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November 11, 1977

**Safety Analysis Report For
Packaging (SARP) For
USA/9506/BLF (DOE-AL)**

**Reed A. Watkins, Richard E. Bertram,
Richard K. Blauvelt, James F. Griffin,
James B. Peterson and David L. Prosser**



Monsanto

MOUND FACILITY
Miamisburg, Ohio

operated by
MONSANTO RESEARCH CORPORATION
a subsidiary of Monsanto Company

for the
U. S. DEPARTMENT OF ENERGY

Contract No. EY-76-C-04-0053

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PRINTED IN THE UNITED STATES OF AMERICA

Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy \$6.00; Microfiche \$3.00

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Foreword

This report is a compilation of Monsanto Research Corporation (MRC) documentation of development activities to satisfy U. S. Department of Energy and U. S. Department of Transportation shipping and safety requirements as related to the transportation of packages containing nuclear materials.

Although MRC drawings and specifications in the Appendix 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
Attn: Drawing Control
Engineering Department
Miamisburg, Ohio 45342

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1. Summary

This Safety Analysis Report for Packaging (SARP) satisfies the request of the U. S. Energy Research and Development Administration for a formal safety analysis of the insulated drum shipping container identified as USA/9506/BLF(DOE-A1). The report makes available to all potential users the technical information and the limits pertinent to the construction and use of the shipping containers. This SARP includes discussions of structural integrity, thermal resistance, radiation shielding and radiological safety, nuclear criticality safety, and quality control. Complete physical and technical descriptions of the packages are presented. Each package consists of a cylindrical steel inner container centered within an insulated steel drum. The contents may be any radioactive materials that satisfy

the requirements established in this SARP. The results of the nuclear criticality safety analysis show how much of the fissile isotopes may be shipped as Fissile Class I, II, or III in the container.

Design and development considerations, the tests and evaluations required to prove the ability of the container 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 experience in using the container, and a copy of the DOE/OSD/ALO Certificate of Compliance are included. An internal review of this SARP has been performed in compliance with the requirements of ERDA 5201-Part V.

2. Introduction

2.1. GENERAL

DOE Manual chapters 0529 and 5201 require that a Safety Analysis Report for Packaging (SARP) be prepared for each shipping container to be used for shipments of quantities of radioactive material that exceed specified limits. This SARP satisfies the requirement for a formal safety analysis of the shipping container. The SARP includes discussions of structural integrity, thermal resistance, radiation shielding and radiological safety, nuclear criticality safety, and quality control.

The package is used to ship fissile and other radioactive materials that satisfy the safety criteria discussed in this report.

2.2. DESIGN

A steel inner container, the containment vessel, is approximately centered within an insulated drum assembly. Vent holes are provided around the perimeter of the outer drum for release of any gases generated at hypothetical accident fire conditions. The maximum gross weight of the packages is 37 lb.

2.3. TESTS

The container was extensively tested and evaluated to show that it 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 was performed. A nuclear criticality safety analysis was performed for $^{238}\text{PuO}_2$, α -phase plutonium-239, uranium-233 metal, uranium-235 metal, and thorium. The quantities of these materials comprising Class I, Class II, and Class III shipments are summarized in this report.

2.4. QUALITY CONTROL

Established quality control practices are used for receiving and reuse inspections and packaging operations. Inspection criteria and packaging and unpacking procedures are provided in Appendix A and Appendix B, respectively, of this report.

3. Conclusions

3.1. GENERAL

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

The major components of the packaging are the outer steel drum, the insulating materials, and a steel inner container. No shielding is specifically provided; however, shielding may be placed within the inner container.

3.2. CONTENTS OF PACKAGING

The packagings are intended primarily for shipment of Type B and large quantities of solids in special form or in a normal form which is not readily dispersible; however, solid Type A quantities and lesser amounts would be authorized.

The authorized contents are limited only on a basis of physical, chemical, and radiation characteristics (thermal output, physical form and density, behavior of radioactive material under conditions which could be encountered under normal and accident conditions, penetrating radiation and subsequent shielding required, etc.), such that all conditions specified in this report are met. One limitation which can be specifically stated is that liquid radioactive materials are not authorized.

The steel inner container serves as the primary containment under all conditions, and no release of radioactive material would be expected if these packagings

were subjected to the tests specified in DOEM 0529. However, sound practice would dictate that inside the steel inner container "strong and reliable" encapsulation also be used which could reasonably be expected to retain the radioactive materials if the package were subjected to the normal conditions of transport tests.

3.3. STEADY STATE TEMPERATURE PROFILES

Steady state temperature profiles of the shipping container for several internal heat loadings and various packing materials within the steel inner container were determined to ensure compliance with ERDA regulatory requirements and compliance with Mound Laboratory 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 heat load capability was determined to be 7.0 W. With a heat load of 7.0 W: (1) the maximum external surface temperature of the steel drums would be 107°F, which is well below the maximum of 122°F stated in the regulations, (2) the maximum temperature at the external surface of the inner container would not exceed 300°F when the package is in 100°F ambient air (normal conditions of transport), and (3) the maximum temperature at the external surface of the inner container would not exceed 435°F when the package is subjected to the fire test (hypothetical accident conditions). The 300°F temperature will have no significant effect on the steel inner container, nor will the Firedike insulation discolor at this temperature. At 435°F (hypothetical accident condition), the steel inner container will retain its integrity.

3.4. INTERNAL PRESSURE

The internal pressure capability of the packaging at various temperatures was thoroughly evaluated. The weakest component was found to be the welded bottom plate of the steel inner container with a capability of 627 psi at 500°F. This pressure capability is sufficiently high to contain the pressures which would result from heating the air environment (1 atm) trapped during packaging operations to the temperatures reached during normal shipment and hypothetical accident conditions.

3.5. PACKAGE STANDARDS

Detailed analyses with respect to Part II of DOEM 0529 have shown that: (1) packaging materials and the package contents will not cause any significant reactions even at hypothetical accident condition; (2) Positive closures are used that will prevent inadvertent opening and in addition, seals are secured to the drum closures; (3) No lifting devices, as such, are provided on the packaging; (4) There are no tiedown devices used with this packaging; (5) The static load requirement, normal to and uniformly distributed along its length, will be met; and (6) The steel inner container (containment vessel of this packaging) will withstand an external pressure of 25 psi without loss of contents.

3.6. NORMAL CONDITIONS OF TRANSPORT

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. 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 7.3 psi (0.5 atm) reduced external pressure requirement is well within the design capability. Similar packages have withstood years of transport with no occurrence of significant damage due to normal vibration. The water spray test would have no adverse effect on this metal drum packaging. Tests have shown that the 4-ft drop tests and the 1-ft corner drops (where required) will not significantly reduce the effectiveness of the packaging. Tests have shown that the penetration test results in small minor dents in the steel outer packaging, having no significant effect. Compressive tests with five times the authorized gross weight of the packages were conducted and produced no detectable effect. The reduction in total effective volume of the packaging on which nuclear safety is assessed did not exceed 5%. In addition, the effective spacing on which nuclear safety is assessed between the center of the containment vessel and the outer surface of the packaging was not reduced by more than 5%. In both cases the reduction was much less than 5%.

3.7. HYPOTHETICAL ACCIDENT CONDITIONS

The sequence of four hypothetical accident tests was performed, and the package satisfied these requirements. The damage sustained in the 40-in. puncture test was insignificant. The maximum outside surface temperature of the inner container was determined to be 435°F when fire tested after an initial uniform package temperature of 100°F. The inner container passed the water immersion test with no leakage.

3.8. CRITICALITY

Criticality limitations for shipment of fissile material in the 9506 shipping container were calculated for uranium-233, uranium-235, plutonium-238, and plutonium-239 metals. The quantities of each of these isotopes permitted for Fissile Class I, II, and III shipments are listed on the DOE Certificate of Compliance as shown in Appendix C.

3.9. RADIATION SHIELDING

The radiation shielding analysis shows that the quantities of $^{238}\text{PuO}_2$, plutonium-239, and uranium-235 metal and oxides authorized for transport will result in exposure rates much less than the allowed 200 mrem/hr and 10 mrem/hr at the package surface and 3 ft from the package surface, respectively. A shielding analysis for shipment of other contents should be performed by the shipper to ensure that appropriate DOT specifications are met.

3.10. QUALITY CONTROL

Established quality control practices are implemented during all phases of fabrication of the shipping containers 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 ensure proper handling and to provide documentation of these operations.

4. Packaging Description

4.1. GENERAL

In this section sufficient information is given regarding the design intent and the design detail to accurately identify the shipping container and to provide the basis for the evaluation of the package. The shipping container consists of a steel drum outer container and a steel inner container (the containment vessel) that is approximately centered within the drum by a glued "stack" of rigid insulating material. A sketch of this assembly is shown in Figure 4-1. The package is identified as USA/9506/BLF (DOE-AL). The maximum gross weight and overall dimensions are given in Table 4-1.

Table 4-1 - MAXIMUM GROSS WEIGHT AND OVERALL DIMENSIONS

Package Identification Number	9506
Drum Size (gal)	4
Maximum Gross Weight (lb)	37
Overall Diameter (in.)	11 3/4
Overall Height (in.)	14 3/4

The container is fabricated in accordance with the following drawings and specifications:

- MRC Drawings AYC760065 and AYC760064
Inner Container Body and Inner Container Cover.
- MRC Drawing
Drum Assembly.
- MRC Drawing
Acceptance and Reuse Inspections.

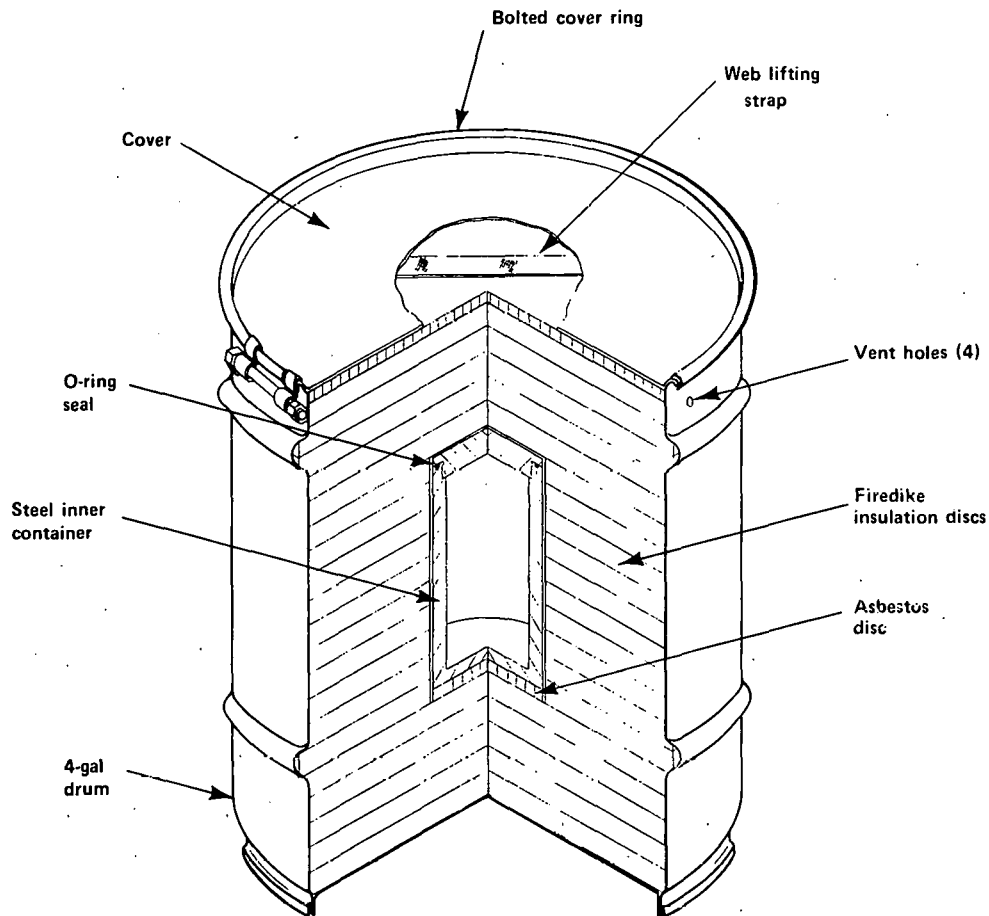


FIGURE 4-1 - 9506 shipping container assembly.

No shipping container materials are normally used as neutron absorbers or moderators. No shielding is normally required, although appropriate shielding may be placed inside the inner container when necessary.

4.2. DESIGN INTENT

The package was designed to be a much smaller version of the USA/5790/BLF (ERDA-AL) and USA/5791/BLF (ERDA-AL) packages, [1] except as specified in this report. The package is intended for shipment of special and normal form materials (for example, encapsulated materials). The quantities and types of materials are limited by the results of the tests and evaluations presented in this report. Shipments are generally made by commercial carrier, and several packages are frequently shipped simultaneously. The packages are relatively inexpensive, are easy to use and maintain without special tools, and may be reused frequently. They are designed to provide the required containment during normal transportation and hypothetical accident conditions.

The packages are insulated with Firedike* to provide protection for the inner containers at hypothetical accident fire conditions. The Firedike "stack" is glued to prevent convective heat transfer. The Firedike insulation will not cause overheating of the contents when the maximum permissible decay heat load is shipped.

The inner container is designed in accordance with the American Society of Mechanical Engineers (ASME) code. The internal pressure capability is sufficient to contain the pressure buildup resulting from

*Product of Johns-Manville, Inc.

heating the atmospheric air, which is trapped during packaging operations, to the maximum temperatures at accident conditions.

No special devices are required for tie-down or lifting. The package may be strapped in place as required during transportation. The package is intended to be lifted manually.

4.3. STEEL DRUM

The outer container for the package is an open-head steel drum with a gasket and closure ring. A metal identification plate is welded to the outside of the drum body, and security seals are fastened to the closure during shipment. The drum specifications are listed in Table 4-2.

Table 4-2 - SPECIFICATIONS FOR OUTER STEEL DRUM

Drum Size (gal)	4
Specification	MS27684-2
Gauge Body & Heads	20
Inside Diameter (in.)	10 1/2
Approximate Inside Height (in.)	13 1/2

4.5. INNER CONTAINER

The cylindrical steel inner container, which is supported within the insulation, is the containment vessel for the radioactive materials. It is shown in Figure 7-1. It consists of a 3 in. diameter cylinder with a cover which is screwed on to engage at least five threads. The cylinder body is machined to form a groove for an O-ring seal between the body and the cover. The bottom is welded in place. Silicone O-rings are acceptable.

No valves or gauges are used. Packaging materials, such as copper turnings, are used to position the materials being shipped within the inner container. The inner container must pass a helium leak test with no detectable leak greater than 1×10^{-4} std. cm³/sec when fitted with a test cover which allows filling with 15 psig helium. The dimensions of the inner container are given in Table 4-3.

