Proceedings of the 17th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2013
August 18-23, 2013, San Francisco, CA, USA

435-B TRANSPORT PACKAGING TESTING AND EVALUATION

Philip W. Noss
AREVA Federal Services LLC
Federal Way, Washington, USA

ABSTRACT

AREVA Federal Services LLC, under contract to the Los Alamos National Laboratory's Offsite Source Recovery Project, has developed a new Type B(U)-96 package for the transport of unwanted or abandoned radioactive sealed sources. The sources were used primarily in medical or industrial devices. To promote public safety and mitigate the possibility of loss or misuse, the Offsite Source Recovery Project is recovering and managing sources worldwide. The package, denoted the 435-B, is designed to accommodate the sources within internal gamma shields. The sources may be located in the IAEA's Long Term Storage Shield (LTSS), or within the original service shield of an intact device. Since the sources are separately shielded, the package does not include any shielding of its own. To accommodate material not in special form, the package provides leak tight containment.

As a part of licensing activities, certification testing has been performed. A test plan was developed which identified the specific free drop and puncture tests necessary to evaluate all of the unique features of the packaging. These features include the requirement to absorb free drop energy at the top end by deforming the containment boundary, a heavy payload that could damage containment from the inside in an impact, a dual thermal shield that could be ripped open from puncture, and an array of crush tubes at each end whose performance required validation. Testing was performed with the polyurethane impact limiter foam at minimum and maximum temperatures. Finite element analysis was extensively performed to determine the worst case orientations for free drop testing. Particular challenges for the test were the need to open and re-close the test units in between tests, the challenge presented by two very different payload and internal lodgment types, and leakage rate testing with the test volume at a temperature below freezing. This paper reviews the package design and discusses the test planning and results.

INTRODUCTION

Unwanted gamma sources present a risk to the public through loss or misuse. To reduce this risk, the Offsite Source Recovery Program, under the direction of the US National Nuclear Security Administration's Global Threat Reduction Initiative (NA-21) is recovering unwanted, disused, or abandoned radioactive sources so they can be safely stored and finally disposed of. The sources were primarily used in medical devices (i.e., teletherapy heads) or industrial irradiators. The sources may be removed and placed in the IAEA's Long Term Storage Shield (LTSS), or may be left within the original service shield. In order to transport the LTSS or the shielded devices to a more secure storage or disposal site, a Type B package is required.

435-B PACKAGING DESCRIPTION

An exterior view of the packaging is shown in Figure 1, and a cross-section in Figure 2. The packaging consists of a ½-inch [13 mm] thick, vertical cylinder with torispherical ends, which serves as the containment boundary. An internal impact limiter is located inside each torispherical end. These structures consist of an array of thin-walled tubes that absorb some of the free drop energy of the payload. The tube array matches the torispherical shape on one side and is flat on the other side, and is attached to a ½-inch [13 mm] thick aluminum plate, thus creating a cylindrical payload cavity 43.5 inches [1,105 mm] in diameter and approximately 60.3 inches [1,532 mm] long. During transport, the payload rests on the lower internal impact limiter. All structural materials, except as noted, are made from Type 304 stainless steel.

At the lower end of the containment boundary is located a thick, forged steel bolted flange closure. The closure is sealed with a 3/8-inch [10 mm] diameter butyl elastomer in a bore-type configuration, and held closed by 24, 1-1/4 inch [32 mm] diameter alloy steel closure bolts. To protect the closure from hypothetical accident impacts and fire heat, an external impact limiter is permanently attached to the lower flange. The limiter is made using rigid, closed-cell polyurethane foam and a ¼-inch [6 mm] thick outer shell. The top of the limiter is tapered to save weight, shed water, and deflect the hypothetical puncture bar impact. The closure bolts are accessed through tubes located in the impact limiter, which are covered by a rain/fire shield. To limit the temperature of the containment boundary in the hypothetical fire, a double thermal shield is placed on the package side, and a single thermal shield is placed on the upper torispherical head.

To configure the LTSS payload within the packaging, an aluminum weldment lodgment is utilized, as shown in Figure 3. For transport of the intact shielded devices, an inner container, consisting of a stainless steel weldment with a bolted lid is utilized, as shown in Figure 4. The maximum weight of a shielded device is 3,500 lb [1,587 kg], and the maximum weight of the payload and lodgment or inner container is 5,160 lb [2,340 kg]. The maximum gross weight of the 435-B is 10,100 lb [4,580 kg].

