

Lessons Learned in the Development of a Small Light Weight Package for a Drum

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ABSTRACT

An extensive, design by test program for light weight package meeting Type A Fissile requirements, was performed over a seven month duration. The package weight required it to pass both the 9m (30ft) drop and crush tests. Several options were developed and tested simultaneously before selecting an optimum configuration that was then tested for certification by the U.S. Nuclear Regulatory Commission (NRC). Once approved, the package TN-55 will provide a means of shipping 55-gallon drums of radioactive material that meet the new regulations for an industry that has long relied on drums as a primary container.

INTRODUCTION

The standard 55 gallon (208 liter) drum has been the main stay of the nuclear industry for handling radioactive materials both in the front end of the fuel cycle and the waste disposal part of the industry. As the industry and regulations have progressed the expectations for the simple drum have greatly increased as has the packaging that has been designed to handle the drums.

In the early days of performance based transportation package requirements the focus was on the survivability of the drop events and the thermal or fire events. The basic requirement was that the lid stayed on. As the understanding of the requirements advanced definitions of survivability have changed. It became no longer acceptable for the lid to just stay on. It had to be leak testable both before and after the events. This meant survivability of not only the body and lid of the package but the gaskets as well.

With the acceptance of the 1996 International Atomic Energy Agency (IAEA) regulations No. TS-R-1 (ST-1, Revised) the US NRC adopted significantly different rules for small light weight packages. These rules apply to packages that weigh less than 500 kg (1100 lbs), have a density less than 1000 kg/m² (62.4 lb/ft²) and have radioactive contents greater than 1000 A₂, if not fissile material (Par727). Unlike the IAEA regulations the package must withstand both a 9 meter (30 ft) drop event as well as a 9 meter 30 ft crush test by a 500 kg (1100 lb) 1 meter square (40 inch square) plate (US Code of Federal Regulations Title 10 Section 71.55).

Although this test is not applicable to most containers it has unique ramifications to smaller packages such as the 208 liter (55 gallon) drum. The requirement changes completely how a package is protected. For all of the other regulatory loads the package must be protected by a force acting from the outside to the center of the package. For the crush test the force comes from both sides of the package and must be transferred through the package without detrimentally affecting the contents within.

DESIGN CONDITIONS

The development of this package was based on the need to ship slightly enriched uranium powder that had a very low density. Also it was restricted by the fact that the receiving facility required the use of drums for handling the uranium oxide. The type of package required was a Type A package since the material being shipped, Uranium Oxide, had an unlimited A_2 quantity. The low activity of the material being just over 1% enrichment meant that the although classified as a fissile material package the criticality control could be easily achieved by keeping the material confined in the drums. The apparent package to address these needs was the N-55 (USNRC Docket 71-9070), a simple over pack for a standard 55 gallon drum. This Type B package being one of the oldest packages that had been designed to meet the performance regulations did not meet the current regulations and had its contents restricted to solid non-dispersible materials since the drum did not have provisions for leak testing. However, the basic package design had been modified with leak testable liners and successfully used in packages such as the PAS-2.

The driving force became the need to be able to get the package to pass the 9m (30ft) crush test with a 500kg (1100 lb) 1 meter square steel plate. The apparent easy solution to this was to strengthen the package so that the over pack could carry the load around the drum and minimize any distortion to the confinement barrier of the drum. The added strength could be added with the addition of structural material. The additional structural material would also allow the package to carry heavier payload. The combination of the heavier package design and the heavier payload could easily make the package exceed the 500kg (1100 lb) cut off point where the crush test was not required. However, the combination of the low density material and the need for an economical transportation system demanded that the increase of the package weight be kept to a minimum while the weight of the payload was increasing.

Not only did the package weight need to be minimized but the size of the package needed to be unchanged. The 81.3 cm (32 in) diameter of the package had to remain unchanged to allow the packages to be shipped three wide in an enclosed trailer. The need to maximize the payload material moved on each truck load was a restraint in the amount of strengthening the package could undergo.

