

US EPA ARCHIVE DOCUMENT

# Environmental Technology Verification Report

## Baghouse Filtration Products

### Inspec Fibres 5512BRF Filter Sample

Prepared by



ETS, Incorporated



Research Triangle Institute

Under a Cooperative Agreement with



ET ✓ ET ✓ ET ✓

# **Environmental Technology Verification Report**

## **Baghouse Filtration Products**

### **Inspec Fibres 5512BRF Filter Sample**

Prepared by

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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/>

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### 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  $\mu\text{m}$  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 Inspec Fibres' filter sample 5512BRF during the period of March 31-April 5, 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 <sup>3</sup>	cubic feet
g	grams
G/C	gas-to-cloth ratio (filtration velocity)
gr	grains
gr/dscf	grains per dry standard cubic foot
g/dscm	grams per dry standard cubic meter
g/h	grams per hour
g/m <sup>2</sup>	grams per square meter
h	hours
in.	inches
in. w.g.	inches of water gauge
m	meters
mbar	millibars
m/h	meters per hour
m <sup>3</sup> /h	cubic meters per hour
mm	millimeters

MPa	megapascals
ms	milliseconds
NA	not applicable
NIST	National Institute of Standards and Technology
oz/yd <sup>2</sup>	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

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### 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 Kenneth Spindola of Inspec Fibres.

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For more information on Inspec Fibres' 5512BRF baghouse fabric, contact

Kenneth Spindola  
Inspec Fibres  
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Hopedale, MA 01747  
(508) 478-2414  
p84@kersur.net

## 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"<sup>1</sup> and the "Test/QA Plan for the Verification Testing of Baghouse Filtration Products."<sup>2</sup> This protocol incorporated all requirements for quality management, 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  $180 \pm 9$  m/h ( $9.8 \pm 0.5$  fpm) and  $18.4 \pm 3.6$  g/dscm ( $8.0 \pm 1.6$  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 (5512BRF) were supplied to ETS directly from the manufacturer (Inspec Fibres) with a letter signed by Kenneth Spindola, Sales Manager of High Performance Fibers, 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 Inspec Fibres 5512BRF filter fabric is a 16 oz/yd<sup>2</sup> 100% scrim supported P84 needlefelt.

**SECTION 4  
VERIFICATION OF PERFORMANCE**

**4.1 QUALITY ASSURANCE**

The verification tests were conducted in accordance with an approved Test/Quality Assurance (QA) Plan.<sup>2</sup> 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**

Tables 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<sup>3</sup>/h (3.4 cfm)] is also shown in Table 3. This pressure drop ranged from 11.27 to 12.38 cm w.g. (4.44 to 4.87 in. w.g.) for the three filter samples tested. The residual pressure drop increase ranged from 5.03 to 5.14 cm w.g. (1.98 to 2.02 in. w.g.) for the samples tested.

**TABLE 3. SUMMARY OF VERIFICATION RESULTS FOR  
INSPEC FIBRES/5512BRF**

Test Run Number	V005-1	V005-2	V005-3	Average
PM 2.5 (g/dscm)*	0.00057	0.00030	0.00028	0.00038
Total PM (g/dscm)	0.00060	0.00036	0.00030	0.00042
Average Residual Pressure Drop (cm w.g.)	11.27	12.38	11.63	11.76
Residual Pressure Drop Increase (cm w.g.)	5.03	5.14	5.13	5.10
Mass Gain of Sample Filter (g)	1.59	1.39	1.43	1.47
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**

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**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.<sup>1</sup> High efficiency filters are installed upstream of the flow controllers and pumps to prevent contamination or damage caused by the dust. The cleaning system consists of a compressed-air tank set at 0.52 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  $1.0 \pm 0.5 \mu\text{m}$  mass mean diameter and  $76 \pm 10 \%$  less than  $2.5 \mu\text{m}$  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  $0.93 \pm 0.09 \text{ g}$  and a reference fabric maximum pressure drop of  $1.84 \pm 0.18 \text{ cm w.g.}$  to proceed with verification testing.

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

**TABLE A-1. SUMMARY OF CONTROL TEST RESULTS**

	<b>Requirement</b>	<b>Measured Value</b>	<b>Met Requirements?</b>
<b>Mass Mean Diameter, <math>\mu\text{m}</math></b>	$1.0 \pm 0.5$	1.36	Yes
<b>% Less than 2.5 <math>\mu\text{m}</math></b>	$76 \pm 10$	69	Yes
<b>Weight Gain, g</b>	$0.93 \pm 0.09$	0.84	Yes
<b>Maximum Pressure Drop, cm w.g.</b>	$1.84 \pm 0.18$	1.71	Yes

**Analysis**

The equations that were used for verification analysis are described below.

- $A_f$  = Exposed area of sample filter,  $\text{m}^2$
- $C_{ds}$  = Dry standard outlet particulate concentration of total mass,  $\text{g/dscm}$
- $C_{2.5ds}$  = Dry standard outlet particulate concentration of PM 2.5,  $\text{g/dscm}$
- $d$  = Diameter of exposed area of sample filter,  $\text{m}$
- $F_a$  = Dust feed concentration corrected for actual conditions,  $\text{g/m}^3$
- $F_s$  = Dust feed concentration corrected for standard conditions,  $\text{g/dscm}$
- $G/C$  = Gas-to-cloth ratio,  $\text{m/h}$
- $M_t$  = Total mass gain from Andersen Impactor,  $\text{g}$
- $M_{2.5}$  = Total mass gain of particles equal to or less than 2.5  $\mu\text{m}$  diameter from Andersen Impactor,  $\text{g}$ . 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,  $\text{cm w.g.}$
- $P_i$  = Residual pressure drop for  $i$ th filtration cycle,  $\text{cm w.g.}$
- $P_s$  = Absolute gas pressure as measured in the raw gas channel,  $\text{mbar}$
- $Q_a$  = Actual gas flow rate,  $\text{m}^3/\text{h}$
- $Q_{ds}$  = Dry standard gas flow rate,  $\text{dscmh}$
- $Q_{2.5ds}$  = Dry standard gas flow rate for 2.5  $\mu\text{m}$  particles,  $\text{dscmh}$
- $Q_{st}$  = Standard gas flow rate for a specific averaging time,  $t$ ,  $\text{dscmh}$
- $t$  = Specified averaging time or sampling time,  $\text{s}$
- $t_c$  = Average filtration cycle time,  $\text{s}$
- $T_s$  = Raw gas channel temperature,  $^{\circ}\text{F}$
- $w_f$  = Weight of dust in feed hopper following specified time,  $\text{g}$ . 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,  $\text{g}$ . Because of vibrations causing short-term fluctuations to the feed hopper, it is recommended that this value be measured as a 1-min average.

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

- 460 =  $0^{\circ}\text{F}$ , in  $^{\circ}\text{R}$
- 1013 = Standard atmospheric pressure,  $\text{mbar}$
- 528 = Standard temperature,  $^{\circ}\text{R}$

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.

