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Safety Analysis Report For Packaging (SARP): USA/9507/BLF (ERDA-AL), Model AL-M1

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Monsanto

MOUND FACILITY
Miamisburg, Ohio

operated by
MONSANTO RESEARCH CORPORATION
a subsidiary of Monsanto Company

for the
U. S. DEPARTMENT OF ENERGY

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FORWARD

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

Contents

ACKNOWLEDGEMENTS

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 three insulated drum shipping containers identified as USA/9507/BLF (ERDA-AL), also called AL-M1, configurations 1, 3, and 5.

This 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 on configurations 1 and 3 was previously presented in a Safety Analysis Report for Packaging (SARP)[1].

Complete physical and technical descriptions of the packages are presented. Each package consists of an inner container centered within an insulated steel drum. The contents are plutonium-239 and uranium-235 in configurations-1 and -3. The results of the nuclear criticality safety analysis show how much of the fissile isotopes may be shipped as Fissile Class I or II for these containers. The configuration-5 package contains tritiated water held on sorbent material.

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, and a copy of the ERDA/OSD/ALO Certificate of Compliance are included. An internal review of this SARP has been performed in compliance with the requirements of ERDA 5201-Part V.

Reference

1. J. F. Griffin, D. A. Edling, and C. D. Winemiller, Safety Analysis Report for Packaging (SARP): Model AL-M1 Nuclear Packaging, MLM-1981 (Nov. 30, 1972), 80 pp.

2. Introduction

In January 1968, Monsanto Research Corporation, Mound Laboratory, obtained a Certification of Approval for Fissile-Large Quantity Shipping Containers authorizing use of the shipping container designated AL-M1 configuration -1 by the Operational Safety Division of the Albuquerque Operations Office (OSD/ALO) for the U.S. Atomic Energy Commission, now the U.S. Energy Research and Development Administration. The Department of Transportation subsequently granted special permit DOT-SP-5549 for this container in March 1968. In July 1968, approval was granted by OSD/ALO for use of similar shipping containers designated AL-M1 configurations -2 and -3 for shipments under the National Security Exemption which do not require a DOT special permit. Approval for National Security Exemption shipments in a container designated AL-M1 configuration -4 was granted by OSD/ALO in April 1969. Design and testing of the configuration -5 package was completed in 1976 and this report provides the first formal documentation of this package. This report satisfies the OSD/ALO request for a safety analysis for the family of AL-M1 containers and the requirement for a bound distributable document providing pertinent information for all potential users as specified in ERDA M 0529-Part V F.

Configurations -1, -3, and -5 are equivalent from a safety standpoint and are discussed in this report. No configuration -2 containers were ever fabricated and the design is now obsolete along with configuration -4. Therefore, neither configuration -2 nor -4 is discussed in this report. This safety report demonstrates that packages comprised of AL-M1 configurations -1, -3, and -5 shipping containers and the radioactive materials shipped in them are in full compliance with ERDA[1] and DOT[2] safety requirements.

The AL-M1 containers are used to ship plutonium-239, uranium-235, and tritium adsorbed on a solid. Plutonium-239 and uranium-235 may be shipped in configurations -1 and -3, whereas configuration -5 is designed for tritium adsorbed on solid materials.

Since permit DOT-SP-5549 authorized only shipment of up to 9.0 kg of uranium-235 in the form of metal of any uranium-235 enrichment, all other shipments including other radioactive materials have been made based on analysis of the shipments with OSD/ALO approval. Approximately 150 shipments have been made safely in AL-M1 containers since 1968. No radioactive materials have been released from the packages during any of these shipments.

The design of the AL-M1 containers is patterned after the Hanford Atomic Products Operations (now Battelle Northwest), Richland, Washington, shipping container Model D19-9-90. In 1968, a Hanford report[3] containing a complete evaluation of the D19-9-90 container, including the results of tests simulating hypothetical accident conditions, was submitted by Monsanto Research Corporation, Mound Laboratory, to the AEC and the DOT in lieu of actual tests on the AL-M1 containers to assure compliance with regulatory requirements. The validity of basing the AL-M1 container design and the initial safety evaluation on the Model D19-9-90 container for the purpose of obtaining permit DOT-SP-5549 has since been proven by the results of actual tests performed at Mound Laboratory.

The packages are illustrated in Figures 4-1, 4-2, and 4-3. All three configurations utilize a 55-gal steel drum outer container lined internally with 3 1/2 in. of insulation to protect the inner container from impact and fire. The configuration-1 primary containment vessel is a 9 1/2-in. i.d. stainless steel inner container sealed with a silicone O-ring. A spacer is provided which centers the inner container within the insulated drum assembly. A vent is provided through the lid of the drum for release of any vapors. The configuration-3 primary containment vessel is basically the same as configuration-1, except that it is aluminum and the 13-in. i.d. precludes use of a spacer between it and the insulated drum assembly.

Configuration-5 has an inner container designed to contain tritiated water adsorbed on a solid and consists of a 6 5/8-in. o.d. stainless steel cylinder with valves and fittings. This cylinder is designed for calorimetric assay of contents and bakeout for reuse. In the assembled package, an insulating spacer protects the inner container and centers it within the insulating outer drum assembly.

A sequence of four hypothetical accident tests was performed to prove the containers' ability to provide containment of the radioactive materials under severe accident conditions and to establish design parameters for any subsequent inner container designs or modifications. The four tests (the free drop, puncture, thermal, and water immersion) are defined by the ERDA and the DOT to simulate transportation accident conditions.

Figure 10-19 shows the minor damage to the configuration-1 package resulting from the free drop and puncture tests. The thermal tests did not cause any observable damage to the inner containers as a result of the water immersion tests.

Additional special tests and evaluations were performed to completely establish the package integrity and operating limits. The inner containers of configuration-1 and -3 were reassembled following the hypothetical accident test sequence and found to be helium leak tight when charged to 30 psig. Configuration-5 was tested in the same manner, except that the charge was 10 psig rather than 30 psig, and determined to be helium leak tight. It is established that the configuration-1 inner container can be pressurized to 10 psig, and the configurations-3 and -5 inner containers can be loaded at an air or inert gas pressure of one atmosphere at ambient temperature conditions without exceeding safe pressures in a subsequent hypothetical accident.

Calculations were made for configuration -1 to show that a radioactive decay energy of 10 W will potentially cause an additional inner container temperature rise of only 2.5°F during the thermal test. A similarly negligible temperature rise would also occur for the configurations-3 and -5 containers. A maximum contents weight of 20 kg is established. The radioactive contents, as well as several packing materials which may be placed within the various inner containers, were evaluated to prove that they will not cause the packaging to be breached under accident test conditions.

A nuclear criticality analysis was performed and is included in this report. Configurations-1 and -3 were determined to be equivalent from a nuclear criticality safety standpoint. Configuration -5 will not contain any fissile materials. The results of the criticality analysis for configurations-1 and -3 indicate that up to 1.8 kg of plutonium-239 or 5.7 kg of uranium-235 can be shipped as Fissile Class I, and up to 4.3 kg of plutonium-239 or 16.8 kg of uranium-235 can be shipped as Fissile Class II.

A sequence of photographs is included to illustrate the accident test equipment, procedures, and results.

References

1. "Safety Standards for the Packaging of Fissile and Other Radioactive Materials", Chapter 0529, U.S. Energy Research and Development Administration - ERDA Manual, Washington, D.C., approved December 21, 1976.
2. "Hazardous Materials Regulations of the Department of Transportation", R. M. Graziano's Tariff No. 31, effective March 31, 1977.
3. C. L. Brown, Class I Shipping Container for Fissile Material, HWSA-3995 (December, 1964).

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 configurations-1, -3, and -5 shipping containers are of similar basic design but the inner containers differ. The major components of the packaging are the outer steel drum, the insulating materials, and the inner containers. No shielding is specifically provided.

3.2 Contents of Packaging

The AL-M1 packages are designed for shipment of Type B and large quantities of radioactive materials as specified in this report. The configurations-1 and -3 packages are intended for shipment of up to 4.3 kg of plutonium-239 generating 10 W of decay heat or up to 16.8 kg of uranium-235. A maximum contents weight of 20 kg was established for configurations-1 and -3.

The configuration-5 package is intended for shipment of up to 100,000 Ci of tritiated water immobilized on a sorbent such as molecular sieve. This is approximately 10 g of tritium and produces approximately 3.3 W of decay heat. Any proposed shipments of more than 100,000 Ci of tritium exceed the evaluations of this SARP and must be separately evaluated. A maximum of 2000 g of water may be sorbed on molecular sieve or silica gel in a single package. A maximum of 3000 g of water may be sorbed on Florco, a typical commercial clay absorbent. Any other sorbent must be evaluated by the user and a corresponding maximum quantity of water established. Total organic compounds, e.g., decontamination solvents such as alcohol, must not exceed 1% of this water content. Halogenated compounds, e.g., decontamination and degreasing solvents such as Freon and trichloroethylene, which can be introduced into water or decomposed, should not be used in systems which will generate tritiated water to be loaded into these containers. No free standing water is permitted.

Evaluation of the plutonium-239, uranium-235, tritium, and the packaging materials at 300°F proved that the materials will not cause the packaging to be breached under accident test conditions. Analysis of other inner container materials or designs and of other materials to be shipped must be based on the conditions established by the hypothetical accident tests.

3.3 Steady State Temperature Profiles

Steady state temperature profiles of the shipping containers for several heat loadings within the inner containers were determined to ensure compliance with ERDA regulatory requirements, 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 for each configuration and resulting temperatures were determined and are shown in Table 3-1.

With the heat loads up to the authorized values for each packaging, (1) the maximum external surface temperature of the steel drums would be 101°F, which is well below the maximum of 122°F stated in regulations, and (2) the maximum temperatures at the external surface of the inner container would not exceed 111°F for configurations-1 and -3 or 116°F for configuration-5 when the package is in 100°F ambient air (normal conditions of transport). These temperatures will have no significant effect on the inner containers and the inner containers will retain their integrity even when the packages are subjected to the specified 1/2 hr fire test.

In addition, for the configurations-1 and -3 packages a maximum permissible inner container exterior surface temperature during normal conditions of 300°F was selected. This temperature is

TABLE 3-1. MAXIMUM HEAT LOAD AND RESULTING TEMPERATURES FOR EACH CONFIGURATION

Configuration	Maximum Heat Load Capability (W)	Maximum External Drum Temperature (°F)	Maximum External Surface Temperature of Inner Container at Normal Conditions (°F)
1	10	101	111
3	10	101	111
5	3.3	100	116

sufficiently low to ensure safety and sufficiently high to permit shipments with up to 10 W of thermal decay heat. It is not known that an additional heat load and resulting temperature would be unsafe. A maximum temperature at the exterior surface of the inner container during accident conditions is established at 500°F for configurations -1 and -3 and at 255°F for configuration-5.

3.4 Internal Pressure

The internal pressure capability of all three inner containers at various temperatures was thoroughly evaluated by ASME code calculations. The configuration-1 inner container can be pressurized to 10 psig, and the configuration-3 inner container can be loaded to atmospheric pressure at ambient temperature conditions without exceeding the established accident condition maximum pressures of 25 psig and 10 psig, for these two containers respectively, at a maximum accident temperature of 300°F within the inner containers. The internal pressure allowed by ASME code for the configuration-5 inner container is 218 psig at 300°F. By comparison, the maximum possible pressure which can be generated within the inner container at the maximum accident condition temperature of 255°F is less than 100 psig. It is necessary to ensure that the configuration-5 inner container be loaded to pressures of less than or equal to 1 atm absolute, and the package must normally be shipped within 30 days after loading. If the package is not shipped within 30 days, the internal pressure must be measured. If at that time the pressure is greater than 10 psig, then steps must be taken to reduce the pressure to 1 atm prior to shipment.

3.5 Package Standards

Detailed analyses with respect to Part II of ERDAM-0529 have shown that: (1) Packaging materials and the package contents will not cause any significant reactions even at hypothetical accident conditions. (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 the packagings. There are, however, two alternate drum types, one of which has I-bar rolling hoops. An analysis was made of the effects of a commonly used method of moving by fork lifts with two forks positioned beneath one of these I-bar rolling hoops. Such lifting will have no significant effect on the packagings. (4) The AL-M1 drums which have I-bar rolling hoops are also equipped with two stirrup-shaped tiedown fixtures which are fastened to the I-bar rolling hoop 180° apart. These tiedown devices were evaluated and found to satisfy requirements. (5) The static load requirement, normal to and uniformly distributed along its length, will be met. (6) The inner containers (containment vessels) will withstand an external pressure of 25 psi without loss of contents.

3.6 Normal Conditions of Transport

Related testing and engineering evaluations demonstrated that the requirements are satisfied for tests simulating the normal conditions of transport (heat, cold, pressure, vibration, water spray, free drop, corner drop, penetration, and compression). Heat from direct sunlight at 130°F or cold of -40°F will not increase or decrease the temperature of the packages 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 packages. Thirty-foot drop tests have shown that the 4-ft drop tests and the 1-ft corner drops will not significantly reduce the effectiveness of the packages. Tests on other packages and calculations have shown that the penetration test results in only minor dents in the outer steel packaging.

Compression tests on other similar containers with five times the authorized gross weight of the packages were conducted and produced no detectable effect. This testing is supplemented with an evaluation. The reduction in total effective volume of the packaging on which nuclear safety is assessed did not exceed 5%. In addition, the effective spacing on which nuclear safety is assessed between the center of the containment vessel and the outer surface of the packaging was not reduced by more than 5%. In both cases the reduction was much less than 5%.

3.7 Hypothetical Accident Conditions

The sequence of four hypothetical accident tests was performed and the packages satisfied these requirements. The drum closures were modified to ensure 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 by 1/2-hr fire tests to be less than 500°F for configurations-1 and -3 and 255°F for configuration-5. All three inner containers passed the water immersion test with no leakage.

3.8 Criticality

The criticality safety analysis established that configurations-1 and -3 were equivalent from a nuclear criticality safety standpoint. The results of the criticality analysis indicate that up to 1.8 kg of plutonium-239 or 5.6 kg of uranium-235 can be shipped as Fissile Class I, and up to 4.3 kg of plutonium-239 or 16.8 kg of uranium-235 can be shipped as Fissile Class II in configurations-1 and -3. The allowable number of packages per shipment for Fissile Class III quantities is also established. There is no criticality hazard for configuration-5.

3.9 Radiation Shielding Analysis

The AL-M1 configurations-1 and -3 shipping containers are used for transport of plutonium-239 and uranium-235. The radiation dose rate at the surface of these containers will be insignificant for the materials described in this SARP.

Configuration-5 of the AL-M1 shipping container is used for transport of tritiated water only. The shielding provided by the primary containment is sufficient to attenuate the beta radiation to nonmeasurable levels at the outer surface.

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. Package Description

4.1 General

The three AL-M1 configurations designated 1, 3, and 5 are illustrated in Figures 4-1, 4-2, and 4-3, respectively. All three configurations utilize the same insulating drum assembly. The sealed inner containers are the primary containment vessels for shipments of plutonium-239 and uranium-235 in configurations-1 and -3 and for sorbed, tritiated water in configuration-5. The appropriate Monsanto Research Corporation drawings are given in Table 4-1.

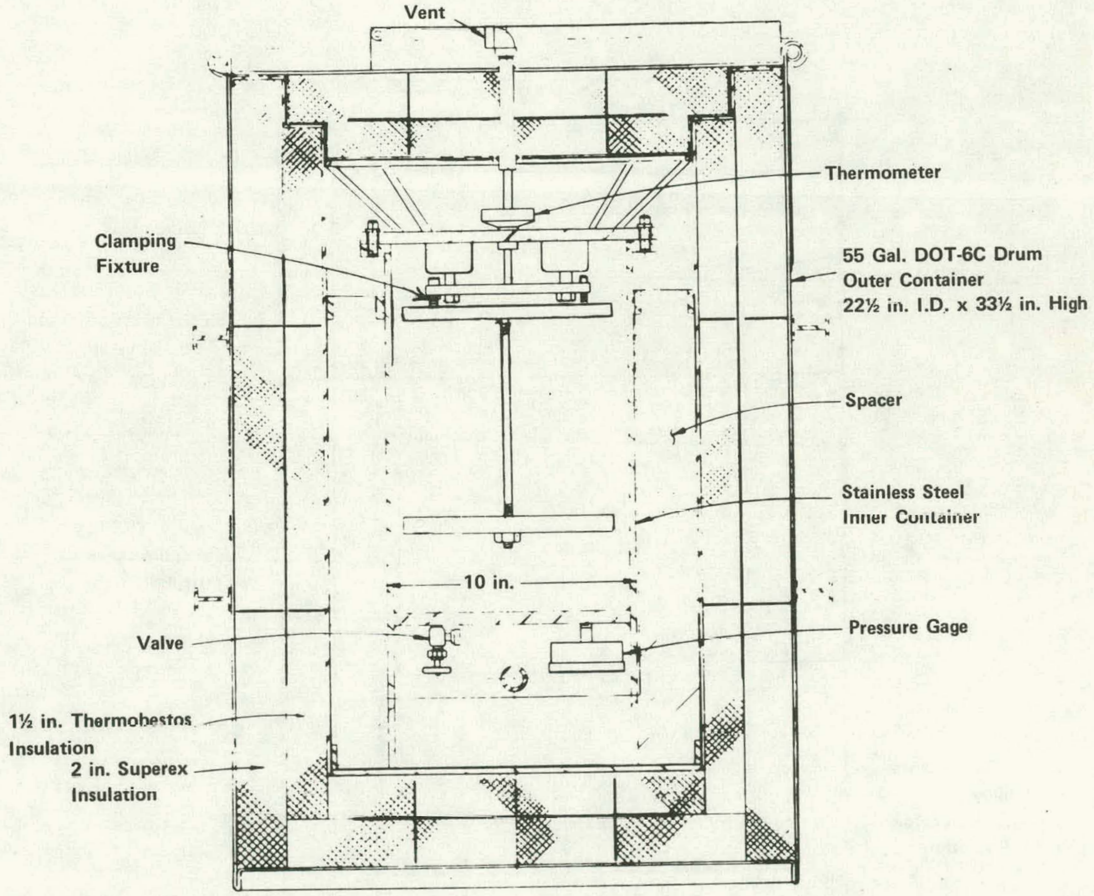


FIGURE 4-1 - Sketch of AL-M1 configuration-1.

4.2 Steel Drum

The outer container is one of two alternative 55-gal, open-head, steel drums. The alternatives are a DOT Specification 17C drum with rolled or swaged rolling hoops or a DOT Specification 6C drum with I-bar rolling hoops. Both of these drums have 16 gauge steel in the body and head. A vent is provided through the center of the lid to permit vapors to escape. A metal identification plate is welded to the outside of the drum body. A bolted skirt provides additional fastening strength for the closure ring of the drum lid.

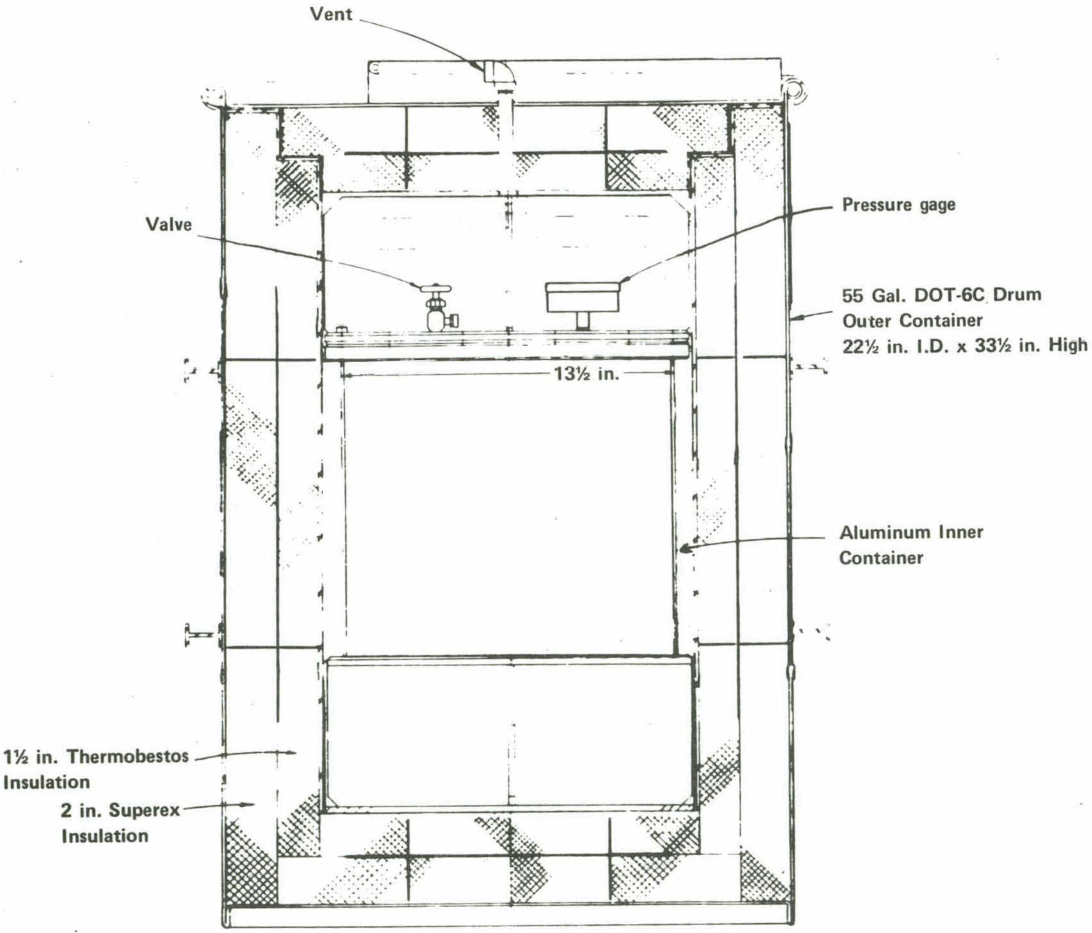


FIGURE 4-2 - Sketch of AL-M1 configuration-3.

4.3 Insulation

Drum assemblies made prior to 1973 utilized a combination of 2 in. of Superex and 1-in. of Thermobestos (Johns-Manville) insulation to line the 55-gal drum. The insulation protected the inner containers against impact and heat. It was held in place within the 55-gal drum with stainless steel sheet and is completely covered internally with stainless steel sheet to form a 15-in. diameter x 25-in. high cylindrical cavity. The Superex (Johns-Manville) layer was located adjacent

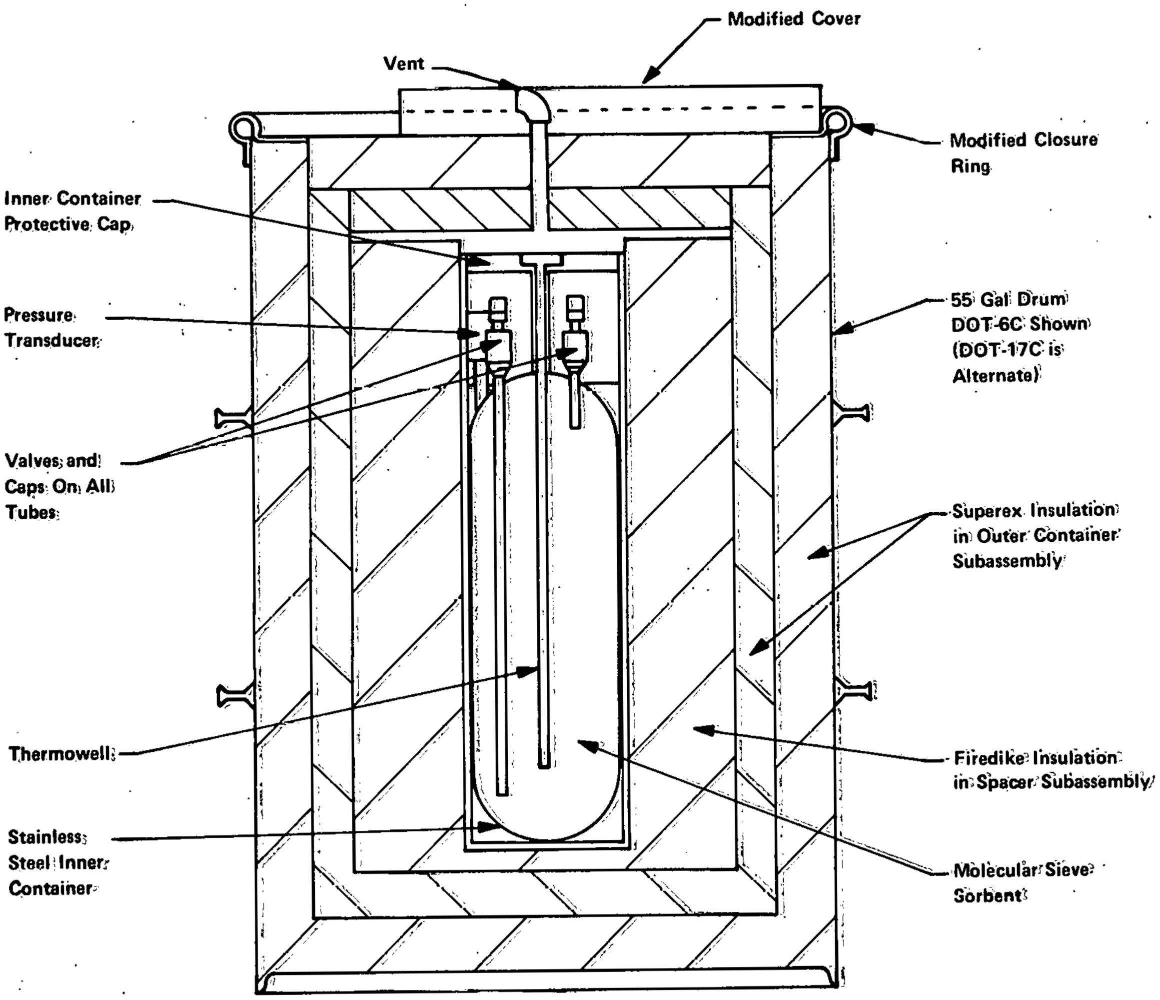


FIGURE 4-3 -- Sketch of AL-M1 configuration-5.

TABLE 4-1. APPLICABLE DRAWINGS FOR ALL CONFIGURATIONS

Insulating Drum Assembly Common to All Three Configurations	AYD 740425
Configuration-1	
Assembly	4-6934
Spacer	4-6897
Inner Container Cylinder	4-6896
Inner Container Cover	3-5623
Configuration-3	
Assembly	4-9271
Inner Container	4-8618
Configuration-5	
Insulating Spacer	AYD 760626
Inner Container	AYE 740198

to the drum wall and the Thermobestos layer was located adjacent to the internal cavity. The maximum service temperature for Superex is 1900°F and the thermal conductivity at 500°F is 0.71 BTU in./ft^2/°F/hr. Thermobestos has a maximum service temperature of 1200°F and a thermal conductivity at 500°F of 0.50 BTU in./ft^2/°F/hr. Due to its asbestos content, the Thermobestos product became obsolete, and in 1977 the design was changed to provide an alternative. The alternative consists of Superex-2000 formed and glued to fill the entire space formerly filled by the two types of insulation. The stainless steel insulation spacers were eliminated, but the stainless steel cavity liner was retained. This alternative arrangement is considered to provide a slight improvement in both protection from hypothetical accident fire conditions and dissipation of steady internal heat loads.

4.4 Spacers

A spacer is used in configuration-1 to center the inner container within the insulated drum assembly cavity with an air gap of at least 2-1/4 in. in all directions between the inner container and the Thermobestos insulation. This gap may be packed with dry ice coolant. The configuration-3 package does not utilize a spacer since a larger diameter inner container is accommodated.

An insulating spacer is used in configuration-5 to center and protect the inner container. The insulating material in this spacer is Fire Dike (Johns-Manville).

4.5 Inner Containers

The stainless steel configuration-1 inner container measures 9 1/2-in. i.d. by 15 1/2-in. internal height with 1/4-in. thick wall. It utilizes a silicone O-ring seal and is equipped with a valve, a pressure gage, and a thermometer. An internal clamping fixture mounted to the lid is used to secure the contents. A handle is provided at the top, and the body wall is extended at the bottom to protect the valve and pressure gage. The handle at the top and the extension at the bottom also provide sufficient size to secure the inner container within the insulated drum assembly.

The configuration-3 inner container is similar except that it is aluminum and measures 13 in. i.d. by 13 in. internal height with a 1/4-in. thick wall. Stiffeners used on the top and bottom end plates also provide handles, protection for the valve and pressure gage, and sufficient size to secure the inner container within the insulated drum assembly.

The configuration-5 inner container is a cylindrical vessel nominally 6 5/8 in. o.d. by 23 7/8 in. overall height. The container is made with 316 stainless steel and has a top cap which is sealed with O-rings and which protects and provides secondary tritium containment for bellows valves, fittings, and a pressure transducer. The primary containment vessel is normally loaded with molecular sieve pellets or other material for sorption of tritiated water. The container is designed for assay of contents by insertion in a calorimeter and for loading-unloading by direct connection to external tritium systems in order to thermally regenerate the sorbent bed.

5. Contents of Packaging

5.1 General

It is necessary to prove that the contents of the containers will not cause the inner containers to be breached during normal transportation or accident test conditions. The contents of the configuration-1 and configuration-3 packages include the radioactive plutonium-239 and uranium-235 as well as the packaging materials such as polyethylene bags, wood, sponge, and foam. These materials were evaluated at 300°F in an earlier SARP[1] and the results are summarized in Section 5.2.

The material which is to be packaged (loaded) in the inner container of configuration-5 is limited to tritiated water or tritiated water contaminated with organic compounds, i.e., solvents, not to exceed 1% of the water content. The tritiated water is immobilized on a sorbent, such as molecular sieve, and meets the transport criteria for a 'solid'. These materials are described and evaluated in Section 5.3.

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. The criteria are:

1. Quantity of isotopes.
2. Maximum amounts of radioactivity.
3. Chemical and physical form.
4. Material density.
5. Moderating ratios.
6. Configurations as required for nuclear safety evaluations.
7. Maximum amount of decay heat.
8. Maximum pressure buildup.
9. Leak tests.
10. Loading restrictions and limitations.

5.2 Plutonium-239 and Uranium-235

The AL-M1 containers are used to ship plutonium-239 and uranium-235 separately and in various combinations. Approximately 150 shipments have been made safely in AL-M1 containers since 1968. No radioactive materials have been released from the packages during any of these shipments. The anticipated maximum quantity of material to be shipped produces 10 W(th) as a result of radioactive decay energy.

Evaluation of the plutonium-239, the uranium-235, and the packing materials at 300°F proved that these materials will not cause the packaging to be breached under accident test conditions. Analysis of other inner container materials or designs and of other materials to be shipped must be based on the conditions established by the hypothetical accident tests.

Unalloyed plutonium-239 enriched to approximately 95% is shipped after being doubly packaged in polyethylene bags which are sealed with tape in the configurations-1 and -3 containers. Up to 4.3 kg of plutonium-239 generating 10 W(th) of radioactive decay heat may be shipped. For the purpose of the plutonium-239 evaluation at 300°F, it is assumed that the plutonium can be exposed to all the air contained within the inner container void spaces, even though the polyethylene bags would prevent this from actually happening. At 300°F, the surface plutonium, which is exposed to the air, would oxidize and would expand approximately 10% on being converted to plutonium oxide which would then separate from the metallic surface. This would not create any immediate hazard, but would necessitate special contamination control procedures on subsequent opening. A 20% decrease in the pressure resulting from the reaction of the oxygen would not cause the container to be breached. There is no evidence that plutonium would cause the packaging to be damaged.

Solid uranium-235 metal pieces are securely fastened in the clamping fixtures provided in the configurations -1 and -3 inner containers, up to 16.8 kg may be shipped as fissile Class II. Additional packaging materials such as polyethylene bags for contamination control are not usually required since the low level alpha contamination can be controlled using appropriate handling procedures for loading and unloading. The configuration-3 inner container may be shipped either filled with air at atmospheric pressure or filled with an inert gas such as helium or argon at atmospheric pressure. The configuration-1 inner container may be shipped containing air at atmospheric pressure or an inert gas at up to 10 psig pressure. The choice of the gas used depends on product specification requirements.

The uranium metal is evaluated at the most severe accident test environment which is taken to be air at 300°F. Since the melting point of the uranium is 2070°F, and oxidation in air forms an adherent oxide coating, the uranium metal will not change its physical form at 300°F in air. Oxidation is slow and will not consume sufficient oxygen to decrease the pressure a measurable amount. There is no evidence that uranium metal would react or otherwise change in any way that would reduce the integrity of the package during normal transportation or accident test conditions.

Also, test results do not provide any evidence indicating that the wood, sponge, or foam packing materials would cause the AL-M1 configuration-1 and -3 containers to be breached at 300°F. Low temperatures in normal transportation will not damage the materials since the minimum recommended service temperature for all three of the foam and sponge materials is -100°F.

5.3 Tritium

The quantity of tritium to be shipped in each configuration-5 container is arbitrarily limited to a maximum of 100,000 Ci or about 10 g of tritium. This quantity does not generate enough heat from radioactive decay (3.3 W) to cause any significant temperature rise in the inner container. It should not be assumed that quantities of tritium greater than 100,000 Ci would be hazardous, but no attempt has been made in this SARP to evaluate such larger quantities. Any proposed shipments exceeding 100,000 Ci must, therefore, be separately evaluated and approved.

In addition to this limitation on total tritium, the quantity of tritiated water is also limited. For three common materials evaluated as sorbents, the allowed maximum quantities of water are shown in Table 5-1.

TABLE 5-1. WATER LOADING LIMITS FOR THREE SORBENTS

Sorbent Material	Sorbent Quantity (kg)	Maximum Allowed Water Loading (g)
Molecular Sieves 4A, 5A, or 13 x	5.6	2000
Silica Gel	6.4	2000
Commercial Clay Absorbent[a]	4.2	2500

[a] A typical montmorillonite clay, Florco, Floridin Company, Pittsburgh, Pa., was tested.

The column labled "sorbent quantity" indicates the minimum weight of sorbent which should be loaded into the inner container. The column labled "maximum allowed water loading" represents quantities which ensure that no free liquid will exist within the container. In actual tests, equivalent quantities resulted in loaded sorbents which did not cling to container surfaces and retained the normal free-flowing properties of dry granular solids.

None of these materials in itself constitutes a hazard to the container (eg. corrosion, combustion, pressure) under any of the normal or hypothetical accident conditions.

The quantity of water to be shipped is determined by weight difference of the filled and unfilled package. Other types of solid sorbent material may be used provided that the user carefully evaluates the water sorbing capacity of the material. No free liquid is allowed. The user must also determine that any such sorbent material will not in itself become a hazard to the container under any of the normal or hypothetical accident conditions.

The heat load from tritium decay to helium-3 for the maximum amount of tritium is 3.3 W. The formation of helium-3 from natural tritium decay amounts to a generation rate of less than four liters/year for 100,000 Ci of tritium. With a void volume of 20% in the sorbent, the pressure in the

10-liter inner container would thus rise only about 30 psi in one year.

The tritium must be in the form of tritiated water (HTO); organic compounds e.g., decontamination solvents such as alcohol, must not be present in amounts greater than 1% of the water content of the package. This limitation ensures that excessive pressure buildup due to radiolysis will not occur over long storage periods. No unsafe pressure increase will occur at these specified concentration levels of tritium and organic compounds.

The internal pressure buildup due to radiolysis is an increase toward an equilibrium partial pressure of hydrogen formed by dissociation of water due to energy absorbed from the β emissions of radioactive tritium.

The magnitude of this pressure buildup is a function of time and organic compound contaminant type and concentration. It is not expected to exceed 40 psi and will typically be 10 psi or less after several months when organic compound contaminant levels are below 1%, as suggested above.

Thus, the total pressure in the configuration-5 inner container several months after loading and sealing will (at normal conditions) be roughly the sum of three partial pressures. These are 1) air or inert gases trapped in the container at the time of loading, 2) helium-3 decay product, and 3) hydrogen from radiolysis. At that time the pressure could be expected to be 15 to 20 psig.

During hypothetical accident fire conditions this pressure would rise for two reasons. First, the heating of the gaseous contents to 255°F will increase the absolute partial pressures by a factor of about 1.35. Second, the vapor pressure of the sorbed water would become significant at the elevated temperature. The vapor pressure of free liquid water forms an upper limit for the vapor pressure of sorbed water. At 255°F this is 32.5 psia.

In summary, a configuration-5 container which is loaded and sealed and then subjected to hypothetical accident fire conditions several months later is expected to have a maximum internal pressure of substantially less than 100 psig. The exact magnitude of this pressure depends upon several variables. Therefore, safe practice dictates:

1. Content of organic compounds, such as alcohol, below 1% of water content;
2. Loading at one atmosphere or less;
3. Normal shipment within 30 days after loading, or;
4. If shipment is not made within 30 days, the internal pressure must be measured (e.g., using the built-in pressure transducer). If at that time the pressure is greater than 10 psig, then steps must be taken to reduce the pressure to a maximum of one atmosphere prior to shipment;
5. Occasional monitoring of internal pressure during extended storage periods.

Each configuration-5 inner container is leak tested with helium for a leakage rate of less than 10^{-6} cm^3/sec at time of manufacture. A tritium check by ionization monitoring is used by the shipper and receiver to ascertain that a filled container is free of leaks.

