Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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TEST REPORT

DOT 7A TYPE A LIQUID PACKAGING

E. T. Ketusky, Savannah River National Laboratory

C. Brandjes, Ameriphysics, LLC

T. J. Benoit, Argonne National Laboratory

May 2017

SRNL-STI-2017-00308, Revision 0

SRNL.DOE.GOV

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Printed in the United States of America

Prepared for
U.S. Department of Energy

Keywords: *7A Type A, Liquid*

Retention: *Permanent*

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REVIEWS AND APPROVALS

AUTHOR:

Qgel_rspc ml Dgjc 3-02-0./5

E. T. Ketusky, SRNL Packaging Principal Engineer Date

TECHNICAL REVIEW:

Qgel_rspc ml Dgjc 3-02-0./5

J. L. England, SRNL Program Manager Packaging Technology, Date

APPROVAL:

Qgel_rspc ml Dgjc 3-02-0./5

J. S. Bellamy, Manager Date
SRNL Packaging Technology and Pressurized Systems

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ACRONYMS AND ABBREVIATIONS

A	Ambient
ALARA	As Low as Reasonably Achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ANL	Argonne National Laboratory
BD	Bottom Down
C	Loading Evaluated by Analysis
CG	Center of Gravity
CGOB	Center of Gravity over Bottom Corner
CGOT	Center of Gravity over Top Corner
CL	Centerline
CFR	Code of Federal Regulations
CRCQ	Cold Rolled Commercial Quality
CS	Carbon Steel
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPDM	Ethylene Propylene Diene M-class
H	Horizontal
HAC	Hypothetical Accident Conditions
HVYTAL	Heavy Type A Liquid Packaging
IAEA	International Atomic Energy Agency
ID	Inner Diameter
LDPE	Low Density Polyethylene
M&TE	Materials and Test Equipment
na	not applicable
nc	not computed
NCT	Normal Conditions of Transport
NNSA	National Nuclear Security Administration
NE	Nuclear Engineering
NRC	Nuclear Regulatory Commission
OD	Outer Diameter
Paragon	Paragon Die & Engineering Company
PSD	Power Spectral Density
psi	pounds per square inch
psig	pounds per square inch gauge
PT&PS	Packaging Technology and Pressurized Systems

QA	Quality Assurance
SARP	Safety Analysis Report for Packagings
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRPT	Savannah River Packaging Technology
SRS	Savanah River Site
SHSC	Socket Head Screw
SS	Stainless Steel
TI	Transport Index
TID	Tamper Indicating Device
UN	United Nations
VTD	Vertical Top Down
VTU	Vertical Top Up
WSCA	Tungsten Shielded Cask Assembly

PREFACE

This test report documents the performance of Savannah River National Laboratory's (SRNL's) U.S. Department of Transportation (DOT) Specification 7A; General Packaging, Type A shielded liquid shipping packaging and compliance with the regulatory requirements of Title 49 of the Code of Federal Regulations (CFR).

The primary use of this packaging design is for the transport of radioactive liquids of up to 1.3 liters in an unshielded configuration and up to 113 mL of radioactive liquids in a shielded configuration, with no more than an A_2 quantity in either configuration, over public highways and/or commercial aircraft.

The contents are liquid radioactive materials sufficiently shielded and within the activity limits specified in173.435 or 173.433 for A_2 (normal form) materials, as well as within the analyzed thermal heat limits. Any contents must be compatibly packaged and must be compatible with the packaging.

The basic packaging design is based on the U.S. Department of Energy's (DOE's) Model 9979 Type A fissile shipping packaging designed and tested by SRNL. The shielded liquid configuration consists of the outer and inner drums of the 9979 package with additional low density polyethylene (LDPE) dunnage nesting a tungsten shielded cask assembly (WSCA) within the 30-gallon inner drum. The packaging model for the DOT Specification 7A, Type A liquids packaging is HVYTAL.

1.0 GENERAL INFORMATION

This section presents a general description of the DOT Specification 7A Type A liquid content packaging (HVYTAL), the liquid content evaluated as its payload, acceptable payload shipping configurations and features special to its use. This test report documents compliance with the regulatory safety requirements of 49 CFR Parts 173.24, 173.24a, 173.27, 173.410, 173.412, 173.461 – 173.466 and 178.350.

1.1 INTRODUCTION

In support of the Mo-99 production program, and other similar medical isotope programs at Argonne National Laboratory (ANL), ANL Nuclear Engineering was tasked with providing technical assistance, design, testing, and procurement of a transportation packaging. The packaging is initially for the transport of Type A quantities of Mo-99, in liquid form, in commerce through the use of public highways and/or commercial aircraft. Additional Type A liquid isotopes are also authorized.

In conjunction with the Packaging Technology and Pressurized Systems (PT&PS) organization of the SRNL and Paragon Die & Engineering Company (Paragon), it was determined the best packaging system for the Mo-99 liquid content would be based on the design of the DOE 9979 Type A fissile packaging with an ANL designed WSCA nested in LDPE dunnage. Since the 9979 packaging is currently licensed by both the DOE and U.S. Nuclear Regulatory Commission as a Type A fissile shipping packaging for solid contents, and complies with the regulatory safety requirements of 10 CFR 71 and 49 CFR 173, the 9979 has been demonstrated through extensive testing to withstand the rigorous testing required for a DOT 7A Type A liquid content packaging.

The results of analysis and testing of the HVYTAL design demonstrate compliance with the regulatory safety requirements for Type A packagings for liquids per 49 CFR 173.465 and 49 CFR 173.466. The Transport Index (TI) associated with the package will be established by measurement at time of shipment. However, the TI will be limited to 10.0 for road transport or cargo aircraft and 3.0 for passenger carrying aircraft.

The maximum calculated dose rate for the Mo-99 content on the external surface of the package is 18.76 mR/hr per AMP-01-17 (see Appendix D). This calculation is very conservative since it does not take into account shielding associated with the wall thickness of the inner and outer drums, the 55-gallon metal drum liner, and the BETAFOAM™ material. The actual dose rate on the exterior of the package may exceed the calculated dose rate identified in this report, but may not exceed the regulatory limits identified in 49 CFR 173.441.

1.2 PACKAGING DESCRIPTION

The HVYTAL is a drum style packaging and is designed to transport Mo-99 liquid salts (1.0M NaOH) and other Type A liquid compounds with similar characteristics totaling less than or equal to one A_2.

1.2.1 Packaging

Major packaging components include an internally insulated 55-gallon outer drum and a 30-gallon inner drum. For the shielded configuration, the 30-gallon inner drum contains a WSCA nested in LDPE dunnage. The 55-gallon drum possesses a steel liner that protects foam insulation material within the 55-gallon drum. The 30-gallon drum is positioned both radially and axially within the 55-gallon outer drum.

The WSCA, when utilized, is located within the 30-gallon drum and is nested in LDPE dunnage filling the majority of the void within the 30-gallon drum. The WSCA is surrounded by approximately 5.62 inches LDPE radially and 7.81 inches LDPE top and bottom. The 55-gallon outer drum and 30-gallon inner drum are both closed utilizing reinforced split-ring devices. The WSCA is closed utilizing six American National Standards Institute (ANSI) B18.3 3/8 – 16 UNC – ¾ HS HCS hexagon socket head screw caps.

The foam material between the 55-gallon outer drum wall and the liner provides both structural support and thermal insulation for the 30-gallon drum and its contents. There are no external impact limiters or other energy-absorbing features, nor any engineered structural features for lifting or tie-down.

Table 2-4 lists detailed material specifications. Section 7.3, Instructions, Procedures, and Drawings specifies how the packaging design drawings and subsequent drawing revisions are controlled. The packaging assembly is defined by drawing R-R1-G-00030 given in Appendix A and is illustrated in Figure 1-1.

A fully loaded HVYTAL package shall not exceed 419.7 lbs. This limit includes all package contents including radioactive material, WSCA or other shielding (when used), LDPE dunnage, absorbent, packing, and thermal insulating materials. Component weights reported in this section, unless otherwise specified, are estimated weights based on nominal dimensions and are documented on the engineering drawings in Appendix A. Nominal and maximum estimated weight of the packaging components are reported in Section 2.1.3. Figure 1-2 shows the general dimensions of an empty packaging assembly. The content envelope, listed in Section 1.2, limits package contents to materials with low decay-heat rates. Heat transfer by the HVYTAL to its ambient surroundings is passive.

The radioactive contents of the HVYTAL are limited to one A_2.

The 30-gallon drum closure lid includes a pressure relief device to ensure an over pressure condition does not occur during transport. This device does not permit continuous venting under normal conditions of transport.

The HVYTAL is not designed or evaluated for the transport of fissile material exceeding the limits identified in 49 CFR 173.435. Therefore, a criticality evaluation was not performed.

The HVYTAL design incorporates a WSCA as a specific shielding feature for materials requiring shielding. Shielding calculations for the WSCA are based on an A_2 quantity of the radioisotope Mo-99 and applicable gamma emitting daughter Tc-99m. Maximum calculated dose rate on the exterior of the WSCA containing an A_2 quantity of Mo-99 is 213.1 mR/hr (contact) with a maximum calculated dose rate on the exterior surface of the shipping package of 18.76 mR/hr. The TI will be determined at the time of shipment and shall not exceed the regulatory limits of 3.0 for passenger-carrying aircraft or 10.0 for cargo aircraft only or transport by public highway. Since these dose rates are less than the applicable limits for radiation levels in 49 CFR 173.441(a), no additional consideration for shielding is necessary. Section 4.0 quantifies dose rates under Normal Conditions of Transport (NCT).

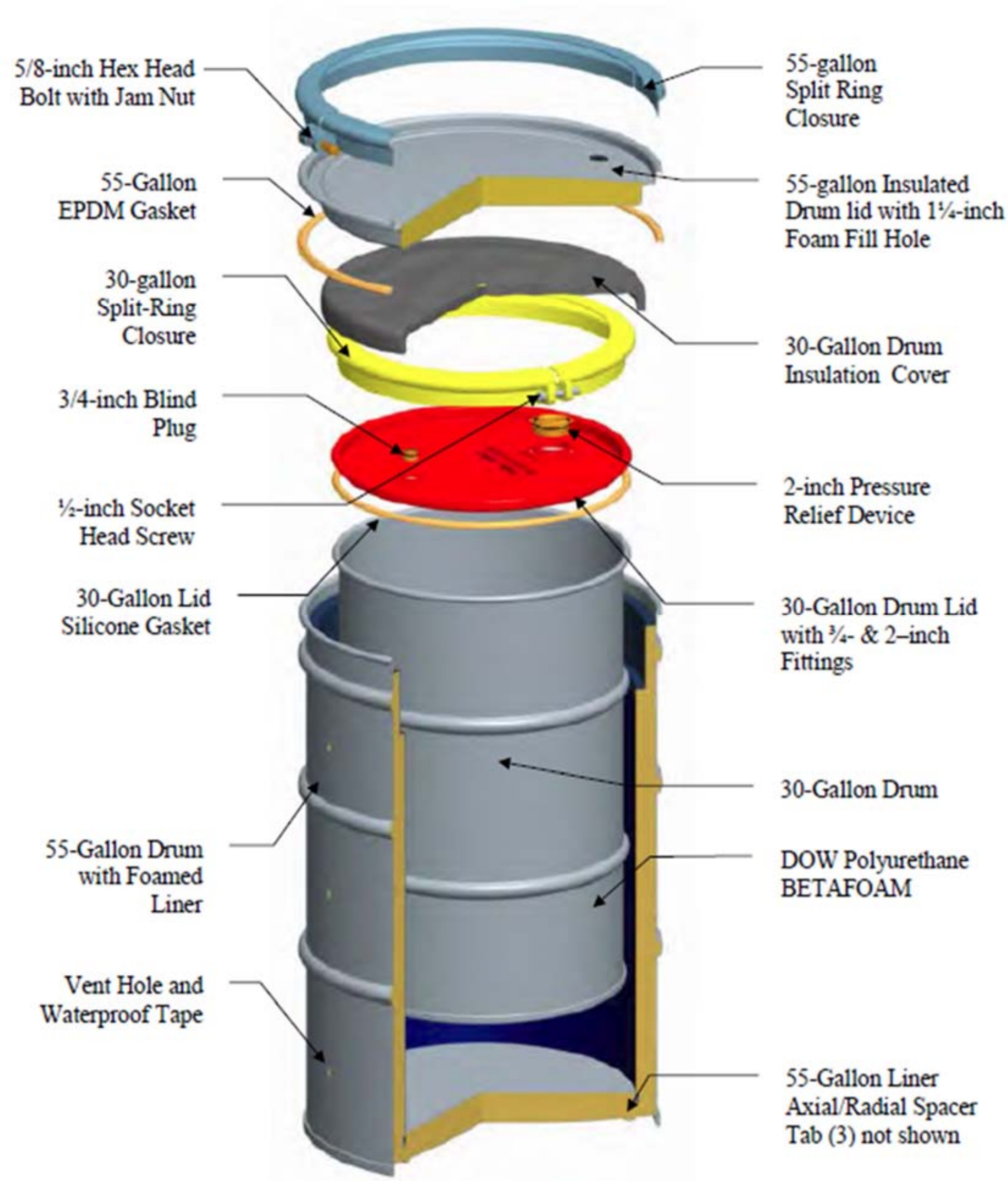

Figure 1-1 HVYTAL Shipping Packaging without Tungsten Shielded Cask Assembly (WSCA) and Low Density Polyethylene (LDPE) Dunnage

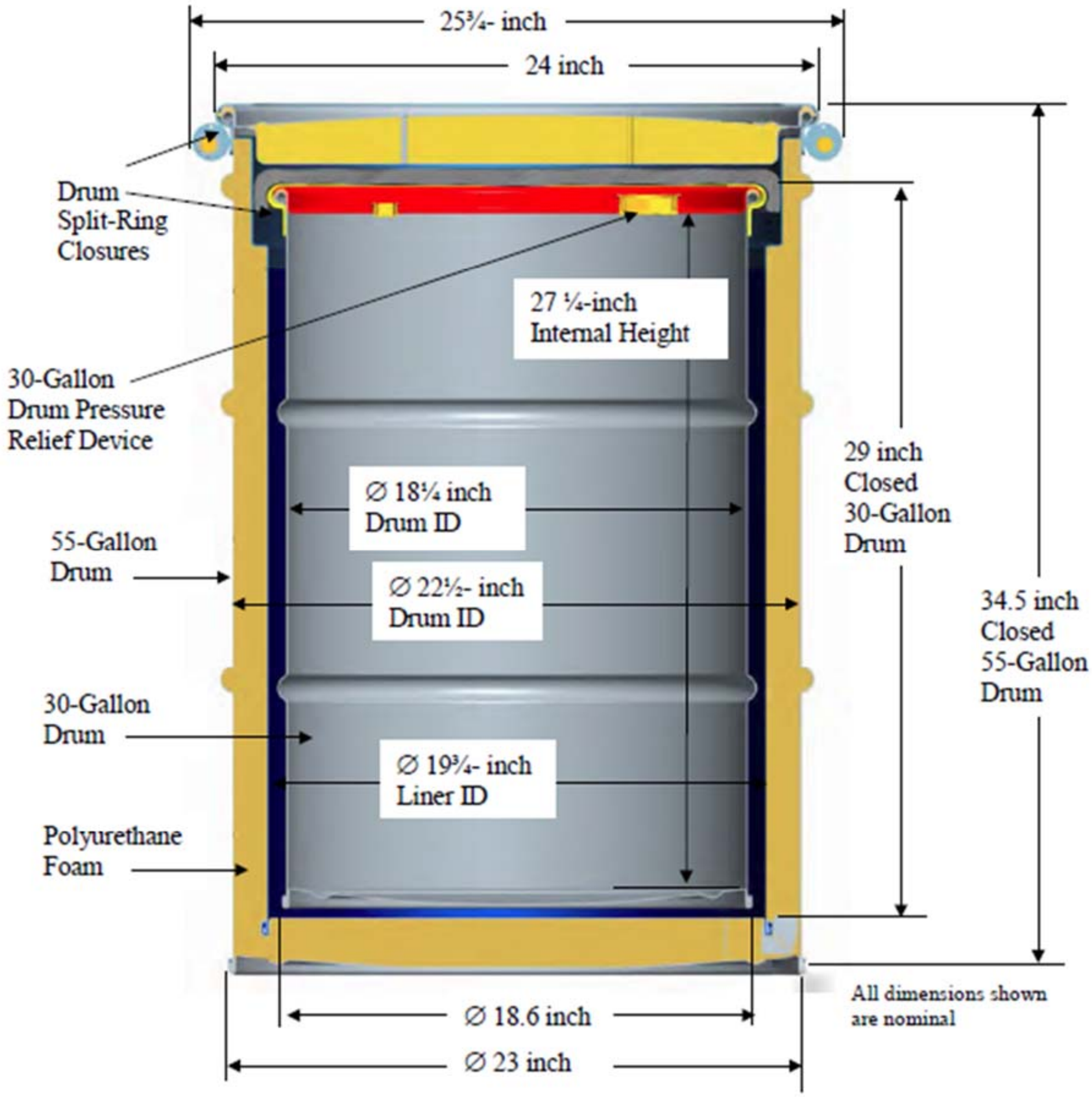

Figure 1-2 HVYTAL Shipping Packaging General Dimensions

1.2.1.1 Drums and Closures

The HVYTAL packaging design incorporates two sizes of commercial removable head drums (30- and 55-gallon). The inner 30-gallon drum complies with applicable provisions for 7A Type A packaging in 49 CFR 178.350. The 55-gallon drum is modified to include a steel liner welded to the inside of the drum body and under its closure lid. Polyurethane foam insulation fills the cavities formed between the liner and drum components. The insulated 55-gallon drum functions as the containment boundary for the package's radioactive contents.

1.2.1.1.1 55-Gallon Outer Drum

The general outside dimensions of the 55-gallon outer drum are approximately 24 inches in diameter by 34½ inches high when closed. The 55-gallon drum body and lid both incorporate liners fabricated from carbon steel. The liner assemblies are welded to the inside of the drum body and lid forming cavities filled with 24 lb/ft^3 polyurethane foam called BETAFOAM™. Nondestructive methods are used to verify complete filling of each 55-gallon drum body and drum lid.

The drum body is fabricated from 16-gauge carbon steel and the welded liner is fabricated from 16- and 18-gauge carbon steel. The 55-gallon drum wall includes nine ½-inch vent holes uniformly spaced axially and circumferentially covered with waterproof tape. The primary purpose of the tape is to prevent water or moisture from entering the drum through the holes under normal conditions of transport (NCT), even though the polyurethane foam is not functionally affected by the presence of moisture. One 1¼-inch diameter foam fill hole in the drum bottom is covered with waterproof tape. The estimated weight of the 55-gallon outer drum without its lid is 140.3 lbs. Figure 1-2 illustrates the HVYTAL packaging assembly, and drawing R-R2-G-00057, given in Appendix A, defines the design.

The 55-gallon closure lid is fabricated from 16-gauge carbon steel and incorporates a shallow liner (pan) formed from 16-gauge carbon steel. The pan is nominally 1.4 inches deep by 20¾ inches in diameter and is welded to the bottom of the closure lid. The formed cavity is filled with the 24 lb/ft^3 BETAFOAM™ through a hole in the top of the lid and is subsequently covered with waterproof tape. The 55-gallon drum lid weighs approximately 24 lbs. When installed the lid assembly extends into the drum body liner. An Ethylene Propylene Diene M-class (EPDM) gasket seals the drum closure. Figure 1-2 illustrates the closure lid assembly and drawing R-R2-G-00059 defines the design.

The 55-gallon outer drum is closed with a split-ring closure device fabricated from 12-gauge carbon steel. The closure device is similar to standard commercial C-ring closures used on most open-head drums but is halved and incorporates two 1-inch flange extensions, one extending horizontally and the other vertically from the C-ring. Lugs are welded at each end of the two split-rings. Each split-ring is identical, with one 1½-inch lug threaded with ⅝-11UNC-2B thread and the other with a ¾-inch diameter through-hole. The closure device secures the closure lid to the drum via two 3½-inch long, ⅝ carbon steel hex head bolts and jam nuts. Each lug includes a 0.13-inch hole to receive a tamper-indicating device (TID) as defined in drawing R-R1-G-00027 (see Appendix A). The 55-gallon split-ring closure weighs approximately 9.8 lbs. Figure 1-3 shows a split-ring closure device installed on a 55-gallon drum. The estimated nominal weight of the 55-gallon outer drum assembly (body, closure lid and split-ring closure device) is calculated to be 174.5 lbs (see drawing R-R1-G-00029 in Appendix A).

1.2.1.1.2 30-Gallon Drum

The general outside dimensions of the 30-gallon drum is 18.6 inches in diameter by 29 inches high when closed (Figure 1-2). The drum and its closure lid are fabricated from 18- and 16-gauge carbon steel, respectively. The lid incorporates two standard commercially stamped and threaded bung hole flanges, one ¾ inch in diameter and the other 2 inches in diameter (Figure 1-3). The 2-inch bung hole is fitted with a 2-inch pressure release plug that is designed to open between 12 to 15 pounds per square inch gauge (psig) to limit buildup of internal pressure. The ¾-inch fitting is sealed with a standard ¾-inch non-venting drum plug. A formed silicon gasket seals the 30-gallon drum closure. The 30-gallon drum lid gasket includes a 2-inch flange with pressure relieving plug and a ¾-inch flange with plug; both include formed neoprene gaskets (see drawing R-R1-G-00028 in Appendix A for the design). The 30-gallon drum with lid and split-ring closure weighs approximately 43.6 lbs.

The 30-gallon drum split-ring closure device is similar to the closure device used to close the 55-gallon outer drum except for the smaller size and low profile lugs as shown in Figure 1-3. The drum split-ring closure device is fabricated from 12-gauge carbon steel. Low profile lugs are welded at each end of the two split-rings. Each split-ring is identical, with one lug threaded with 1/2-13UNC-2B thread and the other with a through-hole. The split-ring secures the closure lid to the drum via two 2½-inch long, ½-inch carbon steel socket head screws. Each lug includes a 0.13-inch hole to receive a TID as defined in drawing R-R1-G-00026. The 30-gallon split-ring closure weighs approximately 7.2 lbs. Figure 1-3 shows a split-ring closure device installed on a 30-gallon drum.

1.2.1.1.3 <u>Tungsten Shielded Cask Assembly (WSCA)</u>

The general outside dimensions of the WSCA are 6.63 inches in diameter by 11.63 inches high when closed (including cover weldment) (see Figure 1-4). The WSCA body and closure plug are fabricated from tungsten billet and in final form allows for approximately 1.75-inch thick tungsten shielding on each side, top and bottom. The closure plug is connected to 0.25-inch thick tungsten plate (cover) with four ANSI B18.3 -¼ - 20 UNC – 5/8 hexagon socket head cap screws. The cover has a lifting weldment attached to it for lifting the closure plug and/or WSCA. The closure plug and cover are secured to the WSCA body with six ANSI B18.3 – ⅜ – 16 UNC – ¾ hexagon socket head cap screws. The WSCA weighs approximately 191.5 lbs. Figure 1-4 contains the CAD drawing of the WSCA.

