Environmental Technology Verification

Baghouse Filtration Products

GE Energy
QG061 Filtration Media
(Tested May 2007)

Prepared by

RTI International

ETS Incorporated

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

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EPA Cooperative Agreement CR 831911-01

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Notice

This document was prepared by RTI International[*] (RTI) and its subcontractor ETS, Inc. (ETS) with partial funding from Cooperative Agreement No. CR 831911-01 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.

[*] RTI International is a trade name of Research Triangle Institute.

Foreword

The Environmental Technology Verification (ETV) Program, established by the U.S. Environmental Protection Agency (EPA), is designed to accelerate the development and commercialization of new or improved technologies through third-party verification and reporting of performance. The goal of the ETV Program is to verify the performance of commercially ready environmental technologies through the evaluation of objective and quality-assured data so that potential purchasers and permitters are provided with an independent and credible assessment of the technology that they are buying or permitting.

The Air Pollution Control Technology Verification Center (APCT Center) is part of the EPA's ETV Program and is operated as a partnership between RTI International (RTI) and EPA. The center verifies the performance of commercially ready air pollution control technologies. Verification tests use approved protocols, and verified performance is reported in verification statements signed by EPA and RTI officials. RTI contracts with ETS, Inc. (ETS) to perform verification tests on baghouse filtration products, including filter media.

Baghouses are air pollution control devices used to control particulate emissions from stationary sources and are among the technologies evaluated by the APCT Center. The APCT Center developed (and EPA approved) the Generic Verification Protocol for Baghouse Filtration Products to provide guidance on these verification tests.

The following report reviews the performance of GE Energy's QG061 filtration media. ETV testing of this technology was conducted during May and June 2007 at ETS. All testing was performed in accordance with an approved test/QA plan that implements the requirements of the generic verification protocol at the test laboratory.

Availability of Verification Statement and Report

Copies of this verification report are available from:

- RTI International
  Engineering and Technology Unit
  P.O. Box 12194
  Research Triangle Park, NC 27709-2194

- U.S. Environmental Protection Agency
  Air Pollution Prevention and Control Division (E343-02)
  109 T. W. Alexander Drive
  Research Triangle Park, NC 27711

Web Site:

http://www.epa.gov/nrmrl/std/etv/vt-apc.html#bfp (electronic copy)

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

APCT Center	Air Pollution Control Technology Verification Center
APPCD	Air Pollution Prevention and Control Division
BFP	baghouse filtration product
cfm	cubic feet per minute
cm	centimeters
cm w.g.	centimeters of water gauge
dia.	diameter
ΔP	pressure drop
dscmh	dry standard cubic meters per hour
EPA	U.S. Environmental Protection Agency
ETS	ETS, Incorporated
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
GVP	generic verification protocol
g/dscm	grams per dry standard cubic meter
g/h	grams per hour
g/m^2	grams per square meter
hr	hours
in.	inches
in. w.g.	inches of water gauge
kg/m^2	kilograms per square meter
kPa	kilopascals
m	meters
mbar	millibars
min	minutes
m/h	meters per hour

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

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SECTION 1

INTRODUCTION

This report reviews the filtration and pressure drop (ΔP) performance of GE Energy's QG061. Environmental Technology Verification (ETV) testing of this technology/product was conducted during a series of tests May 23, 2007 and June 01, 2007, by ETS, Inc. (ETS), under contract with the Air Pollution Control Technology Verification Center (APCT Center). The objective of the APCT Center and the ETV Program is to verify, with high data quality, the performance of air pollution control technologies. Control of fine particle emissions from various industrial and electric utility sources employing baghouse control technology is within the scope of the APCT Center. The APCT Center program area was designed by RTI International (RTI) and a technical panel of experts to evaluate the performance of particulate filters for fine particle ($PM_{2.5}$) emission control. Based on the activities of this technical panel, the *Generic Verification Protocol for Baghouse Filtration Products* was developed. This protocol was chosen as the best guide to verify the filtration performance of baghouse filtration products (BFPs). The specific test/quality assurance (QA) plan for the ETV test of the technology was developed and approved in May 2000 with an approved update in February 2006. The goal of the test was to measure filtration performance of both $PM_{2.5}$ and total PM as well as the pressure drop characteristics of the GE Energy technology identified above.