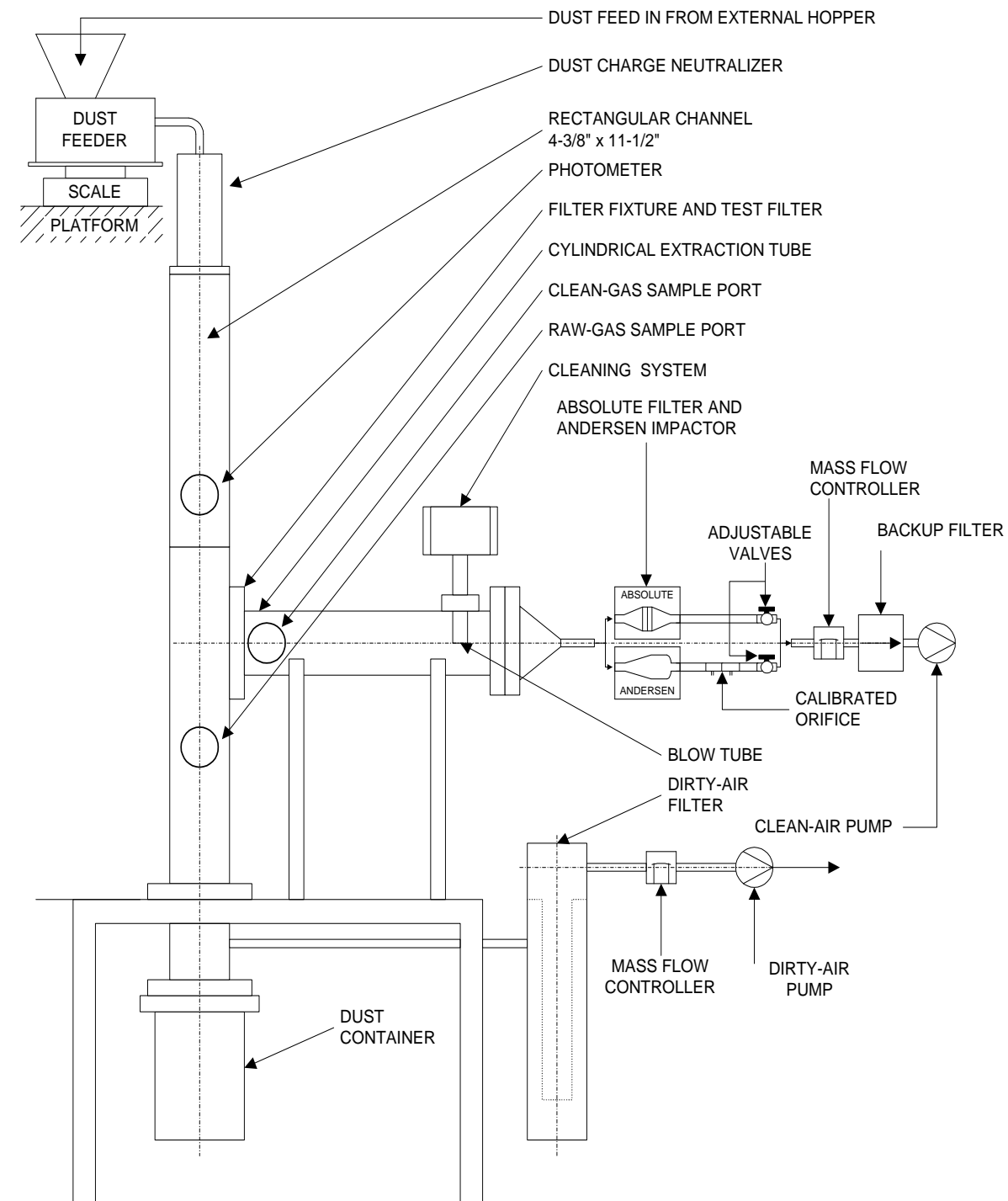


Figure A-1. Diagram of FEMA Test Apparatus

**Appendix B**

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**CERTIFICATES OF CALIBRATION**

# Measurement Controls, Inc.

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

Telephone (704) 875-2034  
Fax (704) 875-3480

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

**RE-CERTIFICATION OF CALIBRATION**

**ROCKWELL S-275 # 009548**

<u>FLOW RATE</u>	<u>VOLUME</u>	<u>Y</u>	<u>AVE. Y</u>
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

Customer: **KLAUS SCHAEFER GMBH**      Flow Transducer  
 Model: HFC-203  
 S/N: 123917

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			Flow Unit Correction Factors				Std. Conditions				
CDR#				Cal Due	Type	From	To	K	T	P	V		
648	DMM: CDR-	63	11/4/99	Gas	Air	AIR	1.0000	1.0000	0°C	760 mmHg	181.2 µp		
	Thermometer: CDR-	703	7/20/00	Units	SLPM	SLPM	1.0000	1.0000					
C0=	-0.0146919	Manometer: CDR-	772	5/16/00	Temp	0°C	0.0°C	1.0000					
C1=	32.124769	Barometer: CDR-	772	5/16/00	Other			1.0000					
C2=	-0.726126				Ktot=			1.0000					
C3=	0.04774077												
C4=	-0.0048432	CDR#	648	1/24/00									
C5=	0.00021761												

Reference Indication		Pres/Temp/Visc. Factor					Ref. Flow		Indicated Flow			Deviation	
Mano	Temp	Pres				Flow	Flow	Flow	Flow	Flow			
"H <sub>2</sub> O	°C	mmHg	Kt	Kp	Kv	Kpv	ALPM	SLPM	SLPM	Volts	SLPM	%FS	%PT
							Air	AIR	AIR	AIR			
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

Customer:	KLAUS SCHAEFER GMBH	Flow Transducer Model: HFC-203 S/N: 119148
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	T	P
CDR# 650 ;	DMM: CDR- 407	Gas	Air	AIR	1.0000	0°C	
	Thermometer: CDR- 509	Units	SLPM	SLPM	1.0000	760 mmHg	
C0= -0.0035382	Manometer: CDR- 714	Temp	0°C	0.0°C	1.0000	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	Temp	Pres	Kt	Kp	Kv	Ktpv	Flow	Flow	Flow	Flow	Flow	%FS	%PT	
"H <sub>2</sub> O	°C	mmHg					ALPM	SLPM	SLPM	Volts	SLPM			
							Air	AIR	AIR		AIR			
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: *ES*

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 # BUILDING**  
 Lab Main

**TODAY'S DATE**    **ITEM #**  
 9/20/99            2

**NEXT CALIBRATION DUE**  
 August 31, 2000

**MODEL**            **SERIAL NUMBER**  
 262SMA-FR        16157

**CAPACITY**        **READABILITY**  
 62g/205g         +/- .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	0.099998g	-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

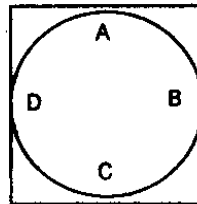
**COMMENTS**

New Unit Set Up -

**CUSTOMER REQUIREMENTS:**

**CORNER LOAD TEST**

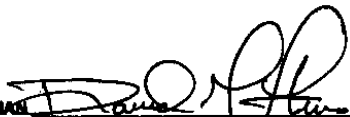
**CORNER LOAD TEST WT.**  
 10.000028g



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

**FRONT**

*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

<u>Material</u>	<u>Assumed Density at 20°C</u>	<u>Range</u>
Stainless Steel	7.85g/cm <sup>3</sup>	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/cm<sup>3</sup>.

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

<u>Material</u>	<u>Assumed Density at 20°C</u>	<u>Range</u>
Stainless Steel	7.85g/cm <sup>3</sup>	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/cm<sup>3</sup>.

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) 886-1600 • FAX (856) 886-1601

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

<u>Material</u>	<u>Assumed Density at 20°C</u>	<u>Range</u>
Stainless Steel	7.85g/cm <sup>3</sup>	1g

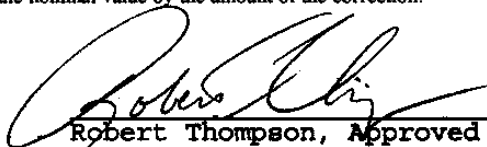
Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

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/cm<sup>3</sup>.

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 08066-0087 USA • PHONE (856) 686-1800 • FAX (856) 686-1801

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

<u>Material</u>	<u>Assumed Density at 20°C</u>	<u>Range</u>
Stainless Steel	7.85g/cm <sup>3</sup>	100 g

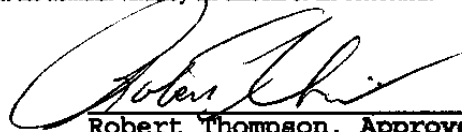
Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

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/cm<sup>3</sup>.