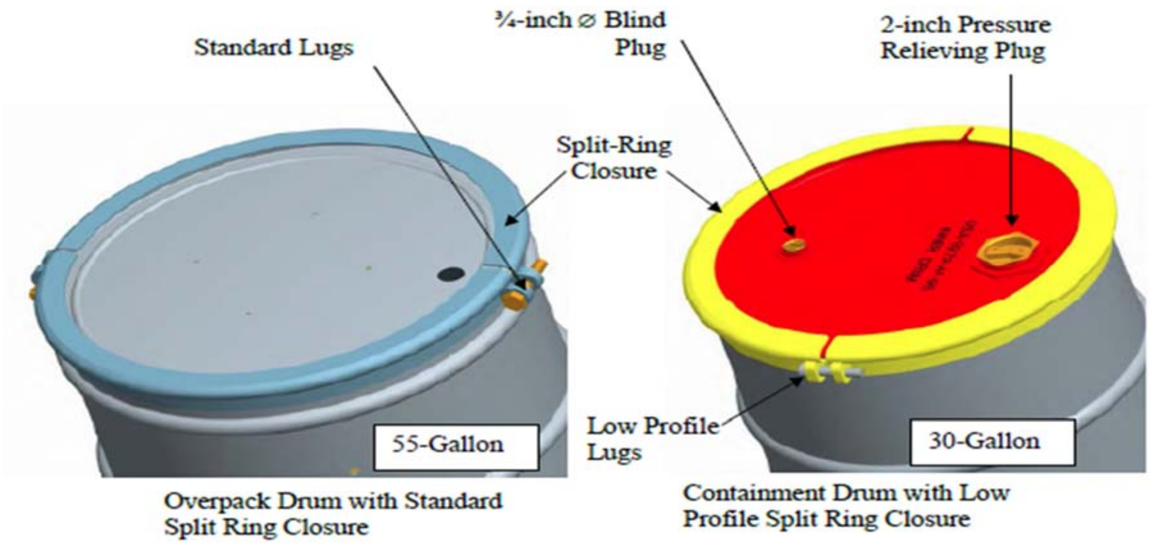

Figure 1-3 Split-Ring Closure Installed on 30- and 55-Gallon Drum Assemblies

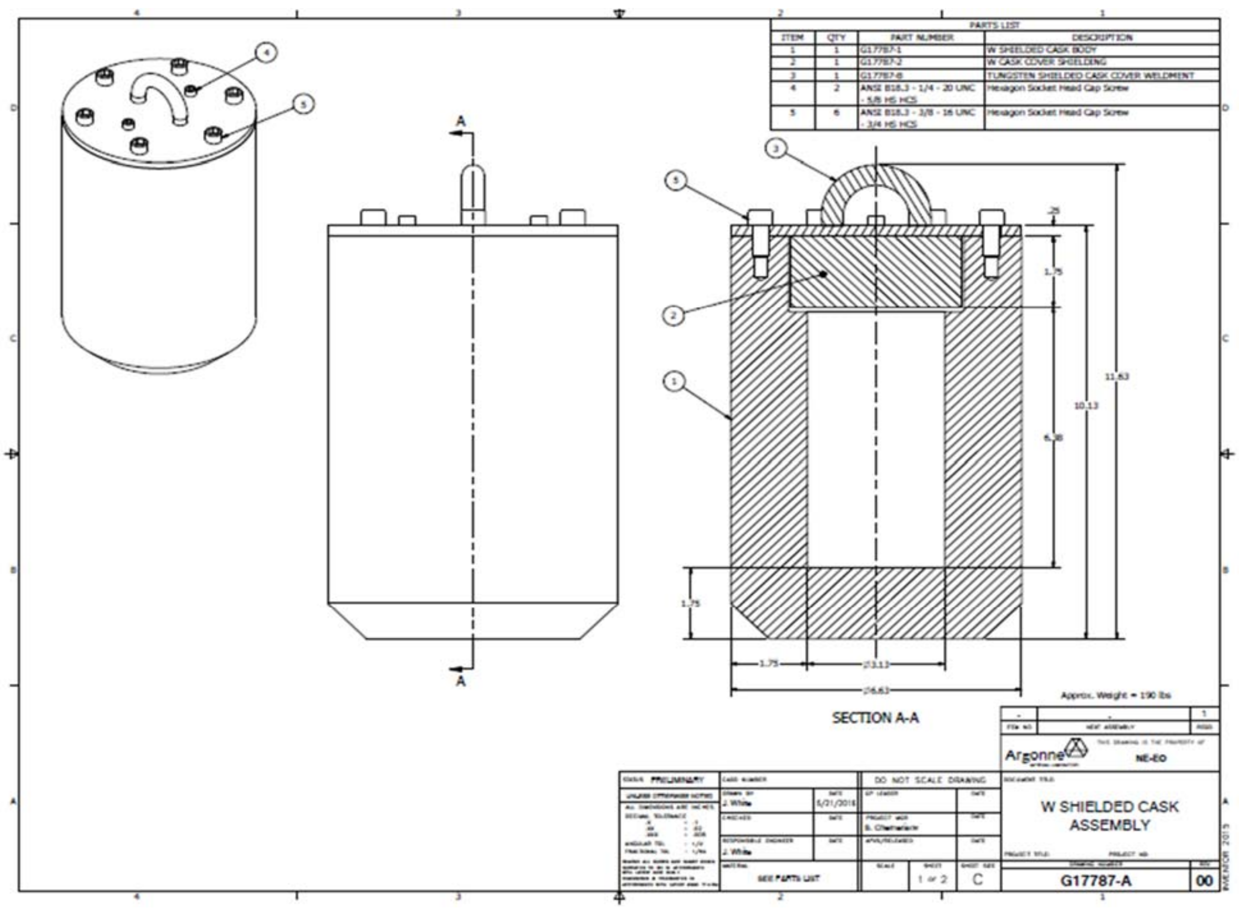

Figure 1-4 Tungsten Shielded Cask Assembly (WSCA)

1.2.2 Contents

1.2.2.1 Contents of Packaging

The payload for the HVYTAL packaging includes all radioactive and non-radioactive materials contained within the 30-gallon drum. The radioactive liquid content is bounded by 1.3 liters or less, be ≤ one A_2 , and meets surface dose rates identified in 49 CFR 173.441(a). The WSCA radioactive contents include any liquids containing similar radioactive and physical properties (e.g., dose rates, gamma emission energies, viscosity) as that contained in Mo-99 solution 1.0 M NaOH and molybdenum (viscosity similar to water).

1.2.2.2 Payload Limits and Restrictions

The following limits apply to HVYTAL package contents:

- Payload decay heat is limited to a maximum of 1.3 watts.
- Payload mass is limited to a maximum of 205.4 lbs (93.2 kg).

- Payload volume limits:
  - 113 mL of liquid content when utilizing the WSCA.
  - 1.3 L of liquid when not utilizing the WSCA.
  - Suitable absorbent material to absorb twice the volume of the liquid contents and in a location to contact liquid in the event of leakage.
  - Due to variability of liquid contents, the user must ensure no potential degradation to packaging materials.
- Maximum activity is limited to one A_2.
  - For materials requiring the use of the WSCA, shielding calculations are based on 16 Ci of Mo-99 and associated daughters.

The following forms of materials are prohibited as content in the HVYTAL:

- Pyrophoric materials
- Cryogenic liquids
- Compressed gasses
- Chemically reactive substances'

Payload is all radioactive and non-radioactive material; non-radioactive contents include all secondary containers, LDPE dunnage, WSCA, absorbent material, liquids vial (i.e., metal or plastic), packing, and other dunnage material.

1.2.2.3 General Payload Configuration

All contents are required to be packaged in the HVYTAL inner 30-gallon drum. As tested payload configuration consisted of the following (working inside out):

- One 125 mL stainless steel vial containing 113 mL water/fluorescent dye solution
- One WSCA
- One 884-gram carbon steel plate placed underneath WSCA (added additional weight to bound testing configuration and not required for shipment)
- 112.3 grams of granular absorbent material
- Approximately 3.89 cubic feet (8.4 lbs) of LDPE dunnage

1.2.3 Operational Features

1.2.3.1 Split-Ring Closure Installation

Installation of the split-ring requires striking each half with a rubber hammer as the bolts are torqued, and the process continues until sustaining required torque. The repeated striking and torque sequence is necessary to overcome the static friction between the drum closure and split-ring connection. With fully applied torque, the ends of the split-ring halves must retain a visually discernible gap. Jam nuts are then tightened against the unthreaded lugs on the 55-gallon drum. (The 30-gallon split-ring closure does not include jam nuts.)

- Specified torque values:
  - 55-gallon drum
    - Hex head bolts on split-ring assembly – 40 ft-lbs ± 5 ft-lbs
  - 30-gallon drum
    - Hex head bolts on split-ring assembly – 40 ft-lbs ± 5 ft-lbs
    - ¾-inch bung – 15 ft-lbs ± 10%
    - 2-inch pressure relief fitting - 30 ft-lbs ± 5 ft-lbs

1.2.3.2 Tungsten Shielded Cask Assembly Closure Installation

Installation of the WSCA closure plug required the placement of the closure plug onto the body of the WSCA and lining up the bolt holes on the closure plug with the threaded holes in the shield body. Install each of the six ANSI B18.3 – ⅜ – 16 UNC – ¾ hexagon socket head cap screws, hand tight, connecting the closure plug and body. In a star pattern sequence, tighten each of the hexagon socket head cap screws to 20 ft-lbs ± 2 ft-lbs.

1.2.3.3 Drum Hoisting

A lifting device may be necessary for loading the 30-gallon drum into the 55-gallon outer drum. Figure 1-5 illustrates an example of a drum lifting device. Users may develop their own lifting device and use with their own internal procedures.

Figure 1-5 Example of Drum Lifting Device

2.0 TESTING EVALUATION

This section presents the test results and analyses demonstrating the HVYTAL shipping packaging is in compliance with the 49 CFR Parts 173.24, 173.24a, 173.410, 173.412, 173.415, 173.461 – 173.466 and 178.350.

2.1 DESCRIPTION OF TESTING

2.1.1 Discussion

The HVYTAL is based on the DOE 9979 Type A fissile packaging system, with the exception of using a WSCA and additional LDPE dunnage inside of the 30-gallon inner drum. The shipping packaging consists of an insulated 55-gallon outer drum containing a 30-gallon drum. The 55-gallon drum functions to protect the inner 30-gallon drum and its contents under NCT events and is considered the containment boundary for the packaging. The carbon steel liner within the outer drum provides a form for the foam insulation and protects against foam abrasion during normal loading/unloading operations. The 30-gallon drum provides additional containment for the packaging payload during NCT and under test conditions. The overall packaging is nominally 23 inches in diameter and 34½ inches in height (Figure 1-2). Both the 30-gallon drum and 55-gallon drum use split-ring closure devices, which provide a positive closure and seal between drum lid and body. The closure lid of the 30-gallon drum features a commercial pressure relieving plug to release pressure during over-pressurization events.

The HVYTAL includes two forms of insulation. The insulating materials of the outer drum consist of BETAFOAM™ (Dow BETAFOAM 87100/87124 Data Sheet) and Kao-Tex Quilt™ fabric (Thermal Ceramics Kao-Tex Quilt™ Product Data Sheet). The BETAFOAM™ components react when mixed to form a closed cell, high density, polyurethane structural foam that adheres to primed metal surfaces. These components are formulated to fill the outer drum insulation cavities before the mixture sets. A pan-shaped Kao-Tex Quilt™ blanket provides local thermal protection to the 30-gallon drum closure.

Table 2-4 lists the material specifications. Additional material requirements and fabrication specifications are detailed in Section 2.3.1.

2.1.2 Design Criteria

Criteria employed in the design of the HVYTAL packaging comply with Sections 173.465 and 173.466 of 49 CFR. Testing analysis presented in this test report demonstrates compliance with the requirements of 49 CFR 173.

The packaging assembly is qualified principally by testing of five 9979 packaging prototypes, performed during the licensing of the 9979, and one HVYTAL packaging prototype containing the WSCA, LDPE dunnage and liquid contents in a stainless steel vial. Table 2-1 details the test matrix used to comply with 49 CFR 173.465 and 49 CFR 173.466 requirements. Table 2-2 shows the testing for certification of the 9979 used as bases for HVYTAL.

Containment of its payload within the 55-gallon outer drum, under the influences of the testing specified in 49 CFR 173.465 and 173.466, is the final measure of HVYTAL structural performance adequacy. To address brittle fracture, 9979 packaging prototypes were physically tested for the Hypothetical Accident Condition (HAC) 30-foot drop, crush and puncture with the packaging temperature initially at -20°F.

Since the HVYTAL utilizes the 9979 as the primary basis for its packaging design, all tests conducted on the 9979 during licensing are directly relevant to the testing and certification of the HVYTAL and will be utilized for such throughout this report.

Table 2-1 HVYTAL Required Testing Matrix

Type A Liquid Requirements	Criteria	HVYTAL Testing	9979 Comparison
49CFR 173.465 49CFR24(a)	Vibration and shock		X
49CFR 173.465	1.2-meter free drop	X	
49CFR 173.465	1.0-meter penetration	X	
49CFR 173.465	Stack test		X
49CFR 173.465	Water spray	X	
49CFR 173.466	9-meter free drop	X	
49CFR 173.466	1.7-meter penetration	X	

Table 2-2 9979 Testing Matrix for Comparative Analysis

Pkg ID		Initial Conditions		Normal Conditions of Transport									Hypothetical Accident Conditions							
55-Gallon Drum Serial Number	30-Gallon Drum Serial Number	Package Pressure	Package Temperature (°F)	Heat (Solar, 100°F)	Cold (-40°F, no sola(r)	Pressure Variations (External)	Vibrations	Water Spray	4-ft Free Drop	Corner Drop (1-ft)	Compression	Penetration	30-ft Drop	Crush	Puncture	Thermal	3-ft Immersion – fissile	50-ft Immersion – all	290-psi	Leak Test
1	1	A	-20	-	VTU	C	-	-	-	-	-	-	H	H	H	C	C	C	na	na
2	2	A	A	-	-	C	-	-	CGOT	CGOT	-	H	CGOT	CGOB	-	C	C	C	na	na
3	3	A	A	-	-	C	-	VTU	CGOT	CGOT	-	H	CGOT	H	-	C	C	C	na	na
4	4	A	A	-	-	C	-	-	-	-	-	-	VTD	VTU	H	C	C	C	na	na
5	5	A	A	-	-	C	-	VTU	-	-	VTU	-	-	-	-	C	C	C	na	na

A - Ambient
BD - Bottom Down
C - Loading Evaluated by Analysis
CGOB - Center of Gravity over Bottom Corner
CGOT - Center of Gravity over Top Corner
H - Horizontal
na - Not applicable
VTD - Vertical Top Down
VTU - Vertical Top Up
“-“ - No Testing Performed

2.1.3 Weights and Centers of Gravity

Figure 2-1 illustrates the packaging components and centers of gravity (CGs) location of the empty packaging. The CGs of HVYTAL packaging components are all located on the longitudinal axis of the packaging. The 30-gallon drum is also centered within the 55-gallon drum. The CG of a loaded package could be shifted vertically or laterally corresponding to the asymmetrical weight distribution of the payload, though, due to practical weight density limitations, it will not shift significantly for the maximum payload condition. Based on the variability of content types, the shift in package CG away from an empty packaging CG was calculated to be approximately 6 inches in the vertical direction and 4 inches radially and is illustrated in Figure 2-1. The calculation and pre-prototype tests show that a shift in CG would not adversely affect the structural performance of the packaging under the test conditions addressed in this section.

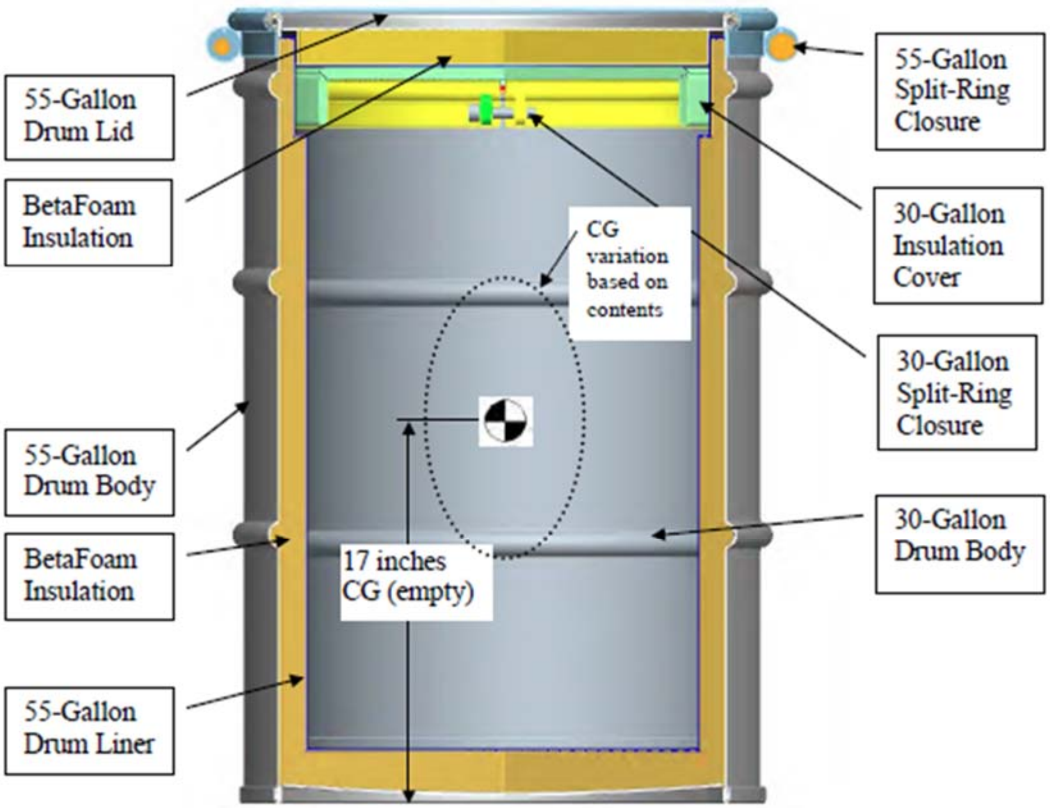

Figure 2-1 Center of Gravity Location of Empty Packaging

Table 2-3 summarizes 9979 and HVYTAL packaging and component weights based on the engineering drawings, calculated values, and measured weights. The maximum loaded weight of the HVYTAL is 419.7 lbs.

Table 2-3 Packaging Component Weights

Packaging Component	Nominal Weight (lbs.)	Maximum Calculated Weight (lbs.)	Measured Weight (lbs.)
	Appendix A Engineering Drawings	Calculated (M-CLC-G-00376)	
55-gallon outer drum (body, lid & split-ring)	174.5	175	172.6
Body (only)	140.3	nc	nc
Lid & Split-Ring (only)	34	nc	nc
Insulation Cover	0.5	1.5	nc
30-gallon outer drum (body, lid & split-ring)	50.3	50	52[1]
Tungsten Shielded Cask Assembly			191.5
Maximum Loaded Weight			419.7

[1] Weight includes the addition of LDPE dunnage.

2.2 MATERIALS

2.2.1 Material Properties and Specifications

Table 2-4 lists the materials used in the fabrication of the HVYTAL packaging design. The drum bodies, closure lids, and closure devices are called out as American Society for Testing and Materials (ASTM) A1008, though similar sheet material may be substituted, provided similar ductility and strength properties are provided.

The materials used in fabrication identified in this section include only those used in fabricating components associated to the containment system associated to the packaging system (i.e., 55-gallon outer drum, 30-gallon inner drum, split-ring closure rings and bolts).

2.2.1.1 ASTM A1008 Cold Rolled Commercial Quality (CRCQ) Carbon Steel

Specification ASTM A-1008 CS [ASTM A1008/1008M]

Size 12 ga, 16 ga, 18 ga [Table 2-4]

Young's Modulus = E = 29.0×106 pounds per square inch (psi) [ASME BPVC Section II]

Yield Stress* = Sy = 20 ksi to 40 ksi @ 70°F [ASTM A1008/1008M, Table 3]

Tensile Stress = Su = Not specified [ASTM A1008/1008M, Table 3]

Elongation ε > 30 % [ASTM A1008/1008M, Table 3]

Weight Density, ρstl = 0.284 lb/in3 [ASME BPVC Section II]

Allowable Stress Use in Analysis will be ⅔ of the lower bound yield = 13,300 psi

* Strength values for commercial steel are non-mandatory and are supplied in the specification as a guide.

2.2.1.2 55-Gallon Outer Drum Split-Ring Closure Bolts

Specification		ASTM A-320 L7.	[Ref. 13]
Size		⅝-11UNC-2A, by 3.5 inch long, hex head	
Young's Modulus	= Ebolt	= 29.0×106 psi	[ASME BPVC Section II, Table TM-1]
Yield Stress	= Sy	= 105,000 @ 70°F	[ASTM A320/A320M, Table 1]
Tensile Stress	= Su	= 125,000 psi @ 70°F	[ASTM A320/A320M, Table 1]
Elongation		ε = 16 %	[ASTM A320/A320M, Table 1]

2.2.1.3 30-Gallon Drum Split-Ring Closure Bolts

Specification		ASTM A-574 Grade A.	[ASTM A-574]
Size		½-13UNC-2A, by 2.5 inch long, Socket Head	
Maximum Tensile Load = 25,500 lb			[ASTM A574, Table 4]
Young's Modulus	= Ebolt	= 29.0×106 psi	[ASME BPVC Section II, Table TM-1]
Yield Stress	= Sy	= 153,000 @ 70°F	[ASTM A574, Table 1]
Tensile Stress	= Su	= 180,000 psi @ 70°F	[ASTM A574, Table 1, 4]
Elongation		ε = 10%	[ASTM A574, Table 1]

Table 2-4 Packaging Components and Material Specifications

Component 30-Gallon Drum	Material Specifications (Form, Specification, Type/Grade)
Drum body/bottom	18-gauge sheet, ASTM A1008, CRCQ carbon steel, 1A2/X235/S and 1A2/Y1.5/150, interior drum body and cover lined with reddish brown epoxy phenolic coating 0.6 – 0.8 mil DFT approximately, exterior painted black per Skolnik PN LQ10003
Drum closure lid	16-gauge sheet, ASTM A1008, CRCQ carbon steel
Drum closure gasket	Parker seals, 58435S or 59498S gasket, silicone compound S7364, 60 durometer
Bung hole pressure relieving plug	Rieke packaging systems, S-220-2 Rieke® VISEGRIP II® pressure relief plug, 2-inch, release pressure 12 to 15 psi, resealing by 3 psi, EPDM white-washer/gasket
Bung hole blind plug	Tri-Sure®, G¾ (20 mm) steel (Std) R-type metal plug zinc plated round EPDM white-washer/gasket
Bung hole ¾-inch flange and gasket	Tri-Sure®, G¾ (20 mm) steel type flat (STD) flange zinc plated EPDM white-washer/gasket
Bung hole 2-inch flange and gasket	Tri-Sure®, G2 (50 mm) steel type flat (STD) flange zinc plated EPDM white-washer/gasket
Split-ring closure	12-guauge sheet, ASTM A108, CRCQ CS

Component 30-Gallon Drum	Material Specifications (Form, Specification, Type/Grade)
Split-ring closure lugs	ASTM A108 grade 12L14 carbon steel
Split-ring closure screws	½-13UNC-2A x 2½-inch long, socket head screw, ASTM A574, ASME B18.3
Drum body/bottom/cover	16-gauge sheet, ASTM A1008, CRCQ carbon steel, 1A2/X430/S, interior non-lined (painted) exterior painted green pantone 360
Split-ring closure	12-gauge sheet, ASTM A1008, CRCQ carbon steel
Split-ring closure lugs	ASTM A108 Grade 12L14 CS
Split-ring closure bolts	5/8-11UNC-2A x 3½-inch long, full thread, hex head bolt, ASTM A320L7, ASME/ANSI B18.2.1, B1.1, cadmium plate per ASTM B766, Class 5 Type III or zinc plate per ASTM B633, Class SC-1, Finish Type III
Split-ring closure lock nut	5/8-11UNC-2B, hex jam nut ASTM, Grade A zinc coated
Drum metal lining	16/18-gauge sheet, ASTM A1008, CRCQ carbon steel (after welding painted alkyd enamel-color optional)
Drum lid gasket	EPDM "D" style, GE5500-01, ASTM D1056
Identification plate	16-gauge (0.06 REF), ASTM A1008 carbon steel, lettering filled with epoxy paint, high temperature, glossy black
Waterproof tape	Fasson® 2.0 mil clear polystyrene/S246/40#SCK (Spec # 12323), colored black
Drum liner and lid liner	16/18-gauge sheet, ASTM A1008, CRCQ carbon steel
Foam insulation	Dow BETAFOAM™ 87100/87124, 24 lb/ft^3 (free-rise density)
Thermal insulation blanket	Kao-Tex Quilts, superwool plus 1-inch 4pcf compressed to ½-inch 8 pcf, quilted with E grade fiberglass fabric (Thermal Ceramics Product Information Sheet and Thermal Ceramics Product Catalog)

Table 2-5 Mechanical Properties of BETAFOAM™ 87100/87124

Material Parameter	Property
ASTM D1621 compressive strength, ambient	1,320 psi
Poisson's ratio	0.34
Young's modulus, compression	45,000 psi
Coefficient of linear thermal expansion (*Compression Test Data for BETAFOAM™ 87100/87124*)	3.5 to 5.0 x 10^{-5} in/in/°F
Water absorption	0.76%
Density (free-rise)	24 lb/ft^3
Manufacturer supplied (*Compression Test Data for BETAFOAM™ 87100/87124*) compressive stress vs. strain behavior (ambient)	See Figure 2-2

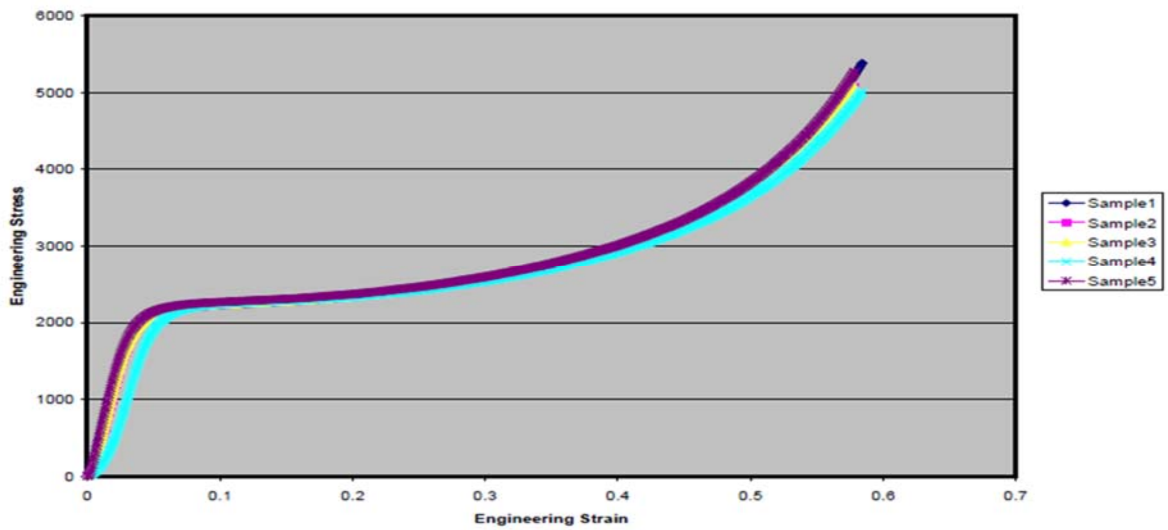

Figure 2-2 Stress-Strain Curve for BETAFOAM™ 87100/87124

2.2.2 <u>Effects of Radiation on Materials</u>

The only HVYTAL packaging components potentially damaged by radiation are elastomeric gasket materials. The silicone rim-closure gasket for the 30-gallon drum, EPDM gasket for the 55-gallon outer drum, and the EPDM gaskets used on all the bung hole flanges in the closure lids are unaffected by the effects of payload dose. The calculated dose to these components from Section 4 is much less than 106 rads/year. This dose rate is low and will have no significant effect on elastomer performance.

