TEST/QA PLAN

FOR THE VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS

EPA Cooperative Agreement No. CR829434-01-1
RTI Project No. 0209309
ETS Project No. 98-277

Prepared by:

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PART A. PROJECT MANAGEMENT

A1.0 Title and Approval Sheet

A1.1 Title

Test/Quality Assurance Project Plan (Test/QAPP) for the Verification Testing of Baghouse Filtration Products (BFPs).

NOTE: This Test/QA Plan has been structured to conform with the format of the EPA document *EPA Guidance for Quality Assurance Project Plans (EPA QA/G-5).*

A1.2 Approval

This Test/QA Plan has been reviewed and approved by the following program participants:

APCT Center Director:	A. R. Trenholm	*Signed by Andrew Trenholm*	Date:	*9/1/06*
APCT Center Quality Manager:	W. C. Eaton	*Signed by W. Cary Eaton*	Date:	*9/7/06*
APCT Center Task Leader:	A. R. Trenholm	*Signed by Andrew Trenholm*	Date:	*9/1/06*
BFP Task Leader:	J. C. Mycock	*Signed by J. C. Mycock*	Date:	*9/1/06*
EPA APCT Project Manager:	M. Kosusko	*Signed by Michael Kosusko*	Date:	*9/12/06*
EPA APCT Quality Manager:	P. W. Groff	*Signed by Paul W. Groff*	Date:	*9/12/06*

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A3.0 Distribution List

The following is a list of individuals who will receive copies of the approved Test/QA Plan and any subsequent revisions.

Name	**Role**	**Organization**
Mike Kosusko	EPA APCT Project Manager	EPA/APPCD
Paul Groff	EPA APCT Quality Manager	EPA/APPCD
Andrew Trenholm	APCT Center Director	Research Triangle Institute
Cary Eaton	APCT Center Quality Manager	Research Triangle Institute
Andrew Trenholm	APCT Center Task Leader	Research Triangle Institute
John Mycock	BFP Task Leader	ETS, Inc.
John McKenna	Verification Test Leader	ETS, Inc.
Sharon Winemiller	Test-Specific QA Officer	ETS, Inc.
Terry Williamson	Test-Specific Manager	ETS, Inc.
John Mycock	Test-Specific Report Manager	ETS, Inc.

A3.1 List of Acronyms

The following is a list of acronyms that are used in this Test/QA Plan.

ADQ	Audit of Data Quality
ANSI/ASQC	American National Standard Institute/American Society for Quality Control
APCT	Air Pollution Control Technology
APPCD	Air Pollution, Prevention, and Control Division
ASQ	American Society for Quality
ASTM	American Society for Testing and Materials
BFPs	Baghouse Filtration Products
DQO	Data Quality Objective
EPA	United States Environmental Protection Agency
ETV	Environmental Technology Verification
FEMA	Filter Efficiency Media Analyzer
G/C	Gas-to-Cloth Ratio
LIMS	Laboratory Information Management System
LTG	LTG GmbH, Karlsruhe, Germany (Company that manufactures FEMA apparatus)
MSDS	Material Safety Data Sheet
NAAQS	National Ambient Air Quality Standards
NIST	National Institute of Standards and Technology
PE	Performance Evaluation
PM	Particulate Matter (Includes PM 2.5)
PM 2.5	Particulate Matter 2.5 micrometers and Smaller
QA	Quality Assurance
QAO	Quality Assurance Officer
QC	Quality Control
QMP	Quality Management Plan
RTI	Research Triangle Institute
SAC	Stakeholders Advisory Committee
SOP	Standard Operating Procedure
TSA	Technical Systems Audit
VDI	Verein Deutscher Ingenieure
w.g.	Water Gage

A4.0 Project Organization

The U.S. Environmental Protection Agency (EPA) has overall responsibility for the Environmental Technology Verification (ETV) Program for Air Pollution Control Technology (APCT). Research Triangle Institute (RTI) is EPA's verification partner in this effort. The APCT Center has selected Baghouse Filtration Products (BFPs) as a technology to be verified.

Management and testing within the BFP program is performed in accordance with procedures and protocols defined by a series of quality management documents. These include:

1. EPA's Quality Management Plan (QMP) for the overall ETV program,
2. RTI's Environmental Sciences and Engineering (ESE) Quality Manual,
3. the QMP for the overall APCT Center,
4. the Generic Verification Protocol for Baghouse Filtration Products, and
5. a Test/QA Plan prepared by each participating testing organization.

ETS, Inc. has indicated an interest in being and demonstrated the necessary qualifications to be a participating testing organization for the BFP program and has prepared this Test/QA Plan to describe BFP testing under their responsibility.

As a participating testing organization, ETS will conduct laboratory tests on baghouse filtration products, analyze data, and prepare the draft verification reports and verification statements. The various quality assurance (QA) and management responsibilities are divided between EPA, RTI, and ETS key project personnel as defined below. The lines of authority between key personnel for this project are shown on the project organization chart in Figure 1.

A4.1 Roles and Responsibilities

Project management responsibilities are assigned to personnel from:

1. The United States Environmental Protection Agency (EPA),
2. Research Triangle Institute (RTI), and
3. ETS, Inc. (ETS).

A4.1.1 EPA

EPA is responsible for the overall Environmental Technology Verification (ETV) project oversight. The EPA Project Manager for the ETV Program is Mike Kosusko. Verification responsibility encompasses approval of project plans and reports and ensuring that plans are implemented according to schedule. He requests the resources necessary to meet project objectives and requirements.

Paul Groff is EPA's APCT Quality Manager. He is responsible for ensuring that the EPA Quality and Management Plan (QMP) requirements are fulfilled and may perform quality audits and evaluations of participating organizations. He will be available to resolve any QA issues relating to conformance to EPA's QA requirements. Specific functions and duties of the EPA Quality Manager include approving the contents of this Test/QA Plan and subsequent revisions and reviewing QA reports prepared by RTI, including QA evaluations and audits. For further information concerning the EPA organizational structure, see EPA QMP Part A, Section 1.0 at http://www.epa.gov/etv/qmp.htm.

A4.1.2 RTI

RTI is responsible for the overall ETV APCT Center. Andrew Trenholm of RTI is the APCT Center Director and will manage program activities and coordinate them with the Stakeholders Advisory Committee (SAC). Supporting the APCT Center Director in matters of quality is Cary Eaton who holds the position of APCT Center Quality Manager. For the BFP effort, Andrew Trenholm is also the APCT Center Task Leader.

A4.1.3 ETS

ETS, as a participating testing organization, is responsible for the development and implementation of this Test/QA Project Plan. John Mycock is the BFP Task Leader. All EPA and RTI individuals listed above are responsible for approving ETS' QMP and this Test/QA Plan, and for verifying ETS' E4 standing in accordance with the requirements set forth by the EPA Quality and Management Plan.

ETS, Inc. will perform BFP verification testing as a participating testing organization and will use the LTG Filtration Efficiency Media Analyzer (LTG/FEMA) test apparatus as specified in this Test/QA Plan to meet the specifications of the generic verification protocol for baghouse filtration products. ETS is responsible for specific test planning and execution as well as test data evaluation and reporting. Figure 1 details the project's organization.

A4.2 Verification Test Roles and Responsibilities

The ETS verification test personnel will be organized into the following key areas of responsibility.

- Verification Test Leader
- Test-Specific Manager

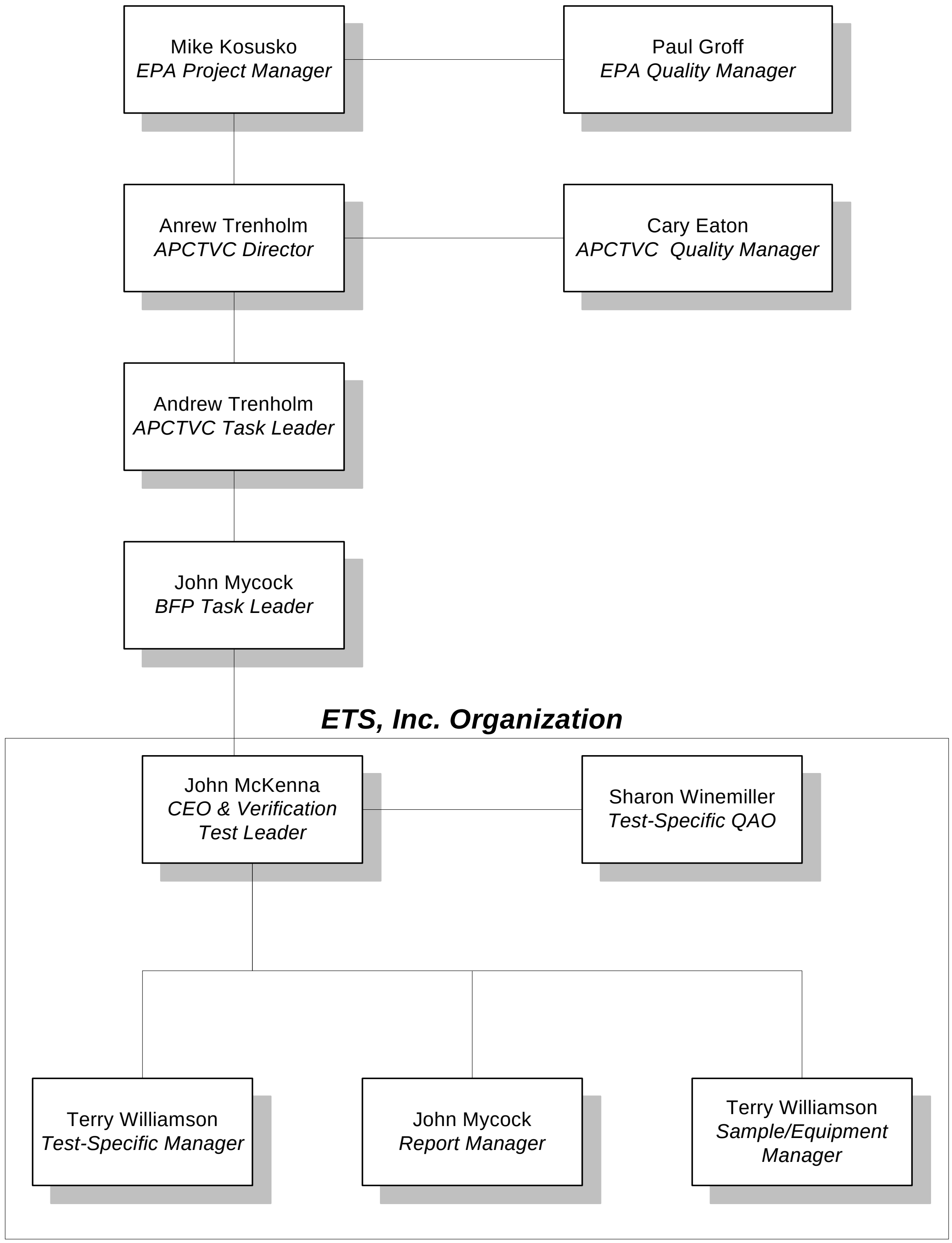

Figure 1. Project Organization

- Test-Specific Quality Assurance Officer
- Report Manager
- Sample/Equipment Manager

The responsibilities of each of the above positions are detailed below.

A4.2.1 Verification Test Leader

John McKenna will serve as the overall ETS Verification Test Leader and is the final link in the ETS chain of command. The Verification Test Leader will serve as backup to the Test-Specific Manager for technical support and any communications between the involved parties and ETS. The Verification Test Leader will provide scheduling and administrative support to the testing program. McKenna will supervise the development of all draft verification reports and draft verification statements generated in this project and assist in their review and approval. The Verification Test Leader is also responsible for any corrective action implementation procedures that might arise from performed audits.

A4.2.2 Test-Specific Manager

Terry Williamson will serve as the Test-Specific Manager. The Test-Specific Manager's duties include implementing verification testing procedures, test execution, and assisting in the development of draft project reports. The Test-Specific Manager will also review all aspects of the testing program to ensure proper communication among all parties, review the sampling and recovery procedures as executed, and provide on-site data review. The Test-Specific Manager is responsible for the verification of the test data, spreadsheets, template accuracy, and preparation of the draft verification statement and the draft verification report.

A4.2.3 Test-Specific Quality Assurance Officer

Sharon Winemiller will be the Test-Specific QAO. The Test-Specific QAO will work independently of the project management team and is responsible for procedures that determine if the verification test is being conducted in accordance with QA/QC requirements. The Test-Specific QAO is also responsible for inspections and technical assessments to verify compliance with QA/QC goals. The Test-Specific QAO will independently review test data and laboratory results, and will assist in the preparation of the draft verification reports and draft verification statements that are generated from this project.

A4.2.4 Report Manager

John Mycock will be responsible for the draft verification report and draft verification statement development and data validation. The Report Manager supervises the review of all raw test data and checks all spreadsheet templates for accuracy. He reports any inconsistencies to the Test-Specific Manager and the Test-Specific QAO.

A4.2.5 Sample/Equipment Manager

Terry Williamson will receive and secure all incoming samples and is responsible for the correct preparation of all sampling dust and filter media awaiting verification testing. The Sample/Equipment Manager is also responsible for obtaining and retaining in stock reference polyester media and aluminum oxide test dust for calibrations and comparisons. The Sample/Equipment Manager confirms a direct chain-of-custody and reviews all sample identification numbers against the actual test data sheets for accuracy. Any discrepancies are reported to the Verification Test Leader. Terry Williamson also distributes the samples to the appropriate verification testing areas.

In the event that key personnel changes need to be made, the APCT Verification Center at Research Triangle Institute will be informed.

A5.0 Problem Definition

(The generic verification protocol provides extended discussions on problem definition from which portions of the following have been extracted.)

A5.1 Background

Baghouses and their accompanying filter media have long been one of the leading particulate control techniques for industrial sources. Increasing emphasis on higher removal efficiencies has helped the baghouse to be continually more competitive when compared to other generic control devices. With the issuance of the PM 2.5 NAAQS, owners/operators of existing baghouses will have to consider fine particulate removal effectiveness when making decisions on purchasing baghouse filtration media.

Since EPA has issued a National Ambient Air Quality Standard (NAAQS) for 2.5 µm primary particulate matter (PM 2.5), *40 CFR part 50, Section 50.7*, a strong interest exists in verifying the performance of control systems for fine particulate matter (PM).

A5.2 Problem Statement

At present, there is no independent, objective test method for characterizing the performance of baghouse filter devices. Owners/operators wishing to evaluate baghouse performance rely on test information that is provided by vendors. Hence, there is a need for independently verified performance data for baghouse components. Since there are many different physical configurations that can be used in the design of a baghouse, there is a large, but limited, offering of filter media from which the bags are generally fabricated. Hence, characterization of the performance of the filter media used in bag fabrication is a more general solution, and it is amenable to less costly test designs. For this reason, testing of the filter media itself is the subject of this verification technology.

The specified test equipment makes it possible to conduct measurements under defined conditions with regard to, among other parameters, filtration velocity (G/C), dust loading, particle size distribution, and cleaning requirements. Controlled conditions make it possible for the users to make informed decisions concerning the performance of baghouse filtration media.

A5.3 Objective

Based on discussions with the BFP technical panel, the objective of the ETV Baghouse Filtration Products (BFP) program is to produce for the public credible test reports and verification statements regarding PM 2.5 (particulate matter that is 2.5 µm diameter or less) removal performance by tested baghouse filtration media. Testing will be performed according to this Test/QA Plan which responds to the specifications of the *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001)* and the SOP, Appendix C, which is derived from VDI Method 3926, Part 2, "*Testing of Filter Media for Cleanable Filters Under Operational Conditions,*" as described in section 2.3 of the generic verification protocol.

A6.0 Project/Task Description and Schedule

(The generic verification protocol provides extended discussions on project/task descriptions from which portions of the following have been extracted.)

The purpose of this Test/QA Plan is to document the detailed procedures that ETS will follow during the verification testing of baghouse filtration products. The test apparatus that will be used to determine filtration media performance, and the basic approach for determining PM 2.5 outlet concentration, is derived from VDI method 3926. The complete SOP that includes these modifications is provided in Appendix C.

A6.1 Description of the Work to be Performed

The verification test will be approximately a 5-day test to verify the performance of samples of commercially ready baghouse filtration media relative to PM 2.5. A verification test will include three identical test runs, on three separate sample specimens. Each verification test run will include a 10,000 pulse conditioning period, a 30 pulse recovery period, and a performance evaluation test period spanning 6 hours. At the conclusion of the three verification test runs the sample media performance evaluation results, in the form of a draft Verification Report and draft Verification Statement, will be prepared by ETS. ETS will submit the draft Verification Report and draft Verification Statement to the APCT Center for review and approval. The APCT

Center will submit the draft verification report and draft Verification Statement to the vendor and will incorporate changes and resolve any issues. The APCT Center will then submit the draft verification reports and draft Verification Statements to the EPA for review and approval. The APCT Center will again incorporate changes suggested by EPA and will resolve any issues that arise. The focus of the verification testing is to determine the value of the verification parameters that are listed in Section A6.1.1.

A6.1.1 Measurements that are Expected During the Course of the Project

The filtration and cleaning conditions are specified to be comparable with conditions that prevail in actual baghouse operation. Detailed measurement procedures can be found in the SOP, which is located in Appendix C.

