

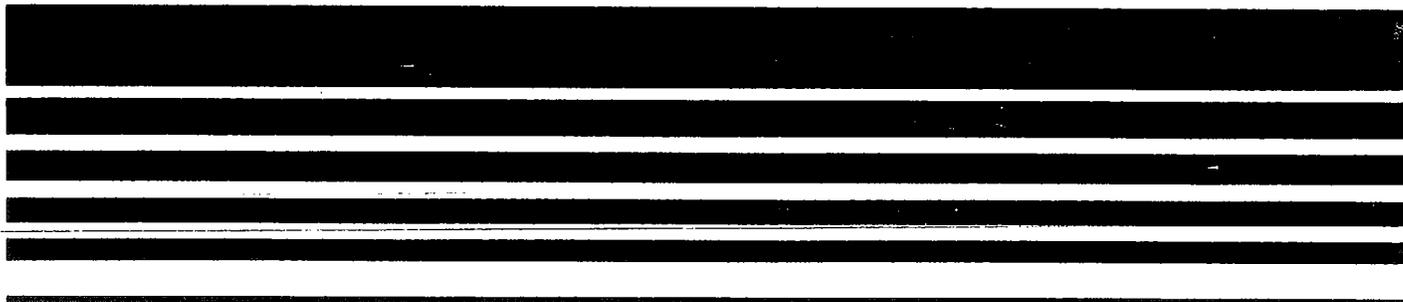


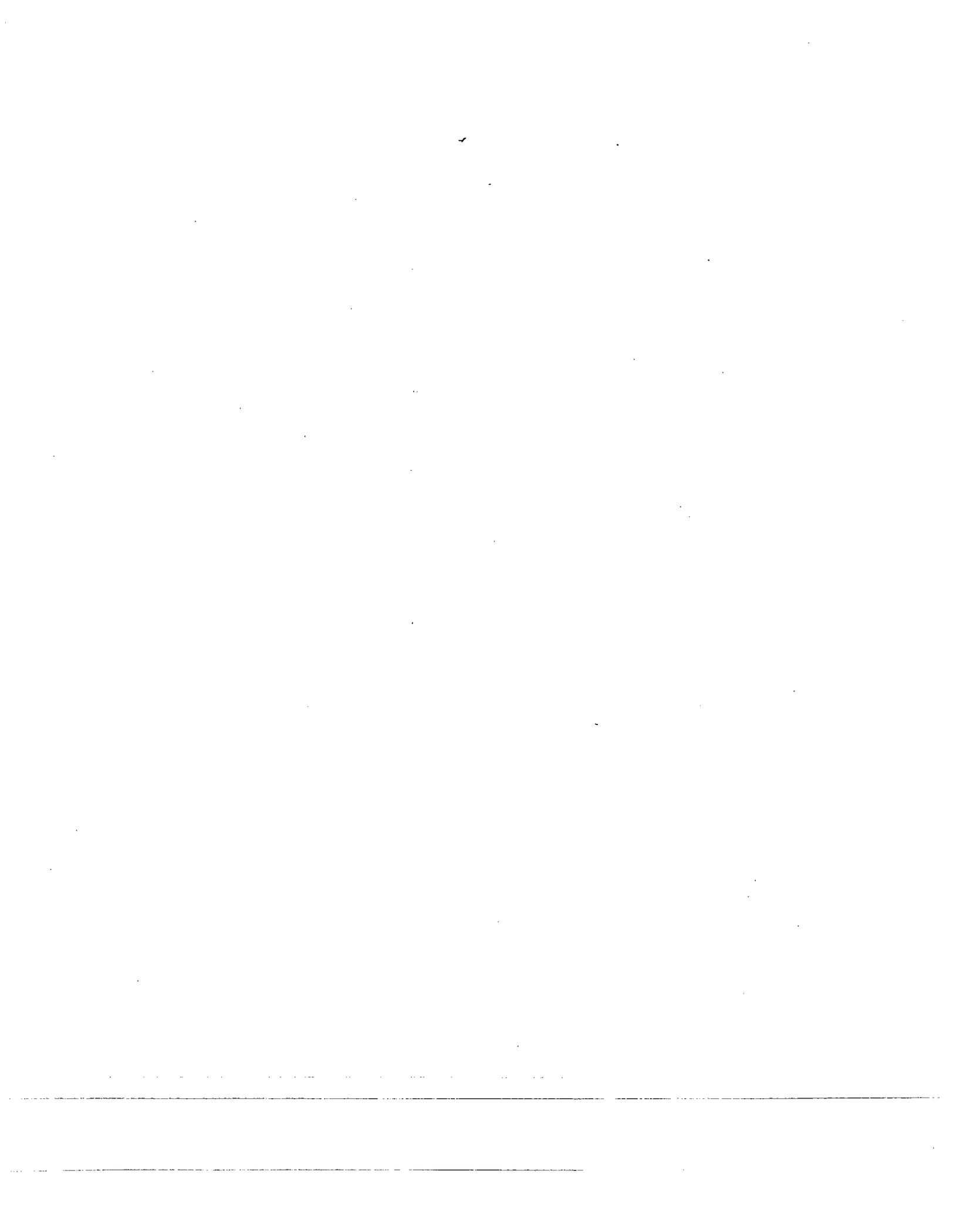
APTI

Course 470

Quality Assurance
for Air Pollution
Measurement Systems

Student Reading Material
Chapters 17-20





Usage of this material

This material has been developed and assembled to provide training and is not intended to be used for regulatory purposes, or to be a substitute for, nor interpreted as official Agency policy. Every attempt was made to reflect the technical state of art and regulatory information as of the date of publication.

Lesson 17

Quality Assurance Guidance for PM_{2.5} Ambient Air Monitoring - Part I

Lesson Goal

Familiarize students with EPA quality assurance regulations and guidance for PM_{2.5} ambient air quality monitoring.

Lesson Objectives

1. Recall that the data quality objective (DQO) process serves as the driving force for the QA system and that the DQOs for PM_{2.5} are 10% coefficient of variation (CV) for total precision and $\pm 10\%$ for total bias.
2. Recall the following goals for accuracy of the sampler's flow rate: within $\pm 2\%$ of the audit device during multipoint verification/calibration; $\pm 4\%$ during one-point verification checks and audits; and within $\pm 5\%$ of the sampler's design flow rate of 16.67 L/min.
3. Recall that the formal specifications for PM_{2.5} samplers are in 40 CFR Part 50 Appendix L, and the formal QA/QC requirements are in 40 CFR Part 58 Appendix A.
4. Identify the EPA QA guidance documents for PM_{2.5} listed below in References Section.
5. Explain the meaning of the words *shall*, *must*, *should*, and *may* in terms of QA/QC regulations and guidance.
6. List at least two of the essential elements of a PM_{2.5} method.
7. Describe the basic differences between a reference method and an equivalent method.
8. List at least two conditions or effects that limit the degree to which a PM_{2.5} reference or Class I equivalent method can precisely determine the mass concentration of PM in the atmosphere.
9. List at least two laboratory operator prerequisite qualifications for persons involved in PM_{2.5} laboratory operations, and two field operator prerequisite qualifications for persons involved in PM_{2.5} field operations.
10. Recall three health and safety warnings to heed when operating PM_{2.5} samplers.
11. Recall the difference between the PM_{2.5} sampler inlet and the PM_{2.5} sampler impactor and filter holder assembly.
12. State the frequency of precision checks for collocated samplers.
13. Recall the acceptance criteria for external PM_{2.5} audits.
14. List at least four items to be considered when siting a PM_{2.5} sampler.

15. Recall the need for calibrating a PM_{2.5} sampler in terms of actual volumetric flow rate as opposed to the standard volumetric flow rate.
16. List at least five flow rate standard devices.
17. Recall the fundamental working principles of the Fortin mercurial type barometer and the precision Aneroid barometer.
18. List two types of leak checks specified for use with PM_{2.5} samplers.
19. Recall the readability and repeatability requirements of the analytical microbalance used for PM_{2.5} measurements.
20. Recall the environmental factors that must be controlled when using a microbalance for PM_{2.5} mass measurement.
21. List the range of mass reference standards for PM_{2.5}.
22. Discuss the PM_{2.5} filter handling precautions that are necessary to avoid measurement errors.
23. List at least five filter defects to look for in conducting a visual inspection of PM_{2.5} filters.

References

U.S. Environmental Protection Agency. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part II, Section 2.12, Monitoring PM_{2.5} in Ambient Air Using Designated Reference or Class I Equivalent Methods*, November 1998.

Revised Requirements for Designation of Reference and Equivalent Methods for PM_{2.5} and Ambient Air Quality Surveillance for Particulate Matter; Final Rule. U.S. Environmental Protection Agency, 40 CFR, Parts 53 and 58, Federal Register, July 18, 1997.

National Ambient Air Quality Standards, for Particulate Matter, Appendix K- Interpretation of the National Ambient Air Quality Standards for Particulate Matter, and Appendix L-Reference Method for the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere; Final Rule. U.S. Environmental Protection Agency, 40 CFR Part 50, Federal Register, July 18, 1997.

U.S. Environmental Protection Agency. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I, Ambient Air Quality Monitoring Program Quality System Development*. EPA 454/R-98-004, August 1998.