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

# 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

<u>Material</u>	<u>Assumed Density at 20°C</u>	<u>Range</u>
Aluminum	2.7 g/cm <sup>3</sup>	1 mg

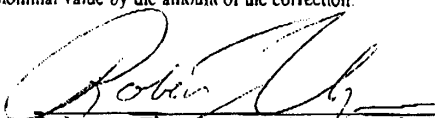
Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

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/cm<sup>3</sup>.

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

# 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

<u>Material</u>	<u>Assumed Density at 20°C</u>	<u>Range</u>
Stainless Steel	7.85g/cm <sup>3</sup>	50 g
Stainless Steel (mg)	7.95 g/cm <sup>3</sup>	300 mg

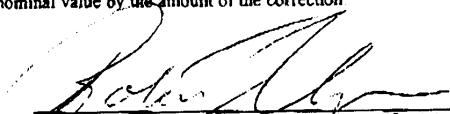
Tested with Reference Standards Traceable to the National Institute of Standards & Technology through NIST Test Number 822/254480.

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/cm<sup>3</sup>.

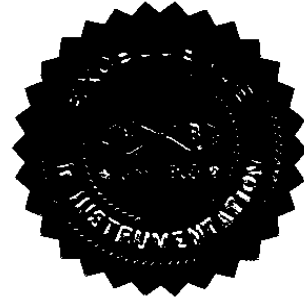
Nominal Mass Value	Serial Number	Correction *	Tolerance (+ or -)
50 g		+0.0580 mg	0.120 mg
300 mg		-0.0037 mg	0.010 mg

\* 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*  
Richard D. Livergood  
Calibration Specialist

*James R. Robinson*  
James R. Robinson  
Vice President, Calibration Services

**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



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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 Institute 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: J. David McGraw

TITLE: J. DAVID MCGRAW, VP

Reviewed By: \_\_\_\_\_

DATE: 12/7/99

---

**VERIFICATION TESTING SHEETS**

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS  
SUMMARY OF RESULTS

RUN ID.	V005-1	V005-2	V005-3	Average
FABRIC DESIGNATION	5512BRF-1	5512BRF-3	5512BRF-5	
MANUFACTURER	Inspec Fibres USA	Inspec Fibres USA	Inspec Fibres USA	
DUST FEED	Pural NF	Pural NF	Pural NF	
<u>DUST DATA</u>				
Mass Mean Diameter (µm)	1.36			1.36
% Less than PM 2.5	68.99			68.99
<u>CONDITIONING PERIOD</u>				
Date Started	3/31/00	4/3/00	4/4/00	
Time Started	10:47	13:46	14:09	
Time Ended	19:07	22:06	22:29	
Test Duration (min.)	500	500	500	500
<u>RECOVERY PERIOD</u>				
Date Started	4/3/00	4/4/00	4/5/00	
Time Started	7:05	7:21	7:12	
Time Ended	7:10	7:24	7:15	
Test Duration (min.)	5	3	3	4
<u>PERFORMANCE TEST PERIOD</u>				
Date Started	4/3/00	4/4/00	4/5/00	
Time Started	7:30	7:40	7:55	
Time Ended	13:30	13:40	13:55	
Test Duration (min.)	360	360	360	360
<u>VERIFICATION TEST RESULTS</u>				
Mean Outlet Particle Conc. PM 2.5 (g/dscm)	0.00057	0.00030	0.00028	0.00038
Mean Outlet Particle Conc. Total mass (g/dscm)	0.00060	0.00036	0.00030	0.00042
Increase in Residual Pressure Drop (cm w.g.)	5.03	5.14	5.13	5.10
Average Residual Pressure Drop (cm w.g.)	11.27	12.38	11.63	11.76
Mass Gain of Filter Sample (g)	1.59	1.39	1.43	1.47
Average Filtration Cycle Time (s)	6	6	6	6

R1/E1V PRELIMINARY TESTING  
 DUST CHARACTERIZATION - PURAL NF  
 ANDERSEN IMPACTOR PARTICLE SIZING  
 GRAVIMETRIC ANALYTICAL DATA AND RESULTS

RUN NUMBER: V005  
 TEST DATE: 03/30/00

Sample I.D.	Wash Vol.(ml)	Stage	Initial Filter Mass (g)	Initial Beaker Mass (g)	Total Initial Mass (g)	Total Final Mass (g)	Mass Difference (g)	Negative Difference? (g)
VDI-00-16	50	Acetone Wash**	NA	0	0	0	0.00000	NA
00-16-1		1	1.37729	0	1.37729	1.37842	0.00113	NA
00-16-2		2	1.46203	0	1.46203	1.46254	0.00051	NA
00-16-3		3	1.56375	0	1.56375	1.56571	0.00196	NA
00-16-4		4	1.53885	0	1.53885	1.54418	0.00533	NA
00-16-5		5	1.52107	0	1.52107	1.53082	0.00975	NA
00-16-6		6	1.52476	0	1.52476	1.53804	0.01328	NA
00-16-7		7	1.48916	0	1.48916	1.50099	0.01183	NA
00-16-8		8	1.59118	0	1.59118	1.59716	0.00598	NA
00-16-9		9	1.54975	0	1.54975	1.55844	0.00869	NA
Total							0.05846	

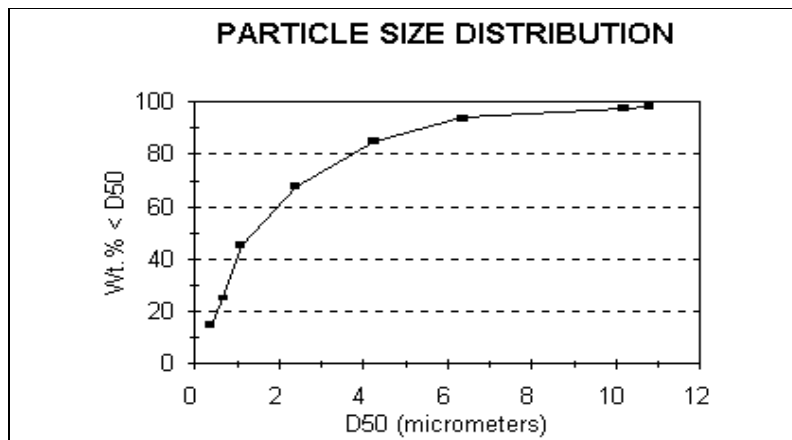
IMPACTOR PARTICLE SIZING RESULTS

Impactor Flow Rate: 0.184 cfm  
 Isokinetics: 106.20 %  
 Viscosity of Gas: 0.000163 poise

STAGE	Particulate Mass (g)	Cummulative % Less Than Diameter	D50 Cut Point (micrometers)*
1	0.00113	98.07	10.80
2	0.00051	97.19	10.18
3	0.00196	93.84	6.36
4	0.00533	84.72	4.25
5	0.00975	68.05	2.39
6	0.01328	45.33	1.09
7	0.01183	25.09	0.67
8	0.00598	14.86	0.37
9	0.00869		

Mass Mean Diameter, micrometers 1.36  
 % Less Than PM 2.5 68.99

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



C-4

**DUST CHARACTERIZATION  
FOR TEST SERIES:**

**V005**

**DATE** 03/30/00  
**START TIME** 10:19  
**END TIME** 10:24  
**STACK LENGTH** 111 mm  
**STACK WIDTH** 291 mm  
**STACK AREA** 0.0323 m<sup>2</sup>  
**NOZZLE I.D.** 1.797 in.  
                   0.046 m  
**METER BOX GAMMA** 0.9927  
**BAROMETRIC PRESSURE** 28.78 in. Hg  
**TEST DURATION** 5 min.  
**METER VACUUM** 2.0 in. Hg

