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Development of the HS99 Air Transport Type A Fissile Package

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ABSTRACT
An air-transport Type A Fissile radioactive shipping package for the transport of special form uranium sources has been developed by the Savannah River National Laboratory (SRNL) for the Department of Homeland Security. The Package model number is HS99 for Homeland Security Model 99. This paper presents the major design features of the HS99 and highlights engineered materials necessary for meeting the design requirements for this light-weight Type AF packaging. A discussion is provided demonstrating how the HS99 complies with the regulatory safety requirements of the Nuclear Regulatory Commission. The paper summarizes the results of structural testing to specified in 10 CFR 71 for Normal Conditions of Transport and Hypothetical Accident Conditions events. Planned and proposed future missions for this packaging are also addressed.

INTRODUCTION
The HS99 air-transport packaging was designed by the Savannah River National Laboratory (SRNL) for the Department of Homeland Security (DHS) to comply with the packaging safety requirements of Title 10, Part 71 of the Code of Federal Regulations (10 CFR 71) to receive a Certificate of Compliance for the shipment of Type A Fissile quantities of material.[1] To support the testing required by 10 CFR 71 in the development of the HS99, SRNL fabricated five prototypes packagings were that were subjected to the tests for Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAT). The HS99 package, including contents, is less than 150 lbs. to accommodate the weight limitations for shipment using commercial air–transport.

In the development of the HS99, a series of preliminary destructive tests were conducted at Savannah River Site (SRS) using varies materials to optimize the final packaging configuration and design for the HS99 packaging [2] (Figure 1). The HS99 packaging comprises an inner Carrier Assembly that secures the radioactive content within an insulated 10-gallon Overpack Assembly. The Carrier Assembly provides convenient means of handling the contents. The Overpack Assembly includes a threaded Overpack Plug insulated with TR-19™ Block Insulation that secures the Carrier between two silicone-covered, aluminum foam Spacers. An integral Liner Weldment separates the Carrier from the insulation materials (polyurethane foam, ceramic insulation, composite shell). A Quick Lever Lock Ring is used to secure a standard Drum Cover to the top of the Package.

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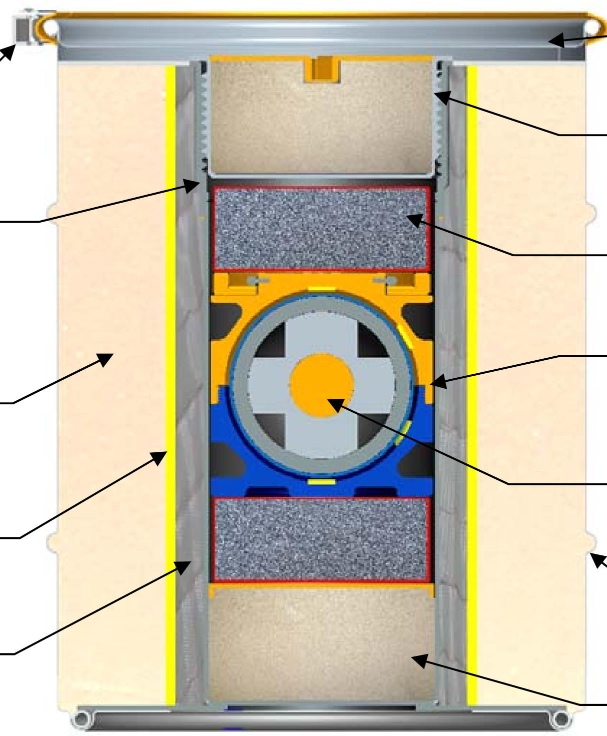


Figure 1 HS99 Packaging Configuration

PACKAGING DESIGN FEATURES AND PERFORMANCE REQUIREMENTS

The HS99 packaging is designed to permit overnight air transport of a 5-inch diameter special form content. The following functional design features and requirements and package performance were evaluated under the required regulatory NCT and HAC tests and by analysis:

Functional Design Features and Requirements

- A removable carrier for the spherical contents.
- A threaded closure plug to secure the contents centered within the packaging cavity.
- Energy-absorbing, aluminum foam packing material to secure the contents.
- A 10-gallon stainless steel drum configuration for durability and configuration that permits stacking.
- A maximum gross weight of less than 140-pounds.
- Standard tools and equipment required for assembly, handling and maintenance.