The original N-55 package was transported by placing the package on a pallet. Since this pallet would count against the total shipping weight it was decided to add a built in handling system into the package by adding forklift pockets on the bottom of the package. Not only did these provide a means of handling the package but they also provided added strength to the package and ability to resist damage from the crush test.

CONTAINMENT

Two different containment boundaries were tested. The standard single bolted ring closure of the drum was not pursued do to its reputation in the industry of failing in various impact tests. Two different drum designs were pursued. One used a double lidded closure where a rolled ring was added to the inside of the drum and a flat plate was bolted to that ring with a gasket. The outer ring remained a single bolt ring closure. The second closure that was tested and found to work in combination with the over pack was a modified version of the clamshell closure developed by the Savannah River Plant. The only change to that drum closure was that the neoprene drum gasket was replaced by a braided ceramic high temperature material. The ceramic gasket was lightly coated with silicone rubber to secure any of the fibers from entering the uranium oxide. Both closures were tested and found to contain the material. The clamshell closure was chosen for licensing due to the relative ease of use. In all cases a heavy duty 16 gage drum was used.

The package tare weight amounts to approximately one-third of the total weight of the package, maximizing the contents that can be transported while still meeting the facility interface requirements that necessitate the use of a standard drum. The light weight nature of the package provided minimal thermal protection requiring the development of high temperature gaskets to allow survival of the containment boundary. These gaskets made from basically incompressible material allowed for the package to maintain containment throughout the regulatory events. The gasket, rated above the regulatory accident condition temperature, survived all testing while providing complete containment of contents which was in the form of a fine dispersible powder. The gasket demonstrated its ability to confine the material through the drop, crush, thermal, and post fire immersion tests.

The TN-55 package was developed by a design-by-test program where various design considerations were tested. A key aspect of the test program was using the proper simulated payload to adequately model the uranium oxide powder that was to be shipped. The simulated payload chosen was aluminum oxide powder that had similar particle size distribution and behavior for all testing.



Fig. 1. Drum in package after testing

DROP TEST

The 9m (30 ft) drop test (10 CFR 71.73 (c) 1) was not a significant challenge in itself to the package. The original N-55 design from which this package was based had been tested several times in the past, by different organizations, in various orientations. The only significant challenge that these tests had demonstrated in the past was that the closure mechanism latches could be damaged in the drops and that the riveted construction of some of the joints could be challenged. The new package design addressed these considerations by going to welded joints and providing a redundant closure mechanism. Due to the size restrictions added latches could not be used. Between the latches, self locking bolts were added. Although not as user friendly as the latches the bolts provide redundant load paths that could survive the

drop test and allow the lid and body shells to work together to provide protection through the crush and burn test.

As was expected the package performed very well in all the drop tests both under the normal conditions of transport and the hypothetical accident conditions.

CRUSH TEST

As noted earlier the crush test was one of the major changes that had occurred in the regulations from the time performance based regulations were first adopted to the present. Many older packages have been taken out of service due to this requirement. Although the IAEA regulations state for lighter weight packages of less than 500 kg (1100 lbs) the crush test replaces the 9m (30ft) free drop test, the US NRC requires it to occur in addition to the free drop tests. That difference requires the damaged package from the drop event to protect the contents from the crush test. The lid had to stay on and the uranium oxide had to stay confined.

Experience has shown that a bare drum was unable to resist the crush forces. Therefore, a protective shell is required around the package. The most likely form of failure of the package is the crush of the drum body separating it from the drum lid.

To achieve this required protection with a minimum amount of weight increase the package was reinforced by making the angles at the closure continuous. and reinforcing the fiberglass inner shell that previously only closed off the foam and provide a thermal break in transferring heat from the outer shell to the drum and contents. The inner fiberglass shell at the ends was strengthened by increasing the number of glass layers and also through the addition of plywood making a composite construction. The fiberglass shell was further strengthened by the use of Aramid fabric, also known as Kevlar®, a widely recognized brand name. High strength materials added to the lay-up not only added to the bending strength of the shell but also provide continuous tear resistant shell that could confine the contents even if the resin cracked.

