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Safety Analysis Report for Packaging (SARP)

Multihundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC)

J. F. Griffin, E. W. Johnson,
L. F. Rodriguez and D. L. O'Brien

Monsanto

ATOMIC ENERGY COMMISSION ★ UNITED STATES OF AMERICA ★

MOUND LABORATORY *Operated for the U.S. Atomic Energy Commission*

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Safety Analysis Report for Packaging (SARP): Multihundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC)

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Issued: June 28, 1974

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ABBREVIATIONS

cpm	counts per minute
dpm	disintegrations per minute
fps	feet per second
FSA	Fuel Sphere Assembly
GE	General Electric
GE-ESP	GE, Energy Systems Program (Philadelphia,Pa)
GE-SD	GE, Space Division
GE-VFSC	GE, Valley Forge Space Center
GIS	Graphite Impact Shell
HSA	Heat Source Assembly (same as IHS)
HSSC	Heat Source Shipping Container (same as MHW-IHS-SC)
IHS	Isotope Heat Source
LASL	Los Alamos Scientific Laboratory (University of California)
MHFT	Multi-Hundred (Watt) Fuel (Sphere) Tag; usually followed by a number to identify each sphere
MHW	Multi-Hundred Watt
MHW-IHS-SC	Multi-Hundred Watt Isotope Heat Source Shipping Container
ML	Mound Laboratory (Monsanto Research Corp., Miamisburg, Ohio)
MRC	Monsanto Research Corporation
μm	Micrometer or micron
ORNL	Oak Ridge National Laboratory, Tennessee
PICS	Post Impact Containment Shell
PISA	Post Impact Shell Assembly
RSC	RTG Shipping Container
RTG	Radioisotope Thermoelectric Generator
SPC	Storage Protection Container
WTHS	Walk-Through Heat Source

LIST OF ILLUSTRATIONS

FOREWORD

This report is a compilation of Monsanto Research Corporation (MRC) documentation of development activities to satisfy U. S. Atomic Energy Commission and U. S. Department of Transportation shipping and safety requirements as related to the transportation of packages containing nuclear materials. In this case,we are concerned mainly with the Multi-Hundred Watt Isotopic Heat Source Shipping Container. A great deal of supporting documentation has also been supplied by General Electric Company and has been modified for presentation in this Safety Analysis Report for Packaging (SARP) as Appendix III.

Although many MRC and GE engineering drawings and specifications have been reduced or reformatted, all are controlled documents with appropriate references to their latest technical updating and editorial changes. For this reason, many specifications are preceded by a lead sheet indicating the original total number of pages and date of latest revision.

To obtain the latest revision to any engineering drawings or written specifications, inquiries may be directed to the following address:

Monsanto Research Corporation
Mound Laboratory
Attention: Drawing Control
Engineering Department
Miamisburg, Ohio 45342

SUMMARY

This Safety Analysis Report for Packaging (SARP) satisfies the U. S. Atomic Energy Commission's request for a formal safety analysis of the Multi-Hundred Watt (MHW) Isotope Heat Source shipping container. The report makes available to all potential users the technical information and limits pertinent to the construction and use of this shipping container. This SARP includes discussions of structural integrity, thermal resistance, radiation shielding and radiological safety, nuclear criticality safety, and quality control. Much of the information was previously submitted to AEC/OSD/ALO as a draft of this SARP and provided the basis for obtaining interim approval to ship until the SARP could be finalized. A complete physical and technical description of the package is presented. The packaging consists of a finned cask completely enclosed within a cage-type carrier and the contents consist of a high integrity MHW heat source producing nominally 2400 W from the decay of 4.2 kg of ^{238}Pu isotope in the form of a solid oxide. The results of the nuclear criticality safety analysis show that 6.3 kg of Pu may be shipped as Fissile Class I, whereas the MHW heat source contains only 5.3 kg of total plutonium.

Design and development considerations, the tests and evaluations required to prove the capability of the containers to withstand normal transportation conditions, and the sequence of four hypothetical accident conditions (free drop, puncture, thermal and water immersion), are discussed.

Tables, graphs, dimensional sketches, photographs, technical references, loading and shipping procedures, Mound Laboratory's experience in using the container, and a copy of the AEC/OSD/ALO interim certificate of compliance are included. An internal review of this SARP has been performed in compliance with the requirements of AECM 5201-Part V.

INTRODUCTION

AEC Manual Chapters 0529 and 5201[1] require a Safety Analysis Report for Packaging (SARP) for each shipping container to be used for shipments of quantities of radioactive material which exceed specified limits. A draft SARP was prepared and reviewed by Monsanto Research Corporation, Mound Laboratory, and submitted to the Operational Safety Division of the Albuquerque Operations Office (OSD/ALO), U. S. Atomic Energy Commission, in December, 1973. The draft provided the basis for the Interim Certificate of Compliance (AEC-AL USA/9503 BLF) which was issued by the AEC in February, 1974. This SARP satisfies the AEC requirement for a final formal safety analysis of the Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC) (see Figure 1).

The SARP includes discussions of structural integrity, thermal resistance, radiation shielding and radiological safety, nuclear criticality safety, and quality control.

As of June, 1974, one shipment, the MHW "Q-1" heat source, was made in the MHW-IHS-SC and a second MHW heat source, designated "F-1", was successfully packaged (see Figures 2 and 3) and is temporarily being stored in the shipping container at Mound Laboratory. The "Q-1" heat source was unpackaged by GE personnel at King of Prussia, Pennsylvania, and no problems were encountered.

The MHW-IHS-SC is designed to transport the MHW encapsulated radioisotopic heat source outside the plant boundaries. It meets the requirements of both the Department of Transportation[2] and the Atomic Energy Commission,[3] and the unique requirements of the MHW heat source. A complete physical and technical description of the package is presented. The MHW-IHS-SC packaging consists of a finned cask completely enclosed within a cage-type carrier. The finned cask is a stainless steel helium leak-tight cylindrical container which is designed specifically for the MHW heat source. External fins are provided to dissipate the heat from radioactive decay of the plutonium. Figures 4 through 7 show additional details of the finned cask including the mounting pins, and vibration and shock isolators (Figure 4), the guide pins (Figure 5), the flexible stainless steel hose (Figure 6), and the finned cask cover (Figure 7). The carrier consists of a metal mesh cage welded to a steel base, which can be easily handled using a fork lift or hand pallet truck. During shipment of the Storage Protection Container (SPC), the void between the SPC and the finned cask is filled with an atmosphere of 99% pure helium. The valves and gauges for the helium filling operations are shown in Figure 8. Instrumentation is provided to monitor and record temperature, shock, and vibration during loading, transportation, and unloading operations. The temperature sensors are shown in Figure 9. The maximum allowable gross weight of the loaded package is taken to be 3000 lb, although the actual gross weight when containing a MHW heat source is somewhat less than 2700 lb.

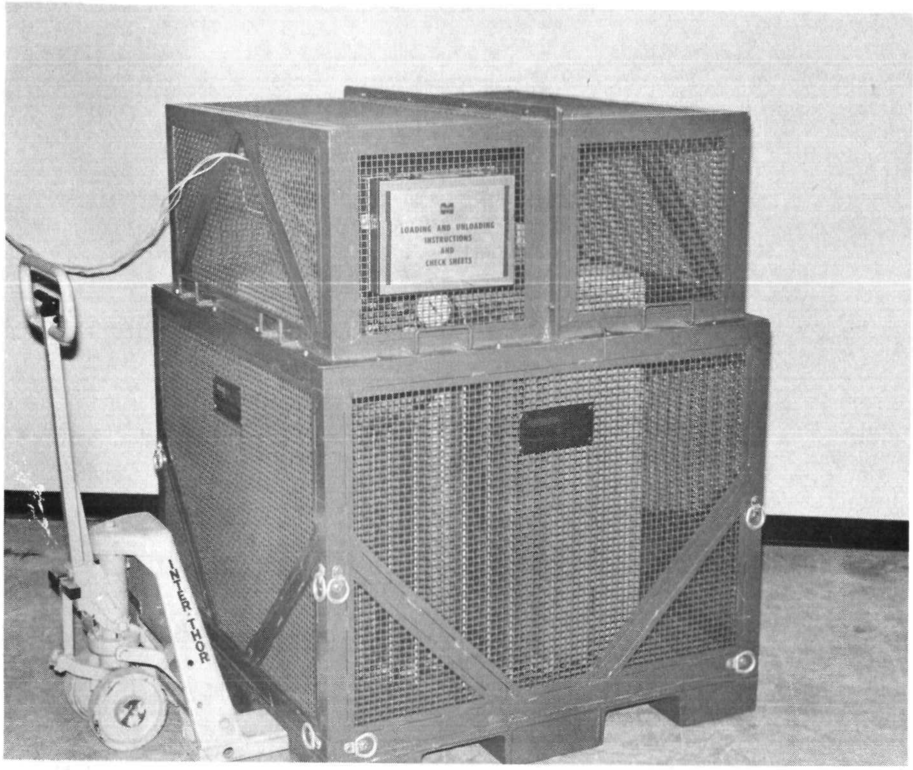


FIGURE i-1 - Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC).

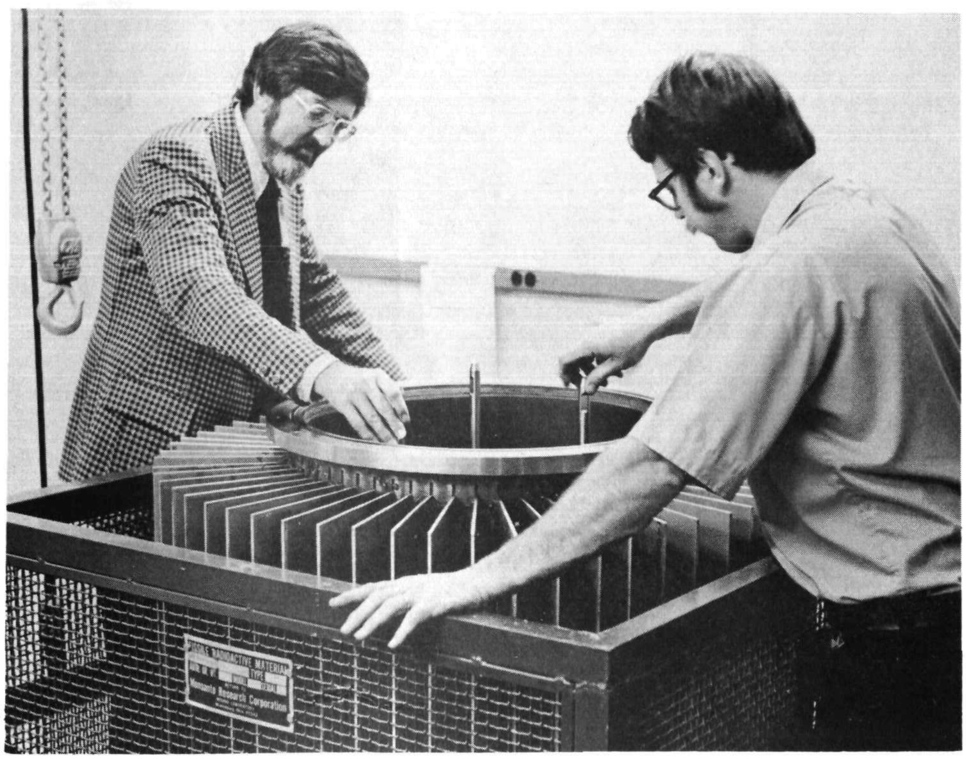


FIGURE i-2 - Final preparations are being completed prior to loading the MHW "F-1" heat source into the shipping container.

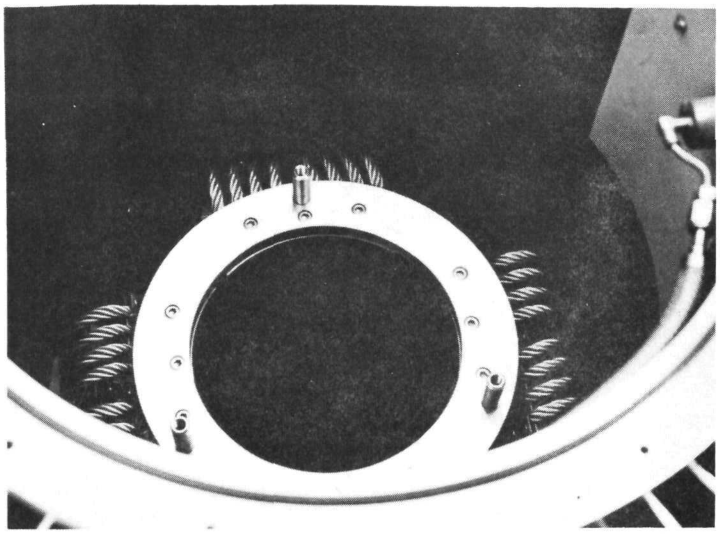


FIGURE i-4 - Three internally threaded pins are used to securely fasten the Storage Protection Container (SPC) inside the finned cask. Three of the four helical vibration and shock isolators are shown.

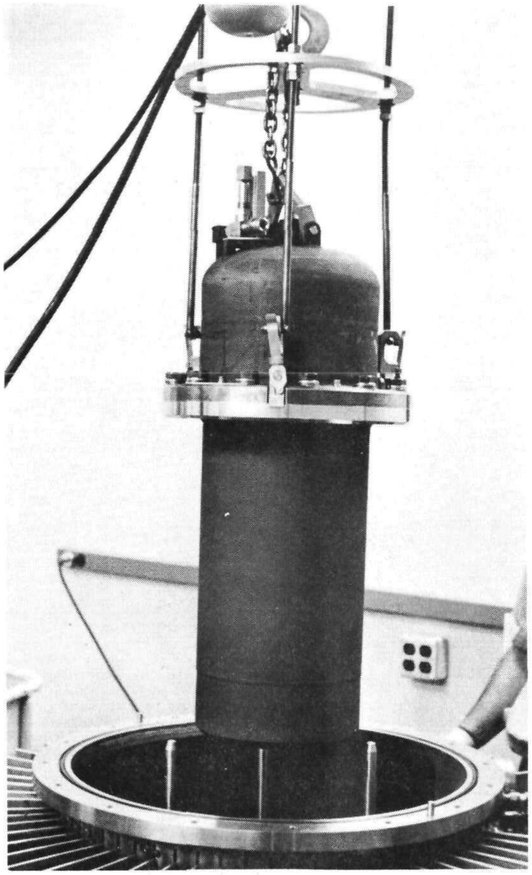


FIGURE i-3 - The MHW "F-1 heat source is contained within the Storage Protection Container (SPC) which is being lowered into the shipping container.

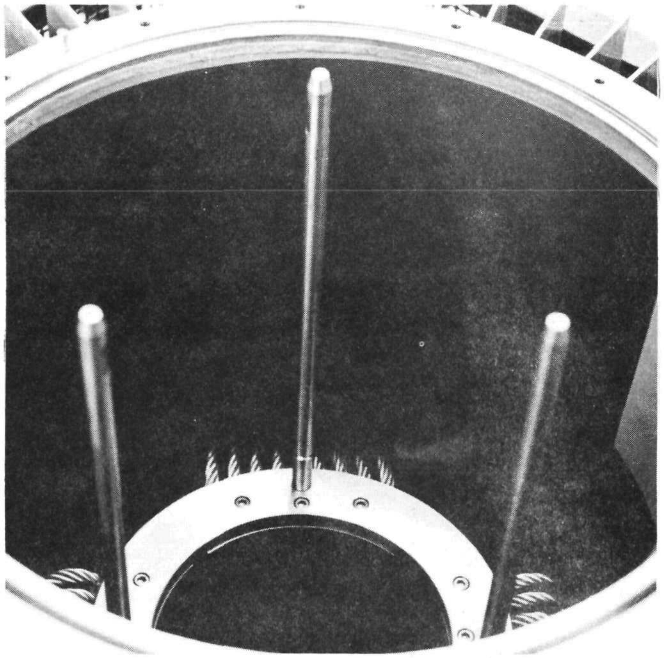


FIGURE i-5 - Three guide pins are temporarily fastened in place during loading operations. The black iron titanate emissive coating on the inside surface of the finned cask greatly enhances heat transfer.

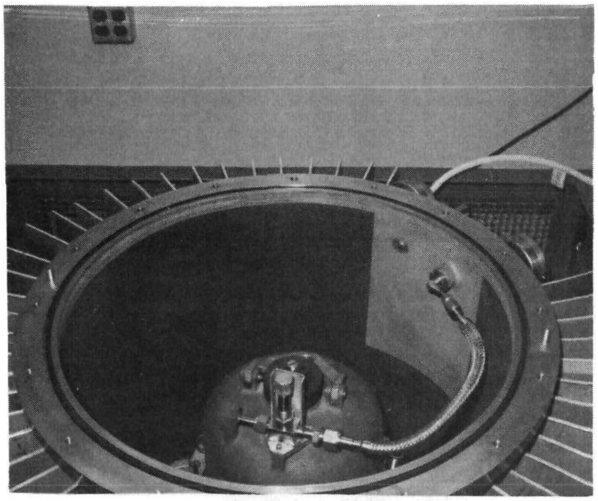


FIGURE i-6 - A flexible steel hose is provided for monitoring the Storage Protection Container (SPC) during storage operations.

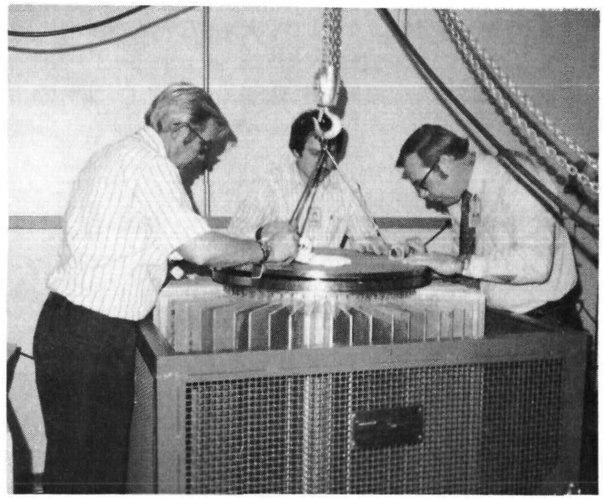


FIGURE i-7 - The finned cask cover is lowered in place using a hoist.

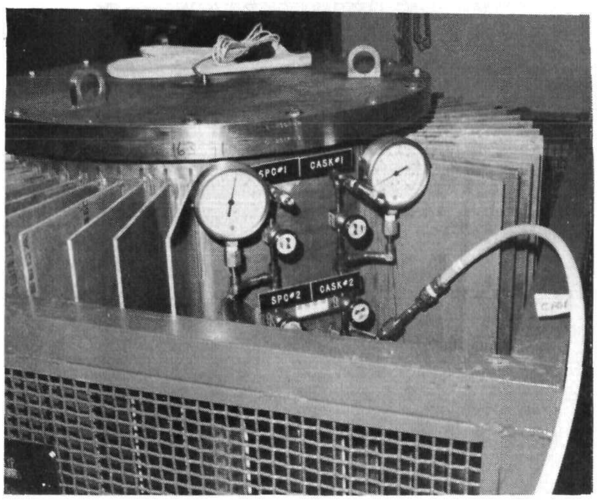


FIGURE i-8 - Gauges are provided to monitor the pressure of the helium atmosphere within the finned cask during shipment and storage.

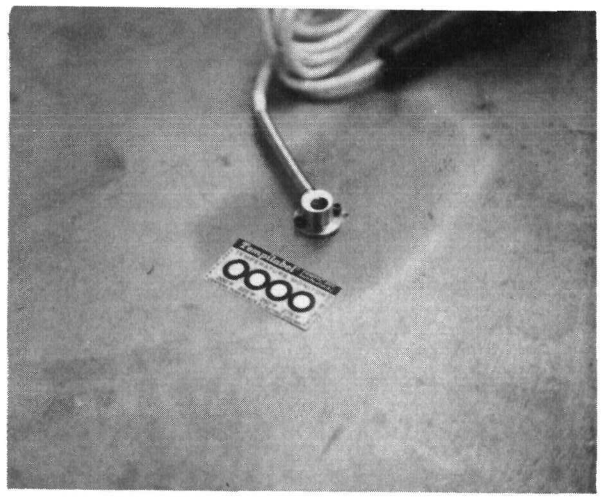


FIGURE i-9 - A temperature sensor and label are placed at the center of the finned cask cover during shipment.

The contents of the shipping container consist of a high integrity MHW heat source producing nominally 2400 W of heat from the decay of ^{238}Pu in the form of a solid oxide. The MHW-IHS-SC can safely dissipate up to 3500 W of thermal decay energy. Each MHW heat source contains approximately 4.2 kg (73,000 Ci) of encapsulated ^{238}Pu isotope. This amount is equivalent to a total of 5.3 kg of Pu which is approximately 80% ^{238}Pu, 16% ^{239}Pu, and 4% other Pu isotopes. The half life of ^{238}Pu is 87.4 yr. The fuel is hot pressed plutonium oxide, which is 80-85% of the theoretical density, encapsulated in a 0.025-in. wall iridium sphere within a 0.46-in. thick wound graphite protective sphere. A total of 24 such spheres are contained within a 0.010-in. thick iridium cylindrical can which is sealed inside a Storage Protection Container (SPC) for handling and shipping operations. Details of the MHW heat source design are provided in the CONTENTS OF PACKAGING section of this report. It is not intended that the contents of the MHW-IHS-SC be necessarily limited to the MHW heat sources, but no additional need for the shipping containers has yet been identified. It is intended that all shipments including other radioactive materials must be based on analysis of the shipments for the purpose of obtaining formal OSD/ALO approval.

Established quality control practices were used from the inception of the MHW-IHS-SC design to the final inspection and packaging operations. Several visits were made to the fabricator and records and photographs were used to document the progress. Figures 10 through 16 show various stages of progress during fabrication and testing including milling the grooves for the fins (Figure 10), dye penetrant examinations (Figure 11), the cask mounting tabs (Figure 12), the cask cover (Figure 13), attachment of the fins (Figure 14), the inside of the carrier (Figure 15), and installation of the finned cask in the carrier (Figure 16). Inspection criteria and packaging and unpackaging procedures are provided in Appendix I and Appendix II, respectively, of this report.

Extensive tests and evaluations were performed to show that the container will function effectively with respect to all required standards, and when subjected to normal transportation conditions and the sequence of four hypothetical accident conditions (free drop, puncture, thermal and water immersion). In addition, a steady state temperature profile test (see Figures 17 and 18), vibration test (see Figure 19), and shock test (see Figure 20) were performed. A nuclear criticality safety analysis determined that up to 6.3 kg of Pu may be shipped as Fissile Class I, whereas the MHW heat source contains only 5.3 kg of Pu.

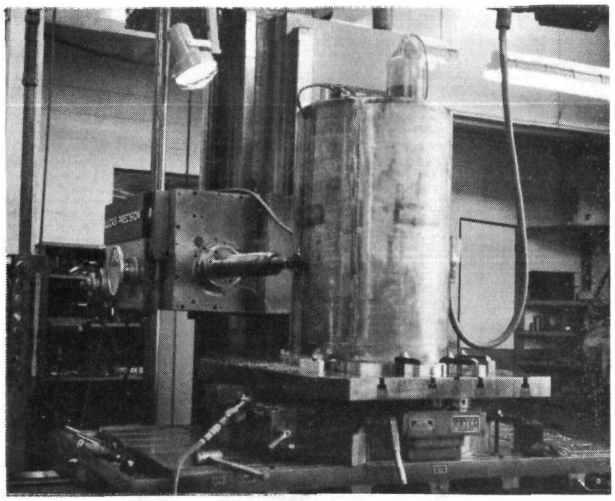


FIGURE i-10 - Grooves are milled in the cask body wall for securing the fins in place.

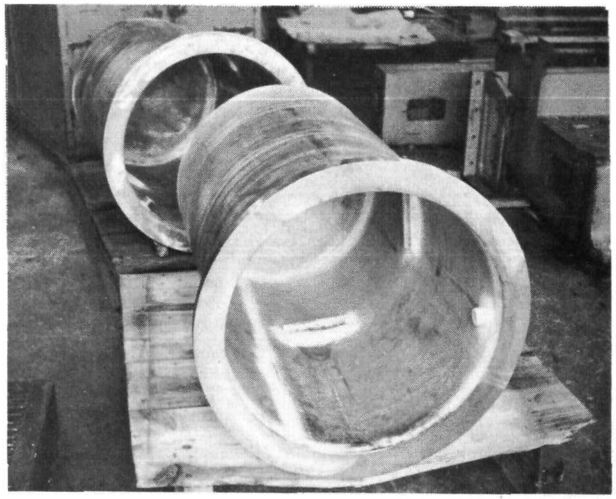


FIGURE i-11 - Dye penetrant examination of all welds on the cask body was performed.

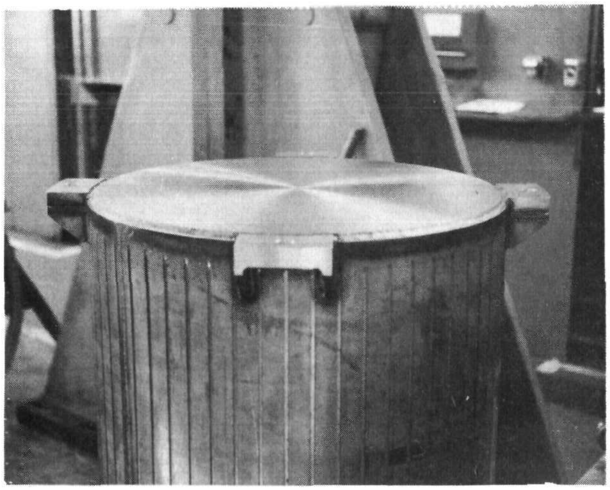


FIGURE i-12 - Four mounting tabs are located at the cask bottom.

FIGURE i-13 - The cask covers are shown during fabrication.

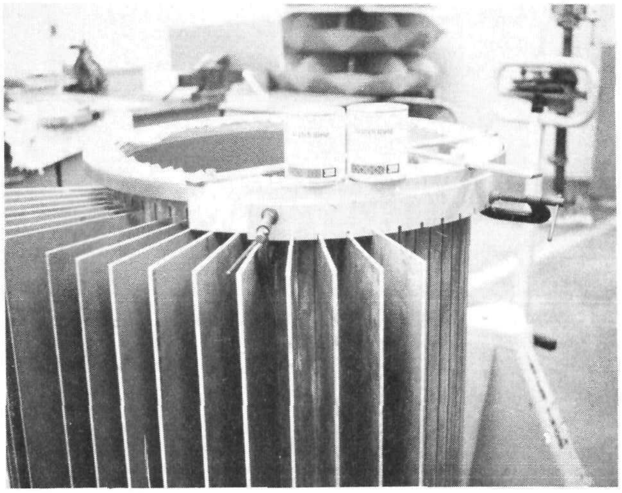


FIGURE i-14 - Special fixtures and adhesives were used to attach the aluminum fins to the stainless steel cask body.

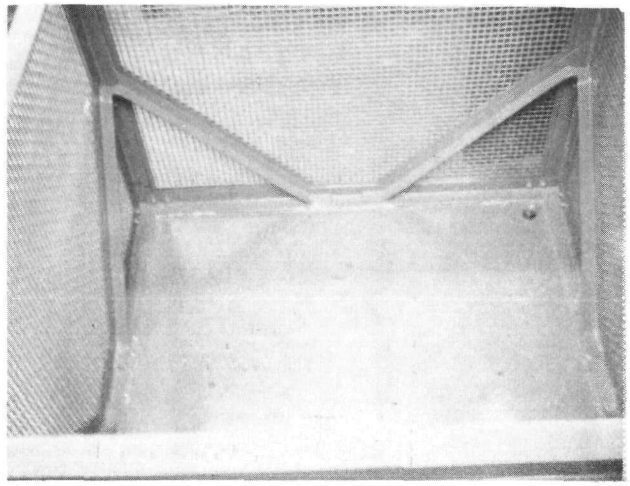


FIGURE i-15 - The inside of the carrier is shown prior to installation of the Finned Cask.

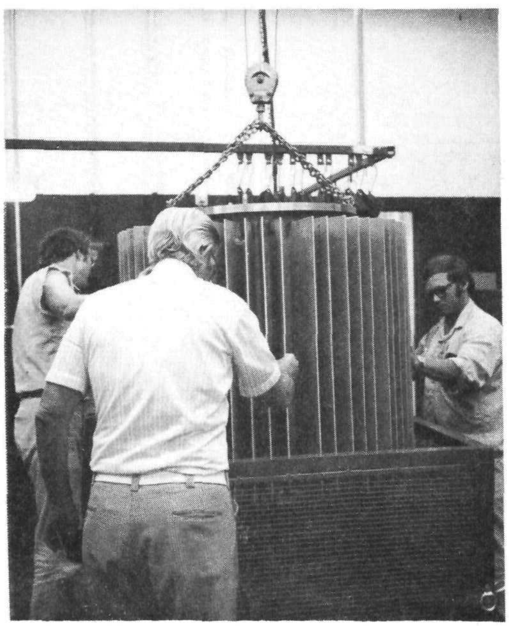


FIGURE i-16 - The finned cask is being installed in the carrier.

FIGURE i-17 - A steady-state thermal profile test was performed.

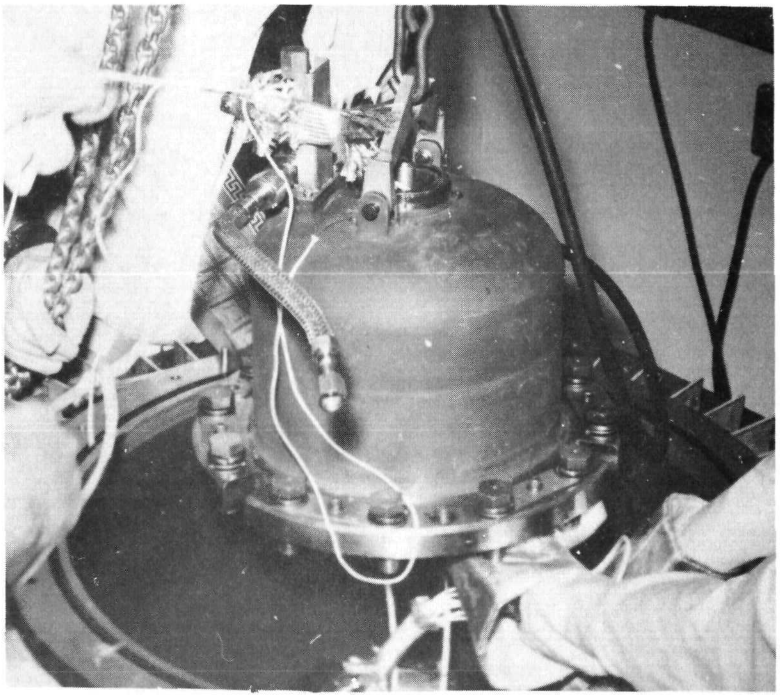


FIGURE i-18 - The Storage Protection Container (SPC) was disassembled while still hot after the thermal profile test.

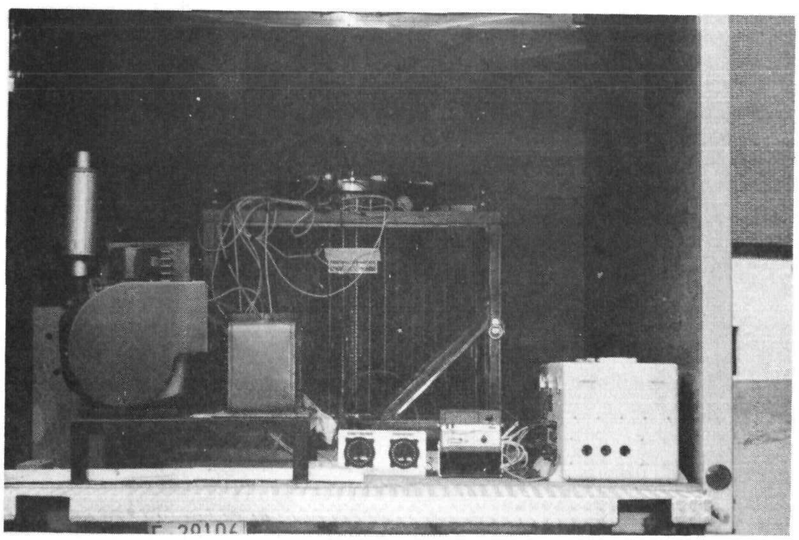


FIGURE i-19 - A road vibration test was performed to assure the shock and vibration isolators met design requirements.

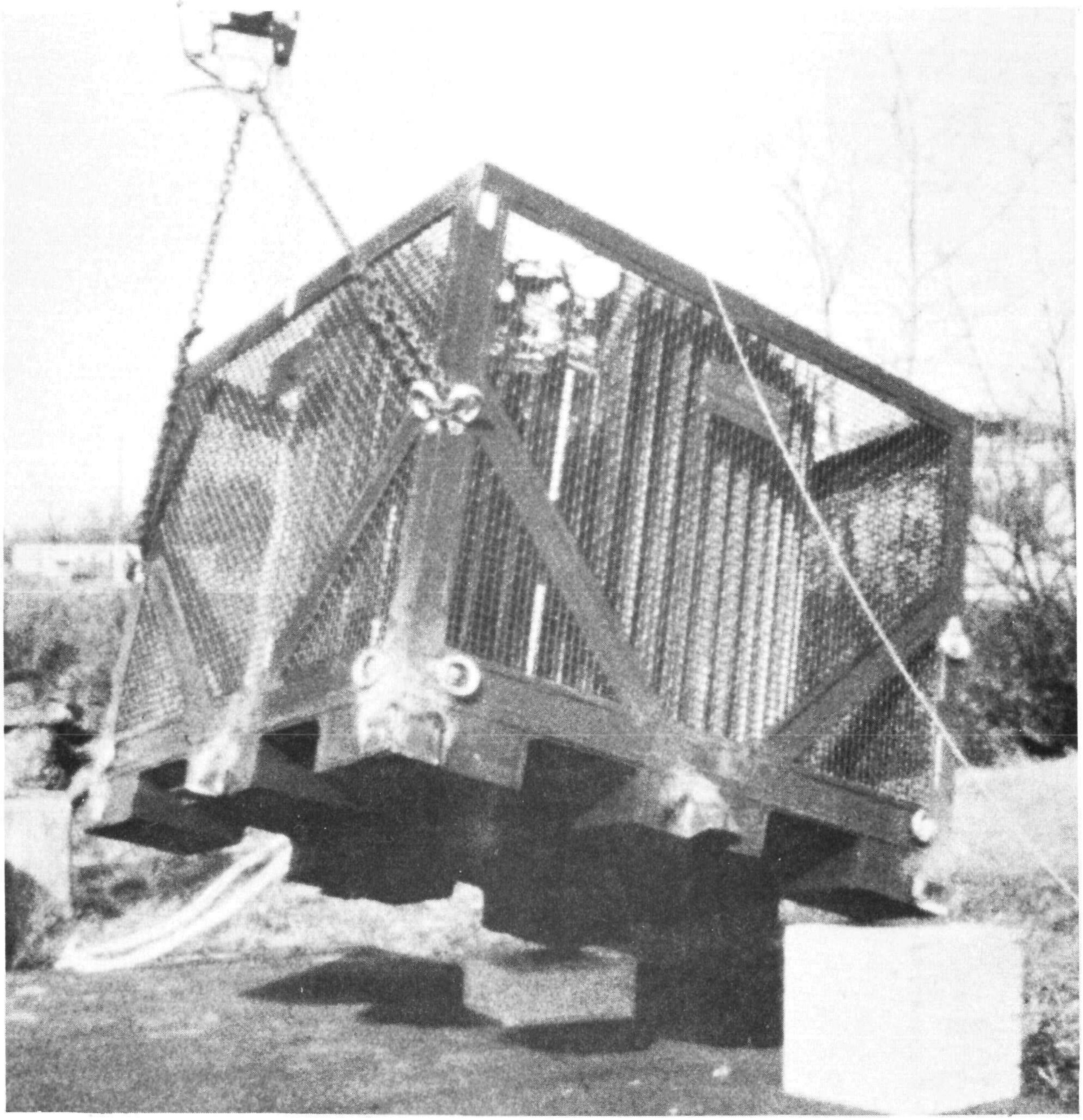


FIGURE i-20 - An 18-inch corner drop was performed to assure the shock and vibration isolators met design requirements.

CONCLUSIONS

When packaged within the specified limits, the MHW-IHS-SC is in compliance with the requirements of the AEC, the DOT, and the unique requirements of the MHW heat source. The package is fabricated in accordance with specified standards, will maintain its integrity during normal transport conditions, and will not release radioactive materials in excess of regulation requirements during hypothetical accident conditions.

It is intended that this section of the SARP will provide a summary of the conclusions which are determined in the subsequent sections of the report. In doing so, the parameters are established which are essential to safe use of the shipping container.

The shipping container is used for offsite shipments of high integrity MHW heat sources. Each heat source consists of 24 spherical modules. The 24 Fuel Sphere Assemblies (FSAs) provide the necessary containment for the radioactive plutonium to satisfy the safety requirements. An additional degree of protection is provided by the MHW-IHS-SC and the Storage Protection Container (SPC). Since it is not practical to demonstrate complete containment by the MHW-IHS-SC or the SPC, the MHW FSAs are considered the primary containment vessels. The SPC contributes to the containment and it is estimated to provide an attenuation effect of 10^{19} for PuO_2 vapor and 3 for any PuO_2 particulate material under normal transport conditions. It is estimated that a maximum of 3 μCi of plutonium could be released from the SPC at the hypothetical accident test conditions. This is far less than the maximum permissible amount of plutonium which is 0.01 Ci. The attenuation factors for accident conditions are 10^5 for vapor and 3 for particulates. This accounts for the possibility that the SPC will probably not be totally gas tight at accident conditions. Based on indirectly related test data, the internal surfaces of the SPC are not expected to become contaminated during normal transportation or after lengthy storage times. Oxygen leakage into the SPC during accident conditions could result in oxidation of only a small amount of graphite within the heat source. Thus, no PuO_2 release is expected as a result of graphite oxidation. The new frit type vents should present a higher degree of design confidence than the previous vent design (discussed in the draft SARP) because the data obtained for the new vents are more positive. It is concluded that the SPC/IHS will contain the radioactive PuO_2 within specified limits at accident conditions. Evaluation of the heat source materials proved that they will not cause the packaging to be breached under accident test conditions. It is not intended that the contents of the MHW-IHS-SC be necessarily limited to the MHW heat sources, but no additional need for the shipping containers has yet been identified. It is intended that all shipments of other radioactive materials must be based on analysis of the shipments for the purpose of obtaining formal OSD/ALO approval.

The steady state temperature profile of the shipping container, when containing an SPC, was determined to assure compliance with DOT/AEC regulatory requirements, compliance with GE product specifications, to establish the appropriate temperatures for evaluation of the contents, and to establish the maximum heat load capability of the shipping container. The maximum external surface temperature, when containing 2400 W, was found to be 135°F (57°C) under the carrier base plate. This is considerably cooler than 180°F (82°C), which is the maximum acceptable value for sole use shipments. The maximum SPC exterior surface temperature was determined to be 477°F (247°C). It is concluded that 200°F (93°C) is an appropriate temperature for evaluation of the finned cask pressure capability for normal transportation of the MHW heat sources. The results of the steady state temperature profile tests compare favorably with the design calculations. A maximum heat load of 3500 W was established for the contents of the shipping container. This is sufficiently low to assure a considerable margin of safety and sufficiently high to provide for anticipated requirements. (The MHW heat source produces nominally 2400 W.) When containing a heat source producing 3500 W, the maximum accessible external surface temperature was calculated to be 153°F (67°C), which is well below the 180°F (82°C) maximum for "sole use" shipments.

The internal pressure capability of the finned cask at various temperatures was thoroughly evaluated. The weakest component was found to be the bolted cover which has a maximum allowable working pressure of 43 psig at 100°F (38°C), 36 psig at 200°F (93°C), 28 psig at 500°F (260°C), and 23 psig at 1000°F (538°C). These results clearly demonstrate that the finned cask is capable of safe pressure containment for shipment of the MHW isotope heat source when pressurized to approximately 7 psig at 200°F (93°C). Also, the Viton o-ring will provide a seal indefinitely under these conditions.

A maximum content weight (SPC containing the IHS) of 270 lb is anticipated and, based on the design capability of the isolators, 300 lb is established as the maximum contents weight without additional evaluation or modifications. The maximum gross weight of the shipping container is taken to be 3000 lb, although the actual weight when containing a MHW heat source is approximately 2700 lb.

Extensive evaluations showed that the container will function effectively with respect to all required standards. In Part II of AECM 0529, general standards are specified for materials, closures, lifting devices, and tiedown devices in addition to structural standards pertaining to load resistance and external pressure. The packaging materials and the package contents will not cause any significant reactions even at hypothetical accident conditions. Positive closures prevent inadvertent opening and seals are secured to the closures during shipment. The lifting lugs for the finned cask cover, the carrier baseplate which is used for lifting the entire container, and the tiedown rings are shown to satisfy all requirements. The package capability exceeds the load resistance requirement by a factor of 100 and exceeds the external pressure requirement by a factor of 2.

Related testing and engineering evaluations adequately demonstrated that the requirements of the normal conditions of transport tests (heat, cold, pressure, vibration, water spray, free drop, corner drop, penetration, and compression) are satisfied although none of the tests was specifically performed for this purpose. Heat from direct sunlight at 130°F (54°C) or cold of -40°F (-40°C) will not increase or decrease the temperature of the packaging beyond design capabilities. The maximum temperature capability of the finned cask is established as 375°F (191°C). The 7.3 psi (0.5 atm) reduced external pressure requirement is well within the design capability. Road vibration tests and 18-inch corner drop tests were successfully performed and assured that the shock and vibration isolators met design requirements and provided evidence that normal vibration, and a 4-ft free drop or a 1-ft corner drop will not significantly reduce the effectiveness of the packaging. The water spray would have no adverse effect on the all-metal container. Calculations showed that the finned cask is capable of withstanding nearly 50 times the energy available from the penetration test without yielding and 20 times the energy load specified in the compression test without exceeding the maximum allowable stress.

Testing and evaluation of the shipping container when subjected to the sequence of four hypothetical accident tests verified that the container would not jeopardize the primary containment of the radioactive materials provided by the MHW heat source and would, in fact, provide additional protection. The free drop test was performed and evaluations of the puncture, thermal, and water immersion tests were performed. The results did not indicate there would be any damage that would cause release of the specified radioactive materials in excess of regulation requirements. The testing and evaluations also established design parameters for any subsequent modifications, and established parameters for evaluation of the radioactive materials. The 30-ft drop test was performed using a full scale MHW-IHS-SC, packaged with an SPC containing an electrical heat source simulator. The container was oriented in a flat upside down position to assure maximum damage to the SPC. The test severely damaged the carrier cage such that the finned cask was no longer attached to it nor would remain contained within it. The finned cask cover was distorted to the extent that the cask would no longer contain helium pressure. The stainless steel cask body remained intact and the SPC remained firmly secured to the fixtures inside the cask. There were no punctures to the SPC, changes in shape, or any other type of observable deformation of the SPC, except for damage to the SPC valve assembly. The valve mounting plates were damaged and the valve stem was broken, but there was no apparent damage to the fitting and tubing from the valve to the SPC. Disassembly of the SPC proceeded normally and there was no evidence of any damage that would affect the SPC metal o-ring seal. In addition to the actual drop test, potential damage resulting from a side or corner drop was considered. It was concluded that the actual drop test orientation caused as much or more damage to the SPC than any other orientation and provided the necessary information for subsequent evaluations of the shipping container. The puncture test will not puncture the finned cask cover since this requires 4 times the available energy. A conservative approach to the thermal evaluation was taken. The temperature profiles were calculated at steady state rather than only after a 1/2-hr long test. The resulting maximum temperature of the plutonium fuel was 2670°F (1466°C) which is less than the normal operating temperature of the fuel when operated with vacuum in the heat source gaps. The maximum surface temperature of the SPC was estimated to be 1581°F (861°C). The results indicate that the thermal test would not cause temperatures in excess of the normal operating temperatures of the PICS and fuel when operated with vacuum in the gaps. At the thermal test temperature of 1475°F (802°C), the finned cask will not contain the helium atmosphere, but will remain structurally rigid. Water will leak into the finned cask, but not into the SPC, as a result of the water immersion test. The thermal shock resulting from this test will not breach the containment vessels.

The criticality safety analysis, based on the density analog technique, established that the MHW-IHS-SC, containing up to 6.3 kg of plutonium, can be shipped as Fissile Class I, and up to 9.8 kg of plutonium can be shipped as Fissile Class II. (The MHW heat source contains only 5.3 kg of Pu.) These results are in agreement with more sophisticated calculations performed by LASL using Monte Carlo computer techniques.

The radiation shielding evaluation and experimental data obtained for the "Q-1" and "F-1" heat sources, show that the total dose rate at any accessible point on the surface of the shipping container will be less than 200 mrem/hr as required. However, the Transport Index as measured 3 ft from the side of the shipping container will slightly exceed 10 mrem/hr. Thus, "sole-use of vehicle" shipments are made in order to satisfy regulations.

Established quality control practices were implemented during all phases of fabrication of the heat source and the shipping container, as well as for packaging and unpackaging operations. Visual, dimensional, and functional inspections are performed. In addition, detailed packaging and unpackaging procedures are provided to assure proper handling and to provide documentation of these operations.

SECTION A
PACKAGING DESCRIPTION

CONTENTS:

A. PACKAGING DESCRIPTION

A.1. General

This packaging description is intended to provide sufficient information regarding the design intent, sufficient design detail to accurately identify the Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC), and to provide the basis for evaluation of the packaging. The MHW-IHS-SC is identified as AEC-AL USA/9503/BLF. The calculated gross shipping weight is approximately 2,680 lb and the overall size is 5 ft. high x 4 ft. x 4 ft. Eight containers were fabricated in accordance with the following drawings and specifications:

MRC Dwg. 5-2059	Multi-Hundred Watt Isotope Heat Source Shipping Container
MRC Dwg. 5-2060	Carrier Body
MRC Dwg. 5-2061	Carrier Cap
MRC Dwg. 5-2062	Cask
MRC Dwg. 1-14841	Welding and Inspection of 304 and 304L Stainless Steel Containers
MRC Dwg. 1-14596	MHW-IHS-SC Acceptance and Reuse Inspections

The MHW-IHS-SC consists of a carrier which completely encloses a finned cask as seen in Figure A-1. The contents of the shipping container is the MHW Isotope Heat Source (IHS), which consists of the Storage Protection Container (SPC) (Figure A-2), the heat source, and other hardware within the SPC (see page B-4 "Contents of Packaging"). The SPC is suspended within the finned cask and is supported by four stainless steel vibration and shock isolators to protect the IHS from damage during normal handling and transportation. Valves and pressure gauges are provided on the finned cask for cover gas back-fill and monitoring operations during shipment and storage. MHW shipments are accompanied by instrumentation for measuring and recording temperature, vibration, and shock.

No shipping container materials are specifically used as non-fissile neutron absorbers or moderators. No shielding is normally required to meet requirements for shipments in a sole use vehicle.

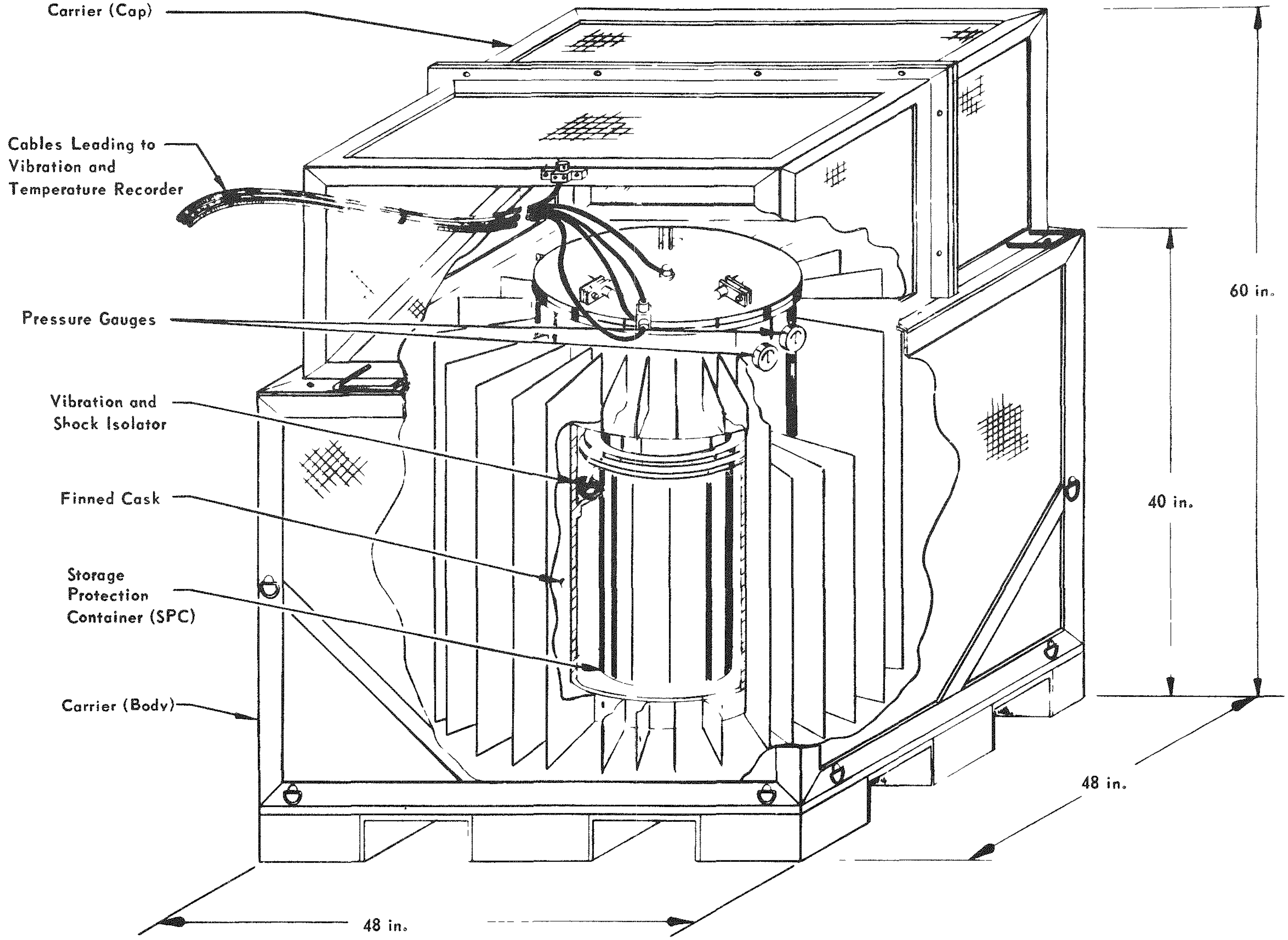


FIGURE A-1 - Cutaway view of the Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC).

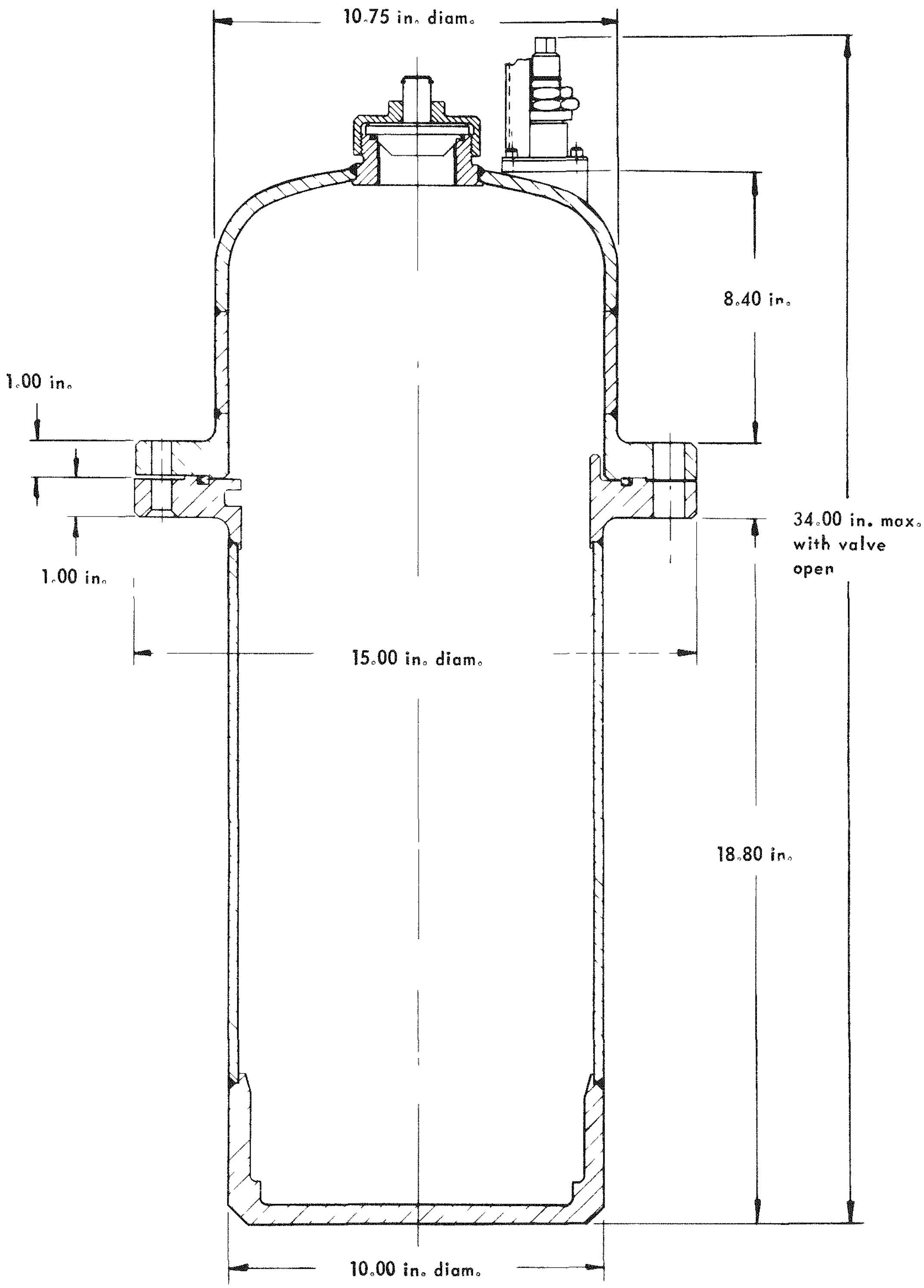


FIGURE A-2 - Storage Protection Container (SPC).

A.2. Design Intent

The MHW-IHS-SC is designed specifically for transportation and storage of the MHW-IHS. The IHS, including the SPC, is considered the contents of the shipping container and provides the necessary containment for the ^{238}Pu. Each of the 24 Fuel Sphere Assemblies (FSA) within the IHS, is considered the containment vessel for the contained ^{238}Pu solid (see Section B). Therefore, the MHW-IHS-SC alone is not intended to provide containment of normal form radioactive material under either normal transport test conditions or hypothetical accident test conditions. The shipping container is designed such that is will not contribute to the possibility of a radioactive release, i.e., by not permitting excessive damage to occur to the primary containment vessels during normal or accident test conditions.

Guidelines used for the design include criteria regarding frequency of use, storage and handling requirments. Only one shipment is planned for each container, but a limited number of additional shipments, such as return of the IHS to Mound Laboratory for rework or disassembly, are possible. It is assumed that each shipping container will be packaged and unpackaged six times, will be used for storage of the IHS for a period of one year, and must be sufficiently gas tight so that the helium atmosphere does not need to be recharged more frequently than once per month.

Handling features are based primarily on utilization of a fork lift. For short moves, where a fork lift is not practical, the shipping container may be moved using a hand pallet truck. Selection of tie-down rings is based on AECM 0529 requirements for use with chains or cables provided with the transport vehicle. The shipping container is designed so that packaging and unpackaging operations may be performed quickly to avoid unnecessary radiation exposure and with readily available tools.

It is not intended that the shipping container alone will provide sufficient shielding to meet transportation requirements; however, the combination of the shipping container and the sole use transport vehicle are sufficient to comply with AEC/DOT requirements for radiation dose levels during transportation. Shielding requirements during on-site storage are dependent on available facilities and must be evaluated as a separate requirement.

The MHW-IHS-SC is designed with external fins to passively dissipate a minimum of 2,400 W of heat during normal transportation in order to maintain an external surface temperature of less than 180^{o}F (82^{o}C) in accordance with AEC/DOT requirements for sole use shipments. Also, the container is designed to maintain the external surface of the SPC at a temperature of less than 700°F (371°C) to satisfy a General Electric Company requirement for assuring the product quality of the IHS hardware.

GE requires an inert atmosphere within the finned cask to prevent oxidation of the SPC during shipping and storage. (This is not essential for the containment of ^{238}Pu.) Selection of a 99% pure helium atmosphere at up to 10 psig pressure was based on the excellent heat transfer characteristics of helium. It is anticipated that other inert gases could be shown to be acceptable, if necessary. For safe containment of the helium pressure an American Society of Mechanical Engineers[4] (ASME) code design pressure of 36 psig at 200°F was selected for the finned cask. A pressure relief valve, set at 33 psig pressure, is used to assure safe release of the helium atmosphere in case of an accidental over-pressure. The gages and valves mounted to the exterior wall of the finned cask are intended for observation of the pressure within the finned cask during shipment and storage and within the SPC during storage when the flexible hose is connected from the SPC to the valve manifold.

GE specifications for isolation of shock and vibration are intended to assure protection of the heat source hardware, such as the gas management system and thin-walled outer can. Containment of the radioactive materials is not jeopardized by normal shock and vibration. The SPC shock response is to be less than 15 g when the shipping container is subjected to a series of 18-in. high drop tests. The vibration amplification factors are to be ≤ 6 (dimensionless) at frequencies of ≤ 26 Hz, and ≤ 1 at frequencies greater than 26 Hz during normal transportation.

A documented history of the IHS shock, vibration, and temperature environment is required during handling and shipping operations. Ambient temperature, the finned cask cover temperature, and shock and vibration at the finned cask cover are measured and recorded on magnetic tape for subsequent evaluation and, if necessary, comparison with experimental correlations to determine the IHS conditions. In addition to the sensitive instrumentation required to record the data, GO/NO-GO shock indicators of various ratings such as 15, 50, and 100 g, as well as temperature sensitive pellets, are used to provide positive indicators during handling and shipping.

A.3. Carrier

The carrier which consists of a steel body and an aluminum cap, is illustrated in Figure A-3. The carrier protects the finned cask from damage and provides personnel protection from heat and radiation. The base of the carrier is constructed to serve as a four-way steel pallet. Tie-down rings on the frame are used to secure the shipping container within the transport vehicle. The carrier is of welded construction weighing approximately 1310 lb. The overall height is slightly less than 62 in., including the carrier cap flange at the top. The overall base is slightly less than 49 x 49 in., including the metal case, tie-down rings, and other minor protuberances.

The carrier body is fabricated entirely of steel. It is only 42 in. high to provide easy access to the finned cask. The base plate of the carrier body is a 48 x 48 x 3/4-in. thick steel plate. Sections of ten-in. channel iron are welded to the underneath side of the base plate to provide fork lift or hand pallet truck access from all four sides for lifting the entire assembly. Four tapped holes are provided in the base plate for securing the finned cask in place using 3/4-in. high-strength Century-20 bolts. The framework is fabricated of 2 x 2 x 5/16 in. thick angle iron. Heavy gauge steel screen is welded to the framework so that the finned cask is completely enclosed during shipment and it is well ventilated to permit the heat to escape.

The carrier cap is fabricated entirely of type 6061-T6 aluminum for light weight and convenient manual handling by two or three men. The two sections of the carrier cap are bolted together and may be conveniently removed as individual sections to facilitate operations during storage of the IHS in the shipping container. The framework is primarly 1 1/2 x 2 x 1/4 in. thick aluminum angle and heavy gauge aluminum screen is welded to the framework. Handles are provided for lifting the carrier cap and access ports are provided for the instrumentation cables.

Several accessories are shipped with, or are an integral part of, the carrier. Two all-weather metal cases are fastened to the carrier cap for shipment of tools and instructions. A rubber tube is mounted inside the carrier cap for shipment of a set of three guide pins required for packaging operations. The required identification is provided on four nameplates which are fastened to the exterior of the carrier body. There are 16 tie-down rings, each having a holding capacity of 2 tons, that are fastened to the steel frame of the carrier body at the corners. The eight which are intended for normal use are located 20 in. from ground level, and an additional eight are located 6 in. from ground level.

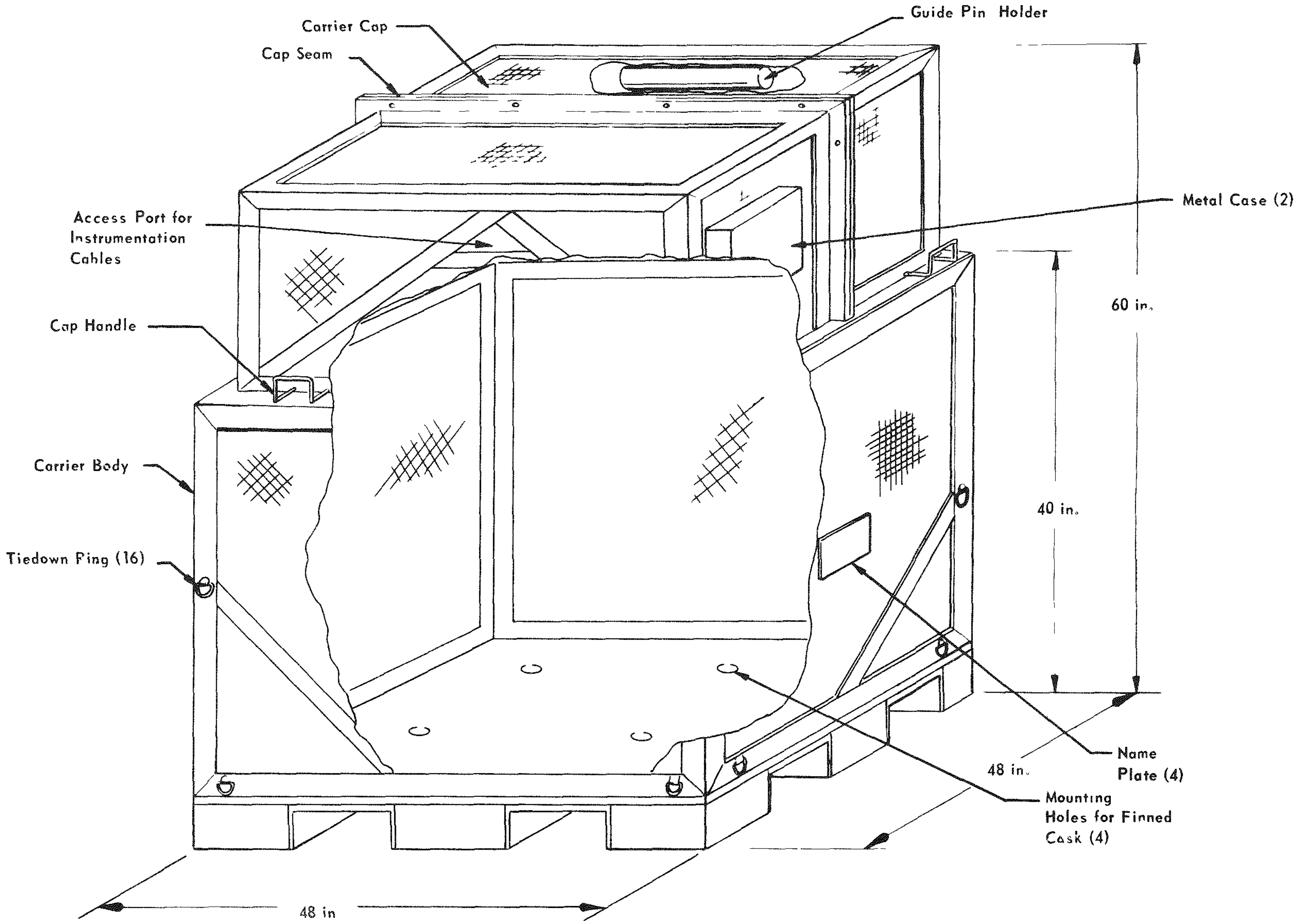


FIGURE A-3 - Carrier design.

A.4. Finned Cask External Features

The basic construction of the finned cask and the external features are discussed in this section. The cask is a 304 stainless steel, helium leak tight cylindrical pressure vessel with 60 aluminum fins to dissipate heat (see Figure A-4). The overall height, including the cover lifting lugs, is slightly less than 43 in., and the overall diameter from fin tip to fin tip is also slightly less than 43 in. The calculated weight of the finned cask is approximately 1100 lb.

The body of the finned cask is a welded 304 stainless steel cylinder with a flanged closure at the top which is sealed with a 1/4-in. cross-sectional diameter Viton o-ring. The body is 40-in. high externally and is 24 3/4-in. o.d. It is fabricated of 3/8-in. thick plate and the effective thickness of the body wall is 1/4 in. as a result of the 1/8-in. deep grooves which have been machined in the wall for installation of the fins. The top flange, which is 1-in. thick, and the bottom plate, which is 3/4-in. thick, are welded both internally and externally to the body wall.

The top cover is 28 1/2-in o.d. and is 3/4-in. thick plate. The effective thickness of the cover at the seal is 0.69 in. as a result of a 0.06 in. relief which is finished to provide the o-ring sealing surface. The top closure is bolted together using 16 stainless steel 3/4 in. x 16-thread/in. x 1 3/4-in. long hex head cap screws located on the 27 in. diam bolt circle. Two 303 stainless steel 3/8 diam. x 1 3/4-in. long guide pins are used to assure proper orientation of the cover on the finned cask. Three lifting lugs are welded to the cask cover for lifting the cover only. The thinnest section of the lugs is 3/8 in. During shipment, GO/NO-GO shock indicators are fastened to the lifting lugs. The calculated weight of the cover plate is 140 lb.

Extending radially from the cask body are 60 fins to provide sufficient heat transfer area for natural convection cooling to the ambient air. The fins are type 6061-T6 aluminum. Each fin is inserted into a 1/8-in. deep groove in the cask body and joined to the body using Scotch-Weld No. 1751 B/A (3M Co.), which is a high thermal conductivity, aluminum filled, two-part epoxy structural adhesive. A 1/4-inch fillet of the adhesive is applied to both sides of the fin at the joint to provide an additional cross-sectional area for heat transfer. A special fixture was used during fabrication to assure that the fins are equally spaced. The fins are 3/16-inch thick and extend radially 8 7/8-in. from the cask wall. The vertical lengths are as follows:

No. of Fins	Vertical Fin Length (in.)
50	35 1/2
3	33 1/2
6	24 5/8
1	20 5/8

The vertical lengths vary to provide space for the valve manifolds and access to the mounting tabs at the bottom.

Valve manifolds for the SPC and the finned cask are welded and braced to the outside wall of the cask body. Both manifolds are 1/4-in. stainless steel tubing with two bellows sealed valves (Nupro Company) in series and a 30-in. vacuum/30-psig pressure compound gauge (Ametek) located between the valves. A Viton o-ring sealed adjustable pop-off relief valve (Nupro Company), set at 33 psig, is provided in the cask valve manifold to preclude accidental over pressure. The cask valve manifold is used for evacuation and filling with helium prior to shipment and observation of the pressure during shipment and storage. The SPC is not open to the SPC valve manifold during shipment; this manifold is primarily for storage operations. The connectors to the valve manifolds are 1/4-in. VCR fittings, which use nickel gaskets to effect the seals.

The finned cask is mounted to the carrier using four high strength Century-20, 3/4 in. x 10-thread/in. x 1-7/8 in. long hex head cap screws which fit through the four mounting tabs. Each mounting tab is 4 1/4 in. x 2 5/8 in. x 1-in. thick; these tabs are securely welded to the wall of the cask at the base.

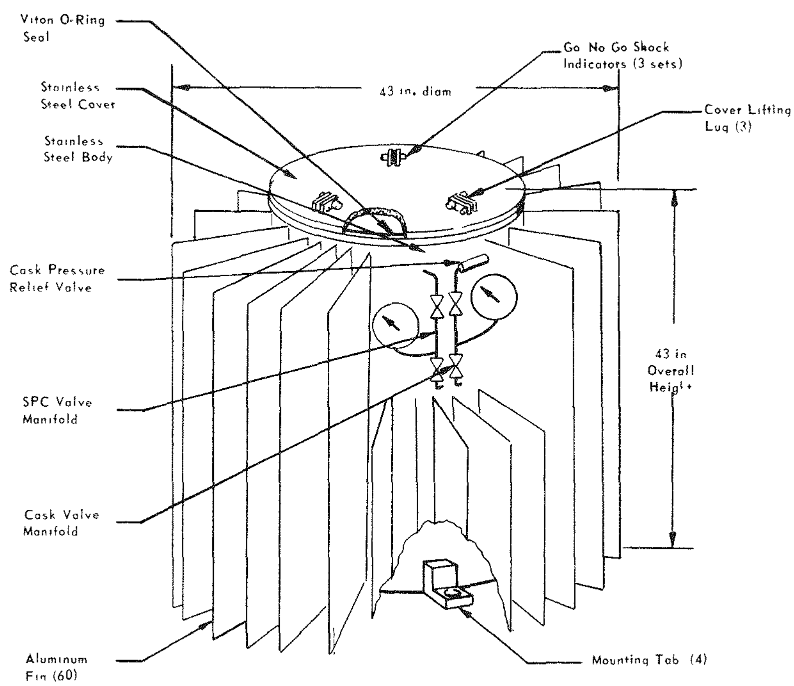


FIGURE A-4 - Finned cask external features.

A.5. Finned Cask Internal Features

The finned cask provides a protective environment for the IHS by using a 99% pure helium atmosphere, an emissive coating for improved heat transfer from the SPC to the cask, and a shock and vibration isolation system. The internal features are illustrated in Figures A-5, 6, and 7. The finned cask is 24-in. i.d. and 39 3/16-in. internal height with the cover closed for use. Clearances between the SPC and the finned cask are 2 in. at the top, 3 in. at the bottom, and range from a minimum of 4 1/2 in. at the SPC flange to 7 in. near the bottom at the sides as shown in Figure A-5. The calculated internal void volume of the finned cask during shipment of the IHS is 8.5 $ft.^3$ (241 liters), based on an estimated volume of 1.5 $ft.^3$ (43 liters) occupied by the IHS.

A 0.003 to 0.005-in. thick iron titanate coating, applied to the internal cylindrical walls and bottom of the cask, provides a high emissivity of 0.80 to 0.85 for radiant heat transfer from the SPC to the cask. The coating is not applied to the finned cask cover, the isolator mounting fixtures or the internal cylindrical wall area where the valve manifolds are attached externally and there are, therefore, no fins attached externally.

A 12-in. long x 3/8-in. nominal diam. flexible stainless steel hose, with a pressure rating of 5,000 psi, is provided for storage operations. During storage, the SPC valve is opened and the pressure within the SPC is monitored while the SPC is in the finned cask protective environment. The hose is connected to the SPC and the finned cask using VCR (Cajon Co.) fittings with nickel gasket seals. The VCR fitting connected to the finned cask is welded to a 1 1/2-in. diam. stainless steel boss which protrudes 1 3/8 in. into the cask void.

The SPC flange is secured in place for shipment using the three pins and bolts seen in Figure A-6. The hold down ring, which is 15-in. o.d. x 3/8-in. thick 304 stainless steel, functions as the interface between the three pins used to secure the SPC and the four shock and vibration isolators which suspend the SPC within the finned cask. The three bolts used to secure the SPC are 1/2 - 13 x 1 1/4-in. long Century-20, which is a high strength steel alloy. The chromate plating on the bolts prevents galling at high temperature, but is damaged during use so that these bolts are not reusable. Although not illustrated, a standard 3/4-in. socket wrench is securely attached to the head of each bolt to facilitate assembly and disassembly. The three pins are 316 stainless steel and are 0.75 in.-o.d. x 2.65 in.-long with 1/2 - 13 x 1 3/8-in. deep internal threads to accept the bolts, leaving a wall thickness of 1/8 in. for the threaded portion. Each pin is secured to the hold-down ring with a 3/16-in. diam. x 1 1/4-in. long roll pin and a 1/8-in. wide flange at the base of the pin.

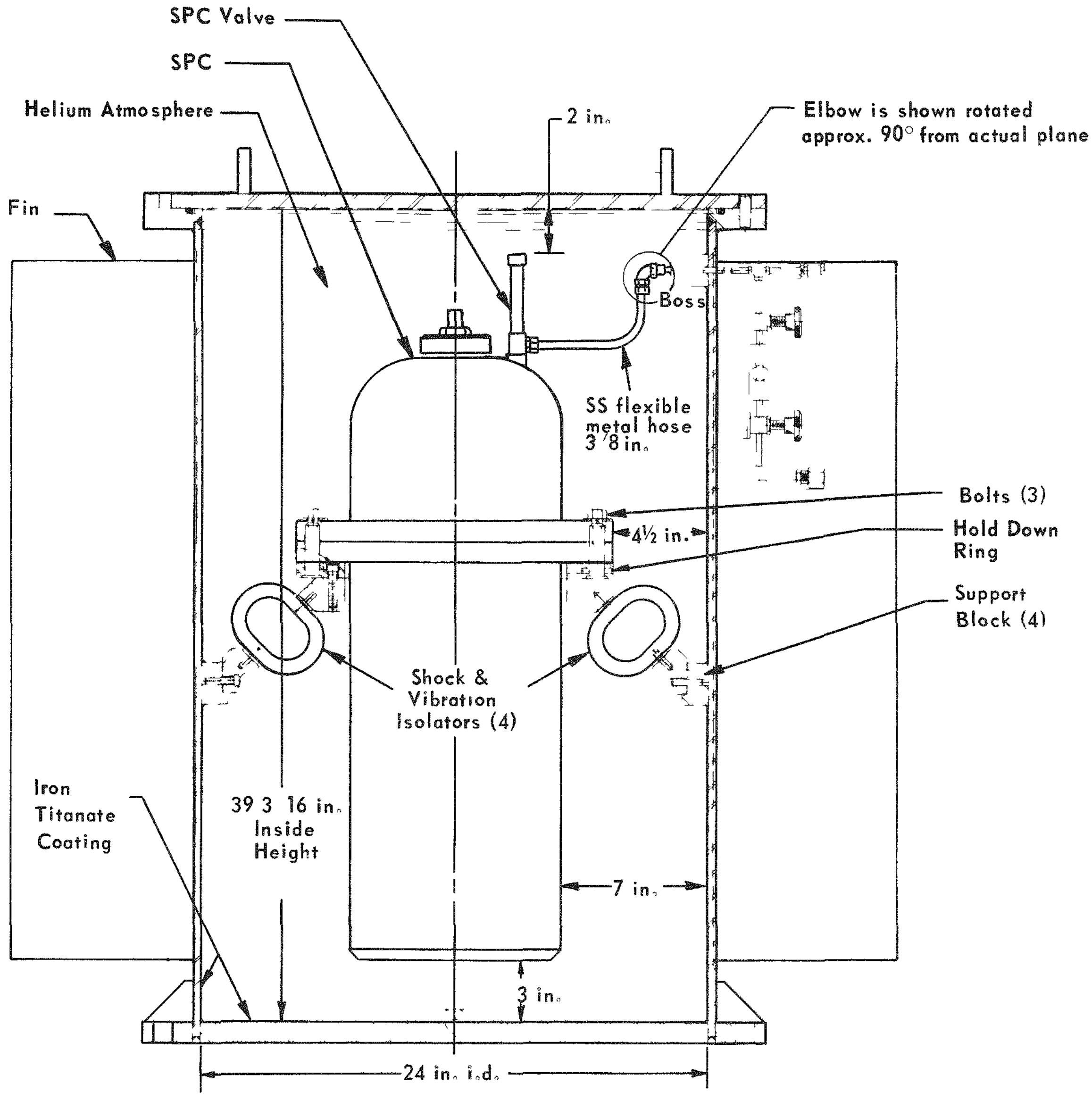


FIGURE A-5 - Finned cask internal features.

