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Safety Analysis Report for Packaging (SARP): USA/5790/BLF (ERDA-AL) and USA/5791/BLF (ERDA-AL)

James F. Griffin, Richard E. Bertram, Richard K. Blauvelt, Don A. Edling, Thomas M. Flanagan, James B. Peterson, and David L. Prosser

MASTER

April 30, 1976

Research and Development Report

MOUND LABORATORY
Miamisburg, Ohio
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MONSANTO RESEARCH CORPORATION
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A Subsidiary of Monsanto Company

MOUND LABORATORY

Miamisburg, Ohio 45342

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FOREWORD

This report is a compilation of Monsanto Research Corporation (MRC) documentation of development activities to satisfy the U. S. Energy Research and Development Administration and the 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
Attention: 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 two insulated drum shipping containers identified as USA/5790/BLF ERDA-AL and USA/5791/BLF ERDA-AL. 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. Much of the information was previously submitted to ERDA/OSD/ALO and the Department of Transportation (DOT) and provided the basis for obtaining special permits DOT-SP-5790 and DOT-SP-5791 as well as the Interim Certificates of Compliance until the SARP could be prepared. Complete physical and technical descriptions of the packages are presented. Each package consists of a modified DOT Specification 2R cylindrical steel inner container centered within an insulated steel drum. The contents may be any radioactive materials which satisfy the requirements established in this SARP. A shipment of plutonium-238 in the form of a solid oxide is evaluated in this SARP as an example. 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 for each container.

Design and development considerations, the tests and evaluations required to prove the ability 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 experience in using the containers, a copy of the AEC/OSD/ALO Certificate of Compliance is 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

In August, 1968, Monsanto Research Corporation, Mound Laboratory, obtained Certification of Approval for Fissile-Large Quantity Shipping Containers authorizing use of the shipping containers designated AL-M3 and AL-M6 by the Operational Safety Division of the Albuquerque Operations Office (OSD/ALO) for the U. S. Atomic Energy Commission. Mound Laboratory documents and drawings were submitted as supportive material in requesting the interim certificate.(1-5) The Department of Transportation subsequently granted special permits DOT-SP-5790 and DOT-SP-5791 for these containers in October, 1968.

In October, 1974, Interim Certificate of Compliance number USA/5790/BLF (AEC-AL) was issued for the AL-M3 package and number USA/5791/BLF (AEC-AL) was issued for the AL-M5, AL-M6, and AL-M7 packages by OSD/ALO. The AL-M5 and AL-M7 packages are no longer required and, therefore, are not covered by this report.

ERDA 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 which exceed specified limits. This SARP satisfies the requirement for a formal safety analysis of the two shipping containers. The SARP includes discussions of structural integrity, thermal resistance, radiation shielding and radiological safety, nuclear criticality safety, and quality control.

The packages are used to ship fissile and other radioactive materials which satisfy the safety criteria discussed in this report. An example shipment of a heat source containing plutonium-238 in the form of a solid oxide is evaluated in Section 5. From 1968 through 1975, 395 shipments were made safely in the containers. No radioactive materials were released from the packages during any of these shipments.

2.2. DESIGN

The design of the containers is similar to the Department of Transportation Specification 6M packaging. The packages are designed to transport radioactive and fissile materials safely by common carrier in accordance with DOT and ERDA requirements. A complete physical and technical description of the packages is presented. Both packages are of the same basic design but differ in size. The nominal sizes of the outer steel drums are 12 and 55 gal. The package identification numbers are AL-M3 for the 12-gal and AL-M6 for the 55-gal size. In each, 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 drums for release of any gases generated at hypothetical accident fire conditions. The maximum gross weights of the packages are 90 lb for the 12-gal size and 300 lb for the 55-gal size.

2.3. TESTS

The containers were extensively tested and evaluated to show that they 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 $^{238}PuO_2$, α-phase plutonium-239, uranium-233 metal, and uranium-235 metal. 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 unpackaging procedures are provided in Appendix I and Appendix II, respectively, of this report. A copy of the OSD/ALO approval is included in Appendix C.

2.5. REFERENCES

1. R. A. Wolfe, Nuclear Criticality Safety Evaluation of Nine Different Size Shipping Containers, Rev. November, 1967.

2. Monsanto Research Corporation, Sketch #1, #3, #4 and #5, Rev. July, 1968.

3. R. A. Wolfe, Nuclear Criticality Safety Evaluation of Four Different Size Shipping Containers, July, 1968.

4. R. A. Wolfe, Nuclear Criticality Safety Evaluation of Nine Different Size Shipping Containers, Rev. November, 1967.

5. R. D. Madding and R. E. Vallee, Design Modification and Evaluation Testing of a DOT-6M Type Container, January, 1969.

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 two shipping containers are of the same basic design but differ in size. 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 solids and large quantity solids in normal or special form; 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 inner steel 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 ERDA M-0529. Sound practice would dictate that "strong and reliable" packaging be used inside the inner steel container 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 containers for several internal heat loadings and various packing materials within the inner steel container were determined to assure 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 containers.

The maximum heat load capabilities for each size packaging were determined to be:

Nominal Size Package (gal)	Maximum Heat Load Capability (W)	Maximum External Drum Temperature (°F)
12	30	112
55	42	106

With heat loads up to the authorized values for each packaging: (1) the maximum external surface temperature of the steel drums would be 112°F, which is well below the maximum of 122°F stated in regulations, (2) the maximum temperatures 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 500°F when the package is subjected to the fire test (hypothetical accident conditions). The 300°F temperature will have no significant effect on the inner steel container, nor will the Firedike insulation discolor at this temperature. At 500°F (hypothetical accident condition), the steel inner container will also retain its integrity when the package is subjected to the fire test for the specified time, 1/2 hr.

Note that guidance on heat loading which maintains a contents surface temperature of 750°F or less is provided on pages 6-9 and 6-10 of this document.

3.4. INTERNAL PRESSURE

The internal pressure capability of both packagings at various temperatures was thoroughly evaluated. The weakest component was found to be the welded bottom plate of the inner steel container. However, the pressure capabilities are sufficiently high to contain the pressures which would result from heating the air environment trapped during packaging operations (1 atm) to the temperatures reached during normal shipment and hypothetical accident conditions.

3.5. PACKAGE STANDARDS

Detailed analyses with respect to Part II of ERDA M-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 which will prevent inadvertent opening and in addition, seals are secured to the drum closures; (3) No lifting devices, as such, are provided on either of the packagings; however, an analysis was made of the effects of the commonly used method of moving by fork lifts with two forks positioned beneath the drum. Such lifting will have no significant effect on the packagings; (4) There are no tie-down devices used with these packagings; (5) The static load requirement, normal to and uniformly distributed along its length, ..., will be met; and (6) The inner steel containers (containment vessel of both packagings) 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 packagings 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 these all-metal packagings. 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 packagings. Tests have shown that the penetration test results in small minor dents in the outer steel 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 both packages satisfied these requirements. The drum closures were modified to assure integrity when subjected to the 30-ft drop test. The damage sustained in the 40-in. puncture test was insignificant. The maximum outside surface temperatures of the inner containers were determined to be 237°F for the 12-gal size and 244°F for the 55-gal size when fire tested after an initial uniform package temperature of 100°F. Both inner containers passed the water immersion test with no leakage.

3.8. CRITICALITY

The criticality safety analysis established quantities of fissile materials allowable for shipment in both packagings as Fissile Class I, II and in some cases III. One example of these values is given below for the plutonium-239 α-phase:

Size Packaging	Maximum Authorized Quantity (kg) F.C. I	F.C. II
55 gal	<4.4 kg	≤5.0 kg

3.9. RADIATION SHIELDING

The radiation shielding analysis shows that the quantities of $^{238}PuO_2$ 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.

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 containers and to provide the basis for the evaluation of the packages. The two shipping containers (Figures 4-1 and 4-2) are of the same basic design but differ in size. They are generally referred to in this report by the nominal size of the steel drum outer container. In both sizes, a steel inner container, the containment vessel, is approximately centered within an insulated drum assembly. The 12-gal package is identified as USA/5790/BLF (ERDA-AL) and the 55-gal size is identified as USA/5791/BLF (ERDA-AL). The maximum gross weights and overall dimensions are given in Table 4-1.

The containers are fabricated in accordance with the following drawings and specifications:

MRC Dwg. AYD750138	12-gal shipping container, Model AL-M3
MRC Dwg. AYD750148	55-gal shipping container, Model AL-M6
MRC Dwg. SPA740977	Acceptance and Reuse Inspections

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 containers when necessary.

4.2. DESIGN INTENT

The two packages were designed to be used in much the same manner as the Department of Transportation Specification 6M packages except as specified in this report. The packages are intended primarily for shipment of normal and special form solids in physical forms which are not readily dispersible. 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 to provide protection for the inner containers at hypothetical accident fire conditions. The type of insulation and the thickness are selected to preclude overheating when containing the maximum permissible decay heat load.

Each inner container is designed in accordance with the American Society of Mechanical Engineers (ASME) code. The internal pressure capability of each is sufficient to contain the pressure buildup resulting from heating the atmospheric air, which is trapped during packaging operations, to the maximum temperatures at accident conditions.

Table 4-1

MAXIMUM GROSS WEIGHTS AND OVERALL DIMENSIONS

Package Identification Number	Nominal Size (gal)	Maximum Gross Weight (lb)	Overall Diameter (in.)	Overall Height (in.)
AL-M3	12	90	14.6	21.1
AL-M6	55	300	23.9	34.8

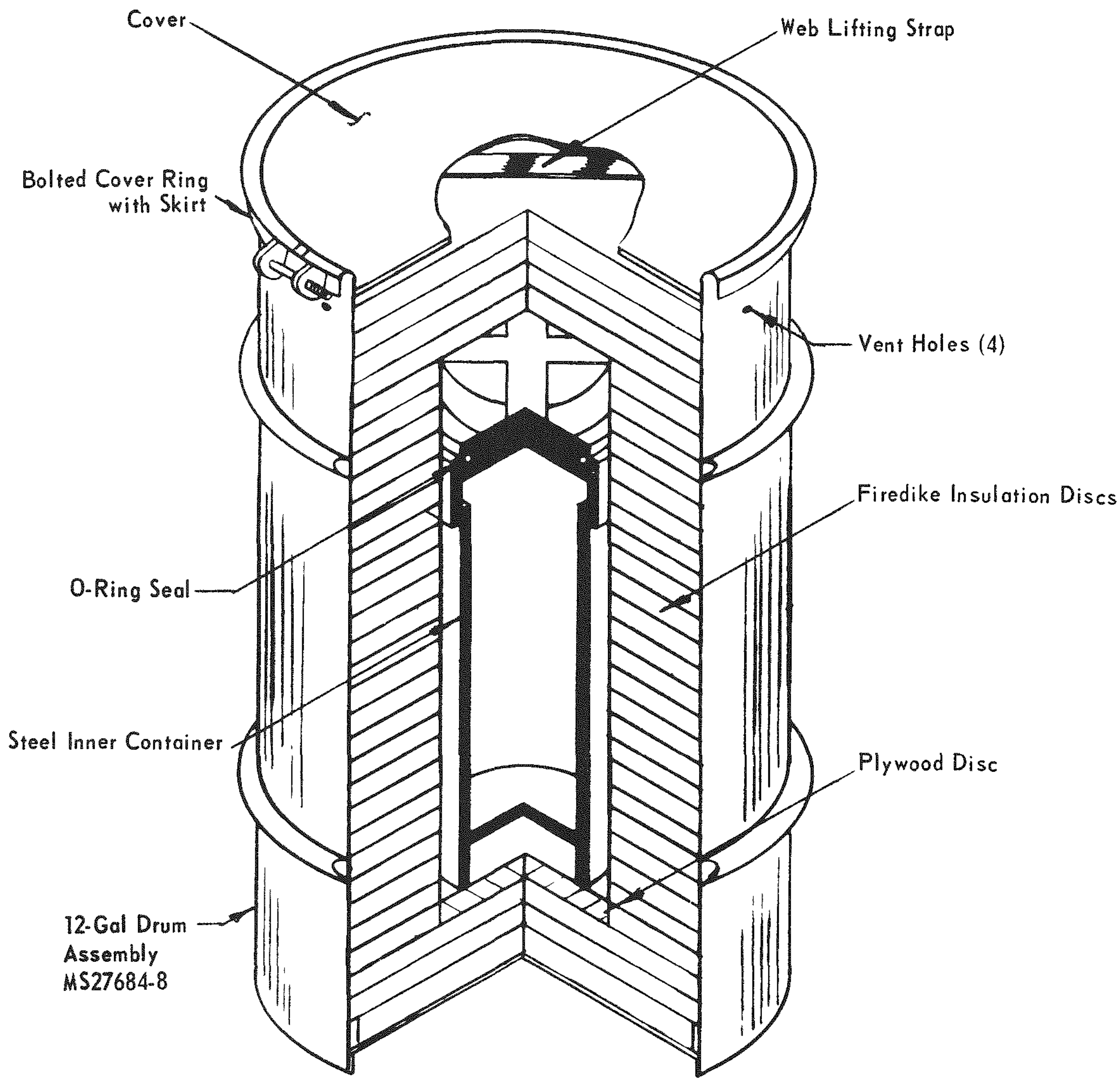


FIGURE 4-1 - Twelve-gallon drum shipping container Model AL-M3 USA/5790/BLF(ERDA-AL).

No special devices are required for tie-down or lifting. The packages may be strapped in place as required during transportation. The packages are intended to be lifted using drum handling equipment or a fork lift, in which case, the tines are placed under the bottom of the drum.

4.3. STEEL DRUMS

The outer container for each package is an open head steel drum. The drums are vented to permit escape of any vapors during the hypothetical accident fire and the vents are sealed with waterproof tape during normal use. A metal identification plate is welded to the outside of the drum body and security seals are fastened to the closure during shipment. The closure ring for both sizes has been modified to keep the drum lid in place during the 30-ft drop test. The drums used are listed in Table 4-2.

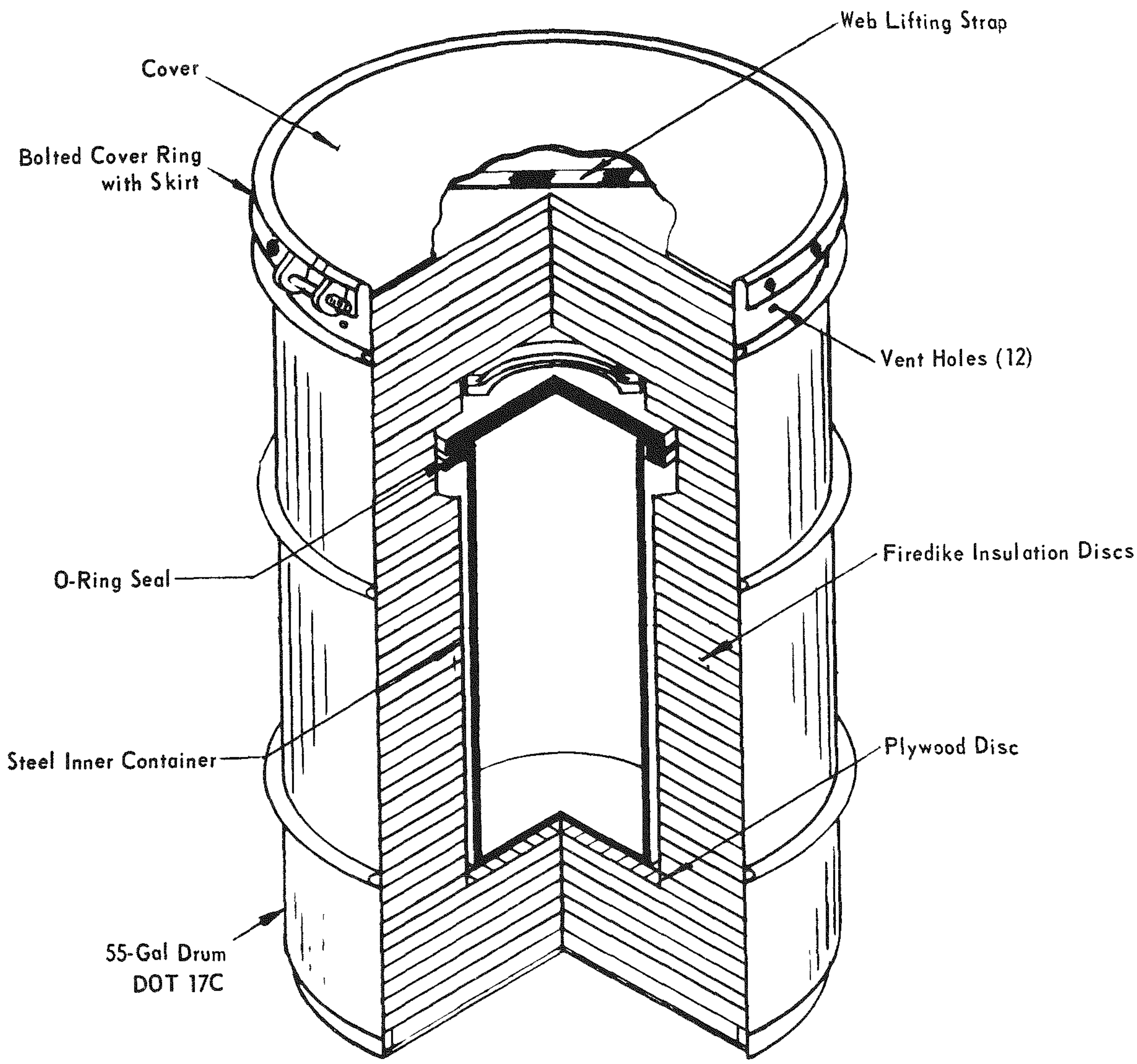


FIGURE 4-2 - Fifty-five-gallon drum shipping container Model AL-M6 USA-5791/BLF(ERDA-AL).

Table 4-2

SPECIFICATIONS FOR OUTER STEEL DRUMS

Nominal Size (gal)	Specification	Gauge Body/Heads	Inside Diameter (in.)	No. of 1/4-in. Diam. Vent Holes
12	MS-27684-8	20/20	13.8	4
55	DOT-17C	16/16	22.5	12

4.4. INSULATION

Firedike-1085 (Johns-Manville) insulating material is used in both sizes to protect the inner containers from impact and heat. Firedike has a density of approximately 24 lb/ft^3 and consists of mineral wool fibers which offer exceptional fire protection. The flame resistance rating is Class A - Incombustible, and the flame spread rating is Class I (0-25). Firedike discolors significantly at 400°F. The Firedike consists of 5/8 in. thick discs and rings glued together with B. F. Goodrich CA-108 nonflammable latex adhesive to eliminate air gaps. A plywood disc is glued to the bottom of the cavity which contains the inner container to provide a bearing surface for the inner container during shipment. This protects the Firedike from wear. The insulated cavity cover has a web strap attached to facilitate handling. The combined thickness of the Firedike at the top and bottom and the minimum thickness of the Firedike at the side (at the inner container flange area) are given in Table 4-3.

4.5. INNER CONTAINER

The cylindrical steel inner containers, which are nested within the insulation, are the containment vessels for the radioactive materials. They are similar in design to the Department of Transportation Specification 2R containers except as specified in this report. Two closure styles are used. In the 12-gal package, the inner container closure is a standard 4-in. pipe plug which is modified to provide an o-ring seal. The inner closure for the 55-gal package is a flanged assembly with an o-ring seal. Silicone and Viton o-rings are acceptable. No valves or gauges are used. Various packaging materials, such as aluminum pellets, nickel spheres, steel wool, and copper turnings, are used to position the materials being shipped within the inner containers. The inner containers must pass a helium leak test with no detectable leak greater than 1×10^{-5} std. cm^3/sec when filled with 15 psig helium. The dimensions of the inner containers are given in Table 4-4.

Table 4-3

THICKNESS OF INSULATION IN EACH DRUM

Package Nominal Size (gal)	Firedike Thickness Top and Bottom (in.)	Minimum Firedike Thickness at Sides (in.)
12	2	4
55	7	6

Table 4-4

INNER CONTAINER DIMENSIONS

Package Nominal Size (gal)	Body o.d. (in.)	Body Wall (in.)	Flange o.d. (in.)	Overall Outside Height (in.)	Inside Height (in.)	Bottom Plate Thickness (in.)	Top Plate Thickness (in.)	Minimum Flange Thickness (in.)
12	4.5	0.250	-	14.1	10.0	0.250	0.484	-
55	7.0	0.250	9.88	17.9	16.0	0.250	0.484	0.438

5. CONTENTS OF PACKAGING

5.1. GENERAL

The materials which can be packaged in the containers are not necessarily limited to the examples given in this section. The examples discussed are some materials which have been shipped: fissile and other radioactive materials which are dry solids in normal or special form not readily dispersible, and with no removable contamination.

5.2. SPECIAL FORM

The radioactive material is placed in capsules some of which comply with the special form criteria. The special form capsules to date have consisted of either plutonium-238 or plutonium-239 in dry form. Two types of special form capsules which may be shipped in the containers have been subjected to the DOT hypothetical accident tests or equivalent. The results are reported in References 1, 2, and 3.

5.3. NORMAL FORM

The normal form radioactive material has consisted of the same plutonium materials noted above. Other materials of normal form have been uranium and thorium anhydrous oxide powders and small amounts (<20 mg) of thorium nitrate powder. The plutonium powder was placed in either center post cans (Figure 5-1) or in nested cans with an o-ring seal (Figures 5-2 and 5-3). The pellet or cermet form was welded into stainless steel cans which were subjected to a helium leak rate test. The uranium and thorium powders were placed in glass vials which were in turn placed in o-ring sealed metal cans as shown in Figure 5-3. Lead shielding was placed around the metal cans, when necessary, to meet the required transportation index.

