September 2000

Environmental Technology Verification Report

Baghouse Filtration Products

Standard Filter Corporation PE16ZU Filter Sample

Prepared by

ETS, Incorporated

Research Triangle Institute

Under a Cooperative Agreement with

EPA United States Environmental Protection Agency

ETV ETV ETV

Environmental Technology Verification Report

Baghouse Filtration Products

Standard Filter Corporation PE16ZU Filter Sample

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EPA Cooperative Agreement CR 826152-01-2

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Office of Research and Development
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September 2000

Notice

This document was prepared by ETS, Inc. (ETS) under a contract with Research Triangle Institute (RTI) with funding from Cooperative Agreement No. CR826152-01-2 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

   Web site: http://etv.rti.org/apct/index.html
   or http://www.epa.gov/etv *(click on partners)*

2. **USEPA / APPCD**
   MD-4
   Research Triangle Park, NC 27711

   Web site: 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) pilot of the Environmental Technology Verification (ETV) Program. The performance factor verified was the mean outlet particle concentration for the filter fabric as a function of the size for particles equal to and smaller than 2.5 μm in aerodynamic diameter (PM 2.5). The ETV APCT Pilot Program developed a generic verification protocol for testing baghouse filtration products that is based on a modified VDI Method 3926. The protocol was developed by RTI and ETS, reviewed by a technical panel of experts, and approved by 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 and 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 Standard Filter Corporation's filter sample PE16ZU during the period of July 17-20, 2000. Mean outlet particle concentrations for total mass and PM 2.5 were determined. In addition, the following verification parameters were measured and reported: 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
DH	orifice pressure drop
Dia.	diameter
DP	pressure drop
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
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)
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^2	grams per square meter
h	hours
in.	inches
in. w.g.	inches of water gauge
m	meters
mbar	millibars
m/h	meters per hour
m^3/h	cubic meters per hour
mm	millimeters

MPa	megapascals
ms	milliseconds
NA	not applicable
NIST	National Institute of Standards and Technology
oz/yd^2	ounces per square yard
Pa	pascals
PM	particulate matter
PM 2.5	particulate matter 2.5 micrometers or smaller in aerodynamic diameter
psi	pounds per square inch
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 Toby Wiik of Standard Filter Corporation.

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For more information on Standard Filter Corporation's PE16ZU baghouse fabric, contact

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Standard Filter Corporation
5928 Balfour Court
Carlsbad, CA 92008
(760) 929-8559 ext. 116
toby@standardfilter.com

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.

The U.S. EPA's partner in the Air Pollution Control Technology (APCT) program is Research Triangle Institute (RTI). The APCT program, with the full participation of the technology developer, develops plans, conducts tests, collects and analyzes data, and reports findings. The evaluations are conducted according to a rigorous protocol and quality assurance and quality control oversight. The APCT Program 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 incorporated 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 Test/QA Plan details how the test laboratory (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:

- Dust characterization (first sample fabric verification test only),
- 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 180 ± 9 m/h (9.8 ± 0.5 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

The samples of filter fabric (PE16ZU) were supplied to ETS directly from the manufacturer (Standard Filter Corporation) with a letter signed by Toby Wiik, Director of Engineering, Standard Filter Corporation, attesting that the filter media were selected at random in an unbiased manner from commercial grade media and have not been treated in any manner different from the media provided to customers. The manufacturer supplied the test laboratory with nine 46 by 91 cm (18 by 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 that is used to calculate the face area of the tested specimen.

SECTION 3
DESCRIPTION OF FILTER FABRIC

The Standard Filter Corporation PE16ZU filter fabric is a stratified microdenier polyester non-woven product for use in fine particulate capture. It is intended to be a low-pressure drop, high efficiency material.

SECTION 4
VERIFICATION OF PERFORMANCE

4.1 QUALITY ASSURANCE

The verification tests were conducted in accordance with an approved Test/Quality Assurance (QA) Plan.[2] The EPA Quality Manager conducted an independent assessment of the test laboratory in February 2000 and found that the test laboratory was equipped and being operated as specified in the Test/QA Plan. The ETS Quality Assurance Officer and APCT Quality Assurance staff have reviewed the results of this test and have found that the results meet data quality objectives in the Test/QA Plan. Certificates of Calibration for the flow meters, flow transducers, weights, high resolution balance, 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-h 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 average residual pressure drop across each filter sample at the nominal 180 m/h (9.8 fpm) filtration velocity [for a flowrate of 5.8 m^3/h (3.4 cfm)] is also shown in Table 3. This pressure drop ranged from 13.82 to 14.96 cm w.g. (5.44 to 5.89 in. w.g.) for the three filter samples tested. The residual pressure drop increase ranged from 4.18 to 7.11 cm w.g. (1.65 to 2.80 in. w.g.) for the samples tested.

TABLE 3. SUMMARY OF VERIFICATION RESULTS FOR STANDARD FILTER CORPORATION FABRIC PE16ZU

Test Run Number	V012-1	V012-2	V012-3	Average
PM 2.5 (g/dscm)*	0.0000046	0.0000094	0.0000142	0.0000094
Total PM (g/dscm)	0.0000078	0.0000125	0.0000361	0.000019
Average Residual Pressure Drop (cm w.g.)	14.96	14.89	13.82	14.56
Residual Pressure Drop Increase (cm w.g.)	7.11	6.81	4.18	6.03
Mass Gain of Sample Filter (g)	1.63	1.69	1.49	1.60
Average Filtration Cycle Time (s)	6	6	6	6

*****Standard conditions: 101.3 kPa (14.7 psia) and 20 °C (68 °F).

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 *[Date will be added after verification statement is signed and it is placed on the web*.] of the Verification Statement and 3 years thereafter.

SECTION 5
REFERENCES

1. Generic Verification Protocol for Baghouse Filtration Products, Research Triangle Institute, Research Triangle Park, NC, February 2000. Available at the Website http://etv.rti.org/apct/pdf/baghouseprotocol.pdf.

2. Test/QA Plan for the Verification Testing of Baghouse Filtration Products, ETS, Incorporated, Roanoke, VA, February 1999. (Appendix C of this document is a standard operating procedure.)

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 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 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, SOP, 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 0.52 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 was performed at the beginning of the first verification test. 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 h and sealed in an airtight container prior to its insertion into the FEMA apparatus. The dust characterization results had to meet the requirements of 1.0 ± 0.5 μm mass mean diameter and 76 ± 10 % less than 2.5 μm to continue the verification test series.

The second control test that was performed was the reference value 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 value test measurements must meet the following requirements of weight gain of reference fabric equal to 0.93 ± 0.09 g and a reference fabric maximum pressure drop of 1.84 ± 0.18 cm w.g. to proceed with verification testing.

The control tests met the specified requirements for dust mass mean diameter and reference fabric weight gain. Although the dust was from the same lot as used in all previous verification testing, it exceeded the maximum requirement for percentage less than 2.5 µm. While this phenomenon was not fully understood, it was decided to proceed with the verification tests, based on the rationale that the dust would be at least as challenging as, if not slightly more challenging than the dust employed in the previous tests. If the dust had failed to meet the minimum requirement for this parameter, the tests would have been postponed pending a suitable resolution.

While the reference fabric maximum pressure drop value was under specification, it is felt that the data are correct as measured and that the test apparatus was functioning properly and accurately. Subsequent to the reference values tests and prior to commencing the verification test, an extensive review of test procedures, calibration records, and pre-test calibration check procedures for the test apparatus and associated instruments was conducted and found to be in accordance with the procedures outlined in the "Test/QA Plan for the Verification Testing of Baghouse Filtration Products."[1] Specifically, each pressure transducer was calibrated against an oil manometer to within 0.1 in. w.g. at three different points. All pressure drop transducers were found to be accurate with no adjustment necessary; the dust feed scale calibration was checked and found to be accurate; all flow meters were checked and found to be accurate within the specified range.

In summary, based on this review and on our best professional judgment, we saw no reason to disqualify the data, and a decision was made to proceed with the verification tests.

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	1.0 ± 0.5	0.63	Yes
% Less than 2.5 µm	76 ± 10	89	No
Weight Gain, g	0.93 ± 0.09	0.97	Yes
Maximum Pressure Drop, cm w.g.	1.84 ± 0.18	1.56	No

Analysis

The equations that were 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
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 ith 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, 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}

