

Recent Package Testing Successes at Oak Ridge National Laboratory

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ABSTRACT

Oak Ridge National Laboratory (ORNL)'s history of testing of radioactive material packages dates back to the early 1960s, and includes the testing of hundreds of different packages of all shapes and sizes. This paper provides an overview of ORNL's new Packaging Research Facility (PRF) at the National Transportation Research Center (NTRC), and describes recent package testing successes conducted at the NTRC from September 2002 to September 2003.

1. PACKAGING RESEARCH FACILITY AT THE NTRC

The NTRC PRF builds upon the extensive package design, evaluation, and testing activities undertaken by ORNL since the early 1960s. Previously, ORNL package test facilities primarily centered around two drop pads located at ORNL: a small drop pad facility located on the main ORNL site and a much larger drop pad built at the ORNL Tower Shielding Facility (TSF). The TSF was capable of dropping casks up to 100 ton (90.7 MT) from a height of 9 m (30 ft). The TSF drop facility was used for a variety of drop tests from 1975–1984. Most package tests since that time have been conducted on either small drum-type packages [<300 kg (<660 lb)] or on scale models of full-sized casks [$<3,000$ kg ($<6,600$ lb)], not requiring the capacity of the TSF. Due in part from the lack of use over the past twenty years, the TSF is slated for decommissioning.

The PRF provides the capability to conduct a wide variety of performance tests and is capable of supporting the testing and post-test evaluations required for a variety of package designs, including Type A and Type B packages.



Figure 1. The ORNL National Transportation Research Center, near Oak Ridge, Tennessee

Package test capabilities at the PRF include two drop pads: a small 4- x 6-ft drop pad located inside the PRF with a capacity over 1,430 kg (over 3,150 lb) and serviced by a 5 ton overhead bridge crane and a much larger 8- x 20-ft drop pad located immediately outside the PRF serviced by a 100-ton (90.7-MT) capacity portable crane. This larger drop pad has a capacity of 12,727 kg (28,000 lb) for free drops from heights up to 9 m (30 ft). The design and certification of the NTRC drop pads is documented in a recent ORNL report [1].

The PRF is a 225-m² (2,400-ft²) facility that enables efficient preparation of package test units for tests. In addition to performing typical drop tests, the PRF also supports a wide variety of package testing capabilities. Equipment includes a Lansmont Model 10000-10 Touch-Test Vibration system [2,720-kg (6,000-lb) capacity], a Lansmont Model 152-30K Compression Test system [13,636-kg (30,000-lb) capacity], and a Lansmont Precision Drop Tester (PDT-15) for small packages. The PRF also has a variety of tools and portable equipment that support conducting a full range of pre- and post-test measurements of package test specimens, including leak tests using both pressure drop (1×10^{-5} sensitivity) and helium (1×10^{-8} sensitivity) methods. The NTRC package testing program benefits from easy access to other ORNL capabilities that provide high-speed videography (up to 2000 fps), radiography services, and dynamic data acquisition for measurement of package mechanical loads due to impact.

While the PRF does not have the on-site capability to perform Type B thermal (fire) tests, it does have a thermal monitoring data acquisition computer system capable of 72 channels of input from Type K thermocouples to monitor test units during thermal tests. Thermal tests are conducted using heat-treating furnaces at some of the larger steel mills in the eastern U.S., and the NTRC has utilized this approach for thermal tests of four different packages since that time. The PRF is also supported by a Computer Laboratory that provides a full range of modern computer workstations for data acquisition and storage as well as the ability to perform shielding, criticality, and thermal analysis of package designs. Each package test typically generates hundreds of megabytes of data, mostly as digital images and video segments of each phase of each test sequence. All these resources are brought together to provide customers with high-quality test documentation to support preparation of Safety Analysis Reports (SARs) that facilitate applications to competent authorities for package design certifications. Package testing activities at PRF are conducted in compliance with customer-specified requirements and are performed under the QA Plan and procedures of the Package Testing Program [2].

2. PACKAGE TESTING SUCCESS STORIES

Building on over 40 years of package testing experience on hundreds of packages, ORNL continues its successful package testing into the 21st century. The remainder of this paper describes various aspects of tests conducted at the new PRF during the period from September 2002 through September 2003. Table 1 provides a summary of those package tests.

Table 1. Summary of Recent Package Tests Conducted by ORNL at the NTRC

Package	Test units	Tests conducted	Purpose of tests
Rackable Can Storage Box	2	28 ft drop test - c.g. ¹ over corner drop - slap down drop	Confirm design integrity from maximum credible storage drop height.
ES-2100 Package	4	Full NCT ² and HAC ³ tests	Tests to confirm package design meets new dynamic crush test requirements.
DT-20 Package	1	NCT and HAC drop tests	Confirm containment vessel integrity to specific payload configuration.
DPP-2 Package	7	Full NCT and HAC tests	Tests to support certification of this new package design.
BRM Shielded Over Pack	1	Full NCT tests	Confirm containment is maintained under Type A package test conditions.
Fernald Silo IP-2 Waste Package	5 provided; 3 tested	Drop tests per IP-2 - side, top down drops - c.g. over corner drop	Confirm containment integrity of waste package intended for disposal of wastes from the Fernald Silo 1 and 2.
RAJ-II BWR Fresh Fuel Package	2	HAC drop/puncture tests - slap down drops - end drop	Tests to support U.S. certification of this package design.