U.S. Environmental Protection Agency. *Quality Assurance Guidance Document, Model Quality Assurance Project Plan for the PM_{2.5} Ambient Air Monitoring Program at State and Local Air Monitoring Stations (SLAMS)*. EPA-454/R-98-005, April 1998.

Section I. Introduction

This lesson is Part I of two lessons on the formal EPA quality assurance/quality control requirements and guidance pertaining to ambient air monitoring for PM_{2.5} using reference methods or Class I equivalent methods. Part II is contained in Lesson 18. The material in this Lesson is extracted from Subsections 1 through 7 of EPA's QA Handbook, Vol. II, Part II, Section 2.12, Monitoring PM_{2.5} in Ambient Air Using Designated Reference or Class I Equivalent Methods, EPA November 1998. PM_{2.5} refers to particles with a mean aerodynamic diameter less than or equal to 2.5 μm. On July 18, 1997 EPA promulgated new PM standards including NAAQS for PM_{2.5}, in 40 CFR Part 50, Federal Register Vol. 62, No.138. Appendix L, of the Part 50 rules, contains the Federal Reference Method for the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere. Also, on the same date, EPA promulgated final rules in 40 CFR Part 53 and 58, titled Revised Requirements for Designation of Reference and Equivalent Methods for PM_{2.5} and Ambient Air Quality Surveillance for Particulate Matter.

Appendix A of Part 58, which contains quality assurance/quality control requirements for State and Local Air Monitoring Stations (SLAMS), was revised to include quality assurance/quality control requirements for monitoring PM_{2.5}. To assist State and local agencies in effectively implementing the new PM_{2.5} monitoring requirements, EPA issued the PM_{2.5} QA Handbook, Section 2.12.

Section I of this Lesson addresses the purpose and applicability of Section 2.12 of the QA Handbook; the use of the terms *shall*, *must*, *should*, and *may*; an overview of reference and equivalent methods for PM_{2.5}; and limitations of the reference and equivalent methods. Section II covers the basic qualifications of laboratory and field operations personnel, training suggestions, and health and safety precautions. Section III presents summaries of the principles of the reference method, calculations of mass concentration, sampler design illustrations, field QA/QC checks, laboratory QA/QC checks, and a summary of sampling procedures. Section IV covers the procurement of equipment and supplies for field and laboratory PM_{2.5} monitoring operations, including reference or equivalent method samplers, calibration equipment, flow check devices, audit equipment, filter media, filter cassettes, filter handling containers, the analytical microbalance, and mass reference standards. Section V addresses sampler installation, including spatial and temporal scales; probe siting requirements; safety, electrical, and security considerations; and PM_{2.5} sampler installation procedures.

Section VI discusses calibration procedures, including flow rate measurement systems, traceability and certification, flow rate calibration procedures, calibration of sampler temperature and pressure sensors, leak checks, and multipoint and single point verifications or calibrations. Section VII addresses filter preparation and analysis, including the microbalance, mass reference standards, filter handling, and filter integrity checks.

Purpose of the QA Guidance Document

The major purpose of Section 2.12 of the PM_{2.5} QA Handbook is to assist control agency monitoring personnel in the use of reference methods or Class I equivalent methods for monitoring ambient air for PM_{2.5}. It provides clarifications and supplemental information for the monitoring regulatory requirements, and also includes recommended quality assurance procedures and guidance to assist agencies in achieving the data quality objectives (DQOs) established for PM_{2.5} monitoring. The goal for acceptable measurement uncertainty is 10% coefficient of variation (CV) for total precision and $\pm 10\%$ for total bias. In addition the following accuracy goals for the sampler's flow rate have been established: $\pm 2\%$ of the audit device during multipoint verification/calibration; $\pm 4\%$ during one-point verification checks and audits; and $\pm 5\%$ of the sampler's design flow rate of 16.67 L/min.

Applicability

Section 2.12 of the PM_{2.5} QA Handbook is primarily applicable to PM_{2.5} ambient air monitoring with reference methods carried out by State and local air monitoring agencies in their State and local air monitoring stations (SLAMS) air surveillance networks. The document is also applicable to other organizations required to carry out SLAMS or SLAMS-related PM_{2.5} monitoring and to any PM_{2.5} monitoring activity for which the PM_{2.5} reference method measurements are to be entered into the Aerometric Information and Retrieval System (AIRS) database. The recommendations and guidance in this document — to the extent that they go beyond the specific regulatory requirements set forth in the method or in the sampler-specific requirements contained in a particular sampler's operation or instruction manual — are not mandatory or binding. However, monitoring agencies are strongly encouraged to adopt and follow the recommendations and guidance to help ensure that monitoring data are of acceptable quality. Where a high level of data quality is needed, following the recommendations and guidance is also strongly encouraged for any PM_{2.5} monitoring activity using reference or Class I equivalent methods.

The Section 2.12 document is not a full description of a PM_{2.5} monitoring method and does not substitute for the formal method description as set forth in the PM_{2.5} reference method. Also it is not a replacement for the sampler-specific requirements contained in the associated operation or instruction manual, which is an official part of each designated reference or equivalent method for PM_{2.5}.

Conventions

Where the QA PM_{2.5} document refers to mandatory method requirements, the terms “shall” and “must” are used, and a supporting reference to the applicable section of the reference method regulation is generally provided. Use of the word “should” indicates an activity or procedure that is strongly recommended to help achieve a high level of measurement data quality but is not formally required by the method itself. Finally, the word “may” is used to indicate activities or suggestions that are optional or discretionary. The use of these terms is generally consistent with American National Standards Institute/American Society for Quality Control (ANSI/ASQC) E4-1994 guidance (ANSI/ASQC 1994).

Overview of Reference and Equivalent Methods for PM_{2.5} Monitoring

A “method” for PM_{2.5} generally consists of the following:

- A PM_{2.5} sampler or analyzer designed, built, and sold by a particular manufacturer
- An operation or instruction manual provided by the instrument manufacturer that describes the proper use and operation of the sampler or analyzer
- The other operational and QA requirements necessary to obtain reliable PM_{2.5} concentration measurements.

Methods used for monitoring PM_{2.5} in SLAMS or SLAMS-related air monitoring are required to be either reference or equivalent methods as designated by EPA under the requirements and provisions of 40 CFR Part 53. For most SLAMS purposes, reference and equivalent methods may be used interchangeably, and a particular method’s identity as either a reference or an equivalent method is irrelevant. However, for some purposes, such as collocated auditing, a reference method may be specifically required. A current publication, List of Designated Reference and Equivalent Methods, identifying all methods that have been designated as reference or equivalent methods by EPA, is available from any EPA Regional Office or by writing to “Department E” (MD-46), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. The U.S. EPA’s AMTIC web site, <http://www.epa.gov/ttn/amtic/>, contains several sites with information on all the designated Reference and Equivalent methods for the criteria pollutants and will include PM_{2.5} methods as they are designated and updated. Refer to the topic “What’s New?” for the latest updates.

Reference Methods

All formal sampler design and performance requirements and the operational requirements applicable to reference methods for PM_{2.5} are specified in Appendix L of 40 CFR Part 50. These requirements are quite specific and include explicit design specifications for the type of sampler, the type of filter, the sample flow rate, and the construction of the sample collecting components. However, various designs for the flow rate control system, the filter holder, the operator interface controls, and the exterior housing are possible. Hence, various reference method

samplers from different manufacturers may vary considerably in appearance and operation. Also, a reference method may have a single filter capability (single sample sampler) or a multiple filter capability (sequential sample sampler), provided there are no deviations in the design and construction of the sample collection components specified in the reference method regulation. A $PM_{2.5}$ method is not a reference method until it has been demonstrated to meet all the reference method regulatory requirements and has been officially designated by EPA as a reference method for $PM_{2.5}$.

Equivalent Methods

Equivalent methods for $PM_{2.5}$ have a much wider latitude in their design, configuration, and operating principle than reference methods. These methods are not required to be based on filter collection of $PM_{2.5}$; therefore, continuous or semicontinuous analyzers and new types of $PM_{2.5}$ measurement technologies are not precluded as possible equivalent methods. Equivalent methods are not necessarily required to meet all the requirements specified for reference methods, but they must demonstrate both comparability to reference method measurements and similar $PM_{2.5}$ measurement precision.

The requirements that some (but not all) candidate methods must meet to be designated by EPA as equivalent methods are specified in 40 CFR Part 53. To minimize the difficulty of meeting equivalent method designation requirements, three classes of equivalent methods have been established in the 40 CFR Part 53 regulations, based on the degree to which a candidate method deviates from the reference method requirements. All three classes of equivalent methods are acceptable for SLAMS or SLAMS-related $PM_{2.5}$ monitoring. But not all types of equivalent methods may be equally suited to specific $PM_{2.5}$ monitoring requirements or applications.

Class I equivalent methods are very similar to reference methods, with only minor deviations, and must meet most of the reference method specifications and requirements. The requirements for designation as Class I equivalent methods are slightly more extensive than the designation requirements for reference methods. Also, because of their substantial similarity to reference methods, Class I equivalent methods operate very much the same as reference methods, and most of the information and guidance in the Section 2.12 document is also applicable to Class I equivalent methods.

