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Initial Engineering Evaluations of the New In-glovebox Container Designs

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ABSTRACT

Containers play a pivotal role in nuclear materials management at Los Alamos National Laboratory and across the Department of Energy (DOE) complex. The complicated nature of constantly crediting containers due to continuously changing requirements, have increased the challenges on defining the containers performance objectives. Issues have emerged that allude to the need for changes in the way containers are managed in specific environments. Factors such as Material-At-Risk (MAR) and Damage Ratio (DR) are well known and documented for containers used outside the glovebox; however, designing containers for in glove-box applications is more complicated with new requirements. A new Requirements Documentation (RD) has outlined the primary performance objectives for in-glovebox use including being able to withstand a glovebox fire, a drop or fall from a minimum height of 12 feet and a leak test that is completed by immersing the container in water to a depth of up to 6 inches above the top of the container for a duration of two hours. The new proposed container has two different closing mechanism designs including an upright strike-less latch design and a Buttress thread design. Initial engineering evaluations show both the latch container and threaded design can achieve a DR value of 0.01 after a drop, but the threaded design is the solely water tight container after the drop. Glovebox fire testing is planned in the near future along with post fire water ingress testing. The new container will also be able to be incorporated into other existing container systems, such as the SAVY-4000. This paper will discuss the various container designs being evaluated for the aforementioned applications.

Introduction

With increasing requirements on crediting the performance of glovebox storage containers there is an increasing need to optimize packing configurations within SAVY-4000 containers for storage outside a glovebox. The SAVY-4000 is the primary outer containment for containers being removed from within a glovebox. It has become apparent that a focused effort to establish a new set of requirements and design specifications in support of a new in-glovebox container is needed. Various aspects of container usage have been considered as part of this effort. These include key parameters such as ergonomics, handling requirements, drop testing, in-glovebox fire testing and water ingress testing[1],[3].

Containers have always played an important role at Technical Area 55 (TA-55) Los Alamos National Laboratory (LANL) and across the Department of Energy (DOE) complex. Due to the complicated nature of crediting containers within the Documented Safety Analysis (DSA) for TA55, issues have arisen that made the need for changes in the way we manage containers. Transitioning to a new set of general use in-glovebox container options will help facilitate a standardized approach which will result in replacing a number of containers currently in use. The transition to one container type and design would greatly reduce user confusion since there will only be one container design in use that meet all necessary requirements while also improving the facility safety envelope. The new general purpose designs will be adequately evaluated prior to implementation against the new requirements document (RD) and approved through the LANL Nuclear Materials Storage and Disposition Board (NMSDB) [2].

The container that is currently widely used for glovebox work, is the Vollrath slip lid container, seen below in Figure 1. This container is a 304 stainless steel (SS) slip top container used across all programs at TA-55 for general in-glovebox use. The slip lid container is tapped to create a seal between the lid and body when packaged for storage outside a glovebox, which the tapped container has not been tested. Further, the slip lid container has never been tested to any set of requirements and thus not certified as water tight with respect to Criticality Safety nor does it have DR value to reduce MAR [4]. MAR values (Material-At-Risk) is defined as the amount of hazardous material available to be acted on by a given physical stress while the DR (Damage Ratio) represents fraction of the MAR that is affected by the accident [11]. The need to replace the container with a tested and certified container is necessary to elevate the possibility of water entry or the adverse results from proposed accident scenarios.

Figure 1. Vollrath slip lid

Performance Requirements Identification

The new RD defines the design requirements for the new general use container designs for glovebox work. The intent behind this document is to capture key aspects of container function and performance considerations across a variety of programmatic process needs for both filtered/vented and hermetic seal containment options [5]. The main drivers for this new container involves Criticality requirements for the container to remain water tight under accident scenarios and MAR credibility for the container to be able to prevent the release of material under accident scenarios. Integration into other existing container systems, such as packaging optimization for use within the DOE Manual 441.1-1 compliant SAVY-4000.