As specified in the approved *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001)* the BFP Verification parameters will consist of:

- outlet particle concentration, PM 2.5 (g/dscm [gr/dscf]),
- outlet particle concentration, total mass (g/dscm [gr/dscf]),
- average residual pressure drop (3 seconds after cleaning pulse) during the 6-hour performance test period (cm w.g. [in. w.g.]),
- initial residual pressure drop of 6-hour performance test period (cm w.g. [in. w.g.]),
- residual pressure drop increase, determined by subtracting the initial residual pressure drop value from the final residual pressure drop value from the 6-hour performance test period (cm w.g. [in. w.g.]),
- average filtration cycle time during the 6-hour performance test period (s),
- number of filtration cycles during performance period, and
- mass gain of verification sample filter at test completion (g), (measured from new fabric filter mass, after 10-pulse cake removal, as stated in VDI method 3926).

A6.1.2 Schedule for the Work Performed

One verification test includes test runs on three identical, randomly selected media samples supplied by the manufacturer requesting the test. The testing schedule for each test run requires approximately 24 hours of LTG/FEMA apparatus operation. It commences with a conditioning period of 10,000 rapid-pulse (i.e., 3 second) cycles to simulate long term usage. Upon completion of the conditioning period, a recovery period of 30 normal (i.e., when the pressure drop across the media reaches 4 inches w.g.) pulses is initiated. Once the recovery period is concluded, a performance test period lasting 6 hours is initiated.

A6.1.3 Records and Reports

Within 30 days from the completion of the verification test, a draft verification report and a draft verification statement will be prepared by the Report Manager and submitted to the APCT Verification Center for review. The report will include, but not be limited to, a description of the test method and equipment, a summary of the test data that were recorded during the execution of the test, calibration and maintenance data, which will include which instruments are being calibrated, calibration dates, and a quality assurance section detailing all technical assessments that were performed and all quality control reports. As part of the draft report, the draft verification statement will be prepared. The statement will be a short summary of the detailed verification report. An example verification statement can be found in Appendix A of the *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001).*

For further information on records and documentation management refer to Section A9.0. Refer to section A9.2.2 and A9.2.3 for more detailed information pertaining to the verification statement and the verification report, respectively.

A7.0 Quality Objectives and Criteria for Measurement Data

Quality assurance (QA) encompasses the organization and program within which quality control (QC) activities are performed. Quality control activities accompany all verification testing activities and procedures to provide control of data quality and to quantify the quality of data resulting from those procedures. Each verification test will include QA activities as specified in this section.

A7.1 Quality Objectives

The Data Quality Objectives (DQOs) specified in Table 1 relate to each run and detail the control limits that define a valid test. A test may be invalidated due to operator error, as well as events such as breakage, equipment failure, or failure to achieve the specified DQOs. In the event that a critical measurement is invalidated, the run will be repeated on a new test sample. The decision to repeat a test run will be made by the Test-Specific Manager and the Verification Test Leader at the time of the error. A review of completeness for each test run will be made by the Test-Specific Manager in the daily test logs.

Annual calibration procedures will be performed as described in the *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001)*.

Table 1. Data Quality Objectives

Verification Parameter	Quality Objective [%]	Residual Pressure *[cm w.g.]*	Flowrate - Raw Gas Pump *[m^3/hr]*	Flow rate - Clean Gas Pump *[m^3/hr]*	Mass Gain *[g]*	Time *[sec.]*
		Measurement Objectives for Associated Critical Measurements				
Wt. gain of ref. fabric *[g]* [with respect to APCT reference value]	±40					
Maximum pressure drop *[cm w.g.]* [with respect to APCT reference value]	±40					
Mean Outlet Particle Concentration, PM 2.5 *[g/dscm]*	±15		± 0.3	±0.09	± 0.00005	
Mean Outlet Particle Concentration, Total Mass *[g/dscm]*	±15		± 0.3	±0.09	± 0.00005	
Average Residual Pressure Drop *[cm w.g]*	± 5	± 0.127				
Initial Residual Pressure Drop *[cm w.g]*	± 5	± 0.127				
Residual Pressure Drop Increase *[cm w.g.]*	±5	±0.127				
Mass Gain of Filter Sample *[g]*					± 0.05	
Average Filtration Cycle Time *[s]*	± 1					± 1
Number of Filtration Cycles	Depends on cycle time					± 1

If measurement objectives are attained, the DQOs are attained. The measurement objectives are assumed to be attained if a propagation of errors analysis is performed and all solutions are within the specified ranges. Refer to *Attaining the Quality Objectives for the Mean Outlet Particle Concentration (PM 2.5 or total)*, Appendix A, for a propagation of errors analysis. Section B.5 on quality control requirements describes the actions necessary to attain the measurement objectives.

A7.2 Measurement Performance Criteria

Table 2 presents the test specifications for the proposed test program. This table shows the acceptable levels of bias and precision needed for a valid test, along with the methods used to determine these measurements. Refer to section D4.0 for further information pertaining to accuracy (bias) and precision. For more information related to determining accuracy and precision, refer to sections D4.1 and D4.2. Accuracy is the degree of agreement of a measurement (or average of measurements) with an accepted reference or true value. Precision is a measure of instrumental mutual agreement of replicate measurements. Completeness is a measure of valid data compared to the amount that is expected under correct operating conditions. Section B.5 gives more detail on the performance criteria for individual measurements.

A8.0 Special Training Requirements/Certification

All participants of the verification test program will have completed required training courses prior to being assigned to the BFP verification test program. The results of the training programs will be maintained in the individual’s LTG/FEMA training file. The Verification Test Leader and the Test-Specific Manager have extensive experience in filtration efficiency measurements, understand filtration mechanisms that lead to particle collection in filters, are familiar with the characteristic shape of filtration efficiency curves, and are knowledgeable of particle transport in sample lines.

The Test-Specific Manager must be thoroughly familiar with operation of the specified BFP verification test apparatus, use of flow measurement devices, and operation and sampling methods associated with use of the impactor.

A8.1 Training

ETS provides two training programs that are applicable to the test program. Upon employment, each field employee is required to attend a safety training program. Once per year, ETS offers a sampling methods training course to all new employees. The 1-week program indoctrinates the employees to the basics of the most common test methods.

Table 2. Test Specifications

Constant Parameter	Nominal Value	Acceptable Bias*	Acceptable Precision**	Instrument	Frequency
Test Dust Particle Size Percentage (Pural NF)	50% <2.5 µm (Avg. 3 runs)	+40 - 10	± 0.0001 g Filter mass Gain per weighing	Andersen Impactor, Model 50-900 (as Determined by Analytical Balance)	Monthly and Each New Batch
Test Dust Mass Mean Aerodynamic Diameter (Pural NF)	1.5 µm (Avg. 3 runs)	± 1 µm	± 0.0001 g Filter mass Gain per weighing	Andersen Impactor, Model 50-900 (as Determined by Analytical Balance)	Monthly and Each New Batch
Filter Sample Diameter, mm (in.) (Exposed diameter is 140 mm, 5.51 in.)	150 (5.88)	± 1.6 (1/16)	± 1.6 (1/16)	Filter Cutter	Each Test Specimen
Total Inlet Raw Gas Flowrate, m^3/hr (cfm)	5.8 (3.4)	± 0.3 (0.2)	± 0.01 (0.006)	Mass Flow Controller	Quarterly Flow Check
Clean Gas Flowrate, m^3/hr (cfm)	1.85 (1.10)	±0.09 (0.06)	± 0.01 (0.006)	Mass Flow Controller	Quarterly Flow Check
Sample Gas Flowrate, m^3/hr (cfm)	1.13 (0.67)	± 0.06 (0.03)	± 0.01 (0.006)	Mass Flow Controller	Quarterly Flow Check
Filtration Velocity (G/C Ratio)***, m/hr (fpm)	120 (6.6)	± 6 (0.3)	± 1.2 (0.07)	Mass Flow Controller and Filter Sample Area	Each Test.
Pressure Drop Trigger for Cleaning	1,000 Pa (4.0 in. w.g)	±0.127 cm w.g (0.05 in. w.g)	± 0.127 cm w.g (0.05 in. w.g)	Pressure Transducer	Each Test.
Rapid Pulse Cleaning Cycles (0 - 10,000), sec.	3	± 1	± 1	Datalogger Clock	Beginning of Each Test
Pulse Duration, ms	50.0	± 5.0	± 1.0	Pulse Regulator	Each Test
Pulse Cleaning Pressure, MPa (psi)	0.52 (75.0)	± 0.03 (5.0)	± 0.007 (1.0)	Pulse Regulator	Each Test
Gas Temperature, ° C (°F)	(25) 77	± (2) 4	± 1	Thermocouple	Each Test
Inlet Dust Concentration, g/dscm (gr/dscf)	18.4 (8.0)	± 3.6 (1.6)	± 0.22 (0.1)	Dust Load Cell and Mass Flow Controller	Continuously
Minimum Aggregate Mass Gain for Impactor Substrate Filters, g	0.0001		± 0.00005	Andersen Impactor, Model 50-900 (as Determined by Analytical Balance)	Each Test
Charge Neutralizer				Polinium-210 alpha source	Replace Annually
Dust Feeder Operation, g/hr	100	± 20	± 20	Dust Load Cell	Each Dust Loading Operation

* Acceptable bias = For the test to be valid, the instrument reading must record a value within listed range. For example, the ±4 degrees accuracy means that the temperature reading of the gas must be within the range of 73 to 81 ° Fahrenheit.
** Precision = The precision of the instrument reading. For example the thermometer or thermocouple that is used to measure temperature must record temperature within 1 degree of actual.
*** Filtration Velocity (G/C) = Clean Gas Stream Volume / Exposed Area of Filter Sample =1.10 cfm / 0.166 ft^2 = 6.6 fpm = 1.85 m^3/hr / 0.01539 m^2 = 120 m/hr

Training also includes orientation to the data sheets and equipment available at ETS. Each employee is informed of the ETS policies and procedures to ensure that accurate and complete test data are obtained. Each operator is given a training manual that includes sample data sheets, and ETS policies and procedures.

In addition, all personnel who will be operating the test apparatus must complete a 16-hour LTG/FEMA operation training program by a LTG representative or an appropriate ETS designate, three successful 30-cycle reference media tests, as stated in the Generic Verification Protocol Section 2.4, and one complete verification test run (one conditioning period, recovery period, and performance period) using the reference media and reference dust prior to being considered a qualified LTG/FEMA apparatus operator.

A8.2 Certification

ETS, Inc. has submitted its baghouse filtration products quality management plan to comply with the requirements of the *American National Standard, Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (ANSI/ASQC E4-1994)*. ETS' quality management plan was submitted on June 18, 1999, and is on file with the APCT Verification Center. ETS, Inc. also complies with the APCT and EPA Quality Management Plans. ETS may be audited at any time by EPA, its representatives, or the APCT Verification Center to ensure compliance with these documents and that all requirements are met.

There is no special certification that the ETS testing staff must obtain prior to operating the LTG/FEMA apparatus. However, the testing staff must complete the training requirements listed in section A8.1 prior to operating the test apparatus.

A9.0 Documentation and Records Management

Proper documentation and recordkeeping is critical to ensure quality data. The proper reporting format, combined with data validation, facilitates investigation into the quality of the data and of the report and statement generated for the project. All verification reports and verification statements will be submitted to the APCT Verification Center in electronic format (WordPerfect). All records and documents will be maintained at ETS for 7 years from the date of final payment from the APCT Center Office.

A9.1 Data Reporting Packages

Specific documentation and recordkeeping requirements for this project are separated into test operation records and data handling records.

A9.1.1 Test Operation Records

The following test operation records will be an integral part of the test program.

- **Chain-of-Custody Records** - Chain-of-custody sheets will be completed to allow tracking of the samples from collection through verification test completion. This action minimizes any chance of sample loss or possibility of sample tampering.

- **Material Safety Data Sheets** - MSDS documentation for the reference dust will be kept on file at the test apparatus site.

- **Daily Test Logs** - Accurate and complete logs will be kept on all daily activities. The LTG/FEMA operator is responsible for completing the logs. These logs document all activities, and include sampling times, process delays, equipment failures, any deviations from this Test/QA Plan or standard testing practices and procedures, and all quality control measurements that were conducted. The operator records test data and notes on daily test logs prepared specifically for these tests (presented in SOP, Appendix A). The sheets are designed to prompt the test operator for all required test information:

  - Testing date, time, and operator.
  - Manufacturer and model number of filter samples.
  - QA checks on the equipment and data.
  - Test conditions (temperature, relative humidity, atmospheric pressure).

  The Test-Specific Manager is responsible for reviewing the daily test logs for completeness and verifying that all information has been included.

- **Sample Label** - Sample labels will be applied to all samples that are accepted for the verification test. Sample labels will be applied to track sample testing and to minimize chance of possible loss and mixup.

- **Record-of-Consumables** - The record-of-consumables will track the quantities of consumable items that will be used in the verification test, the expiration date (if applicable), and the required consumable test dates.

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- **Inspection/Acceptance Requirements** - The Inspection/Acceptance Requirements form for critical supplies and consumables will track the test requirements, frequency, and acceptance status of the reference materials and dust. This form will also record the storage condition for each material.

- **Log for Tracking Supplies and Consumables** - The log for tracking supplies and consumables will contain the arrival dates of all consumable items, the required testing for each item, and the expiration date (if applicable).

A9.1.2 Data Handling Records

Specific measures will be used to track and ensure the generation of quality data. These records will convert raw data into reportable quantities and units, incorporate proper use of significant figures, and provide data validation to show that QC criteria have been met.

- **Daily Test Logs** - All hand-recorded data will be recorded using indelible ink. A single line will be drawn through recording errors and initialed by the responsible person. Standardized spreadsheets will be used to create computer generated test results.

- **Data Review Records** - The test logs are released to the report manager at the conclusion of the test program. The test files are reviewed by the report manager, any errors are corrected, and the files are given a unique file identification under a standardized identification system. Each verification test series will be labeled with a file number identifying the test specific identification. For example, V004-R1.

  The appropriate laboratory data are entered into electronic spreadsheets, the results reviewed for reasonableness, and the files saved. Two copies of the documents will be created. One copy will be maintained at ETS in a fireproof cabinet, and a second copy will be sent to the APCT Verification Center Quality Manager for BFP Verification Testing for storage.

- **QA/QC Data Records** - The Report Manager and Test-Specific QAO review the data and examine any data discrepancies or outlying data points. Any corrective actions are recorded and documented. The Internal QAO hand-calculates one data set from the performance test period and compares it to the computer generated spreadsheets for accuracy. This calculation check is included in the final data package. A comparison of the quality control measurements with the data quality objectives is also performed and included in the final data package.

A9.2 Data Reporting Package Format and Documentation Control

The verification statement will be that found in Appendices A of the *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001).* The contents of the supporting data reporting packages will be consistent with the requirements and procedures used for data validation and data assessment described in this Test/QA Plan. All records taken to achieve the objective of the project and the QA performance functions will be components of the data reporting packages.

A9.2.1 Document Control

All test documents will remain the responsibility of the Test-Specific Manager from their generation until their release to the Report Manager. The Report Manager is responsible for and should be aware of the location of all documents from test completion until the draft report is completed.

The draft verification report and draft verification statement are reviewed at ETS by the BFP Task Leader, the Verification Test Leader, the Test-Specific QAO, the Test-Specific Manager, and the Report Manager. Following release by ETS to APCT Center, the draft verification report and draft verification statement are sent by APCT Center to the manufacturer for comment. Once issues and comments from the manufacturer have been resolved, the draft verification report and draft verification statement are reviewed by the APCT Verification Center, including the APCT Center Task Leader, the APCT Center BFP Quality Manager, the APCT Center Quality Manager, and the APCT Center Director. Once APCT Center issues have been resolved the APCT Center Task Leader will send the draft verification report and draft verification statement to the EPA Project Manager and EPA Quality Manager for review and approval. The final Verification Statement will be signed by the Director of EPA's National Risk Management Research Laboratory. Two copies of the verification report and verification statement will be archived. The original copy of the draft report and statement will be stored at ETS in a fireproof cabinet in a limited access storage room. All computer files, spreadsheets, figures, tables, schematics, and report texts will be archived in this room. The finalized copy will be stored at the APCT Verification Center for storage. A second finalized copy will be sent to ETS for storage as well. Computer files are generally kept on the ETS network for 6 months after the conclusion of the test program. All archived files and reports will be kept in ETS' custody for a minimum of 7 years after the final payment of the assistance agreement between ETS and the APCT Center.

A9.2.2 Verification Statement

The Verification Statement, which is a brief summary of the verification test report, will include the following information:

- Product manufacturer,
- Model or style number,
- Brief description of tested filter media,
- Test date and location,
- Testing firm,
- Summary test conditions
- Outlet particle concentration (PM 2.5 and total mass),
- Average residual pressure drop during performance test period,
- Initial residual pressure drop of 6-hour performance test period
- Residual pressure drop increase during performance test period (final - initial),
- Average filtration cycle time during performance test period,
- Mass gain of sample media at test completion,
- Number of cleaning cycles during 6-hour performance test period, and
- Non-standard test conditions (if applicable).

The verification statement will also include a statement that the APCT Center BFP Quality Manager has reviewed the test results and the QC data and has concluded that the data quality objectives given in the generic verification protocol have been attained.

A9.2.3 Verification Report

The Verification Report is a fully documented test report containing a complete description of the test method and equipment, and the results of all measurements. The report will also contain any QC and QA activities that are relevant to the specified verification test. The Verification Report will include:

- All test specimen information, as stated in Verification Statement, plus
- Data from the reference media,
- Test data result spreadsheets ,
- Results of control tests,
- Quality assurance results,
- Equipment calibration data,
- Comparison between DQOs and test results, and
- Deviation from the approved generic verification protocol (requires APCT approval).

