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Revision History

Document Number	Effective Date	Action	Description
1.0	04/22/15	New Plan	Initial plan document.
1.1	04/24/2015	Revision	Removed references to hazards and controls, which are not needed in a plan document.

SAVY 4000 Container Filter Design Life and Extension Implementation

LA-UR-15-22395

April 2015

Murray E. Moore, Kirk Reeves, D. Kirk Veirs, Paul H. Smith, Timothy A. Stone

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1.0 INTRODUCTION

1.1 Overview

The SAVY 4000 is a general purpose, reusable container for the storage of solid nuclear material inside a nuclear facility. The canister has a permitted loading for material with a thermal output not to exceed 25 watts. This wattage limit applies to all containers, regardless of their size.

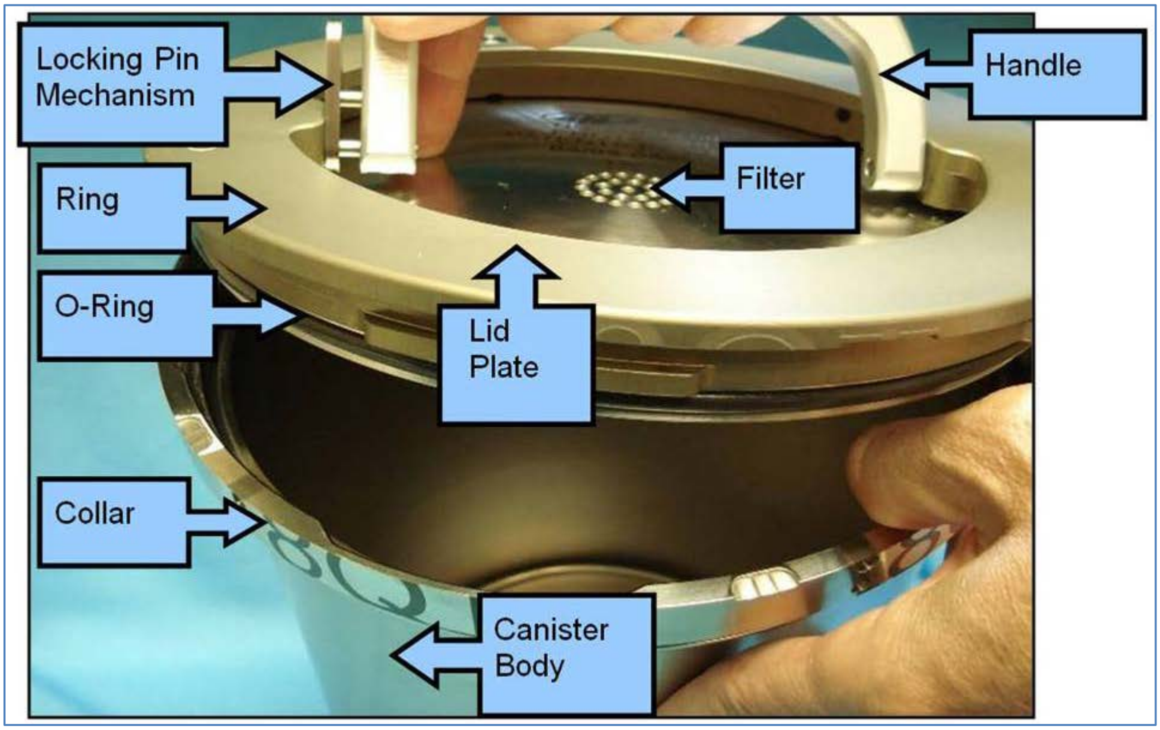

Figure 1. The Primary Components of the SAVY 4000 Container Series

The SAVY 4000 container lid has an integrated filter of silica and alumina fibers that prevents pressurization and hydrogen build-up inside the container and prevents particulate release. The filter is protected on its' upper (external) surface by a polytetrafluoroethylene (PTFE, e.g Gore-TEX®, Teflon®) membrane that allows gases to pass through the filter but blocks liquid water, thereby facilitating shedding of water.

1.2 Purpose

The scope of this document describes the plan to examine the filter design life and extension implementation of the SAVY 4000 canister. This includes monitoring and measuring the long term performance of the filter and membrane components. A desired in-service life of 40 years or more would substantially reduce the number of containers requiring periodic repackaging and/or container maintenance. A longer life for the containers would also reduce worker exposure and costs.

1.3 Scope

Extending the in-service life of the PTFE membrane, and therefore the design life of the SAVY 4000 will be based on laboratory studies of the PTFE membrane under service conditions over the first five years of container usage. (The PTFE water resistant membrane outside the ceramic filter material is not considered part of the containment barrier.)