Performance Requirements

- Normal Conditions of Transport
  - Vibrations 49CFR178.608 / 10 CFR 71.71(c)(5)
  - Water Spray 49CFR173.465(b) / 10CFR 71.71(c)(6)
  - 4-ft Free Drop 49CFR173.465(c)(1) / 10CFR 71.71(c)(7)
  - 1-ft Corner Drop 49CFR173.465(c)(2) / 10CFR 71.71(c)(8)
  - Compression 49CFR173.465(d) / 10CFR 71.71(c)(9)
  - Penetration 49CFR173.465(e) / 10CFR 71.71(c)(10)
- Hypothetical Accident Condition
  - 30-ft drop 10CFR 71.55(f)(1)(i)/71.73(c)(1)
  - Crush, 1100-lb plate 10CFR 71.55(f)(1)(ii)/71.73(c)(2)
  - Puncture 10CFR 71.73(c)(3)
  - (4-ft drop onto 6-in probe; designed for 550-lb bar dropped from 10 feet)
  - Thermal 1,475°F 10CFR 71.73(c)(4)
  - (analyzed for 30-minutes and 60-minute duration)
  - 90 m/s impact 10CFR 71.7x (designed to survive; testing not required)
  - 3-ft Immersion 10CFR 71.73(c)(5)(6) (3-ft and 50-ft Immersion)

PACKAGING DESIGN FEATURES

The HS99 Assembly comprises the Overpack Assembly, the Carrier Assembly and Spacers. Fabrication in accordance with 49 CFR 178.500[3], the American Welding Society (AWS) D1.6[4], and ASME Boiler and Pressure Vessel Code (B&PVC), Section VIII, Division 1[5]. A brief description of the packaging components and materials follows.

Overpack Assembly

The Overpack Assembly utilizes a modified Department of Transportation Specification 20-GA stainless steel (SS) open-head sanitary-style 10-gallon drum with two integral rolling hoops for rigidity. The Overpack is nominally 14-1/16 inches diameter measured to the outside of the wall and 19-1/8 inches high to the top of the lever lock closure ring. The lever lock ring includes a tab to facilitate installation of a tamper indicating device (TID). The Drum Cover incorporates an ethylene propylene diene M-class (EPDM) closure gasket for weather protection. The bottom of the Overpack incorporates a 1/2-inch diameter by 0.083-in wall ASTM A269 SS tube welded to an ASME SA-693 Type 630, 17-4, age hardened SS plate to provide stiffness and puncture resistance to the drum bottom plate drum. A formed foot-ring in the drum bottom facilitates package stacking.

The center Liner Weldment of the Overpack is fabricated from ASME SA-213 TP 304/304L SS seamless tube having a nominal inside diameter (ID) of 6 inches with a 1/8-inch wall section; a ½-inch thick 3-inch long top section is machined with an internal 6.375-4UN 1B thread. An 1/8-inch thick ASME SA-240 304/304L SS Liner Shelf is welded within the bottom section of the Liner to center the Carrier Assembly within the package. A cylindrical block of TR-19™ insulation is secured between the Liner Shelf and a 6-inch OD, 11 gauge (0.119-inch thick) ASME SA-693 Type 630, 17-4, heat treated to H1150. This plate provides puncture resistance to the bottom of the Overpack Liner. The top of the Liner Weldment is a

7-inch ID by 14-inch outside diameter (OD) 11 gauge (0.119-inch thick) disk fabricated from ASME SA-693 Grade 630, 17-4, heat treated to H1150.

