Testing and Versatility of the SAVY 4000 Nuclear Material Container – 15634

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ABSTRACT

The SAVY 4000 container was designed by Nuclear Filter Technology, Inc. to meet DOE M441.1-1 requirements for safe storage of nuclear material, and it is currently being used at Los Alamos National Laboratory, Livermore National Laboratory, Idaho National Laboratory and Nevada National Security Site. The 316L stainless steel container can be manufactured in a range of sizes from 1 quart to 10 gallon [1] capacity, it can be opened and closed easily by hand, it is sealed with a Viton® O-ring, and the filter retains particulates and resists liquid water entry while allowing hydrogen gas to escape. This innovative design has proven to provide benefits and uses beyond its original intent. For example, the container was tested in a simulated facility design basis accident involving high temperatures, fuel fire, and subsequent drop, and the damage ratio was measured. This has allowed the LANL plutonium facility to take credit for a material-at-risk reduction of approximately two orders of magnitude for material stored in the SAVY 4000 container. In addition, the water resistant filter allows the nuclear facility to credit the container as a safety feature to mitigate the risk of a criticality accident in the event of facility sprinkler system activation. The container has also been approved to transfer small quantities of solid nuclear material by hand carry between Los Alamos facilities, and it has been approved and used as a waste container for transuranic waste destined for the Waste Isolation Pilot Plant. The 1 quart capacity container and the future 2 quart design both fit inside the 9977 shipping container, and this has facilitated the transport of nuclear material from Idaho National Laboratory to Nevada Nuclear Security Site, obviated the need for repackaging the material for storage upon arrival. Finally, Los Alamos has recently contracted with Nuclear Filter Technology, Inc. to perform testing to certify the SAVY 4000 container as a DOT Type A liquid transport container. This paper will provide an overview of the various testing regimes and describe the resulting versatility of the container for nuclear material containment.

INTRODUCTION

The Department of Energy (DOE) issued DOE M 441.1-1, *Nuclear Material Packaging Manual*, in March 2008 to protect workers who handle nuclear material from exposure due to loss of containment of stored materials. The Manual specifies a detailed approach to achieve high confidence in containers and includes requirements for container design and performance, design-life determinations, material contents, and surveillance and maintenance to ensure container integrity over time. The materials considered within the scope of the Manual include actinides stored outside an approved engineered-contamination barrier that could result in a worker exposure of greater than 5-rem Committed Effective Dose Equivalent (CEDE) if containment is lost.

Nuclear Filter Technology, Inc. (NucFil) and LANL developed the SAVY 4000 container as a simple, robust, and reusable container for storing solid nuclear materials. The SAVY 4000 series of containers includes eight sizes (1, 2, 3, 5, 8, 12 quart, 5 and 10 gallon) and will eventually replace the current "Hagan"-style containers of the same sizes. The design of this container includes a filter to prevent pressurization and to facilitate the release of hydrogen, thus preventing flammable gas mixtures from forming. The filter must also prevent radiological particulate release. The filter ensures that only minimal

[1] One quart to ten gallon are container designations; therefore, SI units are not provided. See Table 1 for container details.

differential pressure (1 kPa for the quart-size and 2 kPa for the gallon-size containers) is possible during use. In this respect, the container is not a pressure vessel but a lightweight, worker-friendly container. The SAVY 4000 is a general purpose, reusable container designed for the storage (inside a nuclear facility) of solid nuclear material with a permitted loading of up to 25 watts. This wattage limit applies to all containers, regardless of their size. One of the main features of the design is its simplicity relative to a typical Type B DOT-compliant shipping container. The primary reliance on the HEPA filtered nuclear facility to protect public safety in a design basis accident scenario allows the design features of the container to be specifically (but not exclusively) targeted at protecting nuclear workers from both external and internal radiation dose. The filtered design obviates the need for heavy, pressure-vessel-type construction or welded closures. Thus, the design promotes ease of use and rapid opening and closing to minimize external worker dose during handling, while providing protection from internal worker dose through aerosol particulate containment over a relatively long storage period (five years minimum). Once the container is closed, it provides a credited engineering control and allows workers to handle the containers without the need for respirator protection. It is light enough for hand-carrying, and it protects the worker if the container is accidentally dropped from as high as 3.66 m. The design also includes a nesting feature such that each container fits inside the next larger size. Figure 1 below shows a SAVY 4000 container with labels identifying each of the primary components.