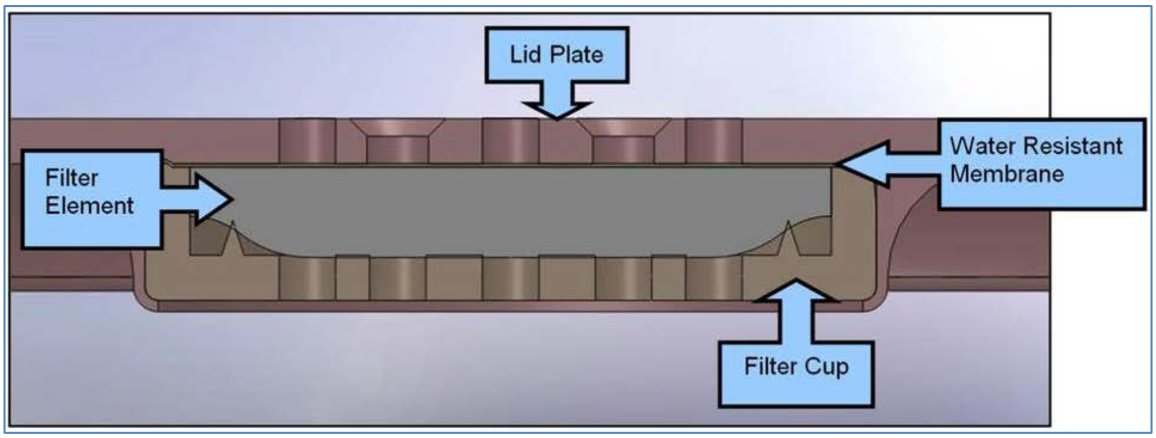

Figure 2. Filter Assembly Schematic

The life-limiting components of the SAVY 4000 design are the Viton®-based o-ring and the PTFE membrane which is known to be susceptible to degradation after exposure to elevated temperatures, acidic environments, and ionizing radiation (Anderson LL et al 2013). The ceramic fibers of the filter are part of the containment barrier, whereas the PTFE membrane is not. In the SAR (Safety Analysis Report for the SAVY 4000), radiation resistance is satisfied through material selection, as well as design configuration.

The PTFE membrane is backed by a connective layer, or scrim (of non-woven polyester), which prevents degradation of the PTFE membrane. The lid assembly consists of a stainless steel lid containing an alumina fiber ceramic filter and an external PTFE membrane (above the filter material). The filter assembly or “puck” is pressed into a machined receptacle on the underside of the lid and crimped in place. Neither the filter element nor the water-resistant membrane is sealed with adhesive.

The NFT Test Plan identified the Viton®-based o-ring and the PTFE filter membrane as having the lowest-service temperatures of all the container components. (The maximum operating temperature of the PTFE membrane is 130 °C.) Therefore, the o-ring and the PTFE membrane were expected to suffer degradation and failure due to elevated temperature exposure before any of the other component materials.

The filter element is composed of ceramic fibers held together by a binder, but the actual material specifications are proprietary to NFT. The fibers of the filter element create a torturous path which captures particulates while allowing the passage of gas. Gas flow through the filter maintains an equalized interior pressure in the SAVY 4000 canister, compared to the surrounding ambient atmosphere. Additionally, the filter allows gas to diffuse based on partial-pressure differential.

Per design specification requirements, the semi-permeable membrane of the NG SNMC (a.k.a. the new generation SAVY 4000 nuclear canister) shall "prevent water entry up to 12 inches water column differential pressure." The semi-permeable membrane (Gore-TEX™) is a purchased item, patented and manufactured by W. L. Gore & Associates, Inc. (Newark, DE).

Information provided by Gore identifies that the semi-permeable membrane (MMT-341 material) is composed of an expanded polytetrafluoroethylene (PTFE) layer with a radiation resistant support known as a scrim (non-woven polyester). According to the manufacturer this material retains its water resistance after radiation exposure in excess of 10 times the specified amount. As a result, the semi-permeable membrane of the SAVY 4000 is considered to comply with the radiation resistance design specification requirements.

The filter is designed to allow for a minimum hydrogen gas diffusivity rate of 2.4 x 10-5 mol s-1 mole– fraction-1, to deliver a minimum of 200 cm3 min-1 of air at no more than 0.25 kPa pressure differential, to capture greater than 99.97% of 0.45 µm mean diameter DOP aerosol at the rated flow with a DOP concentration of 65 ± 15 µg l-1, to prevent water entry up to 3.0 kPa, and to capture greater than 99.0% of 0.45 µm mean diameter DOP aerosol at a minimum 200 cm3 min-1 of air at no more than a 1.25 kPa differential pressure after being subjected to a thermal environment of 500 °C for a period of two hours.

