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Environmental Technology Verification

Baghouse Filtration Products

Donaldson Company, Inc.
Dura-Life #0701607 Filtration Media
(Tested October 2011)

Prepared by

RTI International

ETS Incorporated

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

Environmental Technology Verification Report

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EPA Cooperative Agreement CR 83416901-0

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Notice

This document was prepared by RTI International[*] (RTI) and its subcontractor ETS Incorporated (ETS) with partial funding from Cooperative Agreement No. CR 83416901-0 with the U.S. Environmental Protection Agency (EPA). The document has been subjected to RTI/EPA's peer and administrative reviews and has been approved for publication. Mention of corporation names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products.

[*] RTI International is a trade name of Research Triangle Institute.

Foreword

The Environmental Technology Verification (ETV) Program, established by the U.S. Environmental Protection Agency (EPA), is designed to accelerate the development and commercialization of new or improved technologies through third-party verification and reporting of performance. The goal of the ETV Program is to verify the performance of commercially ready environmental technologies through the evaluation of objective and quality-assured data in order to provide potential purchasers and permitters an independent, credible assessment of the technology that they are buying or permitting.

The Air Pollution Control Technology Center (APCT Center) is part of the EPA's ETV Program and is operated as a partnership between RTI International (RTI) and EPA. The APCT Center verifies the performance of commercially ready air pollution control technologies. Verification tests use approved protocols, and verified performance is reported in verification statements signed by EPA and RTI officials. RTI contracts with ETS Incorporated (ETS) to perform verification tests on baghouse filtration products, including filter media.

Baghouses are air pollution control devices used to control particulate emissions from stationary sources and are among the technologies evaluated by the APCT Center. Baghouses and their accompanying filter media have long been one of the leading particulate control techniques for industrial sources. Increasing emphasis on higher removal efficiencies has helped the baghouse to be continually more competitive when compared to the other generic PM control devices to the point where the baghouse is now the control option of choice for most industrial applications. The development of new and improved filter media has further enhanced baghouse capability to control fine PM over an expanded range of industrial applications. The APCT Center developed (and EPA approved) the *Generic Verification Protocol for Baghouse Filtration Products* to provide guidance on these verification tests.

The following report reviews the performance of Donaldson Company, Inc.'s Dura-Life #0701607 Filtration Media. ETV testing of this technology was conducted during October 2011 at ETS. All testing was performed in accordance with an approved test/quality assurance (QA) plan that implements the requirements of the generic verification protocol at the test laboratory.

Availability of Verification Report

Copies of this verification report are available from the following:

- RTI International
  Discovery & Analytical Sciences
  P.O. Box 12194
  Research Triangle Park, NC 27709-2194

- U.S. Environmental Protection Agency
  Air Pollution Prevention and Control Division (E343-02)
  109 T. W. Alexander Drive
  Research Triangle Park, NC 27711

Web Site: http://www.epa.gov/etv/vt-apc.html (electronic copies)

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List of Abbreviations and Acronyms

APCT Center	Air Pollution Control Technology Center
BFP	baghouse filtration product
cfm	cubic feet per minute
cm	centimeter(s)
cm w.g.	centimeter(s) of water gauge
dia.	diameter
ΔP	pressure drop
dscmh	dry standard cubic meter(s) per hour
EPA	U.S. Environmental Protection Agency
ETS	ETS Incorporated
ETV	Environmental Technology Verification
FEMA	filtration efficiency media analyzer
fpm	feet per minute
g	gram(s)
g/dscm	gram(s) per dry standard cubic meter
g/m^3	gram(s) per cubic meter
G/C	gas-to-cloth ratio (filtration velocity)
gr	grain(s)
gr/dscf	grain(s) per dry standard cubic foot
GVP	generic verification protocol
h	hour(s)
in.	inch(es)
in. w.g.	inch(es) of water gauge
kPa	kilopascal(s)
m	meter(s)

m/h	meter(s) per hour
m^3/h	cubic meter(s) per hour
mbar	millibar(s)
min.	minute(s)
mm	millimeter(s)
MPa	megapascal(s)
ms	millisecond(s)
osy	ounce(s) per square yard
Pa	pascal(s)
PM	particulate matter
$PM_{2.5}$	particulate matter 2.5 micrometers in aerodynamic diameter or smaller
psi	pound(s) per square inch
psia	pound(s) per square inch absolute
QA	quality assurance
QC	quality control
RTI	RTI International
s	second(s)
scf	standard cubic feet
t	time
VDI	Verein Deutscher Ingenieure
µm	micrometer(s)
°C	degree(s) Celsius
°F	degree(s) Fahrenheit
°R	degree(s) Rankine

Acknowledgments

The authors acknowledge the support of all those who helped plan and conduct the verification activities. In particular, we would like to thank Michael Kosusko, U.S. Environmental Protection Agency's (EPA's) Project Officer, and Bob Wright, EPA's Quality Manager, who both work as part of EPA's National Risk Management Research Laboratory in Research Triangle Park, NC. Finally, we would like to acknowledge the assistance and participation of Donaldson Company, Inc. personnel, who supported the test effort.