2.3 FABRICATION AND EXAMINATION

2.3.1 <u>Fabrication</u>

2.3.1.1 30- and 55-Gallon Drums

The 55-gallon drum was designed, fabricated, and tested in accordance with United Nations (UN) Drum Specification 1A2, as directed by 49 CFR 178 Subpart L for solid and liquid type drums. Prior to the installation of the vent holes, foam insulation and liner, the 55-gallon drum design satisfied the performance requirements specified for Packing Group I tests; in addition the 55-gallon drum also met the testing requirements identified in 49 CFR 173.465 and was qualified as a DOT 7A, Type A drum for solids.

The 30-gallon drum is designed, fabricated, and tested in accordance with UN Drum Specification 1A2, as directed by 49 CFR 178 Subpart L for solid and liquid type drums. The 30-gallon drum meets the same performance standards for a Packing Group I bearing drum in addition to Packing Group II tests for liquids. Additionally, the 30-gallon drum also meets the testing requirements identified in 49 CFR 173.465 and is qualified as a DOT 7A, Type A drum for solids.

2.3.1.2 55-Gallon Drum

The 55-gallon drum body is fabricated of 16-gauge (0.0598-inch) ASTM A1008 CRCQ carbon steel in accordance with 49 CFR 178.504(b) per specification 1A2/X430/S for removable-head drums. See drawing R-R2-G-00057 in Appendix A.

The drum liner is fabricated from 16- and 18-gauge ASTM A1008 CRCQ carbon steel and welded to the upper inside region of the drum. Welding is per standard American Welding Society (AWS) practices specified in AWS D1.3. The diameter of the top lip of the liner, and welded on liner tabs at its base, position the liner both radially and axially within the drum for welding and subsequent foaming operations, see Figure 1-1.

The drum lid liner is fabricated from 16-guage ASTM A1008 CRCQ carbon steel and welded to the drum lid per AWS D1.3. The liner forms a nominally 2-inch deep × 20¾-inch diameter section which serves as a form to confine Dow BETAFOAM™ 87100/87124. A 1¼-inch diameter hole in the lid is used as a port for filling the lid liner volume with foam. Figure 1-3 illustrates the closure lid assembly detailed in drawing R-R2-G-00059 in Appendix A.

2.3.1.3 30-Gallon Drum

The 30-gallon drum body and its closure lid are fabricated from 16-gauge (0.0598-inch) CRCQ carbon steel per ASTM A1008. The 30-gallon closure lid incorporates two standard threaded bung hole flanges (¾-inch and 2-inch) stamped and sealed into the face of the drum cover with EPDM gaskets. The ¾-inch flange is sealed with a mating steel drum plug and EPDM gasket. The 2-inch flange is sealed with a threaded 2-inch steel pressure-relieving plug, Rieke S-220-2, which limits internal pressure by relieving gases between 12 and 15 psig. A white EPDM gasket seals the pressure-relieving plug to the flange.

A 60 shore durometer Parker 58435S or 59498S gasket produced from high temperature silicone compound S7364-60 (Parker Seals Material Report) seals the joining of drum body and closure lid (see drawing R-R4-G-00062). Figure 1-3 illustrates the 30-gallon drum assembly detailed in drawing R-R2-G-00028 in Appendix A.

2.3.1.4 Split-Ring Closure

The split-ring closure device is fabricated from 12-gauge ASTM A1008 CRCQ carbon steel and tested in accordance with industry standards for drum closures. The split-ring closure device is similar to the standard C-Section drum closure but with 1-inch horizontal and vertical leg extensions. The split-rings are roll formed on a 13 die progress roller from metal strip. Each end of each split-ring has a welded on lug (¾-inch outer diameter [OD] × ⅝-inch thick for 55-gallon, ½-inch OD × ½-inch thick for 30-gallon) fabricated from ASTM A108 Grade 12L14 carbon steel. Each split-ring half is identical, with one lug threaded and the other with a through-hole.

The carbon steel split-rings are finished with a powder coat gray paint. In addition to protecting the carbon steel from rusting the paint, it eliminates sharp edges that may be present from the rolling process.

The 55-gallon drum split-ring lugs are threaded at ⅝-11UNC-2B, and use two 3½-inch long ASTM A320-L7, ⅝-11UNC-2A hex-head bolts. Each bolt passes through the unthreaded lug of one segment to mate with the threaded lug of the other segment. After applying appropriate torques, "-2b" hex jam nuts (std 23/64-inch thick) ASTM 194, Grade 2H are tightened against the unthreaded lugs (drawing R-R1-G-00027, Appendix A).

The 30-gallon drum split-ring lugs are threaded at ½-13UNC-2B, and use two 2½-inch long ASTM A574 ½-13UNC-2A socket-head screws. Each screw passes through the unthreaded lug of one segment to mate with the threaded lug of the other segment.

2.3.1.5 Foam Insulation

Dow Automotive 24 lb/ft^3 polyurethane BETAFOAM™ fills the cavities of the 55-gallon outer drum and the liner. The BETAFOAM™ 87100/87124 is a rigid polyurethane high-density structural foam produced by rapidly mixing two components BETAFOAM™ 87100 and BETAFOAM™ 87124 under high shear conditions. The two-part mixture is metered through a precision mixing nozzle by the gram weight. The foam was originally designed for the automotive industry for increasing the crashworthiness of automotive body structure cavities.

<u>Prototype foam installation</u>: For the HVYTAL, as with the 9979, the foam is injected into the cavity formed between the 55-gallon drum and its liner to protect the container against events encountered during transportation. The tested drums were produced by filling the drum cavity in three separate pours that occurred over approximately 10 minutes. Foam was injected from the top rim of the drum through a ¾-inch fill port. The free-rise density of the foam is 24 lb/ft^3. When poured in a confined space, the foam "overpacks" and its density increases slightly. The overpack density is approximately 15%, 28 lb/ft^3.

2.3.1.6 Insulation Cover

A shallow pan-shaped Kao-Tex Quilt™ thermal blanket, 21½ inches in diameter by ½-inch thick, is positioned above the installed 30-gallon drum and under the 55-gallon drum closure lid. The blanket material is manufactured by Thermal Ceramics Company. The blanket is a lightweight mat of bulk ceramic fibers sandwiched between two sewn layers of strong, high-temperature E-fiberglass woven cloth. The woven fiberglass is flexible, has excellent vibration resistance, and is unaffected by moisture. The ceramic fibers weigh 4 lb/ft^3 and form the core insulation rated for continuous service up to 1,800°F. The continuous-service limit for the cloth covering ranges between 1,200°F to 1,700°F.

2.3.2 Examination

2.3.2.1 Drums

The 1A2 30-gallon drum is tested and inspected to qualify as Packing Group I for solids and Packing Group II for liquids. The 1A2 drum tests include:

- Drop (1.8 m – solid; 1.5 m – liquid)
- Leakproofness (34.5 kPa)
- Vibration
- Hydrostatic (150 kPa)
- Stacking (961 kg)

Additional testing for qualification as a DOT 7A Type A container (for solids) includes water spray, penetration, free drop (254 kg), stacking (1,179 kg), and vibration.

Prior to the modification to include the inner liner, BETAFOAM™ and vent holes, the 55-gallon drum was inspected and tested as a Packing Group I for solids. The 1A2 drum tests include: drop (1.8m), leakproofness (34.5 kPa), vibration, hydrostatic (150 kPa), and stacking (961 kg) and further qualified as a DOT 7A Type A container.

Acceptance for the 1A2 drop, leakproofness, and water spray tests is no visible leakage (solid or liquid). Acceptance for the stacking test is no visible distortion that could affect the drum's performance, and acceptance for the vibration test is no deterioration or leakage. Acceptance is similar for the DOT 7A Type A testing.

Drawings R-R2-G-00057 and R-R2-G-00059 in Appendix A require the 55-gallon drum liner weldment and drum lid weldment to be tested hydrostatically at 5 psig for not less than 5 minutes. Acceptance is no leakage. Additionally, all welds are examined visually per AWS D1.3.

2.3.2.2 Foam Insulation

When the BETAFOAM™ expands and cures, it exerts some mechanical load on any confining structure. Verification of liner perpendicularity and circularity is required after the foam installation. During foaming operations, samples of foam from each lot/batch are collected and tested for free-rise density, thermal conductivity, and compressive strength.

Production foam inspection: In production, the 55-gallon drum is inverted and the packaging supplier injects the foam through a 1¼-inch fill hole in the bottom of the drum. The production drum body includes nine ½-inch vent holes drilled after foaming for visual inspection of the foam installation. Each vent hole is covered with tape after the drum has cooled to room temperature. Appendix F specifies foam installation and acceptance testing requirements.

2.4 GENERAL REQUIREMENTS FOR PACKAGINGS AND PACKAGES

The HVYTAL design complies with the general standards for packages in 49 CFR 173.24, 173.24a, 173.27, 173.410 and 173.412.

2.4.1 Minimum Packaging Size

The HVYTAL outer 55-gallon drum is nominally 23 inches in diameter and 34½ inches in height. The 30-gallon payload drum is nominally 18.6 inches in diameter and 29 inches in height. The smallest overall dimension of either component is larger than the regulatory 4-inch minimum.

The liner inner diameter (ID) is 19¾ inches sized to accept the 30-gallon drum. The upper section of the liner (~4¼ inches) steps up to a 21-inch ID, for clearance with the 30-gallon drum closure.

2.4.2 Tamper-Indicating Feature

Closure of HVYTAL packaging occurs in two stages, first the 30-gallon inner drum and then the 55-gallon outer drum. A split-ring closure device secures each closure lid to each drum body. The bolt lugs of the split-ring closure incorporate drillings parallel to the bolt holes specifically to receive a TID. A second TID joins the second set of bolt lugs and completes tamper-securing of the HVYTAL packaging.

2.4.3 Positive Closure

A split-ring closure device secures each closure lid to each drum body. The split-ring closure utilizes two threaded fasteners torqued to design specifications. Figure 1-4 shows a split-ring closure installed on a 55-gallon drum. Once installed, the bolt torques and applicable TIDs prevent accidental opening of the package.

2.5 LIFTING AND TIE-DOWN STANDARDS FOR ALL PACKAGES

2.5.1 Lifting Devices

The HVYTAL design does not incorporate any engineered structural features for lifting the packaging. Therefore, this section is not applicable.

2.5.2 Tie-Down Devices

The HVYTAL design does not incorporate any engineered structural features that could serve as tie-down devices. Therefore, this section is not applicable.

2.6 NORMAL CONDITIONS OF TRANSPORT GENERAL PACKAGING STANDARDS, DESIGNS AND TESTING

This section demonstrates, through full scale performance tests (Table 2-2), analysis, and similarity, that the HVYTAL packaging design and construction complies with the general standards for all packages in 49 CFR 173.24 and 173.24(a), the general design requirements of 49 CFR 173.410, and when subjected to the Type A packaging tests, 49 CFR 173.465 and 173.466. Structural evaluation influences include thermal effects, pressure effects, vibration and shock, water spray in-leakage, drop impacts, stacking compression, and penetration impact. The evaluation shows there will be no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging.

The packaging design of the HVYTAL utilizes the 9979 design for containment; all of the tests that were performed during licensing of the 9979 are directly relevant to the performance and qualification of the HVYTAL. As justification to the performance of the HVYTAL / 9979, during licensing three 9979 prototypes (SN-02, SN-03 and SN-05) were subjected to 10 CFR 71 NCT testing at ambient temperature (South Carolina winter conditions) with maximized simulated payload of greater than 200 lbs (which is similar in weight as the HVYTAL content of 219.7 lbs) contained within the 30-gallon drum. These conditions bound all content payload configurations.

2.6.1 <u>Heat</u>

2.6.1.1 Summary of Pressures and Temperatures

For the purposes of evaluating the HVYTAL for pressure and temperature, the analysis that was performed on the 9979 is directly relevant to the performance and qualification of the HVYTAL. All conditions and parameters that were analyzed for the 9979 either meet or exceed the conditions and parameters that are associated with the acceptable payload of the HVYTAL. The maximum heat generation from the contents associated with the 9979 is 3.5 watts compared to the maximum heat generation from the Mo-99 contents of the HVYTAL of 0.0515 watt.

For the purposes of this report, the pressure and temperature analysis that was addressed in Chapter 2 of the 9979 Safety Analysis Report for Packagings (SARP) is included (S-SARP-G-00006). In addition, the bounding temperature calculation that was performed for the HVYTAL packaging is included in Appendix C.

Table 2-6 summarizes the structural inputs for pressure and temperature from the Chapter 3 thermal analyses of the 9979 SARP (S-SARP-G-00006). The drum shells are thin-wall construction, such that through-wall temperature gradients are not a structural issue.

Table 2-6 NCT Pressure and Temperature Inputs for Structural Evaluation

Feature	30-Gallon 3-Gallon Drum		55-Gallon Overpack	
	Min	Max	Min	Max

Temperature	-40°F	149°F	-40°F	154°F
Pressure	n/a	21.16 psia*	n/a	n/a

*Rieke pressure relieving plug releases between 12 to 15 psig.

2.6.1.2 Differential Thermal Expansion

Differential thermal expansion is possible due to (1) thermal gradients or (2) material gradients.

2.6.1.2.1 <u>Thermal Gradients</u>

Based on the low internal heat generation (less than 1.3 watts) and the inability of thin sheet metal to support a through-wall temperature gradient, the only thermal gradient of significance occurs when the 30-gallon drum temperature is different from the 55-gallon outer drum (either hot-cold, or cold-hot). Assuming each component is at a bounding temperature extreme, the relative size change of the 30-gallon drum is:

$$\Delta hgt = \alpha \cdot L \cdot \Delta T = 8e-6 \, {}^{in/in}\!/_{\circ F} \cdot 29'' \cdot (154-(-40)) = 0.045 inch$$

(Less than design clearance)

2.6.1.2.2 <u>Material Gradients</u>

Differential expansion between the polyurethane foam and the steel shell is identified as a bounding condition, because of the poured in place construction (no gaps) and the order of magnitude difference in expansion coefficients between foam and steel. Assuming thermal expansion equilibrium in the 70°F range (e.g., the fabrication temperature), the 154°F 55-gallon outer drum temperature would result in a bounding foam expansion (unit length) of:

$$\Delta = \Delta\alpha \cdot L \cdot \Delta T = \left\{5e^{-5} \, {}^{in/in}\!/_{\circ F} - 8e^{-6} \, {}^{in/in}\!/_{\circ F}\right\} \cdot 1.'' \cdot (154^{\circ} F - (70^{\circ} F)) = 0.0035 inch/inch$$

This low expansion demand is accommodated by the combined flexibility of the drum shell or liner and the static condition flexibility of the foam itself.

2.6.1.3 External Package Temperature

49 CFR 173.410(i)(1) states that temperature on the accessible surfaces of the package shall not exceed 50°C (122°F) at an ambient temperature of 38°C (100°F) with no account taken for insulation. To show compliance, a bounding temperature calculation is performed in X-CLC-A-00108 (Attachment 1).

2.6.1.4 Stress Calculations

The temperature and pressure conditions shown in Table 2-6 are combined with the 10 CFR 71 reduced and increased external pressure conditions. A bounding stress calculation is performed in M-CLC-A-00376 to American Society of Mechanical Engineers (ASME) III-NB Service-A criteria (or equivalent for non-code materials). The results show acceptable drum performance.

2.6.2 Cold

Section 2.1.2 addresses the performance of the materials under low temperature conditions. Stress conditions are bounded by the temperature and pressure extremes comprising the load cases in calculation M-CLC-A-00376.

2.6.3 Reduced External Pressure

The packaging is evaluated under the conditions of reduced ambient pressure, 3.5 psia, per 49 CFR 173.412(f). The effect of evaluating the packaging design to air transport at 35,000 feet (3.5 psia), under NCT conditions (insolation, 100°F ambient, maximum wattage), results in differential pressure of 17.66 psig (21.16 psia – 3.5 psia) in the 30-gallon drum, Appendix C. At these conditions, the pressure relieving plug opens until the differential pressure drops and the plug reseals. The packaging design is also evaluated for ground transport. Evaluating the highest route in the United States (Loveland Pass, Hwy. 6, 11,990 feet) under the same NCT conditions (insolation, 100°F ambient, maximum wattage) results in differential pressure of 11.81 psig (21.16 - 9.35 psia). If it is assumed the packaging is transported in a covered conveyance, the differential pressure is 8.15 psig (17.5 – 9.35 psia), Appendix C. Under both sets of conditions, the pressure relieving plug in the 30-gallon drum will not open.

Evaluation for all reduced external pressure conditions, combined with a maximum internal pressure, shows the pressures are within the capacity of both the 55-gallon outer drum and the 30-gallon inner drum.

2.6.4 Increased External Pressure

Increased external pressure conditions are evaluated in M-CLC-A-00376. The results show that the worst case demand from external pressure, combined with minimum internal pressure, is adequately within the buckling and geometric instability limits of either the 55-gallon outer drum or 30-gallon drum.

2.6.5 Vibration

Shipping and vibration loads are evaluated in M-CLC-A-00376 and by comparison to other packagings of similar design. The vibration levels are prescribed by the composite over-the-road power spectral density (PSD) depicting random accelerations of the safe-secure trailers and safeguards transporters normally used to transport National Nuclear Security Administration (NNSA) drum-type packages. The PSD is obtained from Appendix F of Safety Guide SG-100 and shown in Figure 2-3. The calculation results show that the load levels are within the elastic load limits of the packaging components. Fatigue and bolt evaluations are shown acceptable.

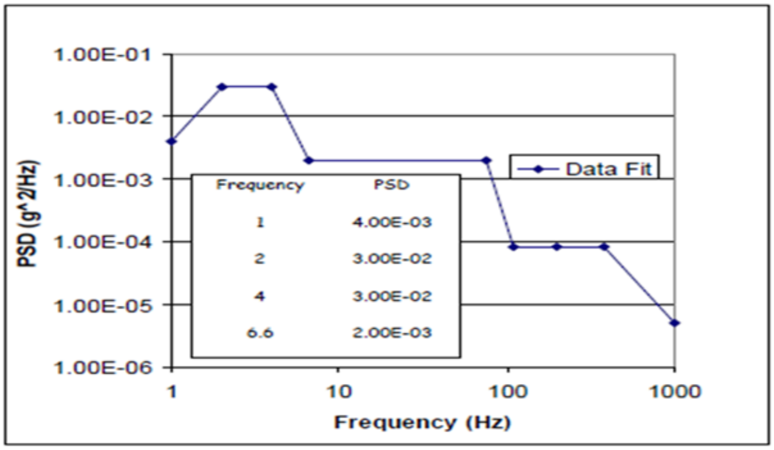

Figure 2-3 Safe-Secure Conveyance Power Spectral Density with Data Points Overlain

The analysis for vibration and shock testing of the HVYTAL packaging was performed through a comparison testing that was performed on the 9979 and the AT-400 during licensing. Vibration and shock testing was performed on the prototype 9977 (SNL 2111/MS0447) and AT-400 (SAND97- 0018) packagings at Sandia National Laboratory and on the bulk tritium shipping packaging at Clemson University (S-SARP-G-00004). These packagings incorporate polyurethane foam within their design for impact and thermal protection in the same way as the 9979 (i.e., foam injected into a drum with a formed liner). Following vibration tests, these packagings were subjected to NCT and HAC testing. Packaging evaluations performed following these tests showed no indication of upset to their packaging configurations. By similarity, the polyurethane foam construction of the 9979, and thus the HVYTAL, will not be affected by vibration and shock loads.

Additionally, 30- and 55-gallon drum fabrication specified by 49 CFR 178.500 are vibration tested in accordance with 49 CFR 178.601(c)(1) and 49 CFR 178.608.

The drum split-ring closures are torqued to 40 ft-lbs when assembled. The calculated vibratory loads produced by vibration and shock do not exceed 4G and is not sufficient to overcome the prevailing bolt torque during transportation (M-CLC-G-00376).

2.6.6 Water Spray

The HVYTAL packaging consists of an insulated 55-gallon outer drum and a steel 30-gallon inner drum. The insulation is protected by the steel liner and otherwise impervious to water due to its closed-cell structure. Both drum closures are gasketed and the water-spray test has no significant effect on the 55-gallon outer drum structure or 30-gallon drum as shown in testing of the HVYTAL.

For demonstrating compliance with 49 CFR 173.465(b), *the water spray test must precede each test or test sequence prescribed in this section*, a spray test was performed on the HVYTAL packaging prior to performing the additional tests identified in 49 CFR 173.466. The additional tests identified in 49 CFR 173.466 are required to qualify the HVYTAL as a DOT 7A Type A packaging containing a liquid content. Results of this spray test and tests performed on the HVYTAL packagings are as follows:

In performing the additional tests identified in 49 CFR 173.466, the HVYTAL packaging was subjected to the water spray test as identified in 49 CFR 173.465(b) prior to performing the test identified in 173.466. The spray test was performed at Paragon Die and Engineering Company (Paragon D&E) Grand Rapids, MI facility inside their vehicle storage area. Based on visual examination performed before and after the water spray test, the drum did not retain water and the integrity of the drum was not compromised. A well formed by the drum lid remained full and overflowing with water for the duration of spray testing. The rate of water spray significantly exceeded the regulatory requirement of 2 inches/hour. Based on visual examination, the water spray test has no adverse effect on the HVYTAL packaging.

Figure 2-4 Water Spray Test HVYTAL Prototype

2.6.7 <u>Free Drop</u>

2.6.7.1 Unyielding Surface

49 CFR 173.465(c)(5), in addition to 10 CFR 71.71(c)(7) and 71.73(c)(1,) require packagings to be dropped onto an unyielding surface. The International Atomic Energy Agency (IAEA) regulations (Specific Safety Requirements No. SSR-6, para. 717) describes an unyielding surface as a “flat, horizontal surface of such character that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase damage to the specimen.” The IAEA advisory material further specifies an example of an unyielding target as a steel plate at least 1.57 inches thick floated to a concrete block mounted on firm soil or bedrock, where the combined mass of the steel and the concrete is at least 10 times that of the test packaging (paragraph 717.2).

