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Ballistics Testing of the 9977 Shipping Package for Storage Applications

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ABSTRACT

Over the past two years, the Model 9977 Shipping Package has been subjected to a series of ballistics tests. The purpose of the testing was to determine if the 9977 would be suitable for use as a storage package at a Savannah River Site facility. The facility requirements are that the package must not release any of its contents following the impact in its most vulnerable location by a .223 caliber round. A package, assembled to meet all of the design requirements for a certified 9977 shipping configuration and using simulated contents, was tested at the Savannah River Site in March of 2011. The testing was completed and the package was examined. The results of the testing and examination are presented in this paper.

BACKGROUND

Radioactive materials are stored in a variety of locations throughout the DOE complex. At the Savannah River Site (SRS), materials are stored within dedicated facilities. Each of those facilities has a documented safety analysis (DSA) that describes accidents that the facility and the materials within it may encounter. Facilities at the SRS are planning on utilizing the certified Model 9977 Shipping Package as a long term storage package and one of these facilities required ballistics testing. Specifically, in order to meet the facility DSA, the radioactive materials (RAM) must be contained within the storage package after impact by a .223 caliber round. In order to qualify the Model 9977 Shipping Package for storage in this location, the package had to be tested under these conditions.

DISCUSSION

Preparation for Testing and Preliminary Tests

In order to test the 9977 Shipping Package, the storage configuration had to be determined. It was decided that the storage configuration to be used for this testing was the same as the configuration used within one of the facilities at the SRS. This configuration included both an inner aluminum tube within the package 6-inch diameter containment vessel (6CV), known as a 3013 Sleeve, and also another aluminum tube outside of the containment vessel, known as a Heat Dissipation Sleeve (HDS). Although these sleeves have other safety functions, their properties also aid the 9977 shipping package in passing the ballistics testing. The tested configuration, as seen in Figure 1, includes (from the outside-in) the stainless steel drum body, polyurethane foam, a ceramic fiber insulating blanket, the stainless steel drum liner, the aluminum HDS (or the bottom Load Distribution Fixture (LDF) at certain heights), the stainless steel containment vessel, the aluminum 3013 Sleeve, the stainless steel 3013 container, and simulated contents. Since the purpose of these tests was to demonstrate that no damage occurred to the 3013 Containers that would cause them to release RAM, the 3013 Containers were modified for leak testing by the installation of a threaded port in their lids. Prior to any package testing, all 3013 Containers were leak tested and confirmed to be "leaktight" per ANSI N14.5.

The preliminary testing for this configuration was performed in March of 2010 at the SRS Advanced Tactical Training Academy (ATTA) firing range on a 9977 Shipping Package that was a partial mock-up of the storage configuration. The package did not have a HDS, since its design was still preliminary, but it did have a prototype 3013 Sleeve within the 6CV. A total of four shots were fired (using two different caliber rounds, a .223 and a larger caliber bullet) into the package. Two rounds were fired to impact the package at a location near its bottom where the bullet trajectory would pass through the drum liner and the Bottom LDF. Having the bullet impact at that location simulated the performance of a package having an HDS as the HDS and Bottom LDF are made of the same material and have the same radial thickness. The other two shots were fired at a location between the Top and Bottom LDFs. This allowed for a good evaluation of the benefits provided by the HDS and the 3013 Sleeve and to determine what modifications might be necessary if the package did not fare favorably in the testing.