The OD of the Liner is covered with a nominally ¾-inch thick ceramic fiber Insulation Cylinder wrapped with alternating layers of resin-infused fiberglass and Kevlar® which forms an approximately 5/16-inch thick Composite Shell for puncture resistance. The cylindrical volume between the Composite Shell and drum wall is filled with polyurethane BETAFOAM™ through a fill-port in the bottom of the drum. The polyurethane foam forms an approximately 2¾-inch thick radial by 14-inch OD rigid cylinder that provides thermal insulation and impact protection.

Overpack Plug

The Overpack Plug is fabricated from ASME SA-479, UNS-S21800, Armco Nitronic-60 SS bar. The plug is machined with a 6.375-4UN 1A thread, with a 7-inch diameter by 1/8 inch thick top flange. The inside of the plug is machined to receive a nominally 5-7/8 inch diameter by 3-inch thick disk of TR-19™ Block Insulation. A 0.12-inch thick plate, ASME SA-693, Type 630, 17-4PH, heat treated to H1150, is welded to the plug top to encapsulate the TR-19™ Block Insulation and to provide puncture resistance. A recessed cylindrical feature is machined in the center of the 17-4 plate to receive a standard ½-inch drive socket to facilitate opening and closing the package.

Carrier Assembly

The Carrier consists of two machined threaded caps (5.25-12 UN 2B/2A) fabricated from ASME SB-221, 6061 Grade T6511 aluminum round bar. When threaded together, the two caps form a 5.15-inch diameter spherical cavity that secures the 5-inch spherical special form source. The Carrier Assembly is hard coat anodized to prevent thread galling and to provide a durable surface. Eight ¾-inch diameter felt pads with adhesive backing are secured to the inside of each Carrier half and provide an approximate 1/16-inch thick cushion between the Carrier Assembly and content. The top half of the Carrier Assembly includes a lifting handle to allow loading and unloading of the Carrier Assembly from the package.

Spacers

An aluminum foam Spacer is placed above and below the Carrier Assembly to center it within the Overpack. The spacers are made from 6101-T6 aluminum open-celled Duocel® foam having a density of 9-12% (relative to the solid aluminum) and nominal crush strength of 330 psi. The spacers are nominally 5¾ inches in diameter by 2¼ inches in height, including a 1/16-inch sheet of commercial-grade silicone rubber bonded to the surfaces of the aluminum foam with a Silicone Rubber Adhesive Sealant (RTV159). The silicone covers rough edges on the aluminum foam surface to provide a smooth, durable handling surface. A lifting bail made from stainless steel braided wire is attached to each Spacer for facilitate assembly into the Overpack.

TESTING SUMMARY AND 10CFR71 COMPLIANCE

The evaluation of the HS99 performance when subjected to the required NCT and HAC tests and analysis demonstrates compliance with 10 CFR Part 71 for transporting the special form content. The orientations for the regulatory tests were chosen to maximum damage to the package prototypes. The results of the NCT tests show that there will be no loss of effectiveness and “no loss or dispersal of (simulated) radioactive contents” of the HS99 packaging since damage was limited to minor scuffing and denting to the exterior of the package. The results of the HAC testing demonstrated that the HS99 Overpack remained intact and that there was no loss of the its solid radioactive material. The thermal analysis showed the integrity of the special form content was not compromised due to the 30-minute thermal event, remaining below the design limit of 660°F. The criticality analysis shows a 5x5x5 array of HS99 packages would remain subcritical with the conservative assumption of the absence of all Overpack materials. For shipment by air, per 10 CFR 71.55(f) and IAEA TS-R-1, for a single package, the radioactive material was shown to remain subcritical assuming total package loss and total loss of source integrity.

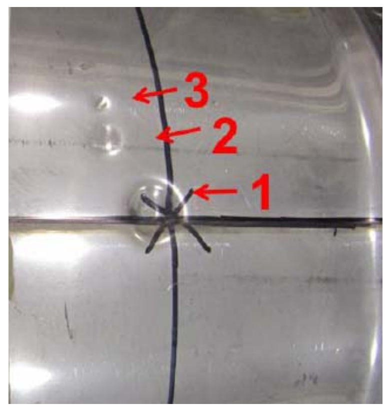
10CFR71 Regulatory testing was performed at the National Transportation Research Center located in Oak Ridge, Tennessee.

