

**Filtration Performance Screening using
ASTM/ETV Test Methodology
Conducted for
Process Systems & Components, Inc.**



ETS, INC.

***Pollution Control Consultants Specializing
In Testing, Training, Troubleshooting and
Testimony***

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ETS CONTRACT NUMBER 05-250-L

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CLIENT: Process System

SITE: N/A

CLIENT P.O. NO: CH#14245

FABRIC TYPE: Felt

CLIENT CONTACT: John Wroblewski

BAGHOUSE TYPE: Pulse Jet

ETS CONTRACT NO: 05-250-L

PROGRAM: Filtration Performance Screening

DATE: December 19, 2005

APPLICATION: N/A

1.0 INTRODUCTION

ETS, Inc. was retained by Process Systems & Components, Inc. to conduct screening tests on one sample of felt fabric.

2.0 TEST PROGRAM

The testing was conducted in the ETS Filtration Performance Test Apparatus to determine the filter sample's performance with respect to the following parameters:

- ◆ Outlet particulate emissions (PM 2.5)
- ◆ Outlet particulate emissions (total mass)
- ◆ Initial residual pressure drop
- ◆ Increase in residual pressure drop
- ◆ Average residual pressure drop
- ◆ Mass weight gain of the filter sample
- ◆ Average filtration cycle time
- ◆ Number of filtration cycles

3.0 TEST PROCEDURE:

Testing was conducted in accordance with ASTM Test Method D6830-02 and with the test specifications and conditions as detailed in the Generic Verification Protocol for Baghouse Filtration Products (BFP) developed by the Air Pollution Control Technology Verification Center (APCTVC) which is part of the U.S. EPA's Environmental Technology Verification (ETV) Program and is operated in partnership between RTI and EPA. The protocol was adapted from the German VDI Method 3926, and modified for ETV and is available at etv.rti.org/apct/pdf/GVP_Revised.pdf. There was one exception to the protocol specification:

- ◆ The test program consisted of one run rather than three runs as specified in the protocol.

4.0 TEST APPARATUS AND TEST DESCRIPTION:

The test apparatus is shown in Figure 1. The test run consisted of three test phases. To simulate long term operation, the filter sample was first subjected to a conditioning period which consisted of 10,000 rapid pulse cleaning cycles under continuous dust loading. During this period, the time between cleaning cycles is maintained at three seconds. No filter performance parameters are measured during the conditioning period. The conditioning period was immediately followed by a recovery period, which allows the filter sample to recover from the rapid pulsing. The recovery period consisted of 30 normal filtration cycles under continuous 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 inch w.g.) is reached. At this point, the test filter is cleaned by a pulse of compressed air. Immediately after pulse cleaning the pressure fluctuates rapidly inside the test duct. Some of the released dust immediately re-deposits on the test filter. The pressure then stabilizes and returns to normal. Thus, the residual pressure drop across the filter is measured three seconds after conclusion of the cleaning pulse. It is monitored and recorded continuously throughout the recovery and

performance test period. The performance test period immediately followed the recovery period for a cumulative total of 10,030 cycles after the test filter was installed in the test apparatus. The performance test period is six hours in duration and during this phase normal filtration cycles and constant dust loading are maintained and recorded. Outlet mass and PM 2.5 dust concentrations are measured using an inertial impactor located downstream of the test filter. The weight gain of each impactor stage substrate is measured to within 0.00001 grams. Test conditions throughout the test were as follows:

- ◆ Test dust: Pural NF Alumina (1.5 ± 1.0 micron mass mean diameter)
- ◆ Inlet dust feed rate: 100 ± 20 grams/hr. ($18.4 \pm$ grams/scm)
- ◆ Filtration Velocity: 120 ± 6 m/hr.
- ◆ Gas Temperature: $25^{\circ} \text{C} \pm 2^{\circ} \text{C}$
- ◆ Pulse Cleaning Pressure: 75 psi

5.0 TEST RESULTS:

The following table summarizes the results measured during the performance test phase of the test runs. Detailed information for the conditioning, recovery and performance test phases is provided in Tables I and II and Appendix A.

PARAMETER	FABRIC #1
PM2.5 Emissions (g/dscm)	0.0000155
Total Mass Emissions (g/dscm)	0.0000155
Initial Residual Pressure Drop (cm w.g.)	2.84
Residual Pressure Drop Increase (cm w.g.)	0.84
Average Residual Pressure Drop (cm w.g.)	3.05
Filter Sample Weight Gain (grams)	0.10
Average Filtration Cycle Time (seconds)	271
Number of Filtration Cycles (or Pulses)	79

TABLE I

SUMMARY OF TEST RESULTS (METRIC UNITS)

TESTING OF BAGHOUSE FILTRATION PRODUCTS

PROCESS SYSTEMS & COMPONENTS SUMMARY OF RESULTS AT 2 M/MIN

ETS CONTRACT NUMBER: 05-250

DATE: 12/16/2005

RUN ID.	250-R1
FABRIC DESIGNATION	250-1
MANUFACTURER	Process Systems & Components
DUST FEED	Pural NF
<u>CONDITIONING PERIOD</u>	
Date Started	12/7/2005
Time Started	11:02
Time Ended	19:22
Test Duration (min.)	500
<u>RECOVERY PERIOD</u>	
Date Started	12/8/2005
Time Started	7:01
Time Ended	9:06
Test Duration (min.)	125
<u>PERFORMANCE TEST PERIOD</u>	
Date Started	12/9/2005
Time Started	7:55
Time Ended	13:55
Test Duration (min.)	360
<u>VERIFICATION TEST RESULTS</u>	
Mean Outlet Particle Conc. PM 2.5 (g/dscm)	0.0000155
Mean Outlet Particle Conc. Total mass (g/dscm)	0.0000155
Initial Residual Pressure Drop (cm w.g.)	2.84
Change in Residual Pressure Drop (cm w.g.)	0.84
Average Residual Pressure Drop (cm w.g.)	3.05
Mass Gain of Filter Sample (g)	0.10
Average Filtration Cycle Time (s)	271
Number of Pulses	79
<u>REMOVAL EFFICIENCY (%)</u>	
Dust Conc (g/dscm)	18.00
PM 2.5 *	99.99989
Total Mass **	99.99991