Section 2 documents the procedures and methods used for the test and the conditions over which the test was conducted. A description of the GE Energy's QG061 filtration media is presented in Section 3. The results of the test are summarized and discussed in Section 4, and references are presented in Section 5.

This report contains summary information and data from the test as well as the verification statement. Complete documentation of the test results is provided in a separate data package and audit of data quality report. These reports include the raw test data from product testing and supplemental testing, equipment calibrations results, and QA and quality control (QC) activities and results. Complete documentation of QA/QC activities and results, raw test data, and equipment calibrations results are retained in ETS's files for seven years.

SECTION 2

VERIFICATION TEST DESCRIPTION

The baghouse filtration products were tested in accordance with the APCT Center *Generic Verification Protocol for Baghouse Filtration Products*[1] and the *Test/QA Plan for the Verification Testing of Baghouse Filtration Products*.[2] This protocol incorporated all requirements for quality management, QA, procedures for product selection, auditing of the test laboratories, and reporting format. The Generic Verification Protocol (GVP) describes the overall procedures to be used for verification testing and defines the data quality objectives. The values for inlet dust concentration, raw gas flow rate, and filtration velocity used for current verification testing have been revised in consultation with the technical panel since posting of the GVP. These revisions are documented in Section A7.1 of the test/QA plan. The test/QA plan details how the test laboratory at ETS will implement and meet the requirements of the GVP.

2.1 DESCRIPTION OF THE TEST RIG AND METHODOLOGY

The tests were conducted in ETS's filtration efficiency media analyzer (FEMA) test apparatus (Figure 1). The test apparatus consists of a brush-type dust feeder that disperses test dust into a vertical rectangular duct (raw-gas channel). The dust feed rate is continuously measured and recorded via an electronic scale located beneath the dust feed mechanism. The scale has a continuous read-out with a resolution of 10 g. A radioactive polonium-210 alpha source is used to neutralize the dust electrically before its entry into the raw-gas channel. An optical photo sensor monitors the concentration of dust and ensures that the flow is stable for the entire duration of the test. The optical photo sensor does not measure concentration. A portion of the gas flow is extracted from the raw-gas channel through the test filter, which is mounted vertically at the entrance to a horizontal duct (clean-gas channel). The clean-gas channel flow is separated in two gas streams, a sample stream and a bypass stream. An aerodynamic "Y" is used for this purpose. The aerodynamic "Y" is designed for isokinetic separation of the clean gas with 40 percent of the clean gas entering the sample-gas channel without change in gas velocity. The sample-gas channel contains an Andersen impactor for particle separation and measurement. The bypass channel contains an absolute filter. The flow within the two segments of the "Y" is continuously monitored and maintained at selected rates by adjustable valves. Two vacuum pumps maintain air flow through the raw-gas and clean-gas channels. The flow rates, and thus the gas-to-cloth ratio (G/C) through the test filter, are kept constant and measured using mass flow controllers. A pressure transducer is used to measure the average residual pressure drop of the filter sample. The pressure transducer measures the differential pressure across the filter samples 3 seconds after the cleaning pulse. The pressure drop measurements are then averaged as described in Appendix C, Section 4.4.1 of the GVP.[1] High-efficiency filters are installed upstream of the flow controllers and pumps to prevent contamination or damage caused by the dust. The cleaning system consists of a compressed-air tank set at 0.5 MPa (75 psi), a quick-action diaphragm valve, and a blow tube [25.4 mm (1.0 in.) dia.] with a nozzle [3 mm (0.12 in.) dia.] facing the downstream side of the test filter.

Mean outlet particle concentration is determined when a portion of the gas flow is extracted from the raw-gas channel through the test filter, which is mounted vertically at the entrance to a horizontal duct (clean-gas channel). The clean-gas flow is separated using an aerodynamic "Y" so that a representative sample of the clean gas flows through an Andersen impactor that determines the outlet particle concentration.

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

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

- Conditioning period,
- Recovery period, and
- Performance test period.

To simulate long-term operation, the test filter was first subjected to a conditioning period, which consists of 10,000 rapid pulse cleaning cycles under continuous dust loading. During this period, the time between cleaning pulses is maintained at 3 seconds. No filter performance parameters are measured in this period.