The 435-B is to receive certification by the NRC as a Type B(U)-96 using the most stringent requirements applicable from either 10 CFR 71 [1] or TS-R-1 [2]. Since the contents may be in normal form, the containment must be leaktight per ANSI N14.5–1997 [3].

CERTIFICATION TEST PLANNING

Demonstration of the safety of the 435-B packaging was performed via full scale test of three prototype units (CTU). A test plan was developed which identified the specific free drop and puncture tests necessary to evaluate all of the unique features and potential vulnerabilities of the packaging. Extensive computer analysis utilizing LS-Dyna© explicit dynamic finite element software was performed to determine the worst-case free drop orientations. It was determined that the following should be demonstrated by physical testing:

- The ability of the upper internal impact limiter and upper torispherical head to absorb the combined energy of free drop and puncture drop impacts;
- The ability of the internal impact limiters and payload lodgment or inner container to protect the containment shell from damaging interactions with the heavy payload;
- The integrity of the external thermal shields after exposure to the puncture bar impact;
- The ability of the lower external impact limiter to protect the vent port, bolt heads, and thermally important features near the closure flange;

- The leak tight integrity of the containment boundary following the worst-case sequence of free drop and puncture impacts.

Two CTUs used the LTSS payload and one used the inner container payload with a dummy shielded device. To limit the effects of damage accumulation, no more than two test series were applied to any of the CTUs. Each test series consisted of one, Normal Conditions of Transport (NCT) 1.2 m free drop, one, Hypothetical Accident Conditions (HAC) 9 m free drop, and one, 1 m puncture drop. The leaktight integrity of the CTUs were confirmed after each series was complete and prior to opening the CTU. To obtain the maximum free drop impact magnitude, most testing was performed at minimum temperatures. One test was performed at warm temperatures to obtain the maximum deformation of the polyurethane foam.

Since the computer model was to be benchmarked using data from the test, it was necessary to inspect the interior before any damage accumulation from different free drop tests could occur. To avoid loss of important information regarding damage and deformation of the internal components, the package was opened after each test sequence. This could be expected to present some difficulties due to the fact that the external impact limiter is permanently attached to the lower flange, and the closure bolts are only accessible at the bottom of relatively long, narrow tubes. Damage to the access tubes could render the bolts inaccessible. Thus, the sequence of tests was carefully planned in such a way that access to the bolt heads was preserved, as much as possible, through the first test of the two-test sequence. This planning paid off in the ability to successfully open and re-close the test units between tests, despite some challenges presented by the damage deformations. A lesson learned regarding helium leakage rate testing of very cold test articles was that even in a semi-arid climate, the moisture in the air will form frost on the test volume surfaces. It took a very long time to lower the pressure in the test volume to the required test level by subliming the frost. Leakage rate testing should occur with the test volume above freezing, if possible.

A total of six, NCT free drops, six, HAC free drops, and seven puncture drops were performed on the three CTUs. Each NCT and HAC free drop was instrumented with redundant active accelerometers. The test results consisted of impact magnitude, residual closure bolt torque, deformation measurements, and a leakage rate. The testing was performed in Richland, Washington, during December, 2011.

CERTIFICATION TEST RESULTS

Due to the fact that the packaging has only one external impact limiter, most impact orientations include some deformation of the upper torispherical head, which is part of the containment boundary. The most challenging of these impacts is in the center-of-gravity (CG) over top knuckle orientation, in which all of the drop energy must be absorbed over only a portion of the upper head. In addition, a puncture impact must also be sustained in the same area. The combined deformations of the free drops (NCT and HAC) and the puncture drop are shown in Figure 5. A helium leakage rate test on the containment boundary using the leaktight criteria of ANSI N14.5–1997 [3] confirmed that the 435-B containment boundary is able to sustain the worst-case strain and remain leak tight.

Both payload types (LTSS and shielded devices) are heavy lead and steel objects, which, if uncontrolled in an impact, could compromise the containment boundary from the inside. The most challenging orientation was the side drop with cold foam, which applied the greatest forces on the payload in the lateral direction against the containment boundary sides. In both cases, the payload was prevented from inflicting any damage to the containment boundary. The lodgment of the LTSS and the inner container used with the shielded device were each able to protect both the containment boundary of the packaging as well as the shielding integrity of the payload.