Table 4-3 - INNER
CONTAINER DIMENSIONS

Body o.d. (in.)	3.00
Body Wall (in.)	0.38
Body i.d. (in.)	2.25
Maximum Inside Height (in.)	4.63
Thread Size	2 3/8 x 16

REFERENCE

1. J. F. Griffin, R. E. Bertram, R. K. Blauvelt, D. A. Edling, T. M. Flanagan, J. B. Peterson and D. L. Prosser, Safety Analysis Report for Packaging (SARP): USA/5790/BLF(ERDA-AL) and USA/5791/BLF(ERDA-AL), MLM-2242 (April 30, 1976), 89 pp.

5. Contents of Packaging

5.1. GENERAL

Material shipped in the container consists of fissile and other radioactive material either in normal or special form as dry solids which are not readily dispersible.

5.2. SPECIAL FORM

The radioactive material is sealed in capsules that comply with special form requirements. The material consists of fissile and other radioactive materials as dry solids. The capsule has been subjected to all the DOT tests for special form material and has passed them successfully.

5.3. NORMAL FORM

The radioactive material in normal form consists of fissile and other radioactive material as dry solids that are not readily dispersible. Examples of the materials may be plutonium-238, plutonium-239 powders or pellets, uranium-233, -235 and thorium oxide powders, and thorium nitrate powder. The materials are not necessarily limited to these examples. The material is placed either in nested cans with an O-ring seal (Figures 5-1 and 5-2) or in glass vials which are in turn placed in the O-ring sealed metal can shown in Figure 5-2. Lead shielding is placed around the metal cans when necessary to meet the required radiation levels.

5.4. THERMAL OUTPUT

The thermal output of cans holding plutonium-238 is determined by calorimetry to ensure that the thermal content placed in the shipping container does not exceed the maximum allowable heat load for the containers as stated in Section 6. The

inner container, after being loaded, is normally surrounded by packaging materials such as described in Section 6.

5.5. SPECIFIC CRITERIA

Section B (page 3) of the ALO SARP Guide suggests certain criteria that should be considered in describing the contents. Information concerning the applicable criteria is given in this section.

5.5.1 Quantity of Isotopes

The quantity of isotopes shipped in each container is limited by the physical, chemical, and radiation characteristics of the isotope to be placed in the inner container. Isotopes controlled by the inner container volume and radiation output include the thorium, uranium, and plutonium-239 isotopes because these isotopes do not generate any appreciable amount of decay heat. On the other hand, the plutonium-238 isotope does provide significant amounts of decay heat. Accordingly the maximum quantity of plutonium-238 which can be placed in the container is 210 Ci, as limited by the 7.0 W maximum heat load capability of the container (see Section 6). The plutonium-238 material normally consists of approximately 80 wt % plutonium-238; 16 wt % plutonium-239; 3 wt % plutonium-240; and considerably lesser quantities of plutonium-236, plutonium-241, and plutonium-242. The material also contains no more than 1% of other actinide materials.

5.5.2 Maximum Amounts of Radioactivity

The maximum amount of radioactivity expressed in curies is:

Plutonium-238	210 Ci
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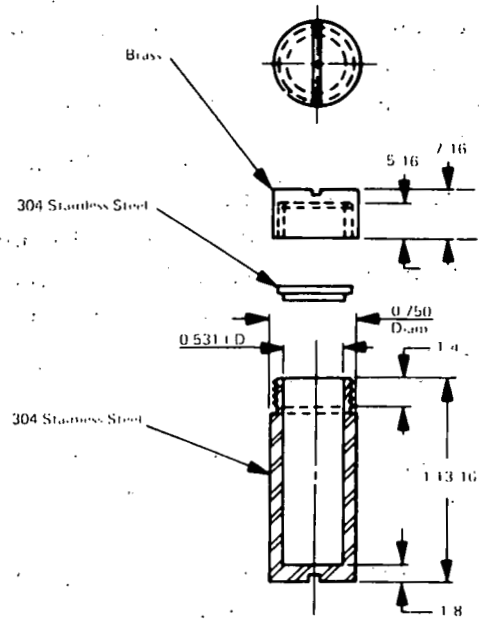


FIGURE 5-1 - Plutonium inner capsule (dimensions in in.).

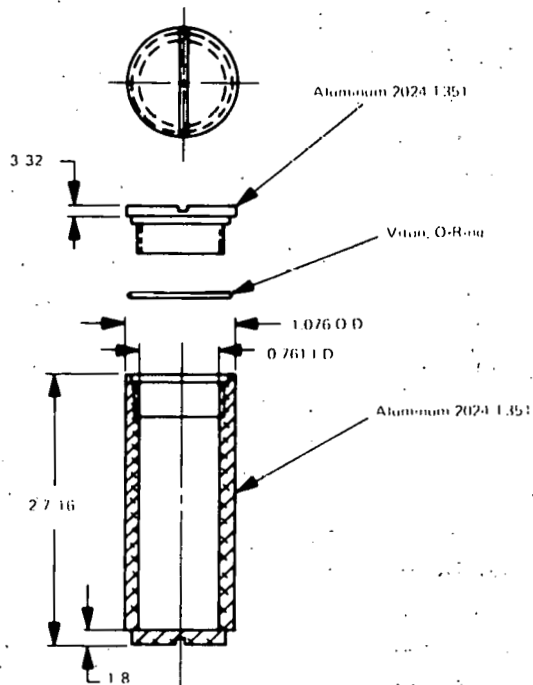


FIGURE 5-2 - Plutonium outer capsule (dimensions in in.).

Plutonium-239 290 Ci
Uranium-235 0.013 Ci

The permissible quantities of uranium-233 are not established here since, as discussed in Section 12.2, the shielding requirements could be the limiting factor. Thus the shipper must evaluate the shielding requirements and establish quantity limits for uranium-233 shipments on a case-by-case basis.

5.5.3. Chemical and Physical Form

The radioactive material may be present as an oxide or nitrate and can exist either as a loose powder within a metal can or in a pressed form.

5.5.4. Material Density

The density of the radioactive materials varies. Some are loosely packed powders whereas others exist as pressed pellets. Plutonium-238, oxide, for instance, when present as a compacted form can have a density as high as 9.5 g/cm³.

5.5.5. Moderating Ratios

Not applicable.

5.5.6. Configurations as Required for Nuclear Safety Evaluations

See section on criticality.

5.5.7. Maximum Amount of Decay Heat

The maximum amount of decay heat is 7.0 W.

5.5.8. Maximum Pressure Buildup in the Inner Container

All radioactive materials which may be shipped in the container do not decompose at temperatures generated during the hypothetical accident fire condition even when the maximum allowable wattage is present in the container. The plutonium-

238 material does generate significant quantities of helium as part of its decay mode. Fortunately the rate of generation is rather modest, amounting to 0.1 std. cm³/W per month. In addition, most of the helium is held tightly in the crystal lattice of the material and does not begin to escape in appreciable quantities until the material is heated to 2200°F which is well above the temperature that the inner container will reach under hypothetical accident fire conditions. The only significant pressure increase in the inner container will be from the heating of the gas trapped in the container at the time of sealing if the container is exposed to fire. Thus, the internal pressure would rise from 1 atm at the time of loading to 1.65 atm (10 psig) at hypothetical fire conditions (see Section 6).

5.5.9. Leak Tests

All capsules are tested for leakage before being packed into the inner container. Radioactive contamination checking or helium leak testing of the contents is used to ensure that the capsule is free of leakage.

5.5.10. Loading Restrictions and Limitations

Packaging procedures are given in Appendix B.

6. Steady-State Temperature Profiles

6.1. PURPOSE

The steady-state temperature profiles of the package and its contents were determined to ensure compliance with DOT, DOE, and NRC regulatory requirements and conformance with any product specifications and to establish the appropriate temperatures for evaluation of the contents. Also, the steady-state data obtained at the heat loads tested experimentally were used to determine the maximum heat load capability of the package.

6.2. TEST EQUIPMENT AND

PROCEDURES

The tests were performed using the equipment illustrated schematically in Figure 6-1. A 1/4 in. diameter x 1-1/2 in. long electric heater was installed inside a primary can packed with lead shot which was then installed within the inner container to simulate a radioactive heat source. The primary can was centered within the inner container using lead shot for run 1, nickel spheres for run 2,

and steel wool for run 3. The electrical wires and thermocouples were fed through small holes in the drum head and inner container. A wattmeter was used to determine the heat loads.

A digital thermometer with ice-point compensation was used to obtain the temperature data at several locations. The thermocouples used to measure surface temperatures were welded in place. Figure 6-2 shows the thermocouple locations.

The type K chromel-alumel thermocouples (No. 2-9 in Figure 6-2) were connected to a selector switch, 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 digital thermometer. The four type T copper-constantan thermocouples (No. 10-12 and ambient) were used similarly. The type J iron-constantan thermocouple, which was fastened to the heater (No. 1), was connected to a temperature controller so that the entire system would be safely shut down if the heater temperature exceeded a preset temperature.

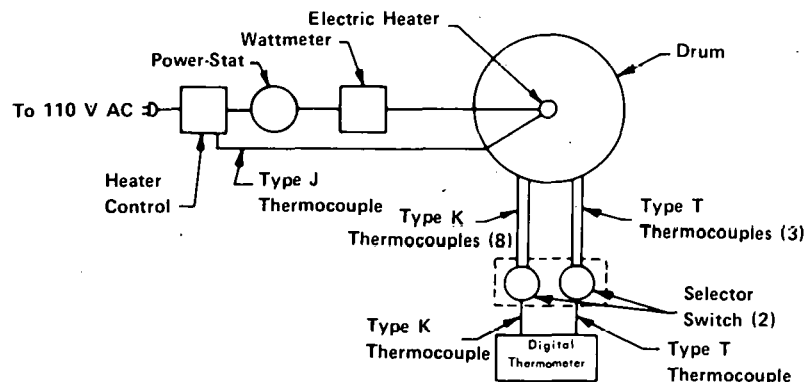


FIGURE 6-1 - Schematic of thermal test equipment.

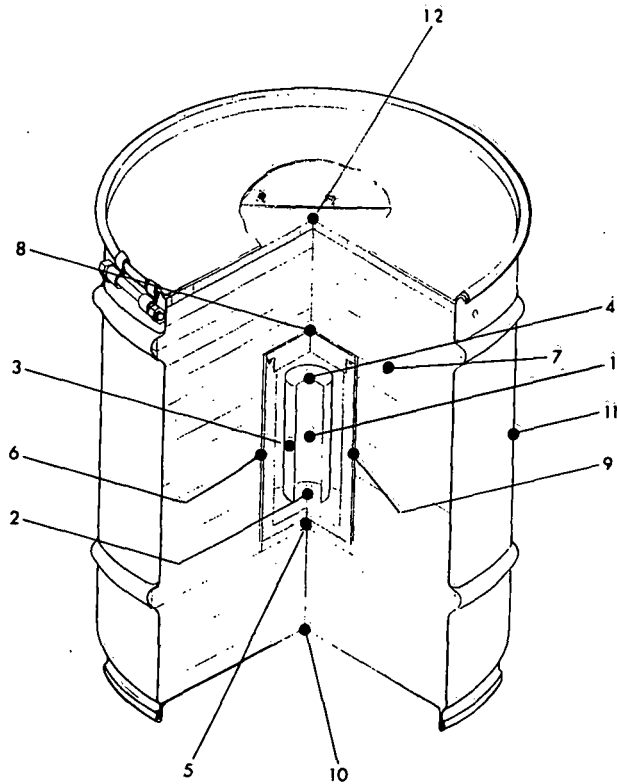


FIGURE 6-2 - Thermocouple locations.

The heating procedure required approximately one day for each set of data. The heat load was set at the desired value, and the temperature profile throughout the package was allowed to reach steady state. A complete set of temperature values was then obtained, and the procedure was repeated until a maximum heat load of 10 W was reached. The temperature increases during the equilibration periods were studied to verify that steady state conditions were reached. The ambient temperature was determined at each heat load at a location approximately 1 ft from the side of the drum. On completion of run 1 and run 2, the package was disassembled and then reassembled using a different packing material between the primary can and the inner container.

6.3. TEST RESULTS

The experimentally determined steady state temperatures are presented in Table 6-1. All temperatures listed in the table have been adjusted to an ambient temperature of 100°F (38°C) to represent normal conditions of transport on a hot day for comparison with DOT and ERDA/NRC regulations. The maximum temperatures are plotted in Figure 6-3. The heater temperatures when using the three packing materials are also shown in Figure 6-3.

Another significant result of the tests was that there was no evidence that the heating and cooling caused any misfit, galling, or other damage to the package.

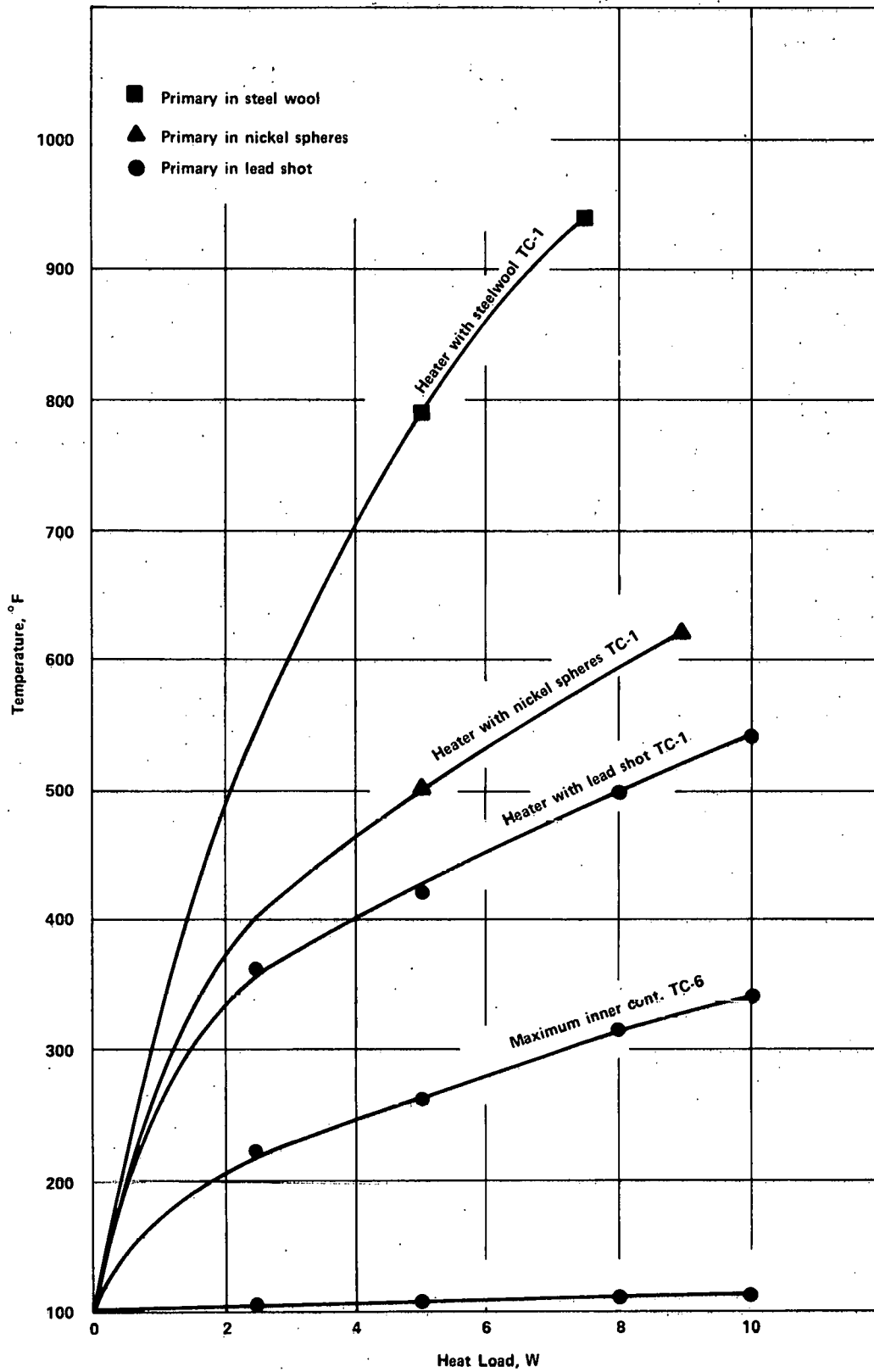


FIGURE 6-3 - Steady state temperature variation with heat load for 4-gal package.