Class II equivalent methods are filter-collection-based methods that differ more substantially from the reference method requirements. The requirements for designation as Class II methods may be considerably more extensive than for reference or Class I equivalent methods, depending on the specific nature of the variance from the reference method requirements.

Class III equivalent methods cover any $PM_{2.5}$ methods that cannot qualify as reference or Class I or II equivalent methods because of more profound differences from the reference method requirements. This class encompasses $PM_{2.5}$ methods such as continuous or semicontinuous $PM_{2.5}$ analyzers and potential new $PM_{2.5}$ measurement technologies. The requirements for designation

as Class III methods are the most extensive, and, because of the wide variety of $PM_{2.5}$ measurement principles that could be employed for candidate Class III equivalent methods, the designation requirements are not explicitly provided in 40 CFR Part 53.

Limitations of $PM_{2.5}$ Reference and Class I Equivalent Methods

There are several conditions or effects that limit the degree to which a $PM_{2.5}$ reference or Class I equivalent method can precisely determine the mass concentration of particulate matter in the atmosphere. One limitation is maintaining the specified ambient air flow rate through the sampling inlet and filter assembly. The flow rate determines the size of the particles that will be collected. The effects of this limitation are minimized by following sampler construction requirements and by employing procedures and checks to ensure the proper flow rate is maintained within close tolerances.

Another important limitation involves changes in the weight of a collected sample due to mishandling, chemical reactions, and volatilization. Handling procedures, choice of filter media, humidity and temperature control of the filter and sample during collection and subsequent processing, and promptness in weighing the sample following collection all help control filter artifacts. The chemical makeup of the $PM_{2.5}$ particulate matter will vary with sampling location and source. Thus, the magnitude of $PM_{2.5}$ weight changes due to chemical and physical processes will also vary with site location.

Weight loss due to mechanical removal of particles from the filter is minimized by carefully removing the filter, in its cassette, from the sampler, storing the filter/cassette in a protective container during transit to the weighing laboratory, and carefully removing the filter from the cassette, conditioning the filter, and neutralizing the static charge on the filter before weighing.

The choice of an essentially neutral polytetrafluorethylene (PTFE) media filter as the collecting surface minimizes the weight gain that occurs when sulfate-containing particles form by chemical reactions of sulfur dioxide gas at the surface of alkaline media such as glass fiber filters. Appendix A of Section 2.12 discusses this effect and gives a procedure for measuring the alkalinity of filters. If nitric acid vapor is present at a sampling location, it can deposit on a PTFE filter and cause small weight gains in proportion to the amount of nitric acid present in the atmosphere. This weight gain may not be controllable. Weight losses can occur due to thermal or chemical decomposition or evaporation of compounds like ammonium nitrate (NH_4NO_3), which releases ammonia and nitric acid as gases. Semivolatile organic compounds (SVOCs) may be part of the sample makeup; if so, they may evaporate and cause sample weight losses. Such weight losses are minimized or standardized by maintaining the sampler temperature near ambient conditions during the sampling process, keeping the sample cool during transport to the laboratory, and promptly conditioning and weighing the sample following its receipt in the laboratory. Weight gain or loss due to absorption or desorption of water vapor on the filter or on the particulate matter is minimized by specifying low moisture pickup for manufactured filters and by conditioning the filters within specified humidity and temperature ranges, both before use and after

receipt from the field.

Errors in the gravimetric analysis of samples can also result from the buildup of electrostatic charge on filters during their manufacture or during sampling. This static buildup will interfere with the microbalance weighing, but it can be reduced or eliminated by the use of Polonium-210 (^{210}Po) antistatic strips before the weighing process begins.

Section II. Personnel Qualification, Training, and Health and Safety Warnings

Although many of the terms associated with PM_{2.5} monitoring are very similar to the terminology associated with PM₁₀ ambient monitoring, a number of new terms have been initiated with the promulgation of the PM_{2.5} regulations. As a result, a listing of "Key Terms" is included in Section 2.12 of the QA Handbook. A copy of this listing is included as Table 17-1. The general aspects of personnel qualifications, training, and guidance are discussed in Volume II, Part I, Section 4 of the QA Handbook. SLAMS reporting organizations or State or local agencies may find information from this reference as well as specific information about PM_{2.5} monitoring in the Section 2.12 document and other sources helpful in developing an appropriate PM_{2.5} monitoring training program for their organization.

The responsibility for ensuring appropriate training of personnel belongs to management. In addition, the Quality Assurance Manager or Coordinator of the respective organization should be actively involved in overseeing this training program. This should include emphasizing to management the critical need for adequate training. Also, it should address recommending that the organization's personnel be tested or examined to evaluate the success of training and identify any need for additional emphasis.

Laboratory Personnel Qualifications

For PM_{2.5} monitoring, all laboratory personnel should be familiar with general environmental procedures and related equipment. Microbalance operators must be very knowledgeable and attentive to details concerning the extra care needed to determine the mass of PM_{2.5} ambient air samples. Training for persons involved in laboratory PM_{2.5} operations should include the use of appropriate methods to determine temperature, pressure, and relative humidity (RH) in the laboratory; the proper use of the microbalance and antistatic devices; and the labeling and archiving of samples in the laboratory. It should also include the calculating of the mass and concentration of particulate matter, and the reporting of data to the reporting organization's data bank and EPA's AIRS.

Field Personnel Qualifications

Field operations personnel should be familiar with environmental field measurement procedures and techniques. Likewise, they should be conscientious and attentive to detail to ensure the collection of the highest quality PM_{2.5} data. Persons qualified to perform PM_{2.5} field monitoring should be able to calibrate, operate, and audit the sampler; troubleshoot, maintain, and perform minimum maintenance of the sampler; use common methods to determine atmospheric temperature and pressure, and RH in the field; and enter data in the reporting organization's data bank, and EPA's AIRS.

TABLE 17-1. DEFINITIONS OF KEY TERMS

Term	Definition
Accuracy	The degree of agreement between an observed value and an accepted reference value; includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations.
Actual conditions	The actual ambient temperature and pressure of a gas at the time its volume (or volumetric flow rate) is measured.
Analyst	A staff member who weighs the new and used filters and computes the concentration of PM _{2.5} in µg/m ³ .
American National Standards Institute (ANSI)	Administrator and coordinator of the U.S. private sector voluntary standardization system.
American Society for Testing and Materials (ASTM)	A professional organization that develops and distributes protocols for testing and provides reference standards.
ASTM Class 1 standards	The standards for weighing operations with a microbalance. Certified by ASTM.
Bias	The systematic or persistent distortion of a measurement process that causes errors in one direction.
Cassette	A device supplied with PM _{2.5} samplers to allow a weighed Teflon [®] filter to be held in place in the sampler and manipulated before and after sampling without touching the filter and to minimize damage to the filter and/or sample, during such activities.
Class I equivalent method	An equivalent method for PM _{2.5} sampling based on a sampler that closely meets the specifications for reference method samplers (40 CFR Part 58, Appendix L), with only minor deviations, as defined by EPA.
Class II equivalent method	An equivalent method for PM _{2.5} sampling, as defined by EPA, that is based on a sampler having more significant deviations from the reference method sampler specifications than a Class I equivalent method.
Class III equivalent method	An equivalent method for PM _{2.5} sampling, as defined by EPA, that is based on a device that incorporates major modifications to the reference method sampler, or is based on a fundamentally different design or principle of measurement.
Collocation	The placement of a second PM _{2.5} sampler (known as the duplicate sampler) near a primary network sampler. Comparison of results from the two samplers is used to estimate the precision and bias of the primary sampler.

Control chart	A graphical presentation of quality control (QC) information over a period of time. If a procedure is "in control," the results usually fall within established control limits. The chart is useful in detecting defective performance and abnormal trends or cycles, which can then be corrected promptly.
Downtube	The vertically oriented tube that connects the PM _{2.5} sampler inlet to sampler components inside the sampler case. To check the sample flow rate, the sampler inlet is removed from the downtube and a flow rate standard is connected in its place.
Electrostatic charge buildup	A buildup of static electrical charge on an item, such as the PM _{2.5} filter, which makes it difficult to handle, attracts or repels particles, and can influence its proper weighing.
Equilibration chamber	A clean chamber usually constructed of plastic or glass, held at near constant temperature and humidity, used to store and condition PM _{2.5} filters until they and their collected particulate sample (if the filters have been exposed) have reached a steady state of moisture equilibration.
Field blank filter	New filters, selected at random, that are weighed at the same time that presampling weights are determined for a set of PM _{2.5} filters and used for QA purposes. These field blank filters are transported to the sampling site in the same manner as the filter intended for sampling, installed in the sampler, removed from the sampler without sampling, stored in their protective containers inside the sampler's case at the sampling site until the corresponding exposed filter(s) is (are) retrieved, and returned for postsampling weighing in the laboratory, where it is handled in the same way as an actual sample filter and reweighed as a QC check to detect weight changes due to filter handling.
Flow adapter device	A tight-fitting connecting device that is inserted in place of the PM _{2.5} sampler inlet on the upper end of a sampler's downtube and used to connect a flow rate calibration or audit device to check the sample flow rate.
Flow calibration device	A National Institute of Standards and Technology (NIST)-traceable flow-determining apparatus (also called a flow rate standard) that is attached to the flow adapter device and used to assist in measuring and setting the volumetric flow rate of air into the sampler. Bubble flowmeters, piston flowmeters, and orifice devices are the most common types of flow rate standards.
Flow check filter	A standard PM _{2.5} filter that is placed in the sampler during the flow check procedure; it is later discarded and not used for sampling.