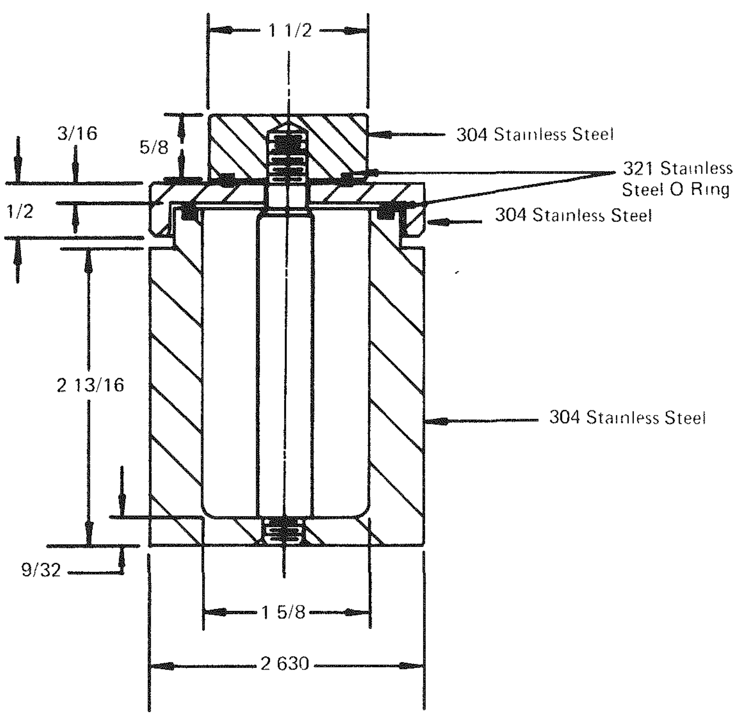


FIGURE 5-1 - Plutonium powder storage and shipping capsule (dimensions in inches).

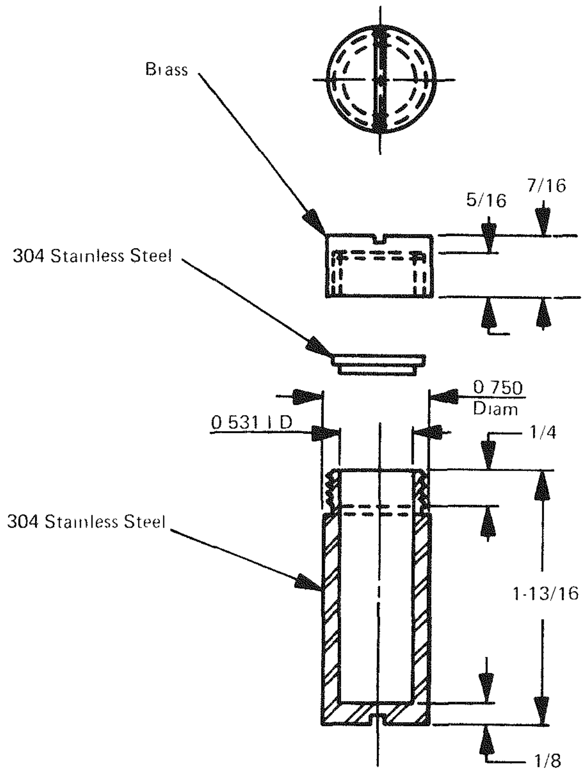


FIGURE 5-2 - Plutonium inner capsule (dimensions in in.).

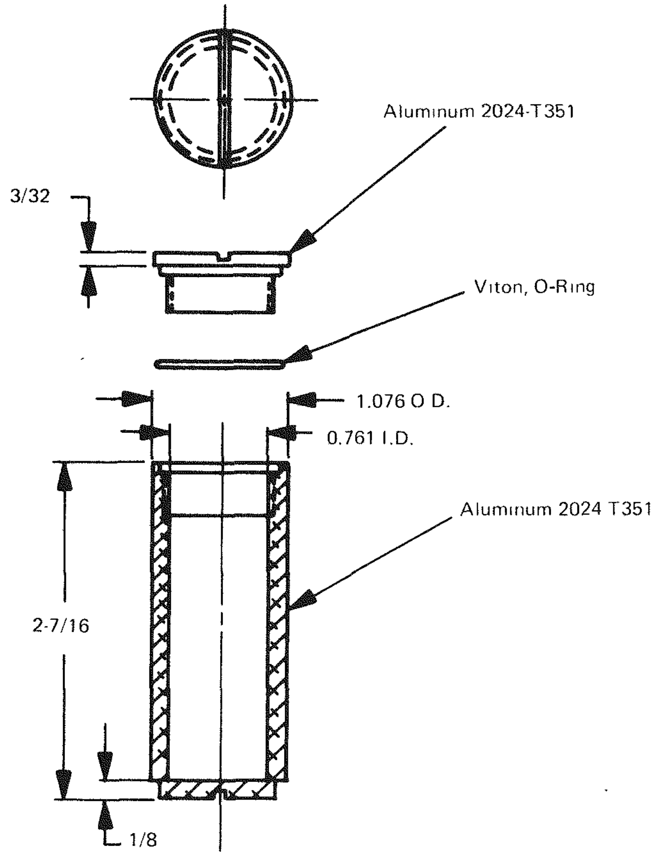


FIGURE 5-3 - Plutonium outer capsule (dimensions in in.).

5.4. THERMAL OUTPUT

The thermal output of cans holding plutonium-238 material was determined by calorimetry to ensure that the thermal content placed in the shipping containers will not exceed the maximum allowable heat load for the containers as stated in Section 6. The cans, including that of the special form, after insertion into the inner container are 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 which should be considered in describing the contents. Information concerning the applicable criteria are 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 include the thorium and uranium isotopes and plutonium-239 because these isotopes do not generate any appreciable amount of thermal decay heat. For example, the 55-gal container can hold up to 1,000 g of thorium oxide. On the other hand, because the plutonium-238 isotope does provide significant amounts of thermal decay, the quantity which can be placed in the inner container is limited as follows:

12-gal	30 W	910 Ci
55-gal	42 W	1,270 Ci

The plutonium-238 material normally consists of approximately 80 at. % plutonium-238, 16 at. % plutonium-239, 3 at. % 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 impurities.

5.5.2. MAXIMUM AMOUNTS OF RADIOACTIVITY

The maximum amounts of plutonium-238 in each container are as follows:

Container Size (gal)	Plutonium-238 (Ci)
12	910
55	1,270

5.5.3. CHEMICAL AND PHYSICAL FORM

The radioactive materials shipped were present as nitrate or oxide and existed either as loose powder or in pressed form.

5.5.4. MATERIAL DENSITY

The density of the radioactive material varied. The thorium and uranium isotopes were loosely packed powders whereas the plutonium isotopes were pressed forms which had densities up to 9.5 g/cm^3.

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 amounts of decay heat for each container are as follows:

Container Size (gal)	Maximum Decay Heat (W)
12	30
55	42

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 helium as part of its decay mode. Fortunately, the rate of generation is rather modest amounting to 0.1 ml/mo/W. In addition, the helium is held tightly in the crystal lattice of the material and does not begin to escape until the material is heated to 2200°F which is well above the temperature that the inner container is expected to see under hypothetical accident fire conditions. The only pressure increase in the inner container which will occur if the package is exposed to fire will be from the heating of air trapped in the container at the time of sealing. This pressure increase will be nominal and should not exceed 20 psig. Therefore, there will be no appreciable pressure increase in the container.

5.5.9. LEAK TESTS

All material is tested for leakage before being packed into the inner container. Radioactive contamination checking or helium leak testing is used to determine that the material is free of leakage.

5.5.10 LOADING RESTRICTIONS AND LIMITATIONS

Loading procedures are given in Appendix II.

5.6. REFERENCES

1. W. R. Amos, Milliwatt Generator Heat Source Progress Report: May 16 - June 15, 1975, Mound Laboratory (July 6, 1973).

2. W. R. Amos, Milliwatt Generator Heat Source Progress Report: July 16 - August 15, 1975, Mound Laboratory (September 6, 1973).

3. C. G. Anderson and W. B. Cartmill, Navy Heat Source Safety Tests, MLM-2208(LD), Mound Laboratory (June 18, 1975), 41 pp.

6. STEADY-STATE TEMPERATURE PROFILES

6.1. PURPOSE

The steady-state temperature profiles of each package and its contents were determined experimentally to ensure compliance with DOT, ERDA, and NRC regulatory requirements and conformance with any product specification 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 each package.

6.2. TEST EQUIPMENT AND PROCEDURES

The tests were performed using the equipment illustrated schematically in Figure 6-1. Figure 6-2 shows the equipment and the 12-gal package during the test. A 3/4-in. diameter x 7-3/4-in. long electric heater was installed inside the inner container to simulate a radioactive heat source. Separate tests were made for each size with the heater packaged in steel wool (See Figure 6-3) or simply suspended within the inner container air environment at atmospheric pressure in order to determine the heater temperatures when these packaging methods were used. Also, a series of tests was performed using the 12-gal size for evaluation of copper turnings, nickel spheres, lead shot, and aluminum pellets for packaging materials (See Figure 6-4). The electrical wires and thermocouples were fed through small holes in the drum head and inner container cover. A wattmeter was used to determine the heat loads.

A digital thermometer was used to obtain the temperature data at several locations. The thermocouples used to measure surface temperatures were welded in place. Figure 6-5 shows the 12 thermocouple locations for the 55-gal size; thermocouples were located similarly for the 12-gal size. The eight type-K thermocouples (No. 2-9) 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 three type-T thermocouples (No. 10-12) were used similarly. The type-J thermocouple, which was fastened to the heater (No. 1), was connected to a temperature controller so that the entire system would safely shut down if the heater temperature exceeded a preset temperature.

The heating procedure required approximately one week 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 heat load of 60 to 70 W was reached. The temperature increases during the equilibration periods were studied to verify that steady state conditions were reached. The ambient

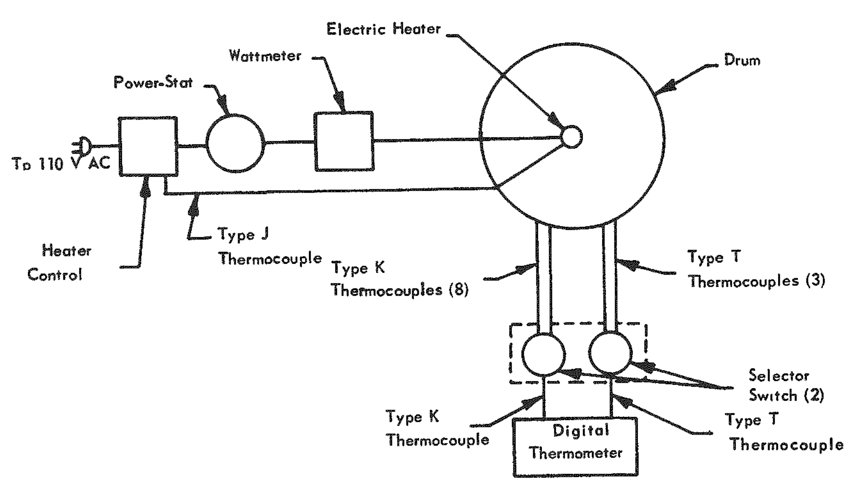


FIGURE 6-1 - Schematic of thermal test equipment.

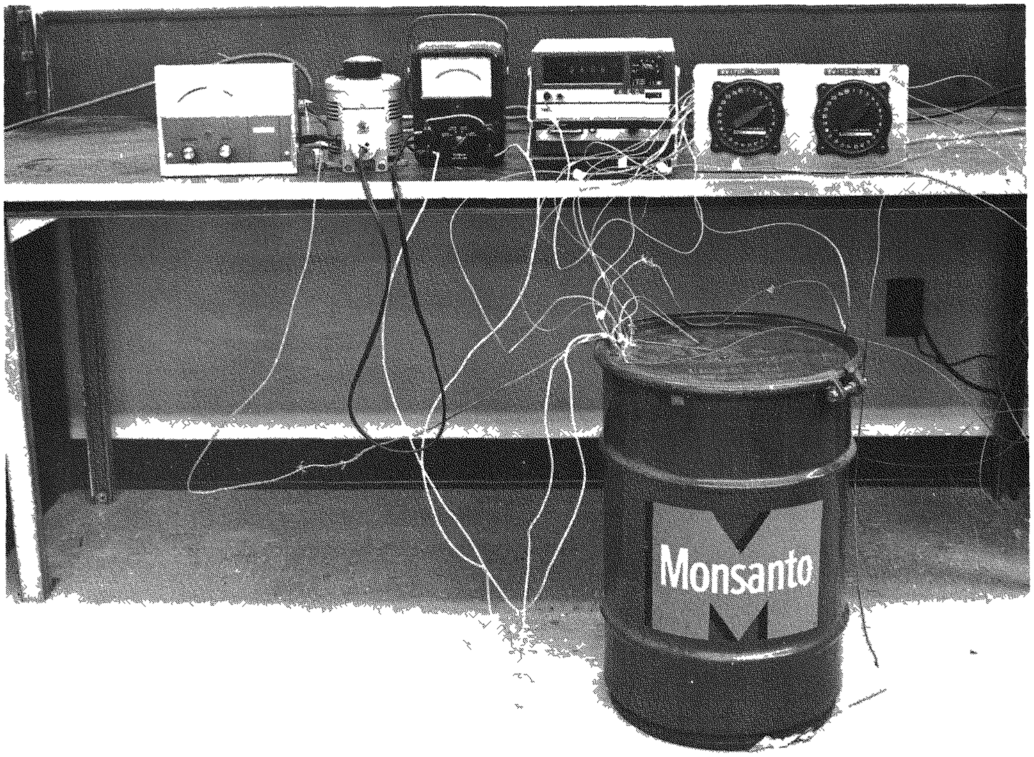


FIGURE 6-2 - Temperature profile testing set-up 12-gal package.

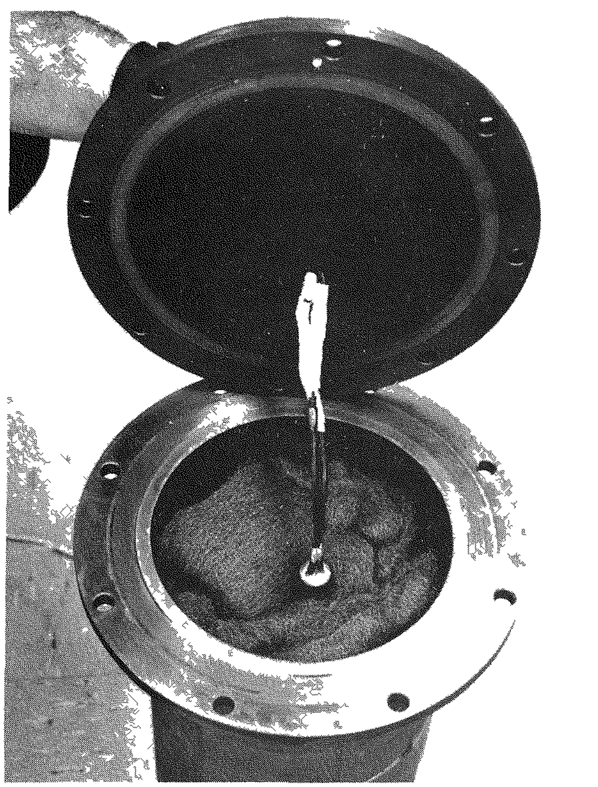


FIGURE 6-3 - Heater and steel wool packaging materials for 55-gal package.

temperature was determined at each heat load by averaging several readings taken at 0.5 to 1 ft away from the sides and top of the drum.

6.3. TEST RESULTS

The experimentally determined steady state temperatures are presented in Table 6-1 for the 12-gal size and in Table 6-2 for the 55-gal size. All temperatures listed in these tables 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 found for each drum exterior, inner container, and heater are plotted in Figure 6-6 for the 12-gal size and Figure 6-7 for the 55-gal size. The heater temperature data at steady state for the various packaging materials tested in the 12-gal package are presented in Table 6-3 and shown graphically in Figure 6-8.

The two graphs (Figures 6-6 and 6-7) clearly show that a higher heat load may be packaged in the 55-gal size without exceeding the inner container temperature

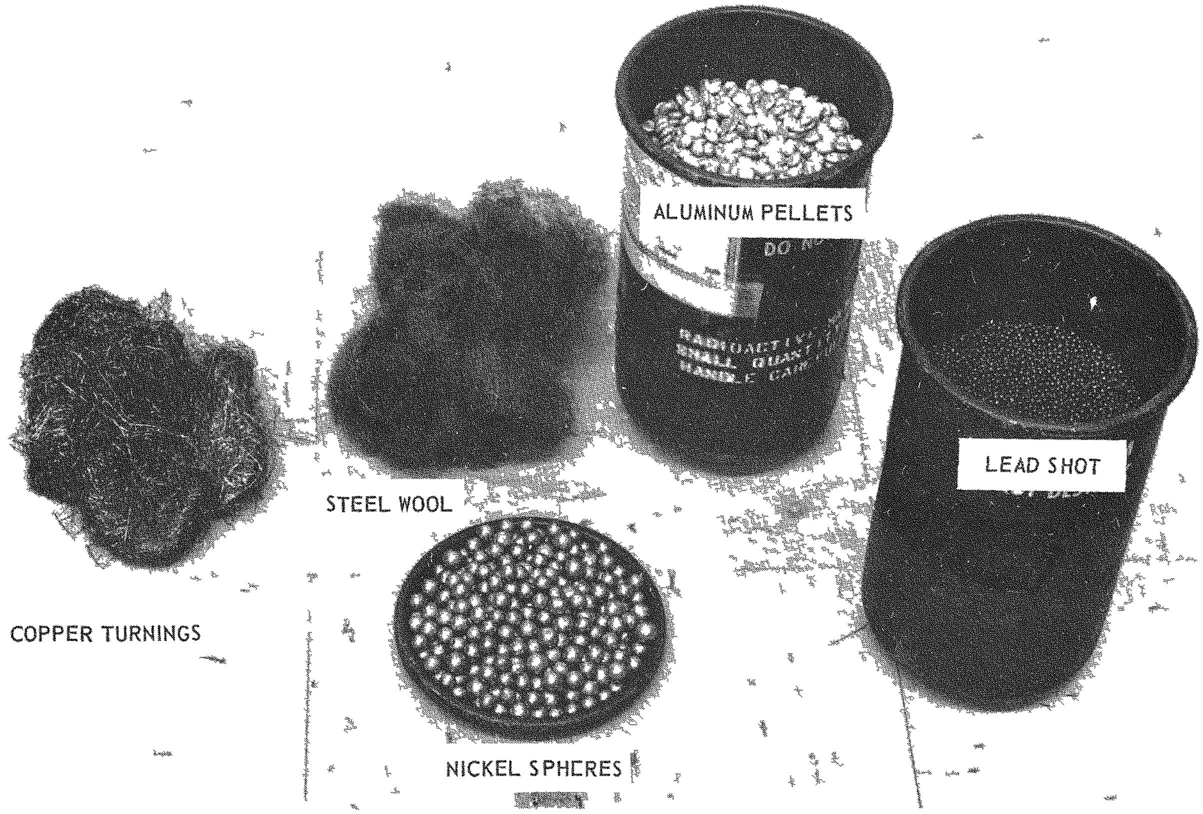


FIGURE 6-4 - Packaging materials tested in 12-gal package

capabilities. The exterior drum surface temperature was lower for the 55-gal size than for the 12-gal size because of the larger exterior surface area. Also, Figures 6-6 and 6-7 show that the resulting heater temperatures in steel wool and air are similar for both sizes. Figure 6-8 illustrates that the aluminum pellets performed the best and the steel wool performed the poorest of the packaging materials tested. The results are discussed in detail in Section 6.4.

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 packages except for discoloring the Firedike at approximately 400°F.

