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Filter Measurement System for Nuclear Material Storage Canisters (Including Altitude Correction for Filter Pressure Drop)

End of FY2014 Report

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Contents

1. Summary

Two LANL FTS (Filter Test System) devices for nuclear material storage canisters are fully operational. One is located in PF-4 (i.e. the TA-55 FTS) while the other is located at the Radiation Protection Division's Aerosol Engineering Facility (i.e. the TA-3 FTS). The systems are functionally equivalent, with the TA-3 FTS being the test-bed for new additions and for resolving any issues found in the TA-55 FTS.

There is currently one unresolved issue regarding the TA-55 FTS device. The canister lid clamp does not give a leak tight seal when testing the 1 QT (quart) or 2 QT SAVY lids. An adapter plate is being developed that will ensure a correct test configuration when the 1 or 2 QT SAVY lids are being tested.

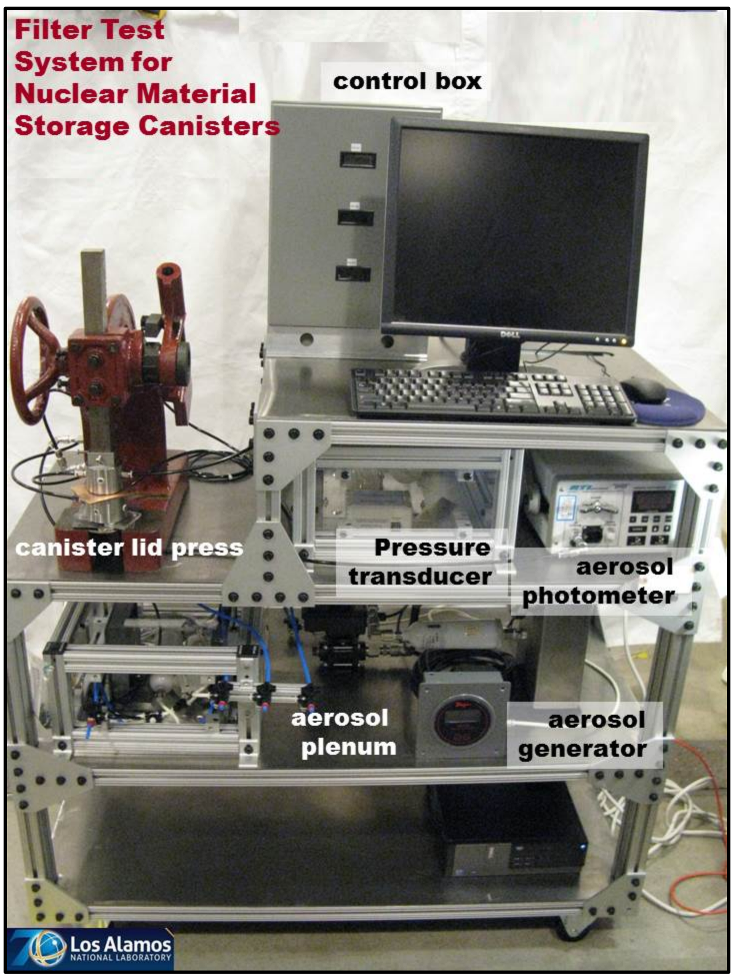


Figure 1. Filter Test System for TA-55 operations. (Note: The control box in this photo was rebuilt in FY2014.)

2. Introduction

In FY2013, two FTS (Filter Test System) units were developed at Los Alamos National Laboratory to measure the percent penetration (aka leakage) of test aerosol by nuclear storage canister filters (Figure 1). One FTS unit at LANL TA-55 has been testing canisters that have already been used to store nuclear material. The other FTS unit is in TA-3 at the LANL Radiation Protection Division's Aerosol Engineering Facility. The TA-3 system is not used to test in-use canisters, but it does have an expanded analytical capability, compared to the TA-55 system.

In FY2014, the TA-55 FTS device was used to measure a reference set of 16 (sixteen) canister filters that are the property of NFT Inc (Golden, CO). All of the canister lids in this reference set are of the older (1980s) Hagan type design. Two physical parameters were measured: the percent aerosol penetration, P%, and the filter pressure drop, ΔP (inWC). This data was collected prior to the unit being moved into TA-55.

