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Additional Ballistic Testing of Radioactive Material Shipping Packages

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ABSTRACT

For a number of years Savannah River National Laboratory (SRNL) has been performing ballistics tests on a variety of radioactive material shipping packages. During that time, results of the testing has been used to validate the ability for the shipping packages to be used within storage areas and included within the areas' documented safety analysis. The results have been quite similar for the different package types; however, there have also been differences in the damage caused to the packages using the same testing methods. This paper will discuss the similarities and the differences that the packages experienced as well as recommendations for future designs to be capable to withstand the testing.

BACKGROUND

The K-Area Complex (KAC) at the Savannah River Site (SRS) receives and stores nuclear materials inside of Type B shipping Packages. The shipping packages serve a safety function, as they would prevent the release of nuclear material during normal and hypothetical accident conditions within the facility. Since all accidents must be considered and then either tested or analyzed, ballistics testing on these shipping packages has been performed to validate the ability of the shipping package to withstand such an event. To date, three Type B shipping packages have undergone ballistics testing; the 9975, the 9977, and the ES-3100.

BALLISTIC TESTING FACILITY

The ballistics testing has been performed at various locations, with the most recent tests being performed at the Advanced Tactical Training Area (ATTA) at SRS. The ATTA range provides a safe testing environment and provisions have been made at the range to allow for remote firing of the weapon used in the test.

TESTING RESULTS AND COMPARISONS

The three packages that have been tested were subjected to criteria which were compliant with facility requirements. The criterion that allows for passing the test is that the innermost vessel, a DOE-STD-3013 container, must not withstand any damage that permits the material contained within the 3013 to have a viable leak path outside of the package. Each package tested to the facility requirements has passed this test, as discussed below.

9975

The 9975 was the first package tested for inclusion into the Documented Safety Analysis (DSA) for the K-Area Complex. The results, documented in S-TRT-K-00001, Revision 7, demonstrated that the 9975 can withstand the impact of the round fired from an M-4 rifle. As stated in the above document,

> "*[t]he first round impacted at the top half of the container. The round penetrated the outer skin of the container but did not penetrate the Primary Containment Vessel. No physical damage was observed on the wall of the Primary Containment Vessel.*
>
> *The second round impacted at the lower half of the container. The Results[sic] were the same as observed from the first round fired*."

After the two shots reported above, a third shot was taken into the 9975 with the same result of the round not penetrating through the Primary Containment Vessel. Based upon this test the 9975 was included in the K-Area Complex DSA as an approved storage package.

9977

The 9977 was the second package tested for inclusion into the KAC DSA. The 9977 was subjected to similar testing as the 9975. Again, multiple shots from an M-4 were fired into the 9977 which survived the impacts, as documented in S-TSM-G-00003, Revision 0. S-TSM-G-00003 states that,

> "*There were four shots taken into the 9977 with a standard M4 Rifle...Two shots were made into the package at a location attempting to penetrate the middle of the upper 3013 within the package and two shots were made into the package at a location attempting to penetrate the lower 3013.*"
>
> "*The drum lid subassembly was removed, the top load distribution fixture was removed, the CV was opened, and both of the 3013 containers were removed. Neither of the two 3013 containers had any damage caused by the impact of the four rounds being shot into the package.*"
>
> "*The two 3013 containers were leak-tested to determine if they had sustained any damage. The leak tests were successful as both were leaktight per ANSI N14.5.*"

The 9977 was included in the KAC DSA as an approved storage package.

ES-3100

The ES-3100 was the latest shipping package to be tested. The testing followed a similar testing regimen. An M-4 rifle was used to fire multiple shots into the ES-3100. The results of the ES-3100 testing were documented in a report, S-TSM-G-00006, Revision 0. As stated in S-TSM-G-00006,

> "*There were five shots taken into the ES-3100 with an M4 rifle…*"

Due to issues with the gun mount which caused point-of-impact errors, more shots than the two originally planned were taken at the ES-3100. Damage caused by the additional shots required the CV to be destroyed in order to retrieve the 3013 containers for leak testing and, as stated in the test report,

> *"…the CV was cut in order to remove the 3013 containers."*

Once the 3013 containers were removed, they were tested to ensure leak-tightness. The report states,

> *"The two 3013 containers were tested for leak-tightness and both were verified to be leaktight per ANSI N14.5."*

The ES-3100 must undergo one additional test in order to be accepted into the KAC DSA. This testing is expected to be completed in the summer of 2014.