Figure 1. The SAVY 4000 Series and Primary Components

The SAVY 4000 container is composed of two primary sub-assemblies: the body and the lid. The body and lid are attached to one another with a bayonet-style closure such that the lid fits tightly within a collar attached to the body. The user achieves a leak-tight seal by pushing the lid downward into the collar, resulting in radial compression of the O-ring in a “piston groove” configuration between the body collar and the lid. The lid locks into place by rotating the locking ring made of aluminum until a spring-loaded, stainless steel pin engages with a hole in the collar. No tools are required to open or close the container. The lid has a built-in filter made up of silica and alumina fibers that prevents pressurization and hydrogen build-up inside the container and prevents particulate release. The filter is protected on the outside by a polytetrafluoroethylene (PTFE) membrane that allows gases to pass but blocks water and other liquids, thereby facilitating shedding of water. The containers and lids are interchangeable within a given container size, and the assembly does not need to be checked for leaks at each closure. Four of the filter vent holes are threaded for attaching a fitting for helium leak testing an assembled container at the time of manufacture and during surveillance. An aluminum handle is attached to the lid with stainless steel pins for manual handling and lifting. Holes in the collar allow water to drain off the lid in the event of facility sprinkler activation and allow for the installation of a tamper indicating device (TID). The internal components that form the containment barrier are made of 316L stainless steel for corrosion resistance. The SAVY 4000 series consists of eight container sizes (1, 2, 3, 5, 8, 12 quart, 5 and 10 gallon, nominal), all of which are addressed in this report. The overall primary dimensions (rounded to the nearest 0.1 cm), inner volumes (rounded to the nearest 0.01 l) and weights (rounded to the nearest 0.1 kg) of the containers can be found in Table 1. The minimum inner diameter is the minimum diameter of the locking collar through which contents must pass. A summary of the allowable material contents is given in Table 2.

Table 1. Overall Primary Dimensions and Weights for the SAVY 4000 Container Series

Size	Overall Diameter (cm)	Overall Height (cm)	Minimum Inner diameter (cm)	Usable Inner Height (cm)	Inner Volume (l)	Gross Weight (kg)	Tare Weight (kg)	Payload Max Weight (kg)[1]
1 qt	12.1	15.0	9.3	11.1	0.96	10.0	1.5	8.5
2 qt	12.1	25.4	9.3	21.5	1.78	12.2	2.0	10.2
3 qt	16.6	20.2	13.8	17.2	3.07	15.0	2.6	12.4
5 qt	19.6	25.3	16.8	22.2	5.19	18.1	3.4	14.7
8 qt	22.5	29.1	19.7	26.1	8.61	20.0	4.3	15.7
12 qt	25.4	35.4	22.6	32.4	13.50	22.2	5.4	16.8
5 gal	29.8	40.5	26.0	35.7	19.40	24.9	8.6	16.3
10 gal	39.3	45.6	35.5	40.5	40.95	39.9	11.9	28.0

[1]Note that drop testing was performed with payloads slightly in excess of the payload maximum weight shown.

Table 2. Overall Primary Dimensions and Weights for the SAVY 4000 Container Series

Content	Bounding Case
Identification and maximum quantity of radioactive material	Any actinide material with A_2 quantity in grams greater than the A_2 value of Heat Source plutonium oxide (0.0020 g) is allowed up to 25 watts or by other existing limits (container weight, criticality , external dose limit)
Maximum heat load	25 watts
Chemical form	Allowed: All materials unless specifically not allowed Allowed with restrictions: metals that can undergo expansion are required to be in hermetically sealed inner containers Not Allowed: Materials with IDC codes C02X, C19X, C39X, C40X, C61X, GXXX, KXXX, LXXX, N69X, R12X, and R59X, MXXJ, and M76X (X is generic for any number or letter).
Physical form	Allowed: Solids; Prohibited: liquids and gases
Maximum Normal Operating Pressure	Differential pressure across container boundary of 1 kPa for quart-size containers, 2 kPa for the gallon-size containers