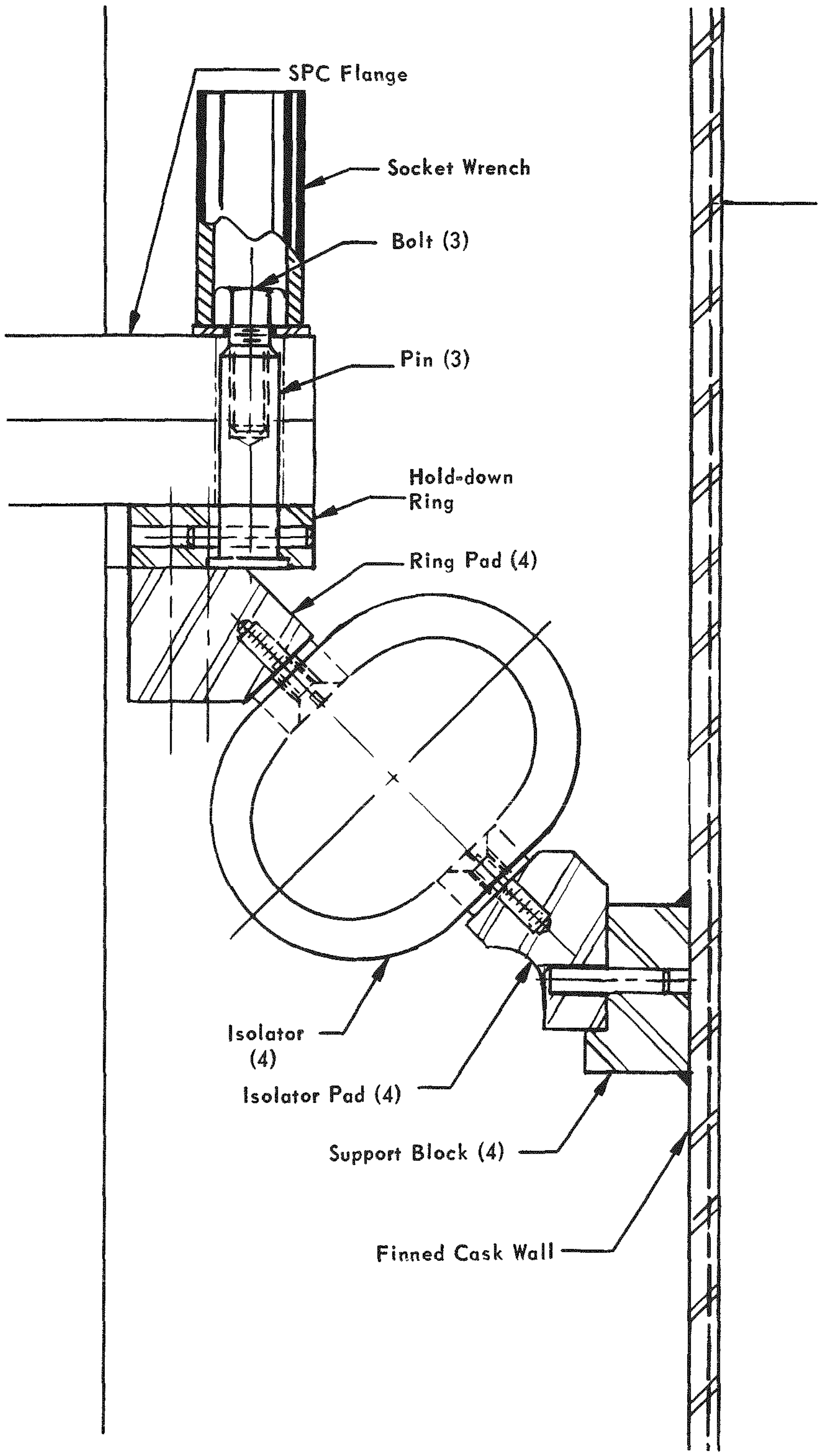
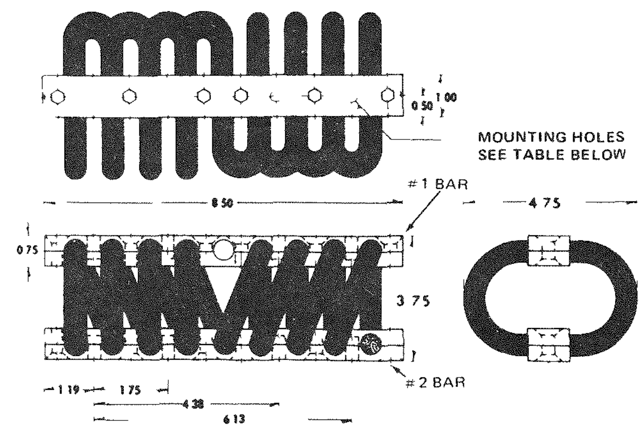


FIGURE A-6 - Isolator mounting fixtures.

AEROFLEX

MOUNTS–SHOCK AND VIBRATION
SERIES CB1400– 20
1/2" WIRE ROPE



TOLERANCES	
X	± 10 (2 540 mm)
XX	+ 03 (762 mm)
XXX	+ 010 (254 mm)

PART NO CODE CB1400 20 (XX)

XX	MOUNTING HOLES	
C2	#1 BAR / #2 BAR	33 DIA THROUGH COUNTERSUNK INSIDE 82° X 66 DIA 8 HOLES
I2	#1 BAR / #2 BAR	¼ 28 NF 2B THREADED INSERT 8 HOLES
CI	#1 BAR	33 DIA THROUGH COUNTERSUNK INSIDE 82° X 66 DIA 4 HOLES
	#2 BAR	¼ 28 NF 2B THREADED INSERT 4 HOLES

MATERIALS & FINISHES

MATERIAL	Resilient Element	Wire Rope Stainless Steel per MIL-C 5424
	Retainer Clips	Stainless Steel
	Attachment Screws	Alloy Steel
	Wire Rope Retainer Bars	Aluminum Alloy 6061 T6
FINISH	Wire Rope	Per MIL C 5424
	Retainer Clips	Passivated per MIL-S 5002
	Attachment Screws	Cadmium Plate per QQ-P-416
	Wire Rope Retainer Bars	I d ted pe MIL-C 5541

TYPICAL SPECIFICATIONS

MIL E 16400
MIL S 901
MIL M 17185
MIL E 5400
Munson Road Test
MIL STD 810
MIL E 5272
MIL C 172
MIL T 5422
MIL C 5584
Railroad Humping Test

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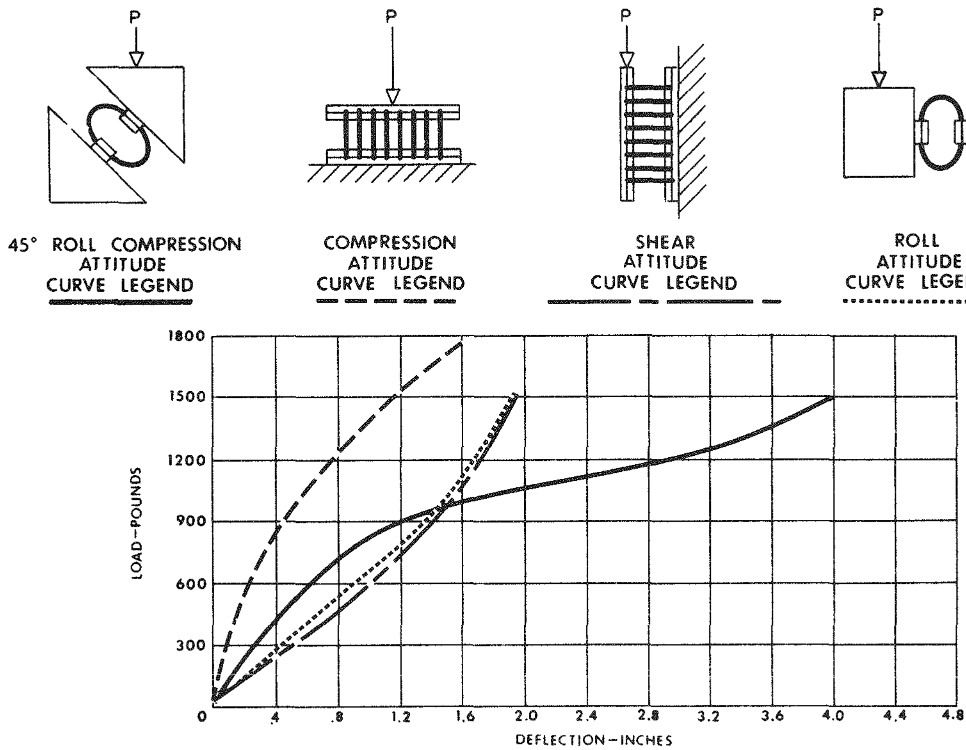
FIGURE A-7(a) - Shock and vibration isolator design. (This illustration was reprinted by permission of Aeroflex Laboratories, Inc.)

AEROFLEX MOUNTS—SHOCK AND VIBRATION



TYPICAL VIBRATION PERFORMANCE VS. INPUT AMPLITUDE

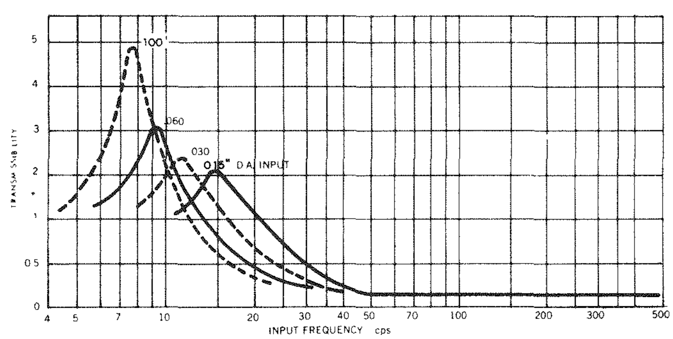


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FIGURE A-7(b) - Isolator design (cont'd).

The support block, isolator pad, and ring pad (Figure A-6) for each isolator are all 7-in. long, irregularly shaped, 304 stainless steel fixtures designed to orient each shock and vibration isolator at a 45^{o} angle with sufficient clearance space. The isolators are also located at a height which approximately coincides with the center of gravity of the SPC. The methods of fastening these pieces together are tabulated as follows:

Pieces Fastened	Methods of Fastening
Finned cask wall to support block.	Welded complete 16-in. perimeter of support block.
Support block to isolator pad.	4 ea. 3/8-16 x 1 1/4-in. long stainless steel socket head cap screws, and
	2 ea. 3/16-in. diam. x 1 1/4-in. long 304 stainless steel roll pins.
Isolator pad to isolator.	4 ea. 5/16-18 x 1 1/4-in. stainless steel flat head screws.
Isolator to ring pad.	4 ea. 5/16-18 x 1 1/4-in. stainless steel flat head screws.
Ring pad to hold down ring.	3 ea. 3/18-16 x 1 3/4-in. stainless steel socket head cap screws.

The four shock and vibration isolators, illustrated in Figure A-7, are constructed of 1/2-in. diameter stainless steel wire rope. The wire rope is coiled in a helical shape eight full turns. The overall length of each isolator is 8 1/2 in. and the larger diameter is 4 3/4 in. The isolators are manufactured entirely of 300 series stainless steels to provide satisfactory performance at temperatures up to 1,000^{o}F.

SECTION B

CONTENTS OF PACKAGING

CONTENTS:

B. CONTENTS OF PACKAGING

B.1. General Description of MHW-IHS

The USAEC, Division of Space Nuclear Systems, has initiated work on an advanced heat source convertor design, designated as the Multi-Hundred Watt (MHW) program. The following paragraphs describe this particular unit.

The MHW heat source consists of 24 spherical modules, each containing 100W power, and arranged in a 4 x 6-element cylindrical matrix. The fuel is pressed plutonium oxide (PPO), which is encapsulated in a 0.020-in. thick post impact containment shell (PICS) of iridium metal; each sphere is encased in a 0.46-in. thick wound graphite impact energy absorber. The four-sphere tiers are then inserted in graphite reentry aids, and the entire assembly is welded in an 0.010-in. thick outer container as shown in Figure B-1.

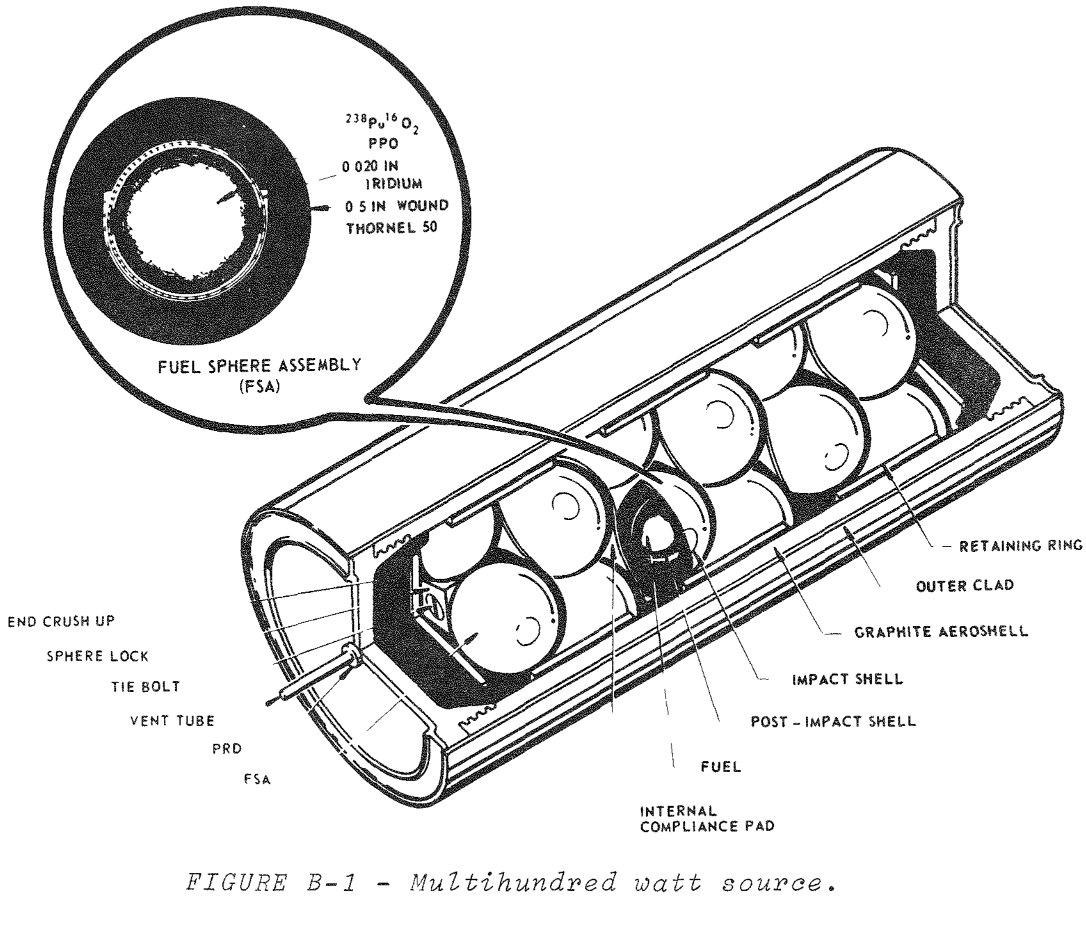


FIGURE B-1 - Multihundred watt source.

B.2. Drawings and Specifications*

The following is a list of applicable drawings and specifications relevant to the MHW-IHS and are included in Appendix IV. indicated.

A	MRC Spec No	Description	Page
	1-14941	Multi-Hundred Watt Material Specification Iridium Blank	IV-2
	1-14942	Multi-Hundred Watt Material Specification Sheet & Foil	IV-9
	1-14944	Multi-Hundred Watt Hydroforming Iridium Hemisphere Specification	IV-15
	1-14905	Multi-Hundred Watt MHW Fuel Sphere Assembly Acceptance	IV-21
	SPA740056	Multi-Hundred Watt MHW Heat Source Assembly Acceptance Specification (Draft)	IV-33
	1-14813	Multi-Hundred Watt Fuel Specification	IV-38
B.	MRC Dwg No		
	4-10942	Multi-Hundred Watt Post Impact Containment Shell, MRC Product Iridium	IV-42
	3-9313	Multi-Hundred Watt Weld Shield	IV-43
	3-9317	Multi-Hundred Watt Contamination Cover	IV-44
	3-9318	Multi-Hundred Watt Hemisphere	IV-45
	3-9329	Multi-Hundred Watt Blank, Iridium	IV-46
C	GE Dwg No		
	47C302509	Cap and Body Matched, Concentric Design Impact Shell	IV-47
	47E302635	Isotope Heat Source ASM Ground Handling Configuration	IV-48
	47C303127	Particulate Shield Assembly Frit Design	IV-49
	47B303131	Filter Assembly	IV-50
	47B303132	Weld Disk	IV-51
	47B303153	Weld Disk Washer	IV-52
	NS-0060-02-78	Fabrication of Bonded Frit Vents	IV-53
	47J302521	Isotope Heat Source	IV-60
	MRC Dwg No		
D.	2-15211	Shield Disk	IV-61
	2-15212	Disk	IV-62
	3-8985	Hemisphere - Female	IV-63
	3-8986	Hemisphere - Male	IV-64
	4-10475	Post Impact Containment Shell	IV-65

*NOTE: Enlarged copies of these drawings may be obtained by writing to Monsanto Research Corporation, Engineering Drawing Control, Mound Laboratory, Miamisburg, Ohio 45342.

B.3. <u>Contents of Packaging</u>

Under Section B (page 3) of the AEC/ALO guide for writing SARP's several specifics are requested.

These are:

a. "Describe the quantity of isotopes" - Each fuel sphere contains 100 ± 2 watts; Each HSA contains 24 spheres with a restrictive thermal inventory of 2410 ± 18 W (approximately 4200 g ^{238}Pu isotope), From MRC Dwg. 1-14813, it can be noted that "80 ± 2% of the atoms of plutonium shall be of atomic weight 238" (Section 4.1.1). The remaining plutonium atoms are approximately 16% ^{239}Pu, 3% ^{240}Pu and considerably lesser quantities of ^{236}Pu, ^{241}Pu and ^{242}Pu. Other actinide impurities are defined in Section 4.1.4 to not exceed 1% of the total plutonium; however, there is some ingrowth of ^{238}Pu daughters, as the fuel ages.

b. "maximum amounts of radioactivity" - see also above.

c. "chemical and physical form" - the fuel is a hot-pressed oxide solid (see pp. IV-38, IV-41).

d. "material density" - The material density is defined to range within 80-85% of theoretical density. This is not a specification call-out but is a measureable parameter (see p. IV-40)

e. "moderating ratios" - Not applicable.

f. "configurations as required for nuclear safety evaluations" - See section on criticality (Section G).

g. "the maximum amount of decay heat" - The MHW IHS is designed to utilize the decay heat; this quantity is at present 2410 W.

h. "maximum pressure build-up in the inner container" - As the PISA is a vented structure, the design pressure build-up is nil (see Appendix III).

i. "leak tests" - Both PISA and IHS leak check analyses are covered. See paragraphs 6.3 and 8.4 in 1-14905 and 6.3.2 in SPA740056 (p. IV-21 and p. IV-33, respectively).

j. "any loading restrictions and limitations" - This is covered in the loading procedures covered elsewhere (Appendix II and Conclusions).

B.4. Hardware Responsibilities

The GE/MRC/ORNL interface responsibilities for providing both design and hardware follow:

MHW-Radioisotopic Thermoelectric Generator Program
Heat Source Responsibility Matrix

Task	Item	Responsible Organization
I.	Hardware Fabrication/Procurement	
	a. Fuel Form Sphere	MRC
	b. Simulant Fuel Form Sphere	MRC
	c. Post-Impact Containment Shell	MRC
	d. PICS Blanks	
	1. Production	ORNL
	2. Specification	MRC
	e. Sheet Iridium	
	1. Production	ORNL
	2. Specification	MRC
	f. Vents, PICS	
	1. Production	GE
	2. Specification	GE
	g. Remaining Hardware (See Attachment I)	GE
	h. Heat Source Shipping Containers	MRC
	i. Storage Protection Container	GE
II.	HSA Drawing	GE
III.	Component/Subassembly Drawings	
	a. All Hardware (See Attachment I)	GE
	b. Heat Source Shipping Containers	MRC
IV.	Material Specifications	
	a. Fuel	MRC
	b. Fuel Simulant	MRC
	c. Post-Impact Containment Shell	GE
	d. Outer Clad Coating	GE
	e. Outer Clad	GE
	f. Remaining Hardware (See Attachment I)	GE
	g. Heat Source Shipping Containers	MRC
V.	Acceptance Specifications	
	a. Fuel Form	MRC
	b. Simulant Fuel Form	MRC
	c. Heat Source Assembly	MRC
VI.	Data Package	MRC
VII.	Receiving Inspection of Government Accepted Products	
	a. All Hardware Except Post-Impact Shell	MRC
	b. Heat Source Assembly	GE
	c. Heat Source Shipping Containers	GE

Acceptance of hardware at GE for the U.S. Government is the responsibility of Sandia QA. Acceptance of product that is the responsibility of MRC is performed by AEC/DAO/QAIA.

B.5. <u>SPC/IHS (Containment by the SPC)</u>

During a telecon on December 14, 1973, Mr. E. L. Barraclough, AEC/ALO suggested that it would be advisable to consider the affect of the SPC in the assembly as far as contributing favorably to the containment of radioactivity.

a. <u>Normal Operations</u>

The specification for the SPC (GE document No. CP47A14615) states that, "the reliability of (the) IHS shall not be degraded as a result of utilizing the SPC" (para. 3.2.3). The facts that (1) the 700°F SPC temperature does not adversely affect the IHS (para. 4.2.1), and (2) that the leak rate of the SPC is defined to be <1 psi in 48 hr (see pp. 24-25 and Tables I and II), infer an additional attenuation can be realized over that attributed to the IHS alone.

Viscous flow of a gas through a capillary may be computed as follows:

$$Q = \frac{5.362 \times 10^{-4}}{\eta} \frac{d^4}{\ell} P_a \ (P_2 - P_1) \qquad \text{[Eq. 1]}$$

where Q = throughput ($\mu \cdot \ell \cdot sec^{-1}$),
η = viscosity
d = pore diam (in.),
ℓ = length (in.),
P_a = average pressure ($\mu \cdot$bar),
$P_2 - P_1$ = Delta P ($\mu \cdot$bar, or 6.9×10^4 $\mu \cdot$bar = 1 psi).

From Equation 1, it may be noted that the equivalent capillary size for the 1/4 in. flange area may be found by conversion as follows:

$$d^4 = \frac{Q \ \eta \ \ell}{5.362 \times 10^{-4} \ P_a \ (P_2 - P_1)} \qquad \text{[Eq. 2]}$$

Using Equation 2, the sample calculation would reduce as follows:

$$d^4 = \frac{(3.36 \ \mu \cdot \ell \cdot sec^{-1})(3 \times 10^{-4} \ \text{poise})(0.25 \ \text{in.})}{(5.362 \times 10^{-4})(1.034 \times 10^{6} \ \mu \cdot \text{bar})(5.17 \times 10^{4} \ \mu \cdot \text{bar})}$$

$$d^4 = 8.79 \times 10^{-12}$$

and

$$d = 1.7 \text{ mil}$$

If the escaping gas is saturated with PuO_2 vapor at 300°C, it may be noted that 0.44 ℓ of volume escapes every 48 hr and the quantity of PuO_2 entrained is <<1 μ Ci. The physical size of the equivalent diameter is also such that if randomly distributed about the 30-in. circumference, it seems unlikely that a sizable weight fraction of suspended fines particles would be able to be swept into the HSSC area.

The enhancement factors for having the SPC about the IHS in normal operation appear to be as follows:

Vaporized PuO_2: ~19 orders of magnitude (arrived at by using the vapor pressure equation, $\log P = 7.381 - \frac{28890}{T}$, from MLM-1691).[5]

Suspended PuO_2: > 3 during shipment (but undoubtedly much greater than this in reality; difficult to quantify).

b. Accident Conditions

The response of the SPC to the hypothetical accident conditions will result in loss of the seal with a rapid (< hours) drop in pressure to ambient.

It is reported elsewhere that the maximum potential hypothetical accident temperatures are (from Appendix III, pp. III-33, Table 6, Case 5)

SPC: 1581°F (860°C)
IHS: 2171°F (1188°C)

From this, the vaporization effects are attenuated by a factor of $\sim 10^5$ over an accident fire in which the IHS is at the same temperature but with no SPC around it (from vapor pressure formula given earlier).

The suspended particulate cut-down is greater than a factor of 2.5 but again, the actual containment would be significantly greater as the apertures will cause some hang-up of particulate which cannot be accurately assessed here. (Note: This may be considered as a straight pressure decrease with ~40% of the cover gas exiting through the leak, the remaining gas holding the particulate material.

c. Structural

The SPC will obviously absorb some energy in deformation during the 30-ft drop accident condition. The actual quantity is not calculable; drop or impact conditions are certainly well covered in Appendix III for the IHS and its components.

d. Conclusion

The SPC does not detract from the safety in operation of the IHS/SPC/HSSC combination in either normal or accident conditions and will *a priori* decrease the quantity of possibly released contamination by a factor of approx. 2.5 or greater. Substituting GE-obtained maximum escape values, the presence of the SPC can decrease the proposed maximum quantity of 7 μCi to ~3 μCi.

B.6. <u>Accident Condition Assessment</u>

As it is not practical to demonstrate complete containment via HSSC nor SPC means (see B.5 above), some additional rationale is given to support the tenet that the IHS (HSA) is a "primary containment vessel".

a. <u>Measured and Calculated Levels of PuO_2 from an FSA and IHS</u>

A recent LASL letter from S. E. Bronisz to T. J. Dobry, Jr., (January 15, 1974), contains the following analysis:

"There is no direct information about the distribution of plutonium contamination in a MHW heat source or generator now, but such information will be obtained when the qualification generator is disassembled. We can estimate a possible distribution by examining the measurements that Dan Pavone made when he disassembled MHFT-22, an FSA held at vacuum operating temperature (1268°C on the external GIS surface) for 12.2 Msec (3400 hr) in a threaded closure POCO graphite can.

The levels of contamination he found were:

POCO exterior	nil, direct count
POCO interior	2×10^3 cpm, direct count
GIS exterior	1×10^4 cpm, direct count
GIS interior	$>10^5$ (a) cpm, direct count
PICS exterior	$>10^5$ (a) cpm, swipe count

(a) The upper detection limit of the counter."

"A chemical assay of the entire GIS found 625 μg of ^{238}Pu on and in it. This is equal to ~11 mCi of fuel. Based on the swipe counts, we would guess that a similar amount was on the exterior of the PICS."

"The vents were all plugged, but there was a small crack in the PICS which may have been venting helium (and PuO_2) during the test. This behavior may not be representative of the flight vents, but we have tested none of the new designs and must assume that it is."

"If we assume that MHFT-22 is representative of the flight FSA's in a generator after a few months of operation, we can estimate the plutonium will be as follows:

Location	Single FSA	Fuel Heat Source
Inside GIS	20 mCi	480 mCi
Inside Aeroshell/ outside GIS	4.5 nCi	108 nCi
Outside Aeroshell/ inside clad	---	nil[a]
Outside Clad	---	--[b]

[a] MRC's loading operation should not put any contamination between the aeroshell and clad.

[b] If the GMS operates properly, the only contamination on the outside of the heat source would be that left by the loading cycle. I believe that it will be very little. The actual quantity should be available from the walk-through heat source fit-up exercise."

Also, in the case of an accident condition, the rate of influx of oxygen into the HSSC volume is given as

$$M = DA \frac{(C_2 - C_1)}{d} t, \qquad [Eq. 3]$$

where M = Mass/quantity
D = Diffusion coefficient
C = Concentration
t = time (1/2 hr or 1800 sec)
d = thickness (0.25 in. or 0.625 cm)
A = Area

or

$$\mathring{M}(g\ cm^{-2}) = (0.178\ cm^2 sec^{-1})(1\ cm^2)\frac{(0.000286\ g\ cm^{-3})}{(0.625\ cm)}(1800 sec)$$

$$\mathring{M} - 0.1469\ g\ cm^{-2} \text{ in } 1/2 \text{ hr}$$

or

$M \simeq 0.05$ g during acident conditions where ~1/3 cm^2 of area opens up due to gasket failure.

As $V_{HSSC} \sim 290\ell$ and $V_{SPC} \sim 40\ell$

$V_{void} \sim 250\ell$

or $C_{HSSC} = 2 \times 10^{-7}\ g\ cm^{-3}$

or, with $\sqrt{\frac{1300}{300}}\left(\sqrt{\frac{T}{T}} \text{ factor}\right)$, $c \simeq 4 \times 10^{-7}\ g\ cm^{-3}$.

Since the SPC "C" Ring will fail and create a gap through which oxygen-contaminated gas may diffuse, a similar analysis may be performed, viz.

$$\mathring{M}(g\ cm^{-2}) = (0.178\ cm^2\ sec^{-1})(1\ cm^2)\frac{(4 \times 10^{-7}\ g\ cm^{-3})}{(0.625\ cm)}(1800\ sec)$$

$$M(g) = (2.05 \times 10^{-4})(0.25\ cm^2) \simeq 0.5 \times 10^{-4}\ g$$

if ~1/4 cm^3 is opened during failure of the "C" ring.

or M = 50 μg inside the SPC.

If we assume that all 50 μg are available to oxidze the aero-shell through a leak in the IHS can, <20 μg of carbon would be eroded (as insignificant quantity, equivalent to a cube 0.02 cm on edge!).

b. Conclusion
From the above, it is obvious that there is apparently no release of PuO_2 from the HSSC in an accident environment upon failure of seals which permit oxygen to intrude in the inner cavities. The FSA graphites will remain intact and the FSA will contain the radioactive material.

B.7 Effect of New Vents on SARP

Earlier (section B.6) argument was performed to justify potential release values based upon the "old" vent design discussed previously in section B.2, p. B-8.

To verify that the bonded (diffusion bonded at 1900°C for three hours by GE Company) frit vent does not detract from the existing rationale, MRC has performed the following evaluations.

a. Particulate Retention and Flow Measurements
Quantities ≤0.1 mg of "fines" having a size range of <6 μm diameter were noted during cold particulate retention testing at Mound Laboratory. This is in the area of detectability limitation and is at least as good as for the "old style" welded sandwich vent design. The high temperature sintering provides a more positive spacing and permitted flow measurements directly. The consistency of these measurements validates their reproducible flow rates (letter from E. W. Johnson to A. J. Sattolo, December 20, 1973).

b. Vent Vibration Test
To verify that the bonding steps mentioned in B.7 were adequate in imparting mechanical stability to the vent, MRC vibrated a ThO_2-fueled FSA at 1000°C under defined LES 8/9 launch conditions. The vibration spectrum used is shown in Figure B-2. Post-mortem showed both vents to be open (one exhibited normal flow characteristics whereas the second seemed lower by a fraction of ~10 but still >> He generation rate of a fuel sphere). Photographs and photomicrographic cross-sections of this study are on file at Mound Laboratory.

c. Conclusion
Inclusion of new frit-type vents does not detract from the safety analyses; in fact, they should present a higher design confidence as to consistency.

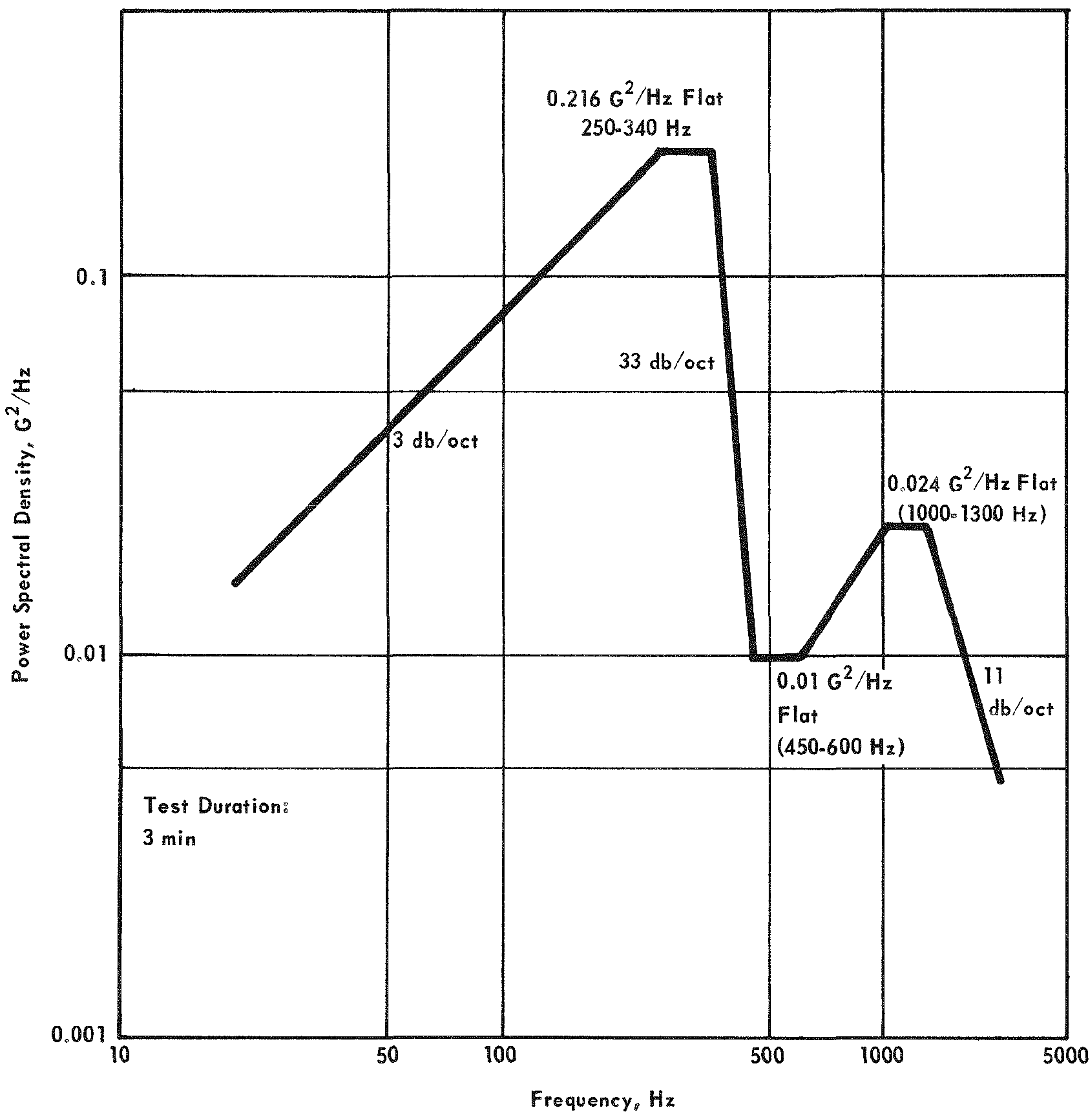


FIGURE B-2 - Reference Vibration Spectrum.

SECTION C

INTERNAL PRESSURE CAPABILITY AND PACKAGE STANDARDS EVALUATION

CONTENTS:

Section C - Part 1

INTERNAL PRESSURE CAPABILITY

C.1. General

The internal pressure capability of the finned cask was thoroughly evaluated. The evaluation clearly demonstrates that the vessel is capable of safe pressure containment when pressurized for shipment of the MHW isotope heat source at approximately 7 psig.

The basic structure of the finned cask is shown below in Figure C-1. It is a cylinder with a welded bottom plate and a bolted cover sealed with a 1/4 in. diameter cross section Viton o-ring. It is fabricated entirely of 304 stainless steel and the welds were subjected to visual and dye penetrant examinations during fabrication. A complete description of the finned cask is presented in the Packaging Description section of this report.

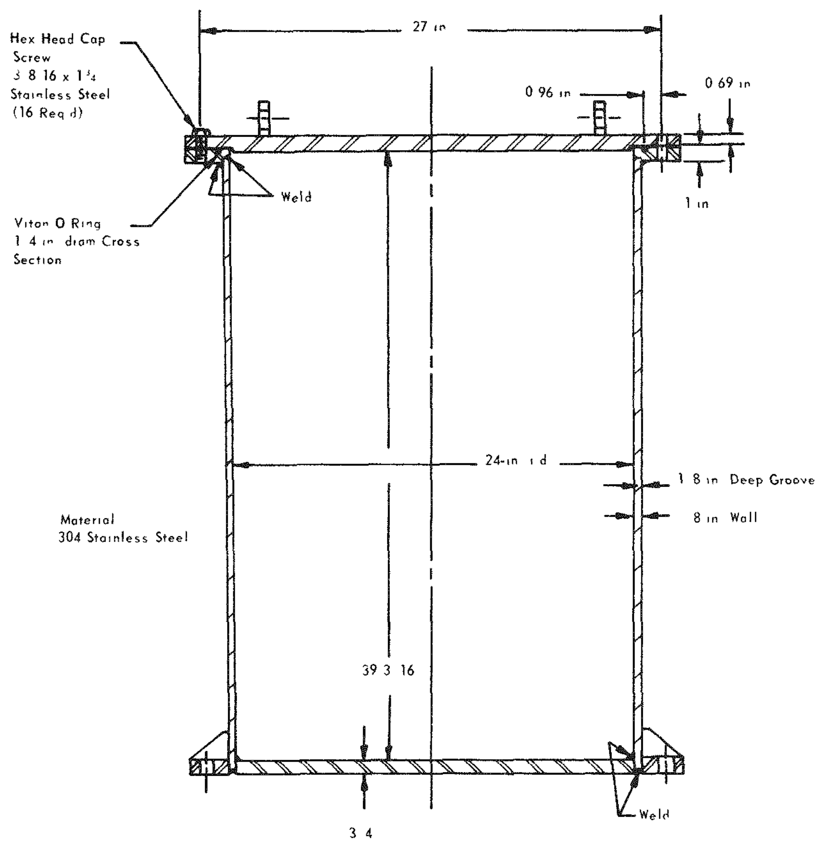


FIGURE C-1 - Finned cask basic structure.

C.2. Calculations

Calculations for the internal pressure capability of the finned cask at 200°F (93°C) are presented and the results at temperatures up to 1500°F (816°C) are tabulated. A separate calculation is required for each of the three basic components, which are the cylindrical cask body, the welded bottom, and the flanged cover. The maximum pressure capability is then based on the values for the flanged cover since these are the lowest values for the three components.

The maximum allowable working pressure of the cask body is calculated according to the following:

$$P = \frac{SEt}{R + 0.6t} \quad \text{(ASME Code, Page 11)*}$$

where P = Maximum allowable working pressure, psi

S = Maximum allowable stress, S = 15,600 psi

E = Welded joint efficiency, E = 0.70,

R = Inside radius of cask, R = 12 in.,

t = Wall thickness, t = 0.25 in.

Substitution of the appropriate values into the above equation yields:

$$P = \frac{(15{,}600)\ (0.70)\ (0.25)}{(12) + (0.6)\ (.25)}$$

$$P = 225 \text{ psi}$$

The cask bottom is doubly welded to the cask body. Its pressure capability is calculated as follows:

$$P = \frac{S}{C}\left(\frac{t}{2R}\right)^2 \quad \text{(ASME Code, page 21)}$$

where,

P = Maximum allowable working pressure, psi

S = Maximum allowable stress, S = 15,600 psi,

C = Factor accounting for method of attachment, C = 0.3,

R = Inside radius of cask, R = 12 in.,

t = Thickness of bottom plate, t = 0.75 in.

*ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1971.

The resulting calculation is as follows:

$$P = \frac{(15,600)}{(0.3)} \left(\frac{0.75}{2 \times 12} \right)^2$$

$$P = 51 \text{ psi}$$

The calculation for the cask cover is similar to that for the cask bottom except that, because it is attached by bolts, the edge moment must be accounted for. The applicable equations are as follows:

$$P = \frac{S}{C} \left[\left(\frac{t}{2R} \right)^2 - \frac{1.78 \; W \; h_G}{S \; (2R)^3} \right] \quad \text{(ASME Code, page 21)}$$

$$W = H + H_p, \text{ and} \quad \text{(ASME Code, page 219)}$$

$$H = \frac{\pi}{4} (2R)^2 \; P,$$

where P, S, C, t, and R are as defined above and

W = Total bolt load, lb,

H = Hydrostatic end force exerted by maximum allowable working pressure, lb,

H_p = Force to assure tight joint, $H_p = 0$ for the Viton o-ring since it is considered self sealing, and

h_G = Gasket moment arm, $h_G = 0.96$ in.

Combining, rearranging, and simplifying, the pressure equations yield the following:

$$P = \frac{S}{C} \left(\frac{t}{2R} \right)^2 \Bigg/ \left(1 + \frac{1.78 \pi \; h_G}{8 \; RC} \right)$$

$$P = \frac{(15,600)}{(0.3)} \left(\frac{0.69}{24} \right)^2 \Bigg/ \left(1 + \frac{1.78 \pi \times 0.96}{8 \times 12 \times 0.3} \right)$$

$$P = 36 \text{ psi}$$

Thus, the pressure capability of the finned cask at 200°F, based on the capability of the flanged cover, is 36 psi.

It should be noted that the 1/8-in. deep grooves in the finned cask wall will not alter the pressure capability as a result of stress concentration in the metal near the groove radius. Although stress concentration does exist in this area, the stress level is very low and will not cause the material to yield. Even under a cyclic load, stress concentration would not reduce the pressure capability of the cyclindrical cask wall below the capability of the flanged cover.

C.3. Results

The maximum allowable stress values and the results of the calculations at elevated temperatures are tabulated as follows:

Temperature, °F	Maximum Allowable Stress (S), psi	Maximum Allowable Working Pressure, psi		
		Body	Bottom	Cover
100	18,700	269	61	43
200	15,600	225	51	36
500	12,100	174	39	28
1,000	9,700	140	32	23
1,500	1,400	20	5	3

These results are also presented in Figure D-2 which shows the maximum allowable working pressure, in accordance with ASME Code, as a function of the temperature for the finned cask cylindrical body, the welded bottom plate, and the bolted cover. The pressure capability decreases gradually for each curve up to approximately 1000°F and then decreases rapidly.

The weakest component is the bolted cover which has a maximum allowable working pressure of 36 psig at 200°F (93°C). The brackets at the low temperature end of each curve show the normal operating temperature of the finned cask when containing the MHW isotope heat source as determined from the steady state temperature testing which is discussed elsewhere in this report. The dashed line at 33 psig shows the pressure relief valve setting and the broken line illustrates the helium pressure increase within the finned cask when initially filled to 1100 torr absolute pressure (6.6 psig) at ambient temperature. Also shown near the bottom of Figure D-2 is the duration of time the Viton o-ring is expected to provide a seal when heated to the corresponding temperatures.

It is obvious from Figure D-2 that the finned cask pressure capability is significantly greater than the normal operating pressure of the helium atmosphere. As the temperature increases, the helium pressure increases and the pressure capability decreases. At approximately 750°F (399°C) the helium will be released through the pressure relief valve and the Viton o-ring will begin to leak after a short period of time. At the hypothetical accident test temperature of 1475°F (802°C), the finned cask will not contain the helium atmosphere, but will remain structurally rigid.

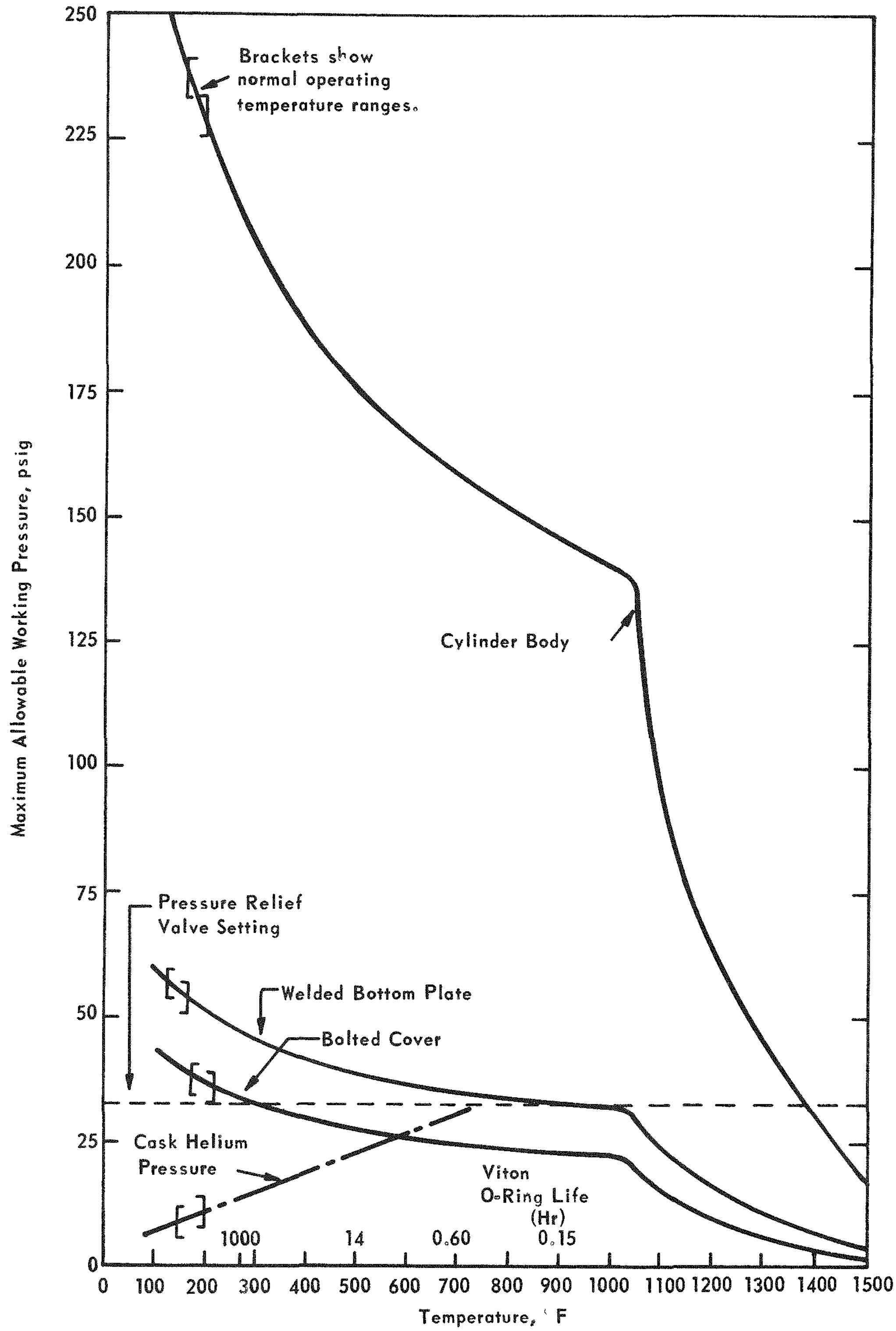


FIGURE C-2 - Finned cask maximum allowable working pressures at elevated temperatures.

Section C - Part 2

PACKAGE STANDARDS EVALUATION

C.1. General

In Part II of AECM 0529, general standards are specified for materials, closures, lifting devices and tie-down devices in addition to structural standards pertaining to load resistance and external pressure. The purpose of this evaluation is to provide the necessary supporting information which verifies that the MHW-IHS-SC is in compliance with these standards.

C.2. Materials

The packaging materials and the package contents will not cause any significant reactions even at hypothetical accident conditions. Design materials were carefully selected and this has been verified by testing, and by experience gained with the container during packaging, unpackaging, storage, and shipping operations for the MHW heat sources designated "Q-1" and "F-1."

C.3. Closures

Positive closures, utilizing several bolts, which prevent inadvertent opening, are used on both the carrier and the finned cask. In addition, seals are secured to the carrier and cask closures and the valves during shipment.

C.4. Lifting Devices

It is required that lifting devices which are an integral part of the package be capable of lifting three times the weight of the package and any attachments without generating stress in any material of the package in excess of its yield strength. The three lifting lugs on the cover of the finned cask were tested and evaluated and the carrier base-plate was evaluated with respect to this requirement.

It was verified that the cover lifting lugs satisfy this requirement by simply lifting the cover, while hot, using only one of the three lifting lugs. This test caused no observable damage and it is concluded that all three of the lifting lugs are capable of lifting three times the weight of the cover. Each of the stainless steel lifting lugs has a rectangular cross section of 1/2 in. x 7/16 in., at the thinnest location. An evaluation is presented below which establishes the maximum capability of the lifting lugs.

When the cask cover is lifted, bending stresses will occur in the plate as well as tensile stresses in the lugs. Details of the cask cover are shown in Figure 1. The cask material is 304 stainless steel with a specified yield strength of 30,000 psi and the weight of the cover is 140 lb. To satisfy requirements, each of the three lifting lugs must resist 140 lb, which is 1/3 of the total weight requirement. This concentrated load will cause bending stresses in the plate. The maximum bending stress is obtained by, conservatively, assuming that a triangular portion of the plate, as shown in Figure C-1, is resisting the moment due to the concentrated force at Point A. The plate is assumed fixed along B-C.

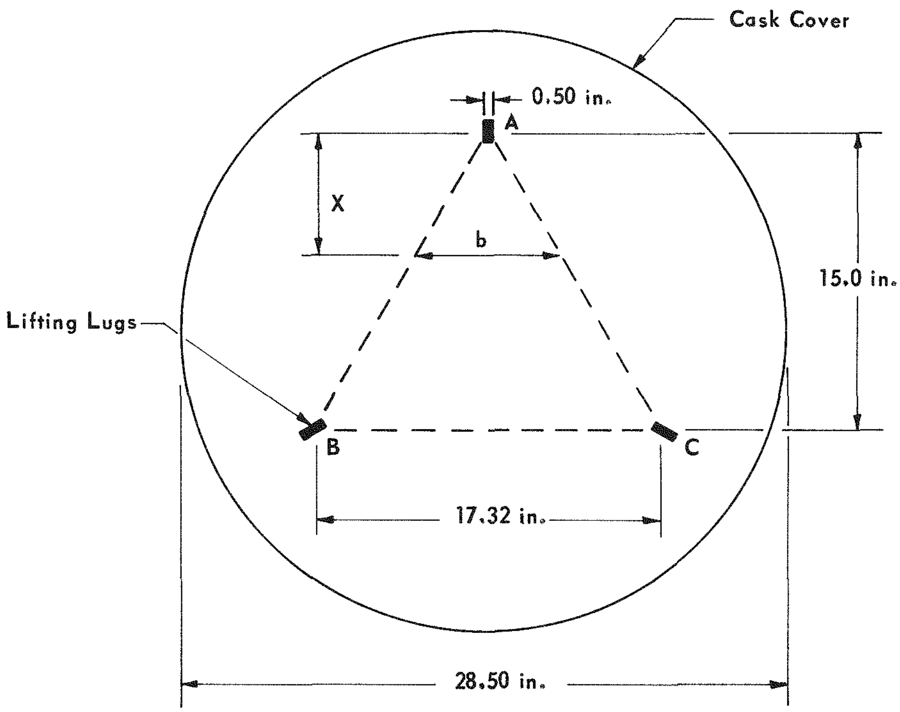


FIGURE C-1 - Cask cover lifting lug evaluation.

At any distance (X) from A, the width (b) is given by

$$b = 0.50 + 1.12X \text{ in.}$$

Then, at X = 15 in.,

$$b = 17.32 \text{ in.}$$

The maximum bending stresses due to the 140 lb. load at A occurs along B-C and is

$$S_{max} = \frac{6M}{bt^2}$$

where S_{max} = the maximum bending stress (psi),

M = the bending moment, M = (140) (15) in. lb ,

b = width, b = 17.32 in., and

t = plate thickness, t = 0.75 in.

Thus,

$$S_{max} = \frac{6(140)\ (15)}{17.32(0.75)^2} = 1300 \text{ psi.}$$

Since the distributed weight of the plate was not included in the determination of the maximum moment, the result is conservative. The maximum bending stress is only 4% of the material yield stress. The details of the cover lifting lugs are shown in Figure C-2. The minimum cross sectional area of a lug is

$$A = 0.50\ (0.87) = 0.435\ \text{in.}^2$$

The maximum tensile stress is then calculated as follows:

$$S = \frac{P}{A} = \frac{140}{0.435} = 322\ \text{psi}$$

This value is only 1% of the specified yield strength. Thus, the bending stress in the cover plate and the tensile stress in the lifting lug are both insignificant compared to the strength of the cover plate and the lifting lugs.

The entire container is lifted using a fork lift or hand pallet truck. Sections of 10-in. channel are welded to the bottom of the carrier base plate to provide access from all four sides as seen in Figure C-3. When the container is lifted, the maximum stresses will occur in the base plate due to potential bending. The base plate is supported by six channel sections as shown in Figure C-3. Another combination of six channel supports is used when lifting is from the left or right hand side of the container. The maximum gross weight of the container is 3000 lb, of which 1400 lb is the maximum cask weight and 1600 lb is the maximum carrier weight.

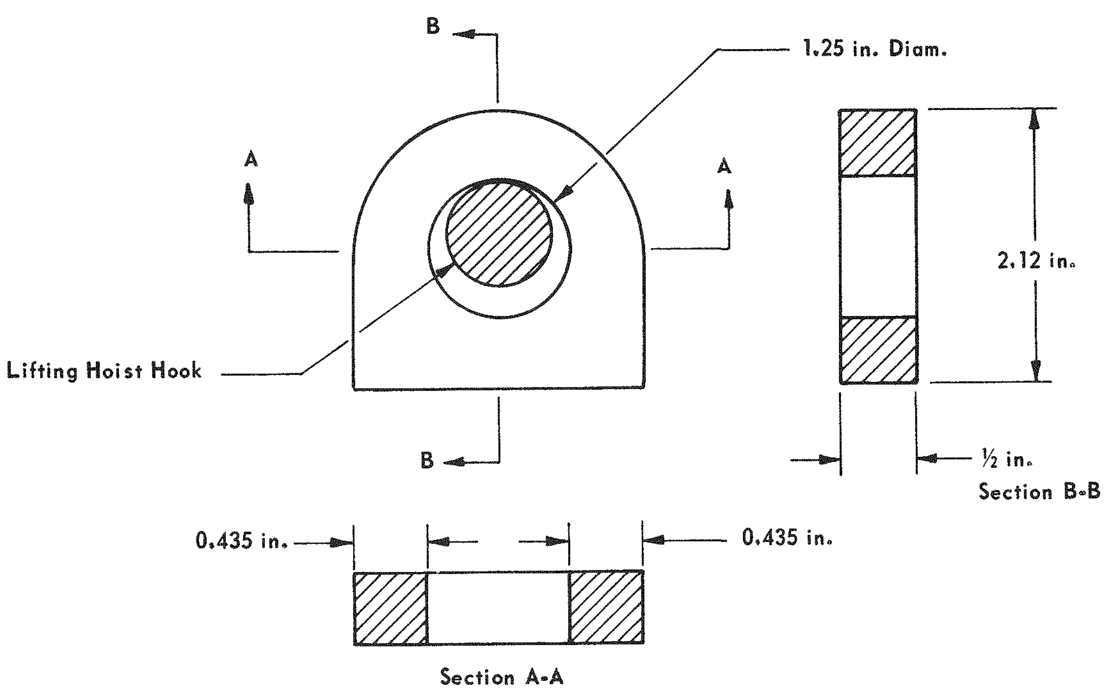


FIGURE C-2 - Lifting lug details.

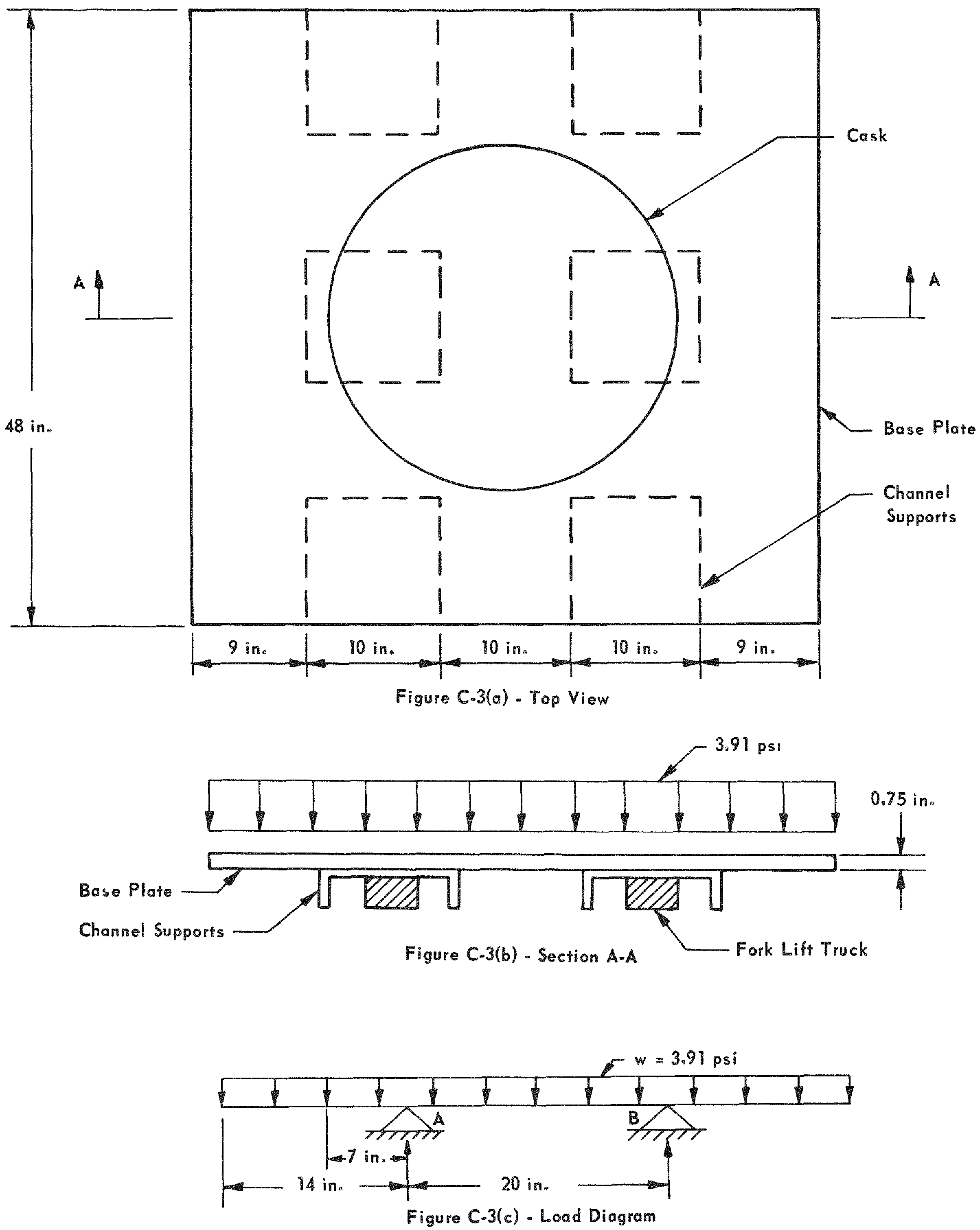


FIGURE C-3 - Base plate lifting evaluation.

The yield strength of the plate material is 27,000 psi per ASME Pressure Vessel Code.[4] For this analysis, three times the package weight (3x3000 = 9000 lb) is assumed to be uniformly distributed over the base plate area. Thus,

$$P = \frac{\text{Weight}}{\text{Area}} = \frac{9000}{(48)(48)} = 3.91 \text{ psi}$$

Considering a 1 in. wide strip (b) through the center of the plate, as shown in Figure C-3 (c), the maximum bending moment, which occurs at point A, is

$$M_{max} = (3.91 \text{ psi})\ (14 \text{ in.})\ (7 \text{ in.})\ \ (1 \text{ in.}) = 383 \text{ in. lb}$$

where the distances are illustrated in Figure C-3. The maximum plate bending stress is then

$$S_{max} = \frac{6M_{max}}{bt^2} = \frac{6\ (383)}{(1)\ (0.75)^2} = 4075 \text{ psi}\ .$$

The maximum bending stress is only 15% of the yield stress of the material which is 27,000 psi. Furthermore, this is a conservative result because the supports are not actually point supports, but are 10 in. wide. Also, the cask is approximately one half of the weight of the MHW container, and it is supported directly by the interior channel sections. Accounting for this consideration would decrease the maximum bending stress derived above by approximately 50%.

C.5. Tiedown Devices

AEC Manual Chapter 0529 specifies that tiedown devices, which are a structural part of the package, must be capable of withstanding simultaneously 10*g* longitudinal, 5*g* lateral, and 2*g* vertical loads without exceeding the yield strength of the material. This requirement is applied to the four cask mounting tabs used to secure the finned cask to the carrier base plate. This is based on postulating that failure of the mounting tabs under severe load could breach the cask; although this type of failure would not cause any loss of the radioactive materials. Since the carrier base plate and the eight tiedown rings attached to the carrier framework are not structural parts of the package, a tentative RDT standard[6] is applied to these components. The standard proposes that all parts of the tiedown system that are not considered structural parts of the package be so designed and fabricated such that static stresses would not exceed the yield strength if the package were subjected to a sustained acceleration of 2*g* forward or backward, 1*g* sideways, or 2*g* vertically. It is shown in this section that the MHW shipping container satisfies the applicable requirements set forth in AEC Manual Chapter 0529 and in the RDT standard. Failure of the devices under excessive load will not impair the ability of the package to meet the requirements of the other general standards.

The mounting fixtures for securing the finned cask to the carrier base plate are evaluated first. The mounting configuration is illustrated in Figure C-4, which shows the four mounting tabs,

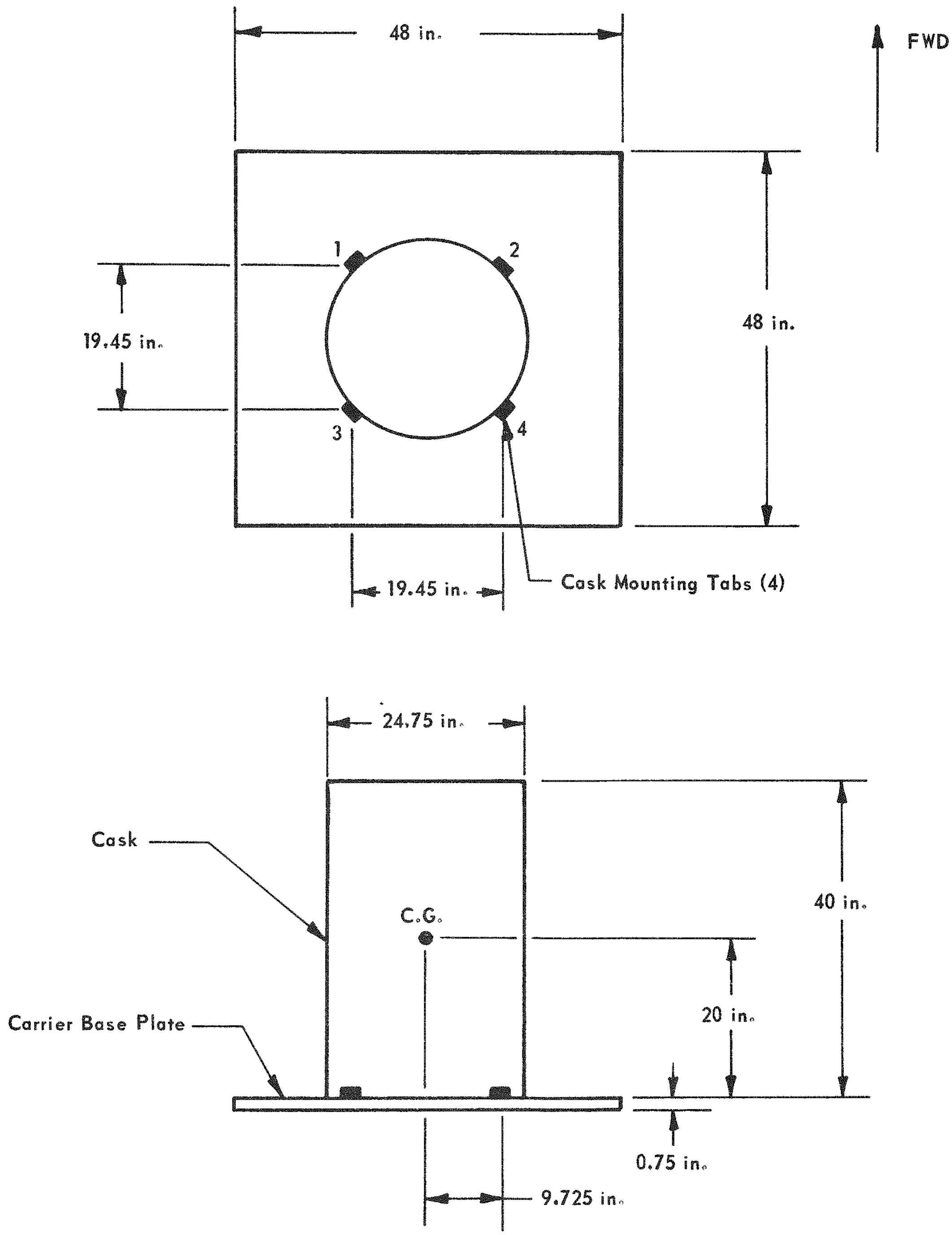


FIGURE C-4 - Cask mounting configuration.

designated 1 through 4. The tabs are welded to the cask body and bolted to the carrier base plate. Inertia loads will cause tension in the mounting bolts which, in turn, causes bending stresses in the tabs and the carrier base plate. In the following evaluation, the maximum inertia load of a mounting bolt is found to be 11,148 lb and the resulting maximum stress in the mounting tab is determined to be 16,000 psi, which is only 53% of the yield stress of the 304 stainless steel. The maximum load in the base plate is found to be 1,440 lb and the resulting maximum stress in the base plate is 5,380 psi, which is 20% of the yield stress of the steel.

The simultaneous application of 10*g* longitudinal, 5*g* lateral, and 2*g* vertical inertia loads is illustrated in Figure C-5. The maximum weight of the cask and its contents is 1400 lb and the distance between tabs is 19.45 in. Each of the inertia loadings specified above is first considered separately and the results are then combined. The longitudinal inertia load of 10*g* (10 x 1400 lb = 14,000 lb) will cause tensile stresses in bolts 3 and 4 and compressive stresses in bolts 1 and 2. The magnitude of these bolt loads (P) can be found by summing moments about point A (See Figure C-5). Neglecting the weight of the cask, for the present, the moments are summed as follows:

$$2P(19.45 \text{ in.}) = (14{,}000 \text{ lb})(20 \text{ in.}) \qquad (1)$$

$$P = 7{,}198 \text{ lb},$$

where P is the bolt load for bolts 3 and 4.

Vertical equilibrium requires that

$$P_1 = P_2 = -7{,}198 \text{ lb}. \qquad (2)$$

The negative sign indicates compression. Therefore,

$$P_1 = -7{,}198 \text{ lb},$$

$$P_2 = -7{,}198 \text{ lb}, \qquad (3)$$

$$P_3 = +7{,}198 \text{ lb, and}$$

$$P_4 = +7{,}198 \text{ lb}$$

Next, the lateral inertial loading of 5*g* (7,000 lb) is considered. For this loading, bolts 1 and 3 will be in tension and bolts 2 and 4 will be in compression. The magnitudes of the bolt loads are determined by summing moments about point B as follows:

$$2P(19.45 \text{ in.}) = 7{,}000 \text{ lb } (20 \text{ in.}), \qquad (4)$$
$$P = 3{,}600 \text{ lb},$$

where P is the bolt load for bolts 1 and 3.

Vertical equilibrium requires that

$$P_2 = P_4 = -3{,}600 \text{ lb} \qquad (5)$$

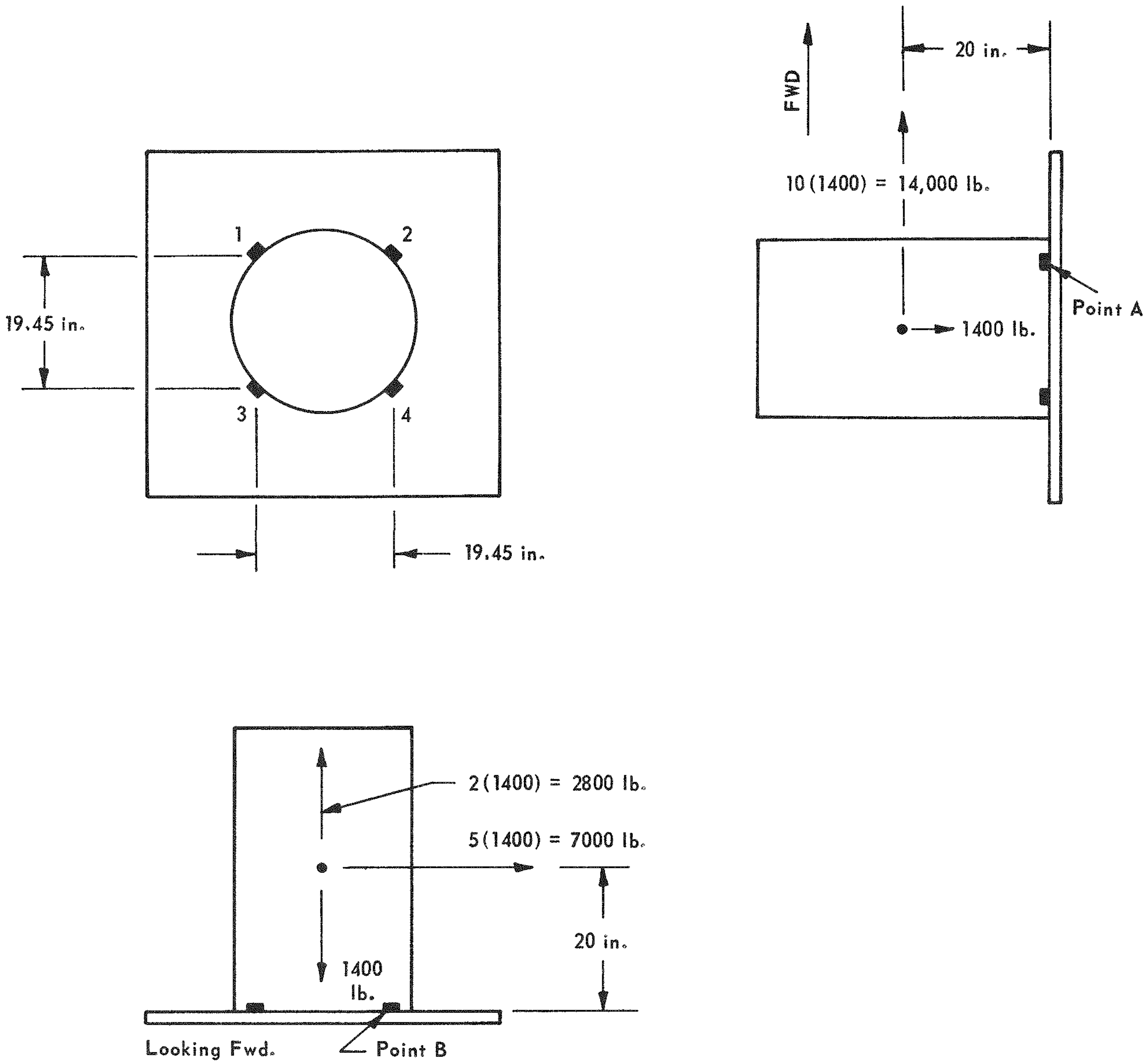


FIGURE C-5 - Cask mounting inertia loads.

where the negative sign, again, indicates compression. Then,

$$P_1 = +3,600 \text{ lb},$$
$$P_2 = -3,600 \text{ lb},$$
$$P_3 = +3,600 \text{ lb, and} \tag{6}$$
$$P_4 = -3,600 \text{ lb}.$$

Finally, the vertical loading of 2g is considered. Here the weight of the cask is included in the analysis and the resulting vertical loading becomes 2g - 1g = 1g = 1400 lb. For this loading condition, each bolt will develop tensile stresses of equal magnitude. Equilibrium in the vertical direction requires

$$P_1 = P_2 = P_3 = P_4 = \frac{1400}{4} = 350 \text{ lb}. \tag{7}$$

Therefore,

$$P_1 = 350 \text{ lb},$$
$$P_2 = 350 \text{ lb},$$
$$P_3 = 350 \text{ lb, and} \tag{8}$$
$$P_4 = 350 \text{ lb}.$$

The three inertia loads determined above (equations 3, 6, and 8) for each bolt are added together (P_1 = -7,198 + 3,600 + 350 = 3,248 lb) to obtain the resultant bolt forces as follows:

$$P_1 = -3,248 \text{ lb},$$
$$P_2 = -10,448 \text{ lb},$$
$$P_3 = +11,148 \text{ lb (maximum), and} \tag{9}$$
$$P_4 = +3,948 \text{ lb},$$

Thus, the maximum bolt load is 11,148 lb. Since each bolt is 3/4 in. nominal diam with a minimum cross-sectional area of 0.3345 in.^{2}, the maximum tensile stress developed in the bolt is

$$S_{max} = \frac{P_{max}}{A} = \frac{11,148}{0.3345} = 33,300 \text{ psi}. \tag{10}$$

This is only 17% of the 200,000 psi tensile strength of the bolts. The bolts, therefore, satisfy AECM 0529 requirements as well as the tentative RDT Standard.

The maximum stress developed in the cask mounting tab, based on the maximum load of 11,148 lb, was found using a finite element method of stress analysis. A widely used computer program and an IBM 360 computer were used to perform the calculations. The computer program (SOLID SAP) is described and sample calculations are provided by Wilson.[7] The calculations were performed using 148 node points and 116 plate bending elements. The results of the analysis indicate that the maximum stress developed in the cask mounting tab due to the bolt load of 11,148 lb is 16,000 psi. Since this is only 53% of 30,000 psi, the yield stress for the 304 stainless steel, the mounting tabs satisfy the AECM 0529 requirements for devices which are a structural part of the package.

The RDT standard for non-structural parts is applied to the carrier base plate. The requirements are satisfied if the stresses are less than the material yield stress when a longitudinal inertia loading of $2g$ is applied since the lateral and vertical loads will cause less stress than the longitudinal load. It has previously been shown that a longitudinal inertia load of $10g$ (14,000 lb) develops bolt loads of 7,198 lb (See Equation 3). The maximum bolt load for a $2g$ loading (2,800 lb) is proportional and is

$$P = \frac{7{,}198 \text{ lb } (2{,}800 \text{ lb})}{14{,}000 \text{ lb}} = 1440 \text{ lb}. \qquad (11)$$

Thus, bolts 1 and 2 will be in compression, bolts 2 and 4 will be in tension, and the magnitude of each load is 1440 lb. A finite element analysis, similar to that for the mounting tab discussed above, was performed in order to determine the resulting maximum stress in the carrier base plate. The calculations were performed with 85 node points and 60 plate bending elements using the SOLID SAP computer program. The results of this analysis indicate that the maximum bending stress developed due to the 1,440 lb load is 5,376 psi. Since this value is only 20% of the material yield stress, which is 27,000 psi, the RDT standard is satisfied.

Next, is an evaluation of the tiedown system which is comprised of the eight rings fastened to the carrier framework, and is used to secure the shipping container in the transport vehicle with chains or cables. It is assumed that (1) the container itself is perfectly rigid, (2) the cross-sections of all cables are identical, and (3) the center of mass coincides with the centroid of the cask. The maximum gross weight of the container is 3,000 lb. The maximum cable load is shown below to be 1835 lb and the resulting stress is 690 psi. Since this is only 3% of the yield stress, the RDT standard is satisfied.

The cable tiedown configuration for the carrier is shown in Figure 6. The RDT standard requires that the stresses developed in the carrier framework be less than the material yield stress when an inertia load of $2g$ is applied longitudinally, when an inertial load of $1g$ is applied laterally, or when an inertial load of $2g$ is applied vertically. Since the vertical load requirement obviously causes less stress than the other two loads, no calculations are necessary for the vertical case. The inertial loading conditions are shown in Figures 7 and 8. The longitudinal load of $2g$, shown in Figure 7, is considered first. Since chocking is used to prevent slipping of the container along the transport vehicle floor, the container will tend to overturn

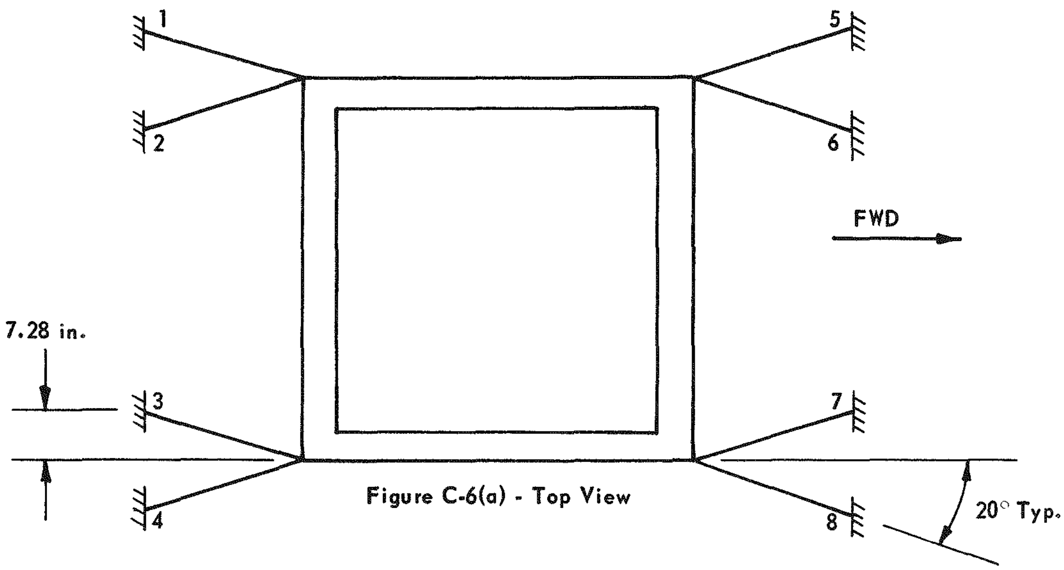


Figure C-6(a) - Top View

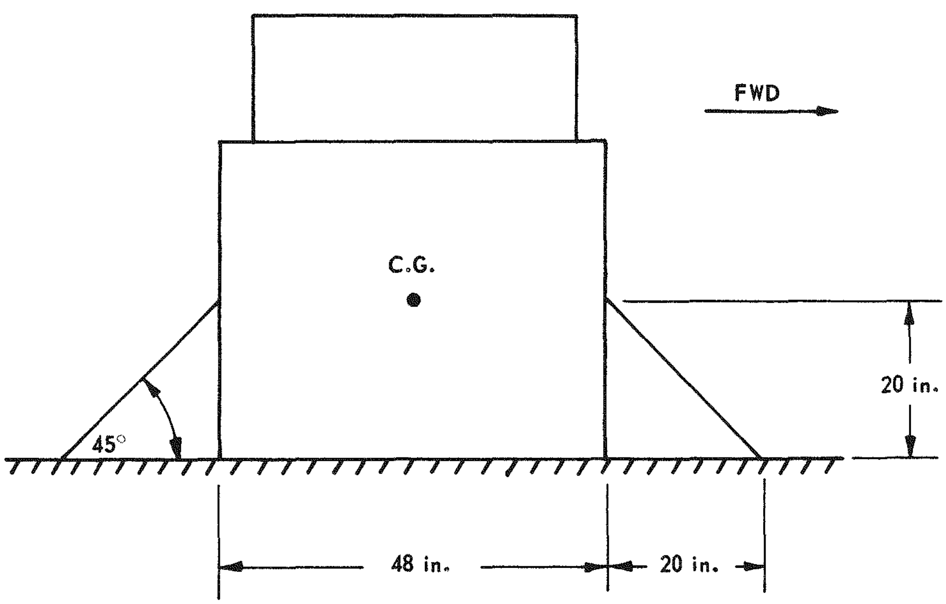


Figure C-6(b) - Side View

FIGURE C-6 - Carrier tiedown configuration.