Table 6-1 - STEADY-STATE TEMPERATURE
TEST AT 100°F AMBIENT TEMPERATURE

Thermocouple Number and Location	Steady State Temperature (°F)				
	Watts =	2.5	5	8	10
<u>HEATER</u>					
TC-1 Heater Surface		364	422	500	543
<u>OUTSIDE PRIMARY CAN</u>					
TC-2 Near Bottom		228	273	327	353
TC-3 Near Side		251	301	360	389
TC-4 Near Top		222	265	317	342
<u>OUTSIDE INNER CONTAINER</u>					
TC-5 Bottom Center		221	263	316	341
TC-6 Side Mid-Height		221	264	316	342
TC-7 Top Cover Side		218	260	311	336
TC-8 Top Center		219	261	312	337
<u>FIREDIKE</u>					
TC-9 Inner Surface		218	260	311	336
<u>DRUM EXTERIOR</u>					
TC-10 Bottom Center		104	105	106	107
TC-11 Side Mid-Height		105	106	108	110
TC-12 Top Center		103	104	106	107

6.4. MAXIMUM HEAT LOAD

CAPABILITY

The maximum heat load capability is determined for the package based on the maximum capability of the inner container and the Firedike since these are the limiting factors for this package. The drum exterior surface temperature at the maximum heat load is determined. Also in this section, guidance is provided regarding packaging materials based on the heater surface temperature data.

The maximum permissible temperature for the exterior surface of the inner container during normal transportation is selected at 300°F (149°C) when the package is in 100°F ambient air. The 300°F temperature is selected to ensure the Firedike insulation will not be discolored. (It will discolor significantly above 400°F.) This temperature is sufficiently low so that the inner container will not exceed design capabilities even at the hypothetical accident fire temperature of 435°F (224°C). The pressure capability of the inner container is based on 500°F. The life of Silastic or Viton O-rings is indefinitely long at 300°F. At 500°F the life is 7 hr for Silastic and 4 hr for Viton. Based on the 300°F maximum temperature for the inner container surface during normal transportation and the resulting temperature increases at hypothetical accident conditions (see Section 10), the resulting maximum heat load capability and external drum temperature at 100°F ambient temperature, as shown in Figure 6-3, are given in Table 6-2. The maximum capability of the package is based on the 300°F limitation, and the estimated maximum temperature in a fire is approximately 65°F below the specified maximum of 500°F.

Table 6-2 - MAXIMUM HEAT LOAD CAPABILITY AND TEMPERATURES

Maximum Heat Load Capability (W)	7.0
Maximum Drum External Surface Temperature (°F)	107
Inner Cont. Maximum Steady State Temperature at 100°F Ambient (°F)	300
Inner Cont. Temperature Increase Resulting from Hypothetical Fire (°F)	135
Inner Cont. Maximum Temperature with Heat Load and Hypothetical Fire (°F)	435

The maximum temperature of 107°F (42°C) for the exterior drum surface shown in Table 6-2 is less than the permitted maximum accessible external surface temperature of 122°F (50°C); thus, this is not a limiting factor for determination of the maximum heat load capability. The maximum heat load listed is considered sufficiently high to provide for anticipated requirements and sufficiently low to provide a reasonable margin of safety.

The heater surface temperature data shown in Figure 6-3 provide a comparison between the packaging materials tested and provide a basis for establishing guidelines which may be used to ensure that package contents will not reach excessive temperatures. For any given heat load, temperatures were lowest with lead shot and highest with steel wool. The heater temperatures provide guidance for estimating product heat source surface temperatures during shipment. However, the actual temperature of a product being shipped will depend on the particular characteristics of that product; for example, a smaller surface area will result in a higher surface temperature. In general, it is necessary to consider the specific characteristics of the material being shipped and the temperature capability in order to ensure compliance with requirements.

7. Internal Pressure Capability

7.1. GENERAL

The internal pressure capabilities of the inner container were thoroughly evaluated according to procedures given in the ASME Pressure Vessel Code [1]. The evaluation clearly demonstrates that the vessel is capable of safe pressure containment during normal transportation and hypothetical accident conditions.

Calculations for the internal pressure capability of the inner container at up to 100°F are presented, and the results for temperatures at 300°F and 500°F are then tabulated. A separate calculation is required for each of the three basic components, which are the cylindrical body, the welded bottom, and the cover. The maximum pressure capability is then based on the value for the welded bottom since this is the lowest value for the three components.

7.2. BODY CALCULATIONS

The basic structure of the inner container is shown in Figure 7-1. It is a cylinder of AISI 1026 C.D.S. with welded bottom plate and a screwed on cover both of AISI 1018 C.R.S. The cover is sealed with a silicon O-ring. It is fabricated of mild steel, and the welds are examined after fabrication (see Appendix A). The maximum allowable working pressure of the seamless tubing body is calculated according to the following:

$$P = \frac{SEt}{R + 0.6t}$$

where P = Maximum allowable working pressure, psi,

S = Maximum allowable stress (derived from data for AISI 1025 steel

given in reference 1), S = 18,750 psi at -20 to 100°F, 17,360 at 300°F, and 16,320 at 500°F,

E = Welded joint efficiency, E = 1 for seamless tubing,

R = Inside radius of inner container, R = 1.125 in.,

t = Wall thickness, t = 0.375 in.

Substitution of the appropriate values for a temperature of 100°F into the above equation yields:

$$P = \frac{(18,750) (1) (0.375)}{(1.125) + (0.6) (0.375)}$$

$$P = 5,208 \text{ psi.}$$

The results of the seamless body calculations for other temperatures are shown in Table 7-1.

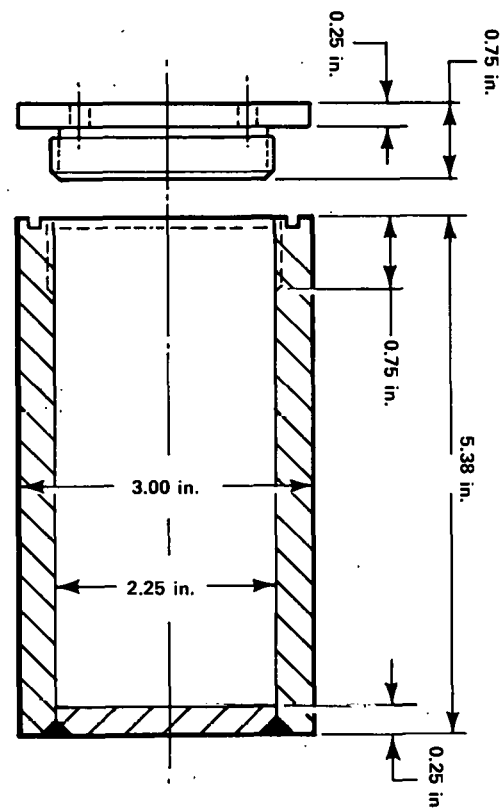


FIGURE 7-1 - 9506 inner container.

Table 7-1 - INNER CONTAINER BODY
PRESSURE CAPABILITY CALCULATIONS

Inside Radius (in.)	Body Wall Thickness (in.)	Internal Pressure Capability (psig)		
		At -20 to 100°F	at 300°F	at 500°F
1.125	0.375	5208	4822	4532

7.3. WELDED BOTTOM PLATE

CALCULATIONS

The inner container bottom is welded to the body. Its pressure capability is calculated as follows:

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

where P = Maximum allowable working pressure, psi,

S = Maximum allowable stress (derived from data for AISI 1020 steel given in reference 1),
S = 17,500 psi at -20 to 100°F,
16,200 at 300°F, and 15,230 at 500°F,

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

R = Inside radius of inner container, R = 1.125 in.,

t = Thickness of bottom plate,
t = 0.25 in.

The resulting calculation is as follows:

$$P = \frac{17,500}{0.3} \left(\frac{0.25}{2 \times 1.125} \right)^2$$

$$P = 720 \text{ psi.}$$

The required parameters and the results of the welded bottom plate calculations for other temperatures are shown in Table 7-2.

7.4. COVER DESIGN

The top cover seals the inner container by a screwed flange tightened against a compressible O-ring seal. The critical points which were examined in this analysis were: (1) shear strength of external and internal threads, (2) tensile strength of external threads, (3) the effect of stress concentrations at the relief undercut beneath the flange, and (4) the strength of the silicone O-ring seal under load.

The limiting condition for the cover was determined to be the shear strength of the external threads and only this calculation will be illustrated. The permissible loading on the external threads of the flange is given by the formula,

$$P_e = A_e \times L \times S_e$$

Table 7-2 - INNER CONTAINER WELDED BOTTOM
PLATE PRESSURE CAPABILITY CALCULATIONS

Inside Radius (in.)	Bottom Wall Thickness (in.)	Internal Pressure Capability (psig)		
		At -20 to 100°F	at 300°F	at 500°F
1.125	0.25	720	667	627

where, P_e = Minimum strength in shear of external threads, lb,
 A_e = Minimum area in shear of external threads,
= 4.0409 in.²/in. for 2-3/8 x 16 UN Class 2A thread
 L = Engagement length, in.,
= 0.3125 in.
 S_e = Allowable shear stress for AISI 1018 material, psi
= 10,500 psi at 100°F, 9722 psi at 300°F, and 9138 psi at 500°F.

The calculation at 100°F gives

$$P_e = 4.0409 \times 0.3125 \times 10,500 = 13,259 \text{ lb}$$

The equivalent internal pressure, P , is found by dividing the above load by the internal area, where

$$P = 13,259 / \left(\frac{\pi}{4} (2.25)^2 \right) = 3335 \text{ psi at } 100^\circ\text{F}$$

The loading greatly exceeds the limiting loading of 720 psi which was determined in Section 7.3 for the welded bottom plate; the results of these calculations for other temperatures are shown in Table 7-3.

An examination of the silicone O-ring design indicates that the ring will be safely confined within the main body groove when the cap is assembled and

torqued to closure. The O-ring will be compressed to about 81% of its initial diameter at this time. The manufacturer's pressure rating on this O-ring seal is 1500 psi. This pressure exceeds the limiting allowable pressure due to the bottom plate. Thus, the O-ring pressure capability is not limiting. The maximum continued service operating temperature of the silicone O-ring is listed as 450°F in the manufacturer's design literature; this is greater than the maximum temperature of 435°F to which the inner container would be exposed during the hypothetical accident (fire) conditions.

7.5. RESULTS AND CONCLUSIONS

Comparison of the resulting internal pressure capability calculations for the three basic components indicates that the welded bottom plate is the weakest component for the inner container. Thus, the ASME Code maximum allowable working pressures are those shown in Table 7-2. The pressure capabilities, e.g., 627 psig at 500°F, are sufficiently high to contain the 10 psig pressure which would result from heating the air environment trapped during packaging operations at 1 atm to the temperatures reached during normal shipment and during hypothetical accident conditions.

Table 7-3 - INNER CONTAINER COVER PRESSURE CAPABILITY CALCULATIONS

Inside Radius (in.)	Cover Thickness (in.)	Internal Pressure Capability (psig)		
		At -20 to 100°F	at 300°F	at 500°F
1.125	0.25	3335	3088	2902

7.6. REFERENCES

1. J. M. Guy, et al., ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division 1, The American Society of Mechanical Engineers, New York, N. Y. (1974).
2. R. C. Boucher, "Strength of Threads," Product Engineering, November 27, 1961.
3. C. Lipson, G. C. Noll, and L. G. Clock, "Significant Stress and Failure," Product Engineering, July 1949.

8. Package Standards Evaluation

8.1. GENERAL

In Part II of DOE Manual Chapter 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 purpose of this evaluation is to provide the necessary support information which verifies that the package is in compliance with these standards.

8.2. MATERIALS

The packaging materials and the package contents will not cause any significant reactions even at hypothetical accident conditions. Design materials were selected on the basis of test data and past experience with container packaging, unpacking, storage, and shipping.

8.3. CLOSURES

Positive closures, using bolts and screwed threads which prevent accidental opening, are used on the drum and the inner container. In addition, seals are secured to the drum closures during shipment.

8.4. 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.

No lifting devices, as such, are provided on the shipping container. The maximum gross weight of the package is only 37

lb and the package can be handled manually.

8.5. TIEDOWN DEVICES

ERDAM 0529 specifies that the 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.

No tiedown devices are used and the packages are normally retained in place within the transport vehicle by other packages or are strapped in place.

8.6. LOAD RESISTANCE - BEAM LOADING

The requirement is that the container not yield when supporting five times its loaded weight in beam action. For this requirement the container will be analyzed as a horizontal simple beam with a uniformly distributed load along its major axis. Figure 8-1 shows the container in its loaded position.

The loaded weight, W_t , of the container was taken as 37 lb.

For effective length, $L = 14.12$ in., the distributed load becomes $W = 5 W_t/L = 5(37)/14.12 = 13.1$ lb/linear in.