Design selection

The current state of the art nuclear material container filters utilize a ceramic fiber with a polytetrafluoroethylene (PTFE) membrane to achieve a water-resistant filter seal [6]. This membrane will likely become degraded in the event of a fire and the container will no longer be water-resistant. The PTFE membrane will also degrade with exposure to alpha radiation. A new filter has been created with a porous inorganic material with hydrophobic properties that maintains or exceeds the current performance criteria for particulate filtration efficiency, pressure differential, sufficient air flow and hydrogen diffusion. The new filter has the base ceramic fiber with the addition of a perfluorooctyl-trichlorosilane (PFOTS) treatment [6]. The new filter has been implemented into the latch design as seen in Figure 2.

Figure 2. Final prototype for the strike-less design

The latches were tack welded on the container 120 degrees apart from each other. The distance between the final placement of each latch and the lid was dependent on the gasket compression. The desired compression on the gasket is approximately 20%, by estimating the squeeze at 20% compression through the model, the location of the latches were welded into place. The handle on the lid consisted of a 1/8” diameter 316L stainless steel bar, bent in 4 places at 90°. The handle was assembled onto the lid by fitting the ends into small stainless steel housings that are tacked welded onto the lid. The housing for the handle is hollow which allows the handle to rotate freely along its axis. The complete assembly of the strike-less latch design can be observed above in Figure 2.

The container below utilizes a unique buttress threaded design. This unique thread is used to handle extreme axial pulse loading or burst in the axial direction [7]. One side of the thread is perpendicular to the axis while the flank angle is slanted at 45°. The combination equates to a longer thread base for increased shear strength on the threads [7]. This particular design is often used in machinery for sealing type threads. In addition, for this particular design, the features from this thread are relied on for the relief of pressurization. The threads are acting as a tortuous path for gas when significant pressure builds within the container, resulting in the removal of a filter. The sealing will be compensated by also creating a knife edge seal at the contact surface between the lid and the body. This feature will assist with keeping the container water tight. The lid was fully machined from an aluminum bronze material; the two distinct materials were chosen so galling between the threads can be mitigated. A new knob was also machined to assist with closing the threaded lid onto the body. The complete assembly of the Buttress thread design can be observed below in Figure 3.

Figure 3. Final prototype of the buttress threaded design

Preliminary Results

Initial engineering evaluation was conducted on both the threaded and latch designs, testing included water ingress testing and drop testing with a cerium oxide (CeO_2) simulant. The initial engineering evaluation provides a basis for design performance where the water ingress was measured before and after drop testing while also measuring the mass loss to estimate the airborne mass loss (g) and respirable mass loss (g). Measuring the mass loss is key to determining the damage ratio (DR value) for each design while the airborne mass loss and respirable mass loss can then be used to calculate the Airborne Release Fraction (ARF) and Respirable Release Fraction (RRF) which are all properties used to evaluate a release from a container that will affect co-located workers with respect to uptake defined in the Department of Energy Handbook 3010 (DOE HDBK 3010) [9]. The ARF measurement is the fraction of mass that has become aerosolized into the air and the RRF measurement the fraction of mass from the ARF measurement that is now respirable to the co-located workers, for this effort only airborne mass loss and respirable mass loss were investigated due to determining the DR value.

Water ingress testing required the use of a test vessel that held the 6" of water column, timer and a mass balance. Each container was weighed before and after being submersed to determine mass difference. This was done on a Monobloc sr64001 balance with an accuracy of 0.1 grams and a maximum measurement of 64100 grams. The containers were weighted down to eliminate the buoyancy effect that causes the containers to rise as seen below in Figure 4. Both containers remained submerged for 2 hours then pulled and effort was made to dry the outer surfaces before post weight measurement were recorded. Table 1 below, shows the pre drop water ingress results assuming a density of water to be 1g/ml.