* $(\text{Dust Concentration} * 0.7735) - \text{PM 2.5 Outlet Concentration} * 100$
Dust Concentration * 0.7735

** $\text{Dust Concentration} - \text{Total Mass Outlet Concentration} * 100$
Dust Concentration

TABLE II

SUMMARY OF TEST RESULTS (ENGLISH UNITS)

TESTING OF BAGHOUSE FILTRATION PRODUCTS
 PROCESS SYSTEMS & COMPONENTS SUMMARY OF RESULTS AT 2 M/MIN
 ETS CONTRACT NUMBER: 05-250 DATE: 12/16/2005

RUN ID.	250-R1
FABRIC DESIGNATION	250-1
MANUFACTURER	Process Systems & Components
DUST FEED	Pural NF

CONDITIONING PERIOD

Date Started	12/7/2005
Time Started	11:02
Time Ended	19:22
Test Duration (min.)	500

RECOVERY PERIOD

Date Started	12/8/2005
Time Started	7:01
Time Ended	9:06
Test Duration (min.)	125

PERFORMANCE TEST PERIOD

Date Started	12/9/2005
Time Started	7:55
Time Ended	13:55
Test Duration (min.)	360

VERIFICATION TEST RESULTS

Mean Outlet Particle Conc. PM 2.5 (gr/dscf)	0.0000068
Mean Outlet Particle Conc. Total mass (gr/dscf)	0.0000068
Initial Residual Pressure Drop (in. w.g.)	1.12
Change in Residual Pressure Drop (in. w.g.)	0.33
Average Residual Pressure Drop (in. w.g.)	1.20
Mass Gain of Filter Sample (g)	0.10
Average Filtration Cycle Time (s)	271
Number of Pulses	79

RESIDUAL PRESSURE DROP

At Start of:	
Conditioning Period (in. w.g.)	0.46
Recovery Period (in. w.g.)	1.33
Performance Test Period (in. w.g.)	1.12

REMOVAL EFFICIENCY (%)

Dust Conc (gr/dscf)	7.87
PM 2.5 *	99.99989
Total Mass **	99.99991

* $(\text{Dust Concentration} * 0.7735) - \text{PM 2.5 Outlet Concentration} * 100$
 Dust Concentration * 0.7735

** $\text{Dust Concentration} - \text{Total Mass Outlet Concentration} * 100$
 Dust Concentration

Tests Performed By:

Terry G. Williamson
Manager/Fabric Filtration Services

Reviewed By:

A handwritten signature in black ink, appearing to read "J. McKenna", written over a horizontal line.