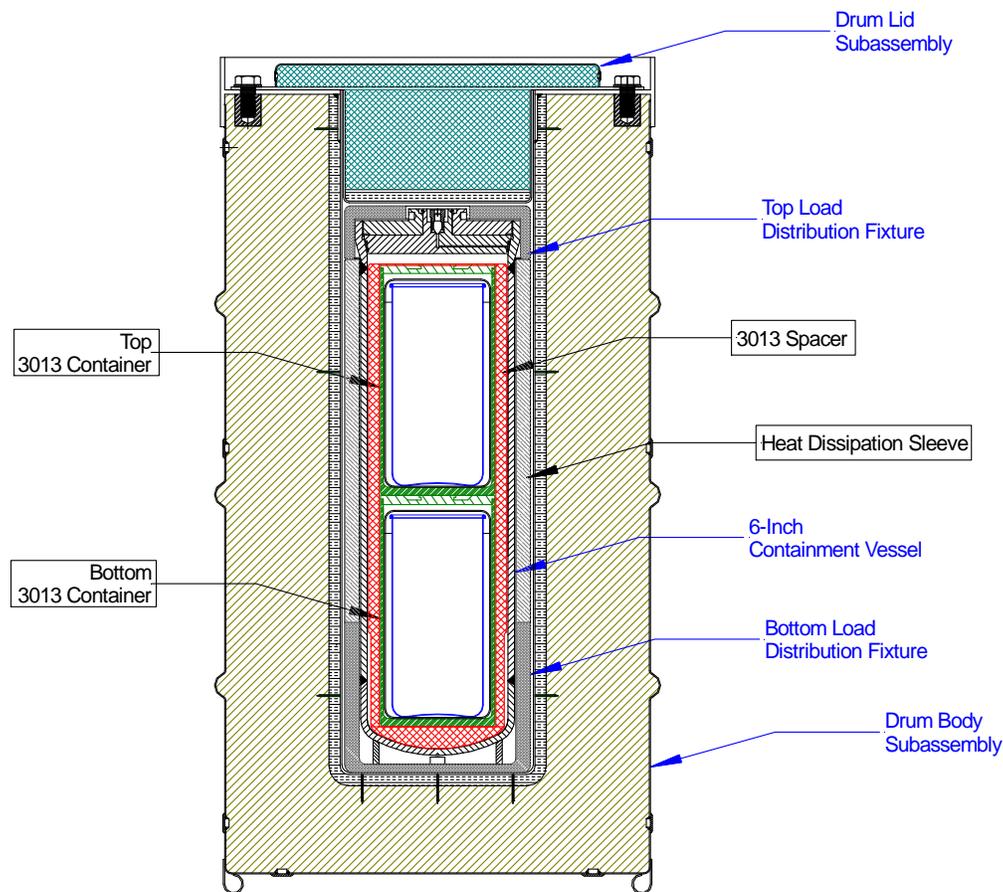


Figure 1 – Model 9977 Configuration with Two 3013 Containers

The first shot was fired at the upper drum elevation with the .223 caliber ammunition. The second shot was also with the .223 ammunition but was aimed at the lower elevation, (See the “Red” arrows in Figure 2). The third shot was aimed at the lower drum elevation, with the large caliber ammunition. The fourth shot was taken at the upper elevation with the large caliber ammunition.

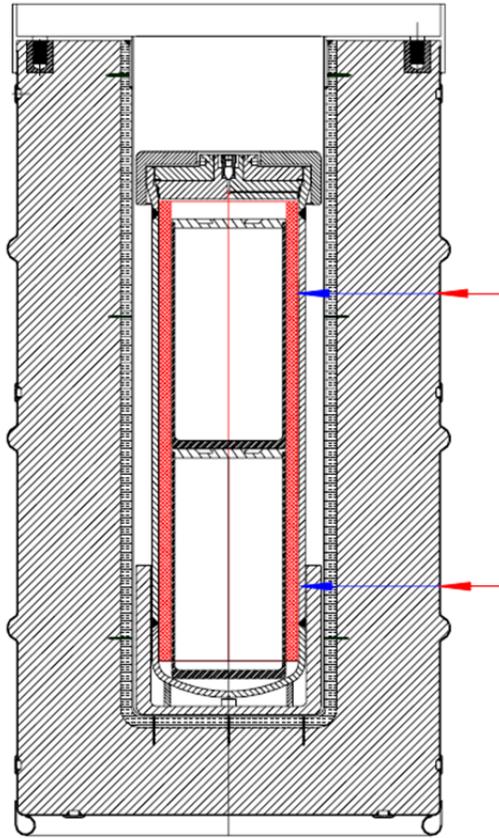


Figure 2 – Locations of Preliminary Test Shots

The Package was transferred to the Savannah River National Laboratory (SRNL) immediately after the test. The 6CV and the Bottom LDF were removed from the drum liner as a unit. The Bottom LDF was sufficiently deformed as to be wedged onto the 6CV and the two were not able to be separated. The LDF could be moved enough to get an indication of the damage caused by the bullet impacts, but nothing conclusive was determined at that time. The damage caused by the large caliber round to the upper section of the 6CV and the Contents was sufficient to prevent the top 3013 from being removed from the 3013 Sleeve.