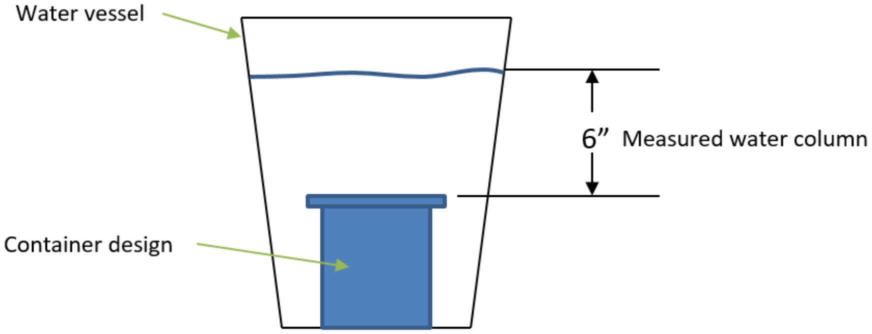


Figure 4. Water ingress testing schematic

Table 1. Pre drop water ingress

Pre-Drop Water Ingress Results	
Latch design	0.9 g
Threaded design	18.4 g

The Respirable Release Fraction Measurement Chamber (RRFMC) is a 20-foot tall, HEPA filtered and airtight drop tower. The maximum drop height is 4.88 m and maximum drop mass is 68.0 kg. The minimum detectable mass value is 2.7×10-7 g (unit density assumed). It is a unique capability for measuring a non-toxic test powder CeO_2 aerosol release from a dropped nuclear material storage container. The system can directly measure ARF and RRF for plutonium and uranium surrogates under various accident conditions [10]. It also equipped with two hi-speed cameras for video capture of the drop impact from two axial directions.

Each container is placed on a platform and lifted by an electric winch, and released at a predetermined drop height. The platform (platen) is pneumatically driven and falls away from the container faster than the container's velocity induced by gravity. After the dropped containers fall onto an impact plate, the filtered air flow in the RRFMC transports any released powder through an air mixer to an aerosol particle counter, where airborne particulate concentrations are measured [10].

In a drop test, background dust on the internal wall surfaces of the RRFMC is re-suspended during impact events. To account for this effect, controlled drops (with no test powder) create a measurable increase in re-suspended aerosol within the RRFMC, and these background values are measured and subtracted from the values with test powder.

For actual drop tests, three replicate tests of controlled drops (with the same potential energy of the tested container) were performed to measure the background resuspension aerosol. The background values for the respirable and airborne mass are determined at different potential energy values. These values are variable from drop to drop; therefore, the background must be determined for each drop, especially in the cases of significant powder release from previous experiments. The container potential energy in Joules can be determined from equation (1) [9].

$$PE = m * g * h \tag{1}$$

where:
m = container mass
g = gravitational acceleration, and,
h = drop height

The container potential energy for a drop height of 12' is 324J, the average respirable mass and average airborne mass are calculated for each design and can be seen within Table 3 and 5. The amount of release respirable material is defined as the Source term in equation (2), S(g) where [9].

$$S(g) = MAR * DR * ARF * RF * LPF \tag{2}$$

MAR(g) = Material At Risk
DR = Damage Ratio=ms/MAR
ARF = Airborne Release Fraction = ma/ms
RF = Respirable Fraction = mr/ma
LPF = Leak Path Factor, assumed to be 1.0 for container testing

Furthermore:
ms(g) = spilled mass
ma(g) = the mass of airborne (aerosolized) material, and,
mr(g) = the respirable mass of airborne material defined as less than 10 μm aerodynamic equivalent diameter.

In each drop, the angle was noted both before the drop and at the time of impact. The angle at impact is determined based on the high speed video footage, using the edge of the impact plate as the zero datum and determining the angle of the container based on that datum using a digital angle finder held against the computer screen. The drop angle chosen was the orientation of center of gravity over top corner of the container (CG over top corner), this orientation is considered to be worst case and will impose the most damage onto the container.

The latched design was dropped with a payload weight that is considered to be the maximum for the 3 qt size, the simulant was inclusive with the payload. The container payload was comprised of metal shot to achieve the desired test mass with loose CeO_2 powder directly on top of the shot as seen in Figure 5. The details of the drop are included in Table 2.