During licensing of the 9979, the NCT 1-foot and 4-foot drop tests were performed using a 4-foot square by 3-inch thick steel plate bonded to an abandoned concrete foundation of Building

8343 in N-Area at the Savannah River Site (SRS). The steel pad floats on approximately ¾ inches of grout and is anchored to the building footer by five ⅝-inch diameter, 7-inch long, Hilti™ lag bolts, one at its center and four at the plate corners (see Figure 2-4). The combined weight of the base plate and concrete footer is approximately 6,000 lbs. The 6,000-lb pad weight is greater than 14 times the maximum tested weight of the 9979 (420.2 lbs).

The drop tests of the HVYTAL were performed in the loading dock area at the Paragon D&E facility in Grand Rapids, MI. The 4-foot drop and 30-foot drop test were performed using a 5-foot square by 4.5-inch thick steel plate weighing approximately 4590 lbs placed on a flat concrete pad with a minimum depth of 6 inches. The weight of the test plate is greater than 10.9 times the maximum tested weight of the HVYTAL (419.7 lbs).

2.6.7.2 4-Foot Drop Results

2.6.7.2.1 <u>Test Results for the 9979 Packaging</u>

Following the water spray and corner drop testing, 9979 prototype SN-03 was prepared for 4-foot free drop testing. The packaging was oriented top-down, with CG over corner, and with impact targeted directly on the lugs of the split-ring closure device. The drop event bent the device slightly, warping the closure device out of plane at the site of impact by approximately ¼ inch. SN-02 was also dropped in the same CG orientation and received similar damage (see Figure 2-5). The split-ring lugs contacted the 55-gallon outer drum body and dented it slightly, but neither punctured the skin of the drum nor loosened the closure. Results from testing of prototypes SN-02 and SN-03 were consistent (M-TRT-A-00019).

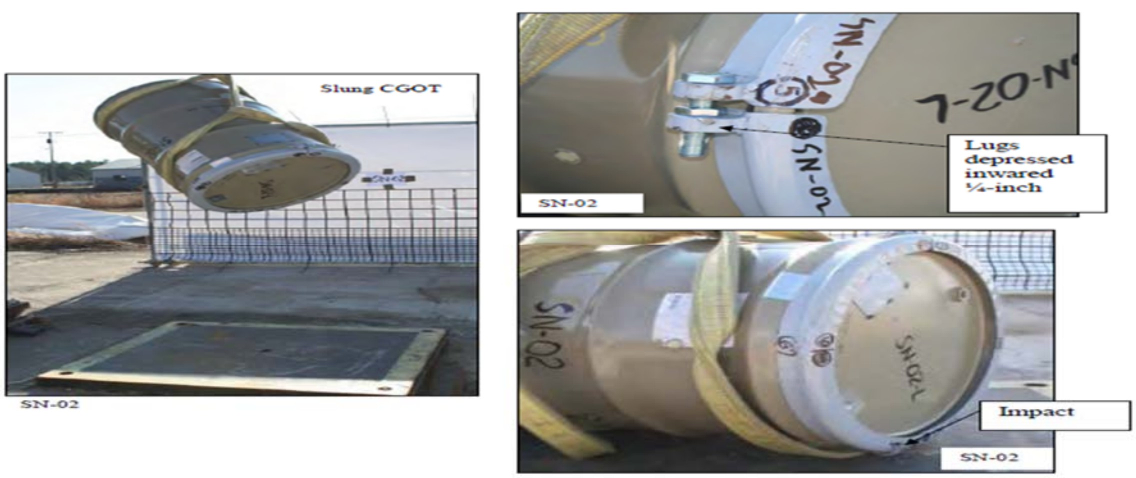

Figure 2-5 4-Foot Free Drop Test – Setup and Damage to Prototype SN-02

2.6.7.2.2 <u>Test Results for the HVYTAL Packaging</u>

Following the water spray testing, the HVYTAL prototype was prepared for 4-foot free drop testing. The packaging was oriented top-down, with CG over corner, and with impact targeted directly on the lugs of the split-ring closure device. The drop event bent the device slightly, warping the closure device out of plane at the site of impact by approximately ¼ inch. The split-ring lugs contacted the 55-gallon outer drum body and dented it slightly, but neither punctured the skin of the drum nor loosened the closure. Results from testing of the HVYTAL prototype and the results received from the 9979 prototypes SN-02 and SN-03 were consistent.

Figure 2-6 4-Foot Free Drop Test – Setup and Damage to Prototype HVYTAL

2.6.7.3 30-Foot Drop Results

2.6.7.3.1 Test Results for the 9979 Packaging

Four 9979 prototypes, SN-01 through SN-04, were subjected to 30-foot drop impacts. Three of the prototypes, SN-02, -03 and -04 were tested at ambient temperature (South Carolina winter conditions) with maximized simulated payload of greater than 200 lbs contained within the 30-gallon drum. These conditions bound all content payload configurations. For these three prototypes, the form of the simulated content, a mixture of sand and pea-gravel, was chosen to load the packaging while providing minimal structural support to the packaging during the HAC drop/crush events. The fourth prototype, SN-01, was assembled without payload and was chilled to -20°F in an environmental chamber (M-TRT-A-00019). It was chosen to be tested without payload because it was believed, based on previous packaging testing, these conditions (no payload and -20°F) would provide the greatest damage to the packaging when subjected to the sequential HAC tests.

2.6.7.3.2 Summary of 30-foot Drop Results

The 30-foot free drop testing of the 9979 design utilized prototypes SN-01 through SN-04. The top-down CG over corner impact (SN-03, SN-02) produced the most dramatic deformation, with the lug region of the closure pushed down just over 1 inch to contact the uppermost drum rolling hoop. The top-down vertical impact (SN-04) slightly buckled the skin of the 55-gallon outer drum adjacent to the impact zone . The horizontal impact (SN-01) included the effects of temperature saturation at -20°F and flattened the contacting ends of the outer drum slightly. Overall, 30-foot free drop impact testing of these 9979 design prototypes neither breached the skin of the outer drum nor loosened the split-ring closure device. Damage was largely superficial. All similarly tested pre-development packagings demonstrated this characteristic, including packagings designed with significantly less robust structures.

2.6.7.3.3 Test Results for the HVYTAL Packaging

One HVYTAL prototype was subjected to the 9-m (30-foot) drop test in accordance with 49 CFR 173.466(a)(1). The drop tests were performed at ambient temperature (approximately 54°F) with maximized simulated payload of 205.4 lbs contained within the 30-gallon drum. The form of the simulated content is as follows:

- One 125 mL stainless steel vial containing 113 mL water/fluorescent dye solution
- One tungsten shielded cask assembly (WSCA)
- One 884-gram carbon steel plate placed underneath the WSCA (added additional weight to bound testing configuration)
- 112.3 grams of granular absorbent material
- Approximately 3.89 cubic feet (8.4 lbs) of LDPE dunnage

2.6.7.3.4 Summary of 30-foot Free Drop Testing Results

The 9-m (30-foot) free drop testing of the HVYTAL design utilized one prototype for testing. Based on the information associated with the testing of the 9979, it was determined that the top-down CG over corner impact produced the most dramatic deformation. The test result was the lug region of the closure pushed down just over 1 inch to contact the uppermost drum rolling hoop (see Figure 2-7). Overall, 30-foot free drop impact testing of the HVYTAL (as with the 9979) design prototype neither breached the skin of the outer drum nor loosened the split-ring closure device. Damage was largely superficial.

Figure 2-7 30-Foot Free Drop Test –Damage to HVYTAL Prototype

2.6.8 Stacking Test

The analysis for stacking test of the HVYTAL was performed through a comparison testing that was performed on the 9979. Stack testing that was performed on the 9979 is directly applicable to that of the HVYTAL. As discussed previously, both the 9979 and the HVYTAL are of the same design, and the content weight within the 30-gallon inner drum is similar. The calculated maximum weight of a 9979 package, fully loaded, is 426.5 lbs, and the maximum weight of the HVYTAL package, fully loaded, is 419.7 lbs, thus bounded by the test performed on the 9979 packaging.

The 9979 was tested in accordance with 10 CFR 71.71(c)(9) which contains the same requirements as that stated in 49 CFR 173.465(d). The calculated maximum weight of the tested 9979 package, fully loaded, is 426.5 lbs. In accordance with 10 CFR 71.71(c)(9) and 49 CFR 173.465(d)(i), 2,165 lbs (32.5 lbs over the requirement of 5 × package weight) were applied to the 9979 prototype SN-05 for 24 hours and demonstrated no effect on the packaging (M-TRT-A-00019). Figure 2-8 illustrates the stacking test of prototype SN-05.

Figure 2-8 9979 Stack Test

2.6.9 Penetration

The analysis for the penetration test of the HVYTAL packaging was completed through the performance of two separate penetration tests. For each of the tests, the HVYTAL prototype was positioned horizontally, and received an impact from a 13.2-lb penetration bar falling 1.7 m (5.5 feet) directly onto and normal to the non-reinforced span near mid-height of the 55-gallon outer drum (between rolling rings). For the first test, the target area was one of the vent paths located near mid-height of the 55-gallon outer drum. For the second test, the target area was a non-reinforced span near mid-height of the 55-gallon outer drum (between rolling rings).

The first penetration test was designed so that the impact of the test bar would strike directly onto the 55-gallon outer drum at one of the vent paths that is located near mid-height of the 55-gallon outer drum (between rolling rings). The vent path is an area of the 55-gallon outer drum that has had the drum material removed and the BETAFOAM™ insulation is exposed but covered with waterproof tape. In accordance with 49 CFR 173.466(1), the 6 kg (13.2 lb.) penetration bar was dropped from a height of 1.7 m (5.5 feet). The bar slightly dented the surface of the 55-gallon outer drum (BETAFOAM™ insulation) to a depth of about 1/16 inch. There was no breach through the BETAFOAM™ insulation into the cavity of the 55-gallon outer drum. Figure 2-9 shows the penetration test with the waterproof tape still adhered to the drum and after the waterproof tape had been removed for observation of result. The penetration test performed on the vent path section of the drum resulted in a superficial indention and will have no effect on packaging performance.

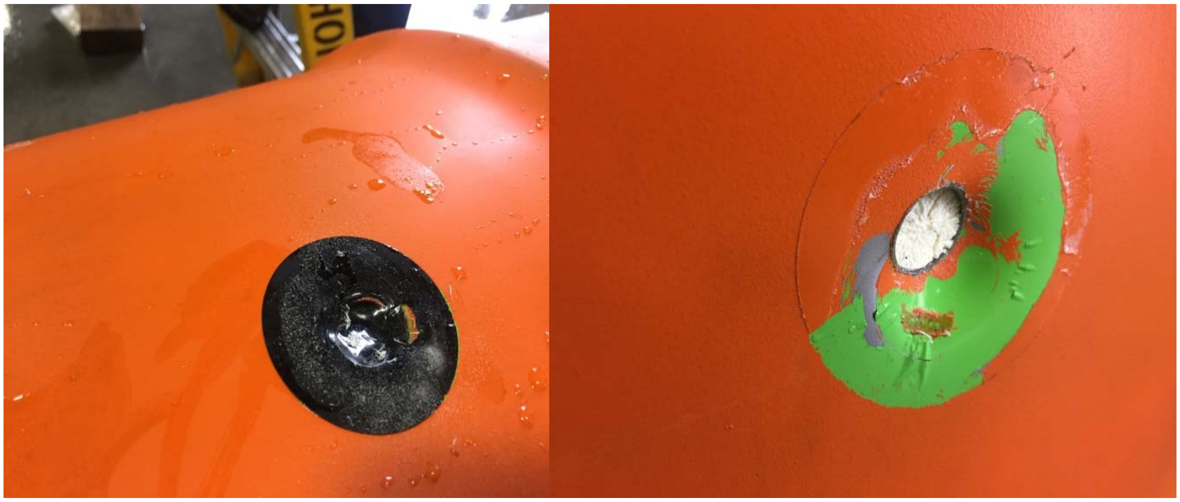

Figure 2-9 Penetration Test – BETAFOAM™ Insulation as Target

The second penetration test was designed so the impact of the test bar would strike directing onto and normal to the non-reinforced span near mid-height of the 55-gallon outer drum (between rolling rings). The bar slightly dented the surface of the 55-gallon outer drum to a depth of about 1/16 inch (Figure 2-10). The penetration test performed on the non-reinforced span near mid-height of the 55-gallon outer drum resulted in a superficial indention and will have no effect on packaging performance.

Figure 2-10 Penetration Test – Non-Reinforced Span

2.6.10 <u>General Requirements for Transportation by Aircraft</u>

The analysis for determining acceptability of the HVYTAL packaging in accordance with 49 CFR 173.27(c) was completed through analytical testing of the 30-gallon inner drum. As previously discussed, the containment system of the HVYTAL is comprised of a 55-gallon outer drum and a 30-gallon inner drum. The 55-gallon outer drum has been fabricated to include a steel liner containing BETAFOAM™ insulation. The 30-gallon inner drum consists of a UN Specification 1A2 drum that has been tested and inspected to qualify as Packing Group I for solids and Packing Group II for liquids. The UN 1A2 drum tests include: drop (1.8 m – solid; 1.5 m – liquid), leakproofness (34.5 kPa), vibration, hydrostatic (150 kPa), and stacking (961 kg). In addition, the 30-gallon inner drum has undergone additional testing for qualification as a DOT 7A Type A container (for solid content), testing included water spray, penetration, free drop (254 kg), stacking (1,179 kg), and vibration.

The 30-gallon drum requires a hydrostatic pressure test per 49 CFR 178.605 which meets the pressure requirements identified in 49 CFR 173.27(c). The hydrostatic pressure test requires the drum vendor to pressure test at least three samples from each drum lot at 150 kPa (21.7 psig) for 5 minutes. Closure-lid vents must be sealed. Acceptance is no visible water leakage from the packaging.

The hydrostatic test requirement for a liquid packaging is specified to ensure additional integrity and robustness of the 30-gallon drum.

2.6.11 Summary of Testing

The major packaging damage observed as a result from the physical testing of the HVYTAL and through comparative analysis of testing performed on the 9979, resulted in only superficial damage to the packaging. Based on these observed conditions of the packaging following testing, it is concluded the HVYTAL designs ensure containment of content under all packaging performance requirements.

2.7 DESCRIPTION OF THE CONTAINMENT SYSTEM

This section describes the containment characteristics of the HVYTAL shipping packaging. The packaging is designed, fabricated, and shown by physical test and analysis to meet the requirements of 49 CFR 173 for a DOT 7A Type A packaging suitable for liquid contents.

The HVYTAL packaging is designed to transport liquid radioactive material. The packaging has demonstrated through testing and analysis to safely contain the material under the requirements 49 CFR 173.465 and 173.466.

The containment system, as defined by 49 CFR 173.403, is the assembly of components of the packaging intended to retain the radioactive material. The radioactive material of the HVYTAL package is limited to one A_2 (total activity), permitting transport in a Type A package. Since the HVYTAL content is Type A liquid, the packaging is designed to meet the requirements of 49 CFR 173.24, 173.24a, 173.27, 173.410, 173.465 and 173.466.

Containment for the HVYTAL is provided by a 55-gallon outer drum fabricated to include a steel liner containing BETAFOAM™ and a 30-gallon inner drum. The 30-gallon inner drum is fabricated as a DOT 7A Type A (for solids), with closure sealed by a high temperature silicone gasket. The drum is rated for pressure retention of 21.7 psig (150 kPa), and the closure is secured by a patented split-ring closure device. The closure lid of the 30-gallon drum includes ¾-inch and 2-inch bung hole flanges. The ¾-inch flange is closed with a steel (non-venting) zinc-plated plug with white EPDM gasket; the 2-inch flange is closed with a Rieke S-220-2, VISEGRIP II pressure-relieving plug with EPDM gasket that limits drum pressures between 12 and 15 psig.

The 30-gallon drum assembly is protected by the 55-gallon outer drum. The 55-gallon outer drum split-ring closure includes two sets of 5/8-inch thick x 1½-inch diameter steel lugs used to close the 55-gallon drum. Each lug includes 0.13-inch hole to facilitate installation of a TID; upon closure, the drum cannot be opened unintentionally. The containment boundary of the HVYTAL is the 55-gallon outer drum.

Section 1.2 describes the HVYTAL design in detail. Appendix A lists the drawings that define the design, and Section 2.2 lists the materials of construction.

2.8 CONTAINMENT UNDER NORMAL CONDITIONS OF TRANSPORT

The testing evaluation in Section 2.6 demonstrates the containment boundary as described in Section 3.1 remains intact following all testing criteria as required under 49 CFR 173.465 and 173.466, showing that there is no loss or dispersal of radioactive material under NCT.

Drop testing (4 feet and 30 feet) of fully loaded prototype HVYTAL as described in Section 2.6 and demonstrated “no loss or dispersal of (simulated) radioactive contents” (water with fluorescent die). After completion of the drop testing, the HVYTAL 55-gallon outer drum closure bolts remained tight. Further, external impact damage amounted to little more than scuffed paint or a minor dent from a penetration tests, consistent with “no significant increase in external radiation levels." Fully loaded packagings subjected to the series of water spray, free drop, and penetration impacts demonstrated no water entry and no degradation or loss of effectiveness of the containment system (either the outer 55-gallon drum or the 30-gallon inner drum).

3.0 SHIELDING EVALUATION

The shielding evaluation performed for the HVYTAL is described in this section. This evaluation demonstrates the HVYTAL is in compliance with the performance requirements specified in 49 CFR 173.441.[2]. These regulations specify the dose rate limits for an undamaged package are 200 mrem/h at the accessible surface of the package and 10 mrem/h at 1 meter from the accessible surface of the package. Shielding analysis results based on 16 Ci of Mo-99 content demonstrate the HVYTAL complies with the federal regulations for non-exclusive use. The overall results are shown in Table 3-1. It has been demonstrated for the 16 Ci Mo-99 contents, the requirements of 49 CFR 173.441 for radiation dose rate limits are met for NCT.

3.1 DESCRIPTION OF SHIELDING DESIGN

3.1.1 Design Features

The HVYTAL packaging design consists of an insulated 55-gallon outer drum surrounding a 30-gallon drum. Split-ring closure devices secure the drum closure lids, and the 55-gallon outer drum with steel liner and insulation provides the structure of the packaging. The HVYTAL is based on the DOE Model 9979 packaging, a drum style packaging designed to ship radioactive uranium metals, oxides, and other solid compounds totaling less than one A_2.

The HVYTAL design includes a 30-gallon carbon steel drum nested closely inside an insulated, 55-gallon carbon-steel outer drum. The 55-gallon drum is nominally 22½ inches in diameter and 34½ inches in height. The 30-gallon drum is nominally 18¼ inches in diameter and 29 inches in height. The 30-gallon drum is located both radially and axially within the 55-gallon drum by the close fit of the liner. The foam material molded in place between the shell of the 55-gallon drum and the liner provides both structural support and thermal insulation. Section 1.0 describes the physical arrangement of the HVYTAL. Section 2.0 provides detailed material specifications. The primary purpose of the HVYTAL shipping packaging is to maintain containment of radioactive liquid contents. Payload mass is limited to a maximum of 205.4 lbs (~93.2 kg), including radioactive material, handling conveniences (e.g., vials or bottles), shielded insert, and packing dunnage. Maximum volume of radioactive liquid allowed in the HVYTAL is 1.3 liters for materials in a non-shielded configuration and 113 milliliters of liquid shipped in the WSCA (shielded) configuration.

The HVYTAL design incorporates a WSCA as a specific shielding feature for materials that require shielding. Shielding calculations for the WSCA are based on one A_2 quantity of the radioisotope Mo-99 (16 Ci) and applicable gamma emitting daughter Tc-99m (8.8949 Ci). The 16 Ci of Mo-99 solutions are used as the bounding case for this shielding evaluation. The dose rates from gamma radiation were calculated using MicroShield 8.03. Table 3-1 summarizes the maximum calculated dose rates for NCT for the bounding physical configuration of the radioactive material contained within the WSCA, adjacent to the inner surface of the 30-gallon drum, and the contact dose rate on the exterior surface of the 55-gallon drum and compares the results against the regulatory limits for shipment in commerce. The dose rates reported in Table 3-1 bound the dose rates at all measurement and source locations.

Table 3-1 Summary Table of External Radiation Levels

Normal Conditions to Transport	Tungsten Shield (contact) mSvh (mrem/h)	Tungsten Shield (1 cm) mSvh (mrem/h)	30-gallon Inner Drum mSvh (mrem/h)	55-gallon Outer Drum mSvh (mrem/h)	TI
Radiation					
Gamma	2.131 (213.1)	0.172 (172.7)	0.1289 (128.9)	0.01876 (18.76)	1.0
Regulatory Limits					
49 CFR 173.441(a)	N/A	N/A	N/A	0.200 (200)	10
49 CFR 175.700(b)(1)(i)					3.0
*TI will be measured at time of shipment.					

Radioactive liquid material shipped in the HVYTAL packaging system, not requiring the use of the WSCA, is limited to a maximum on-contact dose rate of 200 mrem/h on the exterior of the 55-gallon drum and a TI of no more than 10.

3.2 SOURCE SPECIFICATION

The radioactive contents are grouped broadly into the following two categories:

1) Up to 1.3 liters of radioactive liquid material, packaged in either plastic or metal convenience handling containers containing no more than one A_2 quantity of material. Once packaged the maximum dose rate on the exterior of the package shall not exceed 200 mrem/h and the TI shall not exceed 10. Note – Materials shipped via passenger carrying aircraft have a more restrictive TI of 3.0.

2) Up to 113 milliliters of radioactive liquid material packaged in the WSCA containing similar radioactive properties of a 16 Ci Mo-99 solution. The activity is limited to no more than one A_2 quantity of material. Maximum external dose rate of the package shall not exceed 200 mrem/h and the TI shall not exceed 10. Note – Materials shipped via passenger carrying aircraft have a more restrictive TI of 3.0.

3.3 SHIELDING MODEL

3.3.1 Configuration of Source and Shielding

A model was developed to calculate expected dose rates on the exterior surface of the WSCA, the exterior of the 30-gallon drum, and the on-contact dose of the exterior of the 55-gallon drum. This model was developed using MicroShield 8.03 with a contents activity of 16.090 Ci (Mo-99), 2.1171E-08 Ci (Tc-99), and 8.8949 Ci (Tc-99m). The contents were modeled as a cylinder that is 5.0 cm high by 3.75 cm radius. Dose point’s placement included locations at 8.62 cm (contact of the WSCA), 9.26 cm (1 cm from contact of the WSCA), 23.178 cm (exterior surface of the 30-gallon drum), and 28.575 cm (exterior surface of the 55-gallon drum). The model did not include the shielding associated to either of the drums or insulation material. The MicroShield 8.03 (Calculation AMP-01-17) is provided in Appendix D.

3.3.2 Material Properties

The model does not include the drums or insulation material. The density of the source region (modeled as a cylinder of water) is 1.0 g/cm3. The WSCA is modeled as being 4.5 cm thick with a density of 19.3 g/cm3.

3.4 SHIELDING EVALUATION

3.4.1 Methods

This section quantifies dose rates under NCT.

Radiation transport calculations were performed using MicroShield 8.03. Maximum calculated dose rate on the exterior of the WSCA containing an A_2 quantity of Mo-99 is 213.1 mR/hr (contact), and 172.7 mR/hr at 1 cm, with a maximum calculated dose rate on the exterior surface of the shipping package of 18.76 mR/hr. The transport index will be determined at the time of shipment and shall not exceed the regulatory limits of 3.0 for passenger-carrying aircraft or 10.0 for cargo aircraft only or transport by public highway. Since these dose rates are less than the applicable limits for radiation levels in 49 CFR 173.441(a), no additional consideration for shielding is necessary.

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4.0 PACKAGE OPERATIONS

This section identifies the minimum procedural elements needed to ensure that users operate the HVYTAL package in accordance with its design. Implementation of these elements ensures safe performance of the HVYTAL package under NCT.

The procedural elements described in this section meet the requirements of 49 CFR 173.

The procedural elements cover fundamental steps required for packaging inspection, handling, receipt, and unloading. Also included are requirements for preparation of an empty packaging for shipment and storage.

The procedural elements are presented sequentially in the order in which they should be performed.

4.1 GENERAL INFORMATION

All users of the HVYTAL package shall have the current training in accordance with 49 CFR Subpart H – Training. Prior to the use of the packaging, the user shall have been trained and tested on the information contained within this Type A test report that shall include, but not be limited to, allowable contents, handling, and closure operations.