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

REFERENCES

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

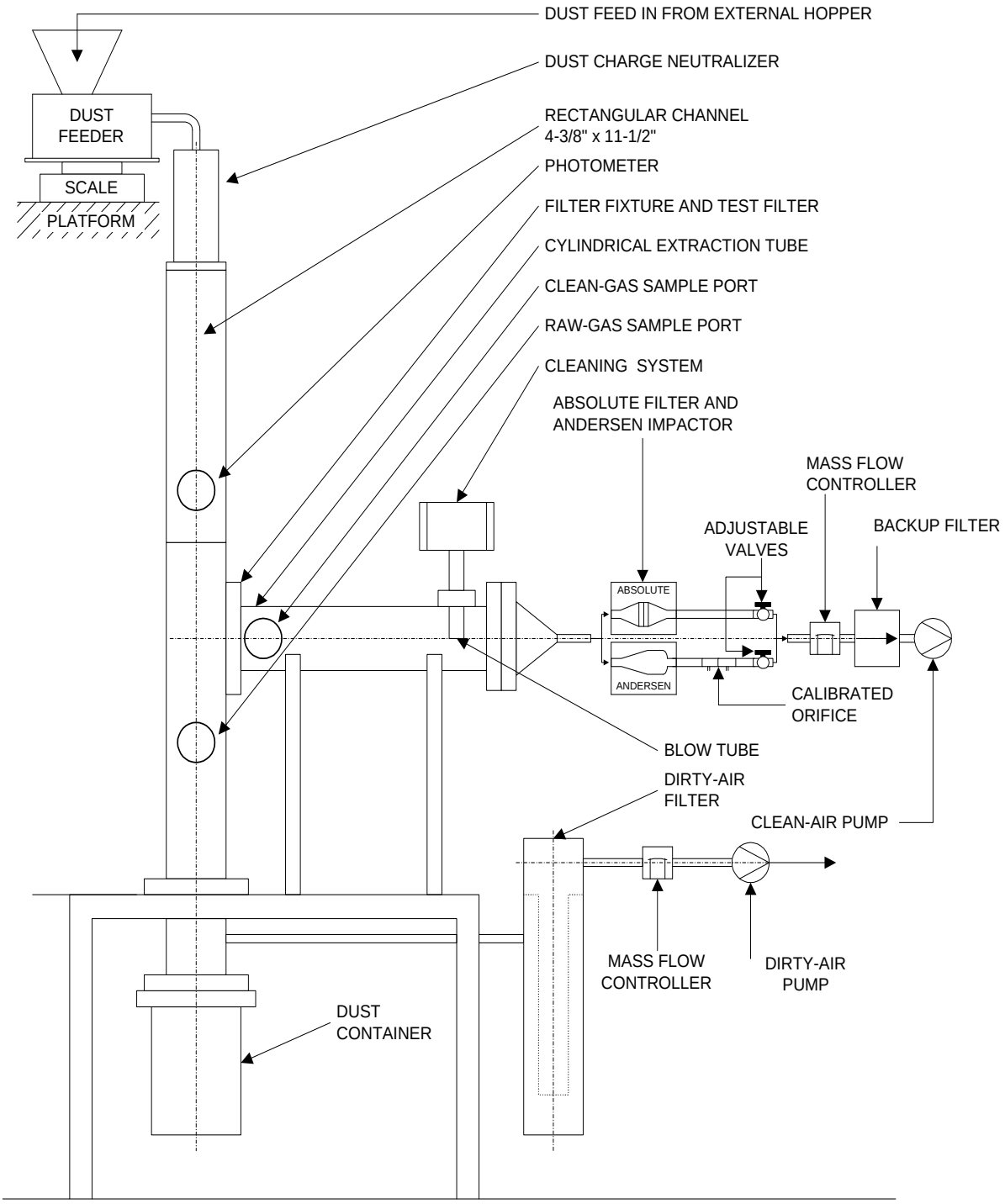


Figure A-1. Diagram of FEMA Test Apparatus

Appendix B

CERTIFICATES OF CALIBRATION

Measurement Controls, Inc.

107 Center Lane
P.O. Box 997
Huntersville, NC 28070

Telephone (704) 875-2034
Fax (704) 875-3460

June 8, 1999
ETS, INC. Attn: Bill Hayes

RE-CERTIFICATION OF CALIBRATION

ROCKWELL S-275 # 009548

FLOW RATE	VOLUME	Y	AVE. Y
90 CFH	1.9980	1.00002	
	1.9980	1.00002	
	1.9970	1.00052	1.0002
60 CFH	1.9960	.99931	
	1.9970	.99881	
	1.9960	.99931	.9991
33 CFH	1.9920	1.0006	
	1.9940	.99958	
	1.9930	1.0001	1.0001

OVERALL AVERAGE Y= .9998

Calibration performed on American Bell Prover # 2989, certification dated 10-23-95, certified to 0.00% Error and traceable to the N.I.S.T.

By
Measurement Controls, Inc.

Larry B. Lane

Data Sheet - 5 Point

Positive Pressure Calibration Data Sheet

Teledyne Electronic Technologies Hastings Instruments

11/1/99

Flow Transducer
Model: HFC-203
S/N: 123917

Customer: KLAUS SCHAEFER GMBH

Range: 0 TO 100.0 SLPM OF AIR @ 0°C

Laminar Flow Element
Model:
S/N:

TET-HI No.: 202085

FS mv: 1.084

CH

Ref. Standard		Ref. Std Documentation			
					Cal Due
CDR#	648	DMM:	CDR-	63	11/4/99
		Thermometer:	CDR-	703	7/20/00
C0=	-0.0146919	Manometer:	CDR-	772	5/16/00
C1=	32.124769	Barometer:	CDR-	772	5/16/00
C2=	-0.726126				
C3=	0.04774077				
C4=	-0.0048432		CDR#	648	1/24/00
C5=	0.00021761				

Flow Unit Correction Factors				Std. Conditions	
Type	From	To	K		
Gas	Air	AIR	1.0000	T	0°C
Units	SLPM	SLPM	1.0000	P	760 mmHg
Temp	0°C	0.0°C	1.0000	V	181.2 µp
Other			1.0000		
Ktot=			1.0000		

Reference Indication			Pres/Temp/Visc. Factor				Ref. Flow		Indicated Flow			Deviation	
Mano "H_2O	Temp °C	Pres mmHg	Kt	Kp	Kv	Ktpv	Flow ALPM	Flow SLPM Air	Flow SLPM AIR	Flow Volts	Flow SLPM AIR	%FS	%PT
3.59	22.5	772	0.924	1.020	0.993	0.936	107.5	100.6	100.58	5.000	100.0	-0.6%	-0.6%
2.80	22.4	772	0.924	1.019	0.993	0.936	85.1	79.6	79.65	4.000	80.0	0.3%	0.4%
2.06	22.4	772	0.924	1.018	0.993	0.935	63.4	59.3	59.29	3.000	60.0	0.7%	1.2%
1.35	22.5	772	0.924	1.017	0.993	0.934	42.1	39.3	39.30	2.000	40.0	0.7%	1.7%
0.67	22.5	772	0.924	1.017	0.993	0.933	21.0	19.6	19.63	1.000	20.0	0.4%	1.9%
0.00	22.5	772	0.924	1.016	0.993	0.932	0.0	0.0	-0.01	0.000	0.0	0.0%	

Calibration Performed By: CH

Calibration Date: 10/30/99

Recommended recalibration due date by: 10/31/00

All Calibrations are in compliance with MIL-Std-45662A

All instruments are calibrated with standards traceable to the National Institute of Standards and Technology

Data Sheet - 5 Point

Positive Pressure Calibration Data Sheet

Teledyne Electronic Technologies Hastings Instruments

4/7/99

Flow Transducer
Model: HFC-203
S/N: 119148

Customer: KLAUS SCHAEFER GMBH

Range: 0 TO 200 SLPM OF AIR

Laminar Flow Element
Model:
S/N:

TET-HI No.: 201547 **FS mv:** 0.861

Ref. Standard		Ref. Std Documentation			Flow Unit Correction Factors				Std. Conditions	
					Type	From	To	K		
CDR#	650	DMM: CDR-	407		Gas	Air	AIR	1.0000	T	0°C
		Thermometer: CDR-	509		Units	SLPM	SLPM	1.0000	P	760 mmHg
C0=	-0.0035382	Manometer: CDR-	714		Temp	0°C	0.0°C	1.0000	V	181.2 µp
C1=	62.277749	Barometer: CDR-	714		Other			1.0000		
C2=	-1.7904816				Ktot=			1.0000		
C3=	0.12004571									
C4=	-0.0055349									
C5=	5.2275E-05									

Reference Indication			Pres/Temp/Visc. Factor				Ref. Flow		Indicated Flow			Deviation	
Mano "H_2O	Temp °C	Pres mmHg	Kt	Kp	Kv	Ktpv	Flow ALPM	Flow SLPM Air	Flow SLPM AIR	Flow Volts	Flow SLPM AIR	%FS	%PT
3.82	23.1	765	0.922	1.011	0.991	0.924	217.3	200.9	200.91	5.00	200	-0.5%	-0.5%
3.00	23.1	765	0.922	1.010	0.991	0.924	173.5	160.3	160.26	4.00	160	-0.1%	-0.2%
2.22	23.1	765	0.922	1.009	0.991	0.923	130.6	120.5	120.51	3.00	120	-0.3%	-0.4%
1.46	23.4	764	0.921	1.007	0.991	0.919	87.5	80.4	80.37	2.00	80	-0.2%	-0.5%
0.71	23.6	764	0.920	1.006	0.990	0.917	43.4	39.8	39.75	1.00	40	0.1%	0.6%
0.00	23.6	764	0.920	1.005	0.990	0.916	0.0	0.0	0.00	0.00	0	0.0%	

Calibration Performed By: [signature]

Calibration Date: 4/07/99

Recommended recalibration due date by: 4/8/00

All Calibrations are in compliance with MIL-Std-45662A

All instruments are calibrated with standards traceable to the National Institute of Standards and Technology

CALIBRATION CERTIFICATE

Applied Weight Technology,Inc.-1216 Willie Spoon Lane-Burlington,NC 27217
TEL 336-570-2511 / FAX 336-226-4832

ETS, Inc.
1401 Municipal Road

Roanoke, VA 24012

CONTACT
Terry Williamson

DEPARTMENT
Field Prep.