As noted in each of the reports documenting the results of the ballistic testing, the Type-B shipping packages all passed the facility testing requirements for ballistics tests that are necessary for inclusion into the KAC DSA.

MAJOR DIFFERENCES

While all three of these packages use drum style overpacks protecting their cylindrical containment vessel(s), there are significant differences in their designs. Below are brief descriptions of each of the three packages.

9975

The following description is derived from the 9975 Certificate of Compliance found on the RAMPAC website (www.rampac.energy.gov/docs/certificates/1029975-96.PDF).

The components of the packaging include the drum, insulation, bearing plates, primary containment vessel (PCV), secondary containment vessel (SCV), lead shielding, and aluminum honeycomb spacers. The nominal net weight of the packaging ranges from 350-374 lb. The drum is fabricated as a 35-gallon bolted lid drum of 18-gauge Type 304L stainless steel. The insulation material that surrounds the containment vessels is fiberboard/Celotex®. The fiberboard is regular grade wall sheathing material with a nominal density of 15 lb/ft3 and comes in ½-inch thick sheets that are bonded together into top and bottom subassemblies with a water-based carpenter's glue. Placed over and glued to the top fiberboard/Celotex® subassembly is an air shield made of stainless steel. The radiation shielding configuration is a lead cylinder assembly that surrounds the PCV/SCV double containment assembly. The shielding assembly consists of an approximately 7¼-inch ID x 20-gauge 304L stainless steel cylinder with a 20-gauge bottom, surrounded by lead that is nominally ½ inch thick. An aluminum lid, ½ inch thick, completes the assembly.
The PCV is fabricated from 5-inch, Schedule 40, seamless, Type 304L stainless steel pipe (0.258-inch nominal wall) and has a standard Schedule 40, Type 304L stainless steel pipe cap (0.258-inch nominal wall) at the blind end.
The SCV is fabricated from 6-inch, Schedule 40, seamless, Type 304L stainless steel pipe (0.280-in nominal wall) and has a standard Schedule 40, Type 304L stainless steel pipe cap (0.280-inch nominal wall) at the blind end.

9977

The following Description is derived from the 9977 Certificate of Compliance found on the RAMPAC website (http://rampac.energy.gov/docs/certificates/1029977.PDF).

The components of the package include the drum, insulation, Containment Vessel (CV), Load Distribution Fixtures (LDFs) and Contents containers. The maximum weight of the packaging is 250 lbs, with a maximum payload of 100 lbs, and a maximum gross weight of 350 lbs. The drum body is a closed unit consisting of a shell, top deck plate, reinforcing rim (vertical flange), and a liner assembly, with the volume between the liner assembly and drum shell filled with shock-absorbing thermal insulating materials. The drum shell and liner are fabricated of 18-gage (0.048-inch) Type 304L stainless steel (SS). The drum's top deck plate is fabricated of 3/16-inch thick Type 304L SS plate. The top portion of the drum incorporates a 3/16-inch thick reinforcing rim (vertical flange) and both reinforces the drum head and protects both the closure lid and the bolts during Hypothetical Accident Condition (HAC) events. The drum closure lid is fabricated from ⅛-inch thick Type 304L SS plate. Eight ⅝-inch by 1¼-inch long heavy hex-head bolts with ⅝-inch plain, narrow Type B washers secure the lid to the top deck plate of the drum body. To simplify drum-closure operations, the threaded inserts that receive the drum closure bolts are welded to the underside of the drum's top deck plate. Two layers of insulation material fill the volume between the drum liner and shell. First, two ½-inch thick blankets of Fiberfrax® insulation are wrapped around and attached to the sides and bottom of the liner. The remaining volume between the Fiberfrax® and the drum wall is filled with General Plastics FR-3716 polyurethane foam (also known as Last-A-Foam®). The nominal densities of Fiberfrax® and FR-3716 foam are 7-to-10 lb/ft3 and 16 lb/ft3, respectively. The combined thickness of the two insulators is approximately 4.95 inches radially (i.e., between the liner and the drum shell) and approximately 4.52 inches axially (i.e., between the liner bottom and drum bottom).