The configuration-5 inner containers are made of 316 L stainless steel to provide maximum resistance to corrosion. However, they are not intended to contain corrosive agents, and the user must ensure that none are introduced. In particular, halogen compounds e.g., decontamination and degreasing solvents are to be avoided. These include (but are not necessarily limited to) halogenated hydrocarbons such as Freon propellants and solvents like trichloroethylene. Hence, halogenated compounds which can be introduced into water or decomposed should not be used in systems which will generate tritiated water to be loaded into these containers.

Loading and unloading procedures are given in Appendix B.

Reference

1. J. F. Griffin, D. A. Edling, and C. D. Winemiller, Safety Analysis Report for Packaging (SARP) Model AL-M1 Nuclear Packaging, MLM-1981 (November 30, 1972), 80 pp.

6. Steady State Temperature Profiles

6.1 Purpose

The steady-state temperature profile of each configuration was determined to ensure compliance with DOT, ERDA, and NRC regulatory requirements. Also, the steady-state results were used to determine the maximum heat load capability of each package.

6.2 Test Equipment and Procedures

Two separate tests were performed to determine the steady state temperatures of the inner container outside surfaces and drum outside surface for the AL-M1 packages. The configuration-5 inner container surface temperature and all AL-M1 outside drum surfaces temperatures are based on measurements made for a similar 55-gal package designated USA/5791/BLF(ERDA-AL). The equipment used for this testing is illustrated in Figure 6-1, and the procedures and detailed results are presented in the SARP[1] for the 5791 package. A second test was performed on an AL-M1 configuration-1 package using similar equipment to establish the temperature of the inner container outside surface for the configuration-1 and configuration-3 packages.

6.3 Test Results

The experimentally determined steady state temperatures are presented in Table 6-1 and shown graphically in Figure 6-2. All temperatures listed in the table have been adjusted to an

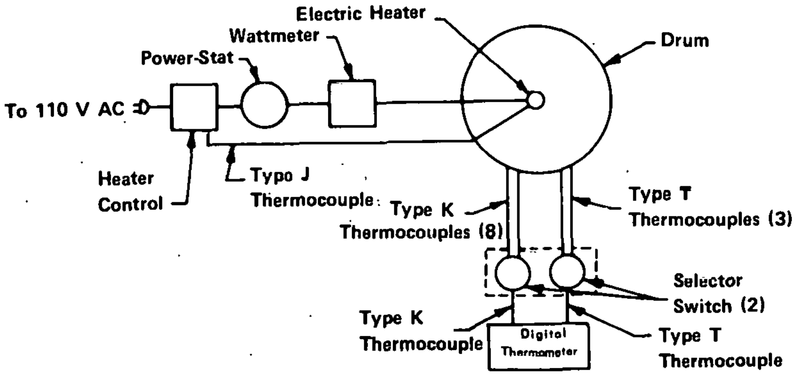


FIGURE 6-1 - Schematic of thermal test equipment.

TABLE 6-1. STEADY-STATE TEMPERATURE RESULTS FOR AL-M1 PACKAGES AT 100°F AMBIENT TEMPERATURE

Configuration	Contents Heat Load (W)	Drum Outside Surface Temp. (°F)	Inner Container Outside Surface Temp. (°F)
1 and 3	10	101	111
5	3.3	100	116

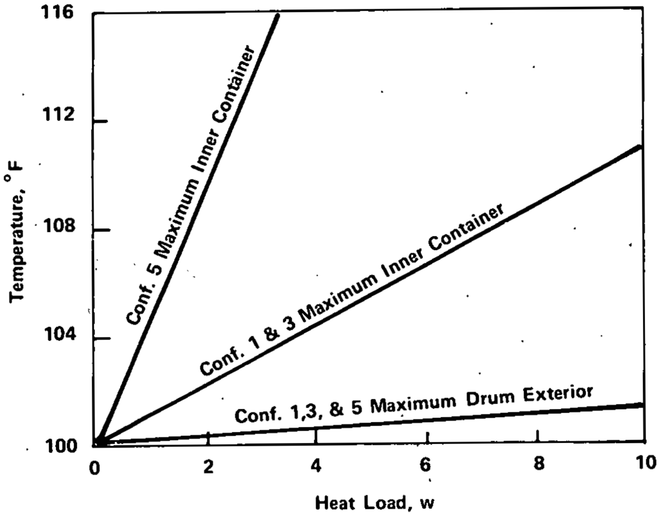


FIGURE 6-2 - Steady state temperature variation with heat load for AL-M1 packages at 100°F ambient.

ambient temperature of 100°F to represent normal conditions of transport on a hot day for comparison of the resulting package temperatures with DOT and ERDA/NRC regulations.

The configuration-1 inner container outside surface temperature increased 11°F above ambient when a heat load of 10 W was used. Thus, the resulting temperature at 100°F ambient is 111°F. This value is also applicable to the configuration-3 package since the insulated drum assembly is identical for these two configurations.

The exterior drum temperature data obtained for the 55-gal 5791 package is directly applicable to all AL-M1 configurations since they are also 55-gal drum packages. It was found that the exterior surface temperature increased 8.6°F above ambient at a heat load of 66.5 W. This is interpolated linearly to obtain the resulting temperature increases of 1.3°F at a 10 W heat load and essentially no increase at a 3.3 W heat load.

The inner container exterior temperature data obtained for the 55-gal 5791 is conservative (high) when applied to the AL-M1 configuration-5 package. These data were linearly interpolated to obtain a value of 16°F for a 3.3 W heat load. Thus, the maximum temperature at 100°F ambient is estimated to be 116°F.

In conclusion, it was found that the steady state temperatures of the AL-M1 packages are well within safe limits. The maximum temperatures for the exterior drum surface shown in Table 6-1 are all less than the permitted maximum accessible external surface temperature of 122°F. Another significant result was that there was no evidence that the heating and cooling caused any misfit, galling, or other damage.

Reference

1. J. F. Griffin et al., Safety Analysis Report for Packaging (SARP): USA/5790/BLF(ERDA-AL) and USA/5791/BLF(ERDA-AL), MLM-2242 (April 30, 1976), 89 pp.

7. Internal Pressure Capability

7.1 General

The internal pressure capabilities of all three AL-M1 configurations were evaluated in detail. These evaluations are given in the following for each configuration in turn.

7.2 Configuration-1

The configuration-1 inner container is shown in Figure 7-1. It is a stainless steel flanged cylinder measuring 9 1/2 in. inside diameter by 15 1/2 in. internal height with a 1/4-in. thick wall. The configuration-1 inner container, when loaded at the prescribed 10 psig or less, will be exposed to a maximum internal pressure of 12 psig at the normal transport temperature of 111°F (see Section 9.2) and a pressure of 21 psig at the hypothetical accident temperature of 300°F (see Section 10.7).

ASME code[1] calculations for the cylindrical shell, top and bottom plates, flange, and bolt capabilities are given as follows:

7.2.1 CYLINDRICAL SHELL

For cylindrical shells with longitudinal or circumferential weld joints,

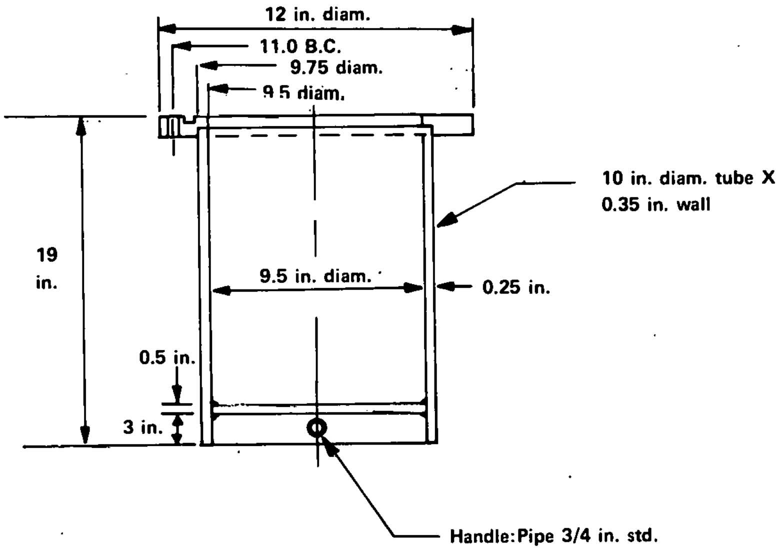


FIGURE 7-1 - Sketch of configuration-1 inner container.

the allowable internal pressures, P_l and P_c respectively, are

$$P_l = SEt/(R + 0.6t)$$

$$P_c = 2SEt/(R - 0.4t)$$

where

S = maximum allowable stress in psi;

E = joint efficiency, dimensionless;

t = wall thickness in inches;

R = inside radius in inches.

For the case, we find from Table UHA-23 of Reference 1 that S = 15.6 kpsi in the range 20°F to 200°F and S = 11.9 kpsi at 300°F. We have dimensions R = 4.75 in. and t = 0.25 in. Also, for seamless shells we have E = 1.

Using these values, we calculate for normal conditions (111°F),

$$P_l = \frac{(15,600)(1)(0.25)}{(4.75) + 0.6(0.25)} = 796 \text{ psi}$$

$$P_c = \frac{2(15,600)(1)(0.25)}{(4.75) - 0.4(0.25)} = 1677 \text{ psi.}$$

Similarly, for hypothetical accident conditions (300°F),

$$P_l = \frac{(11,900)(1)(0.25)}{(4.75) + 0.6(0.25)} = 607 \text{ psi}$$

$$P_c = \frac{2(11,900)(1)(0.25)}{(4.75) - 0.4(0.25)} = 1280 \text{ psi}$$

In both cases the smaller allowable pressures, P_1, control the design and compare favorably with the maximum expected normal and accident condition differential pressures of 12 psi and 21 psi respectively. Thus, the cylindrical shell will contain these pressures with a large margin of safety.

7.2.2 BOTTOM PLATE

The bottom plate has an allowable pressure, P, given by

$$P = St^2/Cd^2, \text{ or } t = d\sqrt{CP/S}$$

where

S = maximum allowable stress in psi;

t = thickness of plate in inches;

C = attachment factor, dimensionless;

d = diameter in inches.

The attachment factor is evaluated as

$$C = 0.5(t_r/t_s)$$

where

t_r = required thickness of seamless cylindrical shell for the required pressure, P_r, in inches;

t_s = actual shell thickness, in inches.

We evaluate t_r from a form of the equation of the previous section,

$$t_r = P_r d/(2SE - 0.6P_r)$$

Thus, at normal conditions

$$t_r = \frac{(27)(9.5)}{(15,600)(1) - 0.6(12)}$$

$$= 0.016 \text{ in.}$$

$$C = 0.5 \frac{(0.016)}{(0.25)} = 0.032.$$

This result is less than 0.3; thus, we follow code and use C = 0.3 to find the required thickness,

$$t = (9.5) \sqrt{\frac{(0.3)(12)}{(15,600)}} = 0.14 \text{ in.}$$

This is less than the actual thickness of 0.5 in.

The allowed pressure is

$$P = \frac{(15,600)(0.5)^2}{(0.3)(9.5)^2} = 144 \text{ psi.}$$

Similarly, at accident conditions

$$t_r = \frac{(36)(9.5)}{(11,900)(1) - 0.6(21)}$$

$$= 0.028 \text{ in.}$$

$$C = 0.5 \frac{(0.028)}{(0.25)} = 0.056.$$

Thus, we again use C = 0.3 to find a required thickness of

$$t = 9.5 \sqrt{\frac{(0.3)(21)}{(11,900)}} = 0.22 \text{ in.}$$

and the allowable pressure is

$$P = \frac{(11,900)(0.5)^2}{(0.3)(9.5)^2} = 110 \text{ psi.}$$

These allowable pressures compare favorably with the maximum expected pressures. Thus, the bottom plate will contain these pressures.

7.2.3 FLANGE

The flange design was analyzed in detail, including O-ring gasket compression as related to bolt loading, bolt load (tension and shear) from internal pressure, longitudinal hub stress, and radial and tangential flange stress. All flange stress criteria were met, and actual bolt loads were found to be less than 1/2 the maximum allowable.

7.2.4 TOP PLATE

The top plate design will conform to ASME Boiler Code Section UG-34 - Unstayed Flat Heads and Covers.

The applicable formula for thickness from Section UG-34(2) is

$$t = d \sqrt{CP/S + 1.78\, Wh_G/Sd^3},$$

where

t = thickness, inches;

P = internal pressure = 21 psi at $300^{\circ}F$;

S = allowable stress = 11,900 psi at $300^{\circ}F$;

C = head attachment factor = 0.3 [Figure UG-34(k)];

W = bolt load at operative conditions = 1,639 lb at 21 psi;

d = diameter of O-ring seal = 9.972 in.;

h_G = gasket moment arm = $\frac{B.C.- d}{2} = \frac{11-9.972}{2}$ = 0.514 in. For both circle, B.C. = 11 in.

With these values

$$t = 9.972 \left[\frac{(0.3)(21)}{11,900} + \frac{(1.78)(1.639)(0.514)}{(11,900)(9.972)^3}\right]^{1/2}$$

t = 0.26 in. (required vs. 0.5 in. provided).

Now rewriting equation UG-34(2) in terms of pressure gives

$$P = \frac{S}{C}\left[\frac{t^2}{d^2} - 1.78\ Wh_G/Sd^3\right] .$$

Solving for allowable pressure gives

$$P = \frac{11,900}{0.3}\left[\frac{(0.5)^2}{(9.972)^2} - 0.000127\right]$$

P = 95 psi allowable,

for a margin of safety, M.S., of

M.S. = (95/21) - 1 = 3.5.

The design of the top flange is adequate.

7.2.5 SUMMARY

Table 7-1 is a summary of these results for configuration-1. The design is adequate to contain the maximum internal pressure at hypothetical accident conditions.

7.3 Configuration-3

The configuration-3 inner container is shown in Figure 7-2. It is an aluminum flanged cylinder with external spacing plates. The inside diameter is 13 in., and the inside height is 12 7/8 in. The cylindrical wall is 1/4 in. thick and the top and bottom plates are 3/8 in. thick.

When loaded at the prescribed pressure of 0 psig, this configuration-3 inner container will be exposed to maximum internal pressures of 1 psig at the normal transport temperature of $111^{\circ}F$ (see Section 9.2) and 6 1/2 psig at the

TABLE 7-1. CONFIGURATION-1 INTERNAL PRESSURE ANALYSIS AT 300°F

Part	Allowable Load or Pressure	Actual Load or Pressure
Cylindrical Shell	607 psi	21 psi
Bottom Plate	110 psi	21 psi
Top Flange Hub Stress	11,900 psi	84.9 psi
Bolts	669 lb/bolt	205 lb/bolt
Top Plate	95 psi	21 psi

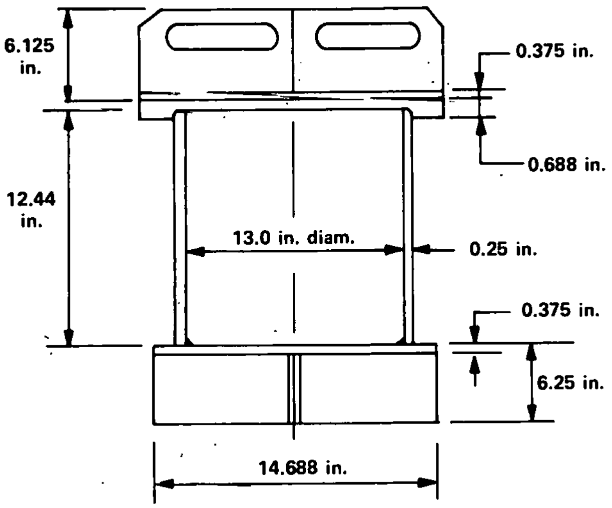


FIGURE 7-2 - Sketch of configuration-3 inner container; aluminum with stainless steel bolts.

hypothetical accident temperature of $300^{\circ}F$ (see Section 10.7).

ASME code calculations for the internal pressure capabilities of this configuration-3 inner container were similar in type to those for the configuration-1 inner container as outlined in Section 7.2. The results of these calculations are summarized in Table 7-2. The design is adequate to contain the maximum internal pressure at hypothetical accident conditions.

7.4 Configuration-5

The inner container for the Model AL-M1 configuration-5 assembly is shown in Figure 7-3. It consists of a 12-in. long x 6-in. diameter hollow pipe section with dished head elements welded to each end. A cylindrical pipe section is welded to the bottom of the assembly to support it in a vertical position. A protective capped cylinder is placed over the top cap to protect four nozzle protrusions that provide access to the interior of the container. Neither the top nor the bottom cylindrical projection significantly affects pressure containment.

At hypothetical accident conditions, the inner container will be exposed to a maximum internal pressure of 100 psi at a temperature of $300^{\circ}F$. This pressure represents the sum of three

TABLE 7-2. CONFIGURATION-3 INTERNAL PRESSURE ANALYSIS AT $300^{\circ}F$

Part	Allowable Load or Pressure	Actual Load or Pressure
Cylindrical Shell	124 psi	6 1/2 psi
Bottom Plate	25 psi	6 1/2 psi
Top Flange Hub Stress	12,600 psi	519 psi
Bolts	649 lb/Bolt	76 lb/Bolt
Top Plate	22 psi	6 1/2 psi

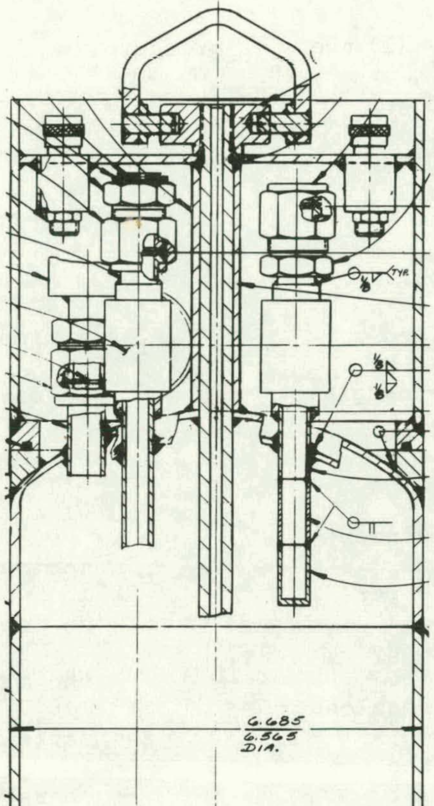


FIGURE 7-3 - AL-M1 configuration-5 inner container [2].

partial pressures which could be developed under such conditions: (1) the vapor pressure of water, (2) hydrogen gas from radiolysis, and (3) enclosed air or inert gas. As shown in the stress analysis which follows, the inner container can safely withstand this environment with an adequate margin of safety.

The analysis of the pressure containment capability of the assembly will be performed in three parts: the main body; the capped end sections; and the nozzles that project from the top cap of the assembly.

All the structural components investigated in this section are composed of Type 316L stainless steel. This material is rated at a design strength of 11,800 psi at 300°F under Section VIII of the ASME Boiler and Pressure Vessel Code (1974 Edition) which is the basis of this analysis.

7.4.1 MAIN CYLINDER BODY

Reference 1 lists the following two formulas for determining the maximum allowable working pressure of a cylindrical shell exposed to internal pressure:

$$P_1 = SEt/(R + 0.6t) \qquad [1]$$

and

$$P_c = 2SEt/(R - 0.4t) \qquad [2]$$

where

P_1 = maximum working pressure based on circumferential stress reaching the allowable stress, S;

P_c = maximum working pressure based on longitudinal stress reaching the allowable stress, S;

S = maximum allowable stress at operating temperature (11,800 psi at 300°F);

E = joint efficiency for the welded joint connecting the main cylinder to the end caps (E = 0.65 based on Table UW-12 of Ref. 1);

R = inside radius of cylindrical shell = 3.1785 in;

t = thickness of shell body = 0.134 in.

With this terminology the equations resolve into the following working pressures:

$$P_1 = \frac{(11,800)(0.65)(0.134)}{3.1785 + 0.6\ (0.134)}$$

$$= 315 \text{ psi at } 300^{\circ}\text{F},$$

and

$$P_1 = \frac{2(11,800)(0.65)(0.134)}{3.1785 - 0.4\ (0.134)}$$

$$= 659 \text{ psi at } 300^{\circ}\text{F}.$$

The maximum permissible working pressure at an operating temperature of 300°F is therefore 315 psi in the main cylinder body. This exceeds the maximum operating pressure at that temperature (100 psi) and the resulting margin of safety is

$$MS = (315/100) - 1 = 2.15 \qquad (3)$$

7.4.2 CAPPED END SECTIONS

Section UG-32, "Formed Heads, Pressure on Concave Side", of Reference 1, lists the following formula for evaluating the allowable working pressure in a torospherical head:

$$P = SEt/(0.885L + 0.1t) \qquad (4)$$

where

P = maximum working pressure, psi;
S = maximum allowable stress at operating temperature = 11,800 psi at 300°F;
t = thickness = 0.134 in.;
L = inside dish radius = 5.31 in.;
E = head-to-shell joint efficiency = 0.65.

Substituting and solving results in the following maximum working pressure:

$$P = \frac{(11,800)(0.65)(0.134)}{(0.885)(5.31 + 0.1)(0.134)}$$

$$= 218 \text{ psi at } 300^{\circ}\text{F}.$$

The margin of safety against failure at the 300°F operating condition is

$$MS = (218/100) - 1 = 1.18$$

which, although lower than that for the main cylinder body, demonstrates that the design is satisfactory.

7.4.3 NOZZLE PROJECTIONS

Four nozzles protrude from the top cap of the container assembly. The nozzles are used for filling and emptying the container and for monitoring the contents. All four nozzles are 1/2 in. in outside diameter; the wall thicknesses are, in sequence, 0.047, 0.047, 0.065, and 0.156 in. Three nozzles extend to the interior of the container; the fourth nozzle penetrates the end cap only.

The allowable weld stress permitted for nozzles attached by fillet welds is listed in Reference 1 as 49% of the shear stress of the vessel material. The shear stress, in turn, is equivalent to 0.577 times the allowable effective stress which is 11,800 psi at $300^{\circ}F$. The permissible fillet weld strength is then

$$S_{wf} = (0.49)(0.577)(11,800)$$
$$= 3336 \text{ psi at } 300^{\circ}F$$

where

S_{wf} = allowable shear stress in fillet weld, psi.

The allowable weld stress for nozzles attached by groove welds in shear is listed in Reference 1 as 60% of the shear stress of the vessel material. The permissible groove weld strength is then

$$S_{wa} = (0.60)(0.577)(11,800)$$
$$= 4085 \text{ psi at } 300^{\circ}F$$

where

S_{wa} = allowable shear stress in groove weld, psi.

For convenience, the nozzles will be grouped by wall thicknesses in the following investigation of their load capacity.

7.4.3.1 1/2 x 0.047-in. Wall Nozzles

Figure 7-4 shows a typical nozzle attachment to the top cap of the container. The nozzle is attached to the container by a groove weld in shear. The thickness of the groove weld will be taken as the thickness of the top cap (0.134 in.).

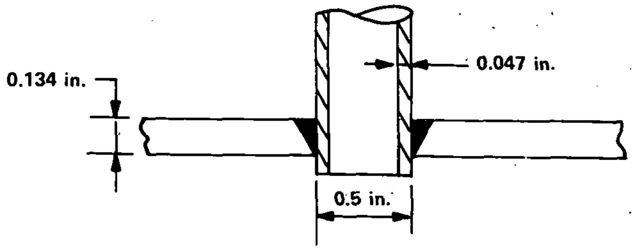


FIGURE 7-4 - Typical nozzle attachment at end cap.

The strength of the groove weld, F_{wa}, is determined by multiplying the allowable shear stress, S_{wa}, by the weld thickness and the circumferential length of weld. This gives

$$F_{wa} = 4085(0.134)(\pi)(0.5) = 860 \text{ lb.}$$

The maximum internal pressure, (P_{max}) weld, that the weld can withstand is then found by dividing the weld strength, F_{wa}, by tube area over which the internal pressure will act.

$$(P_{max}) \text{ weld} = \frac{F_{wa}}{\pi(D^2/4)} = \frac{(860)(4)}{\pi(0.5)^2}$$

$$= 4,380 \text{ psi.}$$

Because the nozzle will be subjected to the same internal pressure as the main container, its strength under that loading will next be evaluated. The maximum allowable internal pressure in the nozzle will be obtained by applying Eq. (1) to the nozzle dimensions.

Eq. (2) will not be evaluated at this condition because the circumferential pressure stress is the limiting case in a cylinder exposed to internal pressure loading. Applying Eq. (1) produces the allowable internal pressure in the nozzle.

$$P_1 = \frac{(11,800)(0.65)(0.047)}{0.25 + (0.6)(0.047)}$$

$$= 1296 \text{ psi at } 300^{\circ}\text{F}.$$

Because the value P_1 is less than (P_{max}) weld, it represents the limiting case for this nozzle. The margin of safety for this nozzle is then

$$MS = (1296/100) - 1 = 12 \text{ at } 300^{\circ}\text{F}$$

and the integrity of the nozzle under the maximum pressure loading is assured.

7.4.3.2 1/2 x 0.065 in. Wall Nozzle

Figure 7-5 shows the method used to attach the 0.065 and 0.156 in. nozzles to the main assembly. The attachment is made via fillet welds on either side of the cap. The minimum weld thickness is limited to 70% of the nozzle wall thickness by the restrictions of Reference 1 and this value will be used in the investigation which follows.

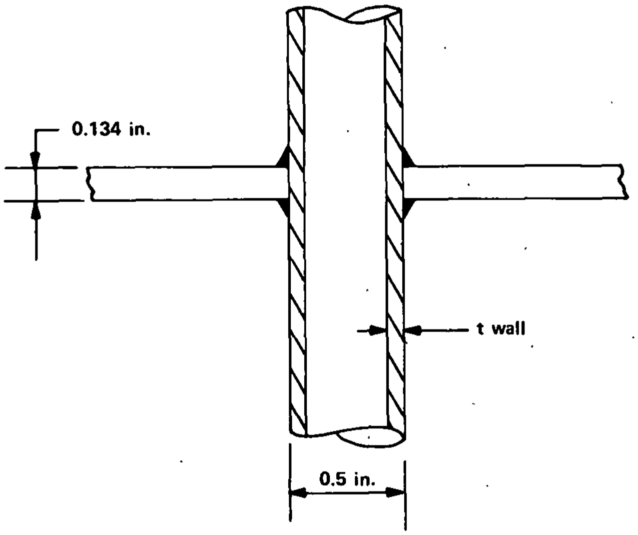


FIGURE 7-5 - Typical nozzle penetration at end cap.

The strength of the nozzle-end cap weld connection is given by

$$F_w = 0.7(t_{wall})(S_{wf})(\text{lgth})(2 \text{ welds})$$

where

$t_{wall} = 0.065$ in.

length = $\pi(0.5 \text{ in.}) = 1.57$ in.

F_w = weld strength, lb.

This becomes

$$F_w = 0.7(0.065)(3336)(1.57)(2)$$

$$= 477 \text{ lbs at } 300^{\circ}\text{F}.$$

The maximum internal pressure that the weld can withstand is then

$$(P_{max})\text{weld} = \frac{F_w}{\pi D^2/4} = \frac{(477)(4)}{\pi(0.5)^2}$$

$$= 2429 \text{ psi at } 300^{\circ}\text{F}.$$

The pressure capacity of the nozzle body as a pressure vessel is found by applying Eq. (1).

$$P_c = \frac{11{,}800(0.65)(0.065)}{0.25 + (0.6)(0.065)}$$

$$= 1725 \text{ psi at } 300^{\circ}\text{F}.$$

The limiting case for this nozzle is determined by P_c. The margin of safety is then

$$MS = (1725/67) - 1$$

$$= 25 \text{ at } 300^{\circ}\text{F}.$$

7.4.3.3 1/2 x 0.156 In. Nozzle

Analysis of the capacity of this nozzle follows the procedure used in the previous case. Figure 7-5 represents the weld arrangement at this penetration.

The strength, F_w, of the weld connection is found as

$$F_w = 0.7(0.156)(3336)(1.57)(2)$$

$$= 1144 \text{ lb at } 300^{\circ}\text{F}.$$

The weld can therefore safely resist a container internal pressure of

$$(P_{max}) \text{ weld} = \frac{1144 \times 4}{\pi(0.5)^2}$$

$$= 5826 \text{ psi at } 300^{\circ}\text{F}.$$

The capacity, P_c, of the nozzle body as a pressure vessel is obtained through application of Eq. (1) to the tube dimensions. This gives

$$P_c = \frac{11{,}800(0.65)(0.156)}{0.25 + (0.6)(0.156)}$$

$$= 3482 \text{ psi at } 300^{\circ}\text{F}.$$

Because P_c is less than (P_{max}) weld, it represents the limiting condition for this nozzle. The margin of safety is

$$MS = (3482/67) - 1$$

$$= 51 \text{ at } 300^{\circ}\text{F}.$$

The ability of the nozzle to withstand the maximum pressure application has been demonstrated.

7.4.4 SUMMARY

Table 7-3 summarizes the results of the analysis of the pressure-containing capacity of the Model AL-M1 configuration-5 inner container. Since the maximum internal pressure to which the container will be exposed is 100 psi at

300°F the design is shown to be adequate.

TABLE 7-3. RESULTS OF INTERNAL PRESSURE STUDY FOR CONFIGURATION-5 INNER CONTAINER

Component	Allowable Pressure at 300°F (psi)
Main Body Cylinder	315 Circumferential 659 Longitudinal
End Caps	218
Nozzles:	
1/2 x 0.047 in.	1296
1/2 x 0.065 in.	1725
1/2 x 0.156 in.	3482

The overall limiting pressure capability is shown to be that of the end cap. Its value is 218 psi at an operating temperature of 300°F. The overall margin of safety is, therefore,

$$MS = (218/100) - 1 = 1.18$$

The design is satisfactory.

References

1. <u>ASME Boiler and Pressure Vessel Code</u>, 1974 Edition.
2. <u>MRC Drawing No. AYE-740198</u>, Inner Container AL-M1, Configuration-5.
3. <u>Marks Mechanical Engineers Handbook</u>, 6th Edition, McGraw-Hill, 1958.
4. <u>Welded Fittings and Flanges</u>, Grinnell Corporation #WFF-20.

8. Package Standards Evaluation

8.1 General

In Part II of ERDA 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 550 lb for the packages.

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 and bolts that prevent accidental opening are used on 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 these shipping containers. 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 either beneath the bottom of the drum as shown in Figure 8-1 or, in the case of 6C drums with I-bar rolling hoops, under the upper rolling hoop as shown in Figure 8-2. The 17C drums with swaged rolling hoops should not be lifted by the rolling hoops. The following evaluations show that, using these prescribed lifting methods, supporting three times the weight of the packages will not generate stresses

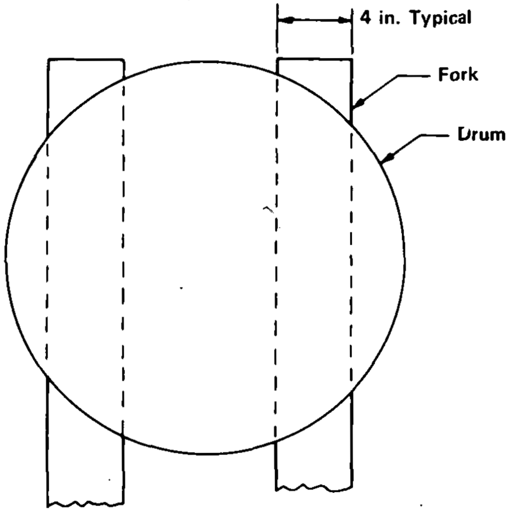


FIGURE 8-1 - Lifting drum from bottom with fork lift.

in excess of the yield strength of the mild steel drums.

The maximum gross weight of the 55-gal container is taken to be 550 lb and three times this weight is 1650 lb. In lifting from the bottom, 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:

$$S \doteq \frac{1650 \text{ lb}}{(4 \text{ places})(4)(0.0598 \text{ in.})}$$

$$= 1725 \text{ psi.}$$

The calculated stress is less than the 27,000 psi yield strength of the mild steel drums.

In lifting 6C drums by positioning the forks beneath the outer flange of the rolling hoop, the load is reacted at two points as shown in Figure 8-2. The maximum bending stress occurring in the hoop is determined in the following manner. Assume that the section of the web A-B resists the 825-lb load alone and the load carrying capability of the flange is neglected. The flange is assumed to distribute the load along the

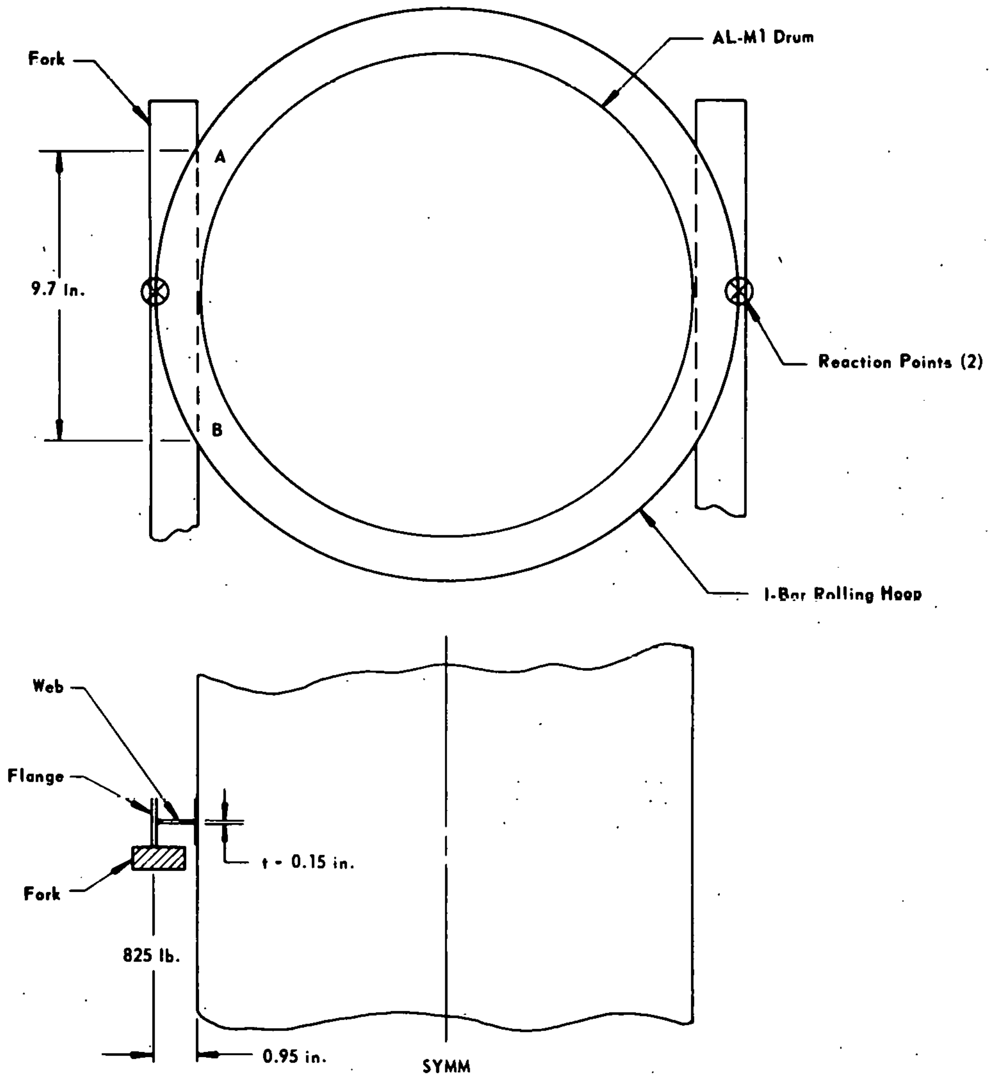


FIGURE 8-2 - Lifting a 6C drum at rolling hoop with fork lift. This lifting method is not to be used on 17C drums.

edge of the web. The maximum bending stress in the hoop is given by

$$S_{max} = 6M/bt^2,$$

where

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

M = the bending moment, $M = (825)(0.95)$ in.-lb,

b = engagement length, $b = 9.70$ in., and

t = web thickness, $t = 0.15$ in.

Thus

$$S_{max} = \frac{6(825)(0.95)}{(9.70)(0.15)^2} = 21{,}500 \text{ psi.}$$

The maximum shear stress in the web is given by

$$S_{max} = W/A$$

where W is the weight and A is the area (b x t).

Thus

$$S_{max} = \frac{825}{A} = \frac{825}{(0.15)(9.7)} = 567 \text{ psi.}$$

Both of these values are conservative since the resisting action of the flange was not included. The minimum yield stress of the ring material is 27,000 psi, as specified by the ASME Code[1]. The I-bar rolling hoop is prevented from slipping due to the corrugation in the drum body.

