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Development and Use of a Bulk Tritium Shipping Package

P. S. Blanton
Savannah River National Laboratory
Savannah River Nuclear Solutions
Aiken, South Carolina 29808
(803) 725-3738
paul.blanton@srnl.doe.gov

P. T. Mann
National Nuclear Safety Administration
Albuquerque, New Mexico
pmann@doeal.gov

K. R. Eberl
Savannah River National Laboratory
Savannah River Nuclear Solutions
Aiken, South Carolina 29808
(803) 725-2656
kurt.eberl@srnl.doe.gov

A shipping package for transporting tritium has been developed for use by the National Nuclear Safety Administration as a replacement for the DOE Model UC-609, a tritium package developed and used by the DOE and NRC since the early 1970s. This paper presents the major design features and highlights the improvements made over its predecessor by incorporating new engineered materials and implementing improved testing, handling, and maintenance capabilities, while improving manufacturability. A discussion will be provided demonstrating how the BTSP complies with the regulatory safety requirements of the Nuclear Regulatory Commission. The paper further summarizes the results of testing to 10 CFR 71 Normal Conditions of Transport and Hypothetical Accident Conditions events. Planned and possible future missions for this packaging will be addressed.

I BACKGROUND

Historically, the Department of Energy (DOE) has had the programmatic need to ship bulk quantities of tritium within the United States. Because of changes in the regulatory requirements governing the shipment of radioactive materials, one of the shipping packages previously used for shipment of tritium, the UC-609, is being replaced with a new shipping package. The UC-609 was designed by Lawrence Livermore National Laboratory and certified for use in the 1970's.[1] The replacement tritium package, the Bulk Tritium Shipping Package (BTSP), designed by Savannah River National Laboratory (SRNL), is in the process of being evaluated for certification for use by the National Nuclear Safety Adminstartion (NNSA). Because of the specific changes to the US NRC regulations and new operational requirements BTSP has many unique features and improvements over its predecessor design.

II PACKAGE DESIGN DESCRIPTION

The BTSP consists of two primary assemblies: an outer drum assembly and an inner containment vessel (CV) assembly. The stainless steel drum assembly includes materials that provide thermal insulation and impact protection for the CV assembly; these materials are contained within the drum and lid assemblies by integrally welded stainless steel liners. Other separate components that comprise the BTSP assembly include an aluminum honeycomb composite cylinder, a fiberglass reinforced silicone pad, aluminum foam spacers, and a thermal pad. The BTSP contents are Type B quantity, normal form and is tritium gas and/or tritium present as a solid on hydride materials. The maximum quantity of tritium is 150 grams giving the package a 50 watt capacity. The gross package weight of the BTSP is 650 lbs with a maximum payload capacity of 120 lbs. The BTSP is designed and tested to comply with 10CFR71 NCT and HAC events (including the crush).[2]

The UC-609 is a Type B Package and also consists of two primary assemblies: its outer drum and CV. It's drum assembly also includes materials that provide thermal insulation and impact protection. The maximum quantity of tritium is 100 grams. The gross package weight of the UC-609 is 500 lbs with a maximum payload capacity of 120 lbs. The UC-609 is designed and tested to comply with 10CFR71 NCT and HAC events (excluding the crush). Figure 1 provides a cross-sectional comparison of the two packages.

II.A Drum Assembly

The BTSP Drum Assembly consists of two stainless steel welded structures, a drum body with integral welded

liner and a reinforced lid. Polyurethane foam and TR-19™ block insulation are used in the drum assembly to provide structural and thermal protection to the CV during transport. The engineered foam, General Plastics Last-A-Foam™, is a rigid polyurethane that intumesces when burned. TR-19™ Block Insulation is an engineered high temperature insulation that fills the lid and drum bottom. The drum lid is secured with twelve, 5/8-inch hex bolts to threaded fittings welded beneath the top surface of the drum body. The CV is centered within the liner and rests on a silicone pad and is covered with a thermal insulating pad. The drum assembly is 50.5 inches high and 24½-inches in diameter.

Celotex, a material that is commonly used in the housing construction, provides thermal and structural protection for the UC-609.

