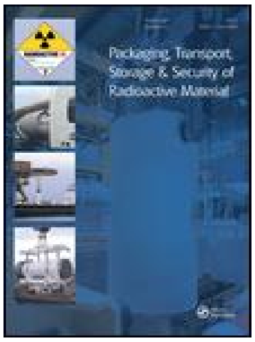

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New generation standard nuclear material container

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Nuclear Filter Technology (NucFil) is working with the Los Alamos National Laboratory (LANL) to design a nuclear material storage container that complies fully with the requirements of DOE M 441·1-1. LANL provided NucFil with a specification that outlines requirements to comply with the manual, as well as to satisfy specific needs of their own. NucFil has taken this specification and designed a container known as the new generation standard nuclear material container (NG SNMC). The premise of the design is a simple, robust container that is easy to use. The sealing mechanism is a single large cross-section, low durometer o-ring. The large cross-section provides a tight seal that has enough elastic rebound to compensate for any distortion of the sealing faces after a potential drop. The low durometer keeps the force required to open and close the container low. Once compressed, the seal is kept in place by a bayonet style closure that is locked in place by a positive mechanical engagement. The components of the container exposed to the load are manufactured of corrosion resistant 316L stainless steel. The container has a filter made of a heat resistant ceramic fibre to retain particles after a fire, and a water resistant membrane to keep moisture out of the container. Pewter shielding can be attached and is latched in place. These features are present in all seven sizes of the NG SNMCs, including 1, 3, 5, 8 and 12 quart and 5 and 10 gallon.

Keywords: Radioactive, Packaging, Storage, Nuclear, Containment

Introduction

Nuclear Filter Technology, LLC (NucFil), has been contracted by the Los Alamos National Laboratory (LANL) to design and test a series of containers for the storage of nuclear materials. The criteria that drive the design of each container is a combination of LANL's interpretation of the US Department of Energy 'Nuclear Material Packaging Manual',[1] and LANL site specific requirements. NucFil applied these criteria and created a series of containers in seven sizes, 1, 3, 5, 8 and 12 quart and 5 and 10 gallon (1, 3, 5, 8, 12, 19 and 38 L). The design series is referred to as the new generation standard nuclear material container, or NG SNMC.

The NG SNMC is designed to be a simple, robust, reusable storage container that is easy to use and can be opened and closed without the use of tools. The sealing mechanism is a single, large cross-section fluoroelastomer o-ring in a piston groove. The durometer of the o-ring is 50 shore A and is made intentionally 'soft' to reduce the force required to close the container. Additionally, the piston seal has been selected for its elimination of time consuming bolt closures traditionally used in face seals. Once the o-ring is compressed, the container is kept sealed by rotating the handle 36°, engaging the bayonet style lock. A spring loaded pin keeps the handle from rotating back unintentionally. A photograph of the 8 quart (8 L) container is shown in Fig. 1.

Design criteria

The criteria of particular importance for the NG SNMC design are thermal performance, corrosion resistance, radiation resistance, filter performance, containment and drop resistance. These criteria guided the container design.

Thermal performance

The payload heat resistance is the ability of the NG SNMC to resist the temperatures generated by the nuclear material placed inside. The criterion is defined as an internal 25 W heat source while the container is sitting on a shelf surrounded by other containers. This criterion is addressed in the container design by the selection of o-ring and filter materials with high temperature resistance.

Corrosion resistance

The corrosion resistance criterion is that the metal components of the container exposed to the internal load must be made of 316L stainless steel. Compliance

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1 8 QT NG SNMC – patents pending

with this criterion is accomplished by specifying the material type on the design drawings.

Radiation resistance

The criterion for radiation resistance is that the NG SNMC must comply with the containment criterion while exposed to $6{\cdot}6\times10^4$ rad/year of X-ray/gamma and $1{\cdot}2\times10^6$ rad/year alpha (45 μm layer) radiation. This criterion is addressed in the container design by selecting o-ring and filter materials with high radiation resistance.

Filter performance

The filter performance criteria are that the filter must: provide a minimum hydrogen diffusivity rate of $2{\cdot}4\times10^{-5}$ mol H_2/s/mole fraction; deliver a minimum flowrate of 200 mL min^{-1} of air at no more than 1′′ water column differential pressure; capture greater than 99·97% of 0·45 μm mean diameter aerosol at the rated flow (efficiency); prevent water entry with up to 12′′ (305 mm) water column pressure; and retain 20% of efficiency and flow after being exposed to 500°C for 2 h. NucFil designed a filter specifically to meet these requirements. The 500°C requirement is the most stringent and required the generation of a new filter. In order to maintain filtration at the high temperature, the filter is created from microdiameter ceramic fibres. The hydrogen diffusivity, flowrate, and particle retention are all standard filtration criteria and define the size, density and thickness of the filter element built into the lid. The water entry requirement necessitated the addition of a hydrophobic membrane to keep water from entering the container.