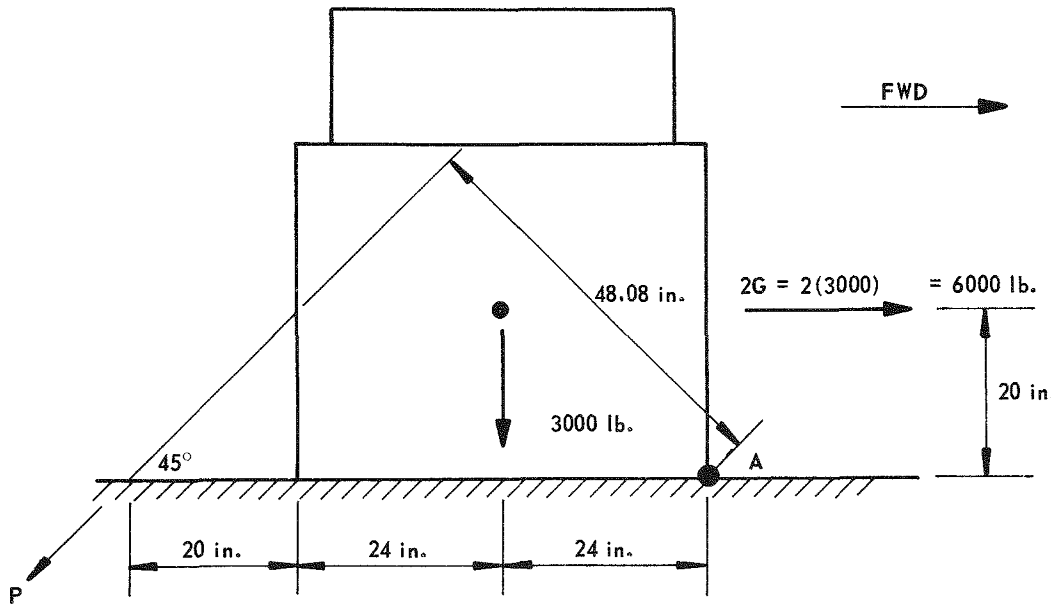


Figure C-7(a) - Tipping About Point A.

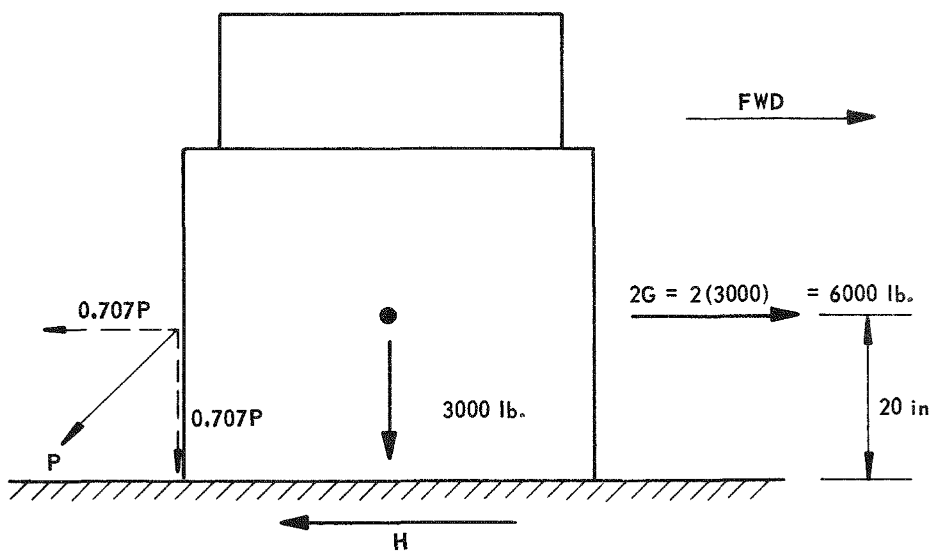


Figure C-7(b) - Sliding

FIGURE C-7 - Longitudinal tiedown inertia loads.

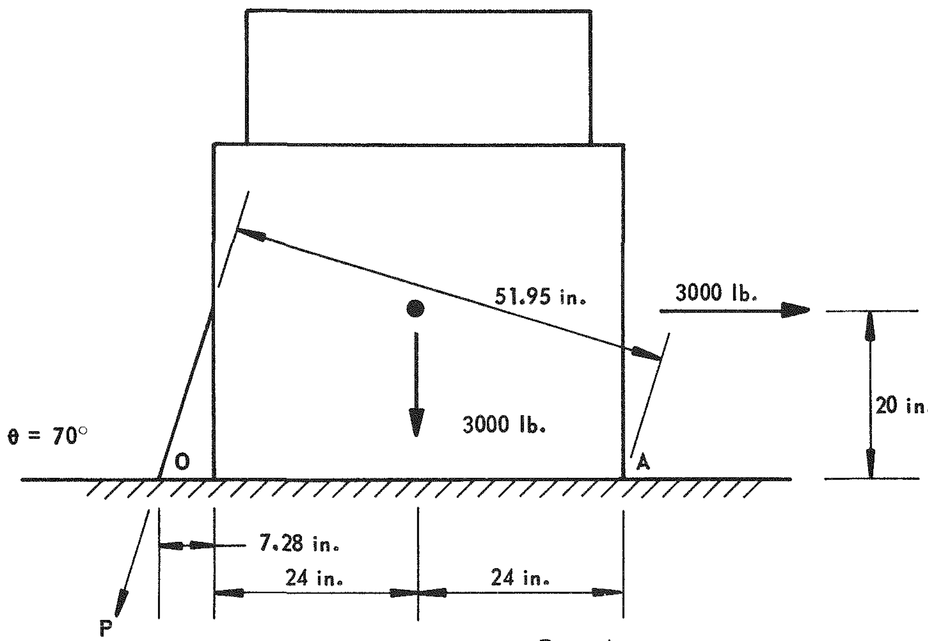


Figure C-8(a) - Tipping About Point A.

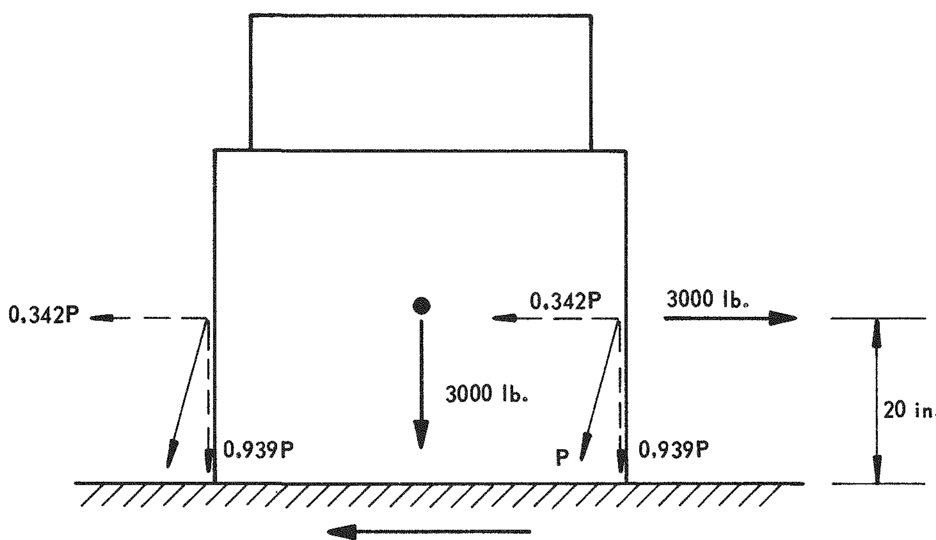


Figure C-8(b) - Sliding

FIGURE C-8 - Lateral tiedown inertia loads.

about point A. To determine the cable loads for this condition, moments are summed about point A as follows:

$$P(48.08 \text{ in.}) + 3000 \text{ lb } (24 \text{ in.}) = 6000 \text{ lb } (20 \text{ in.})$$

Thus, $$P = 998 \text{ lb.} \qquad (12)$$

The force (P) acting on the four cables, labeled 1 through 4 in Figure C-6, is shown in Figure C-7. Each cable load (F) is then

$$F = \frac{(998/4)}{\cos 20^\circ} = 266 \text{ lb.} \qquad (13)$$

If it is conservatively assumed that no chocking is used, the cable forces developed if the container were free to slide along the floor may be determined. This condition is shown in Figure C-7 (b). Equilibrium in the horizontal direction requires that

$$2g = H + 0.707\ P = 6000 \text{ lb}, \qquad (14)$$

where P is the cable load and H is the frictional force along the vehicle floor, as shown in Figure C-7. Using a value of 0.4 for the coefficient of friction between the floor and the carrier, the frictional force (H) is

$$H = 0.4(0.707P + 3000 \text{ lb}) = 0.28P + 1200. \qquad (15)$$

Substituting this into equation (14) yields

$$0.28P + 1200 + 0.707P = 6{,}000 \text{ lb.} \qquad (16)$$

Thus, P = 4,863 lb, where P represents the total load on all four cables. Each cable load is then

$$F = \frac{(4{,}863/4)}{\cos 20^\circ} = 1293 \text{ lb.} \qquad (17)$$

In a similar manner, the cable loads are determined when a lateral inertia load of 1g is applied to the carrier as shown in Figure C-8. With chocking, the carrier will tend to rotate about point A. To determine the cable loads, we sum moments about point A as follows:

$$F\ (51.95 \text{ in.}) + 3000 \text{ lb } (24 \text{ in.}) = 3000 \text{ lb } (20 \text{ in.}). \qquad (18)$$

The equation yields F = -231 lb, and, therefore,

$$F = 0.$$

The negative result indicates that the weight of the container is sufficient to resist any overturning and, thus, there are no cable forces.

Conservatively assuming that no chocking is used and the container will slide along the floor, equilibrium in the horizontal direction requires that

$$0.342P + 0.342P + H = 3000 \text{ lb}, \qquad (19)$$

where H is the frictional force along the floor and P represents the cable forces. Using 0.4 for the coefficient of friction, the frictional force along the floor (H) is

$$H = 0.4\ (0.939P + 0.939P + 3000), \tag{20}$$

$$H = 0.75P + 1200\ .$$

Substituting this into equation 19 yields

$$0.342P + 0.342P + 0.75P + 1200 = 3000\ . \tag{21}$$

Thus, $P = 1255\ \text{lb}$.

The load in one cable is

$$F = \frac{(1255/2)}{\sin 20^\circ} = 1835\ \text{lb}\ . \tag{22}$$

From the analysis above, it is determined that the maximum cable load developed for the required inertia loading condition is 1835 lb. The framework of the carrier consists of 2 in. x 2 in. x 5/8 in. steel angle iron. The eight tiedown rings are secured to the framework and cables are attached to the rings. Since each tiedown ring is rated at 4000 lb load capacity, the rings clearly exceed requirements. The maximum compressional stress in the angle iron framework is determined next. The vertical component of the 1835 lb load (F_v) is calculated as follows:

$$F_v = 1835 \sin 70^\circ = 1724\ \text{lb}\ . \tag{23}$$

The maximum compressive stress in the angle iron is

$$S_{max} = \frac{F_v}{A} = \frac{1724}{(2\ \text{in.} + 2\ \text{in.})(0.625\ \text{in.})} = 690\ \text{psi}\ . \tag{24}$$

This stress is only 3% of the material yield stress, which is 27,000 psi, and the RDT standard is satisfied.

The results of the cask mounting and tiedown evaluations are summarized in Table 1.

Table 1

RESULTS OF CASK MOUNTING AND TIEDOWN EVALUATIONS

Component	Criteria	Maximum Load (lb)	Maximum Stress (psi)	Material Yield Stress (psi)
Cask Mounting Tab	0529	11,148	16,000	30,000
Cask Mounting Bolt	RDT	11,148	33,300	(200,000 tensile)
Carrier Base Plate	RDT	1,440	5,376	27,000
Tiedown Ring	RDT	1,835	(Rated 4000 lb load)	
Carrier Framework	RDT	1,724	690	27,000

C.6 Load Resistance

When regarded as a simple beam supported at its ends along any major axis, the shipping container must be capable of withstanding a static load, normal to and uniformly distributed along its length, equal to five times the fully loaded container weight without generating stresses in any material of the container in excess of the yield strength of that material.

The MHW cask is illustrated in Figure C-9. The cask material is 304 stainless steel with a minimum specified yield strength of 30,000 psi, per the ASME Pressure Vessel Code.[4] The maximum weight of the cask is 1400 lb. Stresses in the cask resulting from the uniform load are determined, as recommended by Shappert,[8] from the following equation:

$$S = \frac{MC}{I} = \frac{M}{Z} ,$$

where

S = stress (psi),

M = maximum bending moment, $M = \frac{5\ WL}{8}$ (in. lb),

$Z = \frac{I}{C}$ = section modulus of cask = $\frac{\pi}{4R_o}(R_o^4 - R_i^4) = \pi R_o^2\ t$ (in.^{3}) for a large diameter, thin-walled cylinder,

W = weight of cask, W = 1400 lb,

L = length of cask, L = 40.0 in.,

R_o = outside radius of cask, R_o = 12.25 in., and

t = effective thickness of cask wall, t = 0.25 in.

The computed maximum bending moment is

$$M = \frac{5\ (1400)(40.0)}{8} = 35{,}000 \text{ in. lb}$$

The computed section modulus is

$$Z = \pi R_o^2 t = \pi(12.25)^2\ (0.25) = 118 \text{ in.}^3$$

The maximum bending stress is then

$$S_{max} = 35{,}000/118 = 297 \text{ psi} .$$

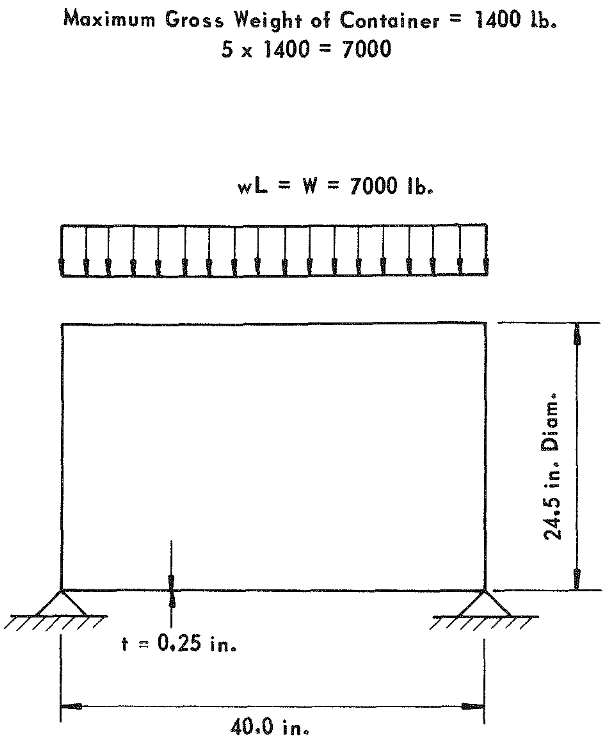


FIGURE C-9 - Load resistance of cask.

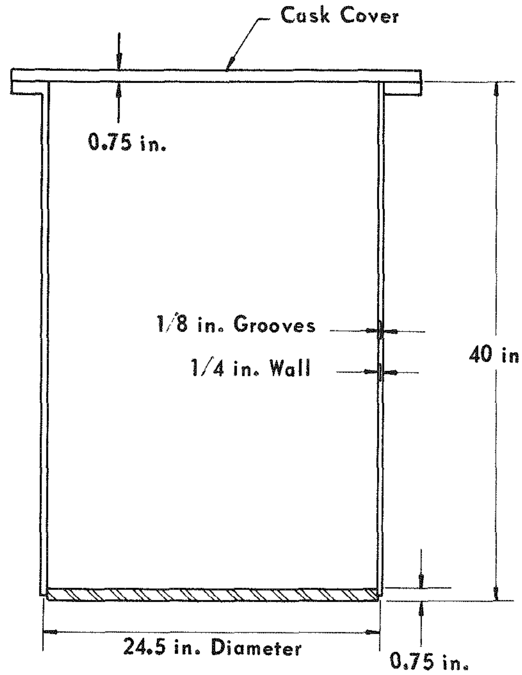


FIGURE C-10 - Cask external pressure.

Since this stress value is only 1% of the material yield stress of 30,000 psi, the MHW cask satisfies the load resistance requirement.

C.7 External Pressure

The containment vessel must be capable of withstanding an external pressure of 25 psi without any loss of radioactive contents. Conservatively, it is assumed that no loss of contents will result if the allowable stress of the finned cask body material is not exceeded and if local buckling does not occur, even though these conditions would not necessarily cause the cask to be breached and would not affect the FSAs, which are the containment vessels. The MHW cask assembly is shown in Figure C-10. It is constructed of 304 stainless steel with an allowable stress of 15,600 psi at 200°F (93°C). The wall thickness of the cask is actually 3/8 in., but 1/8 in. deep grooves have been machined in the wall to accept the aluminum cooling fins. Therefore, 1/4 in. will be used as the thickness. Also, it is assumed, conservatively, that no structural strength is provided by the cooling fins.

First, the maximum bending stresses in the cask cover and the circular bottom end plate are considered. The actual boundary condition of the circular bottom end plate lies somewhere between fixed and simply supported. The cover plate is bolted to the flanged body and is assumed to have simply supported edges. The bottom end plate is welded to the container body and the edge is, conservatively, assumed fixed. The maximum bending stress in uniformly loaded circular plates is given by

$$S_{max} = \frac{1.24\ R^2P}{T^2},\ \text{for simply supported (top cover plate),}$$

and

$$S_{max} = \frac{0.75\ R^2P}{T^2},\ \text{for fixed edge (bottom plate),}$$

where

S_{max} = maximum bending stress (psi),

R = radius of plate, R = 12.25 in.,

P = pressure, P = 25 psi, and

T = thickness of plate, T = 0.75 in.

The maximum bending stress in the cover is then

$$S_{max} = \frac{1.24\ R^2P}{T^2} = \frac{1.24\ (12.25)^2(25)}{(0.75)^2} = 8270\ \text{psi}.$$

The maximum stress in the circular bottom end plate is:

$$S_{max} = \frac{0.75\ R^2P}{T^2} = \frac{0.75\ (12.25)^2(25)}{(0.75)^2} = 5000\ \text{psi}.$$

In the above cases, the maximum bending stresses in the material are only 53% and 32% of the allowable stress.

Second, the maximum membrane stress in the cask body is calculated. It is the hoop stress expressed as

$$S_{max} = \frac{PR}{T}\ ,$$

where

S_{max} = maximum hoop stress (psi),

P = pressure, P = 25 psi,

R = radius of body, R = 12.25 in., and

T = body wall thickness, T = 0.25 in.

Therefore,

$$S_{max} = \frac{25(12.25)}{0.25} = 1225\ \text{psi}.$$

This value is only 8% of the allowable stress.

The third consideration is the buckling strength. The buckling strength of the cask body can be determined by several methods; two methods are employed in this analysis. The allowable external pressure for the vessel is computed using the procedures specified in the ASME Pressure Vessel Code, Section VIII,[4] which provides an extremely conservative value for the critical pressure. A more exact computation for critical pressure is made, for comparison, using an expression from the theory of elastic stability developed by Timoshenko.[9]

The ASME pressure vessel code states that the allowable external pressure is given by the expression

$$P_{allowable} = \frac{B}{D/t} ,$$

where

$P_{allowable}$ = the allowable pressure load of the vessel (psi),

D = diameter of vessel, D = 24.5 in.,

t = thickness of vessel, t = 0.25 in., and

B = constant depending on the ratios D/t and L/t (where L = length of vessel), B = 8500.

For the MHW cask, the allowable pressure load is

$$P_{allowable} = \frac{8500}{24.5/0.25} = 86 \text{ psi}.$$

Obviously, the allowable external pressure is much greater than the required evaluation pressure of 25 psi.

A more exact value of the critical buckling pressure was found using Timoshenko's expression from the theory of elastic stability. The critical pressure load for the stainless steel cask was found to be 537 psi. This value is nearly 6 times greater than that obtained above from the ASME pressure vessel code, which illustrates the conservatism built into the pressure vessel code.

The results of the external pressure calculations are summarized in Table 2.

Table 2

RESULTS OF EXTERNAL PRESSURE CALCULATIONS

Stresses with 25 psi External Pressure	Stress or Pressure Capability (psi)
Material Allowable Stress	15,600
Maximum Bending Stress of Top Cover Plate	8,270
Maximum Bending Stress of Bottom Plate	5,000
Maximum Membrane Stress in Body	1,225
External Pressure Capabilities	
Minimum Required	25
ASME Allowable	86
Theoretical Critical Buckling Pressure	537

SECTION D

STEADY STATE TEMPERATURE PROFILES

CONTENTS:

STEADY STATE TEMPERATURE PROFILES

D.1. Purpose

It is necessary to determine the steady state temperature profiles of the shipping container and its contents to assure compliance with DOT/AEC regulatory requirements, compliance with General Electric product specifications , and to determine the appropriate temperatures for evaluation of the contents. The steady state data obtained at the heat loads tested experimentally and when containing the 2400W "QUAL-1" heat source are also used to determine the maximum heat load capability of the shipping container. These particular tests were performed in cooperation with General Electric personnel to obtain additional information regarding the SPC, but the scope of this section is limited primarily to thermal testing of the shipping container.

D.2. Test Equipment and Procedures

The test was performed using the equipment illustrated schematically in Figure D-1. Figure D-2 shows the shipping container during the test. An electric heater was installed within the SPC to simulate the MHW heat source. The electrical wires and thermocouples were fed through the access port at the top of the SPC and a cap for the access port was fashioned of stainless steel sheet to prohibit bulk helium flow from the SPC to the finned cask during the test. The cap was not intended to be leak tight. A motor driven powerstat (Figure D-3) was used to continuously increase the power at an average rate of approx. 30 W/hr to avoid damaging the heater by thermal shock. Voltage and amperage readings were made periodically and the wattage was calculated according to $W = V \times I$.

A helium atmosphere of 99.96% (calculated) purity was obtained by evacuating and backfilling the SPC and the shipping container simultaneously. Both were at the same pressure since the stainless steel sheet cap on the SPC access port was not leak tight. A slight positive pressure was maintained using a "bubbler" set up, which consisted of a container with a column of oil which was open to the atmosphere. The tubing from the cask was immersed in the oil to a depth of 5 in. As the shipping container was heated, the helium expanded into the tubing and bubbled up through the oil to escape and maintain a slight positive pressure. Helium was continuously fed through the tubing at an average rate of 0.75 SCFM so that, in the event of an accidental temperature decrease, helium, rather than air, would flow into the cask.

A digital thermometer was used to obtain the temperature data periodically and a recorder was used to continuously chart selected temperatures within the SPC. Figure D-4 shows the three multi-pin connectors installed in the finned cask cover for the thermocouple feedthroughs. Most of the thermocouples were welded in place and those on the aluminum fins were inserted into small holes. Figure D-5 shows the two thermocouple selector switches, the digital thermometer, and the recorder, which are also shown schematically in Figure D-1. Fourteen type K (chromel-alumel) thermocouples, attached internally and externally to the SPC, were connected to selector switch No. 1 and a single lead from the selector switch was connected to the digital thermometer. Temperatures were then obtained by simply dialing the thermocouple number and reading the temperature directly on the instrument. Six of the type K thermocouples were wired in parallel with the selector switch and connected to a Leeds & Northrup recorder to provide a means of continuously monitoring the heat-up period. Also, 19 type T (copper-constantan) thermocouples, connected to the cask and carrier, were connected to selector switch No. 2, which was used in the same manner as selector switch No. 1 to obtain the temperature readouts from the digital thermometer.

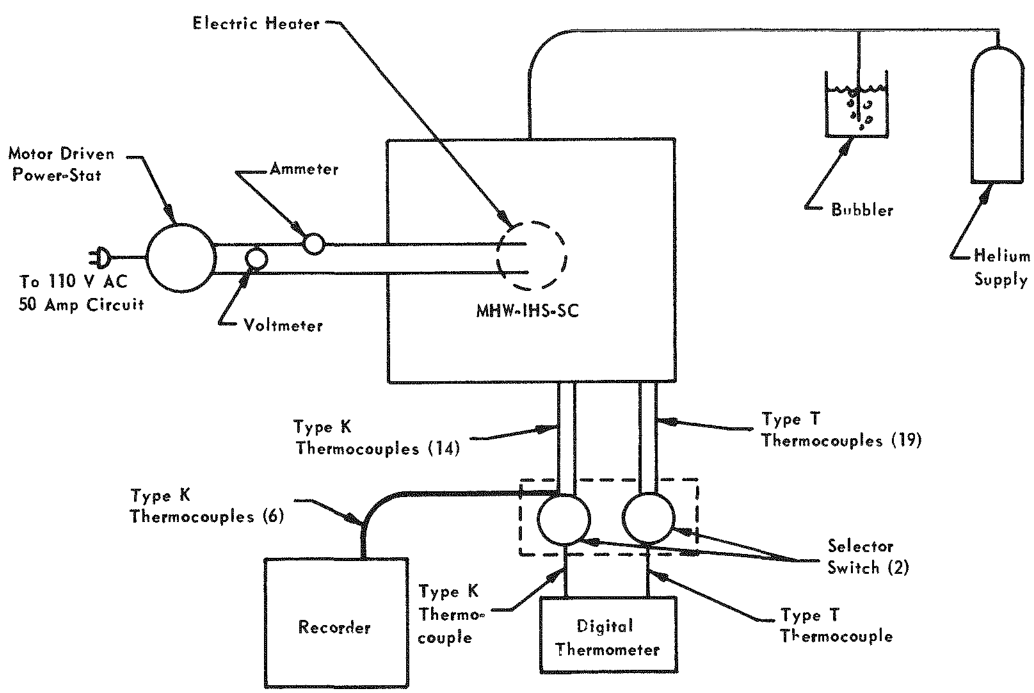


FIGURE D-1 - Schematic of thermal test equipment.

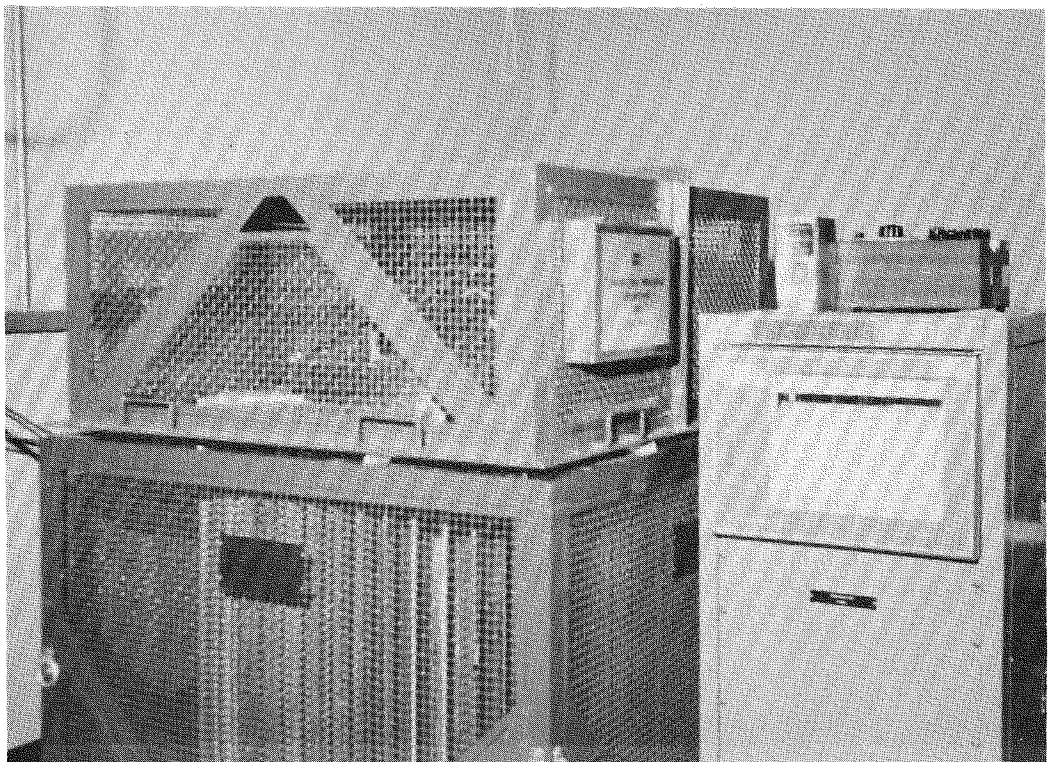


FIGURE D-2 - MHW-IHS-SC temperature profile testing.

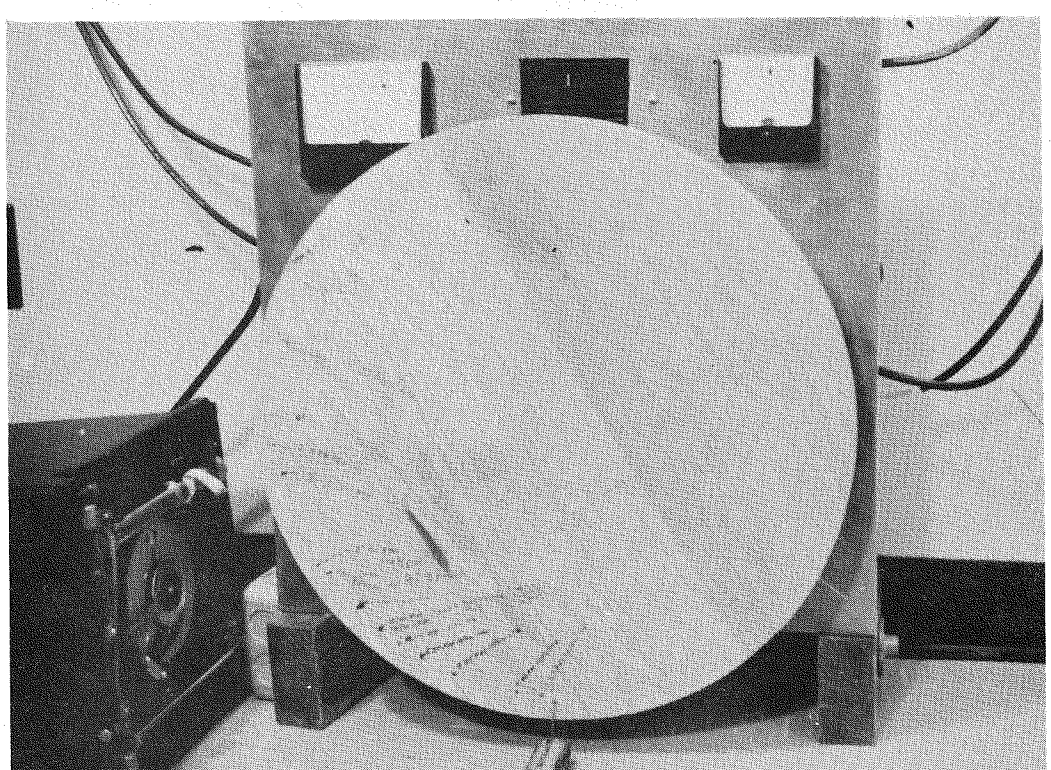


FIGURE D-3 - Power set-up.

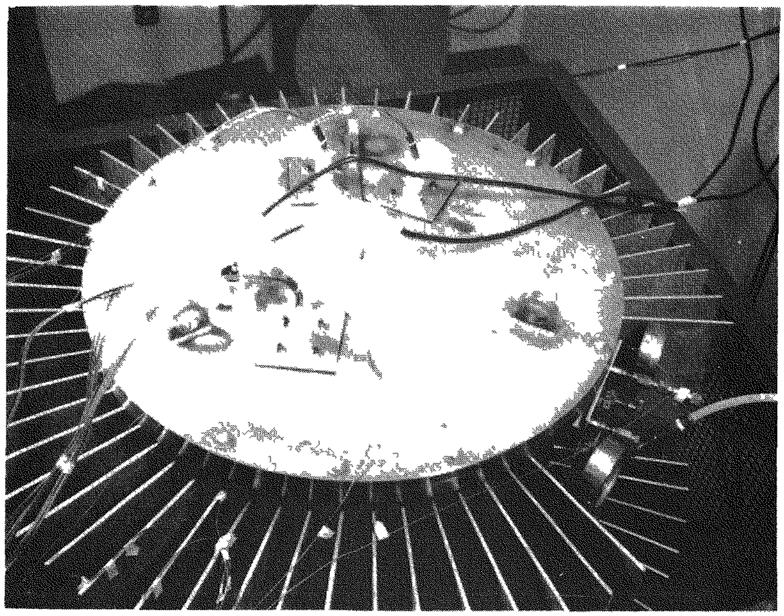


FIGURE D-4 - Electrical and thermocouple feedthroughs in the cask cover.

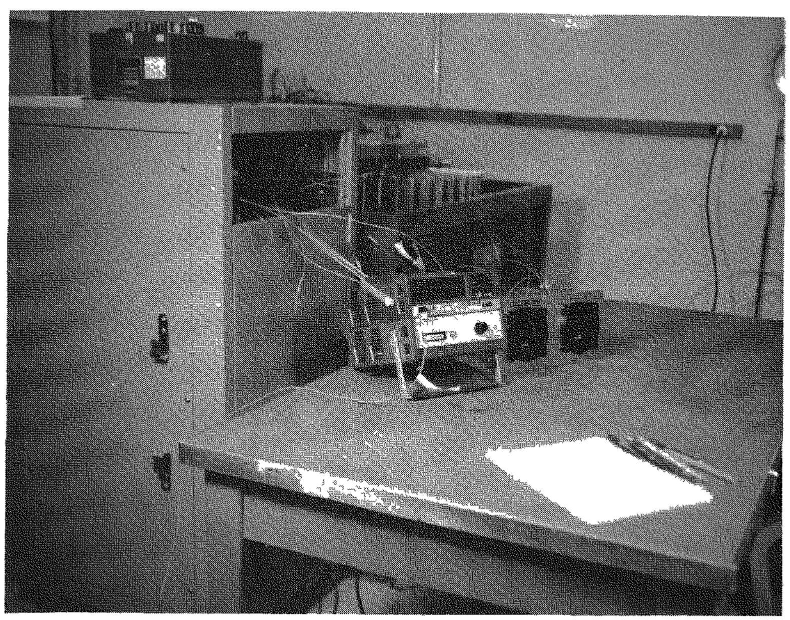


FIGURE D-5 - Temperature measurement equipment.

The heat-up procedure required a total of 110 hr. A set of steady state temperatures was obtained at measured values of 1390 W and 2480 W to provide a basis for extrapolation of the data to establish the maximum heat load capability of the shipping container. It was necessary to increase the power gradually to avoid damaging the electrical heater. The heat-up procedure is summarized as follows:

Increase heat to 1390 W	54 hr
Equilibrate at 1390 W	10 hr
Record Steady State Temperatures	--
Increase Heat to 2480 W	34 hr
Equilibrate at 2480 W	12 hr
Record Steady State Temperatures	--

Thermal equilibrium was verified by studying the temperature increases at various locations during the equilibration period. The temperatures remained essentially constant after the initial four hours of the equilibration period.

The ambient temperature was determined to be 80°F (27°C) based on averaging eight readings at various locations near the shipping container when the heat load to the shipping container was 2480 W. For simplicity, an ambient temperature of 80°F is also assumed for the 1390 W heat load.

An estimate of the horizontal temperature profile across the finned cask cover was obtained when the heat load was 2480 W by pressing a thermocouple against the lid at seven locations. It was determined that the temperature near the outside perimeter, above the Viton o-ring, was approximately 40°F cooler than the center of the cask cover.

D.3. Test Results

Steady state temperatures at experimental heat loads of 1390 W and 2480 W and the experimental ambient temperature of 80°F are presented in Table D-1.

The maximum accessible external surface temperature was found to be 113°F (45°C), Thermocouple (TC #) No. MRC-38,at the location on the underside of the carrier base plate at the center. The maximum SPC external surface temperature was found to be 432°F (222°C), TC #GE-13, on the vertical surface at the center. The maximum finned cask external surface temperature was found to be 198°F (92°C), TC #MRC-25, at the top center of the cask cover.

Another significant result of the test was the determination that the shipping container could be unpackaged while hot with no evidence of misfit, galling, or damage to the shipping container. No oxidation of the SPC or any other damage to the SPC resulting from the shipping container environment was observed. This was further verified as a result of the successful assembly and disassembly for the QUAL-1 shipment.

Table D-1

STEADY STATE TEMPERATURE TEST RESULTS

Thermocouple Number	Thermocouple Location	Steady State Temperature, (°F) at 1390 W	Steady State Temperature, (°F) at 2480 W
	SPC INTERIOR		
GE-8	Iridium Cylinder Center Side	--	1003
	SPC EXTERIOR		
GE-11	Bottom Center	--	399
GE-12	Bottom of Side	--	358
GE-13	Center of Side	300 (Approx.)	432
GE-14	Flange	--	361
GE-15	Top, Near Access Port	--	271
	CASK INTERIOR		
MRC-21	Ring Pad	231	329
MRC-23	Bulk Helium Near Isolator	137	173
MRC-24	Flexible Hose Center	172	227
	CASK EXTERIOR		
MRC-25	Top Center Cover	149	198
MRC-26	Center of Valve Area	131	168
	FIN A		
MRC-27	Top, 1/8-in. from Cask Body	107	127
MRC-28	Top, at Tip	97	110
MRC-29	Center, 1/8-in. from Cask Body	94	112
MRC-30	Center, at Tip	92	103
	FIN B		
MRC-31	Top, 1/8-in. from Cask Body	105	127
MRC-32	Top, at Tip	97	110
MRC-33	Top, at Cask Body Fin Joint	--	146
MRC-34	Center, at Tip	93	106
	CARRIER		
MRC-35	Cap at Top Center	--	93
MRC-36	Center Tie Down	80	84
MRC-37	Bottom Tie Down	82	86
MRC-38	Underneath Base Plate At Center	97	113

D.4. Temperature Profile Adjustments

In addition to the experimental test temperatures obtained using an electrical heater, data were obtained for the QUAL-1 heat source, which was the first plutonium fueled MHW-IHS to be packaged and shipped in the shipping container. During storage prior to shipment, the temperature of the top center of the finned cask cover and the ambient temperature were measured routinely. The highest temperature increase above ambient measured at this location was found to be 126°F (70°C), which is 7% higher than obtained at TC #MLC-25 during the test with the electrical heater. Thus, all of the experimentally measured temperature increases above ambient must be increased by 7% to compensate for the experimental error. Also, the calculated power of 2480 W during the test was slightly high and the value of 2400 W, corresponding to the heat output of the QUAL-1 is used. The specifications require that the heat output be 2410 ± 18 W. The heat load for the intermediate experimental temperature data is decreased proportionally from 1390 W to 1345 W. The ambient temperature must also be adjusted to 100°F (38°C) to represent normal conditions of transport on a hot day for comparison with DOT and AEC requirements. All of the resulting adjusted steady state temperatures are presented in Table D-2 and selected values are illustrated in Figure D-6.

The adjusted value for the maximum accessible external surface temperatures is, therefore, 135°F (57°C) (see Table D-2, MRC-38). This is considerably cooler than 180°F, which is the maximum acceptable value for sole use shipments, and is only slightly above the value of 122°F, which is the maximum acceptable value for other types of shipments. It should also be pointed out that the underside of the base plate may be considered "accessible", but it is not easily accessible and it is not accessible at all to personnel during normal shipment. To be consistent, an ambient temperature of 100°F is assumed for comparison of the SPC exterior temperature with the shipping container design requirement specified by GE. The adjusted value of 477°F is 223°F less than the specified maximum of 700°F. Also, use of 477°F for the SPC exterior surface temperature, for the purpose of evaluating the contents, provides a margin of safety since the SPC exterior surface temperatures measured at the other locations were all cooler.

The finned cask pressure capability is based on selection of 200°F (93°C) as the design temperature. It is necessary to verify that this design temperature is satisfactory. The temperatures of the cask cover obtained experimentally at 80°F (27°C) and the adjusted temperatures at 100°F (38°C) ambient based on the QUAL-1 data are shown in Table 3.

Table D-2

ADJUSTED AND EXTRAPOLATED STEADY STATE TEMPERATURE RESULTS

Thermocouple Number	Thermocouple Location	Adjusted Steady State Temperatures (°F) at 1345 W	Adjusted Steady State Temperatures (°F) at 2400 W	Extrapolated Steady State Temperatures (°F) at 3500 W
	SPC INTERIOR			
GE-8	Iridium Cylinder, Center Side	--	1088	1541
	SPC EXTERIOR			
GE-11	Bottom Center	--	441	597
GE-12	Bottom of Side	--	397	533
GE-13	Center of Side	335	477	625
GE-14	Flange	--	401	539
GE-15	Top, Near Access Port	--	304	398
	CASK INTERIOR			
MRC-21	Ring Pad	262	366	474
MRC-23	Bulk Helium Near Isolator	161	200	241
MRC-24	Flexible Hose Center	198	257	319
	CASK EXTERIOR			
MRC-25	Top Center Cover	174	226	280
MRC-26	Center of Valve Area	155	194	235
	FIN A			
MRC-27	Top, 1/8-in. from Cask Body	129	150	172
MRC-28	Top, at Tip	118	132	147
MRC-29	Center, 1/8-in. from Cask Body	115	134	154
MRC-30	Center, at Tip	113	125	138
	FIN B			
MRC-31	Top, 1/8-in. from Cask Body	127	150	174
MRC-32	Top, at Tip	118	132	147
MRC-33	Top, at Cask Body Fin Joint	--	171	204
MRC-34	Center, at Tip	114	128	143
	CARRIER			
MRC-35	Cap at Top Center	--	114	120
MRC-36	Center Tie Down	100	104	108
MRC-37	Bottom Tie Down	102	106	110
MRC-38	Underneath Base Plate at Center	118	135	153

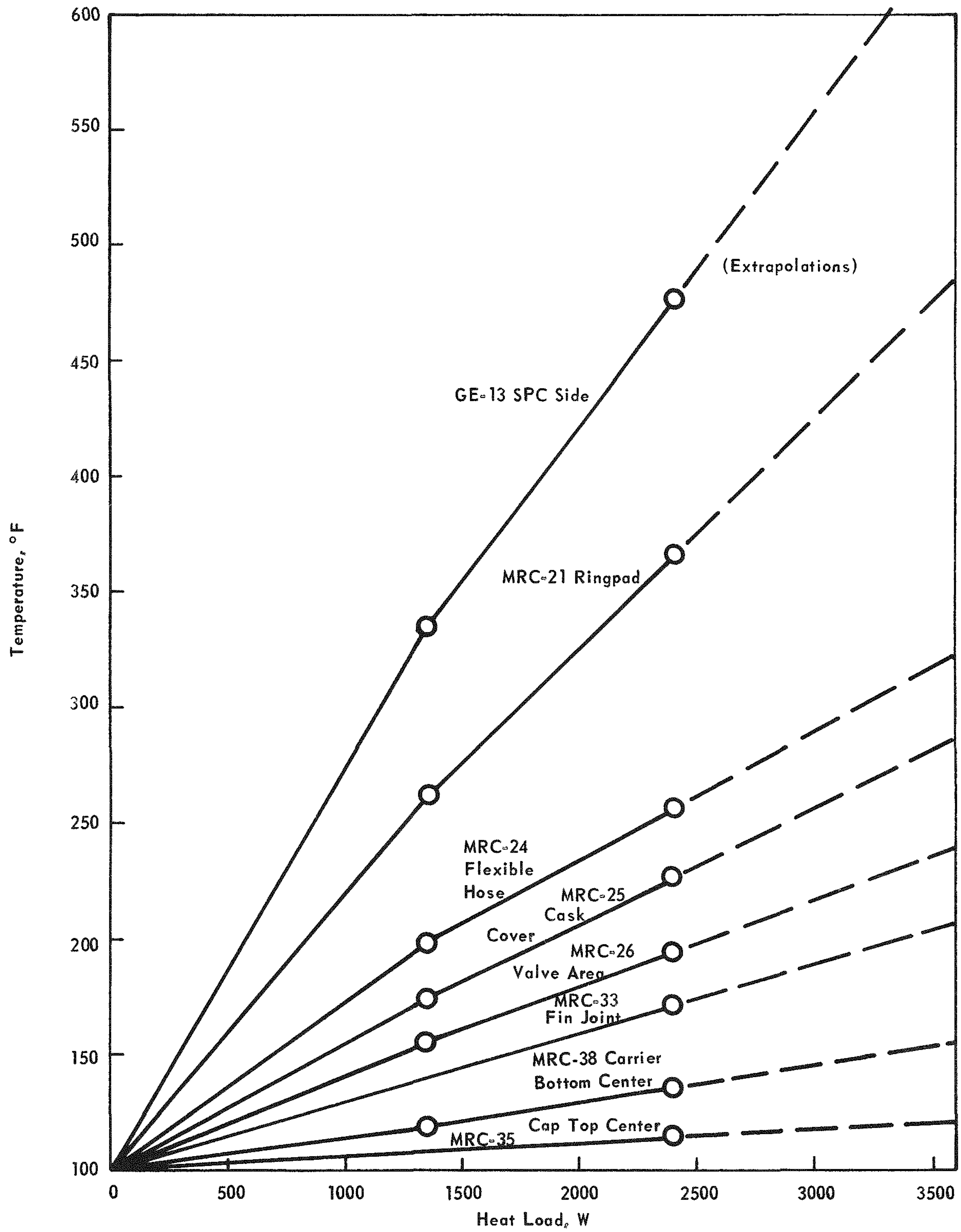


FIGURE D-6 - Temperature variation with heat load.

Table D-3

EXPERIMENTAL AND ADJUSTED TEMPERATURE PROFILES OF FINNED CASK

Thermocouple Number	Location	Experimental Temperature at 80° Ambient (°F)	Adjusted Temperature at 100°F Ambient (°F)
MRC-25	Center of Cover	198	226
------	Cover Above O-Ring	160 (approx.)	186
MRC-26	Center of Valve Area	168	194
MRC-33	Body of Fin Joint	146	171
------	Bottom	<146	<171

The highest adjusted temperature at any location on the finned cask exterior at 100°F (38°C) ambient is 226°F (108°C) at the center of the cover. The Viton o-ring area of the cover was found to be approximately 40°F (22°C) cooler than the center. The bottom of the finned cask is determined to be the location with the lowest temperature, based on the fin temperatures, which indicate that the finned cask body was hotter near the top, and on the measured temperature of only 113°F (45°C), TC #MRC-38,at the underside of the based plate, which the cask rests on. It is concluded that 200°F (93°C) is an appropriate temperature for evaluation of the cask pressure capability for normal transportation of the MHW heat sources which produce a nominal 2400 W of heat. It seems of little value to adjust for the hot spot at the center of the cask cover. The center of the cask cover is of particular interest, however, because it is measured during shipment.

The results of the steady state temperature profile tests compare favorably with the design calculations. The design of the MHW-IHS-SC is based on temperature data obtained for the "Universal Source Container" (USC) which has been approved (DOT-SP-6321) for shipment of up to 1400 W of heat.

D.5. Maximum Heat Load Capability

Determination of the maximum heat load capability of the shipping container is based on linear extrapolation of the adjusted temperatures obtained at 1345 W and 2400 W. Figure D-6 is a graph of the measured temperature increased above ambient temperature at various locations as a function of the heat load and illustrates the extrapolations. Linear extrapolation is conservative, particularly at higher temperatures, since the curves are such that the temperatures actually increase less rapidly as the heat load increases.

A maximum heat load capability of 3500 W is selected for the shipping container. This is sufficiently high to provide for anticipated requirements and sufficiently low to assure a considerable margin of safety. It is not known that heat loads in excess of 3500 W would be unsafe, but additional evaluation and/or testing is required if the shipping container is to be qualified for shipment of higher heat loads. The extrapolated temperatures are shown in Table D-2 and illustrated in Figure D-6. The extrapolated temperatures at key locations with a heat load of 3500 W are summarized in Table D-4 as follows:

Table D-4

EXTRAPOLATED TEMPERATURES AT KEY LOCATIONS

Thermocouple Number	Location	Temperature (°F) Measured @ 2480 W and 80°F	Adjusted to 2400 W and 100°F	Extrapolated to 3500 W and 100°F
GE-13	SPC Exterior	432	447	625
MRC-25	Center Cask Cover	198	226	280
MRC-38	Under Carrier Base Plate	113	135	153

Based on these results, a heat source of 3500 W with the same surface characteristics and heat distribution as the MHW-IHS could be expected to reach a temperature of less than 625°F (329°C) during normal shipment. The value of 280°F (138°C) for the finned cask cover is well within the temperature capability of all of the cask materials and provides a basis for determining the pressure capability of the finned cask for shipments exceeding 2400 W. The maximum accessible external surface temperature of 153°F (67°C) is well below the 180°F maximum for sole use shipments.

SECTION E

NORMAL CONDITIONS OF TRANSPORT EVALUATION

CONTENTS

NORMAL CONDITIONS OF TRANSPORT EVALUATION

E.1. General

AEC Manual, Chapter 0529 requires nuclear packaging to be capable of satisfactory packaging effectiveness and radioactive materials containment when subjected to the following nine tests simulating normal transportation environment and handling conditions:

1. Heat
2. Cold
3. Pressure
4. Vibration
5. Water Spray
6. Free Drop
7. Corner Drop
8. Penetration
9. Compression

The related testing and engineering evaluations described in this section adequately demonstrate that the nuclear packaging requirements are satisfied.

E.2. Heat

Direct sunlight at an ambient temperature of 130°F (54°C) in still air would not increase the temperatures of the packaging or the primary containment vessels in excess of design capabilities.

It is not likely that the MHW-IHS-SC would ever be stored for any length of time in direct sunlight at 130°F (54°C). For completeness, however, the temperatures resulting from this condition are estimated. Shappert's[8] approach establishes the average solar heat load over a 24 hr period as 42 W/ft^2 of projected surface area. The projected area consists of the top surfaces of the finned cask and fins, which are exposed to sunlight shining normal to the shipping container. The shading effect of the mesh carrier cap is ignored for simplicity. The exposed area is calculated as follows:

$$A = \frac{\overset{\text{Cover diam}}{\pi(28.5\text{-in.})^2}}{4\ (144)} + \frac{\overset{\text{fins}}{60}\ \overset{\text{(thickness)}}{(0.1875\ \text{in.})}\ \overset{\text{(exposed length)}}{(7\ \text{in.})}}{144}$$

$$A = 5.0\ \text{ft}^2.$$

Therefore, the solar heat load (Q_s) is

$$Q_s = (5.0\ ft^2)(42\ \frac{W}{ft^2})$$

$$Q_s = 210\ W.$$

The temperature increases that are produced by the additional 210-W heat load are added to the experimentally determined temperatures, produced by the contents, to determine the resulting temperatures. The calculations are linear interpolations/extrapolations of the temperatures reported in the Steady State Temperature Profiles section of this report. The results are summarized in Table 1.

Thus, the heat input from the sun is not expected to increase the cask temperature to its design capability of approximately 375°F (191°C) or the SPC temperature to the specified maximum temperature of 700°F (371°C). The hypothetical accident thermal test evaluation, provided elsewhere in this report, indicates that, even at steady state with an external temperature of 1475°F (800°C), the temperature of the primary containment vessels is less than the anticipated normal operating temperature when used subsequent to shipment.

Table 1

TEMPERATURES AT KEY LOCATIONS IN SHADE AT 100°F AND IN DIRECT SUNLIGHT AT 130°F (54°C)

Thermocouple Number	Location	In 100°F Shade 2400W (°F)	In 100°F Shade 3500W (°F)	Correction for 210W Solar Load (°F)	In 130°F Sun 2400W (°F)	In 130°F Sun 3500W (°F)
GE-13	SPC Exterior	447	625	34	511	689
MRC-25	Center Cask Cover	226	280	10	266	320
MRC-38	Under Carrier Base Plate	135	153	3	168	186

E.3. Cold

An ambient temperature of -40°F (-40°C) in still air and shade will not decrease the effectiveness of the packaging. This would reduce the temperature profile within the package and possibly would be beneficial.

E.4. Pressure

Reduced atmospheric pressure of 0.5 times standard atmospheric pressure is well within the capability of the finned cask. This is equivalent to an increased internal pressure of 7.3 psi above the normal operating pressure of approximately 7 psig (1.5 atm absolute) at one atmosphere external pressure. The internal pressure capability of the finned cask has been thoroughly evaluated and is discussed in the Internal Pressure Capability section of this report. The calculated maximum allowable working pressure (ASME code) is 36 psig (3.5 atm absolute) at 200°F (93°C) which is 22 psi (1.5 atm) in excess of the reduced atmospheric pressure requirement.

E.5. Vibration

Vibration normally incident to transport will not reduce the effectiveness of the packaging. A road test, involving a variety of road conditions, was performed to evaluate the effectiveness of the isolators for protecting the SPC/heat source hardware. Two runs were made, one at operating temperatures, over a 24-mile route which included several sets of railroad tracks and jolts obtained by bumping into a loading dock at low speed. No damage to the MHW-IHS-SC or a ceramic/graphite heat source simulator contained within the SPC was observed as a result of this testing.

E.6. Water Spray

A water spray sufficiently heavy to keep the entire exposed surface of the package, except the bottom, continuously wet during a period of 30 min will not damage the finned cask in anyway or have any effect, other than cooling, on the contents of the MHW-IHS-SC. The MHW-IHS-SC is actually exempt from this test requirement since it is of all metal construction.

E.7. Free Drop

A free drop through a distance of 4 ft onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected would not substantially reduce the effectivensss of the packaging. The four shock and vibration isolators will significantly decrease the shock input to the SPC. This test could damage the aluminum mesh carrier cap, break loose a few fins and, possibly, cause the finned cask to leak helium. Exchange of air for helium in the cask would not significantly reduce the heat transfer from the SPC to the finned cask since, at the SPC temperature, most of the heat transfer is by radiation. Since only 12 fins were broken loose in the 30-ft drop test, it is not possible that a sufficient number of fins would be lost in a 4 ft drop to significantly reduce the heat dissipation. A series of 18-in corner drop tests (2 at operating temperatures) was performed to evaluate the effectiveness of the isolators for protection of the SPC/heat source hardware. No damage to the MHW-IHS-SC or a ceramic/graphite heat source simulator contained within the SPC was observed as a result of this testing. Thus, the type of damage expected in a 4 ft drop would not cause any hazardous conditions or loss of radioactive materials.

E.8. Corner Drop

This test requires a free drop onto each corner of the package in succession or, in the case of a cylindrical package, onto each quarter of each rim, from a height of 1 ft onto a flat essentially unyielding horizontal surface. This test applies only to packages which are constructed primarily of wood or fiberboard, and do not exceed 110 pounds gross weight, and to all Fissile Class II packagings.

This test is not applicable to the MHW heat source shipments in the shipping container because the packaging is of metallic construction, weighs approximately 2680 lb and the shipments are Fissile Class I. However, it is conceivable that the shipping container would be used at some time for Fissile Class II shipments. The 1 ft corner drop is less severe than the 18 in. drop which was discussed in the previous section and would not damage the MHW-IHS-SC in any way that would reduce its volume or effectiveness.

E.9. Penetration

It is necessary to evaluate the impact of the hemispherical end of a vertical steel cylinder, 1-1/4 in. diam, weighing 13 lb, and dropped from a height of 40 in. onto the exposed surface of the package which is expected to be most vulnerable to puncture.

This test could cause minor damage to the aluminum mesh carrier cap, but it is unlikely that it would damage the finned cask and it would have no affect on the SPC. Assuming, conservatively, that the aluminum mesh has no effect on slowing down the steel cylinder and that the cylinder could somehow strike the 3/8 in. thick body of the cask (thinnest area) between the fins, the steel cylinder would not penetrate the finned cask wall. This is shown by comparing the kinetic energy of the cylinder on impact with the energy required to shear the wall. The kinetic energy is equal to the potential energy of the 13 lb cylinder at a height of 40 in. and as calculated as follows:

$$KE = PE = \left(\frac{40 \text{ in.}}{12 \text{ in./ft}}\right) (13 \text{ lb}) = 43 \text{ ft lb}$$

The Machinery's Handbook[10] gives the equation for calculating the energy required to shear the cask body wall as follows:

$$E_p = F_{su} (\pi D t) (t)$$

where E_p = the energy required to shear the cask wall (ft lb),

F_{su} = ultimate shear strength of 304 stainless steel at 200°F (60% of tensile), F_{su} = 45,000 psi,

D = diam of potential hole, D = 1-1/4 in., and

t = cask wall thickness, t = 3/8 in.

The factor (πDt) is the potential shear area of the hole. Substitution into the above equation yields:

$$E_p = (45{,}000)\ (\pi \times 1\text{-}1/4 \times 3/8)\ (3/8)\ (\frac{1\ \text{ft}}{12\ \text{in.}})$$

$$E_p = 2{,}100\ \text{ft lb.}$$

Thus, the required energy is nearly 50 times as great as the energy available and the cask wall would not be penetrated.

E.10. Compression

This test requires a compressive load equal to either 5 times the weight of the package or 2 psi multiplied by the maximum horizontal cross section of the package, whichever is greater. The load must be applied during a period of 24 hr, uniformly against the top and bottom of the package in the position in which the package would normally be transported.

The evaluation is based on a load of 15,000 lb, which is 5 times the maximum gross weight of the package since the alternate criteria yields a value of only 962 lb. The strength of the carrier cap is neglected for simplicity. The finned cask body is illustrated in Figure 1. The wall thickness (t) is actually 3/8 in., except where the grooves have been machined for secure attachment of the fins. The effective wall thickness is, conservatively, taken to be 1/4 in. and the effective outside diam of the cask is 24.5 in.

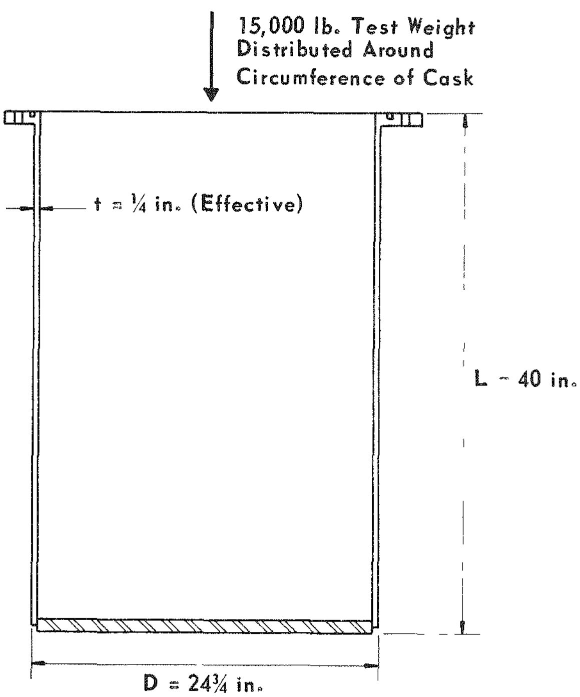


FIGURE E-1 - Compressive load evaluation of finned cask body.

The longitudinal compressive stress (S) is calculated by dividing the load by the cross-sectional area of the cask wall as follows:

$$S = \frac{15{,}000}{\pi Dt}$$

where D is the diameter and t is the wall thickness.

The result is

$$S = \frac{15{,}000}{\pi (24.5)(0.25)}$$

$$S = 780\ \text{psi.}$$

The stress value is only 5% of the allowable stress which is 15,600 psi for 304 stainless steel at 200°F (93°C).

The critical buckling stress of the cylindrical shell when subjected to uniform axial compression is calculated to determine the ultimate capability of the cask. The critical buckling stress (S_{cr}) is given by the following equation:

$$S_{cr} = \frac{Eh}{R\sqrt{3(1-\mu^2)}}$$

where

E = modulus of elasticity, $E = 30 \times 10^6$ psi,

h = cask thickness, h = 0.25 in.,

R = radius of cask, R = 12.25 in., and

μ = Poisson's ratio, $\mu = 0.3$.

Thus, the critical buckling stress is:

$$S_{cr} = \frac{30 \times 10^6 (0.25)}{12.25 \sqrt{3(1-0.09)}} = 370{,}500 \text{ psi.}$$

This value for the ultimate capability is nearly 500 times greater than the longitudinal compressive stress in the cask calculated above. Thus, placing a 15,000 lb load on the top of the finned cask would not damage the finned cask and would have no affect on the SPC.

SECTION F

HYPOTHETICAL ACCIDENT CONDITIONS EVALUATION

CONTENTS:

HYPOTHETICAL ACCIDENT CONDITIONS EVALUATION

F.1. General

AEC Manual, Chapter 0529 requires that packaging for Type B or greater quantities of radioactive materials be capable of satisfactory containment when subjected to the four tests simulating transportation accident conditions as follows:

1. Free Drop
2. Puncture
3. Thermal
4. Water Immersion

The free drop test was performed and evaluations of the puncture, thermal, and water immersion tests were performed. The test and evaluations demonstrated that the MHW-IHS-SC and its contents would not be damaged in any way that would result in a loss of containment in excess of regulation requirements and established the expected condition of the package after being subjected to the tests, for the purpose of the criticality evaluation. Since the primary containment of the radioactive materials is provided by the contents, as discussed in the Contents of Packaging section of this report, the discussion in this section is limited to the shipping container and the SPC exterior.

F.2. Free Drop

This test requires a free drop through a distance of 30 ft onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

A full scale MHW-IHS-SC, packaged with an SPC containing an electrical heat source simulator, was used for the test. The gross weight of the tested package was 2700 lb. The weight of the SPC/electrical heat source was very nearly the same as the SPC/IHS weight of 270 lb. Since the electrical heat source simulator was not functioning properly, electrical heating tapes were wrapped around the bottom section of the SPC and used to heat the assembly for a one day period. At the time of the test, thermocouple measurements indicated temperatures of 151°F (66°C) at the top of the SPC and 357°F (181°C) at the side of the SPC under the heating tapes. The finned cask cover was estimated to be at approximately 130°F (54°C).

A specially designed, 50-ft high, drop tower, equipped with a 2-ton hoist, was used to drop the container from a height of 30 ft onto a steel covered concrete drop pad. The container was oriented in an upside down flat position to assure that maximum damage to the SPC would result since the SPC valve is located at the top near the finned cask cover. The container was actually tilted a few inches. Figure 1 shows the container at the required 30-ft height prior to manual actuation of the quick release hook. From release to impact, no twisting motion was imparted to the container and it was dropped in precisely the initial orientation.

FIGURE F-1 - MHW-IHS-SC at a height of 30 ft prior to the drop test.

The results of the drop test are summarized in Table F-1 and discussed in more detail below. The crash was rather dramatic and sections of the carrier mesh screen landed approximately 10 ft from the container.

Table F-1

DAMAGE RESULTING FROM 30-FOOT DROP TEST

Carrier:	• Base plate bent.
	• Cap/Body seam snapped off.
	• Large mesh sections came out of framework.
	• Four bolts mounting finned cask to carrier stripped internal baseplate threads.
Finned Cask:	• Cover distorted, cover bolts stretched, and lifting lugs on cover crushed.
	• Gauge manifold tubing bent slightly.
	• Helium pressure containment lost.
	• 12 of the 60 fins broke loose.
	• Flexible metal hose stretched and weld joint at SPC valve body partially torn apart.
	• Hold down ring bent and seven screws broken at threaded portions.
SPC Exterior:	• Valve assembly damaged.

The carrier was damaged from the drop beyond its intended normal use (see Figure F-2). The base plate was bent approximately 1 in. at the corners in the vertical direction. The seam attaching the carrier cap to the carrier body snapped off at the welds, thus, preventing any significant crushing of the carrier cap on impact. The large sections of mesh screen came out of the framework and the framework was somewhat distorted. All four of the bolts used to mount the finned cask to the carrier baseplate pulled out of the baseplate, stripping the internal threads. Thus, the finned cask was no longer attached to or contained within the carrier.

The finned cask exterior damage can be easily seen in Figures F-3 and F-4. The center of the cask cover was pushed in approximately 0.5 in. and many of the cover bolts were elongated up to a maximum of 0.1 in. However, no damage to the mating flange on the cask was observed. The lifting lugs on the cover were crushed. The gauge manifold tubing was bent somewhat, but the manifold did not appear to be otherwise damaged. Of the 60 fins initially installed on the cask, 12 broke loose at the epoxy joint

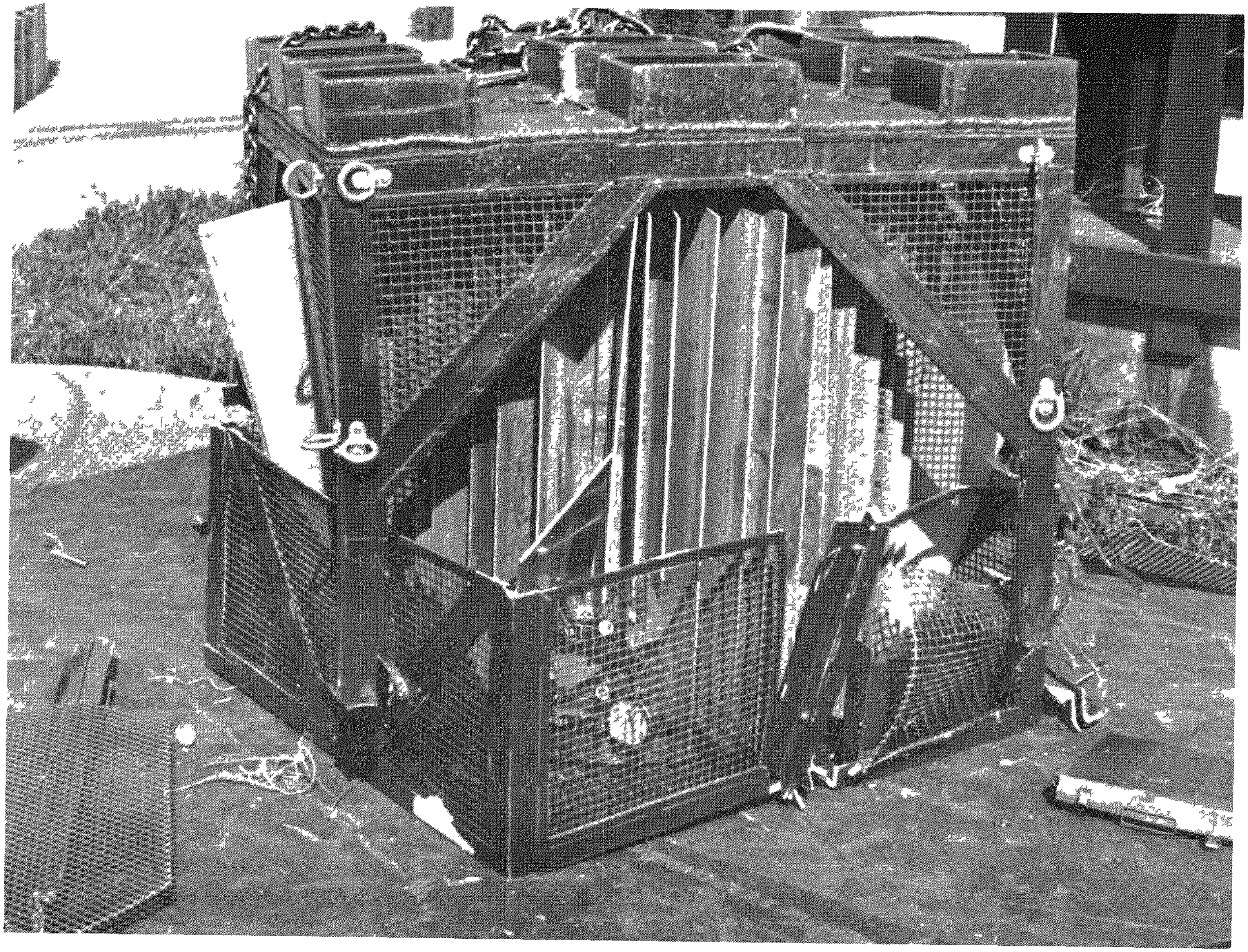


FIGURE F-2 - The carrier was severely damaged as a result of the 30-ft drop.

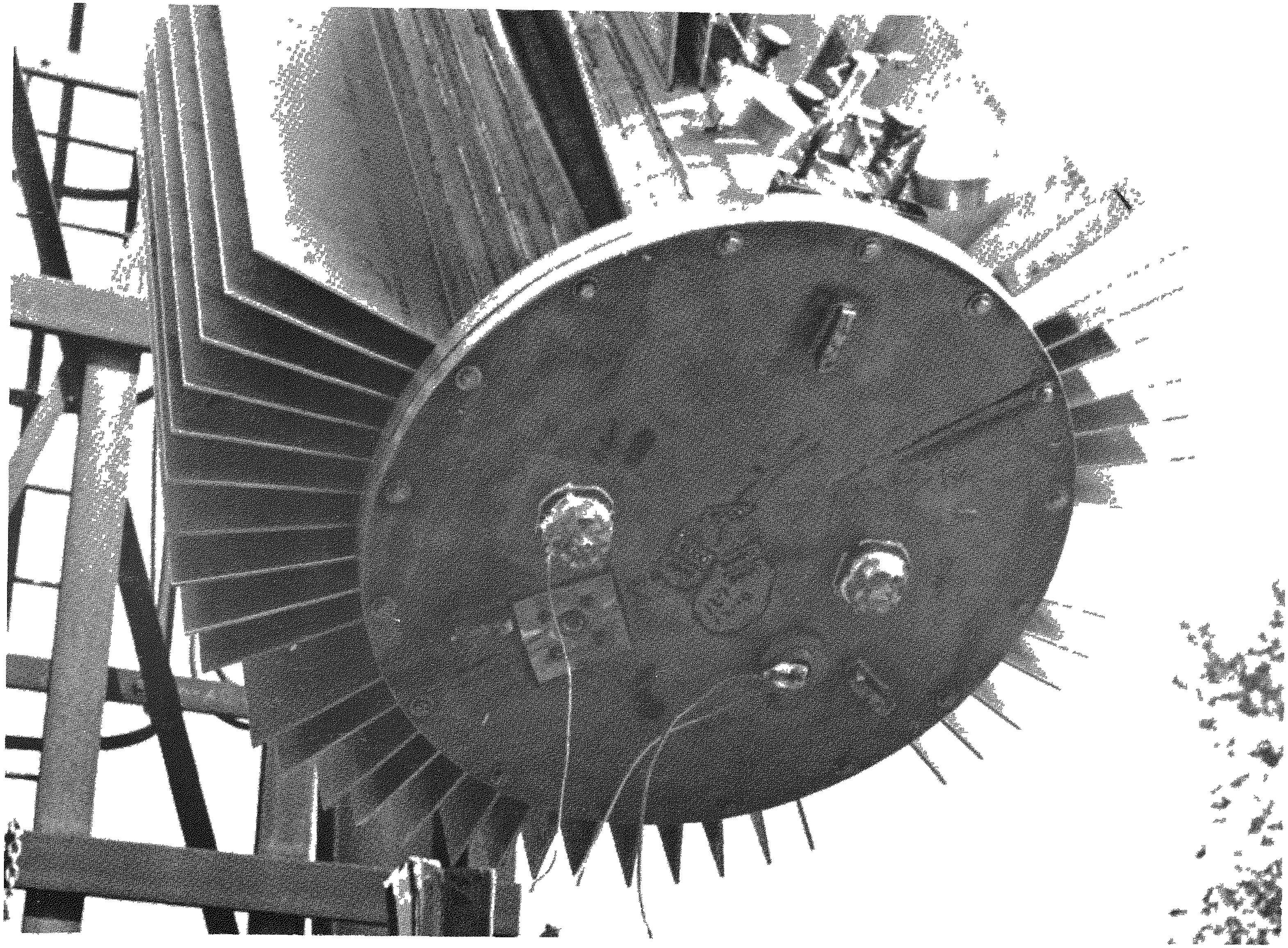


FIGURE F-3 - The finned cask remained intact although the cover was damaged and 12 fins were lost.

FIGURE F-4 - The cask cover seal was lost as a result of stretching the bolts. A gap can be seen between the cover and the mating flange.

where they had been bonded in the grooves of the cask wall. The stainless steel cylindrical cask shell remained intact, but it was found by testing that it would not contain helium pressure due to the distortion of the cover.

Inside the finned cask, only a superficial mark was found on the inside surface of the cask cover where the SPC valve guard plate hit it. The flexible metal hose was permanently stretched and the weld joint on the flexible hose side of the SPC valve body was torn apart approximately 1/2 of its circumference as seen in Figure F-5. This is of little consequence, however, since the SPC valve is always closed during shipment. Also, a design change was made to all other MHW shipping containers which provides more slack in the flexible hose.

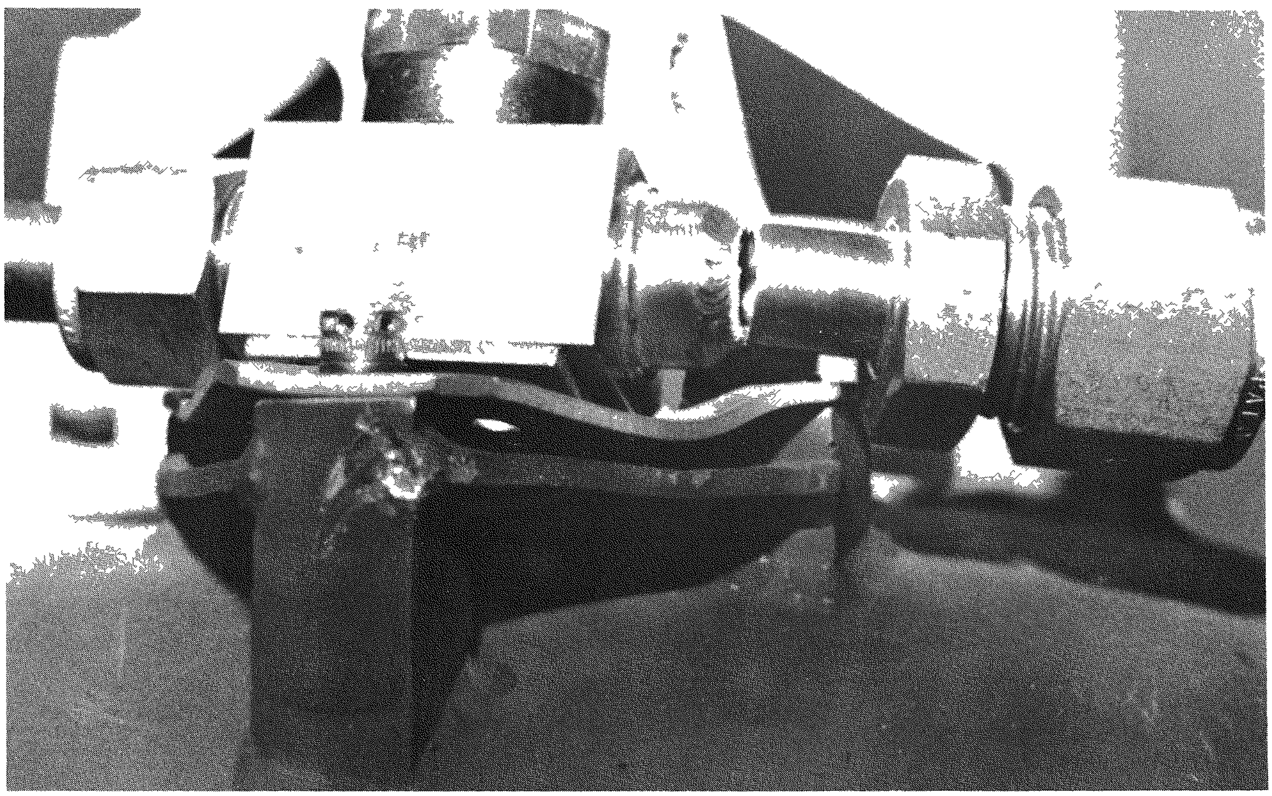


FIGURE F-5 - The weld joint at the SPC valve body adjacent to the flexible metal hose fitting was partially torn apart. The SPC valve is closed during shipment.

The SPC remained firmly attached to the hold down ring (see Figure F-6) and the three pin-bolt assemblies did not appear damaged, although the bolts were only finger tight when removed, rather than at the initial torque value of 80 ft lb. The hardware used to mount the SPC within the finned cask was severely damaged as seen in Figure F-7. All three of the cap screws used to fasten one of the ring pads to the hold down ring were broken at the threaded portion. All four of the screws used to fasten one of the isolators to its ring pad were broken at the threaded portion. The hold down ring was bent approximately 1/4 in. at one location. As a result of this damage and some permanent distortion of the isolators, the final position of the isolator ring varied from 1-3/8 to 2-1/8 in. closer to the finned cask cover. (It was determined that, on impact, the SPC was shifted a maximum of 3 in. with respect to the finned cask.)

Damage to the exterior of the SPC was limited to the valve assembly (see Figure F-8, F-9, F-10, and F-11). The valve mounting plates were bent and partially sheared and the valve stem was broken. The valve was twisted approximately 30° from its initial position (see Figure F-12). There was no apparent damage to the fitting or tubing connecting the valve to the SPC, but it is assumed that small leaks (the same order of magnitude as the design specification) could have resulted. The valve guard was buckled such that its overall height was reduced from 4 in. to 3 in. There was no evidence of damage to the SPC body near the valve or at any other location. Disassembly of the SPC flange proceeded normally and there was no evidence of damage that would affect the seal as can be seen in Figure F-13.