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1.0 INTRODUCTION

This report reviews the pressure drop (ΔP) and filtration performance of Donaldson Company, Inc.'s Dura-Life #0701607 Filtration Media. Environmental Technology Verification (ETV) testing of this technology/product was conducted during a series of tests in October 2011 by ETS Incorporated (ETS), under contract with the Air Pollution Control Technology Center (APCT Center). The objective of the APCT Center and the ETV Program is to verify, with high data quality, the performance of air pollution control technologies. Control of fine-particle emissions from various industrial and electric utility sources employing baghouse control technology is within the scope of the APCT Center. An APCT Center program area was designed by RTI International (RTI) and a technical panel of experts to evaluate the performance of particulate filters for fine-particle (i.e., $PM_{2.5}$) emission control. Based on the activities of this technical panel, the *Generic Verification Protocol for Baghouse Filtration Products*[1] was developed. This protocol was chosen as the best guide to verify the filtration performance of baghouse filtration products (BFPs). The specific test/quality assurance (QA) plan for the ETV test of the technology was developed and approved in May 2000, followed by an approved update in February 2006[2]. The goal of the test was to measure filtration performance of both $PM_{2.5}$ and total particulate matter (PM), as well as the ΔP characteristics of the Donaldson Company, Inc. technology identified above.

Section 2 of this report documents the procedures used for the test and the conditions over which the test was conducted. A description of Donaldson Company, Inc.'s Dura-Life #0701607 Filtration Media is presented in Section 3. The results of the test are summarized and discussed in Section 4, and references are presented in Section 5.

This report contains summary information and data from the test. Vendor comments are included in Appendix A. Complete documentation of the test results is provided in a separate data package report and an audit of data quality report. These reports include the raw test data from product testing and supplemental testing as well as QA and quality control (QC) activities and results. Complete documentation of QA/QC activities and results, raw test data, and equipment calibration results are retained in ETS's files for 7 years.

2.0 VERIFICATION TEST DESCRIPTION

The BFPs were tested in accordance with the APCT Center Generic Verification Protocol for Baghouse Filtration Products[1] and the Test/QA Plan for the Verification Testing of Baghouse Filtration Products.[2] These documents incorporate all the requirements for quality management, QA, procedures for product selection, auditing of the test laboratories, and reporting format. The Generic Verification Protocol (GVP) describes the overall procedures used for verification testing and defines the data quality objectives. The protocol is based on and describes modifications to the equipment and procedures described in Verein Deutscher Ingenieure (VDI) 3926, Part 2, Testing of Filter Media for Cleanable Filters under Operational Conditions, December 1994.[3] The values for inlet dust concentration, raw gas flow rate, and filtration velocity used for current verification testing have been revised in consultation with the technical panel since posting of the GVP. These revisions are documented in Section 4.1. The test/QA plan details how the test laboratory at ETS implemented and met the requirements of the GVP.

