

US EPA ARCHIVE DOCUMENT

Environmental Technology Verification Report

Baghouse Filtration Products

BWF America, Inc. Grade 700 MPS Polyester Felt Filter Sample

Prepared by



ETS, Incorporated



Under a Cooperative Agreement with



US EPA ARCHIVE DOCUMENT



THE ENVIRONMENTAL TECHNOLOGY VERIFICATION
PROGRAM



ETV Joint Verification Statement

TECHNOLOGY TYPE:	BAGHOUSE FILTRATION PRODUCTS	
APPLICATION:	CONTROL OF PM_{2.5} EMISSIONS BY BAGHOUSE FILTRATION PRODUCTS	
TECHNOLOGY NAME:	Grade 700 MPS Polyester Felt	
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(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 substantially 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 that 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 Research Triangle Institute (RTI), in cooperation with EPA's National Risk Management Research Laboratory. The APCT Verification Center has recently evaluated the performance of baghouse filtration products (BFPs) used

primarily to control PM_{2.5} emissions (particles 2.5 μm or smaller in aerodynamic diameter). This verification statement summarizes the test results for the BWF America, Inc.'s filter fabric Grade 700 MPS Polyester Felt.

VERIFICATION TEST DESCRIPTION

All tests were performed in accordance with the APCT draft "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 are measured with an impactor equipped with appropriate substrates to filter and measure PM_{2.5} within the dust flow. Outlet particle concentrations are determined by weighing the mass increase rate of dust collected in each impactor filter stage and dividing by the gas volumetric flow through the impactor.

Particle size is measured while injecting the test dust into the air upstream of the baghouse filter sample. The test dust is dispersed into the flow using a brush-type dust feeder. The particle size distributions in the air are determined both upstream and downstream of the test filter fabric to provide accurate results for penetration of PM_{2.5} through the test filter. All tests are performed using a constant 18.4 ± 3.6 g/dscm (8.0 ± 1.6 gr/dscf) loading rate, a 120 ± 6.0 m/h (6.6 ± 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 μm (average of three impactor runs). All baghouse filtration products are tested in their initial (i.e., clean) condition.

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

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

TECHNOLOGY DESCRIPTION

The BWF America, Inc.'s Grade 700 MPS polyester felt is an 18-20 oz/yd² (0.61-0.68 kg/m²) micro-pore-size high efficiency scrim supported felt, singed cake side. 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 BWF America, Inc.'s Grade 700 MPS polyester felt filter fabric was performed during December 10, 2001 - January 18, 2002 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.

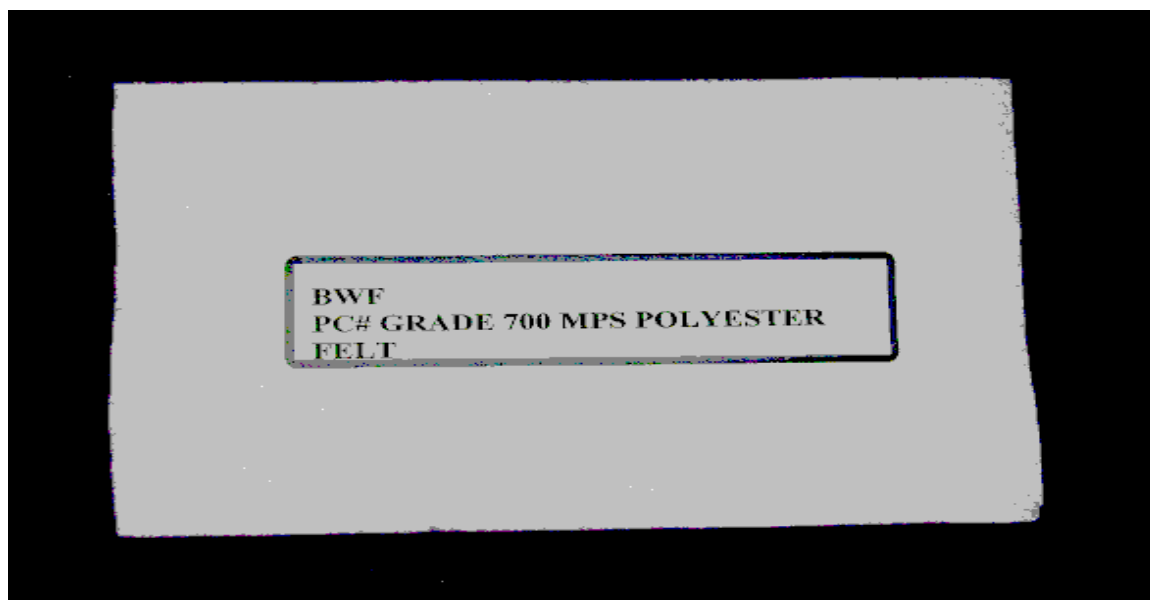


Figure 1. Photograph of the BWF America, Inc.'s Grade 700 MPS Polyester Felt filter fabric

Table 1. Test Conditions for Baghouse Filtration Product Brand/Model: BWF America, Inc.'s Grade 700 MPS Polyester Felt

Test parameter	Value
Dust concentration	18.4 ± 3.6 g/dscm (8.0 ± 1.6 gr/dscf)
Filtration velocity (G/C)*	120 ± 6 m/h (6.6 ± 0.3 fpm)
Pressure loss before cleaning	1,000 ± 12 Pa (4 ± 0.05 in. w.g.)
Tank pressure	0.5 ± 0.03 MPa (75 ± 5 psi)
Valve opening time	50 ± 5 ms
Air temperature	25 ± 2 °C (77 ± 4 °F)
Relative humidity	50 ± 10 %
Raw gas stream flow rate	5.8 ± 0.3 m ³ /h (3.4 ± 0.2 cfm)
Sample gas stream flow rate	1.13 ± 0.06 m ³ /h (0.67 ± 0.03 cfm)
Number of filtration cycles	
• During conditioning period	10,000
• During recovery period	30
Performance test duration	6 h ± 1 s

*Note: filtration velocity for ETV testing reduced to 120 m/h (from 180 m/h) on recommendation of the Technical Panel, as documented in the minutes of its June 21, 2001, meeting (see <http://etv.rti.org/apct/tech/index.cfm>).

Table 2. Baghouse Filtration Product Three-run Average Test Results for BWF America, Inc.'s Grade 700 MPS Polyester Felt

Verification parameter	At verification test conditions	At manufacturer's requested test conditions
Outlet particle concentration at standard conditions* PM _{2.5} , g/dscm (gr/dscf) Total mass, g/dscm** (gr/dscf)	0.0000104 (0.0000045) 0.0000161 (0.0000070)	NA
Average residual pressure drop, cm w.g. (in. w.g.)	6.75 (2.66)	NA
Initial residual pressure drop, cm w.g. (in. w.g.)	6.14 (2.42)	NA
Residual pressure drop increase, cm w.g. (in. w.g.)	1.11 (0.44)	NA
Filtration cycle time, s	37	NA
Mass gain of test sample filter, g (gr)	0.56 (8.64)	NA
Number of cleaning cycles	588	NA

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

* 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.

** Total mass includes the mass of PM_{2.5} 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 deviations from the data quality objectives given in the generic verification protocol do not detract from the usability of the results.

This verification statement addresses five aspects of filter fabric performance: Filter outlet PM_{2.5} concentration, filter outlet total mass concentration, pressure drop (DP), 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 publication date of the verification statement (June 7, 2002) and 3 years thereafter.

Original signed by T. Oppelt 6/3/02
E. Timothy Oppelt Date
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original signed by J. Farmer 6/7/02
Jack R. Farmer Date
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RTI

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

BWF America, Inc. Grade 700 MPS Polyester Felt Filter Sample

Prepared by

Air Pollution Control Technology Verification Center

ETS, Incorporated
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EPA Cooperative Agreement CR 826152-01-3

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Notice

This document was prepared by ETS, Inc. (ETS) under a contract with Research Triangle Institute with funding from Cooperative Agreement No. CR826152-01-3 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.