METHODS

Design Release Rate Test

DOE M 441.1-1, Attachment 4, provides guidance in determining the design-release rate and design-qualification release rate for a variety of stored materials. The Manual requires the utilization of one of the following release rates:

- ANSI N14.5-1997 criteria for leak tight

- 10 CFR 71.51 criteria for no loss of radioactive material

10 CFR 71.51 specifies that for normal transport of radioactive material, there should be no loss or dispersal of radioactive contents, as demonstrated to a sensitivity of $10^{-6}A_2$ per hour, where A_2 represents the threshold quantity of the radionuclide of interest and is given in 49 CFR 173.435.

The SAVY 4000 design-release rate, based on the worst-case allowable contents A_2, is established as 5.6 x 10^{-6} cm^3 s^{-1} of air at 78 kPa at the Maximum Normal Operating Pressure (MNOP) (1 kPa for the quart-size and 2 kPa for the gallon-size containers). The MNOP is very low and as such, creates the potential for unrealistic measured leak rates due to the relatively large effect of diffusion through the O-ring. In an effort to limit the effect of diffusion and ensure accurate leak measurements, the leak-test differential pressure was increased to 10 kPa. Helium leak tests of assembled containers demonstrate that all container sizes meet the design release-rate performance criterion.

Design Qualification Release Rate (Post-Drop)
The SAVY 4000 design qualification leak rate is established as 0.034 cm^3 s^{-1}. This leak rate is sufficiently large that a bubble leak-rate test remains most applicable. However, drop testing results demonstrate that the actual SAVY 4000 post-drop leak rates are far less than the design qualification leak-rate limit. Therefore, testing utilizes mass spectrometer helium-leak testing equipment.

Drop tests demonstrate that the container satisfies the DOE M 441.1 1 performance-drop test requirement at the maximum-storage height relative to the design qualification release-rate and also relative to the much more restrictive design release rate. Qualification was performed exclusively by testing. No scaling effect considerations for the various container sizes were necessary because the maximum gross weights for each size in the drop tests represent maximum allowed payload weights.

The DOE M 441.1-1 drop test requires the container to have a leak rate no greater than the design qualification-release rate following a free-drop test of the container through a maximum handling distance onto a flat, essentially unyielding-horizontal surface in the most damaging orientation. Each container underwent drop testing in seven orientations in order to ensure the bounding of the worst-case orientation (see Figure 2). All drop tests were performed at 22.2 °C ambient conditions.

All drop tests included an internal container loaded with tungsten shot to simulate the design's largest gross weight. All drop tests were performed at a height of 3.66 m. The drop tests used two certification-test units of each size dropped in the seven drop orientations. This approach is considered conservative because multiple drops cause cumulative damage. Multiple drop orientations were selected to ensure that the maximum damaging orientation was bounded. The first test unit was dropped in four orientations identified in Figure 2 in the order of A, G, B, and F, with the second test unit then dropped in three orientations in the order of C, H, and D. The 1-quart test unit represents the only exception to this test protocol, i.e., only one test unit dropped in all seven orientations. Table 3 below summarizes the results of the helium leak rate tests before and after the drops for the Phase 1 and Phase 2 testing. The Phase 1 tests were performed on containers made with the pulsed laser. The Phase 2 tests were performed on containers made with the higher power, continuous wave laser for all container sizes, and on 5 and 10 gallon containers with design changes to reinforce the lid.

