

**THE ENVIRONMENTAL TECHNOLOGY VERIFICATION  
PROGRAM**



U.S. Environmental Protection Agency



**ETV Joint Verification Statement**

<b>TECHNOLOGY TYPE:</b>	<b>BAGHOUSE FILTRATION PRODUCTS</b>		
<b>APPLICATION:</b>	<b>CONTROL OF PM<sub>2.5</sub> EMISSIONS BY BAGHOUSE FILTRATION PRODUCTS</b>		
<b>TECHNOLOGY NAME:</b>	<b>L3650</b>		
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups, which consist of buyers, vendor organizations, permittees, and other interested parties; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Air Pollution Control Technology (APCT) Verification Center is operated by RTI International (RTI), in cooperation with EPA's National Risk Management Research Laboratory. The APCT Verification Center evaluates the performance of baghouse filtration products (BFPs) used primarily to control PM<sub>2.5</sub> emissions (particles 2.5 µm and smaller in aerodynamic diameter). This verification statement summarizes the test results for W. L. Gore & Associates, Inc.'s filter fabric L3650.

## VERIFICATION TEST DESCRIPTION

All tests were performed in accordance with the APCT *Generic Verification Protocol for Baghouse Filtration Products*, available at <http://etv.rti.org/apct/pdf/baghouseprotocol.pdf>. 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. The VDI document is available from Beuth Verlag GmbH, 10772 Berlin, Germany. The protocol also includes requirements for quality management, quality assurance, procedures for product selection, auditing of the test laboratories, and test reporting format.

Outlet particle concentrations from a test fabric were measured with an impactor equipped with appropriate substrates to filter and measure PM<sub>2.5</sub> within the dust flow. 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.

Particle size was measured while injecting the test dust into the air upstream of the baghouse filter sample. The test dust was dispersed into the flow using a brush-type dust feeder. 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<sub>2.5</sub>. All tests were performed using a constant  $18.4 \pm 3.6$  g/dscm ( $8.0 \pm 1.6$  gr/dscf) loading rate, a  $120 \pm 6.0$  m/h ( $6.6 \pm 0.3$  fpm) filtration velocity [identical to gas-to-cloth ratio (G/C\*)], and aluminum oxide test dust with a measured mass mean aerodynamic diameter maximum of 1.5  $\mu$ m (average of three impactor runs). All baghouse filtration products are tested in their initial (i.e., clean) condition.

Each of the three test runs consisted of the following segments:

- Conditioning period – 10,000 rapid-pulse cleaning cycles,
- Recovery period – 30 normal-pulse cleaning cycles,
- Performance test period – 6-hour filter fabric test period with impactor.

## VERIFIED TECHNOLOGY DESCRIPTION

The W. L. Gore & Associates, Inc. company provided the following information about their product. The L3650 is a membrane/fiberglass fabric laminate with a weight of 22 oz/yd<sup>2</sup> (746/ g/m<sup>2</sup>) and used in both GORE® Filtration Products and PRISTYNE® Filter Media Type 6250<sup>\*\*</sup>. Figure 1 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. Three of the swatches were selected at random for preparing three test specimens 150 mm (5.9 in.) in diameter.

## VERIFICATION OF PERFORMANCE

Verification testing of the W. L. Gore & Associates, Inc., L3650 filter fabric was performed during October 18–25, 2005, for standard test conditions at the test facility of ETS, Incorporated, 1401 Municipal Road, Roanoke, VA 24012. Test conditions are listed in Table 1. The overall test results summarized in Table 2 are the averages of three individual tests.

\*Filtration velocity and gas-to-cloth ratio are used interchangeably and are defined as the gas flow rate divided by the surface area of the cloth.

\*\*This verification statement was originally written for a GORE-TEX product name. GORE® is the new product name for GORE-TEX and PRISTYNE® Filter Media Type 6250 was added as it uses the exact same L3650 fabric.