John D. McKenna, Ph.D.
Principal

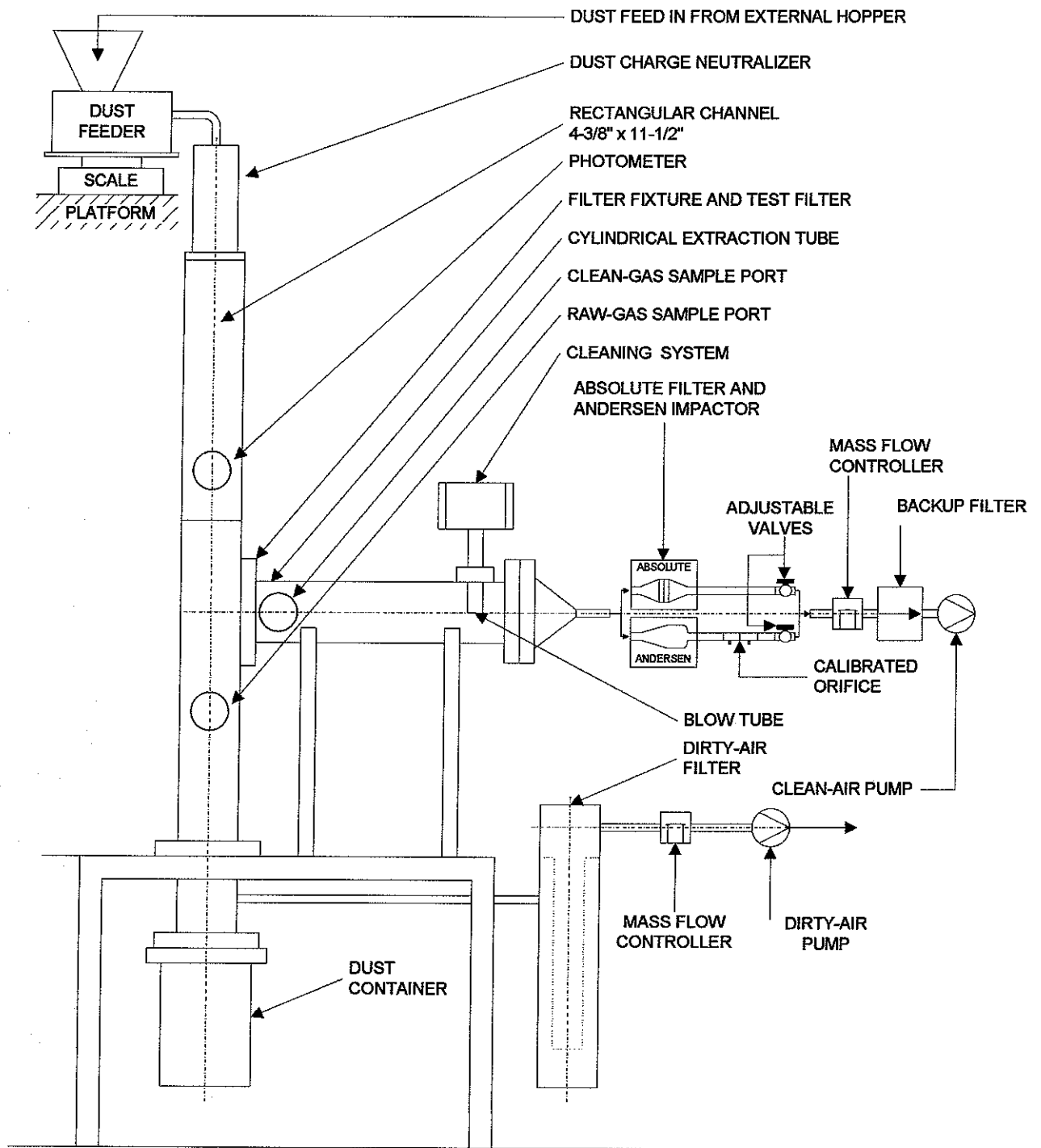


Figure 1 Filtration Performance Test Apparatus

APPENDIX A
TEST DATA AND RESULTS

TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

CONDITIONING PERIOD - 2 M/MIN

RUN ID. 250-R1
 FABRIC DESIGNATION 250-1
 MANUFACTURER Process Systems & Components
 DUST FEED Pural NF
 DATE STARTED 12/7/2005
 TIME STARTED 11:02
 TIME ENDED 19:22
 TEST DURATION 500 min.

NUMBER OF PULSES 10000
 PULSE INTERVAL 3 s

Moisture 0.92 %WV

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)		Average Gas Flow (sm ³ /hr)			Avg. Temp (°C)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
		Initial	Final	Raw	Clean	Total			
0-60	11:02	1753.4	1669.2	3.80	1.78	5.58	23	991.36	119
61-120	12:03	1669.2	1574.2	3.83	1.78	5.61	23	990.72	120
121-180	13:03	1574.2	1473.6	3.83	1.78	5.61	23	990.57	120
181-240	14:03	1473.6	1366.5	3.83	1.78	5.61	24	990.62	120
241-300	15:03	1366.5	1265.2	3.83	1.78	5.61	24	991.46	120
301-360	16:03	1265.2	1162.1	3.83	1.78	5.61	24	991.96	120
361-420	17:03	1162.1	1060.8	3.83	1.78	5.61	23	992.69	119
421-480	18:03	1060.8	963.8	3.83	1.78	5.61	23	993.28	119
441-500 *	18:23	1026.3	929.7	3.83	1.78	5.61	23	993.35	119
AVERAGE OF COMPLETE 500 MINUTE RAW DATA		99	5.60	3.82	1.78	5.60	23	991.66	120

ACCEPTANCE

100
 +/- 20

25
 +/- 2

18.4
 +/- 3.6

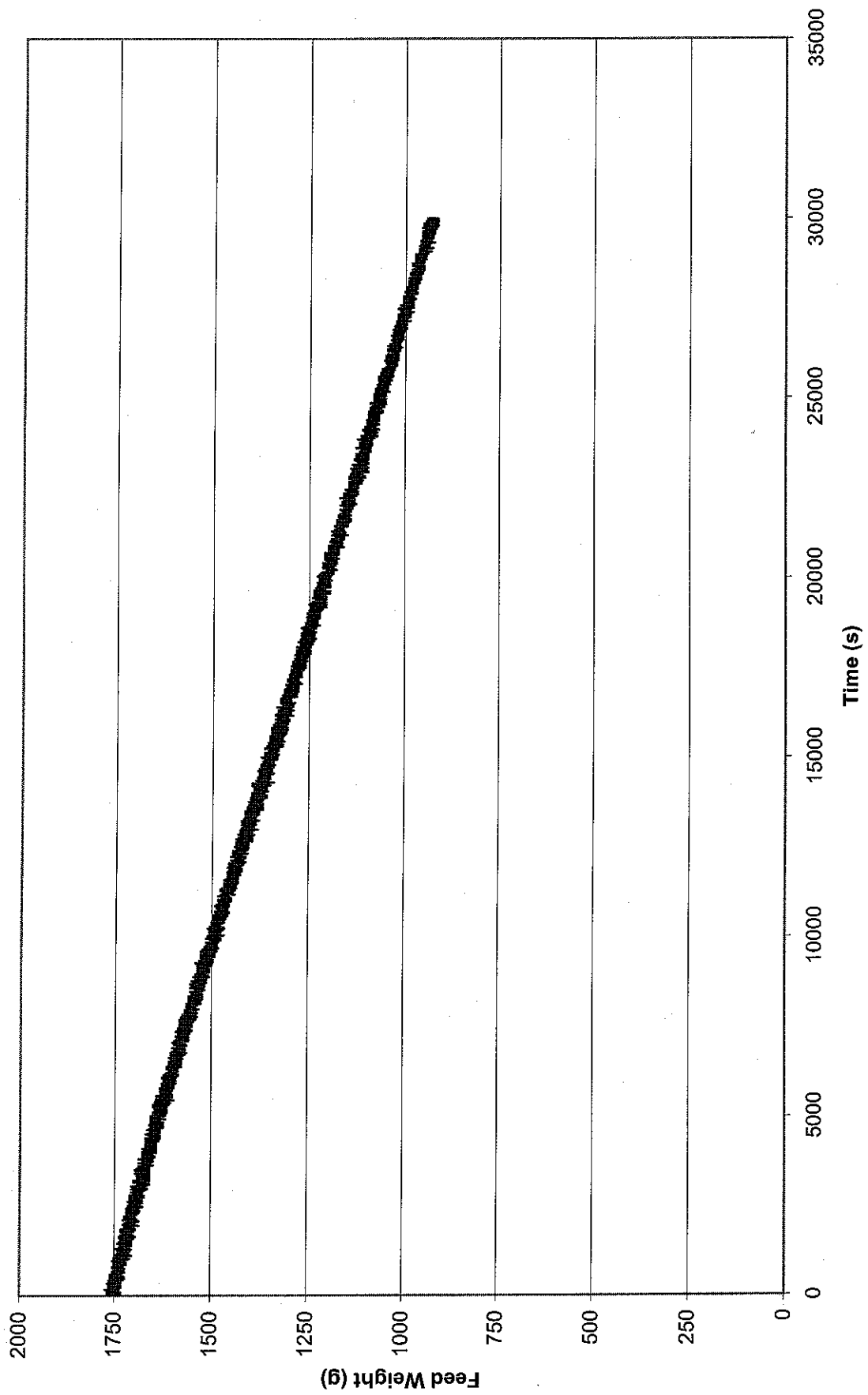
* Test duration is a rolling 60 minute average. The last 60 minute frame was determined by counting 60 minutes back from the last minute of the test.