ROOM # Lab
BUILDING Main

TODAY'S DATE 9/20/99
ITEM # 2
NEXT CALIBRATION DUE August 31, 2000

MODEL 262SMA-FR
SERIAL NUMBER 16157
CAPACITY 62g/205g
READABILITY +/-.00001/.0001
CUSTOMER SPECIFICATIONS N/A

TEST WEIGHT CERTIFICATION INFORMATION

NIST CERTIFICATION #	REPORT NUMBER	WT. SET CALIBRATED	WT. SET CALIBRATION DUE
822 / 253521-94	NC0898C040	August 1998	August 2000
822 / 253521-94	NC0898C041	August 1998	August 2000

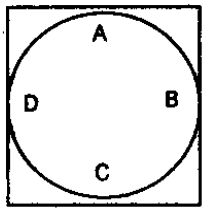
CLASS OF TEST WT.	VALUE OF TEST WT.	READINGS PRIOR TO ADJ.	% ERROR	AFTER ADJ. READING	% ERROR	ZERO TEST
1	0.100001g		-100.0000	0.09998g	-0.0210%	0.00000g
1	1.000015g		-100.0000	1.00000g	-0.0015%	0.00000g
1	10.000028g		-100.0000	9.99998g	-0.0005%	0.00000g
1	100.00001g		-100.0000	99.9998g	-0.0002%	0.0000g
1	*200.00015g		-100.0000	200.0002g	0.0000%	0.0000g

COMMENTS
New Unit Set Up -

CUSTOMER REQUIREMENTS:

CORNER LOAD TEST

CORNER LOAD TEST WT.
10.000028g



FRONT

A	10.00003g
B	9.99998g
C	9.99998g
D	10.00000g

Not Applicable to Mechanical Balances

TECHNICIAN David G. Stevens

TROEMNER

Traceable Certificate

TROEMNER • 201 WOLF DRIVE • P.O. BOX 87 • THOROFARE, NJ 08086-0087 USA • PHONE (856) 686-1600 • FAX (856) 686-1601

Ets Inc
1401 Municipal Road
Roanoke, VA 24012

Test Completed: 09/15/1999
Order Number : 01-1217
Certificate # : 152227A

Description of Weights: Troemner 500 g Elec Cal Cyl Weight

Material	Assumed Density at 20°C	Range
Stainless Steel	7.85g/cm3	500 g

Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

We certify that the weights listed are calibrated to ASTM E617-91 Class 1 tolerances.

The calibration of these weights is based on apparent mass vs. material of density 8.0g/cm3.

Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
500 g	37671	+0.5218 mg	1.200 mg

* Correction is defined as the difference between the mass value of a weight and its nominal value. A positive correction indicates that the mass value is greater than the nominal value by the amount of the correction.

Robert Thompson, Approved Signatory

TROEMNER

Traceable Certificate

TROEMNER • 201 WOLF DRIVE • P.O. BOX 87 • THOROFARE, NJ 08086-0087 USA • PHONE (856) 686-1600 • FAX (856) 686-1601

Ets Inc
1401 Municipal Road
Roanoke, VA 24012

Test Completed: 09/15/1999
Order Number : 01-1217
Certificate # : 152227B

Description of Weights: Troemner 2 kg Elec Cal Cyl Weight

Material	Assumed Density at 20°C	Range
Stainless Steel	7.85g/cm3	2 kg

Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

We certify that the weights listed are calibrated to ASTM E617-91 Class 1 tolerances.

The calibration of these weights is based on apparent mass vs. material of density 8.0g/cm3.

Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
2 kg	37672	+1.0431 mg	5.000 mg

* Correction is defined as the difference between the mass value of a weight and its nominal value. A positive correction indicates that the mass value is greater than the nominal value by the amount of the correction.

Robert Thompson, Approved Signatory

TROEMNER

Traceable Certificate

TROEMNER • 201 WOLF DRIVE • P.O. BOX 87 • THOROFARE, NJ 08086-0087 USA • PHONE (856) 686-1600 • FAX (856) 686-1601

Ets Inc
1401 Municipal Road
Roanoke, VA 24012

Test Completed: 02/07/2000
Order Number : 01-1227
Certificate # : 161484

Description of Weights: Troemner 1g S/S S/K weight

Material	Assumed Density at 20°C	Range
Stainless Steel	7.85g/cm3	1g

Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

We certify that the weights listed are calibrated to ASTM E617-91 Class 1 tolerances.

The calibration of these weights is based on apparent mass vs. material of density 8.0g/cm3.

Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
1 g	45300	+0.0178 mg	0.034 mg

* Correction is defined as the difference between the mass value of a weight and its nominal value. A positive correction indicates that the mass value is greater than the nominal value by the amount of the correction.

Robert Thompson, Approved Signatory

TROEMNER

Traceable Certificate

TROEMNER • 201 WOLF DRIVE • P.O. BOX 87 • THOROFARE, NJ 08086-0087 USA • PHONE (856) 686-1600 • FAX (856) 686-1601

Ets Inc
1401 Municipal Road
Roanoke, VA 24012

Test Completed: 09/15/1999
Order Number : 01-1217
Certificate # : 152227

Description of Weights: Troemner 100 g S/S S/K Weight

Material	Assumed Density at 20°C	Range
Stainless Steel	7.85g/cm3	100 g

Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

We certify that the weights listed are calibrated to ASTM E617-91 Class 1 tolerances.

The calibration of these weights is based on apparent mass vs. material of density 8.0g/cm3.

Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
100 g	37670	+0.0238 mg	0.250 mg

* Correction is defined as the difference between the mass value of a weight and its nominal value. A positive correction indicates that the mass value is greater than the nominal value by the amount of the correction.

Robert Thompson, Approved Signatory

TROEMNER
Henry Troemner LLC

Traceable Certificate

201 Wolf Drive • P.O. Box 87 • Thorofare, NJ 08086-0087 • Phone: 856-686-1600 • Fax: 856-686-1601 • www.troemner.com • e-mail: troemner@troemner.com

Ets Inc
1401 Municipal Road
Roanoke, VA 24012

Test Completed: 08/30/1999
Order Number : 01-1211
Certificate # : 151748

Description of Weights: Troemner 1 mg Weight

Material	Assumed Density at 20°C	Range
Aluminum	2.7 g/cm3	1 mg

Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

We certify that the weights listed are calibrated to ASTM E617-91 Class 1 tolerances.

The calibration of these weights is based on apparent mass vs. material of density 8.0g/cm3.

Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
1 mg	37080	+0.0042 mg	0.010 mg

* Correction is defined as the difference between the mass value of a weight and its nominal value. A positive correction indicates that the mass value is greater than the nominal value by the amount of the correction.

Robert Thompson, Approved Signatory

TROEMNER
Henry Troemner LLC

Traceable Certificate

201 Wolf Drive • P.O. Box 87 • Thorofare, NJ 08086-0087 • Phone: 856-686-1600 • Fax: 856-686-1601 • www.troemner.com • e-mail: troemner@troemner.com

Ets Inc
1401 Municipal Road
Roanoke, VA 24012

Test Completed: 08/20/1999
Order Number : 01-1211
Certificate # : 150843
Weight Set S/N: 36528

Description of Weights: Troemner 50 g - 300 mg Weight Set

Material	Assumed Density at 20°C	Range
Stainless Steel	7.85g/cm3	50 g
Stainless Steel (mg)	7.95 g/cm3	300 mg

Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

We certify that the weights listed are calibrated to ASTM E617-91 Class 1 tolerances.

The calibration of these weights is based on apparent mass vs. material of density 8.0g/cm3.

Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
50 g		+0.0580 mg	0.120 mg
300 mg		-0.0037 mg	0.010 mg

* Correction is defined as the difference between the mass value of a weight and its nominal value. A positive correction indicates that the mass value is greater than the nominal value by the amount of the correction

Robert Thompson, Approved Signatory

Thermometer Calibration Report

Traceable to NIST

29-Dec-99

VWR Scientific Products
1050 Satellite Blvd.
Suwanee GA 30024

Reference No 1544201 JB JB
Distributor VWR Scientific Co.
Customer Rep
Telephone **Fax**

Report No. 992117
Serial No 3C2082
Part No 61099-047

Manufacturer H-B Instrument Company/MW
Item Thermometer, Partial Immersion
Range 18/89°F, 0.2°Div., 108mm Immersion

N.I.S.T. Standard	Instrument Tested	Correction (ITS-90)*	N.I.S.T. Serial No.	N.I.S.T. Test No.	Test Liquid	Emer. Stem** Temperature
20.000° F	19.920° F	0.080	471047	18321	Alcohol	°T
32.000° F	32.000° F	0.000	471047	18321	Ice	°T
50.000° F	50.020° F	-0.020	471047	18321	Water	72.0° F
70.000° F	70.020° F	-0.020	471047	18321	Water	72.0° F
88.000° F	87.980° F	0.020	471047	18321	Water	72.0° F

Ambient Air Temperature: 73° F **Relative Humidity:** 26 %

T - Total Immersion

The Platinum Resistance Thermometer (PRT) serial numbers 419453 and 440026, used to calibrate this thermometer were calibrated with an AC Bridge at a frequency of 90Hz and a constant current of 1.0 mA. This procedure is based on the technical information contained in NIST Technical Note 1265. Comparison points used to calibrate the thermometer range from a temperature of -196.000°C to 420.000°C. PRT calibration uncertainty is estimated not to exceed 0.006°C. The calibration uncertainty of the AC Bridge and PRT is estimated not to exceed 0.026°C. This calibration is traceable to NIST and is in compliance with MIL-STD 45662A and ANSI/ASQC Q9002-1994.

* Observed instrument readings should be increased by positive numbers or reduced by negative numbers indicated by a minus (-) sign.
** Emergent Stem Temperature relates to PARTIAL IMMERSION thermometers ONLY (see reverse).

We report that the thermometer bearing identification marks described above was tested in accordance with NBS Monograph 174, ASTM Method E77 and NIST Special Publication 819. Each instrument was tested at H-B Instrument Company or at manufacturers' laboratory and compared with standards traceable to the National Institute of Standards and Technology (formerly National Bureau of Standards) in accordance with the International Temperature Scale ITS-90 (Adopted September 1989). For a discussion of accuracy obtainable with such thermometers see NIST SP 250-23. As a general guideline, re-certification/re-calibration of thermometers once a year is considered acceptable in most manufacturing and laboratory practices, but each organization must set its own policies.