The maximum bending moment, M_{max} , for this loading is $M_{max} = wL^2/8 = (13.1)(14.12)^2/8 = 326.5$ in.-lb.

For a thin-walled cylinder with radius, $R = 5.25$ in., and wall thickness, $t = 0.031$ in., the moment of inertia, I , is $I = \pi R^3 t = \pi(5.25)^3(0.031) = 14.09$ in.⁴ The section modulus, z , is then

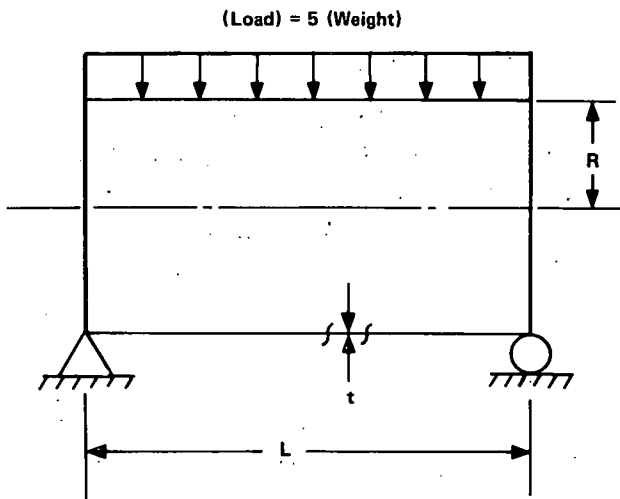


FIGURE 8-1 - Beam loading diagram for package.

$z = I/R = 14.09/5.25 = 2.68 \text{ in.}^3$ and the maximum bending stress, S_{max} , is
 $S_{\text{max}} = M_{\text{max}}/z = 326.5/2.68 = 122 \text{ psi.}$

The calculated bending stress of 122 psi is much less than the yield stress of 27,000 psi [1], and the container, therefore, is adequate as designed.

8.7. EXTERNAL PRESSURE

DOE Manual 0529 requires that the container be capable of withstanding an external pressure of 25 psig with no loss of contents. The inner container, shown in Figure 8-2, consists of three parts: the top cover, the main cylinder, and the bottom plate. The stress arising from the specified external pressure is calculated for each of these parts.

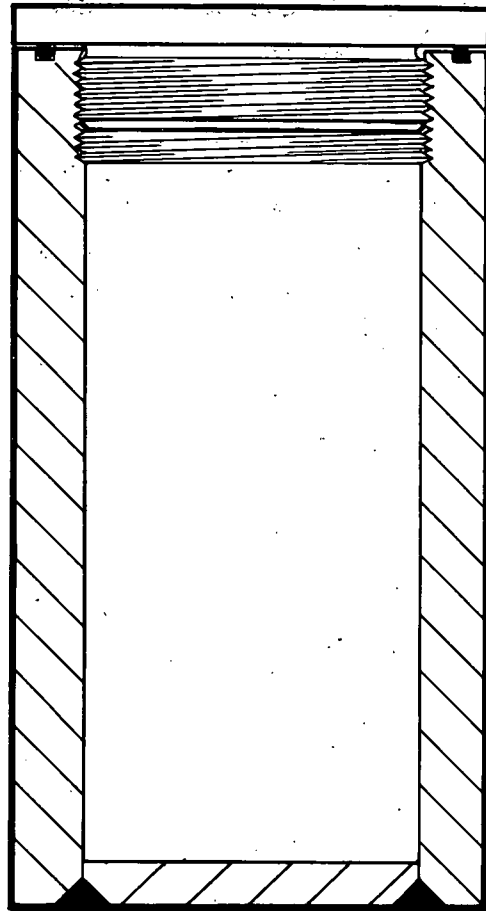


FIGURE 8-2 - Inner container.

Top Cover

The top cover seals against an O-ring, and sealing force is maintained by the torque of screw threads.

It is assumed that under an external pressure the O-ring will be compressed, and the force will be transferred to the screw threads.

$$\text{The external force is } 25 \text{ psi} \times \pi(3.0)^2/4 = 176.7 \text{ lb.}$$

The internal pressure calculations (Chapter 7) determined that the external threads of

the top cover were the critical stress point in the threaded connection.

The effective thread stress [2], S_e , is then $S_e = P/A_e L$ where

P = External force, lb

A_e = Minimum shear area, ext. threads (= 4.0409 in.²/linear in.)

L = Engagement length = 0.3125 in.

Thus,

$$S_e = \frac{176.7}{4.0409 \times 0.3125} = 140 \text{ psi}$$

Main Cylinder

1. The membrane stress in the cylinder is

$$S = PR/t$$

where

R = inside radius = 1.3125 in.

t = wall thickness = 0.375 in.

thus,

$$S = 25 \times 1.3125 / 0.375 = 87.5 \text{ psi.}$$

This is well below the allowable stress value of 15,230 psi at 500°F for AISI 1026 C.P.S. as discussed in Section 7.

2. The buckling strength is

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

where

D = outside diameter = 3.0 in.

t = wall thickness = 0.375 in.

D/t = 8

B = 14,000 (determined from Fig. UCS.28.1, p272 of Reference 1, using L = engagement length = 5.38 in., and L/D = 1.79).

thus,

$$P_{\text{allow}} = 14,000 / 8 = 1,750 \text{ psi.}$$

which is 1,750/25 = 70 times the applied external pressure.

Bottom Plate

With the assumption of complete edge fixity, the equation for stress is [3]

$$S = 1.24 R^2 P / t^2$$

where

R = inside radius = 1.125 in.

P = external pressure = 25 psi

t = plate thickness = 0.25 in.

thus, $S = 1.24 (1.125)^2 25 / (0.25)^2 = 628 \text{ psi}$

This is well below yield stress of 15,230 at 500°F for AISI 1018 C.R.S. as discussed in Section 7.

8.8. REFERENCES

1. J. M. Guy, et al., ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division 1, The American Society of Mechanical Engineers, New York, N. Y. (1974).
2. R. C. Boucher, "Strength of Threads," Product Engineering, Nov. 27, 1961.
3. R. J. Roark and W. C. Young, Formulas for Stress and Strain, McGraw-Hill, 1976.

9. Normal Conditions of Transport Evaluation

9.1. GENERAL

DOE Manual Chapter 0529 requires nuclear packaging to be capable of satisfactory packaging effectiveness and radioactive materials containment when subjected to nine tests simulating normal transportation environment and handling conditions. These tests are:

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

The related testing and engineering evaluations adequately demonstrated that the requirements are satisfied.

9.2. Heat

Direct sunlight at an ambient temperature of 130°F (54°C) in still air would not increase the temperatures of the drum, insulation, or the inner container (primary containment vessel) in excess of design capabilities.

A calculation is presented which estimates the maximum temperature resulting from direct sunlight. The procedure consists of determining the heat load from the sun and the resulting external drum surface temperature which is required to dissipate the solar heat load to 130°F ambient air. Since the temperature increases resulting from the solar heat load throughout the package are less than, or equal to, the corresponding increase at the drum surface, the assumption that these temperature increases are equal throughout the package provides a conservative estimate of the inner container temperature.

Shappert's [1] approach establishes the average solar heat load over a 24-hr period as 42 W/ft² of projected surface area. The maximum possible projected surface area is estimated based on viewing the container, when in an upright position, at an angle perpendicular to a diagonal drawn through the drum and is calculated as follows:

$$A = [(0.97 \text{ ft diam})^2 + (1.22 \text{ ft height})^2]^{\frac{1}{2}} \times (0.97 \text{ ft diam}),$$
$$A = 1.5 \text{ ft}^2.$$

Therefore, the solar heat load (Q_s) is

$$Q_s = (1.5 \text{ ft}^2) (42 \text{ W/ft}^2) = 63 \text{ W}$$

The resulting temperature increase at the drum surface is determined by linear extrapolation of the experimental steady state temperature profile data. Since the drum surface temperature increased 9.5°F above ambient when 10 W was dissipated, the surface temperature increase is estimated to be 60°F when 63 W must be dissipated. Thus, 60°F is determined to be the temperature increase on the surface of the drum and throughout the package resulting from the solar heat load. An additional 30°F must be added to account for the increase in ambient temperature from 100° to 130°F. At the maximum acceptable heat load of 7.0 W the drum surface temperature is then 110 + 60 + 30 = 200°F at an ambient temperature of 130°F in direct sunlight. The temperatures at 100°F in shade (see Section 6) and the results of the above calculations are summarized in Table 9-1.

Thus, the heat input from the sun will not cause the inner container temperatures to exceed design capabilities. In fact, the inner container is designed to withstand the hypothetical accident fire condition temperature of 435°F, as discussed elsewhere in this report. The effectiveness of the steel drums and insulation is not

Table 9-1 - DRUM AND INNER CONTAINER TEMPERATURES IN SHADE AT 100°F AND IN DIRECT SUNLIGHT AT 130°F WHEN CONTAINING MAXIMUM HEAT LOAD

Maximum Contents Heat Load Capability (W)	In 100°F Shade		Intermediate Calculations			In 130°F Sun	
	Drum (°F)	Inner Cont. (°F)	Proj. Area (ft ²)	Solar Load (W)	Solar Increase (°F)	Drum (°F)	Inner Cont. (°F)
7.0	110	300	1.5	63	60	200	390

expected to be reduced as a result of the sun, although the insulation would discolor significantly at 390°F.

9.3. COLD

An ambient temperature of -40°F 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.

9.4. PRESSURE

The usual internal pressure of the inner container at the time of loading is 1 atm. As seen in Section 9.2, the maximum temperature of the inner container when subjected to a combination of normal conditions (sunshine and 100°F ambient) is 360°F. At this temperature, the gases trapped within the sealed inner container would reach an internal pressure of 1.5 atm.

The normal condition external pressure is specified to be 0.5 atm. Thus, the difference between the internal pressure (1.5 atm) and the external pressure (0.5 atm) would be 1.0 atm at the most severe combination of normal conditions. This pressure difference is equivalent to 15 psig and is well within the capability of the inner container. In Section 7 it was shown that this capability is 627 psig at 500°F and 667 psig at 300°F.

9.5. VIBRATION

Vibration normally incident to transport will not reduce the effectiveness of the packaging. The capability of these packages to withstand normal vibration is well established as a result of routine use of similar packaging. Since 1968, approximately 400 shipments have been successfully completed in 5790 and 5791 packaging* with no evidence of damage from vibration.

9.6. 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 package in any way or have any effect, other than slight cooling, on the contents. The package is actually exempt from this test requirement since the external surface is of all-metal construction.

9.7. 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 reduce the effectiveness of the packaging as evidenced by the minor damage sustained from the 30-ft drop test.

*These similar packagings are described in: J. F. Griffin, et al., "Safety Analysis Report for Packaging (SARP): USA/5790/BLF(ERDA-AL) and USA/5791/BLF(ERDA-AL)," MLM-2242 (April 30, 1976).

10. Hypothetical Accident Tests

10.1. GENERAL

DOE Manual Chapter 0529 requires satisfactory performance of packaging when the shipping container is subjected to a series of four tests simulating accident conditions. Escape of radioactive materials must be below defined limits, and the package must remain subcritical. The free drop, puncture, thermal, and water immersion tests must be performed in the listed sequence.

10.2. TEST PACKAGE PREPARATION

A full-scale shipping container was subjected to the complete series of four hypothetical accident tests. The test inner container was packaged using lead shot to simulate maximum contents weight. Chromel/alumel thermocouples were used for temperature measurements inside the inner container. In addition, temperature sensitive paints were applied to the inside and outside walls of the inner container. The paints and labels were formulated to melt at 200°F (93°C), 300°F (149°C), 400°F (204°C), and 500°F (260°C) and were color coded. The metal drum had a chromel/alumel thermocouple attached to its outer surface and one thermocouple placed near the top surface of the drum to measure flame temperature.

During final assembly of the package, the bolt used to fasten the closure ring in place was aligned with the seam of the drum so this could be identified as the weakest part of the drum in the free-drop test.

10.3. FREE-DROP TEST PROCEDURE

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

A drop tower equipped with a hoist was used to drop the package from a height of 30 ft onto a steel-covered concrete drop pad. The package was oriented upside down at a 45° angle so that the bolt on the bolt ring would strike the pad first. The container was dropped in precisely the initial orientation since no twisting motion was imparted to it by the quick release hook used.

10.4. PUNCTURE TEST PROCEDURE

This test requires a free drop through a distance of 40-in. striking, in such a position that maximum damage is expected, the top end of a vertical, cylindrical, mild steel bar mounted on an essentially unyielding horizontal surface. The bar must have a 6-in. diameter, with the top horizontal and its edge rounded to a radius of not more than 1/4 in., and of such a length as to cause maximum damage to the package, but not less than 8-in. long. The long axis of the bar must be perpendicular to the unyielding horizontal surface.

This test was conducted in a manner similar to the Free-Drop Test.

10.5. THERMAL TEST PROCEDURE

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 (800°C) for 30 min with an emissivity of 0.9, assuming the surfaces of the package have an absorptivity of 0.8. The package may not be cooled artificially until 3 hr after the test period, unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hr.

The fire test facility was designed to meet the DOT/ERDA hypothetical accident conditions. To simulate actual conditions, the test facility provides an open, aviation-gasoline-fueled fire. A water spray system was designed into the facility to eliminate the huge volumes of smoke normally associated with open gasoline fires. Wind effects are reduced by 8-ft high firebrick walls on three sides and on the fourth side a 4-ft wall to permit viewing and ease of handling the shipping containers. The base of the fire pit is poured concrete measuring 10 x 10 x 0.5 ft deep. Fuel and seven water spray nozzles are located in the fire pit base which is flooded with water 5 in. deep to avoid excessively heating the pit. A 5-HP fan supplies approximately 8000 ft³/min of air through the air manifold outlets located in two opposing 8-ft sides just above the fire pit.

The 100-octane aviation gasoline is continuously gravity fed to the distribution system from a 5,000-gal, buried tank located approximately 100 ft from the fire pit. The gasoline floats to the surface of the water and burns. The water nozzle spray is directed horizontally providing complete coverage of the burning aviation fuel surface. The water spray reduces the

smoke plume well below maximum allowable requirements.

The package was mounted on a stand 2 ft above the water surface and was centered within the burning area approximately 3 ft from the sides.

The temperatures obtained throughout the tests are plotted as a function of time in Figure 10-1. The temperatures were measured at the locations indicated in Figure 10-2. Chromel/alumel thermocouples and a multipoint recorder were used to monitor the tests.

10.6. WATER-IMMERSION TEST

PROCEDURE

This test is necessary for fissile material packages only. The test requires immersion 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.