In conclusion, it was determined from the drop test that the finned cask will remain intact, but would not contain helium pressure. Since the cask was no longer fastened to the carrier, the carrier is assumed to offer no protection when the container is subjected to the conditions to be evaluated subsequent to the free drop. There were no punctures to the SPC, changes in shape or any other types of observable deformation, except for the damage to the valve assembly. The SPC maximum helium leak rate would remain on the same order of magnitude as the design specification. The electrical heat source simulator hardware suffered breach of the clad and a broken aeroshell. The FSAs, had they been present, would not have been affected based on the aeroshell damage and the LASL drop of the S-6 Test unit (CMB-2064, p. 21).*

*Los Alamos Scientific Laboratory control number for internal correspondence and progress reports.

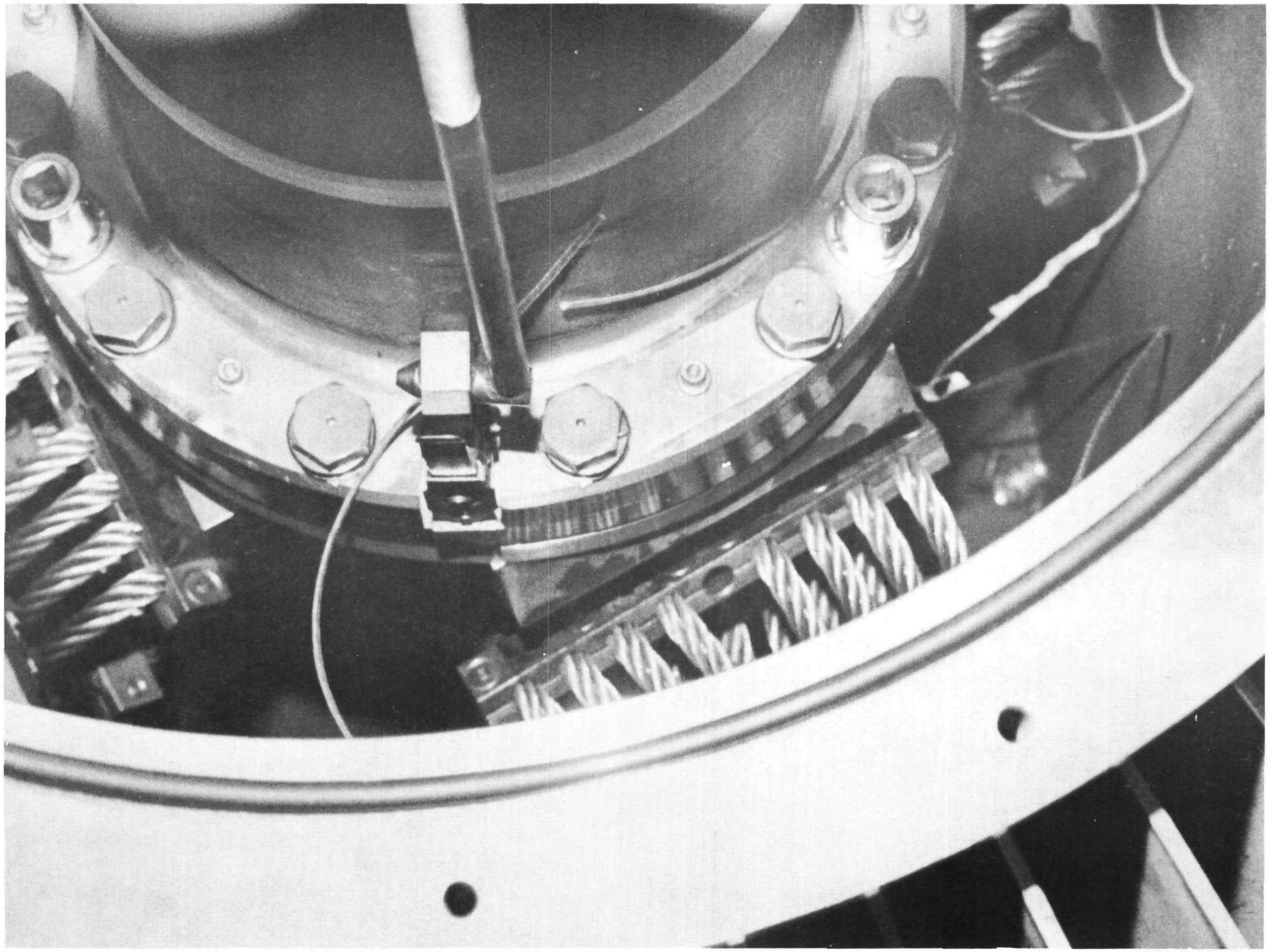


FIGURE F-6 - The SPC remained firmly attached to the finned cask hold down ring.

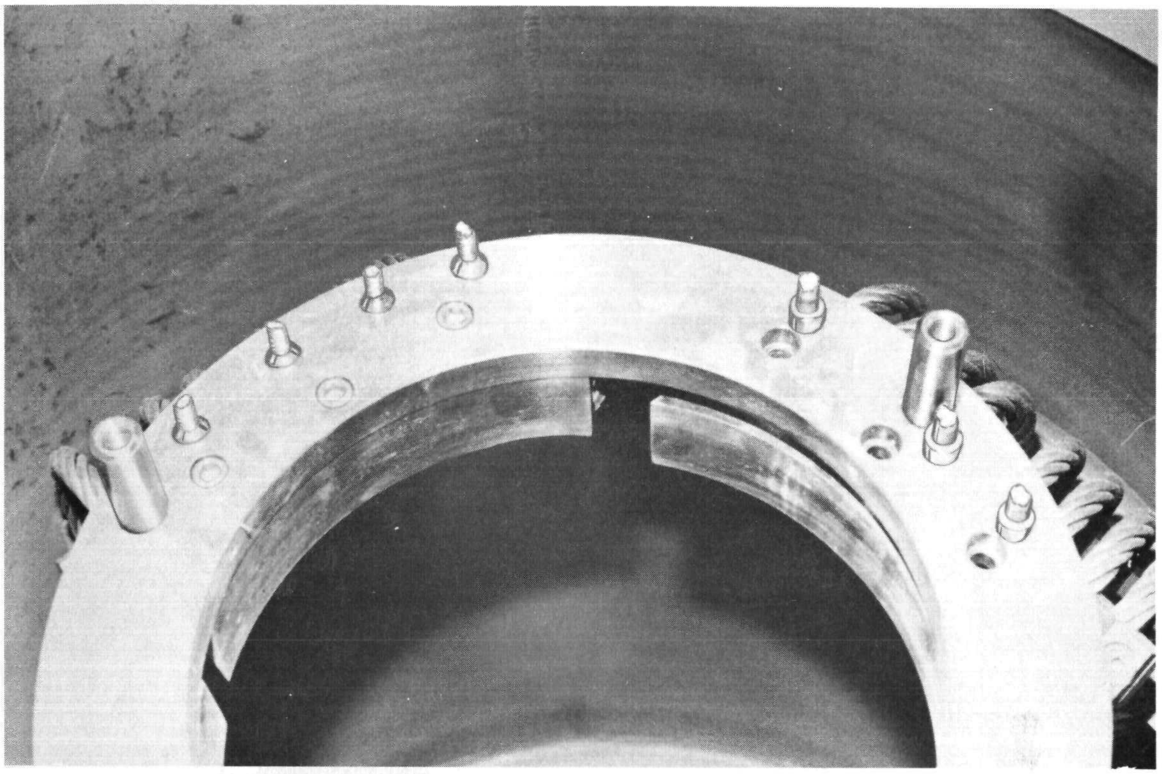


FIGURE F-7 - The hardware used to mount the SPC within the finned cask was damaged. The seven broken screws were placed upside down for the photograph.

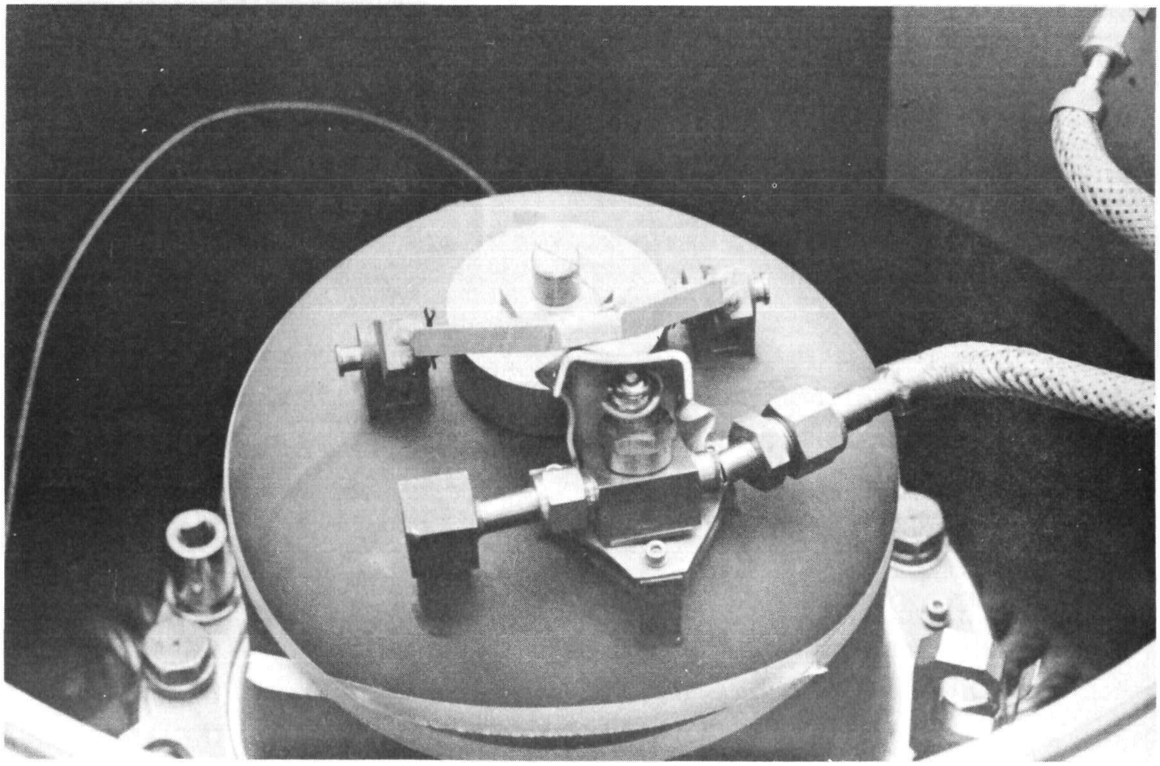


FIGURE F-8 - The SPC valve stem was broken and the valve guard buckled.

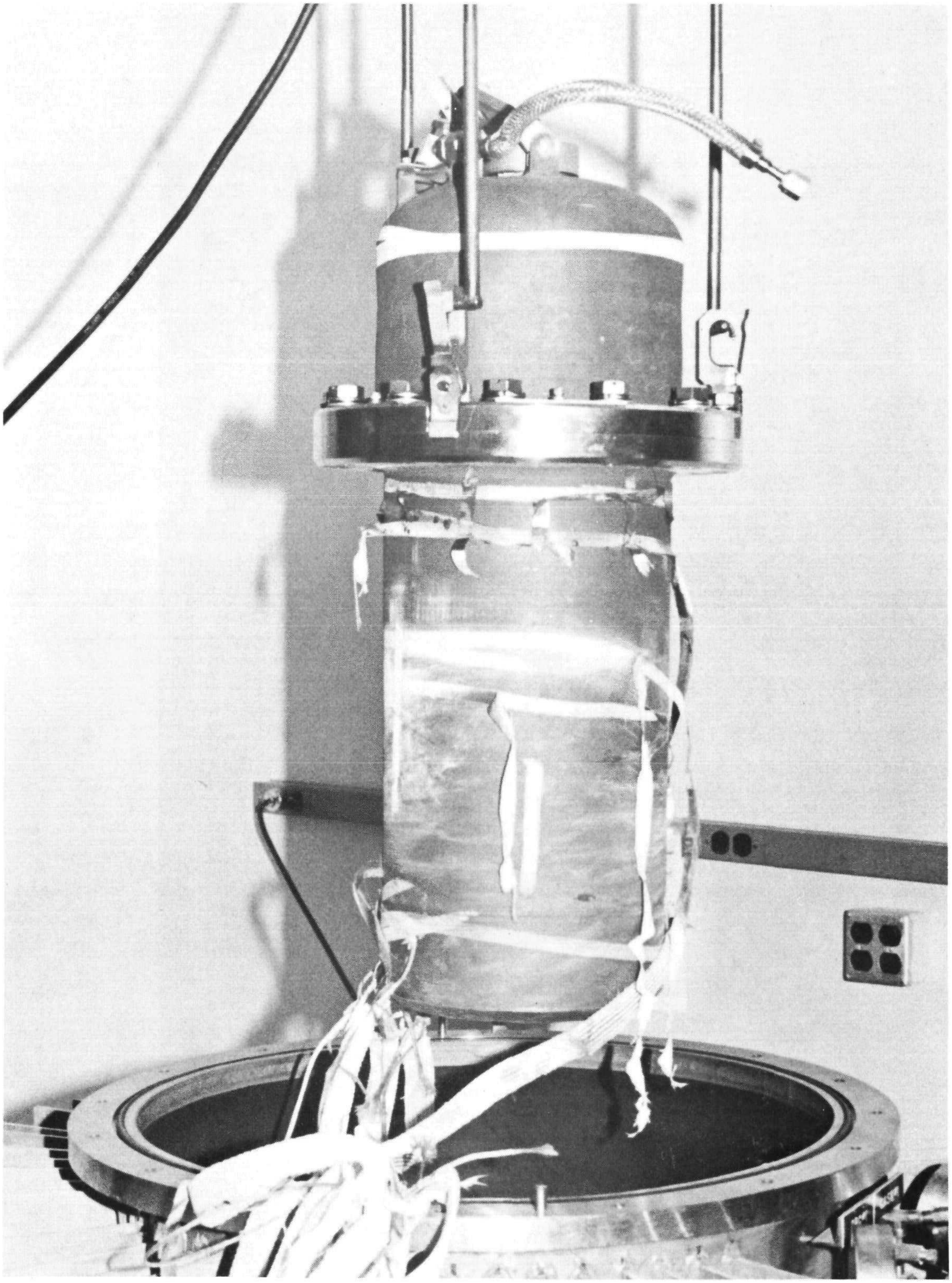


FIGURE F-9 - There was no evidence of damage to the SPC except for the valve assembly at the top.

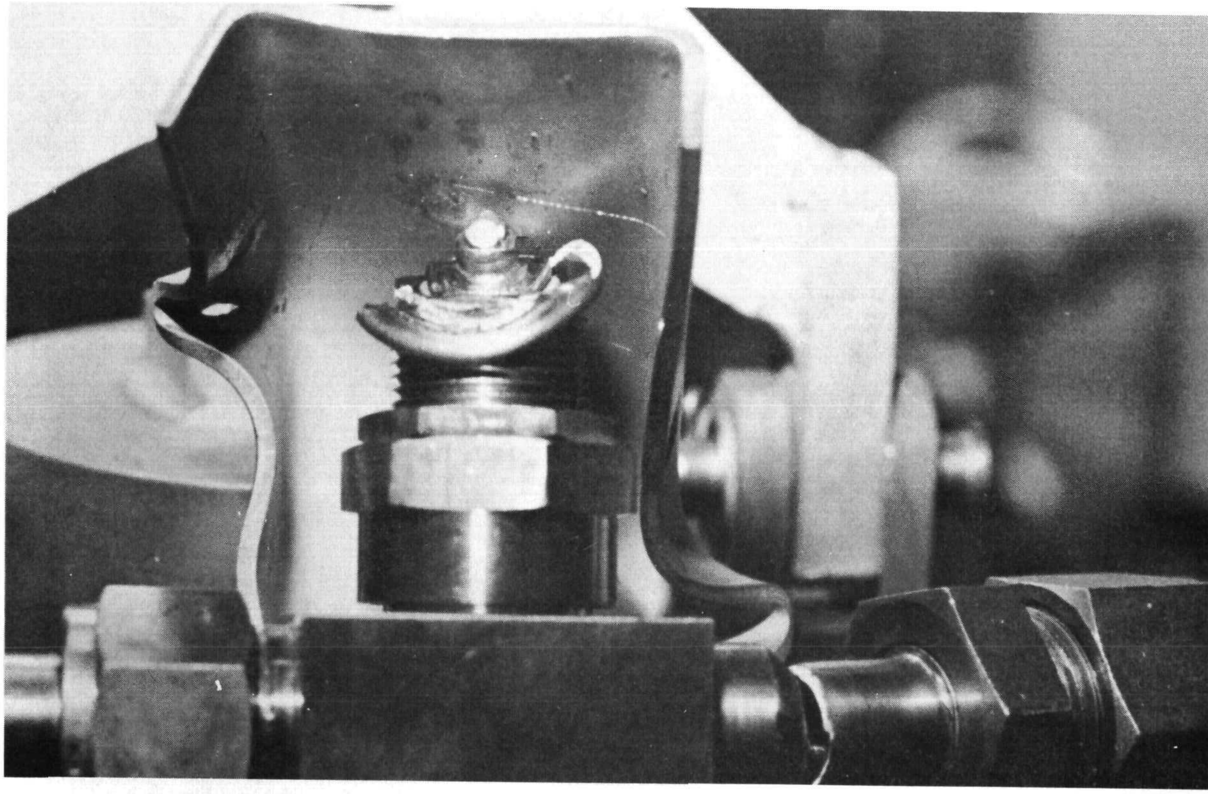


FIGURE F-10 - Closeup of broken valve stem and buckled valve guard.

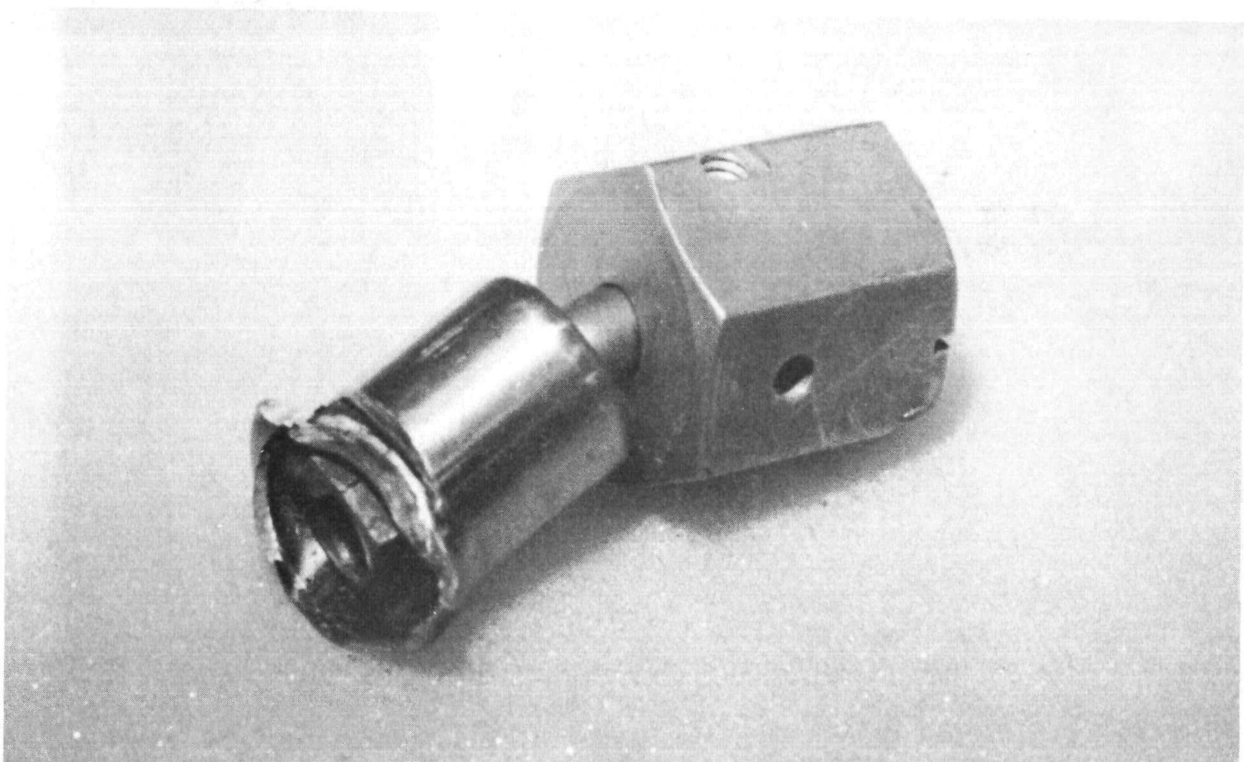


FIGURE F-11 - Valve handle and broken stem.

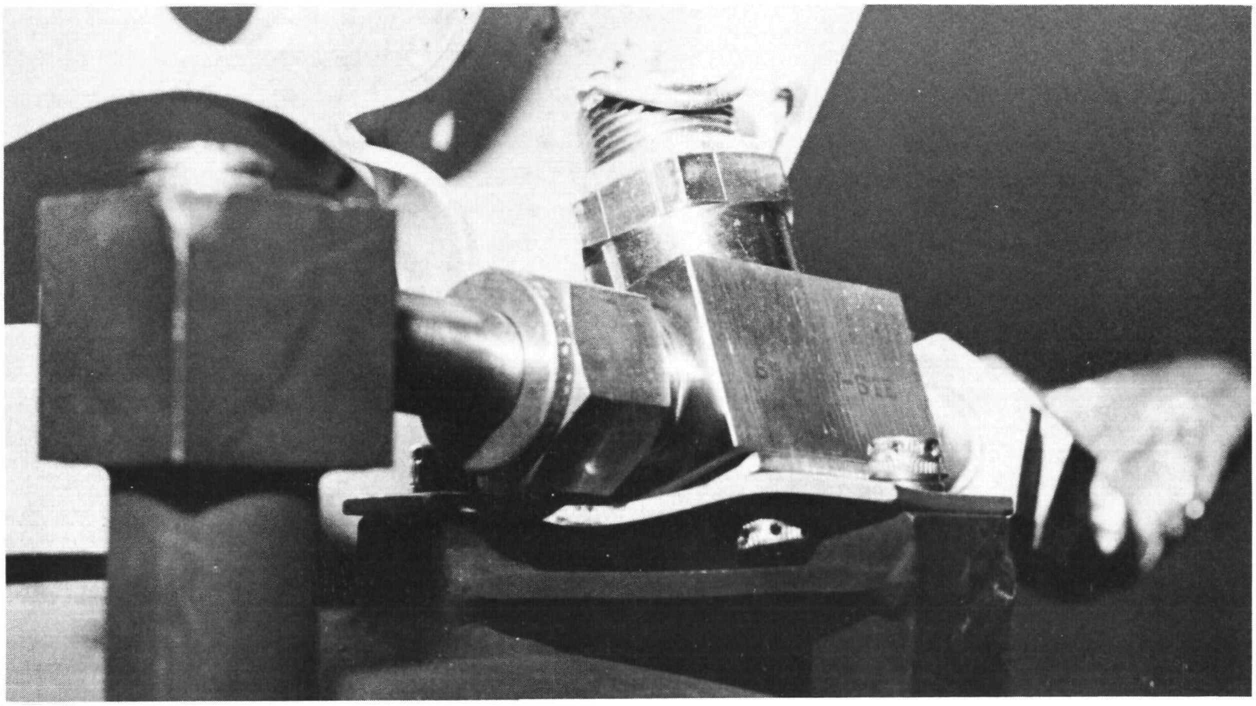


FIGURE F-12 - The valve was twisted approximately 30° from its initial position.

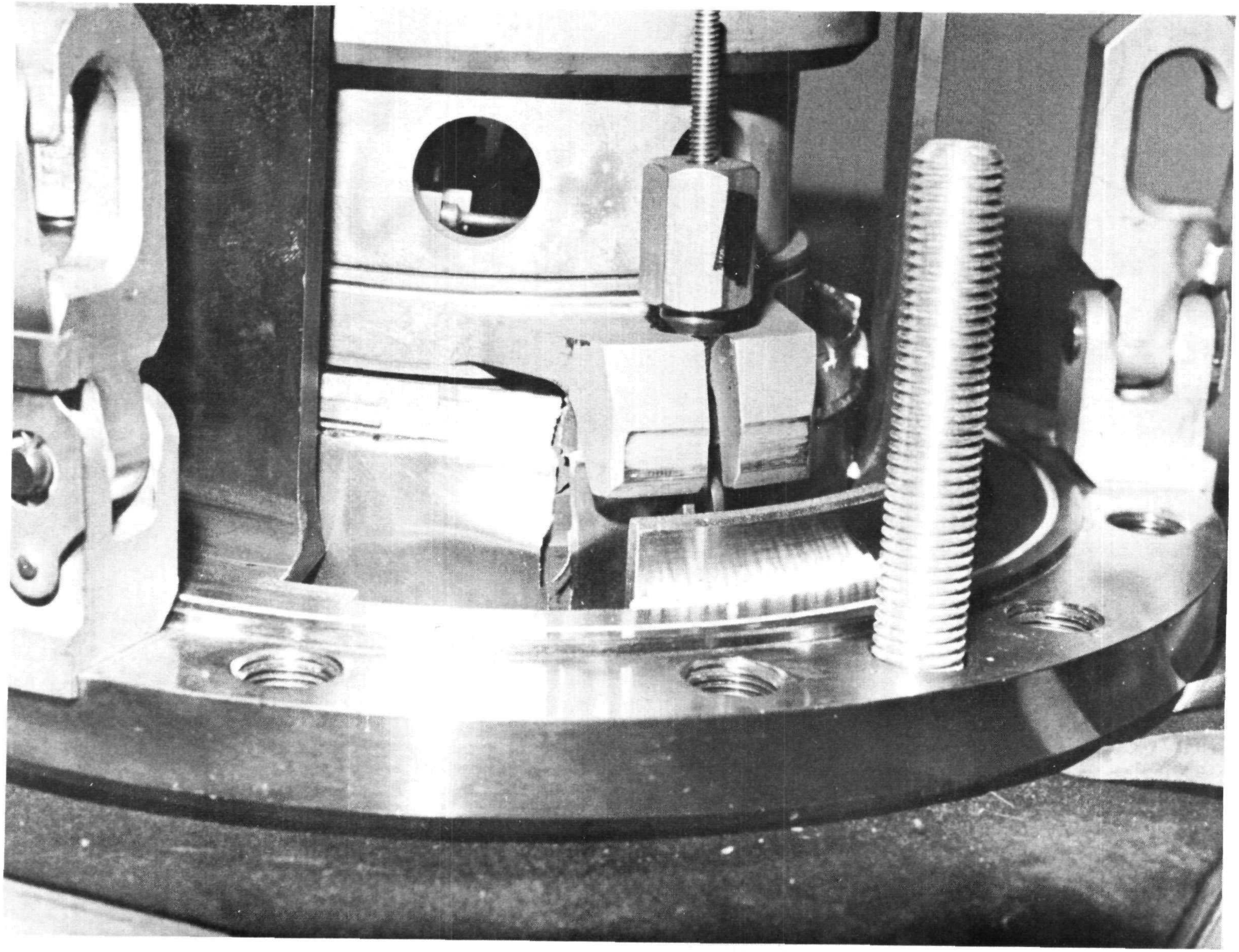


FIGURE F-13 - There was no evidence of damage to the SPC flange seal.

To supplement the actual drop test considered above, additional consideration was given to potential damage in a side or corner drop. This evaluation was based on the observed damage in the actual drop and on a comparison of the energy available from the drop with the energy required to inflict the type of damage postulated. Specifically, it is concluded that the fins will not penetrate the cask wall, the cask cover bolts and alignment pins will not shear so that the cover will remain on the cask, and neither the boss on the cask (to which the flexible hose is connected) nor the ring pad will penetrate the SPC as a result of a side drop. Thus, the actual drop test orientation caused as much or more damage to the SPC as any other drop orientation and provided sufficient information for subsequent evaluation of the shipping container.

F.3. Puncture

This test requires a free drop through a distance of 40 in. striking. in a position maximum damage is expected, the top end of a vertical cylindrical mild steel bar mounted on an essentially unyielding horizontal surface. The bar must be 6 in. diam. and not less than 8 in. long. The long axis of the bar must be perpendicular to the unyielding horizontal surface.

Maximum damage is expected if the MHW-IHS-SC were dropped in a flat upside down orientation on the cylinder such that the cylinder could potentially penetrate the finned cask cover. The aluminum mesh cage will offer no protection against this after the 30 ft drop. The evaluation shows that the finned cask cover would not be penetrated by comparing the kinetic energy of the MHW-IHS-SC on impact with the energy required to shear through the finned cask cover. The kinetic energy is equal to the potential energy of the MHW-IHS-SC at a height of 40 in. It is conservative to use the maximum gross weight (3000 lb) of the container since the finned cask is no longer attached to the carrier after the 30 ft drop. The kinetic energy is given by:

$$KE = PE = \left(\frac{40 \text{ in.}}{12 \text{ in./ft.}}\right) (3000 \text{ lb}) = 10{,}000 \text{ ft lb.}$$

The Machinery's Handbook[10] gives the equation for calculating the energy required to shear the cask cover as follows:

$$E_p = F_{su} (\pi D t) (t)$$

where

E_p = the energy required to shear the cask cover,

F_{su} = ultimate shear strength of 304 stainless steel at 200°F (60% of tensile), F_{su} = 45,000 psi,

D = diam of potential hole, D = 6 in., and

t = cask cover thickness, t = 3/4 in.

The factor (πDt) is the potential shear area of the hole. Substitution into the above equation yields:

$$E_p = (45{,}000)\ (\pi \times 6 \times 3/4)\ \left(\frac{1\ \text{ft}}{12\ \text{in.}}\right)$$

$$E_p = 40{,}000\ \text{ft lb}$$

The energy required is 4 times the available energy from the drop and the finned cask cover would, therefore, not be punctured by the cylinder.

F.4. Thermal

This test requires exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1475°F for 30 min.

This evaluation establishes the expected condition of the MHW-IHS-SC on conclusion of the thermal test and the temperature profile within the package. It is concluded that the maximum possible temperatures of the PICS and the plutonium oxide fuel would not exceed the normal operating temperatures when used with vacuum in the gaps.

The finned cask would remain structurally rigid, but will not be capable of helium containment or prevention of in-leakage of water subsequent to this test. The helium containment capability of the finned cask is established as a function of temperature in the Internal Pressure Capability section (see Figure C-2 of that section) of this report. At approximately 750°F (399°C), the helium would be released through the pressure relief valve and the Viton o-ring would begin to leak after a short period of time. As a result of the 30-ft drop the four bolts used to mount the finned cask to the carrier base plate stripped the internal base plate threads. The thermal test is expected to melt the aluminum carrier cap and the aluminum fins, which have a melting point of 1216°F (658°C). Thus, in the worst case, on conclusion of the thermal test, the stainless steel cask body is expected to remain intact with no fins and separated from the carrier.

An evaluation of the maximum temperatures expected is presented in Appendix III (GE Appendix A, para. A.2.4.3.2.), p. III-31, and is summarized here. The approach is conservative since the steady state temperatures are calculated rather than the temperatures after a thermal test period of only 1/2 hr. The results of the worst case (Case 5, Table A-6 on p. III-33 and Table A-7 on p. III-35 in Appendix III) are shown in Table F-2.

The results indicate that the thermal test would not cause temperatures in excess of the normal operating temperatures of the PICS and fuel when operated with vacuum in the gaps.

Table F-2

MHW SOURCE CONTAINER THERMAL EVALUATION DATA

	Steady State Thermal Test Evaluation Temperature (°F)	Normal Operation with Vacuum in Gaps Temperature (°F)
MHW-IHS-SC Surface	1475 (Test Condition)	----
SPC Surface	1581	----
IHS Surface	2171	2000
PICS Maximum	2480	2650
Fuel Maximum	2670	3050

F.4. Water Immersion

This test requires that fissile material packages be immersed in water to the extent that all portions of the package to be tested are under at least 3 ft of water for a period of not less than 8 hr.

The finned cask will be incapable of preventing in-leakage of water on conclusion of the thermal test. This is accounted for in the Criticality Evaluation presented in this report. Based on testing performed by GE,[11] it is concluded that the thermal shock resulting from immersion in cold water would not cause the containment vessels to be breached.

SECTION G

CRITICALITY EVALUATION

CONTENTS:

CRITICALITY EVALUATION

G.1. General

The purpose of this evaluation is to evaluate the nuclear criticality safety aspects of the Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC). The Density Analog Technique was used in the evaluation of this shipping container.

G.2. The Density Analog Method

This method is described by H. C. Paxton.[12] Using this technique, the number of MHW heat source shipping containers required to form a critical mass was calculated. Fissile Classifications and Transportation Indices for the MHW-IHS-SC were calculated using this method and the guidelines provided in AEC Manual Chapter 0529.

The basic equation is given as follows:

$$M_c \text{ (reflected)} \geq \frac{M_{so} \text{ (bare)}}{(R)\ (M_o)} \left(\frac{\bar{\rho}}{\rho_o}\right)^{-s} \qquad \text{[Eq. 1]}$$

where M_c reflected = minimum water moderated and reflected critical mass.

M_{so} (bare) = minimum bare critical mass for a particular geometry and atomic ratio.

R = ratio between bare critical mass and water reflected critical mass.

M_o = the contribution due to neutron moderation.

$\bar{\rho}$ = density of fissile material per container volume. The reflector savings must be considered whenever significant.

ρ_o = density of the minimum critical mass.

S = Depends upon the size of the fissile unit = 2(1-f).

f = ratio of the mass of a single unit to the critical mass of the same fissile material in a similar shape ("fraction critical")

The values for these parameters that were used in the calculations are shown in Table G-1.

The results of the density analog calculations are conservative in nature when proper assumptions are made. Two assumptions inherent in this method are:

(1) The shipping packages assumed in the calculation are spherical in geometry. The actual packages are parallelepipeds, hence the conservatism implied above.
(2) There are no effects due to poisons and scattering media within the package. These effects will be present and hence the conservatism again.

Table G-1

PARAMETERS FOR THE DETERMINATION OF THE REFLECTED CRITICAL MASSES IN EQUATION 1

Fissile Material	R	M_o	M_{so} (g)	ρ_o(g/cc)
PuO_2	5[a]	1.0[b]	25,500[b]	10.1

[a] Reference 13.

[b] LASL calculations using DTF-IV computer code for an unreflected spherical PuO_2 (80% ^{238}Pu, 20% ^{239}Pu) system.

Additional conservatism is implied by the fact that the criticality data used in these calculations were developed for PuO_2 (80% ^{238}Pu, 20% ^{239}Pu). The actual MHW heat source fuel composition is 80% ^{238}Pu, 16% ^{239}Pu, and 4% other Pu. The additional ^{239}Pu considered in the calculations makes the fuel appear more reactive than it actually is.

Although the presence of graphite was recognized, its excellent neutron moderating properties were not considered during this analysis. However, Pu is considerably more reactive to unmoderated neutrons than to moderated or thermal neutrons. This fact provides additional conservatism in the figures obtained during this analysis.

G.3. Determination of Transportation Criteria

AEC Chapter 0529, Safety Standards for the Packaging of Radioactive and Fissile Materials, specifies the guidelines to be followed when determining Fissile Classes and Transportation Indices for packages of fissile material. Standards H, I, and J in Chapter 0529 cover the specific guidelines used for these calculations.

In order to make the Fissile Class I determination using this technique, a finite number of shipping packages must be assumed equivalent to an unlimited number. The number used was 2500 shipping packages. Specifying a number of packages as infinite allows the use of the density analog approach with respect to the Fissile Class I category.

G.4. Configuration of the MHW Heat Source Assembly Shipping Container

(a) The undamaged shipping container consists of a metal carrier (122.4 cm x 122.4 cm x 142.2 cm) surrounding a finned cask and storage protection container which contains a fully assembled MHW heat source. This geometry is depicted in Figure G-1.

(b) One damaged shipping container consists of the finned cask without the cooling fins (31.4 cm radius, 97.8 cm height cylinder). It was determined that after subjecting the MHW-IHS-SC to hypothetical accident conditions, both carrier and the cooling fins would be damaged extensively and the cask would no longer be water leak tight.

G.5. Results and Conclusions

Although the MHW heat source design calls for a 5.3 kg of Pu fuel load, calculations were made to cover the range between 5.3 and 10 kg in order to establish the shipping container fuel capability.

Table 2 shows the limiting amounts of plutonium isotope per container for the different Fissile Classes. Figure G-2 shows the Transport Indices for Fissile Class II shipments.

It was concluded from this analysis that the shipping container for the present design of the MHW heat source would comply with Fissile Class I transport criteria. This is in agreement with additional calculations performed by LASL using Monte Carlo computer codes.[14]

Table G-2

LIMITING AMOUNTS OF PLUTONIUM
PER SHIPPING CONTAINER

Fissile Class	I	II	III
Amount of Plutonium Per Container	0.015-6.3 kg	6.3-9.8 kg	9.9 kg

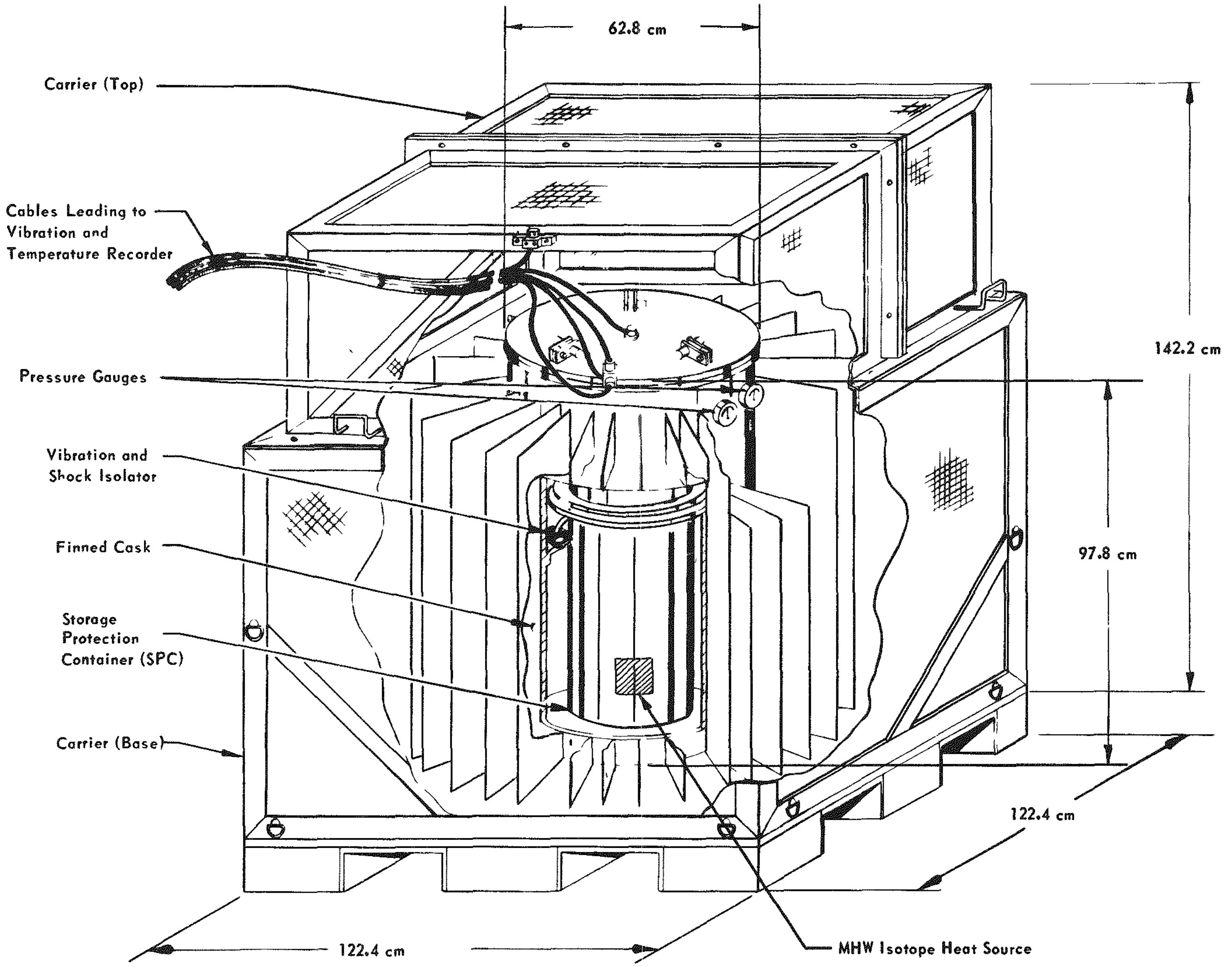


FIGURE G-1 - Multi-Hundred Watt Isotope Heat Source Shipping Container criticality evaluation.

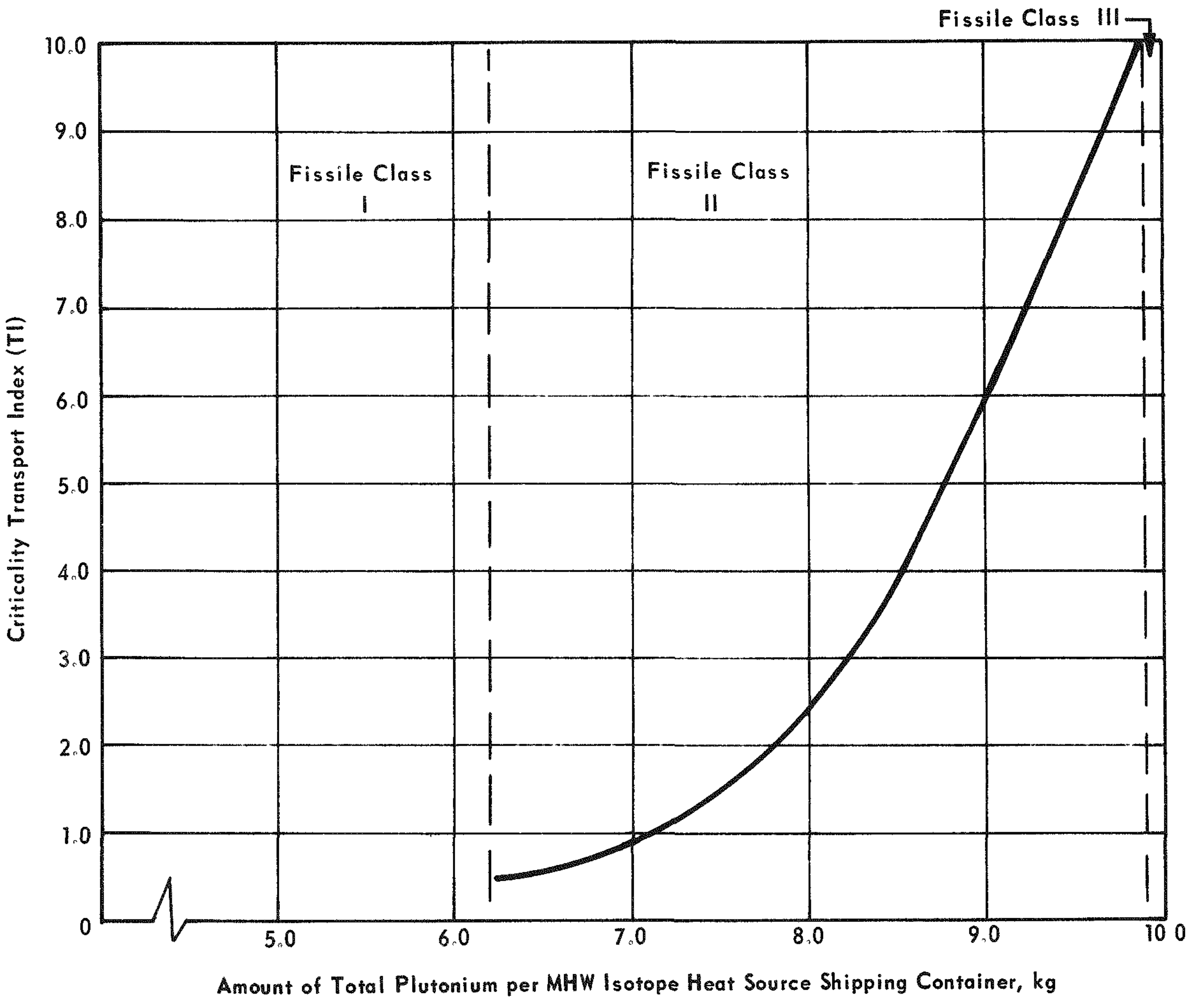


FIGURE G-2 - Criticality transport index as a function of the amount of plutonium in the MHW isotope heat source shipping container.

G.6. Sample Calculations

A sample calculation describing the results obtained with the density analog method when applied to the MHW-IHS-SC is given below. The fuel load assumed in this calculation is the one that the present design of the MHW heat source calls for, 5.3 kg of total plutonium. Calculations were made for both the undamaged and damaged containers.

1. Formula: $M_c \text{ (reflected)} \geq \frac{M_{so} \text{ (bare)}}{(R)\ (M_o)} \left(\frac{\overline{\rho}}{\rho_o}\right)^{-s}$

2. $M_{so} = 25.5$ kg

   $R = 5.0$

   $M_o = 1.0$

   $\rho_o = 10.1$ g/cc

3. Determination of the effective mass (M_{eff}) as a result of reflector savings.

   M_{eff} = reflector savings factor x amount of plutonium in container

   = 1.728* x 5.3

   = 9.16 kg

4. Determination of S

   S = 2(1-f)

   f = ratio of the mass of a single unit to the critical mass of the same fissile material in a similar shape.

   $f = \frac{9.16}{25.5} = 0.36$

   s = 2(1-f) = 1.28

5. Volume of Undamaged Container

   $V = 122.4 \times 122.4 \times 142.2 = 2.13 \times 10^6 \text{ cm}^3$

*Reference 15.

6. Volume of Damaged Container

$$V = \pi(31.4)^2 \ (97.8) = 3.03 \times 10^5 \ cm^3$$

7. Fuel Density in Undamaged Container

$$\frac{9.16 \times 10^3}{2.13 \times 10^6} = 0.0043$$

8. Fuel Density in Damaged Container

$$\bar{\rho} = \frac{9.16 \times 10^3}{3.03 \times 10^5} = 0.030$$

9. The minimum control mass for the undamaged container is

$$M_c \ (\text{reflected}) = \frac{25.5}{(5)\ (1)} \left(\frac{0.0043}{10.1}\right)^{-1.28}$$

$$= 1.05 \times 10^5 \ kg$$

10. Number of containers that constitutes a minimum critical mass is

$$= \frac{1.05 \times 10^5}{9.16} = 11{,}491$$

AEC Chapter 0529 specifies as the first of two requirements for Fissile Class I that any number of undamaged packages should be subcritical under optimum conditions. Since 2500 containers have been defined as an "unlimited number of containers," this requirement is satisfied by the MHW-IHS-SC holding 5.3 kg of plutonium.

11. The minimum critical mass for damaged containers is

$$M_c \ (\text{reflected}) = \frac{25.5}{(5)\ (1)} \left(\frac{0.030}{10.1}\right)^{-1.28}$$

$$= 8757.6 \ kg$$

12. Number of containers that constitutes a critical mass is

$$= \frac{8757.6}{9.16} = 956$$

AEC Chapter 0529 specifies, as the second requirement for Fissile Class I, that 250 containers would be subcritical after subjected to the hypothetical accident conditions described in Chapter 0529.

13. Hence, this shipping container would satisfy the transportation criteria for Fissile Class I.

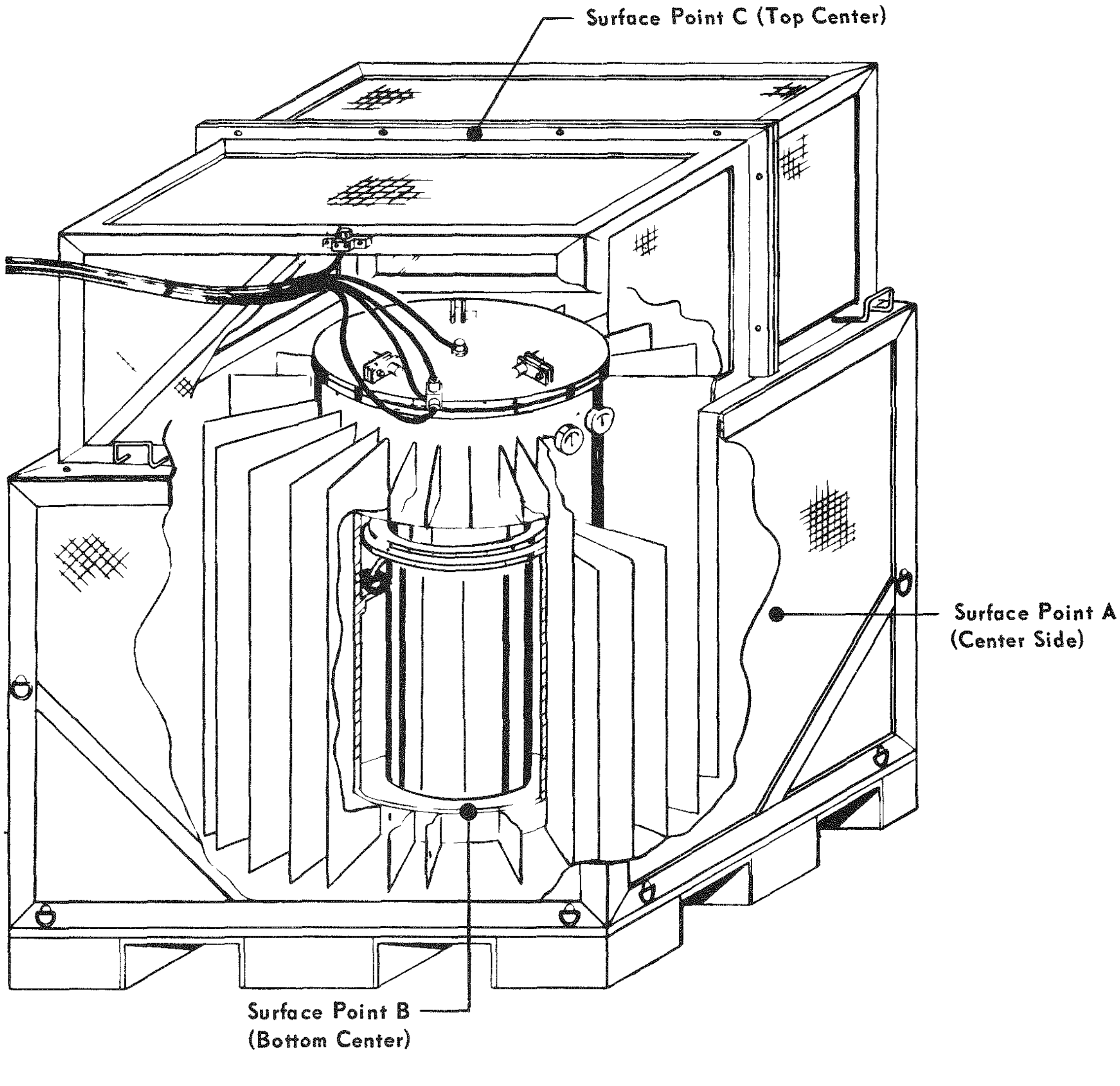
SECTION H

RADIATION SHIELDING EVALUATION

CONTENTS:

H.1. General

The neutron and gamma dose rates from the loaded MHW-IHS-SC were calculated at the various points (i.e., top, bottom, side) shown in Figure H-1 and at three feet from each of these points (i.e., the Transport Index).



H-1 - Multi-Hundred watt isotope heat source shipping container shielding evaluation.

H.2. Discussion of Assumptions

The following assumptions were made:

(1) Point source geometry as opposed to the actual cylindrical source geometry (conservative).

(2) Neutron yield due to (α,η) reactions =

6×10^3 neutrons/(sec)-(g) of ^{238}Pu in the oxide form.

(3) Neutron multiplication due to internal fission was

~20% of (α,η) neutrons.

(4) Due to anisotropy, neutron and gamma dose rates as measured from the ends of the capsule will be ~70% of that measured from the sides, for equal distances from the center of the source.

(5) The ratio of neutron to gamma dose rates is approximately 15 to 1.

(6) For gamma shielding, the linear attenuation coefficient, μ (cm^{-1}), for iron is used since it is a good approximation for the actual package construction materials.

(7) The average neutron energy is approximately 2 MeV.

NOTE:		
	The (α,η) average energy is	~2.25 MeV
	The fission spectrum energy is	~1.00 MeV
	The spontaneous fission energy is	~1.00 MeV

(8) For neutron shielding, the relaxation length (λ) for iron is a good approximation for the actual package construction materials.

H.3. Results and Conclusions

The results of the calculated dose rates at the three points (shown in Figure H-1) are given in Table H-1.

Table H-1

CALCULATED NEUTRON AND GAMMA DOSES FOR THE MULTI-HUNDRED WATT ISOTOPE HEAT SOURCE SHIPPING CONTAINER

Point of Interest	Dose (mr/hr)		
	Neutron	Gamma	Total
Side Surface-Point A	68	3.8	72.8
Bottom Surface-Point B	45	0.95	46.0
Top Surface-Point C	14	0.76	14.8
Side 3 ft from Point A	10.9	0.76	11.7*
Bottom 3 ft from Point B	5.2	0.19	5.4*
Top 3 ft from Point C	4.7	0.19	4.9*

*Equivalent to Transport Index as defined in R. M. Graziano's Tariff No. 27, Hazardous Materials Regulations of the Department of Transportation.

These results show that the total dose rate at any accessible point on the surface of the shipping container will be less than 200 mrem/hr. However, the Transport Index, as measured from the side of the shipping container will exceed 10 mrem/hr and this will require that such shipments be "sole-use of vehicle".

It has been estimated that the total loss of shielding as a result of an accident will cause a radiation dose rate no higher than 170 mr/hr at 3-ft from the external surface of the package. This meets the criteria specified in AEC Chapter 0529, which requires that the radiation dose rate remains under 1000 mr/hr at 3-ft from the surface in hypothetical accident conditions.

Prior to the first MHW-IHS-SC shipment, dose measurements of the gamma and neutron doses were made. At a distance of 3 ft from surface point A (see Figure H-1), the neutron dose was measured at 22 mr/hr and the gamma dose at 1.5 mr/hr for a Transport Index of 23.5. It has been concluded that effects such as radiation backscattering which were not included in the calculation account for the difference between the measured and calculated values.

H.4. Sample Calculations

Calculations for neutron and gamma dose rates on the side surface of the MHW-IHS-SC, and also the Transport Index from this surface, are performed as follows:

Neutron Yield (S):

$$S = \left(4.24 \times 10^{3} \text{ (grams of } {}^{238}\text{Pu in oxide form)}\right) \left(6 \times 10^{3} \text{ neutrons/sec/gram of } {}^{238}\text{Pu in oxide form}\right)$$

$$= 2.54 \times 10^{7} \text{ neutrons/sec.}$$

Neutron Dose Rate:

$$\text{Dose}_n = \frac{S}{4\pi r^2 \text{ (Flux to dose conversion factor)}} = \frac{S}{4\pi r^2 C_f}$$

C_f = 7.3 neutrons/cm^2-sec per 1 mrem/hr*

$$\text{Dose}_n = \frac{2.54 \times 10^{7} \frac{n}{sec}}{4\pi \text{ (61 cm)}^2 \; 7.3 \frac{n/cm^2\text{-}sec}{mrem/hr}} = 74 \frac{mrem}{hr}$$

Fission Multiplication Effect:

(74 mrem/hr) (1.2) = 89 mrem/hr

Anisotropic Flux Distribution:

(89 mrem/hr) (1)** = 89 mrem/hr

Fast Neutron Shielding of Package Materials:

Let x = 5/8 in. or 1.6 cm thick iron,

λ = relaxation length for iron and fast neutrons = 6 cm***,

then using

$$I = I_o \, e^{-x/\lambda},$$

$$I = (89) \, e^{-1.6/6} = (89) \, e^{-.27} = 68 \text{ mrem/hr}$$

Gamma Dose Rates (Unshielded)

From previous measurements at Mound Laboratory on Pioneer 1 and 2 heat sources, it was determined that the ratio of neutron to gamma dose rates is approximately 15:1.

Thus, the gamma dose rate $= \frac{89}{15} = 5.9$ mr/hr.

---

* Reference 16.

** Factor - approx. 0.7 for ends of source.

*** Reference 17.

Effect of Shielding on Gamma Dose Rates:

μ = the Linear Attenuation Coefficient for iron at a gamma photon energy of 0.725 MeV = 0.527 cm^{-1}.

$B(\mu x)$ = Dose build up factor = 1.9*

For shielding effect (I),

let x = 5/8 in., or 1.6 cm.

Then using $I = B(\mu x) I_0 e^{-\mu x}$,

$$I = B\ (\mu x)\ 5.9\ e^{-(0.527)(1.6)}$$

$$= (1.9)(5.9)(0.43) \text{ mr/hr}$$

$$= 4.8 \text{ mr/hr}$$

Calculation of Transport Index (TI):

Using the Inverse Square Law,

$$\frac{\text{Neutron Dose}_1}{\text{Neutron Dose}_2} = \frac{(D_2)^2}{(D_1)^2},$$

$$\frac{68 \text{ at surface}}{\text{TI at 3 ft from surface}} = \frac{(152.4 \text{ cm})^2}{(61 \text{ cm})^2},$$

$$\text{TI} = \frac{(68)(3721)}{23226} = 10.9 \text{ mrem/hr},$$

$$\frac{\text{Gamma Dose}_1}{\text{Gamma Dose}_2} = \frac{(D_2)^2}{(D_1)^2},$$

$$\frac{4.8}{\text{TI}} = \frac{(152.4)^2}{(61)^2}, \text{ and}$$

$$\text{TI} = \frac{(4.8)(3721)}{23226} = 0.77 \text{ mr/hr}.$$

Total Dose Rate:

Side Surface = (Neutron) 68 + (Gamma) 4.8 = 72.8 mrem/hr

3 ft from side surface = (Neutron) 10.9 + (Gamma) 0.77 = 11.7 mrem/hr.

---

*Reference 18.

QUALITY CONTROL

The MHW shipping containers are inspected and the inspections are documented in compliance with AECM 0529. The particulars of the inspections are provided in Mound Laboratory drawing 1-14596 (see Appendix I, pp. I-1 - I-12).

Visual, dimensional, and functional inspections are performed at various stages of fabrication and on receipt of the containers from the fabricator prior to use. Visual and functional inspections are performed after each use prior to reuse.

It is required that the finned cask must pass a helium leak test with no detectable leak greater than 1×10^{-5} std. cc/sec when filled with 15 psig of helium.

In addition to the above inspections, detailed packaging and unpackaging procedures are provided in Mound Laboratory drawing 1-14898 (see Appendix II, pp. II-1 - II-21) to assure proper handling and to provide documentation of these operations.

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P. F. Carpenter, Editor

APPENDIX I

ACCEPTANCE AND REUSE INSPECTIONS

ISSUE	DATE	REVISION	BY	CHK'D	APPRD
A	5-4-74	ORIGINAL ISSUE	ES	FGM	

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ISSUE	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

DWG CLASSIFICATION
LEVEL & CAT UNCL
BY
TITLE
DATE 5-2-74

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR SHIPPING CONTAINER
MHW-IHS-SC ACCEPTANCE AND REUSE INSPECTIONS

		APPROVALS
DRAWN E. SWARTZ	DATE 5/1/74	1
CHECKED	DATE 5474	2
SPONSOR	DATE 5474	3
APPROVED	DATE 5474	4
JOB NO —		

SP
DWG TYPE

CODE IDENT NO 14065

DWG NO 1-14956 SHT 1 OF 16

DAC-73-SA

CONTENTS:

1. G E N E R A L.

1.1 Scope. This is an inspection requirement document for the Multi-Hundred Watt Isotope Heat Source Shipping container (MHW-IHS-SC). It defines the complete receiving acceptance inspection and reinspection prior to reuse to be performed as required by AEC Manual, chapter 0529, including responsibilities, inspection criteria, and documentation records. The purpose of this document is to establish an effective system for assuring compliance with the drawings, specifications and design intent.

1.2 Introduction. The MHW-IHS-SC is a shipping container designed to transport the MHW heat source outside plant boundaries. The MHW heat source contains the radioactive isotope plutonium - 238 in the form of solid plutonium oxide. The shipping container meets the requirements of both the Department of Transportation and the Atomic Energy Commission, and the unique requirements of the MHW heat source. Each MHW heat source produces nominally 2,400 watts of thermal power from the radioactive decay of plutonium - 238. The MHW-IHS-SC consists of a finned cask and a carrier. The finned cask is a stainless steel, helium leak tight cylindrical container with an o-ring seal at the top. It is equipped with external fins for cooling, pressure gages, and vibration and shock isolators. The carrier is a steel pallet with a mesh cage which completely surrounds the finned cask. The heat source is shipped within the storage protection container (SPC) which is not considered part of the MHW-IHS-SC.

2. D O C U M E N T S.

2.1 Required. Monsanto Research Corporation Drawings:

5-2059 - Multi-Hundred Watt Isotope Heat Source Shipping Container - Final Assembly

5-2060 - Carrier Body

5-2061 - Carrier Cap

5-2962 - Cask

1-14841 - Welding and Inspection of 304 and 304L Stainless Steel Containers

1-14898 - Packaging & Unpackaging Procedure Manual for MHW-IHS-SC Shipping Container

2.2 Reference. Safety Analysis Report for Packaging (SARP): Multi-Hundred Watt Isotope Heat Source Shipping Container. MLM-2074.

3. REQUIREMENTS.

3.1 Responsibilities. The fabricator is responsible for assuring that all specification requirements are met and shall utilize accepted quality control measures during fabrication. Monsanto Research Corporation reserves the right to audit the fabricator's facilities and procedures as required. The fabricator shall perform and document the results of the inspection requirements specified in MRC Drawing 1-14841 "Welding and Inspection of 304 and 304L Stainless Steel Containers". MRC Engineering is responsible for establishing inspection criteria for receiving acceptance, for performance of receiving inspections, for establishing inspection criteria for inspections prior to reuse, and for providing this document.

MRC Nuclear Operations Quality Control is responsible for review of the drawings and specifications and to provide review and concurrance for the acceptance inspection plans and test methods as well as the reuse inspection plans and test methods. Quality Control is also responsible for auditing the manufacturing and inspection processes. MRC Nuclear Operations Cost and Reporting Group is responsible for implementation of the reuse inspection program, performance of all reuse inspections and retaining appropriate files to document all inspections. MRC container users are responsible for providing necessary information pertinent to the materials to be shipped, approval and performance of appropriate packaging procedures and the initiation of container procurement and inspection activities in cooperation with the MRC Nuclear Operations Cost and Reporting Group. MRC Administration Waste Management Group is responsible for coordinating related administrative functions.

3.2 Inspection and Acceptance. Each container shall be examined and tested for defects in accordance with Appendix II. Major and critical defects which are found during the examination and/or testing must be corrected prior to acceptance of the container. Nuclear Quality Control shall be notified prior to the inspection or reinspection of the container.

3.2.1 Definition of Defects. Defects are classified as critical, major, or minor. A critical defect is a defect that judgment and experience indicate is likely to result in hazardous or unsafe conditions for individuals using or depending on the container for its intended purpose. A major defect is a defect other than critical, that is likely to result in failure, or to reduce materially the usability of the container for its intended purpose. A minor defect is a defect that is not likely to reduce materially the usability of the container for its intended purpose, or is a departure from established standards having little bearing on the effective use of the container.

3.2.2 Inspection of Major Assemblies. This inspection shall consist of visual, dimensional, and functional examination and tests of major assemblies which make up a complete container.

The major assemblies to be inspected are listed below:

MRC Drawing No. 5-2060 - Carrier Body

5-2062 - Cask

3.2.3 Inspection of Final Assembly. The final assembly shall be examined visually and functionally with regard to meeting the requirements of MRC Drawing No. 5-2059 Final Assembly.

3.2.4 Sampling Plan. Each MHW-IHS-SC is to be inspected for all attributes listed.

3.3 Inspection Record. The cask fabricator is required to complete a "Fabrication and Inspection Certification" as shown in Appendix I. A detailed check list is completed and retained in MRC Nuclear Operations Cost and Reporting Group files, with a copy retained in Nuclear Quality Control, documenting the receiving acceptance and reinspection prior to reuse inspection as shown in Appendices II and III.

SUB-APPENDIX I

MHW-IHS-SC

FABRICATION & INSPECTION CERTIFICATION

FABRICATED BY

CONTAINER SERIAL NUMBER

CONTAINER DRAWING NUMBER

		SIGNATURE	DATE COMPLETED
1.	Component and materials as specified. (Section 2, Dwg. 1-14841).		
2.	Welded as specified		
3.	Visual weld examination acceptable (Section 3).		
4.	Dye penetrant examination acceptable (Section 4, Dwg. 1-14841).		
5.	Dimensions as specified.		
6.	O-ring surface finish as specified.		
7.	Container can be assembled properly.		
8.	Helium leak test acceptable (Section 5, Dwg. 1-14841).		

SUB-APPENDIX II

ACCEPTANCE INSPECTION DATA

for

MHW-IHS-SC

PART A - CARRIER - DRAWING NOS. 5-2060 and 5-2061

1. IDENTIFICATION

1.1 Carrier serial number ____________________.

1.2 Fabricated by ____________________.

2. CARRIER VISUAL INSPECTION	Signature	Date
2.1 All carrier body materials as specified per MRC Drawing 5-2060, items 2A through 2L. (Major)	________	________
2.2 All carrier cap materials as specified per MRC Drawing 5-2060, items 1A through 1N. (Major)	________	________
2.3 Welding has none of the following defects: Missing, incomplete, burn holes, cracked, fractured, not fused. (Major).	________	________
2.4 Material, construction, workmanship acceptable per the following paragraphs:		
2.4.1 No missing parts and all parts are of specified type or design. (Major)	________	________
2.4.2 No components fractured, split, bowed or malformed affecting service - ability. (Major)	________	________
2.4.3 No sharp burrs or slivers that may cause injury. (Critical)	________	________
2.4.4 All operations performed properly. (Major)	________	________
2.4.5 No paint omitted or poorly applied on required areas. (Minor)	________	________

3. CARRIER DIMENSIONAL INSPECTION.

	Signature	Date
3.1 The following overall dimensions are in accordance with the drawings.		
3.1.1 Length is 48 $\pm$ 1/2 in. (Major)		
3.1.2 Width is 48 $\pm$ 1/2 in. (Major)		
3.1.3 Height Body is 40 $\pm$ 1/4 in. (Major)		
3.1.4 Total height is 61 $\pm$ 1/4 in. (Major)		

PART B - FINNED CASK ASSEMBLY - DRAWING NOS. 5-2062 and 4-10804

1. IDENTIFICATION.

1.1 Finned Cask serial number ______.

1.2 Fabricated by ______.

2. VENDOR CERTIFICATION & TEST SAMPLES

2.1 Vendor completed "Fabrication and Inspection Certification, "MRC Dwg. No. 1-14841, Sheet 6.		
2.2 Vendor weld sample satisfactory. (Major)		
2.3 Iron Titanate Coating samples acceptable. (Major)		

3. CASK VISUAL INSPECTION.

3.1 All cask materials as specified per MRC Drawing 5-2062 items 21A through 21AA. (Major)		
3.2 Cask cover plate as specified per MRC Drawing 4-10804. (Major)		
3.3 Iron Titanate Coating appears uniform and only on specified areas. (Major)		

NOTE: Any of the following welding defects will be classified a major finding: missing, incomplete, burn holes, cracked, fractured, not fused.

Item		Signature	Date
3.4	Cask seam welds acceptable. (Major)	______	______
3.5	Support block welds acceptable. (Major)	______	______
3.6	Material, construction, workmanship acceptable per the following paragraphs:		
3.6.1	No missing parts and all are of specified type or design. (Major)	______	______
3.6.2	No components fractured, split, bowed, or malformed affecting serviceability. (Major)	______	______
3.6.3	No burrs or sharp corners that could cause injury. (Critical)	______	______
3.6.4	Cover bolt holes, align with the cask threaded holes. (Major)	______	______
3.7	Fins securely attached and in good contact with the cask. (Major)	______	______
3.8	O-ring groove and matching surface finish (cask cover) acceptable. (Major)	______	______
3.9	Valve manifold spacing acceptable. (Major)	______	______
3.10	Fin grooves properly machined per MRC Drawing 5-2062, Detail E. (Major)	______	______

4. <u>CASK DIMENSIONAL INSPECTION</u>.

Item		Signature	Date
4.1	Sample a minimum of one long fin for the following acceptable dimensions:		
4.1.1	Thickness is 0.19 + 0.02 in. (Major)	______	______

	Signature	Date
4.1.2 Width is 9.0 ± 0.1 in. (Major	________	________
4.1.3 Length is 35.5 ± 0.1 in. (Major)	________	________
4.2 Overall cask dimensions in accordance with Drawing No. 5-2062.		
4.2.1 Height is 40.0 ± 0.1 in. (Major)	________	________
4.2.2 I. D. is 24.00 ± 0.01 in. (Major)	________	________
4.2.3 O.D. Flange is 28.50 ± 0.01 in. (Major)	________	________
4.3 O-ring groove dimensions in accordance with Drawing No. 5-2062 as follows:		
4.3.1 O.D. is 25.430 to 25.490 in. (Major)	________	________
4.3.2 Depth is 0.226 to 0.229 in. (Major)	________	________
4.4 Pin spacing is acceptable as determined using gauge. (Major)	________	________
4.5 Location of the hold down ring is acceptable as follows:		
4.5.1 Height from inside bottom of cask to the top surface of the hold down ring (Detail 37) is 22 1/4 ± 1/4 in. (Major)	________	________
4.5.2 Hold down ring is parallel to the cask bottom surface as determined by measuring the height (Para. 4.5.1) at each pin location (3 measurements) and having a variance of not more than 1/16 in. (Major)	________	________

PART C - MHW-IHS-SC FINAL ASSEMBLY - DRAWING 5-2059

1. VIBRATION ISOLATOR DISIGN, FABRICATION AND CERTIFICATION

1.1 Design and fabrication by ______________ .

	Signature	Date
1.2 Vendor certification of vibration isolator design and fabrication. (Major)	________	________

2. SC FINAL ASSEMBLY VISUAL INSPECTION

2.1 All materials as specified per MRC Drawing 5-2059, items 2 through 15. (Major)

2.2 Name plate as specified per MRC Drawing 1-14599. (Major)

2.3 All materials as specified per MRC Drawing 5-2059, items 18 through 20 and 22 through 32. (Major)

2.4 Vibration isolator and mounting assembly as specified per MRC Drawing 5-2059, items 33 through 44. (Major)

3. SC FINAL ASSEMBLY FUNCTIONAL INSPECTION

3.1 Pressure relief valve set at 33 $\pm$ 3 psig and function's properly. (Major)

3.2 Valve seats are leak tight and helium flow through the gauges and lines is acceptable. (Major)

3.3 Tie down rings securely attached and functioning properly. (Major)

3.4 Shock indicators appear to function properly. (Major)

	Signature	Date
3.5 Metal carrier cap cases function properly. (Major)		
3.6 Assembly can be moved with hand pallet truck. (Major)		
3.7 Functional assembly and disassembly of the necessary hardware as for packaging and unpackaging has been completed satisfactorily. (Major)		
3.8 Functional leak test of the flexible, metal hose acceptable. (Major)		
3.9 Helium leak test performed on cask and manifold with no detectable leak greater than 1 X 10^{-5} std. cc/sec. when filled with 15 $\pm$ 1 psig helium. (Major)		
3.10 Assembly tagged and dated to indicate the inspection results were satisfactory. (Major)		
3.11 Signature of Nuclear Quality Control engineer acceptance of inspection.		

SUB-APPENDIX III

REUSE INSPECTION OF MHW-IHS-SC

Carrier S/N __________

	Initial/Date
1. Check outside and inside for contamination. Removable alpha (highest) _______ d/m/100 cm^2 Location: ______________________	______
2. Remove shipping tags and labels.	______
3. Check for physical damage or missing parts:	______

	Acceptable	Repaired or Replaced
Paint	______	______
Identification Plate	______	______
Iron Titanate Coating	______	______
Fins	______	______
O-Ring	______	______
O-Ring Groove and Matching Surface Finish	______	______
Cover Bolt and Washers	______	______
SPC Hold-Down Bolts (New)	______	______
Shock Indicators	______	______
Tie-Down Rings	______	______
Metal Cases	______	______
Other (Specify)	______	______

4. Pressure relief valves set at 33 ± 3 psig and functions properly.	______
5. Valves and gauges function properly and lines free of any plugs.	______
6. Helium leak test performed with no detectable leak greater than 1 x 10^{-5} std. cc/sec. (sniff test) when filled to 15 psig helium.	______

White: Container File Yellow: Nuclear Q.C. Pink: Shipper File

APPENDIX II

PACKAGING AND UNPACKAGING PROCEDURES

CONTENTS:

ISSUE	DATE	REVISION	BY	CHK'D.	APPRD.
0	2-14-74	ORIGINAL ISSUE	RW	WVD	[illegible]
B	3-14-74	PRIOR NUMERICAL ISSUE DENOTES CONTROLLED ISSUE PER ACO LD2-14876-M14	MB	WVD	JFG
C	5 7 74	REVISION PER ACO LD-2-14876-M15	CC	WVD	JFG
D	8 23/74	REVISION PER ACO LD-2-14876-M19	ES	WVD	JFG

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
ISSUE	D	D	B	B	B	D	C	B	B	B	C	B	B	B	B	D	B	B	B	B	B	B	C	B	B	D	B	B
SHEET	29	30	30A	30B	31	31A																						
ISSUE	B	B	B	B	B	B																						

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR PACKAGING CONTAINER

PACKAGING & UNPACKAGING PROCEDURE MANUAL
MHW-IHS SHIPPING CONTAINER

DWG. CLASSIFICATION	DRAWN R WILKINSON	DATE 2-14-74	APPROVALS
LEVEL UNCL GP	CHECKED WVD/JFG	DATE 2-14-74	1 DLB
DATE 2-14-74 INIT RAD	APPROVED RCR	DATE 2-14-74	2 [illegible]
	JOB NO. 8599		3
	PART NO.		4

DWG. TYPE	CODE IDENT. NO.		
SCI	14065		DWG. NO. 1-14898 SHT. 1 OF 31

1. SCOPE

1.1 This is a procedure manual for users of the Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW-IHS-SC). It sets forth procedures for proper handling of the container when packaging and unpackaging the Storage Protection Container (SPC) and provides samples of the operation sheets to be completed during packaging and unpackaging operations. A parts list is also included.

The MHW-IHS-SC is illustrated on p. 7.

2. INTRODUCTION

2.1 The MHW-IHS-SC is a shipping container designed to transport the MHW encapsulated radioactive isotopic heat source outside plant boundaries. It meets the requirements of both the Department of Transportation and the Atomic Energy Commission, and the unique requirements of the MHW heat source. Shipments are made in accordance with AEC Certificate of Compliance AL-9503.

2.2 Each MHW heat source produces nominally 2,400 watts of thermal power from the decay of plutonium-238 and contains approximately 4200 grams (73,000 Ci) of encapsulated plutonium-238. The MHW-IHS-SC can safely dissipate up to 3500 watts of thermal decay energy.

2.3 The MHW-IHS-SC consists of a finned cask and a carrier. The finned cask is a stainless steel, helium leak tight cylindrical container which is designed specifically for the heat source. It is equipped with external fins for cooling, and vibration and shock isolators to protect the SPC. The carrier is an expanded metal cage on a steel frame and can be easily handled with a fork lift or hand pallet truck. The gross weight of the loaded package is approximately 3000 lbs. During shipment of the SPC, the void between the SPC and the finned cask is filled with an atmosphere of 99% pure helium. Instrumentation is provided to monitor and record temperature, shock, and vibration during loading, transportation, and unloading operations. The appropriate drawings are listed below:

Carrier, MRC Drawings 5-2060 and 5-2061

Finned Cask, MRC Drawing 5-2062

SPC, GE Drawing 47J 302360

MHW Shipping Container Acceptance and Reuse Inspections, MRC Drawing 1-14596.

2.4 In general, these procedures shall be followed in the order they are presented.

3. PACKAGING PROCEDURE

NOTE: The Packaging Operation Sheet provided with the MHW-IHS-SC must be completed while the packaging is being done. A sample is provided in Appendix I of this manual.

3.1 Packaging Preparation

3.1.1 Assure that an inspection has been performed on the container, as required by MRC Drawing 1-14596 and that the inspection certification has been completed.

NOTE: It is intended that the equipment and tools listed in Steps 3.1.2a through 3.1.2o will be used and retained by the shipper and that the tools listed in Steps 3.1.5, 3.1.6 and 3.1.7 will be a separate set which will be shipped with the MHW-IHS-SC. If only one set of tools is on hand, the procedure sequence may be altered so that the tools are loaded into the metal case after the finned cask loading is completed.

3.1.2 Assure that the following equipment and tools are on hand:

a) An Evacuation and Fill System consisting of a 10 psig (minimum) helium supply, a vacuum pump, vacuum and pressure gages. See Figure II-1

b) (Optional) A helium leak detector capable of detecting a leak rate as low as 10^{-4} std. cc/sec.

c) A 1/2 inch socket head ratchet drive with 7/16 and 9/16, inch sockets and a 20-inch long extension (or two 10-inch long extensions).