4.1.1 Planning

Users should prepare written site-specific operating procedures for inspections, tests, and activities that meet the requirements of this section and comply with their facility's operational requirements. This Type A test report, packaging hardware, engineering drawings, and technical specifications should all be considered when preparing procedures. The exact sequence of operational steps specified in this section may be altered to reflect site specific needs. Implementation of this Type A test report and site radiological requirements shall reflect the principles of As Low As Reasonably Achievable (ALARA) as required by the standards for protection against radiation in either Title 10 CFR 830 for DOE or 10 CFR 20.1101(b) for the NRC.

4.1.2 Personnel Qualifications

All personnel who perform duties associated with package operations shall be trained on the requirements of operation and closure of the package.

4.1.3 Equipment

A complete list of equipment (devices, fixtures, tools, hoists, etc.) and materials (with its specification) necessary for packaging operations should be included in each site-specific operating procedures. The procedural activities outlined in this section also list the equipment necessary for the tasks and, where applicable, cite drawings of any special tools. All equipment, gages, instruments, and other measuring and testing devices used in activities affecting package quality shall be properly calibrated and controlled, as specified in the user's Quality Assurance (QA) program.

4.1.4 Quality Assurance

Each site-specific procedure shall document the revision numbers of the Type A test report in effect at the time of that package operation. By doing so, the shipper verifies operating procedures comply with the conditions of approval specified in the Type A test report. The package should document compliance with all procedural elements required by this section. Each site-specific procedure shall include instructions for the operator to follow in the event that a requirement cannot be met during implementation of the procedure. At a minimum, the operator should document the event, then notify the appropriate level of supervision and await further instruction.

4.1.5 Nomenclature

Figure 5-1 illustrates an exploded view of the packaging assembly and call-outs for the nomenclature used in the following procedures.

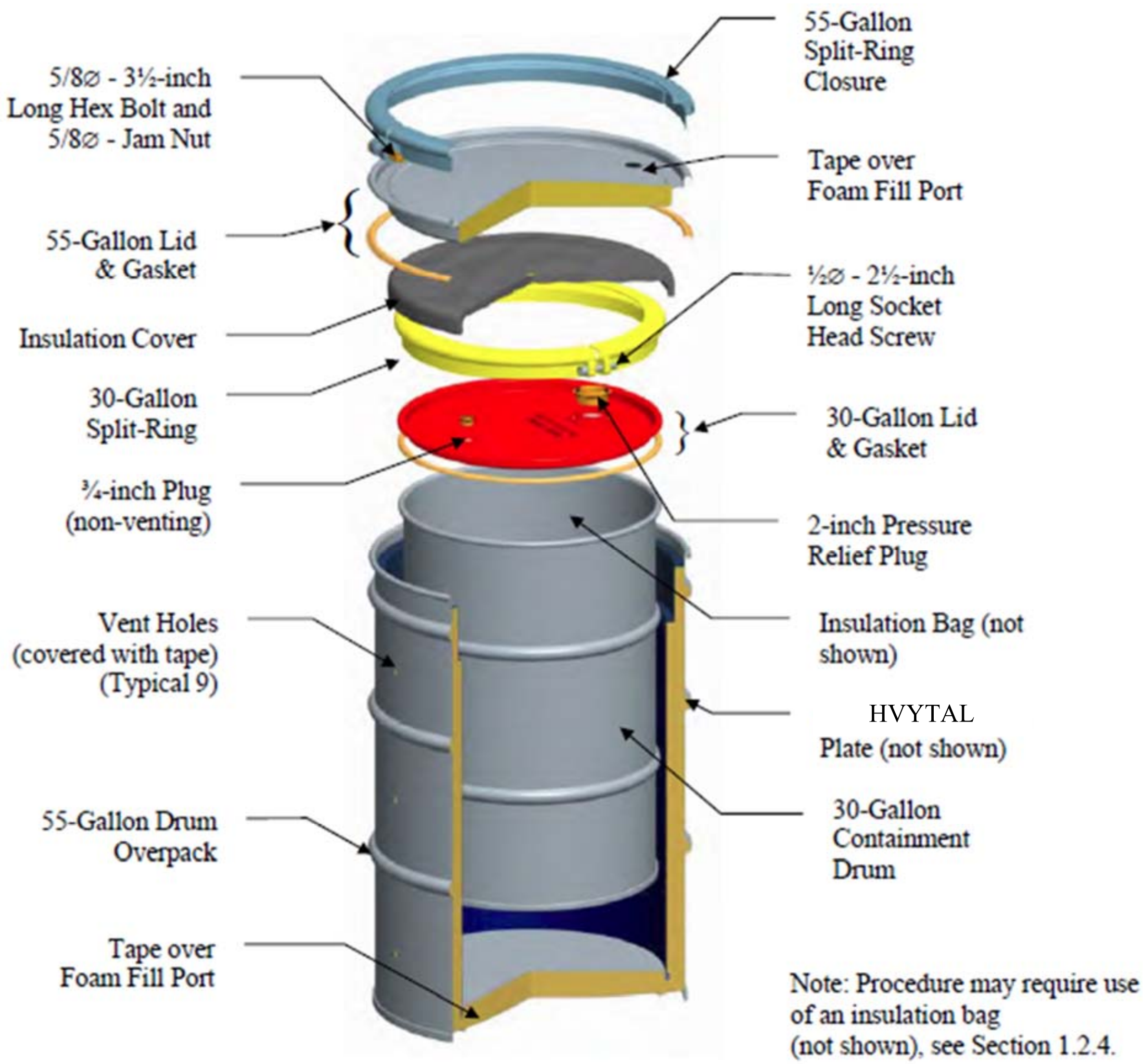

Figure 5-1 HVYTAL Packaging -- Exploded 3-Dimensional Sectional View

4.2 PACKAGE LOADING

Packages shall be loaded and closed in accordance with written operating procedures. Detailed operating procedures shall include, at a minimum, the procedural elements of this section and the completion of QA documentation. Implementation of the procedural elements of this section ensures:

- The condition of the packaging is unimpaired prior to loading,
- the contents are authorized,
- the package is loaded and closed correctly, and

- the package is properly prepared for transport.

4.2.1 <u>Preparation for Loading</u>

Sections 4.2.1.1 and 4.2.1.2 do not need to be performed sequentially. This provision permits contents/payload preparation operations to be performed separately from the initial packaging preparation.

4.2.1.1 Packaging Preparation

1) Verify that the example identification plate, as shown in Figure 4-2, is attached to the 55-gallon outer drum and is legible.

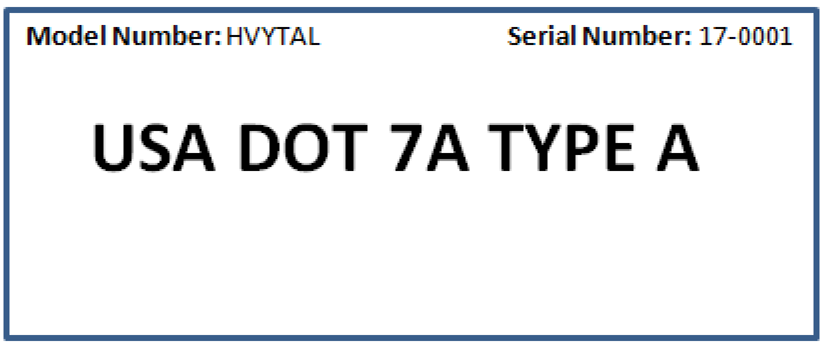

Figure 4-2 Example Identification Plate

Note: USA DOT 7A Type A letters and numerals must be at least 13.0 mm (0.5 inch) in height.

2) Record the packaging model number and the serial number on the loading record.

3) Verify that the waterproof tape covers drum fill and vent holes on the top, bottom, and sides of the 55-gallon outer drum. If damaged or missing, new tape shall be applied prior to transport.

4) Verify the ¾-inch blind plug is undamaged and securely threaded into the 30-gallon drum bung hole with its supplied EPDM gasket. Securely threaded is defined as the plug freely spinning into the threaded opening until the gasket is in firm contact with the bung hole flange then the plug is rotated an additional 90 to 180 degrees. If the plug or its gasket is visually damaged, replace per the manufactures specifications.

5) Verify the Rieke 2-inch pressure relieving plug is undamaged and securely threaded into the 30-gallon drum 2-inch bung hole flange with its supplied EPDM gasket. Securely threaded is defined as the plug freely spinning into the threaded opening until the gasket is in firm contact with the bung hole flange then the plug is rotated an additional 90 to 180 degrees. If the plug or its gasket is visually damaged replace per the manufactures specifications.

6) Verify that the 30- and 55-gallon split-ring closure devices are undamaged and that the bolts match those specified on drawings R-R1-G-00026 and R-R1-G-00027 (see Appendix A), respectively.

7) Verify that the 55-gallon outer drum and 30-gallon inner drum are not damaged (top, bottom, and side) in any way that would affect packaging or transportation operations. Small surface scratches and dents that would not adversely affect packaging or transportation operations are acceptable.

8) Verify that the 30- and 55-gallon drums are empty and dry.

9) Visually inspect the gaskets of the 30- and 55-gallon closure lids. Verify that the gaskets are securely fixed (glued) to their respective closure lids and free of gouges, nicks, cuts, cracks, scratches, or debris that could affect their sealing performance. The 30-gallon lid gasket is silicone and is rust colored. The 55-gallon gasket is EPDM and is black. If either drum closure gasket is found to be damaged, replace per the manufactures specifications.

4.2.1.2 Contents/Payload Preparation

1) Verify that the radioactive contents are in compliance with the current Type A test report.

2) Prior to placement inside the 30-gallon drum, verify the LDPE dunnage and the WSCA and/or radioactive material handling convenience(s) do not show signs of degradation (e.g., tearing, bulging, buckling or corrosion) that could adversely affect the performance of the package.

3) Assemble the contents into a payload configuration described in Section 1.2.2.

4.2.2 <u>Loading of Contents</u>

Facility-specific operating procedures for loading radioactive contents into the 30-gallon drum and for closing the 30-gallon drum shall include, as a minimum, the operational elements listed below. Integration of these procedural elements into facility-specific requirements shall incorporate ALARA principles.

In preparation for loading the 30-gallon drum, all of the steps identified in Sections 4.2.1 and 4.2.1.1 shall have been completed, and all packaging hardware, lifting equipment, and other required apparatus shall be staged and ready.

1) Verify that the weight of the payload (i.e., everything to be placed into the 30-gallon drum) does not exceed 205.4 lbs. Verify that when combined with the packaging the loaded package will not exceed the authorized gross weight of the HVYTAL package, 419.7 lbs.

2) Place the contents within the 30-gallon drum via lifting equipment, as required. Acceptable payload configurations are described in Section 1.2.2.

3) Verify that the closure gasket is in place on the 30-gallon drum closure lid.

4) Install the 30-gallon closure lid and mount the 30-gallon split-ring closure device.

5) Torque the split-ring closure bolts to 40 ±5 ft-lbs in accordance with the closure requirements listed on drawing R-R1-G-00028 (see Appendix A).

6) If required per facility operations, both sets of lugs of the split-ring closure include provision for installation of a wire TID as shown (blue lines) in Figure 4-3.

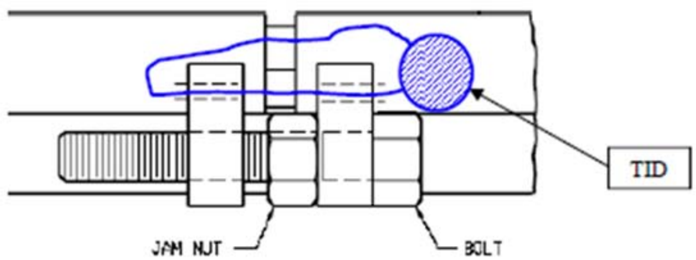

Figure 4-3 Side View of the Top Portion of the Drum, Showing the TID Installation

4.2.3 Preparation for Transport

Package closure shall be performed in accordance with a written procedure that includes the following elements:

1) Health Physics personnel should survey the outer surfaces of the loaded 30-gallon drum and should provide verification that the contamination limits specified in 49 CFR 173.443 (or other established limits) are not exceeded. Health Physics personnel shall document the results of the survey. If the surface contamination measurements exceed the allowable limits, stop work and implement the appropriate contamination control procedures.

2) Install the 30-gallon closure lid and mount the 30-gallon split-ring closure device.

3) Torque the split-ring closure bolts to 40 ±5 ft-lbs in accordance with the closure requirements listed on drawing R-R1-G-00029 (see Appendix A).

WARNING: A fully loaded 30-gallon drum can weigh as much as 250 lbs. Perform lift in accordance with site/facility lifting procedures. An example drum lifting tool is illustrated in Figure 1-5.

NOTE: Verify that the waterproof tape covers the 55-gallon drum fill and vent holes prior to proceeding. Replace if damaged or missing.

4) If required, attach a drum lifting device to the 30-gallon drum split-ring closure device as illustrated in Figure 1-5.

5) Lift and lower the 30-gallon drum into the 55-gallon overpack.

6) Place the insulation cover over the 30-gallon drum closure as shown in Figure 1-2.

7) Install the 55-gallon closure lid and mount the 55-gallon split-ring closure device.

8) Torque the split-ring closure bolts to 40 ±5 ft-lbs in accordance with the closure requirements listed on drawing R-R1-G-00029 (see Appendix A).

9) Install a wire TID through the 0.13-inch diameter holes in each of the two sets of lugs of the 55-gallon split-ring closure assembly as shown (blue lines) in Figure 4-3.

10) Health Physics personnel shall survey the external surfaces of the 55-gallon outer drum for surface contamination and shall provide verification that the specified limits of 49 CFR 173.443 are not exceeded. Health Physics personnel shall document the results of the survey.

11) Health Physics personnel shall perform and document a radiological survey of the closed 55-gallon outer drum including the following:

    a. Determine the maximum radiation level if in contact with the drum top, side, and bottom surfaces. Ensure that none of these radiation levels exceed the limits identified in 49 CFR 173.441(a) of 200 mR/hr.

    b. Determine the maximum radiation level at 1 meter from the drum top, side, and bottom surfaces, in mrem/hr. This is defined as the Transport Index, per 49 CFR 173.403.

    c. Record the TI on the transport record and on the drum's shipping label.

    d. If the TI is greater than 3.0 and transported by air then the package must be transported by Cargo Aircraft only. The TI exceed must never exceed 10.0.

12) Verify that the gross package weight is 419.7 lbs or less.

13) Apply markings and labels as appropriate and required in the applicable modal regulations.

14) Ensure that any special instructions necessary for safe opening of the package are provided to the consignee prior to shipment of the package.

4.3 PACKAGE UNLOADING

Implementation of the following procedures should incorporate ALARA principles. Package receipt shall be performed in accordance with written procedures that include the following elements.

4.3.1 Receipt of Package from Carrier

1) Health Physics personnel shall perform receipt surveys for dose rate and contamination upon receipt.

2) Notify sender if rates exceed those expected.

3) Verify that the TID is unbroken upon receipt.

4) Verify that the package has not sustained any damage that may significantly reduce the packaging performance.

4.3.2 Removal of Contents

Unloading procedures apply to reusable HVYTAL packagings and shall include the following elements:

1) Document the removal of the TID per the receiving site procedures.

2) Open the 55-gallon outer drum by loosening and removing the two split-ring closure bolts.

3) Remove the split-ring closure device and the 55-gallon outer drum closure lid.

4) Survey the bottom surface of the 55-gallon outer drum closure lid for contamination.

5) Remove the insulation cover from atop the 30-gallon drum.

6) Survey the insulation cover and the top surface of the 30-gallon drum closure lid for contamination.

7) Remove the 30-gallon drum using a drum lifting device. An example lifting device is illustrated in Figure 1-5.

   NOTE: The 30-gallon drum could be pressurized. Using appropriate facility precautions, the ¾-inch blind plug may be backed out to relieve any internal pressure.

8) Open the 30-gallon drum by removing the two split-ring closure bolts, and remove its closure lid.

9) Survey the bottom the 30-gallon closure lid surface for contamination.

10) Remove any packing/dunnage and contents from the 30-gallon drum.

11) Survey the interior surface of the 30-gallon drum for contamination.

4.4 PREPARATION OF EMPTY PACKAGING FOR TRANSPORT

If returning package as a DOT regulated EMPTY follow applicable requirements.

If there is no residual (read measurable) radioactive content left in the package, and it is shipped as a non regulated package, it is recommended that the nameplate be covered.

4.5 OTHER OPERATIONS

There are no special operational controls or restrictions for shipping.

4.5.1 Packaging Storage

Store the packaging in facility that provides protection from:

- The effects of temperature extremes and humidity (to prevent condensation)
- Chemical vapors
- Accelerating forces
- Physical damage and airborne contamination (e.g., rain, snow, dust accumulation, dirt, salt spray, and fumes)

Drum assemblies are to be stored with the vent hole plugs in place, the closure lid in place, and the split-ring closure device installed.

4.5.2 Records and Reporting

The package loading record shall be prepared and shall include as a minimum:

- Identification of the packaging by model number and serial number
- Verification that there are no significant defects in the packaging, as shipped
- Type and quantity of material in each package and the total quantity of each shipment
- Date of the shipment
- Any special controls exercised
- Name and address of the consignor and consignee

Records are valid only if stamped, initialed or signed, and dated by authorized personnel or otherwise authenticated.

5.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The acceptance tests and the maintenance program for the HVYTAL packaging described in this section ensure compliance with the requirements of Subpart G of 10 CFR 71. The acceptance tests and the maintenance program shall be conducted in accordance with the QA program described in Section 6.0.

5.1 ACCEPTANCE TESTS

Prior to the first use of each HVYTAL packaging, the purchasing organization shall verify conformance to all design and quality assurance requirements defined in this section, in Section 6.0, and as specified in the engineering drawings in Appendix A. The purchasing organization shall require the supplier to satisfy the fabrication, assembly, inspection, and testing requirements in accordance with the procurement contract and procurement specification (or equivalent). The owner shall verify fabrication and QA records submitted by the supplier to the purchasing organization are complete and traceable for each HVYTAL packaging (i.e., by serial number).

Inspections described in this section provide the owner with verification the packaging meets the inspection criteria and the supplier has fabricated the packaging in accordance with the engineering drawings referenced.

As needed, the owner shall prepare and issue a nonconformance report per the requirements of Section 6.9.

5.1.1 <u>Visual Inspections and Measurements</u>

Throughout the fabrication process, visual inspections, dimensional measurements and tests are performed to assess and verify compliance with all requirements (e.g., component materials and component dimensions) given in the drawings. The inspections, tests, and documentation detailed in the drawings in Appendix A, and the foam insulation detailed in Appendix F, ensure that newly fabricated packagings are complete and operable upon receipt. Destructive and nondestructive methods validate the foam filling procedures and the methodology described in Appendix F ensure complete filling of the drum and lid.

5.1.2 <u>Structural and Pressure Tests</u>

The drums are leak pressure tested in accordance 49 CFR 178.604 and 178.605. In addition, drawing R-R2-G-00057 requires pressure testing of the drum liner.

5.1.2.1 Hydrostatic Pressure Tests

The 30-gallon drum requires a hydrostatic pressure test per 49 CFR 178.605. The drum vendor must pressure test at least three samples from each drum lot at 150 kPa (21.7 psig) for 5 minutes. Closure lid vents must be sealed. Acceptance is no visible water leakage from the packaging.

The hydrostatic test requirement for a liquid packaging is specified to ensure additional integrity and robustness of the 30-gallon drum.

5.1.2.2 Structural Tests

The 30-gallon drum requires structural batch lot testing as Packing Group I for solids and Packing Group II for liquids per 49 CFR 178.603, 178.606, and 178.608. Compliance to 49 CFR 178.603(e) for solids and liquids is a 1.8-meter and 1.5-meter drop onto an unyielding surface with the drum filled with solid and liquid, respectively. Acceptance is no visible leakage of either medium. Compliance with 49 CFR 178.606 is stacking test with the packaging loaded to 961 kg. Acceptance is no visible deformation. Compliance with 49 CFR 178.608 requires vibration of the packaging under the requirements specified. Acceptance is no rupture or leakage from any packaging.

5.1.3 Leakage Tests

The 30-gallon drum is required to pass a leakproofness test per 49 CFR 178.604. The test requires the container to be pressurized with a gas medium to at least 30 kPa and show no leakage of air from the packaging. Acceptance is verified by 100% inspection of the longitudinal drum seam and bottom chime using a bubble test.

5.1.4 Component and Material Tests

The HVYTAL packaging design incorporates a pressure relieving plug within the 30-gallon closure lid. The device is designed to release pressure between 12 and 15 psig and to reseal by 3 psig. The manufacturer shall verify by test the minimum following critical characteristics for the plug: relieving and resealing pressure. The test frequency shall be in accordance with sampling as specified by ANSI/ASQ Z1.4-2008 for an acceptance quality limit not greater than 2.5, as defined in Table II-A and Table II-B for single sampling plans; reduced inspection not permitted.

The HVYTAL incorporates rigid polyurethane foam as an energy impact absorber and thermal barrier. The material tests prescribed in Appendix F shall be performed and documented on each batch of foam used in the construction of the HVYTAL.

5.1.5 Shielding Tests

The HVYTAL design incorporates a WSCA as a specific shielding feature for materials that require shielding. Shielding calculations for the WSCA are based on an A_2 quantity of the radioisotope Mo-99 (16 Ci) and applicable gamma emitting daughter Tc-99m (8.8949 Ci). The dose rates from gamma radiation were calculated using MicroShield 8.03. Table 3-1 summarizes the maximum calculated dose rates for NCT for the bounding physical configuration of the radioactive material contained within the WSCA and adjacent to the inner surface of the 30-gallon drum and the contact dose rate on the exterior of the 55-gallon drum and compares the results against the regulatory limits for shipment in commerce. The dose rates reported in Table 3-1 bound the dose rates at all measurement and source locations.

The packaging design does not incorporate active heat transfer features. Passive heat transfer mechanisms are not significantly sensitive to normal variations in the materials of construction or fabrication methods. Therefore, acceptance of newly-fabricated packagings does not require testing of thermal integrity.

5.1.6 Miscellaneous Tests

Acceptance of newly-fabricated HVYTAL packagings does not require additional acceptance testing other than those identified in this test report.

5.2 MAINTENANCE PROGRAM

The HVYTAL packaging design does not require annual maintenance. The inspections required in Section 5.0 for normal use are sufficient to ensure performance of the package has not been degraded.

The user's procurement organization shall verify by direct inspection, or confirm via QA records, that acceptance testing and inspections were satisfied prior to releasing the HVYTAL packaging for package for shipment, see Section 6.0.

Packaging subassemblies may be repaired, refurbished, or replaced using procedures prepared and approved in accordance with the QA requirements given in Section 6.0.

Structural and Pressure Tests

The HVYTAL packaging design does not require periodic structural or pressure tests.

5.2.1 Leakage Tests

The HVYTAL packaging design does not require periodic or pre-shipment leakage tests. However, the packaging includes gasketed closures that provide weather-proof seals necessary for continued packaging performance. If during routine visual inspections described in Section 4.2.1 these gasket materials are found to be faulty, e.g., are cut, gouged, cracked, etc., that would otherwise be considered to change their performance they shall be replaced. Installation may be performed by the user with the same item as specified by the applicable drawing given in Appendix A.

5.2.2 Component and Material Tests

The HVYTAL packaging design does not include materials or components that require routine annual maintenance. Prior to shipment, pre-loading inspection requirements described in Section 4.2.1 will segregate out units that need repair.

6.0 QUALITY ASSURANCE REQUIREMENTS

The QA requirements for ensuring the safety of the package are provided in this section. Requirements provided include the QA methodology and applicable areas of packaging design, purchasing, fabrication, handling, shipping, storage, cleaning, assembly, inspection, testing, operation, maintenance, repair, and component modification.

QA comprises those planned and systematic actions necessary to provide adequate confidence that a system or component will perform satisfactorily in service.

Section 6.0 establishes QA requirements applying to all activities related to the HVYTAL packaging that are important to safety. All personnel whose activities affect the quality of any aspect of the packaging are subject to the requirements of this section in accordance with their degree of involvement.

Section 6.0 establishes QA requirements applying to the design, procurement, fabrication, handling, shipping, storage, cleaning, assembly, use, periodic inspection, acceptance testing, maintenance, repair and modification of the packagings in accordance with the requirements specified in the DOT regulations.

6.1 QUALITY ASSURANCE ORGANIZATION

This section introduces the packaging design authority, user, procurement agency and supplier QA organizations.