In addition the Verification Report will include all test conditions and operational data including, but not limited to, gas velocity, gas volume, cleaning pressure drop trigger, and relative humidity.

The Verification Report will also provide an overview of the test methods employed, facilities, and equipment used. Data will be presented in a format to permit ready comparison with DQOs. A discussion of problems encountered and an explanation of how these problems were resolved will also be included.

After review of the test results and QC data presented in the draft verification report, the APCT Center BFP Quality Manager will prepare a QA section for inclusion in the report regarding the attainment of the data quality objectives. ETS, Inc. will maintain one copy of all archived files and reports for a minimum of 7 years after the final payment of the assistance agreement between ETS and the APCT Verification Center. All ETS documents that pertain to the verification tests will be maintained on the ETS premises in a fireproof cabinet. The original report copy will be kept at the APCT Verification Center for storage.

An example copy of the Verification Statement is included in Appendix A of the *Protocol for Verification Testing of Baghouse Filtration Products*.

A9.2.4 QA/QC Reports

All control test data, sample inventory logs, calibration records, and certificates of calibration will be stored in a location that is deemed appropriate by the Test-Specific Manager at the ETS facility. The location will ensure that the documents are easily available for reference during calibration, control check, and inventory periods. Calibration records will include such information as the instrument being calibrated, raw calibration data, , calibration dates, and staff conducting the calibration.

Final reports of self-assessments and independent assessments (i.e., technical systems audits, performance evaluations, and audits of data quality) will be retained in the APCT Verification Center with a duplicate copy kept at ETS. Each verification report and verification statement will contain a QA section, which will describe the extent that verification test data comply with data quality objectives.

PART B. MEASUREMENT/DATA ACQUISITION

B1.0 Process Design

Table 1 lists the critical measurements that are associated with the BFP verification test. Critical measurements are required to achieve project objectives. Table 2 identifies the BFP verification test conditions. The BFP test conditions must be met and maintained to perform a valid test series.

B1.1 Test Apparatus

The BFP test apparatus provides an appropriate baghouse filter media test environment. This equipment allows the user to conduct measurements of filter performance under defined conditions with regard to the filtration velocity (Gas-to-Cloth ratio, G/C), particle size distribution, and cleaning requirements. Filtration and cleaning conditions can be varied to simulate conditions that prevail in actual baghouse operations.

The test apparatus (see Figure 2) 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). Two vacuum pumps maintain air flow through the raw-gas and clean-gas channels. During the performance test period only, the clean-gas flow shall be separated into two gas streams, a sample stream and a sample bypass stream. The sample stream will be aerodynamically diverted into an Andersen impactor for measurement. 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 initial, final, and 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 the Appendix C, SOP, section 4.4.1. 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.

B1.2 Test Design

Each Verification Test consists of three test runs. Each test run consists of three sequential phases or test periods: a conditioning period, a recovery period, and a performance test period. The G/C and inlet dust concentrations are maintained at 120 ± 6 m/hr (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.

To simulate long-term operation, the test filter is 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 to recover from rapid pulsing. The recovery period consists 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 in. w.g.) is reached. At this point, the test filter is cleaned by a pulse of compressed air from the clean-gas side. Immediately after pulse cleaning, the pressure fluctuates rapidly inside the test duct. Some of the released dust immediately re-deposits onto the test filter. The pressure then stabilizes and returns to normal. Thus the residual pressure drop across the test filter is measured 3 seconds after the conclusion of the cleaning pulse. Pressure drop is monitored and recorded continuously throughout the filter media recovery and performance test periods of each test run.

Performance testing occurs for a 360-minute 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 dust loading. Outlet mass and PM 2.5 dust concentrations are measured using an inertial impactor located downstream of the test filter at the end of the horizontal (clean-gas) duct. The impactor consists of impaction stages needed to quantify total particulate matter and PM 2.5 concentrations. The weight gain of each stage's substrate is measured with a high resolution analytical microbalance capable of measurement to 0.00001 g. Refer to Appendix C, SOP, for detailed verification test sampling procedures.

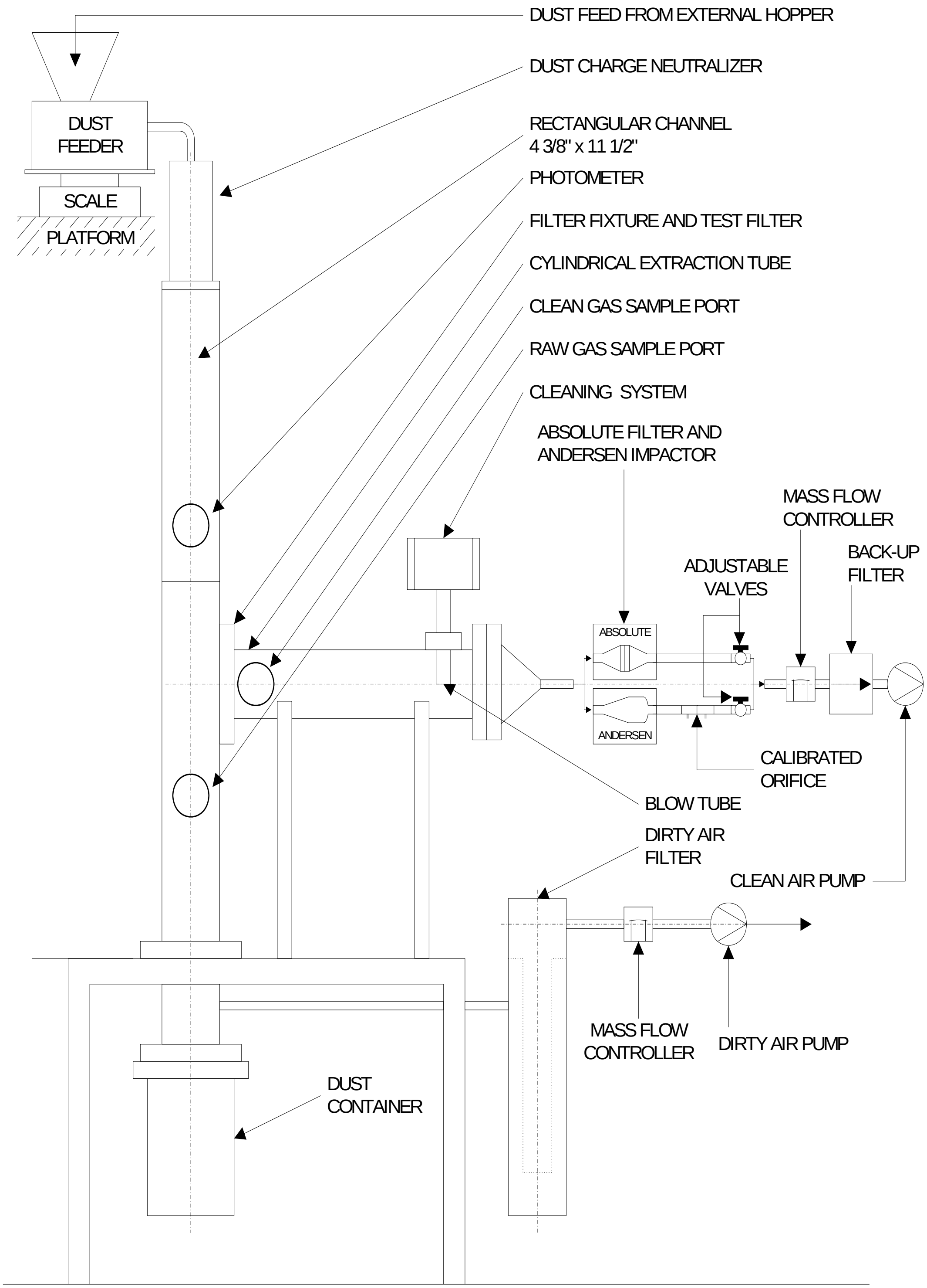

Figure 2. LTG/FEMA Test Apparatus

B2.0 Sampling Methods Requirements

B2.1 Filter Media Samples

Verification test filter media samples will be supplied directly to ETS, Inc. from the manufacturer. The samples will be accompanied by a letter signed by the manufacturer's CEO, president, or other responsible corporate representative, attesting that the media samples were randomly selected as to production run and roll location and are representative of what is supplied to the commercial market. Included in the signed letter will be a description of how the samples were selected. The manufacturer will supply ETS, Inc. with nine samples (46 x 91 cm [18 x 36 in.]); from these ETS, Inc. will select three samples to prepare test specimens. A chain-of-custody form will be filled out when the samples are received by ETS.

For purposes of product identification (by, for example, ETS, Inc., auditors, end-users, and local inspectors), the manufacturer must label or tag the filter media in a reasonably permanent manner to show the name of the manufacturer, type of filter media, all applicable model numbers pertaining to the sample, cake side, and date (year and month) of manufacture; if this information is not present, ETS, Inc. will reject the media for BFP verification testing.

B2.2 Impactor Filter Samples

Impactor samples will be purchased from the impactor manufacturer. Each impactor substrate filter will be stored in aluminum foil and preweighed according to the procedures detailed in the SOP. Each piece of aluminum foil will be labeled to match its corresponding substrate filter. Each label will be made with permanent marker directly on the foil to avoid extra label weight.

B3.0 Sample Handling and Custody Requirements

A key issue in the verification process is the integrity of the sample tested. The goal of sample preparation and management is to ensure that proper sample custody and management practices are implemented to respond to this issue. Sample preparation consists of providing the proper test specimen for verification testing purposes. Sample management is the overall process by which samples are controlled, transferred, handled, and stored from the time of collection through analysis. Sample management refers to those activities aimed at ensuring sample integrity. Chain-of-custody involves establishing accountability for the sample, documenting how the sample is received, tracked, and stored, and defining who has access to the samples and who handles the samples.

- **Sample Chain-of-Custody** - The purpose of sample chain-of-custody is to ensure the traceability of the handling and possession of each sample from the time of collection through the completion of analysis. The following information is requested when samples are shipped to ETS: ETS' name and address, sample identification and letter of sample integrity as described previously in Section B2.0, and test that will be conducted.

A log generated by the Test-Specific Manager is utilized for chain-of-custody. Examples of a chain-of-custody record can be found in Appendix B.

- **Sample Labels** - Exclusive test method sample labels are generated for each incoming sample. These labels must be used on each sample and will be used in sample number order to avoid confusion on a test job. Labels for the impactor filters are written with marker directly on the storage foil so that measurements do not include additional label weight.

B4.0 Analytical Methods Requirements

To simulate dust loading conditions within a baghouse ETS will be using the procedure specified in Appendix C. The performance of the fabric will be determined relative to the verification parameters listed previously in Section A6.1.1.

B4.1 Materials and Apparatus

The required materials that will be used to perform an accurate and valid test are listed below. Any substituted equipment will be comparable to the equipment and performance requirements of the following list and will receive APCT Center approval prior to verification testing and will also be noted in the verification report. For greater detail pertaining to the following equipment, refer to Appendix C, which contains the verification test SOP.

The LTG/FEMA test apparatus, based on the German VDI method 3926, provides an appropriate baghouse filter media test apparatus. This equipment allows the user to measure filter performance under defined conditions with regard to the filtration velocity (G/C), particle size distribution, and cleaning requirements. Filtration and cleaning conditions can be varied to simulate conditions that prevail in actual baghouse operations. For a discussion of components within the test apparatus, refer to section B1.1. For a list of equipment makes, model numbers, and ranges proceed to Table 3.

B4.1.1 Test Apparatus

ETS will perform the BFP verification tests using the specified LTG/FEMA test apparatus. The APCT Center-approved components used with the BFP test apparatus consist of the following items:

- Electronic data logger or programmable logic controller.
- Dust feed weight measurement device.
- Dust feed hopper.
- Thermocouple.
- Pressure transducer.
- Removable clean gas channel.
- Manual pulsing function.

- Test dust (aluminum oxide).

B4.1.2 Test Dust

ETS has obtained Pural NF as the verification test dust to comply with the requirements specified in the *Generic Verification Protocol For Baghouse Filtration Products (October 8, 2001)*. The shipment of Pural NF will be tested for conformance with requirements of the generic verification protocol. The Pural NF must conform to the specification of greater than 99.6% Al_2O_3 content, a mass mean aerodynamic diameter of 1.5 ± 1.0 µm, and a particle size weight percentage of 50% (+40 -10 %) less than 2.5 µm, as determined by the average of three Andersen impactor test runs performed with the test conditions specified in the generic verification protocol, Table 2. The impactor will utilize all five of the manufacturer designed particle size separation stages above the 2.5 µm stage. The stages that capture particles larger than 2.5 µm are used as a filter to prevent larger particles from removing smaller particles in the succeeding stages.

B4.1.3 Analytical Balances and Associated Equipment

- Low resolution analytical balance for sample filters.
- High resolution analytical balance for impactor filter stages.

B4.1.4 Calibration Weights and Associated Equipment

- Dust feed scale.
- Aluminum foil.
- Permanent marker for labeling.
- Tweezers.
- Humidity- and temperature-controlled work space.
- Recovery brush.
- Continuous temperature and humidity monitor with data-logging capabilities.

B4.1.5 Impactor, Collection Substrates, and Associated Materials

- Andersen model 50-900 impactor.
- Collection substrates.
- Acetone.
- Wash bottles.

B4.1.6 Absolute Filter Assembly With Untared Filters

- Absolute filter assembly with untared filters.
- Paraffin film or Teflon tape.

Table 3. Test Apparatus Equipment

Component	Make	Model Number	Performance Capability
Optical Photo Sensor	Sick Optic Electronic	FW 56-D/T	± 0.4 %
Impactor	Andersen	50-900	
Mass Flow Controllers	Hastings Instruments	HFC-202	0 to 12 m^3/hr (0 to 7.1 ft^3/min.) ± 1 %
Dust Feeder	Sensor Techniques Limited	NDF 100	20 to 200 g/hr (0.044 to 0.44 lb/hr)
Thermocouple	LTG GmbH	"K" Type	0 to 250 °C (32 to 482 °F)
Pressure Transducer	Hastings Instruments	223DB-00010AABS	0 to 2000 Pa (0 to 0.29 psi) ± 0.5 %
High Resolution Analytical Balance	Precisa	262SMA-FR	0.00001 g
Low Resolution Analytical Balance	Mettler	P 1210N	0.0001 g
Absolute Filter	Andersen Instruments, Inc.	50-31 (0 or 2)	99.99 %
Temperature and Humidity Monitor	ACR Systems, Inc.	Smart Reader 2	-20 to 40 °C (-4 to 104 °F) ± 10 % RH
Vacuum Pump	Rietschle	VLT 15	15 m^3/hr (ft^3/min.)
Barometer	Princo	Nova Full Range Mercurial	636 to 838 mm Hg (25 to 33 in. Hg).

B4.1.7 Ambient Humidity and Barometric Pressure Measurement Devices

- Barometer.
- Sling psychrometer.
- Ambient humidity measurement monitor.

B4.2 Procedures

Detailed procedures are provided in the attached SOP, Appendix C. Prior to loading the sample filter, the LTG/FEMA test apparatus must be set at a G/C of 120 m/hr (6.6 fpm) and a dust loading of 18.4 g/dscm (8.0 gr/dscf). Before the performance evaluation test can be performed, the sample filter media must be subjected to a conditioning period consisting of 10,000 rapid pulses and a recovery period consisting of 30 pulses at normal test conditions. The sample filter and the absolute filter are loaded into the LTG/FEMA test apparatus, and a sufficient amount of test dust is placed in the dust feed hopper (see Appendix C, SOP section 3.2 for detailed dust amount requirements). Once the LTG/FEMA test apparatus has been prepared, the sample filter media will be subjected to 10,000 rapid pulses at 3-second intervals. The dust loading and the G/C will be calculated on a block average for each 60 consecutive minutes during the test and for the last 60 minutes of each test. The parameters as listed in SOP section 4.4.1 must be measured and recorded to confirm that the conditioning period requirements are maintained.

The recovery period will be a continuation of the conditioning period, except the pulse filtration frequency will be reduced to normal pulse frequency, determined by the 1,000 Pa (4.0 in. w.g.) residual pressure drop. The recovery period does not have to be run immediately after the conditioning period, but the test apparatus and the sample filter must remain unchanged and untouched.

Prior to the commencement of the performance test, the dust must be replenished within the dust feed hopper (see SOP section 3.2), and the impactor must be inserted into the LTG/FEMA test apparatus. The performance test will be performed using normal pulse filtration cycles as required in the recovery period. The performance test will be run for 360 continuous minutes. The recording requirements, as listed in the attached SOP, sections 4.4.1 and 4.4.3.2, will continue to be followed during the performance test period.

If the G/C and the dust loading requirements are not maintained throughout the performance test period, the test will be voided and will be repeated using a new filter sample.

Refer to the SOP, Appendix C, for detailed step-by-step procedural directions.

B5.0 Quality Control Requirements

Data quality objectives and test specifications are shown in Tables 1 and 2, respectively. The quality control limits are specified in Table 4. The means of measuring and verifying the attainment of the data quality objective, and corrective actions that will taken if needed, are discussed below for each item.

B5.1 Test Dust Particle Size Percentage and Mass Aerodynamic Diameter

The mass mean diameter and particle size distribution of the test dust will be measured monthly (or with each new shipment). The determination will be made by the average of three Andersen impactor runs conducted on the raw-gas channel upstream of the test filter. The values obtained from these dust particle size checks will be accumulated in spreadsheet form to allow construction of trend lines with all accumulated data.(see Appendix C, sections 4.3.3 and 4.3.4 for testing procedures).