The LANL (LA-CP-12-00204) specification for (Hagan and SAVY) storage canisters requires the filter shall

- Deliver a minimum of 200 ml/min of air at no more than 1.0 in. water column pressure differential,

- Capture greater than 99.97% of 0.45 micron mean diameter DOP (dioctylphthalate) aerosol at the rated flow with a DOP concentration of 65 ±15 micrograms per liter

Additionally, related to the PTFE (Teflon®) membrane, the filter shall:

- Resist water entry such up to an equivalent pressure of 12 in. water column.

Extending the in-service life of the PTFE membrane, and therefore the design life of the SAVY 4000 will be based on laboratory studies of the PTFE membrane under service conditions over the first five years of container usage.

1.4 Technical Safety Requirements (TSRs)

This procedure does not directly implement any TSR controls.

1.5 Definitions

Term	Definition
DOP	1) Detailed Operating Procedure 2) Di-octyl Phthalate oil
FLM	First Line Manager
FOD	Facility Operations Director
Hagan	A threaded-top stainless steel container with an o-ring seal and a filter installed in the lid.

Term	Definition
NFT	(aka Nuclear Filter Technology, Golden CO)
RP	Radiological Protection
RWP	Radiological Work Permit
SAVY 4000	A stainless steel container with a bayonet-style o-ring closure mechanism with a locking ring and a filter integrated within the lid. All approved SAVY 4000 containers are labeled with “SAVY 4000”.
SNMC	Legacy term for nuclear material containers, that is, Hagan containers, SAVY 4000 containers and filtered 5- and 10-gallon closure-ring drums.
TA	Technical Area

2.0 RESPONSIBILITIES

2.1 First Line Manager

- Responsible for implementation of this procedure.
- Verifies personnel performing the work are fit for duty, trained, and authorized to perform the activity.
- Maintains awareness of and concurs with the selection of the designated person-in-charge (PIC) and alternate PIC.

2.2 Person-in-Charge (PIC)

- Acts as the evolution supervisor.
- Conducts pre-job briefings.
- Confirms compliance with required initial conditions and other prerequisites.
- Ensures applicable paperwork filed.
- Ensures the presence of two people qualified and authorized to perform this procedure.

2.3 Worker

- Responsible for quality.
- Responsible for completing required training.
- Ensures fitness for duty.
- Ensures the presence of two people authorized to implement this procedure, when applicable.

3.0 PERFORMANCE

This section contains a list of possible activities for the container design life and extension program. The activities will be evaluated and approved by two SMEs before they are performed. Extending the in-service life of the PTFE membrane, and therefore the design life of the SAVY 4000 will be based on laboratory studies of the PTFE membrane under service conditions over the first five years of container usage.

3.1 Measure the aerosol capture rate of selected filters over the period of five years.

1. The aerosol capture might be affected by morphological changes in the PTFE membrane. Regular testing will monitor this possibility. Compare this to an operational filter which must capture greater than 99.97% of 0.45 micron mean diameter DOP (dioctylphthalate). (LANL uses PAO, polyalphaolefin, oil as a substitute material for aerosol generation.) At the rated air flow rate, there must be an aerosol (DOP-PAO) concentration of 65 ±15 micrograms mass of aerosol per liter of air.

3.2 Measure the pressure drop of selected filters over the period of five years.

The pressure drop created by the test air flow could change if structural or physical changes occur over the lifetime of the canister filter-membrane composite.

- Compare this to an operational filter which must deliver a minimum of 200 ml/min of air at no more than 1.0 in. water column (0.25 kPa) pressure differential.

3.3 Test the resistance of representative samples of the membrane-filter to water infiltration up to a positive pressure of 12 inches water column.

The amount of water that penetrates through a filter would be measured and recorded. Each SAVY 4000 is tested to ensure that the filter-membrane combination resists water entry in accordance with specifications.

- Compare this to an operational filter which must prevent water entry up to 12 in. water column.