2.1 Description of the Test Rig and Methodology

The tests were conducted in ETS's filtration efficiency media analyzer (FEMA) test apparatus (**Figure 1**). The test apparatus is based on the VDI 3926 Type 1 vertical duct design. The test apparatus consists of a brush-type dust feeder that disperses test dust into a vertical rectangular duct (raw-gas channel). The dust feed rate is continuously measured and recorded via an electronic scale located beneath the dust feed mechanism. The scale has a continuous readout with a resolution of 10 g. A radioactive polonium-210 alpha source is used to neutralize the dust electrically before its entry into the raw-gas channel. An optical photo sensor monitors the concentration of dust and ensures that the flow is stable for the entire duration of the test. The optical photo sensor does not measure absolute concentration, and is, therefore, not the primary concentration measurement for the test. A portion of the gas flow is extracted from the raw-gas channel through the test filter, which is mounted vertically at the entrance to a horizontal duct (clean-gas channel). The clean-gas channel flow is separated into two gas streams, a sample stream and a bypass stream. An aerodynamic "Y" is used for this purpose. The aerodynamic "Y" is designed for isokinetic separation of the clean gas with 40% of the clean gas entering the sample-gas channel without change in gas velocity. The sample-gas channel contains an Andersen impactor for particle separation and measurement. The bypass channel contains an absolute filter. The flow within the two segments of the "Y" is continuously monitored and maintained at selected rates by adjustable valves. Two vacuum pumps maintain air flow through the raw-gas and clean-gas channels. The flow rates, and thus the gas-to-cloth ratio (G/C) through the test filter, are kept constant and measured using mass flow controllers. A pressure transducer is used to measure the average residual ΔP of the filter sample. The pressure transducer measures the differential pressure across the filter samples every 3 seconds; the residual ΔP measurements are those taken 3 seconds after the cleaning pulse. The ΔP measurements are then averaged, as described in Appendix C, Section 4.4.1 of the GVP.[1] High-efficiency filters are installed upstream of the flow controllers and pumps to prevent contamination or damage caused by the dust. The cleaning system consists of a compressed-air tank set at 0.5 MPa (75 psi), a quick-action diaphragm valve, and a blow tube [25.4 mm (1.0 in.) dia.] with a nozzle [3 mm (0.12 in.) dia.] facing the downstream side of the test filter.

Mean outlet particle concentration is determined when a portion of the gas flow is extracted from the raw-gas channel through the test filter, which is mounted vertically at the entrance to a horizontal duct (clean-gas channel). The clean-gas flow is separated using an aerodynamic "Y" so that a representative sample of the clean gas flows through an Andersen impactor that determines the outlet particle concentration. Outlet particle concentrations were determined by weighing the mass increase of dust collected in each impactor filter stage and dividing by the gas volumetric flow through the impactor.

The particle size was measured while a fine dust was injected into the air stream upstream of the filter fabric sample. The particle size distributions in the air were determined both upstream and downstream of the test filter fabric to provide accurate results for penetration through the test filter of $PM_{2.5}$.