II.B Containment Vessel Assembly

The BTSP CV Assembly consists of three components fabricated from 304L SS: the body, lid, and the protective cap and is designed, analyzed, and fabricated as a pressure vessel in accordance with ASME B&PVC, Section III, Subsection NB, with a design condition of 500 psig at 400°F. The assembly weighs approximately 155 pounds and has an internal usable volume of approximately 30-5/8 inches high by 10 inches in diameter with both aluminum internal spacers installed. A C-Ring comprised of an inner Inconel helical spring surrounded by an outer silver-plated Inconel "C" shaped sleeve seals the lid to the CV body. The CV Body includes two full-penetration, complete-fusion, circumferential welds.

The CV Lid is a concave machined head with a concentrically machined flat feature for receiving two fittings, a Bellows Valve and a Quick Disconnect Coupling. The convex bottom of the lid is captured in the CV Body. The machined flat surface has threaded holes to secure the protective cap. The CV protective cap has two design functions; it protects the CV valving from accidental damage and retains leakage to the same level as the CV in the enclosure in accordance with 10CFR71.43(e) in the event of a Bellows Valve failure. Figure 2 illustrates the closure of between the BTSP CV Lid and Body.

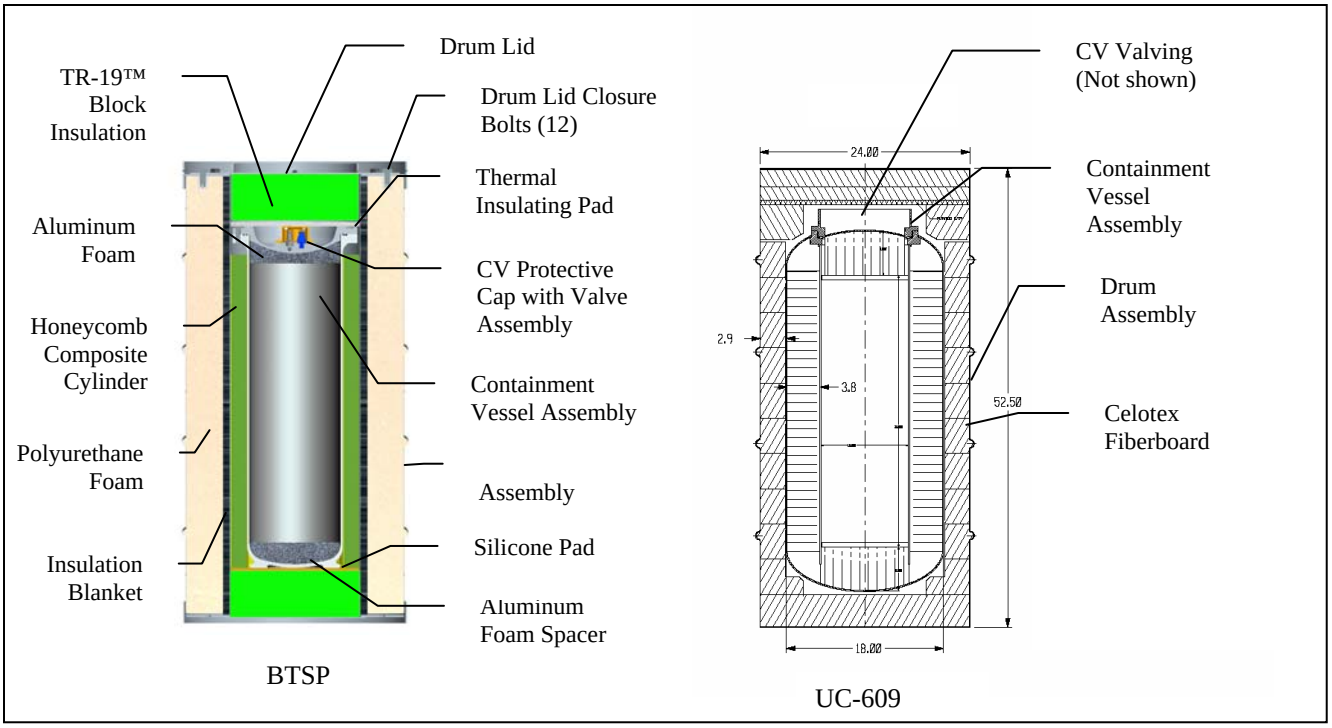

Figure 1. BTSP versus UC-609

The UC-609 includes a CV body, lid and partial valve cover. Valving is protected by a raised rim on top of the CV and the cover but is not credited as a containment boundary. The UC-609 CV assembly is comprised of approximately 18 welds. The CV closure lid is semi-elliptical. A flat copper gasket seals the lid to the CV body. The reduced welding, new valving and the addition of a leak tight valve enclosure are significant manufacturing and leak test improvements for the BTSP.