Table 2. Latch container drop testing results

CeO2 MAR (g)	401.1
Gross Weight Pre-Drop (g)	9001.5
Gross Weight Post-Drop (g)	9001.6
Released Mass, dm (g)	1.8
Drop Orientation	CG over top corner
Pre-Drop Angle	46.7°
Drop Height (ft)	12
Drop Energy (joules)	324
DR value	4.5E-03

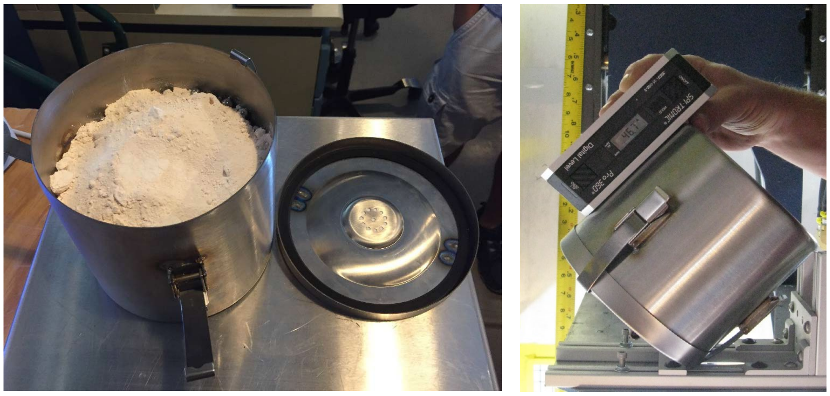


Figure 5. Latch container payload and drop angle determination

When the container hit the impact plate in Figure 6 below, the container deformed and released test powder into the air. Two of the three latches popped open during the impaction, but the lid stayed on. White test powder was spilled on the impact plate, after testing the spilled test powder was swept up and collected, and the remainder was vacuumed up into an analytical open face filter holder. The total collected test powder weight was approximately 1.8037 g [10].

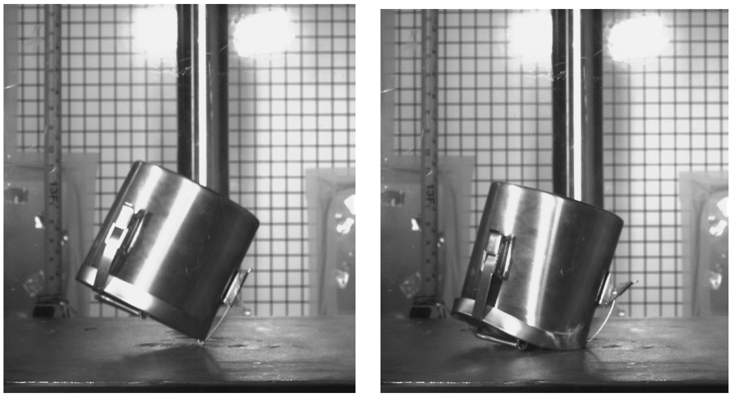


Figure 6. Latch container impact

The gross weight of tested container before drop was 9001.5 g, the gross weight after drop was measured as 9001.6 g. Although, in Figure 7 below you can slightly see CeO2 powder on the impact plate. There is a measurement discrepancy between the initial and final gross weight of the container and the measured released mass. There was a two day time interval between the initial weighing and the drop test. Cerium oxide is hygroscopic, and it is possible the CeO_2 powder absorbed water vapor and increased the overall mass of the container.