6.4. MAXIMUM HEAT LOAD CAPABILITY

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

The maximum-permissible temperature for the inner-container exterior surface 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 containers will not exceed design capabilities even at the hypothetical accident fire temperature of 500°F (260°C). The pressure capability of the inner containers 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 capabilities and external drum temperatures at 100°F ambient temperature, as shown in Figures 6-6 and 6-7, are given in

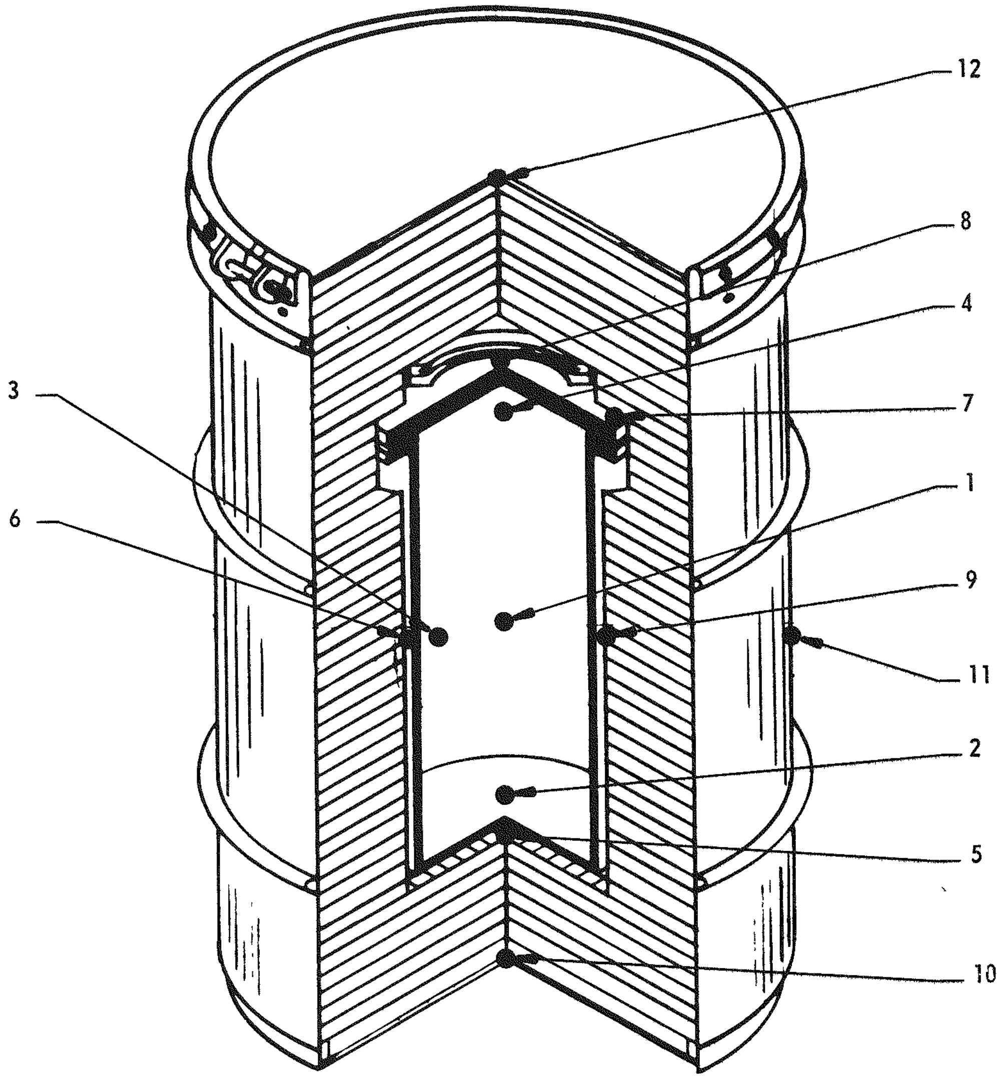


FIGURE 6-5 - Thermocouple locations for 55-gal package.

Table 6-1

STEADY-STATE TEMPERATURE TEST RESULTS FOR 12-GAL PACKAGE AT 100°F AMBIENT TEMPERATURE

Thermocouple No. and Location	Steady-State Temperature (°F) With Steel Wool			With Air		
Watts =	20	37	63	20	31	60
HEATER						
TC-1 Heater Surface	532	744	952	439	541	728
INSIDE INNER CONTAINER						
TC-2 Near Bottom	277	387	515	236	272	372
TC-3 Near Side	410	586	771	253	312	439
TC-4 Near Top	300	429	551	342	411	541
OUTSIDE INNER CONTAINER						
TC-5 Bottom Center	235	325	437	229	283	410
TC-6 Side Mid-Ht.	241	335	450	235	290	417
TC-7 Top Cover Side	234	321	427	234	286	404
TC-8 Top Center	230	312	413	239	290	406
FIREDIKE						
TC-9 Inner Surface	216	302	413	201	246	362
DRUM EXTERIOR						
TC-10 Bottom Center	108	115	122	108	112	119
TC-11 Side Mid-Ht.	108	113	120	105	110	117
TC-12 Top Center	108	111	118	107	109	116

Table 6-2

STEADY-STATE TEMPERATURE TEST RESULTS FOR 55-GAL PACKAGE AT 100°F AMBIENT TEMPERATURE

Thermocouple No. and Location	Steady-State Temperature)°F) With Steel Wool			With Air	
Watts =	30	43.5	64.5	30	66.5
HEATER					
TC-1 Heater Surface	651	809	993	497	715
INSIDE INNER CONTAINER					
TC-2 Near Bottom	241	298	382	253	402
TC-3 Near Side	330	412	525	253	400
TC-4 Near Top	277	338	422	269	405
OUTSIDE INNER CONTAINER					
TC-5 Bottom Center	237	297	374	238	384
TC-6 Side Mid-Ht.	246	305	390	241	382
TC-7 Top Cover Side	226	275	349	236	362
TC-8 Top Center	224	273	346	237	362
FIREDIKE					
TC-9 Inner Surface	225	278	358	222	354
DRUM EXTERIOR					
TC-10 Bottom Center	104	104	104	101	104
TC-11 Side Mid-Ht.	105	106	109	104	109
TC-12 Top Center	104	105	107	104	108

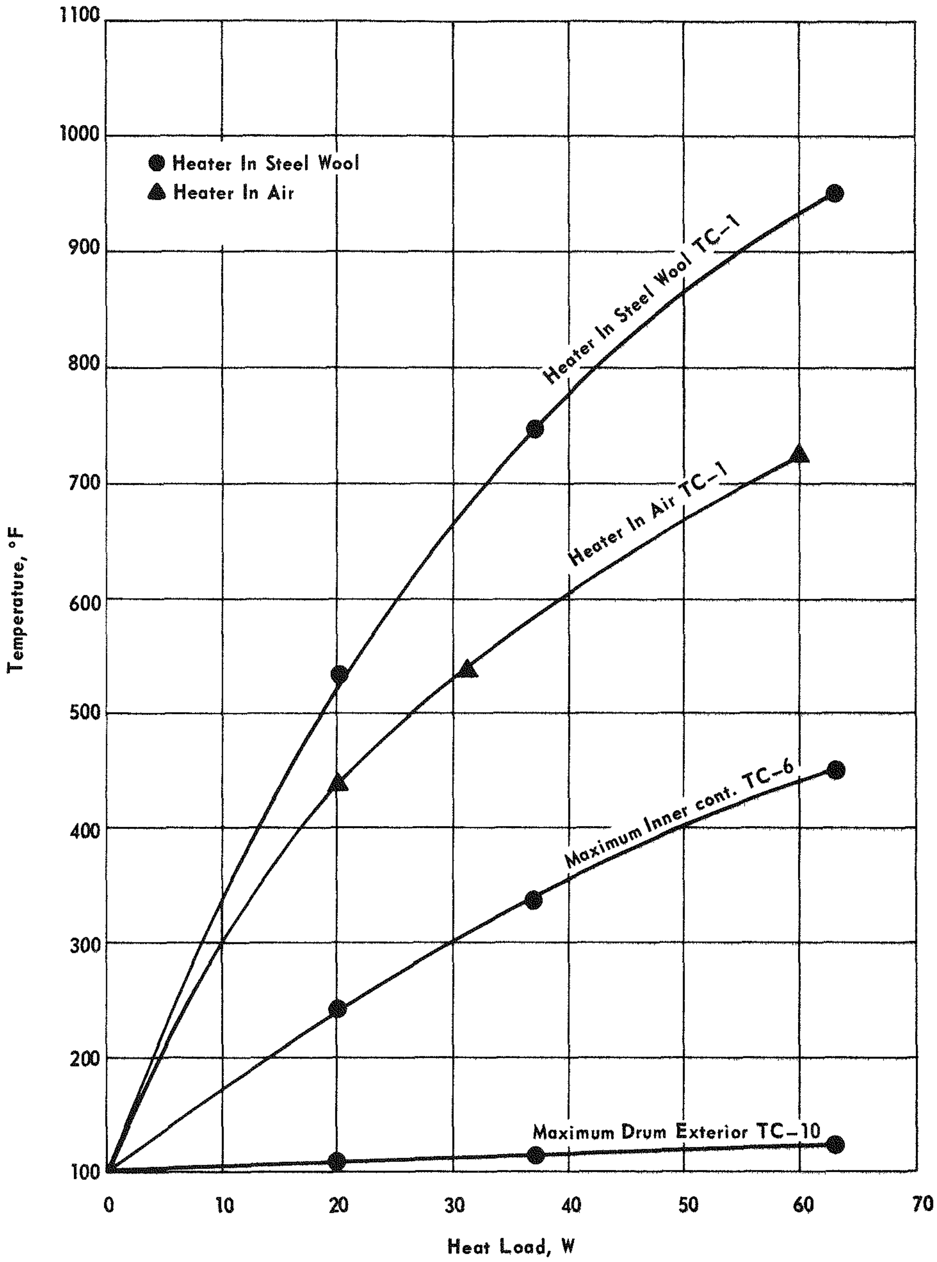


FIGURE 6-6 - Steady state temperature variation with heat load for 12-gal package.

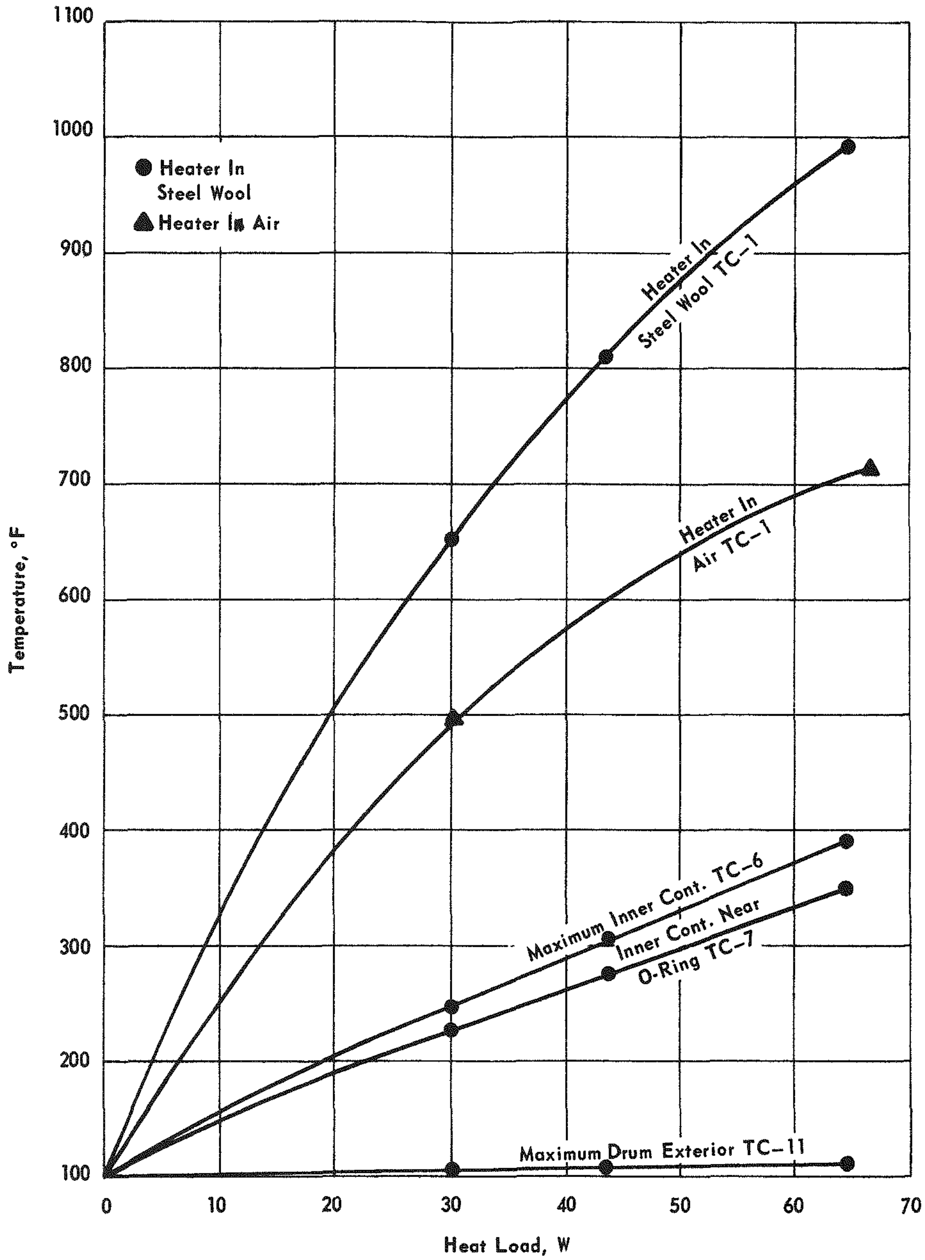


FIGURE 6-7 - Steady state temperature variation with heat load for 55-gal package.

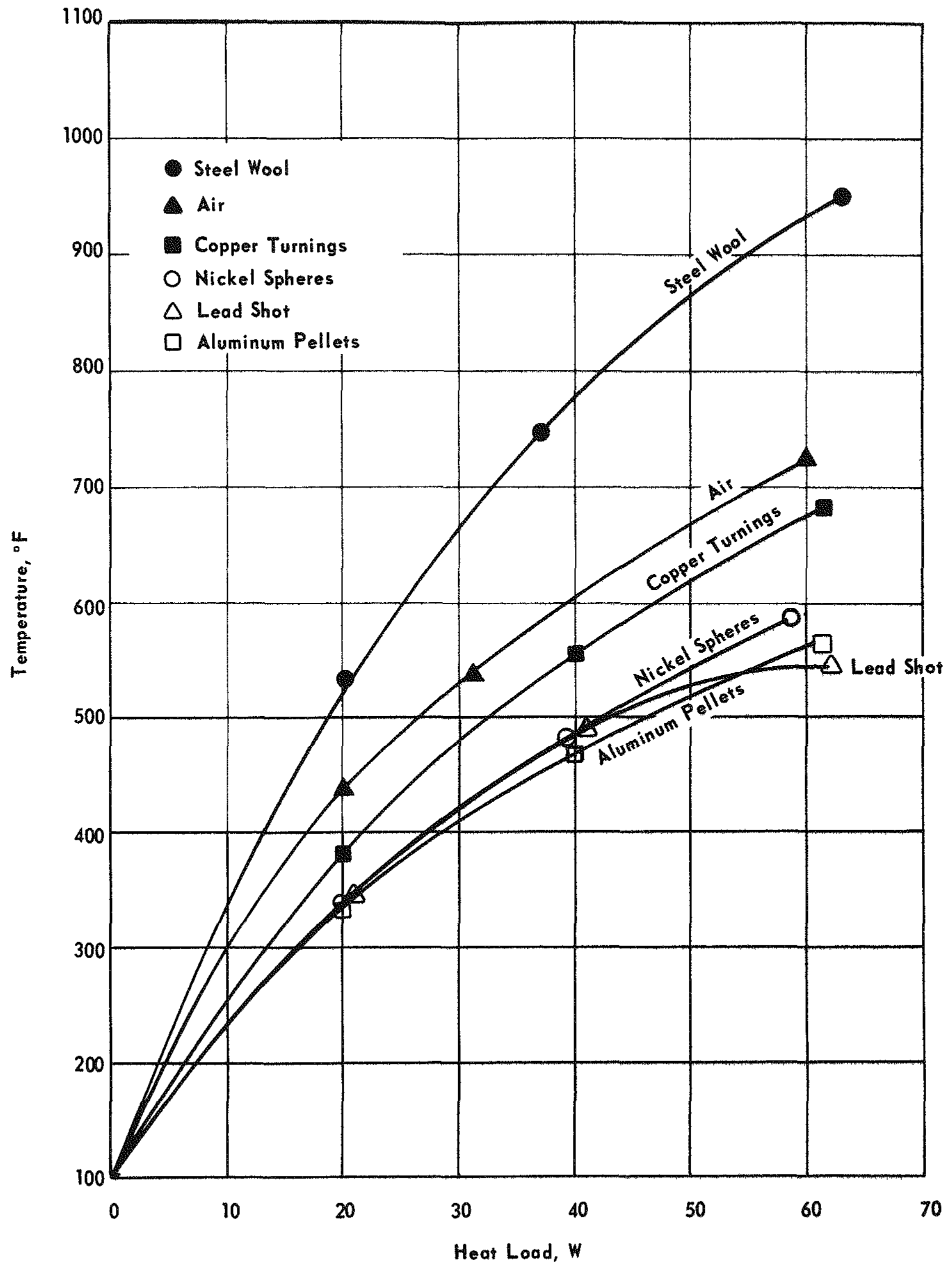


FIGURE 6-8 - Heater surface temperatures at steady state in various packaging materials for 12-gal package.

Table 6-3

HEATER SURFACE TEMPERATURES AT STEADY STATE IN VARIOUS PACKAGING MATERIALS FOR 12-GAL PACKAGE

Packaging Material	Heat Load (W)	Temperature (°F)
Steel Wool	20	532
	37	744
	63	952
Air	20	439
	31	541
	60	728
Copper Turnings	20	362
	40	527
	62	680
Nickel Spheres	20	322
	39	466
	58	584
Lead Shot	21	333
	41	474
	62	559
Aluminum Pellets	20	317
	40	449
	61	566

Table 6-4. The maximum capabilities of the 12- and 55-gal sizes are based on the 300°F limitation and the estimated maximum temperatures in a fire are approximately 60°F below the specified maximum of 500°F.

The maximum temperatures for the exterior drum surface shown in Table 6-4 are all 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 loads listed are 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 6-8 provides a comparison between the packaging materials tested and provides a basis for establishing guidelines which may be used to ensure that package contents will not reach excessive temperatures. The aluminum pellets, lead shot, and nickel spheres performed well as indicated by the lower

Table 6-4

MAXIMUM HEAT LOAD CAPABILITY AND TEMPERATURES

Nominal Size Package (gal)	Maximum Heat Load Capability (W)	Maximum Drum External Surface Temp. (°F)	Inner Cont. Maximum Steady State Temp. at 100°F Ambient (°F)	Inner Cont. Temp. Increase Resulting from Hypothetical Fire (°F)	Inner Cont. Maximum Temp. with Heat Load and Hypothetical Fire (°F)
12	30	112	300	137	437
55	42	106	300	144	444

heater temperatures achieved when these materials were used. For most uses the aluminum pellets are ideal because of their heat transfer capability, light weight, and low price. Use of lead shot is somewhat limited because of its low melting temperature of 621°F (327°C) and weight. The highest heater temperature resulted when steel wool was used and, as a result, it may be necessary to use other packing materials when high wattage amounts of some products are shipped. In addition to the results shown in Figure 6-8, a configuration was tested in which a metal can containing copper turnings was placed inside the inner container: The results were similar to the "air" curve but cannot be compared directly since a smaller heater was used for this test.

The results of the tests using steel wool and air were approximately the same for both packages. Thus, the results for all of the packaging materials tested in the 12-gal size provide reliable guidance for these materials when used in the 55-gal size. However, the actual temperature of an item being shipped will not necessarily be the same as the experimental heater temperatures. Even though the products typically shipped from Mound Laboratory are similar in geometry to the 7-3/4 in. long x 3/4 in. diameter electrical heater used for the testing, the actual temperature of a product being shipped depends on the particular characteristics of that product; for example, a smaller surface area will result in a higher surface temperature.

Most of the products typically shipped from Mound Laboratory can be shipped safely at a surface temperature of up to 750°F (399°C). It is not intended that the 750°F value be interpreted either as a limiting temperature for the contents or that all materials can be shipped safely at 750°F. For example, a product with the same heat transfer characteristics as the heater and with a maximum surface temperature capability of 750°F can be packaged in steel wool in the 55-gal package if the heat load is limited to approximately 38 W. Also, it could be packaged in any of the other materials tested when containing up to the maximum permissible heat loads of 30 W for the 12-gal size and 42 W for the 55-gal size. The above provides an example of how to use the data shown in Figure 6-7. 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 containers were thoroughly evaluated. The evaluation clearly demonstrates that the vessels are capable of safe pressure containment during normal transportation and hypothetical accident conditions.

Sample calculations for the internal pressure capability of the 55-gal package inner container at up to 100°F are presented, and the results for both packages at temperatures up to 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 bolted cover. The maximum pressure capability is then based on the values for the welded bottom since these are the lowest values for the three components.

7.2. BODY CALCULATIONS

The basic structure of the inner container for the 55-gal package is shown in Figure 7-1. It is a cylinder with a welded bottom plate and a bolted cover sealed with a 1/8 in. diameter cross section silicone o-ring. It is fabricated of mild steel, and the welds are examined after fabrication (see Appendix I). 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, S = 10,800 psi at -20 to 100°F, 10,000 at 300°F, and 9,400 at 500°F,
E = Welded joint efficiency, E = 1, for seamless tubing,
R = Inside radius of inner container, R = 3.25 in.,
t = Wall thickness, t = 0.25 in.

Substitution of the appropriate values into the above equation yields:

$$P = \frac{(10,800)\ (1)\ (0.25)}{(3.25) + (0.6)\ (0.25)}$$

$$P = 794 \text{ psi.}$$

The required parameters and the results of the seamless body calculations for both packages are shown in Table 7-1.

7.3. WELDED BOTTOM PLATE CALCULATIONS

The inner container bottom for the 55-gal package is welded to the 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 = 10,800 psi at -20 to 100°F, 10,000 at 300°F, and 9,400 at 500°F,
C = Factor accounting for method of attachment, C = 0.5,
R = Inside radius of inner container, R = 3.25 in.,
t = Thickness of bottom plate, t = 0.25 in.

The resulting calculation is as follows:

$$P = \left(\frac{10,800}{0.5}\right)\left(\frac{0.25}{2 \times 3.25}\right)^2$$

$$P = 32 \text{ psi.}$$

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

7.4. BOLTED COVER CALCULATIONS

The 55-gal container has a bolted cover and a silicone o-ring closure. The 12-gal size has, instead, a screwed pipe plug closure which has been modified to accept an o-ring seal. Since the pipe plug is much thicker than the bottom plate, it is not the limiting factor and no additional calculations are required for this size. A sample calculation is presented for the 55-gal size.