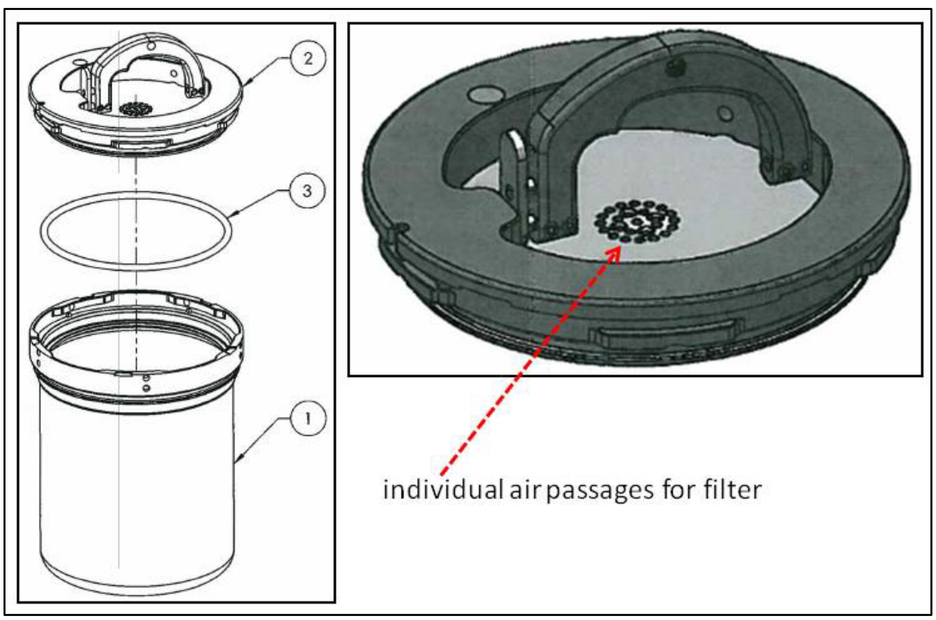


Figure 2. A newer SAVY (2012) type storage canister. (1) Canister (2) Lid. (3) O-ring. Individual holes in the canister lid enable air flow through the integrated filter-lid system.

Figure 3. Hagan type canister lid with hexagonal filter port.

Note on aerosol penetration, leakage, efficiency and capture in air filters.

The terms "penetration" and "efficiency" have been used (Moore et al 2011) for measuring nuclear filter performance. There are distinctions between these terms and "leakage" and "capture", respectively. This report will use the terms "penetration" and "efficiency" to describe filter performance, although the FTS device uses an aerosol photometer for measuring the concentration of aerosol at the locations upstream (C_U) and downstream (C_D) of the tested filter. The two quantities are similar to each other (Table 1) but the photometer measures aerosol concentration based on a light transmission measurement (without regard to particle size), while spectrometer discriminates between aerosols based on the basis of size (diameter).

Table 1. Using a single channel of measurement (i.e. an aerosol photometer) will result in different results than using a multichannel aerosol spectrometer.

	Filter leak testing	**HEPA filters defined by ASME 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. mean size of DOP oil at 0.45 µm).	Aerosol concentrations are measured at each individual particle size (i.e. "essentially monodispersed 0.3 µm" as mentioned in ASME AG-1).
	Leak of Aerosol = L% = 100%*C_D/C_U	Aerosol Penetration = P% = 100%*C_D/C_U
	Capture of Aerosol = 1 - C_D/C_U	E = Efficiency of Aerosol = 1 - C_D/C_U

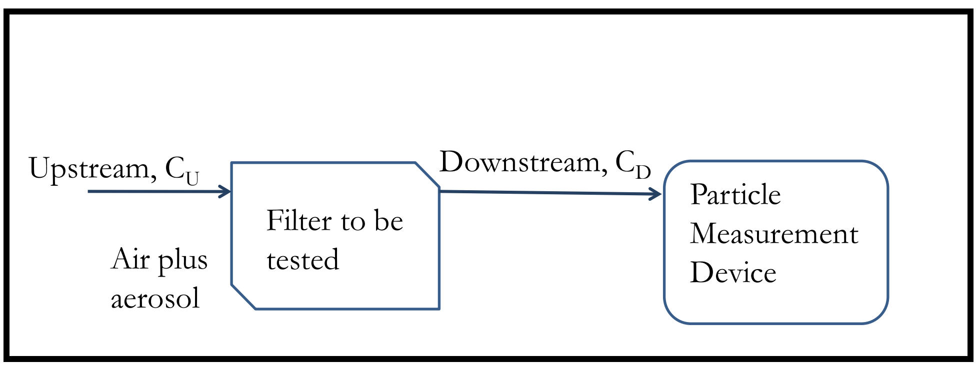


Figure 4. A system sketch illustrates the measurement of filter collection efficiency.

3. Instrument subsystems

At the start of fiscal year 2014, there were subsystems on the FTS Filter Test System that were not fully operational. This report describes the following tasks that were performed to address those issues.

- The main control box for the FTS was not complete, and the finished control unit was not delivered until October 2013.