8.5 Tiedown Devices

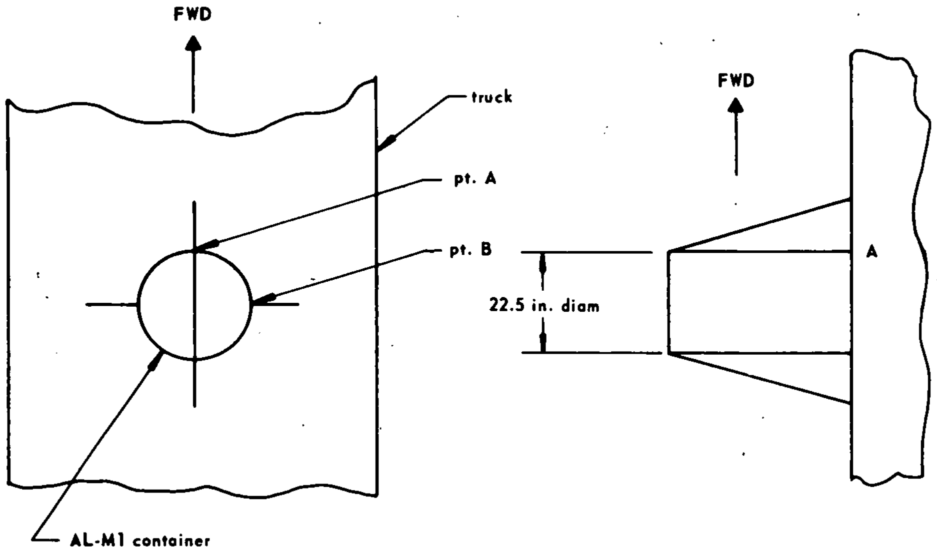
8.5.1 GENERAL

AL-M1 containers with type 6C drums have built-in tiedown fixtures, but those with type 17C drums do not. ERDA Manual Chapter 0529 specifies that tiedown devices that 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. However, this requirement is not applicable to the AL-M1 containers since the tiedown devices on the 6C drums are attached to the outer drum and are, therefore, not a structural part of the package. A Division of Reactor Research and Development standard[2] proposes that all parts of the tiedown system that are not considered structural parts of the package be so designed and fabricated that static stresses would not exceed 75% of the yield strength if the package were subjected to a sustained acceleration of 2-G forward or backward, 1-G laterally, 3-G vertically up or 2-G vertically down. It is demonstrated in this section that the AL-M1 containers with and without built-in tiedown fixtures satisfy the requirements set forth in the RDT standard.

For AL-M1 containers without built-in tiedowns, essentially the same analysis applies when strapping is securely wrapped around the circumference of the drum in order to provide fastening points for transverse tiedown cables or straps. For the analysis to apply, it is necessary for the circumferential strap to be placed 12 in. below the top of the drum and to be restrained against slippage up or down.

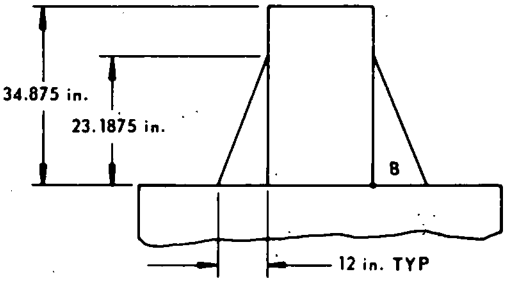
The tiedown devices for the AL-M1 shipping container are detailed in Figure 8-3. Each AL-M1 Type 6C drum is equipped with two stirrup-shaped tiedown fixtures which are fastened to the upper I-bar rolling hoop 180° apart. These are normally used to fasten the container in the transverse direction using a cable (or strap) within the transport vehicle [Figures 8-3 (A) and (C)]. In addition, a tiedown cable (or strap) is placed longitudinally over the top of the drum and securely attached to the floor [Figure 8-3 (A) and (B)]. The I-bar rolling hoop is secured between two corrugations on the drum, thus preventing any vertical slippage of the hoop.

This evaluation of the tiedown stirrups and the I-bar rolling hoop shows that the devices satisfy requirements. Failure of the devices under excessive load will not impair the ability of the package to meet the requirements of the other general standards. The cable forces developed to resist the three inertia loading conditions specified were determined. In several instances, the cable system was statically indeterminate, and the stiffness method of indeterminate analysis was employed. Throughout this analysis, it is assumed that (1) the container itself is perfectly rigid, (2) the cross-sections of all cables are identical, and (3) the center of mass coincides with the centroid of the drum. The maximum weight of the container is 550 lb. Once the cable forces are determined, the



(A) Horizontal Tiedowns

(B) Longitudinal Tiedowns



(C) Transverse Tiedowns

FIGURE 8-3 - Tiedown devices.

stresses in the drum are found for the largest cable forces encountered.

8.5.2 VERTICAL INERTIA LOAD

The vertical inertia loading is considered first. The 3-G vertical upwards loading is shown in Figure 8-4 (A). Since the weight of the container (1 G) must also be included in the analysis, the resulting upward load becomes 3 G - 1 G = 1100 lb. The forces developed in the longitudinal cables (P_1) and the transverse cables (P_2) cannot be determined from the equations of statics alone. In order to determine these cable forces, it is assumed that the vertical loading causes the container to displace upward an amount Δ as shown in Figure 8-4 (A). From the cable geometry as shown in Figure 8-4 (C), it is determined that the displacement (Δ) upward causes a cable elongation of $\Delta \sin \theta$, where θ is the angle that the cable makes with the horizontal. The force in the cable is $(AE\Delta/L) \sin \theta$ and the vertical component is $(AE\Delta/L) \sin^2 \theta$, where L = the original length of cable, A = cross-sectional area of cable, and E = modulus of elasticity. The force $(AE\Delta/L) \sin^2 \theta$ is the stiffness of the cable in the vertical direction and is denoted $\overline{P}$. For the longitudinal cables $\theta = 71.0124^\circ$, $\sin \theta = 0.9456$, L = 36.88 in., and thus

$$\overline{P}_1 = \frac{AE\Delta(0.9456)^2}{36.88}, \text{ and}$$

$$\overline{P}_1 = 0.02425\ AE\Delta. \qquad (1)$$

For the transverse cables $\theta = 62.6375^\circ$, $\sin \theta = 0.888$, L = 26.11, and thus

$$\overline{P}_2 = \frac{AE\Delta(0.888)^2}{26.11}, \text{ and}$$

$$\overline{P}_2 = 0.0302\ AE\Delta. \qquad (2)$$

Equilibrium in the vertical direction requires that

$$2\overline{P}_2 + 2\overline{P}_1 = F, \qquad (3A)$$

$$2(0.0302\ AE\Delta + 0.02425\ AE\Delta) = F \qquad (3B)$$

where F is the actual load. Solving for $AE\Delta$,

$$AE\Delta = 9.18F. \qquad (4)$$

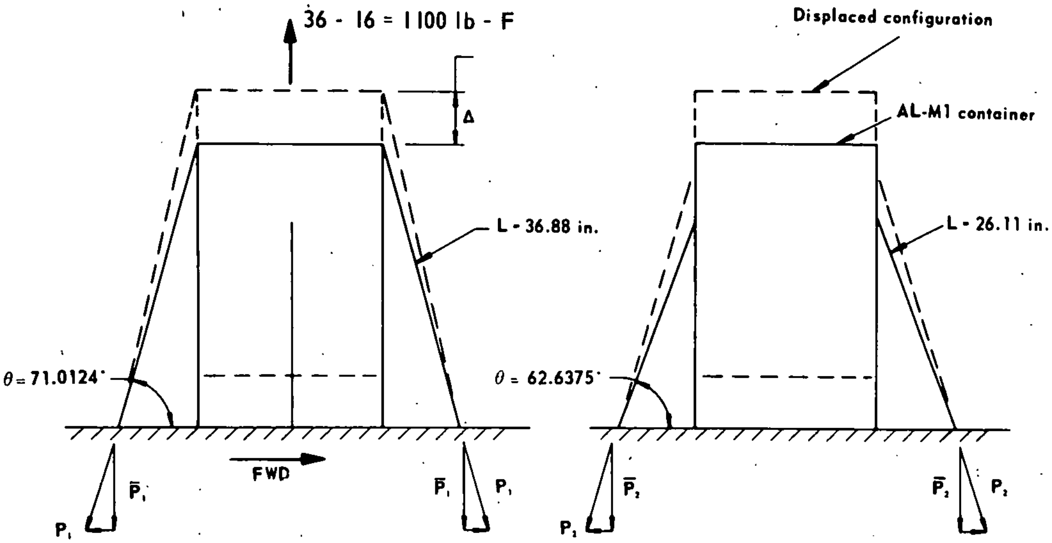
substituting Eq. (4) into Eq. (1) and (2),

$$\overline{P}_1 = 0.02425(9.18F) = 0.223F, \qquad (5A)$$

and

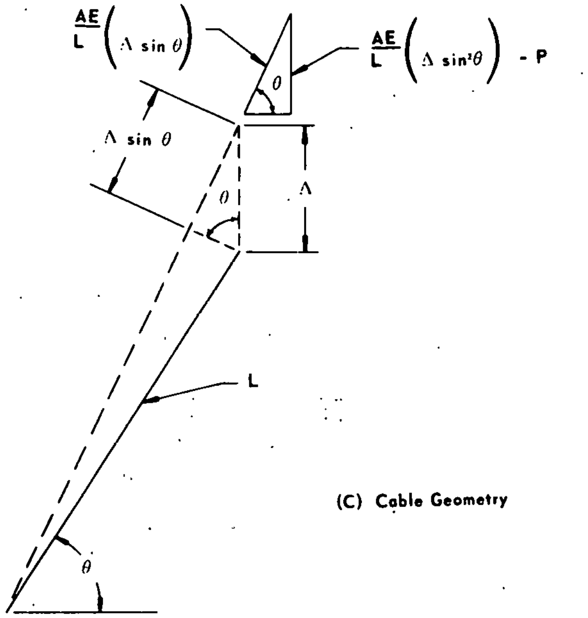
$$\overline{P}_2 = 0.0302(9.18F) = 0.277F \qquad (5B)$$

The longitudinal cable forces (P_1) are found by



(A) Side View

(B) Rear View



(C) Cable Geometry

FIGURE 8-4 - Vertical inertia loads.

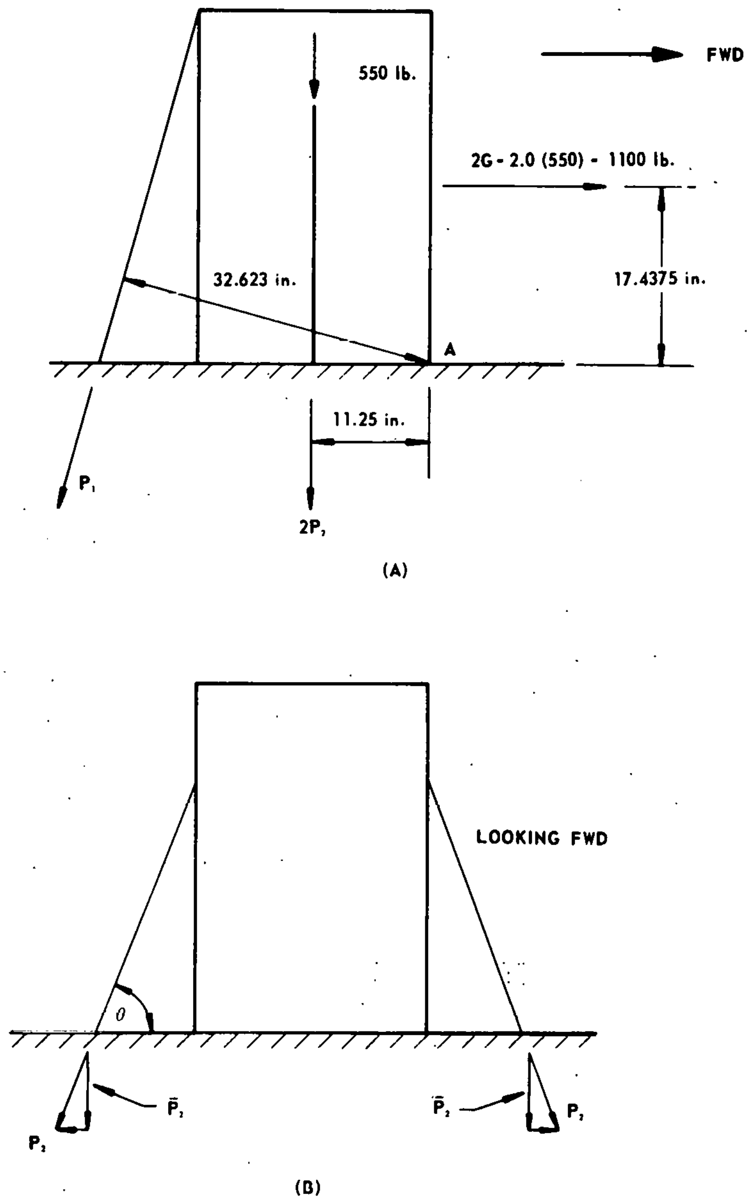


FIGURE 8-5 - Longitudinal inertia loads.

$$P_1 = \overline{P}_1/\sin\theta = 0.223F/0.9456; \qquad (6)$$
$$P = 0.236F.$$

The transverse cable forces (P_2) are therefore

$$P_2 = \overline{P}_2/\sin\theta = 0.277F/0.888; \qquad (7)$$
$$P_2 = 0.312F.$$

The vertical load (F) acting on the AL-M1 container is 1100 lb, and therefore

$$P_1 = 0.236(1100) = 260 \text{ lb}; \qquad (8)$$

$$P_2 = 0.312(1100) = 343 \text{ lb}. \qquad (9)$$

8.5.3 LONGITUDINAL INERTIA LOAD

The next inertia loading considered is the 2-G longitudinal loading as shown in Figure 8-5. Initially it was assumed that the AL-M1 container will tip about point A as shown in Figure 8-6. This can occur only if sufficient frictional forces are developed along the floor. The cable system for this case is also statically indeterminate so a procedure similar to that used previously for the vertical loading will be used here to determine cable forces. Assume that the container rotates about point A an amount $d\phi$ (see Figure 8-6). The corner B of the container moves to B', a distance $Rd\phi$. From the geometry of the system, it is determined that the increase in cable length due to the rotation $d\phi$ is

$$\delta = Rd\phi \cos(\phi + \theta - 90). \qquad (10)$$

The stiffness of the longitudinal cable is then

$$P_1 = \frac{AE\delta}{L} = AEd\phi\left[\frac{R}{L}\cos(\phi + \theta - 90)\right], \qquad (11)$$

where

R = diagonal distance between A-B,
L = length of cable, and
ϕ and θ are angles defined in Figure 8-6.

For the longitudinal cable R = 41.5 in., L = 36.88 in., $\phi = 57.171^\circ$, and $\theta = 71.0124^\circ$. Then

$$P_1 = AEd\phi\,\frac{41.50}{36.88}\cos(57.171 + 71.0124 - 90); \qquad (12)$$
$$P_1 = (0.8845)\,AEd\phi.$$

The geometry of the transverse cables from a longitudinal rotation about point A is shown in Figure 8-7. From this it can be determined that the stiffness of each transverse cable is

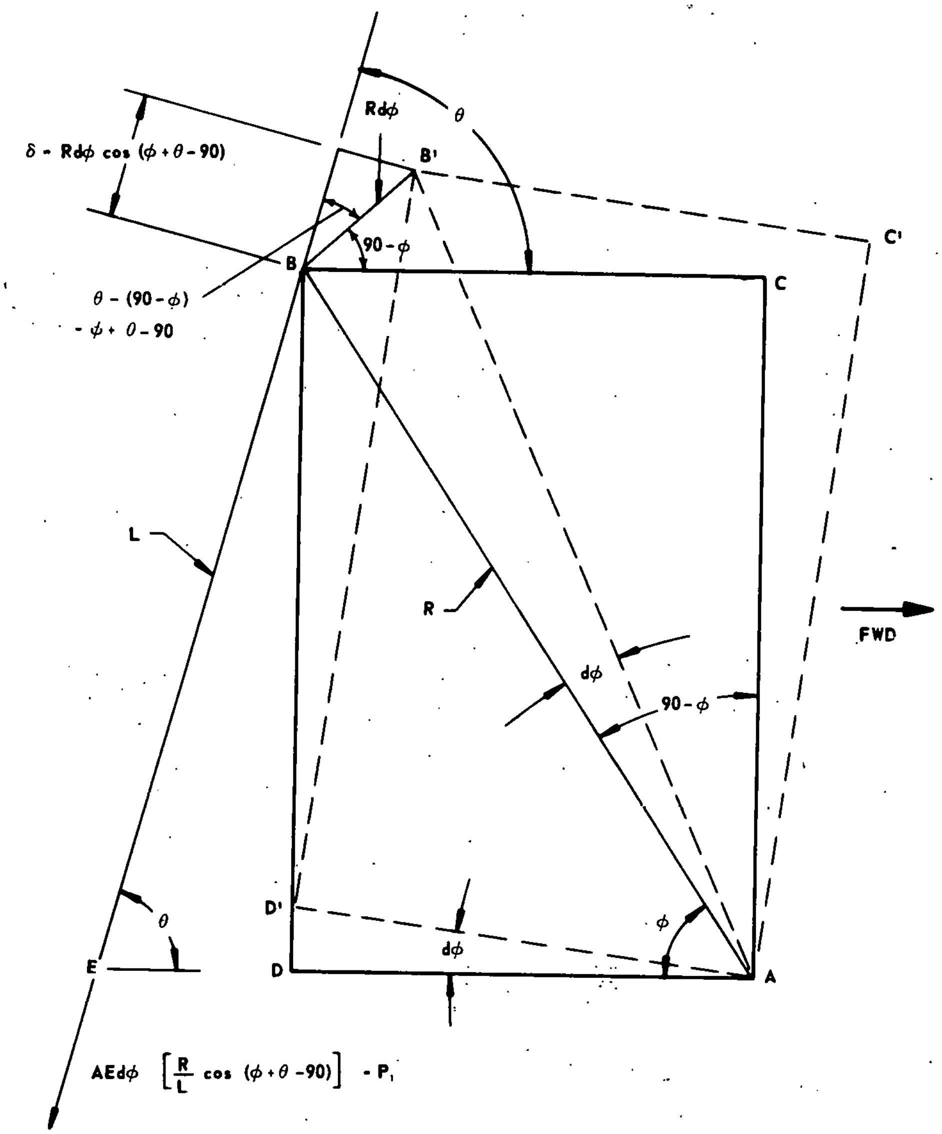


FIGURE 8-6 - Longitudinal cable load.

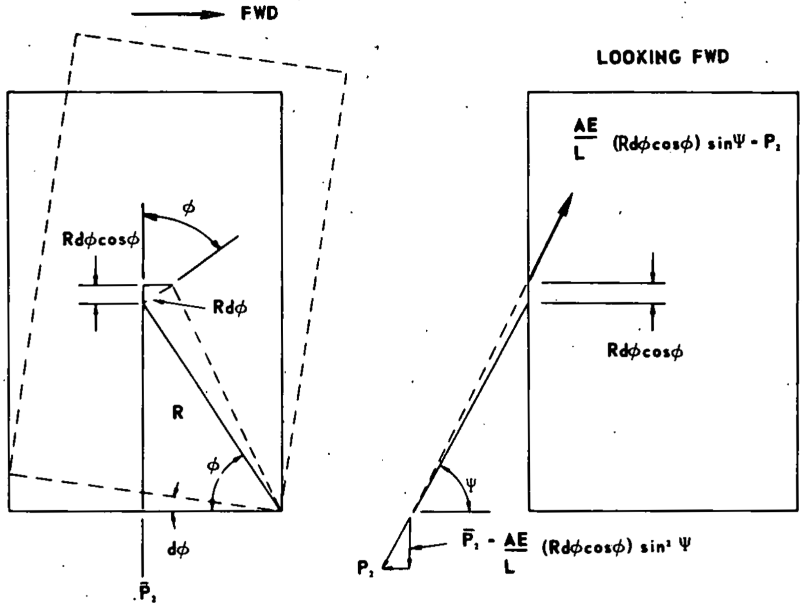


FIGURE 8-7 - Transverse cable load.

$$P_2 = \left[\frac{AE}{L}\ (RD\emptyset \cos\ \emptyset)\ \sin\psi\right], \qquad (13)$$

where ψ is defined in Figure 8-7. The vertical component of the transverse cable force is denoted $\bar{P}_2$ and is

$$\bar{P}_2 = \frac{AE}{L}\left[(Rd\emptyset \cos\ \emptyset)\ \sin^2\psi\right]. \qquad (14)$$

For the transverse cable R = 25.77, L = 26.11, $\emptyset$ = 45.862, ψ = 62.6375, sin ψ = 0.888, and cos $\emptyset$ = 0.4365. Then

$$\begin{aligned} \bar{P}_2 &= AEd\emptyset\ \frac{25.77}{26.11}\ (0.4365)(0.888)^2 \\ \bar{P}_2 &= (0.34)\ AEd\emptyset. \end{aligned} \qquad (15)$$

All forces acting on the container are shown in Figure 8-8. Moment equilibrium about point A requires that

$$\begin{aligned} &32.623(P_1) + 2(\bar{P}_2)(11.25) + \\ &550(11.25) = 1100(17.4375); \\ &32.623\ P_1 + 22.5\ \bar{P}_2 = 12{,}994. \end{aligned} \qquad (16)$$

Substituting Eq. (12) and (15) into (16) and solving for AEd$\emptyset$ gives

$$\begin{aligned} &32.623(0.8845AEd\emptyset) + \\ &22.5(0.34AEd\emptyset) = 12{,}994; \\ &AEd\emptyset = 355.94. \end{aligned} \qquad (17)$$

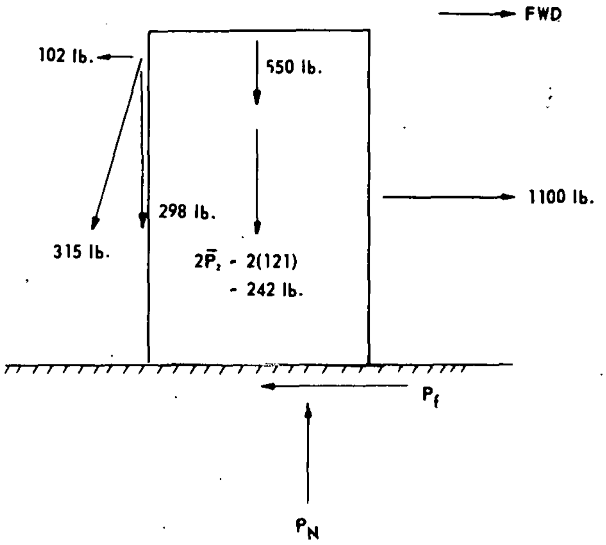


FIGURE 8-8 - Forces due to longitudinal inertia.

Substituting Eq. (17) into Eq. (12) and (13) provides the cable forces from the longitudinal inertia load as follows:

$$P_1 = 0.8845(355.94) = 315 \text{ lb}; \qquad (18)$$

$$P_2 = \bar{P}_2/\sin\psi = (0.34)(355.94)/0.888, \\ = 136 \text{ lb}. \qquad (19)$$

It must now be determined whether sufficient frictional forces can be developed between the floor and container to cause the assumed tipping condition. All loads acting on the container are shown in Figure 8-8. Summing forces in the horizontal direction we find that the frictional force that must be developed is

$$P_f = 1100 - 102 = 998 \text{ lb}. \qquad (20)$$

Summing forces in the vertical direction will provide the total normal force, P_N, acting on the floor,

$$P_N = 2(121) + 550 + 298 \\ = 1090 \text{ lb}. \qquad (21)$$

The coefficient of friction between the floor and container is taken to be 0.4; the maximum frictional force that can be developed is

$$(P_f)_{max} = 0.4(P_N) = 0.4(1090)$$

$$= 436 \text{ lb.} \qquad (22)$$

Thus, the maximum frictional force that can be developed is much less than that force required to cause the container to tip (998 lb). This means that the container will begin to slide along the floor before it will tip about point A.

In order to determine the cable loads from the sliding of the container, all forces acting on the container must be considered as shown in Figure 8-9.

Here the transverse cables (P_2) will not be loaded because of the sliding of the container. With $P_2 = 0$, the cable system is statically determinate. Assuming a coefficient of friction of 0.4, it can be seen from Figure 8-9 that the normal load on the floor is

$$P_N = 550 + P_1 \sin \theta. \qquad (23)$$

The frictional force along the floor is

$$P_f = 0.4(550 + P_1 \sin \theta). \qquad (24)$$

Summing horizontal forces gives

$$(0.3254)P_1 +$$
$$(550 + 0.9457\ P_1)0.4 = 1100,$$

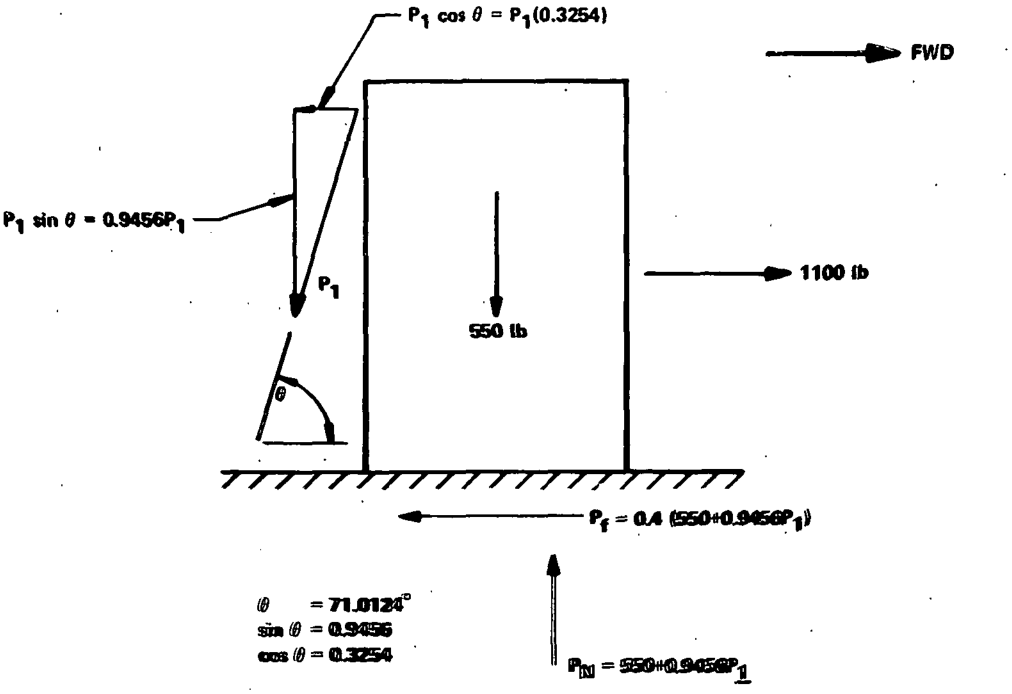


FIGURE 8-9 - Longitudinal sliding forces.

$$P_1 = 1250 \text{ lb, and} \tag{25}$$

$$P_2 = 0.$$

To summarize the results for the longitudinal inertia loading, sliding of the container will occur before tipping, and the maximum longitudinal cable force for the condition is 1250 lb. No transverse cable loads will be developed.

8.5.4 TRANSVERSE INERTIA LOAD

The 1-G transverse inertia loading is shown in Figure 8-10. Again it was initially assumed that the container will tip about point B. Using a similar stiffness procedure as for the longitudinal inertia load, it was determined that for the transverse inertia load a sufficient frictional force could not be developed. Therefore, for this loading the container will slide before it will tip.

In order to determine cable loads from sliding, all forces acting on the container must be considered as shown in Figure 8-11. Here the longitudinal cables (P_1) will not be loaded because of the sliding of the container. The normal load on the floor is

$$P_N = 550 + P_2 \sin \theta. \tag{27}$$

With a coefficient of friction of 0.4, the frictional force along the floor is

$$P_f = 0.4\ (550 + P_2 \sin \Theta\ ). \tag{28}$$

Summing horizontal forces gives

$$0.4(550 + 0.888\ P_2) + 0.46\ P_2 = 550; \tag{29}$$

$$P_2 = 405 \text{ lb.}$$

Therefore, the maximum transverse cable force is developed when sliding occurs and is 405 lb.

8.5.5 DRUM STRESSES FROM MAXIMUM INERTIA LOADS

Once the cable forces are determined, the stresses in the drum and rolling hoop can be found as shown below. From the previous analysis, the maximum transverse cable force of 405 lb was found to occur during the transverse inertia loading. This load is shown acting on the rolling hoop in Figure 8-12. The resulting horizontal force component is 193 lb, and the vertical force component is 360 lb.

It is conservatively assumed that the vertical component is distributed over

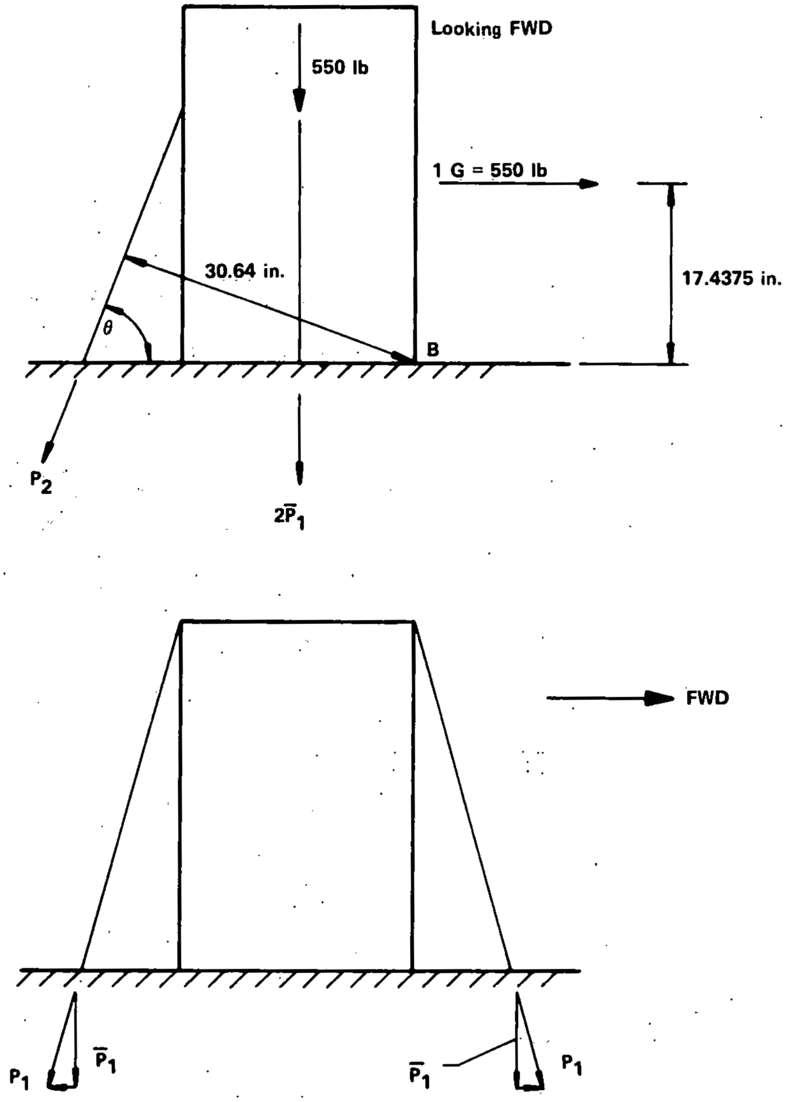


FIGURE 8-10 - Transverse inertia loads.

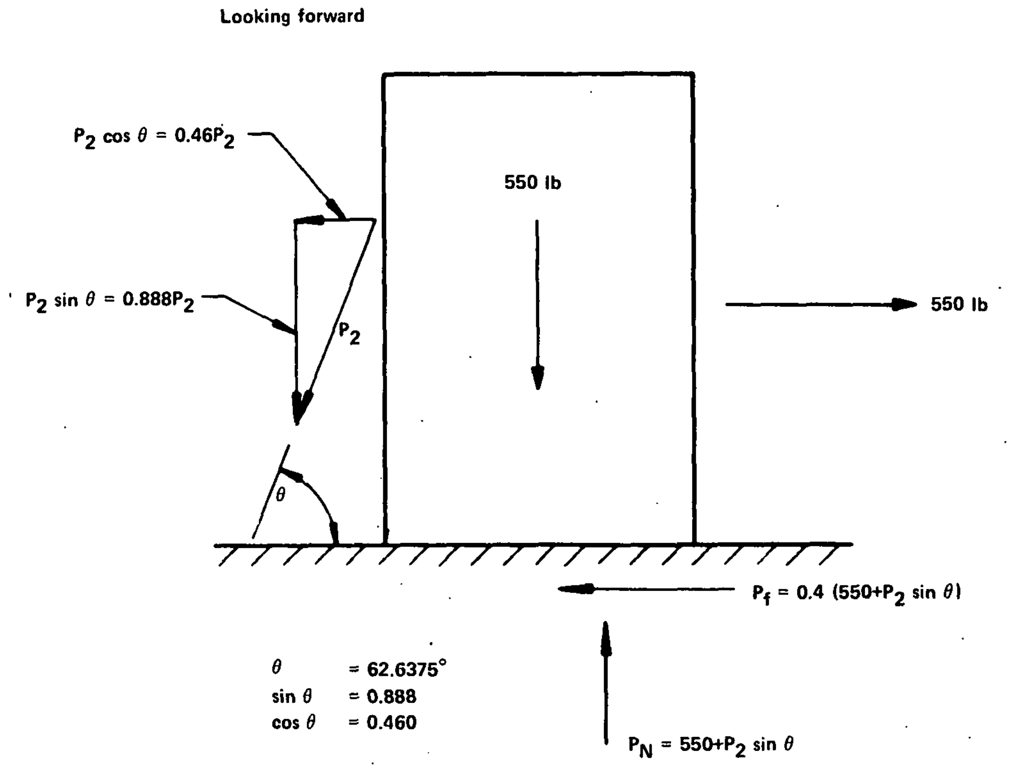


FIGURE 8-11 - Transverse sliding forces.

3 in. of wall perimeter. Since the thickness (t) of the drum is 0.06 in., the cross-sectional area resisting the vertical component is 3t = 0.18 in.^{2} The horizontal component of the cable tension is resisted by the bending action of the rolling hoop. The maximum bending stress in the hoop occurs at the point of application of the load and is calculated as follows:

$$S_{max} = 0.318\ RF/Z,$$

where

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

R = radius of hoop, R = 11.25 in.,

Z = section modulus of hoop, Z = 0.1267 in.^{3}, and

F = horizontal force, F = 193 lb.

Thus, the maximum bending stress acting on the I-bar rolling hoop is

$$S_{max} = \frac{0.318\ (11.25)(193)}{0.1267}$$

= 5448 psi bending stress on I-bar.

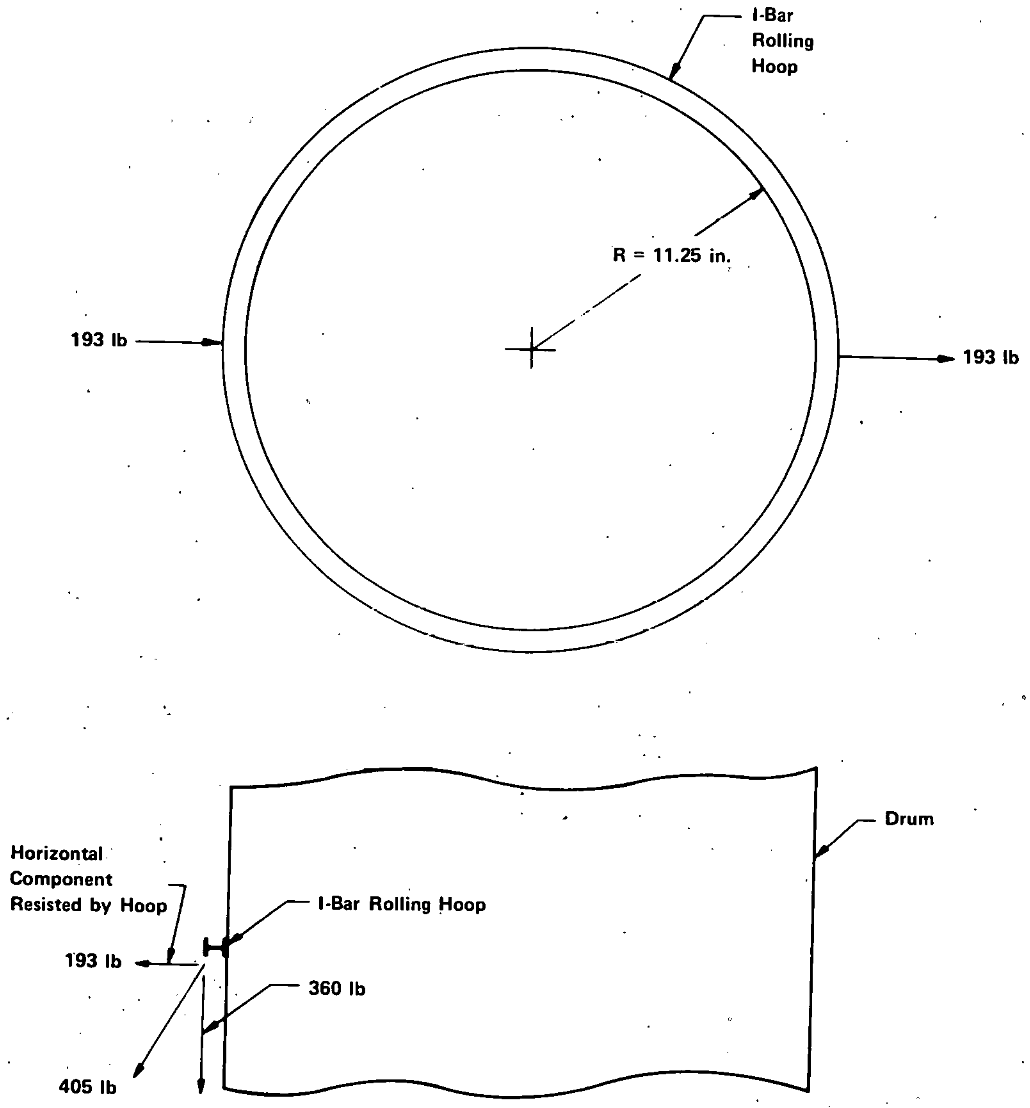


FIGURE 8-12 - Cable forces.

