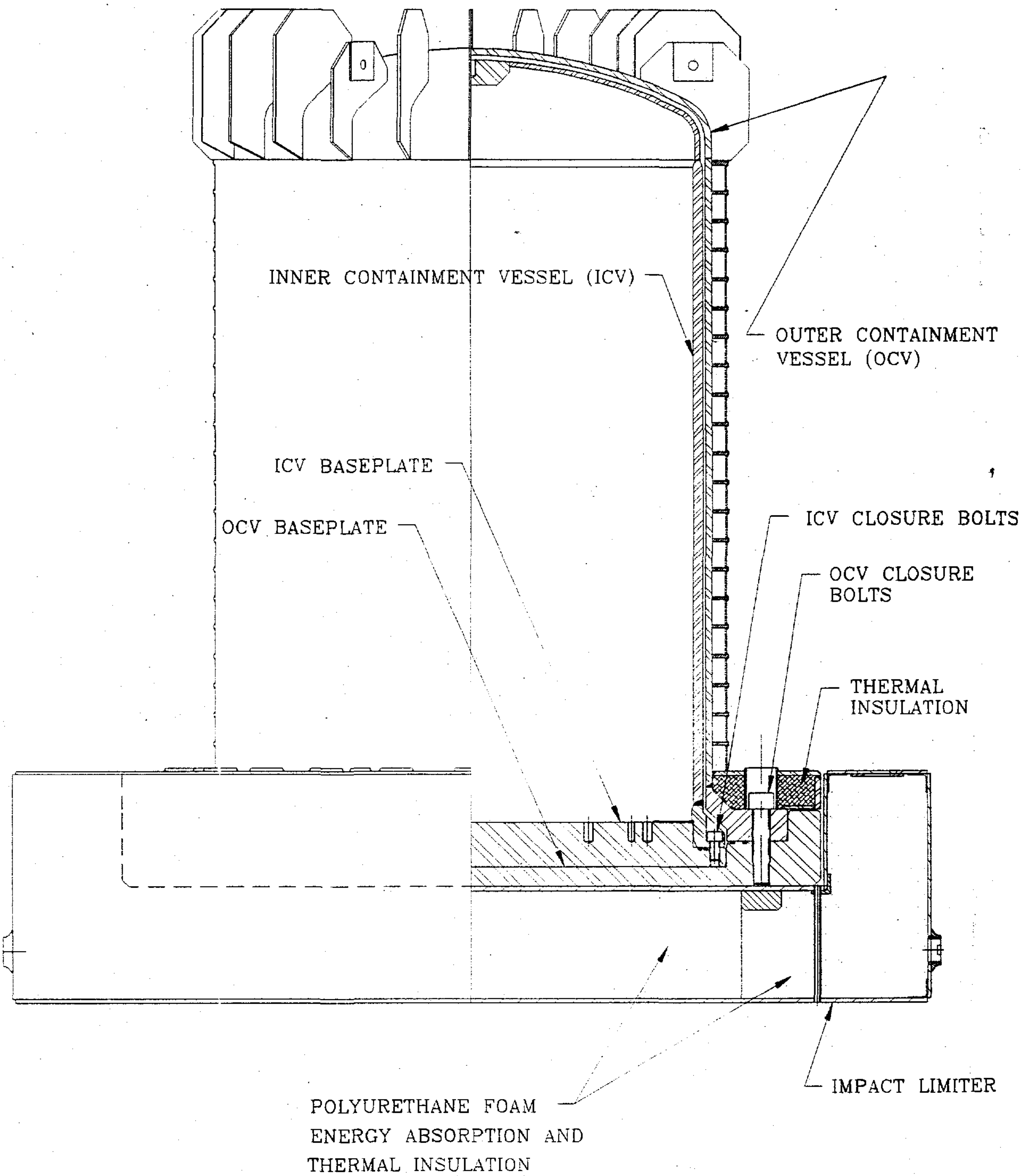

FIGURE 2. Licensed Hardware Assembly Partial Sectional View.

LICENSED HARDWARE PACKAGE DESCRIPTION

The package consists of double containment systems, an impact limiter, and a personnel barrier. The assembled package is approximately 1.9 m (77 in.) tall from the base of the impact limiter to the top of the OCV fins and 1.8 m (70 in.) in diameter at the base of the impact limiter. The assembled weight of the package is approximately 4,250 kg (9,350 lb) including the GPHS RTG, double containments, impact limiter, and personnel barrier.

Containment Systems

The containment systems are independent of each other and are assembled around the RTG payload. The containment systems except the O-ring seals and electronic feed-throughs are fabricated of Type 304L stainless steel. The domed portion of the containment systems is made of nested American Society of Mechanical Engineers torispherical heads. Each containment system consists of a containment vessel setting on a base plate.

The containment vessels are bell-shaped structures that use bolts through the vessel flange into the base plate to hold the containment system together. The inner containment vessel (ICV) consists of a 19.1-mm (0.75-in.) thick wall cylindrical section with a 9.5-mm (0.38-in.) thick head section. The ICV and the ICV base plate are fastened together using twelve 19.1-cm (0.75-in.) diameter alloy bolts. The OCV consists of 12.7-mm (0.50-in.) thick cylindrical wall and head. The OCV and OCV base plate are fastened together using twenty four 31.8-mm (1.25-in.) diameter alloy bolts. The cooling loops are welded to the outside of the OCV's major curvilinear surface. The primary seal between each vessel and its base plate is made with a face seal butyl O-ring. Another butyl O-ring located concentrically outside the primary containment O-ring serves to make a plenum to enable a check of the integrity of the primary containment O-ring seal.