Availability of Verification Statement and Report

Copies of the public Verification Statement and Verification Report are available from the following:

1. **Research Triangle Institute**
P.O. Box 12194
Research Triangle Park, NC 27709-2194

<http://etv.rti.org/apct/documents.cfm>
<http://www.epa.gov/etv> (*click on partners*)

2. **USEPA / APPCD**
MD-E305-01
Research Triangle Park, NC 27711

<http://www.epa.gov/etv/library.htm> (*electronic copy*)
<http://www.epa.gov/ncepihom/>

Abstract

Baghouse filtration products (BFPs) were evaluated by the Air Pollution Control Technology (APCT) Verification Center. The performance factor verified was the mean outlet particle concentration for the filter fabric as a function of the size for particles equal to or smaller than 2.5 μm in aerodynamic diameter ($\text{PM}_{2.5}$). The APCT Verification Center developed a generic verification protocol for testing baghouse filtration products that is based on a modified Verein Deutscher Ingenieure (VDI) Method 3926. The protocol was developed by RTI and ETS, Inc. (ETS), reviewed by a technical panel of experts, and approved by the U.S. Environmental Protection Agency (EPA). The protocol addresses several issues that VDI Method 3926 does not cover, including periodic testing, acquisition of BFP samples for testing, and product definition. A test/quality assurance plan and a standard operating procedure were prepared to address the test procedure, quality assurance, and quality control requirements for obtaining verification data of sufficient quantity and quality to satisfy the data quality objectives.

ETS performed tests on BWF America, Inc.'s filter sample Grade 700 MPS Polyester Felt during December 10, 2001 - January 18, 2002. Mean outlet particle concentrations for total mass and $\text{PM}_{2.5}$ were determined. In addition, the following verification parameters were measured and reported: initial residual pressure drop, residual pressure drop increase, average residual pressure drop, average filtration cycle time, and mass gain of the filter sample.

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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
DP	pressure drop (differential pressure)
dscmh	dry standard cubic meters per hour
EPA	U.S. Environmental Protection Agency
ETS	ETS, Inc.
ETV	Environmental Technology Verification
FEMA	Filtration Efficiency Media Analyzer
fpm	feet per minute
ft ³	cubic feet
g	grams
G/C	gas-to-cloth ratio (filtration velocity)
g/dscm	grams per dry standard cubic meter
g/h	grams per hour
g/m ²	grams per square meter
gr	grains
gr/dscf	grains per dry standard cubic foot
h	hours
in.	inches
in. w.g.	inches of water gauge
kPa	kilopascals
m	meters
mbar	millibars
m/h	meters per hour
m ³ /h	cubic meters per hour

min	minutes
mm	millimeters
MPa	megapascals
ms	milliseconds
NA	not applicable
Pa	pascals
PM	particulate matter
PM _{2.5}	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	Research Triangle Institute
s	seconds
scf	standard cubic feet
scfm	standard cubic feet per minute
VDI	Verein Deutscher Ingenieure
µg	micrograms
µm	micrometers
°C	degrees Celsius
°F	degrees Fahrenheit
°R	degrees Rankine

Acknowledgments

ETS acknowledges the support of all those who helped plan and conduct the verification activities. In particular, we would like to thank Ted Brna, 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 Clint Scoble of BWF America, Inc.

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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved technologies through performance verification and information dissemination. The ETV Program is intended to assist and inform those involved in the design, distribution, permitting, and purchase of environmental technologies.

EPA's partner in the Air Pollution Control Technology (APCT) Verification Center is Research Triangle Institute (RTI). With the full participation of the technology developer, the APCT Verification Center develops plans, conducts tests, collects and analyzes data, and reports findings. The evaluations are conducted according to a rigorous protocol and under quality assurance (QA) and quality control (QC) oversight. The APCT Verification Center verifies the performance of commercial-ready technologies used to control air pollutant emissions, with an emphasis on technologies for controlling particulate matter, volatile organic compounds, nitrogen oxides, and hazardous air pollutants. The program develops standardized verification protocols and test plans, conducts independent testing of technologies, and prepares verification test reports and statements for broad dissemination.

SECTION 2

VERIFICATION TEST DESCRIPTION

The baghouse filtration products were tested in accordance with the APCT "Generic Verification Protocol for Baghouse Filtration Products"¹ and the "Test/QA Plan for the Verification Testing of Baghouse Filtration Products."² This protocol incorporates all requirements for quality management, quality assurance, procedures for product selection, auditing of the test laboratories, and reporting format. The Generic Verification Protocol 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 have been revised since posting of the Generic Verification Protocol. The protocol is being revised to include these and other changes under recommendation or concurrence of the Baghouse Filtration Products Technical Panel. The Test/QA Plan details how the test laboratory at ETS, Inc. (ETS) will implement and meet the requirements of the Generic Verification Protocol.

Mean outlet particle concentration was determined from the Filtration Efficiency Media Analyzer (FEMA) test apparatus. The test apparatus consists of a brush-type dust feeder that disperses test dust into a vertical rectangular duct (raw-gas channel). A radioactive polonium-210 alpha source is used to neutralize the dust electrically before its entry into the raw-gas channel. 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 (gas-to-cloth ratio [(G/C)] and inlet dust concentrations are 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.

Additional details on the test procedure are provided in Appendix A.

2.1 SELECTION OF FILTRATION SAMPLE FOR TESTING

Filter fabric samples of Grade 700 MPS Polyester Felt were supplied to ETS directly from the manufacturer (BWF America, Inc.) with a letter signed by Clint Scoble, President, BWF America, 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 of 140 mm (5.5 in.) in diameter, which is the dimension used to calculate the face area of the tested specimen.

SECTION 3 DESCRIPTION OF FILTER FABRIC

The BWF America, Inc.'s Grade 700 MPS Polyester Felt is an 18-20 oz/yd² (0.61-0.68 kg/m²) micro-pore-size high efficiency scrim supported felt, singed cake side.

SECTION 4 VERIFICATION OF PERFORMANCE

4.1 QUALITY ASSURANCE

The verification tests were conducted in accordance with an approved test/QA plan.² The EPA Quality Assurance Manager conducted an independent assessment of the test laboratory in February 2000 and found that the test laboratory was equipped and operated as specified in the test/QA plan.

The ETS QA Officer and APCT QA staff have reviewed the results of this test and have found that the data presented in the reports generally conform to the test specifications in the generic verification protocol. It should be noted that, because of the highly efficient nature of the filter medium being tested, one or more of the impactor substrate weighings for these results were near the reproducibility of the balance. As a result of this occurrence, the tests do not meet the data quality objectives stated in the test/QA plan for mass gain associated with outlet concentrations. The true values of the outlet concentrations may be more than plus or minus 15 percent of the reported values. Data on calibration certificates for the flow meters, flow transducers, weights, low- and high-resolution balances, thermometer, and humidity logger are provided in Appendix B.

4.2 RESULTS

Table 3 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. Upstream and downstream particle concentration information for each verification test period is provided in Appendix C.

The top portion of Table 3 summarizes three verification tests that were performed under standard verification test conditions. The average residual pressure drop (DP) across each filter sample at the nominal 120 m/h (6.6 fpm) filtration velocity (for a flowrate of 5.8 m³/h [3.4 cfm]) is also shown in Table 3. This pressure drop ranged from 6.62 to 6.90 cm w.g. (2.61 to 2.72 in. w.g.) for the three filter samples tested. The residual pressure drop increase ranged from 0.66 to 1.33 cm w.g. (0.26 to 0.52 in. w.g.) for the samples tested. All three standard condition verification runs were used to compute the averages given in Table 3. The PM_{2.5} concentration average for the three runs is 0.0000104 g/dscm. The total PM concentration average for the three runs is 0.0000161 g/dscm.

Table 3. Summary of Verification Results For BWF America, Inc.’s Grade 700 MPS Polyester Felt

Test Run Number	3V02-R3	3V02-R4	3V02-R5	Average*
PM _{2.5} (g/dscm)**	0.0000047	0.0000219	0.0000047	0.0000104
Total PM (g/dscm)	0.0000078	0.0000297	0.0000109	0.0000161
Average Residual DP (cm w.g.)	6.90	6.62	6.73	6.75
Initial Residual DP (cm w.g.)	6.11	5.81	6.50	6.14
Residual DP Increase (cm w.g.)	1.33	1.33	0.66	1.11
Mass Gain of Sample Filter (g)	0.57	0.52	0.60	0.56
Average Filtration Cycle Time (s)	36	39	36	37

*All three verification runs were used to compute averages.

** 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.

4.3 LIMITATIONS AND APPLICATIONS

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

In accordance with the generic verification protocol, this verification statement is applicable to baghouse filtration products manufactured between June 7, 2002 and 3 years thereafter.

**SECTION 5
REFERENCES**

1. Generic Verification Protocol for Baghouse Filtration Products, Research Triangle Institute, Research Triangle Park, NC, October 2001. Available at http://etv.rti.org/apct/pdf/GVP_Revised.pdf.
2. Test/QA Plan for the Verification Testing of Baghouse Filtration Products, ETS, Inc., Roanoke, VA, February 1999.