Since the 0.1-inch [2.5 mm] thick thermal shields are important in controlling the temperature of the containment boundary and containment elastomer seals in the hypothetical fire, they must remain intact following an attack by the puncture bar. To demonstrate this, an oblique puncture impact was applied to the center of the side wall, through the CG. The results are shown in Figure 6. There was no failure or incipient tearing of the thermal shield. This test also gave confirmation that the containment boundary wall could remain intact under the worst-case oblique puncture impact.

The external impact limiter is designed to protect the sealing area from puncture impact deformation that could affect the integrity of the leak tight containment seal, as well as protect the main flange containment seal and the vent port elastomer seal from excessive fire heat. To demonstrate this, a puncture impact was applied to the upper part of the slanted top surface of the impact limiter. Beside the stated objectives, an additional purpose was to demonstrate the integrity of the rain/fire shield which covers the top of the closure bolt access tubes, and which blocks radiative heat transfer from the fire to the bolt heads and vent port plug. The result is shown in Figure 7. The puncture bar was effectively stopped by edge impact on the ¼-inch [6 mm] thick plate that forms a tube sheet for the bolt access tubes. The rain/fire shield, not shown in the photo, was not significantly deformed.

As stated above, a helium leakage rate test was performed on the containment boundary penetrations (closure and vent port O-ring seals) after each test, before disturbing the seals in any way. After all tests were complete, the entire containment boundary was also subjected to a helium leakage rate test. In each case, the 435-B packaging was leaktight per ANSI N14.5–1997 [3], thus demonstrating the ability of the package to meet the requirements of 10 CFR 71[1] and TS-R-1 [2].

CONCLUSIONS

A leak tight containment packaging, the 435-B, has been developed for the transport of radioactive sources located in a storage shield or in their original service shield. A certification test program has been completed in which the packaging has been subjected to the worst-case series of free drop and puncture drop events. The test plan considered the structural and thermal consequences of the normal conditions and hypothetical accident conditions of transport to the containment and shielding functions of the packaging and payloads. The testing was successfully completed and demonstrated the ability of the packaging to meet all of the requirements of the applicable regulations.

ACKNOWLEDGMENTS

This work was funded through NNSA's Office of Global Threat Reduction (NA-21). Los Alamos National Laboratory is operated by the Los Alamos National Security, LLC for NNSA under contract DE-AC52-06NA25396.

REFERENCES

1. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material*.
2. TS-R-1, *Regulations for the Safe Transport of Radioactive Material*, International Atomic Energy Agency, (IAEA).
3. ANSI N14.5–1997, *American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment*, American National Standards Institute (ANSI), Inc.