6.1.1 Design Authority and Design Agency – Savannah River Packaging Technology

Since the HVYTAL utilizes the same packaging system as the 9979 Type A fissile, the PT&PS organization of the SRNL, who is the design authority of the 9979, is also the design authority for the HVYTAL and is responsible for the changes to, and final acceptance of, the design of the packaging. PT&PS is the SRNS-designated design authority for this packaging.

ANL, Nuclear Engineering, is the design agency and design authority for the WSCA component of the HVYTAL.

6.1.2 Packaging User

A packaging user ships and receives materials in that specific packaging. Users are responsible for implementing the QA controls necessary to ensure that the use, maintenance, testing, and certification of packagings meet the requirements of 49 CFR 173.474 and 49 CFR 173.475. Any organization that intends to maintain, ship, or receive loaded HVYTAL packages or empty packagings is responsible for preparation and implementation of facility-specific, detailed compliance procedures.

6.2 PROCUREMENT DOCUMENT CONTROL

Purchasers of packagings and replacement items shall use a graded QA approach. Procurement agency QA procurement documentation specifications shall contain the applicable requirements including, as appropriate, standards, specifications, codes, documentation, and any other special conditions. Specifications prescribe the necessary inspections, tests, and other pertinent QA considerations as well as packaging, shipping, and handling requirements. The initiator of the purchase requisition or order is responsible for including the applicable QA requirements on the requisition and for obtaining proper approval signatures.

Suppliers are evaluated to assess the supplier's capability to meet the QA program requirements specified in the procurement documents. Also, where sub-tier suppliers are involved, the QA provisions appropriate to these procurements are specified. The extent of the supplier's or sub-tier supplier's QA program depends on the particular item or service being procured.

6.3 INSTRUCTIONS, PROCEDURES, AND DRAWINGS

Activities concerning loading, testing, and shipping are performed in accordance with operating procedures developed by the packaging user. Requirements, including sequential setups, technical constraints, acceptance criteria, and references, will be specified in the written operating procedures. Procedures are issued as controlled documents. Personnel must receive appropriate training in the procedural requirements on the basis of the particular aspects of the procedure in which they are involved. Section 4.0 of this test report provides specific information governing loading and unloading procedures for these packagings. Section 5.0 of this test report provides specific information governing acceptance tests, inspections, and maintenance activities associated with these packagings. Changes in the approved procedures require the same level of approval as the initial issue. The user's organization must prepare written procedures or instructions for repair, rework, modification, and maintenance of packagings and components and obtain approval of these procedures or instructions prior to their use. Inspection, testing, and independent verification, if required, will be included in the procedures. The design agency is responsible for the preparation of packaging design drawings and subsequent drawing revisions. The drawings are issued as controlled documents.

6.4 DOCUMENT CONTROL

The design agency and each user are responsible for the establishment, development, review, approval, distribution, revision, and retention of its own documents. A document is a publication that prescribes requirements for items or activities affecting quality. Documents are controlled to ensure that correct versions (e.g., current revision) are being used and to provide assurance that record requirements are met. Documents requiring control, the level of control, and personnel responsibilities (including training requirements) are defined in departmental procedures. Upon completion, many of these documents become QA records. Documents to be controlled may include:

- Design documents

- Prototype test plan and procedures
- Procurement documents
- QA manuals
- Maintenance and modification procedures and log
- Inspection and test procedures
- Nonconformance reports
- Design change requests
- Shipment documentation
- Repair procedures
- Loading and unloading procedures
- Packaging for transport procedures
- Fabrication records
- Drawings of packagings and components
- Test reports/records (prototype, fabrication, periodic, post-load, and post maintenance or modification)

Revisions to documents are handled in a manner similar to the original issue via review and approvals from the original departments. Document control measures ensure only the currently approved version is available for use at the work facility.

6.5 INTERNAL INSPECTION

The packaging is required to undergo fabrication inspections by the supplier and independent inspections performed by the purchaser. Supplier inspections are designed to ensure that an accepted packaging or item conforms to the tested and certified design criteria.

Independent inspections shall be performed by qualified inspectors. The activities shall include verifications of conformance with accept/reject criteria, completion of prerequisites, personnel qualifications, and equipment calibrations. Inspections shall be performed upon receipt of the packaging, prior to first usage, and annually. Post-loading inspections shall be performed prior to shipment in all cases. Procedures shall be established by the supplier and approved by the purchaser and the design agency to ensure that inspectors are qualified in accordance with applicable codes and standards. The procedures require that the inspection personnel certifications are kept current and that inspection personnel are independent from individuals performing the activity being inspected. The inspections to be performed by qualified personnel shall include the inspections or examinations included in Section 5.0 and Section 6.0. Required inspections and examinations are reported as part of the packaging documentation record.

6.6 CONTROL OF MEASURING AND TEST EQUIPMENT

Measuring and Test Equipment (M&TE) is defined as devices or systems used to calibrate, measure, gage, test, or inspect, in order to control and validate acquired data and to verify conformance to specified requirements. M&TE used for acceptance and verification is maintained under control systems that identify the status of all M&TE. Calibration procedures, as well as vendor manuals, detail the requirements for M&TE calibration (including frequency and maintenance), the use of appropriate standards and organizational responsibilities for establishing, implementing, and ensuring effectiveness of the calibration program. Measuring and test instruments are calibrated with standards traceable to the U.S. National Institute of Standards and Technology.

Procedures are designed to ensure accuracy within established standards and include disposition and/or corrective measures when discrepancies are noted. Damaged or inaccurate M&TE is immediately removed from service until repaired, recalibrated, or replaced. If M&TE is found to be out of calibration, the validity of previously performed inspections is determined and documented. If previously performed inspections are determined to be invalid, a nonconformance report shall be completed and dispositioned in accordance with the requirements of this section. If any M&TE is consistently out of calibration, it shall be repaired or replaced.

6.7 HANDLING, STORAGE, AND SHIPPING CONTROL

The user should develop written operating procedures from the procedural requirements presented in Section 4.0 to address handling and storage of the packaging components. These procedures must identify appropriate information regarding environment, temperature, cleaning and preservation as applicable to meet design requirements. Limited-life components must be addressed in these procedures to ensure replacement within the required period of time. The procedural controls shall apply to the life cycle of the packaging from initial fabrication through the maintenance and repair aspects. These measures shall apply to complete units as well as spare and replacement parts. Procurement documents shall require that items (spare and replacement parts) be controlled in accordance with supplier developed procedures that adequately address handling, storage, and shipping controls.

The user is responsible for shipment of both loaded packages and empty packagings and is responsible for verifying compliance with the requirements listed in Section 4.0. Upon delivery, all packages shall be visually inspected by the receiving organization for obvious damage.

6.8 INSPECTION, TEST, AND OPERATING STATUS

The inspection and operating status of any packaging should be identified clearly by using status indicators (i.e., tags) or records traceable to the individual units.

6.9 NONCONFORMING MATERIALS, PARTS, OR COMPONENTS

6.9.1 Identification

Procedures shall be established, by the user, to identify and document any nonconforming item or activity.

6.9.2 Segregation

Nonconforming items are marked, tagged, segregated, and placed in controlled areas until disposition is complete.

6.9.3 Disposition

The evaluation for disposition of the nonconformance may include the following:

- **Rework**: The process by which an item is made to conform to original requirements by completion or correction.
- **Repair**: The process of restoring a nonconforming characteristic to a condition such that the capability of an item to function reliably and safely is unimpaired, even though that item still does not conform to the original requirements (technical justification required).
- **Use-as-is**: A disposition permitted for a nonconforming item when it can be established that the item is satisfactory for its intended use (technical justification required).
- **Reject**: Action taken to eliminate a nonconforming item from its specified use (scrap, return to supplier, etc.).

Specific action shall be identified in disposition details. In all cases of action, final disposition of nonconformance must be identified and documented, and the documentation must be maintained as a QA record.

6.10 CORRECTIVE ACTION

Nonconforming items shall be promptly identified and the causes of these conditions to prevent recurrence.

The Corrective Action Program should also addresses significant conditions adverse to quality, identified through problem identification and resolution process.

6.11 QUALITY ASSURANCE RECORDS

6.11.1 General

A record is a completed document that furnishes evidence of the quality of items and/or activities affecting quality. Individual packaging QA records shall be maintained for each packaging by model number and serial number (e.g., MODEL HVYTAL SERIAL NO. 17-0001). Record retention periods, at a minimum, shall comply with 49 CFR 173.415(a). The procurement specification defines the documents that suppliers are to generate and when the records are to be submitted. Records must be available for inspection and are valid only if stamped, initialed or signed, and dated by authorized personnel.

6.11.2 Storage, Preservation, and Safekeeping

Designated records-storage facilities (e.g., a vault with fire protection) are strongly recommended to minimize the risk of damage or destruction to the QA records from natural causes, such as extreme temperatures; moisture from rain, snow, or high humidity; insects; mold; or fire. However, in the event that such facilities are not available, Underwriters Laboratory® listed 1-hour rated fire cabinets are recommended. Security systems and facility activity classifications shall be established to prevent access to records by unauthorized personnel.

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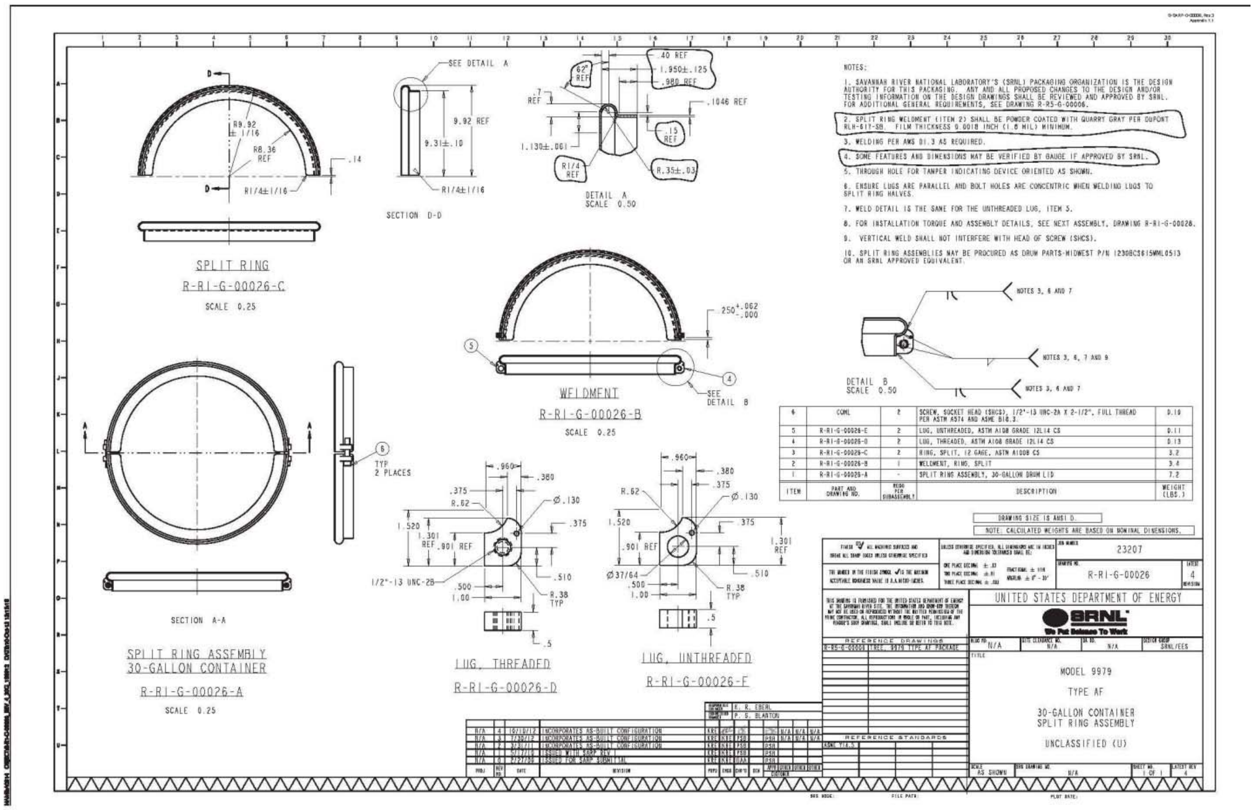
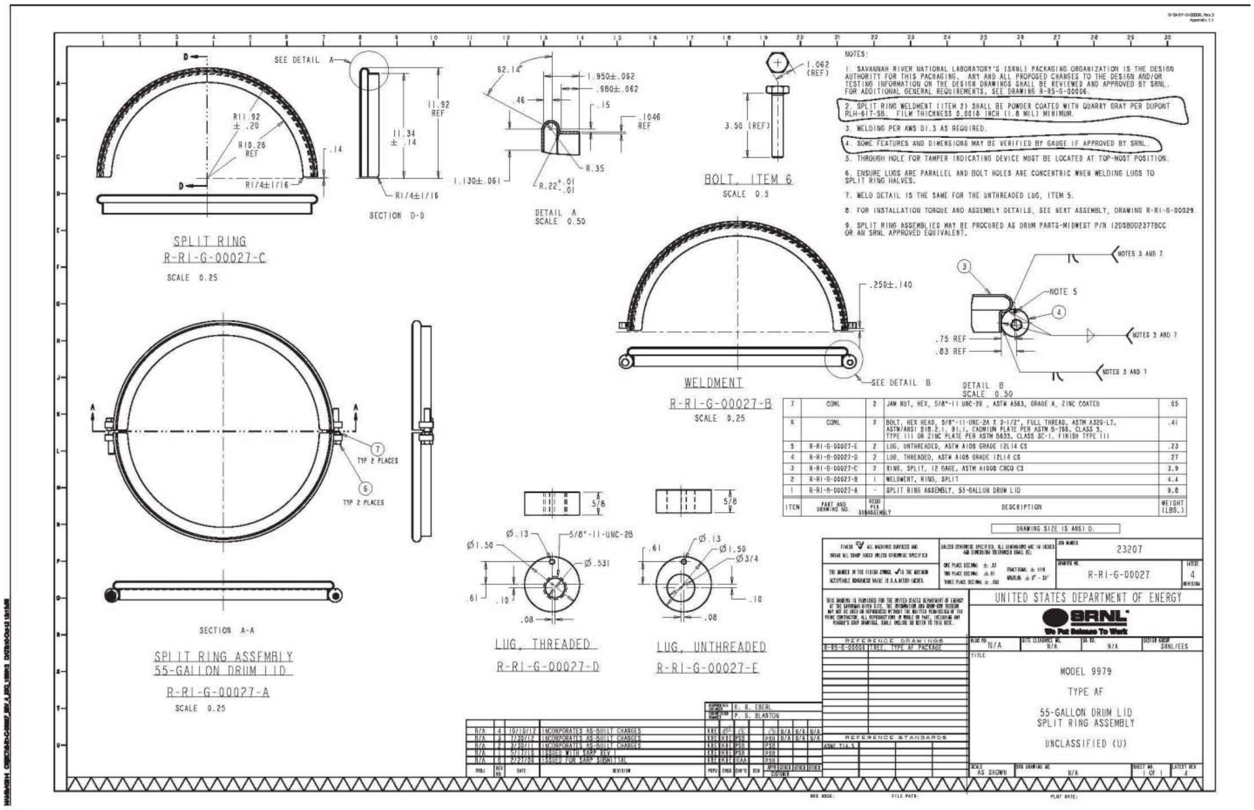
APPENDIX A – HVYTAL CONTAINMENT SYSTEM ENGINEERING DRAWINGS

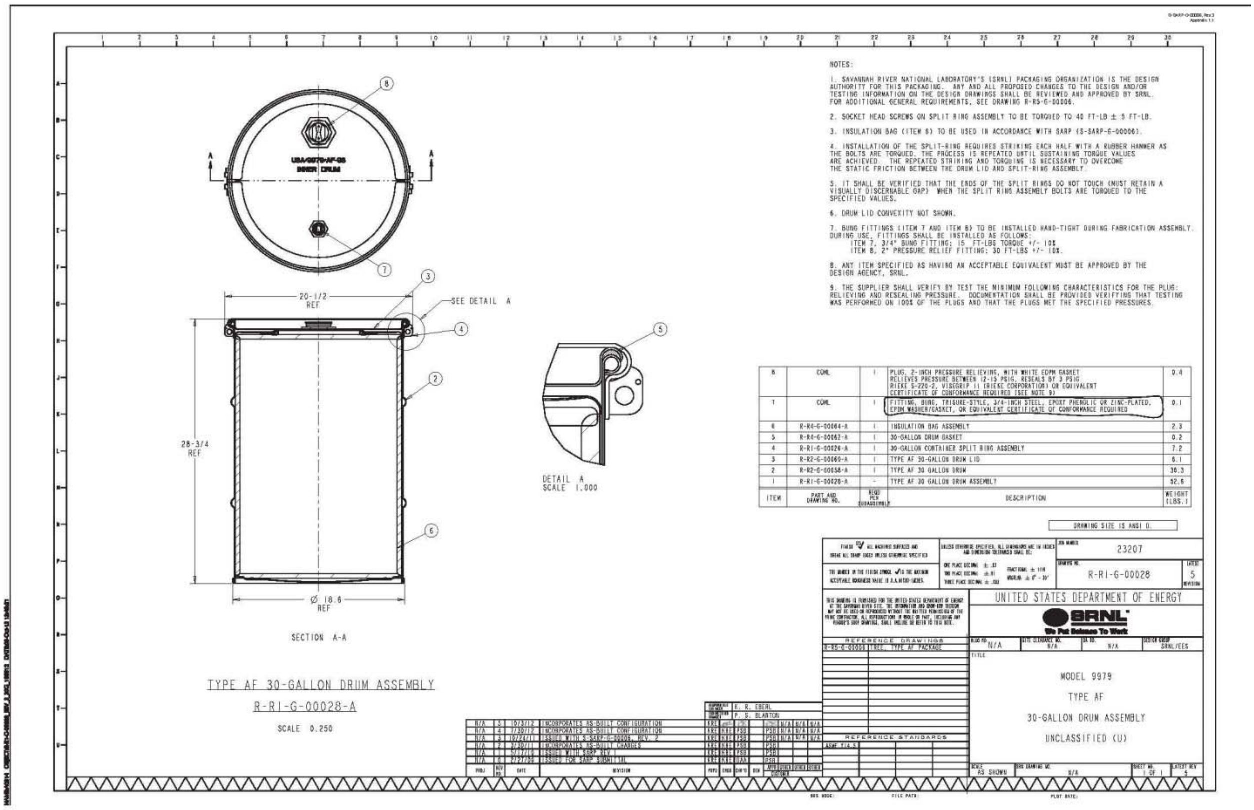
The HVYTAL references Revision 4 of the engineering drawings for the 9979, as the containment system is identical for this packaging.

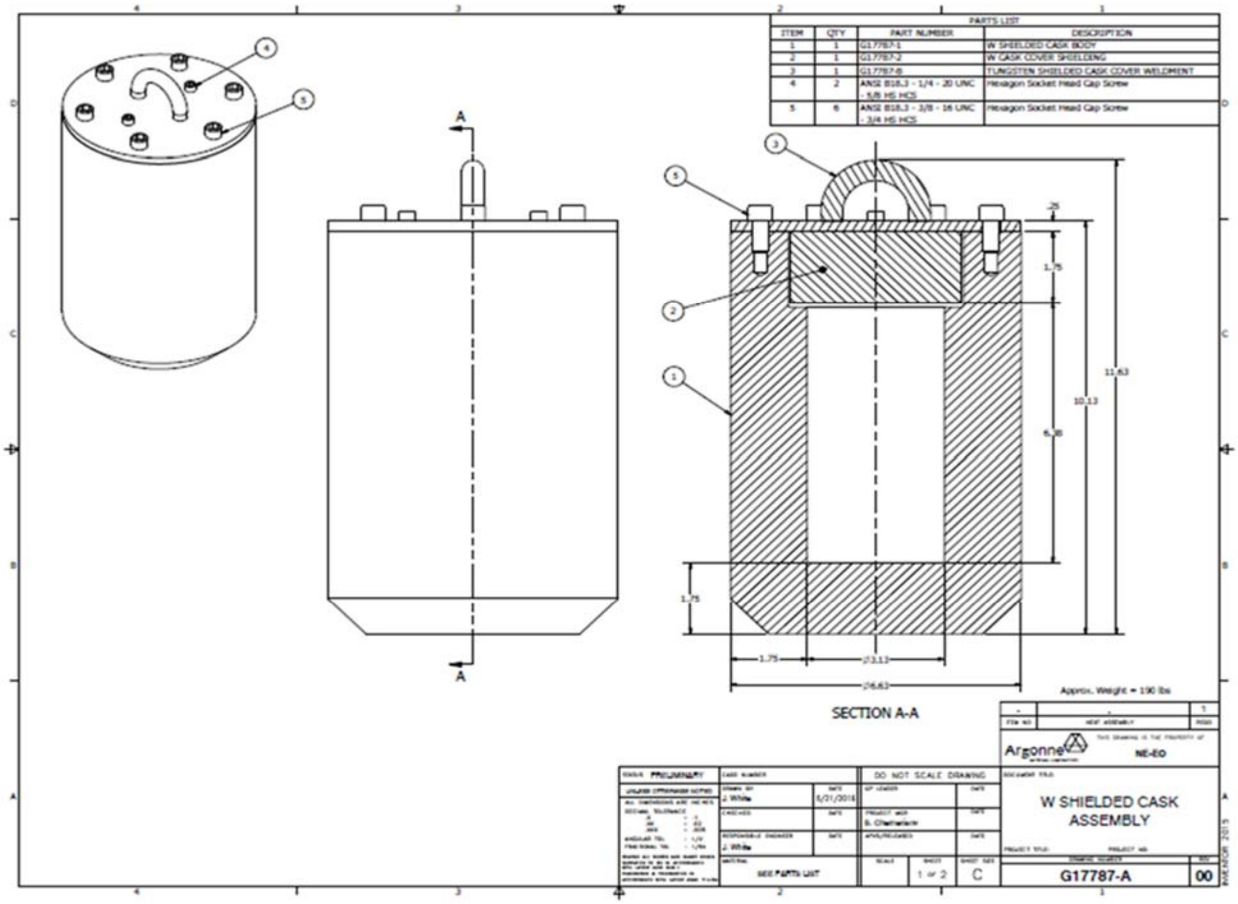
Engineering Drawings of the 9979 Type AF packaging design are the property of Savannah River Nuclear Solutions (SRNS). Engineering drawings defining the 9979 design are listed below.