The compressive stress in the drum wall caused by the vertical component is given by:

$S_{max} = F/A$,

where

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

F = vertical force, $F = 360$ lb, and

A = cross-sectional area, $A = 0.18\ in^2$.

Thus, $S_{max} = 360/0.18 = 2000$ psi compressive stress on drum wall.

The cable that overlaps the drum in the longitudinal direction causes a compressive load on the drum wall identical to that caused by the transverse cables. Again it is conservatively assumed that 3 in. of perimeter resists the vertical component of the cable load. The maximum longitudinal cable stress occurs for the longitudinal inertia load which is 1250 lb. The resulting vertical component is 1182 lb. [1250(sin 71.0124) = 1182] The maximum drum stress for this load condition is

$S_{max} = F/A = 1182/0.18$

= 6566 psi compressive stress on drum top.

All the above stresses are much less than 27,000 psi, which is the specified yield stress of the drum material.

8.5.6 TIEDOWN STIRRUP STRESS DUE TO MAXIMUM INERTIA LOAD

The transverse cables which secure the AL-M1 container built with 6C drums are attached to the rolling hoop with a steel stirrup as shown in Figure 8-13. In the previous sections it was determined that the maximum transverse cable load is 405 lb and occurs when the transverse inertia load of 1 G is acting. In order to compute the maximum stress occurring in the stirrup it is assumed that the 405 lb load is uniformly distributed over a 4-in. length with the ends simply supported as shown in Figure 8-13 (B). The maximum stress equation is

$S_{max} = M_{max}/Z$

where

S_{max} = maximum stress (psi),

M_{max} = maximum moment, $M = PL/8 = 405(4)/8 = 202.5$ in. lb,

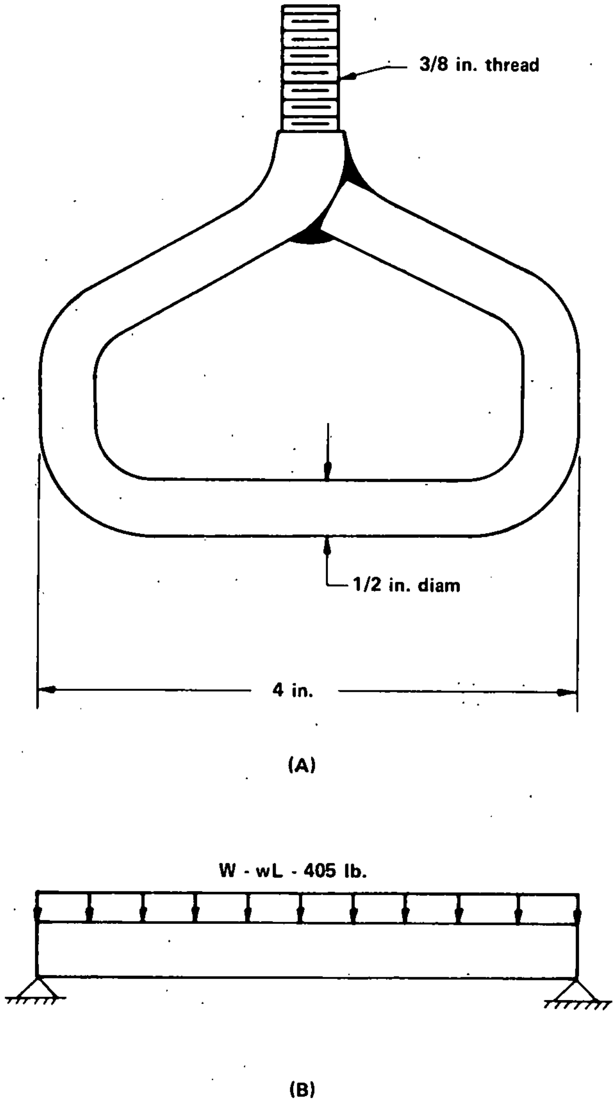


FIGURE 8-13 - Tiedown stirrup used on type 6C drums.

P = cable load, P = 405 lb,

L = length of stirrup, L = 4 in.,

Z = section modulus, $Z = \pi R^3/4 = (\pi/4)(1/4)^3 = 0.01227 \text{ in.}^3$, and

R = radius of stirrup, R = 1/4 in.

Therefore, $S_{max} = 202.5/0.01227 =$ 16,500 lb maximum stress in stirrup.

The maximum stress will actually be somewhat lower since the edges are not actually simply supported but do provide rotational restraint. Yielding of the stirrup material will not occur.

8.5.7 SUMMARY OF RESULTS

The results of all the tiedown calculations are summarized in Table 8-1.

Since all stresses calculated for the calculated inertia loads are well below the 27,000 psi yield stress of the materials, the tiedown devices meet the necessary requirements.

8.6 Load Resistance

8.6.1 GENERAL

When regarded as a simple beam supported at its ends along any major axis, the shipping container must be capable of

TABLE 8-1. SUMMARY OF TIEDOWN CALCULATIONS FOR 6C DRUMS

Forces and Stresses	Upwards Vertical Inertia Load of 3G	Longitudinal Horizontal Inertia Load of 2G	Transverse Horizontal Inertia Load of 1G
Longitudinal Cable Force (lb)	260	1250	0
Transverse Cable Force (lb)	343	0	405
I-bar Maximum Bending Force (lb)	-	-	193
Drum Maximum Compressive Force (lb)	-	1182	360
I-bar Maximum Bending Stress (psi)	-	-	5448
Drum Maximum Compressive Stress (psi)	-	6566	2000
Stirrup Maximum Stress (psi)	-	-	16500

withstanding a static load, normal to and uniformly distributed along its length, equal to five times the fully loaded container weight without generating stresses in any material of the container in excess of the yield strength of that material.

The outer drum is identical for the AL-M1 configurations-1, -3, and -5 and is shown schematically in Figure 8-14. The drum material is low alloy steel with a minimum yield stress of 27,000 psi, as specified per ASME Pressure Vessel Code[1].

8.6.2 DRUM EVALUATION

Stresses in the drum resulting from the uniform load are determined, as recommended by Shappert[3], from the following equation:

$$S = MC/I = M/Z,$$

where

S = Stress (psi),

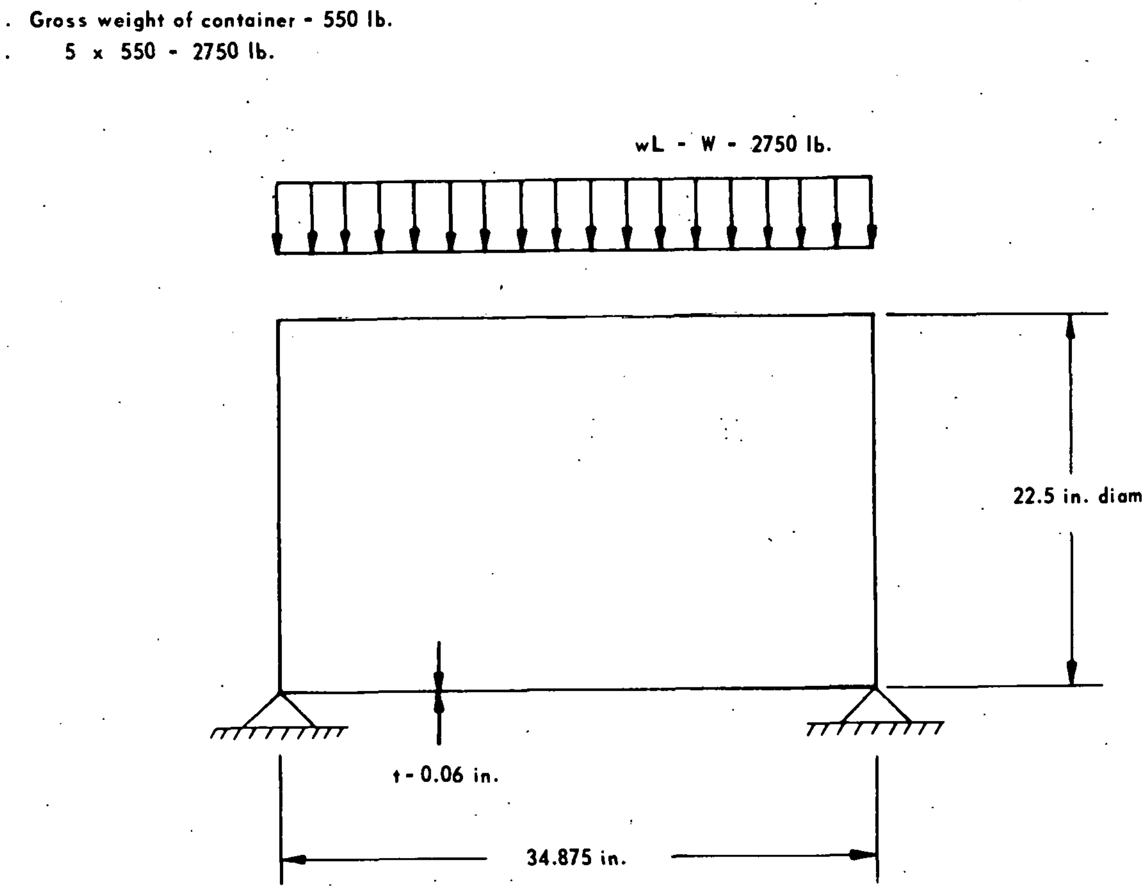


FIGURE 8-14 - Drum load resistance.

M = maximum bending moment,

$M = 5\,WL/8$ (in. lb),

$Z = I/C$ = section modulus of drum

$= \pi(R_o^4 - R_i^4)/4R_o$

$\cong \pi R_o^2 t$ (in.^{3}) for a large diameter, thin-walled cylinder,

W = weight of drum, $W = 550$ lb,

L = length of drum, $L = 34.875$ in.,

R_o = outside radius of drum, R_o = 11.25 in., and

t = thickness of drum, $t = 0.06$ in.

The computed maximum bending moment is

$$M = 5(550)(34.875)/8$$
$$= 12{,}000 \text{ in.-lb.}$$

The computed section modulus is

$$Z = \pi R_o^2 t = \pi(11.25)^2(0.06)$$
$$= 23.85 \text{ in.}^3$$

The maximum bending stress is then

$$S = 12{,}000/23.85 = 500 \text{ psi}$$

Since the material yield stress of 27,000 psi is 54 times as great as the calculated results, the AL-M1 container satisfies the load resistance requirement.

8.7 External Pressure

8.7.1 REQUIREMENT

The containment vessel must be capable of withstanding an external pressure of 25 psi without any loss of contents; that is, no leaks or failure will occur due to yielding. Thus, each of the three AL-M1 configurations is analyzed in the following to determine that 25 psi external loading will not produce stress that exceeds the yield stress at 300°F.

8.7.2 CONFIGURATION-1

This inner container is shown in Figure 8-15. It is made of stainless steel with a yield stress of 11,900 psi at 300°F. First the cylindrical shell is examined using section UG-28 of the ASME Code. It is calculated that the allowable load, P, is

$$P = \frac{B}{(D_{o/t})} = \frac{12000 \text{ psi}}{(10 \text{ in.})/(0.25 \text{ in.})}$$
$$= 300 \text{ psi}$$

where

B is a function of $D_{o/t}$ and L/D_o and is evaluated from Figure UHA-28.1, p. 302, ASME Sec. VIII, Div. 1,

D_o is outside diameter,

t is wall thickness, and

L is length.

Thus, the cylindrical shell has a calculated allowable external pressure of 300 psi which exceeds the 25 psi requirement by a large margin.

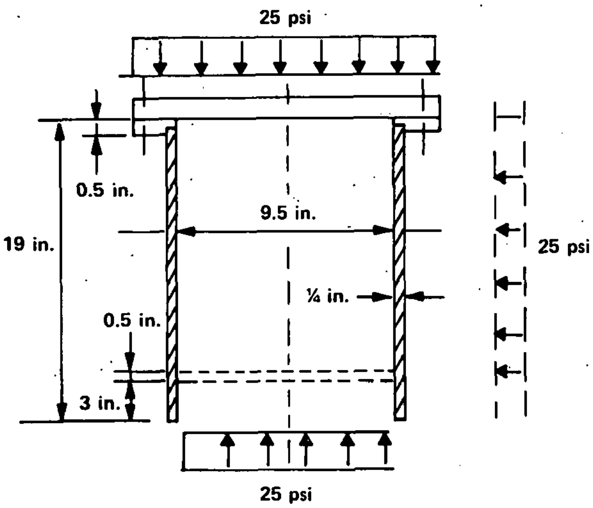


FIGURE 8-15 - Configuration-1 inner container.

The bottom plate approximates a circular plate with semifixed edges under a uniform loading. It is treated as a supported edge plate (higher stress case). The applicable formulas for stress in this plate are:

$S_{max} = 1.24R^2P/t^2$ for circular plate with supported edges.

$$S_{max} = \frac{(1.24)(4.75)^2(25)}{(0.5)^2} = 2798 \text{ psi.}$$

Thus, the yield stress is not exceeded. We now determine the allowable pressure

$$P = \frac{St^2}{(1.24)(4.75)^2} = \frac{11,900\ (0.5)^2}{(1.24)(4.75)^2}$$

$$= 106 \text{ psi}$$

which provides an ample margin of safety, M.S.,

$$\text{M.S.} = (106/25) - 1 = 3.25.$$

The top plate is treated as a uniformly loaded circular plate supported at the O-ring diameter.

$$S_{max} = \frac{1.24\ R^2P}{t^2}$$

$$= \frac{(1.24)(4.985)^2(25 \text{ psi})}{(0.5)^2}$$

$$= 3081 \text{ psi.}$$

We now find the allowable pressure at 300^oF,

$$P = \frac{St^2}{(1.24)(R^2)} = \frac{11,900 \times 0.5^2}{(1.24)(4.985)^2}$$

$$= 96.5 \text{ psi;}$$

again,

$$M.S. = \frac{P_{allow}}{P_{act}} - 1 = \frac{96.5}{25} - 1$$

$$= 2.9$$

thus, the top plate is limiting in configuration-1, but is more than adequate.

8.7.3 CONFIGURATION-3

This inner container is shown in Figure 8-16. It is made of 6061-T64 aluminum and has a yield stress of 25,000 psi at 300°F. Again we first examine the main body cylinder with dimensions as shown.

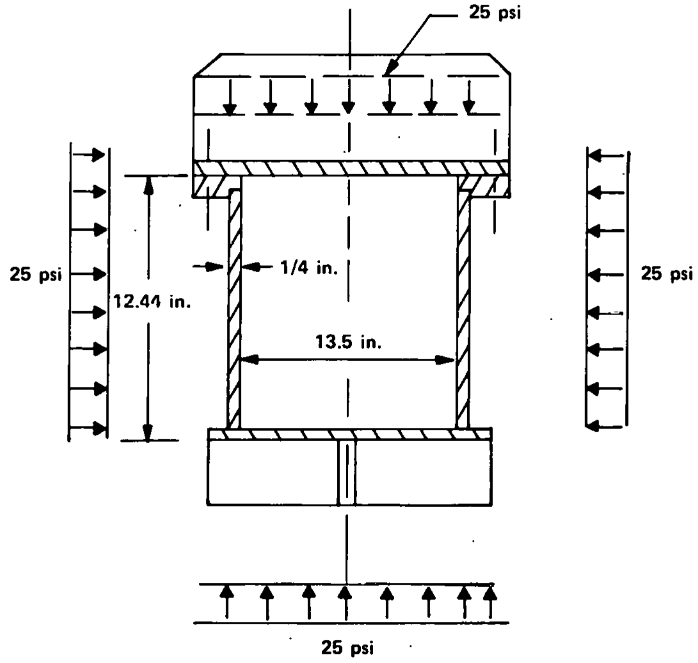


FIGURE 8-16 - Configuration-3 inner container.

From the dimensions shown in Figure 8-16, we have a ratio of outer diameter to wall thickness of

$$D_o/t = 13.5/0.25 = 54.0.$$

We also have a length to diameter ratio of

$$L/D_o = 12.44/13.5 = 0.92.$$

Using Figure UNF-28.30 (in pink addenda) of ASME UG-28C, revised summer 1974, and noting that $D_o/t > 10$, we find the factor

$$B = 9000.$$

From this we calculate the maximum allowable pressure

$$P_{allow} = \frac{4B}{3(D_o/t)} = \frac{4(9000)}{3(54)} = 222 \text{ psi.}$$

Thus, the main body cylinder is adequate and has a margin of safety of

$$M.S. = (222.2/25) - 1 = 7.9.$$

For the bottom plate using Section UG-34, ASME Code, with

C = head attachment factor = 0.5 [Figure UG-34(e) and (f)]

P = design pressure = 25 psi

d = internal diameter = 13.0 in.

S = max. allowable stress value = 25000 psi at 300°F (AL 6061-T64)

t = actual thickness = 0.50 in. (ASME Table UNF-23.1, p. 12)

The required thickness is

$$t = d\sqrt{CP/S} = 13\sqrt{0.50(25/25000)}$$

$$= 0.291 \text{ in.}$$

and the allowable pressure is

$$P_{yield} = \frac{t^2 S}{d^2 C} = \left(\frac{0.50}{13}\right)^2 \left(\frac{25000}{0.50}\right)$$

$$= 74.0 \text{ psi.}$$

Thus, the bottom plate will not yield at the stipulated pressure.

Analysis of the top plate per ASME code follows the same procedure as for the bottom plate only the diameter dimension and the attachment factor will change.

For top plate:

$C = 0.3$, from Figure UG-34 (J) and (R)

$P = 25$ psi

$d = 13.335$ in.

$S_{yield} = 25000.$

Required thickness

$$t_{req} = d\sqrt{CP/S}$$

$$t_{req} = 13.335\sqrt{0.3(25/25000)}$$

$$= 0.23 \text{ in.}$$

versus 0.375 in. provided at gasket ¢.

The allowable pressure with 0.375 in. thick plate is

$$P = \frac{St^2}{Cd^2} = \frac{25000}{0.3}\left(\frac{0.375}{13.335}\right)^2$$

$= 65.9$ psi, at yield which is 263% of that required.

8.7.4 CONFIGURATION-5

This inner container is shown in Figure 8-17. It is made of 316 stainless steel. From the ASME Code Section UG-28(c) revised summer 1974, we have for the main body cylinder of length, $L = 19$ in.; diameter, $D_o = 6.625$ in.; and thickness, $t = 0.134$ in.;

$$L/D_o = 19/6.6 = 2.9$$

$$D_o/t = 6.625/0.134 = 49.4.$$

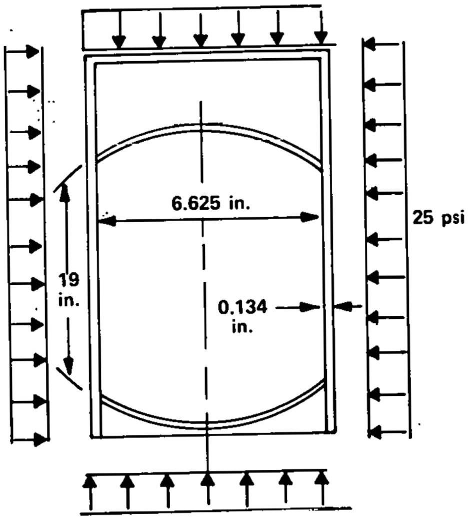


FIGURE 8-17 - Configuration-5 inner container.

Using Figure UHA-28.4 (P-305), we find the factor, B, is

$$B = 9900 \text{ psi (up to } 100^{\circ}F)$$
$$= 7500 \text{ psi } (300^{\circ}F).$$

Then, the allowable pressure, P, is

$$P = B/D_{o/t} = 9900/49.4$$
$$= 200.4 \text{ psi up to } 100^{\circ}F$$
$$= 7500/49.4 = 152 \text{ psi at } 300^{\circ}F.$$

These values are considerably above the required pressure of 25 psi, and thus, the cylinder is adequate.

The dished top and bottom heads will be analyzed under section UG-33 "Formed Heads, Pressure on Convex Side", ASME Code. For this case reference is back to UG-28(d) with the appropriate length factor, L_i, and head thickness, t_h, having values of

$$L_i = 6 \text{ in.}$$
$$t_h = 0.124 \text{ in.}$$

Then

$$L_{i/t_h} = 48.4$$

$$L_{i/100t_h} = 0.484$$

From chart Figure UHA-28.4, p. 305, the factor, B, is

$$B = 14500 \text{ psi at } T = 100^{\circ}F$$
$$B = 11000 \text{ psi at } 100^{\circ}F$$
$$< T < 300^{\circ}F.$$

and the allowable pressure, P, is

$$P = B/(Li/th) = 14500/48.4$$

$$= 300 \text{ psi at } T = 100^{\circ}F$$
$$= 11000/48.4$$
$$= 227 \text{ psi at } 100^{\circ}F < T < 300^{\circ}F.$$

Because the inner cylinder and end caps can safely withstand the required pressure, the container meets the standard for external pressure.

References

1. J. M. Guy et al., ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division 1, ASME, New York, N.Y. (1971).
2. "Fuel Shipping Container Tiedown for Truck Transport" (Standard F8-11T), Division of Reactor Development and Technology, USAEC (January 1975).
3. 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 retain its effectiveness 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 demonstrated that the requirements are satisfied.

9.2 Heat

Direct sunlight at an ambient temperature of 130°F in still air would not increase the temperature of the drum, insulation, or the inner containers in excess of design capabilities.

The calculation applies to all three configurations. The procedure consists of determining the heat load from the sun and the resulting external drum surface temperature that 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 thoughout 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 upright container at an angle perpendicular to a diagonal drawn through the drum. The calculations for a 55-gal drum are as follows:

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

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

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 data for a similar 55-gal package[2]. 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 275 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. 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 10 W the drum surface temperature is then 101 + 36 + 30 = 167°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 preceding calculations are summarized in Table 9-1. It is interesting to note in Table 9-1 that the inner container temperatures for the configuration-5 are slightly higher than those for configurations-1 and -3 even though the internal heat load is substantially less for the configuration-5. This is due to the added thermal insulation provided by the configuration-5 insulating sleeve.

Thus, the heat input from the sun will not cause the inner container temperatures to exceed design capabilities.

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

		In 100°F Shade		Intermediate Calculations			In 130°F Sun	
Configuration	Maximum Contents Heat Load (W)	Drum (°F)	Inner Cont. (°F)	Proj. Area (ft^2)	Solar Load (W)	Solar Increase (°F)	Drum (°F)	Inner Cont. (°F)
1,3	10	101	111	6.54	275	36	167	177
5	3.3	100	116	6.54	275	36	166	182

In fact, the inner containers, as protected by their outer insulating assemblies, 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.

9.3 Cold

The cold test requires evaluation or testing at an ambient temperature of -40°F in still air and shade. It was concluded that this temperature will not decrease the effectiveness of the packages.

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 pressure (ASME code) at 300°F for all configurations is in excess of the 22 psig which would result from the reduced atmospheric pressure requirement.

9.5 Vibration

The vibration test requires that packaging be capable of withstanding vibration normally incident to transport. The capability of the AL-M1 containers to withstand normal vibration is well documented as a result of special tests and routine use. A complete AL-M1 package, including nonradioactive contents, was subjected to laboratory tests which included both lateral and axial shake, rattle, and roll tests for ensuring the product quality of the contents under severe conditions. An actual road test was then performed from Livermore, California, to Miamisburg, Ohio. The road test confirmed that the laboratory tests were more severe than actual road conditions.

Since 1968, approximately 150 shipments over various road conditions have been successfully completed. Neither the special tests nor routine use provides any evidence of damage caused by vibration.

9.6 Water Spray

A water spray sufficiently heavy to keep the entire exposed surface of the package, except the bottom, continuously wet during a period of 30 min will not damage 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 as it was demonstrated that only minimal damage to the drums incurred as a result of the 30-ft drop tests discussed in Section 10 of this report. Also, this test was performed for a 55-gal package by the University of California[3] 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 that 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 weights are in excess of 110 lb, since the configuration-1 and -3 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 disscussed in the previous section and would not damage the packages in any way that would reduce the volume or effectiveness.

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 that 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 Company [4,5]. It is also substantiated for the 55-gal size 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 of 2.0 in the limit (Reference 6, p. 368, Reference 7, p. 40). The effective dropped load striking the drum surface is determined using the limit value as

$$P = 2.0(13\text{ lb}) = 26\text{ lb (for both drum sizes)}$$

Separate calculations will be made for the cylindrical surface and for the 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).

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:

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

$$Y = \frac{26}{30 \times 10^6 (0.0598)}$$

$$\left[0.48\left(\frac{34.81}{11.28}\right)^{0.5}\left(\frac{11.28}{0.0598}\right)^{1.22}\right]$$

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

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.) 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 6, Table X, Case 8)

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

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

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

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 are obtained as follows:

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

$$= 3461 \text{ psi}$$

$$S_T = \frac{3(26)}{(3)(3)(\pi)(0.0598)^2}$$

$$\left(1 - \frac{(0.625)^2}{(11.28)^2}\right) = 769 \text{ psi.}$$

TABLE 9-2. ANALYSIS OF DROPPED ROD ON CYLINDRICAL SURFACE

Container Dimensions (in.)			Bending Stress (psi)	Load Deflection (in.)
Length	Radius	Thickness		
34.81	11.28	0.0598	17,450	0.0073

$$Y = \frac{(3)\ (26)\ (3^2-1)}{(2)(\pi)(30\times10^6)(3^2)(0.0598)^3} \left[\frac{(11.28)^2 - (0.625)^2}{2} - (0.625)^2 \log_e \frac{(11.28)}{(0.625)}\right]$$

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

These results 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 container. This stress (17,450 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 [4,5].

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 although 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 Compressions

This test requires a compressive load equal to either five times the weight of the package or to 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.

TABLE 9-3. ANALYSIS OF DROPPED ROD ON CONTAINER LID

Radius (in.)	Thickness (in.)	S_R (psi)	S_T (psi)	Y (in.)
11.28	0.0598	3461	769	0.107

Previous testing by others indicates that the 55-gal size satisfies the compression requirements. Dow Chemical Company[5] tested a package using two 55-gal drums welded together and loaded with 5,250 lb to qualify it for a 1,050-lb maximum gross weight, which far exceeds the 550-lb maximum gross weight of the 55-gal AL-M1 packages.

The testing was supplemented with an evaluation. Of the two alternate drum types, the DOT 6C has I-bar rolling hoops held in place by rolled-in corrugations whereas the 17-C has only rolled or swaged-in rolling hoops. Relative to compressive loads, however, the same evaluation can be used for both drum types, because the thickness of the sides is the same in both types and the shape of the rolled-in corrugations of the 6C is essentially the same as the shape of the swaged-in rolling hoops of the 17C. The evaluation was based on a load of 2750 lb, which is five times the assumed gross weight of 550 lb. The alternate criteria yield a value of only 804 lb. The 55-gal drum is illustrated in Figure 9-1.

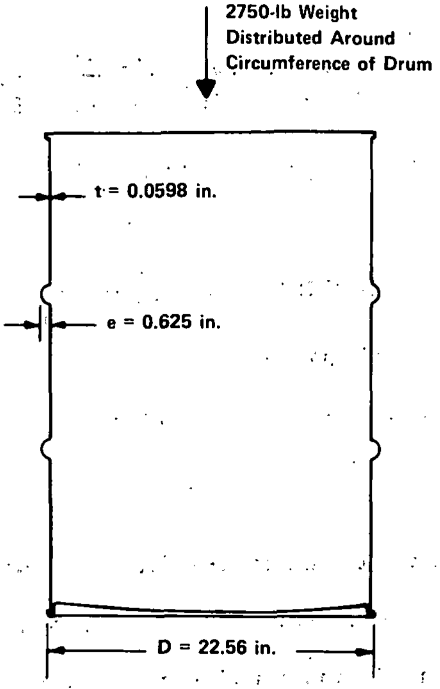


FIGURE 9-1 - Compressive load evaluation for 55-gal drum.

The wall thickness (t) is 0.0598 in., and the outside diameter of the drum is 22.62 in. The longitudinal compressive stress (S) is calculated by dividing the load by the cross-sectional area of the drum wall as follows:

$$S = F/\pi Dt$$

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

The result is

$$S = \frac{2750}{\pi(22.62)(0.0598)}$$

$$= 647 \text{ psi.}$$

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

The bending stress that occurs in the drum rolling hoops was also determined. 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 under conditions of a longitudinal stress resultant. The bending moment and maximum bending stress are then found. The longitudinal stress resultant (S) is given by:

$$S = \frac{F}{\pi D} = \frac{2750}{\pi(22.62)} = 38.7 \text{ lb/in.}$$

The bending moment (M) at the hoop is then

$$M = S(e) = 38.7 \text{ (0.625 in.)}$$
$$= 24.2 \text{ in. lb/in.}$$

where e is the size of the rolling hoop.

The maximum bending stress is

$$S_{max} = \frac{6M}{t^2} = \frac{6(24.2)}{(0.0598)^2} = 40{,}600 \text{ psi.}$$

This 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 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.

The critical buckling stress (S_{cr}) is given by the following equation:

TABLE 9-4. SUMMARY OF DRUM DIMENSIONS AND RESULTS OF COMPRESSION CALCULATIONS

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)
22.62	0.0598	0.625	2750	647	40,600	96,000

(Reference 6, 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, $R = 11.31$ in., and

μ = poisson's ratio, $\mu = 0.3$.

Thus, the critical buckling stress is:

$$S_{cr} = \frac{30 \times 10^6 (0.0598)}{11.31 \sqrt{3}\ (1-0.09)} = 96{,}000 \text{ psi.}$$

This value for the ultimate capability could never be reached in the drum. The critical buckling stress is shown in Table 9-4.

In summary, 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 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.

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. J. F. Griffin et al., Safety Analysis Report for Packaging (SARP): USA/5790/BLF (ERDA-AL) and USA/5791/BLF (ERDA-AL), MLM-2242 (April 30, 1976), 89 pp.
3. J. R. Gaskill and R. D. Taylor, An Improved Shipping Container for Fissile Material, UCRL-14903, University of California (June 3, 1968).
4. 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).
5. 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).

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

7. 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 containers of all three configurations were subjected to the complete series of four tests. The configuration-1 package was prepared with two chromel/alumel fiberglass insulated thermocouples fastened with glass tape to the inner container and extended through the vent port in the drum head as seen in Figure 10-1. Temperature sensitive paints were applied to the bottom surface of the clamping fixture within the inner container, to the exterior surface of the inner container, and to the interior sheetmetal surface of the insulated drum assembly. The temperature sensitive paints were formulated to melt at 100°F, 200°F, 300°F, 400°F, and 500°F and were identified by various colors. Independent tests showed that the paints were accurate within ±2°F. Three bags of lead shot weighing 5 lb each were mounted in the clamping fixture to simulate the contents weight. On final assembly of the package, the bolt used to fasten the closure ring in place was aligned with the seam of the drum so that this could be identified as the weakest part of the drum in the free drop test.

The configuration-3 package was prepared in the same manner as the configuration-1 package. The temperature sensitive paints were applied at considerably more locations. The paints used were formulated to melt at 200°F, 300°F, 400°F, 500°F, and 600°F. Also, the melting temperatures were written on the sides of the inner container and simulated weight cylinder (see Figure 10-2) with paint in stick form. The simulated weight consisted of a 10-in. long by 8-in. diameter steel cylinder weighing 30 lb. It was secured in the holding

FIGURE 10-1 - Package assembly, configuration-1. Temperature sensitive paints and thermocouples were used. The void between the inner container and the drum assembly is frequently packed with ice during shipment.

FIGURE 10-2 - Inner container assembly, configuration-3. The temperature sensitive paint spots and markings are evident. The cylinder in the foreground was used to simulate the typical weight to be shipped. The polyethylene sheet and glass vials were packaged inside.

fixture inside the inner container. Five small glass vials, containing temperature sensitive paint, and a sheet of polyethylene were placed inside the simulated weight. A second sheet of polyethylene was placed in the annular space between the simulated weight and the inside wall of the inner container. One thermocouple was fastened to the inner container as shown in Figure 10-3. The closure bolt was aligned with the drum seam during final assembly.

The configuration-5 package was prepared somewhat differently. The inner container was loaded with 5700 of 1.16 in. diameter Linde 4A molecular sieve pellets, and two liters of water were in turn sorbed onto the molecular sieve material. The container was then helium leak checked at 10 psig using a sniffer probe technique. No leaks were detected and it was estimated that no leaks greater than 1 x 10^{-6} std cm^3/sec were present before the accident tests. For the two drop tests, 164 lb of lead weights were fastened to the outside of the drum to bring the package weight up to 550 lb. Before the fire test, thermocouples were placed at six locations - five within the assembled package (see Figure 10-4) and one on the outer surface of the drum.

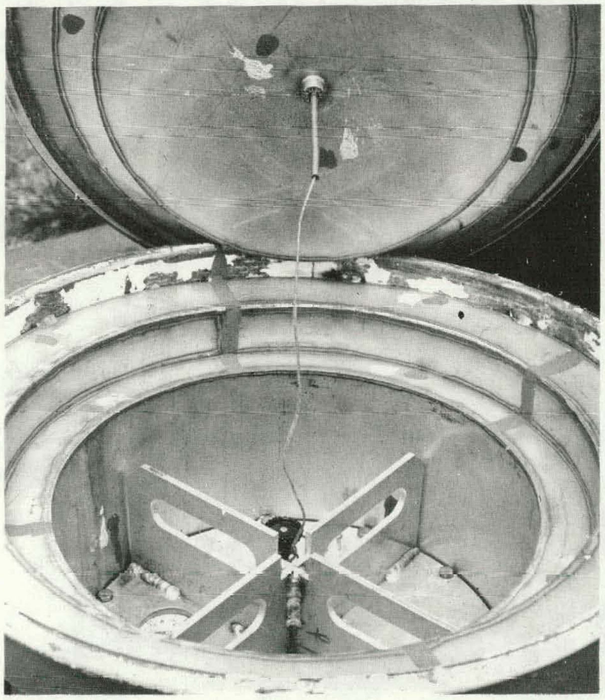


FIGURE 10-3 - Package assembly, configuration-3. Spots of temperature sensitive paints were applied prior to testing.

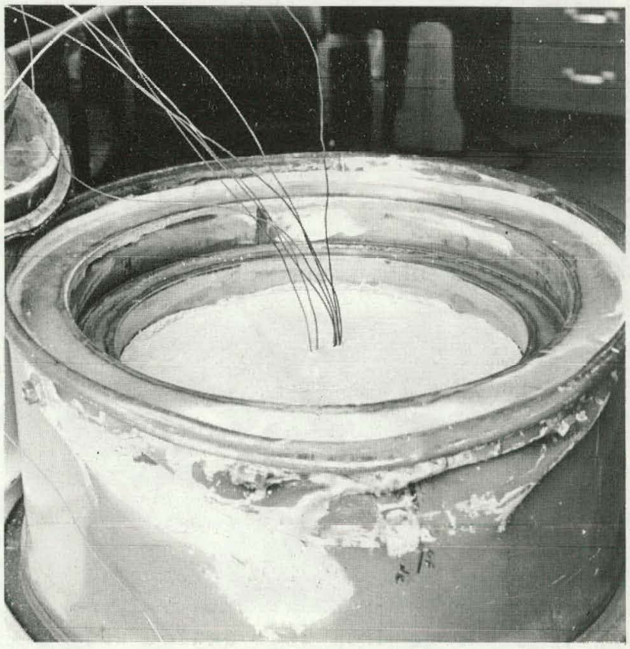


FIGURE 10-4 - Package assembly configuration-5 after the drop tests and prior to the fire test.

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 was equipped with a 2-ton hoist to drop the container from a height of 30 ft onto a steel-covered concrete drop pad. A chain sling was fashioned, and the container was oriented upside down at a 45° angle so that the bolt on the bolt ring would strike the pad first as shown for the configuration-1 package in Figure 10-5.

FIGURE 10-5 - Free drop test angle, configuration-1. The container was oriented upside down at a 45° angle to obtain maximum damage.

Figure 10-6 shows the container at the required 30-ft height just prior to manual actuation of the quick release hook.

Figure 10-7, taken just prior to impact, shows that the container was dropped in precisely the initial orientation since no twisting motion was imparted to it on release.

10.4 Puncture Test Procedure

This test requires a free drop through a distance of 40 in. striking, in the position maximum damage is expected, the top end of a vertical, cylindrical,

FIGURE 10-6 - Free drop test height, configuration-1. The container is seen suspended at the required 30 ft height.

FIGURE 10-7 - Free drop test, configuration-1. Just prior to impact, the container is still oriented at the proper angle.

mild-steel bar mounted on an essentially unyielding horizontal surface. The bar will 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 shall be perpendicular to the unyielding horizontal surface.

This test was conducted in a manner similar to the Free Drop test. Figure 10-8 shows the configuration-1 package suspended 40 in. above the top of the 6-in. diameter cylinder.