**Figure 1. Photograph of W. L. Gore & Associates, Inc.'s L3650 filter fabric**

**Table 1. Test Conditions for Baghouse Filtration Products Brand/Model:  
W. L. Gore & Associates, Inc.'s L3650**

Test parameter	Value
Dust concentration	$18.4 \pm 3.6$ g/dscm ( $8.0 \pm 1.6$ gr/dscf)
Filtration velocity (G/C)	$120 \pm 6$ m/h ( $6.6 \pm 0.3$ fpm)
Pressure loss before cleaning	$1,000 \pm 12$ Pa ( $4 \pm 0.05$ in. w.g.)
Tank pressure	$0.5 \pm 0.03$ MPa ( $75 \pm 5$ psi)
Valve opening time	$50 \pm 5$ ms
Air temperature	$25 \pm 2$ °C ( $78 \pm 4$ °F)
Relative humidity	$50 \pm 10$ %
Total raw gas stream flow rate	$5.8 \pm 0.3$ m <sup>3</sup> /h ( $3.4 \pm 0.2$ cfm)
Sample gas stream flow rate	$1.13 \pm 0.06$ m <sup>3</sup> /h ( $0.67 \pm 0.03$ cfm)
Number of filtration cycles	
• During conditioning period	10,000 cycles
• During recovery period	30 cycles
Performance test duration	$6 \text{ h} \pm 1 \text{ s}$

**Table 2. Baghouse Filtration Product Three-run Average Test  
Results for W. L. Gore & Associates, Inc.'s Fabric L3650**

Verification parameter	At verification test conditions
Outlet particle concentration at standard conditions <sup>a</sup> PM <sub>2.5</sub> , g/dscm (gr/dscf) Total mass, g/dscm <sup>b</sup> (gr/dscf)	<0.000002 (<0.000007) <0.000002 (<0.000007)
Average residual pressure drop, cm w.g. (in. w.g.)	2.45 (0.96)
Initial residual pressure drop, cm w.g. (in. w.g.)	2.36 (0.93)
Residual pressure drop increase, cm w.g. (in. w.g.)	0.18 (0.07)
Filtration cycle time, s	251
Mass gain of test sample filter, g (gr)	0.09 (1.39)
Number of cleaning cycles	87

NA = Not applicable – values shown are for three tests.

<sup>a</sup> Standard conditions: 101.3 kPa (14.7 psia) and 20 °C (68 °F). One or more of the impactor substrate weight changes for these results were near the reproducibility of the balance.

<sup>b</sup> Total mass includes the mass of PM<sub>2.5</sub> and larger particles that passed through the fabric.

The APCT Verification Center quality assurance officer has reviewed the test results and the quality control data and has concluded that the data quality objectives given in the generic verification protocol and test/QA plan have been attained.

This verification statement addresses five aspects of filter fabric performance: filter outlet PM<sub>2.5</sub> concentration, filter outlet total mass concentration, pressure drop ( $\Delta P$ ), filtration cycle time, and mass gain on the filter fabric. Users may wish to consider other performance parameters such as temperature, service life, and cost when selecting a filter fabric for their application.

In accordance with the generic verification protocol, this verification statement is applicable to filter media manufactured between the signature date of the verification statement and 3 years thereafter.

signed by Sally Gutierrez      7/28/06  
Sally Gutierrez      Date  
Director  
National Risk Management Research Laboratory  
Office of Research and Development  
United States Environmental Protection Agency

signed by Andrew R. Trenholm      7/20/06  
Andrew R. Trenholm      Date  
Director  
APCT Verification Center  
RTI International

**NOTICE:** ETV verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and RTI make no express or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of commercial product names does not imply endorsement.

# **Environmental Technology Verification Report**

## **Baghouse Filtration Products**

### **W. L. Gore & Associates, Inc. L3650 Filter Sample**

Prepared by

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### **Notice**

This document was prepared by RTI International\* (RTI) and its subcontractor ETS, Inc. (ETS) with partial funding from Cooperative Agreement No. CR 83191101-1 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.

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\* 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 so that potential purchasers and permittees are provided with an independent and credible assessment of the technology that they are buying or permitting.

The Air Pollution Control Technology (APCT) Verification Center is part of the EPA's ETV Program and is operated as a partnership between RTI International (RTI) and EPA. The 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, Inc. (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. 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 W.L. Gore & Associates Inc.'s L3560. ETV testing of this technology was conducted during October 2005 at ETS. All testing was performed in accordance with an approved test/QA plan that implements the requirements of the generic verification protocol at the test laboratory.