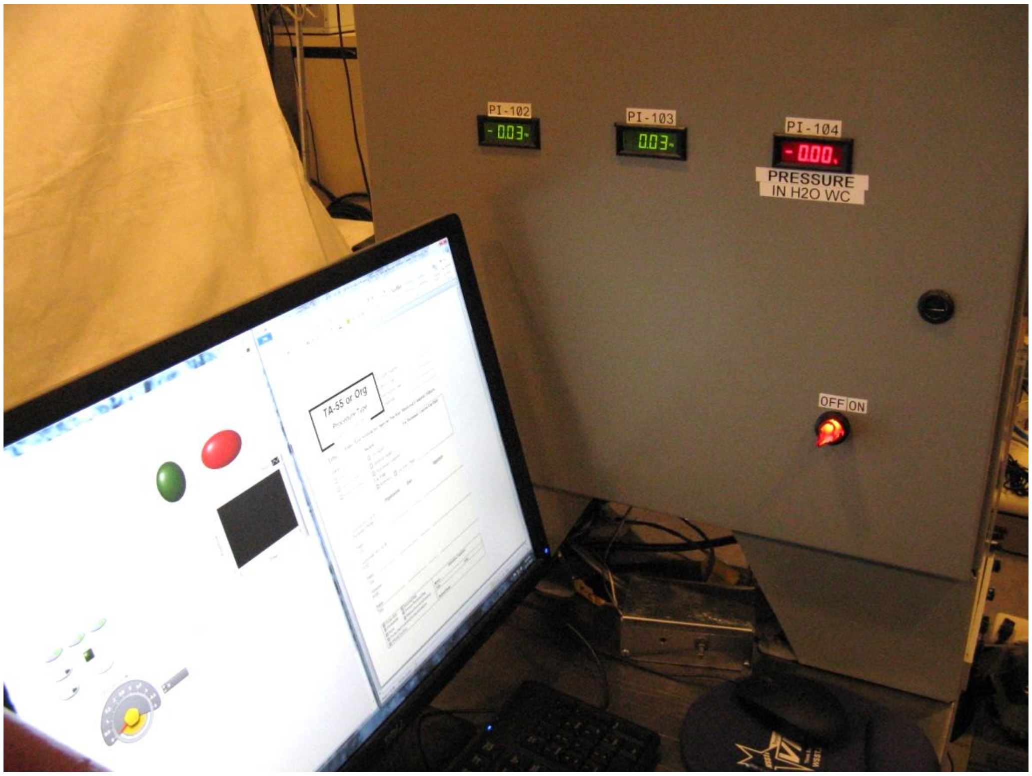


Figure 5. The control box was rebuilt in FY2014. This is the newer (larger) version which was placed into TA-55.

- A custom designed air pump and control system was necessary to provide pressurized air into the aerosol generator. (The ATI 6C aerosol generator pump is intended to produce enough aerosol for HEPA filter testing involving flowrates of a more than one thousand cubic feet per minute. The new smaller pump had to be scaled to produce the same aerosol concentration for air flow rates of 0.2 liters per minute, which is smaller by a factor of about 100,000.)
- The LANL FTS Filter Test System uses three small HEPA filter capsules in its process system. These small filters have a physical volume of about 300 cc, and they are used to isolate and contain excess aerosol in the FTS flow loop. These filters are essentially consumable air cleaners, but they require a maintenance method to measure if they become plugged with aerosol. This maintenance method measures pressure drop for a representative air flow rate, and the method specifies operating parameters for system operation.

4. NFT Hagan lids tested at NFT and at Los Alamos (Quality data comparison)

A series of Hagan filters was tested using the TA-3 FTS to compare the LANL system to that of the NFT system in Golden, CO. The data collected at Los Alamos was then compared to the NFT data and any discrepancies were resolved. On the first comparison attempt, neither the percent penetration (P%) nor the pressure drop (ΔP, inWC) data were found to be statistically similar according to a 95% confidence analysis with an MS-Excel-based statistical paired t-test. By the end of FY2013, the discrepancies for the aerosol percent penetration measurements were corrected. The process is documented in the previous year-end report (LAUR-14-20641).

Three errors affected the pressure drop comparison

Error 1: Flow controller setpoint

However, the pressure drop data was not resolved by the end of FY2013. Upon inspection, it was discovered that the flow controller instrument was not correctly set to deliver a flowrate of 200 accm (actual cubic centimeters per minute). The “accm” unit is based upon the rate of movement of the spatial volume occupied by air at local ambient conditions. The flow controller operates on the basis of the internal mass-based flow (downstream of its transducer). A typical unit for the mass-based air flow would be “sccm” (standard cubic centimeters per minute). To achieve the correct flow-rate of 200 accm through the system, a flow controller set-point of 149 sccm is used. This value was verified using the BIOS Defender 530 flow-meter connected to the upstream aerosol inlet to the system (A more complete explanation of the calculation is included in Appendix C).