In the event the mass mean diameter and weight percent <2.5 μm do not meet the criteria specified in Table 2, the APCT Center will be notified and testing will be suspended until corrective action is taken.

B5.2 Filter Sample Diameter

Procedures for the filter sample preparation are detailed in Appendix C, section 4.2. The procedure for cutting the filter sample is to use the test apparatus sample clamping ring as a template for cutting. This is a go/no-go procedure, samples cut either too small or too large are unusable.

B5.3 Flow Rates (Raw Gas, Sample Gas, and Clean Gas)

The raw-gas, sample-gas, and clean-gas flow controllers will be calibrated quarterly against a dry gas meter as described in section B7.3. The dry gas meter will be calibrated annually by the manufacturer.

B5.4 Gas Temperature

The thermocouple is calibrated quarterly against an ASTM mercury-in-glass thermometer. The thermocouple must agree with the reference thermometer to within ± 1 °F.

B5.5 Inlet Dust Concentration

The dust feed weight cell is calibrated prior to each test series. The calibration is conducted by placing a 2-3 kg NIST-traceable span weight in the weigh hopper prior to each test series. In addition the dust concentration is measured in the raw gas channel. This measurement is made in conjunction with impactor tests described in section B5.1.

B5.6 Weight Gain of Reference Fabric and Maximum Pressure Drop

Once each quarter the test apparatus is calibrated against the APCT supplied reference fabric employing the test dust and test conditions as used for the verification tests. The calibration procedures will comply with those described in section 2.4 of the *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001)* and consists of three 30 cycle reference fabric test runs. As specified in Table 1, the weight gain of the reference fabric and the maximum pressure drop recorded on each of the three reference value test runs must fall within ±40% of the weight gain and maximum pressure drop averages of the APCT reference values. Specifically,

$$0.65\ \text{g} \le \text{mass gain} \le 1.60\ \text{g}$$

$$0.35\ \text{cm w.g.} \le \text{pressure drop} \le 0.85\ \text{cm w.g.}$$

If these criteria are not met, all verification testing is stopped, the APCT Center is notified, and corrective action is taken.

B5.7 Mean Outlet Particle Concentration (PM 2.5 and Mass)

Quality Control procedures for the calibration, inspection, and operation of the test apparatus are described in sections B5.0 - B7.0 of this Test/QA Plan. In addition, procedures for proper pre-test, test, and post-test impactor are described in Appendix C, sections 4.2 - 4.2.3, 4.4.3.1, and 4.5 - 4.5.2. If all of the above procedures are followed, the DQO of ± 15% for these parameters is satisfied.

B5.8 Initial, Final, and Average Residual Pressure Drop Across the Sample

The residual pressure drop across the filter sample is measured 3 seconds after the conclusion of the cleaning pulse (once per filtration cycle). It is monitored and recorded continuously throughout the recovery and performance periods of each test. The pressure transducer is calibrated annually by the manufacturer and is checked against an oil manometer, Dwyer model 424-5, 0.1-in. with accuracy of ± 1%, prior to each test series.

B5.9 Average Filtration Cycle Time

The time between filtration cycles is monitored and recorded continuously throughout the recovery and performance periods of each test. The timer clock is calibrated quarterly to NIST time. If the timer clock is not within 1-second agreement with the NIST signal over a 1-hour period, the timer clock is replaced with a unit that maintains 1-second agreement with the NIST signal over a 1-hour period.

Table 4. Data Quality Limits

Parameter	Frequency and Description	Control Limit
Test Dust Particle Size Percentage	Monthly and each new shipment	+40 - 10 %
Test Dust Mass Mean Aerodynamic Diameter	Monthly and each new shipment	±1.0 µm
Filter Sample Diameter	Each test specimen	± 1.6 mm (0.063 in)
Inlet Raw-Gas Flow rate	Each test run	± 0.3 m^3/hr (0.18 ft^3/m)
Filtration Velocity	Each test run	± 6 m/hr (0.3 ft/m)
Gas Temperature	Raw gas temperature measured each test run	± 2 °C (4 °F)
Inlet Dust Concentration	Raw gas dust concentration measured each test series	± 3.6 g/dscm
Weight Gain of Reference Fabric	Quarterly	± 40 %
Maximum Pressure Drop (with respect to reference fabric)	Quarterly	± 40 %
Mean Outlet Particle Concentration PM 2.5 (g/dscm)	Each test run	± 15 %
Mean Outlet Particle Concentration Mass (g/dscm)	Each test run	± 15 %
Average Residual Pressure Drop Across Sample (cm w.g.)	Each test run	± 5 %
Initial Residual Pressure Drop (cm w.g.)	Each test run	± 5 %
Residual Pressure Drop Increase (cm w.g.)	Each test run	± 5 %
Average Filtration Cycle Time (sec.)	Each test run	± 1 %

B6.0 Instrument/Equipment Testing, Inspection, Maintenance

As part of each test series, tests are performed to assess the reliability and accuracy of the test apparatus. In compliance with the BFP generic test protocol section 2.4, quarterly testing using the reference fabric is conducted to verify the accuracy of the pressure drop transducer and the dust feed rate. Prior to each test series the appropriate instrument settings necessary to achieve the test specification filtration velocity and dust feed rate are determined by physically measuring the gas flow, and calibrating and monitoring the dust-feed load cell. In addition, a dust-feed check consisting of three dust characterization tests will be performed monthly to confirm the concentration and dispersion of dust in the raw-gas channel. These procedures are detailed in Appendix C, Standard Operating Procedures. Should any of these checks not meet the specified criteria, testing is stopped until corrective adjustments are made and re-inspection meets the criteria.

Periodic preventive and corrective maintenance is conducted according to manufacturer's instructions on apparatus and equipment components such as the compressed air system, raw- and clean-gas pumps, and the dust feed system.

B6.1 Equipment Inspection and Maintenance

An effective preventive maintenance program is a necessary step in ensuring quality data. Before each test series the equipment is inspected and its components are cleaned, repaired, reconditioned, and recalibrated when necessary.

Occasional equipment failure is unavoidable despite the most rigorous inspection and maintenance procedures. For this reason, ETS keeps spare equipment for critical testing components.

B7.0 Instrument Calibration and Frequency

Calibration will be performed as outlined in Table 5. In addition to these calibrations, a series of calibration checks are conducted on each instrument at least on a quarterly basis and in many cases prior to each use.

Sections B7.1 through B7.9 provide the calibration check procedure and frequency of checks for each instrument.

If no testing is being performed within the BFP verification program, no calibrations will be performed. Prior to the recommencement of any BFP verification testing, calibrations on all required equipment will be performed.

B7.1 High Resolution Analytical Balance

The high resolution analytical balance will be calibrated by a factory service representative on an annual basis. Prior to each use, the balance will be calibrated using the zero and span functions of the balance. A calibration check will be performed prior to each use using the 1 g calibration weight plus the clean substrate and the aluminum foil it is wrapped in. The tare weight of the clean substrate/aluminum foil is approximately 750 mg. Typical substrate weight gains after testing are expected to range between 1 and 4 mg. The balance should read to calibration weight to within 0.00005 g. If not, repeat the procedure or adjust the balance until the value is obtained.

B7.2 Low Resolution Analytical Balance

The low resolution analytical balance will be calibrated by a factory service representative on an annual basis. Prior to each use the calibration will be checked using the 100-g span weight. The balance should display within 0.05 g of the NIST-certified calibration weight. If not, repeat the procedure or adjust the balance until the value is obtained.

B7.3 Flow Meters and Flow Controllers

The dry gas flow meter will be calibrated annually by the instruments manufacturer. Quarterly calibration checks will be conducted at a single point corresponding to the verification test specification air flows for each instrument. The clean-gas flow instrument will be calibrated at a flow of 1.10 ± 0.06 cfm (flow rate equivalent to a filtration velocity of 6.6 fpm). The raw-gas flow instrument will be calibrated at a flow of 2.32 ± 0.1 cfm. The raw gas flowrate and the clean gas flowrate will equal the total inlet raw gas flowrate of 3.4 ± 0.2 cfm. The sample-gas flow instrument will be calibrated at a flow of 0.67 ± 0.03 cfm. Each calibration will be conducted for a minimum of 10 minutes. A calibration factor will be used to adjust the measurement to that of the wet test meter. If the pretest check deviates by more than 3 %, the flow controller must be re-calibrated.

B7.4 Pressure Transducers

The pressure transducers will be calibrated annually against a reference pressure standard that has been certified against NIST-traceable standards within the past year. Prior to each test series each pressure transducer will be checked against an oil manometer to within 0.25 cm w.g. (0.1 in. w.g.). The pressure transducers will be calibrated at three points, zero, span, and at a pressure typically encountered during the verification tests.

B7.5 Barometric Pressure Transducer

If a barometric pressure transducer is used, it will be calibrated prior to each test against the mercury-in-glass barometer.

B7.6 Thermocouple in Raw-Gas Channel

The thermocouple will be calibrated quarterly against an ASTM mercury-in-glass reference thermometer at 77 ± 4 °F.

B7.7 Continuous Humidity and Temperature

This instrument will be returned to the factory for annual calibration with NIST traceability.

B7.8 Timer Clock

The timer clock should be calibrated quarterly to NIST time, which is obtained from the WWV radio reference signal or from the NIST World Wide Web site, *www.boulder.nist.gov/timefreq/*. If the timer clock is not within 1-second agreement with the WWV or website signal over a 1-hour period, the timer must be replaced with a unit that meets calibration requirements.

B7.9 Dust-Feed Weight Cell

This Instrument will be calibrated prior to each test series. The calibration will be conducted with the dust-feed hopper empty, and placing a 2 kg span weight into the weigh hopper. Calibration weight must meet ASTM class 4 with a NIST/NVLAP-traceable certificate.

Table 5. Instrument Calibrations and Frequency

Instrument	Calib. Frequency	Calibration Method
Low Resolution Analytical Balance	Annual	Factory calibration with NIST-traceable standards.
High Resolution Analytical Balance	Annual	Factory calibration with NIST-traceable standards.
Dry Gas Flow Meter	Annual	Factory Calibration
Pressure Transducers	Annual	Against reference pressure with NIST traceability
Barometric Pressure Transducer	Prior to each use	Against mercury-in-glass barometer
Thermocouple	Quarterly	Against ASTM mercury-in-glass reference thermometer
Continuous Humidity and Temperature	Annual	Factory calibration with NIST traceability
Timer Clock	Quarterly	Calibrate to NIST time
Dust Feed Weight Cell	Prior to each test series	NIST certified span weights

The above calibrations will be recorded for inclusion in the Verification Report.

B8.0 Inspection/Acceptance Requirements for Supplies

The Sample/Equipment Manager will receive reference filter media from the APCT Center . The APCT Center will include a letter attesting that the fabric is identical to the components that were identified in the generic verification protocol. The ETS Sample/Equipment Manager is responsible for maintaining an adequate supply of all other consumable products, including but not limited to, reference dust, absolute filters, impactor substrate filters, and acetone. The Sample/Equipment Manager will verify the manufacturer's information (type, model number, style, etc.,) for consistency and correctness. A supplies log and a chain-of-custody record will be filled out and the correspondence from the APCT Center and other manufacturers will be marked accepted and retained on file.

B9.0 Data Acquisition Requirements (Non-Direct Measurements)

Any data or reference source that is required while determining the verification parameters or compiling the Verification Report, that is not a measured value, will be disclosed within the Verification Report. The reference will include all pertinent information, including the reference source title, section, and important information taken. This requirement includes databases that might be used, programs, literature, and files. All existing data must meet the same quality assurance requirements as are applicable to data generated during the verification tests and must be generated independently from the sample media manufacturer as stated in the ETV quality manual, Appendix C.

B10.0 Data Management

Interim stages of data review and validation will be provided for several key points in the process to minimize revisions if corrections or changes are needed.

Test data will be input into computer spreadsheets following testing. Process data will consist of logs and continuously monitored data. Data will be reduced and analyzed using computer spreadsheets.

B10.1 Data Flow

All testing, data generation, and data analysis are performed within the ETS building. All data is acquired in real time. The following shows the flow of data from its origin in the test laboratory to final storage.

A. Data origination in test laboratory:

Data generated by the LTG/FEMA apparatus:

- Read in real time by a data acquisition computer located at the test rig.

· Temperature.
· Air flow, raw gas, and filtration velocity.
· Filtration cycle time.
· Residual pressure drop.
· Maximum test pressure drop [1,000 Pa (4.0 in. w.g.)].
· Dust feed rate.
· Dust feed concentration stability (photometer)

Data generated manually or by observations:

- Readings are recorded manually on a test run sheet.

· Relative humidity.
· Atmospheric pressure.
· Impactor weight gains.
· Filter specimen weight gain.

B. Inspection of LTG/FEMA data for acceptance at the test site:

After each verification test, the data from the LTG/FEMA data acquisition computer are transferred to a CD labeled with the corresponding test number.

The LTG/FEMA data from the CD is loaded into a spreadsheet program template. The spreadsheet program computes the sample's verification parameters that will be reported in the verification report.

The spreadsheet program is saved to the network and then to a diskette, using the designated test number, to be filed in the data package.

C. Spreadsheets:

Two main spreadsheets are used during data reduction. A data analysis spreadsheet is used to analyze the data from each individual run. There is a data analysis spreadsheet for each of the conditioning, recovery and performance test period. An impactor analysis worksheet is included as part of the performance test spreadsheet to determine impactor data. A data summary spreadsheet is used to combine the results from the triplicate tests and their associated control tests, and to record verification parameter results. Further details pertaining to the spreadsheets, spreadsheet equations, and example spreadsheets are located in the attached SOP, Appendix B.

D. Draft Report Preparation:

The test run sheets are delivered to the Report Manager. The Report Manager inspects the test run sheets for completeness; if there are any omissions, the Report Manager immediately follows up with the Test-Specific Manager to fill in any missing information.

Following the formats for the verification statement and report, as specified in the generic verification protocol, the Report Manager prepares these documents.

The Report Manager will inspect all results for reasonableness and correctness relative to test number, date and times of samples, and sample identification.

The Report Manager will maintain the data package in an appropriate storage area as specified in Section A9.2.1.

E. Long-term Storage:

The original copy of all verification test data, calibration data, certificates of calibration, assessment reports, verification reports, and verification statements will be retained by ETS for a period of not less than 7 years after the final payment of the assistance agreement as per Part A, Section 5.3 of the ETV QMP. A duplicate copy of the verification reports and verification statements will be sent to the APCT Center Office for storage.

B11.0 Reporting

Upon completion of testing, the Report Manager will be responsible for compiling the data summary into a Verification Report. The results of the test program will be evaluated for completeness and representativeness and will include all valid data collected. The report will be submitted in electronic form to the APCT Task Leader within 30 days after completion of sampling. Data and results interpretations will be presented as necessary in the report. The report will contain all items specified in Section 4.0 of the generic verification protocol including but not limited to the following sections:

A: Title Page. The title page includes the client's name, ETS' laboratory information, the client's location and company information, and the date(s) on which the testing was conducted.

B: Table of Contents. The table of contents contains an outline of the test report and page numbers on which the sections appear.

C: Figures & Table. The figures and tables page contains a listing of all figures and tables located throughout the report including corresponding page numbers.

D: List of Abbreviations & Acronyms. A list of all acronyms and abbreviations located throughout report and their definitions.

E: Introduction. The introduction includes a background statement addressing sampling purpose, and sampling type, Also included is the testing objectives for the program

F: Verification Test Description. Verification Test description section describes the principles of operation for the test equipment, the advantages and limitations of the test equipment, ~~and~~ any performance characteristics that affect testing, and the sampling and analytical methods used and their applicability to the testing performed. Sampling data and results, raw data, and laboratory data are referenced to their appropriate sections in the Appendix.

G: Results . The summary of results section presents a summary and comparison of verification parameters and critical measurements determined from the testing performed. This section also includes a summary of laboratory QA/QC characteristics.

Any sampling or analytical problems encountered during the test program are also discussed in this section.

H: References. The reference section includes all material and author information that was used or cited during testing and report procedures.

I: Appendices.

APPENDIX A - Description of the test rig and the methodology
APPENDIX B - Data on Certificates of Calibration
APPENDIX C - Verification Testing Sheets

PART C ASSESSMENT/OVERSIGHT

C1.0 Assessments and Response Actions

The Test-Specific QAO may elect to perform a self-assessment during BFP testing. APCT and/or EPA quality assurance staff may perform an independent assessment, including TSAs, and PEs, during BFP verification tests to determine that the DQOs are met. The Test-Specific QAO will conduct an ADQ for 10 % of all verification test data at the end of each round of the verification tests and will determine if these measurements allow one to determine if the DQOs have been attained. These technical assessments will be performed in accordance with *EPA Guidance for Technical Assessments for Environmental Data Operations*(EPA QA/G-7).

The Test-Specific QAO will report the findings of these internal technical assessments to the Verification Test Leader. The assessment report will recommend corrective actions, if such are indicated by these findings. The Verification Test Leader and the Test-Specific QAO are responsible for developing, documenting, and implementing corrective actions. They will provide a written response to all assessment findings. Each finding will be addressed with specific corrective action steps and a schedule to implement them. Responses to adverse findings are required within 10 working days of receiving the assessment report in accordance with the requirements of Part B, Section 4.3 of EPA's Quality and Management Plan for the Environmental Technology Program. The APCT Center Director will review and approve all corrective actions.

Technical assessments and corrective actions are described in detail in Sections 3.4 and 3.5 of the APCT QMP.