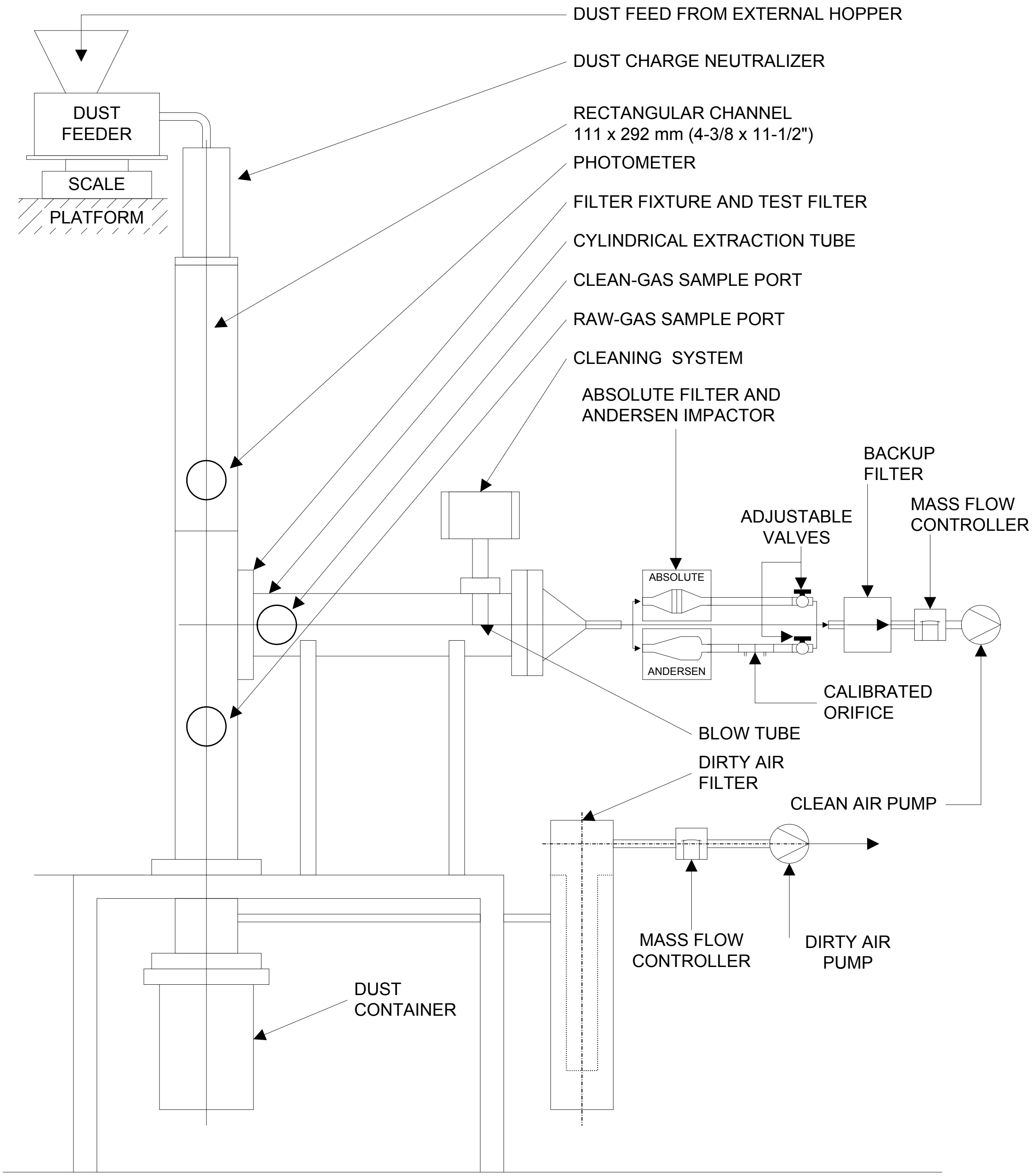

Figure 1. Diagram of filtration efficiency media analyzer test apparatus.

The following series of tests was performed on three separate, randomly selected filter fabric samples:

- Conditioning period
- Recovery period
- Performance test period.

To simulate long-term operation, the test filter was first subjected to a conditioning period, which consists of 10,000 rapid-pulse cleaning cycles under continuous dust loading. During this period, the time between cleaning pulses was maintained at 3 seconds. No filter performance parameters are measured in this period.

The conditioning period is immediately followed by a recovery period, which allows the test filter fabric to recover from rapid pulsing. The recovery period consists of 30 normal filtration cycles under continuous and constant dust loading. During a normal filtration cycle, the dust cake is allowed to form on the test filter until a differential pressure of 1,000 Pa (4.0 in. w.g.) is reached. At this point, the test filter is cleaned by a pulse of compressed air from the clean-gas side of the fabric. The next filtration cycle begins immediately after the cleaning is complete.

Performance testing occurred for a 6-hour period immediately following the recovery period (a cumulative total of 10,030 filtration cycles after the test filter had been installed in the test apparatus). During the performance test period, normal filtration cycles are maintained and, as in the case of the conditioning and recovery periods, the test filter is subjected to continuous and constant dust loading.

The filtration velocity (G/C) and inlet dust concentrations were maintained at 120 ± 6 m/h (6.6 ± 0.3 fpm) and 18.4 ± 3.6 g/dscm (8.0 ± 1.6 gr/dscf), respectively, throughout all phases of the test.

2.2 Selection of Filtration Sample for Testing

Filter fabric samples of Dura-Life #0701607 Filtration Media were supplied to ETS directly from the manufacturer (Donaldson Company, Inc.), with a letter signed by Tom Scalf, General Manager, Donaldson Company, Inc., attesting that the filter media were selected at random in an unbiased manner from commercial-grade media and were not treated differently in any manner from the media provided to customers. The manufacturer supplied the test laboratory with nine 46 x 91 cm (18 x 36 in.) filter samples. The test laboratory randomly selected three samples and prepared them for testing by cutting one test specimen of 150 mm (5.9 in.) diameter from each selected sample for insertion in the test rig sample holder. The sample holder has an opening 140 mm (5.5 in.) in diameter, which is the dimension used to calculate the face area of the tested specimen.

2.3 Control Tests

Two types of control tests were performed during the verification test series. The first was a dust characterization, which is performed monthly. The reference dust used during the verification tests was Pural NF aluminum oxide dust. The Pural NF dust was oven dried for 2 hours and sealed in an airtight container prior to its insertion into the FEMA apparatus. The criteria for the dust characterization test are a maximum mass mean diameter of 1.5 ± 1.0 µm and a concentration between 40% and 90% of particles less than 2.5 µm. These criteria must be met in order to continue the verification test series.