All package tests are conducted according to the specific requirements of each customer – and the extent of the testing activities and test documentation is tailored to the customer's needs. In some cases, a customer may

¹ c.g. = center of gravity

² NCT = Normal Conditions of Transport

³ HAC = Hypothetical Accident Conditions

require a very detailed test plan and test report that documents every aspect of the test, including very detailed measurements, photographic and video graphic evidence of the damage resulting from each test, and confirmation of the containment boundary integrity. In other cases, a customer may only require that ORNL provide physical testing services, with the customer taking responsibility for all other aspects of the test, including all post-test measurements.

2.1 Rackable Can Storage Box (RCSB)

The Rackable Can Storage Box (RCSB), shown in Figure 1, while not a transport package, was the first drop test of a package-like object at the PRF. Two RCSB units were tested in August 2002 for the Y-12 National Security Complex at near Type B drop heights [8.5 m (28 ft)] in two different orientations – a c.g. over corner orientation and a low angle slap down in top-down orientation. The RCSB may be described roughly as a rectangular stainless steel box containing six cylindrical loading positions that are covered by a single rectangular lid that is bolted to the box. The underside of the box is affixed with forklift slots to facilitate movement and stacking. The RCSB box cavity is filled with a heavy borated material that serves as a neutron poison, ensuring subcriticality of the contents. The package contents were simulated with 50 lb. canisters of tungsten carbide grit. ORNL's job was to test the integrity of the design from an accidental drop within the facility and to provide very detailed measurements of package deformations to support subsequent safety analyses.



Figure 1. Testing of the RCSB at the PRF (August 2002)

2.2 ES-2100 Package

The ES-2100 is one of Y-12's new generation of drum-type Type B package designs for shipment of high enriched uranium metals and oxides. The ES-2100 (shown in Figure 2) is a 208-l (55-gal), stainless steel drum that is 57 cm (22-1/2 in) in diameter and 88.3 cm (34-3/4 in) tall fabricated from 16-gauge, 304 stainless steel. The package has an integral annular liner and the space between the liner and outer shell is filled with Kaolite 1600™, a mixture of cement and vermiculite, cast in place. A stainless steel structural member that attaches the annular liner shell to the drum forms the base for 18 threaded studs that are used to secure the drum lid in place. Inside the annular liner is placed a polyurethane insert that provides cushioning for the containment vessel.

Four test units were subjected to the full range of NCT and HAC tests. Drop tests were conducted in December 2002 and included drop and crush tests in side and c.g.-over-corner orientations. In April 2003, the damaged test units were subjected to thermal testing at a commercial steel mill in Chattanooga, Tennessee. Temperature measurements were taken of each test unit during all phases of preheating [over 48 hours at >38°C (100°F)], during each test, and during the natural cooling down period. Following the tests, the test units were returned to PRF for disassembly, leak testing of the containment vessels, and careful documentation of all package damage. The ES-2100 tests were fully documented in a comprehensive test report [3] that was delivered to the customer along with a full set of photographic, radiographic, and video results to support SAR preparation.



Figure 2. Crush Test of ES-2100 at NTRC (December 2002)

2.3 DT-20 Package

The DT-20 is one of the older generations of Y-12 package designs, and was being tested to confirm performance of the containment vessel for specific contents configuration. The DT-20 is roughly a 416-l (110-gal) stainless steel drum containing a large containment vessel for shipping components of the U.S. National Nuclear Security Administration. ORNL prepared a mockup of the contents to simulate specific mass and center of gravity specifications. A single test unit was then subjected to an NCT 1-m drop test, a 9-m HAC drop test, and 1-m puncture test onto a 15-cm steel punch (shown in Figure 3). Following the tests, the package was disassembled and the results were documented [4].



Figure 3. Puncture Test Preparation of the DT-20 Inside the PRF

2.4 DPP-2 Package

ORNL completed full NCT and HAC tests on seven DPP-2 test units in July 2003. The DPP-2 is a new package design under development by Y-12 for certain national defense contents. One undamaged test unit also underwent a fully instrumented thermal test to confirm design assumptions concerning the performance of the Kaolite insulation/impact resistant material. Figure 4 shows a DPP-2 package during thermal testing in a heat-treating furnace. Following all tests, the packages were disassembled, leak tested, and all measurement results were fully documented in an extensive test report to support SAR preparation [5].