Technical personnel working on each task will have the direct responsibility for ensuring that the Test/QA plan is implemented, that the operating parameters are within acceptable limits, and that corrective actions are taken when appropriate. Corrective action will be taken whenever measurements fall outside the limits of the data quality objectives for the critical measurements.

Corrective actions include:

- Problem identification,
- Attempting to find the cause,
- Attempting immediate repairs (if possible),
- Reporting or documenting the problem,
- Planning for corrective action (if major repairs are needed),
- Documenting the corrective actions taken, and
- Recommending changes to instruments, SOPs, etc. to avoid similar future occurrences.

ETS will cooperate with EPA on scheduling EPA's assessments on this program.

C2.0 Reports to Management

The Test-Specific Manager will notify the Verification Test Leader and the Test-Specific QAO when testing under this project is being conducted. The Test-Specific Manager will submit verification reports and verification statements to the Test-Specific QAO. After technical assessments, the Test-Specific QAO will submit the verification reports, and verification statements to the Verification Test Leader. The Verification Test Leader will submit the reports, and verification statements, to the APCT Center for review. After review is complete, the APCT Center will submit the verification reports and the verification statements to the EPA Project Manager for review.

PART D DATA VALIDATION AND USABILITY

D1.0 Data Review, Validation, and Verification Requirements

Data quality audits will be conducted using data quality indicators that require the detailed review of: (1) the recording and transfer of raw data; (2) data calculations; (3) the documentation of procedures; and (4) the selection of appropriate data quality indicators. The data quality indicators that will be used are as follows:

- Use of correct test conditions, as specified in Table 2, for the LTG/FEMA apparatus.
- Adherence to calibration schedule.
- DQOs attained as specified in Appendix A..
- Adherence to standard operating procedures.

All data and/or calculations for flow rates, dust feed rates, moisture content, isokinetic rates, and particle concentrations and mass rates made using a computer software program will be validated by an independent check. All calculations will be spot checked for accuracy and completeness.

In general, all measurement data will be validated based on the following criteria:

- Process conditions are at the required conditions during testing.
- Sample collection procedures are performed as required by SOP.
- Data are consistent with expected results.
- Sampling procedures adhere to prescribed QC procedures.

Any suspect data will be flagged and identified according to the specific deviation from prescribed criteria and their potential effect on the data quality.

All QA/QC results will be reviewed before the data are released; any data that fail to meet the program's QA/QC requirements will be documented and discussed.

D2.0 Data Transformation and Reduction

Standardized forms will be used to record data for each test method. These forms are provided as attachment A to the SOP. All run sheets are to be reviewed daily by the Test-Specific Manager for evaluation of progress, completeness, and nonconforming items. Standardized computer spreadsheets will be used to reduce and analyze data. At the end of each test series, test data will be input into these spreadsheets. Laboratory analytical results may not be available at the end of each test day; however, results will be input as they become available. A standard data set that has been verified by hand will be used to demonstrate the accuracy of the spreadsheet calculations after the test program. Example spreadsheets and run sheets can be found in the SOP Appendices A and B.

D3.0 Validation and Verification Methods

Data validation is a systematic procedure of reviewing data against a set of established criteria to provide a level of assurance of the data's validity prior to their use. Data will be validated internally by QC personnel. All measurement data will be validated based upon process conditions during sampling or testing, acceptable sample collection/testing procedures, consistency with expected and/or other results, adherence to prescribed QC procedures, and the specific acceptance criteria. The data will be coded as valid or invalid based on their adherence to these criteria. Data validation will be conducted at several critical stages of data reduction:

- Checks of raw and reduced data by the Test-Specific Manager;
- Analytical laboratory QC checks by the Test-Specific QAO;
- Spot checks of reduced raw data by the Test-Specific QAO;
- Review of summary tables for consistency with reduced raw data by the Test-Specific QAO; and
- Final report review by the Test-Specific QAO, Verification Test Leader, and Test-Specific manager.

Data validation consists of verification of calculation methodology, consistency of raw, reduced, and summarized data tables, comparison of expected results, and consistency of results among multiple measurements.

Data will be initially validated by the Test-Specific Manager based on the representativeness of the sample, maintenance and cleanliness of sampling equipment, and adherence to the sample collection procedures. The data will also be validated on a daily basis based on process conditions during sampling and adherence to acceptable criteria.

When the data set is complete, the ETS QA personnel will perform an overall review of the data. The review will consider the above listed criteria and the reasonableness and consistency of the data based on a knowledge of the site characteristics and the specific location of the samples. The review will also contain an evaluation of the data in terms of meeting the quality assurance objectives of the program. The acceptance or rejection of the data will be in a uniform and consistent manner based on the established validation criteria. Data will be rejected only if a valid and documented reason is identified.

Validation of spreadsheet calculations used for data reduction will be conducted by entering a QA data set that has been verified by hand. Data flags will be added to all tables to identify special handling procedures or unusual data results. These flags will include:

- Quantities including analytical results that are at or below method minimum detection limits;
- Results for which contamination is suspected;
- Average results that exclude individual test run results; and
- Other special handling procedures or qualifications.

The purpose of validation and verification is to assess the degree to which the data meet the quality specifications outlined in the generic verification protocol and this Test/QA Plan. If deviations are noted, the validation procedures can be used to assess the effect the deviation will have on data usability.

The first step in data validation and verification is to assess that the project, as executed, meets the sampling design. Specific steps are listed below:

- Process data will be reviewed to ensure that the unit was operating within the limits outlined in the project.
- Test dates and times will be reviewed to ensure that testing was performed as scheduled and checked against the project design.
- The methods performed and the reference dust will be checked against the project design.
- Actual procedures documented in the test logs and on test data sheets will be checked against the procedures described in this Test/QA Plan and the SOP.
- Deviations from the Test/QA Plan will be documented.
- Sample custody and preservation will be checked for each sample component against the Test/QA Plan.
- The analytical procedures performed during the test program will be checked against those described in this Test/QA Plan.

Any deviations will be documented in the report. The review of quality control data such as duplicate sampling data and sampling verification checks can be used to validate test collection activities. The review of data from calibration checks, reference media test runs, and other quality control can be used to validate the analytical process. Acceptable precision and bias in these samples would lead one to conclude that the analytical procedures are adequate. Any data that indicate unacceptable levels of bias or precision will be flagged and investigated. This investigation could lead to the discovery of inappropriate sampling activities or analytical procedures, requiring corrective action.

Validation of QC procedures will require a review of the documentation of corrective actions that were taken when QC samples failed to meet acceptance criteria, and the potential effect of corrective actions on the validity of the data.

Validation of data reduction and processing procedures will require selection of 10 % of the data chosen at random. Raw data files including pre-sampling, sampling, calibration, sample handling/custody, analysis, corrective action, and data reduction will be reviewed and sample calculations will be performed. The data will also be reviewed to ensure that data qualifiers have been appropriately associated with the data and appropriate corrective actions have been taken where needed.

All data will follow a chain-of-custody containing checks at each level. The chain-of-custody for all test data collected will be as follows:

1) The data is collected on standardized data sheets.

2) These data sheets are completed, organized, and reviewed by the Test-Specific Manager.

3) The Test-SpecificManager presents the test data package to the Report Manager, who performs an additional review and prepares or organizes the preparation of the draft Verification Report and draft Verification Statement.

4) The draft Verification Report and draft Verification Statement, including the test data, are given to the Test-Specific Manager for review.

5) The draft Verification Report and draft Verification Statement, including the test data, are given to the Test-Specific QA Officer for review.

6) The draft Verification Report and draft Verification Statement, including the test data, are given to the Verification Test Leader for review.

7) The draft Verification Report and draft Verification Statement are sent to the APCT Center for review, approval, and signature.

8) The draft Verification Report and draft Verification Statement are sent to the EPA for review, approval, and signature.

During review of the verification report and verification statement, a Document Control and Review form shall be maintained to track operational review and document custody.

D4.0 Reconciliation with Data Quality Objectives

ETS will complete a Reconciliation of Verification Test Results with Data Quality Objectives form during the verification test series to record if the test results attain the DQOs. Using the results obtained from the project and the comparison with quality assurance objectives, ETS will investigate to identify any abnormal pattern or potential anomalies. ETS and the APCT Center quality assurance staff will have the final evaluation as to whether or not the project met the objectives of the sampling design, and whether or not departures, if any, from QA/QC guidelines are significant and acceptable. The conclusions will be presented in the verification report.

Quality objectives for this project were designed to evaluate various phases (sampling, preparation, analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQOs in Section A7.0. More specifically, the quality objectives were defined in terms of the following data quality indicators:

- Accuracy,
- Precision, and
- Completeness.

D4.1 Accuracy

Accuracy results obtained during the test program will be checked against accuracy criteria in Section A7.2 *Measurement Performance Criteria*. If data do not meet the accuracy quality objectives, ETS will conduct an investigation to uncover and explain the cause.

Accuracy is defined as the agreement between a measurement and the actual (i.e., true) value. For example, accuracy of an analytical measurement is expressed as the percent recovery of an sample at a known concentration prior to analysis, and is expressed by the following formula:

$$Accuracy = \%\ Recovery = \frac{A_T - A_O}{A_F} x 100$$

Where:

A_T = Total amount found in known concentration or standard
A_o = Amount found in sample, and
A_F = Amount added to sample.

D4.2 Precision

In this project, precision will be based on results for triplicate samples in terms of relative standard deviation (RSD). Using the RSD of triplicate samples collected (three sampling runs) and analyzed will provide an evaluation of the overall sampling and analysis precision. Precision results obtained during the test program will be checked against precision criteria in Section A7.2 *Measurement Performance Criteria*. If data do not meet the precision quality objectives, an investigation will be conducted to uncover and explain the cause.

Precision is defined in *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, EPA QA/R-5,* as the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions expressed generally in terms of analysis of samples relative to the average of those results for a given sample using the formula:

$$\%RSD = \frac{\sigma}{\mathrm{X}} x 100$$

Where:

%RSD = Relative standard deviation,
σ = Standard deviation of the triplicate sample results, and
$\bar{X}$ = Average of the triplicate results.

D4.3 Completeness

In this project, completeness is measured by the amount of valid data obtained from the measurement system compared to the amount that was expected to be obtained under correct, normal conditions. Completeness results obtained during the test program will be compared to completeness criteria in Section A7.2 *Measurement Performance Criteria*. If data do not meet the completeness quality objectives, an investigation will be conducted to uncover and explain the cause.

Completeness is a measure of the relative number of analytical data points that meet all of the acceptance criteria for accuracy, precision, and any other criteria required by the specific analytical methods used. The level of completeness can also be affected by loss or breakage of samples during transport, as well as external problems that prohibit collection of the sample.

As part of the data verification and validation process, these data quality indicators will be calculated and compared to data quality objectives for the program. The final test report will address whether or not objectives were met and, if not, the impact on the final data will be determined.

D5.0 Corrective Action Procedures

The following occurrences will require corrective action:

1. QA Goals Not Achieved: This occurrence includes failure to achieve the specified accuracy and completeness criteria.

2. Audit Deficiencies: Two types of audits will be conducted in this program. Internal audits are conducted by the Test-Specific QAO, and external audits are conducted by the APCT Center and/or EPA QA staff. Deficiencies may be identified during systems and/or performance audits.

It is the responsibility of the Test-Specific QAO to bring to the attention of the Verification Test Leader any of the problems listed above. The Test-Specific Manager, Test-Specific QAO, and Verification Test Leader will then review and compare the QA and program goals to determine if the specific QA problem will actually cause a problem in achieving the program goals. If it is determined that the QA goals are too stringent, they will be modified (with approval of the APCT Center Quality Manager) to reflect the current program objectives.

If the QA and program goals are determined to be satisfactory, the Verification Test Leader will review the subject measurement systems and procedures. The Verification Test Leader will proceed to solve measurement system problems as required. When the Verification Test Leader has determined that the problems have been solved, the Test-Specific Manager and the Test-Specific QAO will verify the results. This process may include specific calibration, and systems and/or performance audits. Any remaining problems will be resolved by the Verification Test Leader.

APPENDIX A

Attaining the Quality Objectives for the Mean Outlet Particle Concentration (PM 2.5 or total)

Attaining the Quality Objective for the Mean Outlet Particle Concentration ($PM_{2.5}$ or total)

Let Mean Outlet Particle Concentration ≡ $MOPC = \sum_{i=1}^{3} (C_{po})_i$

where C_{po} = a single measurement of the concentration of the i^{th} run, for i = 1,2,3 (triplicate runs), and

ϵ_{MOPC} ≡ error in MOPC,

Quality objective is: $\epsilon_{MOPC} \leq 15\%$ for triplicate runs.

1. Apportion Total MOPC error as:

$$\epsilon_{MOPC}^2 = \epsilon_{Bias}^2 + \epsilon_{Random}^2 \leq (15\%)^2$$

$\epsilon_{Bias} \leq 10\%$ (maximum allowable deviation from reference fabric results)

$$(0.1)^2 + (\epsilon_{Random}/3)^2 \leq (0.15)^2 \Rightarrow \epsilon_{Random}^2 \leq 3[(0.15)^2 - (0.1)^2] = 0.0375$$

$$\epsilon_{Random} \leq 0.19 = 19\%$$

i.e., total random error in each measurement of the outlet particle concentration must be held to 19 percent or lower in order to attain the quality objective.

2. Each measurement of Outlet Particle Concentration (C_{po}):

$C_{po} = D_{mass}/V_{Outlet}$ where:

$$D_{mass} = \sum_{i=1}^{5} [(SubstrateMass)_{Final} - (SubstrateMass)_{Initial}]_i$$ for impactor stages,

$$= [(Mass1_{Final} \pm \epsilon_{Mass}) - (Mass1_{Initial} \pm \epsilon_{Mass})] + (Mass2_{Final} \pm \epsilon_{Mass}) - (Mass2_{Initial} \pm \epsilon_{Mass}) + (Mass3_{Final} \pm \epsilon_{Mass}) - (Mass3_{Initial} \pm \epsilon_{Mass}) + ...]$$

$$= [(Mass1_{Final}-Mass1_{Initial}) + (Mass2_{Final}-Mass2_{Initial}) + ... + \sum(\epsilon_{Mass})]$$

for impactor stages i = 1, 2, ..., 5 for the 5 stages of the impactor that will be used.

where ϵ_{Mass} = measurement error in each handling and weighting of each substrate.

V_{outlet} = Sampled Volume = $(Flowrate)_{Outlet}$ x (Sampling Time)

$V_{outlet} = V_{imp}$ since the entire sampled volume of the clean gas is drawn through the impactor.

Then $(s_C/C_{po})^2 = (s_D/D_{mass})^2 + (s_V/V_{imp})^2$;

$= 2*5[0.000005/0.00013]^2 + [0.42/7.0]^2 = 0.0184$

where s_C, s_D, and s_V are the measurement errors in C_{po}, D_{mass}, and V_{imp}, respectively, and it is assumed that the cumulative substrate mass gain is uniformly distributed over all 5 stages (C_{po} x V_{imp} = 0.000644 g/5 stages, = 0.00013 g/stage), with 2 weighings per stage (pre- and post-sampling weighing).

s_C/C_{po} ≈ 14%, computed using the following assumed values:

	Value	**Source**
s_D	0.000005 g	½ balance resolution (weighing by difference effectively removes systemmatic error)
n	5	Number of impactor stages + filter
D_{mass}	0.000644 g	=C_{po} x V_{imp} (expected cumulative mass gain per 5 stages
C_{po}	0.000092 g/dscm	Assumes 99.9995% removal efficiency at inlet concentration of 18.4 g/dscm
s_V	0.42 m^3	Table 2, generic verification protocol (0.06 m^3/dscm)
V_{imp}	7 m^3	Sampled volume - through impactor

Since it is estimated that $s_C/C_{po} < \epsilon_{Random}$ (that is, 14% < 15%) for this plan, then it can be reasonably expected that the operating specifications will satisfy the DQOs of Table 2.