Impactor	An inertial particle size separator. A PM _{2.5} Reference or Class I equivalent method sampler uses a specially shaped inlet followed by an impactor that allows only particulate matter of well-defined size ranges to penetrate to the filter collection portion of the collector.
Impactor well	That portion of the sampler inlet where particles larger than 2.5 μm impact and are held by a filter soaked with oil (tetramethyl tetraphenyltrisiloxane) such that they are removed from the sample air stream.
Laboratory blank filter	New filters that are weighed at the time of determination of the presampling (tare) weight of each set of PM _{2.5} filters intended for field use. These laboratory blank filters remain in the laboratory in protective containers during the field sampling and are reweighed in each weighing session as a QC check.
Leak check	Checks made to ensure there are no significant leaks into or within the sampler. An external leak check, which can be carried out automatically by the sampler, is used to detect leakage into the sampler system. An internal bypass leak check is used to determine if any portion of the flow is bypassing the sampler's filter.
Mass reference standard	ASTM- or NIST-traceable weighing standards, generally in the range of weights expected for the filters.
Microbalance	A type of analytical balance that can weigh to the nearest 0.001 mg (that is, one microgram or one-millionth of a gram).
Operator	A staff member who services a PM _{2.5} sampler in routine operation at a field site and who may also be responsible for transporting the sample filters to and from the laboratory.
Orifice flow rate check device	One type of flow rate calibration or check device (transfer standard), often used in the field, based on an established relationship between flow rate and pressure drop across the orifice plate and often used in the field. An orifice's operating characteristics are determined in the laboratory using a flow rate standard such as a soap film flowmeter. Orifice devices generally require temperature and pressure corrections.
P _a	Local ambient (barometric) pressure.
PM _{2.5}	Particulate matter (suspended in the atmosphere) having an aerodynamic diameter less than or equal to a nominal 2.5 μm, as measured by a reference method based on 40 CFR Part 50, Appendix L, and designated in accordance with 40 CFR Part 53.

PM _{2.5} sampler	A sampler used for monitoring PM _{2.5} in the atmosphere that collects a sample of particulate matter from the air based on principles of inertial separation and filtration. The sampler also maintains a constant sample flow rate and may record the actual flow rate and the total volume sampled. PM _{2.5} mass concentration is calculated as the weight of the filter catch divided by the sampled volume. A sampler cannot calculate PM _{2.5} concentration directly.
Polonium-210 (²¹⁰ Po) antistatic strip	A device containing a small amount of ²¹⁰ Po that emits particles (He ²⁺) that neutralize the static charge on filters, making them easier to handle and their weights more accurate.
Precision	A measure of random variation among individual measurements of the same property, usually under prescribed identical conditions. For ambient particulate concentration measurements, precision is usually expressed in terms of a standard deviation estimated by collocated sampling when data are reported to the AIRS database.
Primary National Ambient Air Quality Standard (NAAQS) for PM _{2.5}	The NAAQS for PM _{2.5} is defined in 40 CFR Part 50 as follows: (a) 15 µg/m ³ , annual mean, based on the 3-year average of the annual arithmetic mean PM _{2.5} concentrations, spatially averaged across an area; (b) 65 µg/m ³ , 24-hour average, based on the 3-year average at the 98th percentile of 24-hour PM _{2.5} concentrations at each population-oriented monitor within an area.
Polytetrafluoroethylene (PTFE)	The polymer that is used to manufacture the 47 mm diameter filters for PM _{2.5} Federal Reference Method (FRM) and Federal Equivalent Method (FEM) samplers. Also known as Teflon®.
Q _a	The sampler flow rate expressed at ambient (actual) conditions of temperature and pressure.
QA supervisor or coordinator	A staff member who assists in preparation of the reporting organization's quality plan, makes recommendations to management on quality issues (including training), oversees the quality system's control and audit components, and reports the results.
Readability	The smallest difference between two measured values that can be read on the microbalance display. The term "resolution" is a commonly used synonym.
Repeatability	A measure of the ability of a microbalance to display the same result in repetitive weighings of the same mass under the same measurement conditions. The term "precision" is sometimes used as a synonym.

Standard conditions (EPA)	EPA-designated atmospheric conditions of 1 atm pressure (760 mm Hg) and 25 °C (298 K). [Standard Conditions are not used for reporting PM _{2.5} data; actual (uncorrected) conditions must be used for reporting.]
T _a	The ambient temperature.
Traceable	A term signifying that a local standard has been compared and certified, either directly or by not more than one intermediate standard, to a NIST-certified primary standard, such as a thermometer or standard reference material (SRM).
Transfer standard	A reference standard device (for temperature, flow rate, etc.) that has been compared to a NIST reference standard and is subsequently used to calibrate, audit, or check other measurement systems or devices.
Total Suspended Particulate (TSP)	Particulate matter collected by a high-volume sampler, which has no particular particle size selectivity.
V _a	An air volume measured or expressed at ambient (actual) conditions of temperature and pressure.
WINS	The name given to the design of the particle impactor specified by EPA for reference method samplers for PM _{2.5} ; an acronym for "Well Impactor Ninety Six."

Training

Available means for training laboratory and field personnel are listed below. Each individual should receive training appropriate to his or her duties on the PM_{2.5} monitoring program.

- Initially, train field personnel who are already familiar with high-volume and dichotomous sampler operations and laboratory personnel who are already familiar with weighing room techniques and requirements.
- Have all personnel study the relevant sections of the QA Handbook, the operating manuals for the samplers and/or the microbalance, and the *Code of Federal Regulations* (CFR) citations.
- Develop a training manual and operations checklist.
- Have personnel attend relevant State- or regionally-sponsored training workshops.
- Have personnel attend relevant EPA-sponsored training programs.

- Have personnel watch and study instructional videos that may become available.
- Have experienced operators instruct others through on-the-job training.
- Have newly trained operators pass a hands-on test of procedures.

Health and Safety Warnings

To prevent personal injury, all employees must heed any warnings that are associated with operation of the microbalance, the PM_{2.5} sampler, and any supporting equipment and supplies. Specific health and safety warnings will generally be found at the point in the operating manual or troubleshooting guide where they are most applicable.

In general, health and safety warnings will fall into these categories:

- electrical
- chemical
- equipment placement and stability.

Electrical safety considerations that would apply to the PM_{2.5} sampler include the following:

- Make all electrical connections in accordance with national codes. Always use a third wire grounding arrangement on samplers and any electrical appliances or test rigs. To minimize the possibility of electrical shock and injury, always use a grounded outlet and cord. This process will avoid the possibility of electrocution.
- Electrical supply lines to the PM_{2.5} sampler must be installed so that they are protected from degradation and hazards. Inspect the electrical cords and connections for signs of wear and have an electrician repair or replace them as needed.
- Always unplug the power to the sampler when servicing or replacing parts in areas requiring removal of protective panels.
- Avoid contact of jewelry with electrical circuits. Remove rings, watches, bracelets, and necklaces to prevent shorting and electrical burns.
- Use caution when working near moving parts (such as pumps) to avoid injury.
- Be aware of weather patterns; leave the area if lightning storms approach, since the sampler is elevated and made of conductive metal.

Chemical safety considerations that apply to PM_{2.5} operations include the following:

- Use care in the application of cleaning solvents, greases for O-rings, and silicone oil for the impactor well. Use of gloves is recommended. Wash hands thoroughly after working with chemicals. Provide good ventilation if organic solvents are used. Dispose of chemicals and shop towels properly.
- Mercury metal, a poisonous material, is present in some types of barometers, thermometers, and RH indicators. If liquid mercury is spilled, it must be cleaned up and disposed of properly. Use protective equipment to avoid inhalation of vapors and impermeable gloves to avoid skin contact. Mercury cleanup kits are available. Avoid the use of mercury, if possible, to preclude hazard of mercury exposure.
- Exercise caution when using antistatic devices containing radioactive polonium sources. Keep an inventory of the location and size of antistatic devices. Dispose of the devices in accordance with State and local regulations.

Other Considerations

Avoid touching pump or fan motors, which may be hot. Avoid injury from moving parts, such as fans and filter changing mechanisms.

Equipment placement and stability are important as well. Ensure that the PM_{2.5} sampler(s) and associated equipment are stably mounted to the ground or other surface so that they do not tip over. Electrical wires should be installed so no one will trip over them and be injured. If the sampler is placed on the roof of a building or on another elevated location, ensure that railings are installed and warning signs are placed to prevent falls.

Damage to the PM_{2.5} sampler may result if caution is not taken to install and maintain the device properly. Follow the manufacturer's instructions for maintenance of the pump, for cleaning of the interior and exterior surfaces, and for safe, secure installation.