The second control test, the reference value test, is performed quarterly using the reference fabric and the FEMA apparatus. The reference value test determines the weight gain of the reference fabric, as well as the maximum ΔP (final residual pressure drop). The results of the test verified that the FEMA apparatus was operating consistently within the required parameters. The average fabric maximum ΔP (average of the repeated measurements of final residual pressure drop conducted during the quarter applicable to this test) in a reference value test must be 0.60 cm w.g. ± 40%, and the fabric weight gain average must be 1.12 g ± 40%. Three reference value control test runs were conducted. The results of the control tests are summarized in **Table 1**.

Table 1. Summary of Control Test Results

—	Requirement	Measured Value	Criteria Met
Mass mean diameter, µm	1.5 ± 1.0	2.35	Yes
% Less than 2.5 µm	40%–90%	53.16%	Yes
Weight gain, g	1.12 ± 40%	0.78	Yes
Maximum pressure drop, cm w.g.	0.60 ± 40%	0.36	Yes

Beginning of table description. Table 1 is titled Summary of Control Test Results. The table lists the results of measurements meant to characterize the operation of the test apparatus. The mass mean diameter of the challenge aerosol, the percent less than 2.5 micrometers in diameter, the weight gain of a reference fabric and the maximum pressure drop of the reference fabric were measured. In columns, the table lists the QA/QC requirements, the values measured during the control tests, and whether or not the criteria were met. For this test, all criteria were met. End of table description.

2.4 Analysis

The equations used for verification analysis are described below.

A_f = Exposed area of sample filter, m^2
C_{ds} = Dry standard outlet particulate concentration of total mass, g/dscm
$C_{2.5ds}$ = Dry standard outlet particulate concentration of $PM_{2.5}$, g/dscm
dia. = Diameter of exposed area of sample filter, m
F_a = Dust feed concentration corrected for actual conditions, g/m^3
F_s = Dust feed concentration corrected for standard conditions, g/dscm
G/C = Gas-to-cloth ratio, m/h
M_t = Total mass gain from Andersen impactor, g
$M_{2.5}$ = Total mass gain of particles equal to or less than 2.5 µm diameter from Andersen impactor, g. This value may need to be linearly interpolated from test data.
N = Number of filtration cycles in a given performance test period
P_{avg} = Average residual ΔP, cm w.g.
P_i = Residual ΔP for i^{th} filtration cycle, cm w.g.
P_s = Absolute gas pressure as measured in the raw-gas channel, mbar
Q_a = Actual gas flow rate, m^3/h
Q_{ds} = Dry standard gas flow rate, dscmh
$Q_{2.5ds}$ = Dry standard gas flow rate for 2.5 µm particles, dscmh
Q_{st} = Standard gas flow rate for a specific averaging time, t, dscmh
t = Specified averaging time or sampling time, s
t_c = Average filtration cycle time, s
T_s = Raw-gas channel temperature, °F
w_f = Weight of dust in feed hopper following specified time, g. Because of vibrations causing short-term fluctuations to the feed hopper, this value is measured as a 1-min. average.
w_i = Weight of dust in feed hopper at the beginning of the specified time, g. Due to vibrations causing short-term fluctuations to the feed hopper, this value is measured as a 1-min. average.

Conversion factors and standard values used in the equations are listed below.

460 = 0 °F, in °R
1,013 = Standard atmospheric pressure, mbar
528 = Standard temperature, °R

Area of Sample Fabric, A_f

$$A_f = \frac{(\pi * d^2)}{4}$$

Actual Gas Flow Rate, Q_a

$$Q_a = Q_{ds} * \left[\frac{(T_s + 460) * 1013}{P_s * 528}\right]$$

Gas-to-Cloth Ratio, G/C

$$\frac{G}{C} = \frac{Q_a}{A_f}$$

Standard Dust Feed Concentration, F_s, for a specified time, t

$$F_s = \frac{(w_i - w_f)}{(Q_{st} * t)}$$

Actual Raw Gas Dust Concentration, F_a

$$F_a = F_s * \left[\frac{(T_s + 460) * 1013}{P_s * 528}\right]$$

Dry Standard Clean Gas Particulate Concentration, Total Mass, C_{ds}

$$C_{ds} = \frac{M_t}{\left[Q_{ds} * t * \left(1 - \frac{\%H_2O}{100}\right)\right]}$$

Dry Standard Clean Gas Particulate Concentration, $PM_{2.5,}$ $C_{2.5ds}$

$$C_{2.5ds} = \frac{M_{2.5}}{\left[Q_{2.5ds} * t * \left(1 - \frac{\%H_2O}{100}\right)\right]}$$