Error 2: Electronic data string error

After correcting this this flowrate setpoint and after re-running the filter pressure drop measurements at local Los Alamos conditions, the pressure drop data comparison between NFT and Los Alamos was still not statistically similar, according to a paired t-test analysis. In FY2014, it was discovered that the LabView software was experiencing a data stream error, where a null (zero) value for the pressure drop was randomly being sent at the beginning of a data stream. When the LabView algorithm calculated the average pressure drop from this string, an incorrect lower value was being computed. This was corrected by increasing the time interval between each data point, and also by delaying the measurement of the pressure until the system had fully equilibrated across the canister filter. This interval delay was selected according to engineering judgment, based on observations of the transient behavior of the FTS pressure transducer.

Error 3: Filter pressure drop criterion

For a particular air filter, when pressure drop is measured at two different altitudes, there will be a difference between the two measured pressure drops, due solely to the altitude difference. This is explained in Appendix D. There is about a 7% greater ambient air pressure at Golden (Colorado) compared to Los Alamos, and this atmospheric pressure difference was large enough to prevent a statistical t-test agreement (for 95% confidence) between the two data sets.

5. Software improvements

From the outset of this project, automated operation for the FTS device was a primary development goal. This was achieved in FY13, but there were some issues and improvements that needed to be made, the main control panel layout (for the LabView interface) being the most visible change.

A simplified version of the FTS Filter Test System P&ID diagram was added to the software "heads-up" display. This provides graphical indications to show the real-time aerosol pathway while the tests are running. The operator can observe graphical indicators as pumps are switched on or off, and as valve positions are changed. Different features were created, including: (1) an indicator for the pass/fail condition, (2) a large green or red light on the computer display, as well as (3) the final pressure drop and percent penetration data shown below the indicator of the pass/fail condition.

Previous to FY14, the program exported the data in a (*.lvm) data output format (this is a Labview file, and opens with MS-Excel). While this file type did work as an output format, it was not the most convenient method of displaying the data, so the program output format was changed to an ASCII text file format (Figure 5). The text file format is a clearer format than the (*.lvm) file, and it provides the ability to add additional information if needed.

```
Date and time- 1/13/2015 2:01:27 PM
Operator- Kirk Reeves 237087
Type- SAVY Container
ID Number- 243568-3L-006
Calibration due date- 1/29/15
Measured Percent Penetration- 0.786 %
PASS/FAIL FAIL
Pressure Drop- 0.703 in. WC
PASS/FAIL- PASS
Flow Rate- 0.149 slpm air
Upstream Concentration- 63.550 microgram/L
```

Figure 6 Text file output format. Note the units are expressed as "Percent Penetration".

6. Maintenance procedure

At the time of this report, the draft document "Maintenance of TA-55 FTS (Filter Test System)" is in a mature (draft) status.

The Scope of the maintenance procedure is specific to the Filter Test System (FTS) system located in the TA-55 LANL plutonium facility. Another similar FTS system has been operating in the LANL Aerosol Engineering Facility (TA-03-0130). Only authorized LANL personnel shall perform this procedure. Activities will be planned through this procedure, and two SMEs will concur with each activity before the activity is performed.

Enclosed is a list of possible activities for the TA-55 FTS device:

- Measure the pressure drop in the disposable plastic HEPA capsules, and replace the HEPA capsule if necessary.
- Install mechanical extension on the TA-55 FTS arbor press.
- Remove load cell from the TA-55 FTS device.
- Installation of correct bolts on load binder.
- Maintain ambient aerosol counter (TSI Inc. model 7501; P&ID AI103).
- Flow measurement with FIC102 (the flow controller).
- Refill aerosol generator with PAO oil.

7. Calibration, including UPC User Performed Calibration activities

The FTS Filter Test System requires a complete calibration methodology. In FY2014, this included: (1) writing a draft UPC (User Performed Calibration) procedure, and (2) specifying and purchasing a set of filter standards that will calibrate the TA-55 device based on measurements with the TA-3 device (Brown et al 2014).

Figure 7. Top surfaces of the Hagan, SAVY-4000 and NFT filter standard (clockwise from upper left).

Figure 8. Lower surfaces of the Hagan, SAVY-4000 and NFT filter standard (clockwise from upper left).

Table 2. A summary of the calibration activities of the two different FTS devices.