The calculation for the 55-gal inner container cover is similar to that for the bottom except that, because it is attached by bolts, the edge moment must be accounted for. The applicable equations are as follows:

$$P = \frac{S}{C}\left[\left(\frac{t}{2R}\right)^2 - \frac{1.78\ W\ h_G}{S\ (2R)^3}\right], \quad \text{(Ref. 1, p. 21)}$$

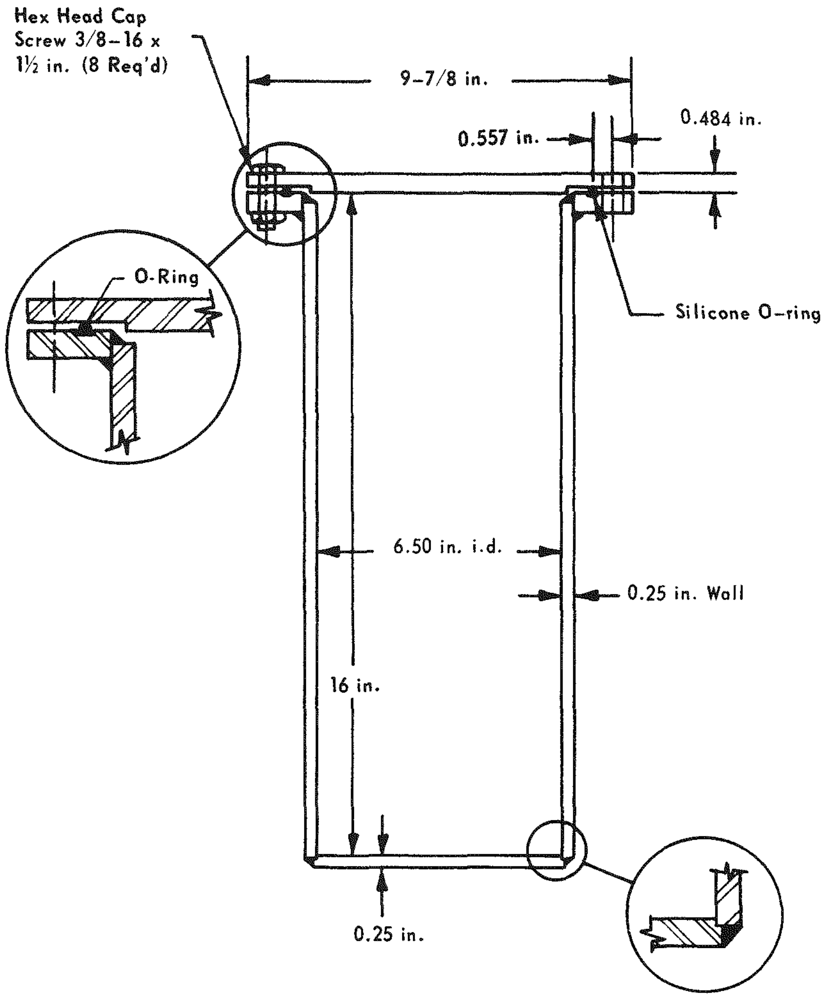


FIGURE 7-1 - Structure of inner container for 55-gal package.

Table 7-1

INNER CONTAINER BODY PRESSURE CAPABILITY CALCULATIONS

Nominal Size Package (gal)	Inside Radius (in.)	Body Wall Thickness (in.)	Internal Pressure Capability (psig)		
			At -20 to 100°F	At 300°F	At 500°F
12	2.00	0.25	1256	1186	1093
55	3.25	0.25	794	750	691

$$W = H + H_p, \text{ and} \qquad \text{(Ref. 1, p. 219)}$$

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

where P, S, C, t, and R are as defined above for the inner container bottom and

- W = Total bolt load, lb,
- H = Hydrostatic end force exerted by maximum allowable working pressure, lb,
- H_p = Force to ensure tight joint, $H_p = 0$ for the silicone o-ring since it is considered self-sealing, and
- h_G = Gasket moment arm, $h_G = 0.557$ in.

Combined, rearranged, and simplified, the pressure equations yield the following:

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

$$P = \left(\frac{10,800}{0.3}\right)\left(\frac{0.4375}{2 \times 3.25}\right)^2 \Big/ \left(1 + \frac{1.78\pi \times 0.557}{8 \times 3.25 \times 0.3}\right)$$

$$P = 117 \text{ psi.}$$

The required parameters and the results of the calculations for the bolted cover calculations are shown in Table 7-3.

Calculations were also performed to ensure that the stresses existing in the flange (as a result of the bolt loads required to seal the container) satisfied requirements. The resulting stress was found to be well below the maximum allowable stress.

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 both inner containers. Thus, the ASME Code maximum allowable working pressures are those shown in Table 7-2. The pressure capabilities are sufficiently high to contain the 20 psig pressure which would result from heating the air environment trapped during packaging operations at one atmosphere to the temperatures reached during normal shipment and during hypothetical accident conditions.

Table 7-2

INNER CONTAINER WELDED BOTTOM PLATE PRESSURE CAPABILITY CALCULATIONS

Nominal Size Package (gal)	Inside Radius (in.)	Bottom Wall Thickness (in.)	Internal Pressure Capability (psig)		
			At -20 to 100°F	At 300°F	At 500°F
12	2.00	0.25	84	80	73
55	3.25	0.25	32	30	28

Table 7-3

INNER CONTAINER BOLTED COVER PRESSURE CAPABILITY CALCULATIONS

Nominal Size Package (gal)	Inside Radius (in.)	Cover Thickness (in.)	Gasket Moment Arm (in.)	Internal Pressure Capability (psig)		
				At -20 to 100°F	At 300°F	At 500°F
55	3.25	0.4375	0.557	117	108	101

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. J. Roark, Formulas for Stress and Strain, McGraw-Hill, New York, N. Y., 4th Ed., 1965.

8. PACKAGE STANDARDS EVALUATION

8.1. GENERAL

In Part II of ERLA Manual 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 packages are in compliance with these standards. The evaluations are based on gross weights of 150 lb for the 12-gal package and 400 lb for the 55-gal package. These values provide conservative results since they are significantly higher than the actual maximum gross weight of 90 lb and 300 lb.

8.2. MATERIALS

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

8.3. CLOSURES

Positive closures, bolts or screwed pipe threads which prevent accidental opening, are used on both the inner containers and the drums. 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 either shipping container. The drum covers and inner containers are generally removed manually and do not require any special devices. The assembled containers are commonly lifted with a fork lift by positioning the forks beneath the bottom of the drum as shown in Figure 8-1.
The following evaluations show that supporting three times the weight of the packages will not generate stresses in excess of the yield strength of the mild steel drums.

A sample calculation is provided for the 55-gal package. The gross weight of the 55-gal container is taken to be 400 lb and three times this weight is 1200 lb. This load is reacted at points as shown in Figure 8-1. Each fork is typically 4 in. wide and the drum wall is 0.0598 in. thick. The maximum stress in the drum is found by dividing the required load by the total cross-sectional area as follows:

$$S = \frac{1200 \text{ lb}}{(4 \text{ places})(4 \times 0.0598 \text{ in.})} = 1250 \text{ psi}$$

The lifting stress in the 12-gal package was determined in a similar manner, and the results are presented in Table 8-1. The calculated stresses are less than the 27,000 psi yield strength of the mild steel drums.

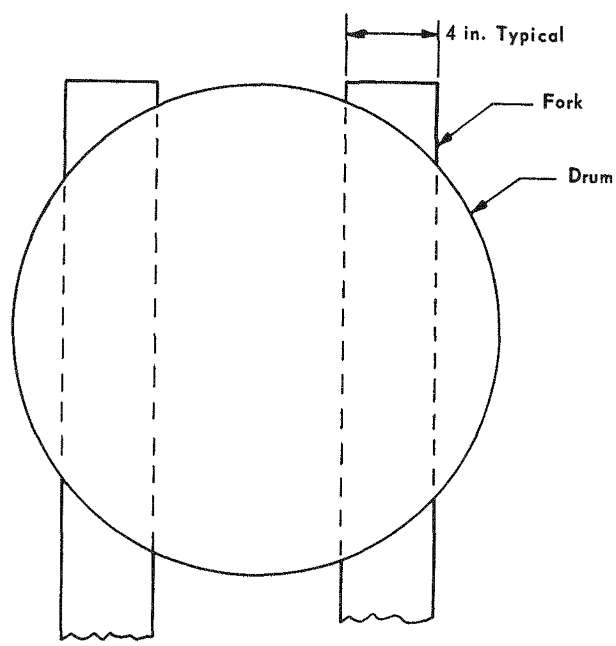


FIGURE 8-1 - Lifting stresses in drum.

Table 8-1

RESULTS OF FORK LIFT STRESS CALCULATIONS

Nominal Size Package (gal)	Drum Wall Thickness (in.)	Assumed Gross Weight (lb)	Maximum Compressive Stress (psi)
12	0.0359	150	781
55	0.0598	400	1250

8.5. TIEDOWN DEVICES

ERDA Manual Chapter 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 on the packages discussed in this report. The packages are normally retained in place within the transport vehicle by other packages or are strapped in place.

8.6. LOAD RESISTANCE

When it is 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.

A sample calculation is presented for the 55-gal package and the results are then tabulated for both packages. The 55-gal size uses a DOT specification 17C drum, which is fabricated of 16 gage mild steel. The drum with the required load is illustrated schematically in Figure 8-2. The drum material is mild steel with a minimum yield stress of 27,000 psi, as specified per ASME Pressure Vessel Code.(1) For the purpose of this evaluation, the gross weight is taken to be 400 lb, although the maximum gross weight is 300 lb. The gross weight used in this evaluation for the 12-gal calculation is also conservatively high.

Stresses in the drum resulting from the uniform load are determined, as recommended by Shappert (2), from the following equation:

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

where S = stress (psi),
M = maximum bending moment,
M = 5 WL/8 (in. lb)

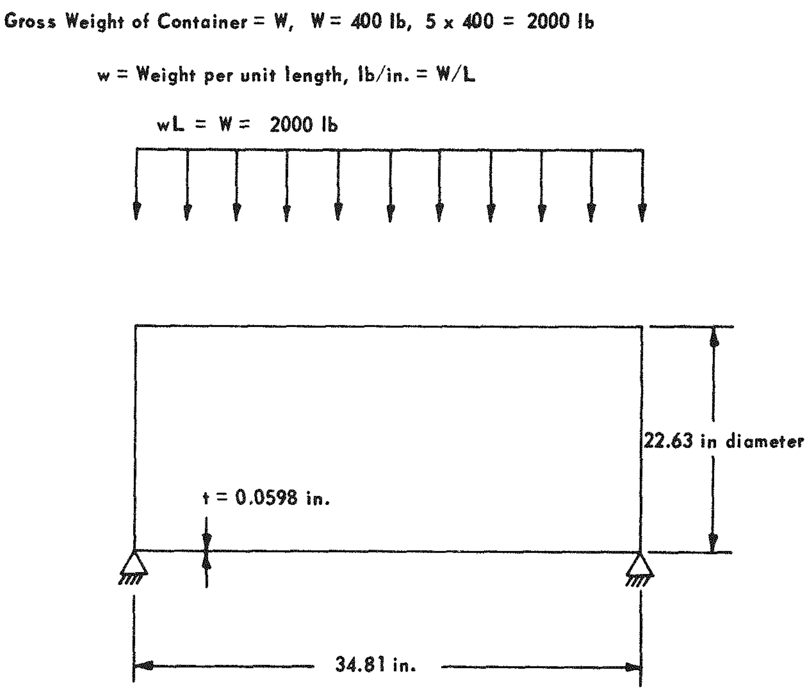


FIGURE 8-2 - Drum load resistance for 55-gal package.

$$Z = \frac{I}{C} = \text{section modulus of drum}$$

$$= \frac{\pi}{4\ R_o}(R_o^4 - R_i^4) = \pi R_o^2\ t\ (in^3)$$

for a large diameter, thin-walled cylinder,

C = maximum distance from neutral axis (in.), $C = R_o$

W = weight of drum, W = 400 lb,

L = length of drum, L = 34.81 in.,

R_o = outside radius of drum, R_o = 11.32 in.,

R_i = inside radius of drum, R_i = 11.25 in., and

t = thickness of drum, t = 0.0598 in.

The computed maximum bending moment is

$$M = \frac{5(400)\ (34.81)}{8} = 8{,}700 \text{ in. lb.}$$

The computed section modulus is

$$Z = \pi R_o^2\ t = \pi(11.32)^2(0.0598) = 24.1 \text{ in.}^3$$

The maximum bending stress is then

$$S = \frac{8{,}700}{24.1} = 361 \text{ psi}$$

Since the material yield stress of 27,000 psi is 75 times as great as the calculated maximum bending stress, the 55-gal drum container satisfies the load resistance requirement. The required data and the results of the load resistance calculations for both sizes are summarized in Table 8-2.

Table 8-2

SUMMARY OF LOAD RESISTANCE DATA AND RESULTS

Required Data	Drum Size 12-Gal	Drum Size 55-Gal
W, lb	150	400
L, in.	21.1	34.81
R , in.	6.94	11.32
t, in.	0.0359	0.0598
Results		
S, psi	364	361
$\frac{S\ yield}{S\ actual}$	74	75

8.7. EXTERNAL PRESSURE

The containment vessel must be capable of withstanding an external pressure of 25 psi without any loss of contents. Conservatively, it is assumed that no loss of contents will result if the allowable stress of the inner container body material is not exceeded and if local buckling loss does not occur even though these conditions would not necessarily cause the inner container to be breached. The inner container of the 55-gal package is shown in Figure 8-3. It is constructed of mild steel with an allowable stress of at least 9,800 psi at 400°F, as specified per ASME Pressure Vessel Code. Sample calculations are presented for the 55-gal package, and the results are tabulated for both packages.

First, the maximum bending stresses in the inner container cover and in the circular bottom end plate are considered.

The actual boundary conditions for the top and bottom plate lie somewhere between fixed and simply supported. The top cover plate is bolted to a flanged body and is assumed to have simply supported edges. The bottom plate is welded to the container body, and the edge of the plate is considered to be fixed. The maximum bending stresses in uniformly loaded circular plates are given by:

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

and

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

where S_{max} = maximum bending stress (psi) = 9,800 psi at 400°F,

R = radius of plate, R = 4.938 in. for the top cover plate and R = 3.313 in. for the bottom plate,

P = pressure, P = 25 psi, and

t = thickness of plate, t = 0.4843 in. for the top cover plate, and t = 0.250 in. for the bottom plate.

The maximum bending stress in the top cover plate is

$$S_{max} = \frac{1.24\ R^2\ P}{t^2} = \frac{1.24\ (4.938)^2(25)}{(0.4843)^2}$$

$$= 3223 \text{ psi}$$

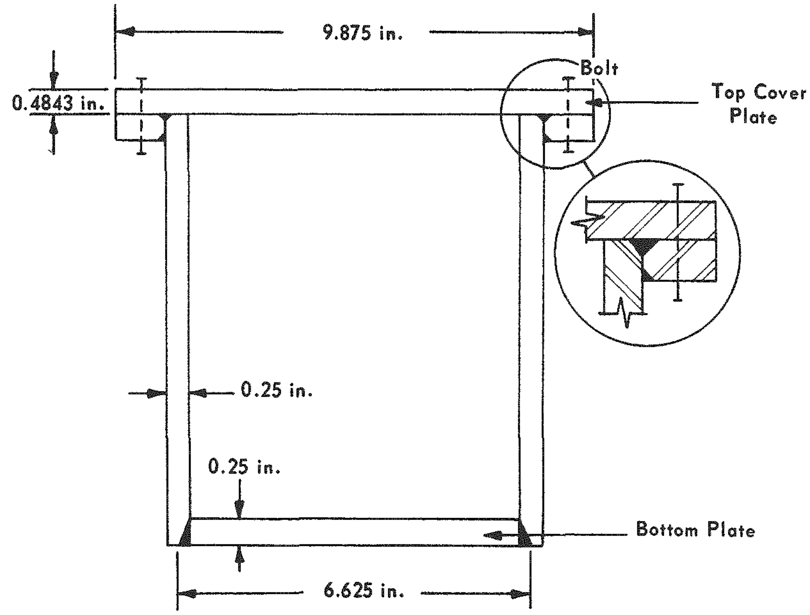


FIGURE 8-3 - Pressure capability of mild steel inner container for 55-gal package.

and the maximum stress in the bottom plate is

$$S_{max} = \frac{0.75\ R^2\ P}{t^2} = \frac{0.75\ (3.313)^2(25)}{(0.25)^2}$$

$$= 3293 \text{ psi}$$

In the above cases, the maximum bending stresses in the material are only 33 and 34% of the allowable stress.

Next, the maximum membrane stress in the inner container 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 = 3.50 in., and
t = body wall thickness, t = 0.25 in.

For the 55-gal package inner container,

$$S_{max} = \frac{25\ (3.50)}{0.25} = 350 \text{ psi}$$

This value for the maximum hoop stress is only 4% of the allowable stress.

The third consideration is the buckling strength of the inner container. The allowable external pressure for the vessel is computed using the procedures specified in the ASME Pressure Vessel Code (1), which provides conservative critical pressures. The 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 = outside diameter of vessel, D = 7.0 in.,
L = length of vessel, L = 16.01 in.,
t = thickness of vessel, t = 0.25 in., and
B = constant depending on the ratios L/D and D/t, B = 12,000 for the 55-gal package inner container.

For the 55-gal package, the allowable pressure load is

$$P_{allowable} = \frac{12,000}{7.0/0.25} = 429 \text{ psi}$$

This calculated value of the allowable external pressure is 17 times greater than the required pressure capability of 25 psi. The required data and the results of the external pressure capability calculations for both sizes are summarized in Table 8-3.

Table 8-3

SUMMARY OF EXTERNAL PRESSURE CAPABILITY DATA AND RESULTS

Required Data	Drum Size 12-Gal	Drum Size 55-Gal
R, top cover, in.	-	4.938
t, top cover, in.	-	0.4843
R, bottom plate, in.	2.063	3.313
t, bottom plate, in.	0.25	0.25
R, body, in.	2.25	3.50
t, body, in.	0.25	0.25
D, body, in.	4.50	7.00
L, body, in.	10.00	16.01
L/D, body	2.2	2.3
D/t, body	18	28
B, psi	12,500	12,000
Resulting Stresses with 25 psi External Pressure (psi)		
Material Allowable Stress	9,800	9,800
Max. bending stress of top cover plate	-	3,223
Max. bending stress of bottom plate	1,277	3,293
Max. membrane stress in body	225	350
Resulting External Pressure Capabilities (psi)		
Minimum required	25	25
ASME allowable	694	429

8.8. REFERENCES

1. J. M. Guy, et al., ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division I, ASME, New York, N. Y. (1971)

2. L. B. Shappert, Cask Designers Guide: A Guide for the Design, Fabrication, and Operation of Shipping Casks for Nuclear Operations, ORNL-NSIC - 68, Oak Ridge National Laboratory, Tennessee (February, 1970), p. 92.

9. NORMAL CONDITIONS OF TRANSPORT EVALUATION

9.1. GENERAL

ERDA 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
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 adequately demonstrate 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 drums, insulation, or the inner containers (primary containment vessels) in excess of design capabilities.

A sample calculation is presented for the 55-gal size and the temperatures resulting from direct sunlight are presented for both sizes. 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 each package are less than, or equal to, the corresponding increase at the drum surface, the assumption that these temperature increases are equal throughout each package provides conservative estimates of the inner container temperatures.

Shappert's (1) approach establishes the average solar heat load over a 24-hr period as 42 W/ft^2 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 for the 55-gal size as follows:

$$A = \left[(1.89 \text{ ft diam})^2 + (2.90 \text{ ft height})^2\right]^{\frac{1}{2}} \times (1.89 \text{ ft diam}),$$

$$A = 6.54 \text{ ft}^2.$$

Therefore, the solar heat load (Q_s) is

$$Q_s = (6.54 \text{ ft}^2)(42 \text{ W/ft}^2) = 275 \text{ W}.$$

The resulting temperature increase at the drum surface is determined by linear extrapolation of the experimental steady state temperature profile data. For the 55-gal size, since the drum surface temperature increased 8.6°F above ambient when 66.5 W was dissipated, the surface temperature increase is estimated to be 36°F when 274 W must be dissipated. Thus, 36°F is determined to be the temperature increase on the surface of the drum and throughout the package resulting from the solar heat load for the 55-gal size. 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 42 W for the 55-gal size, the drum surface temperature is then 106 + 36 + 30 = 172°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 for both sizes are summarized in Table 9-1.

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

Nominal Package Size (gal)	Maximum Contents Heat Load Capability (W)	In 100°F Shade: Drum (°F)	In 100°F Shade: Inner Cont. (°F)	Intermediate Calculations: Proj. Area (ft^2)	Intermediate Calculations: Solar Load (W)	Intermediate Calculations: Solar Increase (°F)	In 130°F Sun: Drum (°F)	In 130°F Sun: Inner Cont. (°F)
12	30	112	300	2.44	102	36	178	366
55	42	106	300	6.54	275	36	172	366

Thus, the heat input from the sun will not cause the inner container temperatures to exceed design capabilities. In fact, the inner containers are designed to withstand hypothetical accident fire conditions, as discussed elsewhere in this report. The effectiveness of the steel drums and insulation is not expected to be reduced as a result of the sun, although the insulation temperatures would approach 400°F, which is estimated to be the temperature at which the Firedike insulation will begin to char slightly.

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 packages and possibly would be beneficial.

9.4. PRESSURE

Reduced atmospheric pressure of 0.5 times standard atmospheric pressure is well within the capability of the inner containers. This is equivalent to an increased internal pressure of 7.3 psi above the maximum normal operating pressure of approximately 14.7 psig (2.0 atm absolute) at 1 atm external pressure. The internal pressure capabilities of the inner containers have been thoroughly evaluated and are discussed in Section 7. The calculated maximum allowable working pressures (ASME code) at 300°F are in excess of 22 psig, which would result from the reduced atmospheric pressure requirement.