**DATA (FOR RAW GAS CHANNEL)**

**Actual Flow** 5.81 m<sup>3</sup>/hr  
                   3.42 cfm  
**Std. Flow** 5.48 scm/hr  
                   3.22 scfm  
**Raw Gas Pressure** 967.96 mbar  
**Sample Gas Temperature** 23.6 ° C  
                                   74.5 ° F

**INTERMEDIATE RESULTS**

**Metered Volume** 0.919 ft<sup>3</sup>  
**Volume @ Std. Cond.** 0.868 scf  
**Volume at Raw Gas Conditions** 0.919 scf  
**Water** 1.14 %  
**Isokinetics** 106.2 %

**METHOD 3 DATA**

**%O<sub>2</sub>** 20.9 **Md** 28.84  
**%CO<sub>2</sub>** 0.0 **Ms** 28.71  
**%CO** 0.0 **Ps** 28.58 in. Hg  
**%N<sub>2</sub>** 79.1  
**O<sub>2</sub>+CO<sub>2</sub>** 20.9

POINT	STACK	DP (in. w.g.)	DH (in. w.g.)	METER	METER TEMPERATURE	
	TEMP (° F)			VOLUME (liters)	INLET (° F)	OUTLET (° F)
1	74.5	1E-05	6.125	5252.86	73	72
				5278.87	78	72
			Volume Change:	26.01	(Avg. of 4 <sup>74</sup> Temps.)	

**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.	V005-1	NUMBER OF PULSES	10000
FABRIC DESIGNATION	5512BRF-1	PULSE INTERVAL	3 s
MANUFACTURER	Inspec Fibres USA		
DUST FEED	Pural NF	% Moisture	0.98 %WV
DATE(S)	3/31/00		
TIME STARTED	10:47		
TIME ENDED	19:07		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total					
0-60	10:47	11:47	1833.5	1733.0	100.5	2.80	2.68	5.48	24.81	972.98	18.5	184.1
61-120	11:48	12:47	1733.0	1607.7	125.3	2.82	2.67	5.49	25.73	972.55	23.0	184.5
121-180	12:48	13:47	1607.7	1484.3	123.4	2.82	2.67	5.49	26.12	971.90	22.7	184.7
181-240	13:48	14:47	1484.3	1355.1	129.2	2.82	2.61	5.43	25.88	970.83	24.0	180.4
241-300	14:48	15:47	1355.1	1282.9	72.2	2.80	2.65	5.45	26.13	970.11	13.4	183.4
301-360	15:48	16:47	1282.9	1174.5	108.4	2.80	2.68	5.48	26.36	969.90	20.0	186.0
361-420	16:48	17:47	1174.5	1061.6	112.9	2.80	2.69	5.49	26.15	970.17	20.8	186.3
421-480	17:48	18:47	1061.6	949.9	111.7	2.80	2.69	5.49	25.61	971.12	20.5	186.0
441-500 *	18:08	19:07	1021.2	914.4	106.9	2.80	2.69	5.49	25.41	971.45	19.7	185.9
AVERAGE (per hour)					110.3	2.81	2.67	5.48	25.82	971.22	20.3	184.5

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.	V005-1	NUMBER OF PULSES	30
FABRIC DESIGNATION	5512BRF-1	AVG. PULSE INTERVAL	9 s
MANUFACTURER	Inspec Fibres USA	AVG . RESIDUAL DP	793.37 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE(S)	4/3/00		
TIME STARTED	7:05 *	% Moisture	1.27 %WV
TIME ENDED	7:10		
TEST DURATION	5 min.		

QA/QC DATA

Test Time (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
		Initial	Final	Total	Raw	Clean	Total				
1-5	7:06 * 7:10	961.1	957.1	4.0	2.81	2.70	5.51	22.9	968.31	0.7	185.5
AVERAGE (per hour)				53.3	2.58	2.69	5.27	22.8	968.47	10.3	184.8

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.	V005-1	NUMBER OF PULSES	3557
FABRIC DESIGNATION	5512BRF-1	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Inspec Fibres USA	AVG. RESIDUAL DP	1104.13 Pa
DUST FEED	Pural NF	CHANGE IN DP	492.3 Pa
DATE(S)	4/3/00	MAX. PRESSURE DROP	1000 Pa
TIME STARTED	7:30		
TIME ENDED	13:30	% MOISTURE	1.27 % WV
TEST DURATION	360 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)				Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total	Sampling					
0-60	7:30	8:30	1656.9	1562.1	94.8	2.81	2.69	5.51	1.06	23.06	967.77	17.4	185.1
61-120	8:31	9:30	1562.1	1461.7	100.5	2.83	2.69	5.52	1.08	23.37	966.80	18.4	185.4
121-180	9:31	10:30	1461.7	1367.4	94.2	2.83	2.69	5.52	1.07	23.76	967.74	17.3	185.4
181-240	10:31	11:30	1367.4	1267.4	100.0	2.83	2.69	5.52	1.05	24.10	967.67	18.4	185.6
241-300	11:31	12:30	1267.4	1166.7	100.7	2.83	2.69	5.52	1.06	24.61	967.46	18.5	186.0
301-360	12:31	13:30	1166.7	1059.6	107.1	2.83	2.69	5.52	1.07	24.96	965.92	19.7	186.6
AVERAGE (per hour)					99.5	2.82	2.69	5.52	1.07	23.98	967.23	18.3	185.7

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)	0.00362 g	Tare Mass	11.50 g
Total Mass Gain	0.00378 g	Final Mass	13.09 g
		Mass Gain	1.59 g

OUTLET CONCENTRATION

Total Volume Sampled	6.90 m <sup>3</sup>
Mean Outlet Particle Concentration - PM 2.5	0.00052 g/m <sup>3</sup>
Mean Outlet Particle Concentration - Total Mass	0.00055 g/m <sup>3</sup>

DATA PROCESSING OPERATOR:

Sharon M. Winemiller - ETS, Inc.