Appendix A

DESCRIPTION OF THE TEST RIG AND THE METHODOLOGY

DESCRIPTION OF THE TEST RIG AND METHODOLOGY

TEST APPARATUS

The tests were conducted in ETS' FEMA test apparatus (Figure A-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 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 averaged as stated in Appendix C, section 4.4.1.¹ 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.

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 that was 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 μm maximum mass mean diameter and at least 66 percent less than 2.5 μm to continue the verification test series.

The original test dust specification was based on data available when the test protocol was first written. Through laboratory practices and information obtained from the dust manufacturer, it was determined that the dust specifications vary with dust lot and batch and therefore the original test protocol specification of the dust cannot be met on a consistent basis. It was elected to proceed with the tests using the dust available at the time of testing. It does not appear that the verification test results were significantly influenced by this shift to a broader size range for the test dust.

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 within

the required parameters. The reference test measurement values have not been established (not enough reference fabric data have been collected for a G/C of 2 m/min to set a new DQO for these parameters).

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

Table A-1. Summary of Control Test Results

	Requirement	Measured Value	Met Requirements?
Mass Mean Diameter, μm	< 1.5	1.38	Yes
% Less than 2.5 μm	> 66	67.47	Yes
Weight Gain, g	*	0.95	Not applicable
Maximum DP, cm w.g.	*	0.69	Not applicable

*Value not established (not enough reference fabric data have been collected for a G/C of 2 m/min to set a new DQO for this parameter).

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 $\text{PM}_{2.5}$, g/dscm
- d = 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 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, 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, $^\circ\text{F}$
- 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 °F, in °R
 1013 = Standard atmospheric pressure, mbar
 528 = Standard temperature, °R

Area of Sample Fabric - A_f

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

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

$$G/C = Q_a / A_f$$

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

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

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}

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

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

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

Filtration Cycle Time - t_c

$$t_c = t/N$$

Average Residual Pressure Drop - P_{avg}

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

REFERENCES

1. Test/QA Plan for the Verification Testing of Baghouse Filtration Products, ETS, Incorporated, Roanoke, VA, February 1999.

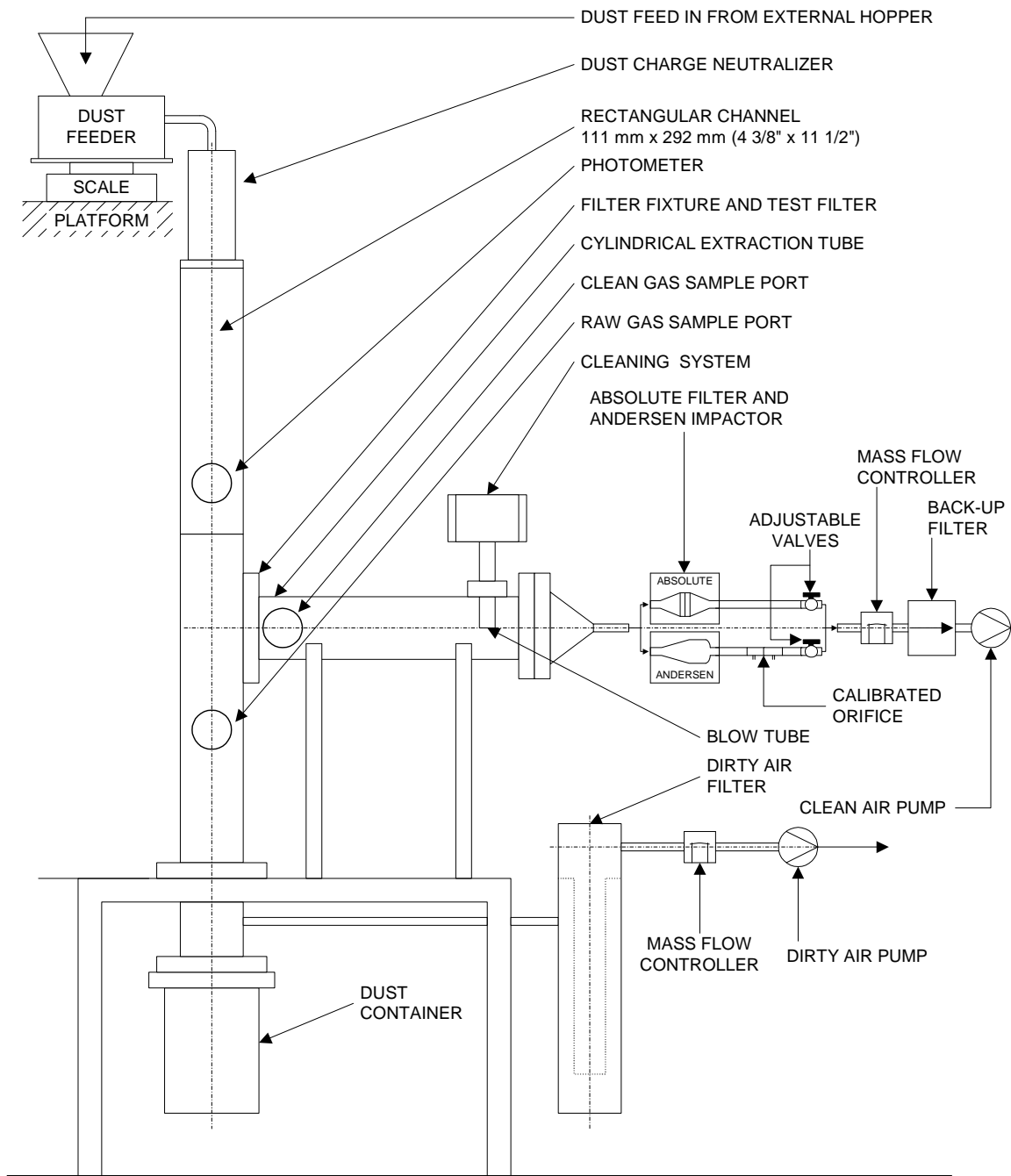


Figure A-1. Diagram of FEMA test apparatus

US EPA ARCHIVE DOCUMENT

Appendix B

DATA ON CERTIFICATES OF CALIBRATION

Table B-1. Status of Instrument Calibrations for Baghouse Filtration Products Verification Tests

Instrument	Measured Parameter	Manufacturer and Model No.	Serial No.	Certificate No.	Date of Certification	Certificate Expiration Date	NIST Traceable ?	Current For Test?
High Resolution Balance	Impactor Substrate Weight	Precisa 262SMA-FR	16157	2420	12/06/2001	12/31/2002	YES	YES
Low Resolution Balance	Sample Filter Weight	Mettler P 1210N	562968	2419	12/06/2001	12/31/2002	YES	YES
2,000 g Weight	Dust Feed Weight Cell	Troemner 2,000 g	37672	10213	01/10/2002	01/10/2003	YES	YES
100 g Weight	Low Resolution Balance	Troemner 100 g	36528	10227	12/06/2001	12/06/2002	YES	YES
1 g Weight	High Resolution Balance	Troemner 1 g	36528	10227	12/06/2001	12/06/2002	YES	YES
1 mg Weight	High Resolution Balance	Troemner 1 mg	36528	10227	12/06/2001	12/06/2002	YES	YES
Thermocouple	FEMA Temperature	LTG GmbH "K" Type	T-1	Calibrated Against Thermometer	11/08/2001	02/08/2002	YES	YES
	Mercury Thermometer*	VWR Scientific	3C2082	992117	12/29/1999	NA	YES	YES

(continued)

Table B-1. Status of instrument calibrations for baghouse filtration products verification tests (continued)

Instrument	Measured Parameter	Manufacturer and Model No.	Serial No.	Certificate No.	Date of Certification	Certificate Expiration Date	NIST Traceable ?	Current For Test?
Relative Humidity	Lab Relative Humidity	ACR Systems, Inc. SR2	66884	19655	12/05/2001	12/05/2002	YES	YES
Pressure Transducer	DP Across Sample Filter	MKS 223BD-00010AABS	145265	STDNN SET #4B	12/05/2001	12/05/2002	YES	YES
Flow Meters	Clean Gas	Hastings HFC-203	123917	Calibrated Against Dry Gas Meter	11/09/2001	02/09/2002	YES	YES
	Raw Gas	Hastings HFC-203	119148	Calibrated Against Dry Gas Meter	11/09/2001	02/09/2002	YES	YES
	Sample Gas	MKS 223BD-00010 AABS	000320459	Calibrated Against Dry Gas Meter	11/09/2001	02/09/2002	YES	YES
	Dry Gas Meter*	Rockwell S-275	009548	Certificate of 10/05/2001	10/05/2001	11/05/2002	YES	YES
Charge Neutralizer	Not Applicable	NRD, LLC Nuclecel P-2031	A2BP590	011250	12/05/2001	12/05/2002	YES	YES

*This device is used locally to calibrate other instruments (for temperature or gas flow, as appropriate).