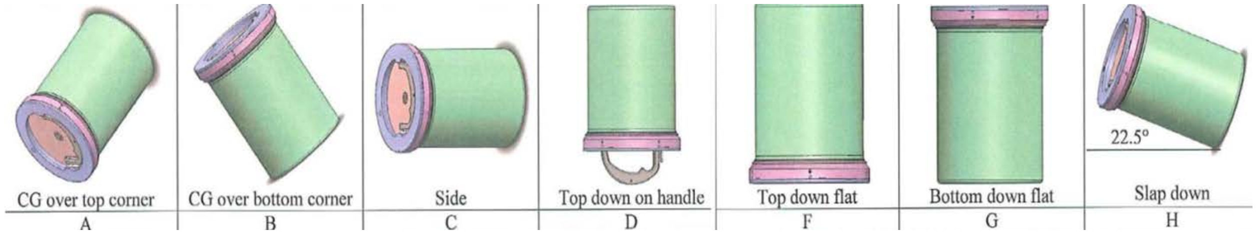

Figure 2. Drop Test Orientations

Table 3. Helium Leak Rate Test Results for Phase 1 and Phase 2 Testing. Passing Criteria < 100 (x 10^{-7} atm cm^3 s^{-1} @10 kPa).

	PHASE 1		PHASE 2	
Container Size	**Pre-drop He Leak Rate Range**	**Post-drop He Leak Rate Range**	**Pre-drop He Leak Rate Range**	**Post-drop He Leak Rate Range**
1 qt	0.4	0.4 - 3.6	1.9 - 2.5	3.1 - 6.0
3 qt	1.7 - 2.7	4.8 - 7.2	0.8 - 1.0	2.1 - 4.1
5 qt	0.3 - 0.6	0.2 - 0.8	0.5 - 0.8	1.6 - 3.6
8 qt	1.7 - 2.3	2.5 - 7.8	0.3 - 0.7	0.4 - 3.4
12 qt	0.2 - 0.7	0.3 - 2.9	0.5 - 1.0	0.4 - 3.6
5 gal	0.6 - 1.6	5.4 - 6.1	1.1 - 2.7	2.2 - 5.6
10 gal	0.3 - 1.2	0.9 - > 9900	1.1 - 3.7	0.8 - 12

Drop Test Results for the 5-Quart SAVY 4000

Drop tests were conducted for all quart sizes of the SAVY 4000 containers as part of a larger series of tests to simulate conditions in a variety of worst-case scenarios. Results of the drop test for the 5-quart containers are summarized here. These results are typical for all quart sizes. See Appendix J for complete drop test results and the post drop acceptance criteria.

Figure 3 shows an example of the drop test payload.

Figure 3. Drop Test Payload Example

Figure 4 shows the alignment of a loaded SAVY 4000 relative to the flat surface prior to rising to 3.66 m before a drop test.

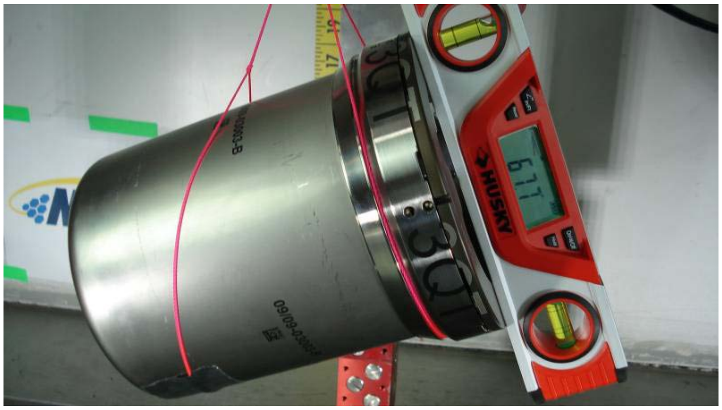

Figure 4. Drop Test Alignment Example

The drop of each SAVY 4000 size included a series of orientations, either until failure or until dropped in all orientations. All drops included an internal container loaded with tungsten shot to simulate the largest gross weight a container is designed to hold. Table 4 shows the maximum gross weight for each test and the tabulated results. All container sizes passed the helium leak rate test before and after the drops.