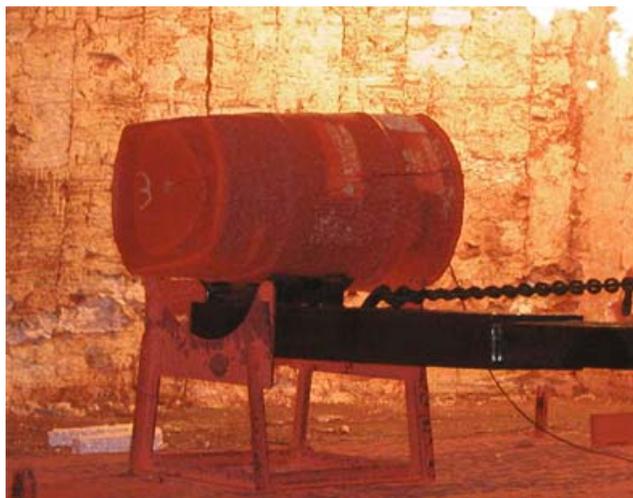


Figure 4. Thermal (Furnace) Test of the Type B Package

2.5 BRM Shielded Over Pack

The BRM Shielded Over Pack System [6] is a simple Type A package design, utilizing an 416-l (110-gal) outer drum and an 321-l (85-gal) inner drum with a sandwich of 10-cm (4-in) lead to provide a shielding of the contents. The inner container is a standard 208-l (55-gal) drum used for a variety of Type A waste materials. In August 2003, ORNL subjected the test unit to the entire series of Type A package tests – vibration, water spray, stacking, penetration, and free drop – specified in the U.S. DOT regulations. The test unit weighed about 2045-kg (4,500-lb) including simulated contents (sand). A mixture of flour and fluorescein dye was used to facilitate detection of leaks from the tests. Test results were provided to the customer in a fairly simple test report [6].



Figure 5. Compression Test of the BRM Shielded Over Pack

2.6 Fernald Silo IP-2 Waste Package

Three Fernald Silo IP-2 Waste Package test units [7] were subjected to IP-2 drop tests 0.9 m (3 ft) at the NTRC in September 2003. The package weighs over 10,000-kg (22,000-lb) and was being developed for disposal of waste sludge that would be mixed in a cement grout for permanent disposal. Due to the weight of the package, ORNL developed a special rigging configuration, shown in Figure 6, to provide protection to the mobile crane from rebound forces following release of the package. Drops were actuated using explosive cable cutters instead of using a solenoid-activated electric release mechanism that is typical of smaller package tests.



Figure 6. Corner Drop of the Fernald Silo IP-2 Waste Package at NTRC

2.7 RAJ-II BWR Fresh Fuel Package

Two RAJ-II BWR fresh fuel packages were subjected to HAC drop and puncture tests at the NTRC in September 2003. One test unit was subjected to a low-angle slap-down orientation with the lid down, followed by a 0.9 m puncture drop onto a 15 cm (6 in) steel punch, at the same initial orientation. The second test unit, shown post-test in Figure 7, was subjected to a 9-m drop in the end-on orientation. This 4.2-m (14-ft) long package, weighing over 2,045-kg (4,500-lb) and after dropping from 30 ft onto the drop pad, remained upright. This left the staff with a new problem – finding a ladder tall enough to re-rig the package so that it could be lowered to the ground safely. This last image is dedicated to long-time ORNL staff member Larry Shappert – after conducting hundreds of drop tests at ORNL since about 1960, Larry managed to stick the landing – a perfect drop. A fitting tribute to an exceptional career – this test ended up being his last as ORNL Test Director before retiring at the end of 2003.

Unlike other tests, the RAJ-II test units were provided “ready-to-go” by the customer, and following the drops the customer removed the units to conduct their own post-test examination. In this regard, ORNL only provided the physical testing services for the customer, and the customer utilized the PRF as a DOE User Facility.



Figure 7. 9-m Drop Test of the RAJ-II BWR Fresh Fuel Package (Perfect Drop)

3. SUMMARY AND CONCLUSIONS

Between 2002 and 2003, ORNL conducted a variety of tests on seven different packages at its new Packaging Research Facility (PRF) at the recently established National Transportation Research Center near Oak Ridge, Tennessee. The following packages were tested: (a) the Rackable Can Storage Box (RCSB); (b) the ES-2100; (c) the DT-20; (d) the DPP-2; (e) the BRM shielded over pack; (f) the Fernald Silo IP-2 Waste Package; and (g) the RAJ II BWR Fresh Fuel Package.

The PRF is a purpose-built testing facility and has successfully taken on all ORNL Package Testing Program activities. In addition to previous capabilities, the PRF now has all weather (indoor) facilities to conduct Type A tests as well as supporting equipment and capabilities to perform a full range of pre- and post-test package

activities. The PRF capabilities include equipment for vibration, compression, leak detection, pre- and post-test measurement, and computer support for data management.

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