DATA PROCESSING OPERATOR:

Randy N. Thornhill

Randy N. Thornhill - ETS, Inc.

Change in Pural NF dust scale reading with time during conditioning period 250-R1



TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

RECOVERY PERIOD - 2 M/MIN

RUN ID.	250-R1	NUMBER OF PULSES	30
FABRIC DESIGNATION	250-1	AVG. PULSE INTERVAL	250 s
MANUFACTURER	Process Systems and Components	AVG. RESIDUAL ΔP	330.97 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL ΔP	282.60 Pa
DATE(S)	12/8/2005	FINAL RESIDUAL ΔP	376.80 Pa
TIME STARTED	7:01 *	CHANGE IN ΔP	94.20 Pa
TIME ENDED	9:06	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	125 min.	% Moisture	0.8 %WV

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)	Average Gas Flow (sm ³ /hr)	Avg. Temp. (° C)	Avg. Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
1-60	7:02 *	Initial 1640.5 Final 1540.0 Total 101	Raw 3.87 Clean 1.81 Total 5.68	21	997.32	17.8	120
61-120	8:02	Initial 1540.0 Final 1434.3 Total 106	Raw 3.88 Clean 1.81 Total 5.69	22	997.44	18.7	120
65-125	8:06 **	Initial 1534.5 Final 1422.9 Total 112	Raw 3.88 Clean 1.81 Total 5.69	22	997.43	19.8	120
AVERAGE OF COMPLETE 125 MINUTE RAW DATA		104	3.86	22	997.38	18.6	120

ACCEPTANCE

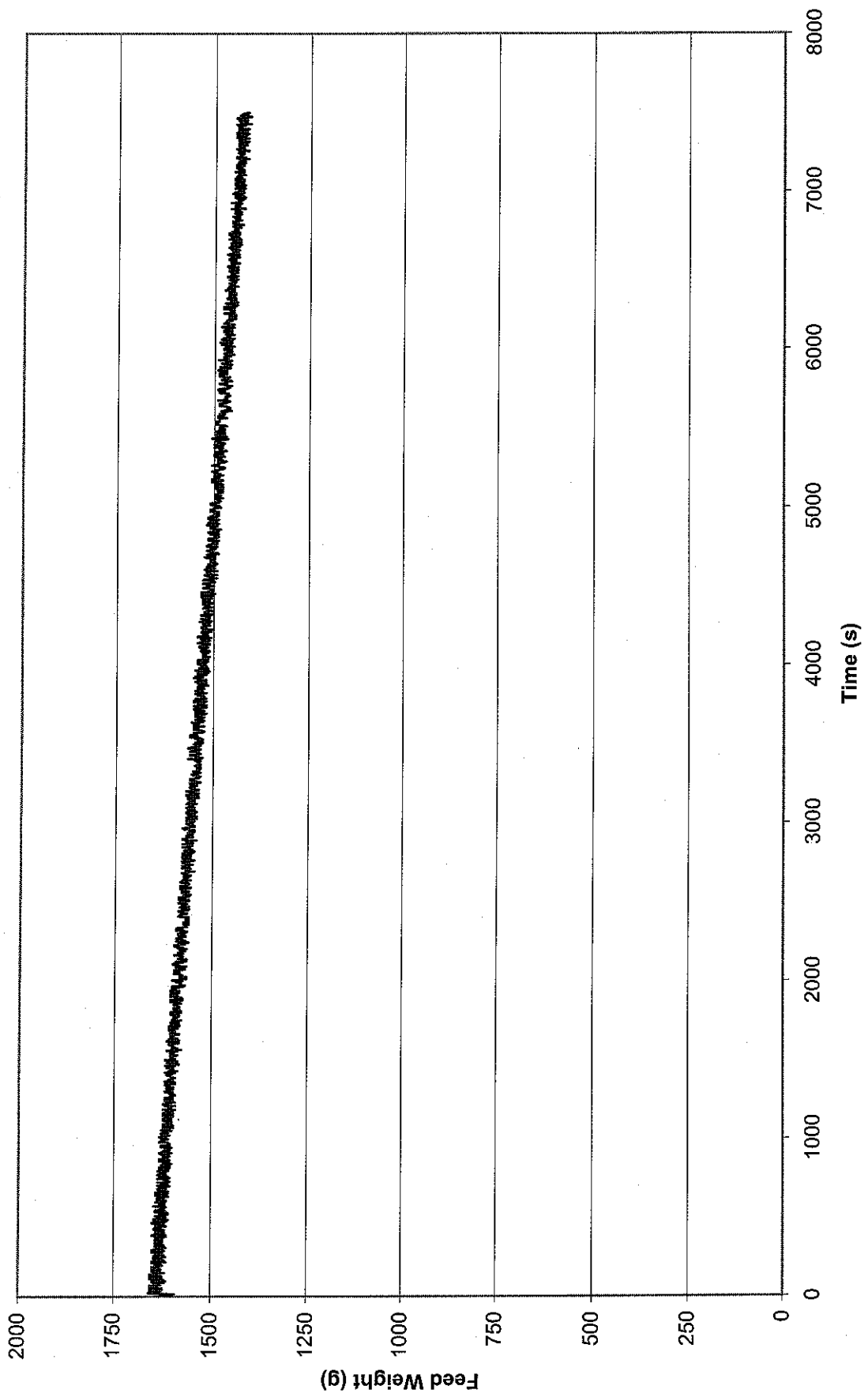
100	25	18.4	120
+/- 20	+/- 2	+/- 3.6	+/- 6