The weighing room must be maintained in a state of good order so that samples are not contaminated, misplaced, or misidentified. The room air must be relatively dust-free and controlled within specified temperature and humidity ranges. The microbalance must be placed on a vibration-free mounting. Care must be taken to avoid bumping the balance because its calibration settings may be disturbed. The calibration weights used to check balance precision and accuracy must be stored in a secure location away from sources of corrosion, and should be used only for filter weighing, used by a knowledgeable analyst, and handled only with plastic tweezers to prevent scoring and weight changes.

Finally, care must be exercised in handling new and used filters. If details concerning weighing, labeling, and transporting filters are not followed to the letter, errors will result. Rough handling of used filters may dislodge $PM_{2.5}$ material. Inadequate conditioning of filters at the specified temperatures and humidities, or long delays between sample retrieval and sample weighing, may lead to positive or negative weight changes and thus inaccurate $PM_{2.5}$ concentrations.

Section III. Summary Information

Sampler Inlet Components and Sample Flow Paths

The reference method for PM_{2.5} particle monitoring is contained in Appendix L of 40 CFR Part 50. The reference method uses a sampler to draw a measured quantity of ambient air at a constant volumetric flow rate (16.67 L/min) through a specially designed particle-size discrimination inlet. The inlet (Figure 17-1) is designed to extract particles from the incoming air sample and remove those particles with aerodynamic diameters greater than 10 µm. The sampled air then flows through an inertial particle size separator (impactor) where particles less than 10 µm but greater than 2.5 µm are collected in the well of the impactor. Figure 17-2 shows the impactor and filter holder assembly. The remaining particles in the PM_{2.5} size range are collected on a 46.2 mm diameter PTFE filter. The required sample period for PM_{2.5} concentration measurements is 23-25 hours (1,380 to 1500 minutes). In situations where the sample period is less than 1,380 minutes, the measured concentration may be used as if it were a valid concentration measurement for determining compliance with the PM_{2.5} National Ambient Air Quality Standard (NAAQS). The value of the concentration in these cases assumes that the PM_{2.5} concentration is zero for the remaining portion of the sampler period and thus represents the minimum concentration that could have been measured for the full 24-hour (1,500) sample period. If the value calculated in this situation is high enough to be an exceedance of the NAAQS, such values would be considered as a valid exceedance. When reporting these values to EPA's Aerometric Retrieval System (AIRS), the value should receive a special code so the data would not be commingled with normal concentration measurements or used for other purposes.

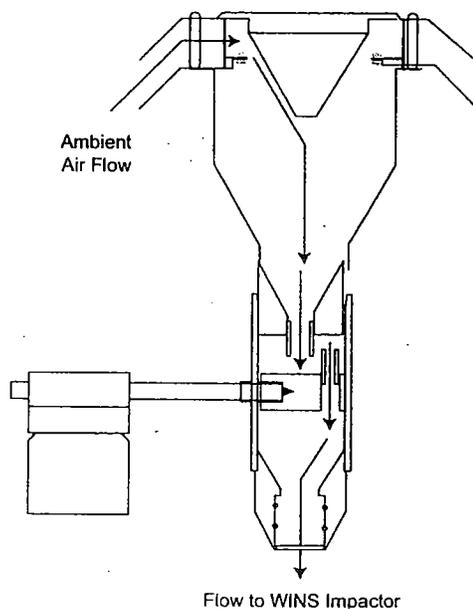


Figure 17-1. Air flow through the PM_{2.5} sampler inlet head.

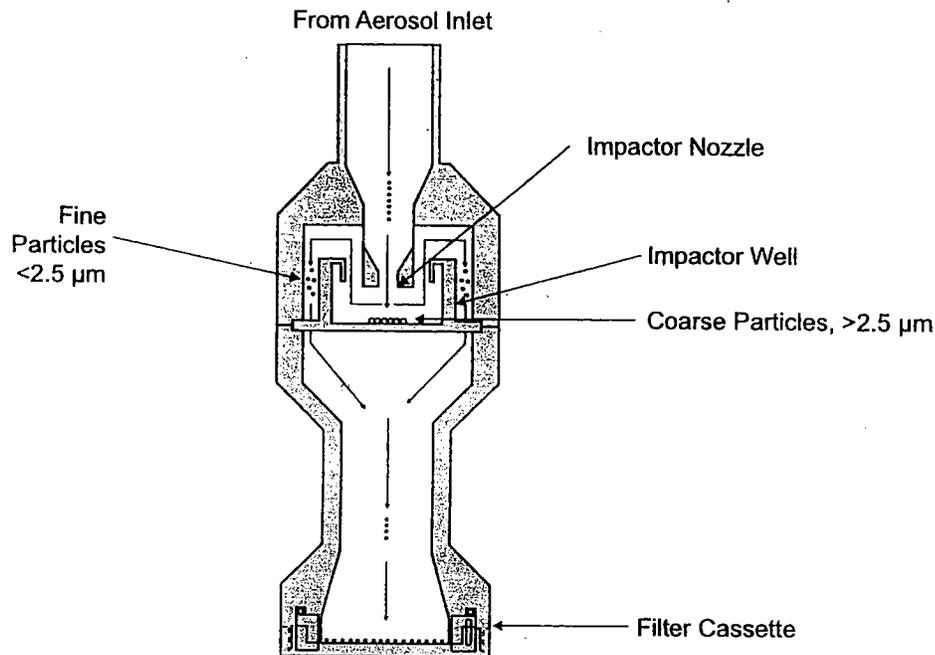


Figure 17-2. Air flow through the PM_{2.5} impactor well and filter holder.

The total volume of air sampled is calculated from the measured volumetric flow rate and the sampling time. The PM_{2.5} mass concentration is computed as the total mass of PM_{2.5} divided by the total volume of air sampled and measured under actual ambient conditions of temperature and pressure. The particle size discriminating features of the reference method sampler, the inlet, downtube, fractionator, filter cassette, and the internal configuration of the filter holder assembly, are all specified by design figures and associated mechanical dimensions, tolerances, materials, surface finishes, assembly instructions, and other necessary specifications. All other aspects of the sampler are specified by required operating functions and performance of the sampler. Testing requirements for reference and equivalent method determinations are contained in 40 CFR Part 53, Subpart E.

Procedures for quality assurance (QA) and quality control (QC) checks for field operations and laboratory operations for PM_{2.5} monitoring are contained in 40 CFR Part 50 and Part 58. In addition, further guidance is provided in Subsection 3 of Section 2.12 in the QA Handbook. In this Section of Lesson 17 a brief discussion of these QA/QC procedures is given along with a summary of the sampling procedures for PM_{2.5}.

Summary of Field and Laboratory QC Checks

Tables showing the field and laboratory QC checks required to collect and process PM_{2.5} data according to the 40 CFR Part 50 and Part 58 regulations are contained in Subsection 3.4 of Section 2.12 in the QA Handbook. Table 17-1 shows the field QC/QA checks. The frequencies of the checks are cross referenced

to the respective regulations and Section 2.12 in the QA Handbook.

Summary of Sampling Procedures for PM_{2.5}

An outline or checklist of the procedures to follow in preparing for a sample run, installing a filter/filter cassette to start a sample run, and ending the sample run is provided in Subsection 3 of the Section 2.12 Document.

Table 17-1. Field QC/QA Checks

Requirement ^a	Frequency	Acceptance criteria	CFR reference	2.12 reference	Information provided
Calibration standards					
Flow rate (FR) transfer standard	1/yr	± 2% of NIST-traceable std.	Part 50, App. L, Sec 9.1, 9.2	Sec. 6.3.3	Certification of traceability
Field thermometer	1/yr	± 0.1°C resolution ± 0.5°C accuracy	Not described	Sec. 4.2.2 and 8.3.2.1.	Certification of traceability
Field barometer	1/yr	± 1 mm Hg resolution ± 5 mm Hg accuracy	Not described	Sec. 4.2.2 and 8.3.2.1.	Certification of traceability
Calibration/verification					
FR calibration	If multipoint failure	± 2% of transfer standard	Part 50, App. L, Sec 9.2	Sec 6.3	Calibration drift and memory effects
FR multipoint verification	Per manual, NLT 1/yr	± 2% of transfer standard	Part 50, App. L, Sec 9.1, 2	Sec 6.3 and 8.3	Calibration drift and memory effects
One point FR verification	1/4 weeks	± 4% of transfer standard	Part 50, App. L, Sec 9.2.5	Sec 6.3 and 8.3	Calibration drift and memory effects
External leak check	Every 5 sampling events	80 mL/min	Part 50, App. L, Sec. 7.4	Sec 6.3 and 8.3	Sampler function
Internal leak check	Every 5 sampling events	80 mL/min	Part 50, App. L, Sec. 7.4	Sec 6.3 and 8.3	Sampler function
Temp. multipoint verification	On installation, then 1/yr	± 2°C	Part 50, App. L, Sec. 9.3	Sec 6.4	Calibration drift and memory effects
One point temp. verification	1/4 weeks	± 4°C	Part 50, App. L, Sec. 9.3	Sec 6.4 and 8.2	Calibration drift and memory effects
Pressure calibration	On installation, then 1/yr	± 10 mm Hg	Part 50, App. L, Sec. 9.3	Sec 6.5	Calibration drift and memory effects
Pressure verification	1/4 weeks	± 10 mm Hg	Part 50, App. L, Sec. 9.3	Sec 8.2	Calibration drift and memory effects
Clock/timer verification	1/4 weeks	1 min/mo	Part 50, App. L, Sec. 7.4	Not described	Verification to ensure proper function
Blanks					
Field blanks	10%	± 30 µg	Part 50, App. L, Sec. 8.2	Sec 7.7	Measurement system contamination