Richard D. Livergood
Calibration Specialist

James R. Robinson
Vice President, Calibration Services

Form 0-592 Rev.3

H-B Instrument Company
P.O. Box 26770, Collegeville, PA 19426-0770 USA
Telephone 1-800-4-TEST-LAB Fax (610) 489-9100
e-mail Address: cal@hbinstrument.com
Website Address: www.hbinstrument.com

Serving the World Since 1903

ACR Systems Inc.
Unit 210-12960 84th Avenue,
Surrey, B.C. V3W 1K7

Telephone: (604) 591-1128
Fax: (604) 591-2252

Toll-free: 1-800-663-7845

Relative Humidity Calibration

Model: SR2 **Serial #: 66884** **Date: 08-04-99**

Calibration Data

Channel	Description	Eqn	Low	Mid	High
CH 0	Int Temp.	45	0.000	0.000	0.000
CH 1	Int RH	71	-0.391	0.000	0.352
CH 2	Ext Temp	45	0.000	0.000	0.000
CH 3	Ext RH	71	0.000	0.000	0.000
CH 4	NA	-	-	-	-
CH 5	NA	-	-	-	-
CH 6	NA	-	-	-	-
CH 7	NA	-	-	-	-

Calibration Reference Instrument

Vaisala 1% RH & Temperature Probe, Model HMP 133Y, Serial Number: 671381

Sensor or Input Type: Internal Relative Humidity

Ambient Temperature at time of test: 25 C

Reference Instrument Reading	Logger Reading
15 %RH	15.08 %RH
50 %RH	49.43 %RH
80 RH%	80.17 RH%

Test Part Number: 19655 Test Technician: tc

The calibration of this data logger is traceable to the National Institue of Standards and Technology (NIST) using the reference instrument above. The reference reading is verified by a daily salt test and calibrated by the manufacturer at monthly intervals. Details are available on request.

NRD, LLC
2937 ALT BLVD
PO BOX 310
GRAND ISLAND, NY
14072-0310

800-525-8076
716-773-7634
716-773-7744 FAX
nrd@ix.netcom.com
a Mark IV Industries Company

LEAK TEST CERTIFICATE

CUSTOMER: ETS INC
1401 MUNICIPAL ROAD NW
ROANOKE VA 24012

P.O. # 7576
S.O. # 069098

Number of devices tested (1)
Tested for (X) Polonium-210 ( ) Americium-241
Leak test method (Wipe) Calibration Source Isotope Plutonium-239 Serial # 193/88
Person performing test (Health Physics)
Analysis performed using (X) Windowless gas flow proportional counter
( ) Scintillation Counter

TEST RESULTS

TYPE DEVICE	MODEL #	SERIAL #	MICROCURIES/SAMPLE
NUCLECEL	P-2031-1000	115608	Less than .0001uCi

Tests are within prescribed limits. All calibration sources are NIST traceable.

SIGNED: [signature]
TITLE: J DAVID MCGRAW, VP
DATE: 12/7/99

Reviewed By: _____

N 11-A (3/99)

Appendix C

VERIFICATION TESTING SHEETS

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
SUMMARY OF RESULTS

RUN ID.	**V012-1**	**V012-2**	**V012-3**	Average
FABRIC DESIGNATION	**PE16ZU-1/9**	**PE16ZU-3/9**	**PE16ZU-5/9**	
MANUFACTURER	**Standard Filter Corporation**	**Standard Filter Corporation**	**Standard Filter Corporation**	
DUST FEED	**Pural NF**	**Pural NF**	**Pural NF**	
DUST DATA				
Mass Mean Diameter (μm)	0.63			0.63
% Less than PM 2.5	88.99			88.99
CONDITIONING PERIOD				
Date Started	7/17/00	7/18/00	7/19/00	
Time Started	14:40	13:40	13:55	
Time Ended	23:00	22:00	22:15	
Test Duration (min.)	500	500	500	500
RECOVERY PERIOD				
Date Started	7/18/00	7/19/00	7/20/00	
Time Started	7:00	7:12	7:15	
Time Ended	7:03	7:15	7:18	
Test Duration (min.)	3	3	3	3
PERFORMANCE TEST PERIOD				
Date Started	7/18/00	7/19/00	7/20/00	
Time Started	7:25	7:34	7:37	
Time Ended	13:25	13:34	13:37	
Test Duration (min.)	360	360	360	360
VERIFICATION TEST RESULTS				
Mean Outlet Particle Conc. PM 2.5 (g/dscm)	0.0000046	0.0000094	0.0000142	0.0000094
Mean Outlet Particle Conc. Total mass (g/dscm)	0.0000078	0.0000125	0.0000361	0.0000188
Increase in Residual Pressure Drop (cm w.g.)	7.11	6.81	4.18	6.03
Average Residual Pressure Drop (cm w.g.)	14.96	14.89	13.82	14.56
Mass Gain of Filter Sample (g)	1.63	1.69	1.49	1.60
Average Filtration Cycle Time (s)	6	6	6	6

RTI/ETV PRELIMINARY TESTING
DUST CHARACTERIZATION - PURAL NF
ANDERSEN IMPACTOR PARTICLE SIZING
GRAVIMETRIC ANALYTICAL DATA AND RESULTS

RUN NUMBER: V012
TEST DATE: 07/17/00

Filter I.D. Sample I.D.	Wash Vol.(ml)	Stage	Tare Filter Mass (g)	Tare Beaker Mass (g)	Total Tare Mass (g)	Total Final Mass (g)	Mass Difference (g)	Negative Difference? (g)
VDI-00-53	50	Acetone Wash	NA	0	0	0	0.00000	NA
VDI-00-53-1		1	1.25990	0	1.25990	1.26060	0.00070	NA
VDI-00-53-2		2	1.19060	0	1.19060	1.19073	0.00013	NA
VDI-00-53-3		3	1.20032	0	1.20032	1.20060	0.00028	NA
VDI-00-53-4		4	1.34735	0	1.34735	1.34800	0.00065	NA
VDI-00-53-5		5	1.18270	0	1.18270	1.18391	0.00121	NA
VDI-00-53-6		6	1.16376	0	1.16376	1.16841	0.00465	NA
VDI-00-53-7		7	1.20974	0	1.20974	1.21474	0.00500	NA
VDI-00-53-8		8	1.16554	0	1.16554	1.16976	0.00422	NA
VDI-00-53-F		9	1.35589	0	1.35589	1.36499	0.00910	NA
						Total	0.02594	

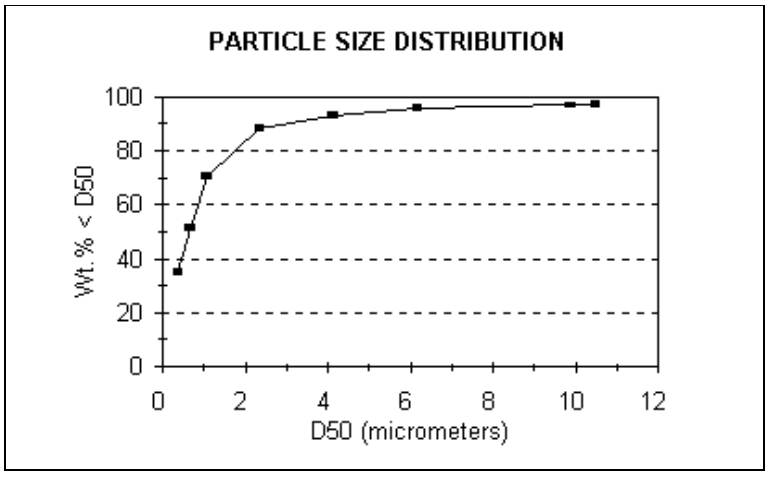
IMPACTOR PARTICLE SIZING RESULTS

Impactor Flow Rate: 0.178 cfm
Isokinetics: 102.66 %
Viscosity of Gas: 0.000162 poise

STAGE	Particulate Mass (g)	Cummulative % Less Than Diameter	D50 Cut Point (micrometers)*
1	0.00070	97.30	10.47
2	0.00013	96.80	9.87
3	0.00028	95.72	6.17
4	0.00065	93.22	4.13
5	0.00121	88.55	2.33
6	0.00465	70.62	1.07
7	0.00500	51.35	0.66
8	0.00422	35.08	0.37
9	0.00910		

Mass Mean Diameter, micrometers 0.63
% Less Than PM 2.5 88.99

* Calculated as an aerodynamic diameter using a particle density of 2.65 g/ml.



DUST CHARACTERIZATION
FOR TEST SERIES V012

DATE	07/17/00	
START TIME	1:46	
END TIME	1:51	
STACK LENGTH	111	mm
STACK WIDTH	291	mm
STACK AREA	0.0323	m^2
NOZZLE I.D.	1.797	in.
	0.046	m
METER BOX GAMMA	0.9927	
BAROMETRIC PRESSURE	28.83	in. Hg
TEST DURATION	5	min.
METER VACUUM	2.0	in. Hg

DATA (FOR RAW GAS CHANNEL)

Actual Flow	5.83	m^3/hr
	3.43	cfm
Std. Flow	5.53	scm/hr
	3.25	scfm
Raw Gas Pressure	975.35	mbar
Sample Gas Temperature	24.5	° C
	76.1	° F

INTERMEDIATE RESULTS

Metered Volume	0.895	ft^3
Volume @ Std. Cond.	0.846	scf
Volume at Raw Gas Conditions	0.892	scf
Water	1.43	%
Isokinetics	102.7	%

METHOD 3 DATA

%O2	20.9	Md	28.84	
%CO2	0.0	Ms	28.68	
%CO	0.0	Ps	28.80	in. Hg
%N2	79.1			
O2+CO2	20.9			

POINT	STACK TEMP (° F)	DP (in. w.g.)	DH (in. w.g.)	METER VOLUME (liters)	METER TEMPERATURE INLET (° F)	METER TEMPERATURE OUTLET (° F)
1	76.1	1E-05	6.125	4622.01	74	72
				4647.35	78	72
			Volume Change:	25.34	(Avg. of 4 temps.)	74

Md - Dry Molecular Weight
Ms - Molecular Weight in Stack
Ps - Static Pressure (Atmospheric)
DH - Orifice Pressure Drop
DP - Pressure Drop

* All measurements are primary measurements and might be converted in subsequent calculations.