Machinists at SRNL were asked to assist with the removal of the Bottom LDF from the 6CV and the removal of the 3013 containers and the 3013 Sleeve from within the 6CV. The Bottom LDF was cut through its side-wall in two locations allowing it to release from the 6CV. With the Bottom LDF removed the damage to the 6CV was visible. Since the damage to the upper portion of the 6CV was so severe, it was decided that the best way to remove the 3013 containers and Sleeve was to cut the bottom off of the 6CV and forcefully remove the 3013 containers through the opening created. The 6CV assembly was chucked into a lathe, was sectioned at a location immediately above the Pipe-Cap-to-Pipe weld, and the Pipe-Cap portion was removed. The 3013 containers were then removed from the 6CV and 3013 Sleeve by force of a hammer and push-bar. The 3013 Sleeve could not be removed from the 6CV due to gross deformations from the bullet impacts.

The results of the preliminary testing were favorable. The Bottom LDF stopped the smaller caliber round (.223) and the Bottom LDF along with the 6CV stopped the larger caliber round. The smaller caliber round also did not penetrate into the 3013 container in the shot fired where there was not a simulated HDS (upper elevation). The larger caliber bullet, as expected, penetrated into the 3013 container.

Phase II Testing

Since the results of the preliminary testing were favorable, it was decided that Phase II of the testing would be a bounding test. Using the large caliber round, two shots would be fired into a test package that was a complete simulation of the final shipping/storage package configuration, including a HDS and a 3013 Sleeve. This testing was performed at the ATTA range in March of 2011 and consisted of firing just two shots into the package. The package was then shipped to and examined at SRNL. The HDS was sufficiently deformed by the two shots as to be wedged onto the 6CV and the unit could not be removed. The package was re-examined the next week and the 3013s were accessed by removing the 6CV Closure Assembly. The damage caused by the large caliber round to the upper section of the 6CV and the 3013 was sufficient to prevent the top 3013 from being removed. A simple vacuum test was attempted through a specially installed port on the top 3013, but the 3013 was unable to hold a vacuum.

The package was prepared for destructive examination and the HDS and 6CV were removed from the drum liner. Once the HDS and 6CV (now wedged together) were removed from the drum it was noticed that there was a chance that the large caliber round penetrated the top 3013. The HDS was then removed from the 6CV. A metal probe was inserted into the hole made by the first shot (see Figure 3). The depth that the probe was inserted into the hole was measured and it was determined that the top 3013 had been punctured. The hole made by the second shot (the lower shot, see Figure 4) was also examined and the probe was again able to be inserted to a depth that indicated the bottom 3013 was most likely punctured as well.



Figure 3 – Upper Shot

Figure 4 – Lower Shot

Failing this test, the parameters within the facility DSA were reviewed to determine exactly what test parameters were necessary to meet the requirements of the DSA. It was determined that this bounding test actually exceeded of the conditions within the DSA. Additional testing would be needed and was performed later that same year.

Final Testing

The final testing of the 9977 Shipping Package used a new HDS, a new 6CV, a new 3013 Sleeve, and two new 3013 containers that are of the same material of construction as previously tested and again met the conditions of the certified drawings, see Figure 1. This testing was performed to meet the exact requirements of the DSA.

The assembled 9977 package was transferred to the ATTA range on June 1, 2011 for testing. The package was set-up for the test and the testing was performed as scheduled on the morning of June 2, 2011. There were four .223 caliber rounds fired at the 9977. Two shots impacted the package at a location attempting to penetrate the middle of the upper 3013 and two shots were made to impact the package at a location attempting to penetrate the lower 3013.

After the testing was completed, the package was partially disassembled while still at the ATTA range. This was done for two reasons. First, there was the desire to immediately determine if the test was successful and, second, there was the desire to remove the 3013 containers from the 9977 Package to prevent additional damage that could be caused during the shipment of the package to SRNL in the transfer vehicle. The 9977 Drum Lid Subassembly was removed, the Top LDF was removed, the 6CV was opened by removing the Closure Assembly, and both of the 3013 containers were removed. Neither of the 3013 containers had any apparent damage caused by the impact of the four rounds being shot into the package.