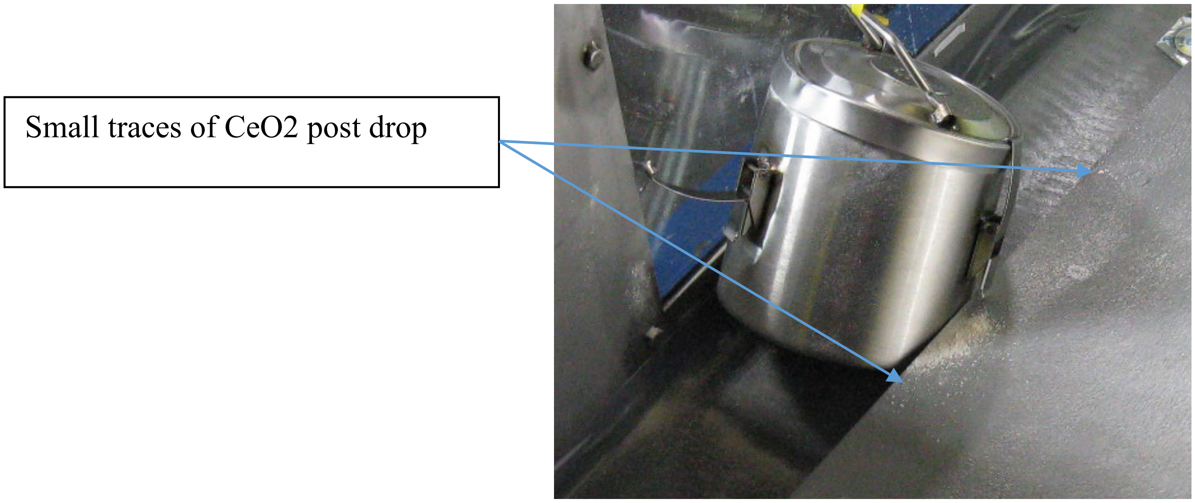

Small traces of CeO2 post drop

Figure 7. Latch container post drop impact image

After subtracting the 324 J facility background from the measured respirable mass and airborne mass, the net respirable mass and net airborne release can be found in Table 3.

Table 3. Spilled (released) mass results of the Latch container

	Respirable mass, g	Airborne mass, g
RRFMC Background at 324 J	6.02E-05 ± 5.41E-05	9.11E-05 ± 8.39E-05
Net Latched design	1.94E-02 ± 1.31E-03	3.22E-02 ± 2.12E-03

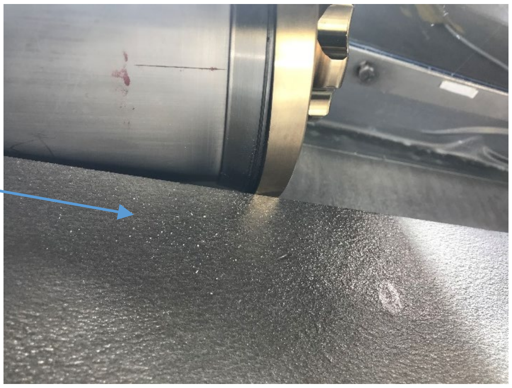
The threaded design was dropped with a payload weight that is considered to be the maximum for the 3 qt size, the simulant was inclusive with the payload. The container payload was comprised of metal shot to achieve the desired test mass with loose CeO2 powder directly on top of the shot as seen in Figure 8 along with the container impact . The details of the drop are included in Table 4.

Table 4. Threaded container drop testing results

CeO2 MAR (g)	402.5
Gross Weight Pre-Drop (g)	9003.7
Gross Weight Post-Drop (g)	9003.7
Released Mass, dm (g)	0.0872
Drop Orientation	CG over top corner
Pre-Drop Angle	41.5°
Drop Height (ft)	12
Drop Energy (joules)	324
DR value	2.17E-04

Figure 8. Threaded container payload and impact images

When the container hit the impact plate as seen above in Figure 8, the container deformed and the lid jumped a thread but stayed on. No visible powder puff was observed in the hi-speed video. However, test powder was observed on the impact plate after the drop [10]. The spilled powder can be observed in Figure 7.



Small traces of CeO2 post drop

Figure 7. Threaded container post drop impact image

After subtracting the 324 J background from the measured respirable mass and airborne mass, the net respirable mass and the net airborne mass released can be found in Table 5.