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

CONDITIONING TEST PERIOD

RUN ID.	V012-1	NUMBER OF PULSES	10000
FABRIC DESIGNATION	PE16ZU-1/9	PULSE INTERVAL	3 s
MANUFACTURER	Standard Filter Corporation		
DUST FEED	Pural NF	% Moisture	1.43 %WV
DATE(S)	7/17/00		
TIME STARTED	14:40		
TIME ENDED	23:00		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	14:40	15:40	1829.4	1718.3	111.1	2.82	2.68	5.50	23.98	975.45	20.5	183.4
61-120	15:41	16:40	1718.3	1616.7	101.6	2.83	2.68	5.51	24.22	975.22	18.7	183.5
121-180	16:41	17:40	1616.7	1515.9	100.8	2.83	2.68	5.51	24.34	975.40	18.6	183.4
181-240	17:41	18:40	1515.9	1413.3	102.6	2.83	2.68	5.51	24.23	975.45	18.9	183.4
241-300	18:41	19:40	1413.3	1313.6	99.7	2.83	2.68	5.51	24.05	975.54	18.3	183.2
301-360	19:41	20:40	1313.6	1217.9	95.7	2.83	2.68	5.51	23.92	975.68	17.6	183.1
361-420	20:41	21:40	1217.9	1127.6	90.3	2.83	2.68	5.51	23.65	976.09	16.6	182.9
421-480	21:41	22:40	1127.6	1038.5	89.1	2.83	2.68	5.51	23.48	976.41	16.4	182.7
441-500 *	22:01	23:00	1096.4	1010.0	86.4	2.83	2.68	5.51	23.44	976.44	15.9	182.7
AVERAGE (per hour)					98.3	2.83	2.68	5.51	23.96	975.68	18.1	183.2
ACCEPTANCE					100 +/- 20				25.5 +/- 2.2		18.4 +/- 3.6	180 +/- 9.0

* 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.	V012-1	NUMBER OF PULSES	30
FABRIC DESIGNATION	PE16ZU-1/9	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Standard Filter Corporation	AVG . RESIDUAL DP	1039.07 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE(S)	7/18/00		
TIME STARTED	7:00 *	% Moisture	1.34 %WV
TIME ENDED	7:03		
TEST DURATION	3 min.		

QA/QC DATA

Test Duration			Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)	Time		Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
1-3	7:01 *	7:03	993.5	989.5	4.1	2.81	2.67	5.48	22.4	976.45	0.8	181.4
AVERAGE (per hour)					80.5	2.81	2.67	5.48	22.4	976.45	14.9	181.4
ACCEPTANCE					100				25.5		18.4	180
					+/- 20				+/- 2.2		+/- 3.6	+/- 9.0

* 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

RUN ID.	V012-1	NUMBER OF PULSES	3599
FABRIC DESIGNATION	PE16ZU-1/9	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Standard Filter Corporation	AVG. RESIDUAL DP	1465.71 Pa
DUST FEED	Pural NF	CHANGE IN DP	696.1 Pa
DATE(S)	7/18/00	MAX. PRESSURE DROP	1000 Pa
TIME STARTED	7:25		
TIME ENDED	13:25	% Moisture	1.34 %WV
TEST DURATION	360 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)				Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	Sample	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	7:25	8:25	1601.8	1499.8	102.1	2.82	2.69	5.52	1.06	22.63	977.24	18.7	183.2
61-120	8:26	9:25	1499.8	1395.9	103.9	2.84	2.70	5.53	1.08	23.19	977.37	19.0	183.7
121-180	9:26	10:25	1395.9	1291.6	104.3	2.84	2.70	5.53	1.08	23.58	976.84	19.1	184.0
181-240	10:26	11:25	1291.6	1189.3	102.3	2.84	2.70	5.53	1.08	23.99	976.94	18.7	184.2
241-300	11:26	12:25	1189.3	1088.8	100.5	2.84	2.70	5.53	1.09	24.23	976.76	18.4	184.3
301-360	12:26	13:25	1088.8	981.2	107.6	2.84	2.70	5.53	1.10	24.53	976.34	19.7	184.5
AVERAGE (per hour)					103.4	2.83	2.70	5.53	1.08	23.69	976.91	19.0	184.0
ACCEPTANCE					100 +/- 20					25.5 +/- 2.2		18.4 +/- 3.6	180 +/- 9.0

GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00003 g	Tare Mass	13.17 g
Total Mass Gain	0.00005 g	Final Mass	14.80 g
		Mass Gain	1.63 g

OUTLET CONCENTRATION

Total Volume Sampled	6.91 m^3
Mean Outlet Particle Concentration - PM 2.5	0.0000043 g/m^3
Mean Outlet Particle Concentration - Total Mass	0.0000072 g/m^3

DATA PROCESSING OPERATOR:

Sharon M. Winemiller - ETS, Inc.

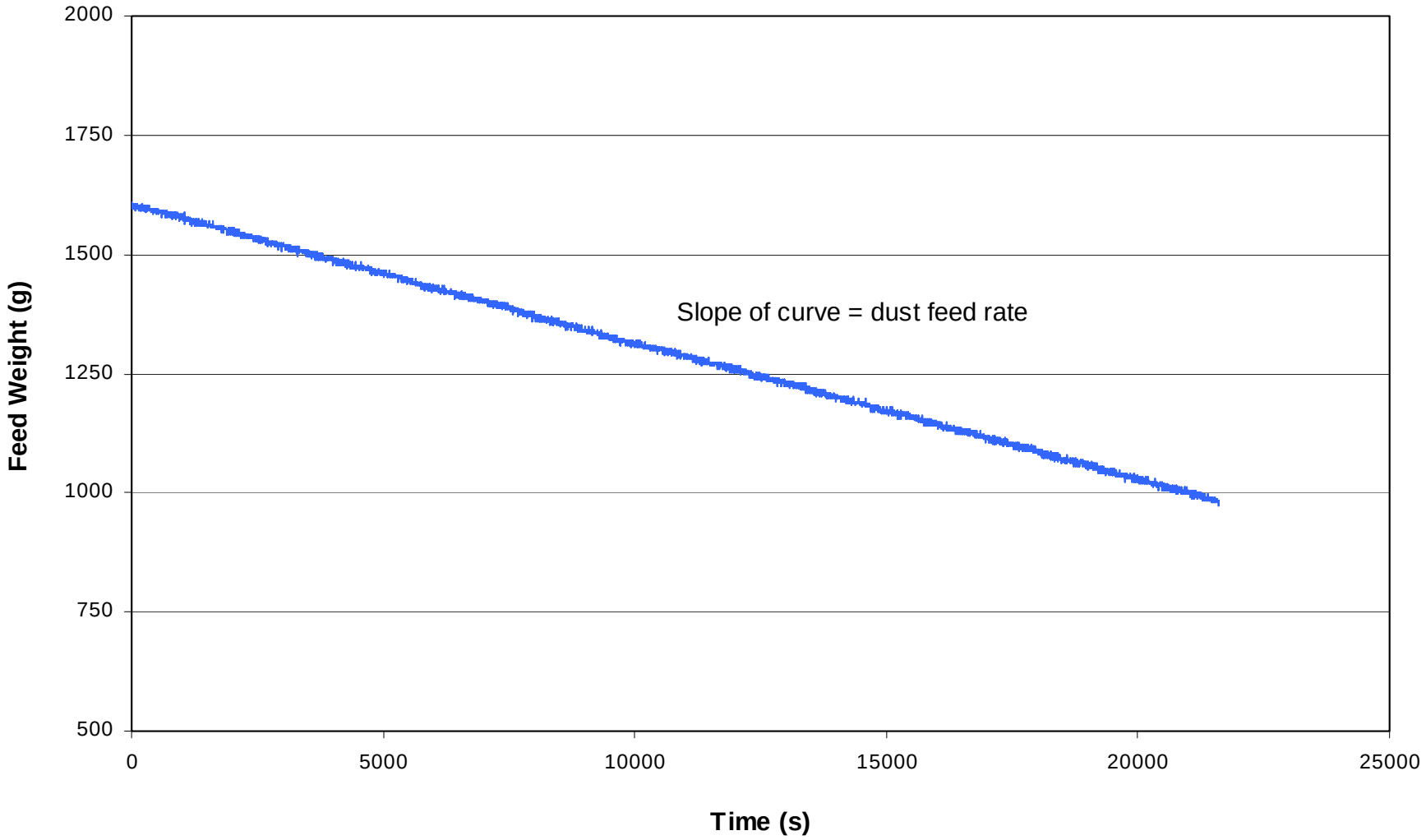


Figure C-1. Change in Pural NF dust scale reading with time during performance test run V012-1.