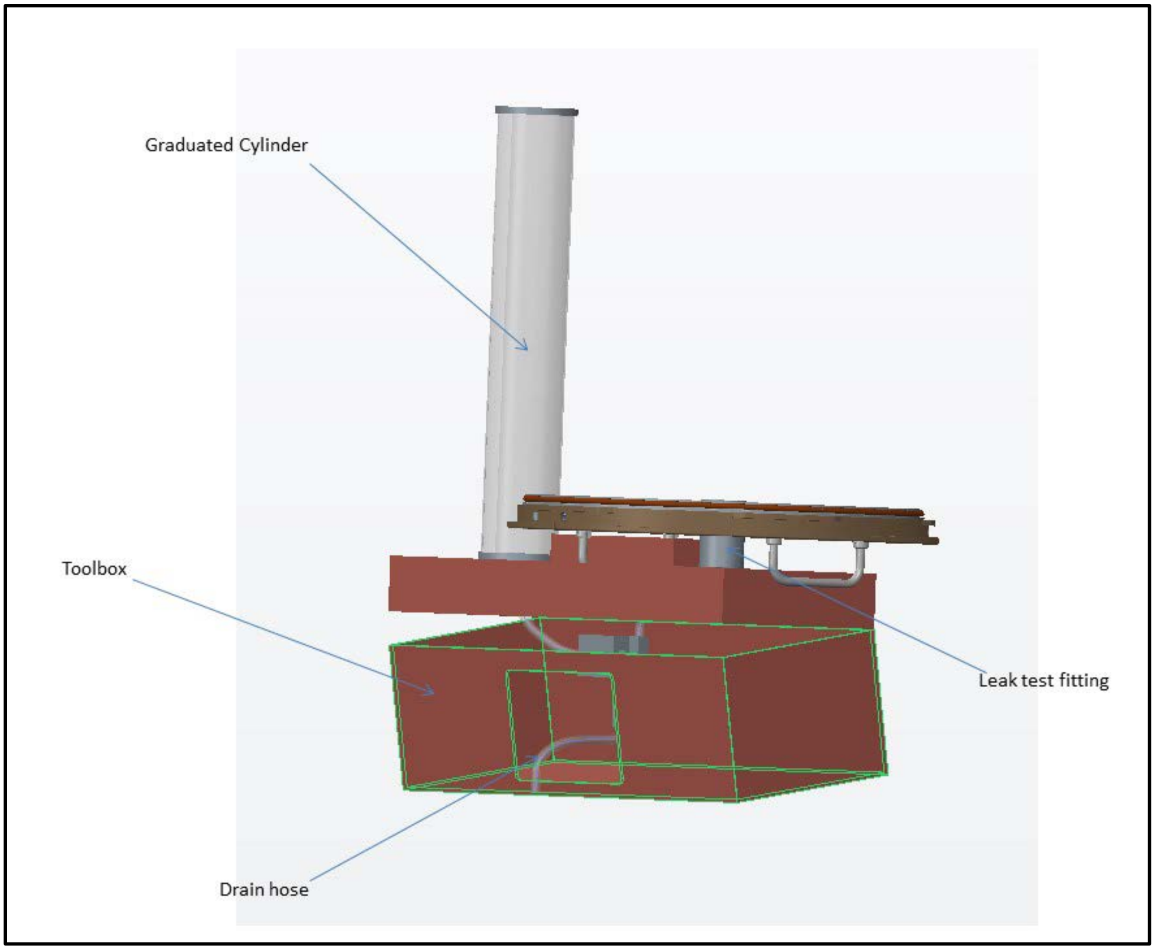

Figure 1. Conceptual drawing of future water leak testing system.

3.4 Optional: Obtain photographs (SEM - scanning electron microscope) of the membrane from representative filter-membrane samples over a period of five years.

1. Morphological changes could be noticed if the materials were photographed on a regular interval. See Appendix 5 for an example of a published study that documented these effects.

3.5 Testing

In the opinion of two SMEs, if a performed activity has the potential to affect the performance of a canister system, measurements can be executed on a set of reference items. The results of these tests and a relevant discussion will be included in the work plan documentation.

3.6 Results

Relevant results will be recorded in updated versions of this procedure.

3.7 Verification/Independent Verification

Not Applicable.

3.8 Records Processing

Records generated by the performance of this procedure are updated into databases that are governed by other procedures and Programs.

4.0 REQUIREMENTS

NOTE 1 The section and the steps in the Performance section are not required to be performed in sequence, unless otherwise stated.

4.1 Planning and Coordination

- A work plan shall be developed for each activity. Relevant descriptions, goals, and requirements will be attached to the sketch sheet. Two SME signatures will be required for concurrence on the activity. After the activity is performed, this document package will be attached to the appendix through a procedure change form. Relevant modifications to the system diagrams, component lists, etc will be performed and added to this procedure.

- The LANL Aerosol Engineering Facility (TA-03-0130) can be used as a staging area for collecting materials, work planning and troubleshooting.
- If required, materials, tools and equipment shall be moved into TA-55 Room 6A before the work is performed.

4.2 Performance Documents

- Applicable documents will be listed here.