Filtration Cycle Time, t_c

$$t_c = \frac{t}{N}$$

Average Residual Pressure Drop, P_{avg}

$$P_{avg} = \frac{\Sigma P_i}{N}$$

3.0 DESCRIPTION OF FILTER FABRIC

The Donaldson Company, Inc. Dura-Life #0701607 Filtration Media is a 10.5 ounces per square yard (osy), polyester felt, self-supported filter media. **Figure 2** is a photograph of the fabric. Sample material was received as nine 46 x 91 cm (18 x 36 in.) swatches marked with the manufacturer's model number, year and month of manufacture, and cake side (the upstream side of the fabric, which is exposed to the particle-laden air, on which the filter cake builds up). Three of the swatches were selected at random for preparing three circular test specimens 150 mm (5.9 in.) in diameter.

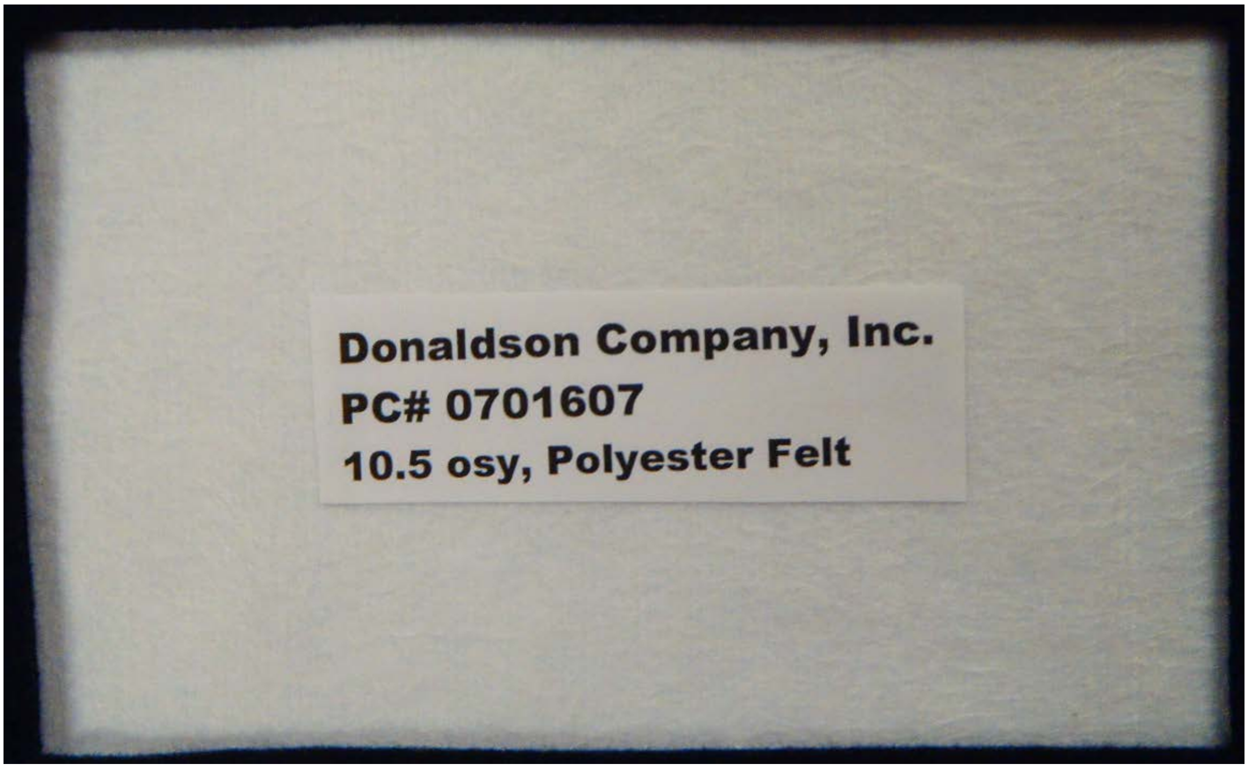

Figure 2. Photograph of Donaldson Company Inc.'s Dura-Life #0701607 Filtration Media.

4.0 VERIFICATION OF PERFORMANCE

4.1 Quality Assurance

The verification tests were conducted in accordance with an approved test/QA plan.[2] The EPA quality manager conducted an independent assessment of the test laboratory in June 2005 and found that the test laboratory was equipped and operated as specified in the test/QA plan.

The ETS QA officer and the APCT Center's QA staff have reviewed the results of this test and have found that the results meet the overall data quality objectives as stated in the test/QA plan.