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

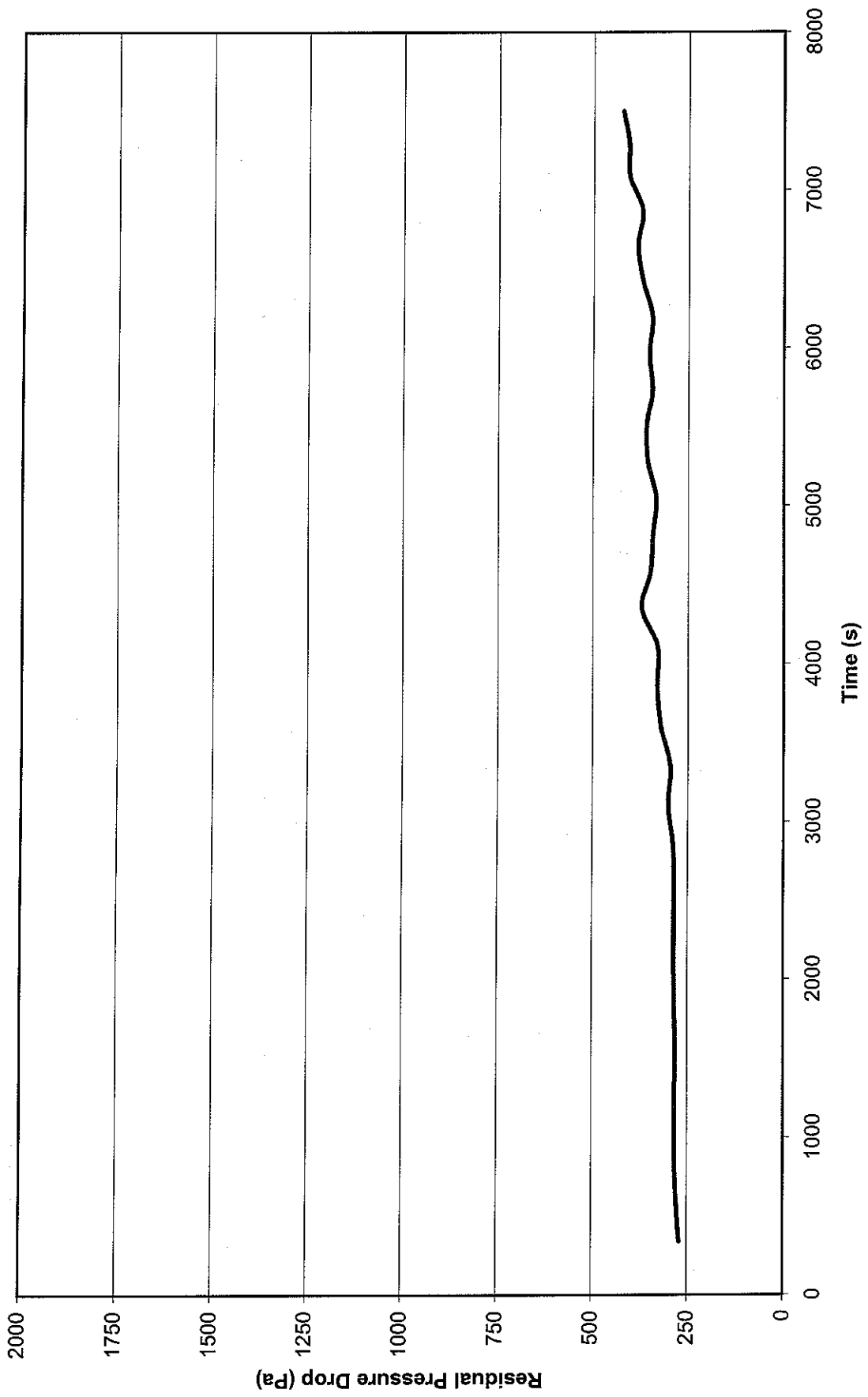
DATA PROCESSING OPERATOR:

Randy M. Helbert

Change in Pural NF dust scale reading with time during recovery period 250-R1



Residual pressure drop across filter fabric during recovery period 250-R1



TESTING OF BAGHOUSE FILTRATION PRODUCTS
 DETAILED SUMMARY OF DATA AND RESULTS

PERFORMANCE TEST PERIOD - 2 M/MIN

RUN ID.	250-R1	NUMBER OF PULSES	79
FABRIC DESIGNATION	250-1	AVG. PULSE INTERVAL	271 s
MANUFACTURER	Process Systems & Components	AVG. RESIDUAL ΔP	298.68 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL ΔP	278.60 Pa
DATE STARTED	12/9/2005	FINAL RESIDUAL ΔP	360.80 Pa
TIME STARTED	7:55	CHANGE IN ΔP	82.20 Pa
TIME ENDED	13:55	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	360 min.	Moisture	0.95 %WV

QA/QC DATA

Test Duration (min.)	Time	Dust Feed (g)	Average Gas Flow (sm ³ /hr)		Avg. Temp (°C)	Avg. Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
		Initial	Final	Raw	Clean	Total	Sample	
0-60	7:55	1623.7	1531.2	3.79	1.78	5.57	1.10	120
61-120	8:56	1531.2	1427.8	3.80	1.78	5.58	1.09	120
121-180	9:56	1427.8	1322.4	3.79	1.78	5.57	1.09	120
181-240	10:56	1322.4	1218.9	3.79	1.78	5.57	1.09	121
241-300	11:56	1218.9	1123.0	3.79	1.78	5.57	1.09	121
301-360	12:56	1123.0	1026.7	3.79	1.78	5.57	1.09	121
AVERAGE OF COMPLETE 360 MINUTE RAW DATA				3.79	1.78	5.57	1.09	121