4.3 Special Tools, Equipment, Parts and Supplies

Possible tools needed for work with the TA-55 FTS system would include:

1. Hand tools (screwdrivers, wrenches, wire cutters, pliers, etc.)

2. Polytetrafluoroethylene (PTFE, i.e. Teflon™) tape for assembling threaded fittings

3. Dow-Corning High Vacuum grease

4. Various NPT fittings

5. Quick connect fittings (e.g. http://www.pisco.com/index.htm, http://www.smcpneumatics.com/)

5.0 MEASURES OF PERFORMANCE

Not applicable.

6.0 REFERENCES

Anderson LL, Blair MW, Hamilton EJ, Kelly EJ, Moore ME, Smith PH, Stone TA, Teague JG, Veirs DK, Weis E and Yarbro TF, Safety Analysis Report for the SAVY 4000 Container

Series, Revision 3. Los Alamos National Laboratory, Los Alamos Controlled Publication, LA-CP 13-01502, 2013

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Ge, G., Mahmood, G. I., Moghaddam, D. G., Simonson, C. J., Besant, R. W., Hanson, S., Erb B., and Gibson, P. W. (2014). Material properties and measurements for semi-permeable membranes used in energy exchangers. Journal of Membrane Science, 453, 328-336.

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Gibson, P. (2005). Water-Repellent Treatments on Battle Dress Uniform Fabric (No. NATICK/TR-05/023). Army Natick Soldier Center, MA, USA.

Moore, ME. 2014 Evaluating the use of PAO (4 cSt polyalphaolefin) oil instead of DOP (di-octyl phthalate) oil for measuring the aerosol capture of nuclear canister filters. LA-UR- 14-25489. Los Alamos National Laboratory.

Nguyen-Tri, P., El Aidani, R., Leborgne, É., Pham, T., & Vu-Khanh, T. (2014). Chemical ageing aging of a polyester nonwoven membrane used in aerosol and drainage filter. Polymer Degradation and Stability, 101, 71-80.

7.0 RECORDS

Activities and updates will be recorded as additions to the appendices in this procedure.

8.0 APPENDICES

Appendix 1

GORE

Medical Membranes

PRODUCT INFORMATION: MMT-341

Reference Pore Size:	5.0 micron
Materials:	Hydrophobic Expanded PTFE membrane on non-woven polyester support
Airflow Resistance:	Maximum individual 21.9 mm H_2O @ 5.33 cm/second face velocity
Airflow:	Minimum individual 150 LPM/cm^2 @ 1 bar (15psi)
Thickness:	Minimum individual 0.19 mm (7.5 mils)
	Maximum individual 0.31 mm (12.0 mils)
Water Entry Pressure:	Minimum individual 0.27 bar (4.3 psi)
Sterilization Modes:[1]	Steam, EtO

[1]These sterilization modes are possible. The ultimate performance is dependent upon device design and application demands.

Q.C. ACCEPTED
NMCMMT09027
DATE/INIT. 8-25-09 KC
Semi-permeable membrane

5-4892 MMT-341 09/08

The above product parameters describe the GORE™ Medical Membrane in the form of cut parts and roll stock.
[illegible]
[illegible]

W. L. Gore & Associates, Inc.
P.O. Box 1550 • Elkton, MD 21922–1550 • US
Phone: 410.392.4440 (US) • 800.455.4670
gore.com/medical_membranes

GORE
Creative Technologies Worldwide

Appendix 2

Nuclear Filter Technology

741 Corporate Circle, Suite R Golden, Colorado 80401

Product Specification Data Sheet

Product Model: NG SNMC 5QT **Spec. Date: 11/30/2010**

Specification: NFT-SAVY-5Q **Spec. Revision: 1**

Drawing Number: 20150000

Usage:

7.4 lb. primary packaging system for interim storage of up to 32.6 lbs and 25 watts of nuclear materials designed to ensure an adequate barrier between contents and workers/public.

Performance Characteristics:

Particle Removal Efficiency:	≥ 99.97% of 0.45μ mass mean diameter poly-dispersed di-octyl pthalate (DOP) aerosol @ ≥ 200 ml/min
Water Entry Pressure:	≥ 12" W.C.
Resistance to Flow:	≤ 1" W.C. DP @ ≥ 200 ml/min
Hydrogen Diffusivity:	≥ 2.4E-05 Mol/Sec/Mol Frac @ 25°C
Notes:	The Helium Leak Rate of the containment boundary (excluding filter) is tested to < 1.47E-05 std cc/sec @ 10 kPa DP

Physical Characteristics:

Filter Media:	Latex-bonded-ceramic
Overall Height:	9.95"
Diameter:	7.70"
Depth in Drum:	Mounted Filter/Lid creates a 6.60" dia. by 8.76" high useful storage volume.
Profile:	0.0"
Material of Construction:	316 L Stainless Steel
Threads:	5 Tooth Bayonet Mount
Type of Seal:	Proprietary 50 Duro Viton O-Ring
Operating Temperature:	Room Temp to +70° C (Room Temp to +158° F)
Shelf-Life:	> 5 Years
Sample Port Media:	NA
Sample Port Seal:	NA
Sample Port Area:	NA
Mounting:	5 Quart SAVY Body
Installation Method:	Hand compressed into bayonet collar of compatible SAVY body followed by rotation of locking ring until pin engages.