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 and special tests which were performed for similar packages. Since 1968, approximately 395 shipments have been successfully completed with no evidence of damage from vibration. Also, the AL-M1 shipping container, which is similar in design, was subjected to laboratory vibration tests which did not cause any damage.

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 any of the packages in any way or have any effect, other than slight cooling, on the contents. The packages are actually exempt from this test requirement since the external surfaces are of all metal construction and the vent holes are sealed with waterproof tape.

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. This is indicated by the fact that only minimal damage to the drums is incurred as a result of the 30-ft drop tests discussed in Section 10 of this report. Also, this test was performed by Dow Chemical Co. for similar 10-gal and 30-gal packages (2,3) and for a 55-gal package by the University of California (4) with only minor damage to the drums. Thus, the minor damage resulting from the 4-ft drop would not cause any hazardous conditions.

9.8. 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-lb gross weight, and to all Fissile Class II packagings.

This test is applicable even though the packages are of metallic construction and the 55-gal size weighs in excess of 110 lb, since the shipping containers can be used for Fissile Class II shipments. The 1-ft corner drop is less severe than the 4-ft drop which was discussed in the previous section and would not damage the packages in any way that would reduce the volume or effectiveness. Also, this test was performed for similar 10-gal and 30-gal packages by Dow Chemical Co. (2,3).

9.9. PENETRATION

It is necessary to evaluate the impact of the hemispherical end of a vertical steel cylinder, 1-1/4 in. in diameter and weighing 13 lb, 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 causes minor damage to the drum surfaces, but does not penetrate them. This was demonstrated by tests performed on similar 10-gal and 30-gal packages by Dow Chemical Co. (2,3). It is also substantiated for both sizes discussed in this report by an engineering evaluation which compares the stress imposed by the dropped rod striking the cylindrical and flat surfaces of the drum to the ultimate strength of the drum material.

The ratio of dynamic load to static weight approaches the value 2.0 in the limit (Reference 5, p. 368, Reference 6, p. 40). The effective dropped load striking the drum surface is determined using the limit value as;

P = 2.0 x 13 lb = 26 lb (for both drum sizes)

Separate calculations will be made for the cylindrical surface and flat, circular top of each container.

The effect of a concentrated load on a cylindrical surface produces the following stress and deflections (Reference 5, Table XIII, Case 7):

$$s = 2.4\ P/t^2$$

$$y = \frac{P}{Et}\left[0.48\left(\frac{L}{R}\right)^{0.5}\left(\frac{R}{t}\right)^{1.22}\right]$$

where:
- s = Hoop bending stress, psi
- P = Applied load (26 lb)
- t = Drum thickness, in.
- y = Vertical deflection of surface, in.
- L = Length of container, in.
- R = Radius of container, in.
- E = Elastic modulus (30,000,000 psi for drum).

A sample calculation will be illustrated for the 55-gal drum. The 55-gal drum has a length of 34.81 in., a radius of 11.28 in. and a thickness of 0.0598 in. The stress and deflection are found as follows:

$$s = (2.4)(26)/(0.0598)^2 = 17{,}450 \text{ psi.}$$

$$y = \frac{26}{30\text{x}10^6\text{x}0.0598}\left[0.48\left(\frac{34.81}{11.28}\right)^{0.5}\left(\frac{11.28}{0.0598}\right)^{1.22}\right]$$

$$= 0.0073 \text{ in.}$$

The resulting stress and deflection will produce only slight surface damage to the container. (Note that the ultimate tensile strength of mild steel is 60,000 psi.) Similar calculations were made for the 12-gal drum size. The results are summarized in Table 9-2.

The following equations apply to a concentrated load at the center of a circular plate with fixed edges. (Reference 5, Table X, Case 8)

$$S_R = \frac{3P}{2\pi\ t^2}\left(1 - \frac{A^2}{R^2}\right)$$

$$S_T = \frac{3P}{3m\pi\ t^2}\left(1 - \frac{A^2}{R^2}\right)$$

$$y = \frac{3P\ (m^2-1)}{2\pi E m^2 t^3}\left[\frac{R^2-A^2}{2} - A^2 \log_e \frac{R}{A}\right]$$

where:
- m = Reciprocal of Poisson's ratio (3 for mild steel)
- A = Radius of point load (0.625 in. for rod)
- $\log_e$ = Natural logarithm
- S_R = Maximum radial stress in plate, psi
- S_T = Maximum tangential stress in plate, psi.

The resulting stresses and deflection in the 55-gal drum are obtained as follows:

$$S_R = \frac{3 \text{ x } 26}{(2)(\pi)(0.0598)^2}\left(1 - \frac{(0.625)^2}{(11.28)^2}\right) = 3461 \text{ psi}$$

Table 9-2

ANALYSIS OF DROPPED ROD ON CYLINDRICAL SURFACE

Nominal Size of Drum (gal)	Container Dimensions (in.) Length	Radius	Thickness	Bending Stress (psi)	Load Deflection (in.)
12	21.1	6.925	0.0359	48,416	0.0124
55	34.81	11.28	0.0598	17,450	0.0073

$$S_T = \frac{3 \times 26}{(3)(3)(\pi)(0.0598)^2}\left(1 - \frac{(0.625)^2}{(11.28)^2}\right)$$

$$= 769 \text{ psi}$$

$$y = \frac{(3)\ (26)\ (3^2-1)}{(2)(\pi)(30\text{x}10^6)(3^2)(0.0598)^3}$$

$$\left[\frac{(11.28)^2 - (0.625)^2}{2} - (0.625)^2 \log_e \frac{(11.28)}{(0.625)}\right]$$

$$= 0.107 \text{ in.}$$

Similar calculations were obtained for the 12-gal drum and are summarized in Table 9-3.

A review of Tables 9-2 and 9-3 shows that the maximum bending stress occurs when the dropped rod strikes the cylindrical surface of the 12-gal container. This stress (48,416 psi) is well below the yield stress of the material and the resulting deflection is small. Therefore, the dropped rod would not penetrate the container and the surface damage would be slight. This is borne out by the results obtained on a similar container during the Dow Chemical Company test program (2,3).

Table 9-3 indicates that the dropped rod will produce appreciable deflections in flat end plates, but that the resulting stresses are relatively minor. This shows that while indentations would occur in the container lids, there would be no penetration. The results of this analysis, therefore, illustrate that the containers are adequately designed to withstand the penetration test.

9.10. COMPRESSION

This test requires a compressive load equal to either five 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.

Previous testing by others indicates that the 55-gal size satisfies the compression requirements. Dow Chemical Co. (4) tested a package using two 55-gal drums welded together with 5,250 lb to qualify it for a 1,050-lb maximum gross weight, which far exceeds the 300-lb maximum gross weight of the 55-gal AL-M6 package.

The above testing is supplemented with evaluations of both sizes and a sample calculation is provided for the 55-gal size. The evaluation is based on a load of 2,000 lb, which is five times the assumed gross weight of 400 lb. The alternate criteria yields a value of only 804 lb. The 55-gal drum is illustrated in Figure 9-1. The wall thickness (t) is 0.0598 in., and the outside diameter of the drum is 22.56 in. The longitudinal compressive stress (S) is calculated by dividing the load by the cross-sectional area of the drum wall as follows:

$$S = \frac{2{,}000}{\pi D t}$$

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

The result is

$$S = \frac{2{,}000}{\pi(22.56)(0.0598)}$$

$$S = 472 \text{ psi.}$$

This stress value is only 2% of the yield stress which is 27,000 psi for mild steel. The results for both sizes are shown in Table 9-4.

The bending stresses that occur in each of the drum rolling hoops are also determined.

Table 9-3

ANALYSIS OF DROPPED ROD ON CONTAINER LID

Nominal Size of Drum (gal)	Radius (in.)	Thickness (in.)	S_R (psi)	S_T (psi)	y (in.)
12	6.925	0.0359	9554	2123	0.182
55	11.28	0.0598	3461	769	0.107

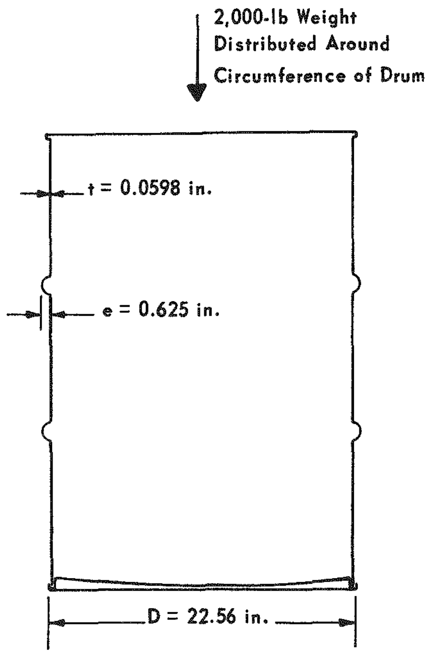


FIGURE 9-1 - Compressive load evaluation for 55-gal drum.

For a conservative approximation, the drum is assumed to act as a beam rather than a shell; i.e., a 1-in. strip of the drum is investigated due to a longitudinal stress resultant. The bending moment and maximum bending stress are then found. The longitudinal stress resultant (S) for the 55-gal drum is given by:

$$S = \frac{2,000}{\pi D} = \frac{2,000}{\pi(22.56)} = 28.2 \text{ lb/in.}$$

The bending moment (M) at the hoop is then

$$M = S(e) = 28.2 \ (0.625 \text{ in.}) = 17.6 \text{ in.-lb/in.},$$

where e is the size of the rolling hoop.

The maximum bending stress is

$$S_{max} = \frac{6M}{t^2} = \frac{6(17.6)}{(0.0598)^2} = 29,500 \text{ psi}$$

The above stress exceeds the 27,000 psi yield strength indicating that such large compressive loadings will yield the material. However, such yielding will be localized and will occur only at the surface of the drum. The cross section is still capable of resisting a collapse due to this loading, and the drums are considered to adequately satisfy this requirement. The results of the calculations for both sizes are shown in Table 9-4.

The ultimate capability of each container is verified by considering the critical buckling stress of the cylindrical shell when subjected to uniform axial compression.

A sample calculation is provided for the 55-gal size. The critical buckling stress (S_{cr}) is given by the following equation: (Reference 5, Table XVI, Case 7):

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

where: E = Modulus of elasticity, $E = 30 \times 10^6$ psi,
h = Drum wall thickness, h = 0.0598 in.,
R = Radius of drum, R = 11.28 in., and
μ = Poisson's ratio, $\mu = 0.3$.

Thus, the critical buckling stress is:

$$S_{cr} = \frac{30 \times 10^6 (0.0598)}{11.28\sqrt{3\ (1-0.09)}} = 96,300 \text{ psi}$$

This value for the ultimate capability could never be reached in the drum. The critical buckling stresses for both sizes are shown in Table 9-4.

In summary, all the resulting longitudinal compressive stresses in the drum body are far below the 27,000 psi material yield stress. On the other hand, the resulting rolling hoop bending stresses are sufficiently high for the 12- and 55-gal sizes to cause localized yielding, but will not cause the drums to collapse. The ultimate critical buckling stress capabilities far exceed any stresses that could be developed from the compression tests. Thus, the drums are considered to satisfy the compression test requirement.

Table 9-4

SUMMARY OF DRUM DIMENSIONS AND RESULTS OF COMPRESSION CALCULATIONS

Nominal Size Drum (gal)	Drum Diam. (in.)	Drum Wall Thick (in.)	Rolling Hoop Size (in.)	Compressive Load Requirement (lb)	Resulting Longitudinal Compressive Stress (psi)	Resulting Rolling Hoop Bending Stress (psi)	Ultimate Critical Buckling Stress Capability (psi)
12	13.85	0.0359	0.375	750	480	30,100	94,100
55	22.56	0.0598	0.625	2000	472	29,500	96,300

9.11. REFERENCES

1. L. B. Shappert, Cask Designers Guide, ORNL-NSIC-68, Union Carbide Corporation, Oak Ridge National Laboratory, Oak Ridge, Tennessee (February 1970), p. 143.

2. F. E. Adcock and W. F. Wackler, RFD Container - Model 1518 for Fissile Class II and Class III Shipments, RFP-1042, Dow Chemical Co., Rocky Flats (April 8, 1968).

3. F. E. Adcock, J. D. McCarthy, and W. F. Wackler, Rocky Flats Model 2030-1 Container (AEC-AL USA/5332/BLF) Safety Analysis Report for Packaging (SARP), RFP-1867 Rev. 1, Dow Chemical Co., Rocky Flats (February 27, 1974).

4. J. R. Gaskill and R. D. Taylor, An Improved Shipping Container for Fissile Material, UCRL-14903, Univeristy of California (June 3, 1968).

5. R. J. Roark, "Formulas for Stress and Strain," McGraw-Hill Book Company, New York, Fourth Edition, 1965, p. 368.

6. J. M. Briggs, "Introduction to Structural Dynamics," McGraw-Hill Book Company, New York, 1964, p. 40.

10. HYPOTHETICAL ACCIDENT TESTS

10.1 GENERAL

ERDA 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

Full scale 12- and 55-gal shipping containers were subjected to the complete series of four hypothetical accident tests. All test inner containers were packaged using lead shot to simulate maximum contents weight. Chromel/alumel thermocouples were used for temperature measurements inside the inner containers. In addition, temperature sensitive paints were applied to the inside and outside walls of the inner containers. 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. Each 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.

On final assembly of the packages, 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 specially designed, 50-ft high, drop tower equipped with a 2-ton hoist was used to drop the packages from a height of 30 ft onto a steel-covered concrete drop pad. The packages were oriented upside down at a 45° angle so that the bolt on the bolt ring would strike the pad first as shown for the 55-gal package in Figure 10-1.

Figure 10-2 shows the container at the required 30-ft height just prior to manual actuation of the quick release hook. Figure 10-3, taken just prior to impact, shows that the container was dropped in precisely the initial orientation since no twisting motion was imparted to it by the quick release hook.

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. Figure 10-4 shows the 55-gal package suspended 40 in. above the top of the 6-in. diameter cylinder. Figure 10-5 shows the container impacting on the cylinder.

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 emmissivity coefficient of 0.9, assuming the surfaces of the package have an absorption coefficient 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

FIGURE 10-1 - Prior to the 30-ft drop, the 55-gal package is attached to the hoist.

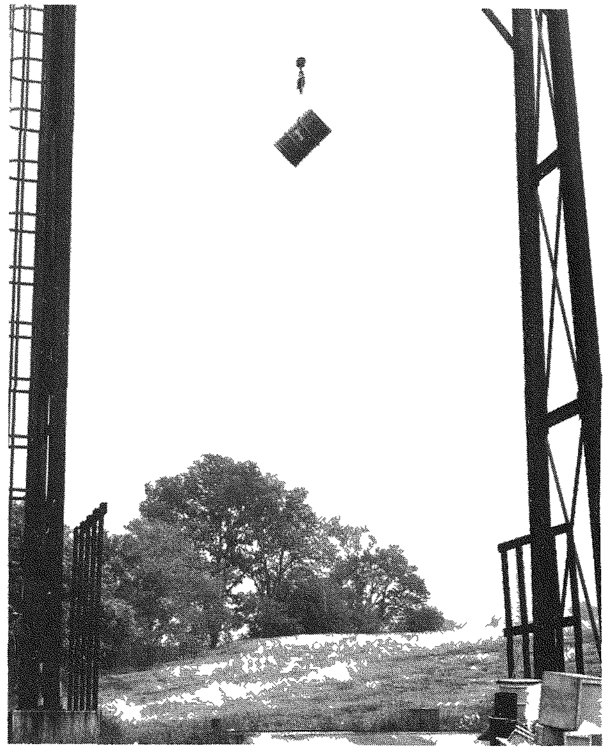


FIGURE 10-2 - The 55-gal container at the required 30-ft height.

FIGURE 10-3 - The 55-gal drum prior to impact.

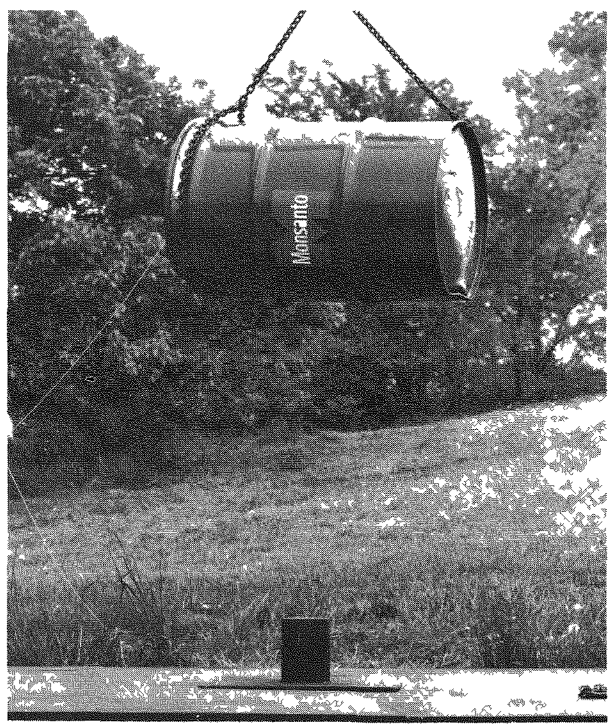


FIGURE 10-4 - The 55-gal drum in place for puncture test.

FIGURE 10-5 - Puncture test impact.

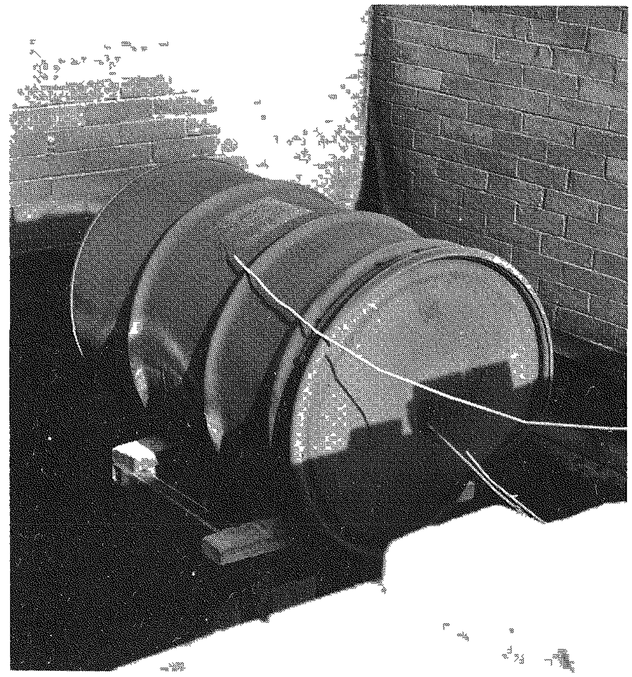


FIGURE 10-6 - The 55-gal container after fire test.

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.(1) 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 ft^3/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 nozzle spray is directed horizontally providing complete coverage of the burning aviation fuel surface. The water spray reduces the smoke plume far below maximum allowable requirements.

The test facility was used to test the 12-gal and 55-gal packages. The 55-gal package is shown after the test in Figure 10-6; it 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 flame temperatures obtained throughout the tests are plotted as a function of time in Figure 10-7. The temperatures were measured at the side of the package. 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 containers were removed from the insulated drum assemblies. The tank was filled to a depth of 51 in. to ensure immersion of all parts of the containers under at least 36 in. of water. Both inner containers were immersed overnight for 20 hr, since it was not convenient to withdraw them after the required 8-hr minimum period.

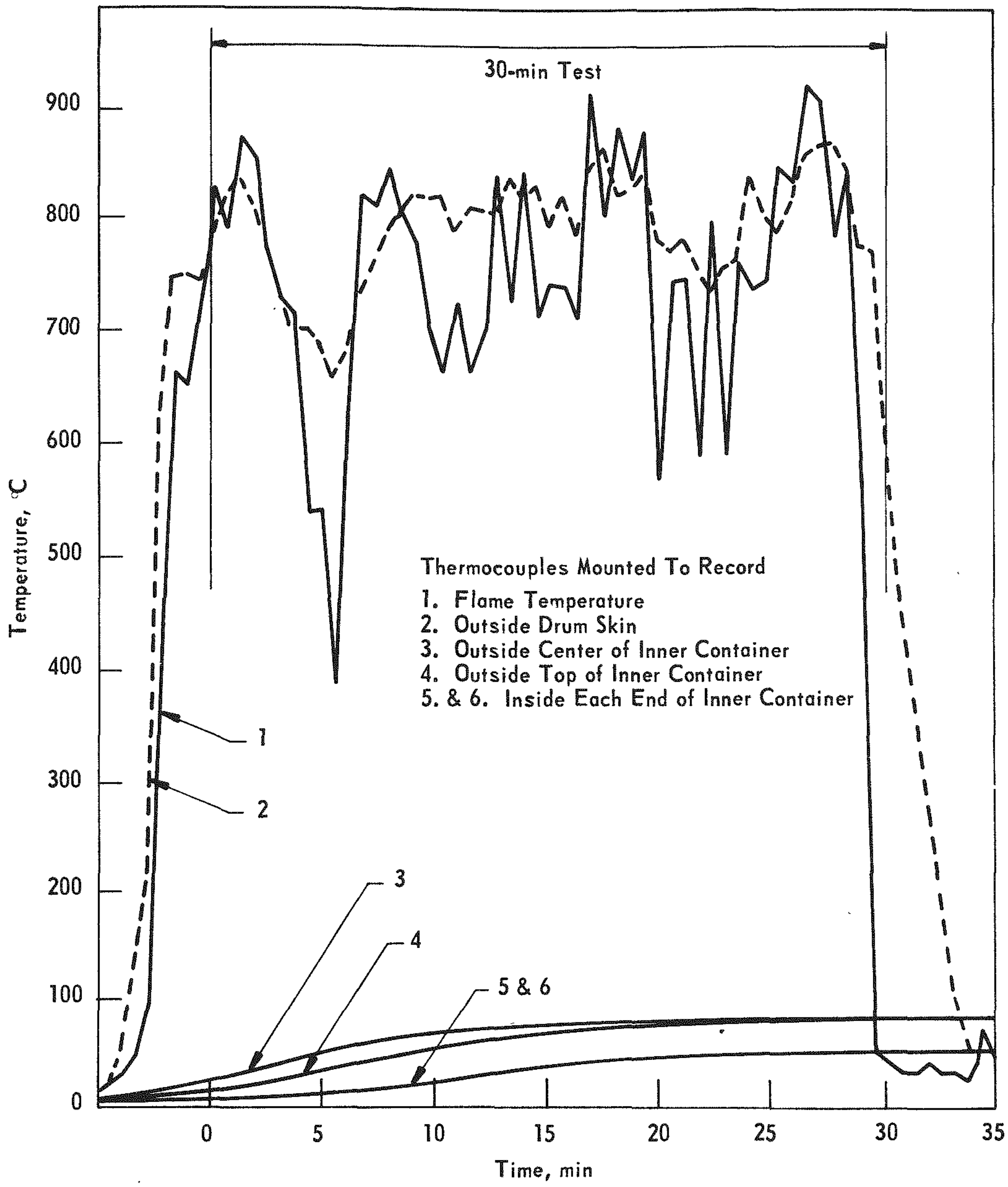


FIGURE 10-7 - Temperatures as a function of time in fire test.