Note: Each of the certificates described in Table B-1 is on file at ETS, Inc.

VERIFICATION TESTING SHEETS

**VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
SUMMARY OF RESULTS AT 2 M/MIN**

RUN ID.	3V01-R3 BWF Grade 700 MPS Polyester	3V01-R4 BWF Grade 700 MPS Polyester	3V01-R5 BWF Grade 700 MPS Polyester	Average
FABRIC DESIGNATION	Felt-7	Felt-9	Felt-8	
MANUFACTURER	BWF	BWF	BWF	
DUST FEED	Pural NF	Pural NF	Pural NF	
<u>CONDITIONING PERIOD</u>				
Date Started	12/12/2001	12/13/2001	1/17/2002	
Time Started	10:49	14:15	12:57	
Time Ended	19:09	22:35	21:17	
Test Duration (min.)	500	500	500	500
<u>RECOVERY PERIOD</u>				
Date Started	12/13/2001	12/13/2001	1/18/2002	
Time Started	7:16	7:16	7:24	
Time Ended	7:52	7:49	7:56	
Test Duration (min.)	36	33	32	34
<u>PERFORMANCE TEST PERIOD</u>				
Date Started	12/13/2001	12/14/2001	1/18/2002	
Time Started	8:01	8:58	8:02	
Time Ended	14:01	14:58	14:02	
Test Duration (min.)	360	360	360	360
<u>VERIFICATION TEST RESULTS</u>				
Mean Outlet Particle Conc. PM 2.5 (g/dscm)	0.0000047	0.0000219	0.0000047	0.0000104
Mean Outlet Particle Conc. Total mass (g/dscm)	0.0000078	0.0000297	0.0000109	0.0000161
Initial Residual Pressure Drop (cm w.g.)	6.11	5.81	6.50	6.14
Change in Residual Pressure Drop (cm w.g.)	1.33	1.33	0.66	1.11
Average Residual Pressure Drop (cm w.g.)	6.90	6.62	6.73	6.75
Mass Gain of Filter Sample (g)	0.57	0.52	0.60	0.56
Average Filtration Cycle Time (s)	36	39	36	37
Number of Pulses	602	557	605	588

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

CONDITIONING PERIOD - 2 M/MIN

RUN ID.	3V01-R3	NUMBER OF PULSES	10000
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-7	PULSE INTERVAL	3 s
MANUFACTURER	BWF		
DUST FEED	Pural NF	Moisture	1.33 %WV
DATE STARTED	12/12/2001		
TIME STARTED	10:49		
TIME ENDED	19:09		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration (min.)	Time		Dust Feed (g)			Average Gas Flow (sm ³ /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
			Initial	Final	Total	Raw	Clean	Total				
0-60	10:49	11:49	1580.4	1505.6	75	3.79	1.77	5.56	24	987.31	13.6	119
61-120	11:50	12:49	1505.6	1413.1	93	3.80	1.78	5.58	24	986.09	16.8	120
121-180	12:50	13:49	1413.1	1315.2	98	3.80	1.77	5.57	24	985.00	17.8	120
181-240	13:50	14:49	1315.2	1217.5	98	3.81	1.77	5.58	24	984.09	17.7	120
241-300	14:50	15:49	1217.5	1115.6	102	3.81	1.77	5.58	24	983.97	18.5	120
301-360	15:50	16:49	1115.6	1012.0	104	3.81	1.77	5.58	24	984.06	18.8	120
361-420	16:50	17:49	1012.0	909.0	103	3.81	1.77	5.58	24	983.95	18.7	120
421-480	17:50	18:49	909.0	803.9	105	3.81	1.77	5.58	24	983.92	19.1	120
441-500 *	18:10	19:09	872.3	770.5	102	3.81	1.77	5.58	23	983.89	18.5	120
AVERAGE FOR 500 MINUTE RAW DATA					97	3.80	1.77	5.57	24	984.76	17.7	120

ACCEPTANCE	100	25	18.4	120
	+/- 20	+/- 2	+/- 3.6	+/- 6

* Test duration is a rolling 60 minute average. The last 60 minute frame was determined by counting 60 minutes back from the last minute of the test.

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

RECOVERY PERIOD

RUN ID.	3V01-R3	NUMBER OF PULSES	30
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-7	AVG. PULSE INTERVAL	71 s
MANUFACTURER	BWF	AVG . RESIDUAL DP	561.90 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE STARTED	12/13/2001		
TIME STARTED	7:16 *	Moisture	1.29 % WV
TIME ENDED	7:52		
TEST DURATION	36 min.		

QA/QC DATA

Test Duration (min.)	Time		Dust Feed (g)			Average Gas Flow (sm ³ /hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
			Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/hr)
1-36	7:17	* 7:52	821.7	768.9	53	3.81	1.78	5.59	22	978.30	9.6	121

* First minute is not considered in calculations due to equipment stabilization.

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

PERFORMANCE TEST PERIOD - 2 M/MIN

RUN ID.	3V01-R3	NUMBER OF PULSES	602
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-7	AVG. PULSE INTERVAL	36 s
MANUFACTURER	BWF	AVG. RESIDUAL DP	675.91 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL DP	598.50 Pa
DATE STARTED	12/13/2001	FINAL RESIDUAL DP	729.20 Pa
TIME STARTED	8:01	CHANGE IN DP	130.70 Pa
TIME ENDED	14:01	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	360 min.	Moisture	1.29 %WV

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm ³ /hr)				Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total	Sample					
0-60	8:01	9:01	1547.7	1483.6	64	3.78	1.78	5.56	1.08	23	978.29	11.7	121
61-120	9:02	10:01	1483.6	1391.1	93	3.79	1.78	5.57	1.08	23	978.30	16.8	121
121-180	10:02	11:01	1391.1	1298.7	92	3.79	1.78	5.57	1.08	23	978.05	16.8	121
181-240	11:02	12:01	1298.7	1202.3	96	3.79	1.78	5.57	1.08	23	976.67	17.5	121
241-300	12:02	13:01	1202.3	1105.0	97	3.79	1.78	5.57	1.08	24	975.78	17.7	122
301-360	13:02	14:01	1105.0	1003.6	101	3.79	1.78	5.57	1.08	24	975.01	18.4	122
AVERAGE FOR 360 MINUTE RAW DATA					91	3.79	1.78	5.57	1.08	23	977.02	16.5	121

ACCEPTANCE	100	25	18.4	120
	+/- 20	+/- 2	+/- 3.6	+/- 6

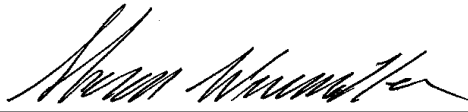
GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00003 g	Tare Mass	14.26 g
Total Mass Gain	0.00005 g	Final Mass	14.83 g
		Mass Gain	0.57 g

OUTLET CONCENTRATION

Total Volume Sampled	6.86 m ³
Mean Outlet Particle Concentration - PM 2.5	0.0000044 g/m ³
Mean Outlet Particle Concentration - Total Mass	0.0000073 g/m ³