APPENDIX B

Example Sample Chain-of-Custody Record
Example Label
Example Record of Consumables
Example Inspection/Acceptance Testing Requirements
Example Log for Tracking Supplies and Consumables

Example
Chain-of-Custody Filter Media Samples

Station Location	Date	Time	Sample Manufacturer	Sample ID Number	No. of Samples	Responsible Individual
Receiving	10-17-99	4:20 pm	BASF	99-577BFP3-A	9	TW
Selection and Preparation	10-25-99	09:00 am	BASF	99-577BFP3-A	9	TW
Pre-test Weighing	10-25-99	09:00 am	BASF	99-577BFP3-A	3	FC
Testing	10-26-99	08:00 am	BASF	99-577BFP3-A	1	AH
	10-27-99	08:00 am	BASF	99-577BFP3-A	1	AH
	10-28-99	08:00 am	BASF	99-577BFP3-A	1	AH
Post-test Weighing	10-27-99	10:00 am	BASF	99-577BFP3-A	1	FC
	10-28-99	10:00 am	BASF	99-577BFP3-A	1	FC
	10-29-99	10:00 am	BASF	99-577BFP3-A	1	FC
Storage	10-25-99	11:00 am	BASF	99-577BFP3-A	9	TW
	10-28-99	11:00 am	BASF	99-577BFP3-A	1	TW
	10-29-99	11:00 am	BASF	99-577BFP3-A	1	TW
	10-30-99	11:00 am	BASF	99-577BFP3-A	1	TW

Example
Sample Label

Manufacturer	
Contract No.	
Test Method	
Sample ID No.	
Type of Media	

Example

Record for Consumables

Unique Identification No.	
Date Received	
Date Opened	
Date Tested	
Date to be Retested	
Expiration Date (If Applicable)	

Example
Inspection/Acceptance Testing Requirements

Critical Supplies and Consumables	Inspection/ Acceptance Testing Requirements	Acceptance Criteria	Testing Method	Frequency	Responsible Individual	Handling/Storage Conditions

Example
Log for Tracking Supplies and Consumables

Critical Supplies and Consumables (Type, ID No.)	Date Received	Meets Inspection/ Acceptance Criteria (Y/N, Include Date)	Requires Retesting (Y/N, If yes, Include Date)	Expiration Date	Comments	Responsible Individual

APPENDIX C

Standard Operating Procedures for Verification Testing of Baghouse Filtration Products Using FEMA Test Apparatus (July 2005)

**STANDARD OPERATING PROCEDURES FOR
ETV VERIFICATION TESTING OF
BAGHOUSE FILTRATION PRODUCTS**

July 2005

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***Pollution Control Consultants
Specializing In
Toxic Emission Measurement and Control***

Contents

1.0 Principal and Applicability

1.1 Principal

A fabric filter sample is subjected to a dust loading under simulated baghouse conditions using a FEMA test apparatus, which is modified from the Verein Deutscher Ingenieure (VDI) Method 3926 test apparatus. The performance of the fabric is determined relative to the following verification parameter:

- Outlet particle concentration, PM 2.5 g/dscm (gr/dscf).
- Outlet particle concentration, total mass g/dscm (gr/dscf).
- Average residual pressure drop (3 seconds after cleaning) cm w.g. (In. w.g.).
- Initial residual pressure drop of 6-hour performance test period, cm w.g. (in. w.g.)
- Residual pressure drop increase (final - initial) cm w.g. (in. w.g.).
- Average filtration cycle time (time required to reach a specified pressure drop after cleaning) s.
- Number of filtration cycles during performance test period
- Mass gain of test sample filter at test completion g.

1.2 Applicability

This method is applicable for the determination of the above verification parameters for flat baghouse filtration fabrics. If a filter structure other than flat swatches are to be tested, the vendor/manufacturer needs to work with ETS to propose a modification for the test apparatus that is acceptable to EPA/APCT and meets all aspects of the data quality objectives identified in the generic verification protocol.

2.0 Definitions

2.1 Residual Pressure Drop Increase

The difference in residual pressure drop over the performance test period calculated by subtracting the average residual pressure drop of the first ten filtration cycles from the average residual pressure drop of the final ten filtration cycles

2.2 Conditioning Period

The period during which the fabric sample is conditioned within the test apparatus by subjecting it to 10,000 pulses with 3 seconds between pulses. Thus, the conditioning period should require 8 hours and 20 minutes for completion. Use a dust load during the conditioning period of 18.4 ± 3.6 g/dscm (8.0 + 1.6 gr/dscf) as specified in the generic verification protocol and Test/QA Plan.

2.3 Dust Shipment

All test dust received in the same shipment and having the same lot number.

2.4 Gas-to-Cloth Ratio

The filtration velocity of the gas stream entering the test fabric in meters per hour as determined by the flow measured in the clean-gas channel (in cubic meters per hour) divided by the exposed surface area of the fabric (in meters squared). The verification test shall maintain a G/C of 6.6 (120 m/hr).

2.5 Residual Pressure Drop

The pressure drop in centimeters, water gauge across the fabric sample contained in the test apparatus three seconds after a specified cleaning pulse.

2.6 Recovery Period

A time period following the conditioning period during which the fabric is allowed to recover from rapid pulsing. The recovery period requires 30 filtration cycles under normal test conditions. Use a grain loading during the fabric recovery period of 18.4 ± 3.6 g/dscm (8.0 + 1.6 gr/dscf).

2.7 Filtration Cycle

The time period between two consecutive cleaning cycles or pulses during testing.

2.8 Filtration Cycle Time

The duration or time expressed in seconds defined by one filtration cycle.

2.9 Performance Test Period

A 360-minute test period following the fabric recovery period during which the verification testing is performed. Pulsing shall occur at a differential pressure of 1,000 Pa (4.0 in. w.g). Use a grain loading during the performance test period of 18.4 ± 3.6 g/dscm (8.0 + 1.6 gr/dscf).

2.10 Test Phase

The particular phase of a test run consisting of either the conditioning period, recovery period, or performance test period.

2.11 Test Run

The sum of three test phases including the conditioning period, recovery period, or performance test period.

2.12 Test Series

Three test runs performed in series.

3.0 Materials and Apparatus

3.1 Test Apparatus and Materials

3.1.1 Test Apparatus: The test apparatus complies with the specifications that are stated in the *Generic Verification Protocol for Baghouse Filtration Products (October 8, 2001)*, which consists of the following component modifications as specified in the following sections.

3.1.1.1 Electronic Datalogger or Programmable Logic Controller: With the ability to record residual pressure drop and filtration cycle time for each filtration cycle during the performance test period and the ability to record dust feed weight, raw-gas flowrate and clean-gas flowrate (including sample bypass and sample-gas flowrate during the performance test period). Recording frequency must allow calculation of all necessary verification data, but must not be less than once per minute.

3.1.1.2 Dust Feed Weight Measurement Device: A scale beneath the entire dust feed mechanism including the dust hopper with a continuous readout capable of measurement to the nearest 10 g.

3.1.1.3 Dust Feed Hopper: A dust feed hopper with a minimum capacity of 1.0 kg of aluminum oxide. Dust

3.1.1.4 Thermocouple: Located in the raw-gas channel upstream of the filter sample. This temperature can be assumed constant throughout the test apparatus.

3.1.1.5 Removable Clean-Gas Channel: The cylindrical clean-gas channel behind the test filter shall be constructed to allow for cleaning as specified in Section 4.2.4.4.

3.1.1.6 Adjustable Sample and Sample Bypass Channels: Following the clean-gas channel, the clean-gas flow shall be separated into two gas streams, a sample and sample bypass. An aerodynamic "Y" shall be used for this purpose. The aerodynamic "Y" shall be designed for isokinetic separation of the clean-gas with 60.2 percent of the clean-gas entering the sample-gas channel without change in gas velocity. The sample-gas channel shall contain an impactor (see section 3.4) for particle separation and measurement. The bypass channel shall contain the absolute filter assembly used in the FEMA test apparatus The sample-gas channel shall be operated at a flow rate of 1.13 $\pm$ 0.06 m^3/hr (0.67 $\pm$ 0.03 acfm), and a sample bypass channel shall be operated at a flow rate of approximately 0.45 m^3/hr (0.43 acfm). Flow in the two gas streams shall be continuously monitored and maintained by adjustable valves. A single pump and mass flow controller may be used on the clean-gas side by joining the sample and sample bypass channels downstream of the impactor and flow control valves, provided proper gas flow rates are monitored and maintained.

3.1.1.7 Manual Pulsing Function: The test apparatus must be configured to allow for manual pulsing when the dust feeder and the air compressor are not in operation.

3.2 Test Dust

Aluminum Oxide Pural NF or equivalent, having an Al_2O_3 content of greater than 98.6 percent. The test dust must meet the following specifications as determined by the procedures of Section 4.3.3.

mass mean diameter:	1.5± 1.0 *u*m
weight percent < 2.5 *u*m:	40-90%

At a dust feed rate of 18.4 g/dscm, approximately 100 g/hr of test dust is required in the test apparatus. A conditioning period of 10,000 pulses at 3 seconds per pulse requires a duration of 8 hours and 20 minutes for a total estimated dust feed of approximately 833 g. The fabric recovery period of 30 pulses may require up to 90 minutes or greater. A dust capacity of at least 300 g is recommended. Likewise, the performance test period of 6 hours requires an estimated dust feed of approximately 600 g. Allow at least an additional 10 percent of dust to account for variations in test conditions.

3.3 Analytical Balances and Associated Equipment

3.3.1 Low-Resolution Analytical Balance for Sample Filters: Capable of measurement to within 0.01 g.

3.3.2 High-Resolution Analytical Balance for Impactor Substrates: Capable of measurement to 0.00001 g. The balance must be equipped with a draft shield enclosure and an anti-static device within the enclosure.

3.3.3 Calibration Weights:

3.3.3.1 Dust Feed Scale: 2 kg span weight. Calibration weights must meet ASTM Class 4 with a NIST/NVLAP Traceable Certificate.

3.3.3.2 Low-Resolution Analytical Balance: 100 g span weight. Calibration weights must meet ASTM Class 4 with a NIST/NVLAP Traceable Certificate.

3.3.3.3 High-Resolution Analytical Balance: 1 g daily-check weight and 50 g span weight for calibration. Calibration weight must meet ASTM Class 1 standards with NIST/NVLAP certification.

3.3.4 Aluminum Foil

3.3.5 Permanent Marker for Labeling

3.3.6 Single Thickness Class 100 Wipes: Crew 33330 by Kimberly-Clark, or equivalent.

3.3.7 Tweezers

3.3.8 Recovery Brush: Suitable for recovery of loose dust from the impactor plates.

3.3.9 Humidity- and Temperature-Controlled Work Space

3.3.10 Continuous Temperature and Humidity Monitor with Data-Logging Capabilities: Smart Reader 2 - Temperature & Relative Humidity Logger by ACR Systems, Inc., or equivalent.

3.4 Impactor, Collection Substrates and Associated Materials

3.4.1 Andersen Model 50-900 Impactor or Equivalent: Capable of capturing total particulate matter and measuring particulate matter having a mean aerodynamic diameter of 2.5 *u*m.

3.4.2 Collection Substrates: Glass fiber substrates and backup filter. Andersen Instruments Incorporated Product Number 50-31(0 or 2) or equivalent.

3.4.3 Acetone: Reagent grade, $\leq$ 0.001 percent residue in glass bottles.

3.4.4 Wash Bottle: Polyethylene or glass for use in the acetone rinsing of Impactor components only. Do not store acetone in the wash bottles.

3.4.5 Paraffin Film or Teflon Tape: For sealing the impactor after assembly and when not in use.

3.5 Absolute Filter Assembly With Untared Filters

As specified in VDI Method 3926, suitable to protect the clean-gas flow measurement device and pump. The filters used in this assembly are not required to be subjected to the handling procedures of Section 4.2.2, as they are not subject to gravimetric analysis. The tester may choose to use these filters for analysis, in which case the procedures of Section 4.2.2 are recommended.

3.6 Ambient Humidity and Barometric Pressure Measurement Devices

3.6.1 Barometer: Capable of reading atmospheric pressure to within 2.5 mm (0.1 in) Hg. In many cases the barometric pressure may be obtained from a nearby National Weather Service station, in which case the tester must subtract 2.5 mm (0.1 in) Hg per 100 feet of elevation increase. (Add 2.5 mm (0.1 in) Hg per 100 of elevation decrease.)

3.6.2 Sling Psychrometer or Ambient Humidity Measurement Monitor: Capable or measuring ambient humidity to within 1 percent relative humidity.

4.0 Procedure

4.1 Pretest Preparation

4.1.1 Data Recording: Prepare data sheets for each test series as shown in Attachment B. All raw data shall be recorded on the data sheets for inclusion in the data package.

4.2 Sample Filter Preparation

4.2.1 Selection: From the nine samples that were received from the manufacturer, randomly choose three sample fabrics.

4.2.1.1 Cutting: Using the clamping ring (see VDI Method 3926, Figure 2b) as a template. Cut at least one sample filter from each of the randomly chosen sample fabrics. Additional sample filters are recommended in preparation for voided test runs. The outer diameter of the sample shall match that of the clamping ring when laid flat. Make sure that the sample filter is homogeneous and free from seams or imperfections.

4.2.1.2 Handling: The sample filter shall be weighed and transported within a labeled, sealable, lightweight container such as aluminum foil or a plastic Ziploc™ bag or equivalent. The container is necessary to capture any loose dust from the filter after testing is completed.

4.2.1.3 Pre Weighing: Calibrate the scale, as stated in section 5.2.2, and weigh the sample filter and container to the nearest 0.01 g.

4.2.2 Impactor Substrate Preparation:

4.2.2.1 Weigh Foils: Cut aluminum foil into sections of at least 6" x 3" sufficient to completely contain an impactor filter and any loose dust captured on the filter. Each foil shall be labeled to match its corresponding filter with a permanent marker that will not rub off during handling.

4.2.2.2 Conditioning: The impactor filters and weigh foils must be equilibrated to a constant temperature between 73-81 °F (23-27 °C) and relative humidity of 40-60 % for at least 24 hours prior to weighing.

(1) Place each filter and its corresponding foil in an open petri dish with the foil unfolded and filter open to the atmosphere.

(2) Arrange the petri dishes on a clean tray or surface. Cover the petri dishes with dust free wipes or dust free boxes with one side open to atmosphere.

(3) Allow the filters, foils, and petri dishes to equilibrate for 24 hours constant temperature between 73-81 °F (23-27 °C) and relative humidity of 40-60 %. The temperature and relative humidity must be continuously measured and recorded. Use a Smart Reader 2 - Temperature & Relative Humidity Logger by ACR Systems, Inc., or equivalent for this purpose.

4.2.2.3 Pre-Weighing: Maintain the temperature between 73-81 °F (23-27 °C) and relative humidity at 40-60 % during weighing. Prior to each weighing, and every hour during extended weighings, calibrate the balance using the zero and span functions of the balance. Check each calibration using the 1 g calibration weight. The balance shall read the calibration weight to within 0.00005 g. If not, repeat the calibration procedure or adjust the balance. Weigh the filters within the weigh foils.

4.2.2.4 Handling: Keep the filters and weigh foils in a closed petri dish to cover and protect the filter and weigh foil during handling. After conditioning, always handle the filters and weigh foils with tweezers. The filters and weigh foils shall not come in contact with any surface except the clean petri dish, tweezers, and the impactor during handling.

4.2.3 Impactor Preparation: Prior to each use:

(1) Rinse all internal surfaces of the impactor including the cone, body, plate holder, and all plates, gaskets and separators that will contain substrates with acetone.

(2) Dry these surfaces with single thickness Class 100 wipes taking care that the impactor parts are not contaminated with ambient dust, oils or fibers.

(3) Assemble the impactor as specified in the manufacturer's operating manual. To reduce the cumulative error caused by multiple weighings, eliminate all stages that separate less than 2.5 µm particle sizes. Stages may be modified to produce the required jet velocity to facilitate separation at 2.5 $\pm$ 0.25 µm. The backup filter may be moved forward to eliminate unnecessary stages and the remaining stages may be loaded without substrates behind the backup filter, or a suitable spacer may be used.

(4) Seal each opening of the impactor with clean paraffin film or Teflon tape to prevent sample contamination until ready for use.

4.2.4 Test Apparatus:

4.2.4.1 Sample Filter: Load the sample filter into the test apparatus as specified in VDI Method 3926.

4.2.4.2 Absolute Filter Assembly With Untared Filters: Load the absolute filter with an untared filter as specified VDI Method 3926.

4.2.4.3 Test Dust: Load the dust feed hopper with a sufficient quantity of test dust for the phase of testing being performed.

4.2.4.4 Cleaning: Prior to each test series. Use Kimberly-Clark Kimwipes or an equivalent lint-free laboratory-grade fabric to clean the surfaces of the clean-gas channel. Rinse the aerodynamic Y and associated fittings with acetone and discard used acetone. Thorough cleaning of the test apparatus is necessary to prevent interference caused by dust reentrainment.

4.3 Preliminary Determinations

4.3.1 Trial Operation: Prior to each test series, determine the instrument settings necessary to obtain an air-to-cloth ratio of 120 m/hr (6.6 fpm) and a dust feed rate of 100 grams/hr. Perform this operation using an untared sample filter not to be used in the test series.

4.3.2 Reference Fabric Verification: Perform once per three months. Obtain a sample of reference fabric from:

APCT Center
APCT Center Director
Research Triangle Institute
3040 Cornwallis Road
Research Triangle Park, NC 27709-2194

Verify the performance of the test apparatus by performing three 30-cycle tests using the reference fabric and the procedures herein. The reference fabric verification is acceptable if the following criterion is met:

$$0.65\text{ g} \le \text{mass gain} \le 1.60\text{ g}$$

$$0.35\text{ cm w.g.} \le \text{pressure drop} \le 0.85\text{ cm w.g.}$$

In the event that the above criterion is not met, adjustments to the test apparatus must be made and the 30-cycle reference fabric verification repeated.

4.3.3 Test Dust Verification: Perform once on each dust shipment and once each month thereafter. The values from these dust characterizations must be accumulated in spread sheet form to allow construction of trend lines with all accumulated data. Each test dust verification test will consist of three test runs using an Andersen Impactor or equivalent are necessary to verify the test dust as specified in Section 3.2.

(1) Prepare the test apparatus as specified in Section 4.2.4. Use an untared sample filter that will not to be used in the test series.
(2) Prepare the impactor for isokinetic sampling as specified in the manufacturers operating manual using all the available stages. Equip the impactor with a stainless steel sampling nozzle capable of isokinetic sample withdrawal from the raw-gas channel. Note, custom sampling nozzles are required for isokinetic sampling in this application. In the development of this method, a nozzle having a sample opening of 1.895 in was required to maintain isokinetic sampling at a sample rate of 5 liters per minute.
(3) Insert the nozzle into the raw-gas channel upstream of the test filter. The nozzle shall be located at least two inches from the channel walls. A bulkhead fitting is recommended between the nozzle and impactor body to seal the nozzle in place with the nozzle inside and the impactor housing outside of the raw-gas channel.
(4) Operate the impactor at a sample rate of 3.5-7.0 liters (0.1-0.2 cubic feet) per minute for a sample duration of 3-5 minutes. A total sample volume of 15-25 liters (0.53-0.88 cubic feet) is recommended.
(5) Follow the impactor preparation, sample recovery, and analyses procedures in Sections 4.2.2, 4.2.3, 4.5.2 and in the manufacturers operating manual.
(6) Using the data reduction procedures in the manufacturers operating manual, calculate the mass mean diameter and weight percent < 2.5 *u*m for the test dust.
(7) Repeat the procedures (1) through (6) above to obtain three valid test runs.