10.7. TEST RESULTS

The results of the hypothetical accident tests are summarized in Table 10-1. The containers passed the drop tests to the extent that the drum covers remained intact and the inner containers did not suffer any observable damage. Modified closures were used since both sizes previously passed only marginally using standard drum closures. The puncture test caused only minor dents in the drums. The 12- and 55-gal sizes passed the immersion tests with no evidence of water leakage into the inner containers. The inner containers were removed from the insulated drum assemblies prior to this test. In addition, after the immersion test, both inner containers were reassembled, using the same o-rings, 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.

Both sizes passed the fire test. The outside surface (side at mid-height) of the 55-gal inner container reached a maximum temperature of 194°F and the inside surface reached 183°F. The silicone o-ring seals used to seal the inner container did not appear damaged in any way. Figure 10-8 shows the charred Firedike insulation after the fire test. The average temperature of the package prior to the fire test was estimated to be 50°F. Thus, a 50°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 194°F + 50°F = 244°F when corrected to 100°F ambient. The results for the 12-gal size were similar except that the inner container reached 205°F and the initial package temperature was 68°F. Thus, a 32°F correction is added to give a resulting maximum temperature of 237°F at 100°F ambient.

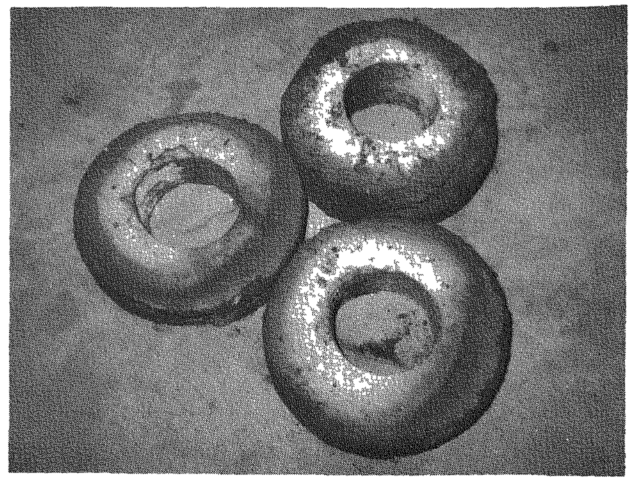


FIGURE 10-8 - Insulation from 55-gal package after the fire test. The Firedike insulation is charred around the outside perimeter.

Table 10-1

RESULTS OF HYPOTHETICAL ACCIDENT TESTS

Drum Size (gal)	Total Package Weight (lb)	30-ft Drop Results	40-in. Puncture Results	Maximum Temperature of Inner Cont. After 30-min Fire (°F)	Immersion Test Results
12	87	Modified Cover Completely intact (3-in. dent)	Minor Dent	237	No Leakage
55	304	Modified Cover Completely Intact (4-in. dent)	Minor Dent	244	No Leakage

10.9. REFERENCES

1. H. Williams and J. F. Griffin, "Smokeless Gasoline Fire Test," presented at the Fourth International Symposium on the Packaging and Transportation of Radioactive Materials, Miami Beach, Florida, September 22-27, 1974, MLM-2159(OP).

11. CRITICALITY EVALUATION

11.1. GENERAL

This analysis defines the quantities of four forms of fissile material comprising Class I, Class II, and Class III shipments for each of the packages. The packages and their significant dimensions are given in Table 11.1.

Table 11-1

EFFECTIVE DIMENSIONS OF SHIPPING CONTAINERS

Drum Nominal Size (gal)	Drum o.d. (in.)	Drum Height (in.)	Effective Cubic Dimension (in.)
12	14.6	21.1	15.2
55	23.9	34.8	25.0

The four forms of fissile material considered are $^{238}PuO_2$ (80% plutonium-238, 20% plutonium-239, and stoichiometric oxide), uranium-235 metal (nominal 100% enrichment), α-phase plutonium-239 metal (including 3% plutonium-240), and uranium-233 metal. Although the mass limits for stabilized δ-phase plutonium-239 are higher, the limits established for the α-phase material should be applied to avoid possible confusion.

11.2. CONDITIONS AND ASSUMPTIONS

Each package consists of a sealed inner container which is approximately centered within the drum by the Firedike insulation. At hypothetical accident conditions, distortion of this outer drum is minimal, so that the interunit spacing of the inner containers in an array of drums is assumed not to decrease. Because of vent holes in the outer container, water will leak into the drum during immersion, but the sealed inner container will not leak. Therefore, it is safe to assume that the fissile material will not go into solution or form a slurry or other intimate mix with neutron moderating material in the event of immersion. Because of the relatively large interunit spacing, water saturation of the Firedike would result in overmoderation of the central units, and little or no interaction of the units would occur. Consequently, it is safe to assume that immersion or other credible damage to the containers would not increase and would likely decrease the reactivity of the array. All calculations below are based on what is believed to be the more conservative situation of interaction of air spaced units, i.e., undamaged containers.

Each central unit is assumed to be spherical and reflected by up to 1/2 in. of steel and a minimum of 5 in. of Firedike. Because of the unknown reflectivity of this combination, the maximum quantity allowed in any one container was arbitrarily established as 0.9 times the minimum water-reflected critical mass of each isotope. These critical masses and the package limits are given in Table 11-2.

Table 11-2

CRITICALITY PARAMETERS FOR FISSILE FORMS

Form	Density of Fissile Isotope (g/cc)	Minimum Reflected Critical Mass (M_c) (kg)	Container Limit (0.9 x M_c) (kg)
$^{238}PuO_2$	9.96	13.3[a]	12.0
^{235}U	18.7	22.8[b]	20.5
α-^{239}Pu	19.3	5.6[b]	5.0
^{233}U	18.5	7.5[b]	6.7

[a]Reference 2
[b]Reference 3

11.3. DETERMINATION OF MASS AND PACKAGE LIMITATIONS

On the recommendation of D. R. Smith from LASL, maximum safe storage arrays for the four isotopes in the two drum sizes were determined from the ANS Nuclear Storage Guide.(1) For this analysis, each fissile unit is assumed to be located at equal spacing on a cubical lattice, with an effective cubical spacing equivalent to the volume of the outer drum. This effective spacing is given for each drum in Table 11-1. The referenced safety guide gives storage limits for cubic cells of 10, 12, 15, 18, and 24 in. Quantities of fissile material per package are given for selected numbers of units such that the reflected array would have a K_{eff} = 0.95. Mass limits for the two drum sizes were calculated for the various numbers of packages by interpolation and extrapolation between effective cubic sizes in the mass tables. For example, the mass limitations for the 12-gal drum, which has an effective cubic dimension of 15.2 in., was determined for 1000 packages by interpolation of values between the 12-in. and 18-in. table values. Likewise, mass limitations for the 55-gal drum were determined by extrapolation of the 24-in. storage array tables.

Determination of Class I, Class II, and Class III shipping limitations depends on obtaining realistic estimates of the numbers of shipping containers required to achieve critical mass of the array.

Class I Shipments

Class I shipments can be made only if any number of identical packages would be subcritical. The term, "any number" is interpreted to be 2500 containers or greater. Any package containing less than the Class I maximum may be shipped as Class I. There are no restrictions on the number of packages in Class I shipments.

Class II Shipments

Class II shipments are based on calculations that at least 25 packages would be required to achieve a critical array. All Class II shipments must specify a package transport index, defined by one of the following relations:

$$I_p = \frac{50}{N_u/5} = \frac{250}{N_u}$$

or

$$I_p = \frac{50}{N_d/2} = \frac{100}{N_d}$$

whichever is the greater of these two.

In these relations, N_u is the number of undamaged containers required to achieve a critical array, and N_d is the number of damaged containers required to achieve a critical array. The maximum number of packages that can be shipped in a Class II shipment is the number for which the summation of the package transport indices is $\leq$50. This maximum number containes a safety factor of 5; i.e., the maximum permissible number of packages in a shipment is 1/5 the number comprising a critical array.

Class III Shipments

A shipment must be Class III if the summation of package transport indices exceeds 50 or if the package transport index of any one package exceeds 10. This condition will be met if less than 25 packages will comprise a critical array. The maximum number of packages in a Class III shipment is 1/2 the number comprising a critical array.

Mass limits for cubic arrays of the two drum sizes were calculated for various numbers of packages required to achieve a K_{eff} = 0.95 as a function of the mass of the fissile isotope, using the tables in Reference 1. Limits for Class I and Class II shipments are given in Table 11-3 for the four isotopes.

Table 11-3

LIMITS FOR MASS (kg) OF FISSILE ISOTOPE PER CONTAINER

Isotope	12 gal	55 gal
$^{238}PuO_2$		
Class I	2.6	4.7
Class II	n.a.	n.a.
^{235}U		
Class I	4.9	12.6
Class II	18.4	(20.5)
^{239}Pu		
Class I	2.5	4.4
Class II	(5.0)	(5.0)
^{233}U		
Class I	2.8	5.8
Class II	(6.7)	(6.7)

Two points are immediately apparent from Table 11-3. The Class I mass limits for $^{238}PuO_2$ are academic. Because of the high heat density of this material (~0.5 W/g), the amount of material that can be shipped in any one container is limited by the heat dissipation characteristics of the container. The drum type of container would never be used for more than a hundred grams of $^{238}PuO_2$, a figure well below the calculated Class I maximum for these containers.

The second point to be noted in Table 11-3 is that, since the maximum amount of material that can be shipped in any one container is no greater than 0.9 x M_c, Class III shipments can be avoided for all combinations except uranium-235 in 12-gal drums. All other shipments may be made as either Class I or Class II, depending on the quantity of fissile material per package.

Values of mass vs number of containers for K_{eff} = 0.95 are given for uranium-235, α-plutonium-239, and uranium-233 in Tables 11-4, 11-5, and 11-6, respectively. In these tables, arrays requiring more than 2500 packages are Class I and are left blank. Class II shipment limitations are based on a safety factor of 5; therefore, to obtain the number of containers that can be shipped Class II, the appropriate number in these tables is divided by 5. If it is desired to ship more than the Class II limit, the shipment must be Class III; the number of packages permissible would be the number from the table divided by 2.

Class II shipments require that the package transport index of each package be no greater than 10; package transport indices are plotted for both packages with uranium-235, α-plutonium-239, and uranium-233 in Figures 11-1, 11-2, and 11-3, respectively. From these figures it is also apparent that the 0.9 x M_c criterion is really the limitation of the Class II shipments.

All prospective shipments of these four isotopes can be properly specified by using Tables 11-4, 11-5, and 11-6 and Figures 11-1, 11-2, and 11-3.

Table 11-4

NUMBER OF PACKAGES COMPRISING A SUBCRITICAL ARRAY (K_{eff} = 0.95) FOR ^{235}U

^{235}U Mass per Package (kg)	12 gal	55 gal
4.9	2500	-
6.0	1968	-
8.0	1000	-
10.0	420	-
12.0	199	-
12.6	-	2500
14.0	105	1750
16.0	57	892
18.0	27	481
20.0	14	250
20.5	12	216

Table 11-5

NUMBER OF PACKAGES COMPRISING A SUBCRITICAL ARRAY (K_{eff} = 0.95) for α-^{239}Pu

α-^{239}Pu Mass per Package (kg)	12 gal	55 gal
2.5	2500	-
3.0	1250	-
3.5	590	-
4.0	270	-
4.4	-	2500
4.5	125	2200
5.0	58	970

Table 11-6

NUMBER OF PACKAGES COMPRISING A SUBCRITICAL ARRAY (K_{eff} = 0.95) for ^{233}U

^{233}U Mass per Package (kg)	12 gal	55 gal
2.8	2500	-
3.0	2167	-
4.0	800	-
5.0	305	-
5.8	-	2500
6.0	125	2300
6.7	64	1100

11.4. SAMPLE CALCULATION

A sample calculation is presented to illustrate use of the tables and graphs presented. The sample calculation assumes that it is desired to ship a quantity of uranium-233 metal in 12-gal drums, with 5.5 kg per drum. From Table 3, the shipment must be at least Class II. The number of containers for which K_{eff} = 0.95 is interpolated from values in Table 6 as follows:

5.0 kg would require 305 containers
6.0 kg would require 125 containers, or a difference of 180 containers.

Number of containers required for 5.5 kg:

305 - 0.5 x 180 = 215 containers

Class II limit = 215/5 = 43 containers.

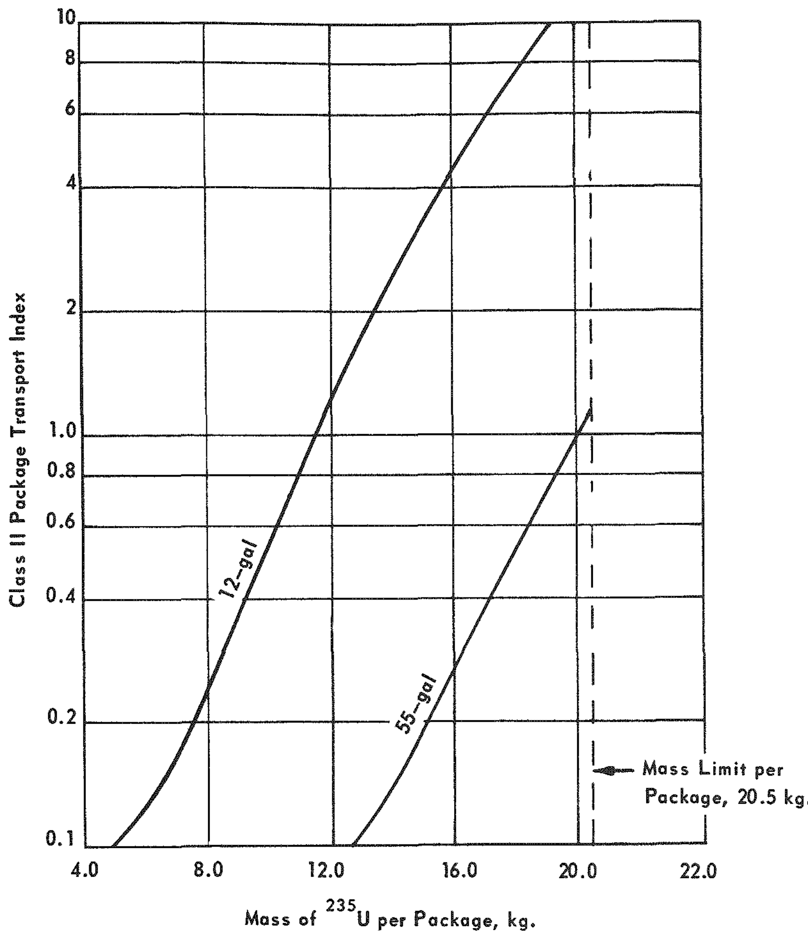


FIGURE 11-1 - Fissile Class II package transport index as a function of uranium-235 mass per package.

Class II transport index = 50/43 = 1.2, which agrees with the value on the proper curve in Figure 11-3.

If it is desired to ship more than 43 containers, the shipment must be Class III, and the shipment limitation would be 215/2 = 107 containers.

11.5. SAFETY FACTORS

Contributing to the conservatism of this evaluation are the following:

1. As was noted above, the calculations are based on reflected air-spaced arrays. Because of the Firedike spacers, the interaction of the central units would likely be less than would be expected from air spacing.
2. Interunit spacing will not decrease significantly with a credible accident, and water immersion of the array will reduce the interaction of the central units.
3. All values calculated in this summary are based on an array with $K_{eff} = 0.95$, rather than $K_{eff} = 1$. Therefore, the Class I and Class II limits shown are very conservative.
4. The fissile central units are assumed to be spherical with almost total iron reflection. It is very unlikely that this geometrically optimum configuration would ever be achieved with any proposed shipments.
5. The absolute maximum amount of fissile material permitted in any one package is only 0.9 times the minimum water reflected critical mass of the isotope; i.e., no one container can achieve criticality under any condition of reflection or moderation. This limit was chosen because of the unknown reflectivity of the steel-Firedike combination around each central unit.

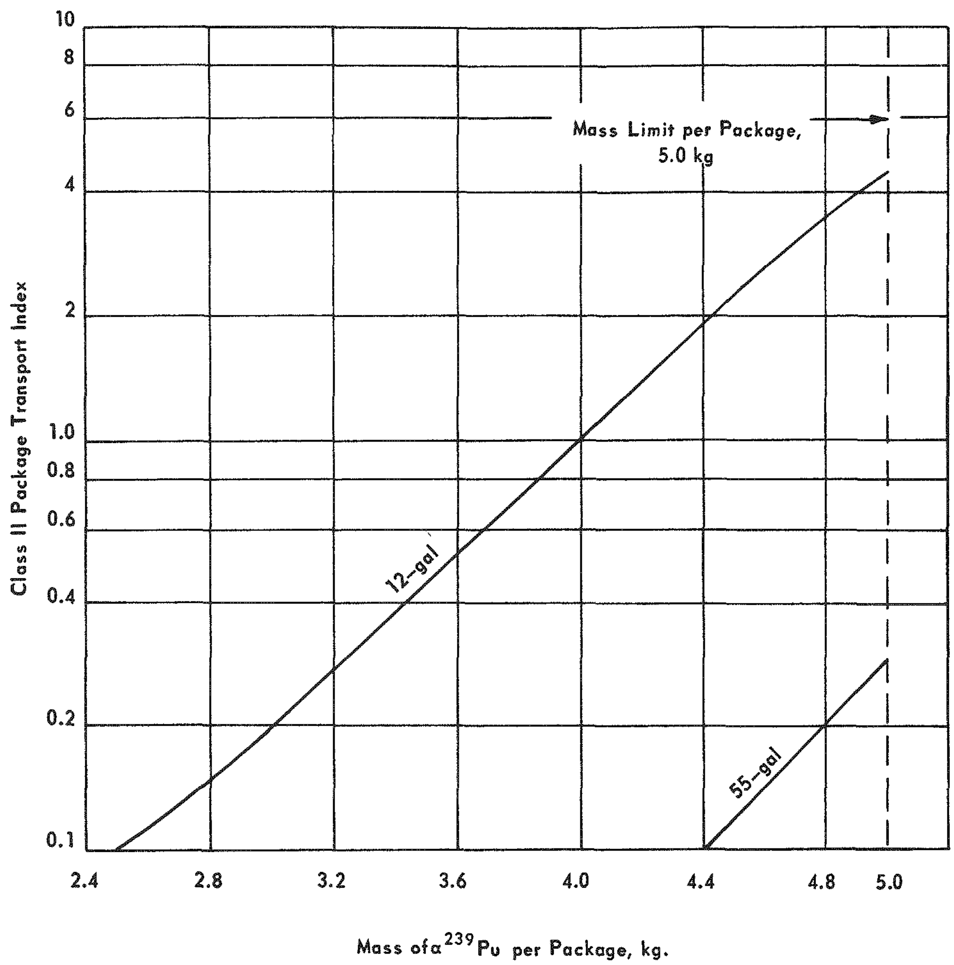


FIGURE 11-2 - Fissile Class II package transport index as a function of α-plutonium-239 mass per package.