A permanently installed, 10-ft diameter by 9-ft deep tank, equipped with a 2-ton hoist, was used. Prior to this test, the inner container was removed from the insulated drum assemblies. The tank was filled to a depth of 51 in. to ensure immersion of all parts of the container under at least 36 in. of water. The inner container was immersed overnight for 20 hr, since it was inconvenient to withdraw it after the required 8-hr minimum period.

10.7. TEST RESULTS

The results of the hypothetical accident tests are summarized in Table 10-1. The container passed the drop test to the extent that the drum covers remained

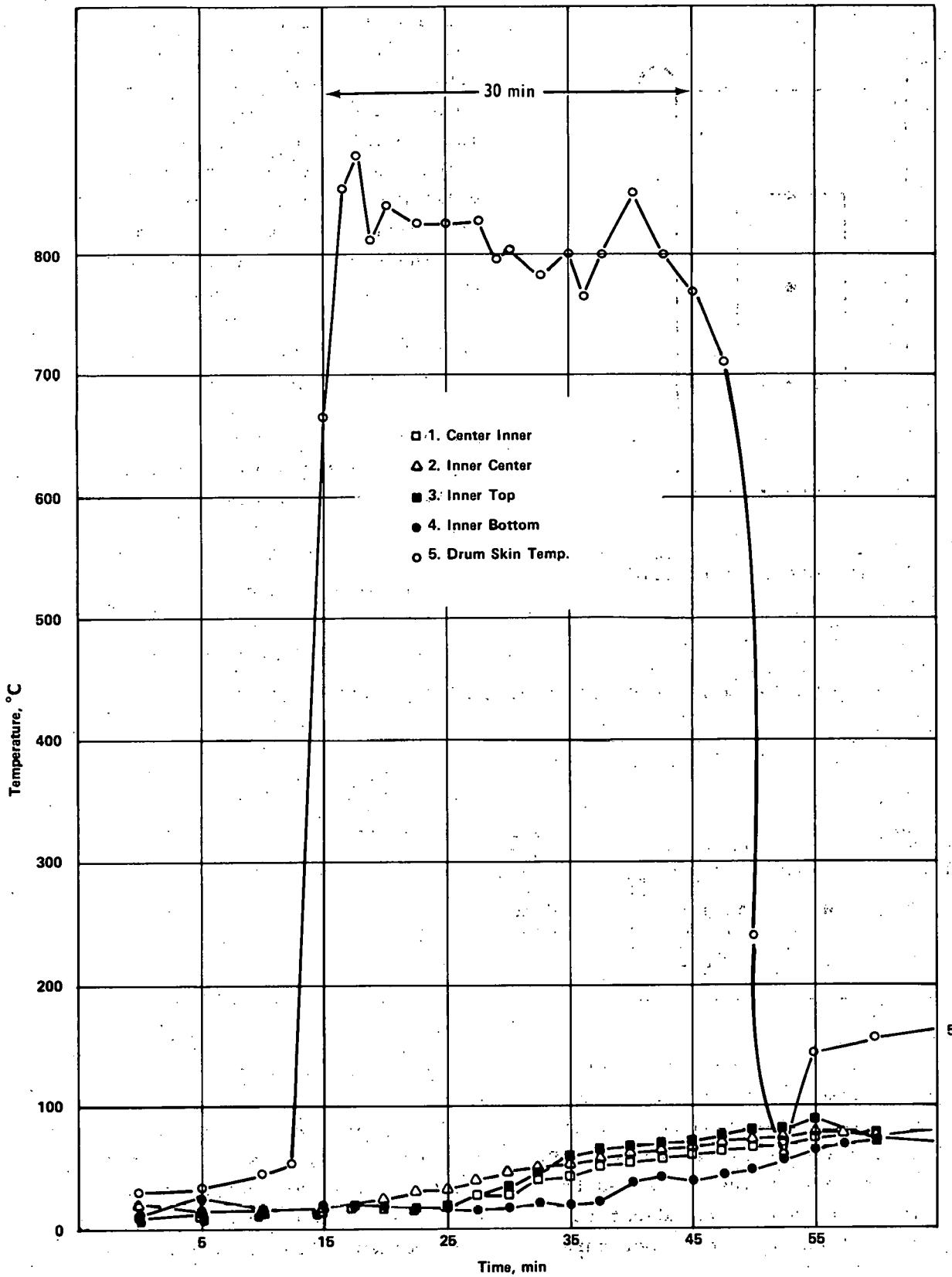


FIGURE 10-1 - Temperatures as a function of time in fire test.

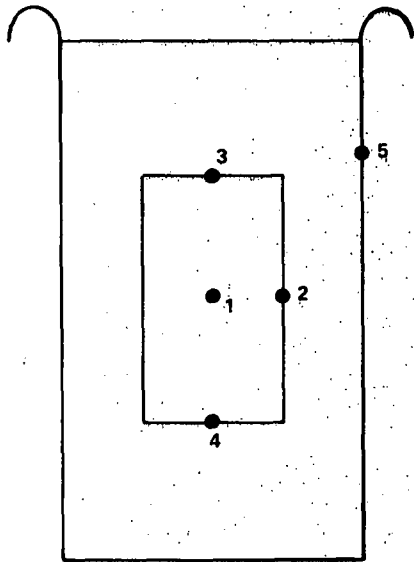


FIGURE 10-2 - Thermocouple locations for fire test.

intact, and the inner container did not suffer any observable damage. The puncture test caused only a minor dent in the drum. The inner container passed the immersion test with no evidence of water leakage into the inner container. The inner container was removed from the insulated drum assembly prior to this test. In addition, after the immersion test, the inner container was reassembled, using the same O-ring, and found to be helium leak tight at an instrument sensitivity of 10^{-4} std cm^3/sec when containing 20 psig of helium pressure.

The package passed the fire test. The top outside surface of the inner container reached a maximum temperature of 200°F , and the interior of the inner container reached approximately the same temperature. The silicone O-ring

Table 10-1 - RESULTS OF HYPOTHETICAL ACCIDENT TESTS

Total Package Weight (lb)	30-ft Drop Results	40-in. Puncture Results	Maximum Temperature (100°F Ambient) of Inner Cont. After 30-min Fire (°F)	Immersion Test Results
37	Welded closure ring lugs. Cover completely intact (3 in. dent)	Minor Dent	235	No Leakage

seals used to seal the inner container did not appear damaged in any way. The average temperature of the package prior to the fire test was estimated to be 65°F . Thus, a 35°F correction must be added to the resulting temperatures to adjust to the required initial package temperature

of 100°F . Based on this, the inner container surface temperature reached $200^\circ\text{F} + 35^\circ\text{F} = 235^\circ\text{F}$ when corrected to 100°F ambient. Thus, as shown in Table 6-2, the maximum inner container temperature with a 7.0 W heat load at the hypothetical accident fire condition is 435°F .

11. Criticality Evaluation and Transport Limits

11.1. GENERAL

The criticality shipping limits for four forms of fissile material to be shipped in DOE-9506 (4-gal drums) shipping containers were evaluated. This shipping container consists of an O-ring-sealed steel inner cylinder centered within the drum by fire retardant insulation. The pertinent dimensions of the inner and outer cylinders are given in Table 11-1.

The four forms of fissile material investigated were uranium-235, plutonium-239, plutonium-238 and uranium-233 metal. The tabulated results may also be applied to compounds of these materials such as oxides, fluorides, chlorides, and nitrates.

11.2. ASSUMPTIONS

In order to evaluate shipping limits, credible accident conditions must be established. At hypothetical accident conditions, distortion of the outer drum is prevented by the fire retardant insulation, so that the inter-unit spacing of the inner containers in an array of drums is assumed to remain constant. During immersion in water, the sealed inner container did not leak. The outer drum,

being vented, will leak. Thus, the fissile material will not mix with moderating material; i.e., the H/X ratio remains almost zero, but the interunit moderation can increase. The interunit spacing is large, however (i.e., 21.75 in.), and is filled with the fire-retardant insulation, so that the interaction between units would be small. In an array of contiguous drums, therefore, the introduction of additional moderating material in the drum would decrease the interaction between units or have little effect on the interaction. Thus, in-leakage of water in the outer drum would have a beneficial or very small effect on reactivity. This assumption was checked and verified by making calculations with the KENO Monte-Carlo criticality code. [1] Thus, the damaged packages will be less reactive than the undamaged ones, and all calculations were made for undamaged packages.

11.3. METHOD

The maximum unit mass in kilograms for a specific number of drums to form a critical array was determined by interpolating the tables given in the "Guide for Nuclear Criticality Safety in the Storage of Fissile materials." [2] This interpolation requires an effective cubic dimension for the drum, which was evaluated by equating the drum volume to a cubical volume. This

Table 11-1 - DIMENSIONS OF INNER CYLINDER AND DRUM

	<u>o.d.</u> <u>(in.)</u>	<u>i.d.</u> <u>(in.)</u>	<u>Inside</u> <u>Height</u> <u>(in.)</u>	<u>Outside</u> <u>Height</u> <u>(in.)</u>	<u>Inner</u> <u>Volume</u>	<u>Effective*</u> <u>Cubic</u> <u>Dimensions</u> <u>(in.)</u>
Inner Container	3.0	2.25	5.13	5.53	20.4 cu.in.	
Drum	10.875			14.25	4 gal	10.98

*Length of a side of a cube of volume equal to that of the drum.

dimension is given in Table 11-1. The values in these tables are based on several conservative assumptions:

- 1) The mass limits for the individual units in an array will produce an array multiplication factor of less than 0.95;
- 2) The arrays are assumed to be reflected with 30 in. of water or 5 in. of concrete;
- 3) All units are assumed to be spherical, which is the most reactive configuration;
- 4) The limits provide for close fitting containers of up to 1/2 in. in thickness;
- 5) The mass limits assume air-spaced arrays, but allow for moderation produced by fire protection systems. (This is conservative, since the insulation which exists between the units would decrease the interaction and reactivity.)

The Fissile Class limits that apply to this container were evaluated as follows: Packages which may be transported in unlimited numbers are designated as Fissile Class I. In evaluating unit mass limits for this class of packages, the "unlimited number" was taken to be 2500.

The Transport Index of a package requiring Fissile Class II designation was evaluated by dividing the number of packages of a critical array into 250. Since the total Transport Index (i.e., the sum of the individual transport indices) of a Fissile Class II shipment must be less than 50, the number of packages shipped Fissile Class II is no more than 1/5 the critical number.

A shipment of packages with a total Transport Index greater than 50 and

individual packages with a Transport Index greater than 10 must be shipped Fissile Class III. The number of packages which can be shipped Class III is one-half the critical number.

11.4. RESULTS

The unit mass limits of the four isotopes for a specified number of packages to produce a critical array (actually, an array $k_{eff} < 0.95$), along with the Transport Index associated with these mass limits, are given in Table 11-2. The mass limits for 2500 units (or packages) are Fissile Class I mass limits. The number of units in a critical array as a function of unit mass for the four isotopes are shown plotted in Figures 11-1 through 11-4; the Transport Indices as a function of unit mass are given in Figures 11-5 through 11-8. The criticality limits given for plutonium-238 are academic, since the mass limits for this isotope are limited by heat dissipation rather than criticality. As a result of the high heat density of this material (~0.5 W/g), the amount of material that would be shipped in any one container will be limited to 7.0 W, which is much lower than the unit masses given in Table 11-2.

As stated in Section 11.2, KENO calculations were used to verify that the assumption of an air-spaced array is conservative as used in obtaining the values in Table 11-2. The KENO calculations were for a specific example case and as such were used as a check and not for developing the results of Table 11-2. The case considered was as square array of 25 units containing plutonium-239 at the mass limit of 4.7 kg per unit. The plutonium was assumed to be distributed evenly throughout the inner cylinder. Calculations were made for an

air-spaced array and arrays containing half density and full density water between the units. The arrays were reflected with 30 cm of water on all sides. The results of these calculations are given in Table 11-3. These results support the assumption that the insertion of moderating material between the units decreases the reactivity of the array.

11.5. SAMPLE EVALUATION OF SHIPMENT

Suppose it is desired to ship 4 kg of uranium-233 per drum. From Table 11-2, this is above the Fissile Class I limit. From Figure 11-8, the Transport Index is

2.0, so 25 packages can be shipped Fissile Class II. If it is desired to ship more than 25 packages, the shipment must go Fissile Class III. From Figure 11-4, 125 packages make up a critical array, so 62 packages can be shipped Fissile Class III.

REFERENCES

1. G. E. Whitesides and N. F. Cross, KENO-A Multi-group Monte Carlo Criticality Program, CTC-5, Computing Technology Center Report, Oak Ridge National Laboratory (September, 1969).
2. Am. Nucl. Soc., Guide for Nuclear Criticality Safety in Storage of Fissile Materials, ANS Pub. N16.5 (ANS-8.7), February 1973.

Table 11-2 - UNIT MASS LIMITS AND TRANSPORT INDICES FOR CRITICAL ARRAYS

Number of Units	Uranium-235 (kg)	Plutonium-239 (kg)	Plutonium-238** (kg)	Uranium-233 (kg)	T.I.
25	14.8*	4.7	4.9	6.1	10
50	11.9*	4.0	4.2	5.1	5.0
100	9.5*	3.4	3.3	4.2	2.5
200	7.4*	2.9	3.0	3.5	1.3
400	6.1*	2.5	2.6	3.0	0.6
600	5.4	2.2	2.3	2.7	0.4
800	4.9	2.1	2.2	2.5	0.3
1000	4.7	2.0	2.1	2.4	0.3
1500	4.0	2.3	1.9	2.1	0.2
2000	3.6	1.7	1.8	1.9	0.1
2500 (Fissile Class I Limits)	3.4	1.6	1.7	1.8	0.1

*Mass of uranium-235 per package limited by physical size of inner container to ~5.9 kg.
 **Mass limit of plutonium-238 per package restricted by maximum heat loading of 7 watts.