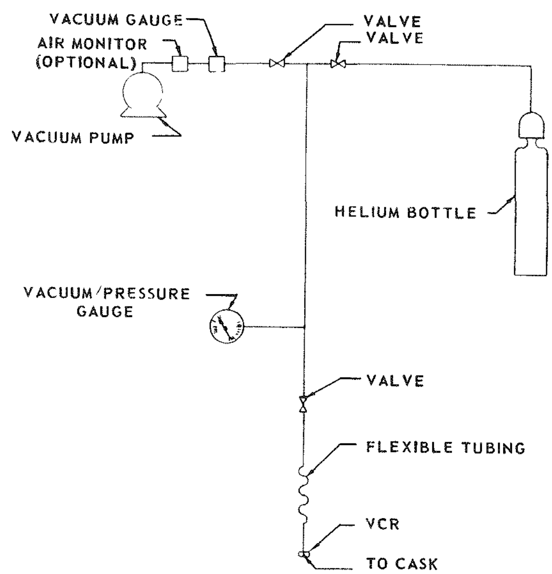

FIGURE II-1 Evacuate and fill system.

d) A torque wrench or combination of torque wrenches of appropriate size to torque the cask cover bolts to 8-10 foot-pounds and the SPC retaining bolts to 80 foot-pounds.

e) Two adjustable wrenches such as ten-inch "Crescent" wrenches.

f) Six pieces of lockwire with lead seal, imprint sealer tool and a pair of wire cutters.

g) Screwdrivers

h) Six each 1/4-inch and three each 1/2-inch spare Cajon VCR nickel gaskets.

i) One 1/4-inch spare Cajon blind female nut.

j) Three 18-inch long guide pins. (MRC Dwg. 2-15399)

k) Two pair of thermally insulated gloves.

l) A hoist capable of lifting up to 500 lb.

m) SPC lifting assembly with safety chain.

n) Finned cask cover lifting fixture.

o) Appropriate health physics instruments, personnel safety equipment and handling devices necessary to provide proper surveillance according to internal operating procedures.

p) A hand pallet truck with a minimum load capacity of 3,000 lbs.

q) Vibration, shock and temperature instrumentation including sensors and cables.

3.1.3. Select three sets of GO, NO-GO shock indicators with mounting fixtures. These may be 3, 7, 15, 50, or 100g shock indicators as required.

3.1.4 Remove the assembled carrier cap. The assembled carrier cap may be handled conveniently by three men.

3.1.5 Place the following items in the metal case mounted inside the assembled carrier cap:

a) Two spare 25 ID x 25-1/2 OD Viton-A O-rings for the finned cask.

b) A 1/2-inch socket head ratchet drive with a 9/16-inch socket and two 10-inch long extensions.

c) An adjustable wrench such as a ten-inch "Crescent" wrench.

d) A pair of wire cutters.

e) Screwdriver

f) Six each 1/4-inch and three each 1/2-inch spare Cajon VCR nickel gaskets.

g) One 1/4-inch spare Cajon blind female nut.

h) Four spare 1/4-20 x 7/8 bolts for the carrier cap.

i) Three spare 3/8-16 x 1-3/4 hex head cap screws for the finned cask cover.

j) Three spare 1/2-13 x 1-1/4 hex head cap screws with washers and socket wrenches attached for securing the SPC in the finned cask.

k) Allen wrench to fit cask cover surface temperature sensor.

3.1.6 Place an adjustable wrench such as a ten-inch "Crescent" wrench and a small screwdriver in the metal case mounted outside the assembled carrier cap. The wrench may be used to remove the assembled carrier cap and the screwdriver may be used for the ambient temperature sensor during unloading operations. Load the GE special SPC socket wrench and SPC gas sample adapter into this metal case if required by GE.

3.1.7 Place three 18-inch long guide pins (MRC Dwg 2-15399) in the rubber tube mounted inside the carrier cap and firmly tighten the hose clamps.

NOTE: The finned cask should normally remain fastened to the carrier base at all times.

3.1.8 Locate the carrier and finned cask assembly such that it is centered beneath a predetermined hoist location to facilitate alignment when the SPC is subsequently lowered into the cask. Use a hand pallet truck to move the carrier.

3.1.9 Remove the finned cask cover using the lifting fixture and hoist. Assure that the O-ring sealing surface is not scratched or nicked during handling.

3.1.10 Assure that the instrumentation battery is charged to 15.5 minimum to 17.5 maximum volts d.c.

3.1.11 Inspect the 25 ID x 25-1/2 OD Viton-A O-ring on the finned cask for cuts or flaws. Replace if necessary.

3.1.12 Fasten the 1/4-inch VCR fitting on the flexible metal hose to the finned cask fitting. A new nickel gasket is required each time a VCR coupling is assembled and the coupling must be tightened to at least 1/8 turn past finger tight.

3.1.13 Attach a new temperature monitoring label with temperature indicators of 200°F to at least 250°F (such as 200, 225, 250 and 275°F) to the finned cask cover near the center.

3.1.14 Screw the three 18-inch guide pins finger tight into the mounting pins on the hold down ring of the finned cask.

3.1.15 Connect the Evacuation and Fill System to the 1/4-inch VCR fitting on the gas manifold for the SPC. A new nickel gasket is required each time a VCR fitting is assembled and the coupling must be tightened at least 1/8 turn past finger tight.

3.1.16 Assure that the vacuum pump is running.

3.1.17 Assure that the Helipak Removal Cart (internal transport cart), normally used to transport the SPC to the packaging area at Mound Laboratory, has been properly located and prepared for removal of the SPC.

3.2 Packaging

CAUTION: The heat source is producing 2,400 watts of heat. Care must be taken to avoid burns from the SPC. Thermally insulated gloves must be worn for operations near the SPC. The procedure should be performed without unnecessary delay so that the SPC will be placed in the MHW-IHS-SC while relatively cool.

3.2.1 Assure that the three lifting lugs provided on the SPC flange are positioned vertically and fasten the lifting assembly to the lifting lugs by lowering the lifting assembly into the Helipak Removal Cart (internal transport cart) and turning it clockwise to engage the feet with the lifting lugs.

3.2.2 Engage the lifting assembly with the hoist.

3.2.3 Fasten the lifting assembly safety chain to the hoist and the SPC lifting handle (top center) with sufficient slack to preclude lifting with the chain during normal operations.

CAUTION: The safety chain is required to preclude accidentally dropping the SPC and damaging its contents. The SPC lifting handle (top center) is not intended for lifting the entire SPC. Surveillance is required to assure that the lifting assembly is engaged with the lifting lugs at all times during handling. Insulated gloves must be worn to avoid burning the hands while making any adjustments.

CAUTION: The electrical hoist at Mound Laboratory must be operated carefully and the SPC must be positioned properly when lowered into the finned cask during the following sequence to avoid accidentally jarring the SPC.

3.2.4 Lift the SPC out of the Helipak Removal Cart (internal transport cart) using the hoist. The SPC must be sufficiently high to clear the 18-inch guide pins extending above the finned cask while performing the following step.

3.2.5 Manually roll the hoist along the trolley track until the SPC is centered above the finned cask.

3.2.6 Align the mating hole in the SPC flange just below the valve with the scribe line on the hold down ring of the finned cask. This orientation enables the flexible hose to assume a gentle 90° bend when subsequently connected to the SPC and the finned cask.

3.2.7 Lower the SPC carefully over the three guide pins until it rests on the hold down ring in the finned cask.

3.2.8 Remove the lifting assembly and safety chain from the SPC and hoist.

3.2.9 Unscrew the three 18-inch guide pins.

3.2.10 Attach each of the three new 1/2-inch bolts with attached 3/4-inch socket wrenches and washers to a 20-inch long wrench extension.

CAUTION: New bolts must be used since the coating is damaged during normal use.

3.2.11 Screw the three bolts finger tight into the pins on the finned cask hold down ring.

NOTE: Steps 3.2.13 to 3.2.19 may be done prior to completion of step 3.2.12.

3.2.12 Wait one-half hour for the three 1/2-inch bolts to heat up and then tighten the bolts to a torque of 80 ± 10 foot-pounds. Retighten the bolts as required until all are at 80 ± 10 foot-pounds torque. Remove the 20-inch wrench extension. The 3/4-inch socket wrench is intended to remain fastened to the bolt head during shipment.

3.2.13 Fasten the 1/2-inch VCR fitting on the flexible metal hose to the SPC valve fitting. A new nickel gasket is required each time a VCR coupling is assembled and the coupling must be tightened at least 1/8 turn past finger tight.

NOTE: The SPC valve was closed prior to being loaded into the Helipak Removal Cart (internal transport cart) and remains closed throughout packaging and shipment.

3.2.14 Evacuate the flexible metal hose to at least 15 torr absolute pressure (0.3 psia). Backfill to 1150 ± 50 torr absolute pressure (7.5 ± 1 psig) with at least 99.99% pure helium. Repeat the evacuation and backfill one additional time.

3.2.15 Check for any leaks by observing that the pressure in the flexible metal hose does not decrease more than 1.0 torr per 5 minutes. Make any repairs required and/or note any leak rate before continuing. The leak tightness of this hose is not necessary for safe shipment, but is required for storage subsequent to shipment.

3.2.16 Close the valve on the finned cask exterior labeled SPC #2.

3.2.17 Close the valve on the finned cask exterior labeled SPC #1.

3.2.18 Disconnect the Evacuation and Fill System from the SPC valve header and replace the 1/4-inch VCR blind female nut on the SPC valve header fitting. Use a new nickel gasket and tighten at least 1/8 turn past finger tight.

3.2.19 Lockwire the SPC #1 and #2 valve handles in place. A hole is provided in each valve handle for this.

3.2.20 Engage the lifting fixture for the finned cask cover with the three lifting lugs provided on the cover and fasten the lifting fixture ring to the hoist. It is necessary to maintain slight tension upward on the lifting fixture to keep it engaged.

3.2.21 Lift the cover and manually roll the hoist along the trolley track until the cover is centered over the finned cask.

3.2.22 Align the cover with the finned cask such that the two guide holes in the cover will fit over the guide pins and with the scribed hole and pin mating. Gently lower the cover in place on the finned cask.

3.2.23 Bolt down the cover with fifteen of the required sixteen 3/8-inch hex head bolts and flat washers using a 9/16-inch socket wrench. Torque the bolts to 8 to 10 foot pounds. The sixteenth bolt will be subsequently installed at the location marked "ACCEL" and will be used to fasten the accelerometer mounting block to the finned cask cover.

3.2.24 Remove the 1/4-inch VCR blind female nut from the lower end of the finned cask valve header and connect the Evacuation and Fill System to this header. Use a new nickel gasket and tighten at least 1/8 turn past finger tight.

NOTE: Step 3.2.25 requires approximately 30 minutes using the Mound Laboratory Evacuation and Fill System.

3.2.25 Evacuate the finned cask to at least 100 torr (1.9 psia). Backfill the finned cask to 1150 $\pm$ 50 torr (7.5 $\pm$ 1 psig) with at least 99.99% pure helium. Repeat the evacuation and backfill one additional time. (On heating to steady state the helium pressure is expected to increase by approximately 50 to 100 torr.)

3.2.26 Leak check the finned cask by observing the pressure loss, if any, and/or any acceptable method such as a helium leak detector to assure that there will be at least one atmosphere absolute pressure of helium in the finned cask after a period of one month. This is equivalent to a pressure loss of 0.7 torr per hour after the temperatures have reached the steady state values. A leak rate of <0.04 std. cc/sec. using a helium leak detector is acceptable.

3.2.27 Close the valve labeled Cask #2, disconnect the Evacuation and Fill System from the finned cask valve header and replace the 1/4-inch VCR blind female nut on the header fitting. Use a new nickel gasket and tighten at least 1/8 turn past finger tight.

NOTE: The cask #1 valve remains open for shipment.

3.2.28 Lockwire the cask #1 and #2 valve handles in place. A hole is provided in each valve handle for this.

3.2.29 Check the outer surface of the finned cask for radioactive contamination and control as necessary.

3.2.30 Assure that the Packaging Operation Sheet has been signed off to document that packaging of the finned cask has been completed.

3.3 Carrier Assembly

3.3.1 Mount the three sets of GO, NO-GO shock indicators to the three lifting lugs on the finned cask cover as shown in Figure II-2.

3.3.2 Feed the instrumentation cables for the three accelerometers and the surface temperature sensor through the access port provided in the assembled carrier cap as shown in Figure II-2. Fasten the accelerometer mounting block to the finned cask cover at the location marked "ACCEL" using the last cover bolt. Screw the surface temperature sensor to the center of the finned cask cover. Install the ambient temperature sensor to the assembled carrier cap immediately above the access port using the attached clip.

3.3.3 Install the assembled carrier cap such that the two guide holes in the cap fit over the guide pins and the scribed hole and pin are mated. The assembled carrier cap can be handled

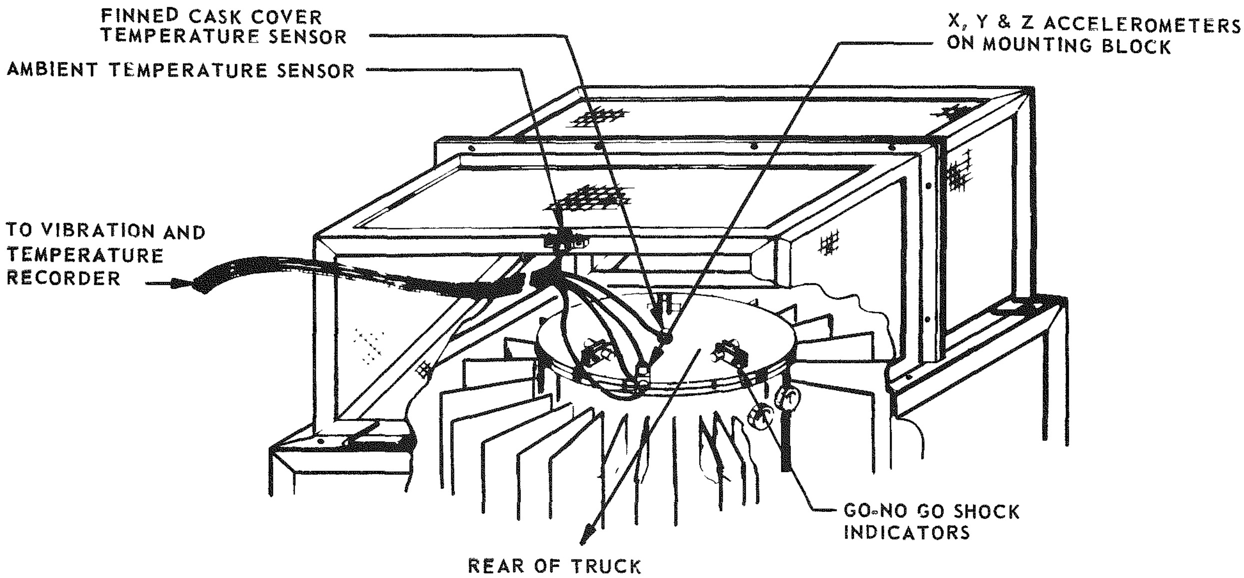

FIGURE II-2 - Installation of temperature sensors and accelerometers.

conveniently by three men. Use a 7/16-inch socket wrench to securely tighten the sixteen 1/4-inch hex head bolts around the perimeter of the cap.

3.3.4 Lockwire the assembled carrier cap to the carrier body using two pieces of lead seal lockwire. Each security seal must fasten together both halves of the carrier cap and the carrier body and the seals must be on opposite sides of the carrier.

3.4 Loading the MHW-IHS-SC into the Transport Vehicle

3.4.1 Turn on the instrumentation in accordance with the instructions stamped inside the instrumentation cover. Use the switch labeled "int" power. Assure that minimum sensitivity is set to 2.5 g's for all three axes by using maximum load settings of 25 g's and threshold settings of 10%. Assure that the time selection wheel is set at 20 minutes.

NOTE: The instrumentation must be on at all times the MHW-IHS-SC is being handled or transported.

CAUTION: The MHW-IHS-SC must be handled carefully to avoid damaging the shipping container or the heat source assembly.

CAUTION: Do not stand near the MHW-IHS-SC during lifting or moving operations. Normally, the container may be moved satisfactorily using a hand pallet truck when raised to a height of approximately 1/8-inch above the floor. Release the hand pallet truck carefully to avoid dropping the container.

3.4.2 Move the MHW-IHS-SC to the transport vehicle using a fork lift or hand pallet truck. The tines may be inserted under the base plate on any of the four sides of the container. Move the instrumentation simultaneously.

3.4.3 Orient the container such that the accelerometers will be located toward the back of the transport vehicle as illustrated in Figure II-2. Load the container and instrumentation into the transport vehicle. The instrumentation may be conveniently lifted into the transport vehicle by two men. The hand pallet truck provided may be used to locate the container within the transport vehicle.

3.4.4 Tie down the container using the eight rings located at the corners of the carrier approximately 20 in. above the base. The recommended tie down locations are shown in Figure II-3. The eight rings located near the base of the carrier are not normally required, but may be used in special circumstances.

3.4.5 Assure that the three sets of GO, NO-GO shock indicators are set.

3.4.6 Tie down the instrumentation in the transport vehicle.

3.4.7 (Optional) Secure a hand pallet truck within the transport vehicle if one is required.

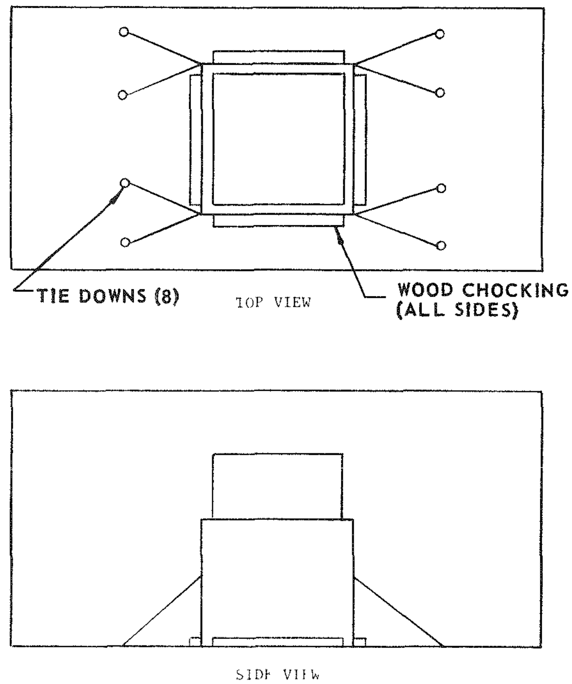

FIGURE II-3 - Tie down locations.

3.4.8 Secure a labeled shipping crate in the transport vehicle for subsequent return of the instrumentation.

3.4.9 Assure that the Packaging Operation Sheet has been signed off to document that all the packaging procedures have been executed.

3.4.10 Just prior to shipment, recheck to be sure that all labels, documents, and radiation surveys are shipped either with the container or with the shipping documents in accordance with DOT and AEC regulations and in-house documents.

3.4.11 Place a copy of this procedure manual and the IHS Traveler in the metal case mounted outside the carrier.

4. UNPACKAGING PROCEDURE

NOTE: The unpackaging instructions are based on utilization of the equipment available at Mound Laboratory. Minor changes in procedures resulting from differences in handling equipment may be necessary, but the sequence of operations performed on the MHW-IHS-SC should not be altered.

NOTE: The Unpackaging Operation Sheet provided with this manual must be completed while the unpackaging is being done.

4.1 Preparation

4.1.1 Provide appropriate health physics instruments, personnel safety equipment and handling devices necessary to conduct this activity according to internal procedures.

NOTE: The metal case mounted to the outside of the carrier contains an adjustable wrench which may be used to remove the assembled carrier cap and, if required, a GE special SPC socket wrench and SPC gas sample adapter. The metal case mounted to the inside of the carrier contains a 1/2-inch socket head ratchet drive with a 9/16-inch socket and two 10-inch long extensions, an adjustable wrench, a pair of wire cutters, and a screwdriver. These are all of the hand tools required to unload the MHW-IHS-SC.

4.2 Removal of the MHW-IHS-SC from the Transport Vehicle

CAUTION: The MHW-IHS-SC must be handled carefully to avoid damaging the shipping container or the heat source assembly.

CAUTION: Do not stand near the MHW-IHS-SC during lifting or moving operations. Normally, the container may be moved satisfactorily using a hand pallet truck when raised to a height of approximately 1/8-inch above the floor. Release the hand pallet truck carefully to avoid dropping the container.

4.2.1 Perform a radiation survey on all exterior surfaces of the MHW-IHS-SC and record the results on the appropriate shipping documents and the Unpackaging Operation Sheet.

4.2.2 Remove all of the tie downs except one. Loosen this one so there is sufficient slack to allow movement of the MHW-IHS-SC to within approximately one foot of the rear of the vehicle.

4.2.3 Locate the instrumentation such that the MHW-IHS-SC may be removed from the vehicle with the instrumentation turned on. The instrumentation may be conveniently handled by two men.

CAUTION: Be sure the MHW-IHS-SC cannot be accidentally removed from the truck in Step 4.2.4.

4.2.4 Move the container to an accessible position at the rear of the truck. A hand pallet truck may be used.

4.2.5 Remove the last tie down.

4.2.6 Unload the MHW-IHS-SC from the transport vehicle using a forklift. Insert the tines under the base plate. Unload the instrumentation simultaneously so that it can remain in operation.

4.2.7 Transfer the MHW-IHS-SC and the instrumentation to an appropriate area for subsequent unpackaging. The forklift or hand pallet truck tines may be inserted under the base plate on any of the four sides.

4.2.8 Turn off the instrumentation package: Depress the "E.O.F." button and release it, wait at least five seconds, and then switch the power to "off". The instrumentation lock combination must be obtained from the Mound Laboratory contact.

4.3 Unpackaging

CAUTION: After the assembled carrier cap has been removed in Step 4.3.1, be careful not to touch the finned cask cover with unprotected hands. It will be approximately 200^{o}F.

4.3.1 Remove the two lockwires attaching the carrier cap to the carrier body.

4.3.2 Unscrew the sixteen 1/4-inch hex head bolts fastening down the assembled carrier cap and unfasten the ambient temperature sensor mounted to the assembled carrier cap immediately above the access port. The adjustable wrench and small screwdriver in the metal case mounted to the outside of the carrier may be used. Remove the assembled carrier cap. The assembled carrier cap may be handled conveniently by three men.

4.3.3 Record the condition of the GO, NO-GO shock indicators and the temperature label located on the cask cover. Remove the GO, NO-GO shock indicator assemblies from the cask cover lifting lugs.

CAUTION: The accelerometers are fragile and must be handled carefully in step 4.3.4. Do not disconnect the small fittings attaching the short cables to the accelerometers.

4.3.4 Remove the temperature sensor and accelerometer mounting block from the finned cask cover and feed the instrumentation cables through the carrier cap.

4.3.5 Disconnect the three Amphenol (large) cable connectors, unscrew the accelerometers from the block and package the accelerometer assembly components (block and accelerometers with short cables only) in the padded carton provided in the labeled shipping crate.

4.3.6 Package the instrumentation, cables, temperature sensors, accelerometer assembly carton, GO, NO-GO shock indicators, and fixtures securely in the labeled shipping crate provided. Do not seal the labeled shipping crate until copy 2 of the Unpackaging Operation Sheet has been included as specified in Step 4.3.21.

4.3.7 Remove the blind female nut from the 1/4-inch VCR coupling on the finned cask valve header and attach a Health Physics type continuous air monitor. Use a new nickel gasket and tighten at least 1/8 turn past finger tight.

CAUTION: Appropriate contamination control measures must be taken during the unpackaging sequence. An air monitor must be located nearby to determine if a release has occurred. Specific steps shall be in accordance with the receiver's radiological control procedures.

4.3.8 Remove the lockwires from the valves labeled cask #1 and #2. Assure that the valve labeled cask #1 is open and open the valve labeled cask #2 to release sufficient helium to assure that no radioactive contamination is present. Control as necessary if contamination is found.

4.3.9 Disconnect the continuous air monitor and release any remaining helium.

4.3.10 Unbolt the finned cask cover using a 9/16-inch socket wrench.

4.3.11 Engage a lifting fixture with the three lifting lugs provided on the finned cask cover and remove the cover using a hoist. (The cover weighs approximately 140 lbs.)

CAUTION: Assure that the O-ring sealing surfaces on the under side of the cover are not scratched or nicked as a result of improper handling.

CAUTION: Do not touch the SPC surface with unprotected hands. The surface temperature may be as high as 500°F during shipment in the MHW-IHS-SC.

4.3.12 Swipe the exposed surfaces of the SPC and finned cask to determine if any radioactive contamination is present. Control as necessary if contamination is found.

4.3.13 Assure the SPC valve has remained closed so that helium will not be released from it during unpackaging operations.

4.3.14 Remove the blind female nut from the 1/4-inch VCR coupling on the SPC valve header and attach a Health Physics type continous air monitor. Use a new nickel gasket and tighten at least 1/8 turn past finger tight.

4.3.15 Remove the lockwires from the valves labeled SPC #1 and #2 and open the valves to release sufficient helium to assure that no radioactive contamination is present. Control as necessary if contamination is found.

4.3.16 Disconnect the continuous air monitor and release any remaining helium.

4.3.17 Disconnect the 1/2-inch VCR fitting which connects the flexible metal hose to the SPC.

CAUTION: Do not unscrew any of the 12 bolts which fasten the SPC flanges together. The three bolts to remove in Step 4.3.18 may be identified by the 3/4-inch socket wrenches which are attached to the bolt heads.

4.3.18 Unbolt the three 1/2-inch hex head bolts fastening the SPC flange to the finned cask hold down ring using the attached 3/4-inch socket wrenches and a 20-inch (or two 10-inch) long extension. (These bolts were torqued to 80 ± 10 foot-pounds prior to shipment.)

4.3.19 Remove the SPC from the finned cask using a lifting assembly and a hoist with at least 500 lb. capacity. Three lifting hooks are provided on the flange of the SPC.

4.3.20 Assure that all container surfaces are free of radioactive contamination and reassemble the container. Be sure to secure all the MHW-IHS-SC components in place as received and replace the tools in the appropriate metal cases.

4.3.21 Assure that the Unpackaging Operation Sheet has been signed off to document that the SPC has been properly unpackaged. Place copy 2 of the completed Unpackaging Operation Sheet in the labeled shipping crate with the instrumentation and return the crate to Mound Laboratory.

4.3.22 Place this procedure manual in the metal case mounted outside the MHW-IHS-SC.

4.3.23 Return the empty MHW-IHS-SC to Mound Laboratory when it is no longer required.

5. EMERGENCY PROCEDURES

5.1 Damage to the MHW-IHS-SC Shipping Container.

5.1.1 Notify responsible personnel immediately.

5.1.2 Check for radiation levels and contamination and take appropriate action according to your radiological control procedures.

5.1.3 Check the GO, NO-GO shock indicators to see if they have been tripped and record the results.

5.1.4 Assemble and record the cause, circumstances, and specific damage done for investigation purposes.

5.1.5 If the damage is superficial, document the cause, circumstances and specific damage done and continue the shipment. The shipper shall determine whether or not the damage is superficial.

5.1.6 If the damage is extensive, assure that both the shipper and the receiver concur regarding an appropriate course of action.

5.2 Loss of helium from the finned cask.

NOTE: Decrease of helium pressure to one atmosphere in the finned cask during normal shipments of the heat source is not considered to be an emergency.

6. MHW-IHS-SC SPARE PARTS

6.1 Carrier

ITEM	NO.	SIZE AND MATERIAL	USE
Ring & Clip	16	4000# Davis Aircraft Prod. FDK-2850.	Tiedown Connection.
Shock Indicator	2	100g - Inertia Switch Corp. Model SR-355	Shock Indicator
Shock Indicator	2	50g - Inertia Switch Corp. Model SR-355	Shock Indicator.
Shock Indicator	2	15g - Inertia Switch Corp. Model SR-355	Shock Indicator
Shock Indicator	2	7g - Inertia Switch Corp. Model SR-355	Shock Indicator
Shock Indicator	2	3g - Inertia Switch Corp. Model SR-355	Shock Indicator
Metal Case	2	Type D - Mine Safety Appliances Co. 04-12030	Tool Kit/Record Storage
Hex Head Cap	32	1/4-20 x 3/4 Century-20 MBI Corp.	Ring and Clip to Carrier
Lock Washer	32	1/4 Century-20 MBI Corp.	Ring and Clip to Carrier
Hex Nut	32	1/4-20 Century-20 MBI Corp.	Ring and Clip to Carrier
Hex Head Cap Screw	24	1/4-20 x 7/8 18-8 Stainless Steel	Carrier Cap to Carrier/Carrier Cap Halves
Lock Washer	24	1/4 I.D. (Regular) 18-8 Stainless Steel	Carrier Cap to Carrier/Carrier Cap Halves
Hex Nut	8	1/4-20 18-8 Stainless Steel	Carrier Cap Halves
Round Head Screw	18	#5-40 x 3/8 18-8 Stainless Steel	Shock Indicators to Finned Cask

ITEM	NO.	SIZE AND MATERIAL	USE
Round Head Screw	6	#10-24 x 7/8 18-8 Stainless Steel	Tool Kit/Record Storage to Carrier
Flat Washer	12	#10 (Wide) 18-8 Stainless Steel	Tool Kit/Record Storage to Carrier
Hex Nut	6	#10-24 18-8 Stainless Steel	Tool Kit/Record Storage to Carrier
Round Head	4	#6-32 x 5/8 18-8 Stainless Steel	Name Plate to Carrier
Flat Washer	8	#6 (Wide) 18-8 Stainless Steel	Name Plate to Carrier
Lock Washer	4	#6 (Regular) 18-8 Stainless Steel	Name Plate to Carrier
Hex Nut	4	#6-32 18-8 Stainless Steel	Name Plate to Carrier

6.2 Cask

ITEM	NO.	SIZE AND MATERIAL	USE
"O" Ring	1	Viton-A, Parker Seal, 2-474, 25 I.D. x 25-1/2 O.D.	Seal Cover
Hex Head Cap Screw	16	3/8-16 x 1-3/4 18-8 Stainless Steel	Seal Cover
Flat Washer	16	3/8 I.D. (Regular) 18-8 Stainless Steel	Seal Cover
Hex Head Cap Screw	4	3/4-10 x 1-7/8 Century-20 MBI Corp.	Finned Cask to Carrier Base
Lock Washer	4	3/4 I.D. (Regular) Century-20 MBI Corp.	Finned Cask to Carrier Base
Flexible Metal Hose Connection	1	3/8 Nom. Hose Dia. 316 Stainless Steel Cincinnati Valve & Fitting Company	SPC to Finned Cask
Hex Head Cap Screw	3	1/2-13 x 1-1/4 Century-20 MBI Corp.	SPC to Finned Cask (Assembled to socket wrench)

ITEM	NO.	SIZE AND MATERIAL	USE
Flat Washer	3	1/2 Century-20 MBI Corp.	SPC to Finned Cask (Assembled to socket wrench)
Helical Isolator	4	Shock & Vibration Isolator Model C-2518-1 Aeroflex Laboratories, Inc.	Ring Pad to Isolator Pad
Flat Head Screw	32	5/16-18 x 1-1/4 Unbrako 16-991-5C-20-S Standard Pressed Steel Co.	Helical Isolator to Ring Pad/ Isolator Pad
Socket Head Cap Screw	12	3/8-16 x 1-3/4 Unbrako 1960 Stainless 6-C-28-S Standard Pressed Steel Co.	Hold Down Ring to Ring Pad
Socket Head Cap Screw	16	3/8-16 x 1-1/4 Unbrako 1960 Stainless 6-C-20-S Std. Pressed Steel Co.	Isolator Pad to Finned Cask Support Block
Compound Gauge	2	30" Vac/30# Press. Model P-1535 Ametek/U.S. Gauge Co.	SPC Gas Manifold & Finned Cask Gas Manifold
Valve, Check	1	Nupro SS-2CA4-3 Nupro Company	SPC Gas Manifold & Finned Cask Gas Manifold
Coupling	3	4 VCR & 4 VCR-1 Cajon Company	SPC Gas Manifold & Finned Cask Gas Manifold
Connector	2	4 SW-7-4-316 Cajon Company	SPC Gas Manifold & Finned Cask Gas Manifold
Tee	4	4-JW-SS Parker-Hannifin	SPC Gas Manifold & Finned Cask Gas Manifold
Valve	4	Bellows H Series Model SS-4H-SW Nupro Company	SPC Gas Manifold & Finned Cask Gas Manifold
Connector	2	4 SW-7-2-316 Parker-Hannifin	SPC Gas Manifold & Finned Cask Gas Manifold
Elbow	2	4-EW-SS Parker-Hannifin	SPC Gas Manifold & Finned Cask Gas Manifold

SUB-APPENDIX I

PACKAGING OPERATION SHEET FOR MHW-IHS-SC

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM	SHEET	MANUAL NUMBER	OPERATION
REUSEABLE RADIOACTIVE SHIPPING CONTAINERS	1 of 2	MD-70152	4

AUTHORIZATION	CLASSIFICATION	EFFECTIVITY	ECN(S) INCORPORATED
[signature]	UNCLASSIFIED	2-28-74	

OPERATION TITLE
PACKAGING MHW-IHS-SC

Source S/N ________ SPC S/N ________ Carrier S/N ________

Initial/Date

1. Container inspection completed. ________
2. Go, No-Go gages installed; temp. labels applied. ________
3. Viton O-ring inspected and installed. QC ____ ________
4. Tools loaded on inside carrier case. ________
5. Instrumentation battery charged _____ Vdc. ________
   (Minimum 15.5 Vdc; maximum 17.5 Vdc)
6. Flexible metal hose leak checked.
   (≤1.0 torr drop in 5 min.) Time Torr
   Hose _____ psig ____ ____
   ____ ____ ________
7. SPC hold-down bolts torqued to 80 ft.lbs. after ½-hour heatup in IHS-SC. Time
   in. ____
   torque ____ ________
8. Blind nut placed on SPC valve header fitting. ________
9. SPC #1 and #2 valve lockwired in place. ________
10. 15 cask cover bolts torqued to 8-10 ft.lbs. ________
11. Cask leak checked (<0.7 torr/hr at steady state temp., or ≤0.04 std cc/min) Time Torr
    Cask _____ psig ____ ____ QC ________
    (Optional) Maximum rate ____
    std. cc/min. ____ ____ ________
12. Cask #1 and #2 valves lockwired in place. ________
13. Installed accelerometers; turned on instrumentation. ________
14. Place packaging and unpackaging manuals plus IHS traveler in the metal case on the carrier. ________
15. Load SC, inst., inst. crate, and (optional) pallet truck on vehicle. QC ____ ____

DISTRIBUTION:

Issue 2.2-28-74

WHITE: Container File
YELLOW: Nuclear Q. C.
PINK: Shipper File

SUB-APPENDIX II

UNPACKAGING OPERATION SHEET FOR MHW-IHS-SC

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM	SHEET	MANUAL NUMBER	OPERATION
REUSEABLE RADIOACTIVE SHIPPING CONTAINERS	1	MD-70152	5

AUTHORIZATION	CLASSIFICATION	EFFECTIVITY	ECN(S) INCORPORATED
[signature]	UNCLASSIFIED	1-30-74	

OPERATION TITLE
UNPACKAGING MHW-IHS-SC

Source S/N ________ SPC S/N ________ Carrier S/N ________

Signature/Date

1. Check for contamination; cask exterior:
   Removable alpha (highest) ______ d/m/100 cm^2 ____________
   Location: ____________________

2. Move IHS-SC and instrumentation to unpackaging area. ____________

3. Instrumentation (secure lock combination from Mound contact at GE-ESP):
   a. Depress "E.O.F."
   b. After more than 5 sec. turn to "off". ____________

4. Go, no-go gage status:

Size (G)	Condition
________	________
________	________
________	________

   ____

5. Maximum temperature indicated on temperature label:
   ________ °F ____________

6. Check cask helium for radioactivity:
   Contamination level ____________ ____________

7. Check for contamination; SPC exterior:
   Removable alpha (highest) ______ d/m/100 cm^2
   Location: ____________________ ____________

8. Check SPC helium for radioactivity:
   Contamination level ____________ ____________

9. Check finned cask internal surfaces for radioactivity:
   Removable alpha (highest) ______ d/m/100 cm^2 ____________

Put Copy 2 in instrument crate for return to MRC-Mound.

Copy 1 - Recipient
Copy 2 - MRC-Mound

Issue 1.1-30-74

APPENDIX III

GENERAL ELECTRIC EVALUATION OF CONTENTS

SOME NOTES CONCERNING APPENDIX III

by Dr. E. W. Johnson, Project Manager
Monsanto Research Corporation
Mound Laboratory, Miamisburg, Ohio

Mr. P. E. Brown, GE-ESP, has kindly provided a rough draft copy of Appendix III for inclusion in this Safety Analysis Review for Packaging (SARP). In this Appendix, considerable analyses and data are presented to justify the FSA/HSA as the primary containment during hypothetical accidents at GE-VFSC, and consequently during shipment from MRC.

Some comments that MRC is providing, which could be considered to supplement the GE document, are listed below.

1. In Appendix IV of this report, we have provided, separately, drawings and specifications such that HSA and FSA details may be more accurately realized.

2. We have noted that there has been no detectable increase in FSA contamination on the GIS surfaces after in-house storage of up to four (4) months in the production of the Walk-Through Heat Source (WTHS). The encapsulation was started on July 11, 1973, and the units placed in storage as FSA's in the PP Building until assembly into the WTHS during October/November 1973. It should be recognized that somewhat lower than operating temperatures were experienced in this storage, probably less than 500°C. Also, for the Q-1 HSA (the first one to be shipped from Mound Laboratory), three of the FSA's listed in the above-mentioned reference will be replaced with "new" prime quality iridium.

3. In Appendix III, Section A.2.4.3.2, GE may wish to consider the thermal test data mentioned earlier in this SARP for ambient temperatures and extrapolate from there.

4. With the approval of GE, MRC has redrawn several figures, as well as edited and retyped some areas of text to improve the quality of this SARP.

GENERAL ELECTRIC EVALUATION OF CONTENTS

A1.0 INTRODUCTION

The possible release of plutonium bearing material from the MHW Isotope Heat Source (IHS) is a matter of concern and has been investigated by experiment and analysis.

The MHW-IHS consists of the following components:

- 24 spheres of solid plutonium-238 dioxide - the fuel spheres,
- 24 iridium post impact shell assemblies (PISA), each containing one fuel sphere,
- 24 graphite impact shells (GIS) each containing a fueled PISA, and constituting a fuel sphere assembly (FSA),
- various graphite support structures holding the FSAs,
- a graphite aeroshell to provide reentry protection,
- an iridium outer clad, and
- a graphite emissivity sleeve.

A functional description of the MHW-IHS is given in Paragraph A2.1. The plutonium-bearing materials are discussed in Paragraph A2.2. The physical and chemical forms of the Pu-bearing materials are:

a. Discrete solid particulates of PuO_2 formed by

   - manufacturing processes,
   - alpha-particle interaction,
   - mechanical shock and vibration, and
   - thermal shock.

b. Molecular vapor, formed by thermal processes. The composition and the partial pressures of the Pu-bearing species are dependent on the composition of the solid phase - its O/Pu ratio - and on the temperature.

Paragraph A2.3 describes how the potential sources of Pu contamination are controlled by:

- decontamination of the PISA external surfaces to less than 2000 disintegrations per minute (dpm);

- monitoring of contamination levels on the successive layers of the IHS containment: the sum total of contamination on all 24 FSAs will not exceed 1000 dpm and the level of smearable contamination on the Ir outer clad is held to not more than 220 dpm;

- retention of particulates by means of the vent filter; and

- minimization of PuO_2 vaporization by maintaining the handling and test temperatures at low values.

Estimates of the maximum release occurring by vaporization, are given for the various temperatures corresponding to the conditions of storage, handling, and operation during various procedures at General Electric Co., Valley Forge Space Center, and elsewhere.

Paragraph A2.4 discusses the possible accidental release of Pu-bearing material from a PISA which has been damaged by external forces, such as impact or explosion, or by excessive internal pressure. The results of impact testing of protected PISAs with both fuel and fuel simulant are given, demonstrating the survivability of the PISA at velocities of $\geq$270 fps.

The interactions of the IHS with the Heat Source Shipping Container (HSSC) and the Storage Protection Container (SPC), or with the RTG Shipping Container (RSC), and the RTG (converter) are shown to minimize potential damage to the FSAs.

The results of testing fueled PISAs at the maximum temperatures, projected for operations at GE, show the ability of the PISA vents to pass He and, thus, prevent build-up of excessive internal pressure for at least two months.

Paragraph A2.5 discusses the control of Pu-bearing materials which may be released from the PISA. The Pu-bearing material released is retained on the inner surfaces of the GIS; this is demonstrated by test data and supported by analysis.

Additional inhibition of release is provided by the successive layers of the IHS including:

- the internal graphite structure and compliance components,

- the aeroshell, and

- the iridium outer clad.

The review concludes that under the normal conditions of transport to and from GEVF and operations at GEVF the potential contamination will be limited to not more than 7.0 microcuries (μCi), total for the full IHS.

A2.0 <u>DISCUSSION</u>

A2.1 Functional Description of the IHS

The MHW plutonium dioxide fuel is contained primarily by the post impact shell assembly, PISA. This containment consists of two hemispheres of iridium, sealed over the fuel sphere by a continuous equatorial weld. Plutonium-238 is an alpha emitter and the useful heat produced by this isotope results from the absorption of the alpha particle energy in the solid structure of the fuel; this generally occurs within about 20 μm of the point of release in the solid. The neutralized alpha particle is a helium atom. The generation rate from the nominal MHW plutonia fuel is around 1.7×10^{-8} cm^3(STP)/sec/g of material. Figure III-1 shows the generation of helium with time for typical MHW components. Because of the helium

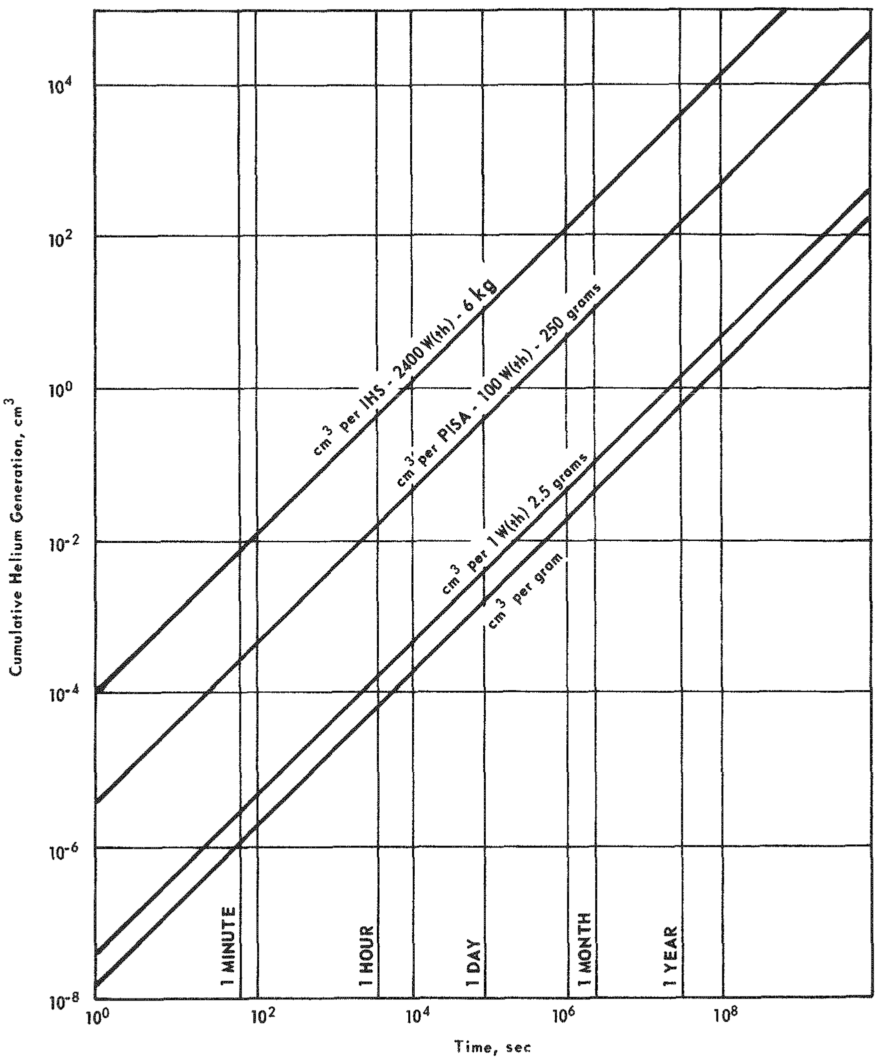

FIGURE III-1 - Helium generation versus time for various MHW components.

generation, the fuel containment must be strong enough to hold the internal pressure or the He must be vented out of the containment. Since the making of a containment of reasonable size and thickness without venting is generally acknowledged to be unsatisfactory because of weight problems, the MHW-PISA is a vented capsule. The vents consist of two 0.005-in. diameter holes at the poles of the spherical fuel capsule (see Figure III-2). These are initially covered by iridium decontamination discs to prevent ingress of decontaminating solution at the time of fabrication. On the inside surface of the sphere, the vent is covered by a labyrinth structure designed to release helium, but to prevent the egress of solid plutonia. This structure is shown schematically in MRC Dwg. No. 10475 (see Appendix IV of this SARP, p. IV-64). After decontamination of the PISA, the decontamination covers are breached to permit helium out-flow. The pisa with the vents now open is placed inside a graphite impact shell (GIS). A threaded cap is placed on the GIS to form a spherical impact containment around the PISA (see Figure III-3).

The GIS consists of a shell of Thornel-50 graphite fiber impregnated and graphitized, having a density 1.2 g/cm^3. The function of the GIS is to prevent the rupture of the PISA on impact with an unyielding surface. The fuel sphere assembly, FSA, consists of the PISA assembled into the GIS. The individual FSA's are assembled into groups of eight in graphite retainers, as shown in Figure III-4. These sub-assemblies are loaded into the graphite aeroshell having threaded closures (see Figure III-5). This structure is contained within an iridium outer clad provided with a graphite emissivity sleeve (see Figure III-6).

A2.2 Sources of Plutonium Release - for Normal Operation

A2.2.1 Plutonium-bearing Species

The plutonium dioxide fuel is the source of any plutonium-bearing material which might be released from the PISA. Under most conditions the chemical form or species of the plutonium-bearing material would be PuO_2. Under certain conditions, it is chemically possible for the monoxide PuO and the metal Pu to be released from the nominal dioxide material, but the quantities are several decades of the magnitude less than the PuO_2.

A2.2.2 Physical Form of Pu-bearing Species

A2.2.2.1 Particulates

The Pu-bearing species can be in the form of solid plutonia dust, consisting of fine particulate material. These particulates may be present on the surface of the plutonia sphere subsequent to manufacture or may be generated as a result of alpha knock-on, or may be produced by mechanical attrition during handling of the sphere after its encapsulation, or may be generated by spallation from the sphere caused by thermal shock. The quantity and the sizes of these particulates are not predictable.

A. Manufacturing residues

The MHW fuel sphere is hot pressed in graphite dies at around 1500°C. The use of graphite can reduce the PuO_2 and even form a thin layer of

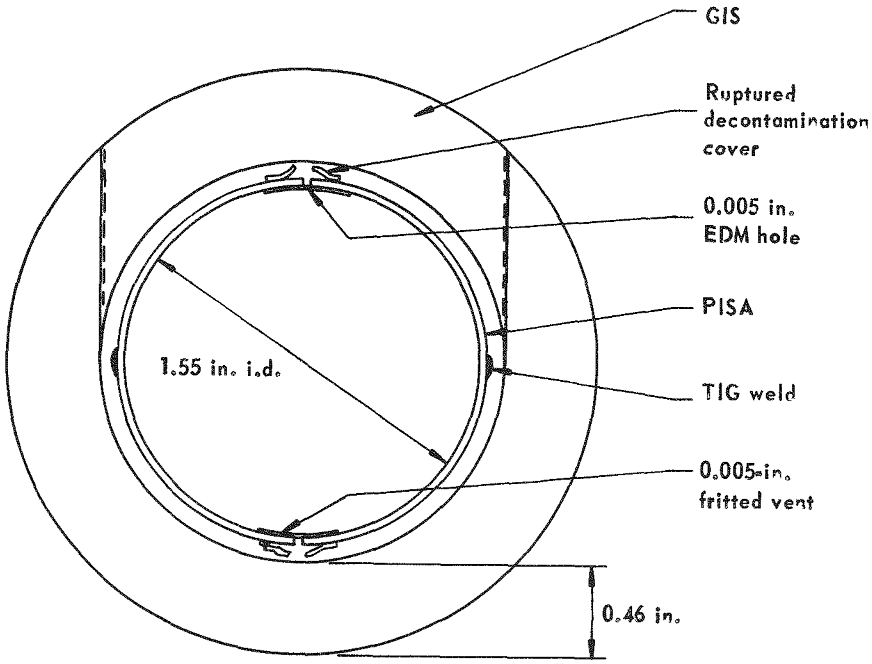

FIGURE III-2 - MHW fuel sphere assembly (FSA): post impact shell assembly (PISA) in graphite impact shell (GIS).

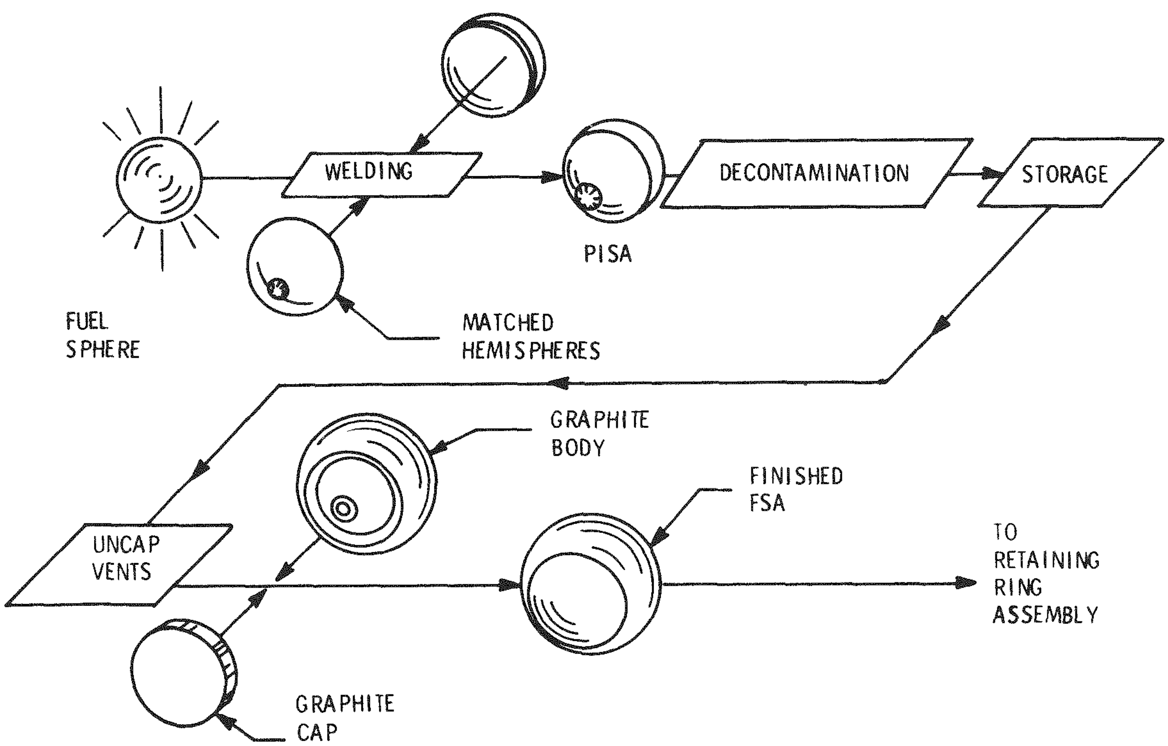

FIGURE III-3 - FSA sequence.

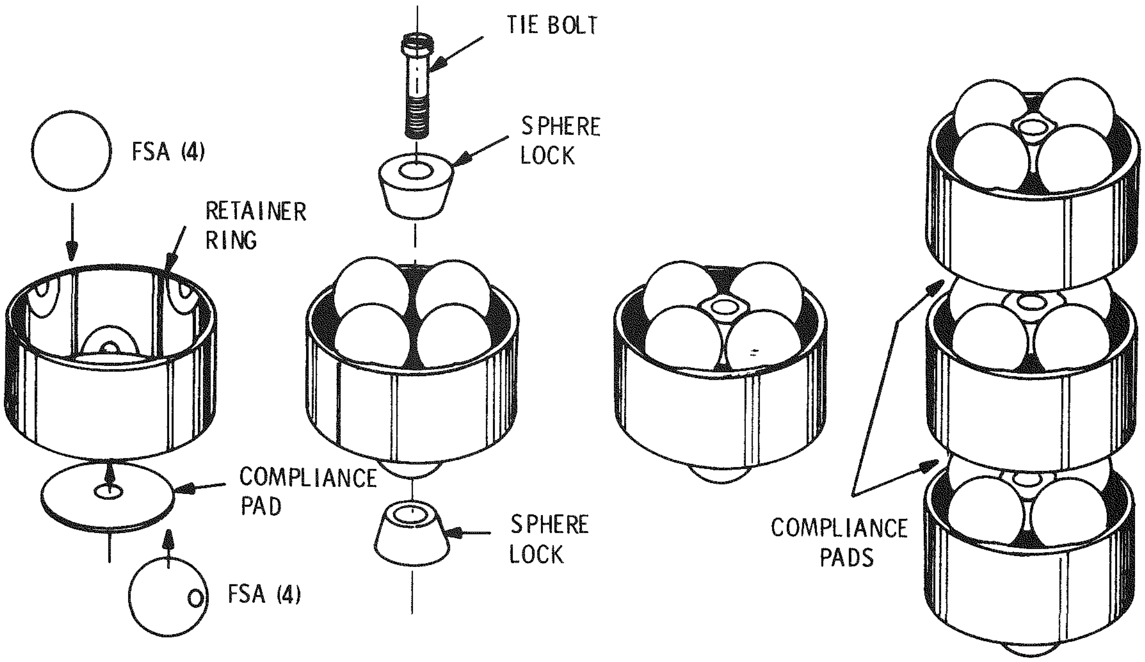

FIGURE III-4 - Retainer ring assembly sequence.

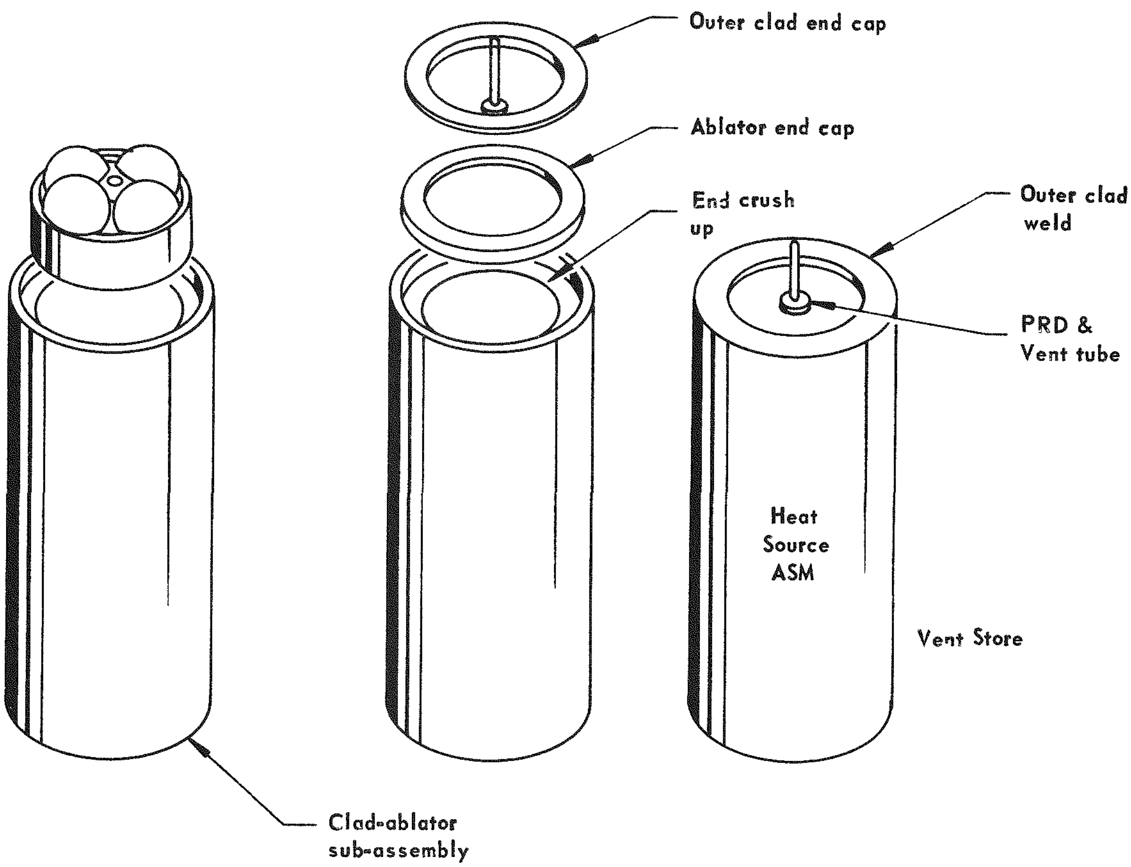

FIGURE III-5 - Final assembly sequence.

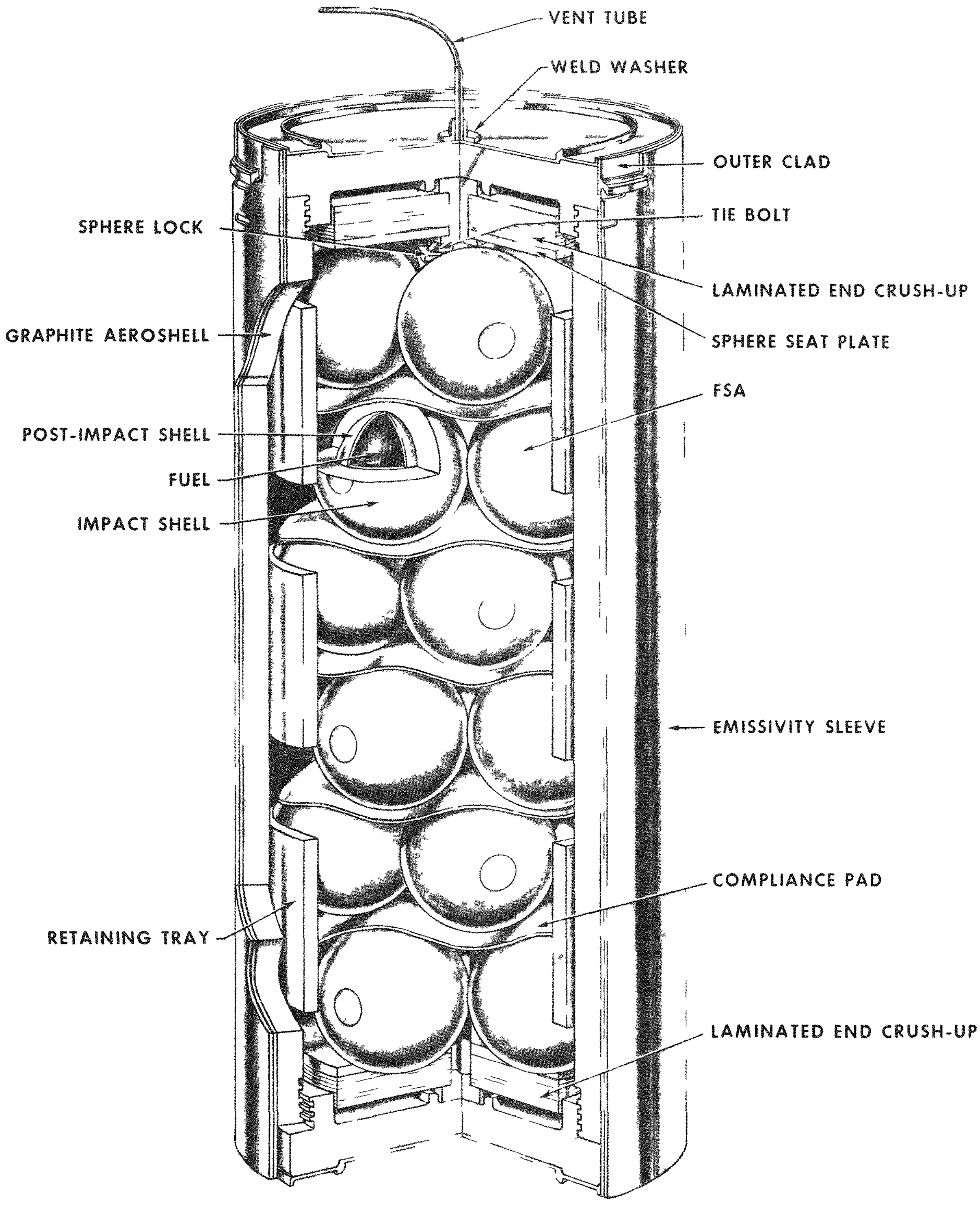

FIGURE III-6 - Heat source assembly

plutonium carbide. The carbon contamination is removed by oxidizing the sphere in an atmosphere of oxygen-16. This procedure also converts any Pu_2C_3 and Pu_2O_3 which may have formed to the dioxide. The fuel is subsequently heat-treated under vacuum at 1500°C. As a precaution against the formation of porosities in the PISA closure weld, loose particulates are removed from the surface of the fuel sphere. However, no measurements of either the size or the quantity of more adherent particulates have been reported.

B. Particulates produced by alpha-particle interaction

Production of particulates from the surface of the fuel sphere by the interaction of the ^{238}Pu 5.49 MeV alpha particles, alpha knock-on, has been evaluated. It has been shown (see p. III-38, Ref. Bohr 13a, Seitz 49b, Seitz 56a) that when a heavy charged particle is stopped in a solid, its kinetic energy is imparted to the atoms of the lattice. Iaptev and Ershler (Ref. Iaptev 56a) performed a number of experiments involving neutrons, fission fragments and alpha particles. In the case of the alpha particles, they determined that the number of atoms knocked out from the surface of a ^{238}Pu metal specimen by its own 5.15 MeV alpha particles was of the order of 2.0×10^{-2} atoms per incident alpha particle. If the simplifying and somewhat conservative assumption is made that the molecules of plutonium dioxide are no more tightly bound than those of the metal, and that the 10% greater energy of the ^{238}Pu alphas produces a non-linear increase of around 25% more knock-ons, then the resulting value for $^{238}PuO_2$ will be approximately 2.5×10^{-2} atoms (molecules) per incident alpha particle.

The range of the 5.49 MeV alpha in PuO_2 is around 20 μm. Since spallation of material can take place only from the outermost layer of the sphere, a volume of around 0.100 cm^3 has been used as the active volume for the MHW sphere. This would contain approximately 1.1 g of PuO at 96% of theoretical density. The specific activity of the MHW fuel is around 5×10^{11} alphas/sec/g. With a sphere area of 45 cm^2, around 2.7×10^8 Pu-bearing atoms/sec/cm^2 will be knocked out. This is roughly equivalent to 5.4×10^{-12} g/sec per sphere and around 1.7×10^2 μg/yr/sphere. This is about five decades of magnitude less than the yield from vaporization of PuO_2 at 1527°C (1800°K). The particulates thus formed are initially molecular in size but may agglomerate to larger sizes.

C. Particulates produced by mechanical and thermal forces

The encapsulated fuel spheres are subjected to various mechanical shock and vibrational stresses in the course of normal handling and shipping. MHFT-11, a typical production sphere from Mound Laboratory, was subjected to the spectrum of vehicle launch vibration (but at significantly higher levels) and was then shipped from Miamisburg, Ohio, to Los Alamos, New Mexico, being exposed in this process to the incidental shocks and vibration associated with normal transport. Measurements of the particulates resulting from all these forces were measured at LASL. The fines in the size range below 10 μm constituted about 0.6% of the total fuel inventory equivalent to 1.5 g, 18 Ci. The fuel sphere was broken into several relatively large chunks and the fines produced probably resulted from the vibratory abrasion of the rough surfaces. Additional LASL data (September 1973) show fines at significantly lower levels.

A2.2.2.2 Molecular vapor

Like all solid materials, PuO_2 has a finite vapor pressure which is very low at room temperature but which increases to substantial levels at higher temperatures. The constituents of the vapor are molecular and nascent oxygen, elemental Pu, PuO, and PuO_2. The amount of these species present in the vapor phase is dependent on both the temperature and the composition of the solid phase itself. Figure III-7 shows the variation of the partial pressures of the Pu-bearing constituents in the vapor phase as the composition of the solid material is varied from an O/Pu ratio of 2.00 down to 1.61 at a single temperature, 1527°C (1800°K). (Ref. Ackermann 66a, Mulford 67a).

The variation of the partial pressures of the three Pu-bearing species above stoichiometric PuO_2 with temperature is shown in Figure III-8 and Table A-1. Figure III-9 shows the maximum unimpeded theoretical emission of the three Pu-bearing species through the two 0.005-in. diameter vents in the MHW-PISA at three temperatures vs time. These figures illustrate that the principal constituent above 800°C is PuO_2 (Ref. Kent 73a). The virtual independence of the pressure of PuO_2 with change in the O/Pu ratio is shown in Figure III-10. It is concluded from these data that computation of the PuO_2 release by vapor transport from the MHW-PISA, under the conditions of proposed use at GE-VFSC will permit evaluation of the maximum hazard to be expected from this source (Ref. Brown 72d and Brown 73a).

A2.3 Minimization of Release of Pu-bearing Material with the PISA Intact

The PISA is designed to minimize the release of Pu-bearing species and is assumed to be free from significant contamination on its external surfaces at the time of manufacture.

A2.3.1 Surface Contamination

The PISA of necessity is assembled and welded in a facility which is contaminated by ^{238}Pu. Some of this material adheres to the external surface of the welded PISA. To remove this before assembly of the PISA into GIS, the external surface of the PISA is cleaned by decontamination methods determined by the fueling agency, MRC/ML. Currently the decontamination process involves chemical dissolution by immersion into a solution which is prevented from entering the sphere through the vent holes. At this time, the vent holes are still covered by the decontamination covers (see Figure III-2). Subsequent to the decontamination, the surface of the PISA is checked for residual contamination which may be adherent to its external surface. This is done by taking a wipe at several places on the surface and counting the alpha disintegrations with appropriate instrumentation. A current proposed specification limits the amount of removable activity on the surface to 2000 dpm. After completion of the decontamination process, the decontamination covers are penetrated or removed to permit the He vents to function. At this time the surface activity is again checked to ensure that no excessive amount of particulate material has accumulated under the decontamination or released by its removal.

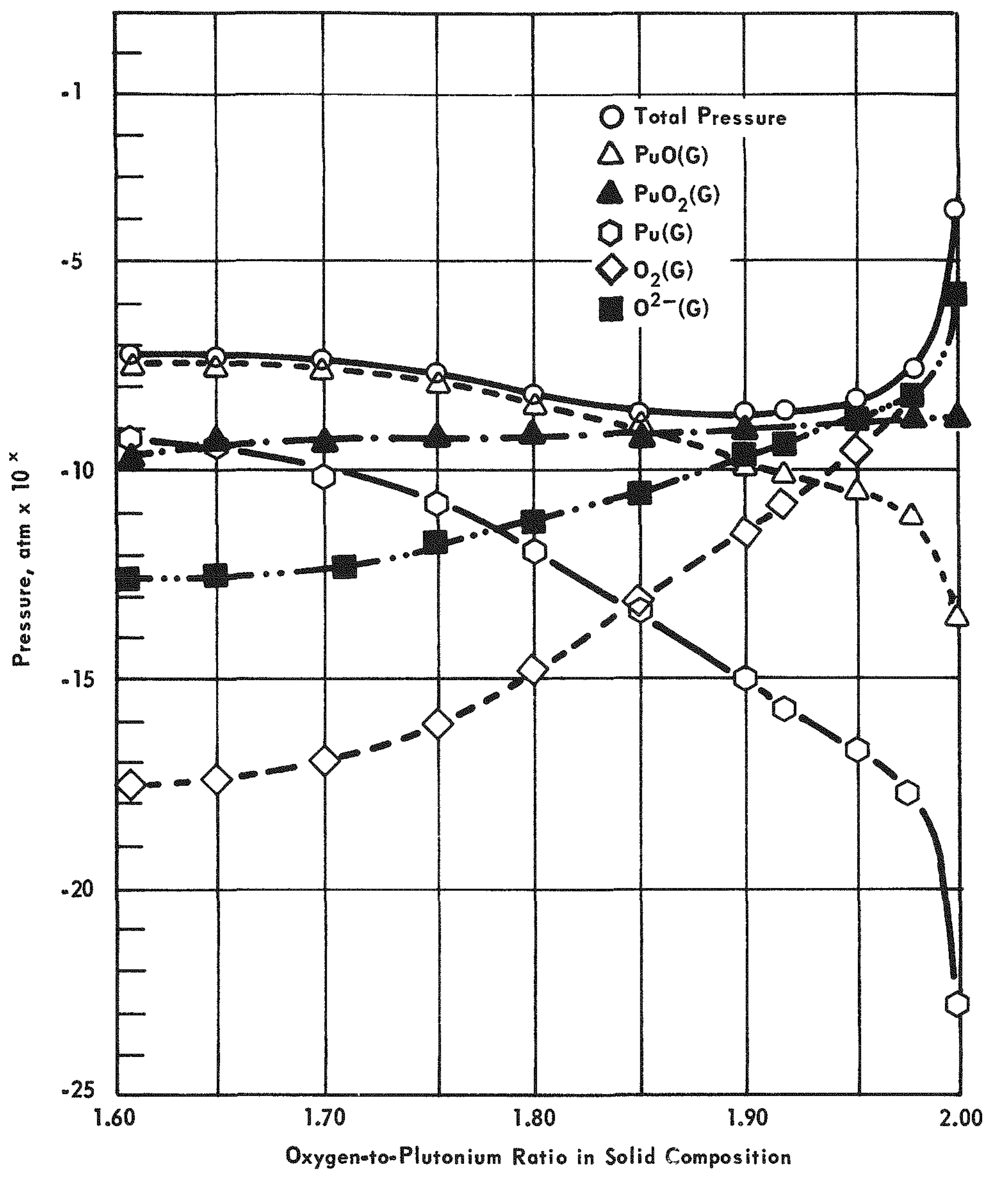

FIGURE III-7 - Vapor pressure over plutonium oxide at 1800°K.

Table A-1

PARTIAL PRESSURES OF Pu-BEARING SPECIES ABOVE $PuO_{2.000}$

Temperature		Partial Pressure - Atmospheres		
°K	°C	Pu	PuO	PuO_2
1000	727	1.3×10^{-27}	9.3×10^{-22}	1.1×10^{-22}
1200	927	4.9×10^{-26}	5.9×10^{-19}	1.0×10^{-17}
1400	1127	6.5×10^{-25}	6.0×10^{-17}	3.7×10^{-14}
1600	1327	4.5×10^{-24}	2.0×10^{-15}	1.7×10^{-11}
1800	1527	1.9×10^{-23}	2.9×10^{-14}	2.0×10^{-9}
2000	1727	0.3×10^{-23}	2.4×10^{-13}	9.0×10^{-8}
2200	1927	1.7×10^{-22}	1.4×10^{-12}	2.0×10^{-6}

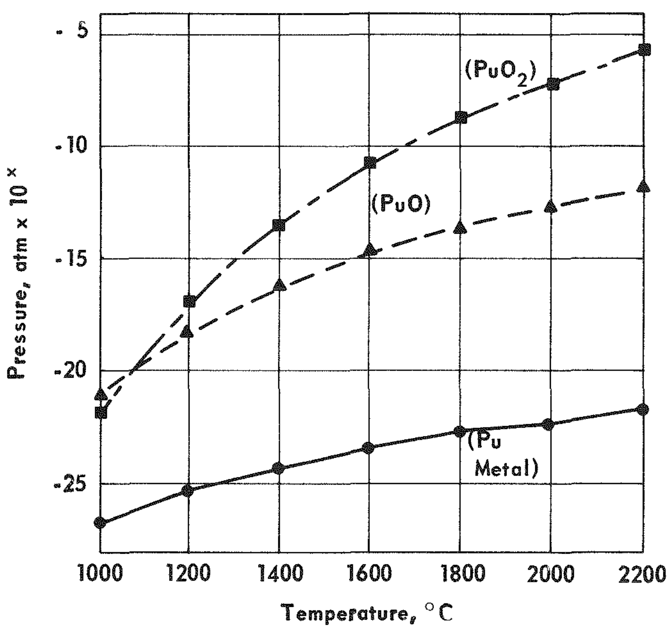

FIGURE III-8 - Vapor pressure vs. temperature (stoichiometric PuO_2).

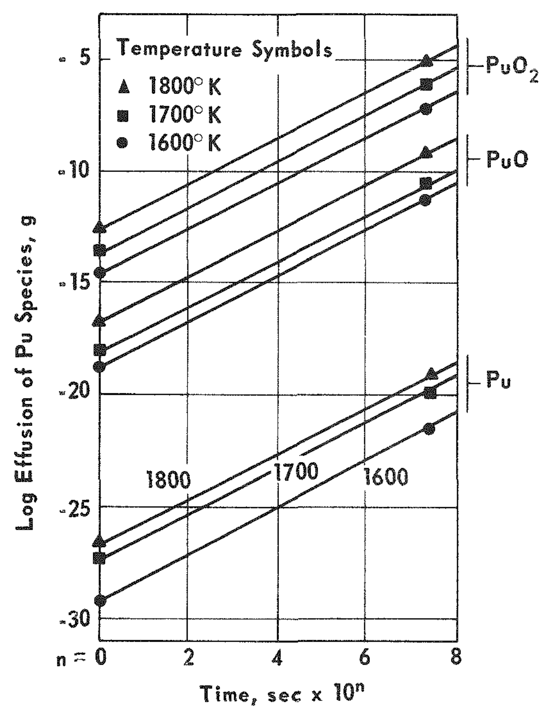

FIGURE III-9 - Effluent from a single MHW PISA (2-0.005" vents)

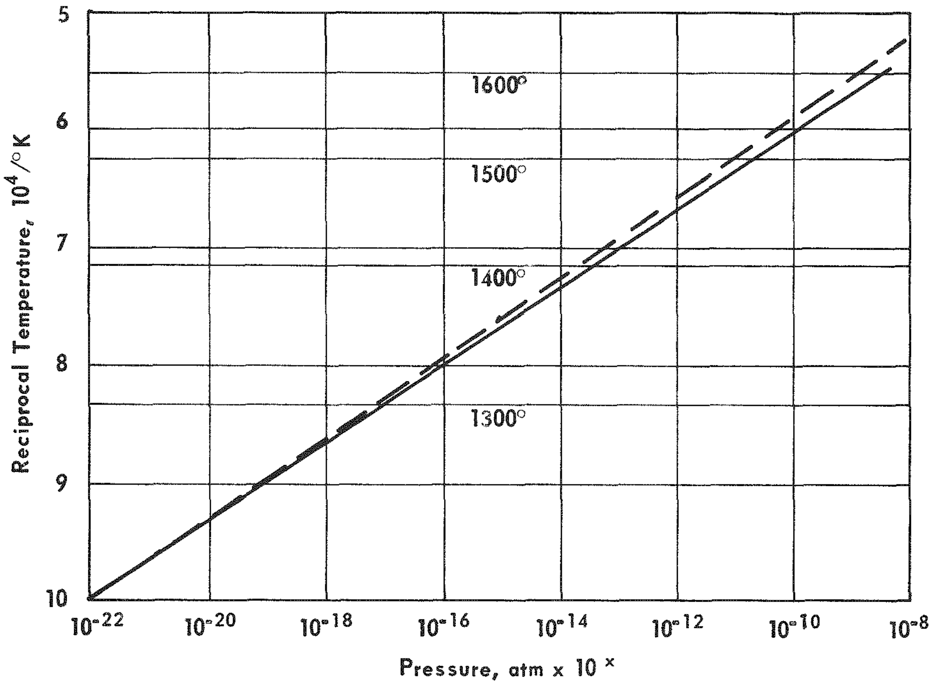

FIGURE III-10 - Variation in the partial pressure of $PuO_2(g)$ with change in the composition of $PuO_2(g)$ from O/Pu 1.85 to 2.00.

After the PISA is assembled in a Pu-free area into the GIS, the contamination level of each GIS is determined by appropriate techniques so that on the external surfaces of all 24 GISs there is no more than a total of 1000 dpm. It is essential that the level of external contamination on the FSA be kept at the practicable minimum in order to preclude excessive contamination of the IHS assembly. The instrumentation to determine the contamination levels on the FSAs must establish these levels beyond question.

The external surface of the IHS is checked before it is loaded into the SPC to determine that its total smearable surface contamination does not exceed 220 dpm.

Under normal conditions for handling and operation at GE-SD, the accessible Pu from the MHW-IHS is thus limited to 10^{-10} Ci, (10^{-4} μCi) as verified by appropriate measurements.

A2.3.2 Retention of Particulates

As noted above in paragraph A2.2.2 particulates may be found from three sources;

- residual powder from the pressing operation,
- particulates generated by alpha knock-on, and
- particles resulting from the thermal/mechanical forces of shock and vibration.

The quantity and size of particulates which may arise are indeterminate and difficult to estimate with any certainty, except in the case of alpha-knock-on. Consequently, the MHW PISA (specifically, the vent filter) is intended to inhibit the release of those particulates, whatever their source. The vent filter design is shown schematically in this SARP on p. IV-49. The filter creates a tortuous path of ample area/volume to permit the release of He but tends to trap solid material. Since the flow rate is slow (refer to Figure III-I), there is no strong force carrying particles through the labyrinth. Test data on the vent filters using thoria particles in size ranges of 10 μm and less have shown the capability of the filters to continue to pass He while not permitting the carry-through of any detectable amount of the particulates. The tests were conducted at ambient and operational temperatures. Flow rates of He were varied over a wide range to determine if carry-through could be affected by velocity. The results were unchanged.