Drawing No.	Revision	Title
R-R5-G-00006	4	9979 Type AF Package Tree
R-R1-G-00026	4	9979 Type AF 30-Gallon Container Split-Ring Assembly (U)
R-R1-G-00027	4	9979 Type AF 55-Gallon Drum Lid Split-Ring Assembly (U)
R-R1-G-00028	5	9979 Type AF 30-Gallon Drum Assembly (U)
R-R1-G-00029	5	9979 Type AF 55-Gallon Drum Assembly (U)
R-R1-G-00030	3	9979 Type AF Packaging Assembly (U)
R-R2-G-00057	7	9979 Type AF 55-Gallon Drum Sub-Assembly and Weldment (U)
R-R2-G-00058	3	9979 Type AF 30-Gallon Drum (U)
R-R2-G-00059	5	9979 Type AF 55-Gallon Drum Lid Sub-Assembly and Weldment (U)
R-R2-G-00060	4	9979 Type AF 30-Gallon Drum Lid with Dual Bung Closures (U)
R-R4-G-00062	3	9979 Type AF 30-Gallon Drum Lid Gasket (U)
R-R4-G-00064	3	9979 Type AF Insulation Bag
R-R4-G-00065	3	9979 Type AF Insulation Cover Assembly for 30-Gallon Drum (U)
R-R4-G-00066	2	9979 Type AF Package Identification Plate (U)


SPLIT RING
R-RI-G-00026-C
SCALE 0.25
SECTION D-D
DETAIL A
SCALE 0.50
WELDMENT
R-RI-G-00026-B
SCALE 0.25
SPLIT RING ASSEMBLY
30-GALLON CONTAINER
R-RI-G-00026-A
SCALE 0.25
SECTION A-A
LUG, THREADED
R-RI-G-00026-D
LUG, UNTHREADED
R-RI-G-00026-E
DETAIL B
SCALE 0.50
NOTES:
UNITED STATES DEPARTMENT OF ENERGY
SRNL
MODEL 9979
TYPE AF
30-GALLON CONTAINER
SPLIT RING ASSEMBLY
UNCLASSIFIED (U)
R-RI-G-00026
23207


NOTES:
1. SAVANNAH RIVER NATIONAL LABORATORY'S (SRNL) PACKAGING ORGANIZATION IS THE DESIGN AUTHORITY FOR THIS PACKAGING. ANY AND ALL PROPOSED CHANGES TO THE DESIGN AND/OR TESTING INFORMATION ON THE DESIGN DRAWINGS SHALL BE REVIEWED AND APPROVED BY SRNL. FOR ADDITIONAL GENERAL REQUIREMENTS, SEE DRAWING R-R5-G-00006.
2. SPLIT RING WELDMENT (ITEM 2) SHALL BE POWDER COATED WITH QUARRY GRAY PER DUPONT RLH-617-SB. FILM THICKNESS 0.0018 INCH (1.8 MIL) MINIMUM.
3. WELDING PER AWS D1.3 AS REQUIRED.
4. SOME FEATURES AND DIMENSIONS MAY BE VERIFIED BY GAUGE IF APPROVED BY SRNL.
5. THROUGH HOLE FOR TAMPER INDICATING DEVICE MUST BE LOCATED AT TOP-MOST POSITION.
6. ENSURE LUGS ARE PARALLEL AND BOLT HOLES ARE CONCENTRIC WHEN WELDING LUGS TO SPLIT RING HALVES.
7. WELD DETAIL IS THE SAME FOR THE UNTHREADED LUG, ITEM 5.
8. FOR INSTALLATION TORQUE AND ASSEMBLY DETAILS, SEE NEXT ASSEMBLY, DRAWING R-RI-G-00029
9. SPLIT RING ASSEMBLIES MAY BE PROCURED AS DRUM PARTS-MIDWEST P/N 12DSBOD2377BCC OR AN SRNL APPROVED EQUIVALENT.
SPLIT RING
R-RI-G-00027-C
SCALE 0.25
SECTION D-D
DETAIL A
SCALE 0.50
BOLT, ITEM 6
SCALE 0.5
WELDMENT
R-RI-G-00027-B
SCALE 0.25
SEE DETAIL B
DETAIL B
SCALE 0.50
NOTES 3 AND 7
NOTE 5
SECTION A-A
SPLIT RING ASSEMBLY
55-GALLON DRUM LID
R-RI-G-00027-A
SCALE 0.25
LUG, THREADED
R-RI-G-00027-D
LUG, UNTHREADED
R-RI-G-00027-E
TYP 2 PLACES
7 | CONL | 2 | JAM NUT, HEX, 5/8"-11 UNC-2B, ASTM A563, GRADE A, ZINC COATED | .05
6 | CONL | 2 | BOLT, HEX HEAD, 5/8"-11-UNC-2A X 3-1/2", FULL THREAD, ASTM A320-LT, ASTM/ANSI B18.2.1, B1.1, CADMIUM PLATE PER ASTM B-766, CLASS 5, TYPE III OR ZINC PLATE PER ASTM B633, CLASS SC-1, FINISH TYPE III | .41
5 | R-RI-G-00027-E | 2 | LUG, UNTHREADED, ASTM A108 GRADE 12L14 CS | .23
4 | R-RI-G-00027-D | 2 | LUG, THREADED, ASTM A108 GRADE 12L14 CS | .27
3 | R-RI-G-00027-C | 2 | RING, SPLIT, 12 GAGE, ASTM A1008 CRCQ CS | 3.9
2 | R-RI-G-00027-B | 1 | WELDMENT, RING, SPLIT | 4.4
1 | R-RI-G-00027-A | - | SPLIT RING ASSEMBLY, 55-GALLON DRUM LID | 9.8
ITEM | PART AND DRAWING NO. | REQD PER SUBASSEMBLY | DESCRIPTION | WEIGHT (LBS.)
DRAWING SIZE IS ANSI D.
23207
R-RI-G-00027
4
UNITED STATES DEPARTMENT OF ENERGY
SRNL
REFERENCE DRAWINGS
REFERENCE STANDARDS
N/A
SRNL/EES
MODEL 9979
TYPE AF
55-GALLON DRUM LID
SPLIT RING ASSEMBLY
UNCLASSIFIED (U)
AS SHOWN
1 OF 1
E. R. EBERL
P. S. BLANTON


NOTES:
1. SAVANNAH RIVER NATIONAL LABORATORY'S (SRNL) PACKAGING ORGANIZATION IS THE DESIGN AUTHORITY FOR THIS PACKAGING. ANY AND ALL PROPOSED CHANGES TO THE DESIGN AND/OR TESTING INFORMATION ON THE DESIGN DRAWINGS SHALL BE REVIEWED AND APPROVED BY SRNL. FOR ADDITIONAL GENERAL REQUIREMENTS, SEE DRAWING R-R5-G-00006.
2. SOCKET HEAD SCREWS ON SPLIT RING ASSEMBLY TO BE TORQUED TO 40 FT-LB ± 5 FT-LB.
3. INSULATION BAG (ITEM 6) TO BE USED IN ACCORDANCE WITH SARP (S-SARP-G-00006).
4. INSTALLATION OF THE SPLIT-RING REQUIRES STRIKING EACH HALF WITH A RUBBER HAMMER AS THE BOLTS ARE TORQUED. THE PROCESS IS REPEATED UNTIL SUSTAINING TORQUE VALUES ARE ACHIEVED. THE REPEATED STRIKING AND TORQUING IS NECESSARY TO OVERCOME THE STATIC FRICTION BETWEEN THE DRUM LID AND SPLIT-RING ASSEMBLY.
5. IT SHALL BE VERIFIED THAT THE ENDS OF THE SPLIT RINGS DO NOT TOUCH (MUST RETAIN A VISUALLY DISCERNABLE GAP) WHEN THE SPLIT RING ASSEMBLY BOLTS ARE TORQUED TO THE SPECIFIED VALUES.
6. DRUM LID CONVEXITY NOT SHOWN.
7. BUNG FITTINGS (ITEM 7 AND ITEM 8) TO BE INSTALLED HAND-TIGHT DURING FABRICATION ASSEMBLY. DURING USE, FITTINGS SHALL BE INSTALLED AS FOLLOWS:
ITEM 7, 3/4" BUNG FITTING: 15 FT-LBS TORQUE +/- 10%
ITEM 8, 2" PRESSURE RELIEF FITTING: 30 FT-LBS +/- 10%.
8. ANY ITEM SPECIFIED AS HAVING AN ACCEPTABLE EQUIVALENT MUST BE APPROVED BY THE DESIGN AGENCY, SRNL.
9. THE SUPPLIER SHALL VERIFY BY TEST THE MINIMUM FOLLOWING CHARACTERISTICS FOR THE PLUG: RELIEVING AND RESEALING PRESSURE. DOCUMENTATION SHALL BE PROVIDED VERIFYING THAT TESTING WAS PERFORMED ON 100% OF THE PLUGS AND THAT THE PLUGS MET THE SPECIFIED PRESSURES.
8 | COML | 1 | PLUG, 2-INCH PRESSURE RELIEVING, WITH WHITE EDPM GASKET RELIEVES PRESSURE BETWEEN 12-15 PSIG, RESEALS BY 3 PSIG RIEKE S-220-2, VISEGRIP II (RIEKE CORPORATION) OR EQUIVALENT CERTIFICATE OF CONFORMANCE REQUIRED (SEE NOTE 9) | 0.4
7 | COML | 1 | FITTING, BUNG, TRISURE-STYLE, 3/4-INCH STEEL, EPOXY PHENOLIC OR ZINC-PLATED, EPDM WASHER/GASKET, OR EQUIVALENT CERTIFICATE OF CONFORMANCE REQUIRED | 0.1
6 | R-R4-G-00064-A | 1 | INSULATION BAG ASSEMBLY | 2.3
5 | R-R4-G-00062-A | 1 | 30-GALLON DRUM GASKET | 0.2
4 | R-R1-G-00026-A | 1 | 30-GALLON CONTAINER SPLIT RING ASSEMBLY | 7.2
3 | R-R2-G-00060-A | 1 | TYPE AF 30-GALLON DRUM LID | 6.1
2 | R-R2-G-00058-A | 1 | TYPE AF 30 GALLON DRUM | 36.3
1 | R-R1-G-00028-A | - | TYPE AF 30 GALLON DRUM ASSEMBLY | 52.6
ITEM | PART AND DRAWING NO. | REQD PER SUBASSEMBLY | DESCRIPTION | WEIGHT (LBS.)
DRAWING SIZE IS ANSI D.
23207
R-R1-G-00028
5
UNITED STATES DEPARTMENT OF ENERGY
SRNL
MODEL 9979
TYPE AF
30-GALLON DRUM ASSEMBLY
UNCLASSIFIED (U)
20-1/2 REF
SEE DETAIL A
28-3/4 REF
Ø 18.6 REF
SECTION A-A
DETAIL A
SCALE 1.000
TYPE AF 30-GALLON DRUM ASSEMBLY
R-R1-G-00028-A
SCALE 0.250


PARTS LIST
ITEM | QTY | PART NUMBER | DESCRIPTION
1 | 1 | G17787-1 | W SHIELDED CASK BODY
2 | 1 | G17787-2 | W CASK COVER SHIELDING
3 | 1 | G17787-8 | TUNGSTEN SHIELDED CASK COVER WELDMENT
4 | 2 | ANSI B18.3 - 1/4 - 20 UNC - 5/8 HS HCS | Hexagon Socket Head Cap Screw
5 | 6 | ANSI B18.3 - 3/8 - 16 UNC - 3/4 HS HCS | Hexagon Socket Head Cap Screw
A
A
SECTION A-A
.25
1.75
6.38
10.13
11.63
1.75
1.75
Ø3.13
Ø6.63
Approx. Weight = 190 lbs
Argonne
NE-EO
PRELIMINARY
DO NOT SCALE DRAWING
J. White
6/21/2016
S. Chamberlain
J. White
SEE PARTS LIST
1 of 2
C
W SHIELDED CASK ASSEMBLY
G17787-A
00

APPENDIX B – PARAGON D&E HVYTAL TESTING DATA

ATTACHMENT 1 – Test Data Collection Sheet

DATA SHEET I.D. NUMBER 10746-01

Test Date: 2/21/2017

- Test Technician - DESCRIBE weight allocation:

Component	Weight / lbs
Inner pig container with dye	3.6
Outer pig	191.5
30 gallon assembly with inner foam, lid and rings	52.0
55 gallon assembly with lid and rings	172.6

- Test Technician - WEIGH and RECORD the following:
  a. Package test weight (lb.): 419.7
  b. Scale's Measuring and Test Equipment (M&TE) number: PDE-149
  c. Calibration expiration date: 1/13/2018

Test Performed By:

Michael Stephens
Print Name (Test Technician) — Signature on file — 2/21/17
Date

Jason Hoezee
Print Name (Test Technician) — Signature on file — 2-21-17
Date

(Order of performance of tests starts with Water Spray Test, then Penetration Test, then 1.2 m (4 ft.) Free Drop Test, and ends with 9 m (30 ft.) Free Drop Test.

ATTACHMENT 1 – Test Data Collection Sheet

Name	Initial Time/Date	Final Time	Results / Observed Effects
Water Spray Test	12:25 2/21/17	1:25	Initial Reading (Inches): 0 Reading after 15 min. (inches): > 6" Reading after 1 hr. (inches): > 6"
Penetration Test	1:28 2/21/17	1:30	Distance from bottom of Penetration Bar to target area (feet): 66" Length /Weight of Penetration Bar: 38.75" 13.5 LBS Resultant Damage Due to Test: • Depth of Penetration (include units): 1/4" • Breach of Drum: Yes / No o If Yes, describe extent of breach:
1.2 m (4 ft.) Free Drop Test	1:43 2/21/17	1:50	Distance from bottom of drum to target area (feet): 4' 3" Drum Orientation Prior to Free Drop: TOP DOWN Drum Orientation at impact / Top of drum to hit pad at 53° ° Impact area of drum: LUG AREA of RING Resultant Damage Due to Test: • Extent of Damage to Drum: 1/8" deflection of Ring • Breach of Drum: Yes / No o If Yes, describe extent of breach: • Inspection of Outer Drum: o Visual Inspection (Access and Describe): MINOR DAMAGE o Inspection with Black Light (Access and Describe): No dye PRESENT

ATTACHMENT 1 – Test Data Collection Sheet

Name	Initial Time/Date	Final Time	Results / Observed Effects
9 m (30 ft.) Free Drop Test	1:59 2/21/17	2:03	Distance from bottom of drum to target area (feet): 30' 4" Drum Orientation Prior to Free Drop: Top down Drum Orientation at Impact / Top of drum to hit pad at 51°, ° Impact area of drum: ON LUG Aligned with seam Resultant Damage Due to Test: • Extent of Damage to Drum: 1.6" Ring deflection • Breach of Drum: Yes / No o If Yes, describe extent of breach: • Inspection of Outer Drum: o Visual Inspection (Access and Describe): Deflection of Ring Bolts intact o Inspection with Black Light (Access and Describe): No dye present • Inspection of Inner Drum: o Visual Inspection (Access and Describe): Minor Damage to Lid Small scuff on sidewall o Inspection with Black Light (Access and Describe): No dye present • Inspection of Shield Pot: o Visual Inspection (Access and Describe): No Damage o Inspection with Black Light (Access and Describe): No dye present

Page 3 of 3

APPENDIX C – THERMAL CALCULATION FOR MO-99 X-CLC-A-00108R0

OSR 45-24 (Rev 4-30-2013)

Proc. Ref. E7, 2.31

Calculation Cover Sheet

Sheet 1 of 6

Project/Task NA	Calculation Number X-CLC-A-00108 Rev. 0	Project/Task Number NA
Title Bounding Temperatures for the DOT Type A 7A Liquid Package with 16 curies of Molybdenum-99	Functional Classification SS Discipline Chemical Process	
Calculation Type ◉ Type 1 ○ Type 2	Type 1 Calculation Status ○ Preliminary ◉ Confirmed	
Computer Program Number ☒ N/A	Version/Release Number NA	
Purpose and Objective The DOT (Department of Transportation) Type A 7A Liquid Package will be used to transport as much as 16 curies of molybdenum-99. The Type A 7A Liquid Package consists of a tungsten shielded cask body that will contain the plastic bottle with the Mo-99 in solution. The shielded cask body will be placed in a drum and the space between the shielded cask body and the drum will be filled with polyethylene foam.	DC/RO Date 4-25-17 Reviewed and determined to be UNCLASSIFIED This review does not constitute clearance for public release DC/RO: Signature on file (James E. Laurinat)	

Summary of Conclusion

The DOT Type A 7A Liquid Package will be used to transport as much as 16 curies of molybdenum-99. Due to the low heat generation and the short half-life of the Mo-99 contents, the Liquid Package will not be significantly warmer than its environment. The outside surface of the package will not approach 50 °C (122 °F) in ambient conditions of 38 °C (100 °F).

The conservatively calculated steady-state temperature at the center of the package is only 40.65 °C (105.2 °F). The outside surface would only be 38.2 °C (100.7 °F). The entire decay energy is only sufficient to heat the package from 38 °C to 39.9 °C (103.8 °F).

REVISIONS

Rev No.	Revision Description
0	Original Issue
1	

SIGN OFF

Rev No.	Originator (Print / Sign & Date)	Verification/Checking Method	Verification/Checker (Print / Sign & Date)	Manager (Print / Sign & Date)
0	Neal M. Askew Signature on file	☐ Design Check (GS/PS only) ☒ Document Review ☐ Qualification Testing ☐ Alternate Calculation ☐ Operational Testing	James E. Laurinat Signature on file	David A. Crowley Signature on file
1		☐ Design Check (GS/PS only) ☒ Document Review ☐ Qualification Testing ☐ Alternate Calculation ☐ Operational Testing		

Additional Reviewer (Print Name) NA	Signature	Date
Design Authority (Print Name) Edward T. Ketusky	Signature on file	
Release to Outside Agency (Print Name) NA		
Security Classification of the Calculation Unclassified		

Calculation Sheet

Project:	Calculation No: X-CLC-A-00108, Rev. 0
Subject: Bounding Temperatures for the DOT Type A 7A Liquid Package with 16 curies of Molybdenum 99	Sheet No. 2 of 6

1.0 Table of Contents

SECTION PAGE #

2.0 Open Items

There are no open items in this calculation.

3.0 References

1. Drawing "W Shielded Cask Assembly." G17787-A, Argonne National laboratory, 6/21/2016.
2. Perry, R. H. and Green D. W., Maloney, J. O., *Perry's Chemical Engineers' Handbook*, Sixth Edition, McGraw-Hill Book Company, 1984.
3. W. M. Haynes, ed., CRC Handbook of Chemistry and Physics, 97th Edition (Internet Version 2017), CRC Press/Taylor & Francis, Boca Raton, FL.
4. Sealed Air Ethafoam® Polyethylene Foam Products, Sealed Air Corporation, Charlotte, NC, http://www.sealedairprotects.com/la/pg/pdf/ethafoam.pdf.
5. Incropera, F. P, and Dewitt, D. P., Fundamentals of Heat Transfer, John Wiley and Sons, 1981.
6. ICRP, 2008. "Nuclear Decay Data for Dosimetric Calculations." ICRP Publication 107. Ann. ICRP 38 (3).
7. N-CLC-H-00719, Rev. 0, "Compilation of Radionuclide Data," J. L. Varble, November 2008.

4.0 Introduction

The DOT (Department of Transportation) Type A 7A Liquid Package will be used to transport as much as 16 curies of molybdenum-99. Because molybdenum-99 (Mo-99) is radioactive and generates heat, the package and its contents will be slightly warmer than the air around the package. The Type A 7A Liquid Package consists of a tungsten shielded cask body that will contain the plastic bottle with the Mo-99 in solution. The shielded cask body will be placed in a drum and the space between the shielded cask body and the drum will be filled with polyethylene foam.

This calculation considers a bounding, simplified, one-dimensional, steady-state model of the heat transfer inside and from the outside surface of the Type A 7A Liquid Package. Mo-99 (half-life of 66 hours) decays quickly to the much more stable technetium-99 (Tc-99 with a half-life of

Calculation Sheet

Project:		Calculation No: X-CLC-A-00108, Rev. 0
Subject: Bounding Temperatures for the DOT Type A 7A Liquid Package with 16 curies of Molybdenum 99		Sheet No. 3 of 6

211,000 years). A brief discussion of the heating that occurs from the total decay of the Mo-99 to Tc-99 will be included.

5.0 Input and Assumptions

I-1. The Type A 7A Liquid Package tungsten shielded cylindrical cask body is a 10.13 inches high by 6.63 inches in diameter. The internal volume is cylindrical and is 6.38 inches high by 3.13 inches in diameter. The tungsten shielding is 1.75 inches thick and weighs about 190 pounds.[1]

I-2. The tungsten shielded cask body will be placed in a 30 gallon drum. The volume between the cask body and the drum will be filled with polyethylene foam. (See appendix.) The nominal dimensions for a 30 gallon drum are 18.25 inches in diameter with a height of 27.20 inches. If the shielded cask is place in the center of the drum, there will be 5.81 inches of polyethylene foam between the shielded cask and the drum wall.

I-3. The thermal conductivity of tungsten is 180 W/m K.[2] The heat capacity of tungsten is 24.3 J/ mole K.[3] Tungsten has an atomic mass of 183.84.[3]

I-4. The thermal conductivity of polyethylene foam varies. Sealed Air Corporation manufactures several varieties of polyethylene foam. Ethafoam® 900 has a thermal conductivity of 0.06 W/m K.[4] Because the foam provides most of the thermal resistance, the calculated temperature gradient across the package is sensitive to this value. A conservative thermal conductivity of 0.04 W/m K will be used for the polyethylene foam.

I-5. The heat generated by decay of molybdenum-99 must be transferred from the solution, through the plastic bottle, through the polyethylene foam, through the metal drum and to the outside air. The thermal resistance of the plastic bottle and the metal drum are neglected. The plastic bottle and metal drum are thin with thermal conductivities that are higher than the polyethylene foam. The natural convection heat transfer coefficients inside the plastic bottle and outside the metal drum are estimated. The natural convection heat transfer coefficient for inside the plastic bottle is estimated to be 50 W/m^2 K. The natural convection heat transfer coefficient for outside the metal drum is estimated to be 5 W/m^2 K. These values are on the low end of those expected for water and air.[5] The calculated temperatures inside the liquid package are not strongly affected by the two assumed natural convection heat transfer coefficients.

I-6. Mo-99 has a half-life of 65.94 hours and a decay energy of 0.541 MeV.[6] 87.7% of Mo-99 decays to the metastable Tc-99m which has a half-life of 6.015 hours and a decay energy of 0.1428 MeV.[6] The remaining 12.3% of the Mo-99 decays directly to the ground state Tc-99.

I-7. Mo-99 has a specific activity of 480,000 curies per gram and a decay heat of 0.00322 watts per curie.[7] Sixteen curies of Mo-99 have a decay heat of 0.0515 watts. Tc-99m has a shorter half-life than Mo-99 and will quickly reach secular equilibrium with its parent isotope. Adding

Calculation Sheet

Project:	Calculation No: X-CLC-A-00108, Rev. 0
Subject: Bounding Temperatures for the DOT Type A 7A Liquid Package with 16 curies of Molybdenum 99	Sheet No. 4 of 6

in the decay energy of 14 curies (87.7% of sixteen curies) of Tc-99m increases the total decay heat to 0.0634 watts.

I-8. It is assumed that the height of liquid contents of the plastic bottle is four inches.

6.0 Analytical Methods and Computations

The overall heat transfer coefficient for a bounding, simplified, one-dimensional, steady-state model of the heat transfer for 7A Liquid Package is[5]

$$U_i = \frac{1}{\frac{1}{h_1} + \frac{r_1}{k_W} ln\frac{r_2}{r_1} + \frac{r_1}{k_f} ln\frac{r_3}{r_2} + \frac{r_1}{r_3}\frac{1}{h_3}} \quad (1)$$

where
U_i = the overall heat transfer coefficient based on the inside area
h_1 = the natural heat transfer coefficient from the solution in the plastic bottle, 50 W/m^2 K
r_1 = radius of the plastic bottle, 1.565 inches, or 0.03975 m
r_2 = radius of the shielded cask, 3.315 inches, or 0.0842 m
r_3 = radius of the 30 gallon drum, 9.125 inches, or 0.2318 m
k_W = thermal conductivity of tungsten, 180 W/m K
k_f = thermal conductivity of polyethylene foam, 0.04 W/m K
h_3 = the natural heat transfer coefficient from the outside of the 30 gallon drum, 5 W/m^2 K.

For the simplified model of the 7A Liquid Package, the overall heat transfer coefficient, U_i, is 0.943 W/m^2 K.

The temperature gradient across the Liquid Package is

$$\Delta T = \frac{Q}{U_i A_i} \quad (2)$$

where
ΔT = temperature difference across the 7 A Liquid Package
Q = decay heat of the contents, initially 0.0634 watts
A_i = the inside surface area of the plastic bottle, 0.0254 m^2.

The calculated temperature across the Liquid Package is 2.65 °C. This value is conservative as it assumes that heat transfer only occurs in the radial direction. It also conservatively neglects the decrease in heat generation that occurs as the Mo-99 decays. Most of the heat transfer resistance of the package is due to the polyethylene foam. The results are insensitive to assumptions for the convective heat transfer coefficients.

Calculation Sheet

Project:	Calculation No: X-CLC-A-00108, Rev. 0
Subject: Bounding Temperatures for the DOT Type A 7A Liquid Package with 16 curies of Molybdenum 99	Sheet No. 5 of 6

Once the Mo-99 has decayed to Tc-99, the actual heat generation decreases by roughly eight orders of magnitude. The energy released as sixteen curies of Mo-99 decays is calculated as follows:

The number of atoms decaying = 16 Ci/4.8E5 Ci/g * mole/98.92g * 6.022E23 atoms/mole
= 2.029E17 atoms of Mo-99 decay.

87.7% of the Mo-99 decays results in Tc-99m, which also decays. So 1.780E17 atoms of Tc-99m decay.

Energy (J) = (atoms Mo-99 * 0.541 MeV = atoms of Tc-99m * 0.143 MeV) * 1.602E-13 J/MeV
= 21,700 joules.

The tungsten shielded cask weighs approximately 190 pounds or 86,400 grams. Tungsten has an atomic weight of 183.84 and a heat capacity of 24.3 J/mol K. If the entire decay energy of the Mo-99 went solely to heating the tungsten, the temperature increase of the tungsten would be

$$\Delta T = \frac{Q}{MC_p} \tag{3}$$

where
Q = decay energy, 21700 Joules
M = moles of tungsten, 86400/183.84 or 470 moles
C_p = heat capacity, 24.3 J/mole K.