Table 11-3 - KENO CALCULATED k_{eff} FOR PACKAGES CONTAINING 4.7 kg of PLUTONIUM-239 IN A 5 x 5 ARRAY

<u>Moderation Between Units</u>	<u>k_{eff}</u>
Air	0.825 ± 0.031
Half Density Water	0.741 ± 0.032
Full Density Water	0.752 ± 0.032

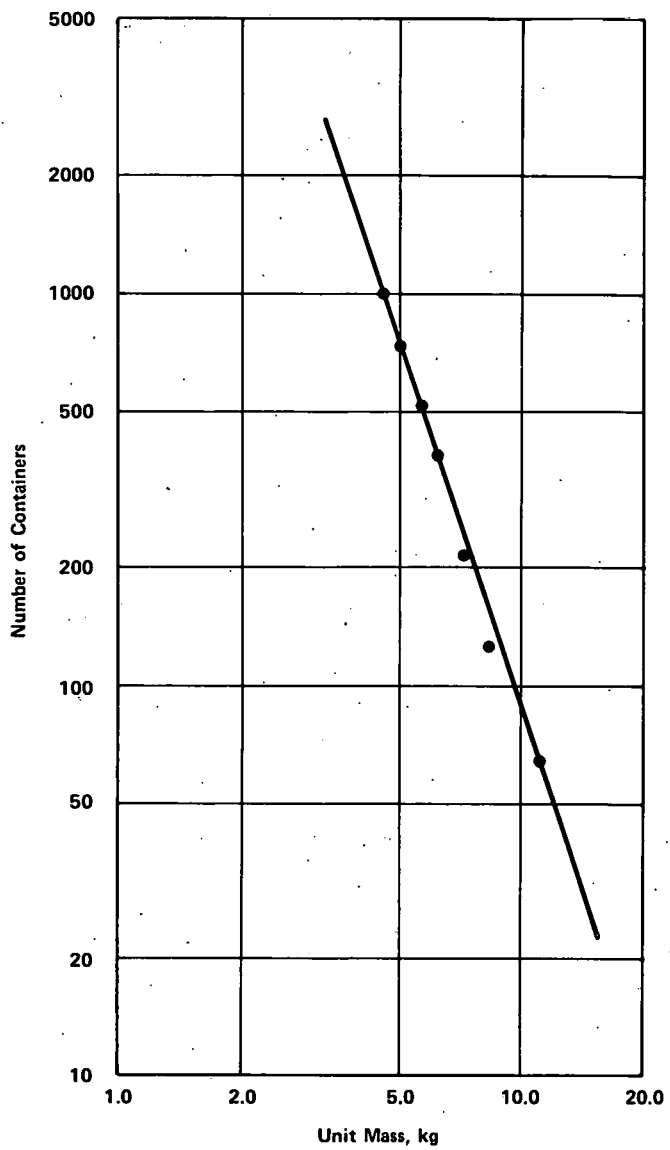


FIGURE 11-1 - Critical number of containers vs unit mass per container for uranium-235.

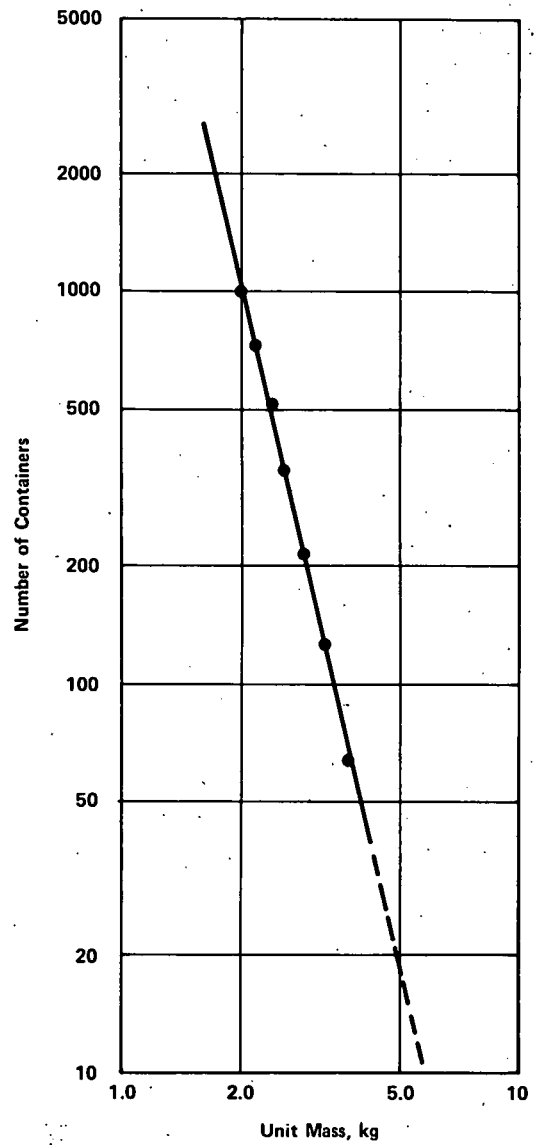


FIGURE 11-2 - Critical number of containers vs unit mass per container for plutonium-239.

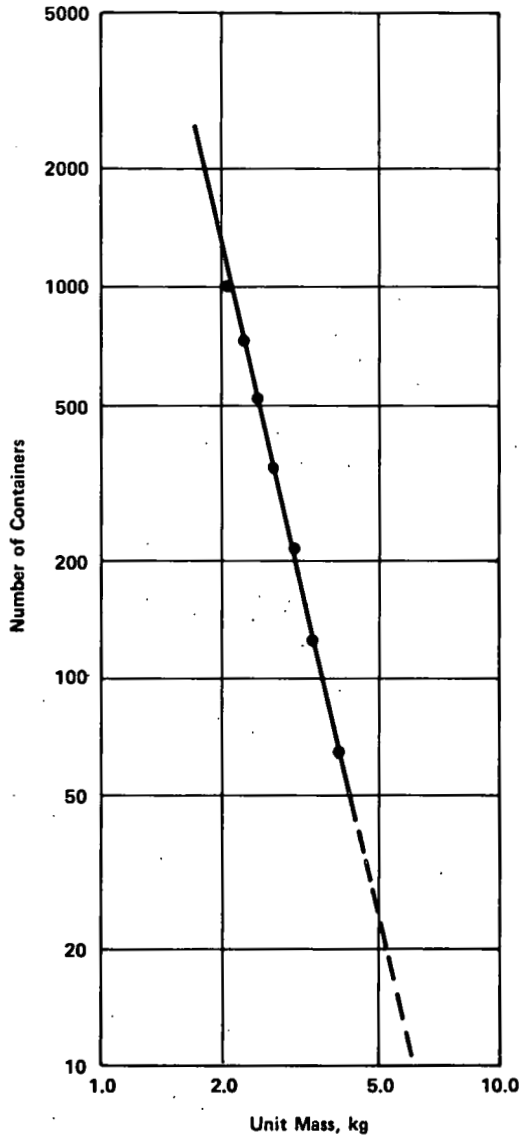


FIGURE 11-3 - Critical number of containers vs unit mass per container for plutonium-238.

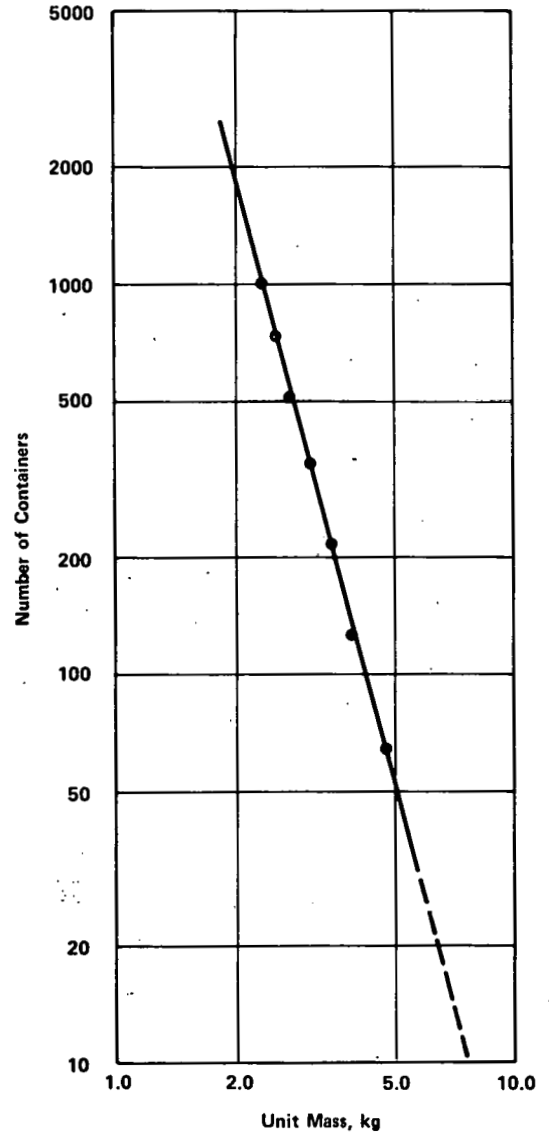


FIGURE 11-4 - Critical number of containers vs unit mass per container for uranium-233.

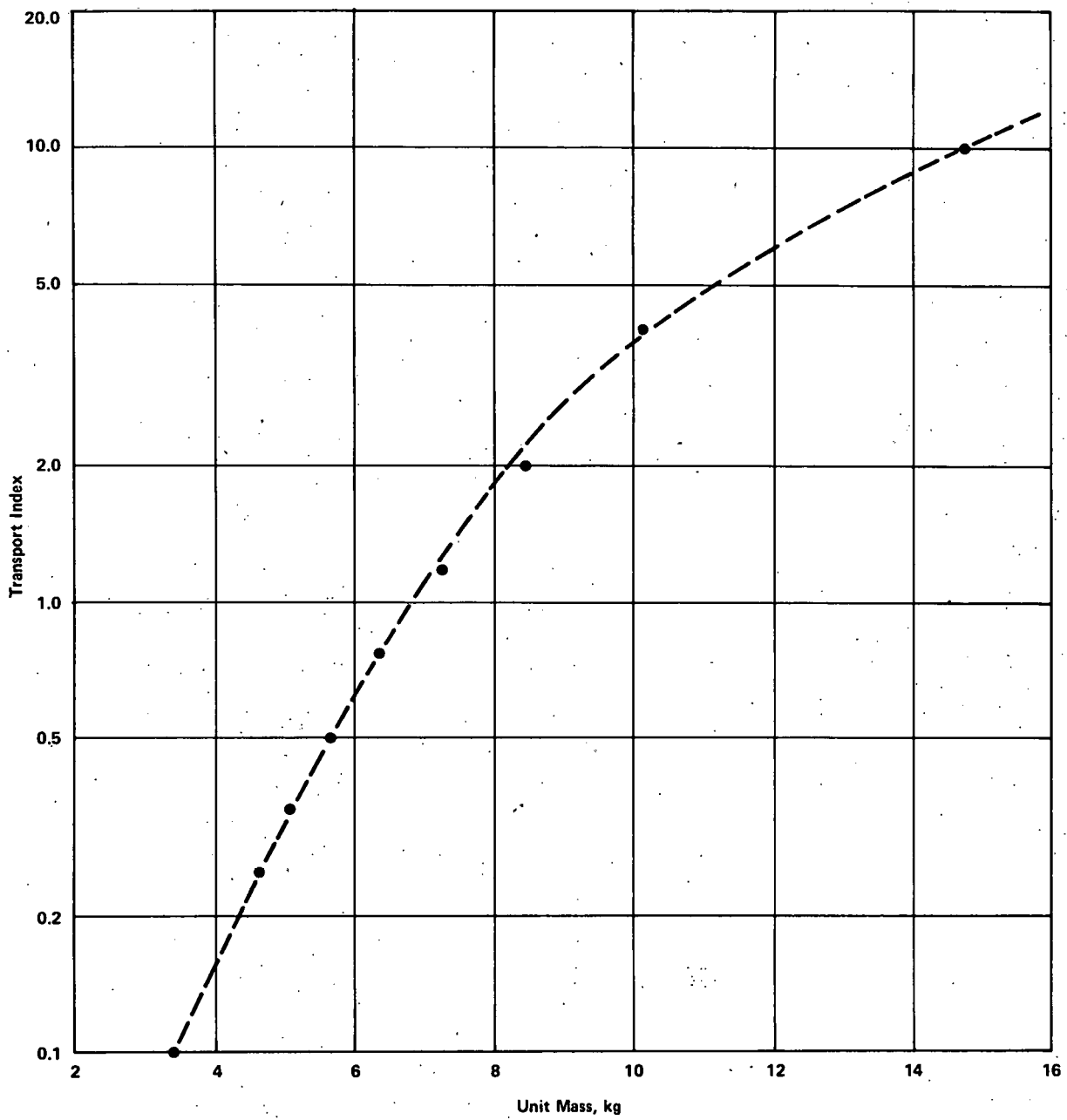


FIGURE 11-5 - Transport index vs unit mass for uranium-235.

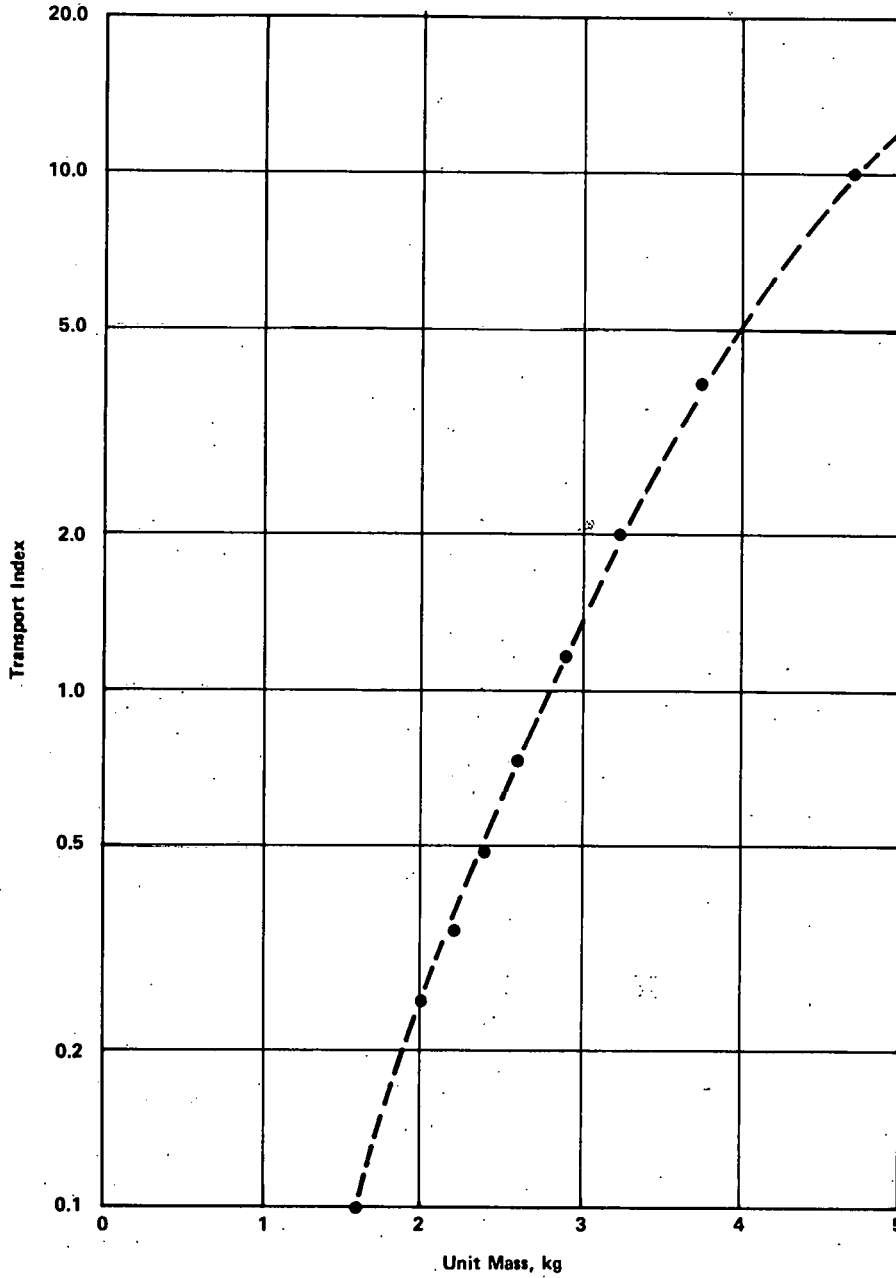


FIGURE 11-6 - Transport index vs unit mass for plutonium-239.