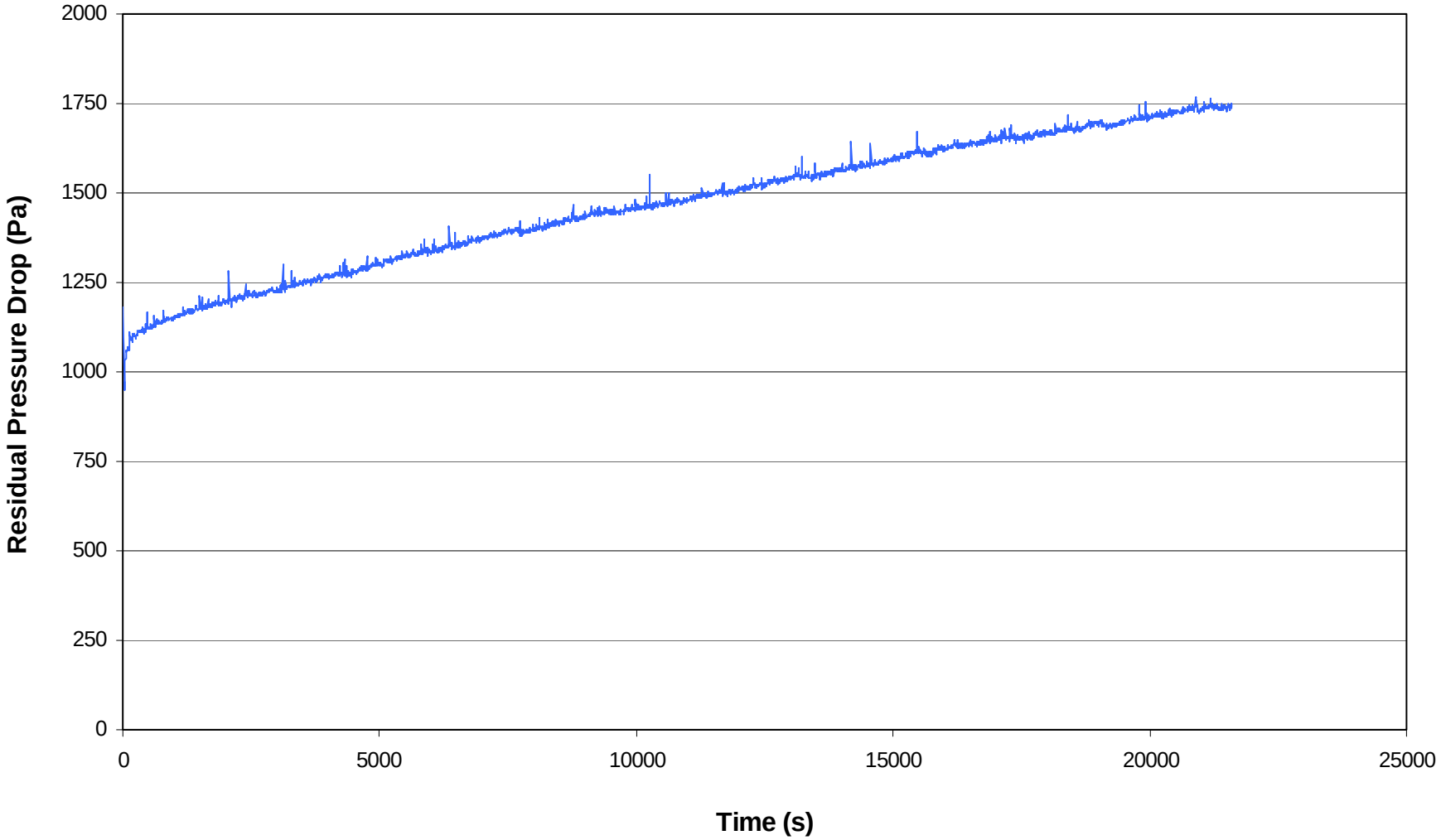


Figure C-2. Residual pressure drop across filter fabric during performance test run V012-1.

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

CONDITIONING TEST PERIOD

RUN ID.	V012-2	NUMBER OF PULSES	10000
FABRIC DESIGNATION	PE16ZU-3/9	PULSE INTERVAL	3 s
MANUFACTURER	Standard Filter Corporation		
DUST FEED	Pural NF	% Moisture	1.49 %WV
DATE(S)	7/18/00		
TIME STARTED	13:40		
TIME ENDED	22:00		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	13:40	14:40	1808.3	1713.1	95.2	2.82	2.69	5.51	24.45	975.90	17.5	184.2
61-120	14:41	15:40	1713.1	1609.0	104.0	2.83	2.70	5.53	24.52	975.58	19.1	184.7
121-180	15:41	16:40	1609.0	1510.4	98.6	2.83	2.70	5.53	24.49	975.28	18.1	184.7
181-240	16:41	17:40	1510.4	1405.7	104.7	2.83	2.70	5.53	24.46	975.26	19.2	184.7
241-300	17:41	18:40	1405.7	1306.3	99.4	2.83	2.70	5.53	24.29	975.06	18.3	184.7
301-360	18:41	19:40	1306.3	1204.2	102.0	2.83	2.70	5.53	24.14	975.01	18.7	184.6
361-420	19:41	20:40	1204.2	1106.5	97.8	2.83	2.70	5.53	24.03	975.18	18.0	184.5
421-480	20:41	21:40	1106.5	1011.8	94.7	2.83	2.70	5.53	23.92	975.48	17.4	184.3
441-500 *	21:01	22:00	1073.2	978.7	94.5	2.83	2.70	5.53	23.86	975.59	17.3	184.3
AVERAGE (per hour)					99.5	2.83	2.69	5.53	24.27	975.35	18.3	184.5
ACCEPTANCE					100 +/-20				25.5 +/-2.2		18.4 +/-3.6	180 +/-9.0

* 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 - E TS, Inc.

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

RECOVERY PERIOD

RUN ID.	V012-2	NUMBER OF PULSES	30
FABRIC DESIGNATION	PE16ZU-3/9	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Standard Filter Corporation	AVG . RESIDUAL DP	1031.37 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE(S)	7/19/00		
TIME STARTED	7:12 *	% Moisture	1.4 %WV
TIME ENDED	7:15		
TEST DURATION	3 min.		

QA/QC DATA

Test Duration	Time			Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)				Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
1-3	7:13	*	7:15	965.0	963.5	1.5	2.81	2.70	5.50	22.7	975.22	0.3	183.6
AVERAGE (per hour)						26.9	2.81	2.70	5.50	22.7	975.22	4.9	183.6
ACCEPTANCE						100				25.5		18.4	180
						+/- 20				+/- 2.2		+/- 3.6	+/- 9.0

* 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

RUN ID.	V012-2	NUMBER OF PULSES	3599
FABRIC DESIGNATION	PE16ZU-3/9	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Standard Filter Corporation	AVG. RESIDUAL DP	1458.25 Pa
DUST FEED	Pural NF	CHANGE IN DP	667.5 Pa
DATE(S)	7/19/00	MAX. PRESSURE DROP	1000 Pa
TIME STARTED	7:34		
TIME ENDED	13:34	% Moisture	1.4 %WV
TEST DURATION	360 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)				Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	Sample	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	7:34	8:34	1790.5	1690.9	99.7	2.82	2.70	5.52	1.08	22.94	975.31	18.3	183.8
61-120	8:35	9:34	1690.9	1581.4	109.4	2.83	2.70	5.53	1.07	23.36	975.09	20.1	184.2
121-180	9:35	10:34	1581.4	1479.3	102.1	2.83	2.70	5.53	1.08	23.59	974.72	18.7	184.3
181-240	10:35	11:34	1479.3	1380.2	99.1	2.83	2.70	5.53	1.08	24.00	974.26	18.2	184.6
241-300	11:35	12:34	1380.2	1272.2	108.0	2.83	2.70	5.53	1.08	24.46	973.98	19.8	184.9
301-360	12:35	13:34	1272.2	1159.9	112.3	2.83	2.70	5.53	1.08	24.62	973.08	20.6	185.2
AVERAGE (per hour)					105.1	2.83	2.70	5.53	1.08	23.83	974.41	19.3	184.5
ACCEPTANCE					100					25.5		18.4	180
					+/- 20					+/- 2.2		+/- 3.6	+/- 9.0

GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00006 g	Tare Mass	12.73 g
Total Mass Gain	0.00008 g	Final Mass	14.42 g
		Mass Gain	1.69 g

OUTLET CONCENTRATION

Total Volume Sampled	6.93 m^3
Mean Outlet Particle Concentration - PM 2.5	0.0000087 g/m^3
Mean Outlet Particle Concentration - Total Mass	0.0000115 g/m^3

DATA PROCESSING OPERATOR:

Sharon M. Winemiller - ETS, Inc.