### **Availability of Verification Statement and Report**

Copies of this verification report are available from:

- RTI International  
Engineering and Technology Unit  
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 Sites:

<http://www.epa.gov/etv/verifications/verification-index.html> (electronic copy)  
<http://etv.rti.org/apct/index.html>

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### List of Abbreviations and Acronyms

APCT	Air Pollution Control Technology
APPCD	Air Pollution Prevention and Control Division
BFP	baghouse filtration product
cfm	cubic feet per minute
cm	centimeters
cm w.g.	centimeters of water gauge
dia.	diameter
$\Delta P$	pressure drop
DQO	data quality objective
dscm/h	dry standard cubic meters per hour
EPA	U.S. Environmental Protection Agency
ETS	ETS, Incorporated
ETV	Environmental Technology Verification
FEMA	Filtration Efficiency Media Analyzer
ft/min	feet per minute
ft <sup>3</sup>	cubic feet
g	grams
G/C	gas-to-cloth ratio (filtration velocity)
gr	grains
gr/dscf	grains per dry standard cubic foot
g/dscm	grams per dry standard cubic meter
g/h	grams per hour
g/m <sup>2</sup>	grams per square meter
hr	hours
in.	inches
in. w.g.	inches of water gauge
kg/m <sup>2</sup>	kilograms per square meter
kPa	kilopascals
m	meters
mbar	millibars
min	minutes
m/h	meters per hour

m <sup>3</sup> /h	cubic meters per hour
mm	millimeters
MPa	megapascals
ms	milliseconds
NA	not applicable
oz/yd <sup>2</sup>	ounces per square yard
Pa	pascals
PM	particulate matter
PM <sub>2.5</sub>	particulate matter 2.5 micrometers in aerodynamic diameter or smaller
psi	pounds per square inch
psia	pounds per square inch absolute
PTFE	polytetrafluoroethylene
QA	quality assurance
QC	quality control
RTI	RTI International
s	seconds
scf	standard cubic feet
scfm	standard cubic feet per minute
VDI	Verein Deutscher Ingenieure
w.g.	water gauge
μg	micrograms
μm	micrometers
°C	degrees Celsius
°F	degrees Fahrenheit
°R	degrees Rankin

### **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, EPA's Project Manager, and Paul Groff, EPA's Quality Assurance Manager, both of EPA's National Risk Management Research Laboratory in Research Triangle Park, NC. Finally, we would like to acknowledge the assistance and participation of W. L. Gore & Associates, Inc. personnel who supported the test effort.

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## SECTION 1

### INTRODUCTION

This report reviews the filtration and pressure drop ( $\Delta P$ ) performance of W.L. Gore & Associates Inc.'s L3560. Environmental Technology Verification (ETV) testing of this technology/product was conducted during a series of tests in October, 2005, by ETS, Inc. (ETS), under contract with the Air Pollution Control Technology (APCT) Verification 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 ( $PM_{2.5}$ ) emission control. Based on the activities of this technical panel, the *Generic Verification Protocol for Baghouse Filtration Products* 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. The goal of the test was to measure filtration performance of both  $PM_{2.5}$  and total PM as well as the pressure drop characteristics of the W.L. Gore & Associates, Inc. technology identified above.

Section 2 documents the procedures and methods used for the test and the conditions over which the test was conducted. A description of the W. L. Gore & Associates, Inc.'s L3560 technology 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 as well as the verification statement. Complete documentation of the test results is provided in a separate data package and audit of data quality report. These reports include the raw test data from product testing and supplemental testing, equipment calibrations results, and QA and quality control (QC) activities and results. Complete documentation of QA/QC activities and results, raw test data, and equipment calibrations results are retained in ETS's files for 7 years.

## SECTION 2

### VERIFICATION TEST DESCRIPTION

The baghouse filtration products were tested in accordance with the APCT Center *Generic Verification Protocol for Baghouse Filtration Products*<sup>1</sup> and the *Test/QA Plan for the Verification Testing of Baghouse Filtration Products*.<sup>2</sup> This protocol incorporated all 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 to be used for verification testing and defines the data quality objectives. The values for inlet dust concentration, raw gas flow rate, and filtration velocity used for current verification testing were 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 will implement and meet 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 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 read-out 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 concentration. 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 in 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 percent 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 pressure drop of the filter sample. The pressure transducer measures the differential pressure across the filter samples 3 seconds after the cleaning pulse. The pressure drop measurements are then averaged as described in Appendix C, Section 4.4.1 of the GVP.<sup>1</sup> 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.