Data on calibration certificates for the flow meters, flow transducers, weights, low- and high-resolution balances, thermometer, and humidity logger are maintained at ETS in a separate data package.

Deviations from the test plan include organizational personnel changes.

The ETS QA officer and the APCT Center's QA staff have also reviewed the results of the control tests, which are summarized in Section 2.3, Table 1. The dust characterization control test met the appropriate requirements of the test/QA plan and verification protocol. The reference fabric tests met maximum ΔP and weight gain requirements established for reference fabric performance in the GVP, indicating the measurement system is operating in control.

4.2 Results

Table 2 summarizes the mean outlet particle concentration measurements for the verification test periods. Measurements were conducted during the 6-hour performance test period. The performance test period followed a 10,000-cycle conditioning period and a 30-cycle recovery period.

Table 2 summarizes the three verification tests that were performed under standard verification test conditions. The average residual ΔP across each filter sample at the nominal 120 m/h (6.6 fpm) filtration velocity [for a flow rate of 5.8 m^3/h (3.4 cfm)] is also shown in Table 2. This ΔP ranged from 2.03 to 2.09 cm w.g. (0.80 to 0.82 in. w.g.) for the three filter samples tested. The residual ΔP increase ranged from 0.17 to 0.24 cm w.g. (0.07 to 0.09 in. w.g.) for the samples tested. All three standard condition verification runs were used to compute the averages given in Table 2. The $PM_{2.5}$ outlet particle concentration average for the three runs is 0.0001289 g/dscm. The total PM concentration average for the three runs is 0.0001745 g/dscm.

Table 2. Summary of Verification Results for Donaldson Company Inc.'s Dura-Life #0701607 Filtration Media

Test Run Number	5V6-R1	5V6-R2	5V6-R3	Average[a]
$PM_{2.5}$ (g/dscm)	0.0001091	0.0001792	0.0000983	0.0001289
Total PM (g/dscm)	0.0001668	0.0002085	0.0001482	0.0001745
Average residual Δ P (cm w.g.)	2.03	2.03	2.09	2.05
Initial residual Δ P (cm w.g.)	1.92	1.90	2.01	1.94
Residual Δ P increase (cm w.g.)	0.19	0.24	0.17	0.20
Mass gain of sample filter (g)	1.88	2.05	1.84	1.92
Average filtration cycle time (s)	158	159	181	166
Number of cleaning cycles	137	136	119	131

[a] All three verification runs were used to compute averages.

Beginning of table description. Table 2 is titled Summary of Verification Results for Donaldson Company Inc.'s Dura-Life #0701607 Filtration Media. The table lists the verified test results for the three replicate test runs and their averages. The table lists the particle concentrations downstream of the sample filters, the pressure drop characteristics, the mass gain of the sample filter, the average filtration cycle time, and the number of cleaning cycles during the test. In separate columns, results for these parameters are listed for each of the three test runs and their averages. End of table description.

4.3 Limitations and Applications

This verification report addresses two aspects of BFP performance: outlet particle concentration and ΔP. Users may wish to consider other performance parameters, such as service life and cost, when selecting a baghouse filtration fabric for their application.

5.0 REFERENCES

1. RTI International. 2001. *Generic Verification Protocol for Baghouse Filtration Products*, RTI International, Research Triangle Park, NC, February. Available at http://www.epa.gov/etv/pubs/05_vp_bfp.pdf (accessed January 4, 2012).

2. ETS Incorporated and RTI International. 2006. *Test/QA Plan for the Verification Testing of Baghouse Filtration Products (Revision 2)*, ETS Incorporated, Roanoke, VA, and RTI International, Research Triangle Park, NC, February. Available at http://www.epa.gov/etv/pubs/600etv06095.pdf (accessed January 4, 2012).

3. Verein Deutscher Ingenieure (VDI). 1994. VDI 3926, Part 2, *Testing of Filter Media for Cleanable Filters under Operational Conditions*, December 1994. Available from Beuth Verlag GmbH, 10772 Berlin, Germany.

APPENDIX A: VENDOR COMMENTS

Donaldson Company, Inc. has been offered the opportunity to comment on the findings of this report. Their comments are presented in Appendix A of the report and reflect their opinions. The Air Pollution Control Technology Center and EPA do not necessarily agree or disagree with the vendor's comments and opinions.