In Conformance with the following Standards or Specifications:

NQA-1 LANL TA55-SPEC-009

Identification Markings: (All items will be marked with the following information at a minimum)

SAVY-4000-05 (Date of Manufacture: (mm/yy)) (Unique Serial Number)

2D Data Matrix Barcode

Engineering: [signature] Quality: [signature]

(303) 384-9785 Fax (303) 384-9579 www.nuclearfilter.com

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Appendix 3

Nuclear Filter Technology
Production / Quality Control
ROUTING SHEET

QAM
09/09
Page 1 of 3

Customer:	Inventory	PO #:	N/A	WO #:	10-818G
Product:	1 Quart SAVY-4000 Lid Sub-Assembly			Quantity:	5
Spec:	55Y-002926 Rev. C			Issued By	L. Anderson
Drawing #:	20111100 Rev 4			QA Approval	CJM
Serial ID:	051101001L THRU 051101005L	Date of Manufacture:	05/11	# of Boxes:	N/A

Testing Criteria

Test	Criteria
Filter Test per SPEC 55Y-002926	>99.97% Efficiency @ ≥ 200 ml/min Flow @ < 1" WC
Hydrogen Diffusion	>2.4E-05 mol H_2/sec/H_2 Mol fraction
Water Entry Test	No visible leaks @ 12" WC

Documents Required

Filter Test Data Water Entry Test Data	Passivation Certification Per ASTM A380-99	Material Certs/CMTR's Hydrogen Diffusion Test Data

Parts List

Part Name	Quantity	MIT #	Issued By	Verified By	Date
Lid (20110200)	5	NMC316L10062	K. CREGER	LLA	07/25/2011
Locking Ring (20110300)	5	NMC7075I0019	K. Creger	LLA	8-4-11
Handle (20110600)	5	NMC606111027	K. Creger	LLA	8-4-11
Filter Cup (20100200)	5	RB31609012	K. CREGER	LLA	07/25/2011
1 QT Locking Ring Plug (20100302-02)	5	NMC304L10070	K. Creger	LLA	8-4-11
Stop Pin (20101600-01)	5	NMC304L10068	K. Creger	LLA	8-4-11
ø1.42" Ceramic Filter Element (91040006)	5	FMMX11001	K. CREGER	LLA	07/25/2011
ø1.615" Semi-Permeable Membrane (90000006)	5	NMCMMT09027	K. CREGER	LLA	07/25/2011
1 QT Handle Pin (20101600-04)	10	NMC304L10068	K. Creger	LLA	8-4-11
1/4" Jam Nut	5	NMC1014I209031	K. Creger	LLA	8-4-11
#10-32 x .285" Long x 1/8" Long Shoulder Bolt (20101671)	20	NMC304L10070	K. Creger	LLA	8-4-11
10-32 x 3/16" Locking Set Screw	10	NMCCPSS11001	K. Creger	LLA	8-4-11
Hand Retractable Plunger (80021670)	5	NMC1266I111042	K. Creger	LLA	8-4-11

Build Procedures

Procedure — Inspection Level (PS 25)	Tech Sign	Date	Inspector	Pass/Fail	Date
(PS 7) Laser Etch Lid in accordance with drawing 20101101	[illegible]	7-28-11	TBK	5/0	7/28/11
(PS 7) Laser Etch Locking Ring top in accordance with drawing 20101101	[illegible]	7-28-11	TBK	5/0	7/28/11
Insert Semi-Permeable membrane into Lid, scrim side down	FLP	7-28-11	TBK	5/0	7/28/11
Insert Ceramic Filter Element into Lid	FLP	7-28-11	TBK	5/0	7/28/11
Insert Filter Cup into Lid bending Lid per dwg	FLP	7-28-11	TBK	5/0	7/28/11
(PS 6) Filter Test per SPEC 55Y-002926	[illegible]	8/2/11	TBK	5/0	8-3-11
(PS 26) Hydrogen Diffusion Test Sample: S1 AQL 2.5	[illegible]	8/4/11	[illegible]	1/0	8-4-11