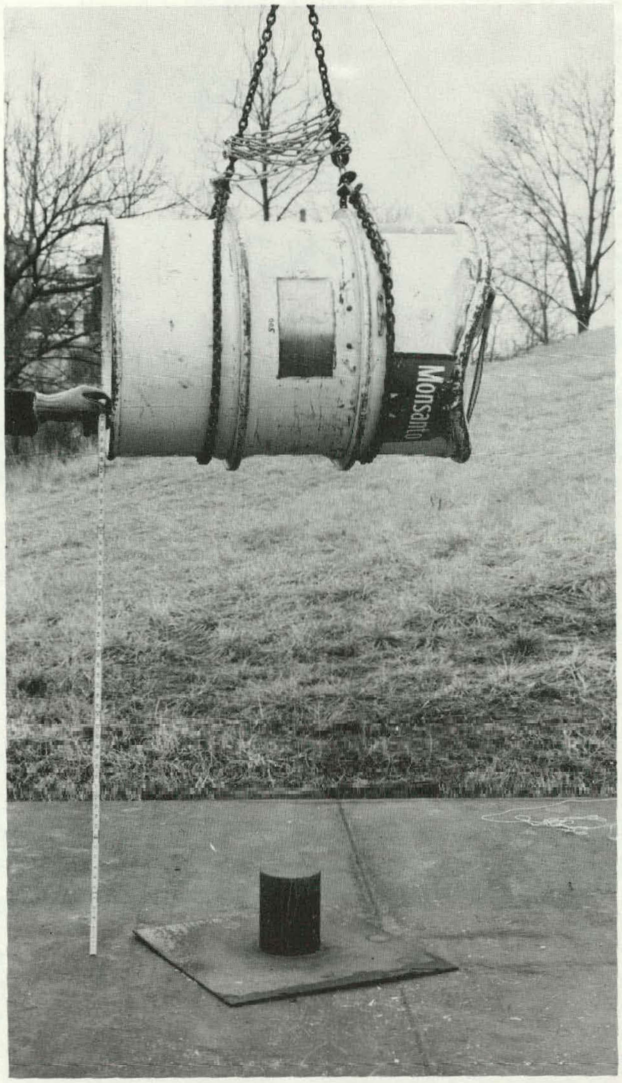


FIGURE 10-8 - Puncture test height, configuration-1.

Figure 10-9 shows the container impacting on the cylinder.

10.5 Thermal Test Procedure

This test requires exposure to a thermal environment in which the heat input to the package is not less than that which would result from exposure of the whole

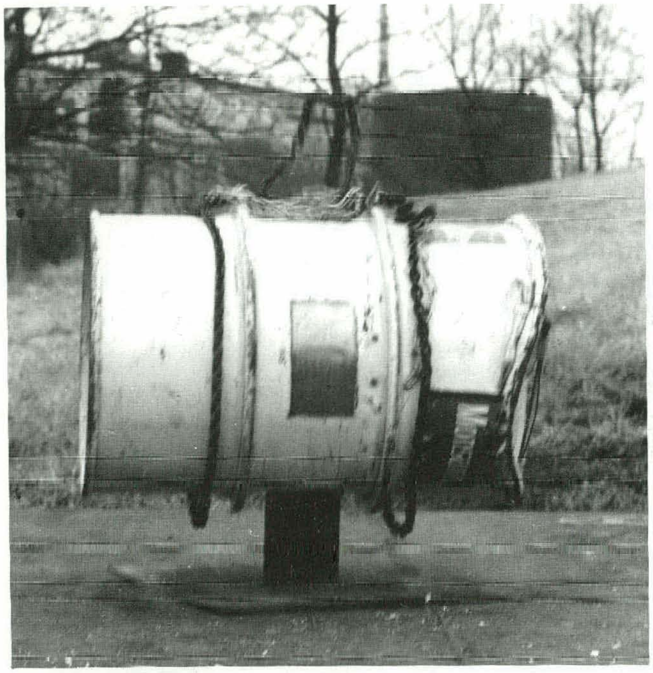


FIGURE 10-9 - Puncture test impact, configuration-1.

package to a thermal radiation environment of 1475°F 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 at Mound Laboratory was designed to meet the DOT/ERDA hypothetical accident conditions. To simulate actual conditions, the test facility provides an open, aviation-gasoline-fueled fire. The facility has been improved several times over the years.

The facility as used for the configuration-1 test is shown in Figure 10-10. The configuration-1 container is shown prior to the test mounted on a stand 2 ft above the water surface. It was centered within the burning area approximately 3 ft from the sides since a 2- to 3-ft flame thickness is equivalent to an infinitely thick wall[1]. The sheet-metal burning pan measuring 8 x 10 x 0.5 ft deep was filled to a depth of 5 in. with water for the aviation gasoline to float on and thereby avoid excessively heating the burning pan. Sheet-metal "blockout boxes" measuring 48 x 6 x 6-in. high were placed within the burning pan to decrease fuel consumption and smoke. The exposed surface area of the aviation gasoline floating on the water was reduced to 60% of the total area within the burning pan by the 16 blockout boxes. Addition of air for more efficient combustion provided additional smoke abatement. The portable diesel air compressor shown in Figure 10-11 supplied approximately 1000 ft^3/min (STP) of air to the fire

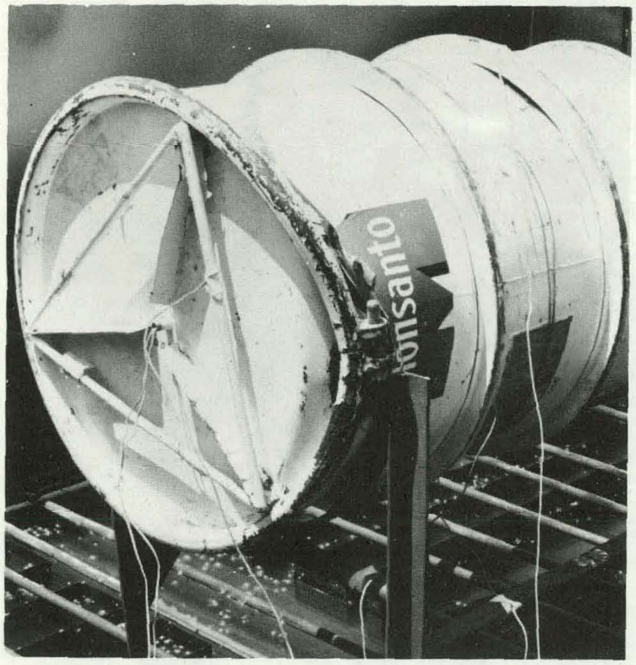


FIGURE 10-10 - Thermal test set-up, configuration-1 with thermocouple attached.

through the air manifold. A valve was provided in each of the 19 air supply pipes so that adjustments could be made to obtain uniform air distribution. Holes of 1/16-in. diameter were drilled horizontally completely through the pipes at 16-in. intervals, and the pipes were mounted in the manifold 6 in. apart. Alternate pipes were drilled with the holes staggered at 3-in. intervals. Sheet-metal panels 4 ft high surrounded the perimeter of the burning pan to reduce wind effects.

After the configuration-1 testing, additional panels were added to provide an 8-ft high wind shield on the west side for the configuration-3 test (see Figure 10-12). The combined effects of the reduction in fuel consumption, the addition of air, and the wind shield reduced the smoke from the black plume, typically produced during open tests[1], to the gray plume as seen in Figures 10-11 and 10-12.

Configuration-5 was fire tested in a facility that had been further improved by a water spray system that virtually eliminates the smoke, as seen in Figure 10-13.

Wind effects are reduced by 8-ft high firebrick walls on three sides. On the fourth side is a 4-ft wall that permits viewing and ease of handling the shipping containers. The base of the fire pit is poured concrete measuring 10 x 10 x0.5 ft deep.[2] 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.

FIGURE 10-11 - Thermal test area, configuration-1 test. The air compressor can be seen in the left background and the temperature recorder in the center background. The fuel flow was controlled at the panel mounted on the outside wall of the concrete block building as seen at the right. Firemen and firefighting equipment are at the far right.

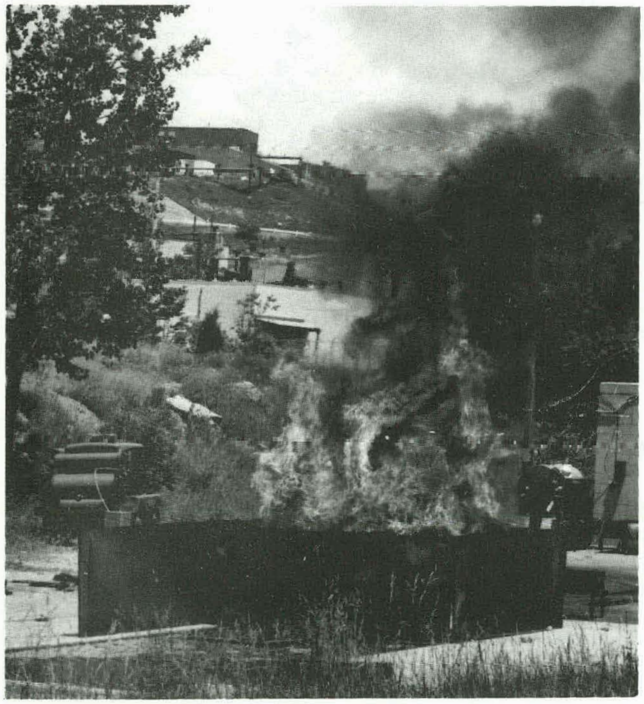


FIGURE 10-12 - Thermal test, configuration-3. A thick continuous wall of flame enveloped the container.

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 flame temperatures obtained throughout the tests are plotted as a function of time in Figure 10-14. The temperatures were measured at the top of the configuration-1 package, the bottom of

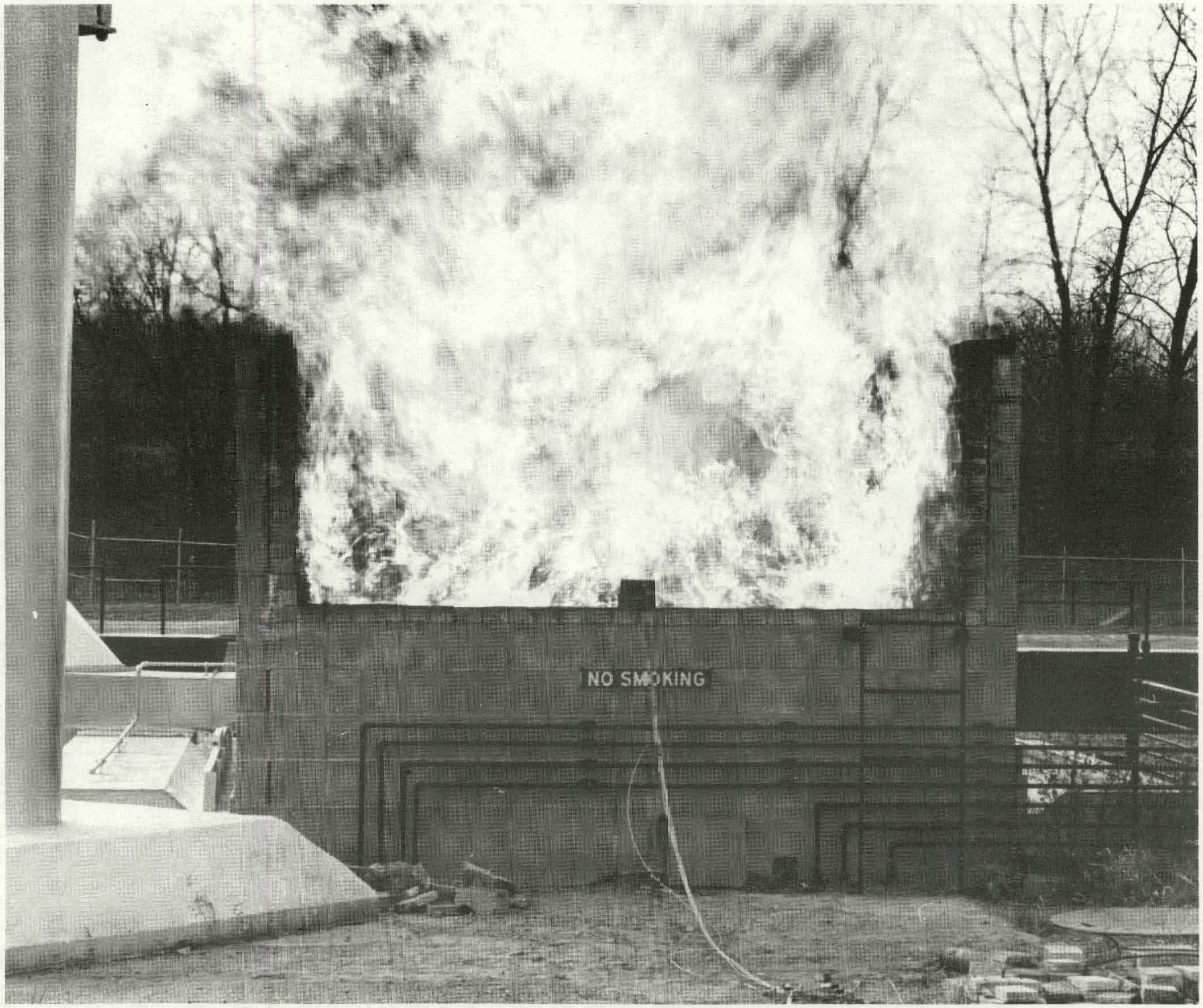


FIGURE 10-13 - Improved fire test facility during burn for configuration-5.

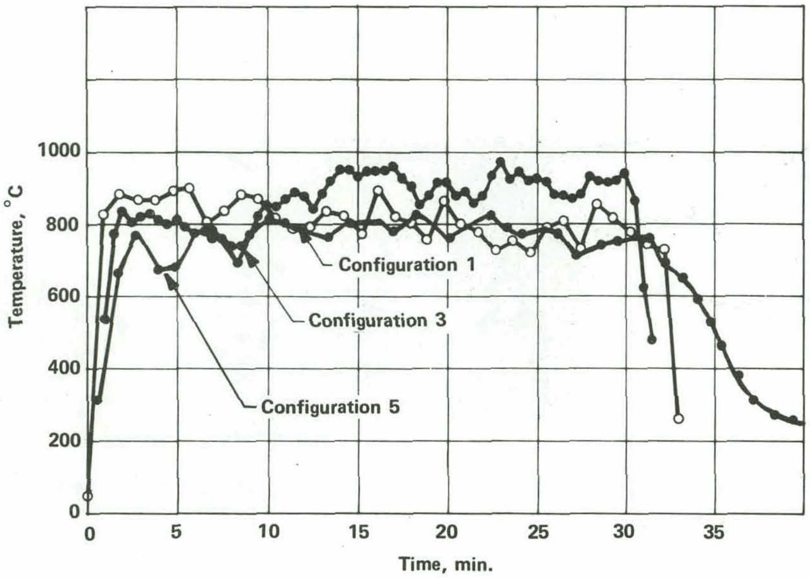


FIGURE 10-14 - Thermal test flame temperatures.

configuration-3, and the side of configuration-5. Chromel/alumel thermocouples and a multipoint recorder were used to monitor the tests. The flame reached the required 1475°F less than 2 min after ignition. Throughout the course of the tests, it was necessary to closely monitor the temperatures and adjust the fuel flow rates. A strong wind blew much of the flame away from the top of the container 20 min after the start of the configuration-1 test, and it was necessary to substantially increase the fuel flow in order to compensate for this. Otherwise, the tests proceeded without incident and a thick, continuous wall of flame enveloped the containers. The fire burned for 32 to 34 min for the tests, and the flames burned out within a few seconds after the fuel flow was stopped. No artificial cooling was used. The flame temperature ranged between 1326°F and 1648°F, fluctuating in the neighborhood of 1475°F during the configuration-1 test, and ranged between 1357°F and 1789°F fluctuating in the neighborhood of 1652°F during the configuration-3 test. During the configuration-5 test the flame temperature ranged between 1225°F and 1578°F, fluctuating in the neighborhood of 1475°F. Fuel consumption was somewhat over 200 gal for each of the tests.

Reliable thermocouple temperature measurements were not obtained for two of the inner containers. On conclusion of the configuration-1 test, the two thermocouples fastened to the inner container were found to have shorted out after the fiberglass insulation melted. In an effort to expediently correct this problem, the configuration -3 thermocouples were sheathed in copper tubing. The copper sheaths remained intact except for the one which contained the thermocouple running through the center of the drum lid to the inner container (see Figure 10-15). All thermocouples functioned properly during the configuration-5 test.

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

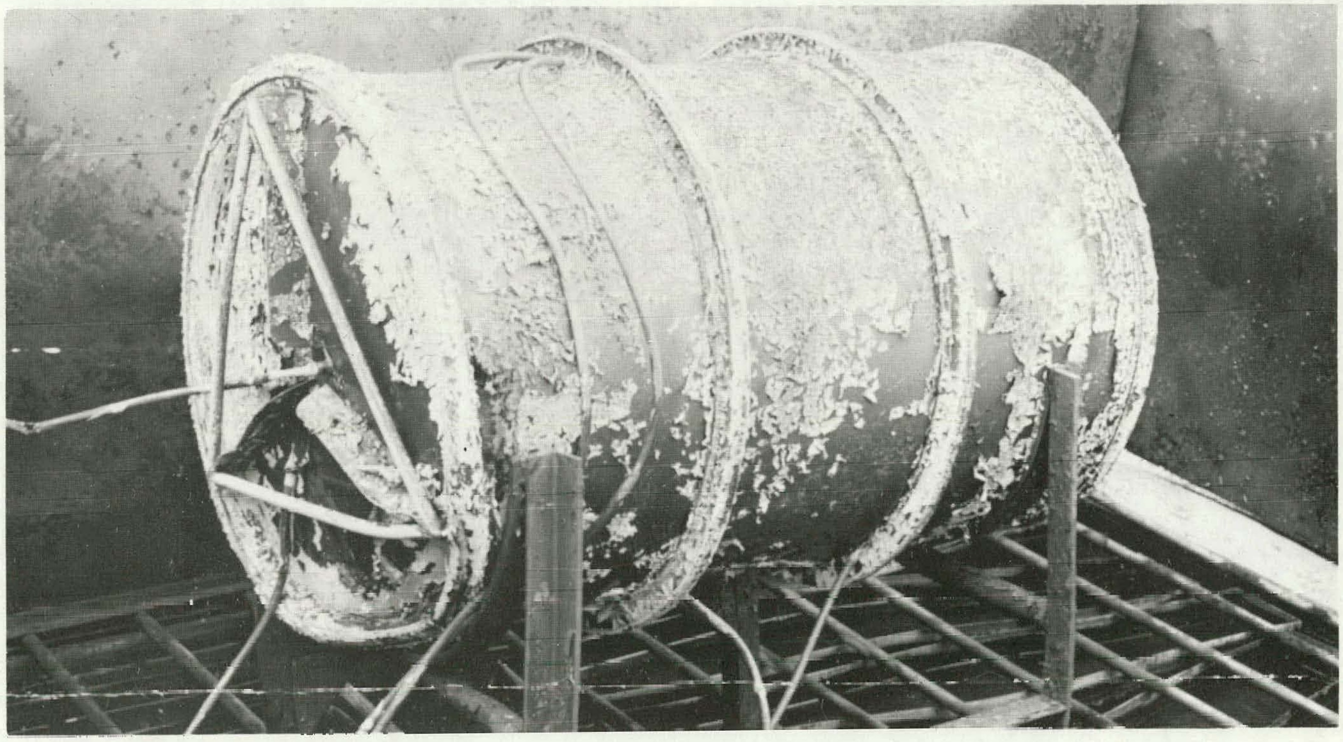


FIGURE 10-15 - After thermal test, configuration-3. There is no apparent damage to the container from the fire other than burning off the paint. The copper sheath for the thermocouple running through the drum lid to the inner container failed.

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. All inner containers were immersed overnight for 20 hr, since it was not convenient to withdraw them after the required 8-hr minimum period. These tests are shown in Figures 10-16, 10-17 and 10-18.

FIGURE 10-16 - Water immersion test equipment, configuration-1. The container is easily lowered into the immersion tank.

10.7 Hypothetical Accident Tests Results

10.7.1 FREE DROP

The 30-ft free drop caused obvious minor damage to the exterior drum surfaces, but did not damage the inner containers in any way that would decrease the containment capabilities. Figure 10-19 was taken immediately following the free drop and puncture tests for the configuration-1 package. It shows that the drum closure ring at the point of impact

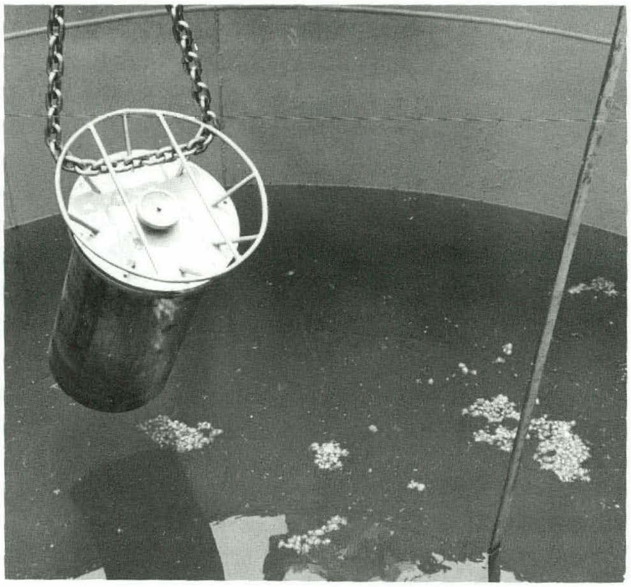


FIGURE 10-17 - Water immersion test, configuration-1. The pole to the right was used to measure the water depth. All parts of the container were under at least three ft of water.

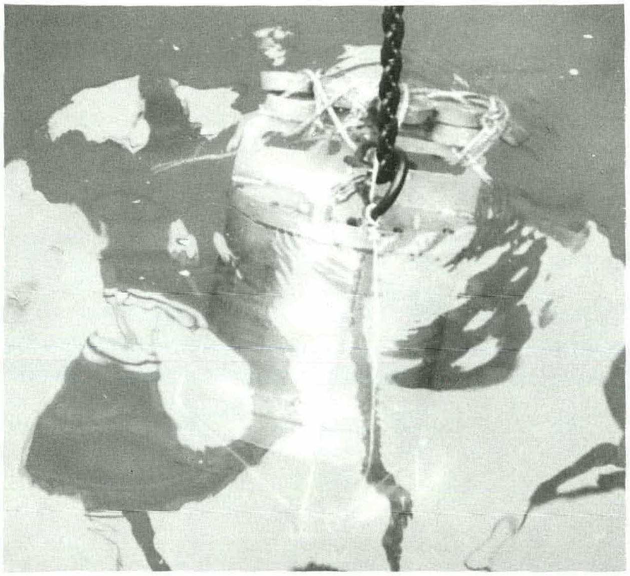


FIGURE 10-18 - Water immersion test, configuration-3. The aluminum container was weighted with lead in order to submerse it.

was displaced, relative to the upright position, a distance of 3 in. vertically and 1-in. horizontally. Figure 10-20 taken with the lid removed shows the damage after the fire test.

Figure 10-21 shows the damage to the lid. It was difficult to lift out the configuration-1 inner container and spacer because the insulated drum assembly was slightly out of round. The configuration-3 and configuration-5 drum assemblies sustained essentially the same damage as the configuration-1 drum assembly.

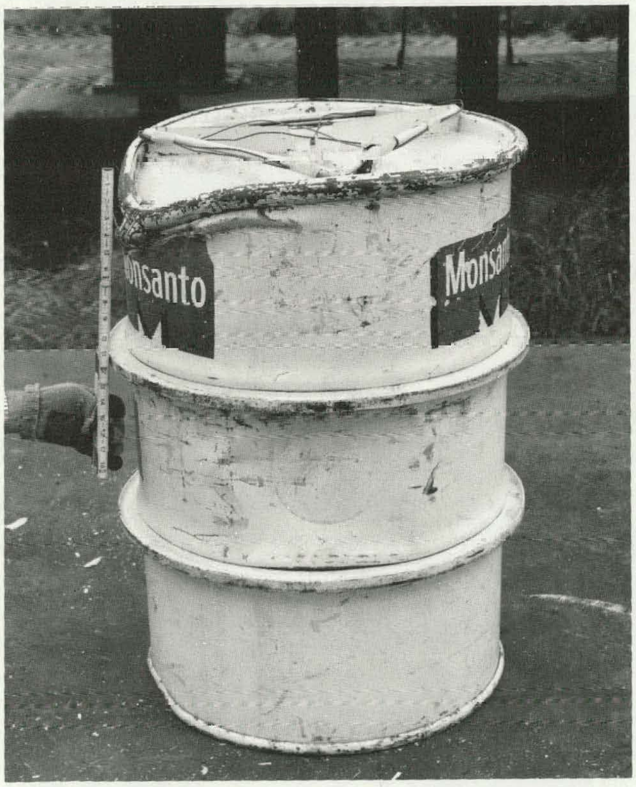


FIGURE 10-19 - After drop and puncture, configuration-1. The dent at the top left resulted from the 30 ft drop and the circular dent at the center resulted from the puncture test.

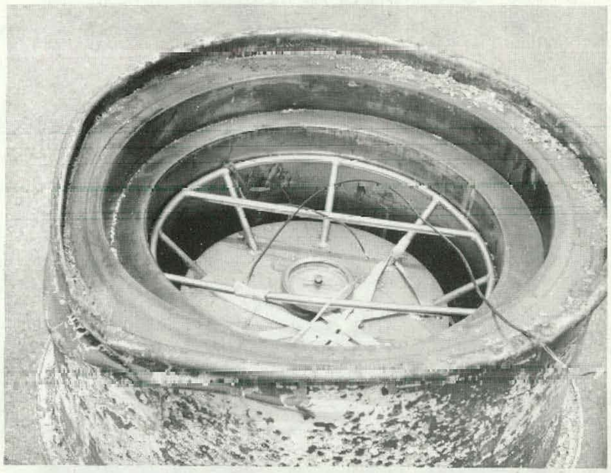


FIGURE 10-20 - Free drop damage to drum, configuration-1.


FIGURE 10-21 - Free drop damage to lid, configuration-1.

Figure 10-22 shows the minor damage sustained by the clampling fixture rods within the configuration-1 inner container. The three rods, which were used to fasten the 5-lb bags of lead shot in place, were bent slightly and one of the three cloth bags of shot

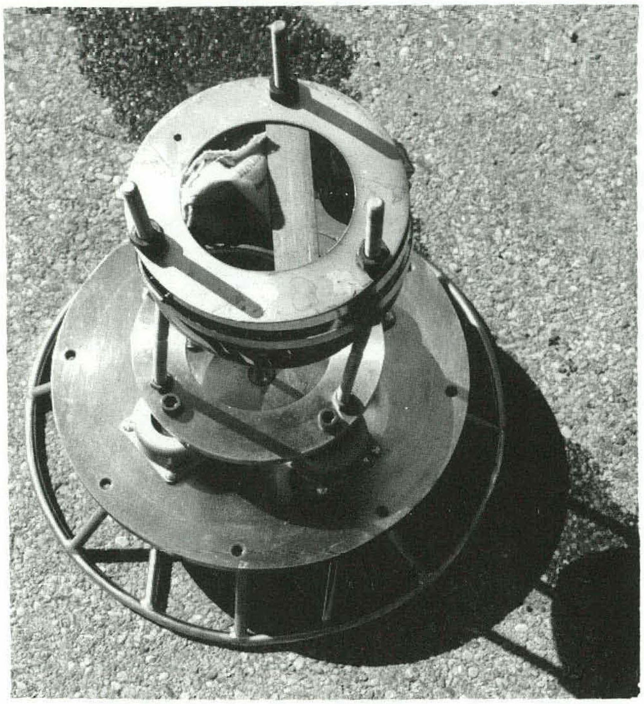


FIGURE 10-22 - Free drop damage to clamping fixture, configuration-1. The three long rods were slightly bent on impact with 15 lb (6.8 kg) fastened near the ends of the rods.

ruptured. Two of the three rods, which extend 2 in. above the top plate of the configuration-3 holding fixture, were bent approximately 30° from vertical (see Figure 10-23) when they hit the inside surface of the inner container lid. No damage was found on the configuration-5 inner container.

A careful visual examination did not reveal any additional damage. Subsequent successful water immersion and helium leak tests of all three configurations, which are discussed later in this report, support the conclusion that no other damage was sustained.

FIGURE 10-23 - Free drop damage to clamping fixture, configuration-3. Two of the three rods were bent on impact with 30 lb (135 kg) fastened inside.

10.7.2 PUNCTURE

The 40-in. drop on the 6-in. diameter cylinder slightly dented the exterior drum surfaces but caused no observable damage internally. Maximum displacement of the drum surface measured 1-in. for the configuration-1 container pictured in Figure 10-19. Maximum displacement of the configuration-3 drum surface was only 1/2-in. Displacement was not measured for the configuration-5 drum, but was similar to the other two.

10.7.3 THERMAL

The results of the 30-min fire at 1475°F were the same for both configuration-1 and -3. The temperature ranges indicated by the temperature sensitive paints were identical at corresponding locations. Neither inner container was damaged.

Observation of the containers during and immediately after the fires was uneventful. The containers did not bulge or deform in any way. The insulation was not observed to smolder or be consumed. The most noticeable change to the drum exterior was that the paint burned off.

The inner containers were removed from the insulated drum assemblies following the thermal test and visually examined prior to the water immersion test. Figure 10-24 shows the bottom of the configuration-1 inner container and Figure 10-25 shows the top of configuration-3 inner container. The glass tape used to hold the thermocouples in place was still slightly tacky. The silicone cement and the plastic valve handles, and a rubber grommet were unharmed. There was no evidence of damage as a result of the fire. The temperature sensitive paints on the external surfaces of the inner containers did not melt (see Figures 10-26 and 10-27). At all locations where the paints were applied on the internal surface of the insulated drum assembly and the enternal surface of the inner containers, the resulting temperature range was 400°F to 500°F for configuration-1 and -3. The 400°F paint melted at all seven locations on configuration-1 and all 20

FIGURE 10-24 - Thermal test visual examination, configuration-1. No damage to the gage and valve on the bottom of the container was observed.

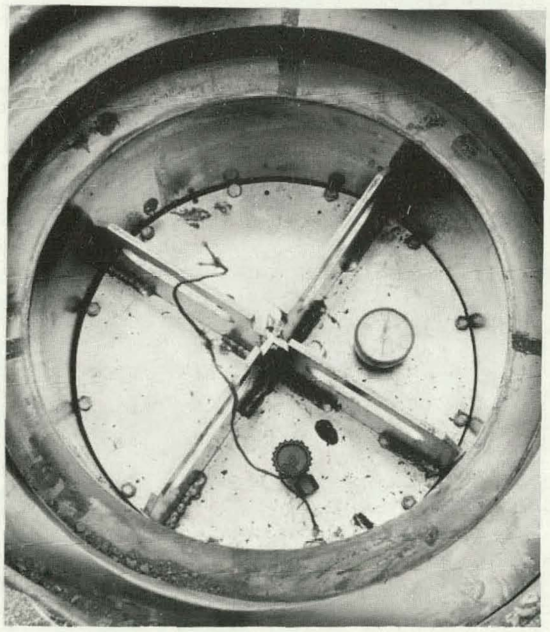


FIGURE 10-25 - Thermal test visual examination, configuration-3. No damage to the gage and valve on the top of the container was observed.

FIGURE 10-26 - Thermal test temperature, configuration-1. The 500°F (260°C) spot of temperature sensitive paint on the side of the inner container did not melt.

FIGURE 10-27 - Thermal test temperature, configuration-3. The 500°F (260°C) and 600°F (316°C) spots of temperature sensitive paint on the exterior surfaces of the inner container did not melt.

locations on configuration-3, but none of the 500°F paint melted at any of these locations. Thus, the temperature range was the same on both sides of the configuration-1 air gap (2-3/16 in.) and on both sides of the configuration-3 air gap (which is only a fraction of an inch).

Subsequent to the water immersion tests, the configuration-1 and -3 inner containers were disassembled and examined for evidence of damage and to determine the maximum temperatures reached internally. Figure 10-28 illustrates that the silicon O-ring, which was used to seal the containers, remained very resilient and appeared "like new." The polyethylene sheet and glass vials that were packaged inside the configuration-3 inner container were not damaged. Folds in the polyethylene sheet located next to the inner container wall as shown in Figure 10-29 partially stuck together, but were easily separated without

FIGURE 10-28 - O-ring undamaged in thermal test, configuration-3. The silicone O-ring remained "like new" and the polyethylene sheet packaged inside was not damaged.

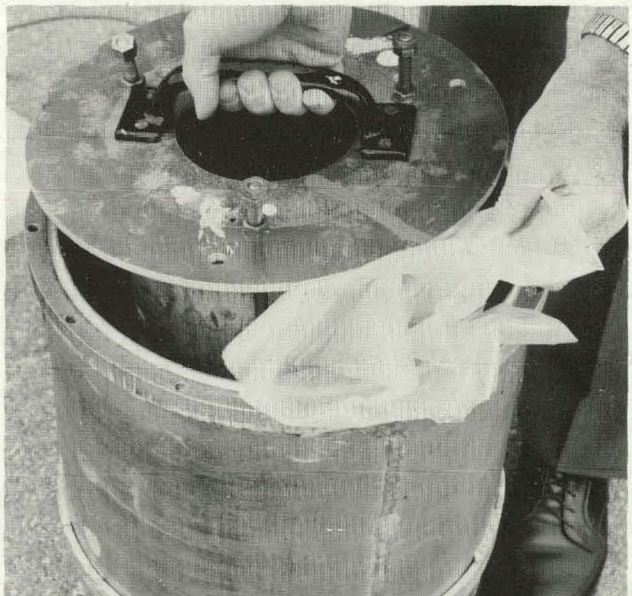


FIGURE 10-29 - Polyethylene after thermal test, configuration-3. The polyethylene sheet located next to the inner container wall stuck together somewhat, but was easily separated.

tearing. The temperature ranged between 200°F and 300°F inside both inner containers as determined by the temperature sensitive paints. Figure 10-30 shows the remaining paints on the cylindrically shaped simulated weight (configuration-3). It can be seen that none of the paints melted at 300°F or above. The spot of 200°F paint that had been brushed on appears partially melted, and the "200°F" marking which had been penciled on melted completely. Some of the 100°F and 200°F paints melted and leaked out of the small glass vials which had been wrapped in polyethylene sheet. Figure 10-31 shows the remaining three spots of paints, 300°F and above, on the end surface of the configuration-1 clamping fixture. Only the 100°F and 200°F paints melted inside the configuration-1 inner container.

The temperatures for the configuration-5 thermal test were monitored by thermcouples and recorded on a multipoint strip chart. The results are shown in Figure 10-12. Figure 10-33 shows the thermocouple locations schematically. The maximum temperature reached on the surface of the inner container was 252°F at the top cap.

In summary, the thermal tests did not cause any observable damage to the inner containers. The temperature at the

FIGURE 10-30 - Thermal test contents temperature, configuration-3. Temperature sensitive paint indicated that the temperature did not exceed 300°F (149°C). The 200°F (93°C) paint is only partially melted.

FIGURE 10-31 - Thermal test contents temperature, configuration-1. The three spots of temperature sensitive paint seen on the end surface of the clamping fixture did not melt indicating that the temperature did not reach 300°F (149°C).

exterior surface of the configuration-1 and -3 inner containers remained below 500°F throughout the tests. The temperature reached 252°F in configuration-5. The maximum temperature within all three inner containers stayed well below 300°F so that selection of this temperature for the safety evaluation of the radioactive materials to be shipped provides an adequate margin of safety.

10.7.4 WATER IMMERSION

Immersion of the inner containers under 3 ft of water for 20 hr did not cause any water leakage into the containers or damage the containers in any way. On disassembly, the configuration-1 and -3 containers were found to be completely dry inside as seen in Figure 10-34 for configuration-1. The cloth bags which contained the lead shot used to simulate the weight shipped were not damp to the touch. The lead shot from the bag which ruptured can be seen at the bottom of the container in the photograph. The test was more stringent than required since only an 8-hr period is required and since cold water in the immersion tank caused the pressure with the inner containers to decrease below atmospheric

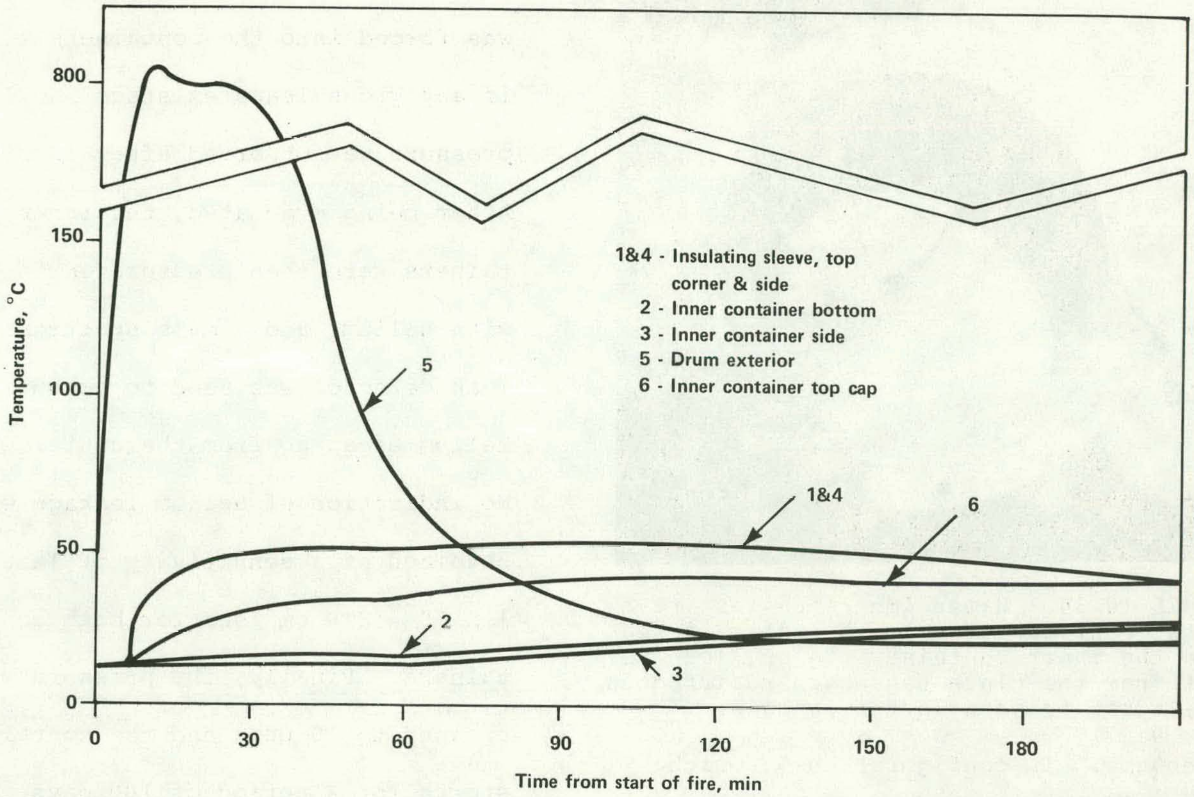


FIGURE 10-32 - Fire test results for configuration-5. See Figure 10-33 for thermocouple locations.