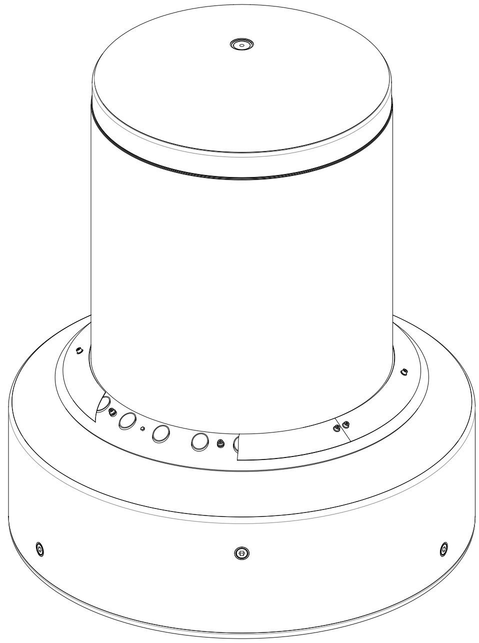


Figure 1. 435-B Packaging, External View

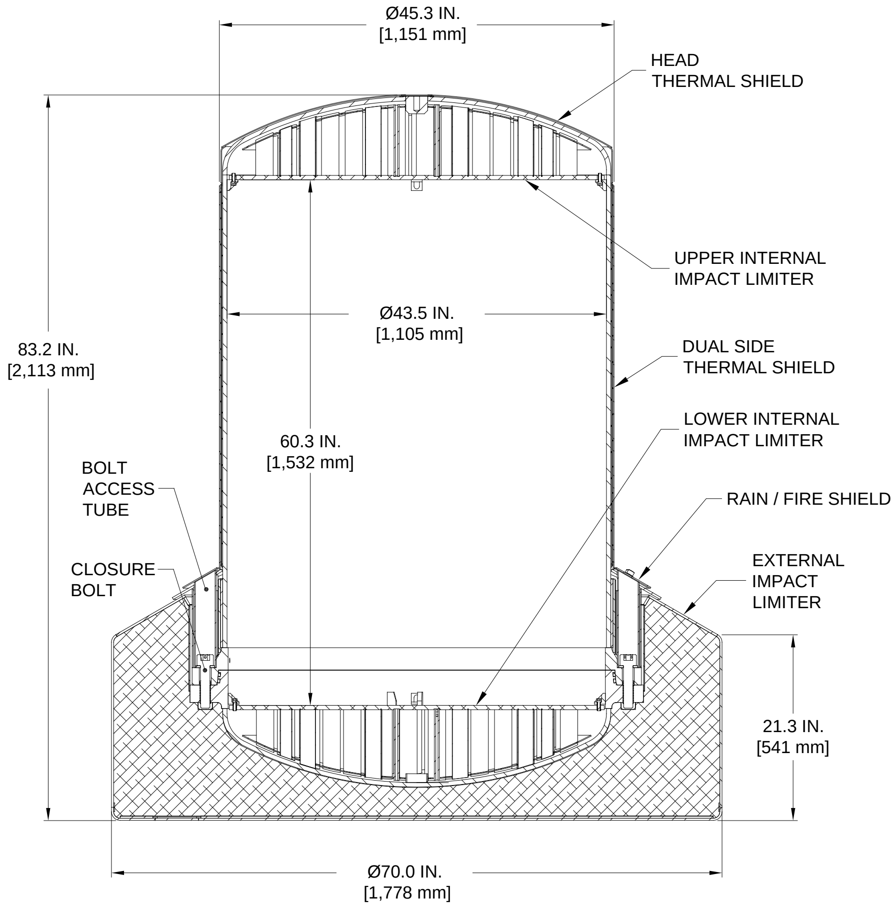
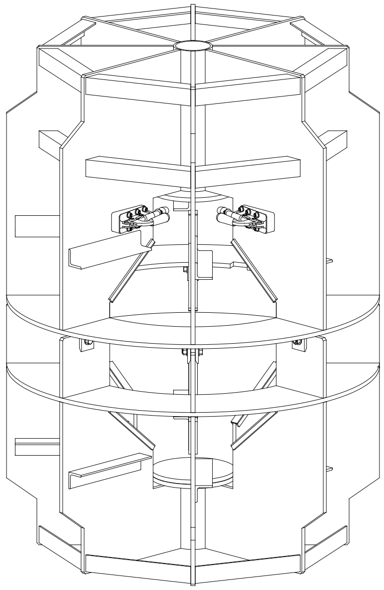


Figure 2. 435-B Packaging, Section View



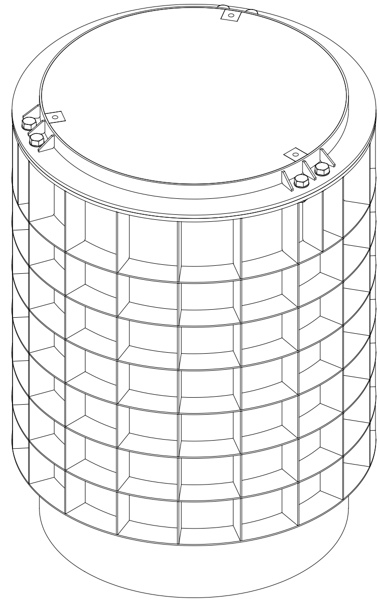


Figure 3. LTSS Lodgment

Figure 4. Shielded Device Inner Container

Figure 5. CG-over-Knuckle Free Drop and Puncture Damage

Figure 6. Puncture Damage to Thermal Shield

Figure 7. Puncture Damage to Bolt Tube Region