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

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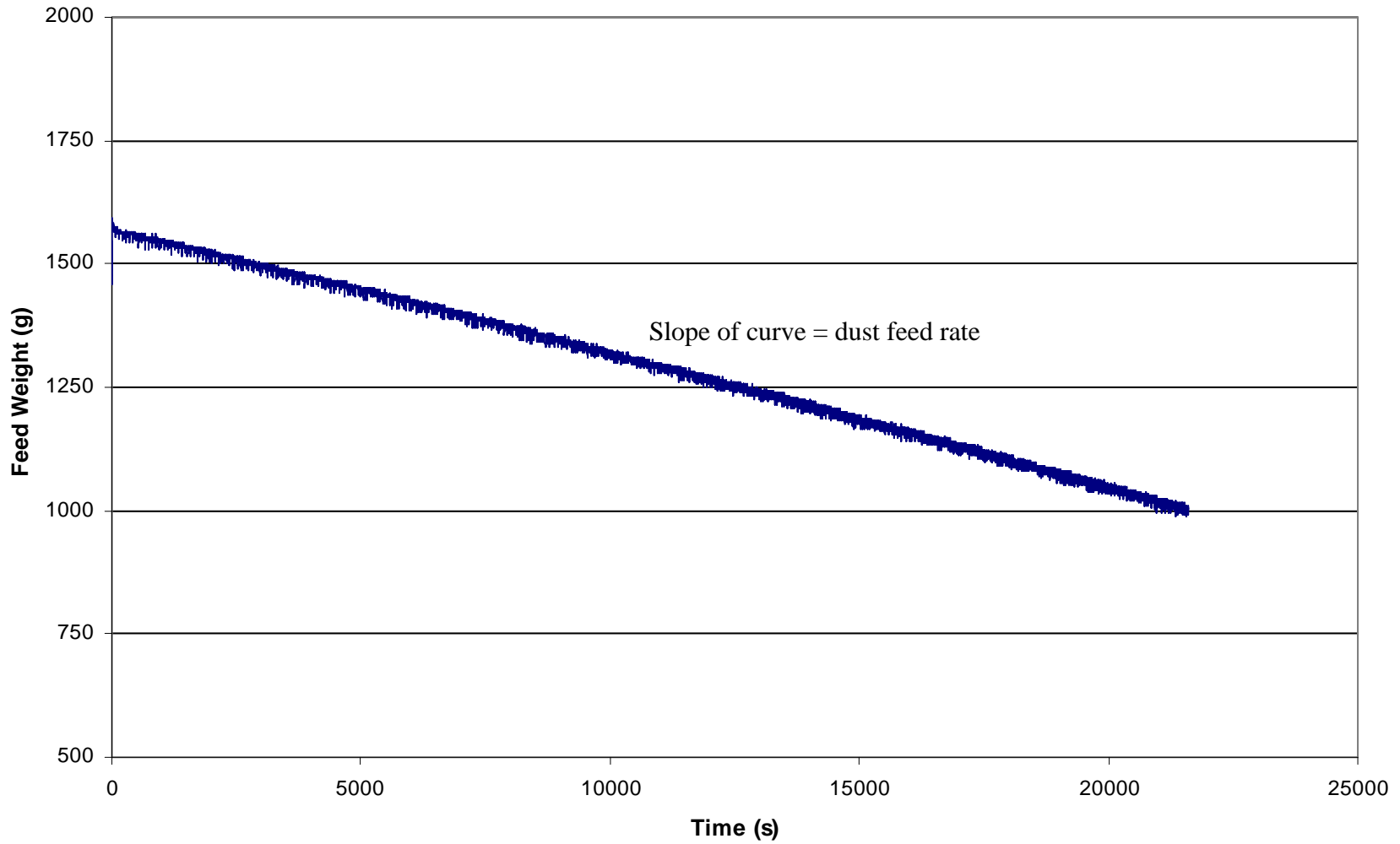


Figure C-1. Change in Pural NF dust scale reading with time during performance test period 3V01-R3

C-7

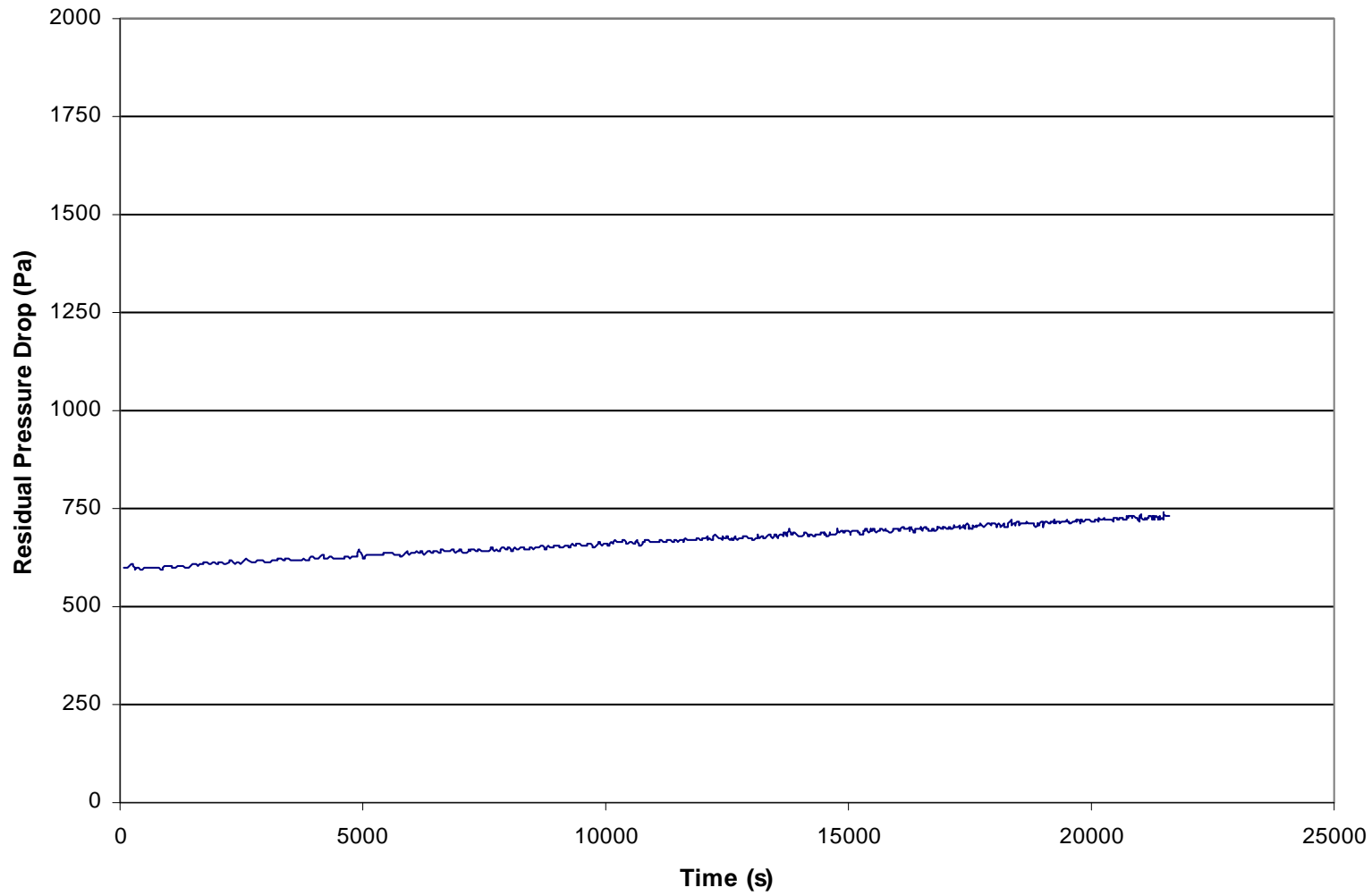


Figure C-2. Residual pressure drop across filter fabric during performance test period 3V01-R3

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

CONDITIONING PERIOD - 2 M/MIN

RUN ID.	3V01-R4	NUMBER OF PULSES	10000
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-9	PULSE INTERVAL	3 s
MANUFACTURER	BWF		
DUST FEED	Pural NF	Moisture	1.50 %WV
DATE STARTED	12/13/2001		
TIME STARTED	14:15		
TIME ENDED	22:35		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm ³ /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total					
0-60	14:15	15:15	1581.3	1486.7	95	3.73	1.75	5.48	24	975.16	17.5	120
61-120	15:16	16:15	1486.7	1382.2	105	3.75	1.75	5.50	24	975.13	19.3	120
121-180	16:16	17:15	1382.2	1281.1	101	3.75	1.74	5.49	24	974.35	18.7	119
181-240	17:16	18:15	1281.1	1182.8	98	3.75	1.74	5.49	24	974.18	18.2	119
241-300	18:16	19:15	1182.8	1085.7	97	3.75	1.74	5.49	24	974.83	18.0	119
301-360	19:16	20:15	1085.7	987.0	99	3.75	1.74	5.49	24	975.06	18.3	119
361-420	20:16	21:15	987.0	888.2	99	3.75	1.74	5.49	24	974.78	18.3	119
421-480	21:16	22:15	888.2	791.4	97	3.75	1.74	5.49	23	974.77	17.9	119
441-500 *	21:36	22:35	854.9	759.1	96	3.75	1.74	5.49	23	974.76	17.7	119
AVERAGE FOR 500 MINUTE RAW DATA					99	3.75	1.74	5.49	24	974.78	18.3	119

ACCEPTANCE	100	25	18.4	120
	+/- 20	+/- 2	+/- 3.6	+/- 6

* Test duration is a rolling 60 minute average. The last 60 minute frame was determined by counting 60 minutes back from the last minute of the test.