Precision Checks					
Collocated samplers	Every 6 days	CV ≤ 10%	Part 58, App. A, Sec. 3.5, 5.5	Sec. 10.2.2	Measurement system precision
Accuracy					
FR audit	1/2 wk (automated) 1/3 mo (manual)	± 4% of audit standard	Part 58, App. A, Sec. 3.5.1	Sec. 10.2.3	Instrument bias/accuracy
External leak check	4/yr	<80 mL/min	Not described	Sec 6.6	Sampler function
Internal leak check	4/yr	<80 mL/min	Not described	Sec 6.6	Sampler function
Temperature check	4/yr	± 2°C	Not described	Sec 8.3	Calibration drift and memory effects
Pressure check	4/yr	± 10 mm Hg	Not described	Sec 8.3	Calibration drift and memory effects
Audits (external assessments)					
FRM performance eval.	25% of sites 4/yr	± 10%	Part 58, App. A, Sec. 3.5.3	Sec 10.2.3	Measurement system bias
External leak check	1/yr or as required	< 80 mL/min	Not described	Sec 6.6.1	Sampler function
Internal leak check	1/yr or as required	< 80 mL/min	Not described	Sec 6.6.2	Sampler function
Temperature audit	1/yr	± 2°C	Not described	Sec 10.2.5	Calibration drift and memory effects
Pressure audit	1/yr	± 10 mm Hg	Not described	Sec 10.2.5	Calibration drift and memory effects

^aRequirements in bold/italics require a change in CFR that is in process.

Section IV. Procurement of Equipment and Supplies

Overview

Designing and setting up an ambient air monitoring network for PM_{2.5} requires procuring sampling equipment and associated supplies as well as appropriate laboratory equipment to determine the PM_{2.5} mass. In this section the focus of the material is on procuring and acceptance testing of the proper equipment for PM_{2.5} monitoring. A detailed description of field operating equipment and laboratory equipment is provided. Also, data handling systems including forms, logs, files, and reporting procedures must be developed and properly documented in order to ensure effective collection and reporting of quality data.

Prior to purchasing equipment and supplies, a listing of the monitoring requirements must be established and budgetary limits formulated. In addition, performance specifications and acceptance criteria must be prepared. When the equipment is received, acceptance testing should be conducted and all results of the tests should be properly documented, including whether the equipment was accepted or rejected. The procurement log will serve as the permanent record for procurement and acceptance testing and provide a useful tool for future monitoring equipment projections.

Procurement Prerequisites –Field Operations

Items to be discussed for field operation equipment include reference or equivalent method samplers, and special calibration equipment to calibrate the sampler for temperature, barometric pressure, and volumetric flow measurements. In addition, for QC procedures a flow verification check device is discussed since it is needed to verify sampler operation at the correct flow rate. Figure 17-3 shows a diagram of an inexpensive and rugged QC flow rate verification device. Audit equipment is similar to the calibration equipment, except all equipment used for audits must be separate from those used for calibrations.

Procurement Prerequisites –Laboratory Operations

For laboratory operations the discussion features such items as filter media, filter support cassettes, filter cassette protective containers, insulated shipping containers, and filter handling containers.

Proper determination of the mass of the collected PM_{2.5} particles requires the purchasing of an analytical microbalance. The capacity of this balance should be adequate to weigh the sample filters, which are typically 100 to 200 milligrams (mg). Also, it must be large enough to weigh the 46.2 mm diameter filters and have a minimum readability of $\pm 1 \mu\text{g}$ and a repeatability of $1 \mu\text{g}$. Another important aspect is the ability to neutralize the buildup of electrostatic charges in the microbalance weighing room and on individual filters. To reduce this problem it may be necessary to procure radioactive antistatic strips and place them

in the weighing room and to pass each filter near an antistatic strip before each filter is weighed. Some consideration should also be given to the use of microbalances with optional data input and output capabilities and automatic tare capabilities to reduce potential data entry errors and the time required to weigh individual filters.

Mass Reference Standards

Mass reference standards (or balance check weights) should be used to verify proper microbalance operation as part of the normal QC checks. These standards should be ASTM Class 1, or Class 1.1 weights, traceable to NIST with an individual tolerance of no more than 0.025 mg. The individual weight tolerances for ASTM Class 1, 1.1, and 2 weights are 0.010 mg, 0.005 mg, and 0.025 mg respectively. The mass reference standards should be selected so as to bracket the maximum and minimum expected filter weights (e.g., 100 to 200 mg) since the mass range of a typical 46.2 mm filter is from 110 to 160 mg. The reference standards should be recertified on a regular basis (yearly or as determined from records of previous recertifications). The recertification should be done at a State weight and measures laboratory or other laboratory that is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP), which is administered by NIST.

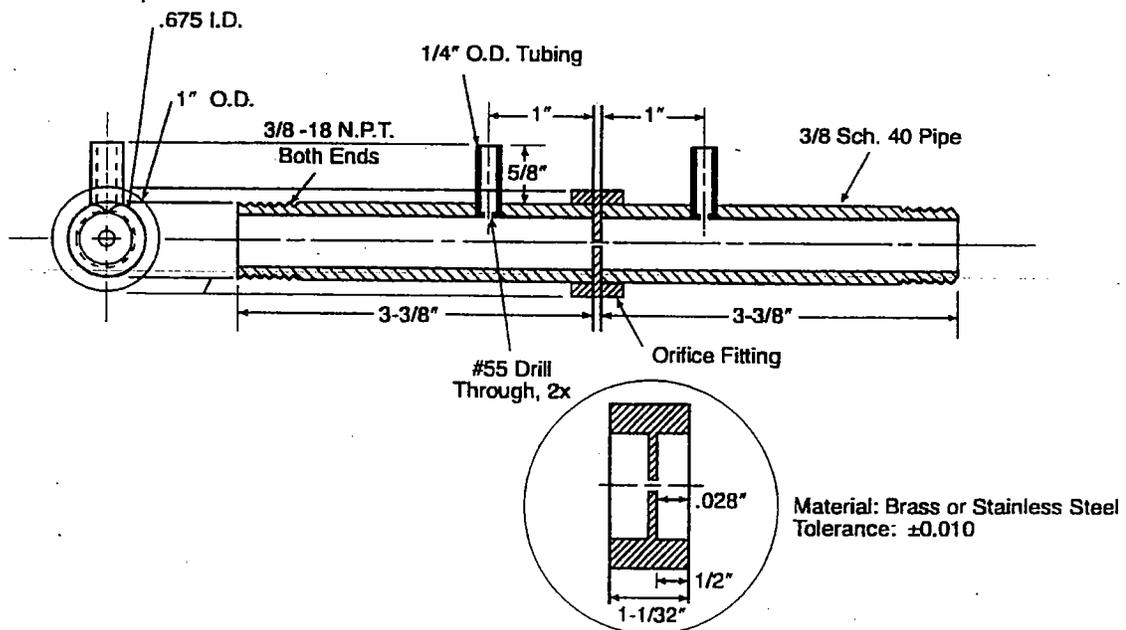


Figure 17-3. Flow rate verification device.

**Table 17-2. Acceptance Checks and Limits for
Procurement of Equipment and Supplies from Reference 1**

Equipment	Acceptance check	Acceptance limits	Action if requirements are not met
Field operations			
Sampler	Sampler and accessories complete; no evidence of damage. Model designated as reference or equivalent method. Pump and display work.	Specifications outlined in 40 CFR Part 50, Appendix L	Reject sampler
Calibration quality assurance/quality control (QA/QC) equipment for flow rate, temperature, pressure, etc.	Accompanied by certificate. Check values against National Institute of Standards and Technology (NIST)-traceable standards.	Within accuracy limits described in Reference 1	Adjust or reject equipment
Audit equipment	Same as for calibration equipment, but must not be the same equipment.	Within accuracy limits described in Reference 1	Adjust or reject equipment
Laboratory operations			
Filters, Teflon [®]	Of correct type and undamaged.	Type as described in 40 CFR Part 50, Appendix L	Reject filters
Filter cassettes	Of correct type and undamaged.	As specified by sampler manufacturer	Reject filter cassettes
Filter/cassette protective containers	Of correct type and undamaged.	As described in Reference 1	Reject protective containers
Filter-handling containers	Of correct type and undamaged.	As described in Reference 1	Reject filter-handling containers
Analytical microbalance	Accompanied by certificate; check values against working standards.	Readability 1 µg, repeatability 1 µg	Adjust or reject equipment
Mass reference standards	Check working standards against NIST-traceable primary standards.	Tolerance ± 25 µg	Reject standards

Section V. Installation of Samplers

Siting Requirements

Prior to initiating a sampling program, safe and secure sampling sites must be selected. In addition the sites selected must provide PM_{2.5} measurements that are representative of the monitoring objectives designated for each site. In selecting the sampling sites, consideration must be given to the spatial and temporal scales of the site. Similar to other State and Local Monitoring Stations (SLAMS) networks, PM_{2.5} spatial scales may range from a small (micro, 0.1 to 0.5 km²) area to large (regional) areas exceeding thousands of square kilometers. The scale of the sampling site will be affected by a number of factors, including the type and size of nearby PM_{2.5} sources, wind direction, and local topography. Appendix D of Part 58 and EPA's 1997 guidance document for network design and optimum site exposure for PM_{2.5} and PM₁₀ provides detailed guidance on required spatial scales as well as procedures for selecting individual spatial scales. For temporal scale site selection, considerations should also be given to the monitoring objective of the site as it pertains to 24-hour averages or annual averages. One site may be appropriate for determining maximum 24-hour concentrations but inappropriate for measuring maximum annual means.