The particle size was measured while a fine dust was injected into the air stream upstream of the filter fabric sample.

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

- Conditioning period,
- Recovery period, and
- 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 is 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 occurs for a 6-hour period immediately following the recovery period (a cumulative total of 10,030 filtration cycles after the test filter has 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 are maintained at  $120 \pm 6$  m/h ( $6.6 \pm 0.3$  fpm) and  $18.4 \pm 3.6$  g/dscm ( $8.0 \pm 1.6$  gr/dscf), respectively, throughout all phases of the test.

## **2.2 SELECTION OF FILTRATION SAMPLE FOR TESTING**

Filter fabric samples of L3560 were supplied to ETS directly from the manufacturer (W. L. Gore & Associates, Inc.) with a letter signed by Dick Winkelmayer, Business Leader for Industrial Dry Filtration, W. L. Gore & Associates, Inc., attesting that the filter media were selected at random in an unbiased manner from commercial-grade media and were not treated in any manner different 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 dust characterization results had to meet the requirements of a  $1.5 \mu\text{m}$  maximum mass mean diameter and between 40 and 90 percent less than  $2.5 \mu\text{m}$  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 pressure drop. The results of the test verify that the FEMA apparatus is operating consistently within the required parameters. Reference values tests are conducted and the average fabric maximum pressure drop and fabric weight gain must meet criteria in the revised test/QA plan.

The results of the control tests are summarized in Table 1.

**Table 1. Summary of Control Test Results**

	<b>Requirement</b>	<b>Measured value</b>	<b>Met requirements?</b>
Mass mean diameter, $\mu\text{m}$	< 1.5	1.30	Yes
% Less than 2.5 $\mu\text{m}$	40 - 90%	73.63	Yes
Weight gain, g	$1.19 \pm 40\%$	0.85	Yes
Maximum $\Delta P$ , cm w.g.	$0.67 \pm 40\%$	0.48	Yes

$\Delta P$  = pressure drop.

Three reference value control test runs were conducted.

## 2.4 ANALYSIS

The equations used for verification analysis are described below.

$A_f$	=	Exposed area of sample filter, $\text{m}^2$
$C_{ds}$	=	Dry standard outlet particulate concentration of total mass, g/dscm
$C_{2.5ds}$	=	Dry standard outlet particulate concentration of $\text{PM}_{2.5}$ , g/dscm
$d$	=	Diameter of exposed area of sample filter, m
$F_a$	=	Dust feed concentration corrected for actual conditions, $\text{g}/\text{m}^3$
$F_s$	=	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 $\mu\text{m}$ 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 pressure drop, cm w.g.
$P_i$	=	Residual pressure drop 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, $\text{m}^3/\text{h}$
$Q_{ds}$	=	Dry standard gas flow rate, dscm/h
$Q_{2.5ds}$	=	Dry standard gas flow rate for 2.5 $\mu\text{m}$ particles, dscm/h
$Q_{st}$	=	Standard gas flow rate for a specific averaging time, t, dscm/h
$t$	=	Specified averaging time or sampling time, s
$t_c$	=	Average filtration cycle time, s
$T_s$	=	Raw-gas channel temperature, $^{\circ}\text{F}$
$w_f$	=	Weight of dust in feed hopper following specified time, g. Because of vibrations causing short-term fluctuations to the feed hopper, it is recommended that this value be measured as a 1-min average.
$w_i$	=	Weight of dust in feed hopper at the beginning of the specified time, g. Because of vibrations causing short-term fluctuations to the feed hopper, it is recommended that this value be measured as a 1-min average.