H:\Traveler2\Active Travelers\2010\801-900 Year 2010\10-818G 1 Qt SAVY Lid Sub Assembly (Phase 2)

Appendix 4

Nuclear Filter Technology

NG SNMC Radiation Resistance

#EE10-005-R2

The purpose of this evaluation is to verify that New Generation Standard Nuclear Material Containers (NG SNMCs) are designed to resist radiation exposure per Los Alamos National Laboratory design specification requirements. The design specification, TA55-SPEC-009, Section 3.2.5, requires:

> "All components of the NG SNMC shall resist radiation exposure of $6.6x10^4$rad/yr x-ray/gamma. The containment boundary, in addition to the x-ray/gamma exposure shall be resistant to $1.2x10^6$rad/yr alpha deposited in a 45 micron layer." The total radiation exposure over the 5 year service life, as required by the design specification, is $3.3x10^5$rads x-ray/gamma and $6.0x10^6$rads alpha.
>
> The containment boundary is defined as any component directly exposed to the physical payload.

The ability of NG SNMC components to resist the specified radiation exposure is dependant upon the material used to fabricate each component. X-ray/gamma and alpha exposure may cause various effects such as embrittlement, degradation, hardening, etc. As a result, resistance to the required radiation limits for NG SNMC components are addressed by material type.

Metal Components
Radiation affects metal components through embrittlement / hardening. The specified levels of radiation exposure are insufficient to negatively impact the function of the metal components. Even if the 45 micron layer alpha exposure were to completely degrade the metal, it would not affect the performance or operation of the NG SNMC.

As a result, all containment boundary metal components of the NG SNMC are considered to comply with the radiation resistance design specification requirements.

Semi-Permeable Membrane
Per design specification requirements the Semi-Permeable Membrane of the NG SNMC shall "prevent water entry up to 12" water column differential pressure." Being unrelated to containment or to the containment barrier this requirement can be verified by establishing that, after exposure to $3.3x10^5$rads x-ray/gamma it will prevent water entry up to 12" water column differential pressure".

The Semi-Permeable Membrane is a purchased item, patented and manufactured by Gor-Tex®. Information provided to NucFil by Gor-Tex® (attached email dated 3/19/09) identifies that the Semi-Permeable Membrane (MMT-341 material) is composed of an expanded polytetrafluoroethylene (PTFE) layer with a radiation resistant support known as a scrim. According to the manufacturer this material retains its water resistance after radiation exposure in excess of 10 times the specified amount. As a result, the Semi-Permeable Membrane of the NG SNMC is considered to comply with the radiation resistance design specification requirements.

O-Ring
The NG SNMC o-ring serves as the primary seal of the NG SNMC container and is therefore a containment boundary component. This O-ring is manufactured by Akron Rubber Development Laboratory (ARDL) and was specifically formulated for this purpose, by ARDL, with the assistance of NucFil Engineering to exceed all containment boundary specification requirements. This formulation, designated NucFil's V2, utilizes Viton® GLT 600 S, a common base polymer used in other Viton® type formulations.

A Parker Viton® compound known as V835-75, similar to the V2 compound of the NG SNMC O-ring, has been extensively analyzed by Westinghouse Savannah River Company (see reference 2). On page 16 this report states, "At such low dose levels (<10rads/hr = <$8.76x10^4$rads/yr), thermal effects dominate overall degradation of the material." As the design requirement dose of $6.6x10^4$rads/yr x-ray/gamma is less than $8.76x10^4$rads/yr, it can be concluded that thermal effects will dominate overall degradation of the similar V2 compound used to manufacture the NG SNMC O-ring. As a result, the x-ray/gamma radiation resistance requirements can be demonstrated by meeting thermal degradation requirements. O-ring service life testing completed by ARDL examined thermal degradation of the o-ring and determined that the service life of the V2 compound vastly exceeds the 5 year design specification requirement (see reference 3). As a result, the NG SNMC O-Ring is considered to comply with the x-ray/gamma radiation resistance design specification requirements.

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Appendix 5

Filter performance is measured as the ratio between the downstream aerosol concentration, C_D, and the upstream aerosol concentration, C_U. Care must be taken to distinguish "leak and capture" from "penetration and efficiency".