Having decided on the general location of a sampling site, careful consideration must also be given to the siting location requirements specified in Appendix E of the Part 58 regulations. The siting requirements included in this Section address items such as unobstructed air flow, sampler inlet height, and collocated sampler spacing criteria. Also discussed in this Section are safety, electrical, and security considerations.

Sampler Installation Procedures

The discussion of selecting the appropriate location for the site and taking the proper steps to insure adequate safety and security is followed by a summary presentation on sampler installation procedures. This topic includes items such as receipt of sampler, laboratory evaluation, setup at the sampling site, and field evaluation. Prior to receipt of the sampler, it is suggested that an individual logbook be prepared for each sampler procured. Having received the sampler, the order should be checked to ensure that the proper model has been received and that all components ordered are accounted for. If any equipment is missing or damaged, notify the manufacturer immediately. Prior to assembly of the sampler, read the instruction manual and become familiar with all components of the sampler.

Laboratory Evaluation of the Sampler

The following activities can most conveniently take place in an indoor laboratory environment. Energize the sampler and check to be sure that the pump, mechanical components, and electronic displays are working. Perform a leak check according to the manufacturer's instructions. Each sampler's procedure will

be somewhat different from the others. The impactor should not have oil in it, and a flow-check filter should be in the filter cassette for this test. Next, check the flow rate at 16.67 L/min and at $\pm 10\%$ of this value according to the manufacturer's instructions. Also, perform checks of the temperature and pressure sensors and conduct a flow verification check according to the manufacturer's instructions. Additional discussions on the flow verification check will be presented in Lesson 18. For sequential samplers, check that the timing and sequencing functions work properly, and if this is the first sampler model of its type received, conduct data downloading exercises to become familiar with the process. If it is a sequential sampler, operate it for at least three consecutive days to test the system. If oil has been added to the impactor well during any of the laboratory tests, remove it before transit to the field site.

Field Evaluation of the Sampler

The following presents a brief overview of the setup at the sampling site. After carefully transporting the sampler to the sampling site, secure the sampler in its predetermined location. The legs of the sampler can be bolted to angle aluminum bars. The bars can be held in the soil with metal stakes or they can be nailed to wooden beams if the sampler is on the surface of a roof. Keep the sampler level and allow space for installation of a collocated sampler and/or an FRM performance evaluation sampler.

Field evaluation of the sampler includes checking all tubing for cleanliness crimps, cracks, or breaks. Next, plug the power cord into a line voltage outlet. The use of waterproof interlocking electrical connectors is recommended to ensure operator safety and to avoid shorts and/or power interruptions. Do not allow any electrical connections to become submerged during periods of inclement weather. Proceed with a leak test with a filter in the filter cassette. Do not use the filter for subsequent sampling. Allow the system to run and equilibrate to ambient conditions for approximately 15 minutes. Follow this up with checks of the temperature and pressure sensors and a flow rate verification check according to the manufacturer's instructions. Correct any problems before proceeding. The sampler is now ready for routine use.

Section VI. Calibration Procedures

Overview

Proper calibration of PM_{2.5} monitoring sampling and analysis equipment must be conducted prior to the initiation of all monitoring programs. In this Section there are suggestions and requirements intended as initial acceptance checks of the calibration of the equipment. However, further checks may be necessary if acceptance specifications are not met. All data and calculations should be recorded in a calibration logbook or on calibration data sheets. A separate logbook or a separate section of a logbook should be used for each apparatus and sampler in the program. Whenever field performance checks of the sampler's flow rate, external or internal leakage rate, temperature, or pressure systems show out-of-tolerance conditions, the operator is cautioned to double-check the equipment, the connections, and the sampler before proceeding with recalibration. It is possible that the sampler is not out of calibration and considerable time and effort could be wasted.

According to 40 CFR Part 50, Appendix L, Subsection 10, the PM_{2.5} sampler flow rate measurement system must be calibrated in terms of the actual volumetric flow rate, (Q_a), at prevailing ambient conditions of temperature and pressure. Prior to the July 18, 1997 promulgation of the revised PM regulations, the use of standard temperature and pressure was the recommended procedure for calculating and reporting PM data. The flow rate measurement system consists of a dry gas meter or other flow sensor, a temperature sensor, a pressure sensor, and associated devices which, as needed, make control adjustments to maintain the set point of the volumetric flow rate in response to variations in temperature and pressure. If the calibration for your flow rate standard or transfer standard is expressed in terms of Q_{std} , conversion to Q_a will be required. The calculations necessary to convert these flow rates are presented in this Section.

In particular this portion of this lesson presents the following aspects of calibration procedures:

- A discussion of Q_a and Q_{std} flow rate designations and their applicability in a PM_{2.5} monitoring program
- Basic calibration procedures and associated calculations for calibration of the sampler's flow rate measurement system
- Discussion of flow rate transfer standards and calibration equipment
- Basic calibration procedures for the sampler's temperature and pressure measurement systems
- Procedures for conducting external and internal leak checks
- Sampler calibration frequency requirements.

General Aspects of Flow Rate Measurement and Sampler Calibration

The particle size discrimination characteristics of both the inlet and the impactor are dependent on specific internal air velocities. A change in the velocity will result in a change in the nominal particle size collected. The velocities are determined by the actual volumetric flow rate (not the mass flow rate) through each device. Accordingly, the actual volumetric flow rate through the sampler's inlet and fractionator must be maintained at a constant value that is as close as possible to the design flow rate specified for the sampler.

The calibration of the sampler's flow rate measurement system must be carried out in terms of actual volumetric units (Q_a or V_a). Results must be recorded in the same units. However, previous measurements for PM_{10} were based on standard units (Q_{std} or V_{std}); thus the certification for some calibration standards may be in terms of standard volumetric flow rate units (Q_{std}). Therefore, it is important to understand the definition for each of these two types of volumetric units and the distinction between them. Before calibration procedures are initiated, the operating agency personnel should review the following flow rate definitions:

- Q_a — Actual volumetric air flow rates that are measured and expressed at existing conditions of temperature and pressure are denoted by Q_a (Q_{actual}). Typical units are L/min and m^3/min . Inlet design flow rates for $PM_{2.5}$ samplers are always given in actual volumetric flow units.
- Q_{std} — Air flow rates that have been adjusted to EPA-standard conditions of temperature and pressure (25°C or 298 K and 760 mm Hg or 101 kPa) are denoted by Q_{std} ($Q_{standard}$). Typical units are L/min and m^3/min . Standard volume flow rates are often used by engineers and scientists because they are equivalent to mass flow rate units. Prior to 1997, standard volumes (derived from standard volume flow rates and the total time of sampling) were also required in the calculation of mass concentration ($\mu g/m^3$) in reporting PM_{10} measurements.

These Q_a and Q_{std} flow rate units must not be confused or interchanged. If necessary, the flow rate units can be converted, provided the temperature and pressure are known. The following conversion formulas can also be used for average flow rates (\bar{Q}_a and \bar{Q}_{std}) over a sampling period by substituting average temperature (\bar{T}_a) and pressure (\bar{P}_a) over the sampling period.

$$Q_{std} = Q_a(P_a/P_{std})(T_{std}/T_a) \quad (17-1)$$

$$Q_a = Q_{std}(P_{std}/P_a)(T_a/T_{std}) \quad (17-2)$$

Where:

- Q_{std} = standard volume flow rate, standard m^3/min
- Q_a = actual volume flow rate, actual m^3/min
- P_a = ambient barometric pressure, mm Hg (or kPa)
- P_{std} = EPA standard barometric pressure, 760 mm Hg (or 101 kPa)
- T_{std} = EPA standard temperature, 298 K ($25^\circ C + 273$)
- T_a = ambient temperature, K (ambient $^\circ C + 273$).