The conditioning period is immediately followed by a recovery period, which allows the test filter fabric to recover from rapid pulsing. The recovery period consists of 30 normal filtration cycles under continuous and constant dust loading. During a normal filtration cycle, the dust cake is allowed to form on the test filter until a differential pressure of 1,000 Pa (4.0 in. w.g.) is reached. At this point the test filter is cleaned by a pulse of compressed air from the clean-gas side of the fabric. The next filtration cycle begins immediately after the cleaning is complete.

Performance testing occurs for a 6-hour period immediately following the recovery period (a cumulative total of 10,030 filtration cycles after the test filter has been installed in the test apparatus). During the performance test period, normal filtration cycles are maintained and, as in the case of the conditioning and recovery periods, the test filter is subjected to continuous flow and constant dust loading.

The filtration velocity (G/C) and inlet dust concentrations are maintained at 120 ± 6 m/h (6.6 ± 0.3 fpm) and 18.4 ± 3.6 g/dscm (8.0 ± 1.6 gr/dscf), respectively, throughout all phases of the test.

2.2 SELECTION OF FILTRATION SAMPLE FOR TESTING

Filter fabric samples of QG061 were supplied to ETS directly from the manufacturer (GE Energy) with a letter signed by Alan Smithies, the engineering manager for fabric filter/membrane at GE Energy, attesting that the filter media were selected at random in an unbiased manner from commercial-grade media and were not treated in any manner different from the media provided to customers. The manufacturer supplied the test laboratory with nine 46 x 91 cm (18 x 36 in.) filter samples. The test laboratory randomly selected three samples and prepared them for testing by cutting one test specimen of 150 mm (5.9 in.) diameter from each selected sample for insertion in the test rig sample holder. The sample holder has an opening 140 mm (5.5 in.) in diameter, which is the dimension used to calculate the face area of the tested specimen.

2.3 CONTROL TESTS

Two types of control tests were performed during the verification test series. The first was a dust characterization, which is performed monthly. The reference dust used during the verification tests was Pural NF aluminum oxide dust. The Pural NF dust was oven dried for 2 hours and sealed in an airtight container prior to its insertion into the FEMA apparatus. The dust characterization results had to meet the requirements of a 1.5 ± 1.0 μm maximum mass mean diameter and between 40 and 90 percent less than 2.5 μm to continue the verification test series.

The second control test, the reference value test, is performed quarterly using the reference fabric and the FEMA apparatus. The reference value test determines the weight gain of the reference fabric as well as the maximum pressure drop. The results of the test verify that the FEMA apparatus is operating consistently within the required parameters. Reference values tests are conducted and the average fabric maximum pressure drop must be 0.60 cm w.g. ± 40% and the fabric weight gain average must be 1.12 g ± 40%.

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

Table 1. Summary of Control Test Results

	Requirement	Measured value	Met requirements?
Mass mean diameter, μm	1.5 ± 1.0	1.32	Yes
% Less than 2.5 μm	40 to 90%	72.2	Yes
Weight gain, g	1.12 ± 40%	1.00	Yes
Maximum ΔP, cm w.g.	0.60 ± 40%	0.49	Yes

ΔP = pressure drop.

Three reference value control test runs were conducted.

2.4 ANALYSIS

The equations used for verification analysis are described below.

A_f = Exposed area of sample filter, 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, this value is 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, this value is measured as a 1-min average.

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

460 = 0 ^oF, in °R
1,013 = Standard atmospheric pressure, mbar
528 = Standard temperature, °R