Testing with live fuel has been plagued by a variety of equipment problems not directly related to the vent filter design. Consequently, no data have been obtained. In fueled systems the efficacy of the filter for retaining particulates has been demonstrated to show no release. The revised reference vent filter design, incorporating a 360° seal weld and check out prior to assembly, was used in the fueled spheres MHFT-15 through MHFT-33. Measurement of the contamination levels in the vent hold area subsequent to removal of the decontamination covers showed <20 cpm for all units, except MHFT-24, which had a reading of 83 cpm in one area and was off-scale in the other. This unit was removed from the test series and sectioned. Metallographic examination of the vent cover assembly showed that the weld of the cover disc had been effected over only about half of the circumference. From this circumstance, it is legitimate to draw two inferences:

(1) in the absence of a tight particulate filter, release of radioactive contamination can occur;

(2) with integral hardware, contamination is maintained at very low levels, <20 cpm.

Additional evidence supporting the efficacy of the vent filters is derived from the behavior of spheres MHFT-29 through -33. These spheres showed less than 20 cpm before being subject to vibration in the Mound Laboratory test facility. After the vibration exposure, MHFT-29 showed around 60 cpm and the remaining spheres remained at less than 20 cpm.

A2.3.3 Control of Plutonium Dioxide Vaporization

Plutonium bearing species are present in the vapor phase at the molecular level; therefore, they can pass through a particulate filter and through the vent. The maximum theoretical rate at which Pu-bearing material, primarily PuO_2, can be emitted through the two 0.005-in. diameter vents in the PISA is determined by the partial pressure at any given temperature. The release rates at various possible operational temperatures: 1327, 1427, and 1527°C, were reported (Kent 73a) by Los Alamos (in LA-5202-MS, March 1973). Using the same computational techniques, the release of Pu-bearing species has been calculated at three temperatures that represent the probable-to-high values expected in the handling of heat sources at GE-SD: 835°C, 1140°C, and 1327°C, at the fuel/PICS interface, which corresponds roughly to storage, shipping, and operation (in an environment of He inside the MHW converter). The maximum release of the Pu-bearing species is plotted as a function of time in Figures III-11, III-12, and III-13. Table A-2 shows the release per second and per year in terms of both grams and curies.

Table A-2

PuO_2 (g) RELEASE FROM MHW-IHS (48-0.005 IN. DIAMETER VENTS)

Temperature	835°C (1530°F)	1140°C (2050°F)	1327°C (2420°F)	1500°C (2732°F)
Grams-Second^{-1}	2.7×10^{-19}	4.1×10^{-14}	6.3×10^{-13}	3.6×10^{-11}
Grams-Year^{-1}	8.5×10^{-12}	1.29×10^{-6}	2.0×10^{-5}	1.2×10^{-3}
Curies-Second^{-1}	3.2×10^{-18}	4.9×10^{-13}	7.8×10^{-12}	4.4×10^{-10}
Curies-Year^{-1}	1.1×10^{-10}	1.6×10^{-5}	2.5×10^{-4}	1.4×10^{-2}

As indicated in Table A-2, the release of PuO_2 increases by around two decades for an increase of 200 Celsius degrees, from 1327°C to 1527°C. To maintain the Pu-bearing release at a reasonable level for testing, the temperature of the IHS will be kept below 1327°C (1600°K) during all activities at GE-SD.

Subsequent to the thermal exercise of the MHW Heat Source at GE, the total release of Pu-bearing material will not exceed 7 μCi.

The values shown in Figures III-11 through 13 and Table A-2 are used in estimating the maximum possible release from this source; in fact, the values are maximum calculated quantities. There is experimental evidence to show that the evaporation of Pu-bearing species from the surface of the fuel sphere does not necessarily result in their transport out of the PISA. In the experiment on the thermal exposure of MHFT-1 at LASL, a thin PuO_2 (the predominant Pu-bearing species at these temperatures and compositions) layer, approximately ≤3 mils thick, was deposited on the internal surface of the PISA. This occurs because of the very slight but real difference in temperature between the surface of the fuel sphere and the internal surface of the PISA. It is considered, therefore, that the possible release through the current vent hole will be somewhat less than that given in the estimate which calculates the maximum possible release through vent holes of this diameter assuming the available partial pressures.

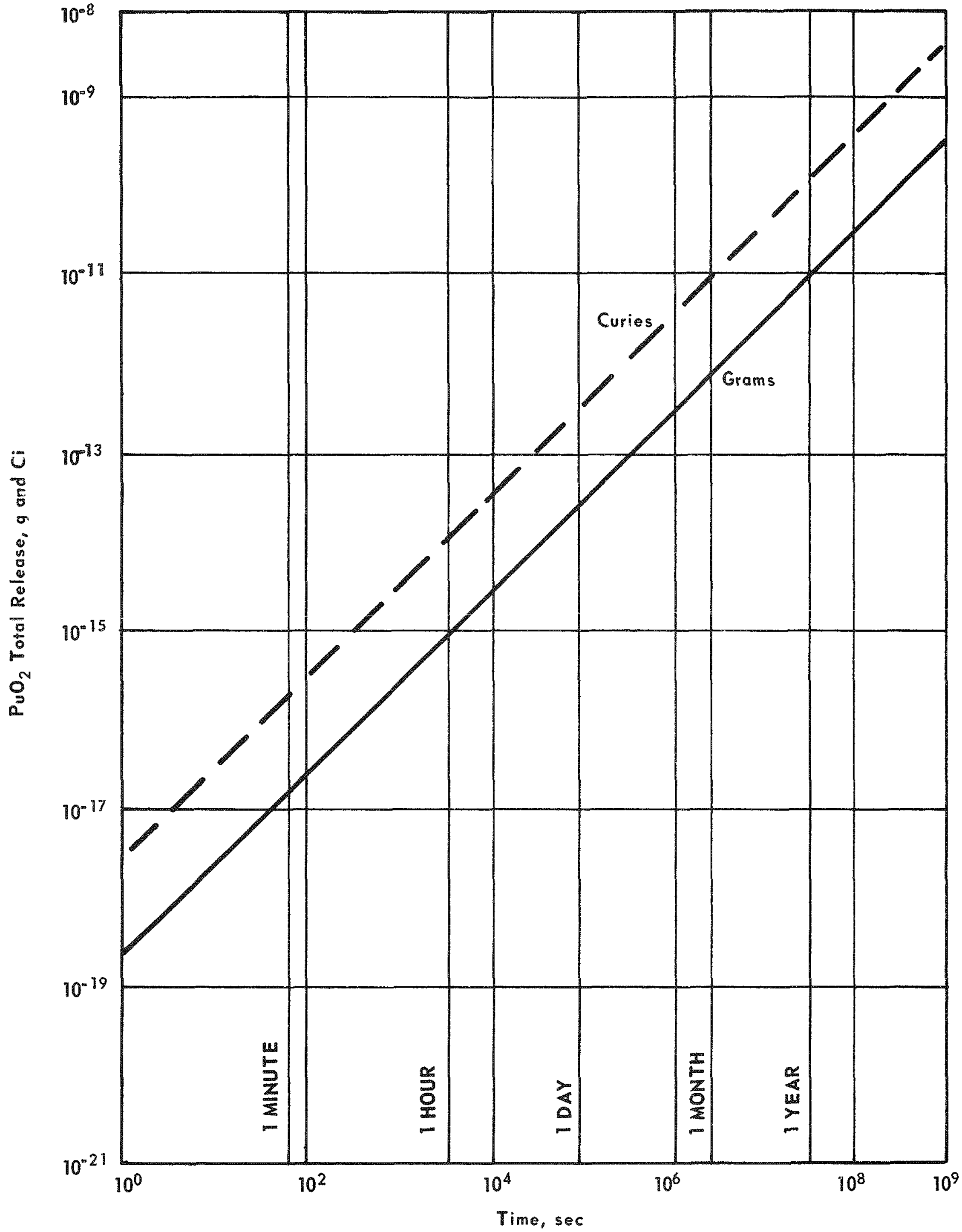

FIGURE III-11 - PuO_2 release versus time at 835°C with 48 vents (HSA).

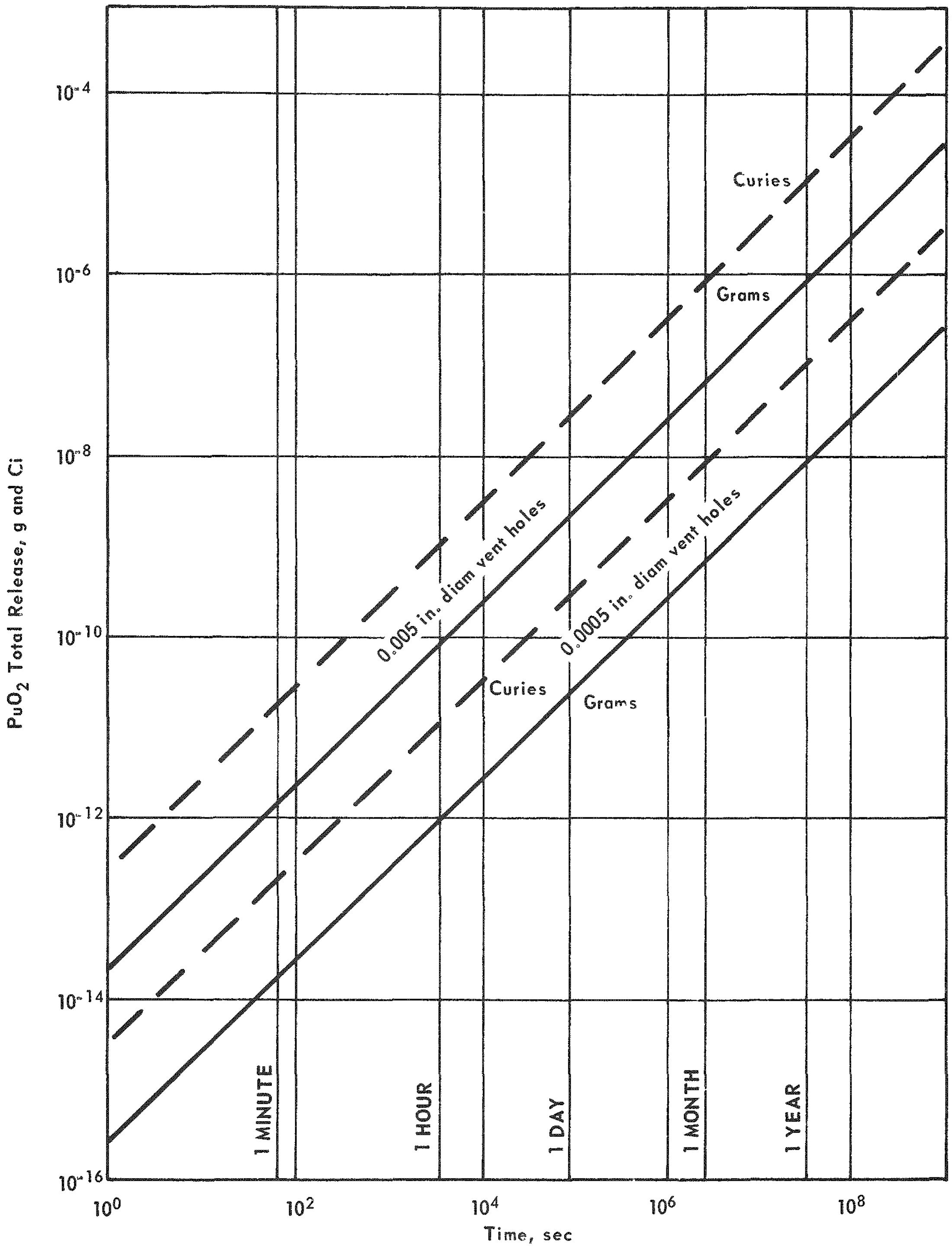

FIGURE III-12 - PuO_2 (g) release versus time - seconds at 1140°C with 48 vents.

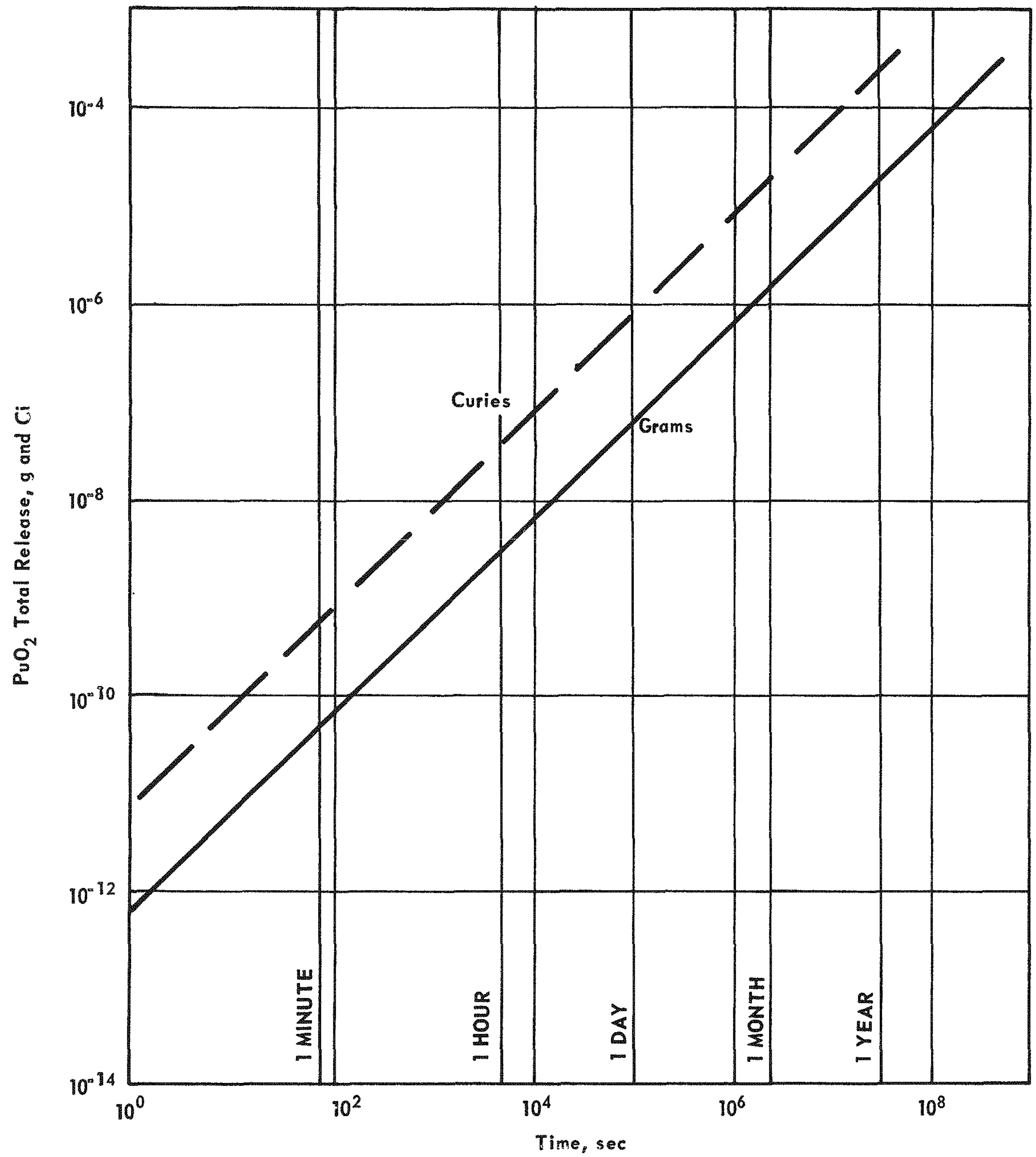

FIGURE III-13 - PuO_2 (g) release versus time - seconds. Full MHW-IHS 48 vents at 1327°C (1600°K, 2420°F).

A2.4 Accidental Release of Plutonium from a Damaged PISA

In the discussion of Paragraph A2.3 (p. III-11) it was assumed that the PISA was intact and that the vents were functioning as designed. It is possible for the PISA to be damaged by external or internal forces, and some of these are considered here.

A2.4.1 Fracture of the PISA by impact

A2.4.1.1 Impact capability of a bare FSA (PISA protected only by GIS)

The principle mode for destruction of the PISA by mechanical forces has been identified as impact on an unyielding surface at terminal velocity after reentry. To verify the efficacy of the GIS, an extensive testing program was carried out by GE in its own facilities and at Sandia Corp. using thoria as a simulant for the mass and size of the fuel. A further series of fueled tests was carried out by LASL. All impact tests were performed at velocities of at least 10% above the experimentally determined terminal velocity of 255 fps, i.e., the impacts were made at ≥280 fps. The early series of tests at GE used a high density simulant, ThO_2 at 97% of theoretical density. These tests showed the ability of the PISA to survive impact without significant deformation of the iridium and often without fracture of the contained thoria. After the initial tests with fuel at LASL and examination of the fuel microstructure, the simulant was changed to model as nearly as possible the mechanical response of the fuel by providing a microstructure like that of the fuel and a similar density to ensure lower mechanical strength. Both intact and deliberately broken fuel and simulant were impacted. The results of the impact tests are summarized briefly in Table A-3.

Table A-3

SUMMARY OF FSA IMPACT TEST RESULTS

Specimen Material and Percent Theoretical Density		Specimen Behavior — Velocity at Impact - Feet Per Second: 270 to 300		300 to 340	
		Pass	Fail	Pass	Fail
ThO_2	95	5	0	1	1
ThO_2	90(1)	8	3(4)	-	1
ThO_2	80(2)	4	2(4)	-	-
ThO_2	76(3)	16	3(4)	6	6(5)
PuO_2	82(6)	4(7)	2(7)	-	-

NOTES:

1. Initial density 80% TD; sintered to 90% TD during Ir heat treatment: 18 hr @ 1500°C.
2. Cold pressed and sintered; fine grain homogeneous
3. Hot pressed; coarse, high fired grains.
4. GIS rotated 45°.
5. GIS rotated 45° in 4 cases.
6. Density of fuel is an average value.
7. All spheres at LASL are fired in a Ta can enclosing the specimen.

A2.4.1.2 Interaction of the FSA with the containment

Impact of a free FSA during transportation to and from GE-VFSC, and during operations at GE-VFSC is not credible. However, a potential accident mode was identified in which the IHS within a shipping container could be dropped from a height of 40 ft onto a concrete platform. The maximum velocity which this package could attain is 51 fps. Assuming that the full velocity of the impact were transmitted through the shipping container to the FSAs, this impact velocity is a factor of at least five lower than the impact velocities to which FSAs have been tested.

Figure III-14 shows schematically how the IHS is contained for shipment; Figure III-6 (see p. III-9) shows how the FSAs are contained within the IHS. When the SPC is replaced by the Radioisotope Thermoelectric Generator (RTG), the converter, the Heat Source Shipping Container (HSSC) is replaced by the RTG Shipping Container (RSC). The MHW-RTG Shipping Container is shown in Figure III-15. Except for handling at the ML/MRC 'F' line and at the GE-VF LAS, the IHS is always handled within one or the other of these double containments. It is necessary, however, to consider the possible interaction between the FSAs in the IHS, if these are subjected to accidental impacts when lodged in either the HSSC or the RSC.

A.2.4.1.2.1 Impact loads on the SPC or RTG in the shipping container

Since tests using the HSSC or RSC with the simulated loading are not currently (Note: MRC subsequently tested the HSSC as discussed in section F) feasible, the problem has been approached analytically. The analysis is based on the assumption that the behavior of the IHS

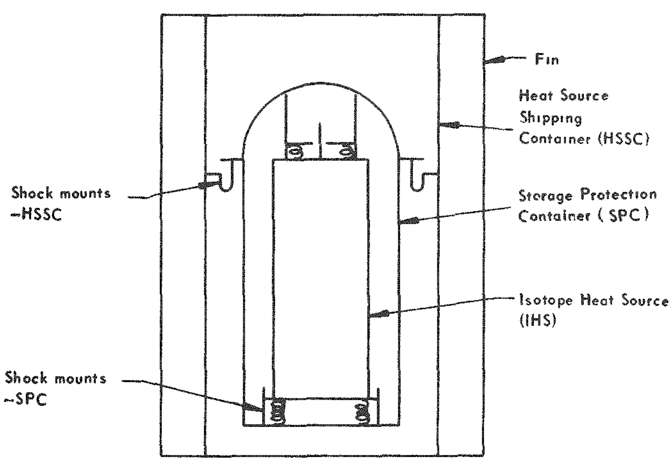

FIGURE III-14 - Schematic of IHS in shipping configuration.

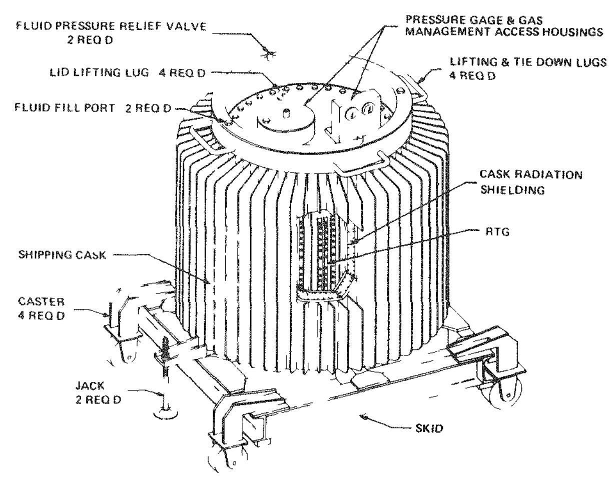

FIGURE III-15 - MHW-RTG shipping container.

with its FSAs will be analogous to that of the fission product isotope container in tests conducted by GE (Hanford Atomic Products Operation) on a fission product isotope shipping container.

Reference Ripperger 63a gives detailed information on the tests which were conducted at the Structural Mechanics Research Laboratory of the University of Texas at Austin. The 28 units dropped were instrumented with accelerometers in numerous locations and in the payload zone so that the transmitted '*g*' loads were measured empirically. The cylindrical models weighed around 600 kg (1300 lb) and were subjected to drops of around 8 meters on their sides, ends, and corners (45°); see Figure III-16. Drops were also made on a 1-1/2-in. diameter by 4-in. long stake and on a step formed by a 8 in. high I-beam. In these tests the inner containment, analogous to the SPC and RTG, was subjected to around 225 *g* maximum.

The HSSC and the SPC and the RSC and the RTG, are integral cylindrical structures and will absorb deformation as continuous structural systems. No sharp projections or protuberences are contained within these structures which could penetrate the FSAs in the event of excessive deformation of the structures.

A drop of one meter by the HSSC/SPC or the RSC/RTG containing the FSAs in the IHS, onto a 6-in. diameter steel bar will not permit penetration through to the IHS. Consequently, the FSAs would not be damaged in such an accident.

It can therefore be concluded that the PISA will provide containment of the PuO_2 during any anticipated impact at GEVF.

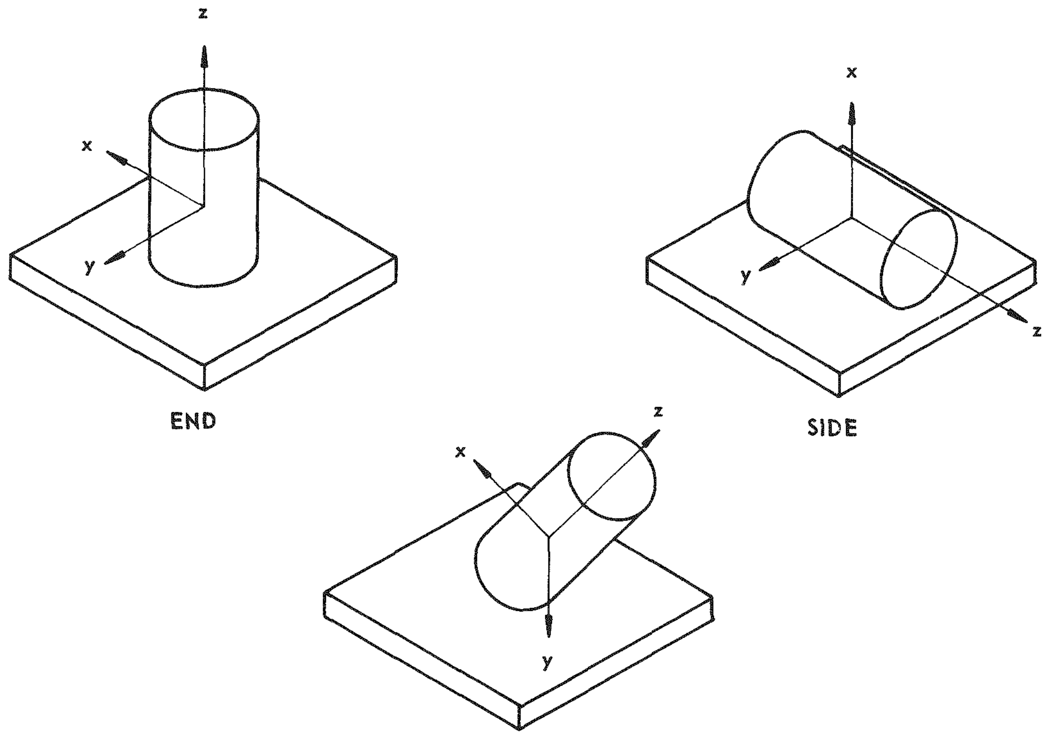

FIGURE III-16 - Axis orientation and drop attitudes.

A.2.4.1.2.2 Impact loads on the bare FSAs

The bare FSAs were impacted against granite at the velocities noted in Table A-3 by GE and LASL(*). In the GE tests with simulant, the total impact contact time, gauged by flash x-ray photography of the impacts, ranges from 300 to 500 μsec. A conservative calculated estimate of the *g* level environment under which the FSAs were shown to survive is:

$F = ma$

$g \text{ level} = F/W$

where:

F = average force (lb) for the duration of the impact

m = total mass of the FSA (slug-ft^2)

a = deceleration rate of the FSA (dy/dt, ft/sec^2)

W = weight of FSA (lb)

v = 300 fps

W = 400 g = 0.882 lb

$$m\,\frac{dv}{dt} = \frac{0.882\ (300 - 0)}{32.2\ (5.0 \times 10^{-4})} = 1.643 \times 10^{4}\ \text{lb} \qquad (1)$$

*LASL impacts of fueled FSAs have been made to date enclosed in Ta cans for reasons of operational safety in the LASL test area.

$$\frac{F}{W} = \frac{1.64 \times 10^4}{0.882} = 1.86 \times 10^4\ g \tag{2}$$

The calculated g level is an average value. For this type of dynamic environment the peak force is approximately 1.8 times the average value

Hence:

$$\text{peak} = 1.8\ (1.8 \times 10^4) \simeq 3.25 \times 10^4\ g \tag{3}$$

Since the FSAs have survived impact environments of around $3.25 \times 10^4\ g$ peak and the expected maximum transmitted g levels (taking no credit for attenuation in the SPC or RTG) are $\ll 500\ g$, the safety margin appears sufficient. It is therefore, concluded that the FSAs will not be damaged by interaction with the other containments even if subjected to the maximum potential impact after a drop of 51 ft. The impact loads to the FSAs are attenuated by the intervening structures.

The preceding discussion and the data presented in the impact test summary Table A-3 (see p. III-20), establish at least the following inferences:

- FSAs with simulant have survived impact at temperatures of 1400°C against granite at velocities up to 315 fps; with fuel the maximum velocity has been 285 fps, this produces g loads of 1.6×10^4 average, 3.2×10^4 peak.
- Inadequacies of the Ir in the PISAs, of the graphite in the GIS and of the test procedures have caused some failures; these have been or are being corrected.
- The impact protection is inherently workable.
- The maximum impact velocity to which the FSAs in the IHS can be credibly exposed at GEVF does not exceed 51 fps; this produces g loads on the FSAs which are calculated not to exceed $5.0 \times 10^2\ g$.
- Damage to the FSAs by penetration of the shipping containment structures is precluded by geometry.
- Damage to the PISAs by impact is not credible.

A2.4.2 Fracture of the PISA by excessive internal pressure

As noted in the preceding discussion, the release of He gas through the PISA/IHS vent system is required to avoid the need for an excessively heavy capsule structure. In the event that the vents on the PISA were totally plugged to prevent He release at the normal generation rate, excessive pressures could build up leading to eventual rupture of the iridium sphere. Plugging of the He vents, which at the time were 0.0008-in. diameter, was observed to occur in several of the PISA's made beginning around February 1972. In the cases of MHFT-1 and MHFT-5,fractures occurred in or near the equatorial weld, and the vents were presumed to be plugged; in the case of MHFT-6,the rupture occurred at the decon disc,and although some transport of Ir was observed,it was not demonstrated that the vents were plugged. The possible fuel release from MHFT-5 and -6 was not reported. The Ir of MHFT-1 cracked/tore in the heat affected zone producing a fissure around 0.5 cm long by about 0.1 mm wide. The fuel release measured for MHFT-1 was around 2×10^5 cpm. In none of the cases where the PISA cracked was the deformation catastrophic.

To test a burst disc concept a sealed PISA was fabricated at ML/MRC with an Ir tube welded into the wall to permit pressurization at temperature. The first of two phases of PICS burst test has been completed. Two decon discs were pressurized to rupture. Burst pressures at 1370°C (2500°F) were 260 psig and 200 psig. There was zero strain of the PICS with a pressurization rate of 80 psi/hr. The PICS with no vent holes was then pressurized to rupture. PICS burst pressure at 1370°C (2500°F) was 600 psig. Strain of PICS with pressurization rate of 200 psi/hr was also zero. The PISA encapsulated a ThO_2 sphere and was enclosed in a GIS.

The failure mode was a non-catastrophic hairline crack which bled down the He pressure rapidly.

Although the cause for vent plugging has not been defined beyond question, the fact of vent plugging is certain. The probable causes were transport of Ir as a gaseous compound or the vapor transport of other volatile compounds [including $PuO_2(g)$] associated with either the fuel or the iridium. The vent hole size has been increased to 0.005 in. diameter and current practice requires chemical cleaning of the Ir to remove surface impurities. This is followed by a thermal scouring of the Ir piece parts at 1500°C to insure the removal of iridium oxides which may have formed on the surface. Heat treatment of the fuel at 1500°C under vacuum will also tend to remove volatile impurities.

MHFT-10 and -11 were baked out for 1 hr at 1500°C to promote recrystallization of the Ir before welding. MHFT-10 was exposed at LASL for 1100 hr at 1150°C and both vents were found open at the end of testing. MHFT-11 was used for vibration testing and was exposed to temperatures of 1000°C; both vents were found open at the end of testing and there was no evidence of Ir transport. The MHW fuel sphere assemblies beginning with MHFT-15 use Ir which has been subjected to both the chemical and the thermal cleaning noted above, to remove extraneous materials and iridium oxides. MHFT-18 from this new series of spheres was exposed at LASL in He at 1250°C for 1000 hr and had both vents operational at the end of testing. For the temperature regimes to which the MHW-IHS will be exposed during tests and handling at GE-VF, the data cited indicate that closure of the vent is improbable. Although there is justifiable concern about the closure of one of the vents in MHFT-19, this specimen was exposed in vacuum for 1100 hr at 1440°C.

The problem of vent plugging has been considered in some detail (Ref. Brown 73b).Vapor deposition of PuO_2 around the Ir grains of the vent filter has unquestionably reduced the free path for He release to the point where it has actually stopped. However, in most of the cases observed, the stoppage does not appear to be permanent since there is erratic release of He ranging from indetectable levels to as much as 50x the generation rate under isothermal conditions. As noted previously, the conditions planned for handling and operation at GE-VF should not produce the conditions which lead to vent stoppage. Tables A-4 and A-5 summarize the condition of the vents of all PISAs tested to date at ML/MRC and LASL.

A2.4.3 Accidental thermal stresses affecting the MHW-PISA

In addition to the accidental impact and internal pressure stresses noted above the MHW-PISA could be subjected to thermal stresses arising from oxidation of the graphite structures of the IHS and from an external fire. The sequence of hypothetical accidents covered by AECM 0529, Annex 2, postulates a series of circumstances which could subject the IHS in its shipping container complex to an impact destroying the integrity of the IHS iridium outer clad permitting atmospheric air to reach the graphite internal structures (see Figure III-6, p.III-9). Subsequently the shipping container with the IHS thus breached could be exposed to the standard transportation fire conditions imposing an external temperature on the shipping container of 800°C (1475°F) for 30 min. Since no direct experiments have been performed to demonstrate the response of the IHS to this concatenation of circumstances, analyses are required to determine whether the IHS will be adversely affected to the point at which the plutonium fuel is exposed.

A2.4.3.1 Effect of air on IHS graphite

Air in contact with hot graphite oxidizes the graphite in an exothermic reaction to form either CO or CO_2. The rate of oxidation is a function of the graphite temperature and the availability of the oxygen supply. To establish a worst case condition, it is assumed that the air is supplied by free convection currents set in

Table A-4

MHFT-1 THRU MHFT-14

Fuel Sphere Assembly Designation	Status	Exposure Conditions: Temp. (°C)	Exposure Conditions: Time (hr)	Exposure Conditions: Environment	Vent Hole Size (in.)	Dimensional Change Reported	He Release Check Method and Result: Mass Spectrometer He Leak Detector: Test Furnace	Mass Spectrometer He Leak Detector: Vacuum Fixture	Bubble Test He @ 20 psig: Vent 1	Bubble Test He @ 20 psig: Vent 2	Metallographic Examination and Results
MHFT-1	C & E	1440	2150	Vacuum	0.0008	Yes: n/a swollen	n/a	Open breached	Closed	Closed	Vapor deposited Ir in vents; breached in HAZ; swelled into GIS
MHFT-2	C & E	1500	18	Vacuum	0.0008	n/a	n/a	n/a	n/a	Closed	Impacted; impact face vent closed
MHFT-3	C & E	1500	18	Vacuum	0.0008	n/a	n/a	n/a	n/a	n/a	Impacted; vent destroyed
MHFT-4	C & E	1500	18	Vacuum	0.0008	n/a	n/a	n/a	Open	Closed	Inpacted; I/F vent closed
MHFT-5 (1)	C & E	1500	18	Vacuum	0.0008	Yes: -0.050 in.	n/a	n/a	Closed	n/a	Vapor deposited Ir(V/D Ir) in vents clad breached in HAZ
MHFT-6 (1)	C & E	1500	18	Vacuum	0.0008	Yes: -0.060 in.	n/a	n/a	n/a	n/a	V/D Ir on interior; vent probably clean, decon cover ruptured
MHFT-7	C & E	1325	18	Vacuum	0.0008	n/a	n/a	n/a	n/a	n/a	V/D Ir on interior; n/a on vent
MHFT-8	C & E	1325 700	18 8000	Vacuum He (storage)	0.0008	n/a	n/a	Closed	Closed	Closed	V/D Ir internally; n/a on vent stored 11 months
MHFT-9 (2)	C & E	1500	18	Vacuum	0.0008	n/a	n/a	n/a	n/a	n/a	V/D Ir on interior; n/a on vents
MHFT-10 (2)	C & E	1500 1150	18 1244	Vacuum Helium	0.0008	Yes: shrank	Open	n/a	Open	Closed	V/D Ir + PuO_2 on interior; n/a on vents
MHFT-11 (2)	C & E	1500 1000	18 7	Vacuum Helium	0.0008	n/a	Open	n/a	Open	Open	No V/D Ir; some V/D PuO_2 on interior; vent area clean
MHFT-12	C & E	1500	18	Vacuum	0.0008	n/a	n/a	n/a	n/a	n/a	Impacted; PICS was destroyed by phosphorous contamination; n/a on vents
MHFT-13	On test	1500 100	18 3000	Vacuum Sea water	0.0008	--	--	--	--	--	On test in sea water
MHFT-14	C & E	1500	18	Vacuum	0.0008	Yes: shrank	Closed	n/a	Closed	Closed	V/D Ir + PuO_2 on interior; n/a on vents

NOTES:
C&E = Test exposure complete and specimen examined
n/a = Not available (not done or not yet reported)
(1) = Decontamination covers left intact during heat treatment
(2) = Partially assembled hemispheres heat treated one hour at 1500°C before final assembly

Table A-5

MHFT-15 THRU MHFT-33

Fuel Sphere Assembly Designation	Status	Temp. (°C)	Time (hr)	Environment	Vent Hole Size (in.)	Dimensional Change Reported	He Release Check Method and Result: Mass Spectrometer He Leak Detector — Test Furnace	Mass Spectrometer He Leak Detector — Vacuum Fixture	Bubble Test He @ 20 psig — Vent 1	Bubble Test He @ 20 psig — Vent 2	Metallographic Examination and Results
MHFT-15	On test	1440	2400 (8-31)	Vacuum	0.0015	nya	Erratic	nya	nya	nya	On test
MHFT-16 (1)	On test	1150	2100 (8-31)	Helium	0.0015	nya	n/a	nya	nya	nya	On test in He
MHFT-17 (1)	On test	1150	2700 (8-31)	Helium	0.005	nya	n/a	nya	nya	nya	On test in He
MHFT-18 (1)	C & E	1250	1365	Helium	0.005	No	n/a	n/a	Open	Open	Clean; vent area free of all V/D material; may be some V/D Ir on interior
MHFT-19	C & E	1440	1105	Vacuum	0.005	No	Erratic; open	n/a	Open	Closed	V/D ceramic around Ir granules in vent filter: PuO_2 +Ca+Si+Al+O
MHFT-20	On test	1440	1500 (8-31)	Vacuum	0.005	nya	Erratic; open	nya	nya	nya	On test in vacuum
MHFT-21 (1)	On test	1250	2200 (8-31)	Helium	0.005	nya	n/a	nya	nya	nya	On test in He
MHFT-22	On test	1440	1800	Vacuum	0.005	nya	Erratic; open	nya	nya	nya	On test in vacuum
MHFT-23 (1)	On test	1150	n/a	Helium	0.005	nya	n/a	nya	nya	nya	On test in He
MHFT-24 (2)	--	--	---	--	--	--	--	--	--	--	Disposal not reported (2)
MHFT-25 (3)	C & E (part)	1440 1850?	857 5 m ?	Vacuum	0.005	n/a	n/a	Open closed	Closed	Closed	Vent(s) showed open before reentry thermal excursion; vent area nya by metallographic examination

Table A-5 (continued)

MHFT-26 (3)	On test	1440 700?	857 720?	Vacuum air	0.005	n/a	n/a	Open	nya	nya	Impacted; not yet dissected; on test in air
MHFT-27 (3)	On test	1440 700?	857 720?	Vacuum air	0.005	n/a	n/a	Open	nya	nya	Impacted; not yet dissected; on test in air
MHFT-28 (3)	C & E (part)	1440	744	Vacuum	0.005	No swelling dimensions n/a	n/a	n/a	Closed	Closed	V/D ceramic around Ir granules in vent filter: PuO_2 + Ca + Si + Al + O + W
MHFT-29,-30, -31(3)	On test	1440	?	Vacuum	0.005	nya	n/a	nya	nya	nya	Additional SST
MHFT-32	C & E	1370	30 m?	Vacuum	0.005	n/a	n/a	n/a	Open	Open	Impacted; vent area clean
MHFT-33	C & E	1370	30 m?	Vacuum	0.005	n/a	n/a	n/a	Closed	Closed	Impacted; vent area clean; metallography shows no apparent vent filter or vent blockage

NOTES: nya = not yet available
n/a = not available (not done, not reported, or not feasible)
(1) = specimens on test in helium-filled furnace; He mass spec. detector cannot be used during testing
(2) = specimen reported contaminated above allowable limits by ML/MRC; not shipped to LASL
(3) = SSTs - safety sequential tests: exposure for 30 days at operational + reentry pulse + impact + post-impact exposure in air
C & E = Test exposure complete and specimen examined

motion by the heat of the IHS and unimpeded by the structures of the shipping container, SC, and the storage protection container, SPC (or the converter, RTG).

The exothermic heating rate is given by:

$$\dot{q}_{exo} = \phi \, \dot{m} \quad BTU/ft^2 sec \qquad (1)$$

where:

$\dot{m}$ = graphite mass loss lb/ft^2 sec

ϕ = 3950 BTU/lb if reactant is CO

ϕ = 10500 BTU/lb if reactant is CO_2

The maximum graphite loss rate, as controlled by the oxygen supply rate (diffusion limited mass loss rate), is:

$$\dot{m}_{DL} = C \, (0.1716) \, h_m = lb/ft^2 \, sec$$

where:

h_m = mass transfer coefficient lb/ft^2 sec

C = 1.0, if reactant is CO

C = 1/2, if reactant is CO_2

Exothermic heating has been calculated assuming the formation of 100 percent CO , since this gives the maximum exothermic heating:

$$\dot{q}_{exo} = 900 \, h_m$$

for CO_2 DL.

The mass transfer coefficient, h_m is given by analogy to the heat transfer coefficient, h, since the Lewis number is approximately one:

$$h_m = h/op$$

Using the laminar free convection heat transfer coefficient for a vertical surface yields:

$$h_m = \frac{0.29}{cp} \left(\frac{\Delta T}{L} \right)^{\frac{1}{4}} \qquad \frac{BTU}{ft^2 \, hr \, {}^\circ F}$$

where:

ΔT = Temperature difference between surface and surroundings °F

L = Surface length

For the IHS

$$h_m = 3.08 \times 10^{-4} \, (\Delta T)^{\frac{1}{4}} \qquad \frac{BTU}{ft^2 \, sec \, {}^\circ F}$$

Figure III-17 shows the values of the CO_2 diffusion limited exothermic heating rate calculated as a function of the IHS surface temperature, assuming the maximum free convection air supply, with the ambient air at 20°C (68°F). At temperatures below 815°C (1500°F), the graphite mass loss rate is lower than the diffusion limit because the oxidation reaction becomes so slow that only a part of the oxygen which is supplied is consumed. The reaction rate mass loss rate is:

$$m_R = 99.5 \exp [-25500/T(°R)] \text{ lb/ft}^2\text{-sec}$$

in air at 760 torr using POCO AXF 5Q graphite rates. Using this mass loss rate in Eq. (1) for 100 percent CO_2 gives the dashed line in Figure III-17. Also shown in Figure III-17, is the convection cooling term calculated as:

$$q \text{ convection} = h\Delta T$$

using the laminar free convection coefficient.

The exothermic heating and convection cooling terms may be treated as a net heating of approximately 1 BTU/ft^2-sec which is the value at 815°C (1500°F). For comparison, the surface flux to reject the internal heat generation of 2400 watts, based on a center section, one dimensional heat flow for the IHS, is 1.11 BTU/ft^2-sec.

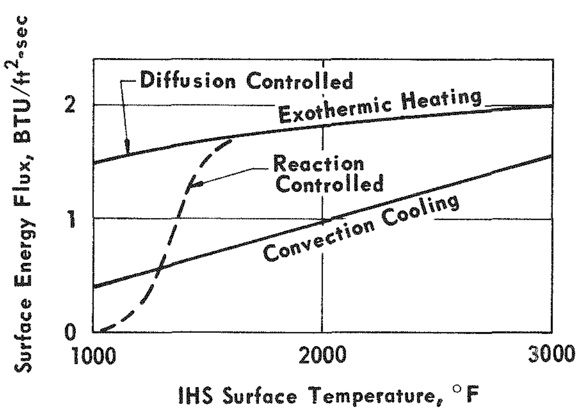

FIGURE III-17 - Surface energy balance for a free standing IHS:

- *Laminar free convection*
- *Air at 70°F*
- *Oxidation of graphite to 100% CO_2*

A.2.4.3.2 Effect of an external fire

In a worst case analysis, the shipping container may be assumed to be at equilibrium at the 'standard' fire temperature, 800°C (1475°F), and the steady state temperature of the SPC and the IHS calculated. The geometry and surface properties used are shown in Figure III-18. The analysis was done with a one dimensional center section model. The one dimensional calculation is based on a section of the IHS which is 2.18 inches in length, the distance between fuel sphere planes.

The IHS area is 49.4 square inches, which for 400 watts of fuel, a single plane of spheres, gives a flux of:

$$\frac{Q_{AB}}{A_A} = 1.11 \text{ BTU/sec-ft}^2$$

(2.11 BTU/sec-ft^2 if exothermic heating is included)

Both conduction and radiation were considered as heat transfer modes from A to B.

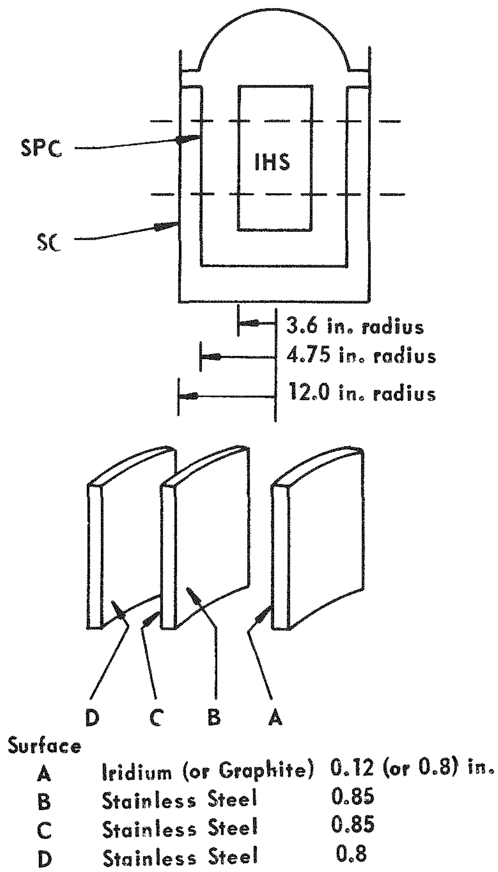

FIGURE III-18 - Configuration.

$$\frac{Q_{AB}}{A_A} = \frac{K_{AB}}{\ell_{AB}} (T_A - T_B) + F_{AB} (\sigma T_A^4 - \sigma T_B^4)$$

Since $Q_{CD} = Q_{AB}$, the flux from C to D is

$$\frac{Q_{CD}}{A_C} = 0.635 \text{ BTU/sec-ft}^2$$
(1.21 BTU/sec-ft^2 if exothermic heating is included)

which is related to temperatures by

$$\frac{Q_{CD}}{A_C} = \frac{K_{CD}}{\ell_{CD}} (T_C - T_D) + F_{CD} (\sigma T_C^4 - \sigma T_D^4)$$

The SC and SPC are assumed to be isothermal, therefore: $T_B = T_C$ and $T_D = 800°C$ (1475°F), so the only unknowns in the above equations are the SPC temperature T_B and the IHS temperature T_A. These equations were solved for various parameters:

ℓ_{AB} = 1.15 in.

ℓ_{CD} = 1.25 in.

K_{AB} = 0.21 BTU/hr-ft °F (Helium at 1900°F) or 0.046 BTU/hr-ft°F (Air at 1900°F)

K_{CD} = 0.2 BTU/hr-ft °F (Helium at 1500°F) or 0.04 BTU/hr-ft °F (Air at 1500°F)

$$F_{AB} = \frac{1}{\frac{1}{\varepsilon_A} + \frac{A_A}{A_B}\left(\frac{1}{\varepsilon_B} - 1\right)}$$

$$F_{CD} = \frac{1}{\frac{1}{\varepsilon_C} + \frac{A_C}{A_D}\left(\frac{1}{\varepsilon_D} - 1\right)}$$

ε_A = 0.18 or (0.8 for emissivity sleeve)

ε_B = 0.85

ε_C = 0.85

ε_D = 0.8

$A_A / A_B = 0.575$, $A_C / A_D = 0.628$

A2.4.3.3 Temperatures produced in the IHS

Steady state temperature distributions in the MHW-IHS have been calculated using a three dimensional model and the THT-D computer program (ref. Quinn 73a) for many different conditions considering either He or vacuum in the gaps. A summary of these analyses is presented graphically in Figure III-19. The temperatures given in Table A- 7 were obtained by locating the IHS surface temperature for the appropriate conditions in Table A-6 along the line labeled SLEEVE and reading the corresponding PISA and fuel temperatures assuming He in the IHS.

Table A- 6 gives the steady state temperatures for the SC, the SPC and the IHS surfaces in the fire environment for several assumptions regarding the internal gas and the graphite reactions. These are conservative values because in the real case, the IHS would not reach a steady state condition after a thirty minute fire. Cases 1 and 3 assume the SC maintains its He pressure; the SPC can contain either He or air without any effect on the temperature. Cases 1 and 2 assume air in the SC and SPC with no reactions between the air and the constituents of the IHS. Cases 4 and 5 assume air in the SC and the SPC and exothermic oxidation of the IHS graphite as discussed above.

Table A- 7 gives the maximum temperatures for the PISA and the fuel assuming He inside the IHS. The corresponding PISA and fuel temperatures with air in the IHS would be about 10°C (18°F) higher. The temperatures for normal operation are also given for comparison. The worst case condition, Case 5, results in a PISA temperature about 100°C (180°F) lower than the operational temperatures. It may be reasonably concluded from this analysis that the impact plus external fire will not destroy the PISA.

Table A- 6

TEMPERATURE SUMMARY °F

Case	SC	SPC	IHS Surface	Emissivity Sleeve	Gaps	Exothermic He
1	1475	1533	1617	Yes	Air or Helium	No
2	1475	1533	1861	No	Air	No
3	1475	1533	1820	No	Helium	No
4	1475	1581	1725	Yes	Air or Helium	Yes
5	1475	1581	2171	No	Air	Yes

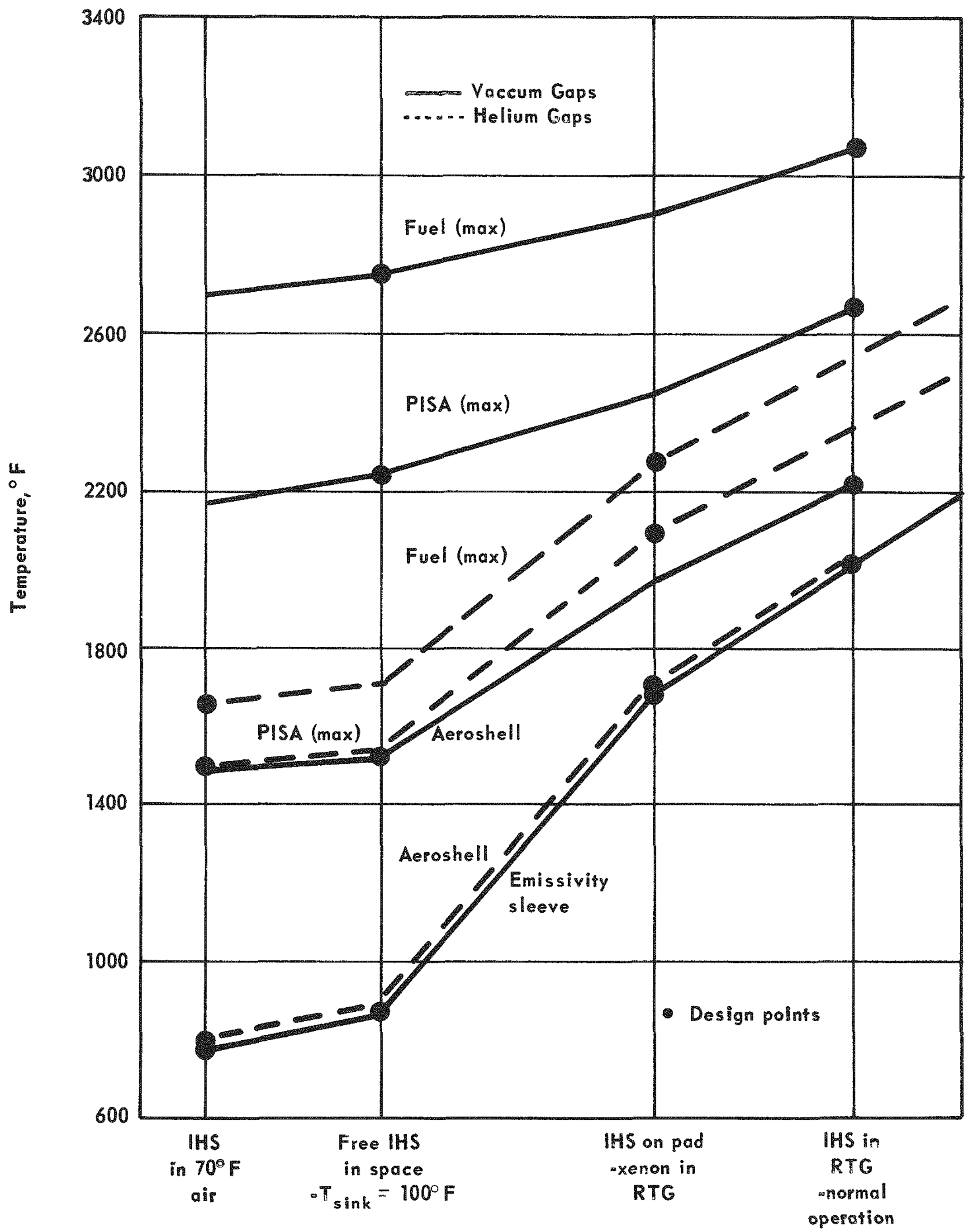

FIGURE III-19 - MHW IHS steady-state temperatures.

Table A-7

IHS TEMPERATURE DISTRIBUTION STEADY STATE-HELIUM IN GAPS

Case	HSA Surface	PICS Maximum	Fuel Maximum
1	1617°F	2040°F	2220°F
2	1861	2230	2410
3	1820	2200	2380
4	1725	2130	2300
5	2171	2480	2670
Normal Operation - Vacuum in Gaps			
	2000	2650	3050

A2.5 Control of plutonium release

Under normal conditions of use, it is recognized that there will be a small amount of plutonium activity on the outside of the PISA from residual contamination not removed at the time of assembly and from Pu-bearing material which may have migrated through the He vent as a vapor. It is expected that the Pu contamination, whatever its source, will be effectively absorbed on the internal surface of the GIS and that the external surface of the GIS/FSA will remain substantially free of contamination. Calculations performed by LASL indicated that the Pu-bearing materials vapor-transported to the inner surface of the GIS would require of the order of $>10^4$ years at a continuous temperature of 1500°C to migrate to the external surface of the GIS/FSA (Ref. CMB-5-C-53, dated February 1971). Although some question has been raised about the validity of these calculations, a review by GE-SD, indicates that there is no substantial error involved in either the concept or the calculations. In addition, two pieces of experimental data have been reported by LASL.

Compatibility test specimen MHW-II-23, in the configuration shown in Figure III-20 was exposed in vacuum at 1450°C for around 6000 hr. Since the effective impermeability of the GIS to Pu is a key concept in the MHW containment design, a check on the penetration of Pu into the POCO-ATJ graphite of the specimen holder was made. A section of the graphite capsule was mounted and cleaned to permit alpha autoradiography. In this procedure, the specimen is placed in direct contact with sensitized photographic material and exposure is triggered by the alpha particles. The zone of the material containing the alpha-active material is thus outlined. Figure III-20 shows the area which contained alpha-active material, in this case Pu. The autoradiograph showed penetration to a depth of about 2 mm, 0.080 in. The Pu concentration is estimated at around 10^2 $\mu Ci/cm^3$ at 2 mm and a lower concentration at the greater depth.

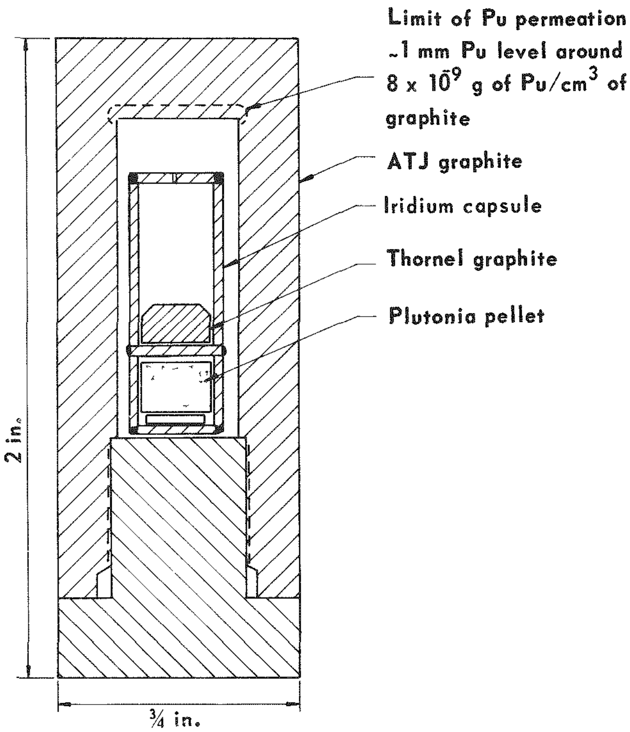

FIGURE III-20 - Specimen MHW-II-23 enclosed>5000 hr in vacuum at 1450°C.

The Pu permeation into the GIS from MHFT-18, a compatibility test sphere, was also measured at LASL, see Figure III-21. The inner surface of the GIS cap showed alpha counts in excess of 10^5 cpm by direct counting. (TWX: Mulford, LASL to Goldenberg, AEC-SNS, 23 July 1973). There was a pit on the cap inner surface corresponding to the position of the PISA vent, about 0.060 in. diam by about 0.020 in. deep. The contamination in this pit was no greater than elsewhere in the cap inner surface, indicating that the contamination was not localized. The GIS cap delaminated about two-thirds of the way into the cap body, leaving a new surface about 0.160 in. from the inner surface. An alpha count taken at this point, however, showed no substantial contamination, arguing that there was no significant permeation of the Pu-bearing material into the GIS after 1100 hr at 1250°C.

The GIS is the first component of the MHW-IHS which inhibits release of Pu-bearing material which might escape from the PISA by any of the

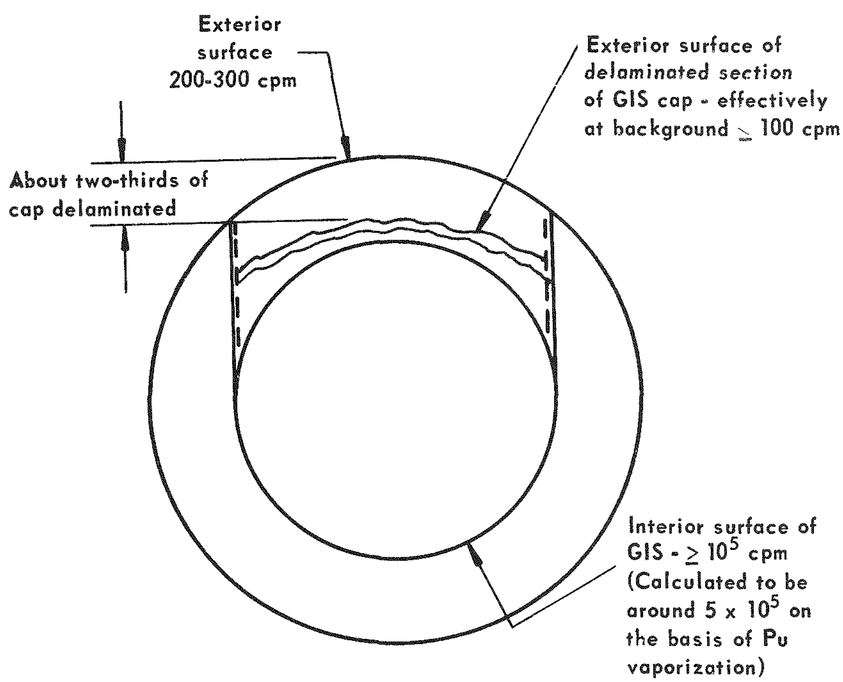

FIGURE III-21 - Alpha radiation levels on MHFT-18 GIS - measured directly after removal of PISA - specimen exposed 1500 hr at GIS surface temperature of 1180°C calculated IR/PuO_2 interface of 1250°C.

possible mechanisms noted in the preceding discussion. Additional protection against any release of radioactive material from the MHW-IHS is provided by all of the internal graphite structural and compliance materials which will tend to scavenge any material which might come out of the GISs. Further retention capability is provided by the IHS aeroshell and the iridium outer clad which permits egress of materials from inside the IHS only through the He vent tube. There are therefore several successive layers of materials which will contain or entrap active material so long as the IHS retains its mechanical integrity.

Even in the event that the IHS were fractured, the maximum calculated quantity of Pu-bearing material which could be available for release would not exceed around 7 μCi. This is the maximum quantity which can be vaporized through the 48 vents of all the PISAs in the IHS, at the operational and credible accident conditions at GE-VF.

However, it must be emphasized that this protection against Pu release, although it is primary, is itself contained within two additional sealed structures at all times except when it is being transferred from the SPC or the RTG and when it is enclosed in the LAS. The SPC, and the HSSC and RSC are fabricated of 0.25-in. thick steel and all closures are sealed by gas tight gaskets. Consequently, during all shipping and handling operations except for transfers, the IHS is provided with very substantial additional protection from damage or Pu release.

A3.0 Summary and conclusions

1. The vented post-impact shell assembly. PISA, which contains the $^{238}PuO_2$ fuel can release a limited amount of contamination to its external surface.

2. Under normal conditions of handling and testing planned for the MHW-IHS at GE-Valley Forge, the only mechanism identified for Pu release is vaporization of Pu-bearing material through the PISA vent. The maximum calculated quantity of Pu which can reach the external surface of the PISA - the internal surface of the graphite impact shell, GIS, - will not exceed around 0.28 μCi per sphere, 7 μCi per IHS containing 24 PISAs, when the IHS is subjected to the time/temperature sequence currently planned. This Pu inventory is not expected to be released from the IHS.

3. Difficulties encountered in the initial stages of the program included:

   a. Leakage of Pu-bearing particulates around the tack-welded PISA vent filter (early design) and around an inadequate and incomplete circumferential weld in the current design.

   b. Cracking of the PISA in the equatorial weld area from excessive He internal pressure when the vents plugged.

4. Leakage of Pu-bearing material around the vent filter has been corrected by better control of the weld process; 33 out of 34 vent filters have successfully contained Pu. Units exceeding the permitted contamination levels are rejected.

5. Plugging of the vents at the temperatures which will be used at GE-VF, has been corrected by:

   a. Chemical and thermal cleaning of the iridium.

   b. Heat treatment of the PuO_2 fuel at 1500°C to remove possible volatile impurities and reduce the O/Pu ratio below 2,000.

   c. Increase of the vent diameter to 0.005 in. diameter.

6. The protected PISAs have been shown to be capable of surviving impact on granite at temperatures of 1400°C and velocities in excess of 280 fps. The maximum impact velocity attainable under the credible accident conditions at GE-VF does not exceed 51 fps.

7. Pu contamination which is retained on or which reaches the external surface of the PISA will be effectively retained by the GIS. Exposure for 5000 hr at 1450°C shows permeation of Pu into graphite of around two millimeters.

8. The handling of the MHW-IHS at GE-VF for the tests currently programmed is not expected to permit a release of more than 7 μCi under the maximum credible accident conditions.

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APPENDIX IV

CONTENTS, DRAWINGS AND SPECIFICATIONS

CONTENTS:

*NOTE: Enlarged copies of these drawings may be obtained by writing to Monsanto Research Corporation, Engineering Drawing Control, Mound Laboratory, Miamisburg, Ohio 45342

MRC SPEC. No. 1-14941

ISSUE	DATE	REVISION	BY	CHK'D.	APP'D
0	9/24/73	ORIGINAL ISSUE	CC		
B	1/7/74	PRIOR NUMERICAL ISSUES OF THIS DRAWING DENOTE CONTROLLED ISSUES PER ACO 1-14941-M1-C	CC		
C	5/7/74	ACO 1-14941-M2-C	CC		CWS

SHEET	1	2	3	4	5	6	7	8	9
ISSUE	C	B	B	C	B	B	B	B	B

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DWG. CLASSIFICATION
LEVEL Unc GP ___
DATE 9-24-73 INIT ___

DRAWN C. CRAFT	DATE 9/73	APPROVALS
CHECKED	DATE 11-14-73	1
APPROVED RCR	DATE 11-15-73	2
JOB NO. —		3
PART NO. —		4

SP
DWG TYPE

CODE IDENT. NO. 14065

DWG. NO. 1-14941 SHT. 1 OF 9

1. GENERAL.

1.1 Scope. This specification is for use in the fabrication and quality control of iridium forming blanks for the Multi-Hundred Watt Program.

1.2 Classification. Iridium shall be supplied in the following type and form:

Type W - 99.52% Ir (Min.) Forming Blank

2. APPLICABLE DOCUMENTS.

2.1 Non-Government Documents. The following documents of the exact issue shown form a part of the specification to the extent specified herein.

STANDARDS and PROCEDURES

ASTM B276 (1965)	Evaluating Cemented Carbides for Apparent Porosity Rec. Practice for
ASTM E45 (1963)	Recommended Practice for Determining the Inclusion Content of Steel

Copies of these documents may be obtained from their control source as listed.

ASTM = American Society of Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

MET-Mat P=FQ-21	ORNL Fabrication of MHW Iridium Hemishell Blanks
MET-NDT-Ir-U1	ORNL Ultrasonic Inspection of Iridium Blanks for Lamilar Discontinuities
MET-NDT-Ir-P1	ORNL Penetrant Inspection of Iridium-Sheet and Blanks

2.2 Reference Documents. The following documents of current issue are to define the requirements of the ORNL procedures:

3-9329 MRC Iridium Blank drawing

2.3 Precedence of Documents. In the event of conflict between this specification or any other document, this specification shall prevail.

2.4 Definitions.

2.4.1 Fibrous Condition is that metallurgical condition of iridium which results after 80-90% warm reduction in thickness from the prior recrystallation and does not exceed the amount of recrystallized grains per ORNL photomicrograph standard WC-53.

2.4.2 Sheet or Ingot is that quantity of iridium used throughout the ORNL fabrication process in accordance with the procedures established in section 2.1.

2.4.3 A lot is that material from a common blend of starting powder nominally 2700 gram. (Typically 15 to 24 blanks)

3. REQUIREMENTS.

3.1 General Material Requirements.

3.1.1 Formulation. The product shall be the type defined in section 1.2 as designated by the applicable drawings. The composition of the finished product shall conform to the requirements of Table 1.

Table I

Chemistry of Iridium Forming Blanks

Element	Max. Content in ppm by Weight (Unless Otherwise Stated)	
	Type W	
	Bulk*	Surface
Ir	99.52% (Min)	99.4% (Min)
Al	50	100
Si	50	100
Fe	50	100
Cr	25	50
Mo	50	100
**C	35	Not Required
**O	50	Not Required
W	2000-4000	6000
Ta	50	100
Ti	50	100
Na	50	100
Ca	50	100

*The sum total of all other noble metals (Rh, Au, Ag, Ru, Pt, and Pd) shall not exceed 400 ppm for Type W and no other single detectable element shall exceed 50 ppm.

**Carbon and Oxygen shall be taken in duplicate per each lot with retention of an historical sample from each sheet.

3.1.2 Surface and Internal Defects.

3.1.2.1 Dye Penetrant Examination. All surfaces excluding areas within 1/16 inch of the blank edges shall be free of pores and cracks in accordance with ORNL Penetrant Inspection of Iridium Sheet and Blanks MET-NDT-Ir-Pl.

3.1.2.2 Visual Examination. All surfaces of each blank shall be examined with exception of the EDM edge. The blank shall be free of well defined slivers, burrs, fissures, cracks, seams, and blisters.

3.1.3 Rework and Retest: Units which have failed a test or requirement may be reworked to correct the defects provided the final product meets all of the specification requirements. Any rework procedures shall be approved by Monsanto Research Corporation. All cleaning operations after the final working operations shall be approved by MRC.

3.1.4 Metallography.

The Microstructure of each sheet sample shall be in the fibrous condition in accordance with section 2.4.1.

The acceptable limits of defects in metallographically prepared specimens shall be in accordance with the following:

Porosity

a) No single void greater than 10 microns
b) Maximum concentration of porosity shall not exceed the level of grouping shown in ASTM B276 Type A, Degree, A-1.

Inclusions

a) There shall be no continuous stringer longer than 0.010 inch
b) The combined length of all continuous stringers and individual inclusions in any 1/4 inch length of a sample shall not exceed a length of 0.015 inch.

Second Phase Material

a) There shall be no second phase material (other than inclusions) detectable at a minimum magnification of 200X.

No Cracks or Laminations

a) None Permitted.

3.1.5 Hardness. The average of 5 hardness values on Type W finished material shall be from 450 to 550 DPH.

3.1.6 Ultrasonic. Each blank shall be free of Ultrasonic indications as specified in section 4.3.2.4.

3.1.7 Dimensions. Blanks shall correspond to the dimensions of the applicable drawings.

4. QUALITY ASSURANCE PROVISIONS.

4.1 Supplier Quality Control Program.

4.1.1 The supplier shall establish and maintain a quality control program satisfactory to MRC that will provide product quality consistent with specifications and known design intent.

4.1.2 The supplier shall produce material in accordance with MRC specifications and known design intent. The supplier must certify as to material quality and be able to provide substantiating quality evidence at the time material is submitted to MRC for acceptance.

4.1.3 MRC shall be accorded the privilege of auditing the fabrication process to assure that the supplier quality control program is functioning effectively.

4.2 Responsibility for Inspection. The supplier shall be responsible for the performance of tests to determine conformance prior to submission of material to MRC, except as noted in sections 6.6 and 6.7.

MRC reserves the right to perform any test deemed necessary to assure compliance with the requirements of this specification. When there is a conflict between the supplier's result and MRC's, MRC shall have the authority for final disposition of acceptance or rejection.

4.3 Quality Conformance Inspections.

4.3.1 Inspections.

4.3.1.1 Visual Examination of Product. One hundred (100) percent of all surfaces of every blank shall be examined, to a maximum of 35X magnification, to determine conformance to 3.1.2.2. Inspection for acceptance shall be performed after completion of all manufacturing operations.

4.3.1.2 Dye-Penetrant Examination of Product. All surfaces of every blank shall be examined with a fluorescent post emulsified penetrant to determine conformance with 3.1.2.1. The following TRACER-TEC Uresco products, or other approved equivalent, shall be used in this inspection:

P 150 - Penetrant
E 153 - Emulsifier
D 495 - Developer

Inspection procedure shall be in accordance with ORNL MET-NDT-Ir-Pl or MRC 1-14945.

4.3.2 Tests.

4.3.2.1 Analysis. A chemical analysis per ORNL MET-Mat P-FQ-21 shall be performed on a sample obtained by the same EDM cutting and grinding operations as done on the final product and after being taken at random from the webbing of the final rolled sheet. A section of the unused sample shall be retained as an historical specimen.

4.3.2.2 Hardness. Hardness tests shall be performed with a diamond pyramid indentor at a load of 500 grams to determine conformance with the requirements of 3.1.5.

4.3.2.3 Microstructure. Using ASTM B276 and E45 examination for conformance to section 3.1.4 shall be performed on one (1) specimen representing all manufacturing operations performed on the final product. This specimen shall be approximately 1/2 x 1/4 inch with its length in the rolling direction and taken from the webbing of each sheet after blanking. A duplicate sample shall be provided to MRC.

An historical sample shall also be maintained as provided in ORNL procedure in section 2.1.

4.3.2.4 Ultrasonic Testing. Using procedures for sheet and plate and in accordance with ORNL ultrasonic inspection document MET-NDT-Ir-U1 no indications (excluding a 1/16 inch band from the blank edge) in excess of those from a 1/32 inch diameter reference standard is acceptable.

4.3.3 Documentation.

4.3.3.1 Test Results. A certified test and inspection report covering the data taken during acceptance testing shall be submitted. The test report shall include the results from each test specified in section 4, plus ingot number, lot number, blank number, and the MRC specification number.

4.3.3.2 Fabrication History. Retrievable records containing all processing information and changes shall be maintained by ORNL for a period of five years from the date of shipment of the final product.

5. PREPARATION FOR DELIVERY.

5.1 Packaging. Each individual blank shall be separated from the others by a suitable material that will not scratch or otherwise change the surface condition of the finished product.

5.2 Weighing. Each blank shall be weighed to the nearest miligram (Mg).

5.3 Identification. Each blank shall be bagged and tagged with its ingot and blank number in accordance with MRC marking specification 1-14684.

CAUTION: DO NOT APPLY ANY MARKINGS DIRECTLY TO BLANKS

5.4 Marking. The exterior package shall be marked with at least the following:

Manufacturer's Name and Address
Point of Delivery (Name and Address)
MRC Specification Number
MRC Order Number
Lot, Ingot, and Blank Numbers of the Items Contained Within

5.5 Certificate of Test. Unless otherwise specified, the supplier shall submit promptly to MRC at the point of delivery a certificate of test showing results of tests to determine conformance to this specification. The certificate shall show this MRC designation, the lot number, the order number, and the ingot number(s) with date of manufacture so that the certificate may be identified with the shipment.

6. DATA PACKAGE. The following information shall be provided with each shipment of components to MRC.

6.1 The serial number of each blank.

6.2 A certificate of inspection listing the fabrication and inspection documents used and a list of all deviations against the product in each shipment.

6.3 A dimensional inspection report which includes all dimensional data requested per drawing.

6.4 The weight of each blank to the nearest milligram.

6.5 Dye penetrant test results.

6.6 A metallographic inspection report for each final rolled sheet is to be provided within one week after shipment.

6.7 Results of visual, chemical, hardness, surface finish, and ultrasonic inspections. (Chemical data to be provided within one week after shipment.)

6.8 All variables data obtained shall be recorded and provided with each shipment.

MRC DWG. No. 1-14942

ISSUE	DATE	REVISION	BY	CHK'D.	APP'D
0	9/24/73	ORIGINAL ISSUE	CC	[illegible]	[illegible]

SHEET	1	2	3	4	5	6	7	8
ISSUE	0	0	0	0	0	0	0	0

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

MULTI-HUNDRED WATT
MATERIAL SPECIFICATION IRIDIUM SHEET & FOIL

DWG. CLASSIFICATION LEVEL UNCL GP ___ DATE 9-24-73 INIT RR	DRAWN C. CRAFT	DATE 9/73	APPROVALS
	CHECKED [illegible]	DATE 11-14-73	1 [illegible]
	APPROVED RER	DATE 11-15-73	2
	JOB NO. —		3
	PART NO. —		4
SP DWG TYPE	CODE IDENT. NO. 14065	DWG. NO. 1-14942	SHT. 1 OF 8

1. GENERAL.

1.1 Scope. This specification is for use in the fabrication and quality control of thin sheet for the Multi-Hundred Watt program piece part components.

1.2 Classification. The Iridium sheet or foil shall be supplied in particular classes and types for subsequent fabrication of piece parts.

Class II (CL-2) for 0.005 inch thick decontamination cover
Class III (CL-3) for 0.005 inch thick weld shield

Type 3 (TY-2) - 99.52 percent Ir (min.)

2. APPLICABLE DOCUMENTS.

2.1 Non-Government Documents. The following documents of the exact issue shown form a part of the specification to the extent specified herein.

STANDARDS

Society

ASTM B276 (1965)	Evaluating Cemented Carbides for Apparent Porosity Rec. Practice for
ASTM E45 (1963)	Recommended Practice for Determining the Inclusion Content of Steel
ASTM E165-65-A2 (1971)	Dye Penetrant Inspection

Copies of these documents may be obtained from their control source as listed.

ASTM = American Society for Testing and Materials
1916 Race Street
Philadelphia, Penna. 19103

2.1.2 PROCEDURES

The Supplier's Iridium Sheet Fabrication Procedures and Specifications shall be approved by MRC.

2.2 Reference Documents. The following documents of the current issue are to define the requirements of the supplier's procedures:

Monsanto Research Corporation - Mound Laboratory piece part drawings

3-9313 Weld Shield
3-9317 Decontamination Cover

2.3 Precedence of Documents. In the event of conflict between this specification or any other document, this specification shall prevail.

2.4 Definitions.

2.4.1 Lot. A lot shall be that quantity of sheet produced from the same ingot in accordance with procedures and inspections established by the supplier and approved by MRC.

3. REQUIREMENTS.

3.1 General Material Requirements.

3.1.1 Type. The product shall be in one of a type and class defined in section 1.2 as designated by the applicable drawings or by specific order.

3.1.2 Formulation. The composition of the finished product shall conform to the requirements of Table 1.

TABLE 1

Element	Max. content in PPM by Weight (Unless Otherwise Stated) Type 3
Ir	99.52% Min.
Al	50
Si	50
Fe	200
Cr	50
Mo	50
C	35
O	50
W	2000-4000
Ta	50
Ti	50
Ca	50
Na	50

The sum total of all other noble metals (Rh, Au, Ag, Ru, Pt and Pd) shall not exceed 400 ppm and no other single detectable element shall exceed 50 ppm.

3.1.3 Surface Finish. Unless otherwise specified the surface finish shall be 32 AA or better.

3.1.4 Identification and Marking. All items in a given shipment shall be bagged and tagged per MRC specification 1-14684 so as to maintain identity of the sheet and lot.

CAUTION: Marking or attachments directly to sheet are unacceptable, except as noted in 3.1.5.2.

3.1.5 Surface and Internal Defects.

3.1.5.1 Dye-Penetrant Examination Class II. One hundred percent (100%) of all surfaces shall be examined and shown to be crack free.

3.1.5.2 Visual Examination. One hundred percent (100%) of all surfaces of finished Class II and III sheet shall be examined for slivers, burrs, fissures, cracks, and blisters and all defective areas marked with a felt tip pen.

3.2 Metallography. The microstructure of acceptable finished material shall be completely recrystallized and no greater than ASTM 5.

4. Quality Assurance Provisions.

4.1 Supplier Quality Control Program.

4.1.1 The supplier shall establish and maintain a quality control program satisfactory to MRC that will provide product quality consistent with specifications and known design intent.

4.1.2 The supplier shall produce material in accordance with MRC specifications and known design intent. The supplier must certify as to material quality and be able to provide substantiating quality evidence at the time material is submitted to MRC for acceptance.

4.1.3 MRC shall be accorded the privilege of auditing the fabrication process to assure that the supplier quality control program is functioning effectively.

4.2 Responsibility for Inspection. The supplier shall be responsible for the performance of tests to determine conformance prior to submission of material to MRC.