Figure 2 shows the NCT water spray and compression tests and typical damage from the 4-foot drop and penetration tests.

Water Spray Test

Damage from 4-ft free drop

Compression Test



Damage from Penetration Test

Figure 2 NCT Testing Configuration and Results

Figure 3 illustrate the HAC horizontal crush configuration along with typical 30-ft drop and crush damage results. Although damage is more significant than after NCT tests, the post-test packaging integrity does not allow loss of content. For the 30-ft drop, the local deformation of the package was greatest for the angled drop orientation (Center-of-Gravity-over-Corner, CGOC) for prototype labeled TU-3. For the crush tests, the greatest damage occurred from the crush plate dropped horizontally. There was surface tearing locally at locations where the stiff 17-4 Plates are welded to the drum wall exposing the polyurethane foam; see picture showing TU1. Figure 3 shows prototype TU5 after it was cut open; it was subjected to a CGOC 30-ft free drop and vertically oriented crush. The dark blemishes on the cut surfaces is from the cutting oil used during the destructive examination. Following the HAC structural testing, the

Overpack Closure Plug in 4 out of the 5 tested packages could be unthreaded. All of the Carrier Assemblies could be opened by hand after being subjected to the testing.

Figure 3 HAC Testing Configuration and Results

ALTERNATE APPLICATIONS

Since the HS99 is a small, light-weight air-transportable package designed for use without special tools, it is an excellent candidate for use in other applications. Two applications for which the HS99 Overpack design is being considered are:

- Type A Liquids Package
- Type B Sample Package

Figure 4 illustrates a proposed Type B configuration using the HS99 Overpack with a shortened version of a Containment Vessel currently used in other SRNL radioactive material shipping packages, the 9975 and the 9978. Since this package would be heavier than the HS99, it would not have to be subjected to the HAC crush tests. The Type A configuration modified for liquids would include a gasket under the Overpack Plug and an inner container that would retain leakage. The configuration would require that the Overpack and inner container not leak as a result of a 30-ft drop.

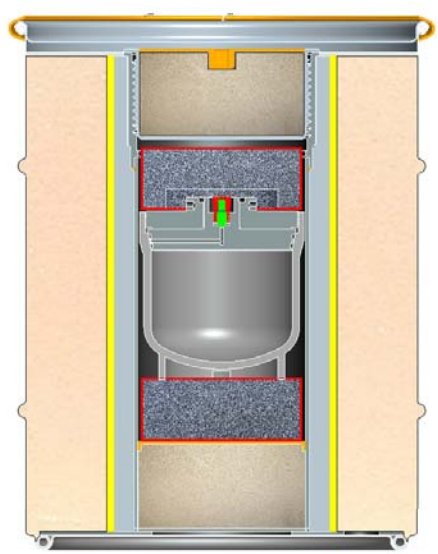


Figure 4 Type B Sample Example

CONCLUSIONS

An air-transport Type A Fissile radioactive shipping package for transporting a special form uranium content has been developed by the Savannah River National Laboratory for the Department of Homeland Security. Design features and engineering materials of construction have been optimized for the performance and functional requirements. Results from testing demonstrate that the HS99 complies with the regulatory safety requirements of the Nuclear Regulatory Commission for an air-transport Type A Fissile radioactive shipping package. The HS99 Overpack is a uniquely candidate for other applications.

REFERENCES

1 Packaging and Transportation of Radioactive Material, Code of Federal Regulations, Title 10, Part 71, Washington, DC (January 2009).

2 Test Report of Developmental Type AF Packaging for Air Transport, M-TRT-A-00022, (July 2011).

3. 49 CFR 178, Subpart L—Non-bulk Performance- Oriented Packaging Standards

4. American Welding Society, AWS D1.6, Structural Welding Code - Stainless Steel

5. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1,, Supports, American Society of Mechanical Engineers, New York, NY (2007).