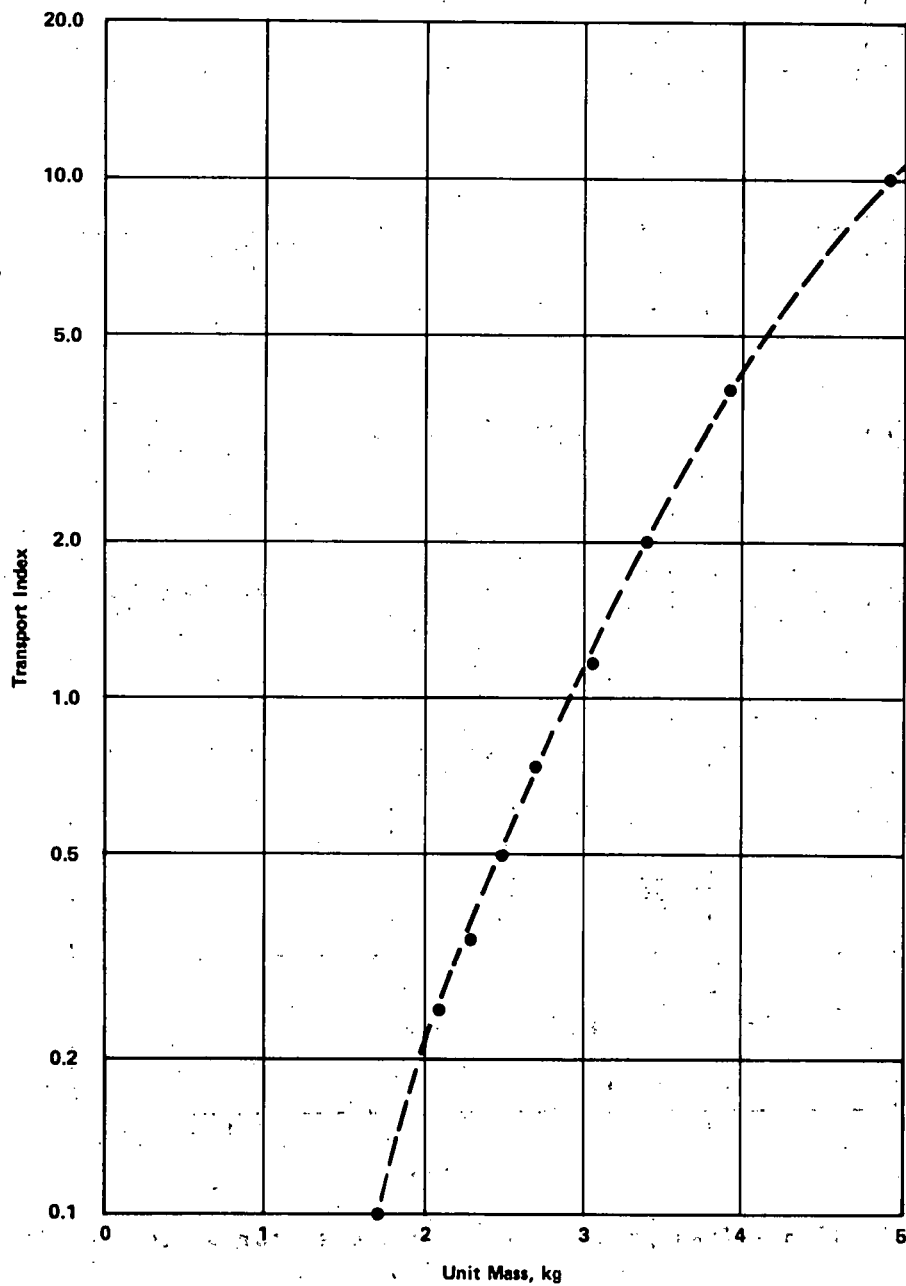


FIGURE 11-7 - Transport index vs unit mass for plutonium-238.

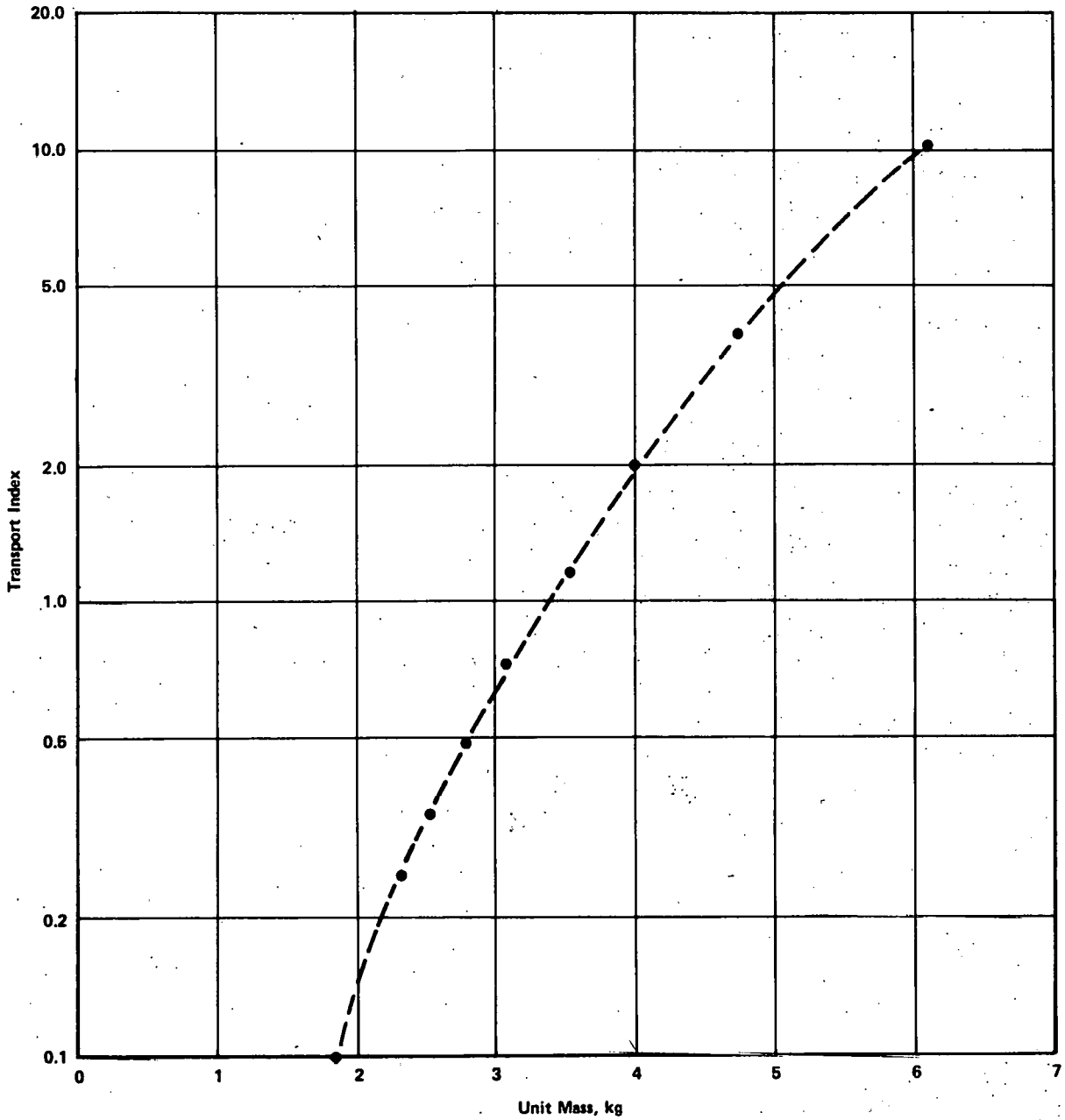


FIGURE 11-8 - Transport index vs unit mass for uranium-233.

12. Radiation Shielding Evaluation

12.1. GENERAL

The neutron and gamma dose rates expected at 3 ft (Transport Index) from the surface were calculated for the subject container.

12.2. ASSUMPTIONS AND DISCUSSIONS

The following assumptions were made:

1. Plutonium-238 dioxide is the radioactive material which is analyzed. This material comprises essentially 100% of the Laboratory shipments. Based upon the known decay radiation spectrums it can be stated that for plutonium-239 metal and oxide and uranium-235 metal and oxide that the maximum permissible quantity per package as determined by criticality analysis and listed in Table 11-2 will not result in a total dose rate in excess of 200 mrem/hr at any accessible point on the surface of the package or result in a total dose rate in excess of 10 mrem/hr at 3 ft from any accessible external surface of the package.

Since the shielding requirements for shipments of uranium-233 vary with the amount of uranium-232 impurity present, the radiation shielding evaluation for this material must be the responsibility of the shipper. The same reasoning is applied to shipments of thorium isotopes since the decay spectrum varies with isotopic content. Again the individual shipper will be responsible for a shielding evaluation.

2. Neutron yield from typical plutonium-238 dioxide shipped is 1×10^4 n/sec-g of plutonium-238. This is somewhat higher than the neutron emission from heat-source grade plutonium-238 dioxide; however, it is assumed that materials that are not as pure as heat-source grade will be shipped at times.
3. Neutron multiplication due to internal fission was ~20% of (α, n) neutrons.
4. Increase in neutron dose rate due to scatter and buildup was ~10% of (α, n) neutrons.
5. The packaging components would not significantly reduce the neutron dose rate.
6. The average neutron energy is approximately 2 MeV.
Note: The (α, n) average energy is ~1.00 MeV.
The fission spectrum energy is ~1.00 MeV.
The spontaneous fission energy is ~1.00 MeV.
7. Point source emission with no correction for anisotropy.
8. Ratio of unshielded neutron to gamma dose rate is approximately 15:1.
9. For gamma shielding the linear attenuation coefficient, $\mu(\text{cm}^{-1})$, for iron is a good approximation for the actual packaging construction materials.
10. The sample is located near the geometric center of the primary packaging and this is approximately the geometric center of the package.

12.3. RESULTS AND CONCLUSIONS

The authorized quantities shown in Table 12-1 for each package will not result in a total dose rate in excess of 200 mrem/hr at any accessible point on the surface or result in a total dose rate in excess of 10 mrem/hr at 3 ft (Transport Index) from any accessible external surface of the package.

Table 12-1 - AUTHORIZED QUANTITIES OF PLUTONIUM-238 (IN OXIDE FORM) PER PACKAGE AND RESULTS OF RADIATION SHIELDING ANALYSIS

Packaging	Quantity Based on Dose Rate Criteria		Authorized Quantity Based on Internal Heating*	
	(g)	(W)	(g)	(W)
4 gal	256	115	16	7.0

*These values, based on internal heating restrictions, are the ones that are applied for shipment.

For the packaging and contents proposed, the dose rates could never exceed 1000 mrem/hr at 3 ft from the external surface of a totally unshielded package; therefore, compliance with ERDAM 0529 F.l.a. is assured.

12.4. SAMPLE CALCULATIONS

Some calculations are given for determining the quantity of plutonium-238 in oxide form which could be placed in the 4-gal package such that appropriate penetrating radiation exposure criteria in 10 CFR 49 are not exceeded.

Neutron Dose Rate:

The neutron dose rate (D_n) was calculated at 13.8 cm (radius of package or surface of package) for 1 g of plutonium-238 in oxide form.

$$D = \frac{S \text{ (Neutron Yield)}}{4\pi r^2 C_f \text{ (Neutron flux to dose rate conversion factor)}} = \frac{S}{4\pi r^2 C_f}$$

where C_f = 7.3 n/cm²-sec per 1 mrem/hr

(Reference 1)

$$D_n = \frac{1 \times 10^4}{4\pi (13.8)^2 (7.3)} = 0.57 \text{ mrem/hr/g of plutonium-238 as oxide}$$

Internal Fission Multiplication Effect:

$$(0.57 \text{ mrem/hr}) (1.2) = 0.69 \text{ mrem/hr}$$

Scatter and Buildup Effect:

$$(0.69) (1.1) = 0.76 \text{ mrem/hr}$$

Gamma Dose Rate:

$$I_0 = \frac{0.57}{15} \text{ mrem/hr} = 0.038 \text{ mrem/hr}$$

Effect of Shielding on Gamma Dose Rates:

π = Linear Attenuation Coefficient
= 0.527 cm⁻¹ for iron for a gamma photon energy of 0.725 MeV.

x = Equivalent thickness of iron shielding for 4-gal packaging.

I₀ = Unshielded gamma dose rate.

$$I = I_0 e^{-\pi x} = 0.038 e^{-0.527 \times 1.111} = 0.021 \text{ mrem/hr}$$

Total Dose Rate:

The total dose rate per gram of plutonium-238 in oxide form is the sum of the neutron and gamma dose rates.

$$D_1 = D_n + D_\gamma = 0.76 + 0.02 = 0.78 \text{ mrem/hr}$$

Allowed Quantity Based on Dose Rate

Criteria:

Surface of Package

Allowed Quantity = 200 mrem/hr : 0.78 mrem/hr/g plutonium-238 as oxide = 256 g

Transport Index (3 ft from surface).

The same procedure was followed to calculate the total dose rate per gram of plutonium-238 at 3 ft from the surface of the package. This value was 0.013 mrem/hr.

Allowed Quantity = $10 \text{ mrem/hr} \div 0.013 \text{ mrem/hr/g}$ plutonium-238 as oxide = 769 g.

Both of these quantities exceed the authorized quantity based on internal

heating, hence the authorized contents were determined based on internal heating restrictions.

12.5. REFERENCE

1. Protection Against Neutron Radiation up to 30 Million Electron Volts, Handbook 63, U. S. Department of Commerce, National Bureau of Standards, Washington, D. C.

13. Quality Control

The shipping containers are inspected and the inspections are documented in compliance with DOE Manual 0529. The particulars of the inspections are provided in Mound Laboratory Drawing No. SPA770530 (see Appendix A p. A-2).