Each containment system is fitted with helium fill ports, and in the case of the ICV, a second vent port. These ports are used to develop a 137.9 kPa (20 lb/in^{2}a) helium atmosphere inside their respective containment boundary. Each vessel also is equipped with leakage rate test ports that access the void between the concentric O-rings to determine the primary containment O-ring seal leakage rate. All vent and test ports are sealed with brass cap screws and fitted with butyl seals.

The electrical feed-throughs used are hermetically sealed and use a strain isolation design and are welded into the package base plates. These feed throughs are designed to accommodate all pressure buildups anticipated in the package during service and accident conditions.

The payload cavity on the inside of the ICV is 1.45 m (57 in.) high at the axial centerline and has an approximate diameter of .86 m (34 in.) The payload cavity also includes a payload shipping rack and barrier plate that secures the payload and insulates the ICV base plate seals and feed-through from any heat that may be generated inside the ICV. The barrier plate remains in place when subjected to the regulatory test requirements of 10 CFR 71.71 and 71.73.

Impact Limiter

The packaging includes an impact limiter that forms the base of the package. The limiter shell is made of Type 304 stainless steel and is filled with two densities of fire resistant polyurethane foam. The limiter's sides, pocket wall, and the annular top, outside of the OCV, is 6.4 mm (0.25 in.) thick. The impact limiter bottom is 7.9 mm (0.31 in.) thick and the pocket floor is 9.5 mm (0.375 in.) thick. This limiter also is equipped with meltout plugs for internal pressure relief and condensate drains for runoff from the OCV cooling jacket. The eight 19.1-mm (0.75-in.) diameter securing bolts to the containment systems are stretch bolts, which absorb impact energy in the 14-mm (0.55-in.) diameter necked down shank and "stretch" rather than break on impact.

Personnel Barrier

At the top of the OCV is a personnel barrier to prevent human contact with the OCV. This open mesh structure allows for air circulation to maximize the convective cooling in this area of the package. The personnel barrier is secured using the same three OCV's fin holes used to lift the package. Because these three OCV fins are reinforced, they are shorter than the remaining fins.

CERTIFICATION TEST ARTICLE DESCRIPTION

The Certification Test Article consists of the double containment systems enclosing a simulated payload and the attached impact limiter. Certain modifications for testing have been incorporated and are described below.

- The Test Article is exempt from the painting requirements of the fabrication drawings;

- Coolant is not placed into the OCV's cooling passages; the coolant relief valves are present;

- Electrical feed-through wiring and connectors are not electrically connected to a source of electric power or cabling outside the OCV;

- A 7.9-mm (0.31-in.) diameter hole is located in the center of the impact limiter bottom plate; the hole is used to measure foam deformation after drop testing and only passes through the bottom plate but not into the foam;

- Striping is applied to the package with the circumferential position of the electrical feed-through identified; four vertical stripes are applied from the bottom center of the impact limiter to the top center of the OCV's head, with one stripe aligning with the OCV's electrical feed-through penetration; a minimum of three circumferential stripes are applied on the OCV exterior, with one stripe at the center of gravity and one stripe 7.62 cm (30 in.) above this stripe; the third circumferential stripe is placed at the discretion of the Test Engineer; another stripe is placed circumferentially at the mid-point height of the impact limiter (i.e., the OCV's base plane);

- A 6.4-mm (0.25-in.) female, national pipe thread port is installed in each bell of the ICV and OCV, which provides access to the ICV or OCV cavity, respectively; these ports are used to introduce and remove the leak test helium gas;

- Accelerometer mounts and accelerometers are located on the Test Article OCV's exterior; and

- Supplemental seal test ports in the ICV flange and OCV base are located approximately 180 degrees from production seal test ports.

CERTIFICATION TEST ARTICLE TESTING

Manufacture Testing

At the manufacturer's facility, measurements are made of the seal areas including assembly with soft copper tubing in place of the O-ring seals to determine actual seal compression. An acceptance leak test was performed before shipping to Westinghouse Hanford Company in Richland, Washington.

Assembly and Leakage Rate Testing

The Test Article was dissembled at the 300 Area of the Hanford Site and reassembled with leakage rate testing performed on the ICV alone and subsequently on the OCV. Each vessel was tested in two stages. First, helium gas was introduced in a polyethylene enclosure around the vessel and a leakage rate detection performed using a mass spectrometer ported to the inside of the vessel. Helium gas is then placed inside the vessel and the primary seal is leakage rate tested by porting the mass spectrometer between the primary and outer test seals. During this test, the vent ports are leakage-rate tested.

Free and Puncture Drop Testing

After assembly and leakage rate testing, the Test Article is transported to the impact test pad. The test pad consists of a concrete block with a 0.2-m (8.5-in.) steel plate surface.

A series of five 1.2-m (4-ft) high free drop tests, which meet the "Normal Conditions of Transport," and five 9.1-m (30-ft) high free drop tests, which meet the "Hypothetical Accident Condition," were performed. For each of these tests, the Test Article was equipped with tri-axial and passive accelerometers.

Following the free drop tests, the Test Article is dropped 1-m (40 in.) onto a 152-mm (6-in.) diameter puncture bar in a series of nine tests. Video cameras were used to record all drops and impacts. Still photos of local damage were made after each test.

Evidence of pre-load torque loss of the OCV bolts was obtained at the end of the 1.2-m (4-ft) free drops and after each 9.1-m (30-ft) drop.

Disassembly and Leakage Rate Testing

After the drop tests, the Test Article was transported back to the 300 Area. The OCV was leakage-rate tested and removed; subsequently, the ICV was leakage-rate tested. The Test Article was then re-assembled and shipped to the manufacturer.

Post-Test Evaluation

The Test Article is disassembled and measurements previously made are repeated. Differences in these measurements are indicative of yielding in the sealing surface regions.

Acknowledgments

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