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

RECOVERY PERIOD

RUN ID.	3V01-R4	NUMBER OF PULSES	30
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-9	AVG. PULSE INTERVAL	67 s
MANUFACTURER	BWF	AVG . RESIDUAL DP	546.60 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE STARTED	12/14/2001		
TIME STARTED	8:07 *	Moisture	1.50 % WV
TIME ENDED	8:40		
TEST DURATION	33 min.		

QA/QC DATA

Test Duration (min.)	Dust Feed (g)			Average Gas Flow (sm ³ /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/hr)		
	Time	Initial	Final	Total	Raw	Clean					Total	
1-33	8:08 *	8:40	846.0	790.0	56	3.76	1.77	5.53	23	971.65	10.3	121

* First minute is not considered in calculations due to equipment stabilization.

DATA PROCESSING OPERATOR:



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VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

PERFORMANCE TEST PERIOD - 2 M/MIN

RUN ID.	3V01-R4	NUMBER OF PULSES	557
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-9	AVG. PULSE INTERVAL	39 s
MANUFACTURER	BWF	AVG. RESIDUAL DP	648.91 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL DP	569.00 Pa
DATE STARTED	12/14/2001	FINAL RESIDUAL DP	699.00 Pa
TIME STARTED	8:58	CHANGE IN DP	130.00 Pa
TIME ENDED	14:58	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	360 min.	Moisture	1.50 %WV

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm ³ /hr)				Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total	Sample					
0-60	8:58	9:58	1529.3	1464.8	65	3.76	1.76	5.52	1.08	23	970.94	11.9	121
61-120	9:59	10:58	1464.8	1371.7	93	3.77	1.76	5.53	1.08	24	970.59	17.1	121
121-180	10:59	11:58	1371.7	1278.0	94	3.77	1.76	5.53	1.08	24	970.32	17.2	121
181-240	11:59	12:58	1278.0	1175.5	103	3.77	1.76	5.53	1.08	24	969.22	18.8	121
241-300	12:59	13:58	1175.5	1072.3	103	3.77	1.76	5.53	1.08	24	967.90	18.9	121
301-360	13:59	14:58	1072.3	970.3	102	3.77	1.76	5.53	1.08	24	967.58	18.7	122
AVERAGE FOR 360 MINUTE RAW DATA					93.2	3.77	1.76	5.53	1.08	24	969.42	17.1	121

ACCEPTANCE	100	25	18.4	120
	+/- 20	+/- 2	+/- 3.6	+/- 6

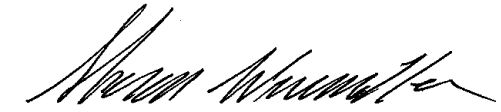
GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00014 g	Tare Mass	14.49 g
Total Mass Gain	0.00019 g	Final Mass	15.01 g
		Mass Gain	0.52 g

OUTLET CONCENTRATION

Total Volume Sampled	6.93 m ³
Mean Outlet Particle Concentration - PM 2.5	0.0000202 g/m ³
Mean Outlet Particle Concentration - Total Mass	0.0000274 g/m ³

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

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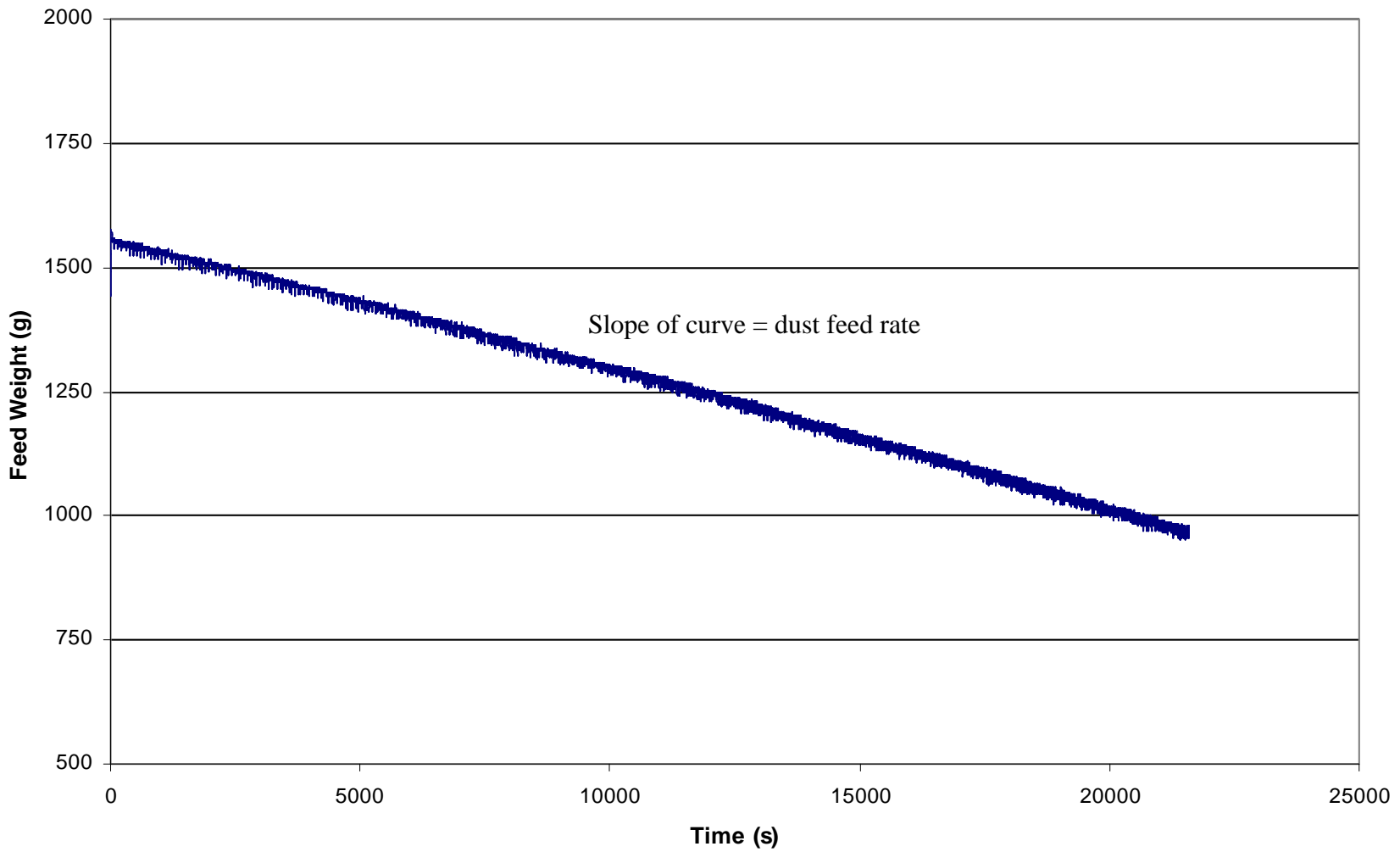


Figure C-3. Change in Pural NF dust scale reading with time during performance test period 3V01-R4