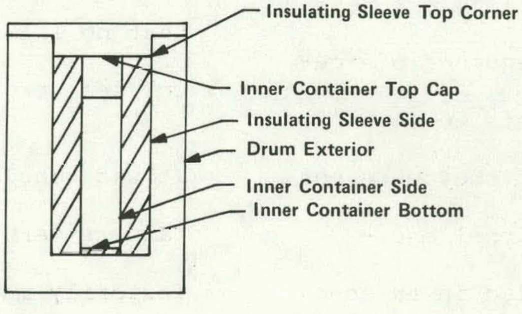


FIGURE 10-33 - Thermocouple locations for configuration-5 fire test.

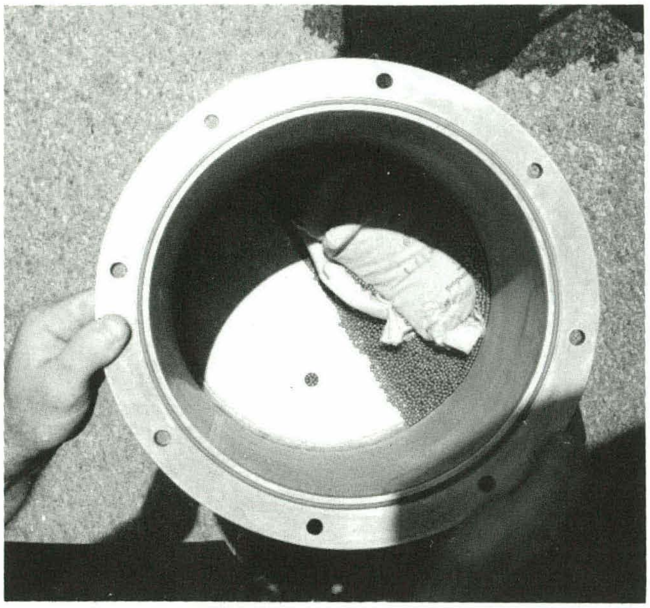


FIGURE 10-34 - Water immersion test results, configuration-1. No water leaked into the inner container. Also, lead shot from the cloth bag which ruptured on impact can be seen in the container.

pressure. In configuration-5, which had been preloaded with two liters of adsorbed water, no indication of any leakage of additional water was found.

10.8 Special Testing and Evaluation

10.8.1 HELIUM LEAK TEST

The stainless steel configuration-1 and -5 and the aluminum configuration-3 inner containers were helium leak tested following the previous sequence of four hypothetical accident tests to obtain additional assurance that they were not damaged. The configuration-1 and -3 containers were reassembled in an as-tested condition including the original silicone O-rings. First, 30 psig of air was forced into the containers to see if any gross leaks existed. No loss of pressure was observed after 15 min. After being evacuated, the inner containers were then pressurized to 30 psig with helium, and a mass spectrometer leak detector was used to measure any helium escaping from the containers. No indication of helium leakage was obtained at a sensitivity of less than 1×10^{-4} STP cm^3/sec for both containers. Finally, the pressure was decreased to 10 psig and the containers stored for a period of 100 days. No change in the pressure gage reading was observed during this period. The configuration-5 inner container was helium leak checked after the hypothetical accident test sequence and no leaks were detected. A sniffer probe technique was used at 10 psig, as before the accident sequence, and it was concluded that no leaks greater than 1×10^{-6} STP cm^3/sec were present.

It was concluded that all three containers were leak proof and had satisfactorily met all test requirements.

10.8.2 HEAT BUILDUP

Calculations were made to determine the heat buildup due to self heating resulting from radioactive decay. This is necessary to establish the maximum temperature of the package and contents during an accident fire. It is assumed that no heat can escape from the inner container. The calculations are based on the configuration-1 stainless steel inner container, which may be considered as a simple 1/40-in. thick, wall cylinder, 16-1/2 in. high and 10 in. in diameter with 1/2-in. thick circular end plates. Based on 4.3 kg of plutonium-239, the maximum thermal decay heat output is 10 W. The accumulation of heat is given by the following equation:

$$q\ (\mathrm{BTU/hr}) = W(\mathrm{lb}) \times C_p\ (\mathrm{BTU/lb\,^{o}F}) \times \Delta T\ (^{o}\mathrm{F/hr}),$$

where

q = heat accumulation = W x 3.41, BTU/W hr,

W = weight of stainless steel = 61.5 lb,

C_p = heat capacity of stainless steel = 0.11, BTU/lb^{o}F,

ΔT = rate of temperature increase, ^{o}F/hr.

Rearranging the above equation and substituting the above values we arrive at the following:

$$\Delta T\ \frac{^{o}\mathrm{F}}{\mathrm{hr}} = \frac{(10\ \mathrm{W})\ (3.41\ \mathrm{BTU/W\ hr})}{(0.11\ \mathrm{BTU/lb\,^{o}F})\ (61.5\ \mathrm{lb})} = 5.0\ ^{o}\mathrm{F/hr}.$$

Since the temperature rise due to self heating would be only 2.5^{o}F during the 30-min fire test, the heat buildup is extremely small when compared to a 300^{o}F test condition. Therefore, the heat buildup from radioactive decay may be regarded as negligible should an accident fire occur. This conclusion also applies to the configuration-3 and -5 packages with self heating outputs of 10 and 3.3 W respectively.

10.8.3 MAXIMUM CONTENTS WEIGHT

The purpose of this section is to justify selection of 44 lb (20 kg) as an upper limit for the weight of the materials to be shipped in the AL-M1 containers. The intent is to specify a maximum weight sufficiently high to meet all anticipated needs and sufficiently low to preclude any hazard potential. It should not be interpreted that quantities exceeding 44 lb (20 kg) are known to be unsafe. The weights of the packages tested are shown in Table 10-1 (the gross weight of configuration-5 included 164 lb (87 kg) of exterior lead weights).

TABLE 10-1. WEIGHTS OF PACKAGES TESTED IN EACH CONFIGURATION

	Gross Weight		Weight to Represent Contents	
	lb	kg	lb	kg
Configuration-1	420	191	15	6.8
Configuration-3	395	179	30	13.5
Configuration-5	550	249	17	7.7

Since an increase in the contents weight to 44 lb (20 kg) does not significantly increase the gross weight of the packages, the drop and puncture tests would cause only the same minor damage to the insulated drum assembly as previously discussed. On the other hand, 44 lb is three times as much weight as that which slightly bent the clamping fixture rods within the configuration-1 inner container on impact. To be consistent with the 300°F temperature used for evaluation of the contents, it is necessary to ensure that the contents will not cause the support rods to bend enough so that the contents will rest against the inner wall, since this wall could reach 500°F during an accident fire. In order to preclude this, it is necessary to specify that any contents weighing more than 15 lb be fastened in the clamping fixture close to the container lid to reduce the torque on impact, rather than at the far end as tested. With this restriction, 44 lb is a reasonable upper limit. The actual tests with configuration-5 demonstrated that the outer drum assembly is not unduly damaged at a gross weight of 550 lb (249 kg).

10.9 Contents Evaluation at 300°F

10.9.1 GENERAL

It is necessary to prove that the contents of the containers will not cause the inner containers to be breached during normal transportation or accident test conditions. The contents include the radioactive plutonium-239, uranium-235 and tritiated water as well as the packaging materials such as polyethylene bags, wood, sponge, foam packing and granular solid sorbents. All of these are stable as initially packaged, and their stability is not known to be altered by impact, vibration, or below-ambient temperatures. Thus, the scope of the contents analysis is limited to establishing what changes would be expected to occur at 300°F and the consequences of these changes. The 300°F temperature is selected as the maximum temperature of the materials under accident fire test conditions. It is sufficiently higher than the actual known temperatures during the fire tests to provide an adequate margin of safety.

10.9.2 PLUTONIUM-239 IN POLYETHYLENE BAGS

Unalloyed plutonium-239 enriched to approximately 95% is shipped after being doubly packaged in polyethylene bags which are sealed with tape. The approach used here is to postulate potential changes at 300°F and then evaluate their likelihood and any consequences. It can be postulated that the polyethylene bags could melt or decompose causing a pressure change and exposure of the plutonium-239 to the air in the inner container. The plutonium-239 could then be oxidized resulting in a pressure decrease.

The two pieces of polyethylene sheet packaged within the configuration-3 inner container during the thermal test remained intact. The piece located inside the simulated weight appeared unchanged and the folds of the piece located between the simulated weight and the container wall stuck together slightly, an indication that the sheet may have begun to melt. The melting point for polyethylene is given in the literature[3] as 230°F. Experimental determinations at Mound Laboratory with polyethylene established the melting range at 185°F to 266°F in air, and 194°F to 275°F in helium. This work also established that degradation begins in air at 410°F, and on continuous heating to 545°F only a 5% weight loss is obtained. Degradation in helium did not begin until 590°F was reached. Clearly, at the selected evaluation temperature of 300°F, polyethylene melts in both air and helium, but does not decompose in either environment. Also the margin of safety provided by selection of 300°F is evident on comparison of the configuration-3 test results with the melting ranges.

For the purpose of the plutonium-239 evaluation at 300°F, it is assumed that the plutonium can be exposed to all the air contained within the inner container void spaces, even though the polyethylene bags would prevent this from actually happening. At 300°F, the surface plutonium, which is exposed to the air, would oxidize at a rate of 0.01 $mg/cm^2/min$. At this rate, 44 hr would be required to consume the available oxygen which is estimated to be 1.6 liters, and 17 g of plutonium would be oxidized. The surface layer of the plutonium metal would expand approximately 10% on being converted to plutonium oxide which would then separate from the metallic surface. This would not create any immediate hazard, but would necessitate special contamination control procedures on subsequent opening. A 20% decrease in the pressure resulting from the reaction of the oxygen would not cause the container to be breached. There is no evidence that plutonium-239 would cause the packaging to be damaged.

10.9.3 URANIUM-235 METAL

Solid uranium-235 metal pieces are securely fastened in the clamping fixtures provided in the configuration-1 and -3 inner containers. Additional packaging materials such as polyethylene bags for contamination control are not usually required since the low level alpha contamination can be controlled using appropriate handling procedures for loading and unloading. The configuration-3 inner container may be shipped either filled with air at atmospheric pressure or it may be filled with an inert gas such as helium or argon at atmospheric pressure. The configuration -1 inner container may be shipped containing air at atmospheric pressure or an inert gas at up to 10 psig pressure. The choice of the gas used depends on product specification requirements.

The uranium metal is evaluated at the most severe accident test environment which is taken to be air at 300°F. Since the melting point of the uranium is 2070°F and oxidation in air forms an adherent oxide coating, the uranium metal will not change its physical form at 300°F in air. Oxidation is slow and will not consume sufficient oxygen to decrease the pressure a measurable amount. There is no evidence that uranium metal would react or otherwise change in any way that would reduce the integrity of the package during normal transportation or accident test conditions.

10.9.4 WOOD, SPONGE, AND FOAM PACKAGING

Wood, sponge, and foam packing materials are used to position, brace, and cushion the radioactive materials inside the configuration-1 and -3 inner containers. These packing materials were tested at 300°F to ensure stability at hypothetical accident test conditions.

The packing materials tested, their uses, and the test results are shown in Table 10-2.

The samples to be tested were placed in a temperature controlled oven and the temperature was increased to 300°F over a 30-min period. The temperature was controlled at 300°F for 70 min. After the oven was turned off, the temperature

TABLE 10-2. EFFECT OF 300°F ENVIRONMENT ON PACKING MATERIALS

Material	Use	Maximum Recommended Service Temperature (°F)	Test Results at 300°F
Fir plywood and solid pine	Positioning and bracing	400	No change
CHR-cohrlastic silicone sponge	Strips used to pad metal clamping fixture	500	No change
Johns-Manville No. 98 sponge rubber tape	Strips used to pad metal clamping fixture	350	No change
Napcofoam type F-706 flexible urethane polyester foam	Massive pieces used to cushion items within metal clamping fixture	275	Tacky, slightly darker color

gradually decreased to 130°F over a 70-min period prior to removal of the samples. No change in the wood samples was observed. The sponge and foam samples felt as resilient as before being heated, but the Napcofoam was slightly tacky. The only change observed on close visual examination was that the Napcofoam became a slightly darker color. The Napcofoam manufacturer confirmed that the material remains structurally sound at temperatures up to 325°F although the surface becomes tacky and darker at temperatures above the recommended maximum service temperature of 275°F.

These test results do not provide any evidence indicating that the wood, sponge, or foam packing materials would cause the AL-M1 containers to be breached at 300°F. Low temperatures in normal transportation will not damage the materials since the minimum recommended service temperature for all three of the foam and sponge materials is -100°F.

10.9.5 TRITIATED WATER

Tritiated water is the contained material in configuration-5. The pressure at 300°F, as evaluated in sections 5.3 and 7.3, will not cause the inner container to be breached. Corrosive impurities in the water contents are a long-term threat even to this 316L stainless steel container since it is reusable. Thus, users must ensure that corrosive impurities are not inadvertantly loaded into the container.

10.9.6 GRANULATED SOLID SORBENTS

Molecular sieve pellets, silica gel, and Florco commercial clay absorbent are acceptable sorbents for use in the configuration-5 inner container. None of these materials will damage this inner container at 300°F.

References

1. J. A. Sisler, Proceedings of the International Symposium for Packaging and Transportation of Radioactive Materials, Albuquerque, New Mexico, 1965, Sandia Corporation, Albuquerque, 1965, pp. 141-186.

2. 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).

3. C. L. Brown, Class I Shipping Container for Fissle Material, HWSA-3995, Hanford Atomic Products Operation, Richland, Wash. (December, 1964).

11. Criticality Evaluation

11.1 General

The purpose of this analysis was to evaluate the nuclear criticality safety aspects of shipping uranium-235 and/or plutonium-239 in configuration-1 or -3 containers. The latest configuration, No. 5, is designated for shipment of tritiated water only, a nonfissile material, and is therefore not treated in this section. Holders of the previous SARP for AL-M1 configurations-1 and -3 should take note that criticality calculations for the shipment of combinations of plutonium-239 and uranium-235 in the same container have been deleted from this version. Anyone wishing to make a shipment of this type may submit a special request for evaluation to the Criticality Control Engineer at Mound Laboratory. From a nuclear criticality safety standpoint, the two container configurations are equivalent. Uranium-235 and plutonium-239 were the only two fissile materials evaluated since present program forecasting did not indicate a foreseeable need to ship other fissile materials in this container. The Fissile Classification was determined for various quantities of fissile material packaged in the subject container.

11.2 The Density Analog Calculation Method

The density analog technique, described by Dr. H. C. Paxton[1], was used to calculate the number of similar containers required to form a critical mass. From this information and the guidelines provided in ERDA Manual Chapter 0529, the Fissile Classifications and the Transport Indices were calculated for the prescribed fissile materials and combinations of materials.

The basic equation is given as follows:

$$M_c \text{ (reflected)} \geq \frac{M_{so} \text{ (bare)}}{(R) \; (M_o)} \left(\frac{\overline{\rho}}{\rho_o} \right)^{-S},$$

where:

M_c reflected - minimum water moderated and reflected critical mass.

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

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

M_o - the contribution due to neutron moderation.

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

ρ_o - Density of the minimum critical mass.

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

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

Table 11-1 gives the values for these quantities that were used in these calculations.

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

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

TABLE 11-1. LIMITING PARAMETERS FOR THE DETERMINATION OF THE REFLECTED CRITICAL MASSES

Fissile Isotope	R	M_o	M_{so} (kg)	ρ_o (g/cm^3)
U-235	13 (Ref. 1)	2.5 (Ref. 3)	49.2 (Ref. 4)	18.7 (Ref. 4)
Pu-239	20 (Ref. 2)	2.5 (Ref. 2)	10.5 (Ref. 4)	19.6 (Ref. 4)

(1) The shipping packages are spherical in geometry. The actual packages are cylinders, hence the conservatism implied above.

(2) There are no effects due to poisons and scattering media within the package. These effects will be present, and hence the conservatism is implied again.

A more accurate method of performing calculations would be to use a "cell-type" computer program employing "multigroup" neutron transport theory. However, the results achieved using the density analog technique are more conservative than the results achieved by the "multigroup" computer calculations. Since the conservative values are not unduly restrictive to Mound Laboratory shipping requirements, more sophisticated calculations were neither attempted nor deemed necessary.

11.3 Calculated Results

The Transport Indices (TIs) were first calculated for quantities of uranium-235 ranging from 6 to 17 kg. Then TIs were calculated for quantities of plutonium-239 ranging from 2 to 4.25 kg. These data are given in Table 11-2 and are also shown in Figures 11-1 and 11-2.

TABLE 11-2. CALCULATED TRANSPORT INDEX FOR AL-M1 (CONFIGURATION-1 AND -3)

Fissile Isotope	Quantity (kg)	Transport Index
^{235}U	6.0	0.1[a] (0.03)
	7.0	0.1[a] (0.05)
	8.0	0.1
	9.0	0.2
	10.0	0.4
	11.0	0.6
	12.0	1.1
	13.0	1.8
	14.0	2.8
	15.0	4.4
	16.0	6.9
	17.0	F.C. III
^{239}P	2.0	0.1[a] (0.04)
	2.5	0.2
	3.0	0.7
	3.5	2.2
	4.0	6.9
	4.2	F.C. III

[a] Value rounded up to 0.1. Actual values appear in parenthesis.

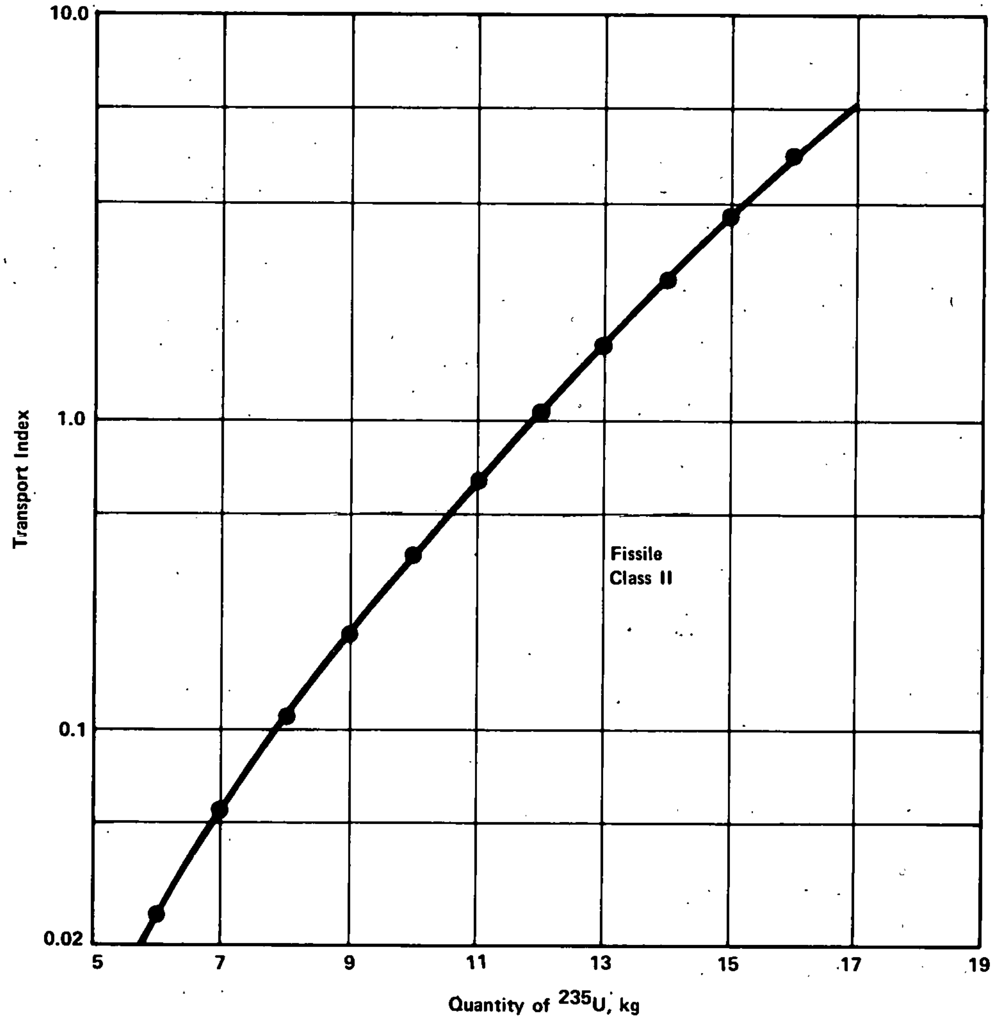


FIGURE 11-1 - Graph of transport index vs quantity of ^{235}U metal in AL-M1 (configurations 1 & 3).

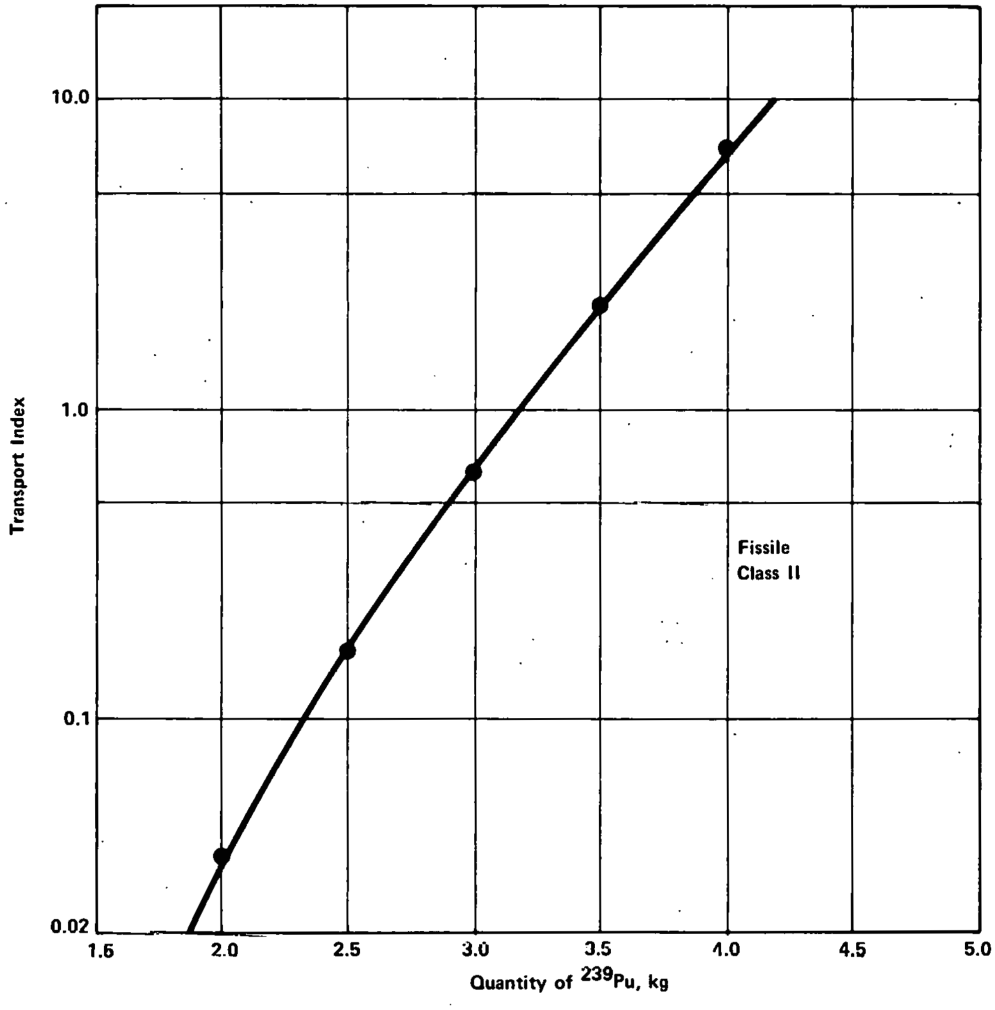


FIGURE 11-2 - Graph of transport index vs quantity of ^{239}Pu metal in AL-M1 (configurations 1 & 3).

Table 11-3 gives the number of containers allowed as Fissile Class III for specific quantities of uranium-235 and plutonium-239.

TABLE 11-3. NUMBER OF ALLOWED FISSILE CLASS III SHIPPING CONTAINERS

Fissile Isotope	Quantity (kg)	Number of Allowed Containers
Pu-239	4.20	11
	4.50	6
	4.75	3
	5.0	2
	5.25	1
U-235	17.0	11
	18.0	7
	19.0	5
	20.0	3
	21.0	2
	22.0	1

These calculations are valid only for systems in which the H/X ratio* is ≤ 2.1. H/X ratios in the range $0 \leq H/X < 2.1$ do not reduce the minimum critical mass for minimally reflected systems and therefore the use of M_{so} = 49.2 kg and 10.5 kg for uranium-235 and plutonium-239 is justified.[5]

For shipments where the H/X ratio is not known or is >2.1, a <u>special request for evaluation must</u> be submitted to the Nuclear Criticality Control Engineer.

The effect of the hypothetical accident condition tests on the package with respect to parameters affecting nuclear criticality were shown by calculation to be insignificant (<1% volume reduction). Thus, the requirements as stated in ERDA Manual 0529, II H. 2., II I.1.b, and II. J. 2 for Fissile Classes I, II, and III are met.

Table 11-4 summarizes the maximum quantities of uranium-235 and plutonium-239 which may be shipped as Fissile Classes I and II. These values apply to metal systems only and an H/X ratio of ≤ 2.1 must be maintained in order for this analysis to be valid.

*H/X ratio = atomic ratio of hydrogen, H, to U-235 and/or Pu-239.

TABLE 11-4. MAXIMUM QUANTITIES[a] OF U-235 AND Pu-239 WHICH MAY BE SHIPPED AS FISSILE CLASSES I AND II

	Fissile Class I (kg)	Fissile Class II (kg)	Fissile Class III (kg)
U-235	0.015 - <5.7	5.7 - 16.8	>16.8
Pu-239	0.015 - <1.9	1.9 - 4.3	> 4.3

[a] Apply only for systems where H/X ratio is 2.1 (H/X ratio = atomic ratio of H to U-235 and/or Pu-239).

11.4 Sample Calculation

Problem: Determine the Transport Index of the undamaged shipping package containing 14.0 kg of uranium-235.

(1) Calculate effective mass based on reflector savings.

$$M_{eff} = \frac{4}{3} \pi (r_{eff})^3 \rho$$

$r_{eff} = r + S$ (reflector savings)*

for a 14.0 kg sphere, $r = 5.63$ cm

$$r_{eff} = r + 0.1^* r$$

$$r_{eff} = 5.63 \text{ cm} + (0.1)(5.63) = 6.19 \text{ cm}$$

$$M_{eff} = 4/3 \pi r^3 = 1.863 \times 10^4 \text{ g}$$

*Reference 2: The value for S assumes 1-in. iron reflector. The 1-in. iron value is actually conservative since less than 1-in. will exist in the package.

(2) Calculate

$$\bar{\rho} = \frac{\text{effective mass of fissile material}}{\text{volume of shipping package}}$$

$$\bar{\rho} = \frac{1.863 \times 10^4 \text{ g}}{2.74 \times 10^5 \text{ cm}^3} = 0.068 \text{ g/cm}^3$$

(3) Calculate f, fraction critical

$$f = \frac{\text{effective mass}}{\text{minimum base critical mass}}$$

$$= \frac{1.863 \times 10^4 \text{ g}}{4.92 \times 10^4 \text{ g}} = 0.379$$

$$S = 2\ (1-f) = 2\ (1 - 0.379)$$

$$= 1.243$$

(4) Calculate mass of base critical array

$$C = M \left(\frac{\bar{\rho}}{\rho_0}\right)^{-S}$$

$$= (49.2) \left(\frac{0.068 \text{ g/cm}^3}{18.7 \text{ g/cm}^3}\right)^{-1.243}$$

$$= 49.2\,[0.0036]^{-1.243}$$

$$= 49.2\,[1076.7]$$

$$= 5.297 \times 10^{4}\text{ kg of U-235}$$

(5) Calculate mass of optimumly moderately and reflected array

$$M_c\ (\text{reflected}) \geq \frac{c}{R\,M_o}$$

$$M_c\ (\text{reflected}) \geq \frac{5.297 \times 10^{4}\text{ kg}}{(2.5)\ (13)} =$$

1630 kg of U-235

(6) Calculate number of packages corresponding to a critical array

$$\frac{1630\text{ kg of U-235}}{18.63\text{ kg/package}} = 87.5\text{ packages}$$

<u>This is Fissile Class II</u>

(7) Calculate the Transport Index

$$\frac{250\text{ packages}}{87.5\text{ packages}} = 2.8\ .$$

References

1. H. C. Paxton, Criticality Control in Operations with Fissile Materials, LASL-3366, Los Alamos Scientific Laboratories (1966).
2. D. R. Smith, Criticality Safety Evaluation of Packages for the Transport of Fissile Material, Unpublished Report (1965).
3. Safety Standards for the Packaging of Radioactive and Fissile Material, ERDA Manual Chapter 0529, pp. 1-19.
4. H. C. Paxton et al., Critical Dimentions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U, TID-7028 (1969).
5. Nuclear Safety Guide, TID-7016 (1961), pp. 14-16.

12. Radiation Shielding Evaluation

The AL-M1 configuration-1 and -3 shipping containers are used for transport of plutonium-239 and uranium-235. The radiation dose rate at the surface of these containers will be insignificant for the materials described in this SARP.

Configuration-5 of the AL-M1 shipping container is used for transport of tritiated water only. The maximum energy of the beta particle for tritium is 18 keV with an average energy of approximately 6 keV. The shielding provided by the primary containment is sufficient to attenuate the beta radiation to nonmeasurable levels at the outer surface.

13. Quality Control

The quality control measures for the AL-M1 containers include the following:

(1) Review by Mound Nuclear Operations Department Quality Control Personnel of all drawings, specifications, and criteria as well as any changes of these documents.

(2) Maintenance of these documents in the formal Mound Laboratory drawing control system. Interested persons may always obtain the latest issues of these documents from Drawing Control and thereby become aware of any changes which may occur after the publication of this SARP.

(3) Vendor requirements and certification associated with the fabrication of the containers. These requirements are shown in Section II of Appendix A.

(4) Acceptance criteria and inspections for new containers. For example, each new inner container must pass a helium leak test with no indication of leakage at a sensitivity of 1×10^{-4} STP cm^3/sec for the configuration-1 and -3 and 1×10^{-6} STP cm^3/sec for the configuration-5. These and other criteria are given in section III of Appendix A. The associated inspection forms are given in Section IV.

(5) Inspections prior to use of the containers. The checksheets for these inspections are shown in Section V of Appendix A. The containers are individually inspected after return to Mound Laboratory and repaired as required. The inspection includes a radioactive contamination check, inspection of the vent to ensure it is not plugged, and a functional fit inspection of the parts.

(6) Loading procedure checklists. These checklists are shown in Appendix B. After the materials to be shipped have been loaded into the inner container, the configuration-1 and -3 containers must pass a leak test with no indication of pressure loss when charged with 10 psig of helium pressure for a period of 15 min. The configuration-5 container is checked in several ways for tritium contamination and leakage. For all configurations, a form is completed on which each of the attributes inspected is listed and the inspector places his initials by each item listed as the inspection is performed. These forms are retained to provide a history of each container.

Acknowledgements

The authors wish to gratefully acknowledge the help of all those who contributed in producing this document. Particular recognition is due to H.B. Kreider, P.H. Lamberger, and E. L. Barraclough for review of the entire manuscript; to J.C. Dauby for a detailed critique of Appendix B; to J.B. Peterson accident tests; to G. G. Brechak for photography; to F. G. Nix for proof reading; and to M. F. Hauenstein for technical editing. In addition, please note that much of the material included in this report was drawn from a previous SARP report (see reference 1, p. 1-1) by J. F. Griffin, D. A. Edling, and C. D. Winemiller.

Appendix A

Acceptance and Reuse Inspections

Contents

SECTION I

INSPECTION REQUIREMENTS

M/C

1-14946		W O NO

ISSUE	DATE	REVISION	BY	CHK'D	APPRD
A	6-7-74	ORIGINAL ISSUE	ES		
B		CHANGED PER ACO LD-2-14876-M57	DM		

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

DWG CLASSIFICATION
LEVEL & CAT UNCL
BY
TITLE
DATE 6-10-74

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR SHIPPING CONTAINER

AL-M1 ACCEPTANCE AND
REUSE INSPECTIONS

DRAWN E. SWARTZ	DATE 6-7-74	APPROVALS	
CHECKED WVB	DATE 5-14-75	1	
SPONSOR	DATE 6-10-74	2	DPE/mp
APPROVED REE/KES	DATE 6/10/74	3	
JOB NO		4	

SP
DWG TYPE

CODE IDENT NO
14065

DWG NO 1-14946 SHT 1 OF

DAC-73-SA

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CODE IDENT NO 14065		DWG NO 1-14946 SHT 2

MRC ML 5317 (12 73)

DAC-73-SACB

1. GENERAL

1.1 Scope. This is an inspection requirement document for the AL-M1 radioactive materials shipping container. Three different AL-M1 packages are designated as configurations-1, -3, and -5.

1.2 This document defines the complete receiving acceptance inspection and reinspection prior to reuse as required by DOE Manual, Chapter 0529, including responsibilities, inspection criteria, and documentation records. The purpose of this document is to establish an effective system for ensuring compliance with the drawings, specifications, and design intent.

2. INTRODUCTION.

2.1 The AL-M1 shipping containers are designed to be used in the off-site transport of special nuclear materials, namely plutonium-239, uranium-235, and tritium. These containers meet the safety requirements of the Department of Energy and the unique requirements of the various materials which are shipped in them.

2.2 Three types of AL-M1 packages, designated configurations-1, -3 and -5, are used. The packages are illustrated in Figures 1, 2, and 3. All three configurations utilize a 55-gal steel outer drum assembly lined internally with 3-1/2 in. of insulation to protect the inner container from impact and fire. The configuration-1 primary containment vessel is a 9-1/2 in. I.D. stainless steel inner container sealed with a silicone or viton o-ring. A spacer is provided which centers the inner container within the insulated drum assembly. A vent is provided through the lid of the drum for release of any vapors. The configuration-3 primary containment vessel is basically the same as configuration-1, except that it is aluminum and the 13 in. I.D. precludes use of a spacer between it and the insulated drum assembly. These two configurations, 1 and 3, are for shipment of plutonium-239 and/or uranium-235. The configuration-5 is for sorbed tritiated water and has a primary container of substantially different design. It is a cylinder of 6-5/8 in. O.D. by 23-7/8 in. overall height made of 316L stainless steel. An insulating spacer is used with this configuration.