C-8

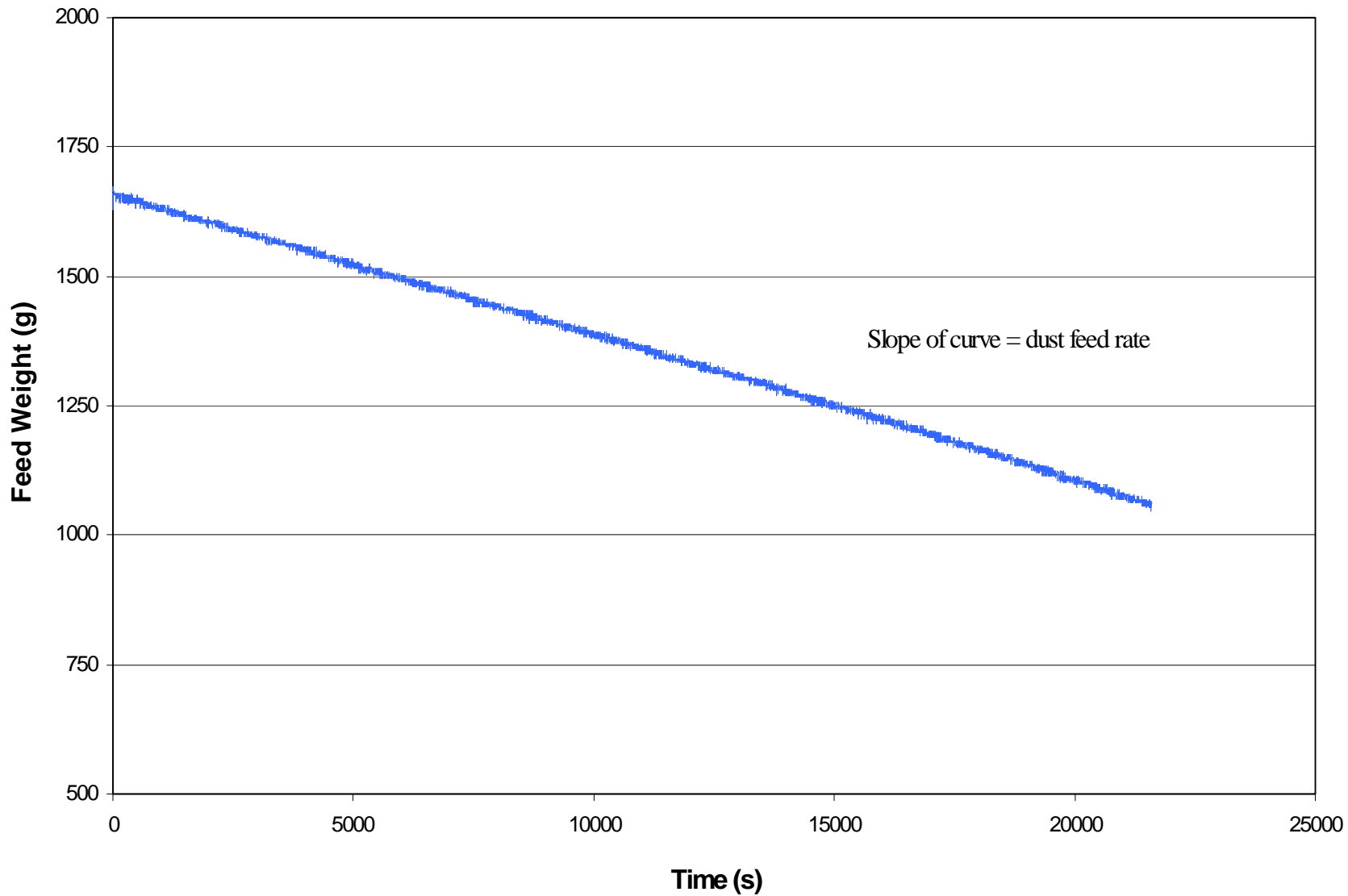


Figure C-1. Change in Pural NF dust scale reading with time during performance test run V005-1.

C-6

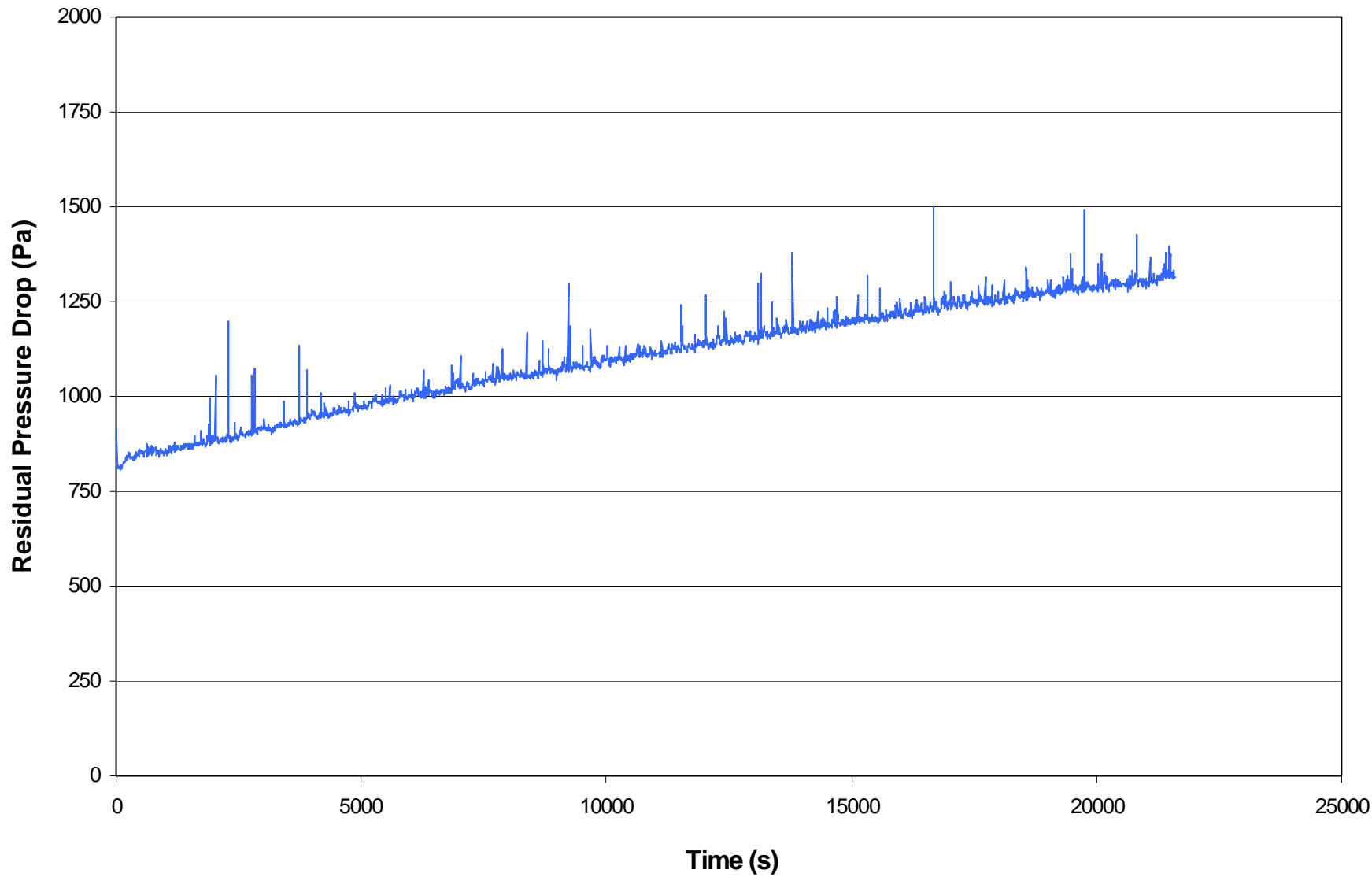


Figure C-2. Residual pressure drop across filter fabric during performance test run V005-1.

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

CONDITIONING TEST PERIOD

RUN ID.	V005-2	NUMBER OF PULSES	10000
FABRIC DESIGNATION	5512BRF-3	PULSE INTERVAL	3 s
MANUFACTURER	Inspec Fibres USA		
DUST FEED	Pural NF	% MOISTURE	1.44 %WV
DATE(S)	4/3/00		
TIME STARTED	13:46		
TIME ENDED	22:06		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total					
0-60	13:46	14:46	1611.5	1510.8	100.8	2.78	2.67	5.45	25.10	964.81	18.8	185.1
61-120	14:47	15:46	1510.8	1396.5	114.2	2.79	2.67	5.46	25.67	964.24	21.2	185.8
121-180	15:47	16:46	1396.5	1273.5	123.0	2.79	2.67	5.46	26.00	963.60	22.9	186.2
181-240	16:47	17:46	1273.5	1137.3	136.2	2.79	2.67	5.46	26.04	963.14	25.3	186.3
241-300	17:47	18:46	1137.3	1008.2	129.1	2.79	2.67	5.46	25.90	962.13	24.0	186.4
301-360	18:47	19:46	1008.2	875.4	132.8	2.79	2.67	5.46	25.48	961.60	24.7	186.2
361-420	19:47	20:46	875.4	801.0	74.4	2.79	2.67	5.46	25.10	960.85	13.8	186.1
421-480	20:47	21:46	801.0	678.4	122.6	2.79	2.67	5.46	24.78	960.20	22.8	186.1
441-500 *	21:07	22:06	753.8	646.0	107.8	2.79	2.67	5.46	24.69	959.92	20.0	186.0
AVERAGE (per hour)					115.9	2.79	2.67	5.46	25.48	962.45	21.5	186.0