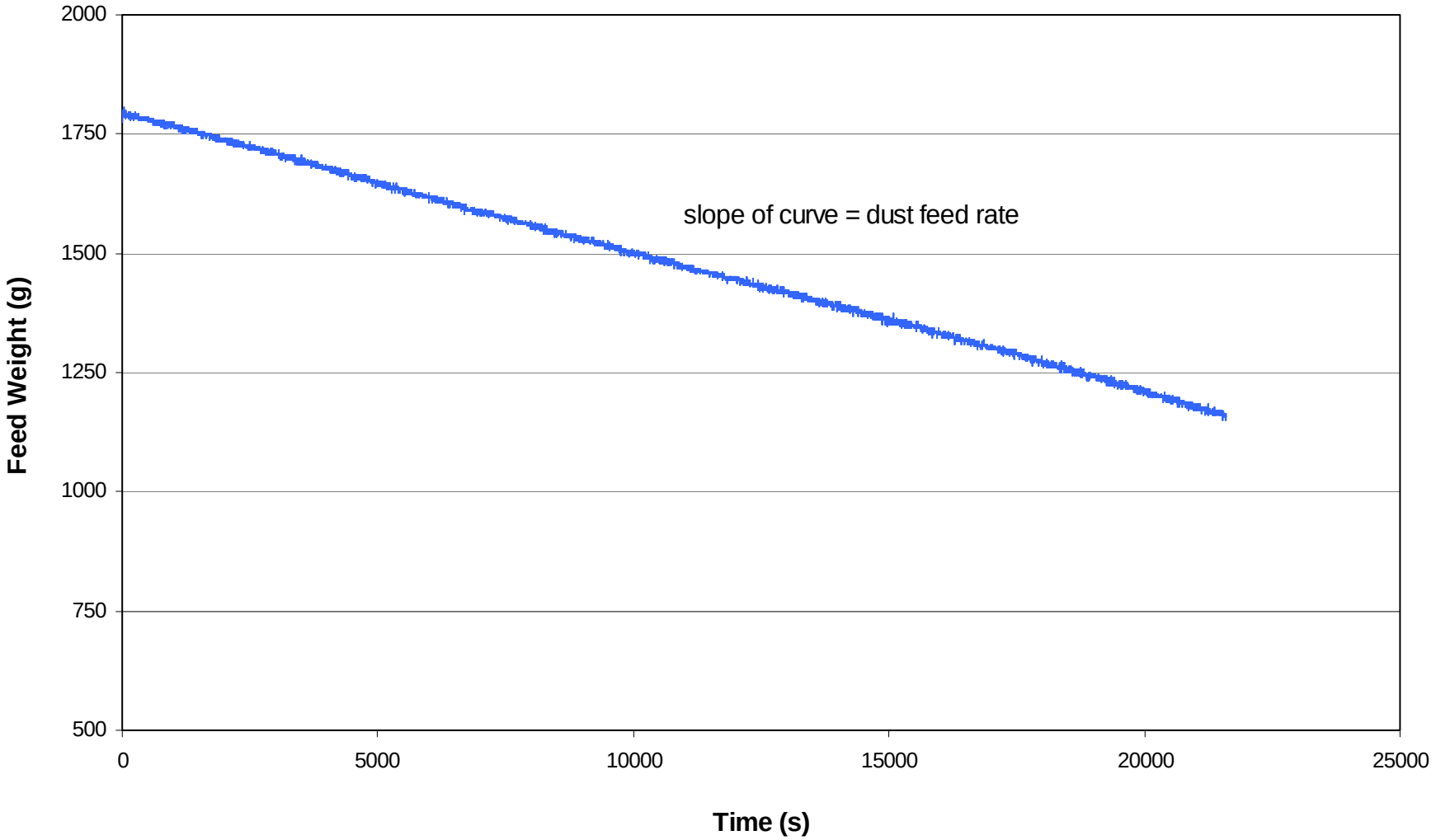


Figure C-3. Change in Pural NF dust scale reading with time during performance test run V012-2.

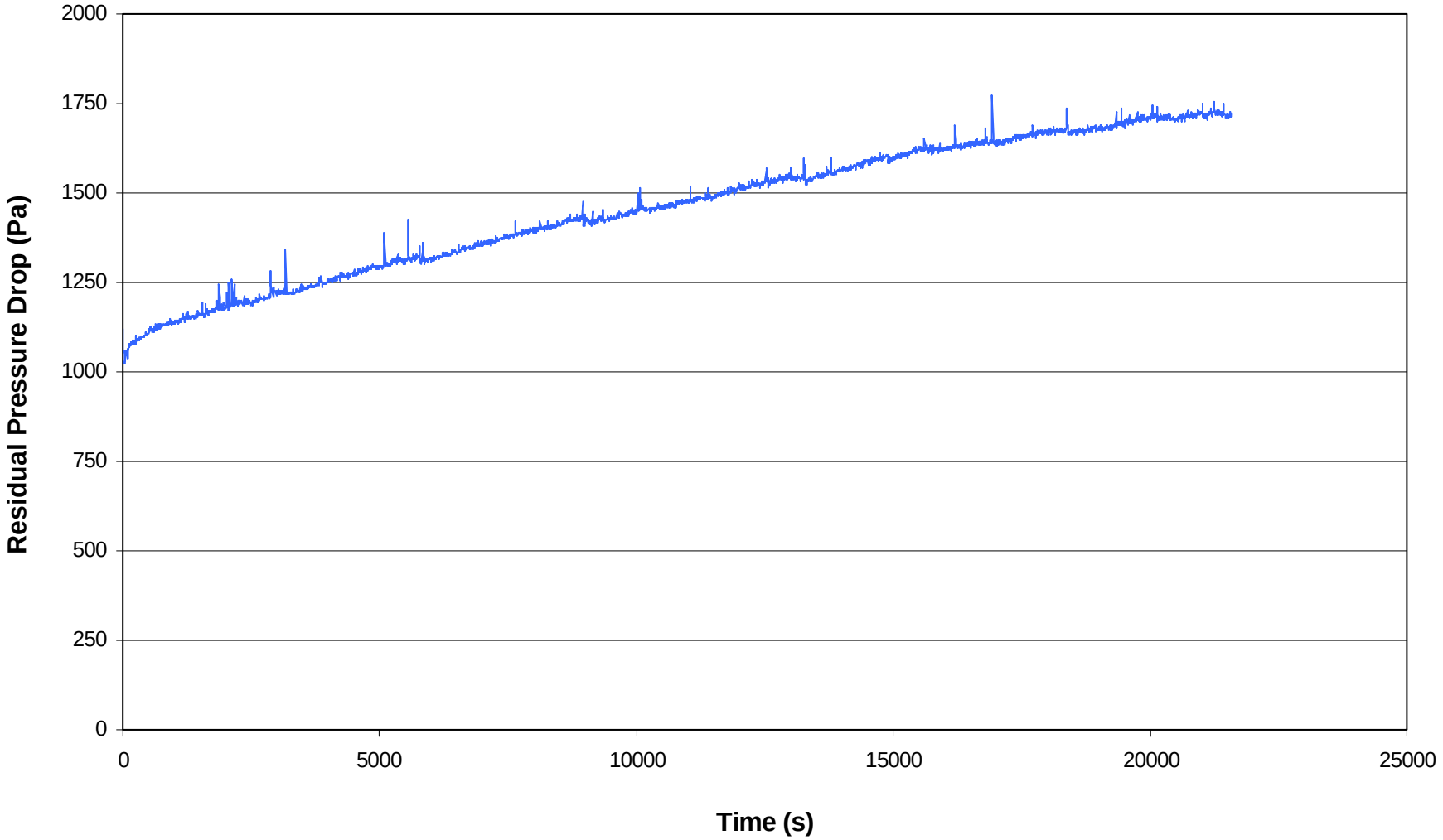


Figure C-4. Residual pressure drop across filter fabric during performance test run V012-2.

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

CONDITIONING TEST PERIOD

RUN ID.	V012-3	NUMBER OF PULSES	10000
FABRIC DESIGNATION	PE16ZU-5/9	PULSE INTERVAL	3 s
MANUFACTURER	Standard Filter Corporation		
DUST FEED	Pural NF	% Moisture	1.50 %WV
DATE(S)	7/19/00		
TIME STARTED	13:55		
TIME ENDED	22:15		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	13:55	14:55	1760.5	1678.9	81.5	2.82	2.69	5.51	24.47	971.86	15.0	185.0
61-120	14:56	15:55	1678.9	1575.6	103.3	2.83	2.70	5.53	24.43	971.45	19.0	185.4
121-180	15:56	16:55	1575.6	1482.8	92.8	2.83	2.70	5.53	24.24	970.95	17.0	185.5
181-240	16:56	17:55	1482.8	1391.1	91.7	2.83	2.70	5.53	24.18	970.29	16.8	185.6
241-300	17:56	18:55	1391.1	1295.7	95.5	2.83	2.70	5.53	24.06	969.04	17.5	185.8
301-360	18:56	19:55	1295.7	1200.1	95.6	2.83	2.70	5.53	23.93	969.65	17.6	185.5
361-420	19:56	20:55	1200.1	1109.3	90.8	2.83	2.70	5.53	23.78	969.96	16.7	185.4
421-480	20:56	21:55	1109.3	1018.1	91.2	2.83	2.70	5.53	23.57	970.58	16.8	185.1
441-500 *	21:16	22:15	1076.4	986.9	89.5	2.83	2.69	5.53	23.56	970.82	16.4	185.0
AVERAGE (per hour)					92.8	2.83	2.70	5.53	24.06	970.49	17.1	185.4
ACCEPTANCE					100				25.5		18.4	180
					+/- 20				+/- 2.2		+/- 3.6	+/- 9.0

* 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.	V012-3	NUMBER OF PULSES	30
FABRIC DESIGNATION	PE16ZU-5/9	AVG. PULSE INTERVAL	7 s
MANUFACTURER	Standard Filter Corporation	AVG . RESIDUAL DP	944.43 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE(S)	7/20/00		
TIME STARTED	7:15 *	% Moisture	1.81 %WV
TIME ENDED	7:18		
TEST DURATION	3 min.		