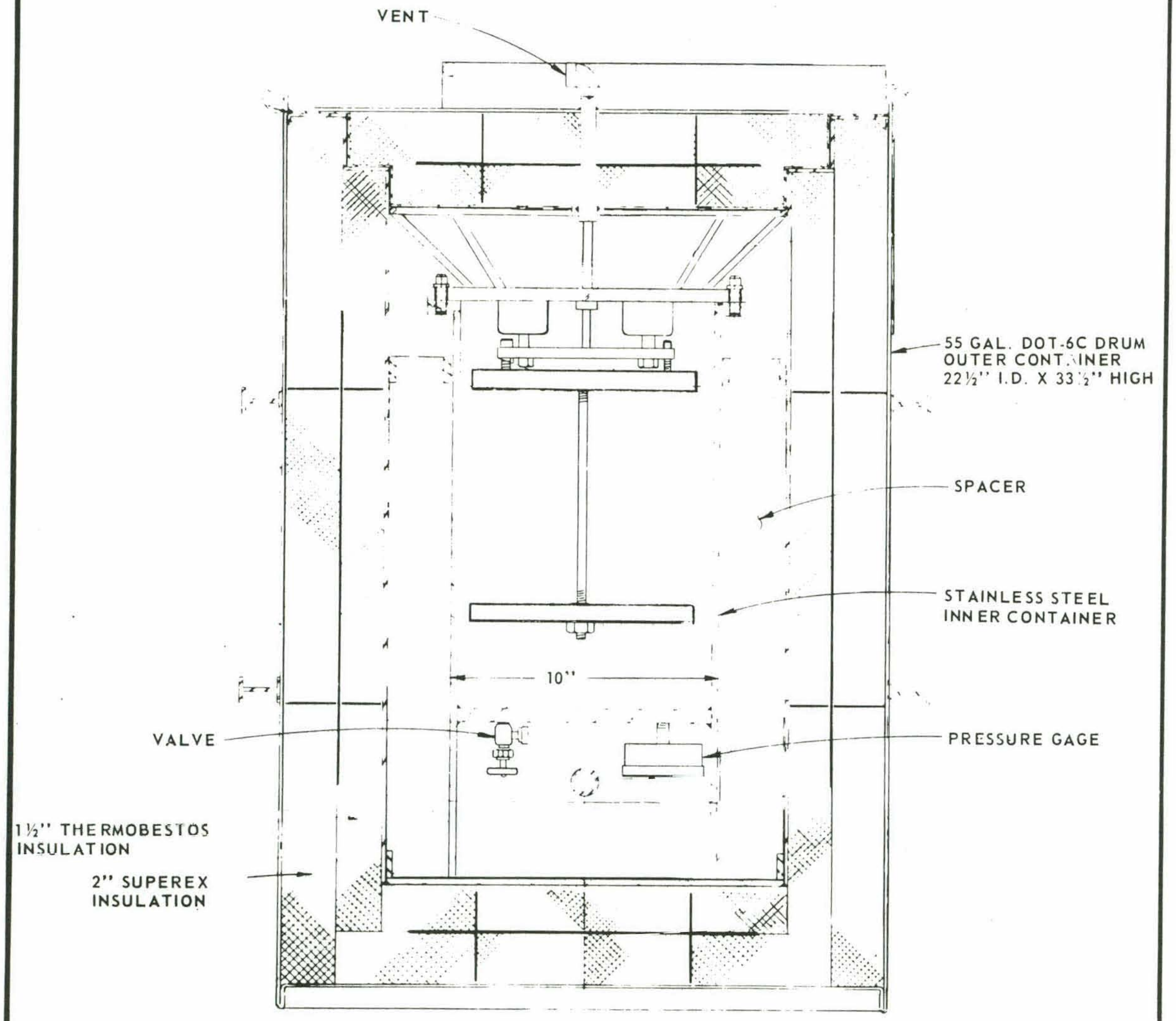

FIGURE 1 - Sketch of AL-M1 configuration-1.

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DAC-72-MASCB

1-14946

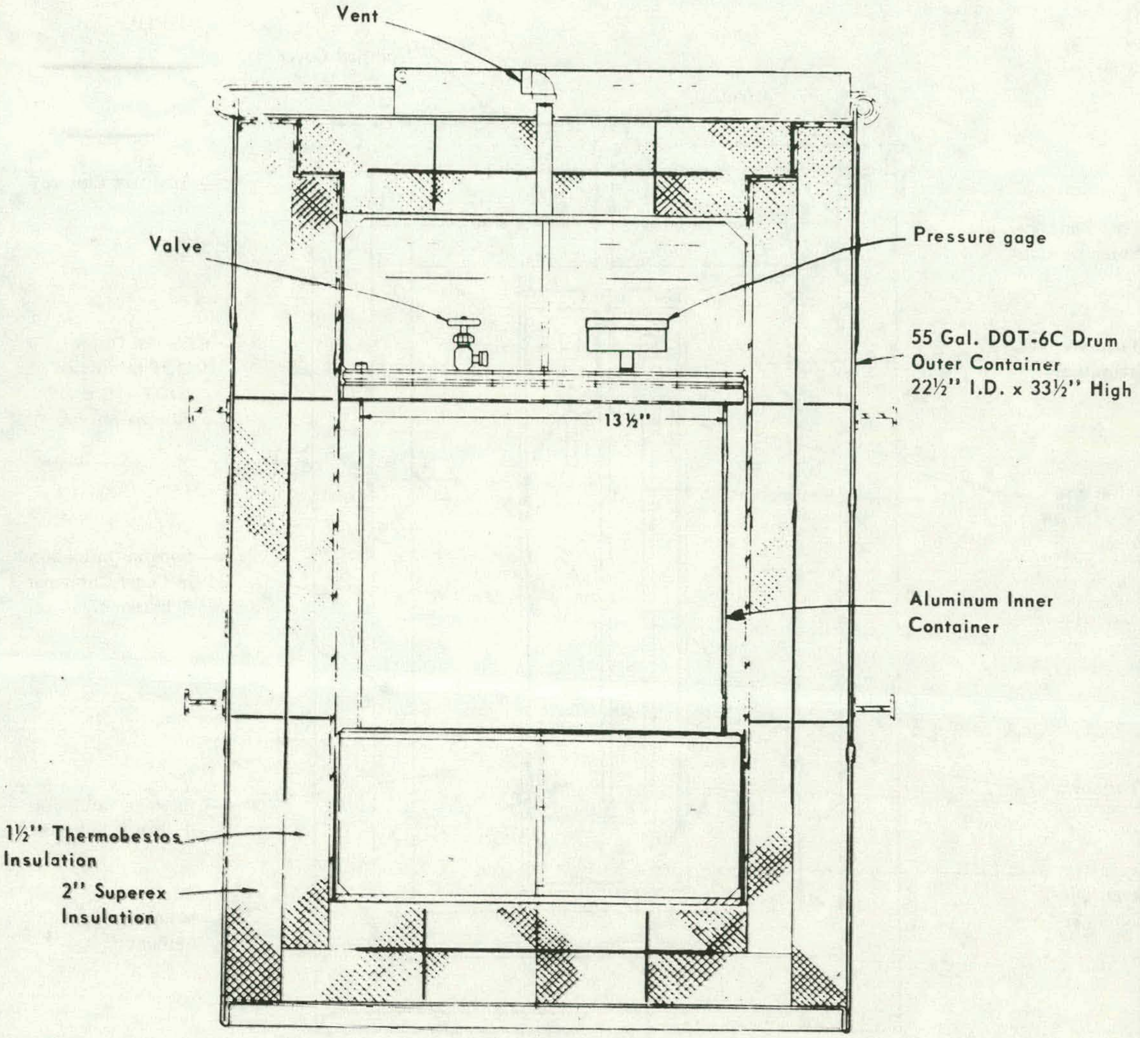

FIGURE 2 - Sketch of AL-M1 configuration-3.

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		DWG. NO. 1-14946 SHT. 5

DAC-72-MA5CB MRC-ML-5317

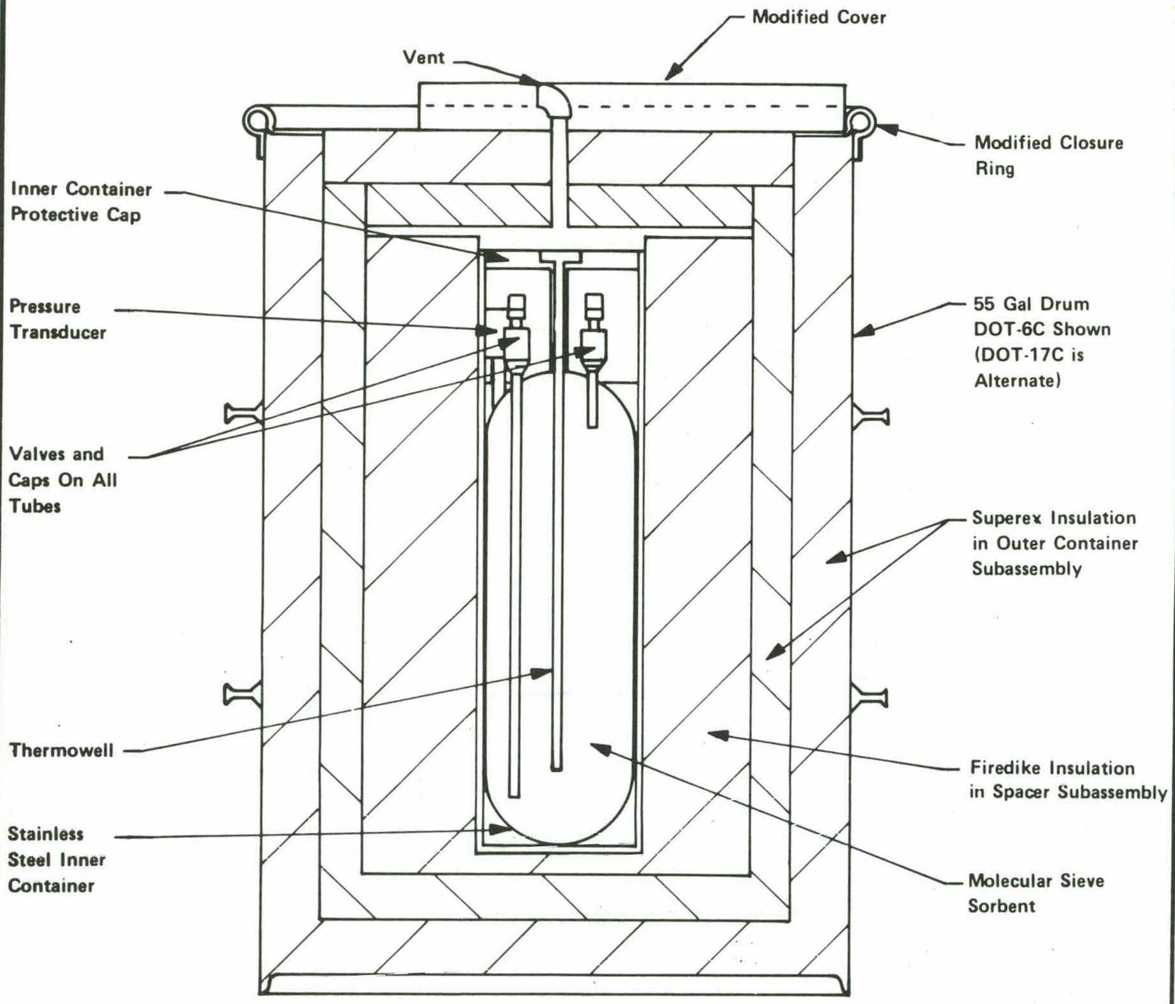

FIGURE 3 - Sketch of AL-M1 configuration-5.

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3. APPLICABLE DOCUMENTS.

3.1 Monsanto Research Corporation Drawings.

AYD740425 - Model AL-M1 Insulated Drum Assembly
AYD740426 - Model AL-M1 Configuration-1 Final Assembly
AYD740427 - Model AL-M1 Configuration-3 Final Assembly
AYD760626 - Model AL-M1 Configuration-5 Insulating Spacer
AYE740198 - Model AL-M1 Configuration-5 Inner Container
1-14841 - Welding and Inspection of 300 Series Stainless Steel Containers
1-14958 - Welding and Inspection of Aluminum Containers

3.2 Other Documents.

1) DOE Manual, Chapter 0529.
2) J. F. Griffin, D. A. Edling, and C. D. Winemiller, Safety Analysis Report for Packaging (SARP): Model AL-M1 Nuclear Packaging, MLM-1981 (Nov. 30, 1972), 80 pp.
3) R. A. Watkins, et al., Safety Analysis Report for Packaging (SARP) Model AL-M1 Nuclear Packaging, MLM-2447 (Sept. 30, 1977).

4. GENERAL PROVISIONS.

4.1 Responsibilities. The manufacturer is responsible for ensuring 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 Nuclear Operations Quality Control is responsible for auditing the Quality Control Program and review of applicable drawings and specifications to ensure that the Quality Control Program is carried out as defined. MRC Nuclear Operations

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4.1 Continued

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 (as applicable) with the specifications of MRC Drawing Nos. 1-14958 and 1-14841 as well as the criteria and check sheets of Divisions ii, iii, and iv of this document (MRC Drawing No. 1-14946).

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:

MRC Dwg. No. AYD740425 - AL-M1 Insulated Drum Assembly (Common to Configurations-1, -3, and -5)
MRC Dwg. No. AYD740426 - AL-M1 Configuration-1 Inner Container
MRC Dwg. No. AYD740427 - AL-M1 Configuration-3 Inner Container
MRC Dwg. No. AYE740198 - AL-M1 Configuration-5 Inner Container
MRC Dwg. No. AYD760626 - AL-M1 Configuration-5 Insulating Spacer

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 Division ii.

4.2.4 Sampling Plan. Each new shipping container shall be inspected for all attributes listed in Division ii.

4.3 Inspection Record. The fabricator is required to submit a completed "Fabrication and Inspection Certificate" (MRC-ML-5537 for aluminum or MRC-ML-6202 for stainless steel) as shown in MRC Drawings No. 1-14958 or 1-41841.

CODE IDENT NO 14065		DWG NO 1-14946 SHT 9

ISSUE

SECTION II

FABRICATION AND INSPECTION REQUIREMENTS AND CERTIFICATION

MRC-CL-5537 FOR ALUMINUM

AND

MRC-ML-6202 FOR STAINLESS STEEL

(VENDOR USE)

M. C

1-14958		W O NO

ISSUE	DATE	REVISION	BY	CHK'D	APPRD.
A	5/23/74	ORIGINAL ISSUE	ES		JFG
B	4/18/75	CHANGED PER ACO LD-214876-M25	CP	wv	
C	4-15-77	CHANGED PER ACO LD-2-14876-M50	DM	WVD	GAB
D		CHANGED PER ACO LD-2-14876-M57	DM		

SHEET							
ISSUE							
SHEET	1	2	3	4	5	6	7
ISSUE	D	A	D	D	D	D	C

DWG CLASSIFICATION
LEVEL & CAT UNCL
BY
TITLE
DATE

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR PACKAGING CONTAINER

WELDING AND INSPECTION OF
ALUMINUM CONTAINERS

DRAWN E.SWARTZ	DATE 5-23-74	APPROVALS
CHECKED	DATE 5-24-74	1
SPONSOR JFG	DATE 5-30-74	2
APPROVED RER	DATE 5-30-74	3
JOB NO		4

SP	CODE IDENT NO	
DWG TYPE	14065	

DWG NO 1-14958 SHT 1 OF 7

DAC-73-SA

TABLE OF CONTENTS

MRC-ML-5317 (12 73)

ISSUE A

CODE IDENT NO 14065

DWG NO 1-14958 SHT 2

DAC-73-SACB

1. SCOPE.

1.1 This specification defines requirements for welding; visual and dye penetrant examinations of the welds; helium leak testing to ensure leak tight welds, fittings, and closures; and certification to assure that all requirements have been met. This specification applies to aluminum containers with wall thicknesses of 0.1 to 0.5 in. and is a supplement to the container drawings.

1.2 All sections of this specification must be complied with unless specifically exempted in writing. Compliance with this specification does not relieve the vendor of the responsibility for quality results.

2. WELDING.

2.1 Welding process to be used -- Gas Tungsten Arc ("GTA" was formerly called "TIG").

2.2 Welding filler material -- The specific welding filler material to be used depends on the particular type of aluminum base metal and shall be used as specified below:

Type of Aluminum Base Metal	Specified Welding Filler Material (AWS-ASTM Classification)
1100	4043
2219	2319
3003	4043
5052	5356
5083	5356
5086	5356
5454	5356
5456	5356
6061	4043
6063	4043
7005	5356
7039	5356

ISSUE	A	D

CODE IDENT NO 14065		DWG NO 1-14958 SHT 3

2.3 Shielding gas - Welding grade argon or helium shall be used on the welding torch and on the underside of the weld to completely protect the weld and hot base metal from the room atmosphere.

2.4 Welding current - Direct current straight polarity welding current shall be used.

2.5 Cleaning procedures - The base material at and adjacent to the weld joint and the filler material shall be cleaned prior to welding. A chemical cleaning procedure may be used with prior approval from Monsanto Research Corporation or the cleaning may be accomplished using the following procedures:

2.5.1 Lightly hand sand with 220 grit garnet paper.

2.5.2 Clean with acetone or MEK on a clean cloth followed by reagent grade isopropyl alcohol on a clean cloth.

2.5.3 Blow off all lint with clean shop air.

2.5.4 Maintain this state of cleanliness until the welds are completed.

2.6 Welds - The fillet weld shall have continuous complete fusion at the root of the weld joint. The butt weld shall have continuous complete penetration through the tube wall. (Standard AWS welding symbols have been used on the drawing.)

2.7 Welding operator qualifications - It shall be the responsibility of the vendor to ensure that the assigned welding operators are competent, experienced, and qualified to perform GTA welding on aluminum.

2.8 Sample - The vendor shall submit one weld sample using the GTA welding process as specified, certified to be of the quality and appearance of welding to be performed on the containers. The sample must be welded simulating job conditions.

The sample will be used by MRC as a reference for acceptance or rejection of the material and workmanship.

ISSUE A D

CODE IDENT NO 14065

DWG NO 1-14958 SHT 4

3. VISUAL EXAMINATIONS.

3.1 A detailed visual inspection of each entire weld shall be made using magnifying equipment with a 4X to 20X magnification reading glass. Any defect greater than those listed in 3.2 to 3.7 shall be cause for rejection.

3.2 Cracks - There shall be no cracks in the welds or in the adjacent base metal.

3.3 Surface Pores - There shall be no surface pores greater than 0.012 in. diameter.

3.4 Surface Contour - The surface of the weld shall be uniform in appearance.

3.5 Weld Size - The fillet weld shall be gaged to ensure that it meets or exceeds the drawing requirement.

3.6 Overlaps - There shall be no cold overlaps on the base metal.

3.7 Undercuts - There shall be no undercuts.

4. DYE PENETRANT EXAMINATION.

4.1 A detailed fluorescent dye penetrant examination of each entire weld shall be made. Any defect greater than those listed in 4.2 and 4.3 shall be cause for rejection.

4.2 Cracks - There shall be no crack indications in the welds or adjacent base metal.

4.3 Surface Pores - There shall be no surface pores greater than 0.012 in. diameter.

MRC-ML-5317 (12-73)

ISSUE	A	C	D

CODE IDENT NO
14065

DWG NO 1-14958 SHT 5

DAC-73-SACB

5. HELIUM LEAK TEST.

5.1 The container shall be successfully helium leak tested in the presence of an MRC representative.

5.2 The vendor shall establish that he can obtain the services of a qualified, experienced operator and the equipment to conduct the helium leak test.

5.3 All welds and fittings must have no detectable leak greater than 1 x 10^{-7} (STP) cm^3/sec.

5.3.1 An elastomer o-ring (such as viton) seal must have no detectable leak greater than 1 x 10^{-7} (STP) cm^3/sec. The entire container with this type of seal must not leak more than 1 x 10^{-7} (STP) cm^3/sec.

5.3.2 A metal o-ring seal (or similar metal to metal seal) must have no detectable leak greater than 1 x 10^{-5} (STP) cm^3/sec. The entire container with this type of seal must not leak more than 1 x 10^{-5} (STP) cm^3/sec.

5.4 The leak detector used for the test must be standardized just prior to the test against a standard leak tube in the appropriate range.

5.5 If the sniffer probe technique is used, the atmosphere within the container must be at least 95% helium at a minimum pressure of 15 psi above atmospheric pressure (psig).

6. CERTIFICATION.

6.1 The "Fabrication and Inspection Certification" form (MRC-ML-5537) shall be completed by an appropriate vendor representative and transmitted to MRC Engineering. This shall constitute certification of the container as meeting minimum requirements.

6.2 Each item on the "Fabrication and Inspection Certification", Sheet 7, shall be signed and dated when all of the necessary operations for that particular item have been completed. It is intended that the inspection will be performed in the sequence listed.

MRC-ML-5317 (12-73)

ISSUE	A	C	D

CODE IDENT NO 14065		DWG NO 1-14958 SHT 6

DAC-73-5ACB

ALUMINUM CONTAINERS

FABRICATION AND INSPECTION CERTIFICATION

FABRICATED BY ______________________

CONTAINER SERIAL NUMBER ______________

CONTAINER DRAWING NO. ________________

		SIGNATURE	DATE COMPLETED
I.			
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.		
II.			
	Vendor review and approval		

MRC-ML-5537 (4-77)

DISTRIBUTION:
WHITE – NUCLEAR QC
YELLOW – SHIPPING CONTAINER ENG.
PINK – FILE

ISSUE B C

CODE IDENT NO
14065

DWG NO 1-14958 SHT 7

MRC-ML-5317 (12 73)

DAC-73-SACB

M/C

		W O NO

ISSUE	DATE	REVISION	BY	CHK'D	APPRD
E	1/6/77	CHANGED PER ACO-LD-2-14876-M45	DM	WVD	
F	4-15-77	CHANGED PER ACO LD-2-14876-M50	DM	WVD	
G		CHANGED PER ACO LD-2-14876-M57	DM		

SHEET								
ISSUE								
SHEET	1	2	3	4	5	6	7	8
ISSUE	G	E	G	D	G	G	G	F

DWG CLASSIFICATION
LEVEL & CAT UNCL
BY W. Reckn
TITLE
DATE 1-24-77

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR PACKAGING CONTAINER

WELDING & INSPECTION OF 300 SERIES STAINLESS STEEL CONTAINERS

DRAWN D. MORRIS	DATE 1-24-77	APPROVALS
CHECKED WVD	DATE 1-24-77	1
SPONSOR R.R.W.	DATE	2
APPROVED W. Reckn	DATE 1-24-77	3
JOB NO 8625		4

SCP	CODE IDENT NO	
DWG TYPE	14065	

DWG NO 1-14841 SHT 1 OF 8

DAC-73-SA

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CONTENTS

ISSUE	C	E

CODE IDENT NO 14066		DWG NO 1-14841 SHT 2

1. SCOPE.

1.1 This specification defines requirements for welding, visual, dye penetrant, and radiographic examinations of the welds; helium leak testing to ensure leak tight welds, fittings, and closures; and certification to ensure that all requirements have been met. This specification applies to 300 series stainless steel containers with wall thickness of 0.05 to 0.25 in. and is a supplement to the container drawings.

1.2 All sections of this specification must be complied with unless specifically exempted in writing. Compliance with this specification does not relieve the vendor of the responsibility for quality results.

2. WELDING.

2.1 Welding process to be used -- Gas Tungsten Arc ("GTA" was formerly called "TIG").

2.2 Welding filler material - The specific welding filler material to be used depends on the particular type of stainless steel base metal and shall be used as specified below:

Type of Stainless Steel Base Metal (AISI)	Specified Welding Filler Material (AWS-ASTM Classification)
301,302,304,308	ER308
304L	ER308L
309	ER309
310	ER310
316	ER316
316L	ER316L
317	ER317
330	ER330
321	ER321 or ER347
347	ER347

2.3 Shielding gas - Welding grade argon or helium shall be used on the welding torch and on the underside of the weld to completely protect the weld and hot base metal from the room atmosphere.

2.4 Welding current - Direct current straight polarity welding current shall be used.

2.5 Cleaning procedures - The base material at and adjacent to the weld joint and the filler material shall be cleaned prior to welding using the following procedures:

2.5.1 Lightly hand sand with 220 grit garnet paper.

2.5.2 Clean with acetone or MEK on a clean cloth followed by reagent grade isopropyl alcohol on a clean cloth.

2.5.3 Blow off all lint with clean shop air.

2.5.4 Maintain this state of cleanliness until the welds are completed.

2.6 Welds - The fillet weld shall have continuous complete fusion at the root of the weld joint. The butt weld shall have continuous complete penetration through the tube wall. (Standard AWS welding symbols have been used on the drawing.)

2.7 Welding operator qualifications - It shall be the responsibility of the vendor to assure that the assigned welding operators are competent, experienced and qualified to perform GTA welding on 300 series stainless steel.

2.8 Sample - The vendor shall submit one weld sample using the GTA welding process as specified, certified to be of the quality and appearance of welding to be performed on the containers. The sample must be welded simulating job conditions.

The sample will be used by MRC as a reference for acceptance or rejection of the material and workmanship.

MRC ML 5317 (12 73)

ISSUE D

CODE IDENT NO
14065

DWG NO 1-14841 SHT 4

DAC-73-SACB

6. HELIUM LEAK TEST.

6.1 The container shall be successfully helium leak tested in the presence of an MRC representative.

6.2 The vendor shall establish that he can obtain the services of a qualified, experienced operator and the equipment to conduct the helium leak test.

6.3 All welds, valves and fittings must have no detectable leak greater than 1×10^{-7} (STP) cm^3/sec.

6.3.1 An elastomer o-ring (such as viton) seal must have no detectable leak greater than 1×10^{-7} (STP) cm^3/sec. The entire container with this type of seal must not leak more than 1×10^{-7} (STP) cm^3/sec.

6.3.2 A metal o-ring seal (or similar metal to metal seal) must have no detectable leak greater than 1×10^{-5} (STP) cm^3/sec. The entire container with this type of seal must not leak more than 1×10^{-5} (STP) cm^3/sec.

6.4 The leak detector used for the test must be standardized just prior to the test against a standard leak tube in the appropriate range.

6.5 If the sniffer probe technique is used, the atmosphere within the container must be at least 95% helium at a minimum pressure of 15 psi above atmospheric pressure (psig).

7. CERTIFICATION.

7.1 The "Fabrication and Inspection Certification" form (MRC-ML-6202) shall be completed by an appropriate vendor representative and transmitted to MRC Engineering. This shall constitute certification of the container meeting minimum requirements.

7.2 The "Fabrication and Inspection Certification" Sheet 8, shall be signed and dated when all the necessary operations for that particular item have been completed. It is intended that the inspection will be performed in the sequence listed.

MRC ML-5317 (12-73)

ISSUE	D	E	F	G

CODE IDENT NO 14065

DWG NO 1-14841 SHT 7

DAC-73-SACB

4. DYE PENETRANT EXAMINATION.

4.1 A detailed fluorescent dye penetrant examination of each entire weld shall be made. Any defect greater than those listed in 4.2 and 4.3 shall be cause for rejection.

4.2 Cracks - There shall be no crack indications in the welds or adjacent base metal.

4.3 Surface Pores - There shall be no surface pores greater than 0.012 in. diameter.

4.4 Dye penetrant examination to be made prior to exterior surface finishing such as glass bead finishing.

5. RADIOGRAPHIC EXAMINATION.

5.1 A detailed radiographic inspection shall be made on each weld utilizing either x-rays or gamma rays to detect discontinuities on the interior of the weld. Two percent penetrameters shall be employed to verify the radiographic quality level of each procedure. Any defect greater than those listed in 5.2 through 5.6 shall be cause for rejection.

5.2 Cracks - There shall be no cracks in the welds or in the adjacent base metal.

5.3 Lack of Fusion - There shall be no indications of lack of fusion in the weld.

5.4 Incomplete Penetration - There shall be no evidence of lack of weld joint penetration.

5.5 Tungsten Inclusions - Tungsten inclusions shall be evaluated the same as porosity.

5.6 Porosity - The following are the acceptance criteria for internal weld porosity. All pores must be generally circular in shape with no sharp corners or tails. There shall be no radiographically detectable pore with a diameter greater than 40% of the thickness, t, of the thinnest member. The total projected area of all the pores in one inch of weld length shall not exceed 5% of the vertical cross sectional area of t square inches (1 inch length times the thickness, t, of the thinnest member of base metal).

ISSUE	C	D	E	F	G

CODE IDENT NO 14065

DWG NO 1-14841 SHT 6

MRC ML 5317 (12 73)

DAC-73-SACB

2.9 Heat treatment - Containers fabricated of 316 or 317 stainless steel must be given a full anneal at 1950 to 2050°F and containers fabricated of 316L stainless steel must be stress relieved at 1600°F ±30°F after welding. Since the purpose of the heat treatments is to obtain maximum corrosion resistance in the welds and the base metal adjacent to the welds, the heat treatment may be eliminated if the buyer has specifically stated that it is not necessary for the intended application.

3. VISUAL EXAMINATIONS.

3.1 A detailed visual inspection of each entire weld shall be made using magnifying equipment with a 4X to 20X magnification reading glass. Any defect greater than those listed in 3.2 to 3.7 shall be cause for rejection.

3.2 Cracks - There shall be no cracks in the welds or in the adjacent base metal.

3.3 Surface Pores - There shall be no surface pores greater than 0.012 in. diameter.

3.4 Surface Contour - The surface of the weld shall be uniform in appearance.

3.5 Weld Size - The fillet weld shall be gaged to assure that it meets or exceeds the drawing requirement.

3.6 Overlaps - There shall be no cold overlaps on the base metal.

3.7 Undercuts - There shall be no undercuts.

ISSUE	D	E	F	G

CODE IDENT NO		DWG NO	SHT
14065		1-14841	5

300 SERIES STAINLESS STEEL CONTAINERS
FABRICATION AND INSPECTION CERTIFICATION

Container ID Number ____________ Container Drawing No. ____________

Fabricated By ____________ Name of Welder ____________

I.

	SIGNATURE	DATE COMPLETED
1. Component 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. Radiographic examination acceptable (Section 5).	____________	____________
6. Dimensions as specified.	____________	____________
7. O-ring surface finish as specified.	____________	____________
8. Container can be assembled properly.	____________	____________
9. Helium leak test acceptable (Section 6).	____________	____________
10. Container tagged and dated to indicate inspection results satisfactory.	____________	____________
11. Vendor review and approval	____________	____________

DISTRIBUTION:
WHITE – NUCLEAR QC
YELLOW – SHIPPING CONTAINER ENG.
PINK – FILE

MRC-ML 6202

MRC-ML-5317 (12-73)

ISSUE	D	E	F

CODE IDENT NO 14065		DWG NO 1-14841 SHT 8

DAC-73-SACB

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SECTION III

ACCEPTANCE INSPECTION CRITERIA
FOR
AL-M1 SHIPPING CONTAINERS

M/C

1-14946		W O NO

ISSUE	DATE	REVISION	BY	CHK'D	APPRD
A	6-7-74	ORIGINAL ISSUE	ES		JBf
B		TYPED ANTICIPATING GENERAL REVISION			

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

DWG CLASSIFICATION
LEVEL & CAT UNCL
BY
TITLE
DATE 6-10-74

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY
MIAMISBURG, OHIO

NUCLEAR SHIPPING CONTAINER

AL-M1 ACCEPTANCE AND
REUSE INSPECTIONS

DRAWN	E. SWARTZ	DATE	6-7-74	APPROVALS
CHECKED	WVB	DATE	5-14-75	1
SPONSOR	J B Atterworth	DATE	6-10-74	2 DPE/mg
APPROVED	RER/KES	DATE	6/10/74	3 RPB
JOB NO				4

SP
DWG TYPE

CODE IDENT NO
14065

DWG NO 1-14946 SHT 1 OF 25

DAC-73-SA

PART A - INSULATED DRUM ASSEMBLY (MRC DWG. AYD740425)

1. IDENTIFICATION.

1.1 Note the drum assembly identification markings on Inspection Data Sheet.

1.2 Note the assembly manufacturer (vendor).

2. VENDOR CERTIFICATION.

2.1 Vendor has certified by letter that all items are as specified per MRC Dwg. AYD740425 or MRC engineering approved equal. (Major)

2.2 Vendor has certified cylinder well (MRC Dwg. Detail 17) successfully passed the hydrostatic test (Dwg. AYD740528, Note 3) prior to installation into insulated drum assembly. (Major)

3. VISUAL INSPECTION.

3.1 Security seal channels are welded to the closure ring and the closure ring bolt has hole for security seal. (Major)

3.2 Drum permanent head marked in accordance with R. M. Graziano's Tariff No. 31. For DOT 6C drums this is "DOT-6C880" and "16/55/year" as in Section 178.99-9. For DOT 17C drums this is "company symbol DOT 17C 16 55 year month" as in Section 178.115-10.

3.3 Drum (DOT 6C only) has two I-bar rolling hoops held in place by a corrugation on each side. (Major)

3.4 Name tag attached and as specified per MRC Dwg. 1-14599. (Major)

3.5 Blue paint on drum exterior acceptable. (Minor)

MRC-ML-5317 (12-73)

ISSUE	B

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3.6 Two Monsanto Company symbols (Red) located as shown on drawing. (Minor)

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

3.8 Adhesive (General Electric RTV) seal completely around interface of cylinder well (MRC dwg. Detail 17) and drum (MRC Dwg. Detail 1). (Major)

3.9 Insulated drum assembly undamaged. (Major)

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

4.1 Guard extends above vent. (Major)

4.2 Cylinder well diameter is 14-7/8 in minimum. (Major)

4.3 Cylinder well inside height of 14-7/8 diameter section is 27-1/8 in. minimum. (Major)

5. <u>DRUM ASEMBLY FUNCTIONAL INSPECTION.</u>

5.1 Vent not plugged as determined by flow check. (Major)

5.2 Drum completely closed and opened successfully. (Major)

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

ISSUE B

CODE IDENT NO 14065

PART B - CYLINDER SUPPORT (SPACER) FOR CONFIGURATION-1 INNER CONTAINER - MRC DRAWING NO. AYD740530

1. IDENTIFICATION.

1.1 Note the Cylinder Support Serial Number on the Inspection Data Sheet.

1.2 Note the spacer manufacturer (vendor).

2. VENDOR CERTIFICATION.

2.1 Vendor has certified that cylinder support is manufactured per MRC Dwg. AYD740530 of the materials specified. (Major)

3. CYLINDER SUPPORT VISUAL INSPECTION.

3.1 Workmanship acceptable and no sharp edges or burrs. (Critical)

4. CYLINDER SUPPORT FUNCTIONAL INSPECTION.

4.1 Cylinder support fits into cylinder well and configuration-1 inner container fits into cylinder support. (Major)

4.2 Cylinder support tagged and dated to indicate inspection results satisfactory. (Minor)

ISSUE	B

CODE IDENT NO 14065		DWG NO 1-14946 SHT 12

PART C - CONFIGURATION-1
INNER CONTAINER MRC DRAWING NO. AYD740426

1. IDENTIFICATION.

1.1 Note the Serial Number on the Inspection Data Sheet.

1.2 Note the manufacturer (vendor).

2. VENDOR CERTIFICATION AND TEST SAMPLER.

2.1 Vendor completed "Fabrication and Inspection Certification" Form No. MRC-ML-5537 (Major)

2.2 Vendor weld sample satisfactory. (Major)

3. INNER CONTAINER VISUAL INSPECTION.

3.1 Compound gage is 30 in. vacuum/60 psig pressure. (Major)

3.2 Valve is 1/4 in. needle valve with pipe cap. (Major)

3.3 Silicone or viton o-ring with nominal 9-3/4 in. I.D. x 10 in. O.D. (Major)

3.4 O-ring groove and cover plate sealing surfaces free of nicks or scratches. (Major)

3.5 Workmanship acceptable and no sharp edges or burrs. (Critical)

3.6 Welds appear acceptable. (Major)

3.7 Inner container undamaged. (Major)

4. INNER CONTAINER DIMENSIONAL INSPECTION.

4.1 Cover plate thickness is 1/2 in. minimum. (Major)

4.2 Bottom plate thickness is 1/2 in. minimum. (Major)

4.3 Flange thickness is 1/2 ± 1/64 in. (Major)

4.4 Body wall thickness is 0.250 ± 0.005 in. (Major)

4.5 Top ring, brace, and cross brace are 3/8 ± 1/64 in. diameter. (Major)

4.6 Socket head screws are stainless steel 5/16 in. diameter x 18 threads per in. x 1 in. long. (Major)

4.7 Overall dimensions as specified per MRC Drawing AYD740426.

Total assembled height is 22-1/2 ± 3/64 in. (Major)

I.D. of body is 9.500 ± 0.005 in. (Major)

O.D. of top ring is 14-5/8 ± 1/64 in. (Major)

5. INNER CONTAINER FUNCTIONAL INSPECTION.

5.1 Valve operates properly. (Major)

5.2 Pressure gage operates properly. (Major)

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

5.4 Helium leak test performed with no detectable leak greater than 1 x 10^{-5} std. cm^3/sec when filled to 15 ± 1 psig helium.