In the event that the mass mean diameter and weight percent < 2.5 *u*m, does not meet the criteria of Section 3.2, the test dust or dust feed system must be corrected and the dust feed verified prior to testing.

4.4 Verification Test Series

Perform one verification test series consisting of three test runs for each fabric tested. A test run consists of the following test phases.

4.4.1 Conditioning Period: Prepare the test apparatus as specified in Section 4.2.4. Subject the fabric to 10,000 pulses at 3 second intervals under the following conditions:

dust loading:	18.4 ± 3.6 g/dscm (8.0 ± 1.6 gr/dscf), calculated on a block average for each 60 consecutive minutes during the test and for the last 60 minutes of each test. For example, if a test ran 125 minutes, block averages are required for 1-60 minutes, 61-120 minutes, and 66-125 minutes.
gas-to-cloth ratio:	120 ± 6 m/hr (6.6 ± 0.3 fpm), calculated on a block average for each 60 consecutive minutes during the test and for the last 60 minutes of each test.

At minimum, the following parameters must be measured and recorded to confirm that the above requirements are met:

Parameter	Units	Minimum Recording Frequency
Fabric Pressure Drop	(Pa or in H_20)	1 minute
Raw-Gas Flow*	(sm^3/hr)	1 minute

Total Clean-Gas Flow*	(sm^3/hr)	1 minute
Sample-Gas flow*	(sm^3/hr)	1 minute
Dust Feed Weight	(grams)	1 minute

*Includes measurement of absolute gas pressure and humidity (which shall be taken once per test day) and gas temperature . Sample-gas flow measurements are necessary during each performance test period.

The conditioning period may be stopped and restarted provided that the above conditions are met and the sample fabric is not manipulated in any way.

4.4.2 Fabric Recovery Period: Continue to operate the test apparatus under the conditions specified in Section 4.4.1, except subject the fabric to normal pulsing, as required for 30 filtration cycles. The fabric recovery period does not need to immediately follow the conditioning period, but must proceed without additional handling, dust loading or pulsing of the sample filter. During the fabric recovery period, ensure that the dust loading and gas-to-cloth requirements of Section 4.4.1 are met.

4.4.3 Performance Test Period:

4.4.3.1 Preparation: Prior to each performance test period, load the test apparatus with dust. Load the sample-gas channel with an impactor which is prepared as described by the procedures of Section 4.2.3. Load the sample bypass channel with an absolute filter.

4.4.3.2 Performance Testing: Operate the test apparatus as specified in Section 4.4.1, except subject the fabric to normal pulsing, as required for a period of 360 minutes. Continue following the dust loading, gas-to cloth, and data capture and recording requirements of Section 4.4.1. In addition, record the following:

Parameter	Units	Recording Frequency
Filtration Cycle Time	(seconds)	once per filtration cycle
Residual Pressure Drop	(Pa or in. H_20)	once per filtration cycle, recorded three seconds after each cleaning pulse
Filtration cycle count	number	each filtration cycle

In the event that the dust loading and gas-to-cloth requirements of Section 4.4.1 are not met, the test run is void and repeated using a new sample filter.

4.5 Sample Recovery and Handling

4.5.1 Sample Filter: Following each test run:

(1) manually pulse the sample filter ten times while the test apparatus is not in operation. This will facilitate removal of the filter cake.

(2) Remove the filter assembly from the test apparatus and place it on a flat surface with the collection side up. Brush or wipe any excess dust from the filter assembly taking care not to add weight to the sample filter.

(3) Remove the sample filter from the filter assembly and place the filter in its labeled weigh container.
(4) Weigh the sample filter to the nearest 0.01 g.

4.5.2 Impactor Substrates and Backup Filter:

(1) Remove the impactor assembly from the test apparatus and transport to a clean, dry surface.
(2) Recover each impactor stage or backup filter into the corresponding weigh foil using clean tweezers taking care not to loose any of the sample. Brush any excess dust or substrate fibers that remain on the impactor stages into the weigh foils using the recovery brush.
(3) Condition the impactor samples by the procedures of Section 4.2.2.2.
(4) Record the post weight of each impactor stage using the weighing and handling procedures of Section 4.2.2.3 and 4.2.2.4.

5.0 Calibrations

Perform the following calibrations for inclusion in the Verification Report referenced in Section 8.0.

5.1 Prior to Each Use

5.1.1 Dust Feed Weight Measurement Device: Check the calibration of the dust feed weight measurement device by placing the 2-3 kg span weight into the weigh hopper. It may be necessary to protect the span weight using a tared Ziploc™ plastic bag or equivalent. The dust feed weight measurement device shall display a weight increase within 10 g of span weight plus the protective bag.

5.1.2 Low-Resolution Analytical Balance: Check the calibration of the low-resolution analytical balance using the 100 g span weight. The low resolution analytical balance shall display within 0.05g of the calibration weight.

5.1.3 Pressure Transducers: Calibrate each pressure transducer against an oil manometer to within 0.1 in. w.g. The pressure transducers shall be calibrated at three points, zero, maximum, and at an intermediate pressure typically encountered during the test program. A simulated pressure may be produced using a squeeze bulb and a vice.

5.1.4 High-Resolution Analytical Balance: Check the calibration of the high-resolution analytical balance using the 1 g span weight. The high resolution analytical balance shall display within 0.00005g of the calibration weight.

5.2 Every Three Months

5.2.1 Microbalance: Use a 1 mg ASTM Class 1 or 2 mass for the quality control check. This weights must be traceable to NIST. Do not use the same weights for the QC check as is used for the day-to-day calibration verifications of the microbalance. The balance display shall agree with the certified value of the QC check weight to within ± 0.00005 g.

5.2.2 Flow Measurement Devices (Calibrated Orifices or Mass Flow Controllers): Calibrate all flow measurement devices using the procedures specified in 40 CFR 60, Appendix A, Method 5, Sections 5.3 or 7.1. The reference standard for the calibration shall be a spirometer/bell prover or a wet test meter that has been certified against NIST-traceable standards within the past year. Calibrate the clean-gas flow measurement device at a single point corresponding to a flow of 1.85 $\pm$ 0.9 m^3/hr (1.1 $\pm$ 0.06 cfm). (equivalent to a gas-to cloth ratio of 120 m/hr, or 6.6 fpm). Calibrate the raw-gas flow measurement device at a flow of 3.95 $\pm$ 0.2 m^3/hr (2.32 $\pm$ 0.1 cfm). Calibrate the sample-gas measurement device at a flow of 1.13 $\pm$ 0.06 m^3/hr (0.67 $\pm$ 0.03 cfm). Conduct each calibration for a minimum of ten minutes. Use a calibration factor to adjust the signal to that of the wet test meter or calibrated dry gas meter.

5.2.3 Thermocouple in Raw-Gas Channel: Calibrate the thermocouple in the raw-gas channel against an ASTM mercury-in-glass reference thermometer at 25^{O}C (77 $\pm$ 4ºF.) Alternatively, calibrate the thermocouple at a thermometric fixed point above and below 25^{O}C (77 $\pm$ 4 ºF, for example use an ice bath and boiling deionized distilled water correcting the reference temperatures for barometric pressure). The thermocouple must agree with the reference point to within $\pm$ 1 ºF.

5.24 Aneroid Barometer (if used): If a mercury barometer is not used, calibrate the aneroid barometer against a mercury barometer every six months. The aneroid barometer shall agree with the mercury barometer to the nearest 0.2 in Hg.

5.2.5Timer Clock: The timer clock shall be calibrated quarterly to NIST time, which is obtained from the WWV radio reference signal or from the NIST World Wide Web site. If the timer clock is not within one second agreement with the WWV or website signal over a one-hour period, the timer must be replaced with a unit that meets calibration requirements.

5.3 Once Per Year

5.3.1 Humidity and Temperature: Either calibrate the continuous humidity and temperature measurement device according to the manufacturer's specifications or obtain a manufacturer's calibration certificate.

5.3.2 Low Resolution Analytical Balance: The low-resolution analytical balance will be calibrated by its manufacturer annually.

5.3.3 High-Resolution Analytical Balance: The high-resolution analytical balance will be calibrated by its manufacturer annually.

5.3.4 Flow Meter: The dry gas meter will be calibrated annually be the manufacturer.

5.3.5 Weights: The weights will be calibrated to NIST traceability annually.

5.3.6 Pressure Transducer: The pressure transducers will be calibrated annually by the manufacturer.

6.0 Calculations

6.1 Nomenclature

6.1.1 Acronyms

A_f	=	Exposed area of sample filter, m^2
C_a	=	Actual outlet particulate concentration of total mass, g/m^3
C_{ds}	=	Dry standard outlet particulate concentration of total mass, g/dscm
$C_{2.5a}$	=	Actual outlet particulate concentration of PM 2.5, g/m^3
$C_{2.5ds}$	=	Dry standard outlet particulate concentration of PM 2.5, g/dscm
d	=	Diameter of exposed area of sample filter, m
F_a	=	Dust feed rate corrected for actual conditions, g/m^3
G/C	=	Gas-to-Cloth Ratio, m/hr
M_t	=	Total mass gain from Andersen Impactor, grams

$M_{2.5}$	=	Total mass gain of particles less than 2.5 *u*m in diameter from Andersen Impactor, grams - this value may need to be linearly interpolated from test data, g
N	=	Number of filtration cycles in a given performance test period
ΔP_i	=	Residual pressure drop for filtration cycle i, cm w.g.
ΔP_{avg}	=	Average residual pressure drop, cm w.g.
P_s	=	Absolute gas pressure as measured in the raw-gas channel, mbar
Q_a	=	Actual gas flow rate , m^3/hr
Q_{at}	=	Actual gas flow rate for a specific averaging time, t, m^3/hr
Q_s	=	Standard gas flow rate, m^3/hr
Q_{st}	=	Standard gas flow rate for a specific averaging time, t, m^3/hr
t	=	Specified averaging time or sampling time, min.
t_c	=	Average filtration cycle time, s
w_f	=	Weight of dust in feed hopper following the specified time, g. Because of vibrations causing short-term fluctuations to the feed hopper, it is recommended that this value be measured as a one-minute average.
w_i	=	Weight of dust in feed hopper prior to the specified time, g. Because of vibrations causing short-term fluctuations to the feed hopper, it is recommended that this value be measured as a one-minute average.

6.1.2 Unit Conversions

To convert to in. w.g. from in. Hg, multiply by 13.6.
To convert to grains from pounds, multiply by 7000.
To convert to ft^3 from m^3, multiply by 35.313.
To convert to grams form pounds, multiply by 453.59.
To convert to seconds from minutes, multiply by 60.

6.1.3 Equivalence Values

Standard atmospheric pressure, in. Hg = 29.92.
Standard temperature at 0 °F = 460 °R.
Standard temperature at 68 °F = 528 °R.

6.2 Area of Fabric - A_f

$$A_f = \frac{1}{4} \times \pi \times d^2$$

6.3 Actual Gas Flow Rate Q_a

$$Q_a = Q_s \times \left[\frac{(T_s + 460) \times 1013}{P_s \times 528} \right]$$

6.4 Gas-to-Cloth Ratio - G/C

$$G/C = \frac{Q_a}{A_f}$$

6.5 Standard Dust Feed Rate - F_s, for a specified time - t

$$F_s = \frac{(w_i - w_f)}{Q_{st} \times t}$$

6.6 Actual Raw-Gas Dust Concentration - F_a

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

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

$$C_{ds} = \frac{M_t}{Q_{ds} \times t \times \left(1 - \frac{\%H_2O}{100}\right)}$$

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

$$C_{2.5ds} = \frac{M_t}{Q_{2.5ds} \times t \times \left(1 - \frac{\%H_2O}{100}\right)}$$

6.9Filtration Cycle Time - t_c

$$t_c = \frac{N}{3600}$$

6.10 Average Residual Pressure Drop - ΔP_{avg}

$$\Delta P_{avg} = \frac{\sum_{i=1}^{N} \Delta P_i}{N}$$

7.0 Data Reduction and Analysis

The procedures in this section apply to the specific data reduction practices used at ETS, Inc. in operation of the FEMA test apparatus. Operating procedures using other equipment at other facilities may be significantly different.

7.1 Data Flow

7.1.1 Types of Data: The verification test apparatus creates two types of data, computer recorded data and test operator recorded data. Test operator recorded data are the data that are recorded onto the verification test runsheets, which will be transferred into computer spreadsheets in future data reduction as described in section 7.4.2. Computer recorded data is the information recorded by the Loggy Program.

7.1.2 Computer Recorded Data: The computer recorded data are saved directly onto the ETS network by the Loggy program. All data and spreadsheet files shall be saved on the ETS network system on the R:\FEMA subdirectory. A separate subdirectory (within R:\FEMA) shall be created for each test series. The files are saved into a file name that is described in section 7.2.

7.1.3 Operator Recorded Data: All information that is recorded by the operator is recorded onto verification runsheets (test log). The operator records the start and stop times, media information, and ambient conditions for the conditioning period, recovery period, and the performance test period. Once all information has been recorded onto the verification test runsheets and the verification test has ended, the test operator signs the runsheet to validate the recorded information. The Test-Specific Manager then releases the verification runsheets into the custody of the data processing operator.

7.1.4 Data Reduction, Report Generation, and Report Review: The data processing operator performs all data reduction and analysis for the verification test. The data processing operator enters the runsheet information into the verification test spreadsheets and reduces the Loggy recorded data as described in section 7.3 and 7.4. Once all information from the Loggy program and the verification runsheets have been entered into the spreadsheets and all analysis has been completed, the runsheets and the summary data sheets are transferred into the Report Manager's custody who prepares the draft verification report and draft verification statement. The Report Manager transfers the draft verification report and draft verification statement to the Test-Specific Manager for review. The Test-Specific Manager transfers the draft verification report, the draft verification statement, the verification runsheets, and the data summary forms to the Test-Specific QAO. The Test-Specific QAO verify's the results for the verification test by performing hand calculations on one spreadsheet data set. The Test-Specific QAO verifies that all QA/QC requirements have been obtained. If all QA/QC requirements have not been satisfied, the Test-Specific QAO notifies the Test-Specific Manager and the Verification Test Leader and the run is voided. If all QA/QC requirements have been satisfied, the Test-Specific QAO transfers the information to APCT Center for final draft preparation.

7.2 ASCII Text Files

Raw data from the Loggy program used in the FEMA test apparatus shall be saved in the appropriate directory as an ASCII text file. Files will be named by the following designation:

aaaabbcd.txt

aaaa - four-letter test series designation
bb - two-letter test phase designation as follows:
cp - conditioning period
rp - recovery period
pt - performance test
c - numerical designation for the test run within a test series (usually 1, 2, or 3). Use additional numbers (4, 5, 6, etc) in the event of a voided test runs.
d - one-letter designation of "x" to signify the residual pressure drop files for the recovery and performance test periods (no designation is given for the complete data file).

7.3 Files Containing Detailed Summary and Results of VDI Data

The first step in reduction of the ASCII text files shall be conducted using Microsoft Excel 2000. The Loggy program will produce two types of files; a basic data files consisting of periodic readings of all data channels, and an "msx" file consisting of the residual pressure drop three seconds after each cleaning pulse. A step-by-step procedure for data reduction is as follows:

7.3.1 Open the ASCII text file in Microsoft Excel using the [File] [Open] commands. Select "Fixed Width" as the type of data in the data file and click on "Next". Identify the appropriate column placements. For the non msx file use the following to separate columns: |Time|irr msx|Raw Gas|Clean Gas|Diff Press|Balance|Fotometer|Pressure|Temperature|Sample (performance test only)|. For the msx text file use the following column separation: |Time|irr msxRaw GasClean Gas|Diff Press|BalanceFotometerPressureTemperatureSample (performance test only)|. When using the "fixed Width" option 7.3.2 is skipped. "Delimited" option can also be used. If "Delimited" option is used, The data will appear un-parsed separated by spaces in column A.

7.3.2 Select column A, and parse the data using the [Data] [Text to Columns] commands. Select Fixed Width as the target data type.

7.3.3 Prepare the data for calculations by deleting all unnecessary columns and arranging as follows.

For the basic data file:

Column A: Time (s)
Column B: Raw-Gas Flow (scm/hr)
Column C: Clean-Gas Flow (scm/hr)
Column D: Fabric Pressure Drop (Pa)

Column E: Dust Feed Weight (g)
Column F: Absolute Gas Pressure (mbar)
Column G: Raw-Gas Temperature (°C)
Column H: Sample-Gas Flow (scm/hr, if applicable - for performance tests only)

For the residual pressure drop file:

Column A: Time (s)
Column B: Residual Pressure Drop (Pa)

The first row of data (for time = 0 seconds) must begin in row 10.

7.3.4 Reduction of The Basic Data File

7.3.4.1 Rename the current data sheet as "A" and insert a blank worksheet after sheet A.

7.3.4.2 Copy the corresponding worksheet from the R:\FEMA\Template directory onto the blank worksheet following sheet A. A separate template is necessary for each test phase.