Containment

The containment criteria are that the NG SNMCs must be leak tight to a rate of $1{\cdot}2\times10^{-6}$ standard cc s^{-1} of helium at an internal differential pressure of 1 kPa and have a minimum design life of 5 years. The seal orientation and o-ring selection are designed specifically to comply with the leak tight criterion. The o-ring and filter material selection are key to identifying a minimum 5 year service life.

Drop resistance

The drop criterion is that the NG SNMC must be leak tight to a rate of $1{\cdot}0\times10^{-4}$ standard cc s^{-1} of helium at an internal differential pressure of 1 kPa after being subject to a drop from 12 feet (3·66 m) with its maximum potential payload onto an essentially unyielding surface (1/2′′, 13 mm thick steel plate on concrete). Compliance is shown by subjecting multiple specimens of each size to a drop and then measuring the containers ability to retain helium (note, the testing is performed through the filter port as the filter itself can not retain helium). Additionally, the filter must retain its performance characteristics after the drop.

Primary sizes

Certain dimensional characteristics of the design are specified by LANL based on facility needs. The container body wall is restricted to a thickness of 0·0299′′ (0·76 mm), and all sizes must fit within the next larger size. Additionally the overall dimensions are restricted. Table 1 shows the approximate primary sizes of the NG SNMC.

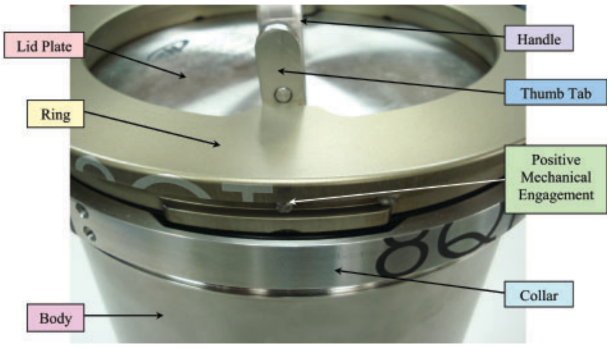
Table 1 shows the gross weight of each size. These values were specified as the weight at which drop resistance must be proven. The containers may be capable of storing more weight than listed, but the drop resistance would be unproven.

Design features

The NG SNMC is designed to be simple to use and yet still provide a tight closure to retain the nuclear materials safely. When fully assembled, there are

Table 1 Approximate primary NG SNMC sizes

Size	Overall height, in	Usable height, in	Outside diameter, in	Inside diameter, in	Empty weight, lb	Gross weight, lb	Load weight, lb
1 QT	6·0	4·8	4·77	3·67	3·3	22	18·7
3 QT	8·0	6·8	6·55	5·45	5·3	33	27·7
5 QT	10·0	8·8	7·70	6·60	6·8	40	33·2
8 QT	11·5	10·3	8·85	7·75	9·3	44	34·7
12 QT	14·0	12·8	10·00	8·90	13·7	49	35·3
5 GAL	15·5	14·0	11·75	10·25	18·3	55	36·7
10 GAL	17·0	15·5	15·00	13·50	31·5	88	56·5



2 Bayonet detail

effectively two components of the container, the body and the lid. The body is composed of a deep drawn, 22 gauge 316L stainless steel container and a machined 'collar' made of 316L stainless steel. The collar is one of the two components that the o-ring compresses against to achieve a seal. The deep drawn container and collar are joined together using laser welding in an effort to reduce the thermal distortion caused by tungsten, inert gas welding. This reduction in distortion assists in keeping the o-ring sealing surfaces circular so the compression is even around the periphery.

The lid is composed of four main pieces, which are the lid plate, the locking ring, the filter and the handle. The lid plate is the opposing component that the o-ring compresses against to achieve a seal and is machined from 316L stainless steel. The locking ring, machined from 7075 aluminium attaches to the lid plate with shoulder screws that allow the two components to rotate independently. This independent rotation is key to reducing o-ring distortion. Once the lid is pressed into the body, the locking ring is rotated into the locked position but the lid plate remains stationary. This means there is no movement of the o-ring, keeping all unnecessary stresses out and increasing its useful life. Figure 2 shows one lug of the bayonet closure as the lid enters the body as it would during normal operation. Table 2 gives a description of each component.

The filter is assembled into the centre of the lid plate on the inside of the container so there can be no tampering with the filter once the NG SNMC is closed. The container is designed for the storage of solid nuclear materials. Since the container is filtered, it has not been designed to withstand any significant internal pressure, nor can the container store free liquids.

In an effort to minimise decontamination efforts, the interior of the NG SNMC has a surface finish better than 63 μin. Additionally the laser welding that joins the body and the collar is on the inside of the container eliminating any 'overlaps' for contaminates to attach.

There are 10 holes on the exterior of the collar. The top set of holes is utilised as the receptacles for the pin that keeps the lid from unlocking unintentionally. The lower set is designed to shed water from the top of the container.

The lid and body have been designed such that the lid can be attached to the body in any of the five orientations. There is no one correct way to attach the lid eliminating any unnecessary operator time (potentially accumulating dose) in orienting the lid to the body.