Area of Sample Fabric, A_f

$A_f = (B * d^2)/4$

Actual Gas Flow Rate, Q_a

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

Gas-to-Cloth Ratio, G/C

$G/C = Q_a / A_f$

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

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

Actual Raw Gas Dust Concentration, F_a

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

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

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

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

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

Filtration Cycle Time, t_c

$t_c = t/N$

Average Residual Pressure Drop, P_{avg}

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

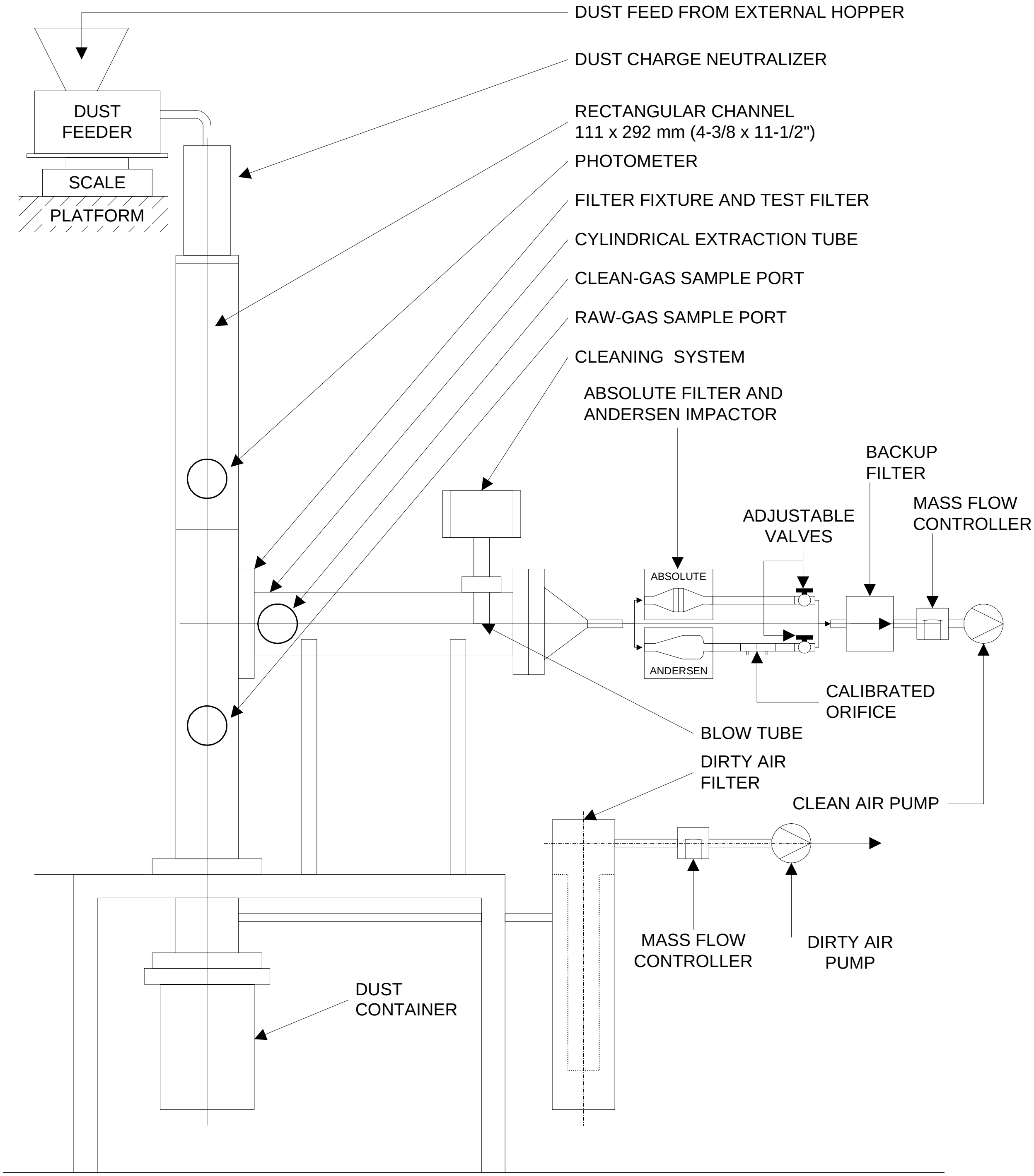

Figure 1. Diagram of FEMA test apparatus

SECTION 3

DESCRIPTION OF FILTER FABRIC

The GE Energy QG061 filtration media is a woven glass substrate with an expanded, microporous membrane, thermally laminated to the filtration/dust cake surface.

SECTION 4

VERIFICATION OF PERFORMANCE

4.1 QUALITY ASSURANCE

The verification tests were conducted in accordance with an approved test/QA plan.[2] The EPA quality assurance manager conducted an independent assessment of the test laboratory in June 2005, and found that the test laboratory was equipped and operated as specified in the test/QA plan.