MRC reserves the right to perform any test deemed necessary to assure compliance with the requirements of this specification. When there is a conflict between the supplier's result and MRC's, MRC shall have the authority for final disposition of acceptance or rejection.

4.3 Quality Conformance Inspections.

4.3.1 Inspections.

4.3.1.1 Visual Examination of Product. One hundred (100) percent of all surfaces of every sheet shall be examined, to a max. of 35X magnification, to determine conformance to 3.1.5. Inspection for acceptance shall be performed after completion of all manufacturing operations and after cleaning.

4.3.1.2 Dye-Penetrant Examination of Product. One hundred (100) percent of all surfaces of every class II sheet shall be examined with a fluorescent post emulsified penetrant to determine conformance with 3.1.5.1. The following TRACER-TEC Uresco products, or other approved equivalent, shall be used in this inspection:

P 150 - Penetrant
E 153 - Emulsifier
D 495 - Developer

Inspection procedure shall be in accordance with ASTM-165, Method A2 and at a magnification of 20 to 35X.

4.3.2 Tests.

4.3.2.1 Analysis. A chemical analysis shall be performed on a sample of the final sheet taken from a given lot as established in supplier's Fabrication and Specification-section 2.1.2 to determine conformance to 3.1.2.

4.3.2.2 Microstructure. Metallographic examinations shall be performed on a minimum of one specimen from each final sheet as established in supplier's Fabrication Procedure and Specification section 2.1.2 to assure compliance with section 3.2.

4.3.3 Documentation.

4.3.3.1 Test Results. A certified test and inspection report covering the data taken during acceptance testing shall be submitted. The test report shall include the results from each test specified in Section 4, the order number, the lot number, and the MRC specification number.

4.3.3.2 Fabrication History. Retrievable records containing all processing information shall be maintained by the Supplier for a period of five years from the date of shipment of the material.

5. PREPARATION FOR DELIVERY.

5.1 Packaging. Each individual sheet shall be separate from the others by a suitable material that will not scratch or otherwise change the surface condition of the finished product. The material shall be packed in substantial exterior containers to assure acceptance by common or other carriers for safe transportation to the point of delivery.

5.2 Marking. The exterior container shall be marked with at least the following information:

Manufacturer's name and address, MRC order number, point of delivery (name and address), type and sheet identification number, MRC specification number and number of items contained within.

5.3 Certificate of Test. Unless otherwise specified, the supplier shall submit promptly to MRC at the point of delivery a certificate of test showing results of tests to determine conformance to this specification. The certificate shall show the MRC specification number, the order number, and lot and type number(s) with date of manufacture so that the certificate may be identified with the shipment.

6. DATA PACKAGE. The following information shall be provided with each shipment of components to MRC.

6.1 The sheet identification number of the finished product.

6.2 A copy of fabrication process identifying heat treats and rolling schedules and QC inspection documents which include a list of all deviations against the product in each shipment.

6.3 A dimensional inspection report which includes all dimensions data as requested by order or per drawings.

6.4 The weight to the nearest milligram.

6.5 Dye penetrant test results.

6.6 Metallographic inspection report for each sheet shall be provided within one week after shipment.

6.7 Results of visual, chemical, and surface finish inspections. (Chemical data to be provided within one week after shipment.)

6.8 All variables data obtained shall be recorded.

ISSUE	DATE	REVISION	BY	CHK'D.	APP'D.
0	10/19/73	ORIGINAL ISSUE	CC		
B	1-16-74	PRIOR NUMERICAL ISSUES CENOTE CONTROLLED ISSUES PER ACO 1-14944-M1-C	CC		
C		PER ACO 1-14944-M2-C	HC		

SHEET	1	2	3	4	5	6	7	8	9
ISSUE	C	B	B	C	B	B	B	B	B

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

MHW

MHW HYDROFORMING IRIDIUM HEMISPHERE SPECIFICATION

DWG. CLASSIFICATION
LEVEL Unclas GP
DATE 10-24-73 INIT

DRAWN C. CRAFT DATE 10/73
CHECKED DATE 11-14-73
APPROVED RER DATE 11-15-73
JOB NO. —
PART NO. —

APPROVALS 1 2 3 4

DWG. TYPE SP
CODE IDENT. NO. 14065
DWG. NO. 1-14944 SHT. 1 OF 9

1. GENERAL.

1.1 Scope. This specification and procedure establishes the requirements applicable to the fabrication and inspection of prime qualified Multi-Hundred Watt iridium components. Quality Control requirements applicable to materials, component formation, inspection, and processes are specified herein.

2. DOCUMENTS.

2.1 Required. The following documents are to be a part of these procedures:

a. Drawings

3-9318	Hemisphere
3-9329	Blank, Iridium

b. Specifications

1-14941	Material Specification Iridium Blank
1-14684	Marking Specification
MD-10058	Quality Control Policy and Program
MD-80026-183	Multi-Hundred Watt Chemical Analysis Specification

2.2 Reference Documents. The following documents are to define the requirements of these procedures.

NS 0060-01-10	GE Iridium Hemisphere Specification
47C303115	GE Hemisphere
47D303085	GE Pics Subassembly
MD-70161-1	Multi-Hundred Watt Hardware Program Operation Sheet

3. REQUIREMENTS.

3.1 Definition of Terms.

3.1.1 Prime Quality refers to those hemispherical shells which conform to the requirements of this document and all the drawings and specifications as described in Section 2.1 above.

3.1.2 Non-conforming Material refers to those hemispherical shells which do not meet all the requirements of this document and all the drawings and specifications as described in Section 2.1 above.

3.1.3 Tag End refers to the ring of excess hemispherical shell material.

3.1.4 Lot refers to those hemispherical shells formed from a common blend of ORNL starting powder nominally 2700 grams. (Typically 15 to 24 blank.)

3.2 Quality Control.

3.2.1 The quality control system shall be consistent with the general principles and policies of MRC-Mound Laboratory document MD-10058, Quality Control Policy and Program.

3.3 Material.

3.3.1 All iridium materials shall be supplied to or purchased by MRC and shall conform to the requirements of the following specifications:

1-14941 Material Specification Iridium Blanks

3.4 Forming.

3.4.1 All iridium hemispherical shells shall conform to the hydroforming procedures described in MRC Multi-Hundred Watt Hardware Program Operation Sheet, MD-70161-1.

3.5 Cleaning.

3.5.1 All surfaces shall be rendered and maintained clean of all foreign matter as per Section 3.7.1.2 Surface ppm.

This shall be done per the cleaning procedures outlined in MD-70161-1.

3.6 Heat Treatment.

3.6.1 The required metallurgical condition of sections 3.7.1.3 and 3.7.1.4 of the hemispherical shells shall be generated as per the heat treat procedures outlined in MD-70161-1.

This operation shall be performed in a high temperature, high vacuum Brew furnace, Model 902 or its equivalent per Operation Sheet MD-70151-15.

3.7 Inspection.

3.7.1 The inspection program shall vertify that all metallurgical, chemical and dimensional attributes conform to this specification and procedure and the applicable documents in Section 2.0.

3.7.1.1 Sample Technique for Quality Control - All chemical and metallurgical analyses will be performed on one fully processed hemisphere taken from each lot as defined in 3.1.4. The selected hemisphere shall be EDM'd into 12 equal pole to equator sections and cleaned per Operation Sheet MD-70161-1, Sub. Operation No. 26. Four equally spaced sections will be sent for chemical analysis (two for bulk and surface and two for analytical back up), four equally spaced sections will be sent for metallurgical analysis, and the remaining four will be held for historical use.

3.7.1.2 A chemical analysis shall be performed on samples as described in 3.7.1.1 to determine conformance to the following:

Element	Bulk ppm
Ir	99.52% (min)
Al	50
Si	50
Fe	50
Cr	25
Mo	50
Ta	50
W	2000-4000
C	35
O	50
Ti	50
Ca	50
Na	50

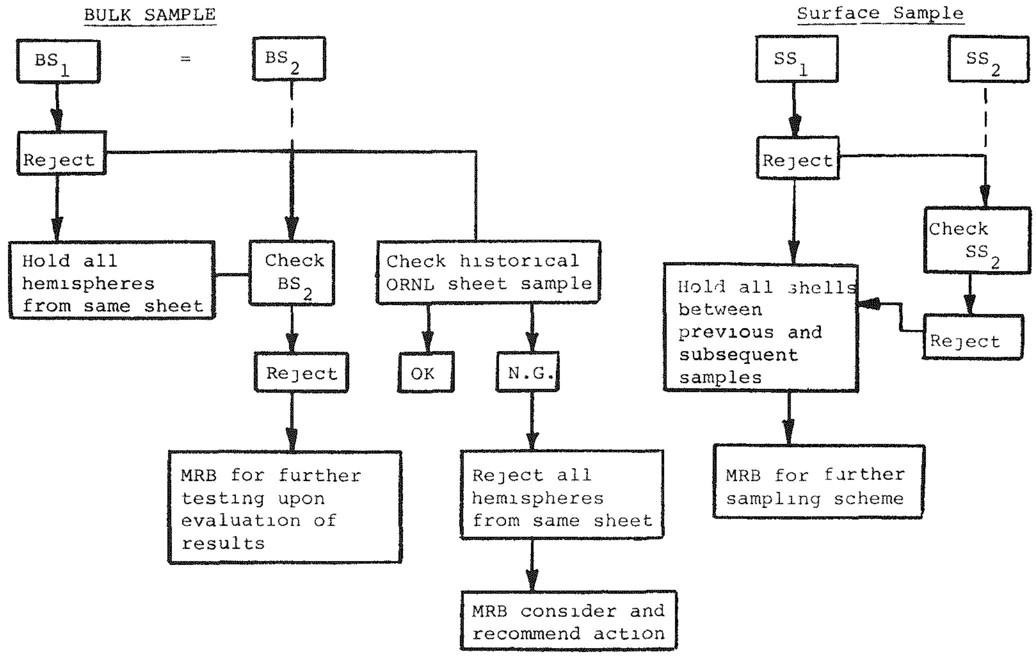
The sum of all other noble metals (Rh, Ru, Ag, Au, Pt and Pd) shall not exceed 400 ppm. No single unspecified element detectable by Spark Source inspection shall exceed 50 ppm. Carbon and oxygen shall be inspected for by using Leco carbon analysis and vacuum fusion respectively. Surface chemistry shall be measured and recorded.

If the chemistry does not conform to the above table, further analysis shall be continued in accordance with the following outline.

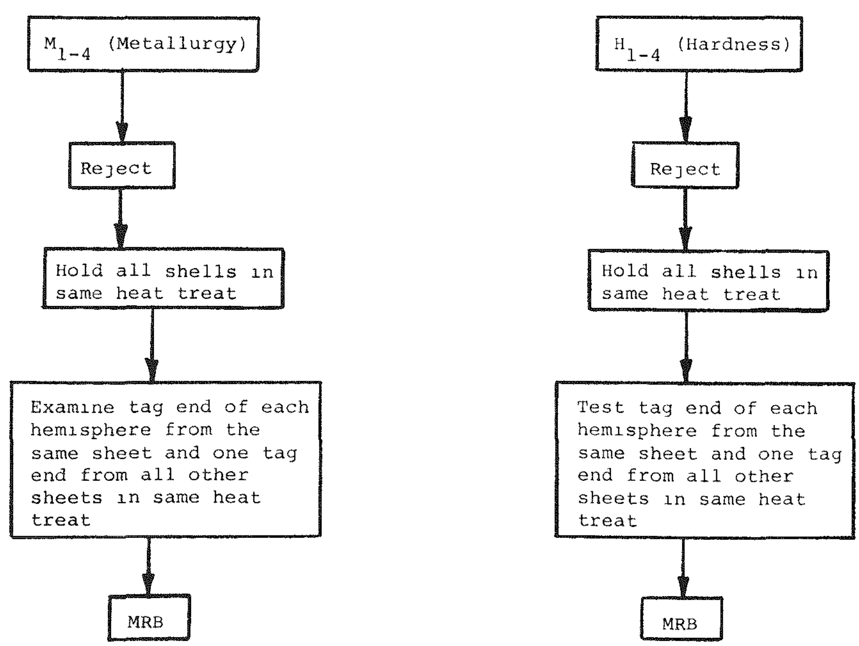
3.7.1.3 Hardness - The microhardness of the fully processed hemisphere shall be DPH-250 to 350 using a DPH indentor and 200 gm load. The averages of three hardness values normal to the centerline shall be taken at the pole, 45°, and equator of at least 2 sections provided in 3.7.1.1. The hardness shall be taken on the unetched surfaces of the mounted sections. If the hardness values of the individual sections are not in conformance with the above noted range, then further testing shall be done in accordance with the outline for hardness on the following page.

3.7.1.4 Microstructure - The grain size of the fully processed hemisphere shall not exceed ASTM grain size 3 and any internal defects shall be kept within the acceptable limits as specified in the following table.

CHEMISTRY SAMPLING OUTLINE



MICROSTRUCTURE AND HARDNESS
SAMPLING OUTLINE



POROSITY	INCLUSIONS	SECOND PHASE MAT'L
a. No single void greater than 10 microns. b. Maximum concentration of porosity shall not exceed the level of grouping shown in ASTM B276, Type A, Degree, A-1.	a. There shall be no continuous stringer longer than 0.010". b. The combined length of all continuous stringers and individual inclusions in any 1/4 inch length of a sample shall not exceed a length of 0.015".	There shall be no second phase mat'l (other) than inclusions) detectable at a minimum magnification of 200X.

There shall be no cracks or laminations.

The microstructure of the entire cross-sectional area of the four sections shall be examined. Any anamolous metallurgical conditions shall be noted and photographed. If the microstructural results do not conform to the above specified requirements, further examination shall continue in accordance with the outline on page 8.

3.7.1.5 Dye Penetrant - There shall be no cracks or pores in any of the surfaces of the fully processed hemispheres as fabricated by the procedures outlined in MD70161-1.

3.7.1.6 Visual. All hemispherical surfaces except for the vent hole interior shall be free of slivers, burrs, fissures, cracks, seams, blisters, oxides, grit, dirt or metal. Visual examination will be made prior to grit blasting and after grit blasting and cleaning.

3.7.1.7 Defect Removal - Defects may be removed provided that such conditioning does not:

a. Violate minimum gage or surface finish established by the applicable drawings.
b. Impart any foreign material; i.e. oxides, grit, shop dirt or metal to the surface of the hemispheres.

MRC DWG. No. 1-14905

ISSUE	DATE	REVISION	BY	CHK'D	APPRD
A	6 27 73	PRELIMINARY ISSUE	CC	GWJ	GWJ
B	8 17 73	EXTENSIVELY REVISED SECTIONS 4 THRU 10 PER ENGINEER'S INSTRUCTIONS	CC	JBM	DF
C	10/4/73	REVISED SECTIONS 2 5.2, 7.2.1, 7.3, 7.4.2 8.1.4, 8.3 AND 9.	CC	JBM	GWJ
D	12/5/73	REVISED 2.2, 5.3, 8.3, 9.2, AND ADDED 4.3.3 AND 10.1.7	CC	[illegible]	[illegible]
A	1 2 74	PRIOR ALAPHEBETICAL ISSUES OF THIS DRAWING DENOTE PRELIMINARY ISSUES ORIGINAL ISSUE	CC	[illegible]	BJF
B	2/12/74	PER ACO 1-14905-M1-C AND ACO 1-14905-M2-C	CC	JBM	BJF
C		PER ACO1-14905-M3-C AND ACO1-14905-M4-C	HC	[illegible]	BJF

SHEET	1	2	3	4	5	6	7	8	9	10	11	12
ISSUE	C	C	B	B	C	B	B	B	B	C	B	C

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

MULTI-HUNDRED WATT

MHW FUEL SPHERE ASSEMBLY ACCEPTANCE

DWG. CLASSIFICATION
LEVEL Unclass GP —
DATE 6-27-73 INIT GWJ

DRAWN C CRAFT	DATE 62773	APPROVALS	[illegible]
CHECKED JBM	DATE 62873	2	
APPROVED RER	DATE 6-28-73	3	
JOB NO —		4	
PART NO. —			

DWG TYPE	CODE IDENT. NO.	
SP	14065	DWG. NO. 1-14905 SHT 1 OF 12

1. GENERAL.

1.1 Scope. This specification defines the acceptance criteria and quality control requirements for the Multi-Hundred Watt fuel sphere assembly.

1.2 Abbreviations. Following are listed some abbreviations used throughout this document.

MHW - Multi-Hundred Watt
PICS - Post Impact Containment Shell
PISA - Post Impact Shell Assembly
FSA - Fuel Sphere Assembly
GIS - Graphite Impact Shell
PRD - Pressure Relief Device (vent)
MRC - Monsanto Research Corporation
GE - General Electric Company
TIG - Tungsten Inert as
EB - Electron Beam

2. DOCUMENTS.

2.1 Applicable Documents. Current issues of the following drawings and specifications form a part of this specification where applicable.

Drawing Numbers:	Description:
47C302135	Fuel Sphere Assy.
47C302509P1	Cap & Body-Mat. (GIS)
47D303085	Post Impact Containment Shell Sub-Assembly
1-14813	Fuel Sphere
3-9318	Hemisphere
3-9313	Weld Shield
3-9317	Decontamination Cover
47B303131	Filter Assembly
1-14941	Material Specification Iridium Blank
1-14942	Iridium Foil Components, MRC/ORNL
1-14944	MHW Hydroforming Iridium Hemisphere Spec.
SPA740033	MHW Tungsten Carbide Grit Blasting Spec.

2.2 Information and Reference Documents: The following documents provide information for fabricating and inspecting the fueled heat sources.

MD-10058	Mound Laboratory Quality Control Policy
MD-10080	Product Index Preparation Instructions
MD1-11533	Procedure for Nonconforming Material Request
MD-10095	Engineering Change Notice Preparation Instructions
MD1-14684	Specification for Marking of Parts and/or Assemblies
SS47A14603	System Specification for the MHW RTG for LES 8 and 9 Satellites (GE Document)
	MRC/General Electric Company MHW Program Interface Agreement

Operation Manual No.	No.	Title
MD-70159	2	Test Capsule Assy. and Insp.
MD-70161	1	Forming of Hemispherical Ir Shells
MD-70161	2	(included in No. 1 above)
MD-70161	3	Rework of Hemispherical Ir Shells
MD-70161	4	MHW Ir Hemisphere Grit Blasting & Cleaning
MD-70161	5	Fabrication of Weld Shield
MD-70161	6	Fabrication of Decon Cover
MD-70161	7	(Reserved for future use)
MD-70161	8	(Reserved for future use)
MD-70161	9	(Reserved for future use)
MD-70161	10	Bake-Out Requirements, MHW
MD-70161	11	Detail Hemisphere Part Assy. & Insp.
MD-70161	12	EB Weld Schedule - Vent
MD-70161	13	EB Weld Schedule - Decon Disc
MD-70161	14	EB Weld Schedule - Weld Shield Butt Weld
MD-70161	15	EB Weld Schedule - Weld Shield Tab Tack Welds
MD-70161	16	Record of Fueled PISA Assy. & Insp.
MD-70161	17	PISA TIG Tack Weld Schedule

Operation Manual No.	No.	Title
MD-70161	18	PISA TIG Weld Schedule
MD-70161	19 thru 22	(Reserved for future use)
MD-70161	23	PISA Decon & FSA Assembly Sequence

2.3 Precedence of Documents. In the event of conflict between this specification and any other documents, this specification shall prevail.

2.4 Changes. Changes in this specification shall be handled in accordance with MD-10095 "Engineering Change Notice Preparation Instruction".

3. REQUIREMENTS.

MRC-Mound Laboratory shall conform to the following requirements.

3.1 Nonconforming Material. Materials or components which do not comply with the requirements of this specification shall be handled in accordance with Mound Drawing 1-11533 "Procedure for Nonconforming Material Request" and the MHW Material Review Board defined in the MRC/GE Interface Agreement.

3.2 Component Identification. The serial number of each component shall be used to control the part for gaging, material control and assembly. Detailed records of the disposition of each component shall be maintained.

4. FUEL SPHERE.

4.1 Fuel. The fuel shall be pressed plutonium oxide (PPO) meeting the requirements of MRC Specification No. MD1-14813.

4.2 Thermal Output. The FSA fuel loading shall be 100 $\pm$ 2 watts. Each sphere shall be measured to $\pm$ 1/2% at a 95% confidence level (2 sigma).

4.3 Cleaved Spheres. Acceptance of spheres exhibiting cleavages shall be made based on a technical assessment of the usability of each sphere.

4.3.1 Reconstructed PPO Sphere Size. The reconstructed PPO fuel sphere shall, while nested within its PICS hemishell, be completely cleared by a second MRC hemishell which has a reduced pole height of 0.74 inch.

4.3.2 PISA Thermal Output. The thermal output shall be determined by calorimetry of the PISA containing the reconstructed sphere to be 100 ± 2 watts measured to ± 1/2% at a 95% confidence level (2 sigma).

4.3.3 Record. PISA's having cleaved fuel spheres shall be recorded and identified by PISA number.

5. GENERAL FABRICATION REQUIREMENTS.

5.1 Inert Gas Process Box Atmospheres and Welding Gases. All final assembly operations will be performed with high purity grade helium which is circulated through an inert gas purifier in the weld and assembly boxes. The monitored O_2, N_2 and H_2O content of the fuel loading, capsule assembly and welding and graphite assembly box atmospheres shall not exceed the values listed in Table 1 below. In the event of gas analyzer breakdown, a 1T bend test will be performed on 0.020 inch thick Ta-10% W specimen which has been TIG welded without torch gas.

The vent disc, decontamination disc and weld shield EB welds will be performed at a pressure less than 5×10^{-4} torr.

The PICS TIG weld will be performed with high purity grade helium torch gas.

TABLE 1

	IN He
O_2 ppm-max	150
N_2 ppm-max	500
H_2O ppm-max	200

5.2 Welding Repair. If in the course of welding or inspection, defects in the weld joint are detected, repairs may be made as follows. TIG closure weld repairs may be made only by using the same automatic welding schedule. EB subassembly weld repairs may be made either by using the same automatic welding schedule or by an autogenous manual repair. After a weld has been repaired but before any weld dressing is performed, the weld shall receive a visual inspection and a dye penetrant inspection (if applicable). If weld dressing is required, the weld shall receive a visual inspection after dressing. Repaired welds shall pass the same requirements as non-repaired welds. Repairs of welds shall be documented and submitted to the GE/MRC MRB for final disposition.

5.3 Example Welds. One TIG example weld will be made prior to each production run. For the purpose of meeting weld requirements the welding performed by the same operators with the same equipment on one joint design in one continuous work period is defined as a production run. Example weld hardware shall be representative of the production hardware.

6. WELD ACCEPTANCE CRITERIA (PICS SUBASSEMBLIES).

6.1 Visual Inspection. All production electron beam welds on the vent discs, decontamination disc and weld shield band shall be given a careful, visual inspection at 20X to 50X magnification. These welds shall meet the following requirements.

6.1.1 Cracks. There shall be no visible cracks in the weld or in the base metal adjacent to the weld. Cracks are acceptable in the weld shield welds which do not propagate into the PICS parent metal and are functionally acceptable.

6.1.2 Surface Pores. There shall be no detectable surface pores in the weld exceeding 0.005" diameter. The total surface porosity in one inch of weld length shall not exceed 2% of an area equal to (1 x t) square inches, where t equals the thickness of the thickest member.

6.2 Leak Test. The hemisphere subassembly shall be helium leak checked after the vent and decontamination disc have been assembled and welded. The assembly shall have a leak rate not to exceed 1×10^{-6} std cc/sec as determined by a mass spectrometer type helium leak detector.

7. WELD ACCEPTANCE CRITERIA [UNFUELED TEST POST IMPACT SHELL ASSEMBLY (PISA)].

7.1 Visual Inspection. All test capsule TIG production welds shall be given a careful, visual inspection at 10X to 30X magnification. These welds shall meet the following requirements.

7.1.1 Bead Width. The weld bead shall not be less than 0.08 in. wide nor more than 0.12 in. wide at any point around the entire weld.

7.1.2 Cracks. There shall be no visible cracks in the weld or in the base metal adjacent to the weld.

7.1.3 Surface Pores. There shall be no detectable surface pores in the weld exceeding 0.010 in. diameter. The total surface porosity in one inch of weld length shall not exceed 2% of an area equal to (1 x t) square inches, where t equals the thickness of the thinnest member.

7.2 Dye Penetrant Inspection. All test capsule TIG production welds shall be given a dye penetrant inspection using an ultrasensitive fluorescent penetrant (Tracer Tech P-150 or equal) to determine if each weld meets the following requirements.

7.2.1 Cracks. There shall be no linear indications in the weld or in the base metal adjacent to the weld.

7.2.2 Surface Pores. There shall be no surface pores in the weld exceeding 0.010 in. diameter. The total surface porosity in one inch of weld length shall not exceed 2% of an area equal to (1 x t) square inches, where t equals thickness of thinnest member.

7.3 Test PISA Example Welds. If a pre-production TIG example weld is used for a particular test capsule production lot, it shall be examined and shall meet the requirements of paragraph 7.1, 7.2, 7.4 and 7.5. The pre-production example weld assembly shall be cut in half to expose the interior of the example weld assembly. Visual and dye penetrant inspections shall be made of the interior to verify that the underbead side of the TIG joint has been completely fused and that no cracks are present in the weld or adjacent base metal. Test capsule production welding may commence if the example weld meets all of the visual inspection criteria.

7.4 Metallographic Inspection. Two sections, one of which is at the weld overlap, shall be removed from the pre-production TIG weld, polished, etched, and examined at 20X to 70X magnification. The weld and adjacent heat affected zone shall be photographed at 20X to 70X magnification for permanent documentation of this inspection. The data obtained in this magnification range shall be used to determine if the weld meets the following requirements.

7.4.1 Cracks. There shall be no cracks in the weld or in the base metal adjacent to the weld.

7.4.2 Pores.

Pre Lot 80 Hemispheres - All pores must be generally circular in shape with no sharp corners or tails. There shall be no single pore with a diameter greater than 60% of the thickness of the thinnest member. There may be any number of pores in one transverse section, but the total cross-sectional area of all the pores shall not exceed that of a single pore of the maximum allowable size.

Post Lot 80 or MRC/ORNL Hemispheres - All pores must be generally circular in shape with no sharp corners or tails. There shall be no single pore with a diameter greater than 0.010 inch. There may be any number of pores in one transverse section, but the total cross-sectional area of all the pores shall not exceed that of a single pore of the maximum allowable size.

7.4.3 Weld Joint Fusion. There shall be no lack of fusion in the TIG weld joint.

7.4.4 Alignment. The inside contours of each half of the PISA sections shall be examined to verify that misalignment appears to be less than 0.004-inch.

7.5 Radiographic Inspection. Straight-through radiographs shall be made of the pre-production TIG example weld after the two metallographic sections have been removed to determine if the weld meets the following requirements.

7.5.1 Cracks. There shall be no cracks in the weld or in the base metal adjacent to the weld.

7.5.2 Pores

Pre Lot 80 Hemispheres - All pores must be generally circular in shape with no sharp corners or tails. There shall be no single pore with a diameter greater than 60% of the thickness of the thinnest member. Total porosity in one inch of weld length shall not exceed 5% of an area equal to (1 x t) square inches where t is the thickness of the thinnest member.

Post Lot 80 or MRC/ORNL Hemispheres - All pores must be generally circular in shape with no sharp corners or tails. There shall be no single pore with a diameter greater than 0.010 inch. Total porosity in one inch of weld length shall not exceed 1.5% of an area equal to (1 x t) square inches where t is the thickness of the thinnest member.

7.5.3 Weld Joint Fusion. There shall be no indication of lack of fusion in the TIG weld joint.

8. WELD ACCEPTANCE CRITERIA [FUELED POST IMPACT SHELL ASSEMBLY (PISA)1].

8.1 Visual Inspection. The pre-production TIG example weld and all production welds shall be given a careful, visual inspection at 10X to 30X magnification. The example weld and all production welds shall meet the following requirements.

8.1.1 Bead Width. The weld bead shall not be less than 0.08 in. wide nor more than 0.12 in. wide at any point around the entire weld.

8.1.2 Cracks. There shall be no cracks in the weld or in the base metal adjacent to the weld.

8.1.3 Surface Pores. There shall be no detectable surface pores in the weld exceeding 0.010 in. diameter. The total surface porosity in one inch of weld length shall not exceed 2% of an area equal to (1 x t) square inches, where t equals thickness of the thinnest member.

8.1.4 Underbead Visual Inspection. The pre-production TIG example weld assembly shall be cut in half to expose the interior of the example weld assembly. Visual and dye penetrant inspections shall be made of the interior to verify that the underbead side of the joint has been completely fused and that no cracks are present in the weld or adjacent base metal. Production welding may commence if the example weld meets all of the visual (not to include dye penetrant) inspection criteria.

8.2 Metallographic Inspection. Two sections one of which is at the weld overlap shall be removed from the pre-production TIG example weld, polished, etched, and examined at 20X to 75X magnification. The weld and adjacent heat affected zone shall be photographed at 20X to 75X magnification for permanent documentation of this inspection. The data obtained in this magnification range shall be used to determine if the welds meet the following requirements.

8.2.1 Cracks. There shall be no cracks in the weld or in the base metal adjacent to the weld.

8.2.2 Pores

Post Lot 80 or MRC/ORNL Hemispheres. All pores must be generally circular in shape with no sharp corners or tails. There shall be no single pore with a diameter greater than 60% of the thickness of the thinnest member. There may be any number of pores in one transverse section, but the total cross-sectional area of all the pores shall not exceed that of a single pore of the maximum allowable size.

Post Lot 80 Hemispheres - All pores must be generally circular in shape with no sharp corners or tails. There shall be no single pore with a diameter greater than 0.010 inch. There may be any number of pores in one transverse section, but the total cross-sectional area of all the pores shall not exceed that of a single pore of the maximum allowable size.

8.2.3 Weld Joint Fusion. There shall be no lack of fusion in the TIG weld joint.

8.2.4 Alignment. The inside contours of each half of the PISA sections shall be examined to verify that misalignment appears to be less than 0.004-inch.

8.3 Decontamination. The surface contamination as determined by a wipe of approximately one-half the surface of the completed PISA shall be less than 2000 disintegrations per minute. The vent activation fixture shall be examined by wipe for contamination after each run. The value shall not exceed 2000 dpm.

8.4 Leak Test. The fueled iridium post impact containment shell assembly shall be helium leak checked prior to the breaking of the decontamination burst disc. The assembly shall have a leak rate not to exceed 1×10^{-6} std cc/sec as determined by a mass spectrometer type helium leak detector.

9. FSA/GIS Assembly.

9.1 Closure. After inserting the PISA in the graphite body, the graphite plug shall be inserted and rotated until a smooth spherical transition is achieved at the cap/body interface. This will occur when the indexing holes on the body and the cap are perfectly aligned. A proper fit may also be achieved when the holes are misaligned or not visible provided no step up or down is noted in the cap/body interface. Observation with the naked eye of the FSA in the glove box (a distance of not more than 36 inches) is adequate for these purposes.

9.2 Decontamination. The surface contamination as determined by a wipe of approximately one-half the surface of the individual FSA's shall total less than 1000 dpm for the total of 24 FSA's in any one HSA.

10. Additional NDT Testing.

MRC-Mound Laboratory shall perform any additional operations or tests which are considered necessary to insure the quality of the completed product. GE shall be informed of any additional work. It will be documented and available for review at Mound Laboratory.

10.1 Data Package. The following information for each shipment will be provided to GE:

10.1.1 The serial number for each fueled FSA and applicable revision levels of specifications and drawings.

10.1.2 A listing of the serial numbers of all components and drawing numbers which make up each final assembly.

10.1.3 A listing and description of all deviations and GE/MRC MRB dispositions associated with each fueled FSA.

10.1.4 The thermal output as determined by calorimetry.

10.1.5 The specific neutron emission rate for each processed fuel sphere.

10.1.6 The surface contamination wipe count as referenced in Sections 8.3 and 9.2.

10.1.7 PISA's having cleaned fuel spheres at the time of loading shall be recorded.

11. DEFINITION SECTION.

Commercial high purity grade and welding grade gases are defined as gases having total impurities less than 50 ppm; 99.995% pure.

ISSUE	DATE	REVISION	BY	CHK'D.	APPR'D
A	1-17-74	ORIGINAL ISSUE	CC	Les	EWJ
B	5-23-74	ACO SPA740056-M1-C & ACO SPA740056-M2-C	ES	Les	BAH

SHEET	1	2	3	4	5	6	7
ISSUE	B	B	B	B	B	B	B

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

MULTI-HUNDRED WATT

MHW HEAT SOURCE ASSEMBLY ACCEPTANCE SPECIFICATION

DWG. CLASSIFICATION: LEVEL Uncl GP — DATE 1-18-74 INIT GWJ

DRAWN CRAFT	DATE 011774	APPROVALS	
CHECKED Les	DATE 1-17-74	1	Gwj
APPROVED RCR	DATE 1-18-74	2	
JOB NO. —		3	
PART NO. —		4	

DWG. TYPE: SP | CODE IDENT. NO. 14065 | DWG. NO SPA740056 | SHT. 1 OF 7

1. GENERAL.

1.1 Scope. This specification defines the acceptance criteria and quality control requirements for the Multi-Hundred Watt heat source assembly.

1.2 Abbreviations. Following are listed some abbreviations used throughout this document.

MHW - Multi-Hundred Watt
FSA - Fuel Sphere Assembly
HSA - Heat Source Assembly
GMS - Gas Management System
TIG - Tungsten Inert Gas

2. D O C U M E N T S.

2.1 Applicable Documents. Current issues of the following drawings and specifications form a part of this specification where applicable.

Drawing Number	Description
47E302635	IHS (HSA) Assy. (Ground Handling Config.)

2.2 Information and Reference Documents. The following documents provide information for fabricating and inspecting the fueled heat sources.

1-14905	MHW Fuel Sphere Assembly Acceptance
MD-10058	Mound Laboratory Quality Control Policy
MD-10080	Product Index Preparation Instructions
1-11533	Procedure for Nonconforming Material Request
MD-10095	Engineering Change Notice Preparation Instructions
	MRC/General Electric Company MHW Program Interface Agreement

Operation Manual No.	No.	Title
MD-70161	24	Assembly of Eight-Pak
MD-70161	25	HSA Assembly & Inspection
MD-70161	26	Outer Clad Tack Weld Schedule
MD-70161	27	Outer Clad Weld Schedule
MD-70161	28	Preparation of SPC, GHC and Loading HSA into SPC

2.3 Precedence of Documents. In the event of conflict between this specification and any other documents, this specification shall prevail.

2.4 Changes. Changes in this specification shall be handled in accordance with MD-10095, "Engineering Change Notice Preparation Instruction".

3. R E Q U I R E M E N T S.

MRC-Mound Laboratory shall conform to the following requirements.

3.1 Nonconforming Material. Materials or components which do not comply with the requirements of this specification shall be handled in accordance with Mound Drawing 1-11533 "Procedure for Nonconforming Material Request" and the MHW Material Review Board defined in the MRC/GE Interface Agreement.

3.2 Component Identification. The serial number of each component shall be used to control the part for gaging, material control and assembly. Detailed records of the disposition of each component shall be maintained.

4. FUEL SPHERE.

4.1 FSA. The FSA's shall be fabricated to meet specification requirements of MD1-14905.

4.2 Thermal Inventory. The twenty-four FSA's utilized in any HSA shall have a summed thermal inventory of 2410 ± 18 watt excluding calorimetry error at time of fuel calorimetry. {The fuel spheres have been calorimetered to an accuracy of ± 1/2% at a 95% confidence level (2 sigma).}

5. GENERAL FABRICATION REQUIREMENTS.

5.1 Inert Gas Process Box Atmospheres and Welding Gases. All final assembly operations will be performed with high purity grade helium which is circulated through an inert gas purifier in the weld and assembly boxes. The monitored O_2, N_2 and H_2O content of the subassembly and assembly and welding box atmospheres shall not exceed the values listed in Table 1 below. In the event of gas analyzer breakdown, a 1T bend test will be performed on 0.020 inch thick Ta-10% W specimen which has been TIG welded with torch gas.

The PICS TIG weld will be performed with high purity grade helium torch gas.

TABLE 1

	Normal and During Final Closure Weld	Allowable Excursion (<4 hours duration)
O_2 ppm-max	150	5,000
N_2 ppm-max	500	* ---
H_2O ppm-max	200	200

*Off scale on analyzer readout. Assume normal ratio of N_2 to O_2 in air.

5.2 Welding Repair. If in the course of welding or inspection, defects in the weld joint are detected, repairs may be made as follows. TIG closure weld repairs may be made only by using the same automatic welding schedule. After a weld has been repaired but before any weld dressing is performed, the weld shall receive a visual inspection and a dye penetrant inspection (if applicable). If weld dressing is required, the weld shall receive a visual inspection after dressing. Repaired welds shall pass the same requirements as non-repaired welds. Repairs of welds shall be submitted to the MRC/GE MRB for formal disposition.

5.3 Graphite Torque Requirements.

5.3.1 Eight-Pak Retaining Bolt. A torque of between 5 and 7 in-lb. shall be impressed upon the retaining bolt at closure.

5.3.2 Aeroshell Torque. The exposed aeroshell end cap shall be screwed down until a maximum torque of 10 ± 1 ft-lb. has been placed upon spanner holes.

6. WELD ACCEPTANCE CRITERIA-OUTER CLAD.

6.1 Visual Inspection. The TIG closure welds shall be given a visual inspection at 10X to 30X magnification. The welds shall meet the following requirements.

6.1.1 Cracks. There shall be no visible cracks in the weld or in the base metal adjacent to the weld.

6.1.2 Surface Pores. There shall be no detectable surface pores in the weld exceeding 0.010-inch diameter. The total surface porosity in one inch of weld length shall not exceed 2% of the area equal to (1Xt) square inches, where t equals the thickness of the thinnest member.

6.2 Dye Penetrant Inspection. The bottom end cap TIG closure weld only shall be given a dye penetrant inspection using an ultrasensitive fluorescent penetrant (Tracer Tech P-150 or equal) to determine if the weld meets the following requirements.

6.2.1 Cracks. There shall be no linear indications on the weld or base metal adjacent to the weld.

6.2.2 Surface Pores. There shall be no surface pores in the weld exceeding 0.010-inch diameter. The total surface porosity in one inch of weld length shall not exceed 2% of an area equal to (1Xt) square inches, where t equals the thickness of the thinnest member.

6.3 Leak Test. The outer clad subassembly (bottom cap welded to cylindrical can) and final HSA shall be helium leak checked with a mass spectrometer type helium leak detector to determine if they meet the following requirements.

6.3.1 Subassembly. There shall be no leaks detected of greater than 1 x 10^{-5} std. cc/sec when the "sniffer technique is used.

6.3.2 HSA. The final assembly shall not have a leak rate exceeding 1 x 10^{-4} std. cc/sec. As an alternate test, the T.I.G. enclosure weld and the area approximately one inch on either side of this weld shall have no leaks detected of greater than 1 x 10^{-5} std. cc/sec using the "sniffer" technique. Alternate test may be used only after the former method has been tried and found to be either unacceptably long in duration or otherwise difficult to perform.

6.4 Verification Welds. Verification closure welds using appropriate caps and weld rings shall be performed periodically during production to verify the facilities and operators are functioning as planned.

7. D E C O N T A M I N A T I O N.

The external surface of the completed HSA shall exhibit a standard wipe value of less than 220 dpm.

8. A D D I T I O N A L N D T T E S T I N G

MRC-Mound Laboratory shall perform any additional operations or tests which are considered necessary to insure the quality of the completed procedure. GE shall be informed of any additional work. It will be documented and available for review at Mound Laboratory.

9. D A T A P A C K A G E.

The following information for each shipment will be provided to GE:

9.1 The serial number for each fueled HSA and applicable revision levels of specifications and drawings.

9.2 A listing of the serial numbers of all components and drawing numbers which make up each final assembly.

9.3 A listing and description of all deviations and GE/MRC MRB dispositions associated from each fueled HSA.

9.4 The total thermal output as determined by calorimetry on individual fuel for FSA components.

9.5 The specific neutron emission rate.

9.6 The surface contamination wipe count as referenced in Section 7.

9.7 Results of Health Physics neutron and gamma does rate measurements at time of shipment.

MRC SPEC. No. 1-14813

ISSUE	DATE	REVISION	BY	CHK'D.	APPRD
0	3 2 73	ORIGINAL ISSUE	CC	38M	EWJ
1	8 10 73	PER ACO 1-14813-M1-C	CC	Les	CWS
C	3-7-74	PRIOR NUMERICAL ISSUES DENOTE CONTROLLED ISSUES- ACO 1-14813-M2-C	HC	Les	CWS
D	4-5-74	PER ACO1-14813-M3-C	HC	Les	CWS

SHEET	1	2	3	4	5
ISSUE	D	C	C	C	D

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

MHW

MHW FUEL SPECIFICATION

DWG. CLASSIFICATION
LEVEL Unclass GP —
DATE 3 15 73 INIT EWJ

DRAWN C. CRAFT DATE 3873
CHECKED 38M DATE 3-15-73
APPROVED R.C. [illegible] DATE 3-21-73
JOB NO —
PART NO. —

APPROVALS
1 [illegible]
2
3
4

SP — DWG TYPE
CODE IDENT. NO. 14065
DWG. NO. 1-14813 SHT. 1 OF 5

1. Scope. This fuel specification defines the chemical and physical requirements for plutonium-238 oxide oxygen-16 exchanged spheres for the Multi-Hundred Watt Program.

2. Applicable Documents.

2.1 Current issues of the following drawings and specifications form a part of this specification where applicable.

GE dwg 47B301663 - Fuel Spheres

2.2 Information and Reference Documents. The following documents provide information for fabrication and inspecting the Multi-Hundred Watt fuel sphere MD-10058 - Mound Laboratory Quality Control Policy; MD-10080 - Product Index Preparation Instructions; MD-10095 - Engineering Change Notice Preparation Instructions; MD-1-11533 - Procedure for Nonconforming Material Request.

Manual No.	Operation No.	Operation Title
MD-70132	1	Analytical Request
	2	Sample Preparation for Am-241 & Pu-236 Determinations
	3	Sample Preparation for Emission Spectrographic Analysis
	5	Sample Preparation for Actinide & Isotopic Analysis
	10	Normality and Total Alpha Determinations
	11	Apparent Density Determination
	12	Plutonium Absorbance Spectrum
	15	Carbon Determination
	16	Impurity Determination by Emission Spectroscopy
	21	Thorium Determination
	24	Am-241 and Pu-236 Determinations
	25	Actinide and Isotopic Analysis
	32	Dissolution Methods
	33	Qualitative Ammonium Determination
	36	Miscellaneous Determination
	37	Uranium Determination in Plutonium
	39	Sample Preparation for Liquid Scintillation Counting
	40	Standard Determination
MD-70133	1	Dissolution of Plutonium Dioxide
	2	$^{238}PuO_2$ Precipitation
	5	$^{238}PuO_2$ Precrushing and Sizing ($<297\mu m$)
	6	Calcining, $^{16}O_2$ Exchange and Sintering ($<297\mu m$)
	20	MHW Sphere Pressing, Preliminary Gaging and Weighing
	21	$^{16}O_2$ Treatment (Sphere)
	22	Vacuum Outgassing (Sphere)
	23	Final Gage and Weighing (Sphere)

2.3 Precedence of Documents. In the event of conflict between this specification and any other documents, this specification shall prevail.

2.4 Changes. Changes in this specification shall be handled in accordance with MD-10095, "Engineering Change Notice Preparation Instruction."

3. Requirements. MRC - Mound Laboratory shall conform to the following requirements:

3.1 Nonconforming Material. Materials which do not comply with the requirements of this specification shall be handled in accordance with Mound Drawing 1-11533, "Procedures for Nonconforming Material Request" and the Multi-Hundred Watt Material Review Board, as appropriate.

4. Feed Materials.

4.1 Plutonium-238 Dioxide. The plutonium-238 dioxide shall meet the limits specified below.

4.1.1 Plutonium-238 Content. 80±2 percent of the atoms of plutonium shall be of atomic weight 238.

4.1.2 Isotopic Composition. Mass isotopic composition of the plutonium shall be determined.

4.1.3 Plutonium-236 Content. Plutonium-236 shall not exceed 2 ppm of the total plutonium content.

4.1.4 Actinide Impurities. The actinide impurities of Am-241, Np, U and Th shall not exceed 1% of the total plutonium content. No individual impurity shall exceed 0.5% when back decayed to date of precipitation.

4.2 Oxygen-16. Not less than 99.98% of the atoms of oxygen shall be atomic weight 16 if gaseous oxygen (O_2)-16 is used.

5. Oxygen-16 Exchanged Sintered Powder Feed.

5.1 Impurities. The total of all nonactinide cationic impurities analyzed in each blended batch of oxygen-16 exchanged sintered powder feed shall not exceed 2850 ppm (powder weight). Fe, Ta, and Si shall not exceed the limits listed in the following table; and the other listed individual elements shall be reported if they exceed the following limits:

Element	Concentration (ppm by powder weight)
Al	150
Ca	300
Cd	50
Co	100
Cr	250
Cu	100
Fe	800
Mg	50
Mn	50
Na	250
Ni	150
Pb	100
Si	200
Sn	50
Ta	200
Zn	50

5.2 Particle Size. The sintered powder feed shall pass through a U.S. Standard Sieve, Series No. 50 or equivalent. (Reference: 297μm).

6. Plutonium-238 Dioxide Sphere.

6.1 Dimensions. All dimensions shall be corrected to 20°C using a thermal expansion coefficient of 9.13×10^{-6} inches per inch per degree Centigrade.

6.2 Diameter. The diameter of the plutonium-238 dioxide sphere shall be 1.465 ± 0.015 inches.

6.3 Thermal Power. Each fabricated plutonium-238 dioxide sphere shall contain a thermal inventory of 100(+3.0/-2.0) watts as measured by calorimetry. Calorimeter error is defined as ±0.5% at the 95% confidence level.

6.4 Specific Neutron Emission Rate. The specific neutron emission rate shall be determined on each as processed plutonium-238 dioxide sphere and shall be no greater than 8.0×10^3 neutrons/second/gram of plutonium-238. (Reference: 6.4×10^3 neutrons/second/gram of total plutonium).

6.5 Non-Integral Sphere. Acceptance of spheres exhibiting cleavages shall be made based on a technical assessment of the usability of each sphere.

7. Testing.

7.1 Additional Testing. Mound will do any additional testing which it considers appropriate to ensure the quality of this fuel form.

7.2 Verification Analysis. One PPO sphere in every 25 spheres shall be subjected to chemical and physical analyses. The carbon content shall not exceed 200 ppm. The O/Pu ratio shall not be less than 1.90 as determined by Thermo Gravimetric Analysis.

7.3 Historical Samples. A portion of each verification sphere shall be retained as a representative historical sample.

8. Records.

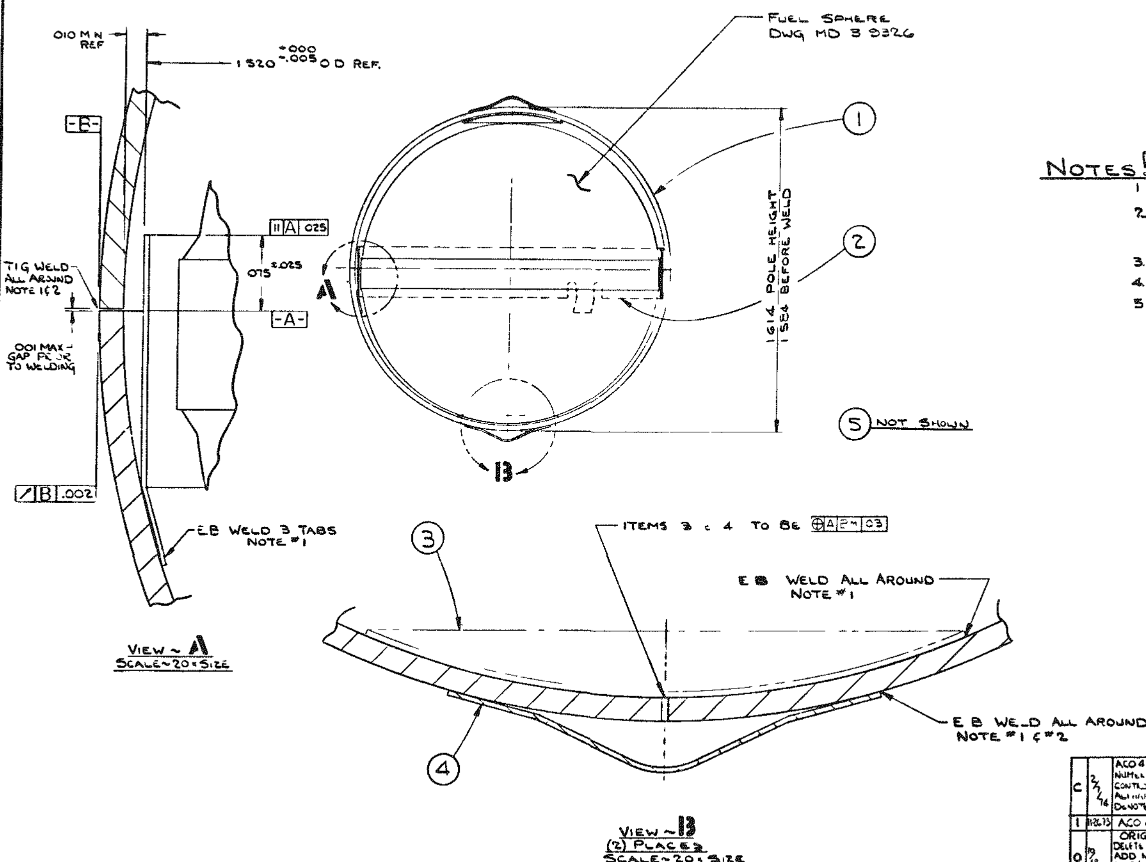
8.1 Retention of Records. All production and analytical data shall be retained in accordance with AEC guidance or product specification requirements.

4 10942

W.O. NO. M 34511 001

BILL OF MATERIAL

DET	DWG N	DESCRIPTION	REQ'D	MAT'L	STOCK SIZE
1	3 9316	HEMISPHERES	2	IRIDIUM	SEE DWG
2	3-9313	WELD SHIELD	1	IRIDIUM	SEE DWG
3		VENT	2	PUR	SEE NOTE 5
4	3 9317	DECONTAMINATION COVER	2	IRIDIUM	SEE DWG
5	39..3	BLANK IRIDIUM		IRIDIUM	SEE DWG



NOTES:

1. ALL WELDING TO BE DONE AT MOUND LABORATORY PER MRC ACCEPTANCE SPECIFICATION MD 1-14505.
2. WELD SHALL NOT LEAK WHEN SUBJECT TO DIFFERENTIAL PRESSURE OF (1) ATMOSPHERE, LEAK RATE SHALL NOT EXCEED 1×10^{-6} STD CC HELIUM/SEC.
3. MAT'L. SPEC IRIDIUM SHEET & FOIL PER DWG MD1 14861 AND/OR MD1-14142
4. MAT'L SPEC. IRIDIUM BLANK PER DWG MD 1-14941
5. ITEM 3 FURNISHED BY G E AND COMPOSED OF THE FOLLOWING:
   - 47C303127 PARTICULATE SHIELD ASSEM (FRIT)
   - 47B303153 WELD DISK WASHER

ISS	DATE	REVISION	BY	CHK'D	APPR'D
C	2/7/74	ACO 4 10142 M4 C PRIOR NUMERICAL ISSUES DENOTE CONTROLLED ISSUES PRIOR ALPHABETICAL ISSUES DENOTE PRELIMINARY ISSUES	LLE		
1	11-26-73	ACO 4 10142 M1-C	LLE		
0	10/18/73	ORIGINAL ISSUE DELETE NOTE 1 & NEW NOTE 1 WAS 2 ADD NOTE 1 & 2 TO TIG WELD 1.612/1.534 WAS 1.612/1.582 ADD E B 3 PLACES	LLE		
F		1.612/1.592 WAS 1.612/1.564	LLE		
E	10/5/73	1.612/1.584 WAS 1.604/1.576 & REV NOTES 1 & 5			
D	9-24-73	REV PER DET REVISIONS	LLE		
C	6-28-73	[illegible] WAS		LLE	
B	6-13	[illegible]			
A	5-.73	PRELIMINARY ISSUE	LLE		

SK-D 2766

DWG TYPE: TOP

TOLERANCES: FRACTIONAL TOL ± 1/64; DECIMAL TOL ± .010; ANGLE TOL ± 1/2°; SURFACE FIN 63; UNLESS OTHERWISE SPECIFIED

PART CLASSIFICATION: LEVEL UNCL; DATE 5 18 73

DWG CLASSIFICATION: LEVEL UNCL; DATE 5 18 73

CODE IDENT NO 14065

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

M H W

POST IMPACT CONTAINMENT SHELL MRC PRODUCT IF

DRAWN: L. L. ETTER DATE 5 18 73
CHECKED: DATE 6-4-73
APPROVED: R E R DATE 6 9 73
JOB NO: 9052
SCALE: 4/1 & 20/1

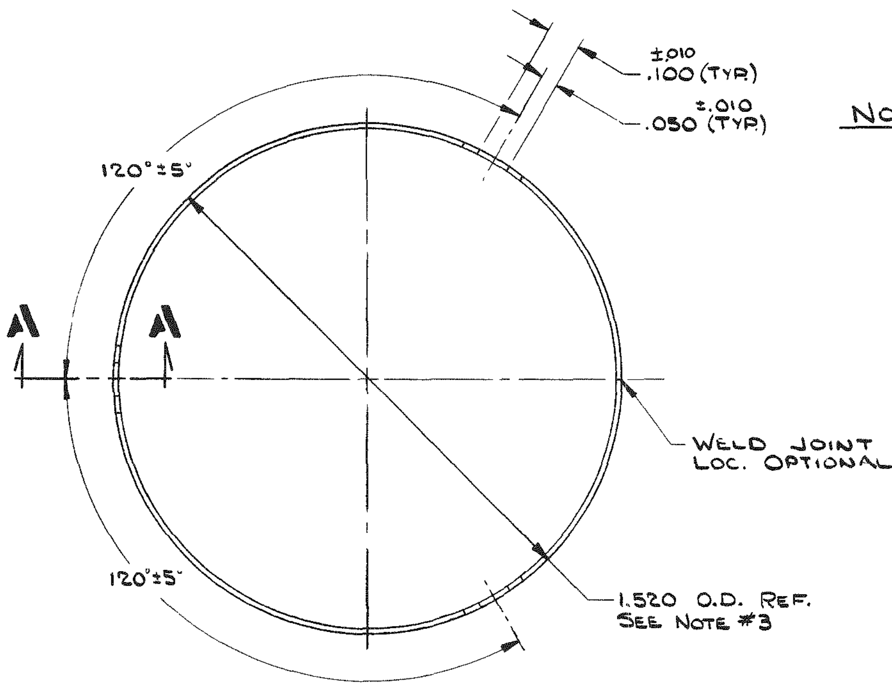
DWG NO 4-10942 SHT 1 OF 1

3-9313

W.O. NO.

BILL OF MATERIAL

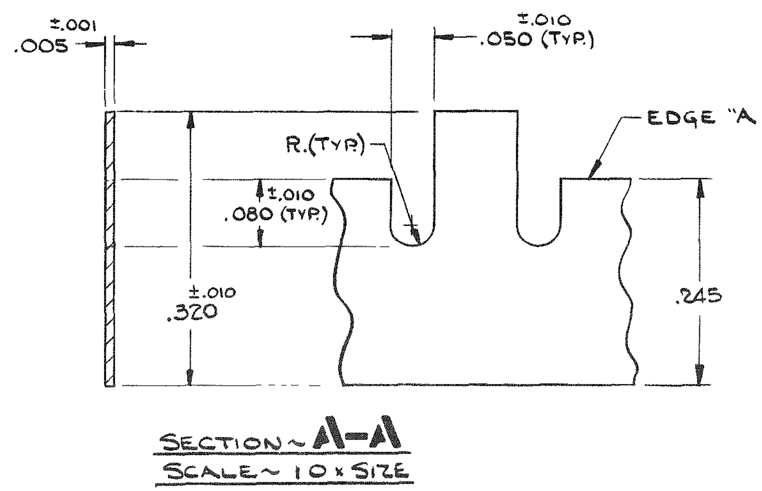
DET.	DWG. NO.	DESCRIPTION	REQ'D.	MAT'L.	STOCK SIZE



NOTES:

1. O.D. APPLIES WHEN RESTRAINED.
2. MAT'L. SPEC., IRIDIUM, SHEET & FOIL PER DWG. MD 1-14861 CLASS III TYPE 2 OR DWG MD1-14942 CLASS III TYPE 3.
3. DEVELOPED LENGTH OF PART 4.741 – 4.762.
4. PART TO BE MANUFACTURED AND IDENTIFIED IN ACCORDANCE WITH MRC FORMING SPECIFICATION SP 1-14958.

(2) 1-REQ'D. ~ IRIDIUM (NOTE #2)



SECTION ~ A-A
SCALE ~ 10 x SIZE

IV-43

ISS	DATE	REVISION	BY	CHK'D	APPRD
C	3/28/74	ACO 4-10942-M6-C PRIOR NUMERICAL ISSUES OF THIS DRAWING DENOTE CONTROLLED ISSUES PRIOR ALPHABETICAL ISSUES DENOTE PRELIMINARY ISSUE	LLE	JEA	[illegible]
1	11-26-73	ACO 4-10942-M1-C	LLE	JEA	[illegible]
O	10-22-73	ORIGINAL ISSUE	LLE	JEA	[illegible]
D	10/19/73	1.520 O.D. REF. WAS 1.520 +.002/−.005 O.D. & ADD SEE NOTE #3	LLE	JEA	BRET
C	9/24/73	NOTE 2-ADD MD1-14942 DELETE IDENTIFICATION MARK & NOTE 3- NOTE 3 WAS 4	LLE	JEA	BRET
B	6-15-73	CLASS & TYPE OF MAT ADDED	JEA	[illegible]	BRET
A	5-22-73	PRELIMINARY ISSUE	LLE	JEA	BRET

DESIGNED FOR PART NO. & ISSUE | REFERENCE DWG & ISSUE: SK-C-2765

DWG TYPE: COM

TOLERANCES:
FRACTIONAL TOL. ~
DECIMAL TOL. ±.005
ANGLE TOL. ±1°
SURFACE FIN. 63
UNLESS OTHERWISE SPECIFIED

PART CLASSIFICATION LEVEL UNCL GP ___ DATE 5-22-73 INIT RER

DWG. CLASSIFICATION LEVEL UNCL GP ___ DATE 5-22-73 INIT RER

CODE IDENT. NO. 14065

FINAL ASSEMBLY DWG. | NEXT ASSEMBLY DWG.

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

M.H.W.

WELD SHIELD

			APPROVALS
DRAWN L.L. ETTER	DATE 5-22-73		1 BRET
CHECKED JEA	DATE 6-4-73		2
APPROVED RER	DATE 6-4-73		3
JOB NO 9052			4
SCALE 4/1 & 10/1			

DWG. NO. 3-9313 SHT. 1 OF 1

DECK- G1

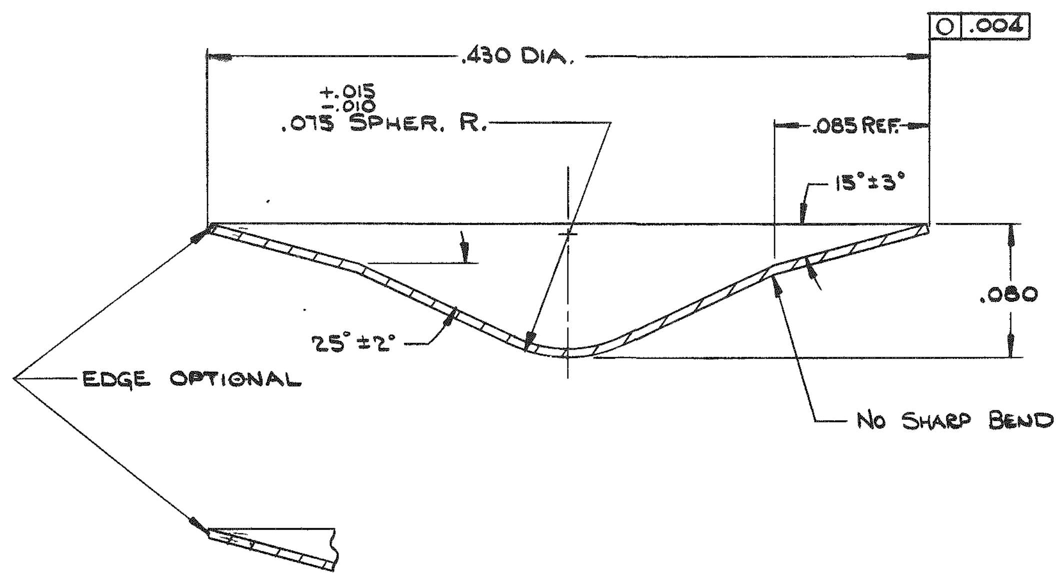
IV-44

3- 9317

W.O. NO.					
BILL OF MATERIAL					
DET.	DWG. NO.	DESCRIPTION	REQ'D.	MAT'L.	STOCK SIZE

NOTES:

1. MAT'L. SPEC., IRIDIUM, SHEET & FOIL PER DWG. MD 1-14861, CLASS II TYPE 2 OR MD 1-14942.
2. PART TO BE MANUFACTURED AND IDENTIFIED IN ACCORDANCE WITH MRC FORMING SPECIFICATION SP 1-14066.



(4) 2-REQ'D.~ IRIDIUM .005 ±.001 THK. (NOTE #1)

ISS.	DATE	REVISION	BY	CHK'D	APPRD.
1	11-26-73	ACO 4-10942-M1-C	LLE	JEA	
0	10-22-73	ORIGINAL ISSUE	LLE	JEA	
C	9/24/73	ADD ROUNDNESS TO .002 TO .430 DIA. NOTE 1-ADD MD1-14942	LLE	JEA	BRET
B	6-19-73	CLASS & TYPE OF MAT. ADDED	JEA		BRET
A	5-22-73	PRELIMINARY ISSUE	LLE	JEA	BRET

DESIGNED FOR PART NO. & ISSUE	REFERENCE DWG. & ISSUE
	SK-C-2772

DWG. TYPE: COM

TOLERANCES:
FRACTIONAL TOL. ± 1/64
DECIMAL TOL. ±.010
ANGLE TOL. ±1°
SURFACE FIN. 63
UNLESS OTHERWISE SPECIFIED

PART CLASSIFICATION
LEVEL UNCL GP.
DATE 5-22-73 INIT RR

DWG. CLASSIFICATION
LEVEL UNCL GP.
DATE 5-22-73 INIT RR

CODE IDENT. NO. 14085

FINAL ASSEMBLY DWG.	NEXT ASSEMBLY DWG.

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

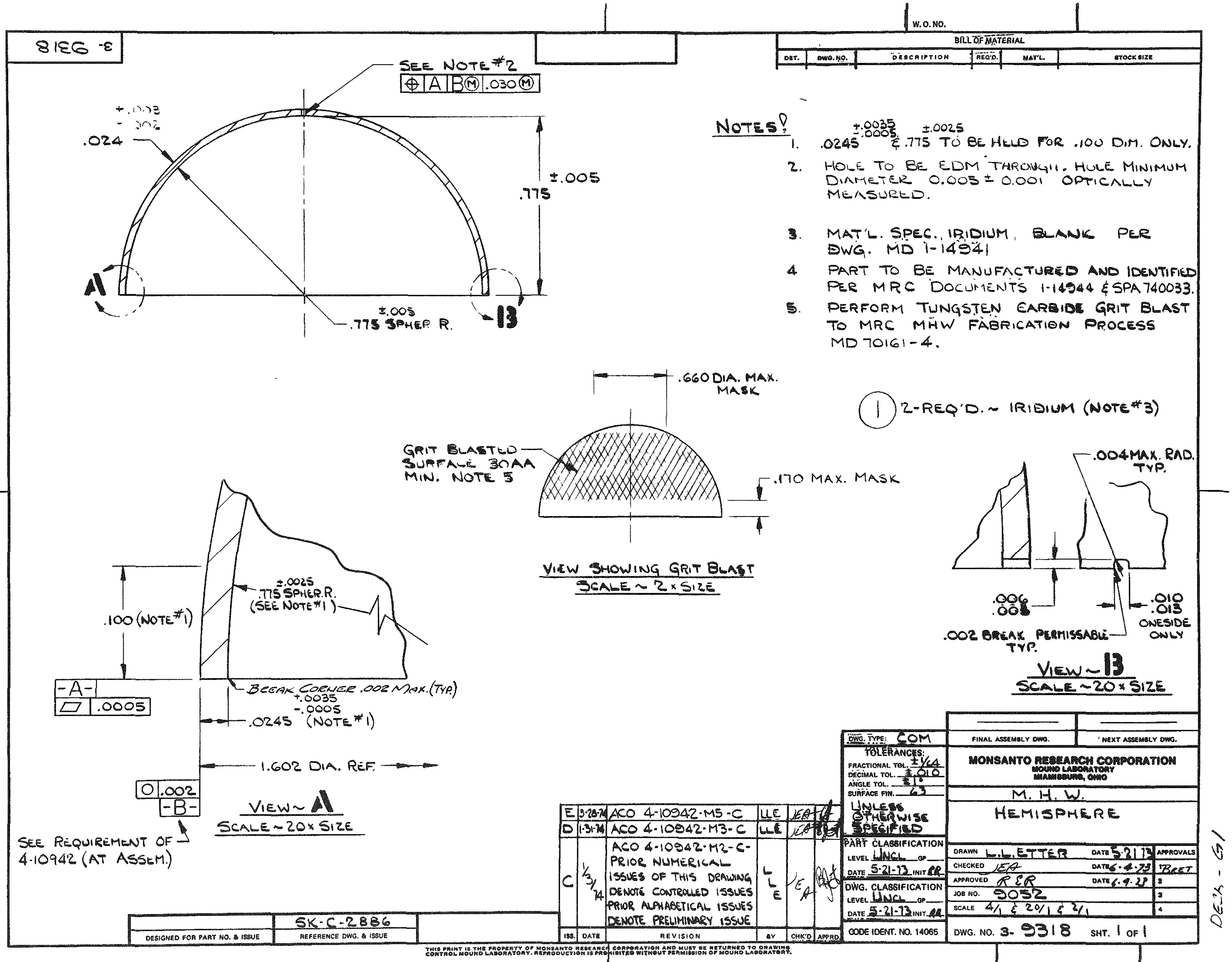
M. H. W.

DECONTAMINATION COVER

DRAWN L. L. ETTER	DATE 5-22-73	APPROVALS	
CHECKED JEA	DATE 6-4-73	1	BRET
APPROVED RER	DATE 6-4-73	2	
JOB NO 3052		3	
SCALE 20/1		4	

DWG. NO. 3- 9317 SHT. 1 OF 1

DECK. G1

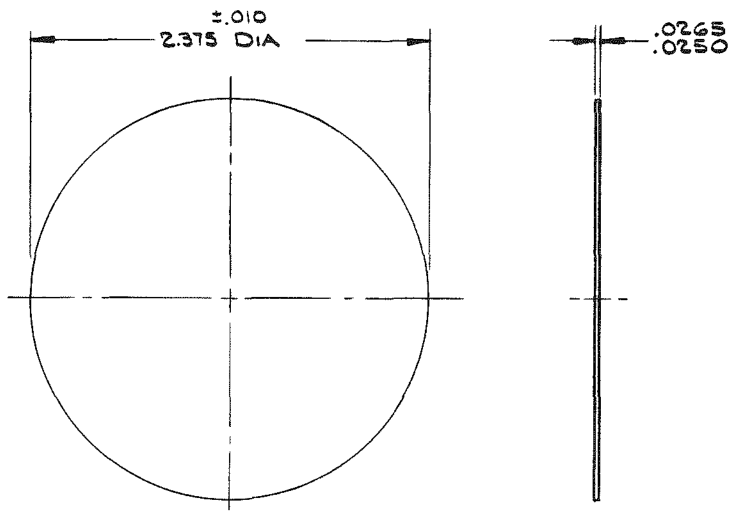

3-9318
W. O. NO.
BILL OF MATERIAL
DET. | DWG. NO. | DESCRIPTION | REQ'D. | MAT'L. | STOCK SIZE
SEE NOTE #2
⊕ | A | B Ⓜ | .030 Ⓜ
+.003 -.002 .024
.775 ±.005
±.005 .775 SPHER R.
A
B
NOTES:
1. .0245 +.0035/-.0005 & .775 ±.0025 TO BE HELD FOR .100 DIM. ONLY.
2. HOLE TO BE EDM THROUGH. HOLE MINIMUM DIAMETER 0.005 ± 0.001 OPTICALLY MEASURED.
3. MAT'L. SPEC., IRIDIUM, BLANK PER DWG. MD 1-14941
4. PART TO BE MANUFACTURED AND IDENTIFIED PER MRC DOCUMENTS 1-14944 & SPA 740033.
5. PERFORM TUNGSTEN CARBIDE GRIT BLAST TO MRC MHW FABRICATION PROCESS MD 70161-4.
.660 DIA. MAX. MASK
① 2-REQ'D. ~ IRIDIUM (NOTE #3)
GRIT BLASTED SURFACE 30AA MIN. NOTE 5
.170 MAX. MASK
VIEW SHOWING GRIT BLAST
SCALE ~ 2 x SIZE
.004 MAX. RAD. TYP.
.006 .008
.010 .013 ONESIDE ONLY
.002 BREAK PERMISSABLE TYP.
VIEW ~ B
SCALE ~ 20 x SIZE
.100 (NOTE #1)
±.0025 .775 SPHER. R. (SEE NOTE #1)
-A-
▱ | .0005
BREAK CORNER .002 MAX. (TYP.)
+.0035 -.0005 .0245 (NOTE #1)
1.602 DIA. REF.
○ | .002
-B-
VIEW ~ A
SCALE ~ 20x SIZE
SEE REQUIREMENT OF 4-10942 (AT ASSEM.)
E | 3-28-74 | ACO 4-10942-M5-C | LLE
D | 1-31-74 | ACO 4-10942-M3-C | LLE
C | 1/3/74 | ACO 4-10942-M2-C- PRIOR NUMERICAL ISSUES OF THIS DRAWING DENOTE CONTROLLED ISSUES PRIOR ALPHABETICAL ISSUES DENOTE PRELIMINARY ISSUE | LLE
ISS. | DATE | REVISION | BY | CHK'D | APPRD.
DESIGNED FOR PART NO. & ISSUE
SK-C-2886
REFERENCE DWG. & ISSUE
DWG. TYPE: COM
TOLERANCES:
FRACTIONAL TOL. ±1/64
DECIMAL TOL. ±.010
ANGLE TOL. ±1°
SURFACE FIN. 63
UNLESS OTHERWISE SPECIFIED
PART CLASSIFICATION LEVEL UNCL GP. DATE 5-21-73 INIT RR
DWG. CLASSIFICATION LEVEL UNCL GP. DATE 5-21-73 INIT RR
CODE IDENT. NO. 14065
FINAL ASSEMBLY DWG.
NEXT ASSEMBLY DWG.
MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO
M. H. W.
HEMISPHERE
DRAWN L. L. ETTER DATE 5-21-73
CHECKED JEA DATE 6-4-73
APPROVED RER DATE 6-4-73
JOB NO. 9052
SCALE 4/1 & 20/1 & 2/1
APPROVALS
DWG. NO. 3-9318 SHT. 1 OF 1
THIS PRINT IS THE PROPERTY OF MONSANTO RESEARCH CORPORATION AND MUST BE RETURNED TO DRAWING CONTROL MOUND LABORATORY. REPRODUCTION IS PROHIBITED WITHOUT PERMISSION OF MOUND LABORATORY.
DEK - G1

3-9329

W.O. NO.

BILL OF MATERIAL

DET.	DWG. NO.	DESCRIPTION	REQ'D	MAT'L.	STOCK SIZE



NOTES:

1. E.D.M FROM SHEET STOCK
2. 32/ A. A. OR LESS EXCEPT FOR EDM EDGE.
3. ALL FLAT SURFACES TO BE GROUND PER ORNL MET-MatP-FQ-21.
4. IRIDIUM PER MRC SPECIFICATION MD1-14941.

(5) MAT'L. ~ IRIDIUM TYPE W (SEE NOTE #4)

ISS	DATE	REVISION	BY	CHK'D	APPRD
1	11-16-73	ACO 4-10942-M1-C	LLE	JEA	BRET
0	10/18/73	ORIGINAL ISSUE .0265/.0250 WAS .0255 .0240 & REV. NOTES 2 & 3	LLE	JEA	
B	9/24/73	IRIDIUM WAS DEVELOPMENT DELETE FLATNESS (2) & NOTES 3 & 4 DET. 5 WAS 9, 2.375 ±.010 WAS 2.375 ±.005	LLE	JEA	BRET
A	6-4-73	PRELIMINARY ISSUE	LLE	JEA	BRET

DESIGNED FOR PART NO. & ISSUE | REFERENCE DWG & ISSUE

DWG. TYPE COM

TOLERANCES:
FRACTIONAL TOL. ~
DECIMAL TOL. ~
ANGLE TOL. ~
SURFACE FIN. ~

PART CLASSIFICATION
LEVEL UNCL GP.
DATE 6-4-73 INIT.

DWG. CLASSIFICATION
LEVEL UNCL GP.
DATE 6-4-73 INIT.

CODE IDENT. NO. 14065

FINAL ASSEMBLY DWG | NEXT ASSEMBLY DWG.

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

M H W.

BLANK, IRIDIUM

DRAWN L.L. ETTER DATE 6-4-73
CHECKED JEA DATE 6-4-73
APPROVED RER DATE 6-3-73
APPROVALS BRET
JOB NO 9052
SCALE 2/1

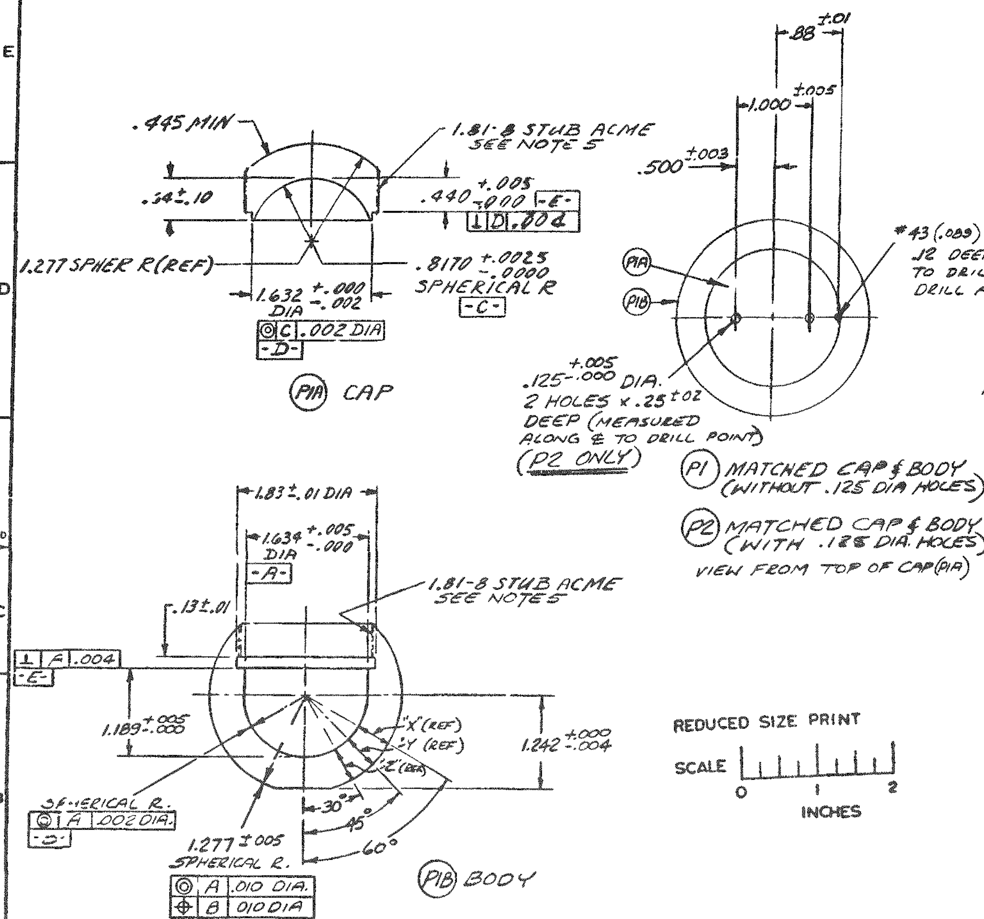
DWG. NO. 3-9329 SHT. 1 OF 1

DEC 14 - 81

SIZE		REV
E	47C302509	F

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	INC AV-1	73	HH
	B	INC. AN-2	4 MAY 73	HH
	C	INC AN-3	73	HH
	D	INC AN-4	73	HH
	E	INC AN-5	73	HH
	F	INC AN-6	DEC 73	HH



NOTES:

1. CAP(P1A) & BODY(P1B) SHALL BE MATCHED. WITH SURFACES "E" OF P1A & P1B IN CONTACT THE OUTSIDE SPHERICAL RADIUS SHALL BE 1.272 TO 1.282, EXCEPT FOR FLAT ON P1B.
2. MARK "GE47C302509P_" & MFG. SERIAL NO. PER 118A1526 CLASS 17.
3. PACKAGING & HANDLING PER SENTENCE 2 OF PARA 5.1 AND PARA 3.3.8 OF GE SPEC NS0060-02-49 AFTER ALL MANUFACTURING & INSPECTION PROCEDURES ARE COMPLETED.
4. DWG TERMS & TOL PER 171A4286.
5. THE INTERFERENCE BETWEEN THE MAJOR DIAMETER OF THE CAP THREAD AND THE MINOR DIAMETER OF THE BODY THREAD SHALL BE A MINIMUM OF 0.018 INCHES ON AT LEAST TWO OF THE THREE THREAD READINGS WHEN MEASURED ON THE FULL THREADS OF THE BODY AND CAP AT THE INDEX DRILL HOLE DIAMETER. THE MATING THREADS SHOULD ENGAGE BY HAND WITHOUT DIFFICULTY AND THE FREE AXIAL TRANSLATION BETWEEN THE CAP AND BODY THREADS SHOULD BE 0.015 INCHES OR LESS WHEN THE CAP IS APPROX. THREE-QUARTERS ENGAGED.