QA/QC DATA

Test Duration	Time			Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)				Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
1-3	7:16	*	7:18	979.7	979.6	0.1	2.81	2.68	5.48	22.7	972.32	0.0	183.0
AVERAGE (per hour)						1.7	2.81	2.68	5.48	22.7	972.32	0.3	183.0
ACCEPTANCE						100				25.5		18.4	180
						+/- 20				+/- 2.2		+/- 3.6	+/- 9.0

* 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

RUN ID.	V012-3	NUMBER OF PULSES	3600
FABRIC DESIGNATION	PE16ZU-5/9	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Standard Filter Corporation	AVG. RESIDUAL DP	1353.83 Pa
DUST FEED	Pural NF	CHANGE IN DP	409.6 Pa
DATE(S)	7/20/00	MAX. PRESSURE DROP	1000 Pa
TIME STARTED	7:37		
TIME ENDED	13:37	% Moisture	1.81 %WV
TEST DURATION	360 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)				Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	Sample	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	7:37	8:37	1496.2	1398.7	97.5	2.82	2.70	5.52	1.09	22.88	973.17	18.0	184.4
61-120	8:38	9:37	1398.7	1297.5	101.1	2.83	2.69	5.52	1.08	23.31	973.94	18.6	183.9
121-180	9:38	10:37	1297.5	1192.2	105.3	2.83	2.69	5.52	1.08	23.53	973.70	19.4	184.0
181-240	10:38	11:37	1192.2	1090.4	101.9	2.83	2.69	5.52	1.08	23.77	973.74	18.8	184.1
241-300	11:38	12:37	1090.4	983.6	106.8	2.83	2.69	5.52	1.08	23.96	974.13	19.7	184.1
301-360	12:38	13:37	983.6	876.4	107.3	2.83	2.69	5.52	1.08	24.08	974.36	19.8	184.2
AVERAGE (per hour)					103.3	2.83	2.69	5.52	1.08	23.59	973.84	19.0	184.1
ACCEPTANCE					100					25.5		18.4	180
					+/- 20					+/- 2.2		+/- 3.6	+/- 9.0

GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00009 g	Tare Mass	13.24 g
Total Mass Gain	0.00023 g	Final Mass	14.73 g
		Mass Gain	1.49 g

OUTLET CONCENTRATION

Total Volume Sampled	6.93 m^3
Mean Outlet Particle Concentration - PM 2.5	0.0000130 g/m^3
Mean Outlet Particle Concentration - Total Mass	0.0000332 g/m^3

DATA PROCESSING OPERATOR:

Sharon M. Winemiller - ETS, Inc.

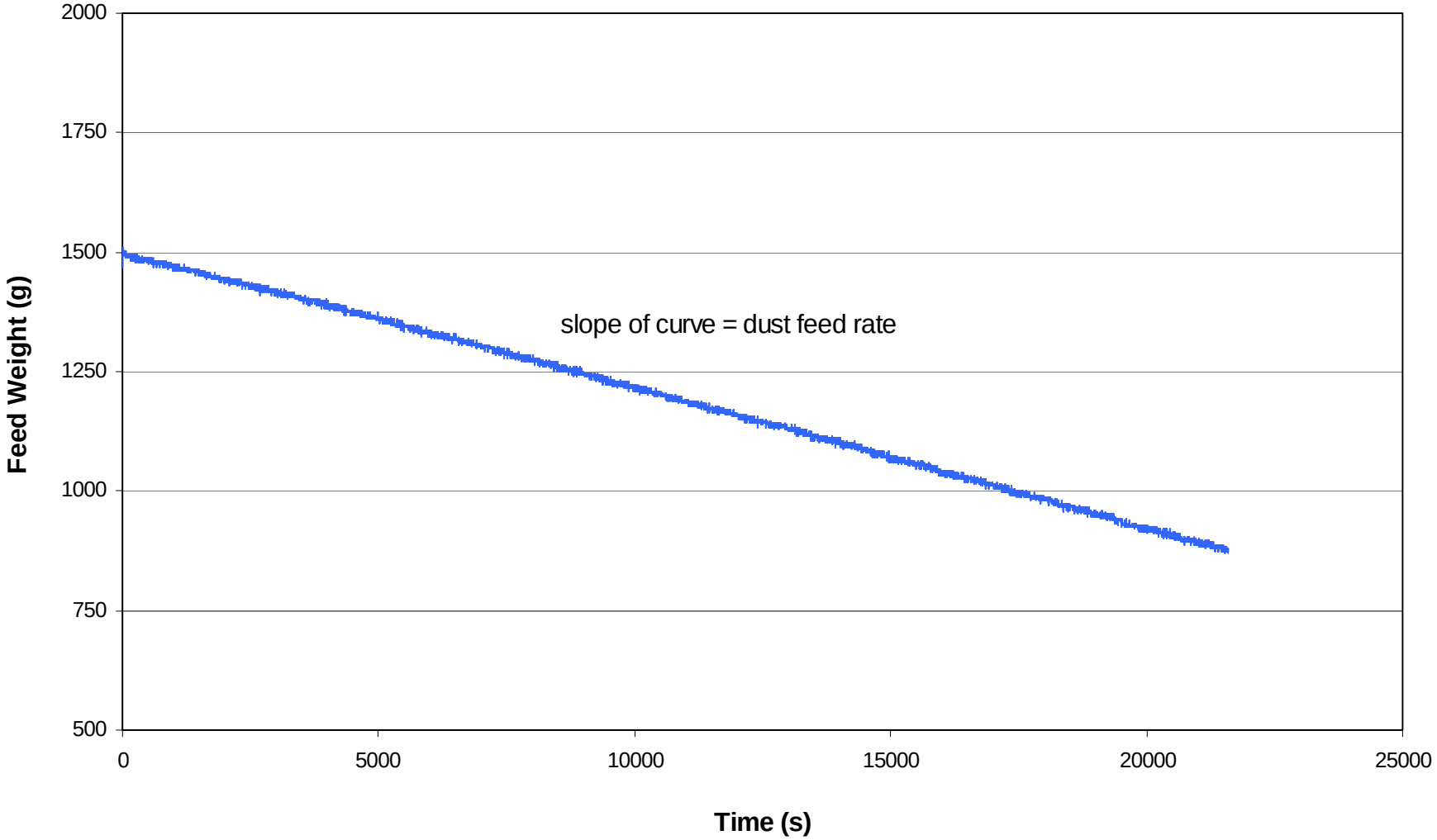


Figure C-5. Change in Pural NF dust scale reading with time during performance test run V012-3.

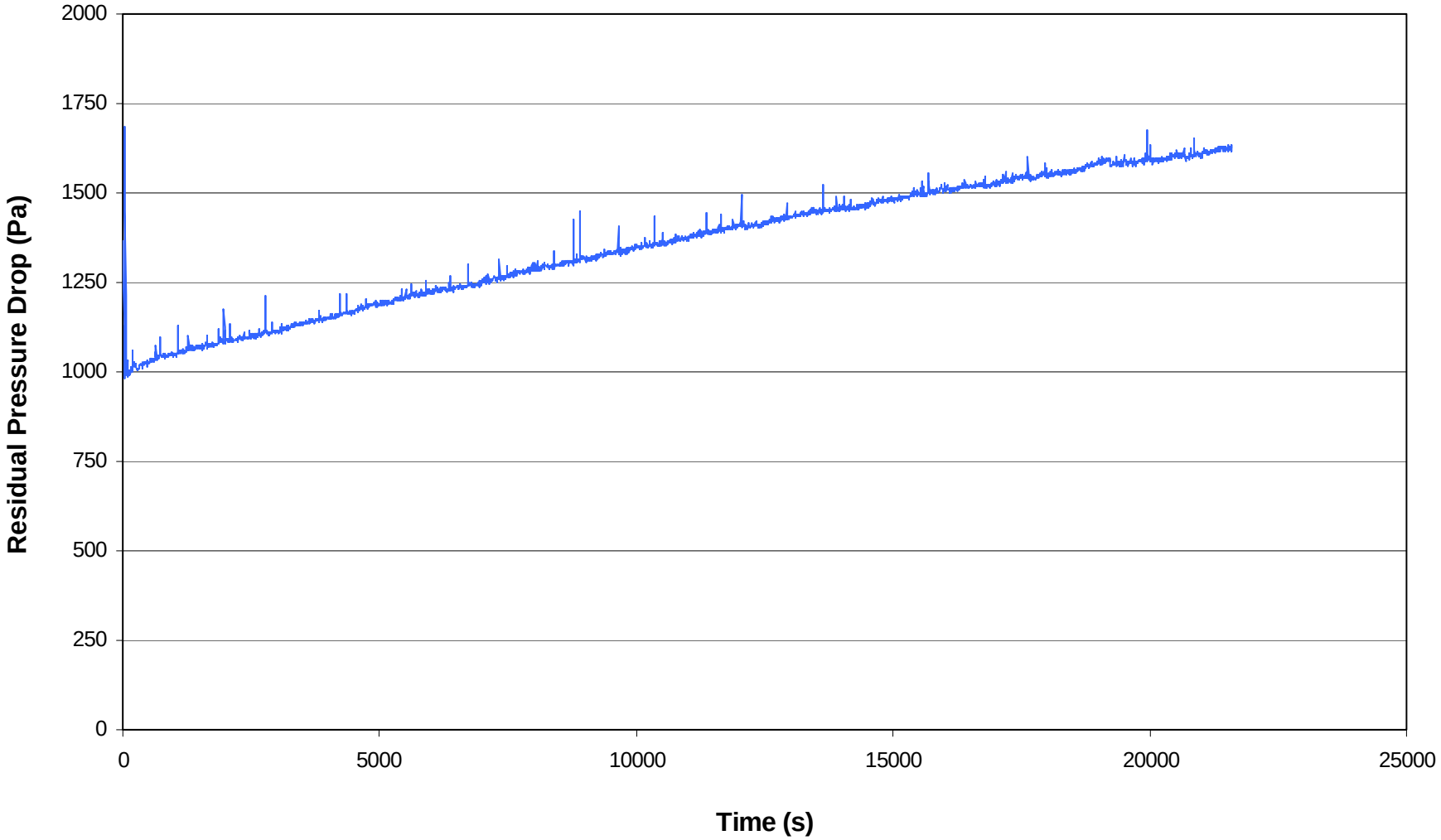


Figure C-6. Residual pressure drop across filter fabric during performance test run V012-3.