ACCEPTANCE

100
+/- 20

25
+/- 2

18.4
+/- 3.6

120
+/- 6

GRAVIMETRIC DATA

IMPACTOR SUBSTRATES	IMPACTOR SUBSTRATES	IMPACTOR SUBSTRATES
Backup Filter (PM 2.5)	0.00010 g	Tare Mass
Total Mass Gain	0.00010 g	Final Mass
		Mass Gain
		12.16 g
		12.26 g
		0.10 g

OUTLET CONCENTRATION

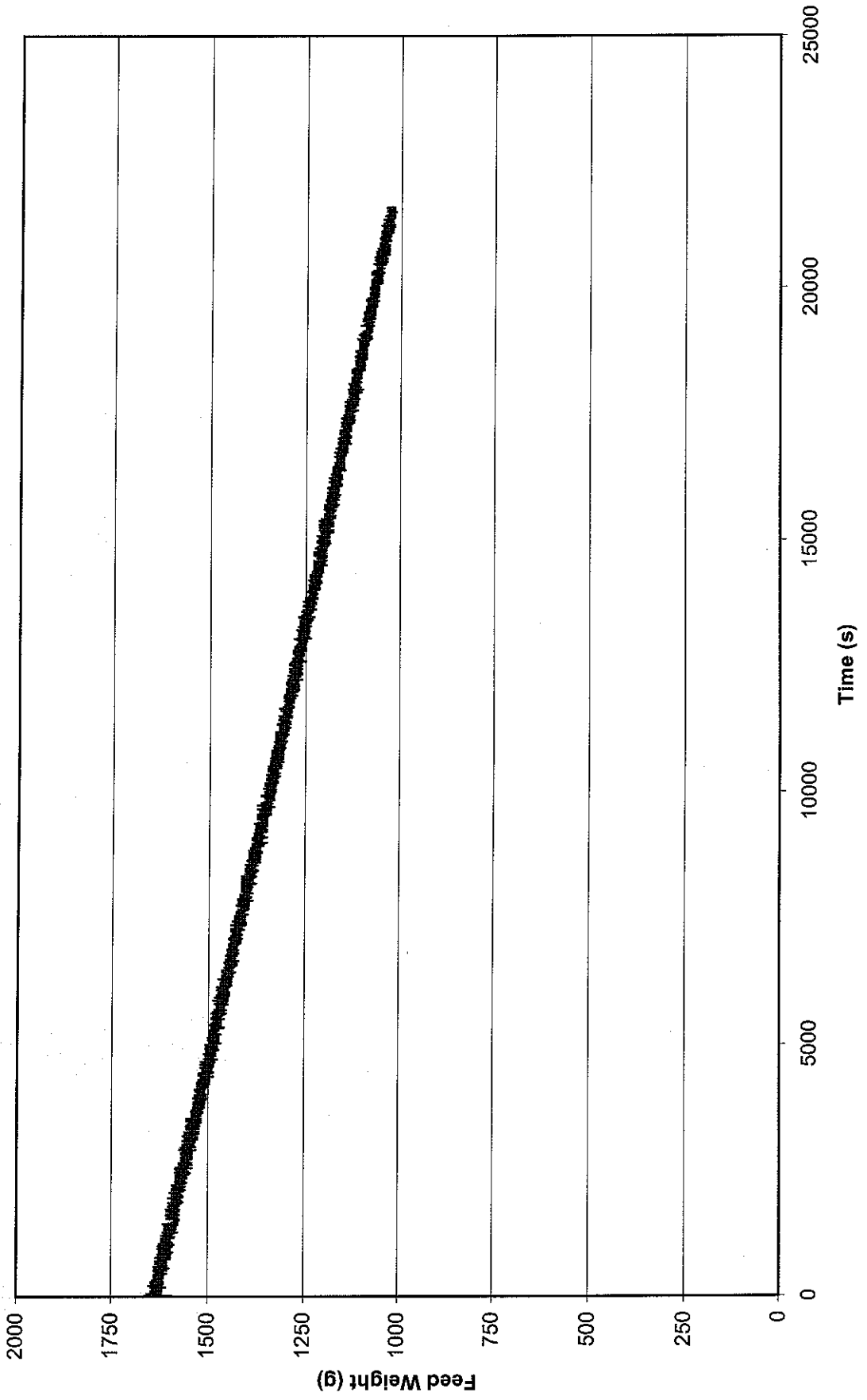
Total Volume Sampled 6.86 m³
 Mean Outlet Particle Concentration - PM 2.5 0.0000146 g/m³
 Mean Outlet Particle Concentration - Total Mass 0.0000146 g/m³

DATA PROCESSING OPERATOR:

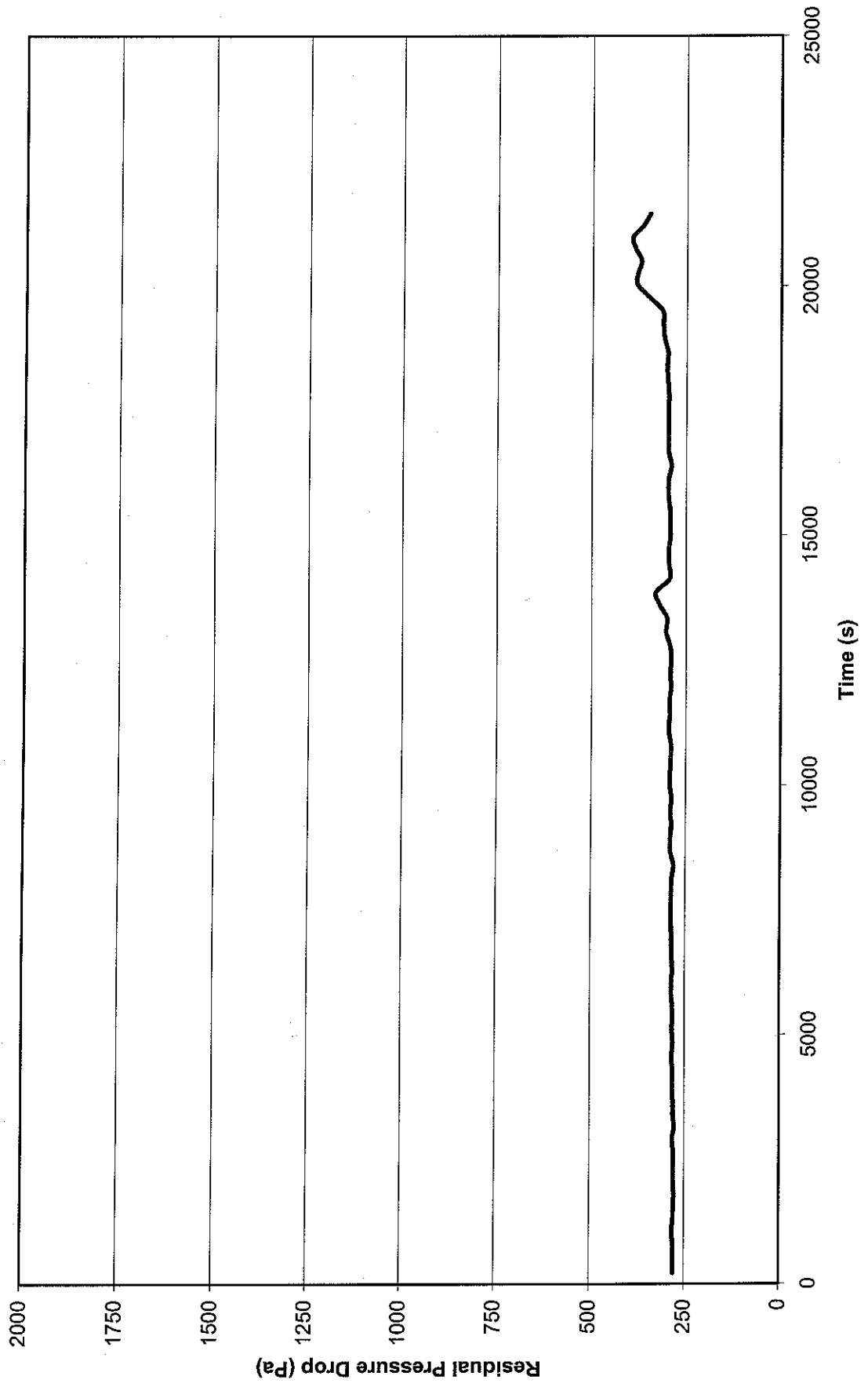
Randy N. Thornhill

Randy N. Thornhill - ETS, Inc.

Change in Pural NF dust scale reading with time during performance test period 250-R1



Residual pressure drop across filter fabric during performance test period 250-R1



TESTING OF BAGHOUSE FILTRATION PRODUCTS

FABRIC PERFORMANCE TESTING

JOB ID

RUN NUMBER **250-R1**

DATE 12/09/05
 START TIME 7:55
 END TIME 13:55
 TEST DURATION 360 min.

GAS COMPOSITIONAL DATA

%O2	20.9	Md	28.84
%CO2	0.0	Ms	28.73
%CO	0.0	Ps	28.77
%N2	79.1		

AMBIENT CONDITIONS

Barometric 29.941 in. Hg
 Gas Moisture Content 0.95 %

SAMPLING DATA

Gas Sample Volume 242.25 ft³
 Volume @ Std.Cond. 230.95 dscf

RAW DATA (FOR CLEAN GAS CHANNEL)

Actual Flow 1.14 m³/hr
 0.67 cfm
 Std. Flow 1.09 sm³/hr
 0.64 scfm
 Raw Gas Pressure 981.12 mbar
 Average Fabric Pressure Drop 670.10 Pa
 6.70 mbar
 Sample Gas Pressure 974.42 mbar
 28.77 in. Hg
 Sample Gas Temperature 22.6 ° C
 72.6 ° F

Md - Dry Molecular Weight
 Ms - Molecular Weight in Stack
 Ps - Static Pressure

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

**TESTING OF BAGHOUSE FILTRATION PRODUCTS
FABRIC PERFORMANCE TESTING**

GRAVIMETRIC ANALYTICAL DATA AND RESULTS

RUN NUMBER: 250-R1
TEST DATE: 12/09/2005

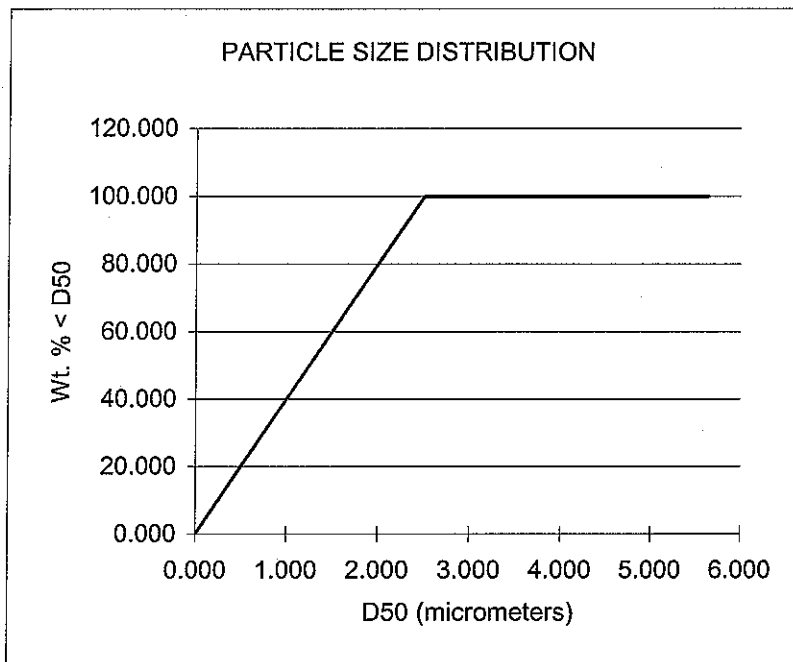
Filter I.D. Sample I.D.	Stage	Tare Mass (g)	Final Mass (g)	Mass Difference (g)*	Negative Difference? (g)
VDI-05-65					
VDI-05-65-1	1	1.00285	1.00285	0.00000	N/A
VDI-05-65-2	2	1.16404	1.16404	0.00000	N/A
VDI-05-65-3	3	1.06542	1.06542	0.00000	N/A
VDI-05-65-4	F	1.08639	1.08649	0.00010	N/A

Total 0.00010

* Final Mass < Tare Mass: assume mass difference - 0.00000.