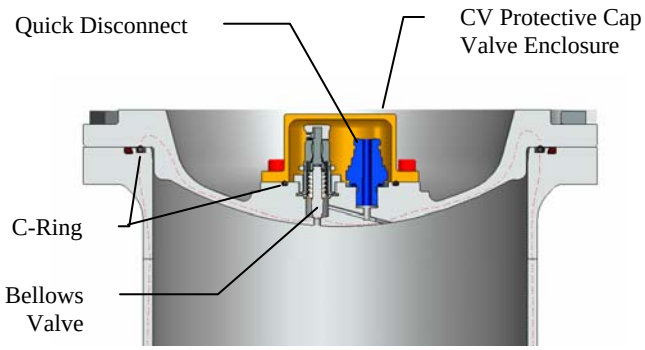

Figure 2. BTSP Containment Vessel Closure

III PACKAGE TESTING

Ten prototype BTSP packagings were fabricated and then regulatory tested under 10CFR71 NCT and HAC conditions according to the guidance described in SG-600.*3* Following testing, the CVs were leakage tested in accordance with ANSI N14.5-1997.*4* All packages were found to be post-test leaktight in accordance with the standard.

III.A CV Closure Testing

In advance of the prototype package tests the design of the containment vessel closure was tested to evaluate the functional performance of the metallic spring-energized C-Rings and its Bellows Valve. Additionally, deuterium permeation Testing was conducted on the C-Ring joint between the CV Lid and CV Body. These test evaluated the spring-energized C-Rings and Bellows Valve to verify their performance during hot and cold conditions and their performance under repetitive use. The C-Ring tests were performed using a Test Flange design that funcitionlly mimics the BTSP lid and flange closure.[5] The Test Flange is shown in Figure 3. The C-Rings are rated for >1,000 °F and > 50,000 psi.

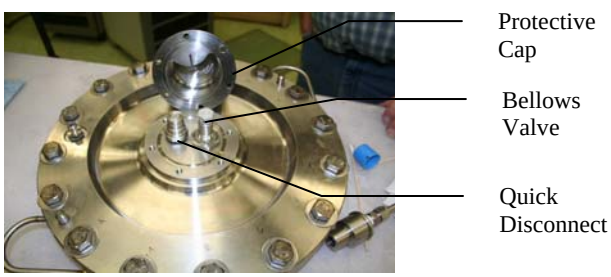

Figure 3. BTSP Test Flange

Additionally, permeation testing was performed on BTSP Prototype PSN-10. These tests were performed to establish the permeation rates through the vessel closure seals. Tests were performed under ambient and elevated temperature conditions.[6] Figure 4 shows the PSN-10 installed on the test permeation manifold. The prototype did not exhibit measurable deuterium permeation.

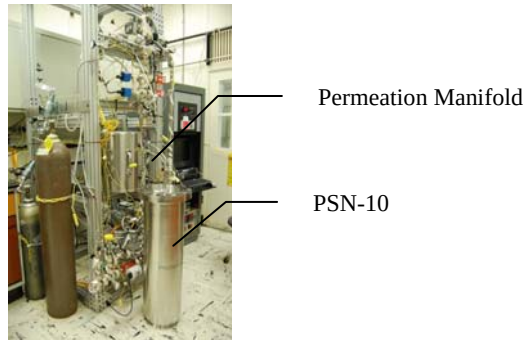

Figure 4. BTSP Deuterium Permeation Test

III.B Regulatory Testing

Regulator NCT and HAC testing was performed on BTSP prototype packages. The testing matrix used is shown in Table 1.