Table 4. Summary of Drop Test Results for 5-Quart-size SAVY 4000

Test Article ID	Gross Weight of Test Item (kg)	Orientation	Post Drop Helium Leak Rate (atm cm^3 s^{-1})	Status
09/09-05005	19.1	CG over top corner	2.0×10^{-8}	Pass
09/09-05005	19.1	Bottom flat down	7.4×10^{-8}	Pass
09/09-05005	19.1	CG over bottom corner	3.8×10^{-8}	Pass
09/09-05005	19.1	Top flat down	4.0×10^{-8}	Pass
09/09-05003	18.4	Slap down	3.4×10^{-8}	Pass
09/09-05003	18.4	Side	4.6×10^{-6}	Pass
09/09-05003	18.4	Top down on handle	8.0×10^{-8}	Pass

Figures 5 through Figure 11 show the damage caused by each drop test of the 5-quart container. The other sizes of containers received similar damage.

Figure 5. Center of Gravity Over Top Corner

Figure 6. Bottom Flat Down

Figure 7. Center of Gravity Over Bottom Corner

Figure 8. Top Flat Down Damage

Figure 9. Slap Down Damage

Figure 10. Side Drop Damage

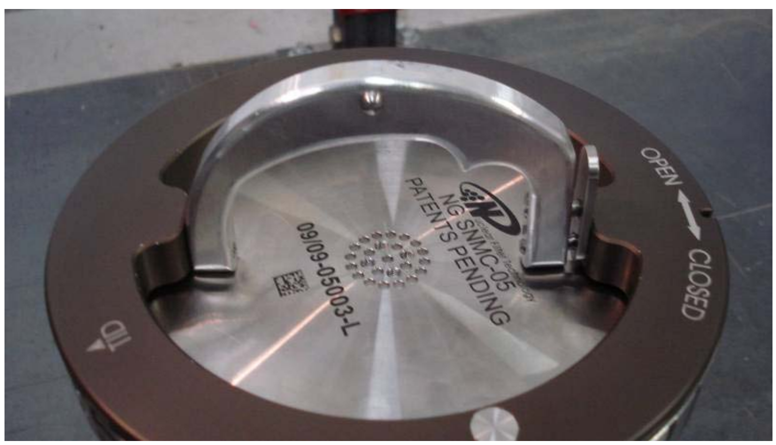

Figure 11. Top Down on Handle Damage

Facility Accident Conditions

Fire/Earthquake:
The SAVY-4000 container was tested in a simulated facility design basis accident involving high temperatures, fuel fire, and subsequent drop, and the damage ratio was measured. This has allowed the LANL plutonium facility to take credit for a material-at-risk reduction of approximately two orders of magnitude for material stored in the SAVY 4000 container. The accident of concern for the LANL Plutonium Facility is a large-scale seismically induced fire on the processing floor. Such an accident could involve large quantities of Plutonium in dispersible forms stored in containers that cannot be counted on to prevent material release. As part of the effort to improve the safety posture of the facility in

the near term, a test method was developed and used to evaluate the capability of storage containers to prevent release of their contents in the event of a seismically induced fire. To provide a defensible basis for testing to the Department of Energy and Congressional oversight, standard test methods were adopted from consensus codes and standards. These tests included a time temperature exposure up to 870°C (Figure 12), and a 20 L Kerosene open-pool fire test (Figure 13). After the thermal tests, containers were dropped from a height of 1.2 m onto a steel plate (Figure 14). The amount of a nontoxic plutonium surrogate released was measured following the drop tests to establish a conservative value of expected material release (referred to as damage ratio) in the event of the facility accident. These thermal and impact test protocols can be used to demonstrate a quantitative value for material release from containers where the assumption of total material release results in unacceptably high accident

Accident Analysis Methodology

- Examine the consequences to the public of a radioactive material release.
- Source term calculated using a five factor formula
  - o Q = MAR X DR X ARF X RF X LPF
  - o MAR = Material at risk
  - o ARF = Airborne release fraction
  - o RF = Respirable fraction
  - o DR = Damage ratio
  - o LPF = Leak path factor
- Damage ratio (DR) is the best candidate for reduction
  - o Represents the fraction of MAR that is impacted by accident
  - o Can be established using engineering analysis and testing (DOE-HDBK-3010-94)
  - o Provides an engineered control to limit release

Figure 12. Furnace Test 1: Type 1 Containers Post Test.