Component instrument	**TA-3 FTS Filter Test System had a quarterly performance check, in addition to…**	**TA-55 FTS Filter Test System**
Flow controller	Annual in-house UPC	
Pressure transducer	Annual in-house UPC	
Aerosol photometer	Annual manufacturer's calibration	
Entire FTS Filter Test System – UPC User Performed Calibration by filter standard	Measure aerosol penetration percent, P%, and filter pressure drop, ΔP, at 200 accm flowrate.	Verify P%, and filter pressure drop at 200 accm flowrate for a transferred filter standard. Use a paired t-test to assess a match of TA-55 to TA-3 data.

<u>Current active documents</u>

- Air Flow Meter Calibration Verification RP-SVS-RIC-DP-92, R0 , Effective Date 9-18-2013

- Pressure (Vacuum) Gauge Calibration Verification RP2-RIC-DP-78, R0, Effective Date 4-10-2013
- Aerosol Engineering Facility Leak Test Procedure RP2-RIC-DP-77, R0 Effective Date 4-10-2013

Documents that started in FY2014 (These are mature draft documents, but they are not completed.)

- UPC User Performed Calibration. Draft title: Nuclear Canister Filter Test System Program Plan
- RP Division procedure. Draft title: Photometer Measurement Verification

Experimental methods developed and demonstrated in FY2014 for FTS calibration operations

- A gravimetric method to verify the accuracy of the aerosol photometer. Test oil aerosol was collected on a lightweight 47mm membrane filter. Based on the measured mass and the air flowrate for the collection filter, the photometer accuracy was verified to less than 2.5% error. (The photometer was later sent to the manufacturer for a full annual calibration.) (See Appendix A.)
- Both the TA-3 and the TA-55 devices were used to measure the percent penetration (P%) and the pressure drop (ΔP) on a filter standard. An Excel template using a paired t-test statistic was developed to provide quick and accessible statistical accuracy verifications. (See Appendix B.) Filter standards for UPC User Performed Calibration of the FTS Filter Test System (Brown at al 2014).

8. Conclusions

There are currently two operational FTS Filter Test Systems. Tests have been conducted in LANL PF-4 on the older style Hagan filters for surveillance purposes. Several necessary steps were performed prior to the PF-4 work, including: (1) writing an approved operating procedure, (2) resolving all aspects of the pressure drop discrepancy, (3) a plan for test certification, as well as addressing any other issues that occurred.

9. References

Brown AD, Runnels JT, Moore ME, Reeves K. 2014. LAUR-14-27446 Final Report: WAS Project No.: 2013-HS-2013008: I. In-Place Filter Testing Instrument for Nuclear Material Containers II. Canister Filter Test Standards for Aerosol Leak Rates. Los Alamos National Laboratory.

Moore ME, Smith PH, Veirs DK, Anderson LL, Klemm R. 2011. Low Flow Filter Efficiency Testing, Los Alamos National Laboratory, Los Alamos Unclassified Report LAUR 11-10891.

Moore ME, Reeves, KP, 2013. Filter Measurement System for Nuclear Material Storage Canisters - End of Year Report FY 2013. Los Alamos National Laboratory, Los Alamos Unclassified Report LAUR-14-20641.

10. Appendices

Appendix A.

photometer filter aerosol mass calibration - MEMoore-2014.xlsx

Index	Logbook KReeves FTS #1	Photo meter	FTS air flow	conv factor	conv factor	Sample time	Aerosol mass	Nuc Filt #5	Filter Intial	Filter Final	Test time	Extraction flow	conv factor	Measured conc	Perc error
		ug/L	cc/min	cc/L	ug/mg	min	mg		mg	mg	min	ALPM	ug/mg	µg/L	%
PAC6	pg. 72	44.65	30000	1000	1000	30	40.19	pg.5	128.1	169.7	30	30.3	1000	45.8	2.47

Appendix B.

Certificate

Los Alamos National Laboratory

UPC User Performed Calibration

FTS Filter Test System

for nuclear material storage canisters

TA-3 FTS at 200 accm airflow.

Date:______________________________

Operator:__________________________

Index	Filter ID	% Leak	ΔP, inWC
1		3.10E-02	0.678
2		3.10E-02	0.848
3		3.10E-02	0.746
4		3.10E-02	0.814
5		3.10E-02	0.916
6		3.10E-02	0.866
7		3.10E-02	0.758
8		3.10E-02	0.828
9			
10			

TA-55 FTS at 200 accm airflow.

Date:______________________________

Operator:__________________________

Index	Filter ID	% Leak	ΔP, inWC
1		3.16E-02	0.648
2		3.17E-02	0.817
3		3.12E-02	0.707
4		3.14E-02	0.794
5		3.14E-02	0.904
6		3.13E-02	0.841
7		3.12E-02	0.735
8		3.18E-02	0.756
9			
10			

Paired t-test for filter leakage percent (aka %penetration).	***0.0008***
If greater than 0.05, the two system data sets match.	***No Match***
Paired t-test for filter pressure drop.	***0.0019***
If greater than 0.05, the two system data sets match.	***No Match***

PC-PA-PLAN-Draft Nuclear Canister Filter Test System Program Plan

The paired t-tests assume two-tailed distributions with a 95% confidence interval.