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

$$460 = 0^{\circ}\text{F, in }^{\circ}\text{R}$$

$$1,013 = \text{Standard atmospheric pressure, mbar}$$

$$528 = \text{Standard temperature, }^{\circ}\text{R}$$

Area of Sample Fabric –  $A_f$

$$A_f = (\pi \cdot d^2)/4$$

Actual Gas Flow Rate –  $Q_a$

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

Gas-to-Cloth Ratio –  $G/C$

$$G/C = Q_a / A_f$$

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

$$F_s = (w_i - w_f) / (Q_{st} \cdot t)$$

Actual Raw Gas Dust Concentration –  $F_a$

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

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

$$C_{ds} = M_t / [Q_{ds} \cdot t \cdot (1 - \%H_2O/100)]$$

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

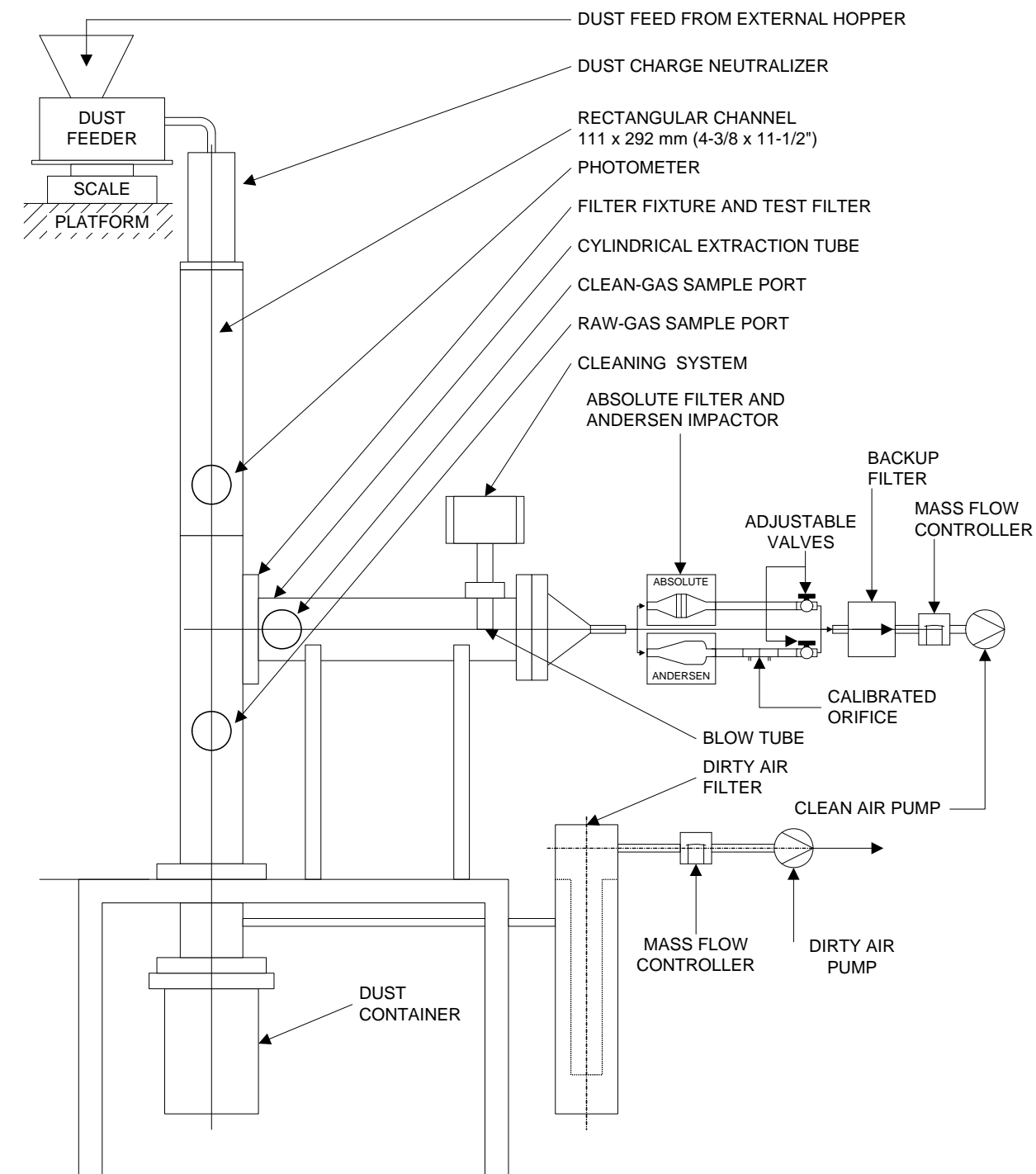
$$C_{2.5ds} = M_{2.5} / [Q_{2.5ds} \cdot t \cdot (1 - \%H_2O/100)]$$

Filtration Cycle Time –  $t_c$

$$t_c = t/N$$

Average Residual Pressure Drop –  $P_{avg}$

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



**Figure 1. Diagram of FEMA test apparatus**

### SECTION 3

#### DESCRIPTION OF FILTER FABRIC

The L3560 is a membrane/fiberglass fabric laminate with a weight of 22 oz/yd<sup>2</sup> (746 g/m<sup>2</sup>) and used in both GORE® Filtration Products and PRISTYNE® Filter Media Type 6250\*.