The calculated tungsten temperature increase is 1.9 °C.

7.0 Results and Conclusions

The DOT Type A 7A Liquid Package will be used to transport as much as 16 curies of molybdenum-99. Due to the low heat generation and the short half-life of the Mo-99 contents, the Liquid Package will not be significantly warmer than its environment. The outside surface of the package will not approach 50 °C (122 °F) in ambient conditions of 38 °C (100 °F).

The conservatively calculated steady-state temperature at the center of the package is only 40.65 °C (105.2 °F). The outside surface would only be 38.2 °C (100.7 °F). The entire decay energy is only sufficient to heat the package from 38 °C to 39.9 °C (103.8 °F).

Using the conservative one-dimensional, steady-state thermal analysis, a package content heat generation of 8.9 watts would increase the package outer surface temperature to 50 °C. Due to the foam insulation, the centerline content temperature would be 400 °C. Limiting the package content heat generation to 1.4 watts would reduce the centerline temperature to 96.5 °C. The package surface temperature would be approximately 42 °C. The outer convective heat transfer coefficient would be reduced due to the low heat flux.

Calculation Sheet

Project:	Calculation No: X-CLC-A-00108, Rev. 0
Subject: Bounding Temperatures for the DOT Type A 7A Liquid Package with 16 curies of Molybdenum 99	Sheet No. 6 of 6

8.0 Appendix

From: Chris Brandjes <cbrandjes@ameriphysics.com>
To: "jeffery.england@srnl.doe.gov" <jeffery.england@srnl.doe.gov>, "edward.ketusky@srnl.doe.gov" <edward.ketusky@srnl.doe.gov>
Date: 08/17/2016 12:14 PM
Subject: Temperature Calculation for Shielded DOT 7A for Air Transport

Jeff and Ed,
Here is the information regarding the temperature calculation that I am requesting in support of the DOT Type A 7A Liquid package that will contain the tungsten inner shield pot.
The material contents consists for 60 mL of Mo-99 Uranyl Sulfate solution containing 16 Ci of Mo-99. The material will be placed in a poly bottle that will be inserted in a Tungsten shield (see attached). The Tungsten shield will be inserted into the 9979 (like) 30 gal inner drum that will be cushioned with polyethylene foam – exact configuration of the foam is still being worked out, but it will be configured so that the Tungsten shield has very little movement (to reduce the piston effect).
Can you please perform a temperature calculation for the 16 Ci of Mo-99 to identify if we comply with the following for our contents (i.e. what is the max temp. increase on the outside of the package).
173.410 (i) For transport by air—
(1) The temperature of the accessible surfaces of the package will not exceed 50 °C (122 °F) at an ambient temperature of 38 °C (100 °F) with no account taken for insulation;
In talking with Ed late last month, this is the back of an envelope calc that was performed: Based on 16 Ci of Mo-99 at the time the packaged is sealed the maximum increase in temperature at the surface of the package after 5 day 1.5 °C
Let me know if you have any questions.

Thanks again for your help with this.

Regards,
Chris Brandjes

APPENDIX D – SHIELDING ANALYSIS FOR THE HVYTAL SHIPPING PACKAGING

MicroShield 8.03
Amphys (8.03-0000)

Date	By	Checked
4/24/17		

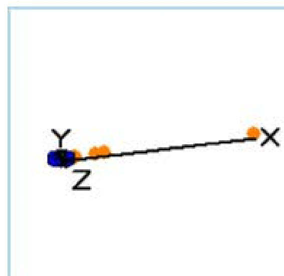
Filename	Run Date	Run Time	Duration
Tunsten 4.5 cm with 8 in dose.msd	April 18, 2017	4:18:30 PM	00:00:01

Project Info	
Case Title	4.5 cm Tunsten
Description	On contact and 1" away
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions	
Height	5.0 cm (2.0 in)
Radius	3.75 cm (1.5 in)

Dose Points

A	X	Y	Z
#1	8.26 cm (3.3 in)	2.5 cm (1.0 in)	0.0 cm (0 in)
#2	9.26 cm (3.6 in)	2.5 cm (1.0 in)	0.0 cm (0 in)
#3	23.178 cm (9.1 in)	2.5 cm (1.0 in)	0.0 cm (0 in)
#4	28.575 cm (11.3 in)	2.5 cm (1.0 in)	0.0 cm (0 in)
#5	128.575 cm (4 ft 2.6 in)	2.5 cm (1.0 in)	0.0 cm (0 in)



Shields

Shield N	Dimension	Material	Density
Source	220.893 cm³	Water	1
Shield 3	4.5 cm	Tungsten	19.3
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input: Grouping Method - Actual Photon Energies

Nuclide	Ci	Bq	μCi/cm³	Bq/cm³
Mo-99	1.6090e+001	5.9534e+011	7.2841e+004	2.6951e+009
Tc-99	2.1171e-008	7.8333e+002	9.5843e-005	3.5462e+000
Tc-99m	8.8949e+000	3.2911e+011	4.0268e+004	1.4899e+009

Buildup: The material reference is Shield 3
Integration Parameters

Radial	10
Circumferential	10
Y Direction (axial)	20

Results - Dose Point # 1 - (8.26,2.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0024	1.220e+09	0.000e+00	3.264e-23	0.000e+00	4.132e-23

0.0024	1.592e+09	0.000e+00	4.258e-23	0.000e+00	5.391e-23
0.0183	5.386e+09	0.000e+00	1.081e-21	0.000e+00	4.996e-23
0.0183	6.918e+09	0.000e+00	1.389e-21	0.000e+00	6.418e-23
0.0184	1.323e+10	0.000e+00	2.672e-21	0.000e+00	1.211e-22
0.0184	1.030e+10	0.000e+00	2.080e-21	0.000e+00	9.424e-23
0.0206	3.090e+09	0.000e+00	7.011e-22	0.000e+00	2.213e-23
0.0206	3.969e+09	0.000e+00	9.007e-22	0.000e+00	2.843e-23
0.0406	5.258e+09	0.000e+00	2.537e-21	0.000e+00	1.081e-23
0.0894	4.543e-03	4.839e-224	9.822e-19	7.447e-227	1.511e-21
0.1405	2.931e+11	1.908e-61	7.044e-19	3.090e-64	1.141e-21
0.1405	2.256e+10	1.468e-62	5.420e-20	2.377e-65	8.779e-23
0.1426	7.043e+07	1.611e-62	1.701e-22	2.619e-65	2.765e-25
0.1811	3.711e+10	2.121e-30	1.139e-19	3.659e-33	1.965e-22
0.3664	8.154e+09	1.279e-02	2.838e-02	2.476e-05	5.496e-05
0.6801	1.538e+09	2.186e+02	6.571e+02	4.227e-01	1.271e+00
0.7396	7.620e+10	2.308e+04	7.091e+04	4.429e+01	1.361e+02
0.778	2.667e+10	1.223e+04	3.798e+04	2.333e+01	7.247e+01
0.8229	7.925e+08	5.569e+02	1.747e+03	1.056e+00	3.312e+00
Totals	**5.172e+11**	**3.609e+04**	**1.113e+05**	**6.910e+01**	**2.131e+02**

Results - Dose Point # 2 - (9.26,2.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0024	1.220e+09	0.000e+00	2.558e-23	0.000e+00	3.239e-23
0.0024	1.592e+09	0.000e+00	3.338e-23	0.000e+00	4.226e-23
0.0183	5.386e+09	0.000e+00	8.475e-22	0.000e+00	3.917e-23
0.0183	6.918e+09	0.000e+00	1.089e-21	0.000e+00	5.032e-23
0.0184	1.323e+10	0.000e+00	2.095e-21	0.000e+00	9.490e-23
0.0184	1.030e+10	0.000e+00	1.631e-21	0.000e+00	7.388e-23
0.0206	3.090e+09	0.000e+00	5.496e-22	0.000e+00	1.735e-23
0.0206	3.969e+09	0.000e+00	7.060e-22	0.000e+00	2.229e-23
0.0406	5.258e+09	0.000e+00	1.989e-21	0.000e+00	8.477e-24
0.0894	4.543e-03	4.428e-224	7.699e-19	6.814e-227	1.185e-21
0.1405	2.931e+11	1.686e-61	5.522e-19	2.730e-64	8.943e-22
0.1405	2.256e+10	1.297e-62	4.249e-20	2.101e-65	6.882e-23
0.1426	7.043e+07	1.422e-62	1.333e-22	2.312e-65	2.167e-25
0.1811	3.711e+10	1.858e-30	8.927e-20	3.205e-33	1.540e-22
0.3664	8.154e+09	1.076e-02	2.387e-02	2.084e-05	4.623e-05
0.6801	1.538e+09	1.780e+02	5.342e+02	3.443e-01	1.033e+00
0.7396	7.620e+10	1.875e+04	5.748e+04	3.597e+01	1.103e+02
0.778	2.667e+10	9.918e+03	3.074e+04	1.892e+01	5.866e+01
0.8229	7.925e+08	4.510e+02	1.412e+03	8.550e-01	2.677e+00
Totals	**5.172e+11**	**2.930e+04**	**9.017e+04**	**5.610e+01**	**1.727e+02**

Results - Dose Point # 3 - (23.1775,2.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0024	1.220e+09	0.000e+00	3.890e-24	0.000e+00	4.925e-24
0.0024	1.592e+09	0.000e+00	5.075e-24	0.000e+00	6.425e-24
0.0183	5.386e+09	0.000e+00	1.289e-22	0.000e+00	5.955e-24
0.0183	6.918e+09	0.000e+00	1.655e-22	0.000e+00	7.650e-24
0.0184	1.323e+10	0.000e+00	3.185e-22	0.000e+00	1.443e-23
0.0184	1.030e+10	0.000e+00	2.479e-22	0.000e+00	1.123e-23
0.0206	3.090e+09	0.000e+00	8.356e-23	0.000e+00	2.638e-24
0.0206	3.969e+09	0.000e+00	1.073e-22	0.000e+00	3.388e-24
0.0406	5.258e+09	0.000e+00	3.024e-22	0.000e+00	1.289e-24
0.0894	4.543e-03	1.860e-224	1.171e-19	2.862e-227	1.801e-22
0.1405	2.931e+11	5.366e-62	8.395e-20	8.690e-65	1.360e-22
0.1405	2.256e+10	4.129e-63	6.460e-21	6.687e-66	1.046e-23
0.1426	7.043e+07	4.479e-63	2.027e-23	7.282e-66	3.295e-26
0.1811	3.711e+10	4.957e-31	1.357e-20	8.551e-34	2.341e-23
0.3664	8.154e+09	2.032e-03	4.496e-03	3.935e-06	8.707e-06
0.6801	1.538e+09	2.984e+01	8.908e+01	5.772e-02	1.723e-01
0.7396	7.620e+10	3.119e+03	9.509e+03	5.984e+00	1.825e+01
0.778	2.667e+10	1.643e+03	5.063e+03	3.135e+00	9.662e+00
0.8229	7.925e+08	7.439e+01	2.315e+02	1.410e-01	4.389e-01
Totals	**5.172e+11**	**4.866e+03**	**1.489e+04**	**9.317e+00**	**2.852e+01**

Results - Dose Point # 4 - (28.575,2.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0024	1.220e+09	0.000e+00	2.551e-24	0.000e+00	3.230e-24
0.0024	1.592e+09	0.000e+00	3.328e-24	0.000e+00	4.214e-24
0.0183	5.386e+09	0.000e+00	8.451e-23	0.000e+00	3.905e-24
0.0183	6.918e+09	0.000e+00	1.086e-22	0.000e+00	5.017e-24
0.0184	1.323e+10	0.000e+00	2.089e-22	0.000e+00	9.462e-24
0.0184	1.030e+10	0.000e+00	1.626e-22	0.000e+00	7.366e-24
0.0206	3.090e+09	0.000e+00	5.480e-23	0.000e+00	1.730e-24
0.0206	3.969e+09	0.000e+00	7.040e-23	0.000e+00	2.222e-24
0.0406	5.258e+09	0.000e+00	1.983e-22	0.000e+00	8.452e-25
0.0894	4.543e-03	1.467e-224	7.677e-20	2.257e-227	1.181e-22
0.1405	2.931e+11	3.816e-62	5.506e-20	6.181e-65	8.917e-23
0.1405	2.256e+10	2.937e-63	4.236e-21	4.756e-66	6.862e-24
0.1426	7.043e+07	3.177e-63	1.329e-23	5.165e-66	2.161e-26
0.1811	3.711e+10	3.398e-31	8.901e-21	5.862e-34	1.536e-23
0.3664	8.154e+09	1.346e-03	2.977e-03	2.606e-06	5.765e-06
0.6801	1.538e+09	1.964e+01	5.861e+01	3.798e-02	1.134e-01
0.7396	7.620e+10	2.052e+03	6.255e+03	3.937e+00	1.200e+01
0.778	2.667e+10	1.080e+03	3.330e+03	2.062e+00	6.354e+00

0.8229	7.925e+08	4.892e+01	1.522e+02	9.273e-02	2.886e-01
Totals	**5.172e+11**	**3.201e+03**	**9.795e+03**	**6.129e+00**	**1.876e+01**

Results - Dose Point # 5 - (128.575,2.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0024	1.220e+09	0.000e+00	1.253e-25	0.000e+00	1.586e-25
0.0024	1.592e+09	0.000e+00	1.634e-25	0.000e+00	2.069e-25
0.0183	5.386e+09	0.000e+00	4.150e-24	0.000e+00	1.918e-25
0.0183	6.918e+09	0.000e+00	5.331e-24	0.000e+00	2.464e-25
0.0184	1.323e+10	0.000e+00	1.026e-23	0.000e+00	4.647e-25
0.0184	1.030e+10	0.000e+00	7.985e-24	0.000e+00	3.617e-25
0.0206	3.090e+09	0.000e+00	2.691e-24	0.000e+00	8.495e-26
0.0206	3.969e+09	0.000e+00	3.457e-24	0.000e+00	1.091e-25
0.0406	5.258e+09	0.000e+00	9.738e-24	0.000e+00	4.151e-26
0.0894	4.543e-03	1.131e-225	3.770e-21	1.740e-228	5.802e-24
0.1405	2.931e+11	2.112e-63	2.704e-21	3.420e-66	4.379e-24
0.1405	2.256e+10	1.625e-64	2.080e-22	2.632e-67	3.370e-25
0.1426	7.043e+07	1.747e-64	6.528e-25	2.841e-67	1.061e-27
0.1811	3.711e+10	1.752e-32	4.371e-22	3.022e-35	7.541e-25
0.3664	8.154e+09	6.596e-05	1.460e-04	1.277e-07	2.826e-07
0.6801	1.538e+09	9.581e-01	2.861e+00	1.853e-03	5.533e-03
0.7396	7.620e+10	1.001e+02	3.053e+02	1.920e-01	5.857e-01
0.778	2.667e+10	5.271e+01	1.625e+02	1.006e-01	3.101e-01
0.8229	7.925e+08	2.386e+00	7.430e+00	4.523e-03	1.408e-02
Totals	**5.172e+11**	**1.561e+02**	**4.781e+02**	**2.990e-01**	**9.154e-01**

APPENDIX E – HVYTAL CLOSURE INSTRUCTIONS

This procedure is for the closure of the HVTAL Packaging System Only

30- AND 55-GALLON OPENHEAD CLOSURE PROCEDURE

1. Inspect gasket for proper seating and remove any residue from drum curl prior to closure lid installation.
2. Place closure lid on drum, making sure the lid gasket is seated against drum curl and gasket is securely recessed in lid channel. The gasket may not protrude outside the closure lid or drum curl or be sagging inside the drum.
3. Place one half of the split-ring closure onto drum, ensuring split-ring closure is oriented so lugs are positioned below the surface of the drum. Tap split-ring closure on side with non-sparking mallet, seating split-ring closure to drum and closure lid.
4. Install second half of split-ring closure in accordance with Step 3 of this procedure.
5. Insert closure bolt into non-threaded lug of split-ring closure. For 55-gallon drum ONLY, thread jam nut onto bolt. Thread closure bolt into threaded lug and tighten to take up slack.
6. Install second closure bolt in accordance with Step 5 of this procedure.
   NOTE – Each split-ring closure assembly requires two closure bolts for correct closure.
7. Torque each closure bolt to 40 ±5 ft-lbs, ensuring the gap between each of the two split-ring ends is approximately the same distance.
   NOTE – Split-ring closure ends must not touch when proper torque is applied.
8. For the 55-gallon drum, tighten jam nut against unthreaded lug.

BLIND PLUG AND PRESSURE RELIEF PLUG INSTALLATION PROCEDURE

Blind Plug Installation

1. Verify the ¾-inch blind plug and supplied EPDM gasket are undamaged.
2. Install EPDM gasket onto ¾-inch blind plug.
3. Securely thread ¾-inch blind plug with EPDM gasket into the 30-gallon drum bung hole. Securely thread is defined as the plug freely spinning into the threaded opening until the gasket is in firm contact with the bung hole flange then the plug is rotated an additional 90 to 180 degrees.

Relief Plug Installation Procedure

1. Verify the Rieke 2-inch pressure relieving plug and white EPDM gasket are undamaged.
2. Install white EPDM gasket onto Rieke 2-inch pressure relieving plug.
3. Securely thread Rieke 2-inch pressure relieving plug with white EPDM gasket into drum 2-inch bung hole flange. Securely threaded is defined as the plug freely spinning into the threaded opening until the gasket is in firm contact with the bung hole flange then the plug is rotated an additional 90 to 180 degrees.

Tungsten Shielded Cask Assembly (WSCA) Closure Procedure

1. Place the WSCA closure plug onto the body of the WSCA and line up the bolt holes on closure plug with the threaded holes in the WSCA body.
2. Install each of the six supplied hexagon socket head cap screws, hand tight, connecting the WSCA closure plug and body.
3. In a star pattern sequence, tighten each of the hexagon socket head cap screws to 20 ft-lbs ± 2 ft-lbs.

****NOTE:**

- This document must be provided with the container to the personnel who are responsible for the shipping and closure. In addition, it must be used as a training document to complete proper closure of your container.
- For this packaging to safely perform to its rated ability, these packaging instructions must be strictly adhered to.

APPENDIX F – ACCEPTANCE TESTS FOR DOW BETAFOAM™ 87100/87124 IN PACKAGING

This appendix establishes the requirements and acceptance criteria for installation, inspection, and testing of rigid, closed-cell, polyurethane foam utilized within the packaging.

1. GENERAL REQUIREMENTS

Polyurethane foam insulation has been used for structural and thermal materials in radioactive material shipping packaging for many years. The foam filling operation has shown to be extremely reliable yielding predictable results as long as the process is controlled. DOW Corporation, the Type A fissile polyurethane foam supplier, specifies all necessary process parameters involved in the foaming operations to ensure product QA.

In practice, the batches of the chemical constituents are prepared for later mixing in accordance with the formulation. Therefore, a foam "batch" is a specific grouping and apportionment of chemical constituents into separate and controlled vats or bins for each foam formulation part. In accordance with formulation requirements, portions from each batch part are mixed to produce the liquid material for pouring into a mold. Thus, a "pour" is defined as apportioning and mixing the batch parts into a desired quantity for subsequent installation (pouring).

To assure that the foaming process is repeatable and that the product is acceptable, a combination of process controls and post-filling verification steps will be implemented. The following sections describe the general requirements for chemical composition, constituent storage, foam material installation and foam pour and test records. The results of these tests shall be documented on a QA Traveler, which shall be submitted to the buyer and maintained in the records for the packaging. The operators shall be trained in the performance of these tests and the results of that training shall be documented and maintained in their training records and submitted with the QA Traveler. The manufacturer's proposed method of pouring polyurethane foam into the production drums to ensure a complete filling of the cavity is to invert the drum and tip it at an angle so that the expanding foam rises and vents from a single high point. A single pour is expected to be used to fill the drums though multiple pours are acceptable. Approved procedures shall be used in conjunction with a quality controlled Production Control Plan to verify a complete filling of the packaging.

During and after the drums are filled with polyurethane, the nine clear ports spaced evenly around the outside of the drum wall will be used to verify the foam pour. The foam dispensing rate during filling is automatically controlled and verification can be validated by comparing pre and post-pour packaging weights. Free-rise pour samples will be tested per batch to verify physical properties, e.g., density, crush strength and thermal properties.

Polyurethane Foam Chemical Composition

The foam supplier shall certify that the chemical composition of the polyurethane foam is as required for BETAFOAM™ 87100/87124. Certification shall include chemical components are in accordance with those specified for BETAFOAM™ 87100/87124.

Polyurethane Foam Constituent Storage

The packaging supplier shall certify that the polyurethane foam constituents have been properly stored prior to use, and that the polyurethane foam constituents have been used within their shelf life.

Polyurethane Foam Installation

Filling the drum with foam shall be performed in accordance with approved procedures. As illustrated in Figure F-1, the drum is inverted such that the foam can rise along the drum axis to ensure a complete foam fill.

To validate the foam filling procedure, one or more foam-filled packagings shall be destructively examined to verify that the foam has completely filled the space between the drum wall and its liner, and the space between the drum lid and its liner. The following methodology for ensuring a complete filling of the drum and lid is approved, however others, such as thermal imaging, ultrasonic evaluation, and radiography, may be utilized if demonstrated to be acceptable and approved by SRNL. These methods specified in a supplier procedure (work instructions, etc.) shall be approved by SRNL.

SRNL approved foam installation method:

- Supplier shall dispense a specified mass of liquid foam during each pour for the drum body and drum lid. Total weight of drum body foam shall meet the requirements specified on drawing R-R2-G-00057; weight of foam in the drum lid shall meet the requirements specified on drawing R-R2-G-00059. Lid and drum body shall be weighed before and after each pour to verify dispensed mass of foam and to verify range of acceptable weights.

- The initial temperature conditions of the drum and ambient temperatures of the room prior to foam installation shall be between 65 and 80ºF.

- The drum shall be inverted and filled as illustrated in Figure F-1. The angle of the drum from vertical for the foam pour shall be 15 ±5 degrees with the drum fill port located at the lowest position of the tilted drum (see Figure F-1). Foam shall be visually observed exiting the drum vent port.

- Nine vent ports, drilled after foaming, shall be used to visually verify the foam fill.

- The drum lid shall be tilted 20 ±5 degrees from horizontal with the fill port located at the highest position on the lid for foaming. Foam shall be visually observed exiting the lid fill port.

- Free-rise pour samples shall be tested per batch to verify the physical properties. All test samples shall be poured from the same batch. Test samples shall be marked with the pour date and a unique pour identification number and controlled during all specified tests.

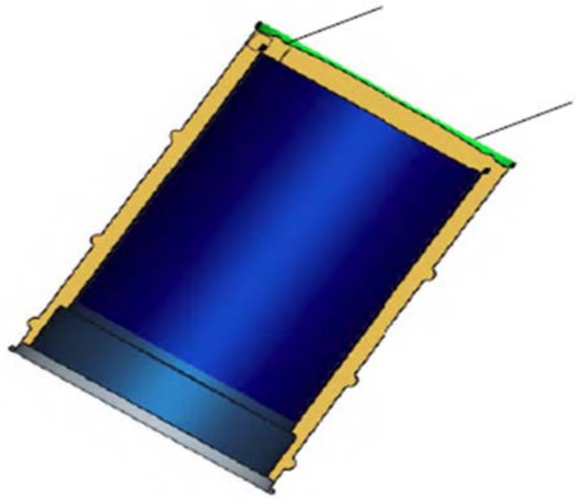


Figure F-1 Foam Installation Schematic

Records of Polyurethane Foam Pour and Test Data

A record of the production pour and testing shall be compiled by the packaging supplier and supplied in accordance with procurement requirements. Documentation for each batch shall include:

- Batch identification, pour procedure, and revision and pour date(s)
- Foam material formulation certification (chemical composition)
- Foam material traceability
- Foaming equipment and mixing nozzle information (model number(s), manufacturer(s), and calibration parameters)
- Physical characteristics (e.g., free-rise properties, mechanical properties and thermal properties)
- Quality Assurance/Quality Control sign-off

PHYSICAL CHARACTERISTICS

The following physical characteristics of the polyurethane foam material are to be measured and documented for each batch from free-rise samples during fabrication of the packaging. If multiple pours are used to fill a packaging, additional batch free-rise testing is not required for each pour. Foam used for a particular packaging shall come entirely from a single batch.

Free-rise sample tests:

- Free-rise density
- Tack-free time
- Gel time
- Crush strength
- Thermal conductivity
- Specific heat