	Leak and Capture	**Penetration and Efficiency**
Example areas of usage	LANL SAVY SAR specification, NucFilt Inc testing, and LANL Industrial Hygiene filter leak testing.	HEPA filter definition given in ASME standard AG-1.
Aerosol Measurement Instrument	Single Channel (Photometer)	Multi-Channel (Spectrometer)
Test Aerosol	The aerosol concentration of a polydisperse distribution of sizes is measured by a single channel photometer (e.g. a normal distribution with a mean size of DOP oil droplets of 0.45 µm).	Aerosol concentrations are measured in discrete channels at each individual particle size (i.e. "essentially monodispersed 0.3 µm" as mentioned in ASME AG-1).
	Leak of Aerosol = C_D/C_U	P = Penetration = C_D/C_U
	Capture of Aerosol = $1 - C_D/C_U$	E = Efficiency = $1 - C_D/C_U$

Source:

Moore, ME. 2014 Evaluating the use of PAO (4 cSt polyalphaolefin) oil instead of DOP (di-octyl phthalate) oil for measuring the aerosol capture of nuclear canister filters. LA-UR- 14-25489. Los Alamos National Laboratory.

Appendix 6

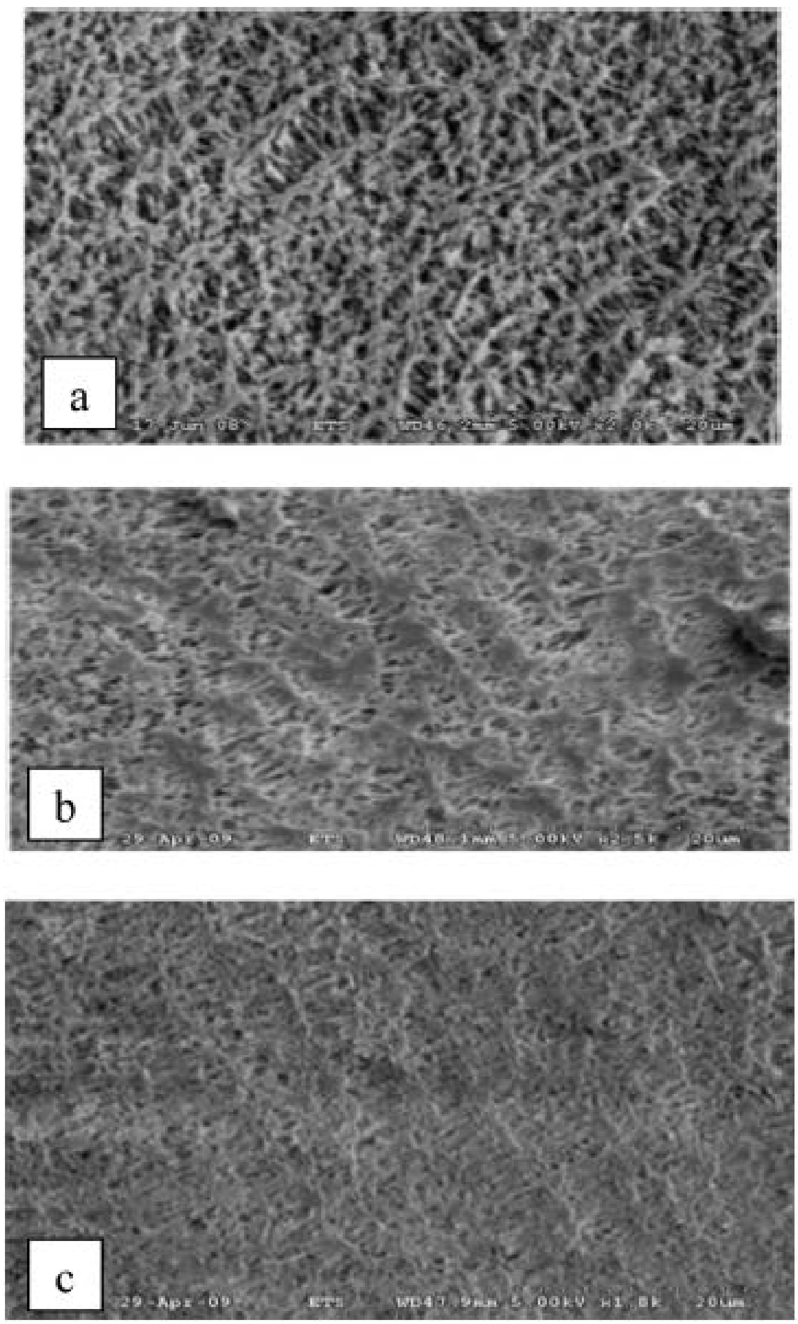

Fig. 20. SEM images of e-PTFE unaged (a) and aged at light intensity of 1.35 W/m^2 and temperature of 70 °C during 48 h (b) and 96 h (c).

Source:

El Aidani, R., Nguyen-Tri, P., Malajati, Y., Lara, J., & Vu-Khanh, T. (2013). Photochemical aging of an e-PTFE-NOMEX® membrane used in firefighter protective clothing. Polymer Degradation and Stability, 98(7), 1300-1310.