### SECTION 4

#### VERIFICATION OF PERFORMANCE

##### 4.1 QUALITY ASSURANCE

The EPA quality assurance 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 APCT Center QA staff have reviewed the results of this test and have found that the results meet data quality objectives as stated in the revised test/QA plan. It should be noted that, because of the highly efficient nature of the filter medium being tested, the impactor substrate weighings for these results were below the reproducibility of the balance. As a result of this occurrence, the tests do not meet the data quality objectives (DQOs) stated in the test/QA plan for mass gain associated with outlet concentrations. Nevertheless, the data were judged usable for their intended purpose. 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.

The verification tests were conducted in accordance with an approved test/QA plan.<sup>2</sup> Deviations from the test plan include organizational personnel changes, corrections to DQO and specification tables to match the GVP approved in October 2001, plus associated revisions. Updates of values to match protocol values include changing the filtration velocity to 120 m/hr, dust feed operation to 100 g/hr, inlet dust concentration to 18.4 g/dscm, mass mean aerodynamic diameter of the dust to 1.5 µm ± 1 µm, and particle size of the dust to 40–90% as specified in the approved 2001 GVP.

The ETS QA officer and APCT Center 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. Reference fabric tests meet revised maximum pressure drop 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.

The top portion of Table 2 summarizes 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

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\* This verification statement was originally written for a GORE-TEX product name. GORE® is the new product name for GORE-TEX and PRISTYNE® Filter Media Type 6250 was added as it uses the exact same L3650 fabric.

(6.6 fpm) filtration velocity [for a flow rate of 5.8 m<sup>3</sup>/h (3.4 cfm)] is also shown in Table 2. This  $\Delta P$  ranged from 2.37 to 2.54 cm w.g. (0.93 to 1.00 in. w.g.) for the three filter samples tested. The residual  $\Delta P$  increase ranged from 0.14 to 0.21 cm w.g. (0.06 to 0.08 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<sub>2.5</sub> concentration average for the three runs is <0.000002 g/dscm. The total PM concentration average for the three runs is <0.000002 g/dscm.

**Table 2. Summary of Verification Results For W. L. Gore & Associates, Inc.'s Fabric L3560**

Test run number	4V2-R1	4V2-R2	4V2-R3	Average*
PM <sub>2.5</sub> (g/dscm)**	<0.000002	<0.000002	<0.000002	<0.000002
Total PM (g/dscm)	<0.000007	<0.000007	<0.000007	<0.000007
Average residual $\Delta P$ (cm w.g.)	2.54	2.43	2.37	2.45
Initial residual $\Delta P$ (cm w.g.)	2.42	2.36	2.30	2.36
Residual $\Delta P$ increase (cm w.g.)	0.21	0.18	0.14	0.18
Mass gain of sample filter (g)	0.09	0.09	0.09	0.09
Average filtration cycle time (s)	221	241	291	251
Number of cleaning cycles	97	89	74	87

\* All three verification runs were used to compute averages.

\*\* The impactor substrate weight changes for these results were below the reproducibility of the balance.

### **4.3 LIMITATIONS AND APPLICATIONS**

This verification statement addresses five aspects of filter fabric performance: filter outlet PM<sub>2.5</sub> concentration, filter outlet total mass concentration, pressure drop ( $\Delta P$ ), filtration cycle time, and mass gain on the filter fabric. Users may wish to consider other performance parameters such as temperature, service life, and cost when selecting a filter fabric for their application.

In accordance with the GVP, this verification statement is applicable to baghouse filtration products manufactured between signature date of the verification statement and 3 years thereafter.

## **SECTION 5**

### **REFERENCES**

1. *Generic Verification Protocol for Baghouse Filtration Products*, RTI International, Research Triangle Park, NC, February 2000. Available at <http://etv.rti.org/apct/pdf/baghouseprotocol.pdf>.
2. *Test/QA Plan for the Verification Testing of Baghouse Filtration Products*, ETS, Inc., Roanoke, VA, February 1999.