Certificate - UPC FTS filter standard paired ttest.xlsx

Appendix C.

<u>Air Flow (Controller) Setpoint</u>

<u>Example:</u> To set the actual test flowrate, Q_{TA}, through the tested filter at 0.200 ALPM, the setpoint air flowrate of the flow controller must be determined with respect to the ambient air pressure in the local environment of the test system.

The listing of the definitions of the quantities are given below, where,

> Q_{TA} = the test flowrate in terms of "actual" units, ALPM, actual liters per minute (e.g. 0.200 ALPM),
>
> Q_{FS} = the air flowrate in the Omega Inc. flow controller FIC102, in "standard" units, SLPM,
>
> P_A = the "actual" air pressure in the room air of the test system (e.g. 11.2 psia in Los Alamos), it must be emphasized this is <u>not</u> the air pressure inside the flow controller, and,
>
> P_S = the "standard" air pressure at sea level (i.e. 14.7 psia), then by extension,

$Q_{FS} = Q_{TA} * (P_A / P_S)$, or

$Q_{FS} = 0.152\ \text{SLPM} = 0.200\ \text{ALPM} * (11.2\ \text{psia} / 14.7\ \text{psia})$,

<u>Therefore, the setpoint of the flow controller needs to be 0.152 SLPM, assuming a desired actual air flowrate of 0.200 ALPM, and a local room air pressure of 11.2 psia. Recent practice has been setting the flow controller setting at "0.149 SLPM air flow".</u>

> c.f. (*Moore ME, Reeves, KP, 2013. Filter Measurement System for Nuclear Material Storage Canisters - End of Year Report FY 2013. Los Alamos National Laboratory, Los Alamos Unclassified Report LAUR-14-20641*.)

Appendix D.

Correction for pressure drop on a filter, measured at different altitudes

Given: Two filter test systems at two locations, in Golden CO and in Los Alamos NM.

ΔP_A = filter pressure drop (inWC) measured at Golden CO

ΔP_B = filter pressure drop (inWC) measured at Los Alamos NM

$\Delta P_{B(C)}$ = filter pressure drop (inWC) measured at Los Alamos NM, corrected to conditions at Golden CO

p_A = ambient to sea level pressure ratio at Golden CO (i.e. 0.81)

p_B = ambient to sea level pressure ratio at Los Alamos NM (i.e. 0.76).

To compare the two pressure drops ΔP_A and ΔP_B to each other, calculate:

$\Delta P_{B(C)} = \Delta P_B * (p_A / p_B)$

Example: From the file mentioned below,

For NCR Hagan canister lid filter #2007.

ΔP_A = 0.678 inWC

ΔP_B = 0.629 inWC,

$\Delta P_{B(C)}$ = 0.629 inWC * (0.81 / 0.76) = 0.670 inWC.

Therefore on a paired t-test analysis, the values of ΔP_A are compared to the values of $\Delta P_{B(C)}$.