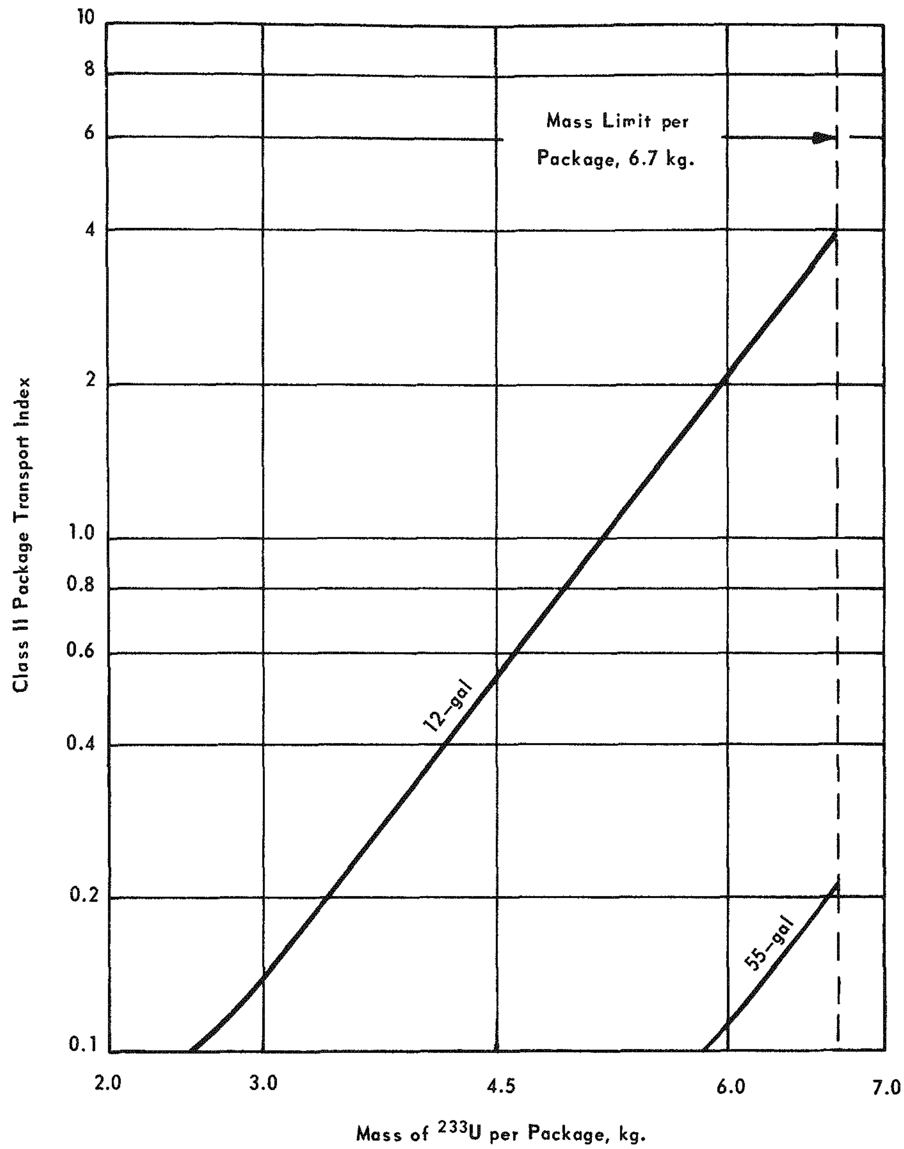


FIGURE 11-3 - Fissile Class II package transport index as a function of uranium-233 mass per package.

11.6. REFERENCES

1. Am. Nucl. Soc., Guide for Nuclear Criticality Safety in the Storage of Fissile Materials, ANS Pub. N16.5 (ANS-8.7), February, 1973.

2. D. R. Smith, LASL, letter to N. Goldenberg, USAEC, November 14, 1969 (U).

3. Nuclear Safety Guide, TID-7016, p. 10 (1961).

4. G. E. Whitesides and N. F. Cross, KENO - A Multigroup Monte Carlo Criticality Program, CTC-5, Computing Technology Center Report, Oak Ridge National Laboratory (September, 1969).

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 both containers.

12.2. ASSUMPTIONS AND DISCUSSION

The following assumptions were made:

1. $^{238}PuO_2$ is the radioactive material which is analyzed. A separate analysis or measurement is conducted for any other isotope(s) shipped.
   - This material comprises essentially 100% of the Laboratory shipments.
2. Neutron yield from typical $^{238}PuO_2$ shipped is 1 x 10^4 n/sec-g of plutonium-238.
   - This is somewhat higher than the neutron emission from heat-source grade $^{238}PuO_2$; 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 ~2.25 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, $\mu(cm^{-1})$, 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 ^{238}Pu (IN OXIDE FORM) PER PACKAGE AND RESULTS OF RADIATION SHIELDING ANALYSIS

Packaging	Quantity Based on Dose-Rate Criteria		Authorized Quantity Based on Internal Heating[a]	
	g	W	g	W
12 gal	417	188	67	30
55 gal	1120	504	93	42

[a]These values, based on internal heating restrictions, are the ones which 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 ERDA M-0529 F.1.a. is assured.

12.4. SAMPLE CALCULATIONS

Sample calculations are given for determining the quantity of plutonium-238 in oxide form which could be placed in the 12-gal package such that the appropriate penetrating radiation exposure criteria in 10CFR49 are not exceeded.

Neutron Dose Rate:

The neutron dose rate (D_n) was calculated at 17.6 cm (radius of package or surface of package) for 1 g of plutonium-238 in oxide form.

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

where C_f = 7.3 n/cm²-sec per 1 $\frac{\text{mrem}}{\text{hr}}$

(Ref. 1)

$$D_n = \frac{1 \times 10^4}{4\pi (17.6)^2 (7.3)} = 0.35 \text{ mrem/hr/g of } ^{238}\text{Pu as oxide}$$

Internal Fission Multiplication Effect:

(0.35 mrem/hr) (1.2) = 0.42 mrem/hr

Scatter and Buildup Effect:

(0.42) (1.1) = 0.46 mrem/hr

Gamma Dose Rate:

$$I_o = \frac{0.46}{15} \text{ mrem/hr} = 0.031 \text{ mrem/hr}$$

Effect of Shielding on Gamma Dose Rates:

μ = 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 12-gal packaging.

I_o = Unshielded gamma dose rate.

$$I = I_o e^{-\mu x} = 0.031\ e^{-0.527 \times 0.726}$$

$$= 0.021 \text{ mrem/hr}$$

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.

$$D_t = D_n + D_\gamma = 0.46 + 0.02 = 0.48 \text{ mrem/hr}$$

Allowed Quantity Based on Dose Rate Criteria:

Surface of Package

Allowed Quantity = 200 mrem/hr ÷ 0.48 mrem/hr/g ^{238}Pu as oxide = 417 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 mrem/hr ÷ 0.013 mrem/hr/g ^{238}Pu as oxide = 769 g.

Both of these quantities exceed the authorized quantity based on internal heating. This was true for both packages analyzed; 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 ERDA Manual 0529. The particulars of the inspections are provided in Mound Laboratory drawing SPA740977 (see Appendix I).

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 inner containers must pass a helium leak test with no detectable leak greater than 1×10^{-5} std. cm^3/sec when filled with 15 psig of helium.

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

APPENDIX A

ACCEPTANCE AND REUSE INSPECTIONS

M/C

SPA740977		W O NO

ISSUE	DATE	REVISION	BY	CHK'D	APPRD
A	4-3-75	ORIGINAL ISSUE	CP	WVD	GAB

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
ISSUE	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

DWG CLASSIFICATION
LEVEL & CAT UNCL
BY RER
TITLE
DATE 5-12-75

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR SHIPPING CONTAINER

5790/91 ACCEPTANCE AND REUSE INSPECTION

DRAWN CP	DATE 4/75	APPROVALS	
CHECKED WVD	DATE 5-7-75	1	JFG
SPONSOR [illegible]	DATE 5/12/75	2	HBK
APPROVED RER	DATE 5-12-75	3	
JOB NO NONE		4	

SP — DWG TYPE

CODE IDENT NO 14065

DWG NO SPA740977 SHT 1 OF 24

DAC-73-SA

1. S C O P E.

1.1 This is an inspection criteria document for the following radioactive materials shipping containers:

Model	Type	Certificate of Compliance	Size
103	AL-M3	5790	12 gallon container
131	AL-M6	5791	55 gallon container

1.2 It defines the complete receiving acceptance inspection and reinspection prior to reuse to be performed as required by Energy Research and Development Administration 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.

2. I N T R O D U C T I O N.

2.1 The special permit number 5790/91 shipping containers are designed to ship offsite radioactive materials, including Pu 238 oxide. They meet the safety requirements of the Energy Research and Development Administration and the unique requirements of the various materials which are shipped in them.

2.2 The two sizes of containers are illustrated in Figures 1 & 2. All have similar basic designs consisting of an outer steel drum and an inner, steel primary container. Space between the steel drum and inner container is packed with insulation to provide for mechanical and thermal shock during accident conditions.

MRC ML 5317 (12 73)

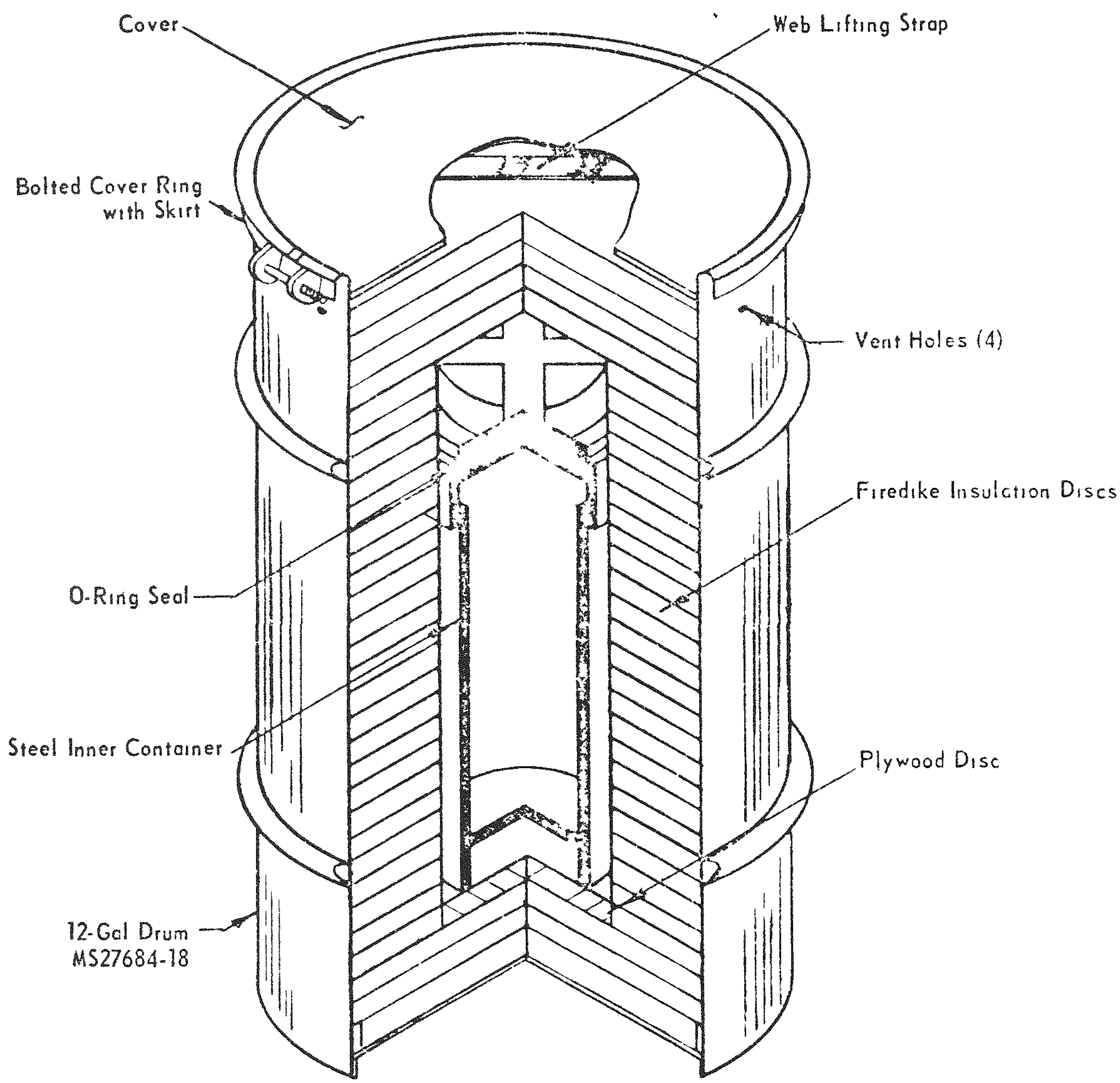
ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 2

DAC-73-SACB

SPA740977



SHIPPING CONTAINER
MODEL 103 AL-M3
USA/5790/BLF(ERDA-AL)
FIGURE 1

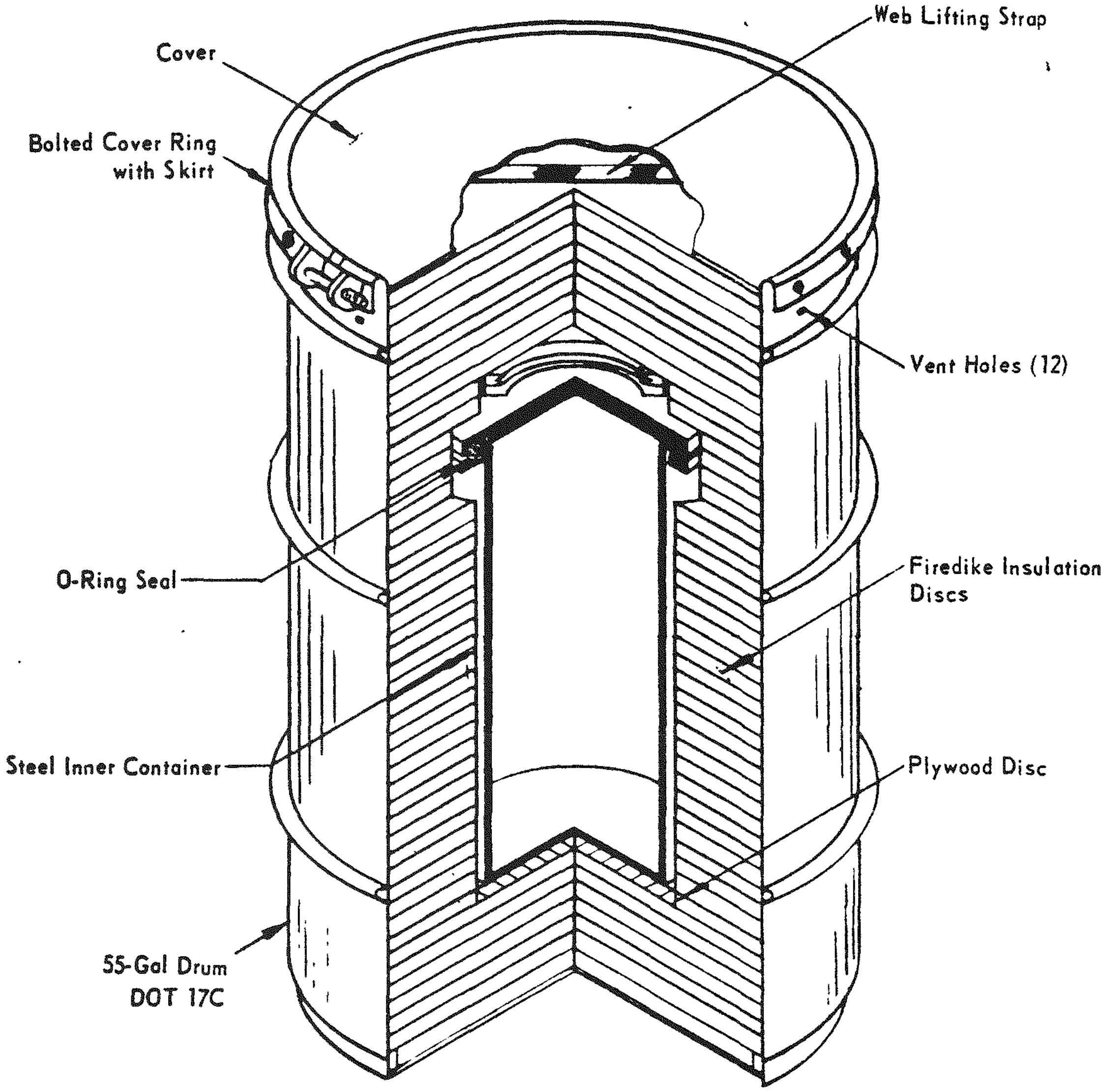
ISSUE A

CODE IDENT NO 14065

DWG NO SPA74 977 SHT 3

DAC-73-SACB MRC ML 531 12 73

SPA740977



SHIPPING CONTAINER
MODEL 131 AL-M6
USA-5791/BLF (ERDA-AL)
FIGURE 2

MRC ML 5317 (12 73)

ISSUE	A

CODE IDENT NO 14065		DWG NO SPA740977 SHT 4

DAC-73-SACB

3. APPLICABLE DOCUMENTS.

Monsanto Research Corporation Drawings:

AYD750138	-	103/AL-M3	Shipping Container Assembly
AYD750140	-	103/AL-M3	Inner Container
AYD750148	-	131/AL-M6	Shipping Container Assembly
AYD750150	-	131/AL-M6	Inner Container

Other Documents.

Energy Research and Development Adminístation Manual, Chapter 0529

Safety Analysis Report for Packing (SARP):

5790/5791 Insulated Drum Nuclear Shipping Containers Identified as Energy Research and Development Administration-AL USA/5790 BLF and Energy Research and Development Administration-AL USA/5791 BLF

4. GENERAL PROVISIONS.

4.1 Responsibilies. The manufacturer is responsible for assuring that all specific requirements are met and shall utilize accepted quality control measures during manufacture. Monsanto Research Corporation reserves the right to audit the manufacturer's facilities and procedures as required. MRC Engineering is responsible for establishing inspection criteria for receiving acceptance and reuse, and for providing this document.

MRC ML 5317 12 73

ISSUE	A

CODE IDENT NO		DWG NO	SHT
14065		SPA740977	5

DAC-73-SACB

4.1 continued

MRC Nuclear Operations Quality Control is responsible for auditing the Quality Control Program and review of applicable drawings and specifications to assure that the Quality Control Program is carried out as defined. MRC Nuclear Operations Cost and Reporting Group is responsible for the receiving acceptance inspection, and retaining appropriate files to document the inspections. MRC container users are responsible for providing necessary information pertinent to the materials to be shipped, appropriate loading procedures for these materials, and the initiation of procurement and reuse inspection activities in cooperation with MRC Nuclear Cost and Reporting Group.

4.2 Inspection and Acceptance. Each container shall be examined and tested for defects in accordance with Appendix I, II, III, and IV.

4.2.1 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.

4.2.2 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:

Part A - Al-M3, 12 gallon - Insulated Drum Assembly

Part B - AL-M3, 12 gallon - Inner Container Assembly

4.2.2 continued

Part C - AL-M6, 55 gallon - Insulated Drum Assembly

Part D - AL-M6, 55 gallon - Inner Container Assembly

4.2.3 Inspection of Final Assembly. The final assembly shall be examined visually and functionally with regard to meeting the requirements of the Final Assembly. Defects which shall be cause for rejection are listed in Appendix II.

4.2.4 Sampling Plan. Each shipping container shall be inspected for all attributes listed in Appendix II.

4.3 Inspection Record. The fabricator is required to submit a completed "Fabrication & Inspection Certificate" (MRC-ML-5537) as shown in Appendix I.

MRC ML 5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 7

DAC-73-SACB

SPA740977

APPENDIX I

FABRICATION AND INSPECTION CERTIFICATION

MRC-ML-5537

(VENDOR USE ONLY)

MRC ML 5317 12 73

ISSUE	A

CODE IDENT NO 14065		DWG NO SPA740977 SHT 3

DAC-73-5ACB

SPA740977

FABRICATION AND INSPECTION CERTIFICATION

FABRICATED BY____________________

CONTAINER SERIAL NUMBER____________________

CONTAINER DRAWING NO.____________________

		SIGNATURE	DATE COMPLETED
1.	Components and materials as specified.		
2.	Welded as specified (Section 2).		
3.	Visual weld examination acceptable (Section 3).		
4.	Dye penetrant examination acceptable (Section 4).		
5.	Dimensions as specified.		
6.	O-ring surface finish as specified.		
7.	Container can be assembled properly.		
8.	Helium leak test acceptable (Section 5).		
9.	Container tagged and dated to indicate inspection results satisfactory.		