Table 1. BTSP NCT/HAC Regulatory Test Matrix

		Initial Conditions		Normal Conditions of Transport									Hypothetical Accident Conditions of Transport							
Drum Serial Number	CV Serial Number	Package Pressure	Package Temperature (°F) (Note 1)	Heat (Solar, 100°F) 10CFR71.71(c)(1)	Cold (-40°F, no solar) 10CFR71.71(c)(2)	Pressure Variations (External) 10CFR71.71(c)(3&4)	Vibrations 10CFR71.71(c)(5) (See Note 8)	Water Spray 10CFR71.71(c)(6)	4-ft Free Drop 10CFR71.71(c)(7)	Corner Drop 10CFR71.71(c)(8) (See Note 2)	Compression 10CFR71.71(c)(9)	Penetration 10CFR71.71(c)(10)	30-ft Drop 10CFR71.73(c)(1)	Crush 10CFR71.73(c)(2)	Puncture 10CFR71.73(c)(3)	Thermal 10CFR71.73(c)(4) (Note 3)	3-ft Immersion – fissile 10CFR71.73(c)(5) (See Note 4)	50-ft Immersion – all 10CFR71.73(c)(6)	290-psi 10CFR71.61 (See Note 5)	Leak Test ANSI N14.5 (Note 6)
1	1	This BTSP Prototype to be tested at SRNL.																		
2	2	A	75	-	-	-	-	-	-	na	-	-	CGT	H	X	VT	na	-	na	na
3	10	A	75	-	-	-	-	-	-	na	Only CV to be tested.						na	X	na	na
4	4	A	75	-	-	-	X	X	BD	na	-	X	BD	VB	X	VT	na	-	na	na
5	5	A	150	-	-	-	-	-	-	na	-	-	H	H	X	VT	na	-	na	na
6	6	A	-20	-	-	-	-	-	TD	na	-	-	H	H	X	H	na	-	na	na
7	7	A	75	-	-	-	-	-	TD	na	-	-	TD	H	X	H	na	-	na	na
8	8	A	75	-	-	-	-	-	H	na	-	-	SD	H	X	H	na	-	na	na
9	9	A	75	-	-	-	-	X	CGT	na	X	-	CGT	CGB	X	VT	na	-	na	na
10	3	A	75	-	-	-	-	-	-	na	-	-	CGT	H	X	VT	Note: This is the practice package.			

Abbreviations:
X – Applicable to SOW; na or "-" – Not applicable to SOW; A – Ambient
BD – Bottom Down; CGT – CG over Top Corner; VB – Vertical, Bottom Up; VT – Vert., Top Up
H – Horizontal; TD – Top Down; SD – Slap Down/Bottom Impact; CGB – CG over Bottom Corner

Notes:
1. Initial temperature conditions to be ± 5 °F.
2. Corner Drop per 10CFR71.71(c)(8) not applicable. BTSP approx. weight is 600 lbs.
3. Thermal Test per 10CFR71.73(c)(4) not applicable to this SOW; included for reference only.
4. 3-ft Immersion- fissile per 10CFR71.73(c)(5) not applicable. BTSP does not transport fissile material.
5. 290-psi evaluation per 10CFR71.61 not applicable. A_2 in BTSP is less than 1000.
6. Leak Test per ANSI N14.5 not applicable to this SOW; included for reference.
7. Actual orientation of Test Package subject to change
8. NCT Vibration Tests shall be performed using a vibration table in accordance with SG-600, Rev. 2.

NCT and HAC testing resulted in minimal damage to the package. The results of the 30-ft drop, crush and fire of representative packages is illustrated below in Figures 5, 6 and 7.

Figure 5. PSN-02 Following 30-ft Center of Gravity Drop

Figure 6. PSN-02 Following Horizontal Crush

Figure 7. PSN-05 and PSN-07 Post Burn

Planned DOE deinvetory missions could require the package to be authorized for shipment of fissile materials.

IV. CONCLUSIONS

Regulatory tests were performed on BTSP prototype packages. Additional functional testing was performed on the BTSP CV design to validate the use of inconnel spring-energized C-Rings. The results of these tests demonstrate the BTSP satisfies the performance requirements imposed by 10CFR71 for Type B Packages.

ACKNOWLEDGMENTS

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