IMPACTOR PARTICLE SIZING RESULTS

STAGE	Particulate Mass (g)	Cumulative % Less Than Diameter	D50 Cut Point (micrometers)
1	0.00000	100.00	5.64
2	0.00000	100.00	5.32
3	0.00000	100.00	2.51
F	0.00010		



BAGHOUSE FILTRATION PRODUCTS
VERIFICATION TESTING

TEST RUN ID: 250-R1
TEST FACILITY: ETS

FABRIC ID: 250-1
DUST: NF

Conditioning Period

Int AP = 115 Pa

CONDITIONING - 0-10000 PULSES
DATE: 12-7-05
START TIME: 11:02
STOP TIME: 19:22
RUN TIME: 8 hr - 20 min

AMBIENT CONDITIONS
Temperature (F): 71
Pressure (in Hg) 29.246

Wet Bulb (F): 55
Humidity (%RH): 35

Recovery Period

FABRIC RECOVERY - 10000-10030 PULSES
DATE: 12-8-05
START TIME: 7:01
STOP TIME: 8:06
RUN TIME: 7500 sec.

AMBIENT CONDITIONS
Temperature (F): 69
Pressure (in Hg) 29.447

Wet Bulb (F): 53
Humidity (%RH): 34

Performance Test Period

PERFORMANCE TEST PERIOD - 6-HOURS
DATE: 12-9-05
START TIME: 7:55
STOP TIME: 13:55
RUN TIME: 6 hrs.

AMBIENT CONDITIONS
Temperature (F): 70
Pressure (in Hg) 29.941

Wet Bulb (F): 56
Humidity (%RH): 42

Operator Signature: [Signature]
ETS, Inc.

HIGH RESOLUTION ANALYTICAL BALANCE DATA SHEET (USE ONE PER IMPACTOR SET)

TEST FACILITY: ETS
 IMPACTOR SET ID: 05-65
 FABRIC ID: 05-250-1
 TEST RUN ID: 250-1

PRE-WEIGHING

Date: 12/7/05
 Start Time: 12:52
 Stop Time: 12:55

POST-WEIGHING

Date: 12-12-05
 Start Time: 7:10
 Stop Time: 7:15

CONDITIONING

Date Time
 Conditioning Start: 12-2-05 16:10
 Conditioning Stop: 12-7-05 12:45
 Conditioning Successful?: (yes)no
 (Attach Temperature and Humidity Data)

CONDITIONING

Date Time
 Conditioning Start: 12-9-05 14:10
 Conditioning Stop: 12-12-05 7:00
 Conditioning Successful?: (yes)no
 (Attach Temperature and Humidity Data)

CALIBRATION DATA:

Time: 12:45 12:45
 Response to 1g weight: 1.00004
 Within 0.00005g? (yes)no

CALIBRATION DATA:

Time: 7:00
 Response to 1g weight: 1.00000
 Within 0.00005g? (yes)no

Stage

0
1
2
3
4
5
6
7
8

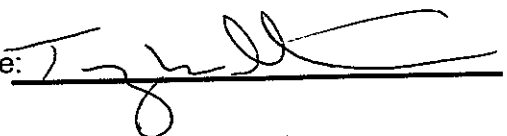
Filter

Pre-Weight* (g)
1.00285
1.16404
1.06542
1.08639

Post-Weight* (g)
1.00285
1.16404
1.06542
1.08649

Weight Gain (g)
0.00000
0.00000
0.00000
0.00010

* Including labeled weigh foils

Operator Signature: 

LOW RESOLUTION ANALYTICAL BALANCE DATA SHEET

TEST FACILITY: ETS
 FABRIC ID: 05-250

CALIBRATION (PRE)

Date: 12-7-05
 Time: 10:05
 Response to 100g Wt.: 100.00
 Within 0.05 g? Yes/no

CALIBRATION (POST)

Date	Time	Calibration (g)	Response Within 0.05 g
12-9-05	14:05	100.01	Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No

Pre-Weight (g)	Post Weight (g)	Weight Gain (g)
12.16	12.26	0.10

Fabric Sample ID	Test Run ID
05-250-1	250-R1

Operator Signature: [Signature]
 ETS, Inc.

BAGHOUSE FILTRATION PRODUCTS
VERIFICATION TESTING

Data Processing Record Sheet

Run ID: 250-R1
Fabric Designation: 250-1
Manufacturer: PROCESS SYSTEMS & COMPONENTS
Date: 12/16/05

Conditioning Period:

Psychrometric:
% Moisture: 0.92 %WV

Recovery Period

Psychrometric:
% Moisture: 0.80 %WV

MSX Text Data File:

Number of Pulses: 30
Average Interval: 249.9 Sec.
Average Differential Pressure Drop: 330.967 Pa
(Avg. Residual dP)
Initial Differential (Residual) Pressure Drop: 282.6 Pa
Final Differential (Residual) Pressure Drop: 376.8 Pa
Change in Differential (Residual) Pressure Drop: 94.2 Pa

Performance Test Period:

Psychrometric:
% Moisture: 0.95 %WV

MSX Text Data File:

Number of Pulses: 79
Average Pulse Interval: 271.443 Sec.
Average Differential Pressure Drop: 298.684 Pa
(Avg. Residual dP)
Initial Differential (Residual) Pressure Drop: 278.6 Pa
Final Differential (Residual) Pressure Drop: 360.8 Pa
Change in Differential (Residual) Pressure Drop: 82.2 Pa

DATA PROCESSING OPERATOR:

Randy M. Thornhill
ETS, Inc.