The 9977 Package and 3013 Containers were then transferred to SRNL later that morning for disassembly and examination. The HDS was sufficiently deformed by the four shots as to be wedged onto the 6CV and the 3013 Sleeve was also wedged onto the 6CV and the unit was not able to be disassembled.

Although the two 3013 containers appeared undamaged, they were leak-tested to determine if this was indeed the case. The leak tests were successful as both 3013 Containers were "leaktight". Therefore, it was determined that the package did not need to be destructively disassembled since the ultimate package performance was established by the 3013 Containers remaining leaktight and the remaining damage to the other package components was irrelevant.

Figure 5 shows the inside of the 3013 sleeve after the final testing. There is a small protrusion on the inside of the 3013 Sleeve where one of the four rounds impacted the drum and traveled through to the 3013 Sleeve, but the 3013 Sleeve was not penetrated. Only one shot produced a protrusion of this size. Figures 6 and 7 show the surfaces of the 3013 containers, adjacent to the point of impact by the rounds, after removal from the 6CV and the subsequent leak testing. There are no indications on the 3013 where the shots impacted the containers nor are there any abrasions on the containers made upon removal from the 3013 sleeve.



Protrusion on inside of 3013 sleeve

Figure 5 – Inside View of the 3013 Sleeve

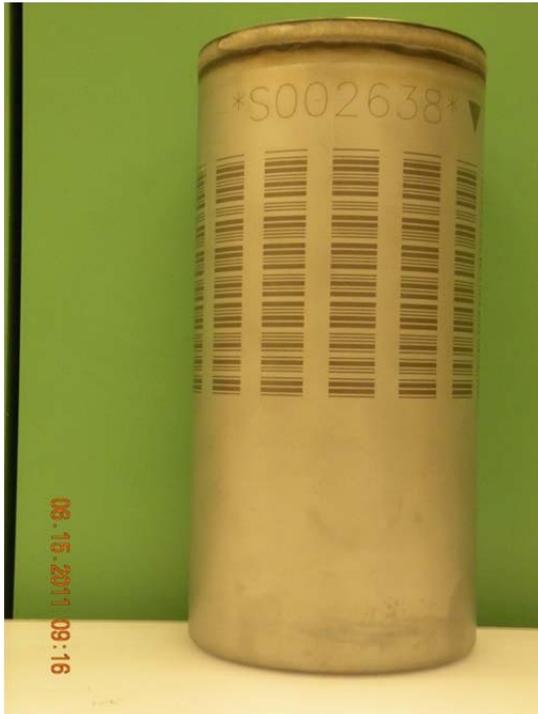


Figure 6 – Upper 3013 Container

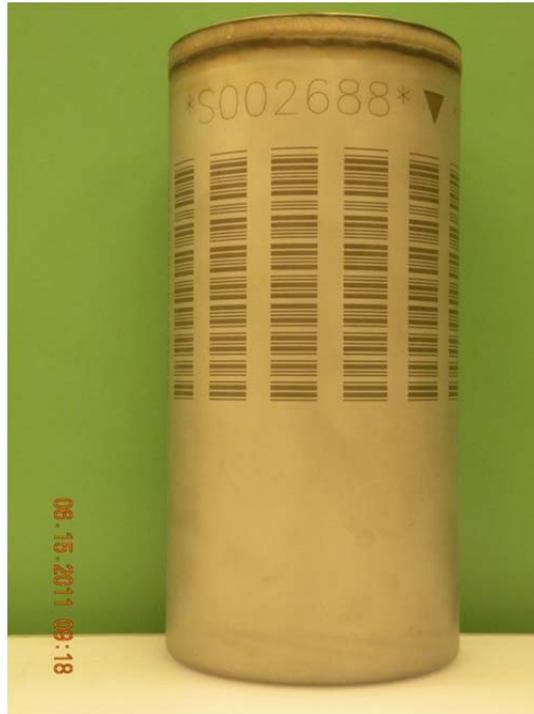


Figure 7 – Lower 3013 Container

CONCLUSIONS

The 9977 Shipping Package successfully passed the final testing that will allow the package to be certified for storage at the SRS. The tested design is currently under review to be certified for shipment.