Table 5. Spilled (released) mass results of the Threaded container

	Respirable mass, g	Airborne mass, g
RRFMC Background at 324 J	6.02E-05 ± 5.41E-05	9.11E-05 ± 8.39E-05
Net Threaded design	5.59E-04 ± 6.81E-05	8.90E-04 ± 1.10E-04

The latched design container test revealed a vulnerability in a CG over top corner drop. Two latches opened in the latched design drop test, with one of those latches coming completely unlatched. Examination of the container after the drop revealed a visible gap between the lid and the container body seen below in Figure 8. The Damage Ratio values for both design types are well below 1% material loss providing a positive closure mechanism with minimum release after an accident scenario and a DR value of at least 0.01.

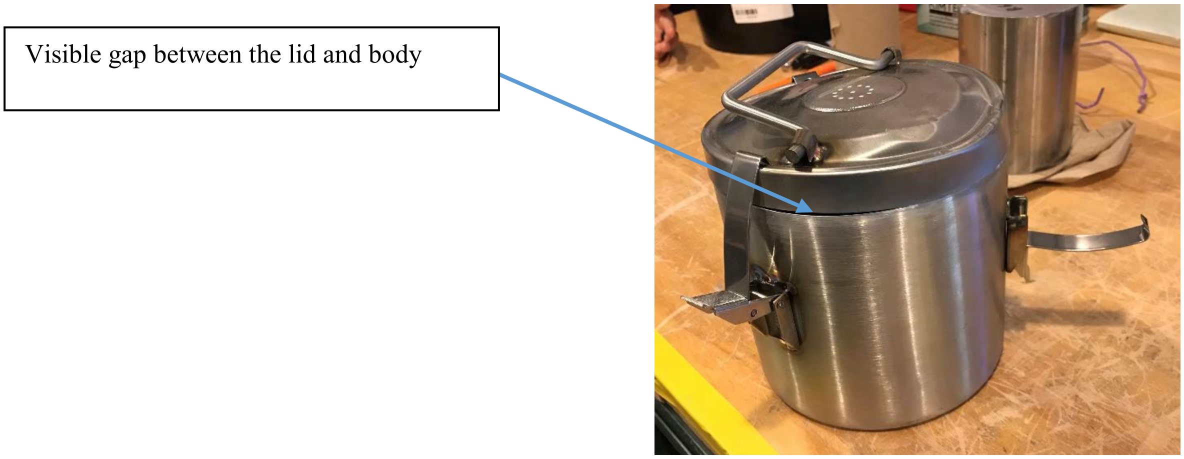


Figure 8. Latch container post drop deformation

Due to the latch design experiencing enough deformation to create a gap between the lid and body, the container was not tested for water ingress, under the current test requirements the container would have filled entirely with water. In contrast, the threaded design was water resistant after the drop results can be seen in table 6.

Table 6. Post drop water ingress results

Pre-Drop Water Ingress Results	
Latch design	N/A
Threaded design	41.1 g

Conclusion

The new prototypes show promise for performance testing based on functionality checks and initial engineering evaluations. Functionality checks included opening/closing of each design and the overall engineering judgment on sealing with emphasis on performance while initial engineering evaluations composed of water ingress testing and drop testing with a plutonium simulant for DR, airborne mass and respirable mass values estimations. Water ingress testing was completed under 6” water column (W.C) for 2 hours while trying to prevent the entry of no more than 50 mil. of water followed by dropping testing at the RRFMC. Glovebox fire testing was not conducted on these containers due to not having access to a convection oven that meets the glovebox fire requirements, this testing is will be completed in the near future. Results show the latched design is water tight at a pristine state while drop testing reveals a 1.8037 g powder loss resulting in DR value of at least 0.01 with minimum airborne mass and respirable mass values, due to the deformation caused at impact the container was not tested and cannot be considered water tight post drop. The threaded design also showed to be water tight at a pristine state while drop testing reveals a 0.00872 g powder loss resulting in a DR value of at least 0.01 with minimum airborne mass and respirable mass values, the threaded design also passed post drop water ingress testing and therefore can be considered water tight after a drop scenario. The threaded design container had about two orders of magnitude less mass loss than the attached design container. Currently, the threaded design container shows more promise than the latched design but, design consideration are being made for better latches.

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