Figure 13. Open Flame Test 1: Full Ignition of Kerosene and Post Test Direct Exposure Containers.

Figure 14. Drop Test: Type I Lid Impact Pre Test.

Results

- Damage ratio for the SAVY wat essentially zero
- Small amounts of surrogate released after drop of the Hagan and slip lid
- Slip lid performed so well that one unit was droped from 3.7 m (12 ft). No surrogate release was observed
- Damaged ratios for slip lid and Hagan ranged from 0.0-0.007
- Added te Haggan and SAVY to the DSA as fire rated containers with DR = 0.01 and DR = 0.05 respectively
- Successfully used SAVY and Hagan Containers to comply with 2011 TSR MAR limits

Fire Sprinkler System Activation

The water resistant filter allows the nuclear facility to credit the container as a safety feature to mitigate the risk of a criticality accident in the event of facility sprinkler system activation. Nuclear material storage containers with filters used at the LANL Technical Area (TA) 55 Facility are considered watertight for criticality safety analysis. During normal operations the filters are not exposed to liquid water and no liquid water entry is reasonable. The accident scenarios that would expose the filters to liquid water are identified, and the worst case conditions for water entry are a water pressure of four to six inches of water column for two hours. The results of tests of the carbon bonded carbon composite filter and the SAVY-4000 container filter under the worst case accident conditions are reported. The carbon bonded carbon composite filter used in NucFil-019/-13 type filters shows no water penetration which is

attributed to the thick filter composed of very hydrophobic material. The SAVY-4000 container filters show small water penetration volumes. The difference in behavior is attributed to the much thinner waterproof membrane used in the SAVY-4000 containers. It is recommended that 10 ml of liquid water be used for all filtered containers as a bounding
value for water entry during accident conditions (Figure 15).

Fig. 15. Experimental setup for water Pen.

Fig. 16. Water is seen on filter of SAVY after 2 hr. exposure to 15.3 cm (six in) of water column

Containers with filters used at TA-55 are considered watertight for criticality safety analysis. During normal operations the filters are not exposed to liquid water and no liquid water entry is reasonable. The accident scenarios that would expose the filters to liquid water are identified and the worst case conditions for water entry are a water pressure of four to six inches of water column for two hours. The results of tests of the carbon bonded carbon composite filter and the SAVY-4000 container filter under the worst case accident conditions are reported. The carbon bonded carbon composite filter used in NucFil-019/-13 type filters shows no water penetration which is attributed to the thick filter composed of very hydrophobic material. The SAVY-4000 container filters show small water penetration volumes. The difference in behavior is attributed to the much thinner waterproof membrane used in the SAVY-4000 containers. It is recommended that 10 ml of liquid water be used for all filtered containers as a bounding value during accident conditions.

Small Sample Transport

The container has also been approved to transfer small quantities of solid nuclear material by hand carry between LANL facilities. An integrated work document was developed to that allows hand carrying of radioactive samples, including Radioactive Sealed Sources, between approved less than Hazard Category 3 (<HC3) radiological facilities and between <HC3 facilities as defined by DOE-STD-1027-92, (Hazard

Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23 Nuclear Safety Analysis Reports) and TA-55 Facility PF-4 along Pecos Rd (LANL TA-55, 50, and 35). The intent is to allow the efficient movement of the most common forms of radioactive samples between approved radiological facilities at LANL that are within walking distance of each other. These activities also include hand carrying material from PF-4 to a selected staging area located along Pecos Rd., or from the staging area to PF-4, in support of an over-the-road shipment with OS-PT (Type A quantities or less only). Radioactive samples may be accountable quantities of Category IV SNM as defined by DOE-STD-1194-2011, Nuclear Materials Control and Accountability, but in all cases Category IV SNM quantities approved for hand carrying are limited to <HC3 quantities of material. Hand carry quantities are limited further to those values permissible by the receiving facility. As an additional limit on fissile materials, quantities shall be limited to <HC3 or Less-Than-Significant (SD130, Nuclear Criticality Program), whichever is the lower value. All radioactive samples for hand carry must be packaged in a SAVY-4000 container following approved procedures. Containers for hand carry must be surveyed and released from any radiological facility per P121, Radiation Protection. Containers with a dose rate that exceeds 250 mSv/hr (2.5 mRem/hr) on contact will require an Radiological Work Permit for hand carrying.