Operation

The opening and closing of the container takes significantly less time than any bolted flange closure. An experienced operator can open and close the container in a matter of seconds.

To close the container, the operator aligns the lid so the lugs match the gaps in any orientation. The operator then releases the handle and places both palms on the locking ring and presses down with equal force until the o-ring compresses and there is metal to metal contact. The operator releases the locking ring and rotates the handle clockwise to the positive stop (36°). The container is now closed and locked.

To open the container, the operator uses his/her thumb to withdraw the spring loaded pin using the 'thumb tab' which is attached to the handle. The operator then rotates the locking ring counter-clockwise to a positive stop and then lifts the handle at an angle. Lifting at an angle is key to reducing the force required to open the container. Trying to lift straight forces the operator to overcome the friction of the entire o-ring engagement, where lifting at an angle requires overcoming only a fraction of the friction.

Table 2 Component description

Component	Description
Lid plate	The lid plate of the NG SNMC is designed to be motion free in this container. The lid plate requires no rotation to achieve a seal, alleviating any stress accumulation or twisting that can occur when an o-ring is compressed with rotation. It is computer numerical control (CNC) machined out of stainless steel with the filter as an integral part of the Lid, keeping it from protruding out of the container.
Handle	The handle is the component of the NG SNMC responsible for opening and closing the container as well as providing a positive mechanical engagement. It is designed for use with either the left or right hand and lies flat in the storage position. The handle is an integral part of the ring.
Thumb tab	The thumb tab is an integral part of the handle and ring and is welded to the positive mechanical engagement. Pressing on the thumb tab 'unlocks' the container so the ring can be rotated to the open position.
Ring	The ring is designed to be CNC machined out of aluminium. Once the lid is pressed in, the ring is rotated by turning the handle, securing it into place with the collar.
Positive mechanical engagement	Keeps the container closed by restricting the ring from rotating to the unlocked position un-intentionally.
Body	The body is designed to be deep drawn out of stainless steel chosen for its corrosion resistance, strength and weight. The height will be cut to accommodate container nesting. The cans will be permanently laser etched with the required identifications and markings.
Collar	The collar is designed to be CNC machined out of stainless steel and laser welded to the body.

Testing

In an effort to confirm compliance with the design criteria, the NG SNMC has been subjected to a series of tests including filter efficiency, water entry, hydrogen diffusion, fire and drop.

Filter efficiency testing

The particle removal efficiency of the filter was tested by inducing a flow of aerosol through the filter. The aerosol particles are controlled in size and the flow is regulated. The aerosol particles were then measured using a forward light scattering photometer on the opposite side of the filter to determine a percentage of the particles that are retained. The pressure differential across the filter is also measured. The higher the pressure drop, the more 'clogged' the filter is.

Water entry testing

Water entry testing is used to determine the pressure at which water will begin to enter the container. The result of the test showed that the water entry pressure is far in excess of the criterion of 12′′ water column.

Hydrogen diffusion testing

A filter's diffusion is affected by its exposed surface area acting like a nozzle in a valve, so the larger the filter, the larger the diffusion. Diffusion testing was conducted to determine the appropriate size filter to comply with the requirement of $2{\cdot}4\times10^{-5}$ mol H_2/s/mole fraction. The result is a filter element nearly 1·5′′ (38 mm) in diameter.

Fire testing

To ensure the container was capable of retaining nuclear material in a fire situation, a simple fire test was conducted. The requirements of the fire test are specified by LANL based on their worst case storage condition fire scenario. The test involved loading the container with commonly used packing materials of cellulose and plastics. For cellulose, the container was loaded with 400 g of paper and for plastic, 200 g of polyvinyl chloride. One hundred grams of a simulated nuclear material called magnetite was measured and then added to the container. The lid was sealed and the container was placed in a kiln at 500°C for 2 h and then allowed to cool. After the test, the container was opened and the magnetite measured. The result was that none of the magnetite escaped the container. The filter was also tested to ensure that it had not become clogged during the test.

3 8 QT drop test

Drop testing

Drop testing proved to be the most difficult of all the criteria to satisfy. The design of the container was altered three separate times in an effort to show that the container could withstand an impact from 12 feet loaded with its gross weight. Figure 3 shows an image of an 8 quart container just after impact. The device you see with the container is a low friction, orienting fixture. The fixture ensures the container does not rotate during the drop and the desired orientation is maintained.

The testing conducted to this point has assumed a worst case orientation of the containers centre of gravity over the locking device. After the three modifications to the container, a design was created that resisted the stresses of a drop where the container complied with the leak criterion after impact.

Conclusion

The NG SNMC has been designed and tested to meet a set of criteria specified by the Los Alamos National Laboratory, and their interpretation of the US DOE 'Nuclear Material Packaging Manual'.[1] The NG SNMC was designed to be a reusable, simple to use, robust set of containers for the storage of nuclear materials.

Reference

1. US Department of Energy: 'Nuclear material packaging manual', III-2 to III-4, 2008.