C-12

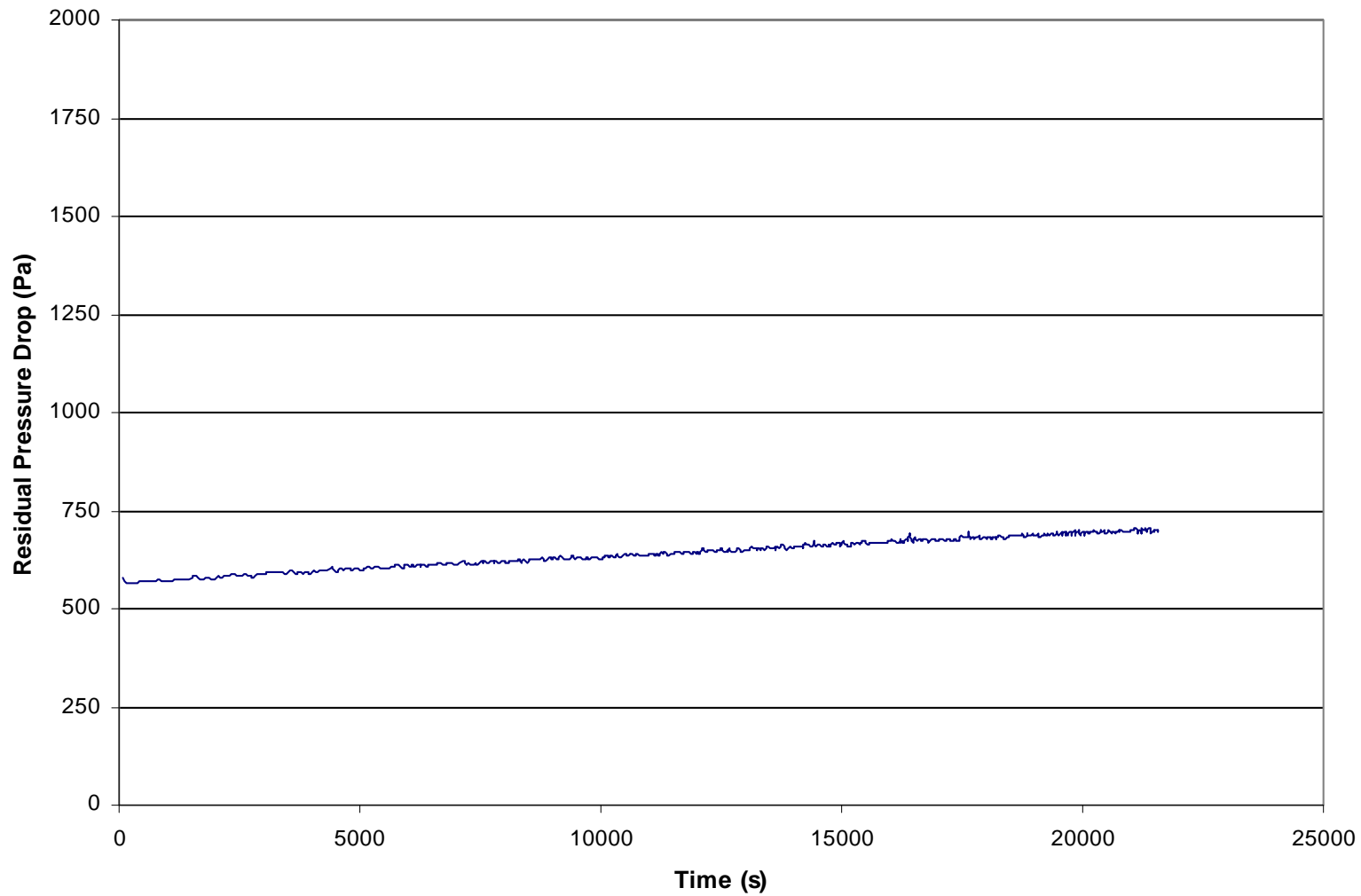


Figure C-4. Residual pressure drop across filter fabric during performance test period 3V01-R4

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

CONDITIONING PERIOD - 2 M/MIN

RUN ID.	3V01-R5	NUMBER OF PULSES	10000
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-8	PULSE INTERVAL	3 s
MANUFACTURER	BWF		
DUST FEED	Pural NF	Moisture	0.93 %WV
DATE STARTED	1/17/2002		
TIME STARTED	12:57		
TIME ENDED	21:17		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm ³ /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total					
0-60	12:57	13:57	1542.5	1452.7	90	3.77	1.76	5.53	23	974.58	16.4	120
61-120	13:58	14:57	1452.7	1355.1	98	3.77	1.76	5.53	23	974.40	17.8	120
121-180	14:58	15:57	1355.1	1248.6	107	3.76	1.77	5.53	23	974.72	19.4	121
181-240	15:58	16:57	1248.6	1142.4	106	3.76	1.77	5.53	24	975.16	19.4	121
241-300	16:58	17:57	1142.4	1030.1	112	3.76	1.77	5.53	23	975.53	20.5	121
301-360	17:58	18:57	1030.1	917.4	113	3.76	1.76	5.52	23	976.02	20.6	120
361-420	18:58	19:57	917.4	813.0	104	3.76	1.76	5.52	23	976.01	19.1	120
421-480	19:58	20:57	813.0	708.1	105	3.76	1.76	5.52	23	975.93	19.2	120
441-500 *	20:18	21:17	773.6	674.3	99	3.77	1.76	5.53	23	975.92	18.1	120
AVERAGE FOR 500 MINUTE RAW DATA					104	3.76	1.76	5.52	23	975.32	19.1	120

ACCEPTANCE	100	25	18.4	120
	+/- 20	+/- 2	+/- 3.6	+/- 6

* Test duration is a rolling 60 minute average. The last 60 minute frame was determined by counting 60 minutes back from the last minute of the test.

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

RECOVERY PERIOD - 2 M/MIN

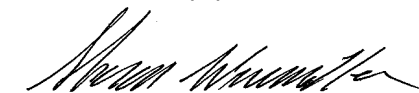
RUN ID.	3V01-R5	NUMBER OF PULSES	30
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-8	AVG. PULSE INTERVAL	64 s
MANUFACTURER	BWF	AVG . RESIDUAL DP	547.63 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL DP	509.90 Pa
DATE STARTED	1/18/2002	FINAL RESIDUAL DP	568.80 Pa
TIME STARTED	7:24 *	CHANGE IN DP	58.90 Pa
TIME ENDED	7:56	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	32 min.	Moisture	0.61 % WV

QA/QC DATA

Test Duration (min.)	Time		Dust Feed (g)			Average Gas Flow (sm ³ /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/hr)
	Start	End	Initial	Final	Total	Raw	Clean	Total				
1-32	7:25	* 7:56	1516.5	1471.1	45	3.79	1.78	5.57	22	979.41	8.2	121

* First minute is not considered in calculations due to equipment stabilization.

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

PERFORMANCE TEST PERIOD - 2 M/MIN

RUN ID.	3V01-R5	NUMBER OF PULSES	605
FABRIC DESIGNATION	BWF Grade 700 MPS Polyester Felt-8	AVG. PULSE INTERVAL	36 s
MANUFACTURER	BWF	AVG. RESIDUAL DP	659.19 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL DP	637.00 Pa
DATE STARTED	1/18/2002	FINAL RESIDUAL DP	701.40 Pa
TIME STARTED	8:02	CHANGE IN DP	64.40 Pa
TIME ENDED	14:02	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	360 min.	Moisture	0.61 %WV

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm ³ /hr)				Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total	Sample					
0-60	8:02	9:02	1471.6	1381.0	91	3.77	1.77	5.54	1.09	22	980.02	16.5	120
61-120	9:03	10:02	1381.0	1281.4	100	3.78	1.77	5.55	1.08	23	980.35	18.1	120
121-180	10:03	11:02	1281.4	1185.2	96	3.78	1.77	5.55	1.08	23	980.52	17.4	120
181-240	11:03	12:02	1185.2	1092.1	93	3.78	1.77	5.55	1.08	23	980.40	16.9	120
241-300	12:03	13:02	1092.1	989.6	103	3.78	1.77	5.55	1.08	23	979.93	18.6	120
301-360	13:03	14:02	989.6	888.0	102	3.78	1.77	5.55	1.08	24	979.51	18.4	120
AVERAGE FOR 360 MINUTE RAW DATA					97	3.78	1.77	5.55	1.08	23	980.12	17.6	120

ACCEPTANCE	100	25	18.4	120
	+/- 20	+/- 2	+/- 3.6	+/- 6

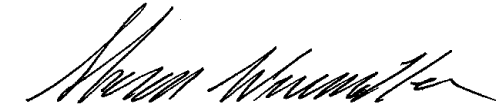
GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00003 g	Tare Mass	14.44 g
Total Mass Gain	0.00007 g	Final Mass	15.04 g
		Mass Gain	0.60 g

OUTLET CONCENTRATION

Total Volume Sampled	6.83 m ³
Mean Outlet Particle Concentration - PM 2.5	0.000044 g/m ³
Mean Outlet Particle Concentration - Total Mass	0.0000103 g/m ³

DATA PROCESSING OPERATOR:



Sharon M. Winemiller - ETS, Inc.