WIPP Compliance
The SAVY 4000 container series has been approved and used as a waste container for transuranic waste destined for the Waste Isolation Pilot Plant.
The key performance characteristics for the SAVY-4000 filter are as follows:
Hydrogen diffusivity: > 2.4 E-05 mole/second/mole fraction at 25 degrees Celsius
Filter efficiency: >99.97% of 0.45 micron mass mean diameter poly-dispersed di-octyl phthalate (DOP) aerosol
Resistance to flow: <1” W.C. DP @ 200 ml/min

Internal shipping container in 9977
The 1 quart capacity container and the future 2 quart design both fit inside the 9977 shipping container, and this has facilitated the transport of nuclear material from Idaho National Laboratory to Nevada Nuclear Security Site, obviated the need for repackaging the material for storage upon arrival.

Figure 17. New 2 Qt. 3.7 meter (12 ft.) drop test and result.

Type B Convenience Container
The one-quart SAVY-4000, which has passed a helium leak test after a 3.7 meter (12 ft) drop (Figure 17) will be used in the Type B shipping process. It is clear that the SAVY-4000 is the equivalent of a metal

can with a crimped-seal closure, a slip lid closure, or site-specific convenience containers. The one-quart SAVY-4000 has been designed to fit into the inner containment vessel of both the 9975/9977 Type B containers. Because of the 12.1 cm radius of the one-quart SAVY-4000, it is a perfect size to fit into the 12.7 cm inner diameter of the 9975/9977. Because DOT Type B containers are used to transport relatively large quantities of plutonium, the benefits of using a container that is approved for storage (thus minimizing repackaging upon receipt) are most pronounced. The ability to ship the materials in the container that they will be stored in will significantly minimize the number of steps needed to safely handle the material, and it will make the overall job of the workers handling these materials easier and safer. An elongated version of the one-quart SAVY-4000 has been designed and is in the process of being manufactured to meet the requirements of several different DOE customers. A longer version of the container is needed to fit items taller than the 15.2 cm height of the container. The dimensions for a 9975/9977 are 15.3x38.1 cm and 15.3x50.8 cm respectively; however, any object over 450g must have a spacer within the container minimizing the diameter to 12.7 cm. The elongated version of the one-quart SAVY-4000 will allow users to ship larger materials without the need to break apart or minimize the pieces being shipped. The one-quart container will maintain the 12.1 cm diameter, but will be elongated to around 20.3 cm in order to fit larger materials.

The SAVY-4000 container was initially designed for the protection of workers during the handling and storage of nuclear and radioactive material. However, because the design of the container works so successfully the idea of using it for transportation is worthy of consideration and testing. If the SAVY-4000 is approved as a DOT Type A container as well as an acceptable inner container for the DOT Type B container} it will improve how hazardous materials are shipped. This will create a safer and easier environment for the workers handling the materials as well as cut the amount of waste created from unpacking and over-packing these materials into new containers.

Type A Testing

The SAVY-4000 must meet a series of requirements before it can be certified for use in shipping environments. In order to be qualified as an acceptable DOT Type A container, the SAVY-4000 must pass four major integrity tests {49 CFR 173.465}. The container must pass the following tests:

- Be "dropped in a matter that will cause the most damage" from a height that is deemed "worst case scenario" {1.2 m (4 ft) for non-liquid contents}.
- "Be subjected for a period of at least 24 hours by 5 times the mass of the actual package or the equivalent of 0.7 kg/cm^2 (1.9 psi)"
- Endure a penetration test where a "13.2 pound bar with a diameter of 3.3 cm (1.3 in) and a spherical tip must be dropped from a height of 1.2 meters (3.3 feet) onto the most vulnerable part of the container."
- Water spray test must be run at the beginning of testing and after each of the tests mentioned previously. "The container must be sprayed with water that simulates rainfall of 5.1 cm (2 in) per hour".