The 9977 is designed with a CV with a nominal ID of six (6) inches (i.e., the 6CV). The 6CV is fabricated from 6-inch, Schedule 40, seamless, Type 304L SS pipe (0.280-inch nominal wall). A standard Schedule 40 Type 304L SS pipe cap (also 0.280-inch nominal wall) is welded to the pipe segment to form a blind end.

The Top and Bottom LDFs are made from 6061-T6 aluminum round bar and fit within the Drum Liner cavity, above and below the 6CV. The LDFs center the 6CV in the liner, stiffen the package in the radial direction, and distribute loads away from the 6CV. The 9977 is evaluated for a content consisting of 3013 stabilized plutonium and uranium oxides shipped in a Dual 3013 configuration. A Heat Dissipation Sleeve (HDS) made of 6061-T6 aluminum, surrounds the outside of the 6CV within the Drum Line cavity, and it is located between the Top and Bottom Load Distribution Fixtures.

ES-3100

The following Description is derived from the ES-3100 Certificate of Compliance found on the RAMPAC website (http://rampac.energy.gov/docs/certificates/1029315.PDF)

The ES-3100 packaging is a cylindrical container that is approximately 43.5 inches in overall height, including the cover and lid and approximately 19 inches in overall diameter. The packaging is composed of an outer drum assembly and an inner containment vessel (CV). The outer drum assembly consists of (a) a reinforced stainless steel, standard military specification 30 gallon drum with an increased length; (b) a cylindrical layer of castable refractory material (Kaolite 1600™), which is comprised of concrete and vermiculite, and which acts as both an impact-absorbing and thermal-insulating material; (c) a cylindrical layer of castable refractory (277-4 special dry mix) for neutron attenuation; (d) an inner steel liner; and (e) a removable top plug that also has a layer of the castable refractory material (Kaolite 1600™) for impact absorption and thermal insulation. The 30-gallon drum is manufactured from 16-gauge Type 304 or 304L stainless steel. The inner liner is also manufactured from Type 304 or 304L stainless steel. The CV is placed inside the outer drum assembly, surrounded by the neutron-attenuating and the impact-absorbing and thermal-insulating materials. It is approximately 32 in. in overall height and 5 in. in overall diameter, and is constructed of Type 304L stainless steel.

Although the designs of the packages are different, each package contains certain properties that give them the strength necessary to withstand the impacts from the M-4 rounds. Each of the

packages has an impact absorbent material enclosed just within the outer drum. Visual inspection seems to indicate that, in all of the tests, the packages' impact absorbers do not significantly absorb the energy from the ballistic projectile. However, each of the packages has additional internal components that do appear to absorb that energy. The 9975 has two, nested containment vessels (CVs) in addition to a lead shielding body. The 9977 has an aluminum 3013 spacer within the CV in addition to the heat dissipation sleeve surrounding the CV. The ES-3100 has a very dense neutron absorber and the CV.

The overall damage to the drums for the 9977 and the ES-3100 were different. The 9977 configuration tested, allowed for the 3013 containers to be removed from the CV without the need to destroy any components. Due to the damage sustained in its impacts, the CV for the ES-3100 had to be cut apart in order to retrieve the 3013 containers for further testing. The damage to the 3013 containers was also different for the two packages as the round fired into the packages penetrated differently for each shot. The figures below show the damage caused by the rounds to each of the 3013 containers. Figures 1 and 2 are the 3013 containers that were removed from the 9977 following the ballistics test. There were no marks on these 3013 containers that were caused by the impact of the rounds. Figures 3 and 4 are from the 3013 containers removed from the ES-3100. Even though the upper 3013 in the ES-3100 suffered significant impact damage to the surface, testing proved that it remained leaktight.