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.	V005-2	NUMBER OF PULSES	30
FABRIC DESIGNATION	5512BRF-3	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Inspec Fibres USA	AVG . RESIDUAL DP	913.10 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE(S)	4/4/00		
TIME STARTED	7:21 *	% MOISTURE	1.50 %WV
TIME ENDED	7:24		
TEST DURATION	3 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
		Initial	Final	Total	Raw	Clean	Total				
1-3	7:22 * 7:24	785.7	780.7	5.0	2.76	2.66	5.43	22.9	955.90	0.9	185.2
AVERAGE (per hour)				98.4	2.36	2.65	5.01	22.9	956.13	19.9	184.5

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.	V005-2	NUMBER OF PULSES	3599
FABRIC DESIGNATION	5512BRF-3	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Inspec Fibres USA	AVG. RESIDUAL DP	1212.77 Pa
DUST FEED	Pural NF	CHANGE IN DP	503.9 Pa
DATE(S)	4/4/00	MAX. PRESSURE DROP	1000 Pa
TIME STARTED	7:40		
TIME ENDED	13:40	% MOISTURE	1.50 %WV
TEST DURATION	360 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)				Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total	Sampling					
0-60	7:40	8:40	1569.7	1487.1	82.6	2.78	2.63	5.41	1.03	23.16	956.61	15.5	182.9
61-120	8:41	9:40	1487.1	1392.0	95.1	2.79	2.63	5.42	1.06	23.43	956.89	17.8	183.0
121-180	9:41	10:40	1392.0	1298.0	94.0	2.79	2.63	5.42	1.04	23.74	957.63	17.6	183.0
181-240	10:41	11:40	1298.0	1201.4	96.5	2.79	2.63	5.42	1.06	24.11	958.24	18.1	183.0
241-300	11:41	12:40	1201.4	1099.1	102.3	2.79	2.63	5.42	1.06	24.31	958.31	19.2	183.1
301-360	12:41	13:40	1099.1	1002.9	96.2	2.79	2.63	5.42	1.06	24.46	958.48	18.0	183.1
AVERAGE (per hour)					94.5	2.79	2.63	5.42	1.05	23.87	957.69	17.7	183.0

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)	0.00182 g	Tare Mass	11.79 g
Total Mass Gain	0.00227 g	Final Mass	13.18 g
		Mass Gain	1.39 g

OUTLET CONCENTRATION

Total Volume Sampled	6.85 m <sup>3</sup>
Mean Outlet Particle Concentration - PM 2.5	0.00027 g/m <sup>3</sup>
Mean Outlet Particle Concentration - Total Mass	0.00033 g/m <sup>3</sup>

DATA PROCESSING OPERATOR:

Sharon M. Winemiller - ETS, Inc.

C-13

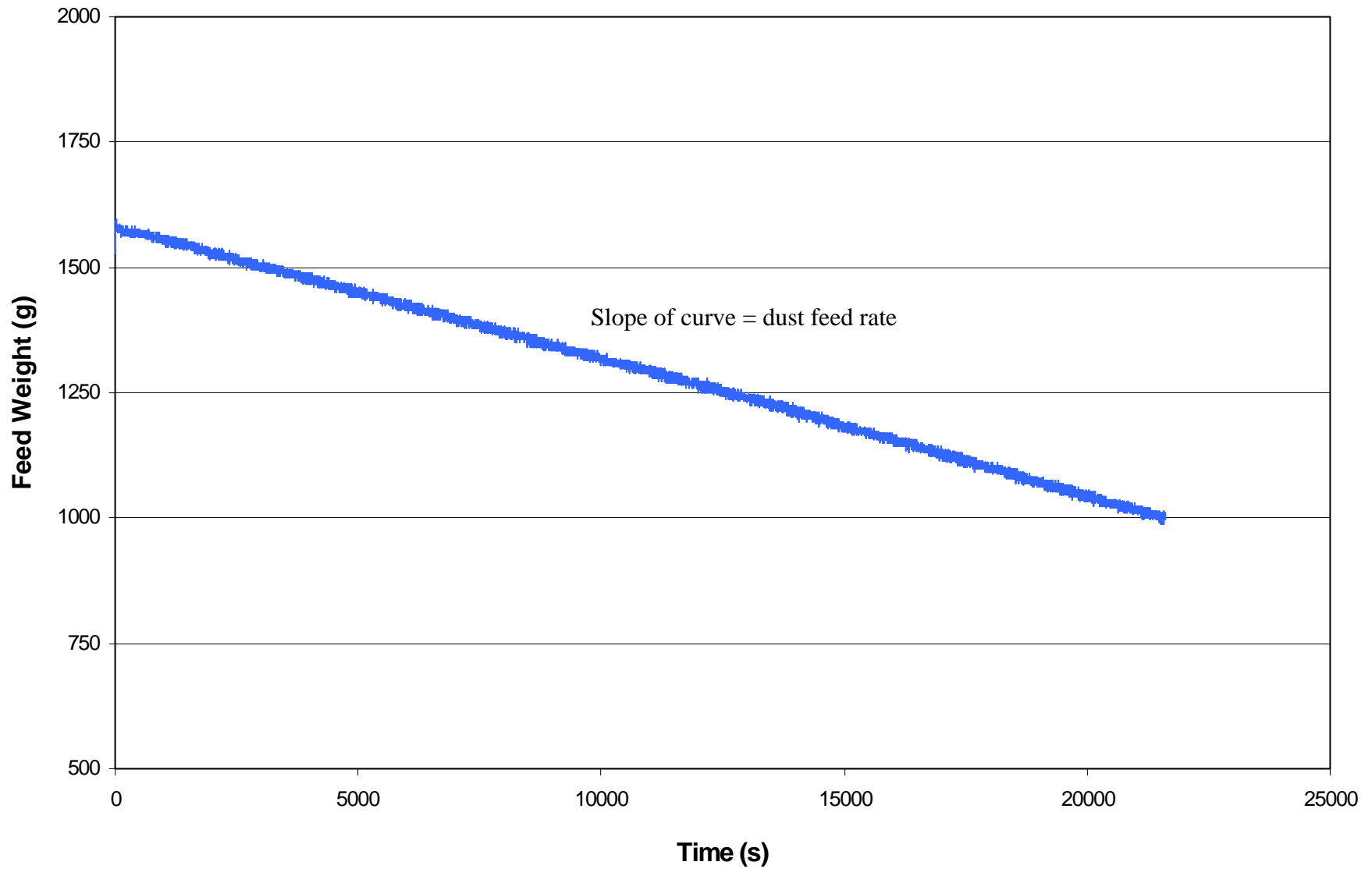


Figure C-3. Change in Pural NF dust scale reading with time during performance test run V005-2.