MRC-ML-5537

DISTRIBUTION
WHITE - NUCLEAR QC
YELLOW - SHIPPING CONTAINER ENG
PINK - FILE

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SH 1 9

APPENDIX II

ACCEPTANCE INSPECTION CRITERIA

For

5790/5791 RADIOACTIVE MATERIALS SHIPPING CONTAINERS

MRC ML 5317 (12 73)

ISSUE	A

CODE IDENT NO		DWG NO SPA740977 SHT 10
14065		

DAC-73-SACB

PART A - Insulated Drum Assembly (MRC Dwg. AYD750138
Model 103/AL-M3 - 12 Gallon

1. IDENTIFICATION.

1.1 Note the Drum Assembly serial number on the Inspection Data Form No. MRC-ML-5794.

1.2 Note the assembly manufacturer. (Vendor)

2. VENDOR CERTIFICATIONS.

2.1 Vendor has certified by letter that all items are as specified per MRC Dwg. AYD750138 or MRC engineering approved equal. (Major)

3. VISUAL INSPECTION.

3.1 Drum permanent head marked MS-27684-23, DOT 17C, 20-10-year manufacture, name or symbol of manufacture. (Major)

3.2 Name tag securely attached and reads as specified per MRC Dwg. AYD750138. (Major)

3.3 Upper third of drum has four vent holes sealed with tape. (Major)

3.4 Drum closure ring has drop forged lugs and closure ring nut and bolt has hole for security seal. (Major)

3.5 Drum closure ring has metal skirt securely welded to edge. (Major)

3.6 Web strap securely fastened for lifting. (Major)

MRC ML 5317 (12 73)

ISSUE	A

CODE IDENT NO 14065		DWG NO SPA740977	SHT 11

DAC-73-SACB

3.7 Workmanship acceptable with no sharp edges or burrs. (Critical)

4. D I M E N S I O N A L   I N S P E C T I O N.

4.1 Drum overall diameter is 14-1/2 ± 1/4 inch. (Major)

4.2 Drum overall height is 21 ± 1/4 inch. (Major)

4.3 Insulated inner cylinder height with the insulated cap assembly removed is 10-3/4 ± 1/4 inch. (Major)

4.4 Insulated cylinder inner diameter is 5-3/4 ± 1/4 inch. (Major)

4.5 Cap assembly inner cylinder height is 4-3/8 ± 1/4 inch. (Major)

4.6 Cap assembly inner cylinder diameter is 5-3/4 ± 1/4 inch. (Major)

5. F U N C T I O N A L   I N S P E C T I O N.

5.1 The cap assembly can be lifted into and out of the drum easily. (Major)

5.2 Insulated drum assembly can be assembled and disassembled easily. (Major)

5.3 Drum tagged and dated to indicate inspection results satisfactory. (Major)

5.4 Signature of Nuclear Quality Control Engineer acceptance of inspection.

MRC ML 5317 (12 73)

ISSUE	A

CODE IDENT NO 14065		DWG NO SPA740977 SHT 12

DAC-73-SACB

PART B - Inner Container Assembly (MRC Dwg. AYD750140 and AYD750141) Model 103/AL-M3, 12 Gallon

1. I D E N T I F I C A T I O N.

1.1 Note the inner container serial number on the Inspection Data Form.

1.2 Note the container manufacturer. (Vendor)

2. V E N D O R   C E R T I F I C A T I O N.

2.1 Vendor has certified by letter all items are specified per MRC Dwg. AYD750140 and AYD750141 or MRC engineering approved equal. (Major)

2.2 Vendor has certified the inner container has passed the helium leak test per MRC Dwg. AYD750140 and AYD750141. (Major)

2.3 Vendor has completed the "Fabrication and Inspection Certification" as shown in Appendix I. (Major)

3. V I S U A L   I N S P E C T I O N.

3.1 Metal plate securely attached with the words "Radioactive Material" stamped or etched into the plate. (Major)

3.2 Welds appear acceptable. (Major)

3.3 Threaded sealing surfaces appear to be in good condition. (Major)

3.4 Workmanship acceptable with no sharp edges or burrs. (Critical)

3.5 Silicon or viton O-ring has no visible damage. (Major)

MRC ML 5317 12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 13

DAC-73-SACB

4. D I M E N S I O N A L   I N S P E C T I O N.

4.1 Container tube outer diameter is 4-1/2 ± 1/64 inch. (Major)

4.2 Container tube height is 12-3/4 ± 1/32 inch. (Major)

4.3 Cap screws into tube such that a minimum of five complete threads are engaged. (Major)

5. F U N C T I O N A L   I N S P E C T I O N.

5.1 Inner container completely disassembled and assembled satisfactorily. (Major)

5.2 Helium leak test performed with no detectable leak greater than 1 x 10^{-7} std. cc/sec when filled to 5 ± 1 psig helium. (Major)

5.3 Inner container tagged and dated to indicate inspection results satisfactory. (Minor)

5.4 Signature of Nuclear Quality Control Engineer acceptance of inspection.

MRC ML 5317 (12 73)

ISSUE	A

CODE IDENT NO 14065		DWG NO SPA740977 SHT 14

DAC-73-SACB

PART C - Insulated Drum Assembly (MRC Dwg. AYD750148)
Model 131/AL-M6 - 55 Gallon

1. IDENTIFICATION.

1.1 Note the Drum Assembly serial number on the Inspection Data Form No. MRC-ML-5794.

1.2 Note the assembly manufacturer. (Vendor)

2. VENDOR CERTIFICATIONS.

2.1 Vendor has certified by letter that all items are as specified per MRC Dwg. AYD750148 or MRC engineering approved equal. (Major)

3. VISUAL INSPECTION.

3.1 Drum permanent head marked DOT 17C, 16-55-year manufacture, name or symbol of manufacture. (Major)

3.2 Name tag securely attached and reads as specified per MRC Dwg. AYD750148. (Major)

3.3 Upper third of drum has twelve vent holes sealed with tape. (Major)

3.4 Drum closure ring has drop forged lugs and closure ring nut and bolt has hole for security seal. (Major)

3.5 Drum closure ring has metal skirt securely welded to edge. (Major)

3.6 Web strap securely fastened for lifting. (Major)

MRC ML 5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 15

DAC-73-SACB

3.7 Workmanship acceptable with no sharp edges or burrs. (Critical)

4. D I M E N S I O N A L   I N S P E C T I O N.

4.1 Drum overall diameter is 23-7/8 ± 1/4 inch. (Major)

4.2 Drum overall height is 34-3/4 ± 1/4 inch. (Major)

4.3 Insulated inner cylinder height with the insulated cap assembly removed is 15-5/8 ± 1/4 inch. (Major)

4.4 Insulated cylinder inner diameter is 7-7/8 ± 1/4 inch. (Major)

4.5 Cap Assembly inner cylinder height is 3-7/8 ± 1/4 inch. (Major)

4.6 Cap Assembly inner cylinder diameter is 10-1/4 ± 1/4 inch. (Major)

5. F U N C T I O N A L   I N S P E C T I O N.

5.1 The cap assembly can be lifted into and out of the drum easily. (Major)

5.2 Insulated drum assembly can be assembled and disassembled easily. (Major)

5.3 Drum tagged and dated to indicate inspection results satisfactory. (Major)

5.4 Signature of Nuclear Quality Control Engineer acceptance of inspection.

MRC ML 5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 16

DAC-73-5ACB

PART D - Inner Container Assembly (MRC Dwg. AYD750150 & AYD750151)
Model 131/AL-M6 - 55 Gallon

1. <u>IDENTIFICATION</u>.

1.1 Note the inner container serial number on the Inspection Data Form.

1.2 Note the container manufacturer. (Vendor)

2. <u>VENDOR CERTIFICATION</u>.

2.1 Vendor has certified by letter all items are specified per MRC Dwg. AYD750150 & AYD750151 or MRC engineering approved equal. (Major)

2.2 Vendor has certified the inner container has passed the helium leak test per MRC Dwg. AYD750150 & AYD750151. (Major)

2.3 Vendor has completed the "Fabrication and Inspection Certification" as shown in Appendix I. (Major)

3. <u>VISUAL INSPECTION</u>.

3.1 Metal plate securely attached with the words "Radioactive Material" stamped or etched into the plate. (Major)

3.2 Welds appear acceptable. (Major)

3.3 O-ring sealing surfaces appear to be in good condition. (Major)

3.4 Workmanship acceptable with no sharp edges or burrs. (Critical)

3.5 Lifting handle for lid securely attached. (Major)

3.6 Silicon or viton O-ring has no visible damage. (Major)

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

4.1 Container tube outer diameter is 6-5/8 ± 1/64 inch. (Major)

MRC ML 5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 17

DAC-73-SACB

4.2 Container tube height is 16-1/4 ± 1/32 inch. (Major)

4.3 Hex head closure bolts are 3/8" dia. x 1-1/2" long. (Major)

4.4 Lifting handle securely fastened. (Major)

5. F U N C T I O N A L   I N S P E C T I O N.

5.1 Inner container completely disassembled and assembled satisfactorily. (Major)

5.2 Helium leak test performed with no detectable leak greater than 1 x 10^{-7} std. cc/sec when filled to 5 ± 1 psig helium. (Major)

5.3 Inner container tagged and dated to indicate inspection results satisfactory. (Minor)

5.4 Signature of Nuclear Quality Control Engineer acceptance of inspection.

APPENDIX III

INSPECTION DATA SHEET

FOR

APPENDIX II, ACCEPTANCE INSPECTION CRITERIA

FOR

5790/5791 RADIOACTIVE MATERIALS

SHIPPING CONTAINERS

MRC ML 5317 (12 73)

ISSUE	A

CODE IDENT NO 14065		DWG NO SPA740977 SHT 19

DAC-73-5ACB

SPA740977

ACCEPTANCE INSPECTION DATA SHEET

Shipping Container Type and Size ___ ___ ___ ___
Insulated Drum Assembly

1. IDENTIFICATION

1.1 Drum serial number ___ ___ ___ ___

1.2 Manufactured by ___ ___ ___

2. VENDOR CERTIFICATION — Signature — Date

2.1 Vendor materials certification

3. VISUAL INSPECTION

3.1 Drum marking

3.2 Name tag

3.3 Vent holes

3.4 Closure ring, bolt and nut

3.5 Closure Ring Skirt

3.6 Web Strap Lifting Handle

3.7 Workmanship

4 DIMENSIONAL INSPECTION

4.1 Drum diameter

4.2 Drum height

4.3 Inner cylinder height

MRC ML 8794 12 76
PAGE 1

DISTRIBUTION

WHITE	NUCLEAR Q C
YELLOW	NUCLEAR COST & REPORTING
PINK	ENGINEERING INSPECTION
GOLDENROD	INSPECTION FILE

MRC ML 5317 12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 30

DAC-73-SACB

	Signature	Date
4.4 Inner cylinder diameter		
4.5 Cap cylinder height		
4.6 Cap cylinder diameter		
5. FUNCTIONAL INSPECTION		
5.1 Cap assembly		
5.2 Insulated drum assembly		
5.3 Drum tagged and dated		
5.4 Q. C. engineer		

Inner Container Assembly

1. IDENTIFICATION

1.1 Inner container serial number ____________

1.2 Manufactured by ______________________________

	Signature	Date
2. VENDOR CERTIFICATIONS		
2.1 Vendor materials certification		
2.2 Vendor leak test certification		
2.3 Fabrication and Inspection certification		
3. VISUAL INSPECTION		
3.1 Metal plate		
3.2 Welds acceptable		
3.3 Sealing surfaces		
3.4 Workmanship		
3.5 Lifting handle attachments		

DISTRIBUTION
WHITE NUCLEAR Q C
YELLOW NUCLEAR COST & REPORTING
PINK ENGINEERING INSPECTION
GOLDENROD INSPECTION FILE

MRC-ML-6794 (2 76)
PAGE 2

MRC ML 5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 21

DAC-73-SACB

SPA740977

	Signature	Date
3.6 Silicon or Viton O-ring		
4. DIMENSIONAL INSPECTION		
4.1 Tube diameter		
4.2 Tube height		
4.3 Hex bolts		
4.4 Lifting handle or hole		
5. FUNCTIONAL INSPECTION		
5.1 Container assembly and disassembly		
5.2 Leak test		
5.3 Container tagged and dated		
5.4 Q. C. engineer		

MRC-ML-5794 (2 76)
PAGE 3

DISTRIBUTION

WHITE	NUCLEAR Q C
YELLOW	NUCLEAR COST & REPORTING
PINK	ENGINEERING INSPECTION
GOLDENROD	INSPECTION FILE

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 22

MRC ML 5317 (12 73)

DAC-73-SACB

APPENDIX IV

REUSABLE CONTAINER INSPECTION AND MAINTENANCE

OPERATION SHEET

FOR

5790/5791 RADIOACTIVE MATERIALS

SHIPPING CONTAINER

MD-70152 (OPERATION 1)

MRC ML 5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 23

DAC-73-SACB

SPA740977

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM	SHEET	MANUAL NUMBER	OPERATION
REUSABLE RADIOACTIVE SHIPPING CONTAINERS	1 of 1	MD-70152	1

AUTHORIZATION	CLASSIFICATION	EFFECTIVITY	ECN(S) INCORPORATED
R D [signature]	Unclassified	10-8-73	

OPERATION TITLE
Use Inspection and Loading (for use with DOT-6M, -5333, -5790, -5791)

USE INSPECTION

New ______ Reuse ______ Specification ______ Serial No. ______

FINDING

1. Remove labels ______
2. Closure ring and locking device ______
3. Thread appearance (remove foreign matter) ______
4. Centering material ______
5. Overall condition (circle one):
   Like New Reworked Scrapped

Date ______________ Signature ______________

LOADING PROCEDURE (GENERAL)

COMPLETED

1. Radioactive material form (special form only in DOT-5333) ______
2. Lute 2R threads/gasket ______
3. Torque 2R closure (if required) ______
4. Place sketch under lid ______
5. Close drum ______
6. Install seal (lead wire) ______
7. Apply labels (Radioactive) ______

Date ______________ Signature ______________

DISTRIBUTION:

White - Container File
Yellow - Nuclear QC
Pink - Shipper File

MRC ML 128

Issue 1 • 10-12-73

ISSUE A

CODE IDENT NO 14065

DWG NO SPA740977 SHT 24

MH ML 5,1 2 73 DAC-73-SACB

APPENDIX B

PACKAGING AND UNPACKAGING PROCEDURES

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. 1 (Figure B-1), is a checklist for use inspection and general loading procedure. 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 Firedyke-plywood filler support. The lid is placed on the drum and held in place with the closure ring. 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 checked as it is 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 CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER

OPERATION SHEET

PROGRAM	SHEET	MANUAL NUMBER	OPERATION
REUSABLE RADIOACTIVE SHIPPING CONTAINERS	1 of 1	MD-70152	1

AUTHORIZATION	CLASSIFICATION	EFFECTIVITY	ECN(S) INCORPORATED
[signature]	Unclassified	10-8-73	

OPERATION TITLE
Use Inspection and Loading (for use with DOT-6M, -5333, -5790, -5791)

USE INSPECTION

New ______ Reuse ______ Specification ______ Serial No. ______

	FINDING
1. Remove labels	______
2. Closure ring and locking device	______
3. Thread appearance (remove foreign matter)	______
4. Centering material	______
5. Overall condition (circle one): Like New Reworked Scrapped	

Date ____________ Signature ____________

LOADING PROCEDURE (GENERAL)

	COMPLETED
1. Radioactive material form (special form only in DOT-5333)	______
2. Lute 2R threads/gasket	______
3. Torque 2R closure (if required)	______
4. Place sketch under lid	______
5. Close drum	______
6. Install seal (lead wire)	______
7. Apply labels (Radioactive)	______

Date ____________ Signature ____________

DISTRIBUTION:

White - Container File
Yellow - Nuclear QC
Pink - Shipper File

MRC ML 128

FIGURE B-1

Issue 1 • 10-12-73

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM	SHEET	MANUAL NUMBER	OPERATION
Milliwatt Generator	1 of 1	MD-70152	9

AUTHORIZATION	CLASSIFICATION	EFFECTIVITY	ECN(S) INCORPORATED
[signature]	Unclassified	October 10, 1974	

OPERATION TITLE
Preparation and Packaging

	Initial	Date
1. Wipe check each source ($\leq$ 20 dpm)	______	______
2. Wrap source(s) individually in nickel foil.	______	______
3. Place inside pressure vessel, surround with metal shot. (Optional)	______	______
4. Place inside 2R container, surround with metal shot or steel wool.	______	______

Distribution:
White - Container File
Yellow - Nuclear QC
Pink - Shipper File

MRC ML 128

FIGURE B-2

Issue 1 • 10-18-74

SHIPPING RADIOACTIVE AND FISSILE MATERIAL

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO 45342

I

PO	CC	MATERIAL CLASSIFICATION	Date Shipment Req.	NO. OF PKGS.	"M L" NUMBER
		☐ U ☐ C ☐ SRD			

SHIP TO

MODES OF TRANSPORTATION	COURIER AGENCY (IF ANY)	ESCORT AGENCY (IF ANY)

ARE FEDERAL SHIPPING REQUIREMENTS MET?	SEALS APPLIED?	PACKAGING AFFIDAVIT ATTACHED FOR AIR SHIPMENTS?
☐ YES ☐ NO	☐ YES ☐ NO	☐ YES ☐ NO

II

Container Identification DOT Approved Package	Contents Isotope Physical Form	Curie Amount	Tr. GP. §173.390	Radiation (Mrem/hr) Surface		Radiation (Mrem/hr) 3'		Surface Contamination dis/min. Primary Removable		Outer Removable		Outer Fixed		Transport Index Max 10/Pkg Radiation	50/Shipment Criticality	
				β-γ	η	β-γ	η	α	β	α	β	α	β		Index	Class

III

RADIATION SURVEY INSTRUMENT USED α ________ β ________ γ ________ η ________

RADIOACTIVE LABELS REQUIRED	None Inner Only	W-I	Y-II	Y-III	White Empty	Others

PERSONNEL INVOLVED IN LOADING OF CONTAINERS

____
____
____
____
____

IV

WAREHOUSE SHIPPING DOCUMENT NUMBER

COMMENTS

	TIME	DATE
Requestor		
Nuclear Criticality		
Health Physics		
Special Material Handling		

DISTRIBUTION

1. Special Matl Handling
2. Nuclear Prog Planning
3. Nuclear Criticality
4. Health Physics
5. ________________

INSTRUCTIONS

1. Requestor complete Part I except M L Number [and Part] II columns 1 and 2
2. Health Physics complete Part II columns 3 5 and [Radiation] portion of column 6 and Part III and insert M L No
3. Nuclear Criticality complete Criticality column 6 of Part II
4. Special Material Handling complete Part IV and [make] distribution
5. See Manual MD 10087 Chapter 6
6. For Empty Containers no M L Number [is] to be [issued]

MRC ML 1245 (4-75)
17 1435

FIGURE B-3

APPENDIX C

ERDA CERTIFICATE OF COMPLIANCE

UNITED STATED ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Form AEC-618
(12-73)
10 CFR 71
AECM 5201

CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1a Certificate Number	1b Revision No	1c Package Identification No	1d. Page No	1e Total No Pages
USA/5790/BLF(ERDA-AL)	1	USA/5790/BLF(ERDA-AL)	1	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)*:	(2) Title and Identification of report or application:	(3) Date
Monsanto Research Corp. Mound Laboratory P.O. Box 32 Miamisburg, Ohio 45342	MLM-2242 "Safety Analysis Report for Packaging (SARP): USA/5790/BLF(ERDA-AL) and USA/5791/BLF(ERDA-AL)"	4-30-76

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:

1. The packaging consists of an O-ring sealed cylindrical steel inner container centered within glued Firedike insulation in a 12-gal. drum. The package model number is AL-M3. The outer drum is provided with 4 vent holes which are sealed with waterproof tape. The overall drum height is 21.1 in. and the overall diam. is 14.6 in.

2. The maximum authorized gross weight is 90 lb and the maximum heat load permissible in the package is 30 watts. The user must assure that the temperature of the contents is acceptably low. The maximum permissible temperature of the outside surface of the inner container is 300^{o}F at ambient conditions and the ASME pressure capability at the accident condition temperature of 500^{o}F is 73 psig.

Authorized Contents - 5790

The authorized contents include the following as metals, oxides, or compounds:

Isotope	Maximum Allowable Quantity
Plutonium-238	30 Thermal Watts Fissile Class I

6a Date of Issuance	6b Expiration Date
April 16, 1976	N/A

FOR THE U.S. ERDA

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

Isotope	Maximum Allowable Quantity
Uranium-235	4.9 Kg as Fissile Class I 18.4 Kg as Fissile Class II 20.5 Kg as Fissile Class III
Plutonium-239	2.5 Kg as Fissile Class I 5.0 Kg as Fissile Class II Fissile Class III Quantities not permitted
Uranium-233	*2.8 Kg as Fissile Class I *6.7 Kg as Fissile Class II Fissile Class III Quantities not permitted

*Maximum allowable quantities based upon criticality analysis, however, radiation levels may be the controlling factor in determination of quantity permitted to be shipped.

UNITED STATED ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Form AEC-618
(12-73)
10 CFR 71
AECM 5201

CERTIFICATE OF COMPLIANCE

For Radioactive Materials Packages

1a. Certificate Number	1b. Revision No.	1c. Package Identification No.	1d. Page No.	1e Total No. Pages
USA/5791/BLF(ERDA-AL)	1	USA/5791/BLF(ERDA-AL)	1	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):	(2) Title and identification of report or application:	(3) Date.
Monsanto Research Corp. Mound Laboratory P.O. Box 32 Miamisburg, Ohio 45342	MLM-2242 "Safety Analysis Report for Packaging (SARP) USA/5790/BLF(ERDA-AL) and USA/5791/BLF(ERDA-AL)"	4-30-76

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.

1. The packaging consists of an O-ring sealed cylindrical steel inner container centered within glued Firedike insulation in a 55-gal. drum. The package model number is AL-M6. The outer drum is provided with 12 vent holes which are sealed with waterproof tape. The overall drum height is 34.8 in. and the overall diam. is 23.9 in.

2. The maximum authorized gross weight is 300 lb and the maximum heat load permissible in the package is 42 watts. The user must assure 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 and the ASME pressure capability at the accident condition temperature of 500°F is 28 psig.

<u>Authorized Contents - 5791</u>

The authorized contents include the following as metals, oxides, or compounds.

Isotope	Maximum Allowable Quantity
Plutonium-238	42 Thermal Watts Fissile Class I

6a. Date of Issuance	6b Expiration Date
April 16, 1976	N/A

FOR THE U.S. ERDA

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

Isotope	Maximum Allowable Quantity
Uranium-235	12.6 Kg as Fissile Class I 20.5 Kg as Fissile Class II Fissile Class III Quantities not permitted.
Plutonium-239	4.4 Kg as Fissile Class I 5.0 Kg as Fissile Class II Fissile Class III Quantities not permitted.
Uranium-233	*5.8 Kg as Fissile Class I *6.7 Kg as Fissile Class II Fissile Class III Quantities not permitted.

*Maximum allowable quantities based upon criticality analysis, however, radiation levels may be the controlling factor in determination of quantity permitted to be shipped.

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