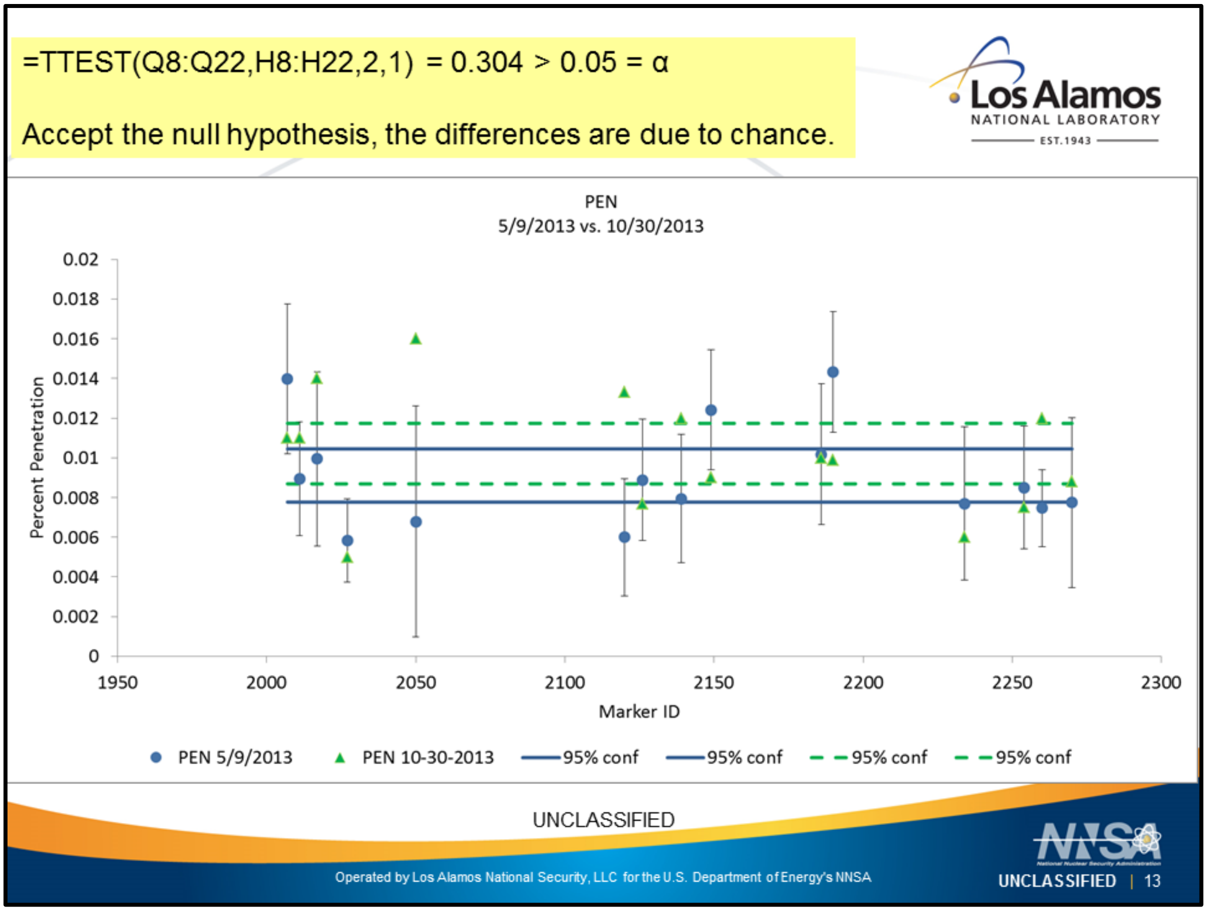
c.f.

(1) file: *PEN and DP TA3 FTS Marker ID NFT filters 5-9-2013 vs 6-21-2013 vs 10-15-13 paired t-test rev5-29-14.xlsx*

(2) Logbook Moore Los Alamos Nuc-Filt Cans #4 pg. 288

Appendix E. These graphs are the summary of the filter penetration and the filter pressure drop t-test agreements. Note the usage of the unit "PEN" in the top graph. By knowledge of process, the graph indicates the aerosol leak percent, P%.

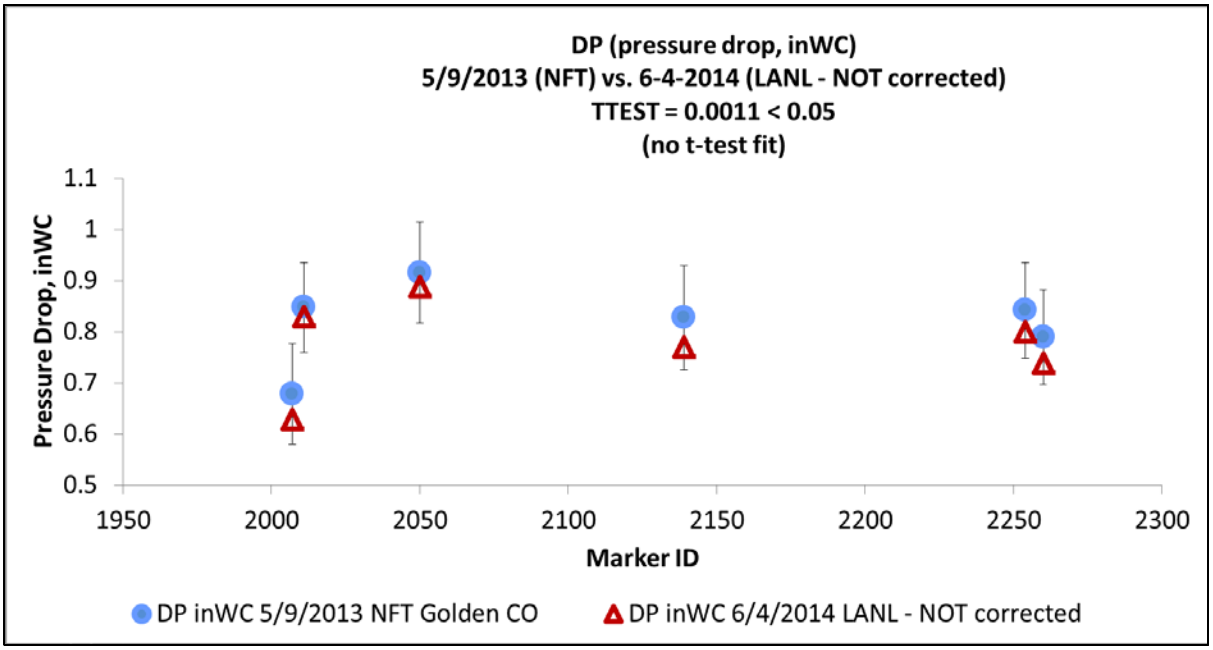
c.f. File: *Moore Reeves LAUR 14-20641 Filter Efficiency Testing - DOE 441.1-1 meeting R6-5-14.pdf*