Visual, dimensional, and functional inspections are performed at various stages of fabrication and on receipt of the containers from the fabricator prior to use. Prior to first use, it is required that

the inner containers must pass a helium leak test with no detectable leak greater than 1×10^{-4} std. cm^3/sec when filled with 15 psig of helium. Visual and functional inspections are performed prior to reuse.

In addition to the above inspections, packaging and unpacking procedures are provided (see Appendix B) to ensure proper handling and to provide documentation of operations.

Acknowledgements

The authors wish to gratefully acknowledge the help of all those who contributed in producing this document. Particular recognition is due to E. W. Johnson, H. B. Kreider, A. F. Schmidt, and E. L. Barraclough for detailed reviews of the manuscript; to R. D. Evans for aid in performing the accident tests; to R. P. Wurstner for steady state temperature tests; and to M. F. Hauenstein for technical editing.

Appendix A:

Acceptance and Reuse Inspections

Contents

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Part 1. Inspection Program - General	A-2
Part 2. Fabrication Form	A-9
Part 3. Initial Acceptance Inspection Criteria and Data Sheets	A-14
Part 4. Use Inspections	A-18

PART 1. INSPECTION PROGRAM - GENERAL

Monsanto Research Corporation Drawing Number SPA770530 describes the general nature of the inspection program for the 9506 packages. This document is reproduced on the following pages.

M/C

						W O NO		
ISSUE	DATE	REVISION				BY	CHK'D	APPRD
A		ORIGINAL ISSUE				DM		
SHEET								
ISSUE								
SHEET	1	2	3	4	5	6		
ISSUE	A	A	A	A	A	A		
			DWG CLASSIFICATION LEVEL & CAT <u>UNCL</u> BY _____ TITLE _____ DATE _____			MONSANTO RESEARCH CORPORATION <small>MOUND LABORATORY</small> <small>EMMAHUSE, OHIO</small>		
						NUCLEAR SHIPPING CONTAINER 9506 ACCEPTANCE AND REUSE INSPECTION		
SCI DWG TYPE			CODE IDENT NO 14005			DRAWN <u>D. MORRIS</u> DATE _____ APPROVALS		
						CHECKED _____ DATE _____ 1		
						SPONSOR _____ DATE _____ 2		
						APPROVED _____ DATE _____ 3		
						JOB NO <u>770530</u> 4		
						DWG NO <u>SPA770530</u> SHT <u>1</u> OF <u>6</u>		

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DAC-73-SA

<p>5.5 <u>Inspection Plan</u>. Each shipping container shall be inspected for all attributes listed in MRC Drawing No. SPA770531.</p> <p>6. <u>U S E I N S P E C T I O N S</u>.</p> <p>6.1 <u>Criteria</u>. Inspections prior to use of the container are required and are specified by MRC Shipping Container Operation Sheet, Manual Number MD-70152, Operation 1. That document also specifies loading procedures.</p> <p>6.2 <u>Documentation</u>. The Operation Sheet, MD-70152 Operation 1, referred to in Section 6.1 above specifies the MRC form which the inspector is required to fill out.</p> <p>6.3 <u>Inspection Plan</u>. Each shipping container, new or used, is to be inspected prior to each use of that container.</p>		
ISSUE	A	
CODE IDENT NO 14065		DWG NO SPA770530 SHT 6

MRC-ML-5317 (12-73)
DAC-73-SACB

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PART 2. FABRICATION FORM

The inspection program outlined in Part 1 of this Appendix A specifies that the fabricator of a 9506 inner container is required to submit a "Fabrication and Inspection Certification" form or forms as specified in MRC Drawing No. SPA770532 which is duplicated on the following page.

				W O NO	
ISSUE	DATE	REVISION	BY	CHK'D	APPRD
A		ORIGINAL ISSUE	DM		
SHEET					
ISSUE					
SHEET	1	2	3	4	
ISSUE	A	A	A	A	
		DWG CLASSIFICATION		MONSANTO RESEARCH CORPORATION <small>MONROE LABORATORY MONROE, LOUISIANA, 70502</small>	
		LEVEL & CAT <u>UNCL</u>		NUCLEAR SHIPPING CONTAINER	
		BY _____		FABRICATION & INSPECTION CERTIFICA- TION 9506 INNER CONTAINER	
		TITLE _____		DRAWN <u>D. MORRIS</u> DATE _____	
DATE _____		CHECKED _____ DATE _____		APPROVALS	
		SPONSOR _____ DATE _____		1	
		APPROVED _____ DATE _____		2	
		JOB NO <u>778532</u>		3	
		DWG NO <u>SPA778532</u> SHT <u>1</u> OF <u>4</u>		4	
SCI	CODE IDENT NO				
DWG TYPE	<u>14885</u>				

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PART 3. INITIAL ACCEPTANCE INSPECTION CRITERIA AND DATA SHEETS

An initial acceptance inspection is required for the inspection program specified in MRC Drawing No. SPA770530 and duplicated in Part 1 of this Appendix A. The criteria for this initial acceptance inspection are specified in complete detail in MRC Drawing No. SPA770531 which is duplicated on the following pages. This same drawing also shows the initial acceptance inspection data sheets which the inspector must fill out. These sheets are Monsanto Research Corporation forms MRC-ML-6354 for the inner container and MRC-ML-6355 for the outer container assembly.

				W O N O			
ISSUE	DATE	R E V I S I O N			BY	CHK'D	APPRD
A		ORIGINAL ISSUE			DM		
SHEET							
ISSUE							
SHEET	1	2	3				
ISSUE	A	A	A				
		DWG CLASSIFICATION		MONSANTO RESEARCH CORPORATION <small>MOUSE LABORATORY MADISON, OHIO</small>			
		LEVEL & CAT <u>UNCL</u>		NUCLEAR SHIPPING CONTAINER			
		BY _____		INITIAL ACCEPTANCE INSPECTION			
		TITLE _____		CRITERIA & DATA SHEETS FOR 9506			
		DATE _____		SHIPPING CONTAINER			
				DRAWN <u>D. MORRIS</u>		DATE	APPROVALS
				CHECKED		DATE	1
				SPONSOR		DATE	2
				APPROVED		DATE	3
				JOB NO <u>770531</u>			4
SCI	CODE IDENT NO						
DWG TYPE	14065						
				DWG NO SPA770531		SHT 1	OF 3

DAC-73-SA

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Initial Acceptance Inspection Criteria and Data Sheet
for 9506 Inner Shipping Container

Identification

Inner container serial number _____
Manufactured by _____

Vendor Certification

1. _____ Form MRC-ML-6352 completed satisfactorily and submitted.

Visual Inspection

1. _____ "Radioactive Material" and serial number clearly stamped or etched onto side and top of container. (Major)
2. _____ Welds appear acceptable. (Major)
3. _____ O-ring and sealing surfaces appear to be in good condition and O-ring fits groove. (Major)
4. _____ Threads appear to be satisfactory. (Major)
5. _____ Workmanship acceptable with no sharp edges or burrs. (Critical)

Dimensional Inspection

1. _____ Container cover and body outer diameter $3 \pm 1/16$ in. (Major)
2. _____ Cover overall thickness $3/4 \pm 1/16$ in. (Major)
3. _____ Cover O-ring lip or shoulder $1/4 \pm 1/16$ in. (Major)
4. _____ Container body $5 \ 3/8 \pm 1/8$ in. (Major)

Functional Inspection

1. _____ Cover and O-ring assembled and disassembled satisfactorily. (Major)
2. _____ Helium leak test (with "dummy" cover) performed with no detectable leak greater than 1×10^{-6} std cc/sec when filled to at least 20 psig. (Critical)

Signature _____ Date _____

DISTRIBUTION: White - Nuclear QC
Yellow - Shipping Container Eng.
Pink - File

MRC-ML-6354

ISSUE

A

CODE IDENT NO

14065

DWG NO SPA770531 SHT 2

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MRC-ML-5317 (12-73)

DAC-73-SACB

PART 4. USE INSPECTIONS

A use inspection prior to each use of the container is required for the inspection program specified in MRC Drawing No. SPA770530 and duplicated in Part 1 of this Appendix A. The particulars of this use inspection are specified by MRC Shipping Container Operation Sheet, Manual Number MD-70152, Operation 1. That document shows MRC form MRC-ML-128 which must be filled out by the inspector. That document also specifies loading procedures and is duplicated in Appendix B of this SARP as Figure B-1.

Appendix B:
Packaging and Unpackaging Procedures

Mound Laboratory Forms MD-70152, Op. 1; MD-70152, Op. 9; and MRC-ML-1245 are completed as the shipping packages are being loaded to ensure compliance with Mound Laboratory procedures. Form MD-70152, Op. 9 (Figure B-2), is a special procedure which must be followed for loading Special Form material. Form MRC-ML-1245 (Figure B-3) is used to record contamination and radiation levels of the container.

Before a shipping package is loaded, all components are visually inspected for damage which could impair its use. Further inspection inevitably occurs as the components are assembled. If some parts are found not to fit properly they are corrected at this time. The inspection section of Form MD-70152, Op. 1, is then completed.

Loading of the container is started after the inspection. Materials of Special Form are handled in accordance with MD-70152, Op. 9. Other contents are wiped and placed in the inner container. Void space in the container is filled with metal shot or wool. The inner container

lid is fastened to the body. The container assembly is placed in the outer drum on the fire retardant filler support.

The fire retardant plug is inserted and the lid is positioned on the drum and held in place with the closure ring. The security seal is attached. The shipping drum is checked for contamination and is surveyed to ensure that the external radiation from the drum complies with the required Transportation Index. As each operation is completed the loading section of Form MD-70152, Op. 1, is so marked. In addition, Form MRC-ML-1245 is completed giving contamination and radiation levels. Radioactive labels are completed and attached to the drum. The package is now ready for shipment.

Unloading a package is basically the reverse of loading it. Upon receipt, the drum is checked for contamination before removal of the lid, and each component is visually inspected while being removed from the package. After the contents are removed from the inner container and checked for contamination, the package is stored for further use.

MONSANTO RESEARCH CORP.
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM REUSABLE RADIOACTIVE SHIPPING CONTAINERS	SHEET 1 of 1	MANUAL NUMBER MD-70152	OPERATION 1
AUTHORIZATION <i>N. H. Brene</i>	CLASSIFICATION Unclassified	EFFECTIVITY 10-12-77	ECM(S) INCORPORATED M5-C
OPERATION TITLE Use, Inspection, and Loading (for use with DOT-6M, 9506, 5790, 5791)			

USE INSPECTION

New _____ Reuse _____ Specification _____ Serial No. _____

FINDING

1. Remove labels.
2. Closure ring and locking device in working condition.
3. Check all containers for contamination and decontaminate as necessary.
4. Thread appears in good condition (remove foreign matter).
5. Centering material in good condition.
6. Overall condition (satisfactory):

Date _____ Signature _____

LOADING PROCEDURE (GENERAL)

COMPLETED

1. Radioactive material form (solid, liquid or gas).
2. Lute inner container threads/gasket.
3. Torque inner container closure (if required).
4. Install insulation.
5. Place compression pad (as required) and sketch under drum lid.
6. Close drum.
7. Install seal.
8. Apply labels (Radioactive).

Date _____ Signature _____

DISTRIBUTION:
White - Container File
Yellow - Nuclear QC
Goldenrod - Shipper File
Pink - Originator

MRC-MI-128
T

FIGURE B-1

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MONSANTO RESEARCH CORP.
MOUND LABORATORY

OPERATION SHEET

PROGRAM REUSABLE RADIOACTIVE SHIPPING CONTAINERS		SHEET 1 of 1	MANUAL NUMBER MD-70152	OPERATION 9
AUTHORIZATION <i>A. U. Brun</i>	CLASSIFICATION Unclassified	EFFECTIVITY 10-12-77	ECN(S) INCORPORATED M5-C	
OPERATION TITLE Preparation and Packaging (Milliwatt Generator)				
			<u>Initial</u>	<u>Date</u>
1. Wipe check each source (≤ 20 dpm).			_____	_____
2. Wrap source(s) individually in nickel foil.			_____	_____
3. Place inside pressure vessel and surround with nickel shot (optional).			_____	_____
4. Place inside inner container and surround with metal shot or steel wool.			_____	_____
DISTRIBUTION:				
White	- Container File			
Yellow	- Nuclear QC			
Goldenrod	- Shipper File			
Pink	- Originator			

MRC-ML-128

T

FIGURE B-2

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Appendix C:
DOE Certificate of Compliance

U. S. Department of Energy
CERTIFICATE OF COMPLIANCE
For Radioactive Material Packages

1a. Certificate Number 9506	1b. Revision No. Original	1c. Package Identification No. USA/9506/BLF(DOE-AL)	1d. Page No. 1	1e. Total No. Pages 2
--------------------------------	------------------------------	--	-------------------	--------------------------

2. PREAMBLE

- 2a. This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189 and 14 CFR 103) and Sections 146-19-10a and 146-19-100 of the Department of Transportation Dangerous Cargoes Regulations (46 CFR 146-149), as amended.
- 2b. The packaging and contents described in item 5 below, meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions."
- 2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application—

(1) Prepared by (Name and address): Monsanto Research Corporation Mound Laboratory P. O. Box 32 Miamisburg, Ohio 45342	(2) Title and Identification of report or application: MLM-2460 "Safety Analysis Report for Packaging (SARP): USA/9506/BLF(DOE-AL)"	(3) Date: Nov. 11, 1977
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4. CONDITIONS

This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions specified in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References:

(a) Description:

The packaging consists of an O-ring sealed cylindrical steel inner container centered within glued Firedike insulation in a 4-gal drum. The overall drum height is 14 3/4 in. and the overall diameter is 11 3/4 in.

(b) Restrictions:

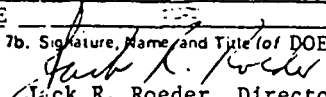
The maximum authorized gross weight is 37 lb. and the maximum heat load permissible in the package is 7.0 W. The user must ensure that the temperature of the contents is acceptably low. The maximum permissible temperature of the outside surface of the inner container is 300°F at ambient conditions.

(c) Authorized Contents:

Powders or pellets of these materials are to be packaged within an additional container which is placed inside the sealed inner container. The authorized contents are uranium-233, uranium-235, plutonium-238, and plutonium-239 in special form or normal form if not readily dispersible. These contents may be dry solids as metals, oxides or compounds.

6a. Date of Issuance: October 31, 1977	6b. Expiration Date: N/A
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FOR THE U. S. DOE

7a. Address (of DOE Issuing Office) Albuquerque Operations Office P. O. Box 5400 Albuquerque, New Mexico 87115	7b. Signature, Name, and Title (of DOE Approving Official)  Jack R. Roeder, Director Operational Safety Division
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