The ETS QA officer and the APCT Center's QA staff have reviewed the results of this test and have found that the results meet the overall data quality objectives as stated in the test/QA plan. It should be noted that, because of the highly efficient nature of the filter medium being tested, the impactor substrate weighings for these results were below the reproducibility of the balance. The relative percent error in the post filter weighing measurements cannot be computed because most of the values were near zero. As a result of this occurrence, the tests do not meet the data quality objectives (DQOs) stated in the test/QA plan for mass gain associated with outlet concentrations. However, as stated in the test protocol, "for highly efficient fabrics, the mass gains stated for these quality objectives may not be achieved in the specified test duration. For these tests it is acceptable for the indicated DQO not to be met."

Deviations from the test plan include organizational personnel changes.

The ETS QA officer and the APCT Center's QA staff have also reviewed the results of the control tests, which are summarized in Section 2.3, Table 1. The dust characterization control test met the appropriate requirements of the test/QA plan and verification protocol. The reference fabric tests meet maximum pressure drop and weight gain requirements established for reference fabric performance in the GVP, indicating the measurement system is operating in control.

4.2 RESULTS

Table 2 summarizes the mean outlet particle concentration measurements for the verification test periods. Measurements were conducted during the 6-hour performance test period. The performance test period followed a 10,000-cycle conditioning period and a 30-cycle recovery period.

Table 2 summarizes the three verification tests that were performed under standard verification test conditions. The average residual ΔP across each filter sample at the nominal 120 m/h (6.6 fpm) filtration velocity [for a flow rate of 5.8 m^3/h (3.4 cfm)] is also shown in Table 2. This ΔP ranged from 2.99 to 3.45 cm w.g. (1.18 to 1.36 in. w.g.) for the three filter samples tested. The residual ΔP increase ranged from 0.04 to 0.15 cm w.g. (0.02 to 0.06 in. w.g.) for the samples tested. All three standard condition verification runs were used to compute the averages given in Table 2. The $PM_{2.5}$ outlet particle concentration average for the three runs is <0.0000167 g/dscm. The total PM concentration average for the three runs is <0.0000167 g/dscm.

Table 2. Summary of Verification Results for GE Energy's QG061 Filtration Media

Test run number	**4V7-R1**	**4V7-R2**	**4V7-R3**	**Average[a]**
$PM_{2.5}$ (g/dscm)[b]	<0.0000167[c]	<0.0000167	<0.0000167	<0.0000167
Total PM (g/dscm)	<0.0000167	<0.0000167	<0.0000167	<0.0000167
Average residual ΔP (cm w.g.)	3.45	3.31	2.99	3.25
Initial residual ΔP (cm w.g.)	3.37	3.26	2.97	3.20
Residual ΔP increase (cm w.g.)	0.15	0.12	0.04	0.10
Mass gain of sample filter (g)	0.10	0.12	0.13	0.12
Average filtration cycle time (s)	174	171	203	183
Number of cleaning cycles	124	126	106	119

[a] All three verification runs were used to compute averages.
[b] One or more of the impactor substrate weight changes for these results was near the reproducibility limit of the balance.
[c] The measured value was determined to be below the detection limit of 0.0000167 grams per cubic meter. The detection limit is for a six-hour test and based on VDI 3926.

4.3 LIMITATIONS AND APPLICATIONS

This verification report addresses two aspects of baghouse filtration product performance: outlet particle concentration and ΔP. 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 GVP, this verification statement is applicable to baghouse filtration products manufactured between signature of the verification statement and three years thereafter.

SECTION 5

REFERENCES

1. *Generic Verification Protocol for Baghouse Filtration Products*, RTI International, Research Triangle Park, NC, February 2000. Available at http://www.epa.gov/nrmrl/std/etv/pubs/05_vp_bfp.pdf. .

2. *Test/QA Plan for the Verification Testing of Baghouse Filtration Products (Revision 2)*, ETS, Inc., Roanoke, VA and RTI International, Research Triangle Park, NC, February 2006. Available at http://www.epa.gov/nrmrl/std/etv/pubs/600etv06095.pdf.