C-14

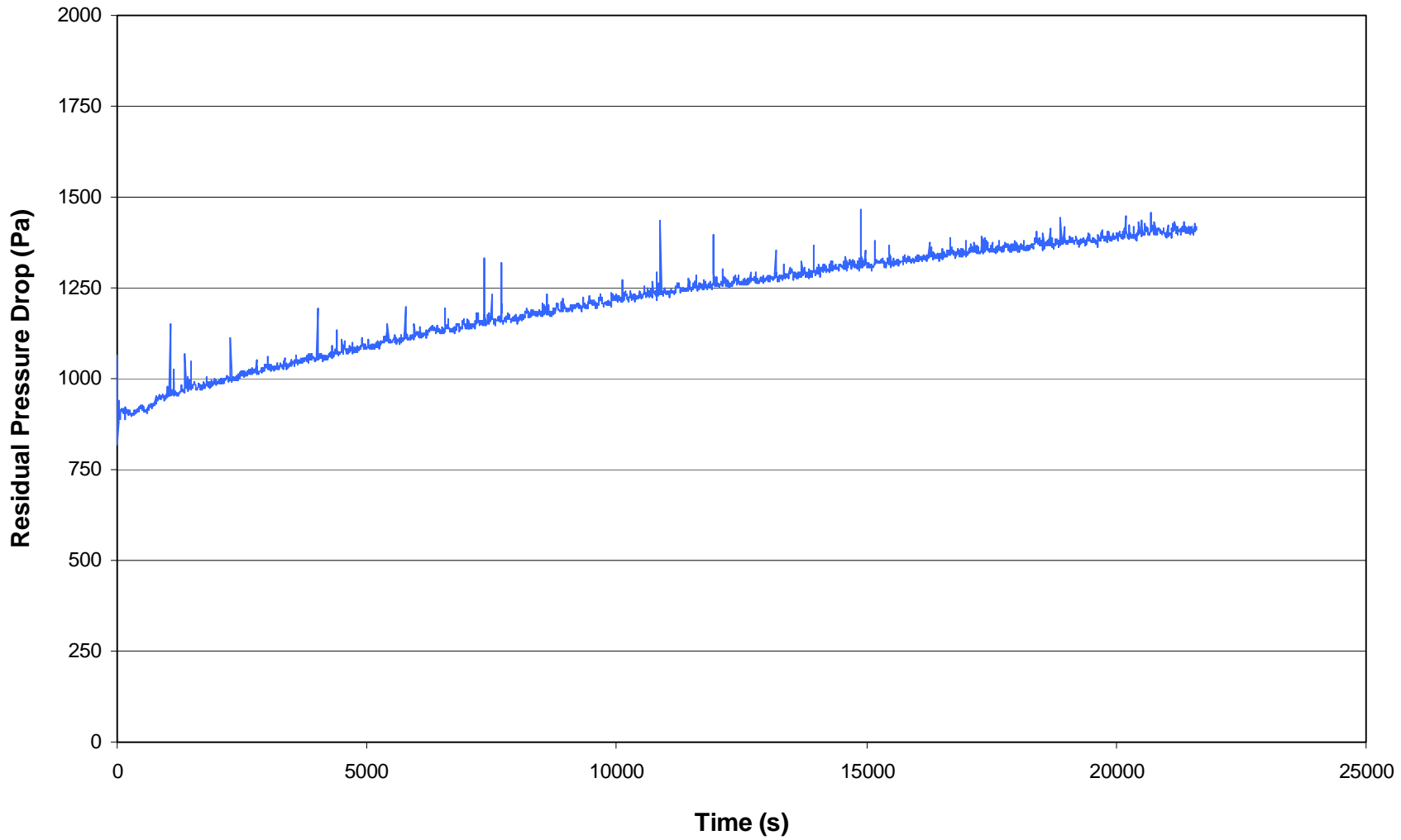


Figure C-4. Residual pressure drop across filter fabric during performance test run V005-2.



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

CONDITIONING TEST PERIOD

RUN ID.	V005-3	NUMBER OF PULSES	10000
FABRIC DESIGNATION	5512BRF-5	PULSE INTERVAL	3 s
MANUFACTURER	Inspec Fibres USA		
DUST FEED	Pural NF	% MOISTURE	1.49 %WV
DATE(S)	4/4/00		
TIME STARTED	14:09		
TIME ENDED	22:29		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total					
0-60	14:09	15:09	1595.1	1492.0	103.0	2.78	2.65	5.43	24.29	958.97	19.3	184.4
61-120	15:10	16:09	1492.0	1383.7	108.4	2.79	2.65	5.44	24.24	958.91	20.2	184.7
121-180	16:10	17:09	1383.7	1273.9	109.8	2.79	2.65	5.44	24.40	958.86	20.5	184.8
181-240	17:10	18:09	1273.9	1158.8	115.1	2.79	2.65	5.44	24.50	959.67	21.5	184.8
241-300	18:10	19:09	1158.8	1089.2	69.6	2.79	2.65	5.45	24.21	961.08	13.0	184.4
301-360	19:10	20:09	1089.2	979.2	110.0	2.79	2.66	5.45	23.91	962.41	20.5	184.1
361-420	20:10	21:09	979.2	875.3	104.0	2.79	2.66	5.45	23.52	963.52	19.4	183.7
421-480	21:10	22:09	875.3	774.6	100.7	2.79	2.66	5.45	23.36	964.32	18.7	183.5
441-500 *	21:30	22:29	840.8	737.0	103.8	2.79	2.66	5.45	23.32	964.51	19.3	183.4
AVERAGE (per hour)					103.0	2.79	2.65	5.44	24.02	961.11	19.2	184.2

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.	V005-3	NUMBER OF PULSES	30
FABRIC DESIGNATION	5512BRF-5	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Inspec Fibres USA	AVG . RESIDUAL DP	861.53 Pa
DUST FEED	Pural NF	MAX. PRESSURE DROP	1000 Pa
DATE(S)	4/5/00		
TIME STARTED	7:12 *	% MOISTURE	0.96 %WV
TIME ENDED	7:15		
TEST DURATION	3 min.		

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)			Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)	
		Initial	Final	Total	Raw	Clean	Total					
1-3	7:13 *	7:15	891.0	889.7	1.3	2.77	2.66	5.43	21.9	967.78	0.2	181.8
AVERAGE (per hour)					25.5	2.76	2.66	5.43	21.9	967.57	4.7	182.5

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.	V005-3	NUMBER OF PULSES	3556
FABRIC DESIGNATION	5512BRF-5	AVG. PULSE INTERVAL	6 s
MANUFACTURER	Inspec Fibres USA	AVG. RESIDUAL DP	1138.86 Pa
DUST FEED	Pural NF	CHANGE IN DP	502.9 Pa
DATE(S)	4/5/00	MAX. PRESSURE DROP	1000 Pa
TIME STARTED	7:55		
TIME ENDED	13:55	% MOISTURE	0.96 %WV
TEST DURATION	360 min.		

QA/QC DATA

Test Duration (min.)	Time	Time	Dust Feed (g)			Average Gas Flow (sm <sup>3</sup> /hr)				Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
			Initial	Final	Total	Raw	Clean	Total	Sampling				
0-60	7:55	8:55	1404.3	1350.7	53.6	2.81	2.62	5.43	1.03	22.24	968.20	10.0	179.6
61-120	8:56	9:55	1350.7	1269.5	81.2	2.82	2.66	5.48	1.05	22.73	968.30	15.0	182.8
121-180	9:56	10:55	1269.5	1174.1	95.3	2.82	2.66	5.48	1.05	23.22	968.43	17.6	182.9
181-240	10:56	11:55	1174.1	1077.3	96.8	2.82	2.66	5.48	1.06	23.71	968.52	17.8	183.1
241-300	11:56	12:55	1077.3	976.2	101.1	2.82	2.66	5.48	1.07	24.11	967.88	18.6	183.5
301-360	12:56	13:55	976.2	870.5	105.7	2.82	2.66	5.48	1.06	24.51	967.55	19.5	183.8
AVERAGE (per hour)					89.0	2.82	2.65	5.47	1.05	23.42	968.14	16.4	182.6

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)	0.00176 g	Tare Mass	12.12 g
Total Mass Gain	0.00192 g	Final Mass	13.55 g
		Mass Gain	1.43 g

OUTLET CONCENTRATION

Total Volume Sampled	6.76 m <sup>3</sup>
Mean Outlet Particle Concentration - PM 2.5	0.00026 g/m <sup>3</sup>
Mean Outlet Particle Concentration - Total Mass	0.00028 g/m <sup>3</sup>

DATA PROCESSING OPERATOR:

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C-18

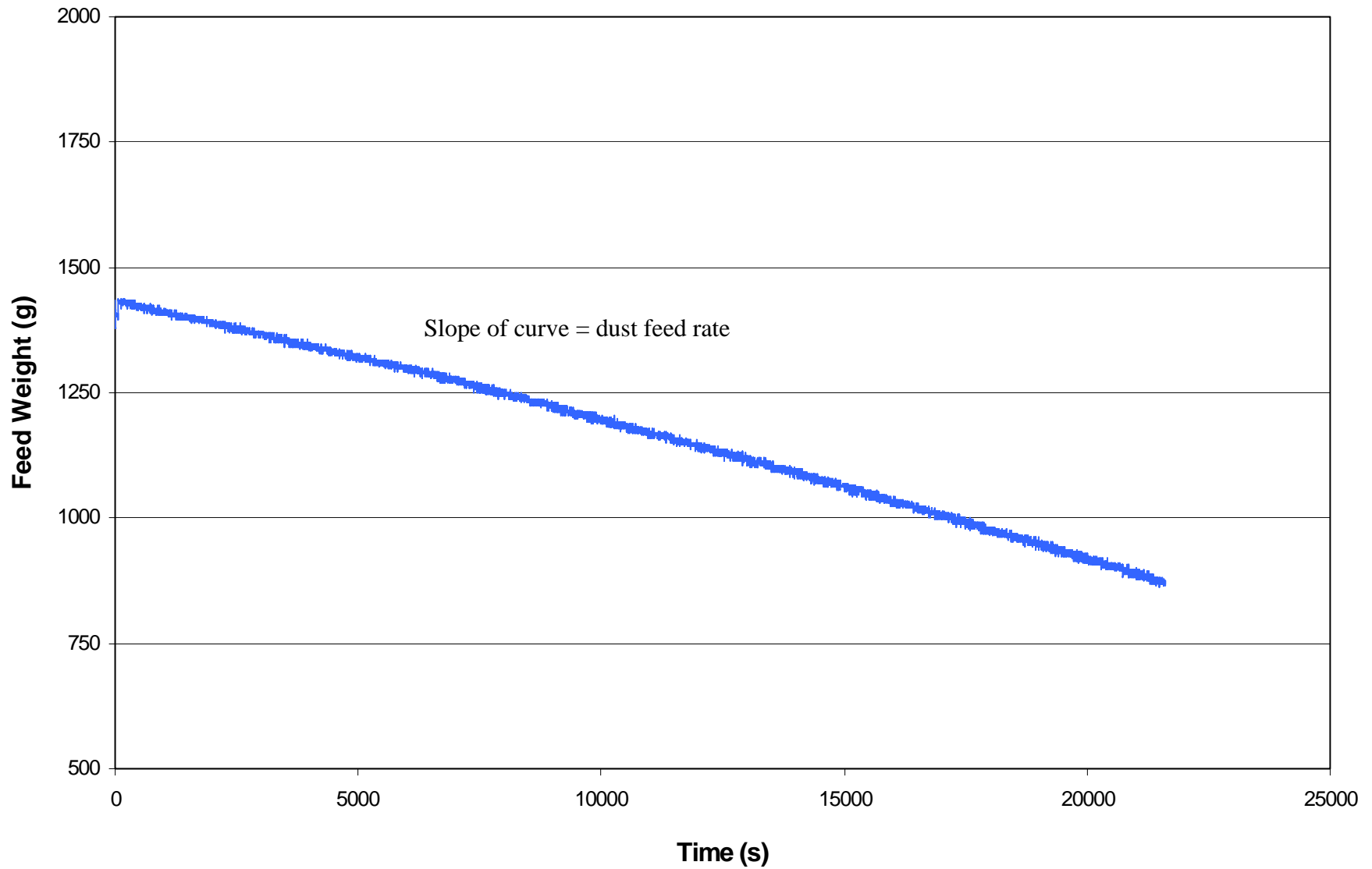


Figure C-5. Change in Pural NF dust scale reading with time during performance test run V005-3.

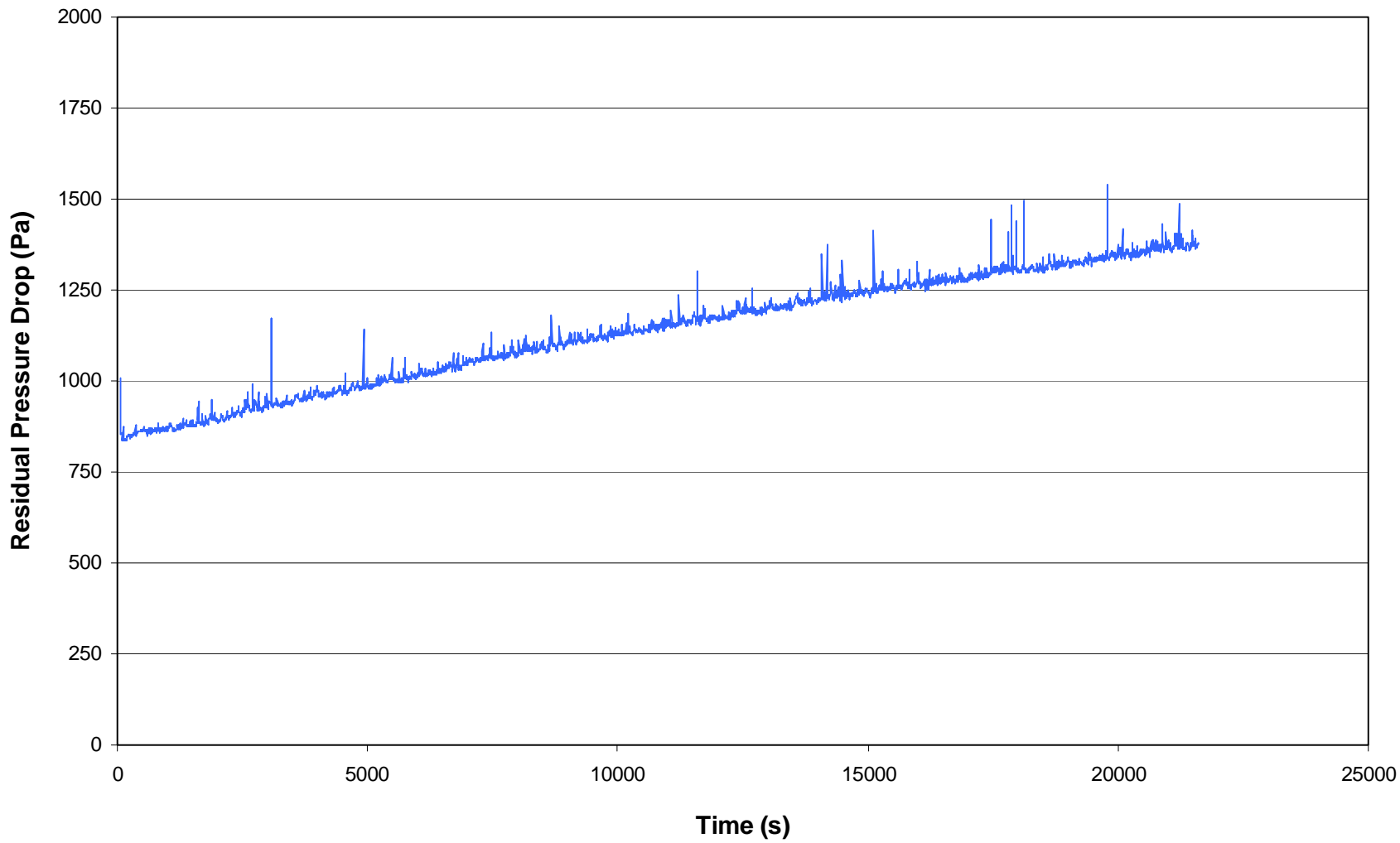


Figure C-6. Residual pressure drop across filter fabric during performance test run V005-3.