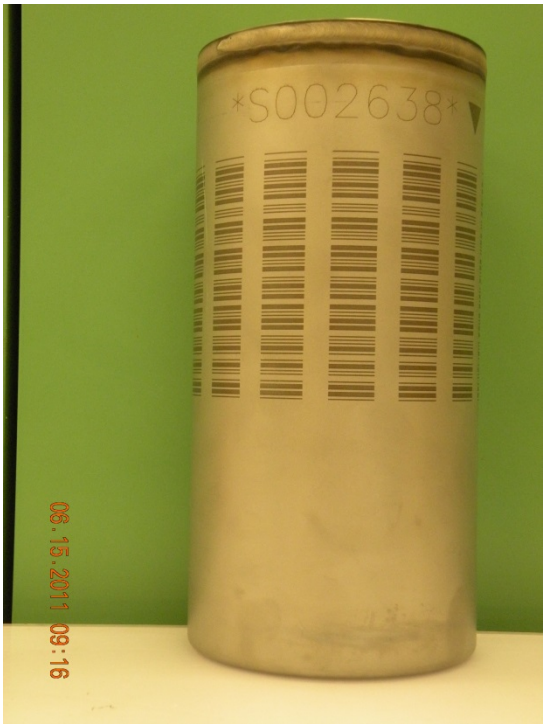

Figure 1 – 9977 Upper 3013

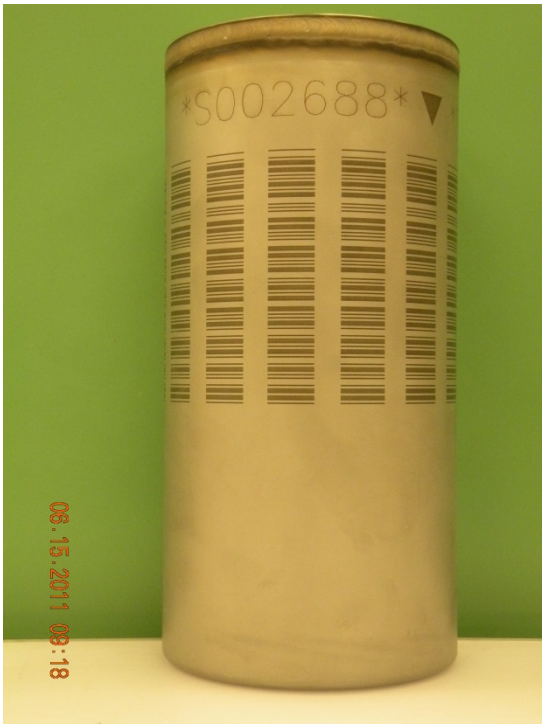

Figure 2 – 9977 Lower 3013

Figure 2 – ES-3100 Upper Shot

Figure 3 – ES-3100 Lower Shot

Again, although the damage to these containers appears quite different, the fact that each of the 3013 containers passed the leaktightness test allows for the packages to be included in the KAC DSA.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

To date, all of the packages that have been considered for inclusion into the KAC DSA have passed the ballistic testing. However, as it can be seen above, some of the results appear to show that significant damage can occur to packages due to this type of impact. Future package designs could incorporate ballistic absorbing materials such as Kevlar or other similar materials. Shipping packages that are intended for storage should be designed with the facility test requirements in mind. The designs can be made incorporating energy calculations to determine the necessary thicknesses and densities of materials to ensure that the package can meet all of the requirements set forth by that facility. Finally, future test articles could be made utilizing "dummy" packages or perhaps even mock-ups of the cross-sections of the packages to prevent having to destroy packages that may have remaining serviceable life.