The reinforced thicker inner fiberglass shell combined with the strengthened outer sheet metal shell with rolled angles at the closure and the forklift pockets at the bottom, provided adequate strength to transfer the load from the crush plate from one side of the package to the other with out major deformation to the drum within.

The package was drop tested in several orientations in combination with various crush drops. These orientations included the crush on the top of the package after a free corner drop, a side crush drop after a corner drop and a side crush after a side drop. The crush plate was positioned to drop over both the body and the lid.

The package was heated to match the hottest normal condition of transport temperatures prior to both the 9m (30ft) and the crush tests. The elevated temperature was necessary since the protective foam used in this package is relatively thin and of a light density. Hence the foam has minimum strength at the higher temperature and would have the tendency to lock up at higher compression percentages applying the worst loading to the package and its contents.

The results of the crush testing were that the lids stayed on in all cases and the contents remained confined.



Fig. 2. Aligning for Crush Test

PUNCTURE TEST

Following the crush test the package must also undergo puncture testing. The package was tested in various orientations including oblique punctures aimed at the drum lid, the corner of the package, and the closure of the package. None of the puncture tests compromised the outer skin of the package nor did it do any significant damage to the package compared to previous tests. The test sequence that did the most damage to the test units was a 1.3 m (4 ft) corner drop, 9m (30 ft) free drop on corner, crush test on side, a puncture test on the damaged corner and an additional puncture attacking the closure was performed on the unit prior to the thermal test.

FIRE TEST

In the original planning for the development and certification of the package, physical thermal testing was not anticipated. The contents were not combustible or temperature sensitive and the basic design had been approved as a Type B package based on thermal analysis. However, it became apparent during the design that since the original design had been completed, many things had been learned about the behavior of packages in fires and the easiest way to address possible questions was to perform the burn test. The package was burned in a pool fire meeting the IAEA (Para. 727) and NRC(10CFR71.73(c)(4)) requirements.

The foam, as expected, burned out about half way through the 30 minute fire. Fire was partially restricted from entering the inner cavity of the package by the use of the ceramic gasket at closure between the lid and body of the over pack. The combination of the foam, fiberglass, and the air gap remaining after the

foam was consumed provided adequate thermal protection. This was indicated that the fiberglass was not consumed by the fire. The ceramic gaskets in the drum itself remained undamaged and the silicon rubber on the gasket also remained intact, preventing any release of material.



Fig. 3. Fire Test

IMMERSION

There are two immersion tests (10CFR71.73(c)(5)) that were addressed for the TN-55. The first is the 0.9m (3ft) test following the fire test and the second is the 15m (50ft) immersion test of an undamaged package. Neither of these tests are normally considered applicable for a package that has an unlimited A_2 value for the contents when the criticality is evaluated based on optimally flooded conditions. Even though the package did not have a pressure tight containment seal, it had to be demonstrated that sufficient water could not get in and entrain the uranium powder then flow out.

Since the over pack had no seal only the drum was submerged and subjected to the immersion testing. The drum that was burned was subjected to the 0.9m (3ft) immersion test and no in leakage of water was detected.

Several drums were subjected to the 8 hr immersion test at 15m (50ft) of water or 23 psig. It was found that the drums would buckle in various modes. The amount of buckling was dependent on the fill level of the drum and if there was any flaws in it such as dents. Two significant factors were noted. One, if the

drum is at least 80% full the drum would not buckle. Two, in all cases even though the body of the drum deformed extensively the lid remained in place and insufficient water leaked in to the drum to even moisten the material significantly. Small amounts of water did leak into the 50% filled drums but it was limited to less than the top 1 inch of powder after 8 hrs. Therefore, the water could not entrain the powder to cause a dispersion of the material.



Fig. 4. Post immersion test with 50% fill

CONCLUSION

A successful light weight package was developed for shipping drums of slightly enriched uranium oxide. The package was developed through the use of a design-by-test program and demonstrated to comply with the regulations by undergoing free drops, crush testing, puncture testing, fire testing, and immersion testing on a full scale basis.