5.5 Inner container tagged and dated to indicate inspection results satisfactory.

PART D - CONFIGURATION-3
INNER CONTAINER MRC DRAWING NO. AYD740427

1. IDENTIFICATION.

1.1 Note the Serial Number on the Inspection Data Sheet.

1.2 Note the manufacturer (vendor).

2. VENDOR CERTIFICATION AND TEST SAMPLES.

2.1 Vendor completed "Fabrication and Inspection Certification" Form No. MRC-ML-5537. (Major)

2.2 Vendor weld sample satisfactory. (Major)

3. INNER CONTAINER VISUAL INSPECTION.

3.1 Compound gage is 30 in. vacuum/60 psig pressure. (Major)

3.2 Valve is 1/4 in. needle valve with pipe cap. (Major)

3.3 Silicone or viton o-ring with nominal 13-1/8 in. I.D. x 13-3/8 in. O.D. (Major)

3.4 O-ring groove and cover plate sealing surfaces free of nicks or scratches. (Major)

3.5 Verify existence of "legs" with handle holes per Details 2A and 2B of MRC Drawing AYD740531 and "legs" on bottom of container per Details 4D and 4E of MRC Drawing AYD740532. (Major)

3.6 Workmanship acceptable and no sharp edges or burrs. (Critical)

3.7 Welds appear acceptable. (Major)

ISSUE B

CODE IDENT NO
14065

DWG NO 1-14946 SHT 15

MRC ML 5317 (12 73)

DAC-73-SACB

3.8 Inner container undamaged. (Major)

4. INNER CONTAINER DIMENSIONAL INSPECTION.

4.1 Cover plate thickness is 1/2 in. minimum. (Major)

4.2 Bottom plate thickness is 3/8 in. minimum. (Major)

4.3 Body wall thickness is 1/4 in. minimum. (Major)

4.4 Leg thickness is 1/4 in. minimum. (Major)

4.5 Helium leak test performed with no detectable leak greater than 1×10^{-5} std. cm^3.sec when filled to 15 ± 1 psig helium. (Major)

4.6 Inner container tagged and dated to indicate inspection results satisfactory. (Major)

5. FINAL CONTAINER ASSEMBLY.

5.1 Weight of assembled container is 365 ± 25 lb. (Minor)

5.2 Shipping container functional assembly and disassembly satisfactory. (Major)

PART E - CONFIGURATION-5
INNER CONTAINER MRC DRAWING NO. AYE740198

1. IDENTIFICATION.

1.1 Note the container identification number on the inspection sheet.

1.2 Note the manufacturer (vendor).

2. VENDOR CERTIFICATION AND TEST SAMPLES.

2.1 Vendor properly completed "Fabrication and Inspection Certification" Form No. MRC-ML-6202. (Major)

2.2 Vendor weld sample satisfactory. (Major)

2.3 Vendor helium leak test accepted by MRC representative. (Major)

3. INNER CONTAINER VISUAL INSPECTION.

3.1 Pressure transducer is Precise Sensors, Inc. Model #70101-200 or MRC Engineering approved equal. (Major)

3.2 Valves are Nupro #SS-8BG-TSW. (Major)

3.3 Bail has shape which will self center lifting hook. (Minor)

3.4 Bottom dished cap does not protrude beyond bottom skirt ring. (Minor)

3.5 No protrusion of top closure nut, bail, or quick disconnect fittings above top lip of container cap. (Major)

3.6 O-ring sealing surfaces free of nicks and scratches. (Major)

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3.7 "Radioactive Material" labels on top cap and container side are acceptable. (Major)

3.8 Container identification labels on top cap, container side, and container top are acceptable. (Major)

3.9 Welds appear acceptable. (Major)

3.10 Container undamaged. (Major)

3.11 Workmanship acceptable and no sharp edges or burrs. (Critical)

4. INNER CONTAINER DIMENSIONAL INSPECTION.

4.1 Container with cap overall height 23.9 in. maximum. (Major)

4.2 Container diameter 6.685 in. maximum. (Major)

4.3 Cajon disconnect fittings center to center horizontal separation 4.31 ±0.05 in. (Major)

4.4 Cajon disconnect fittings vertical separation between sealing surfaces 0.75 ±0.05 in. (Major)

4.5 Primary container wall thickness 0.120 in. minimum. For example, as measured with ultrasonic technique. (Major)

5. INNER CONTAINER FUNCTIONAL INSPECTION.

5.1 Valves operate properly. (Major)

5.2 Pressure transducer functions properly. (Major)

5.3 Container protective cap removed and replaced satisfactorily. (Major)

5.4 Container fits into calorimeter sleeve satisfactorily. (Major)

5.5 Bail functions satisfactorily. (Minor)

5.6 Quick disconnect fittings function satisfactorily. (Major)

5.7 No detectable helium leak in primary container greater than 1×10^{-6} std. cm^3/sec at 15 psi pressure difference between interior and exterior. (Critical)

6. <u>TAG</u>.

6.1 Inner container tagged and dated to indicate satisfactory inspection results. (Major)

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PART F - CONFIGURATION-5
INSULATING SLEEVE MRC DRAWING AYD760626

1. IDENTIFICATION.

1.1 Note the fabricator (MRC or vendor) on the inspection sheet.

2. INSULATING SLEEVE VISUAL INSPECTION.

2.1 Firedike securely glued with no visible gaps. (Major)

2.2 Firedike not crushed or broken. (Major)

2.3 Workmanship acceptable and no sharp edges or burrs. (Major)

3. DIMENSIONAL INSPECTION.

3.1 Inside diameter: 6.75 in. minimum. (Major)
7.00 in. maximum. (Minor)

3.2 Outside diameter: 14.25 in. minimum. (Minor)
14.75 in. maximum. (Major)

3.3 Overall height 25.25 ± 0.25 in. (Major)

3.4 Well depth 24.25 in. minimum without pad. (Major)

4. TAG.

4.1 Sleeve tagged and dated to indicate satisfactory inspection results. (Minor)

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MRC-ML-5317 (12-73)

DAC-73-SACB

SECTION IV

ACCEPTANCE INSPECTION
DATA SHEETS

AL-M1 INSULATED DRUM ASSEMBLY
ACCEPTANCE INSPECTION DATA SHEET

(MRC Drawing AYD740425 and
Ref. Section III, Part A of Drawing No. 1-14946)

1. IDENTIFICATION.

1.1 Drum Identification ______________________

1.2 Vendor ______________________

2. VENDOR CERTIFICATION.

2.1 ______ Letter certifies specified items.

2.2 ______ Well hydrostatic test certified.

3. VISUAL.

3.1 ______ Provision for security seal.

3.2 ______ Permanent head marking.

3.3 ______ Rooling hoops.

3.4 ______ Name tag.

3.5 ______ Blue exterior paint.

3.6 ______ Red Monsanto symbols.

3.7 ______ Workmanship OK and no sharp edges or burrs.

3.8 ______ RTV seal.

3.9 ______ No damage.

4. DIMENSIONAL.

4.1 ______ Guard above vent.

4.2 ______ Well diameter 14-7/8 in. minimum.

4.3 ______ Well depth 27-1/8 in. minimum.

5. FUNCTIONAL.

5.1 ______ Vent open.

5.2 ______ Drum closed and opened successfully.

5.3 ______ Drum dated and tagged as OK.

COMMENTS ____

Signature of Inspector ______________________ Date __________

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

MRC-ML-6378

MRC-ML-5317 (12 73)

ISSUE	B

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SPACER FOR AL-M1 CONFIGURATION-1
ACCEPTANCE INSPECTION DATA SHEET

(MRC Drawing AYD740530 and
Ref. Section III, Part B of Drawing No. 1-14946)

1. IDENTIFICATION.

1.1 _____ Serial number.

1.2 _____ Vendor.

2. VENDOR CERTIFICATION.

2.1 _____ Materials as specified.

3. VISUAL.

3.1 _____ Workmanship OK and no sharp edges or burrs.

4. FUNCTIONAL.

4.1 _____ Spacer fits into drum well and inner container fits into spacer.

4.2 _____ Spacer dated and tagged as OK.

COMMENTS ____

____

____

Signature of Inspector ____________________ Date ____________

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

MRC ML-0070

MRC-ML 5317 (12 73)

ISSUE	B	
CODE IDENT NO 14065		DWG NO 1-14946 SHT 22

DAC-73-5ACB

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INNER CONTAINER FOR AL-M1 CONFIGURATION-1
ACCEPTANCE INSPECTION DATA SHEET

Ref. MRC Drawing No. AYD740426 and
Section III, Part C of Drawing No. 1-14946

1. IDENTIFICATION

1.1 ______ Serial number.
1.2 ______ Vendor.

2. VENDOR CERTIFICATION.

2.1 ______ Form 6202 completed.
2.2 ______ Weld sample acceptable.

3. VISUAL.

3.1 ______ Gage is 30 in. vac/60 psig.
3.2 ______ Valve is 1/4 in. needle with pipe cap.
3.3 ______ O-ring is nominal 9 3/4 in. I.D. x 10 in. O.D.
3.4 ______ O-ring sealing surfaces OK.
3.5 ______ Workmanship OK and no sharp edges or burrs.
3.6 ______ Welds appear acceptable.
3.7 ______ Inner container undamaged.

4. DIMENSIONAL.

4.1 ______ Cover plate 1/2 in. thick, minimum.
4.2 ______ Bottom plate 1/2 in. thick, minimum.
4.3 ______ Flange 1/2 ±1/64 in.
4.4 ______ Body wall thickness 0.250 ±0.005 in.
4.5 ______ Top ring and braces 3/8 ±1/64 in. diameter.
4.6 ______ Stainless socket head screws 5/16 x 18 x 1.
4.7 ______ Overall height 22-1/2 ±3/64 in., body I.D. 9.500 ±0.005, top ring O.D. 14-5/8 ±1/64 in.

5. FUNCTIONAL.

5.1 ______ Valve operate properly.
5.2 ______ Pressure gage operates properly.
5.3 ______ Disassembled and assembled satisfactorily.
5.4 ______ No He Leak greater than 1 x 10^{-5} at 15 psig.
5.5 ______ Dated and tagged as OK.

COMMENTS ____

____

____

Signature of Inspector ________________ Date ____________

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

MRC-ML-6374

MRC-ML-5317 (12-73)

ISSUE	B

CODE IDENT NO 14065		DWG NO 1-14946 SHT 23

DAC-73-SACB

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INNER CONTAINER FOR AL-M1 CONFIGURATION-3
ACCEPTANCE INSPECTION DATA SHEET

Ref. MRC Drawing No. AYD740427 and
Section III, Part D of Drawing No. 1-14946

1. IDENTIFICATION.

1.1 ______ Serial number.

1.2 ______ Vendor.

2. VENDOR CERTIFICATION.

2.1 ______ Form 6202 completed.

2.2 ______ Weld sample acceptable.

3. VISUAL.

3.1 ______ Gage is 30 in. vac/60 psig.

3.2 ______ Valve is 1/4 in. needle with pipe cap.

3.3 ______ O-ring nominal I.D. 13 1/8 in. and O.D. 13 3/8 in.

3.4 ______ O-ring sealing surfaces OK.

3.5 ______ "Legs" as specified.

3.6 ______ Workmanship OK and no sharp edges or burrs.

3.7 ______ Welds appear acceptable.

3.8 ______ Inner container undamaged.

4. DIMENSIONAL.

4.1 ______ Cover plate 1/2 in. thick, minimum.

4.2 ______ Bottom plate 3/8 in. thick, minimum.

4.3 ______ Body wall 1/4 in. thick, minimum.

4.4 ______ Leg 1/4 in. thick, minimum.

4.5 ______ No He leak greater than 1 x 10^{-5} at 15 psig.

4.6 ______ Dated and tagged as OK.

5. FINAL ASSEMBLY.

5.1 ______ Assembled weight 365 ±25 lb.

5.2 ______ Functional assembly and disassembly OK.

COMMENTS ____

____

____

Signature of Inspector ____________________ Date ______________

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

MRC-ML-6375

MRC-ML-5317 (12 73)

ISSUE	B		
CODE IDENT NO 14065		DWG NO 1-14946	SHT 24

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INSULATING SLEEVE FOR AL-M1 CONFIGURATION-5
ACCEPTANCE INSPECTION DATA SHEET

(Ref. MRC Drawing No. AYD 760626 and
Section III, Part F of Drawing No. 1-14946)

1. IDENTIFICATION.

1.1 _____ Fabricator or vendor.

2. VISUAL.

2.1 _____ Firedike well glued with no gaps.

2.2 _____ Firedike not crushed.

2.3 _____ Workmanship acceptable and no sharp edges or burrs.

3. DIMENSIONAL.

3.1 _____ I.D. 6.75 in., minimum and 7.00 in. maximum.

3.2 _____ O.D. 14.25 in., minimum and 14.75 in. maximum.

3.3 _____ Overall height 25.25 ± 0.25 in.

3.4 _____ Well depth 24.00 in., minimum.

4. TAG.

4.1 _____ Dated and tagged as OK.

COMMENTS ____________________

____

____

Signature of Inspector ____________________ Date ____________

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

MRC-ML-6376

MRC-ML-5317 (12-73)

ISSUE	B

CODE IDENT NO 14065		DWG NO 1-14946 SHT 25

DAC-73-SACB

INNER CONTAINER FOR AL-M1 CONFIGURATION-5
ACCEPTANCE INSPECTION DATA SHEET

Ref. MRC Drawing No. AYE740198 and
Section III, Part E of Drawing No. 1-14946

1. IDENTIFICATION.

1.1 Identification number ____________________

1.2 Vendor ____________________

2. VENDOR CERTIFICATION.

2.1 ______ Form 6202 completed.

2.2 ______ Weld sample acceptable.

2.3 ______ Vendor He leak test accepted.

3. VISUAL.

3.1 ______ Pressure transducer is Model #70101-200.

3.2 ______ Valves Nupro #SS-8BG-TSW.

3.3 ______ Bail shaped to take lifting hook.

3.4 ______ Bottom dished cap does not protrude.

3.5 ______ No protrusions above top lip of cap.

3.6 ______ O-ring sealing surfaces satisfactory.

3.7 ______ "Radioactive Material" labels on side and cap top.

3.8 ______ I.D. labels on side, vessel top, and cap top.

3.9 ______ Welds appear acceptable.

3.10 ______ Container undamaged.

3.11 ______ Workmanship acceptable and no sharp edges or burrs.

4. DIMENSIONAL.

4.1 ______ Overall height 23.9 in., maximum.

4.2 ______ Diameter 6.685 in., maximum.

4.3 ______ Cajon center to center 4.31 ±0.05 in.

4.4 ______ Cajon vertical separation 0.75 ±0.05 in.

4.5 ______ Vessel wall 0.120 in. thick, minimum.

5. FUNCTIONAL.

5.1 ______ Valves operate properly.

5.2 ______ Pressure transducer functions properly.

5.3 ______ Cap removed and replaced satisfactorily.

5.4 ______ Container fits into calorimeter sleeve.

5.5 ______ Bail functions satisfactorily.

5.6 ______ Quick disconnects function properly.

5.7 ______ No He leak greater than 1×10^{-6} at 15 psig.

6. TAG.

6.1 ______ Dated and tagged as acceptable.

COMMENTS ____

Signature of Inspector ____________ Date ____________

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

MRC-ML-6377

MRC-ML 5317 (12 73)

ISSUE	B

CODE IDENT NO 14065		DWG NO 1-14946 SHT 26

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SECTION V

USE AND REUSE INSPECTION CHECKSHEETS

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM Reusable Radioactive Shipping Containers	SHEET 1 of 1	MANUAL NUMBER MD-70152	OPERATION 3
AUTHORIZATION W.T.Cave	CLASSIFICATION Unclassified	EFFECTIVITY 9-26-77	ECN(S) INCORPORATED M4-C

OPERATION TITLE
Use Inspection and Loading of AL-M1 Configuration 1 or 3

USE INSPECTION

New_______ Reuse__________ Configuration (1 or 3)_________ Serial No.___________

I. CONTAMINATION LEVEL ACCEPTABLE (REUSE ONLY) __________ __________
Initials Date

II. CHECK LIST

The following inspections and/or actions are required. Do not check off any item until indication action is completed and any defect found has been corrected. Indicate repair by the letters Rpr and replacement by the letters Rpl. A simple check mark is satisfactory to indicate completion of an inspection or action. Enter NA if the inspection or action does not apply.

A. Insulated Drum Assembly

1. Labels, adhesives, etc. removed ____
2. Vinyl emblem ____
3. Paint ____
4. Identification plate ____
5. Tiedown brackets ____
6. Security seal bracket ____
7. Welds
8. Vent ____
9. Closure ring ____
10. Closure bolt ____
11. Interior dry and clean ____
12. Vent not plugged ____
13. Assembles properly ____

B. Cylinder Support (Configuration 1)

1. Clean and undamaged ____
2. Functional fit (drum and inner container) ____

C. Inner Container (Configuration 1 and 3)

1. No physical damage ____
2. Gage ____
3. Valve ____
4. O-ring ____
5. Cap screws ____
6. Welds
7. Braces and fixtures ____
8. No nicks or scratches in sealing surfaces ____
9. Valve operational ____
10. Pressure gage operational ____
11. Passes helium leak test (1×10^{-5} std cc/sec at 15 psig) ____

Signature ______________________ Date ______________________

LOADING PROCEDURE

1. Radioactive material form (solid, liquid or gas). ____________
2. Check and lubricate inner container O-ring. ____________
3. Close and cap inner container check valve(s). ____________
4. Place sketch within insulated drum. ____________
5. Close drum. ____________
6. Install lead wire seal. ____________
7. Apply labels (Radioactive). ____________

Signature ______________________ Date ______________________

DISTRIBUTION:

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

MRC-ML-128

Issue 3 • 10-27-77

ISSUE B		
CODE IDENT NO 14065		DWG NO 1-14946 SHT 27

MRC-ML-5317 (12-73)

DAC-73-SACB

MONSANTO RESEARCH CORP.
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM	SHEET	MANUAL NUMBER	OPERATION
REUSABLE RADIOACTIVE SHIPPING CONTAINERS	1 of 1	MD-70152	14

AUTHORIZATION	CLASSIFICATION	EFFECTIVITY	ECN(S) INCORPORATED
W T Cruz	Unclassified	9-26-77	M4-C

OPERATION TITLE
Use Inspection and Loading of AL-M1 Configuration 5

1. IDENTIFICATION

1.1. Inner container serial number _______ and date of last interior surface evaluation _______

1.2. Outer container serial number _______

1.3. Received from _______

1.4. The following inspections and/or actions are required. Do not check off any item until the indicated action is completed and any defect found has been corrected. Indicate repair by the letters Rpr and replacement by the letters Rpl. A simple check mark is satisfactory to indicate completion of an inspection or action. Enter NA if the inspection or action does not apply.

2. INNER CONTAINER

2.1. _______ Less than 5 years since last interior surface evaluation.
2.2. _______ Regeneration temperature of sorbent.
2.3. _______ Date of regeneration.
2.4. _______ Grams of water loaded.
2.5. _______ Date loaded.
2.6. _______ Ci of tritium loaded (best estimate).
2.7. _______ Primary containment leak checked and no leak through valve.
2.8. _______ Pressure transducer operational. Primary container pressure no more than 1 atm absolute.
2.9. _______ Valves operational and closed.
2.10. _______ Cajon fitting interior dry (e.g., by evacuation).
2.11. _______ Valves capped.
2.12. _______ Exterior surfaces decontaminated.
2.13. _______ No physical damage.
2.14. _______ Welds OK.
2.15. _______ No nicks or scratches in sealing surfaces.
2.16. _______ O-rings dry, grease free, and in good condition.
2.17. _______ Protective cover installed.
2.18. _______ Cover pressurized to 20 psig. No pressure decrease in 30 minutes.
2.19. _______ Cover interior produces less than 180 μCi/m^3 on tritium monitor when pressure released through monitor.
2.20. _______ Gross weight with cover.

3. INSULATING SLEEVE

3.1. _______ Clean and undamaged.
3.2. _______ Surface wipes less than 1000 DPM β.
3.3. _______ Cerawool pad in bottom of well in good condition.
3.4. _______ Large and small diameter Cerawool pads placed on top of inner container, in good condition.
3.5. _______ Sketch and form packed above Cerawool pads.

4. INSULATING DRUM ASSEMBLY

4.1. _______ Paint and vinyl emblem.
4.2. _______ Identification plate.
4.3. _______ Tiedown brackets (as applicable).
4.4. _______ Security seal bracket.
4.5. _______ Welds
4.6. _______ Vent not damaged or plugged.
4.7. _______ Interior dry and clean.
4.8. _______ Assembles properly.
4.9. _______ Closure ring and bolt.
4.10. _______ Old labels, adhesives, etc., removed and correct new labels applied.

DISTRIBUTION

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

Signature _______________

Date _______________

MRC-ML-128

Issue 2 • 10-27-77

MRC-ML-5317 (12-73)

ISSUE	B		
CODE IDENT NO 14065		DWG NO 1-14946	SHT 28

DAC-73-SACB

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Appendix B

Packaging and Unpackaging Procedures

The following Mound Laboratory Forms or their equivalent are completed as the shipping packages are being loaded, assembled, and shipped to ensure compliance with Mound Laboratory procedures and safety precautions for handling radioactive materials:

1) MD-70152, OP.3 (Figure B-1, for configurations-1 and -3 only). This is a use inspection and loading procedure checklist for containers loaded with Pu-239 and U-235.
2) MD-70152, OP.14 (Figure B-2, for configuration-5 only). This is a checklist for use inspection and general assembly procedure when either loaded (filled) or empty inner containers used for tritiated water are shipped.
3) MRC-ML-1245 (Figure B-3, for all three configurations). This form is used by Mound Laboratory to record surface contamination levels of the outer shipping package and to provide documentation to show compliance with all shipping regulations. Equivalent forms will be completed by other users.

Before a container is packaged for shipment, all components are visually inspected for damage or malfunction which would impair their use or create a hazardous condition. All deviations found are corrected and so indicated on the appropriate Operation Sheet of Form MD-70152.

The containers are loaded after the inspection. In the case of configuration-1 or -3 containers, the contents are wiped and placed in the inner container. Void space in the container is filled with inert material. The inner container lid is fastened to the body. The container assembly is placed in the outer drum assembly. 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.3, 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 then ready for shipment.

For loading (filling) configuration-5, the inner container is attached to the filling system with Cajon fittings. The inner container is loaded wither by admitting tritiated water directly or by passing air, containing the HTO, through the dry sorbent. In either case the loading is done through the valve marked "to top". Direct loading with water should be done slowly, because sorbency is exothermic. The maximum loading limits are 100,000 Ci of tritium and 2000 g of water on molecular sieve or silica gel or 3000 g of water on Florco commercial clay adsorbent. The quantity of water is determined by weighing the inner container before and after loading.

After loading the configuration-5 inner container, the valves to the container are closed with a torque wrench. Before being disconnected from the filling system, the tubing and Cajon fittings above the valves should be kept under vacuum until dry. Blind Cajon nuts (caps) are inserted in each Cajon fitting to provide secondary containment. The surface of the container is then decontaminated, allowed to dry, and probed with a tritium monitor for leakage or surface offgassing. If tritium is observed, the decontamination procedure is repeated. If no tritium is detected with the monitor, then surface wipes are taken. Further decontamination is performed as needed until these wipes are below 1000 dis/min beta. No leakage is permitted.

The protective cover is attached to the configuration-5 inner container to protect the valves and transducer from physical damage. Through the quick-disconnect fittings, the leakage from the cover and also from the container is determined by pressurizing the cover to 20 psig. No change in pressure should be observed after 30 min. The pressure is then released through a tritium monitor. If a tritium concentration reading greater than 180 $\mu Ci/m^3$ is obtained, the cap must be removed in order to look for a leak or to repeat the decontamination. The test is then repeated.

If the external surface of the capped configuration-5 inner container yields a surface wipe count of less than 1000 dis/min beta, the container is inserted into the insulated sleeve which is already in place in the outer 55-gal shipping package. The Cerawool insulating pads are placed on the top of inner container and the insulating sleeve. The lid is placed on the drum and held in place with the closure ring. The shipping drum is checked for contamination to ensure compliance with shipment regulations (less than 100 dis/min beta). As each operation is completed, Form MD-70152, OP.14 is so marked. In addition, Form MRC-ML-1245 is completed giving contamination levels and documentation of shipment. Closure seals and labels are attached to the drum. The configuration-5 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 cover, and each component is checked as it is removed from the package. After the contents of a configuration-1 or -3 package are removed from the inner container and checked for contamination, the package is stored for further use. After a configuration-5 inner container is removed from the insulating sleeve and checked for contamination, it is assayed by calorimetry and then stored in a hood until removal of the tritiated water is begun. The pressure is monitored if the container is not emptied within 30 days after filling.

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM Reusable Radioactive Shipping Containers	SHEET 1 of 1	MANUAL NUMBER MD-70152	OPERATION 3
AUTHORIZATION W.T.Carr	CLASSIFICATION Unclassified	EFFECTIVITY 9-26-77	ECN(S) INCORPORATED M4-C

OPERATION TITLE
Use Inspection and Loading of AL-M1 Configuration 1 or 3

USE INSPECTION

New______ Reuse__________ Configuration (1 or 3)________ Serial No.__________

I. CONTAMINATION LEVEL ACCEPTABLE (REUSE ONLY) __________ Initials __________ Date

II. CHECK LIST

The following inspections and/or actions are required. Do not check off any item until indication action is completed and any defect found has been corrected. Indicate repair by the letters Rpr and replacement by the letters Rpl. A simple check mark is satisfactory to indicate completion of an inspection or action. Enter NA if the inspection or action does not apply.

A. Insulated Drum Assembly

1. Labels, adhesives, etc. removed ____
2. Vinyl emblem ____
3. Paint ____
4. Identification plate ____
5. Tiedown brackets ____
6. Security seal bracket ____
7. Welds
8. Vent ____
9. Closure ring ____
10. Closure bolt ____
11. Interior dry and clean ____
12. Vent not plugged ____
13. Assembles properly ____

B. Cylinder Support (Configuration 1)

1. Clean and undamaged ____
2. Functional fit (drum and inner container) ____

C. Inner Container (Configuration 1 and 3)

1. No physical damage ____
2. Gage ____
3. Valve ____
4. O-ring ____
5. Cap screws ____
6. Welds
7. Braces and fixtures ____
8. No nicks or scratches in sealing surfaces ____
9. Valve operational ____
10. Pressure gage operational ____
11. Passes helium leak test (1×10^{-5} std cc/sec at 15 psig) ____

Signature ____________________ Date ____________________

LOADING PROCEDURE

1. Radioactive material form (solid, liquid or gas). ____
2. Check and lubricate inner container O-ring. ____
3. Close and cap inner container check valve(s). ____
4. Place sketch within insulated drum. ____
5. Close drum. ____
6. Install lead wire seal. ____
7. Apply labels (Radioactive). ____

Signature ____________________ Date ____________________

DISTRIBUTION:

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

MRC-ML-128

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FIGURE B-1

MONSANTO RESEARCH CORP.
MOUND LABORATORY

SHIPPING CONTAINER
OPERATION SHEET

PROGRAM REUSABLE RADIOACTIVE SHIPPING CONTAINERS		SHEET 1 of 1	MANUAL NUMBER MD-70152	OPERATION 14
AUTHORIZATION	CLASSIFICATION Unclassified	EFFECTIVITY 9-26-77	ECN(S) INCORPORATED M4-C	
OPERATION TITLE Use Inspection and Loading of AL-M1 Configuration 5				

1. IDENTIFICATION

1.1. Inner container serial number ________ and date of last interior surface evaluation ____________
1.2. Outer container serial number ________
1.3. Received from ________
1.4. The following inspections and/or actions are required. Do not check off any item until the indicated action is completed and any defect found has been corrected. Indicate repair by the letters Rpr and replacement by the letters Rpl. A simple check mark is satisfactory to indicate completion of an inspection or action. Enter NA if the inspection or action does not apply.

2. INNER CONTAINER

2.1. ______ Less than 5 years since last interior surface evaluation.
2.2. ______ Regeneration temperature of sorbent.
2.3. ______ Date of regeneration.
2.4. ______ Grams of water loaded.
2.5. ______ Date loaded.
2.6. ______ Ci of tritium loaded (best estimate).
2.7. ______ Primary containment leak checked and no leak through valve.
2.8. ______ Pressure transducer operational. Primary container pressure no more than 1 atm absolute.
2.9. ______ Valves operational and closed.
2.10. ______ Cajon fitting interior dry (e.g., by evacuation).
2.11. ______ Valves capped.
2.12. ______ Exterior surfaces decontaminated.
2.13. ______ No physical damage.
2.14. ______ Welds OK.
2.15. ______ No nicks or scratches in sealing surfaces.
2.16. ______ O-rings dry, grease free, and in good condition.
2.17. ______ Protective cover installed.
2.18. ______ Cover pressurized to 20 psig. No pressure decrease in 30 minutes.
2.19. ______ Cover interior produces less than 180 μCi/m^3 on tritium monitor when pressure released through monitor.
2.20. ______ Gross weight with cover.

3. INSULATING SLEEVE

3.1. ______ Clean and undamaged.
3.2. ______ Surface wipes less than 1000 DPM α.
3.3. ______ Cerawool pad in bottom of well in good condition.
3.4. ______ Large and small diameter Cerawool pads placed on top of inner container, in good condition.
3.5. ______ Sketch and form packed above Cerawool pads.

4. INSULATING DRUM ASSEMBLY

4.1. ______ Paint and vinyl emblem.
4.2. ______ Identification plate.
4.3. ______ Tiedown brackets (as applicable).
4.4. ______ Security seal bracket.
4.5. ______ Welds
4.6. ______ Vent not damaged or plugged.
4.7. ______ Interior dry and clean.
4.8. ______ Assembles properly.
4.9. ______ Closure ring and bolt.
4.10. ______ Old labels, adhesives, etc., removed and correct new labels applied.

DISTRIBUTION

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

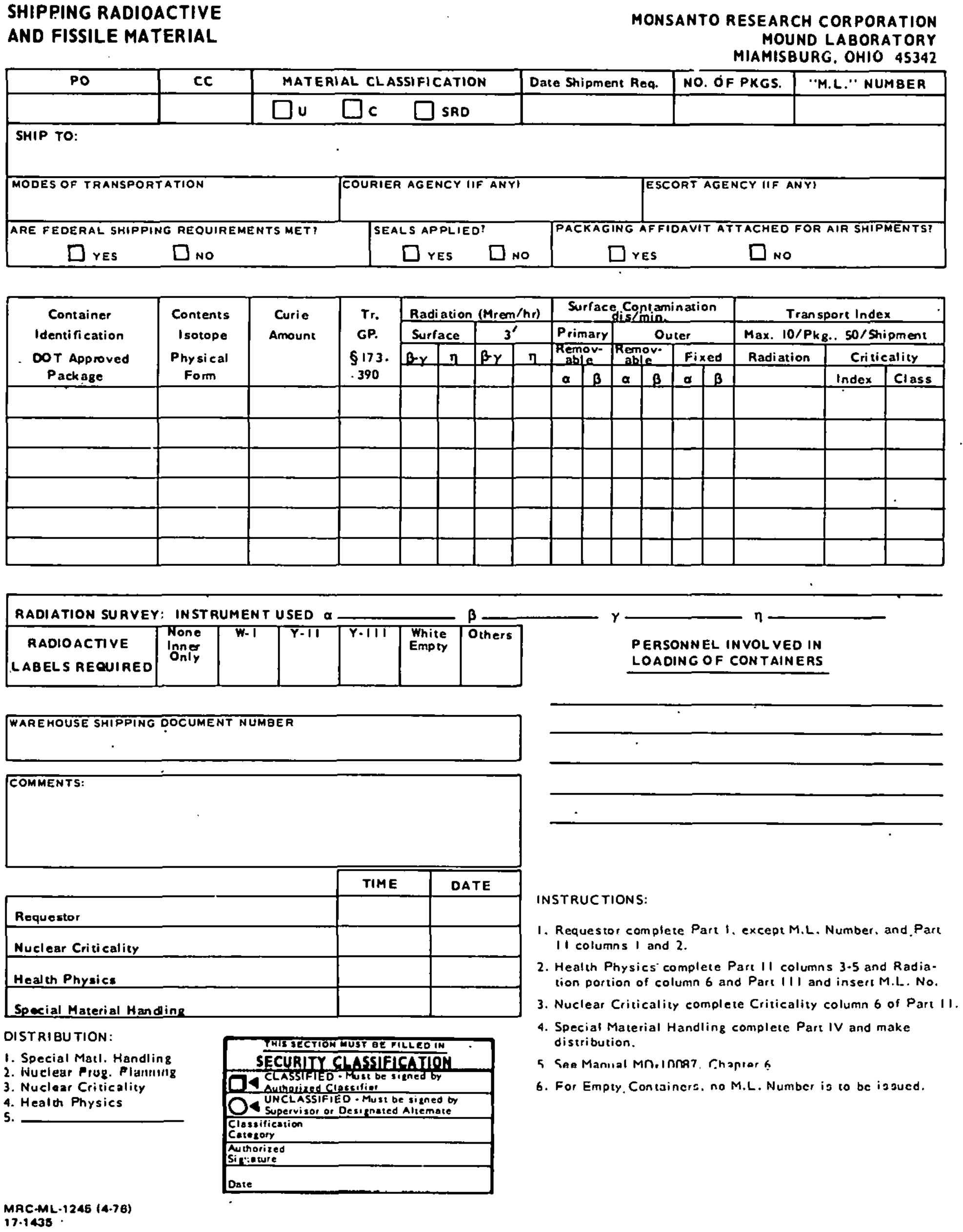
Signature ____________________

Date ____________________

MRC-ML-128

Issue 2 • 10-27-77

FIGURE B-2



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? ☐ YES ☐ NO

SEALS APPLIED? ☐ YES ☐ NO

PACKAGING AFFIDAVIT ATTACHED FOR AIR SHIPMENTS? ☐ YES ☐ NO

II

Container Identification DOT Approved Package	Contents Isotope Physical Form	Curie Amount	Tr. GP. § 173. .390	Radiation (Mrem/hr)				Surface Contamination dis/min.						Transport Index		
				Surface		3'		Primary		Outer				Max. 10/Pkg., 50/Shipment		
				β-γ	η	β-γ	η	Removable		Removable		Fixed		Radiation	Criticality	
								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		

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.

DISTRIBUTION:

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

THIS SECTION MUST BE FILLED IN

SECURITY CLASSIFICATION

☐ ◀ CLASSIFIED - Must be signed by Authorized Classifier

○ ◀ UNCLASSIFIED - Must be signed by Supervisor or Designated Alternate

Classification Category

Authorized Signature

Date

MRC-ML-1245 (4-76)
17-1435

FIGURE B-3

Appendix C

ERDA Certificate of Compliance

UNITED STATES 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/9507/BLF(ERDA-AL)	Original	USA/9507/BLF(ERDA-AL)	1	3

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 Corporation Mound Laboratory P. O. Box 32 Miamisburg, Ohio 45342	MLM-2447 Safety Analysis Report for Packaging (SARP) USA/9507/BLF(ERDA-AL)	9/30/77

4. CONDITIONS

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

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

(a) Description of Packaging

The AL-M1 package utilizes a 55-gal, DOT 6C or 17C, steel drum as an outer container which is lined with 3½ in. of insulation. Inner containers are identified as (a) configuration-1 - a stainless steel inner container 9½ in. I.D. by 15½ in. internal height sealed with a viton or silicone O-ring; (b) configuration-3 - an aluminum inner container 13 in. I.D. by 13 in. internal height sealed with a viton or silicone O-ring; and (c) configuration-5 - a stainless steel inner container 6 5/8 in. O.D. by 23 7/8 in. overall height sealed with valves, fittings, and protective cover.

The configuration is selected as necessary to accommodate the desired contents.

(b) Authorized Contents

Authorized contents for configurations-1 and -3 consist of plutonium-239 and uranium-235, and the authorized content for configuration-5 is tritiated water sorbed on solid material. Contents are limited by the envelope described in Section 3 of the SARP.

6a. Date of Issuance: September 9, 1977	6b. Expiration Date: 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, Director Operational Safety Division

CALCULATED TRANSPORT INDEX FOR AL-M1 (CONFIGURATION-1 AND -3)

Fissile Isotope	Quantity (kg)	Transport Index
^{235}U	6.0	0.1
	7.0	0.1
	8.0	0.1
	9.0	0.2
	10.0	0.4
	11.0	0.6
	12.0	1.1
	13.0	1.8
	14.0	2.8
	15.0	4.4
	16.0	6.9
	17.0	F.C.III
^{239}Pu	2.0	0.1
	2.5	0.2
	3.0	0.7
	3.5	2.2
	4.0	6.9
	4.2	F.C. III

NUMBER OF ALLOWED FISSILE CLASS III SHIPPING CONTAINERS

Fissile Isotope	Quantity (kg)	Number of Allowed Containers
^{239}Pu	4.20	11
	4.50	6
	4.75	3
	5.0	2
	5.25	1
^{235}U	17.0	11
	18.0	7
	19.0	5
	20.0	3
	21.0	2
	22.0	1

(c) Restrictions

Shipments in containers which are modifications of the designs described in the SARP or of contents which differ from or exceed those described in the SARP must be evaluated on an individual basis. Specific limitations are summarized below:

Pressure - The maximum packaging pressure for the configuration-1 inner container is 10 psig (1.7 atm) and for the configurations-3 and -5 inner containers is 0 psig (1 atm) at ambient temperature at time of loading.

Time - A configuration-5 package is to be shipped soon after loading, and the internal pressure of the inner container is to be monitored after 30 days if the tritiated water contents are not removed before that time.

Temperature - With the assembled package at normal ambient conditions, the user of any of the three configurations must ensure that the temperature of the outside surface of the inner container does not exceed 300°F. In addition, at hypothetical accident conditions this temperature can read approximately 500°F in configurations-1 and -3 and 250°F in configuration-5. The user must ensure that the contents are safe at these temperatures.

Weight - The maximum gross weight of the package is 550 lb (250 kg) for all three configurations. The maximum gross weight of the contents of configurations-1 and -3 is 44 lb (20 kg). Contents exceeding 15 lb (6.8 kg) in configurations-1 and -3 must be packaged such that the clamping fixture will not be bent excessively on impact.

Tritiated Water - Free standing liquid water is not permitted in the configuration-5 inner container. Its contents are limited to 2000 g net weight of tritiated water immobilized by sorption on molecular sieve or silica gel. For commercial clay absorbent this limit is 3000 g. The tritium content of this water is limited to 100,000 Ci (10 g).

Heat Load - The configuration-1 and -3 containers are limited to 10 W of radioactive decay energy. The tritium content limit restricts the configuration-5 container to 3.3 W of decay energy.

Distribution

EXTERNAL

TID-4500 UC-71 (163)
J. F. Stevens, DAO
J. A. Chacon, DAO
E. L. Barraclough, ALO (2)
W. C. Purchase, ALO
R. K. Flitcraft, MRC

INTERNAL

H. F. Anderson
A. G. Barnett
R. E. Bertram
R. K. Blauvelt
J. D. Braun
W. T. Cave
D. A. Edling (2)
R. D. Evans
T. M. Flanagan
J. F. Griffin
A. F. Heitkamp
C. W. Huntington
L. V. Jones
H. B. Kreider
P. H. Lamberger (2)
J. R. McClain
J. B. Peterson
T. B. Rhinehammer (5)
A. F. Schmidt
A. R. Stambaugh
R. A. Watkins (10)
M. A. Whitney
H. L. Williams
Publications
Library (15)