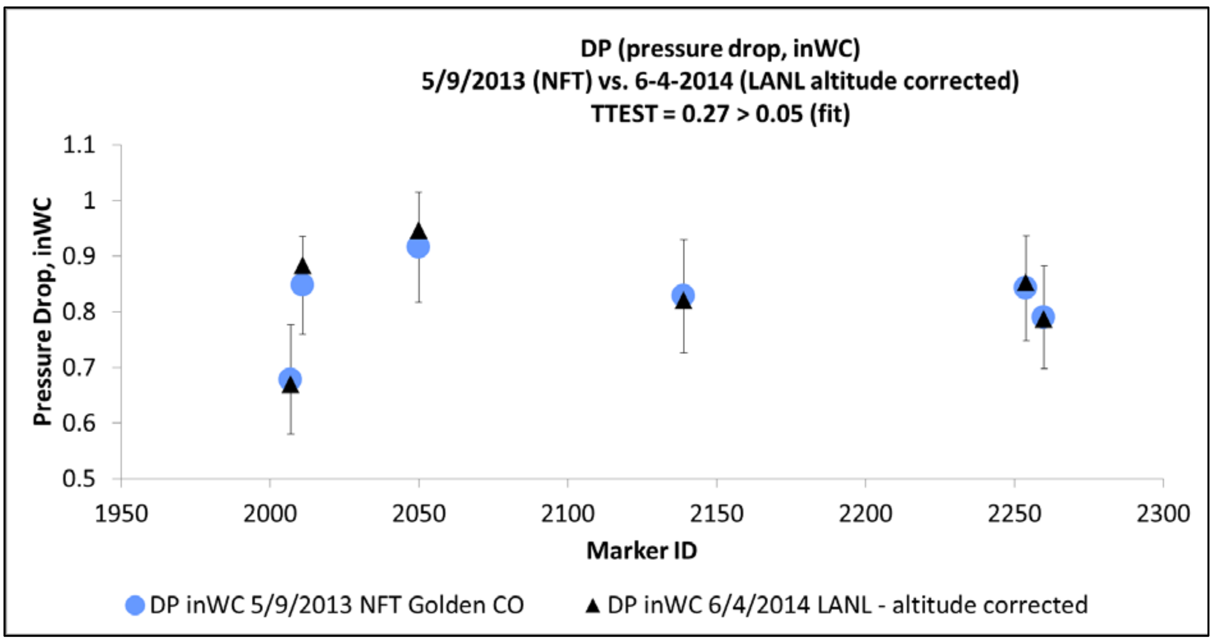


From: *PEN and DP TA3 FTS Marker ID NFT filters 5-9-2013 vs 6-21-2013 vs 10-15-13 paired t-test rev5-29-14.xlsx*

DP inWC 5/9/2013 NFT Golden CO	DP inWC 6/4/2014 LANL - NOT corrected	DP inWC 6/4/2014 LANL - altitude corrected
0.678	0.629	0.670
0.848	0.829	0.884
0.916	0.888	0.946
0.828	0.770	0.821
0.842	0.800	0.853
0.790	0.738	0.787

PEN and DP TA3 FTS Marker ID NFT filters 5-9-2013 vs 6-21-2013 vs 10-15-13 paired t-test rev5-29-14.xlsx


DP (pressure drop, inWC)
5/9/2013 (NFT) vs. 6-4-2014 (LANL - NOT corrected)
TTEST = 0.0011 < 0.05
(no t-test fit)
Pressure Drop, inWC
Marker ID
DP inWC 5/9/2013 NFT Golden CO
DP inWC 6/4/2014 LANL - NOT corrected


DP (pressure drop, inWC)
5/9/2013 (NFT) vs. 6-4-2014 (LANL altitude corrected)
TTEST = 0.27 > 0.05 (fit)
Pressure Drop, inWC
Marker ID
DP inWC 5/9/2013 NFT Golden CO
DP inWC 6/4/2014 LANL - altitude corrected