If the container passes each one of these tests, it may be certified and used as a DOT Type A container. The requirements for use of the SAVY-4000 container as a convenience container inside a Type B 9975/9977 container are that it must be the equivalent of a metal can with a crimped-seal closure, a slip lid closure, or site-specific convenience containers. Obviously, it must also fit inside the Type B inner container.

The SAVY-4000 container was subjected to a series of preliminary scoping tests intended to bound the accident conditions required by the DOT Type A requirements. A series of drop, penetration and a water spray test were performed. The pass/fail criteria for both material release and water penetration was a helium leak test of 1.47x10-s std cm3/s at 10kPa which corresponds to a worker dose rate of <200mSv (5 Rem) CEDE.

Drop Testing
The SAVY-4000 was dropped from 3.7 m (12 ft) in the orientations as described above. This is the drop height required for storage at LANL's Plutonium Facility, and it exceeds by a factor of three the drop height required by the Type A criterion for non-liquid contents. These orientations are believed to encompass the worst-case drop scenario, including the four 0.3 m free drop tests (preconditioning) required for fissile material. A single container was dropped successively in 4 different orientations, and a second container was dropped successively in the remaining orientations. For each test, the container maintained its seal and passed a helium leak test.

Finally, Los Alamos has recently contracted with Nuclear Filter Technology, Inc. to perform testing to certify the SAVY 4000 container as a DOT Type A liquid transport container.

Penetration Test
A 6kg (13.2 pound) bar with a diameter of 3.3 cm (1.3 inches) and a spherical tip was dropped from a height of 1.2 m (4 ft) onto 3 different points on the container (the filter, a point near the weld and the bottom, see Figure 18) that are expected to be the most vulnerable parts of the container. A helium leak test was performed on the container following the penetration and water spray test. The helium leak rate measured after the penetration and water spray tests was $9.1\text{x}10^{-8}$ atm cc/sec. The SAVY-4000 also passed a water spray test after the penetration insults, and no water was found inside the container. Figures 19-22 illustrate the results of Type A liquid testing, including vibration, stacking, bar penetration and 9.2 m (30 ft) drop tests, respectively. Because the filter allows liquid to escape the container, PVC tape was placed over the filter port. Under these conditions, all results were passing with the exception of the bar penetration test.

Figure 18. Damage caused by penetration bar test.

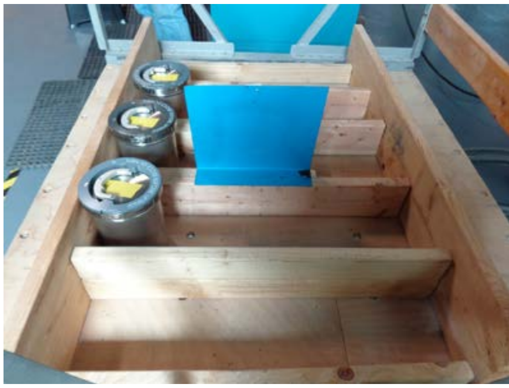

Figure 19. Pre-vibration test

Figure 20. Post vibration test

Figure 20-22. Results of the stacking, penetration and 9.2 m (30 ft) drop tests

CONCLUSIONS

This paper provides an overview of the various testing regimes to which the SAVY 4000 container has been subjected, and describes the resulting versatility of the container for nuclear material containment. The container meets DOE M441.1-1 requirements for storage, and thus prevents worker dose in the event of a dropped container. The container is credited for Material at Risk (MAR) reduction at TA-55 based on fire/drop testing regimes. The containers are demonstrated to be water tight in the event of water sprinkler activation, they are certified for receipt at the Waste Isolation Pilot Plant, and they are approved be used to hand-carry small quantities of radioactive material between LANL facilities. Finally, they have been subjected to Type A liquid testing regimes, and have been found to pass all tests with the exception of the bar penetration test with the filter port sealed with PVC tape.

REFERENCES

1. DOE-STD-1027-92, December 12, 1997, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports

2. Los Alamos National Laboratory System Description SD130 Nuclear Criticality Safety Program