REFERENCE - FOR INSPECTION PURPOSES ONLY

DIM	ANGLE	MIN AVERAGE WALL THICKNESS - 4 READINGS EQUALLY SPACED
X	60°	.4525 (REF.)
Y	45°	.4525 (REF.)
Z	30°	.4525 (REF.)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
ALL SURF

MATERIAL - RESIN IMPREG. T-50 NS0060-02-49

SIGNATURES: DRAWN 15/11/72; CHECKED; ISSUED 15/11/72; ENGR 15/11/72; MFG 15/11/72; MATL 15/11/72; PO 15/11/72; STRESS 15/11/72

GENERAL ELECTRIC

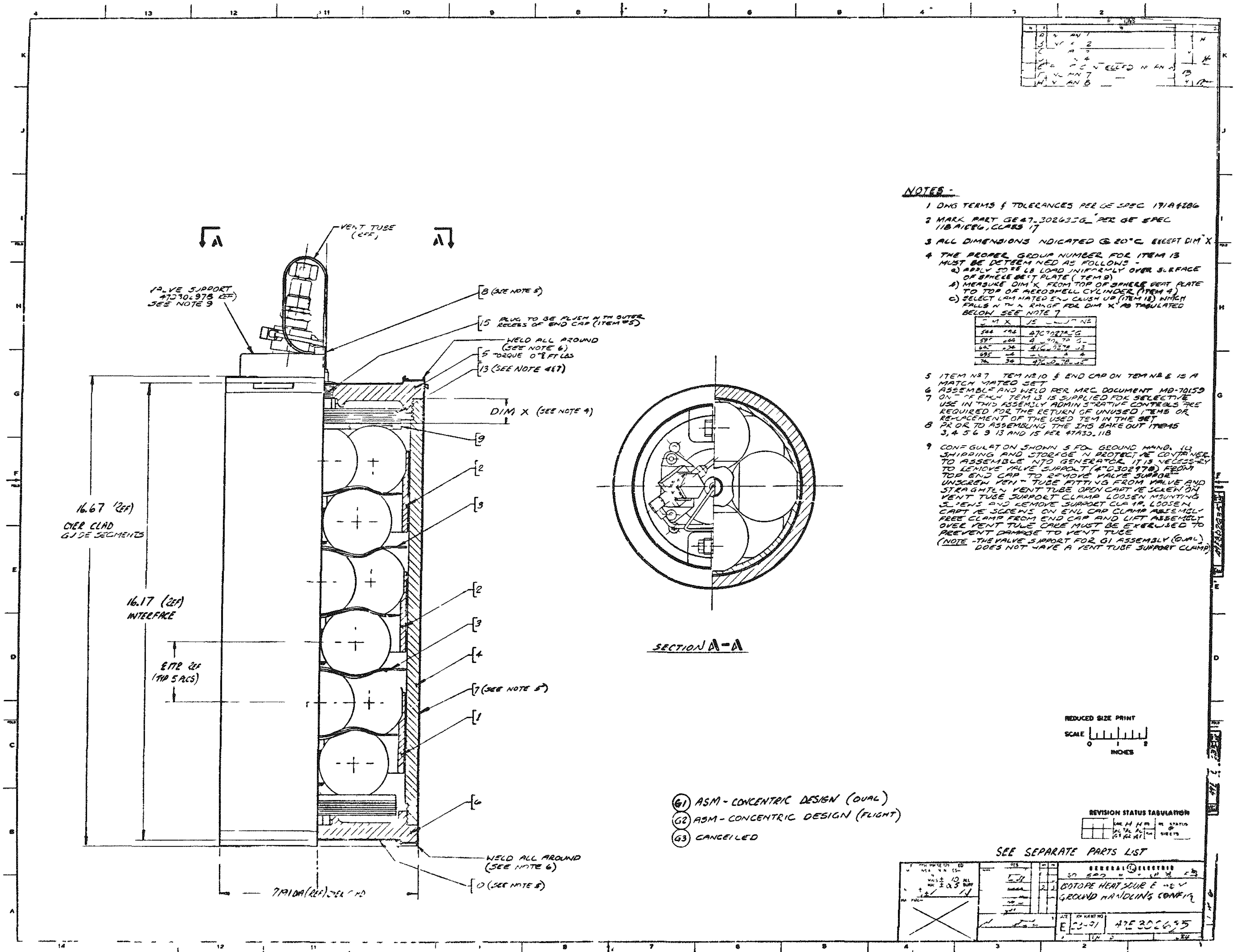
ISAO-550 DEPT LOC PHILA., PA/CCF-8

CAP & BODY MATCHED, CONCENTRIC DESIGN IMPACT SHELL

SIZE C | CODE IDENT NO 23991 | 47C302509

SCALE 1/1 | SHEET 1 OF 1

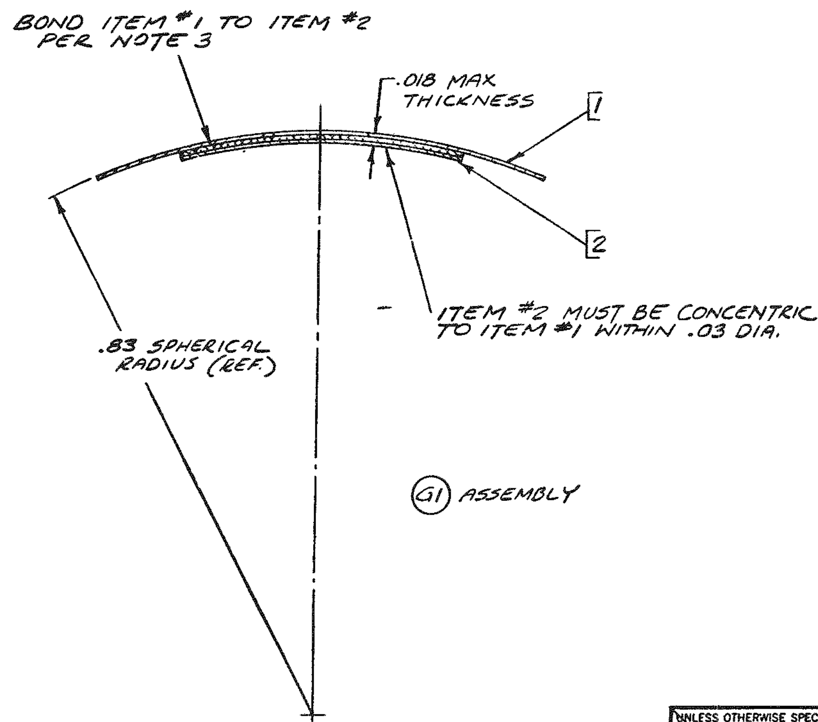
DIST ON MIW-G


VENT TUBE (REF)
VALVE SUPPORT 47C302978 (REF) SEE NOTE 9
8 (SEE NOTE 5)
15 PLUG TO BE FLUSH WITH OUTER RECESS OF END CAP (ITEM #5)
WELD ALL AROUND (SEE NOTE 6)
5 TORQUE 0-8 FT LBS
13 (SEE NOTE 4&7)
DIM X (SEE NOTE 4)
16.67 (REF) OVER CLAD GUIDE SEGMENTS
16.17 (REF) INTERFACE
7 (SEE NOTE 5)
WELD ALL AROUND (SEE NOTE 6)
10 (SEE NOTE 5)
7.191 DIA (REF)
SECTION A-A
NOTES -
1 DWG TERMS & TOLERANCES PER GE SPEC 171A4286
2 MARK PART GE47-302635G_ PER GE SPEC 118A1886, CLASS 17
3 ALL DIMENSIONS INDICATED @ 20°C EXCEPT DIM X
4 THE PROPER GROUP NUMBER FOR ITEM 13 MUST BE DETERMINED AS FOLLOWS -
a) APPLY 50 LB LOAD UNIFORMLY OVER SURFACE OF SPHERE SEAT PLATE (ITEM 9)
b) MEASURE DIM X FROM TOP OF SPHERE SEAT PLATE TO TOP OF AEROSHELL CYLINDER (ITEM 4)
c) SELECT LAMINATED END CRUSH UP (ITEM 13) WHICH FALLS WITHIN RANGE FOR DIM X AS TABULATED BELOW SEE NOTE 7
5 ITEM Nº 7 ITEM Nº 10 & END CAP ON ITEM Nº 8 IS A MATCH MATED SET
6 ASSEMBLE AND WELD PER MRC DOCUMENT MD-70159
7 ONE OF EACH ITEM 13 IS SUPPLIED FOR SELECTIVE USE IN THIS ASSEMBLY ADMINISTRATIVE CONTROLS ARE REQUIRED FOR THE RETURN OF UNUSED ITEMS OR REPLACEMENT OF THE USED ITEM IN THE SET
8 PRIOR TO ASSEMBLING THE IHS BAKE OUT ITEMS 3, 4 5 6 9 13 AND 15 PER 47A33_118
9 CONFIGURATION SHOWN IS FOR GROUND HANDLING, SHIPPING AND STORAGE IN PROTECTIVE CONTAINER. TO ASSEMBLE INTO GENERATOR IT IS NECESSARY TO REMOVE VALVE SUPPORT (47C302978) FROM TOP END CAP. TO REMOVE VALVE SUPPORT UNSCREW VENT TUBE FITTING FROM VALVE AND STRAIGHTEN VENT TUBE. OPEN CAPTIVE SCREW ON VENT TUBE SUPPORT CLAMP. LOOSEN MOUNTING SCREWS AND REMOVE SUPPORT CLAMP. LOOSEN CAPTIVE SCREWS ON END CAP CLAMP ASSEMBLY. FREE CLAMP FROM END CAP AND LIFT ASSEMBLY OVER VENT TUBE. CARE MUST BE EXERCISED TO PREVENT DAMAGE TO VENT TUBE
(NOTE - THE VALVE SUPPORT FOR G1 ASSEMBLY (QUAL) DOES NOT HAVE A VENT TUBE SUPPORT CLAMP)
G1 ASM - CONCENTRIC DESIGN (QUAL)
G2 ASM - CONCENTRIC DESIGN (FLIGHT)
G3 CANCELLED
REDUCED SIZE PRINT
SCALE
INCHES
REVISION STATUS TABULATION
SEE SEPARATE PARTS LIST
GENERAL ELECTRIC
ISOTOPE HEAT SOURCE
GROUND HANDLING CONFIG
47E302635

C 47C303127 A

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	INC. MN-1	4 DEC 73	MH



NOTES:-

1. DWG TERMS & TOLERANCES PER 171A4286.
2. MARK "GE47C303127G1" PER 118A1526, CLASS 17.
3. FABRICATE PER GE SPEC N50060-02-78.

REDUCED SIZE PRINT

SCALE 0 1 2 INCHES

SEE SEPARATE PL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES— TOLERANCES ON: 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ± FRACTIONS ± ALL SURF. ✓

MATERIAL—

SIGNATURES	DAY	MO	YR
DRAWN D V Schmidt	5	11	73
CHECKED F F Bunker	21	11	73
ISSUED	27	11	73
ENGRG	21	11	73
MFG	26	11	73
MATL	21	11	73
FA	26	11	73
PO	27	11	73

GENERAL ELECTRIC

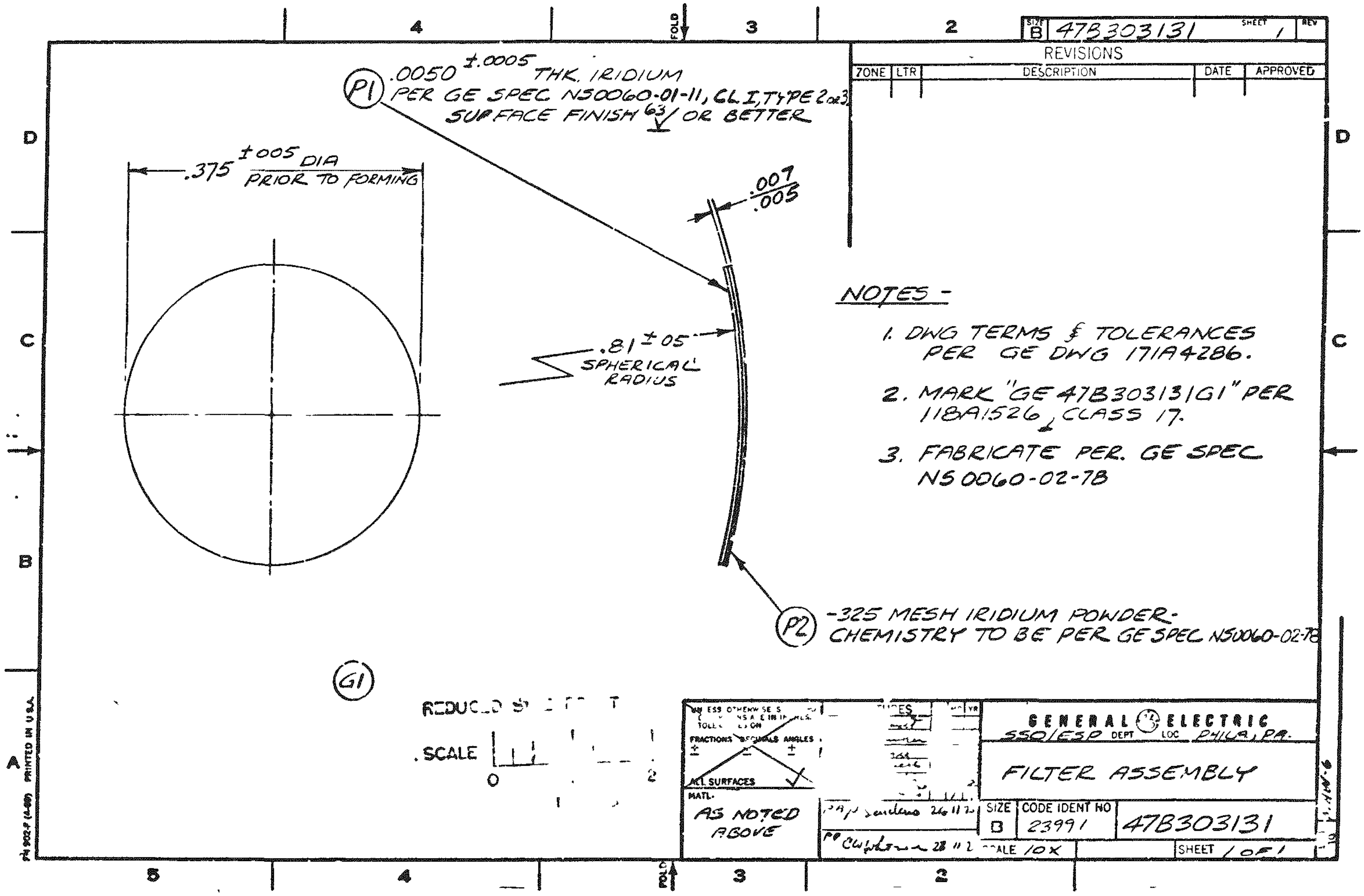
550/ESP DEPT LOC PHILA, PA

PARTICULATE SHIELD ASSY FRIT DESIGN

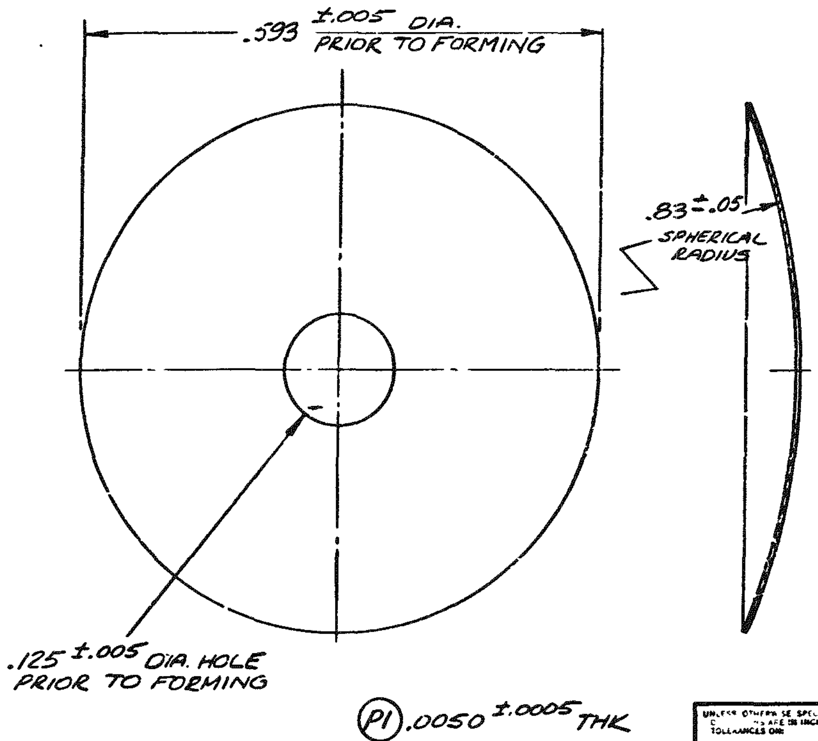
SIZE C CODE IDENT NO 23991 47C303127

SCALE 10X SHEET 1 OF 1

C 47C303127 A



B 47B303131
SHEET 1
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
P1
.0050 ±.0005 THK. IRIDIUM
PER GE SPEC N50060-01-11, CL I, TYPE 2 or 3
SURFACE FINISH 63 OR BETTER
.375 ±.005 DIA
PRIOR TO FORMING
.007
.005
.81 ±.05
SPHERICAL RADIUS
NOTES -
1. DWG TERMS & TOLERANCES PER GE DWG 171A4286.
2. MARK "GE 47B303131G1" PER 118A1526, CLASS 17.
3. FABRICATE PER. GE SPEC N50060-02-78
P2
-325 MESH IRIDIUM POWDER-
CHEMISTRY TO BE PER GE SPEC N50060-02-78
G1
SCALE
FRACTIONS
DECIMALS
ANGLES
ALL SURFACES
MATL-
AS NOTED ABOVE
GENERAL ELECTRIC
SSO/ESP
PHILA, PA.
FILTER ASSEMBLY
SIZE
B
CODE IDENT NO
23991
47B303131
SCALE 10X
SHEET 1 OF 1



NOTES:-

1. DWG TERMS & TOLERANCES PER 171A4286.
2. MARK "GE 47B303132P1" PER 118A1526, CLASS 17.
3. FABRICATE PER GE SPEC. NS0060-02-78.

REDUCED SIZE PRINT

SCALE 0 1 2 INCHES

SIZE B 47B303132 SHEET 1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON: FRACTIONS ± DECIMALS ± ANGLES ±

ALL SURFACES 63

MATL

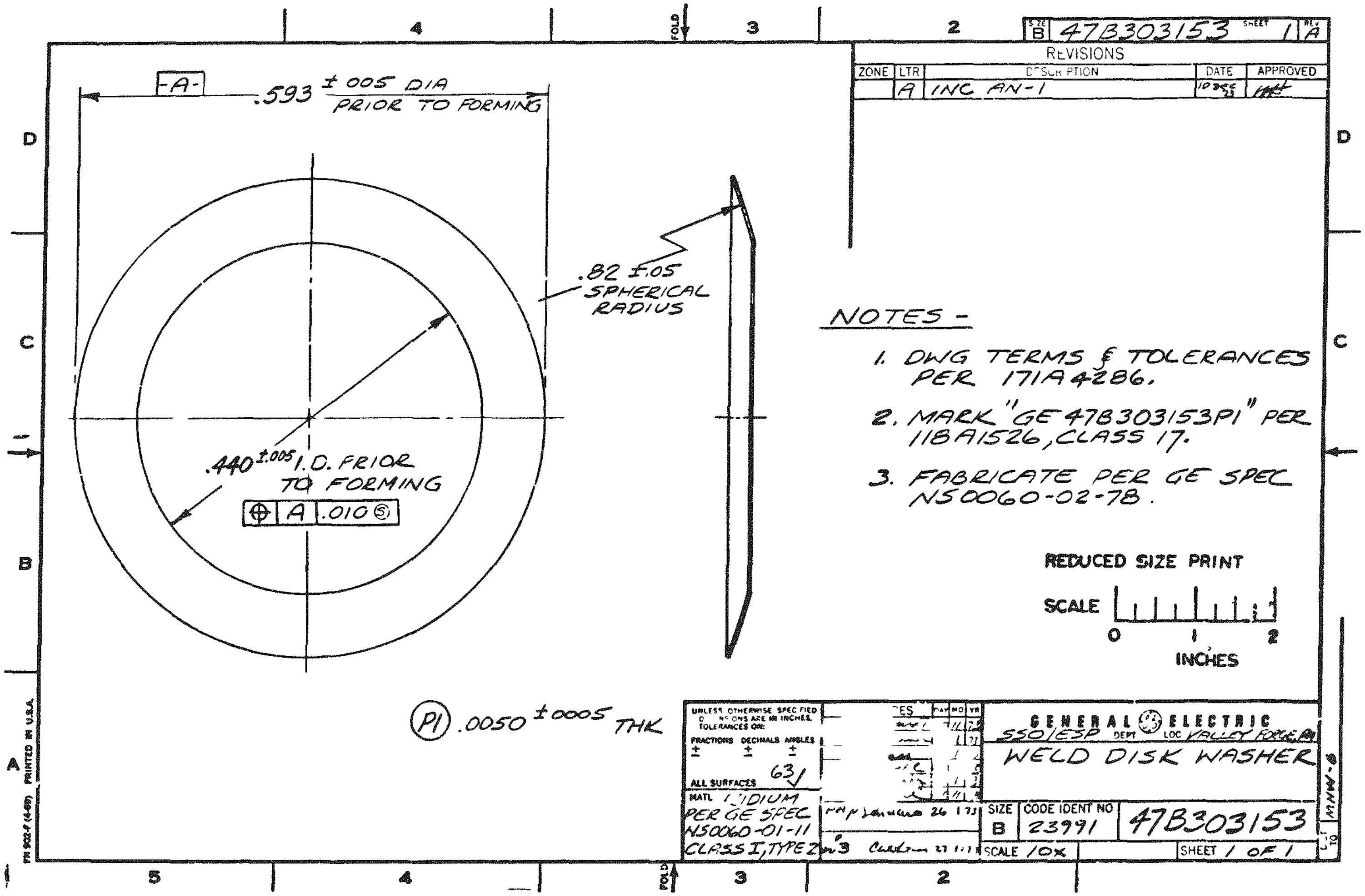
GENERAL ELECTRIC

SSO/ESP DEPT LOC VALLEY FORGE, PA.

WELD DISK

SIZE	CODE IDENT NO	
B	23991	47B303132

SCALE 10 X SHEET 1 OF 1


B 47B303153 SHEET 1 A
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
A INC AN-1
-A-
.593 ±.005 DIA PRIOR TO FORMING
.82 ±.05 SPHERICAL RADIUS
.440 ±.005 I.D. PRIOR TO FORMING
A .010 Ⓢ
P1 .0050 ±.0005 THK
NOTES -
1. DWG TERMS & TOLERANCES PER 171A4286.
2. MARK "GE 47B303153P1" PER 118A1526, CLASS 17.
3. FABRICATE PER GE SPEC NS0060-02-78.
REDUCED SIZE PRINT
SCALE
0 1 2
INCHES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON:
FRACTIONS DECIMALS ANGLES
ALL SURFACES 63
MATL IRIDIUM PER GE SPEC NS0060-01-11 CLASS I, TYPE 2
GENERAL ELECTRIC
SSO/ESP DEPT LOC VALLEY FORGE, PA
WELD DISK WASHER
SIZE B CODE IDENT NO 23991 47B303153
SCALE 10X SHEET 1 OF 1
PRINTED IN U.S.A.
D C B A
5 4 3 2
FOLD

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED
A	Inc. AN's -1, -2, -3, -4, -5, -6	5 FEB 74	[illegible]
B	Inc. AN's -7, -8, -9	5 APR 74	[illegible]
C	INC. AN-10	16 MAY 74	[illegible]

1.0 SCOPE

This procedure defines the processes and inspections to be followed in the fabrication of PICS helium vents. The vents are of the bonded frit design made from iridium foil and -325 mesh iridium powder.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents - None

2.2 Non-Government Documents

Particulate Shield Assembly	47C303127
Filter Assembly & Cover Plate	47B303131
Weld Disk	47B303132
Forming Die	47C303151
Frit and Weld Disk Bonding Fixture	47D302677

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
ALL SURFACES ✓
MATL

SIGNATURES	DAY	MO	YR
DRAWN [signature]	26	11	73
CHECKED			
ISSUED [signature]	27	11	73
ENGRG [signature]	26	11	73
MFG [signature]	27	11	73
MATLS [signature]	26	11	73
[signature] 26/11/73			
[signature] 24/11/73			

GENERAL ELECTRIC
DEPT LOC

FABRICATION OF BONDED FRIT VENTS

SIZE	CODE IDENT NO.	
A	23991	NS0060-02-78
SCALE		SHEET 1 of 7

DIST TO MHW G + S

FN 901P (5-66) PRINTED IN U.S.A.

Vent Test Fixture	47D303122
Washer Weld Disc	47B303153

3.0 REQUIREMENTS

3.1 Equipment

3.1.1 High vacuum furnace - Brew capable of 2000°C temperature and 10^{-6} torr pressure. Furance controlled by means of tungsten - tungsten-rhenium TC with strip chart temperature readout.

3.1.2 Ultrasonic Cleaner.

3.1.3 325 Mesh Screen - 3" Diameter, Stainless Steel, or approved equivalent.

3.1.4 Hydrogen Furnace Capable of 1500°C Operation Temperature

3.1.5 Electron Discharge Machine

3.2 Materials

3.2.1 Prime Materials - Materials shall conform to drawing requirements.

3.2.2 Secondary Materials

Hydrofluoric Acid - CP Grade
Nitric Acid - CP Grade
Acetone - CP Grade
Deionized Water
ATJ Graphite
Tungsten Weight 10 lb weight ± .3 lbs (2.0" ± .1" high x 3.15 ± .05 diameter).

3.3 Required Procedures and Inspections

3.3.1 Parts Fabrication

Vent parts are to be fabricated per applicable dwgs. (section 2.2)

3.3.2 Inspection

All parts are to be inspected for conformance to applicable drawings as well as after bonding (Section 3.3.9).

3.3.3 Cleaning Vent Parts

Parts are to be cleaned according to the following steps after completion of 3.3.2:

(a) Ultrasonic clean in acetone for 15 minutes ± 5 min.
(b) Ultrasonic rinse in deionized water for 15 minutes ± 15 min.
(c) Soak in concentrated hydrofluoric acid for 1 hour ± 15 min.
(d) Ultrasonic rinse in deionized water for 15 minutes ± 5 min.
(e) Clean in 30% solution of nitric acid for 30 minutes ± 5 min.
(f) Double ultrasonic rinse in deionized water for 15 minutes ± 5 min.

3.3.4 Annealing

After cleaning per 3.3.3 all parts are to be annealed in an atmosphere of hydrogen at 1500°C ± 50°C for 15 minutes ± 5 min. Tungsten boats are to be used to contain parts during annealing.

3.3.5 Spheredizing Disks and Washer

The weld disk, cover disk, and weld-disk washer are to be spheredized according to the radius defined in the applicable drawing. This is done by placing one disk at a time in the forming die 47C303151 and impacting the segment of the die several times with a mallet head hammer until the disk takes a permanent shape.

CAUTION: Be certain that the dies are clean and free from particulate matter.

3.3.6 Filter Construction

Place approximately six spheredized disks 47C303131P1 on a clean flat surface with the convex side up and dust with iridium powder. This is done by placing -325 mesh iridium powder in a 3" diameter 325 mesh screen and lightly tapping the screen to allow the powder to coat the surface of the disks uniformly until the base metal is completely coated and obscure. This initial coating is then dusted over the sintered coating and again sintered in hydrogen at 1500°C ± 50°C for 15 minutes ± 5 min. This step is repeated until total weight of the coating is 135 $^{+20}_{-10}$ milligrams. POWDER CHEMISTRY SHALL CONFORM TO REQUIREMENTS STATED ON TABLE I.

3.3.7 Bonding Iridium Frit

The frit coating is to be bonded and formed to meet configuration requirements of drawing 47C303131. This is done by stacking up to 12 disks in fixture 47D302677 spaced with 47D302677 P2-P3 and P4

Blank page

evidence of non-adherent particles or foreign materials which shall cause rejection of the assembly evaluated. Darkening or staining of the components shall be considered acceptable provided that the observed discoloration is tightly adherent since the nature of the process does not lend itself to the maintenance of bright surfaces.

Vent Covers (Part No. 47C303131F( )) - There is no limitation on the number or size of blisters detected by any means.

Weld Disks and Washers - Magnification is not required for acceptance but when used shall not exceed 20X. There shall be no single blister exceeding 0.032 inch in max. dimension. When the max. separation between any 2, or more, blisters is 0.032, the total surface area of all the blisters being considered shall not exceed the area encompassed by a 0.032 inch dia. circle.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

GE shall perform acceptance testing to attest to the conformance of parts and assemblies to requirements stated herein and inspected per 3.3.2.

4.2 Monitoring Procedures for Equipment Used in Process

4.2.1 Brew Furnace

The tungsten-tungsten/rhenium thermocouple shall be checked during every fifth run by means of a calibrated optical pyrometer readout against the temperature readout of the thermocouples. A fifty degree difference shall require recalibration of thermocouple and rejection of parts.

4.2.2 Hydrogen Furnace

Furnace temperature readout shall be checked with a calibrated optical pyrometer reading taken in the thermocouple sensing zone of the furnace. A fifty degree difference shall require recalibration of the thermocouple and rejection of parts.

4.5 Test Methods

4.5.1 Helium Flow Test

The rate of flow of helium is to be measured for each vent and shall range between .06 and .09 cc per second at 1 psi input pressure, at room temperature. The measurement is to be made by assembling the vent in test fixture 47C303121G1 and measuring flow rate by the downward volume displacement of water in a graduated cylinder as a function of time. Total flow test time should be 3 minutes minimum.

4.5.2 Tensile Test

Finished particulate shield assembly tensile testing shall be as indicated in Table II to determine conformance to section 3.3.12. Pull rods, approximately 1/4" dia. x 3 in. long shall be epoxy bonded to the cover disc and weld disc while being held in alignment with a "V" block. The pull-rod filter assembly will then be pulled in an Instron tensile testing machine and loaded until failure of the epoxy resin or filter assembly. Results of all testing shall be reported. All specimens shall be stored for a minimum period of 1 year for historical purposes.

5.0 PREPARATION FOR DELIVERY

Because of the high temperature processing the vents are extremely soft and therefore easily deformed. It is therefore necessary to handle the vents with plastic tweezers and insert them in foam rubber packaging material.

TABLE I

MATERIAL POWDER SPECIFICATION

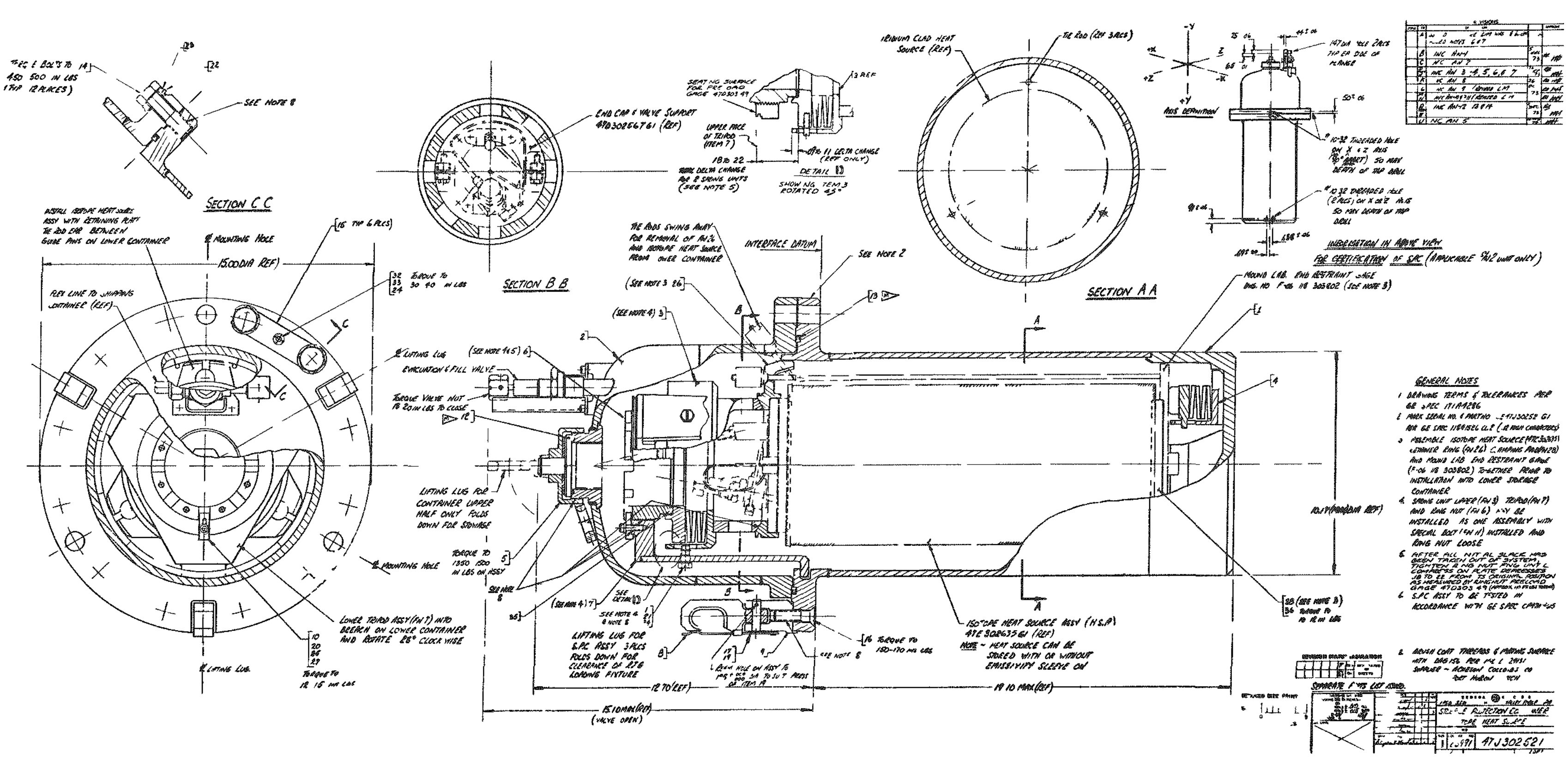
IMPURITY	(MAXIMUM) PARTS/MILLION
Pt.	75*
RH.	50*
Pd.	50*
Ru.	50*
Ag.	50*
Si	50
Fe	50
Cr	20
Al	20
C	Information only
O_2	Information only
Other	**
Ir.	Bal.

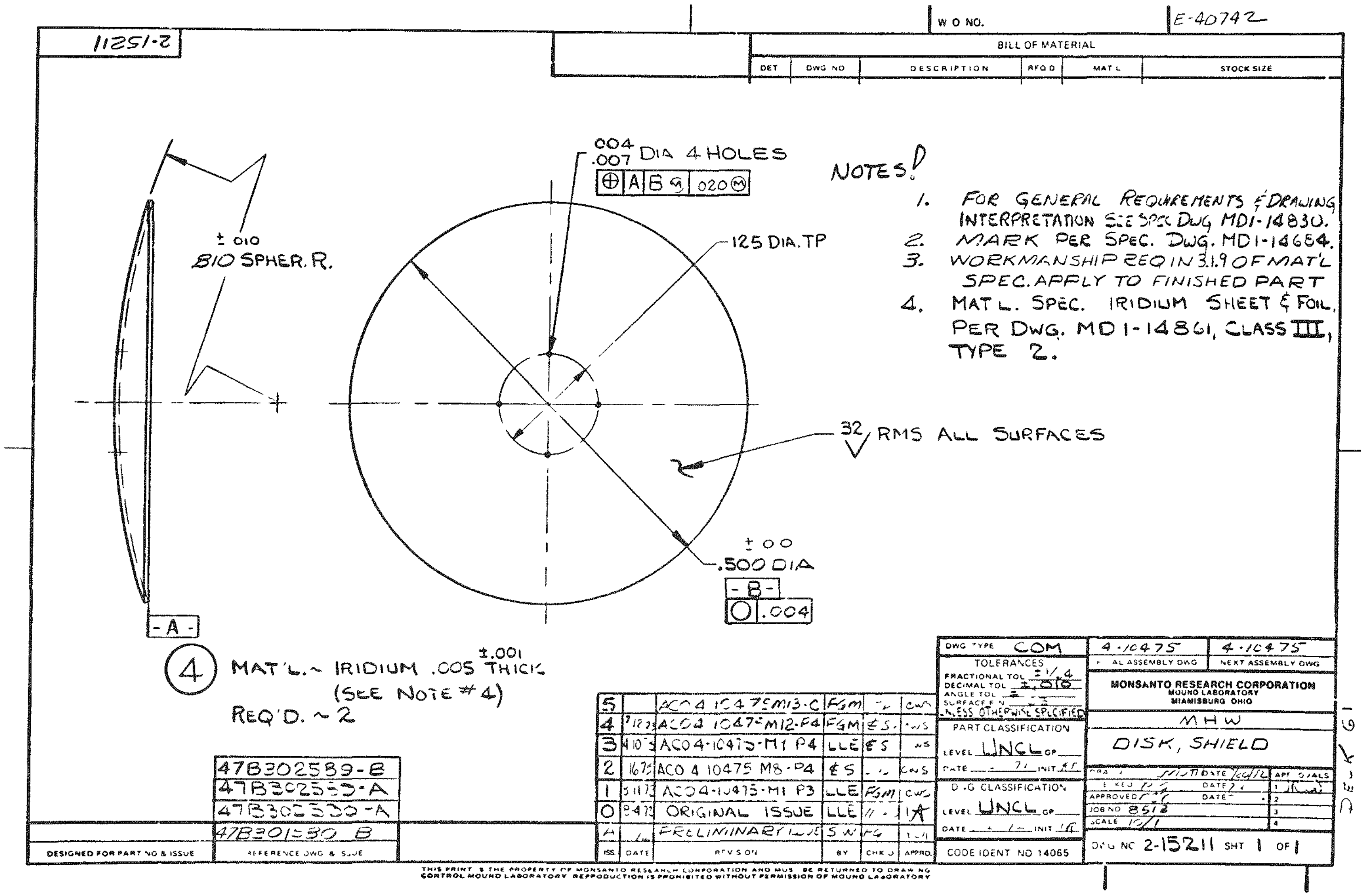
* Total Pt, RH, Pd, Ru, Ag, and Au shall not exceed 200 parts/million.

** Total impurity content shall not exceed .29 percent and no single unspecified impurity shall exceed 40 parts/million.

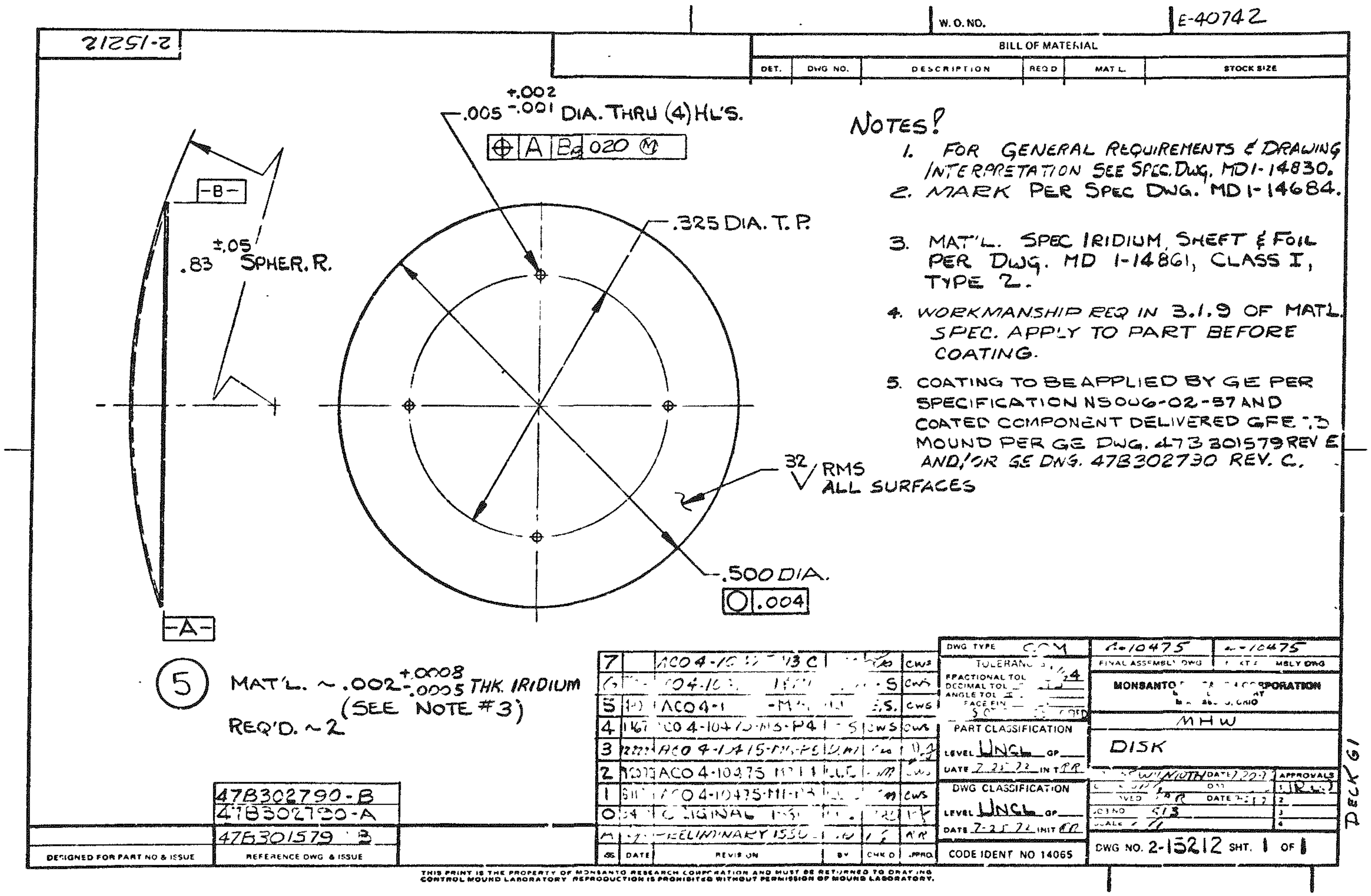
TABLE II

NO. OF SPECIMENS REQUIRED	NUMBER OF BONDING RUNS APPLICABLE
• One per run	Run #1 through Run #10
• One per every two furnace runs	Run #11 through Run#20
• One per every four furnace runs	Run #21 through Remainder of Runs in the Program.


SECTION C C
SECTION B B
SECTION A A
DETAIL B
INTERFACE DATUM
SEE NOTE 2
SEE NOTE 8
15.00 DIA REF
IRIDIUM CLAD HEAT SOURCE (REF)
END CAP & VALVE SUPPORT
LIFTING LUG
EVACUATION & FILL VALVE
LIFTING LUG FOR CONTAINER UPPER HALF ONLY FOLDS DOWN FOR STORAGE
MOUNTING HOLE
ISOTOPE HEAT SOURCE ASSY (H.S.A)
NOTE - HEAT SOURCE CAN BE STORED WITH OR WITHOUT EMISSIVITY SLEEVE ON
19.10 MAX (REF)
12.70 (REF)
GENERAL NOTES
AXIS DEFINITION
47J302521



2-15211
W O NO.
E-40742
BILL OF MATERIAL
DET
DWG NO
DESCRIPTION
RFQ'D
MAT'L
STOCK SIZE
.004 .007 DIA 4 HOLES
A B .020
NOTES:
1. FOR GENERAL REQUIREMENTS & DRAWING INTERPRETATION SEE SPEC DWG MD1-14830.
2. MARK PER SPEC. DWG. MD1-14664.
3. WORKMANSHIP REQ IN 3.1.9 OF MAT'L SPEC. APPLY TO FINISHED PART
4. MAT'L. SPEC. IRIDIUM SHEET & FOIL, PER DWG. MD1-14861, CLASS III, TYPE 2.
±.010
.810 SPHER. R.
.125 DIA. TP
32 RMS ALL SURFACES
±.00
.500 DIA
-B-
.004
-A-
4 MAT'L. ~ IRIDIUM .005 ±.001 THICK (SEE NOTE #4)
REQ'D. ~ 2
47B302589-B
47B302555-A
47B302330-A
47B301530-B
DESIGNED FOR PART NO & ISSUE
REFERENCE DWG & ISSUE
5 AC04 10475 M13-C FGM
4 AC04 10475 M12-P4 FGM ES
3 AC04-10475-M1 P4 LLE ES
2 AC0 4 10475 M8-P4 ES
1 AC04-10475-M1 P3 LLE FGM
0 ORIGINAL ISSUE LLE
A PRELIMINARY ISSUE SW
ISS DATE REVISION BY CHK'D APPRO
DWG TYPE COM
TOLERANCES
FRACTIONAL TOL ±1/64
DECIMAL TOL ±.010
UNLESS OTHERWISE SPECIFIED
PART CLASSIFICATION
LEVEL UNCL
DWG CLASSIFICATION
LEVEL UNCL
CODE IDENT NO 14065
4-10475
4-10475
FINAL ASSEMBLY DWG
NEXT ASSEMBLY DWG
MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG OHIO
MHW
DISK, SHIELD
APPROVED
JOB NO 8512
DWG NO 2-15211 SHT 1 OF 1
THIS PRINT IS THE PROPERTY OF MONSANTO RESEARCH CORPORATION AND MUST BE RETURNED TO DRAWING CONTROL MOUND LABORATORY. REPRODUCTION IS PROHIBITED WITHOUT PERMISSION OF MOUND LABORATORY


2-15212
W. O. NO.
E-40742
BILL OF MATERIAL
DET. | DWG NO. | DESCRIPTION | REQ'D | MAT'L. | STOCK SIZE
.005 +.002 -.001 DIA. THRU (4) HL'S.
.020 Ⓜ
-B-
.83 ±.05 SPHER. R.
.325 DIA. T. P.
32 RMS ALL SURFACES
.500 DIA.
.004
-A-
NOTES:
1. FOR GENERAL REQUIREMENTS & DRAWING INTERPRETATION SEE SPEC. DWG. MD1-14830.
2. MARK PER SPEC DWG. MD1-14684.
3. MAT'L. SPEC IRIDIUM, SHEET & FOIL PER DWG. MD 1-14861, CLASS I, TYPE 2.
4. WORKMANSHIP REQ IN 3.1.9 OF MAT'L. SPEC. APPLY TO PART BEFORE COATING.
5. COATING TO BE APPLIED BY GE PER SPECIFICATION NS006-02-57 AND COATED COMPONENT DELIVERED GFE TO MOUND PER GE DWG. 47B301579 REV E AND/OR GE DWG. 47B302730 REV. C.
5
MAT'L. ~ .002 +.0008 -.0005 THK. IRIDIUM (SEE NOTE #3)
REQ'D. ~ 2
47B302790-B
47B302790-A
47B301579-B
DESIGNED FOR PART NO & ISSUE
REFERENCE DWG & ISSUE
REVISION
DATE
BY
CHK'D
APPRO.
PRELIMINARY ISSUE
ORIGINAL ISSUE
DWG TYPE
TOLERANCES
FRACTIONAL TOL
DECIMAL TOL
ANGLE TOL
PART CLASSIFICATION
LEVEL UNCL
DATE 7-25-72
DWG CLASSIFICATION
LEVEL UNCL
DATE 7-25-72
CODE IDENT NO 14065
A-10475
FINAL ASSEMBLY DWG
MONSANTO RESEARCH CORPORATION
MHW
DISK
APPROVALS
DWG NO. 2-15212 SHT. 1 OF 1
DECK 61
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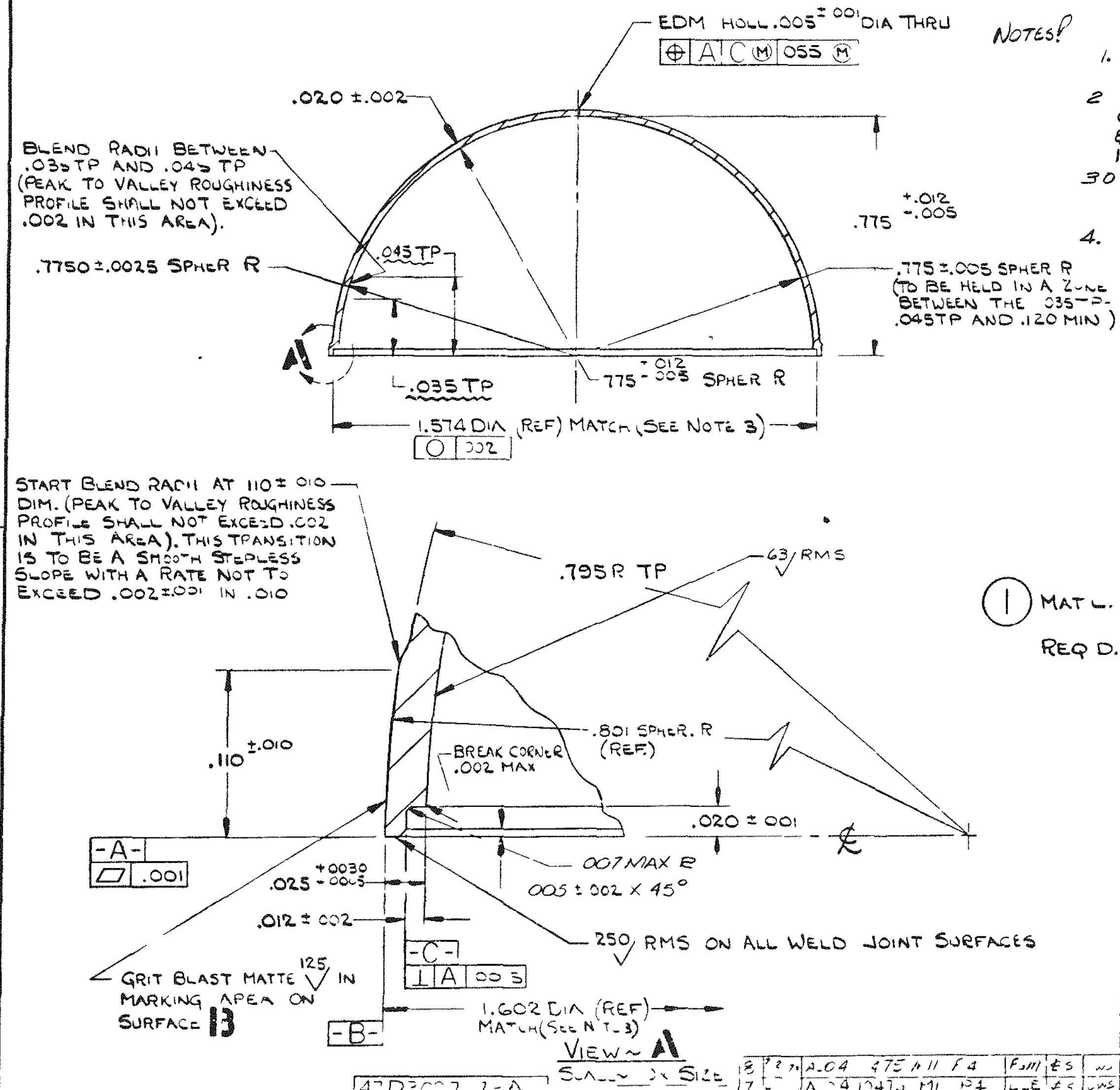
3-8985

W O NO | E 40742

BILL OF MATERIAL

DET	DWG NO	DESCRIPTION	REQ D	MAT L	STOCK SIZE



NOTES:

1. FOR GENERAL REQUIREMENTS & DRAWING INTERPRETATION SEE SPEC DWG MD 1-14330.
2. GRIT BLAST CIRCUMFERENTIAL INDEXING MARK ON OUTSIDE OF EACH PART APPROXIMATELY 20 ABOVE & PARALLEL TO THE EQUATOR. ETCH SERIAL NUMBER WITHIN INDEX MARK PER MARKING SPECIFICATION 1-14684.
3. DIAMETRICAL CLEARANCE OF SURFACES C WHEN PARTS ARE ORIENTED SHALL NOT BE GREATER THAN .004
4. MATL SPEC IRIDIUM HEMISPHERE PER DWG. MD 1-14860, TYPE 3.

① MAT L. ~ IRIDIUM (SEE NOTE #4)
REQ D. ~ 1

18	7	A-04 475 M1 F4			
17		A-04 475 M1 P4			
C		A-04 475 M1-P4			

4-10475 (FINAL ASSEMBLY DWG) | 4-10475 (NEXT ASSEMBLY DWG)

DWG TYPE CONT

TOLERANCES
FRACTIONAL TOL ±1/64
DECIMAL TOL ±.010
ANGLE TOL ±1°
SURFACE FN 63
UNLESS OTHERWISE SPECIFIED

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG OHIO

MHW

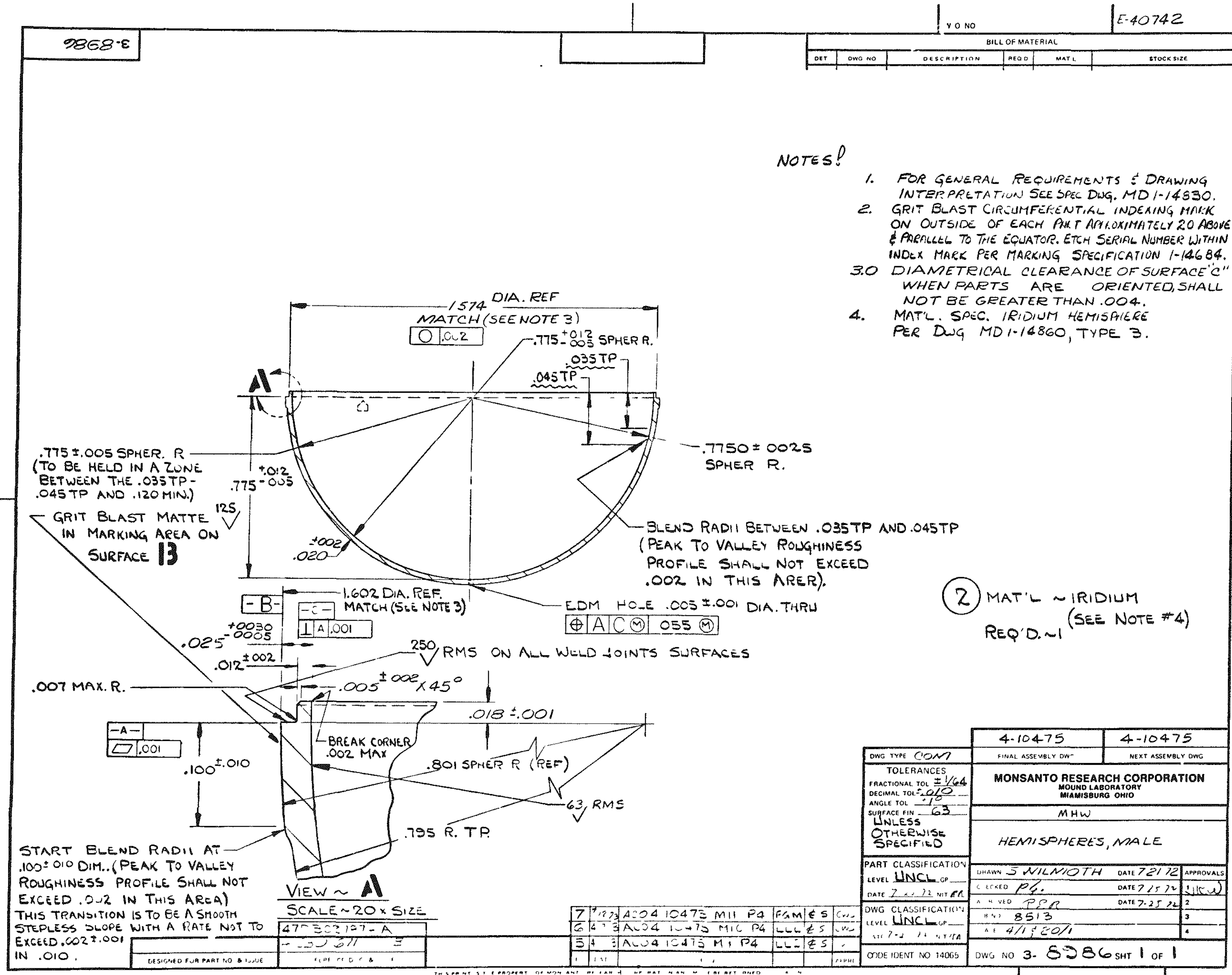
HEMISPHERES FEMALE

PART CLASSIFICATION LEVEL UNCL
DWG CLASSIFICATION LEVEL UNCL

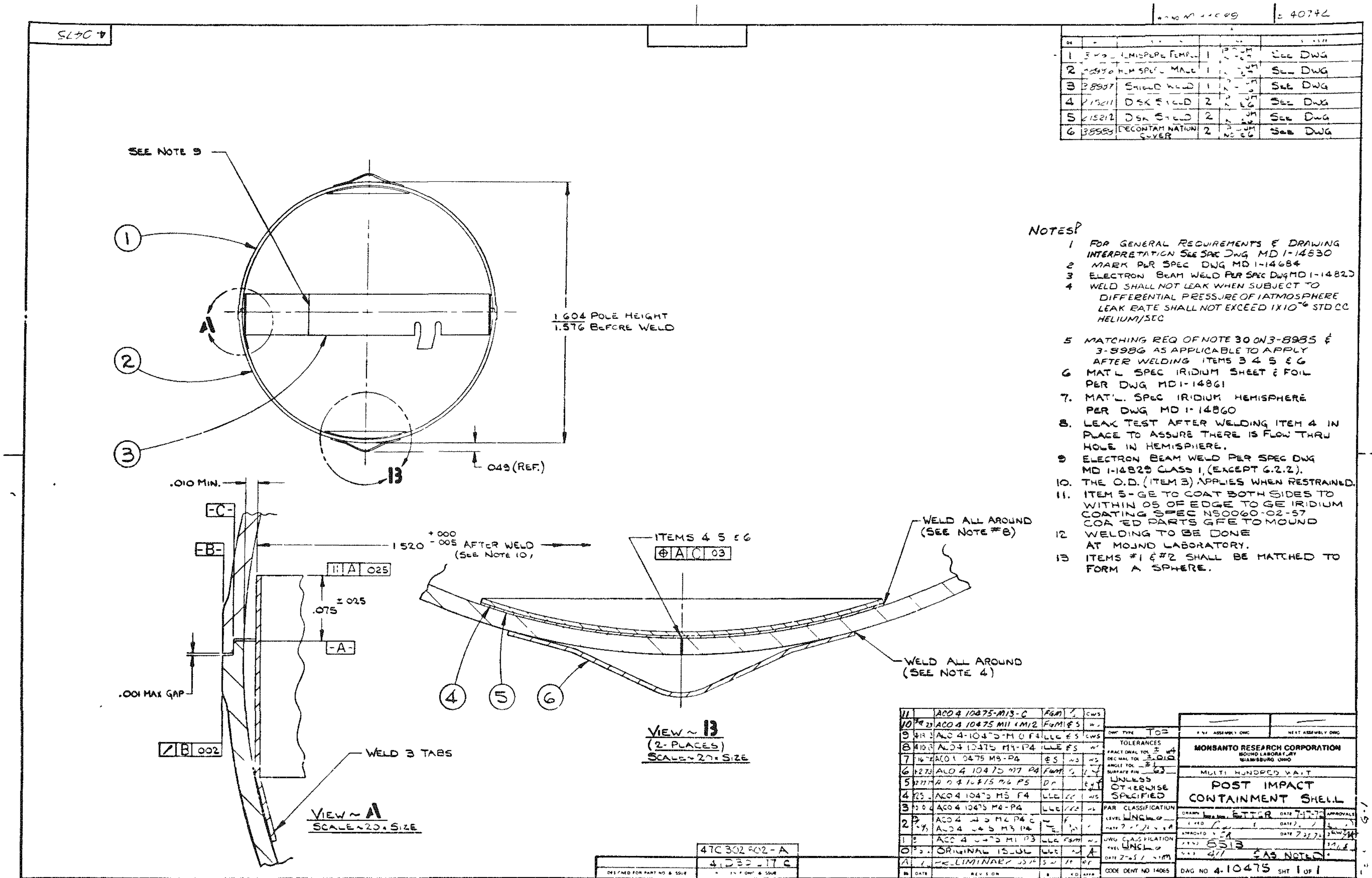
DRAWN S WILMOTH
CHECKED PG
APPROVED

DWG NO 3-8985 SHT 1 OF 1

CONTROLLED BY MOUND LAB. REPRODUCTION PROHIBITED WITHOUT PERMISSION OF MOUND LAB



3-8986
E-40742
BILL OF MATERIAL
DET | DWG NO | DESCRIPTION | REQ'D | MAT'L | STOCK SIZE
NOTES:
1. FOR GENERAL REQUIREMENTS & DRAWING INTERPRETATION SEE SPEC DWG. MD 1-14830.
2. GRIT BLAST CIRCUMFERENTIAL INDEXING MARK ON OUTSIDE OF EACH PART APPROXIMATELY 20 ABOVE & PARALLEL TO THE EQUATOR. ETCH SERIAL NUMBER WITHIN INDEX MARK PER MARKING SPECIFICATION 1-14684.
3.0 DIAMETRICAL CLEARANCE OF SURFACE "C" WHEN PARTS ARE ORIENTED, SHALL NOT BE GREATER THAN .004.
4. MAT'L. SPEC. IRIDIUM HEMISPHERE PER DWG MD 1-14860, TYPE 3.
1.574 DIA. REF
MATCH (SEE NOTE 3)
.775 +.012 -.005 SPHER R.
.035 TP
.045 TP
.775 ±.005 SPHER. R (TO BE HELD IN A ZONE BETWEEN THE .035TP-.045TP AND .120 MIN.)
.7750 ± .0025 SPHER R.
GRIT BLAST MATTE IN MARKING AREA ON SURFACE B
BLEND RADII BETWEEN .035TP AND .045TP (PEAK TO VALLEY ROUGHINESS PROFILE SHALL NOT EXCEED .002 IN THIS AREA).
1.602 DIA. REF. MATCH (SEE NOTE 3)
EDM HOLE .005 ±.001 DIA. THRU
2 MAT'L ~ IRIDIUM REQ'D. ~1 (SEE NOTE #4)
250 RMS ON ALL WELD JOINTS SURFACES
.007 MAX. R.
.005 ±.002 X 45°
.018 ±.001
BREAK CORNER .002 MAX
.801 SPHER R (REF)
.100 ±.010
63 RMS
.795 R. TP.
START BLEND RADII AT .100±.010 DIM.. (PEAK TO VALLEY ROUGHNESS PROFILE SHALL NOT EXCEED .002 IN THIS AREA) THIS TRANSITION IS TO BE A SMOOTH STEPLESS SLOPE WITH A RATE NOT TO EXCEED .002±.001 IN .010.
VIEW ~ A
SCALE ~ 20 x SIZE
4-10475
FINAL ASSEMBLY DWG
NEXT ASSEMBLY DWG
TOLERANCES
FRACTIONAL TOL ±1/64
DECIMAL TOL ±.010
ANGLE TOL ±1°
SURFACE FIN 63
UNLESS OTHERWISE SPECIFIED
MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG OHIO
MHW
HEMISPHERES, MALE
DRAWN S WILMOTH DATE 7 21 72
PART CLASSIFICATION LEVEL UNCL
DWG CLASSIFICATION LEVEL UNCL
8513
CODE IDENT NO 14065
DWG NO 3-8986 SHT 1 OF 1
DESIGNED FOR PART NO & ISSUE



SEE NOTE 9
1.604 POLE HEIGHT
1.576 BEFORE WELD
.049 (REF.)
.010 MIN.
1.520 +.000 -.005 AFTER WELD
(SEE NOTE 10)
.075 ±.025
.001 MAX GAP
WELD 3 TABS
VIEW ~ A
SCALE ~ 20 x SIZE
ITEMS 4 5 & 6
WELD ALL AROUND
(SEE NOTE #8)
WELD ALL AROUND
(SEE NOTE 4)
VIEW ~ B
(2-PLACES)
SCALE ~ 20 x SIZE
NOTES:
1 FOR GENERAL REQUIREMENTS & DRAWING INTERPRETATION SEE SPEC DWG MD 1-14630
2 MARK PER SPEC DWG MD 1-14684
3 ELECTRON BEAM WELD PER SPEC DWG MD 1-14823
4 WELD SHALL NOT LEAK WHEN SUBJECT TO DIFFERENTIAL PRESSURE OF 1 ATMOSPHERE LEAK RATE SHALL NOT EXCEED 1X10-6 STD CC HELIUM/SEC
5 MATCHING REQ OF NOTE 30 ON 3-8985 & 3-8986 AS APPLICABLE TO APPLY AFTER WELDING ITEMS 3 4 5 & 6
6 MAT'L SPEC IRIDIUM SHEET & FOIL PER DWG MD 1-14861
7. MAT'L. SPEC IRIDIUM HEMISPHERE PER DWG MD 1-14860
8. LEAK TEST AFTER WELDING ITEM 4 IN PLACE TO ASSURE THERE IS FLOW THRU HOLE IN HEMISPHERE.
9 ELECTRON BEAM WELD PER SPEC DWG MD 1-14829 CLASS 1, (EXCEPT 6.2.2).
10. THE O.D. (ITEM 3) APPLIES WHEN RESTRAINED.
11. ITEM 5 - GE TO COAT BOTH SIDES TO WITHIN 05 OF EDGE TO GE IRIDIUM COATING SPEC NS0060-02-57 COATED PARTS GFE TO MOUND
12 WELDING TO BE DONE AT MOUND LABORATORY.
13 ITEMS #1 & #2 SHALL BE MATCHED TO FORM A SPHERE.
MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG OHIO
MULTI HUNDRED WATT
POST IMPACT CONTAINMENT SHELL
TOLERANCES
UNLESS OTHERWISE SPECIFIED
CODE IDENT NO 14065
DWG NO 4-10475 SHT 1 OF 1

APPENDIX V

AEC APPROVALS

UNITED STATES
ATOMIC ENERGY COMMISSION
ALBUQUERQUE OPERATIONS OFFICE
P.O. BOX 5400
ALBUQUERQUE NEW MEXICO 87115

FEB 5 1974

Frank K. Pittman, Director
Division of Waste Management and Transportation, HQ
ATTN: William A. Brobst, Ch., Transportation Branch

AEC/AL CERTIFICATE OF COMPLIANCE - DOT SPECIAL PERMIT NO. 9503, AEC-AL USA/9503/BLF

Pursuant to the provisions of CFR-49-173.394-396 and IAD 5201-1 attached in triplicate is Certificate of Compliance (FORM-AEC-618) prepared in accordance with instructions in cited IAD (IAD 5201-1 Paragraph E.)

By copy of this, copies of the Certificate are being forwarded to registered users as appropriate.

Joseph N. Cook
Traific Management Specialist
Contracts Division

LC:JNC

cc: Arthur F. Heitkamp, Monsanto Research Corporation, Mound Lab., P. O. Box 32, Miamisburg, Ohio 45342
Jack F. Stevens, Oper. Safety Engr., DAO
R. J. Katucki, Energy Systems Div., GE, Valley Forge, Pa.
P. O. Box 8661, Philadelphia, Pennsylvania 19101
E. L. Barraclough, Operational Safety Division, ALO

INTERIM

Form AEC-618 (9 72) AECM 5201

U.S. ATOMIC ENERGY COMMISSION

CERTIFICATE OF COMPLIANCE

For Radioactive Materials Packages

1a Number	1b Revision No	1c Page No	1d Total No Pages
AEC - AL USA /9503/BLF	Original	1	2

2 Authority

This certificate is issued pursuant to Sections 173 394 173 395 and 173 396 of the Department of Transportation Hazardous Materials Regulations as amended (49 CFR 170-189 and 14 CFR 103) and AEC Manual Chapters 5201 and 0529

3 CONDITIONS

3a This certificate is issued on the basis of SAFETY ANALYSIS REPORT FOR PACKAGING (SARP)

(1) Prepared by	(2) Number / (3) Date Published
Monsanto Research Corporation Mound Laboratory Miamisburg, Ohio	(2) MLM-2074 (Draft) (3) December 1973

3b The packaging described in the SARP and further described in item 4 below when constructed and assembled as prescribed in the SARP with the contents as authorized herein meets the standards prescribed in DOT regulations

3c The outside of each package must be plainly and durably marked with the letters and number shown in item 1a on this form in accordance with the standards for markings in paragraph 173 24(b) of 49 CFR 173

3d This certificate does not relieve the consignor from compliance with any requirements of the regulations of the U S Department of Transportation or other applicable regulatory agencies

3e Each user of packages approved under this certificate shall register his name and address with the issuing office

4 Description of Packaging and Authorized Contents Restrictions and References

(a) Description of Packaging

The Multi-Hundred Watt Heat Source Assembly Shipping Container (MHW-HSA-SC) consists of several parts which include:

1. a "carrier" which is fabricated of aluminum and steel. The base of the carrier serves as a pallet and provides a means to secure the shipping container in the transport vehicle. The carrier weighs some 1310 pounds with overall dimensions of 62 inches in height and width and length of approximately 49 inches.

2. A finned cask made of stainless steel with aluminum fins which is designed to dissipate 2400 watts of heat. The cask is about 43 inches in height and

TO BE COMPLETED BY AEC

5a Address (of AEC Approving Official)	5b Signature (of AEC Approving Official) / 5c Name and Title (of AEC Approving Official)
Albuquerque Operations Office P. O. Box 5400 Albuquerque, New Mexico 87115	5b [signature] 5c Jack R. Roeder, Director Operational Safety Division
6 Expiration Date (If appropriate): June 30, 1974	7 Date: FEB 1 1974

INTERIM

has an overall diameter of slightly less than 43 inches. Its weight is approximately 1100 pounds.

3. An inner container called the "Storage Protection Container" (SPC) is shock mounted within the finned cask. The SPC is constructed of stainless steel and has dimensions of approximately 11 inches in diameter and 34 inches in height. The Heat Source Assembly is contained within the SPC during shipment.

b. <u>Authorized Contents</u>

Contents of the SPC is the HSA which consists of:

1. 24 fuel spheres of solid plutonium-238 dioxide.
2. 24 iridium post impact shell assemblies each containing one fuel sphere.
3. 24 graphite impact shells each containing a fueled post impact shell.
4. various graphite support structures.
5. a graphite aeroshell, providing reentry protection.
6. an iridium outer clad.
7. a graphite emissivity sleeve.

The HSA contains approximately 6 Kilograms of Pu-238 which generates a nominal 2400 watts of heat energy.

GLOSSARY

DEFINITIONS FROM AEC APPENDIX 0529

"SAFETY STANDARDS FOR THE PACKAGING OF RADIOACTIVE AND FISSILE MATERIALS"

1. Containment Vessel means the receptacle on which principal reliance is placed to retain the radioactive materials during transport.

2. Package means packaging and its radioactive contents.

3. Packaging means one or more receptacles and wrappers and their contents, excluding fissile material and other radioactive material, but including absorbent material, spacing structures, thermal insulation, radiation shielding, devices for cooling and for absorbing mechanical shock, external fittings, neutron moderators, nonfissile neutron absorbers, and other supplementary equipment.

RADIOACTIVE MATERIALS DEFINITIONS

The following definitions are derived from the Code of Federal Regulations Title 49 - Transportation, Part 173.389.

FISSILE CLASSES - The groupings into which radioactive material packages are classified according to the controls needed to provide nuclear criticality safety during transportation. (173.389(a)(1)-(3))

FISSILE MATERIAL - Plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235, or any material containing any of the foregoing. (173.389(a) and 173.396(a))

LARGE QUANTITY RADIOACTIVE MATERIALS - A quantity the aggregate radioactivity of which exceeds that specified in Part 173.389(b). (Large quantities are quantities exceeding a Type B quantity, and also are sometimes referred to as "large sources."

SMALL QUANTITY RADIOACTIVE MATERIALS - A quantity of radioactivity which does not exceed the limits specified in Part 173.391(a). Small quantities and certain radioactive devices 173.391(b), are exempt from specification packaging, marking and labeling requirements, but still are subject to certain requirements, such as shipping paper requirements.

LOW SPECIFIC ACTIVITY MATERIAL - Material in which the activity is essentially uniformly distributed and in which the estimated average concentration per gram of contents does not exceed the specifications of Part 173.389 (c).

SPECIAL FORM RADIOACTIVE MATERIALS - Those materials which, if released from package, might present some direct radiation hazard but would present little hazard due to radiotoxicity and little possibility of contamination. (173.389(g))

NORMAL FORM RADIOACTIVE MATERIALS - Those materials which do not meet the requirements of Special Form Radioactive Materials. Normal form radioactive materials are grouped into "transport groups." (173.389(d))

TRANSPORT GROUP - Any one of seven groups into which normal form radionuclides are classified according to their radiotoxicity and their relative potential hazard in transportation. (173.389(h))

TRANSPORT INDEX - A number placed on a package of "Yellow Label" radioactive materials by the shipper to denote the degree of control to be excercised by the carrier, i.e., the number of yellow labeled packages which may be placed in a single vehicle or storage location. The transport index is actually the measured dose rate of radiation at three feet from the surface of the package. (173.389(i))

TYPE "A" PACKAGING - Packaging which is designed in accordance with the general packaging requirements of Parts 173.24 and 173.393 and which is adequate to prevent the loss or dispersal of the radioactive contents and to retain the efficiency of its radiation shielding properties if the package is subjected to the test prescribed in Part 173.398(b) (Normal conditions of transport). (173.389(j)

TYPE "A" QUANTITY RADIOACTIVE MATERIAL - That material which may be transported in Type "A" Packaging. (173.389(l))

TYPE "B" PACKAGING - Packaging which meets the standards for Type "A" Packaging, and in addition, meets the standards for the hypothetical accident conditions of transport as prescribed in Part 173.398(c).(173.389(k))

TYPE "B" QUANTITY RADIOACTIVE MATERIAL - That material which may be transported in Type "B" Packaging. (173.398(l))

The following definitions, though not derived from the Code of Federal Regulations, Title 49, are held as generally accepted meanings of the terms listed.

ALPHA PARTICLES - One of the three primary forms of radioactive emissions from radioactive atoms. Alpha Particles are positively charged particles emitted from the nucleus of atoms having a mass and charge equal to the nucleus of a helium atom (2 protons + 2 neutrons). Alpha Particles have very little penetrating ability and therefore are chiefly internal radiation hazards. They travel very short distances in air and are shielded very easily.

BETA PARTICLES - One of three primary forms of radioactive emissions from radioactive atoms. Beta Particles are negatively charged particles emitted from the nucleus of an atom and have a mass and charge equal to that of an electron. They travel greater distances in air than alpha particles, have an intermediate penetrating ability, but still are relatively easily shielded.

GAMMA RAYS- One of the three primary forms of radioactive emissions from radioactive atoms. Gamma Rays are not particulate (as opposed to alpha and beta particles) but are short wave length electromagnetic radiations from the nucleus of radioactive atoms. Except for their origin (the nucleus of the atom rather than the outer shell) they are identical in characteristics to X-rays. Gamma Rays are the most penetrating form of radiation and travel great distances in air. They require heavy shielding materials such as lead to attenuate the radiation.

CURIE - An expression of the quantity of radiation in terms of the number of atoms which disintegrate (decay) per second. A curie (Ci) is that quantity of radioactive material which decays such that 37 billion atoms disintegrate per second. One thousandth of a curie is a millicurie (mCi).

RADIATION LEVEL - A term sometimes used instead of radiation "dose rate." It generally refers to the effect of radiation on matter, that is, the energy imparted to and absorbed by matter due to radioactive emissions per unit of time.

MILLIREM - One-one thousandth of a Rem. The rem is a unit sometimes used to express radiation level or dose rate (millirem per hour). Technically speaking, the rem is an expression of radiation level or dose rate which considers the effect of the radiation on persons. Do not confuse millirem with curie.

ENCAPSULATION - A term used to denote an additional fabrication technique often used in preparation of radiation sources, wherein the basic material is physically placed within sealed, high physical integrity capsules or envelopes to provide further assurance that in the event a package breaks and the capsule escapes, there would be little possibility of a spread of particulate contamination.

NUCLEAR CRITICALITY - This term denotes the occurence of an accidental chain reaction with fissile radioactive materials. The purpose of the Fissile Classes is to prevent the occurence of a nuclear criticality during the transport of Fissile Materials. (Controlled nuclear criticality is the objective within a nuclear power reactor)

RADIOISOTOPE AND RADIONUCLIDE - For the purpose of transportation, these terms are synonymous with "Radioactive Materials."

RADIOTOXICITY - A term used to denote the relative hazards of the various radionuclides, that is, their internal radioactive effect within the body.

SWIPE SAMPLE - A test for loose or removable radioactive contamination on surfaces (also sometimes referred to as a "smear" test).

DEPARTMENT OF TRANSPORTATION
Office of Hazardous Materials
Operations Division, TSA-24
400 Sixth Street, S. W.
Washington, D. C. 20590

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