7.3.4.3 Delete all references to the template file using the [Edit] [Replace] command. Replacing the name of the template file with nothing will delete the reference to the template file from the subject data file. Thus, the calculations within the subject worksheet will reference the data within the subject file rather the data within the template file.

7.3.4.4 For the fabric recovery period, change the averaging times in the template to facilitate averaging of each 60-minute block during the test and for the final 60 minutes of each test.

7.3.4.5 Enter the required data from the applicable run sheets, the residual pressure drop file, and the impactor file. Average residual pressure drop, average pulse interval, and number of pulses are calculated in the residual pressure drop file. Total weight gain and backup filter weight gain are calculated in the impactor file. All other data are obtained from the run sheets. Data are to be entered only in the green-colored fields. Do not enter data over black-colored fields.

7.3.5 Reduction of the Residual Pressure Drop File.

7.3.5.1 Average the residual pressure drop for each pulse throughout the run. This value is entered in the basic data file as the average residual pressure drop.

7.3.5.2 In column C, calculate the pulse interval for each row of data. The first pulse interval is the time of measurement for the first pulse minus three seconds. For each subsequent pulse (number n), the pulse interval is calculated by subtracting the time of the previous pulse (n-1) from the time of pulse n. The average of pulse intervals throughout the run is entered in the basic data file as the average pulse interval.

7.3.5.3 In column D, number each pulse. Enter the number of the last pulse as the number of pulses in the basic data file.

7.4 Impactor Data Files

The impactor files are used to reduce the Andersen Impactor data from the performance test period.

7.4.1 Using Excel 2000, select the impactor file template from the R:\FEMA\Template directory and rename it in the directory for the test series. Files will be named by the following designation:

aaaaimpc.wb2

aaaa - four-letter test series designation
imp - designation signifying an impactor run
c - numerical designation for the test run within a test series (usually 1, 2, or 3). Use additional numbers (4, 5, 6, etc) in the event of a voided test runs.

7.4.2 Enter the required data from the applicable run sheets and the basic data file. Sample-gas flow (in scm/hr), raw-gas pressure (in mbar), average fabric pressure drop (in Pa), and average gas temperature (in ^{o}F) are calculated in the basic data . All other data are obtained from the run sheets. Data are to be entered on the "Sampling" and "Gravimetric" pages only in the green-colored fields. Do not enter data over black colored fields.
7.4.3 On the "Calculations" page, ensure the proper material density is entered in cell F5. Use a material density of 2.65 g/cc for the Pural NF dust.
7.4.4 On the "Calculations" page, check the number of jets used to obtain a 2.5 *u*m cut point on plate no. 3 (entered in cell Q13). Plate 3 should be configured with 154 jets for the Pural NF dust and the operating parameters specified herein.
7.4.5 Engage the macro used for calculation of the particle-size cut point by right-clicking the [Solve for D-50's] macro button on the "Calculations" page

8.0 Verification Report

A fully documented test report is required. The verification report shall adhere to the format as specified in the *Generic Verification Protocol for the Baghouse Filtration Products* and the Test/QA Plan.

Attachment A Example Data Sheets

Attachment B Verification Testing Spreadsheets

Attachment A

Example Data Sheets

BAGHOUSE FILTRATION PRODUCTS
VERIFICATION TESTING

TEST RUN ID: ____________ FABRIC ID: ____________
TEST FACILITY: ____________ DUST: ____________

Conditioning Period

CONDITIONING - 0-10000 PULSES
DATE: ____________
START TIME: ____________
STOP TIME: ____________
RUN TIME: ____________

AMBIENT CONDITIONS
Temperature (F): ____________ Wet Bulb (F): ____________
Pressure (in Hg) ____________ Humidity (%RH): ____________

Recovery Period

FABRIC RECOVERY - 10000-10030 PULSES
DATE: ____________
START TIME: ____________
STOP TIME: ____________
RUN TIME: ____________

AMBIENT CONDITIONS
Temperature (F): ____________ Wet Bulb (F): ____________
Pressure (in Hg) ____________ Humidity (%RH): ____________

Performance Test Period

PERFORMANCE TEST PERIOD - 6-HOURS
DATE: ____________
START TIME: ____________
STOP TIME: ____________
RUN TIME: ____________

AMBIENT CONDITIONS
Temperature (F): ____________ Wet Bulb (F): ____________
Pressure (in Hg) ____________ Humidity (%RH): ____________

Operator Signature: ____________

ETS, Inc.

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

TEST FACILITY: ____________________
IMPACTOR SET ID: ____________________
FABRIC ID: ____________________
TEST RUN ID: ____________________

PRE-WEIGHING			POST-WEIGHING		
Date:			Date:		
Start Time:			Start Time:		
Stop Time:			Stop Time:		
CONDITIONING	Date	Time	**CONDITIONING**	Date	Time
Conditioning Start:			Conditioning Start:		
Conditioning Stop:			Conditioning Stop:		
Conditioning Successful?:	yes/no		Conditioning Successful?:	yes/no	
(Attach Temperature and Humidity Data)			(Attach Temperature and Humidity Data)		
CALIBRATION DATA:			**CALIBRATION DATA:**		
Time:			Time:		
Response to 1g weight:			Response to 1g weight:		
Within 0.00005g?	yes/no		Within 0.00005g?	yes/no	

Stage	Pre-Weight* (g)	Post-Weight* (g)	Weight Gain (g)
0			
1			
2			
3			
4			
5			
6			
7			
8			
Filter			

* Including labeled weigh foils

Operator Signature: ____________________

LOW RESOLUTION ANALYTICAL BALANCE DATA SHEET

TEST FACILITY: ______________

FABRIC ID: ______________

CALIBRATION (PRE)

Date: ______________

Time: ______________

Response to 100g Wt.: ______________

Within 0.05 g? yes/no ______________

CALIBRATION (POST)

Fabric Sample ID	Test Run ID

Pre-Weight (g)	Post Weight (g)	Weight Gain (g)

Date	Time	Calibration (g)	Response Within 0.05 g
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No

Operator Signature: ______________

ETS, Inc.

Attachment B

Verification Testing Spreadsheets

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
REFERENCE FABRIC SUMMARY OF RESULTS AT 2 M/MIN
ETS CONTRACT NUMBER: 98-277 DATE: 10/23/02

RUN ID.	RF-1	RF-2	AVERAGE
FABRIC DESIGNATION	101602-1	101602-2	Ref. Fabric
MANUFACTURER	NA	NA	
DUST FEED	Pural NF	Pural NF	
CONDITIONING PERIOD			
Date Started	10/17/2002	10/18/2002	
Time Started	13:28	14:10	
Time Ended	21:48	22:30	
Test Duration (min.)	500	500	500
RECOVERY PERIOD			
Date Started	10/18/2002	10/21/2002	
Time Started	7:03	6:40	
Time Ended	7:46	7:24	
Test Duration (min.)	43	44	44
PERFORMANCE TEST PERIOD			
Date Started	10/18/2002	10/21/2002	
Time Started	7:57	7:32	
Time Ended	13:57	13:32	
Test Duration (min.)	360	360	360
VERIFICATION TEST RESULTS			
Mean Outlet Particle Conc. PM 2.5 (g/dscm)	0.0001518	0.0001553	0.0001536
Mean Outlet Particle Conc. Total mass (g/dscm)	0.0001518	0.0001553	0.0001536
Initial Residual Pressure Drop (cm w.g.)	3.92	3.94	3.93
Change in Residual Pressure Drop (cm w.g.)	1.72	1.85	1.79
Average Residual Pressure Drop (cm w.g.)	5.06	5.16	5.11
Mass Gain of Filter Sample (g)	1.85	1.77	1.81
Average Filtration Cycle Time (s)	43	41	42
Number of Pulses	499	525	512
RESIDUAL PRESSURE DROP			
At Start of:			
Conditioning Period (cm w.g.)	0.12	0.12	0.12
Recovery Period (cm w.g.)	3.52	3.44	3.48
Performance Test Period (cm w.g.)	3.92	3.94	3.93

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

CONDITIONING PERIOD - 2 M/MIN

RUN ID.	RF-1	NUMBER OF PULSES	10000
FABRIC DESIGNATION	101602-1	PULSE INTERVAL	3 s
MANUFACTURER	NA		
DUST FEED	Pural NF	Moisture	1.67 %WV
DATE STARTED	10/17/2002		
TIME STARTED	13:28		
TIME ENDED	21:48		
TEST DURATION	500 min.		

QA/QC DATA

Test Duration	Time		Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)			Initial	Final	Total	Raw	Clean	Total	(° C)	(mbar)	(g/dscm)	(m/h)
0-60	13:28	14:28	1448.3	1356.0	92	3.77	1.75	5.52	24	975.59	17.0	120
61-120	14:29	15:28	1356.0	1262.0	94	3.78	1.76	5.54	23	976.05	17.3	120
121-180	15:29	16:28	1262.0	1166.6	95	3.78	1.76	5.54	23	976.61	17.5	120
181-240	16:29	17:28	1166.6	1072.4	94	3.78	1.76	5.54	23	976.67	17.3	120
241-300	17:29	18:28	1072.4	980.9	92	3.78	1.76	5.54	23	977.32	16.8	120
301-360	18:29	19:28	980.9	883.6	97	3.78	1.76	5.54	23	977.45	17.9	120
361-420	19:29	20:28	883.6	790.2	93	3.78	1.76	5.54	23	978.23	17.1	120
421-480	20:29	21:28	790.2	696.6	94	3.79	1.76	5.55	23	978.48	17.2	120
441-500 *	20:49	21:48	757.0	665.4	92	3.79	1.76	5.55	23	978.60	16.8	119
AVERAGE FOR 500 MINUTE RAW DATA					94	3.78	1.76	5.54	23	977.12	17.2	120
ACCEPTANCE					100 +/- 20				25 +/- 2		18.4 +/- 3.6	120 +/- 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: [signature]

Sharon M. Winemiller - ETS, Inc.

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

RECOVERY PERIOD - 2 M/MIN

RUN ID.	RF-1	NUMBER OF PULSES	30
FABRIC DESIGNATION	101602-1	AVG. PULSE INTERVAL	85 s
MANUFACTURER	NA	AVG . RESIDUAL ΔP	368.53 Pa
DUST FEED	Pural NF	INITIAL RESIDUAL ΔP	344.70 Pa
DATE(S)	10/18/2002	FINAL RESIDUAL ΔP	389.60 Pa
TIME STARTED	7:03 *	CHANGE IN ΔP	44.90 Pa
TIME ENDED	7:46	MAX. PRESSURE DROP	1000 Pa
TEST DURATION	43 min.	% Moisture	1.29 %WV

QA/QC DATA

Test Duration (min.)	Time		Dust Feed (g) Initial	Final	Total	Average Gas Flow (sm^3/hr) Raw	Clean	Total	Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
1-43 *	7:04	7:46	1441.4	1374.5	67	3.8	1.8	5.60	22.2	983.0	12.1	121
AVERAGE FOR 43 MINUTE RAW DATA					94	3.77	1.77	5.54	22	982.95	17.2	119
ACCEPTANCE					100 +/- 20				25 +/- 2		18.4 +/- 3.6	120 +/- 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: [signature]

Sharon M. Winemiller - ETS, Inc.

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

PERFORMANCE TEST PERIOD - 2 M/MIN

RUN ID.	RF-1
FABRIC DESIGNATION	101602-1
MANUFACTURER	NA
DUST FEED	Pural NF
DATE STARTED	10/18/2002
TIME STARTED	7:57
TIME ENDED	13:57
TEST DURATION	360 min.

NUMBER OF PULSES	499
AVG. PULSE INTERVAL	43 s
AVG. RESIDUAL ΔP	495.24 Pa
INITIAL RESIDUAL ΔP	384.00 Pa
FINAL RESIDUAL ΔP	552.30 Pa
CHANGE IN ΔP	168.30 Pa
MAX. PRESSURE DROP	1000 Pa
Moisture	1.29 %WV

QA/QC DATA

Test Duration (min.)	Time		Dust Feed (g) Initial	Final	Total	Average Gas Flow (sm^3/hr) Raw	Clean	Total	Sample	Avg. Temp (° C)	Avg Press (mbar)	Dust Conc. (g/dscm)	G/C Ratio (m/h)
0-60	7:57	8:57	1365.3	1272.1	93	3.79	1.78	5.57	1.09	22	983.60	17.0	120
61-120	8:58	9:57	1272.1	1178.6	94	3.80	1.78	5.58	1.09	23	983.91	17.0	120
121-180	9:58	10:57	1178.6	1086.3	92	3.80	1.78	5.58	1.09	23	984.03	16.8	120
181-240	10:58	11:57	1086.3	990.1	96	3.80	1.78	5.58	1.10	23	984.02	17.5	120
241-300	11:58	12:57	990.1	889.1	101	3.80	1.78	5.58	1.10	24	983.83	18.3	121
301-360	12:58	13:57	889.1	782.9	106	3.80	1.78	5.58	1.10	24	983.25	19.3	121
AVERAGE FOR 360 MINUTE RAW DATA					97	3.80	1.78	5.58	1.09	23	983.78	17.6	120
ACCEPTANCE					100 +/- 20					25 +/- 2		18.4 +/- 3.6	120 +/- 6

GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00098 g	Tare Mass	11.88 g
Total Mass Gain	0.00098 g	Final Mass	13.73 g
		Mass Gain	1.85 g

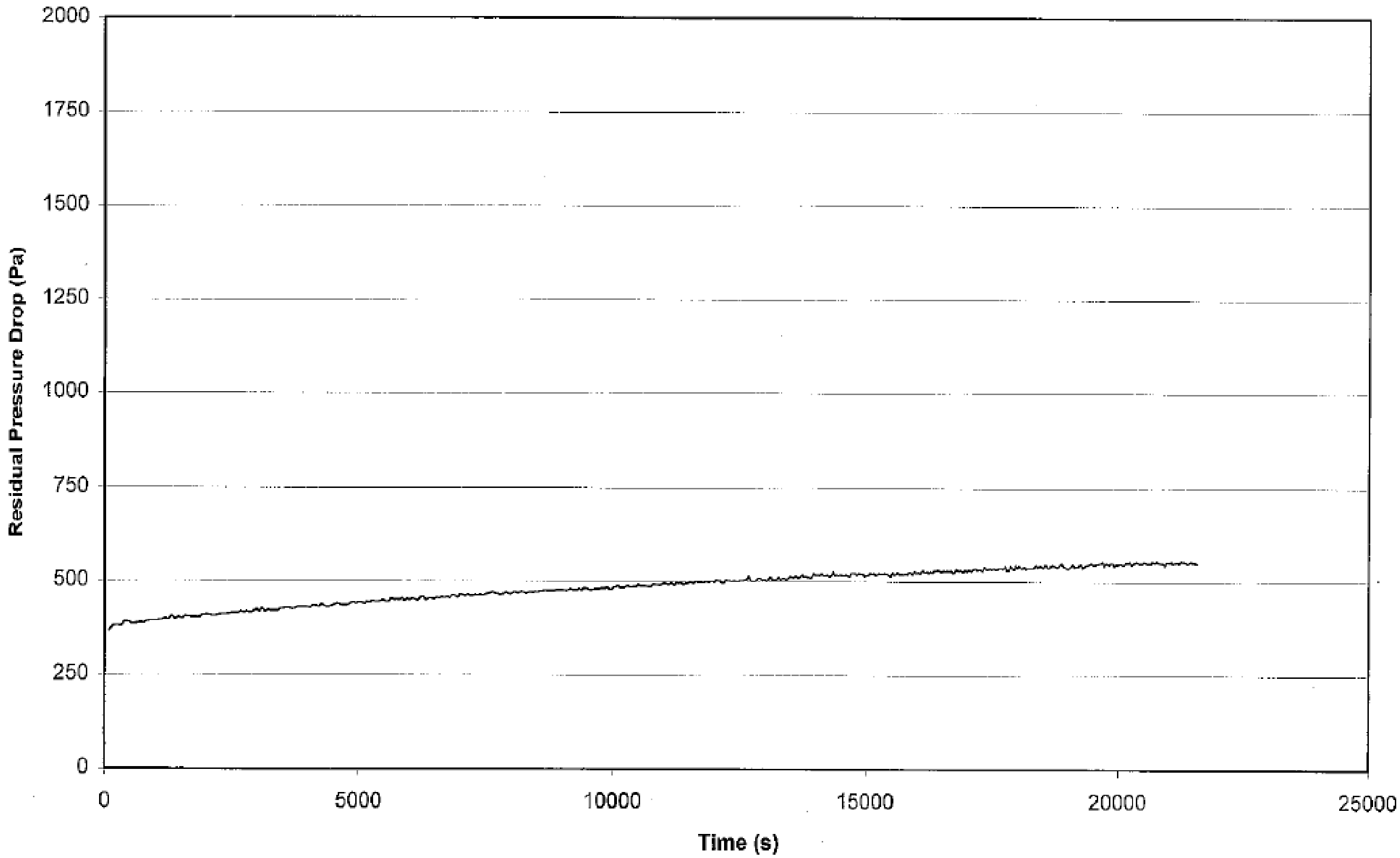
OUTLET CONCENTRATION

Total Volume Sampled	6.87 m^3
Mean Outlet Particle Concentration - PM 2.5	0.0001427 g/m^3
Mean Outlet Particle Concentration - Total Mass	0.0001427 g/m^3

DATA PROCESSING OPERATOR:

Sharon M. Winemiller - ETS, Inc.

Residual pressure drop across filter fabric during performance test period RF-1



Change in Pural NF dust scale reading with time during performance test period RF-1