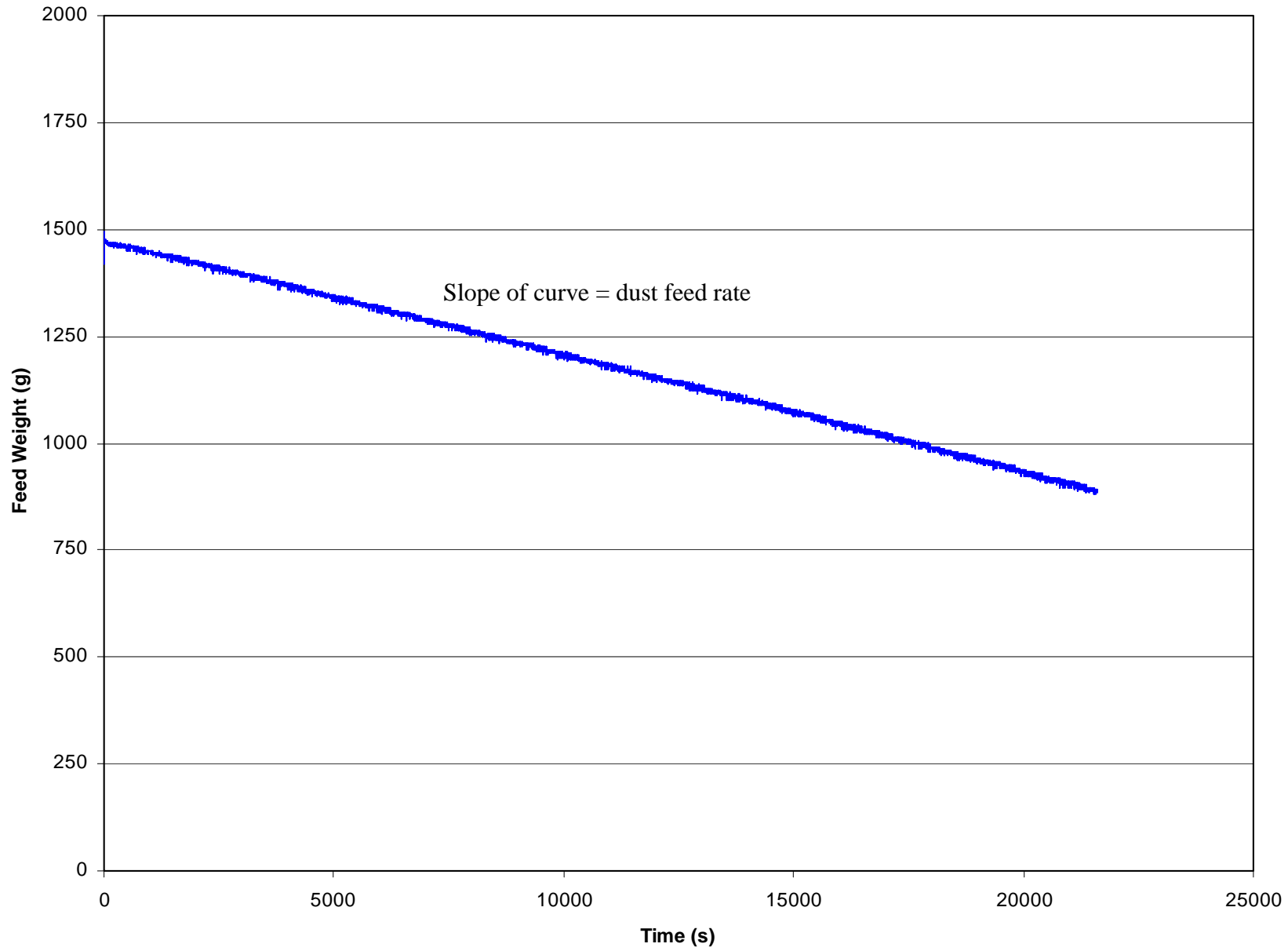


Figure C-5. Change in Pural NF dust scale reading with time during performance test period 3V01-R5

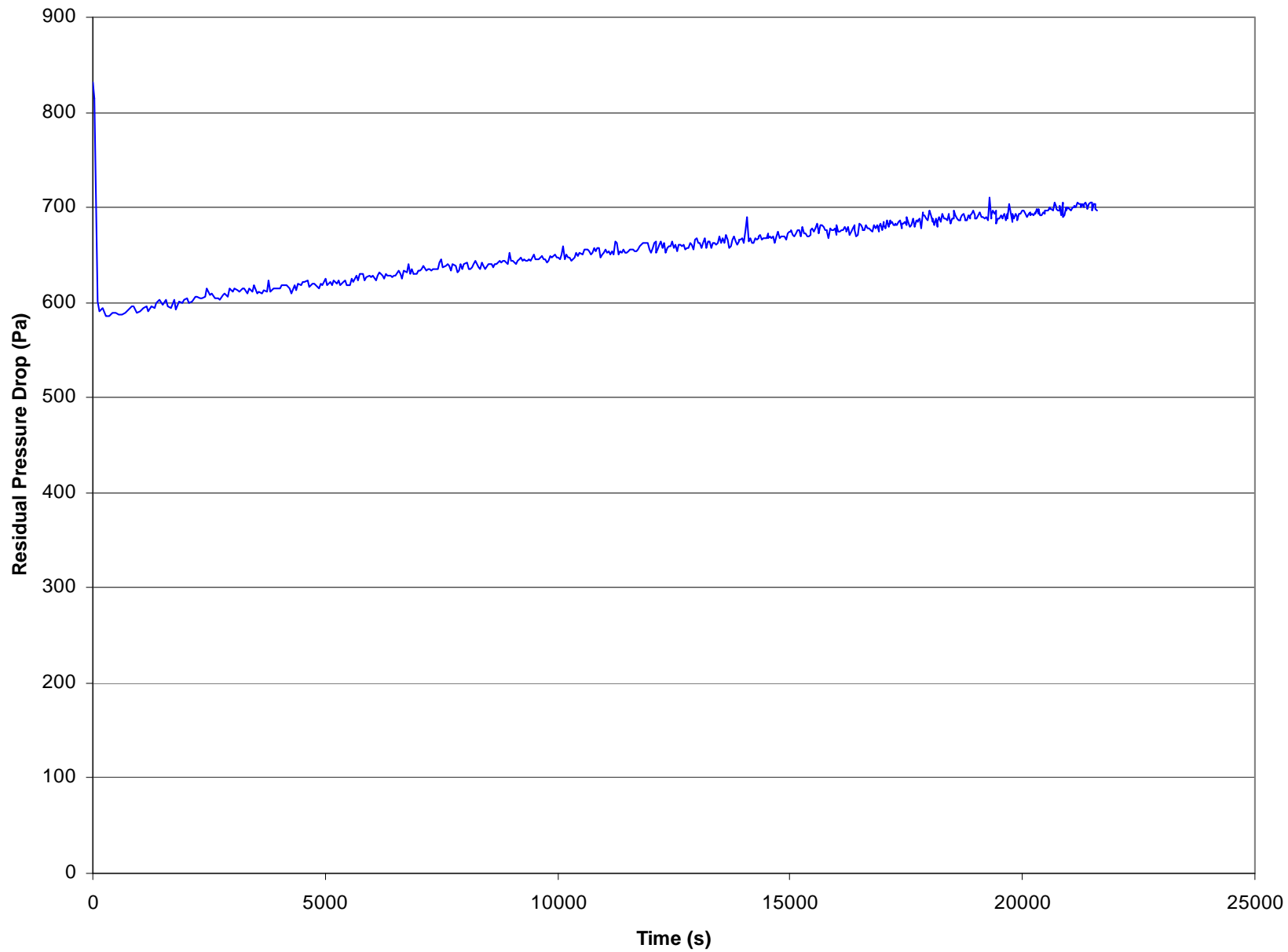


Figure C-6. Residual pressure drop across filter fabric during performance test period 3V01-R5

Appendix D

FABRIC MANUFACTURER'S SUBMITTAL LETTER



7453 Empire Drive #340
Florence, KY 41042

November 2, 2001

ETS, Inc.
1401 Municipal Road
Roanoke, VA 24012

Attn: Mr. Jack Mycock

Ref: VDI Tests, ETV Program Round Three

Dear Jack:

As specified in the General Verification Protocol, BWF America is submitting (9) 18" x 36" samples of our "Grade 700 MPS Polyester Felt" for VDI tests. Each piece is labeled with the requested source information.

These samples were taken from our internal roll #18550, BWF Felt Mill Piece #2762706 at approximately yards 29-34. Twenty (20) pieces were cut and verified for specification. Nine (9) were randomly selected to send to you.

We confirm that this material is commercially available and sold in the world filtration market today. This roll was made in January of 2000.

If you need any additional information, please let us know. Thank you.

Sincerely,

A handwritten signature in black ink, appearing to read "Clinton B. Scoble, Jr.", is written over the typed name.

Clinton B. Scoble, Jr.

Encl: (9) 18" x 36" samples Grade 700 MPS Polyester

(859) 282-4550
1-800-733-2043
Fax: (859) 282-4555