CONCERNS REGARDING ETV EVALUATION OF DONALDSON DURA-LIFE #0701607 (OCTOBER 2011)

Submitted by: Mark Belcher
Engineering Manager – Filtration
Donaldson Company, Incorporated
September 10, 2012

This addendum summarizes Donaldson Company, Inc.'s concerns regarding test results generated for the attached verification report. DCI chooses to not publish a verification statement (per terms of the contract), in order to address these concerns.

HISTORY

DCI has evaluated their proprietary filter media, Dura-Life, many times over several years; these tests were conducted by ETS, the organization that conducts the ETV testing for the Environmental Protection Agency. The results of tests through 2010 fell in a consistent band, with mean $PM_{2.5}$ penetration levels never exceeding .0000479 (see **Table A-1**, below). Also shown in the table are results of testing in 2011, when samples of this media were submitted for official certification. The results indicated significantly higher penetration concentrations; on the order of three times higher than previous results.

Table A-1. Summary of Dura-Life Test Results (2001 – 2011)

ETS, Inc. Test Summary	2001 EPA/ETV Durapex	2004 ETS Dura-Life #1	2004 ETS Dura-Life #2	2010 ETS Dura-Life	2011 EPA/ETV Dura-Life #0701607
Test Date	9/25/2001	03/01/2004	03/18/2004	11/10/2010	10/28/2011
Mean Outlet Particle Conc., $PM_{2.5}$ (g/dscm)	0.0000423	0.0000479	0.0000250	0.0000324	0.0001289
Mean Outlet Particle Conc., Total PM (g/dscm)	0.0000676	0.0000556	0.0000250	0.0000324	0.0001745

Beginning of table description. Table A-1 is titled Summary of Dura-Life Test Results (2001 – 2001). The table lists verified ETV results and other unverified results for five tests. The table lists the test date, the mean $PM_{2.5}$ particle outlet concentration, and the mean total particle outlet concentration. In separate columns, results are listed for five tests over the years 2001 through 2011. End of table description.

ANALYSIS

DCI questioned these results as an anomaly, and worked with EPA and the testing facility to review the test protocol. No specific issues were identified, although it was proposed that variations in media permeability could affect the filtration performance.

At this point, the APCT Center, ETS, and DCI all agreed that further testing may be required to further explain these results. ETS had retained the original test samples from the tests run in 2010 and 2011, and DCI agreed to fund repeat testing of these specific samples. Since the 2011 data was an average of three discrete tests, DCI chose to re-analyze using the sample with performance closest to the average. Repeat tests were run on adjacent areas of the original media samples from 2010 and 2011. The results of this testing are shown in **Table A-2**, on the next page.

Table A-2. Dura-Life Retest Results (2011 – 2012)

ETS, Inc. Test Summary	2010 ETS Original	2012 ETS Retest of 2010	2011 EPA/ETV Original	2012 ETS Retest of 2011
Test Date	11/10/2010	1/28/2012	10/28/2011	1/28/2012
Mean Outlet Particle Conc., $PM_{2.5}$ (g/dscm)	0.0000324	0.0000047*	0.0001091	0.0000282
Mean Outlet Particle Conc., Total PM (g/dscm)	0.0000324	0.0000125*	0.0001668	0.0000315

* Below Method Detection Limit of 0.0000167 g/dscm

Beginning of table description. Table A-2 is titled Dura-Life Retest Results (2011 – 2012). The table compares original test results from years 2010 and 2011 to retest results from year 2012. The table lists the test date, the mean $PM_{2.5}$ particle outlet concentration, and the mean total particle outlet concentration. In separate columns, results are listed for original and retest data. End of table description.

In the repeat of the 2011 test (the test in question), the new penetration values (right-hand column) fell to approximately one fourth of the original values, and now fell in line with historical data. Curiously, similar drops in penetration were found in the repeat test of the 2010 media (note that these penetration values dropped below the Method Detection Limit).

OBSERVATIONS / INTERPRETATIONS

No explanation was found for the dramatic changes in efficiency of both samples. Earlier speculation that permeability variations could be the cause lose credibility, because the penetrations dropped significantly in both repeat tests while the sample areas were supplied from the same specific hand sheets. Additionally, the magnitude of the drop in penetration exceeded that of the initial rise in penetration that started this review; both samples would have required permeability variation at the extremes of all previous samples in order to be the primary cause.

The fact that both repeat tests indicated similar dramatic drops in penetration points to influence by an outside factor, similar to multiplying by a constant. Based on the observations, Donaldson interprets this data as an indication that the variability caused by the test method itself, even though the cause of this variation is not defined. As such, the data generated in this verification report should be considered as invalid.