Any gas flow rate measured or expressed in actual volumetric units (Q_a) is always associated with a particular temperature and pressure of the gas. If either the temperature or the pressure changes, the volumetric flow rate will also change, even though the mass flow rate of the gas remains constant. Therefore, when the flow rate is measured at different locations in the sampler, the volumetric flow rate observed will be different if either the temperature or the pressure is different at the various locations. For example, when a flow calibration device is connected to the sampler inlet, the pressure of the air flow measured by the flow calibration standard will be the ambient barometric pressure. However, the pressure of the flowing air measured by the sampler's flow measurement system will be somewhat lower than the ambient barometric pressure because all flow calibration devices cause some pressure drop. If this pressure drop is negligible ($< 1\%$ or < 4 inches of H_2O), then there is no problem; the pressure can be considered the same for both measurement systems. But if the pressure drop is significant ($> 1\%$ or > 4 inches of H_2O), then the volumetric flow rate measured by the two systems will be different, and this difference should be taken into account when comparing them. Sampler flow rate measurement systems may or may not automatically correct for this pressure change. If not, one of the flow rate measurements must be corrected to the same pressure as the other flow rate before they can be compared. This correction is accomplished using the following formula:

$$Q_1 = Q_2 (P_2/P_1)(T_1/T_2) \quad (17-3)$$

Where:

- Q_1 = actual volume flow rate at pressure and temperature at first measurement point, m^3/min
- Q_2 = actual volume flow rate at second measurement point, m^3/min
- P_1 = pressure at first measurement point, mm Hg (or kPa)
- P_2 = pressure at second measurement point, mm Hg (or kPa)

T_1 = temperature at first measurement point, K ($^{\circ}\text{C} + 273$)

T_2 = temperature at second measurement point, K ($^{\circ}\text{C} + 273$).

Note that in many cases the temperatures will be identical, so that $T_1=T_2$ and the (T_1/T_2) term will equal 1 and therefore will drop out of Equation 17-3.

Calibration of the Sampler Flow Rate Measurement System

A full, detailed, EPA-approved calibration procedure, tailored specifically for each commercially available $\text{PM}_{2.5}$ sampler, is contained in the operation or instruction manual associated with each sampler designated as a reference or equivalent method under 40 CFR Part 53. That specific procedure should be followed carefully and thoroughly to calibrate the sampler. Note that the flow rate measurement system should not be calibrated if the temperature and pressure measurement systems are not also in calibration. In practice, it is suggested that, prior to calibrating the flow measurement system, a leak check should be performed, followed by a verification or calibration of the temperature and pressure measurement systems. If in doubt calibrate these sensors. The information that follows provides additional precautions, guidance, and information on flow rate standards and calibration that may not be contained in the specific instruction manual procedure. It also presents a generic outline of the general procedure used to calibrate the flow rate measurement systems of commercially available samplers. This information can be used to augment the sampler-specific procedures.

General Requirements and Guidance

1. Multipoint calibration and single-point verification of each sampler's flow rate must be performed periodically to establish traceability of subsequent flow rate measurements to an authoritative flow rate standard. Calibration with a flow rate standard (or transfer standard) that is certified against a NIST-traceable standard, transfers the NIST traceability to the sampler's flow rate measurement system. This NIST traceability is required by Appendix A of 40 CFR Part 58.
2. $\text{PM}_{2.5}$ samplers may employ various types of flow rate measurement devices. The specific calibration standard and procedure used for calibration or verification of the sampler's flow rate measurement device will vary depending on the type of flow rate measurement system employed (40 CFR Part 50, Appendix L, Sec. 9.2.1). The sampler's operation or instruction manual identifies one or more types of flow rate or volume standard recommended for calibration and provides a detailed calibration procedure.
3. Calibration of the sampler's flow rate measurement system must be in units of the actual ambient volumetric flow rate (Q_a) (40 CFR Part 50, Appendix L, Sec. 9.2.1).
4. The sampler flow rate measurement system must be calibrated or

verified by installing an unused filter in the filter holder, removing the sampler inlet and connecting the flow rate adapter and flow rate standard to the sampler, in accordance with the instruction manual, so that the flow rate standard accurately measures the sampler's flow rate. The operator should verify that no leaks exist between the flow rate standard and the sampler (40 CFR Part 50, Appendix L, Sec. 9.2.3).

5. The calibration relationship between the flow rate (in actual L/min) indicated by the flow rate standard and by the sampler's flow rate measurement device must be established or verified in accordance with the sampler's operation or instruction manual. Temperature and pressure corrections may be required for some types of flow rate standards (40 CFR Part 50, Appendix L, Sec. 9.2.4). Consult the operations manual for the particular flow rate standard for guidance on the nature and calculation of any corrections that may be required for the standard.
6. Monthly verification of the sampler's flow rate shall consist of one flow rate measurement at the sampler's operational flow rate (40 CFR Part 50, Appendix L, Sec. 9.2.4). This one-point verification of the flow rate measurement system may be substituted for a three-point calibration, provided that a full three-point calibration is carried out upon initial installation of the sampler and at least once per year thereafter and the flow rate measurement system has met the $\pm 2\%$ accuracy requirement (40 CFR Part 50, Appendix L, Sec. 9.2.5) in the previous three-point calibration. A full three-point calibration must be carried out whenever a one-point verification indicates that the sampler's flow rate measurement system differs by $\pm 4\%$ or more from the flow rate measured by the flow rate standard. The one-point verification must be repeated after the three-point calibration as a double-check to ensure the sampler operates properly at the design flow rate of 16.67 L/min following the calibration (40 CFR Part 50, Appendix L, Sec. 9.2.5).
7. Calibration of the sampler's flow rate measurement system must consist of at least three separate flow rate measurements (a multipoint calibration) approximately evenly spaced within the range of - 10% to + 10% of the sampler's operational flow rate (40 CFR Part 50, Appendix L, Sec. 9.2.4). The sampler is required to have the capability to adjust the flow rate over the - 10% to + 10% range (40 CFR Part 50, Appendix L, Sec. 7.4.2). Calibration procedures for the various samplers call for results of three different flow rates to be keyed in to establish the calibration. The sampler's instruction manual will provide additional guidance on flow rate adjustment.
8. Following a calibration or verification, the flow rate adapter and flow rate standard are disconnected from the sampler, and the sampler's inlet is carefully reinstalled. The clean filter remains in place. Then the sampler's normal operating flow rate must be determined (in L/min), using the sampler's flow rate measurement system. If the sampler flow

rate differs by $\pm 2\%$ or more from the required operational value of 16.67 L/min, the sampler flow rate must be adjusted to the specified flow rate (40 CFR Part 50, Appendix L, Sec. 9.2.6). The filter is then removed and the sampler is returned to service.

Flow Rate Calibration Standards

Flow rate standards used for calibrating or verifying the sampler's flow rate measurement device must have an accuracy of $\pm 2\%$. This flow rate standard must be a separate, stand-alone device designed to connect to the flow rate measurement adapter. The flow rate standard must have its own certification and must be traceable to a NIST primary standard for volume or flow rate (40 CFR Part 50, Appendix L, Sec. 9.1.2). Consult the technical literature and vendor's descriptions of various flow rate standards and their performance under various weather conditions before making a decision to purchase.

All flow rate calibration standards must be fully equilibrated to the temperature of the air to be measured. This temperature equilibration can take up to an hour, depending on the temperature at which the standard was stored prior to moving it to the point of use. During this thermal equilibration period, the standard must be exposed to the prevailing air temperature, but it also must be protected from precipitation, wind, dust, solar heating, and other conditions that could affect its accuracy.

Various types of flow rate standards that might be considered for sampler calibration follow:

- **Bubble flowmeters** — Although complete manually operated and timed bubble flowmeters are available, a semiautomatic instrument such as the Gilian flowmeter is easier to use and is more likely to provide more uniform flow rate measurements. Because the liquid used to form the bubbles is usually water-based, a water-vapor correction may be required to compensate for a volume increase due to evaporation of the water in the instrument. Furthermore, the instrument cannot be used below 0°C because the soap solution will freeze.
- **Piston flowmeters** — Automatic dry-piston flowmeters such as the BIOS flowmeter are relatively easy to use and not subject to the water vapor correction or the liquid freezing limitation of the bubble flowmeters. However, they may still be subject to a lower operational temperature limit.
- **Mass flowmeters** — Although mass flowmeters may be considered as calibration standards, they have a number of shortcomings in this application. They have a high pressure drop, which could change the sampler flow rate or otherwise affect the operation of the sampler. Mass flowmeters also require conversion of the measured mass flow rate to the actual volumetric flow rate for comparison to the PM_{2.5} sampler's displayed value. The flow rate measured by the sampler may also have to

be corrected to account for significant pressure drop introduced by the mass flowmeter itself. Finally, mass flowmeters are subject to zero or span drift, particularly over the wide range of temperatures encountered at field sites, so their accuracy should be reverified frequently over a wide temperature range.

- **Orifice devices** — Orifice devices are simple and reliable, but they too require corrections for temperature and pressure and may have a significant pressure drop. They also require a very accurate and sensitive differential pressure measurement device such as a manometer or an aneroid differential pressure gauge, whose accuracy must be reverified frequently. Electronic micromanometers are convenient to use with an orifice device. Readings from electronic micromanometers should be cross-checked against a water manometer prior to a round of sampler verifications or calibrations.
- **Laminar flow elements** — Laminar flow elements generally have a lower pressure drop than orifice devices but otherwise have the same requirements and disadvantages.
- **Wet test meters** — Wet test meters are generally not practical for field use but may be used for laboratory calibrations.
- **Dry gas meters** — Dry gas meters may be considered for field calibration. Some meters may have a substantial pressure drop. They should be checked for leaks and mechanical problems and be recertified at least annually.

NIST Traceability and Certification of Flow Rate Standards

The flow rate standard used for flow rate calibration should have its own certification and should be traceable to other standards for volume or flow rate which are themselves NIST traceable. It is recommended that the “other standards” be either those of a commercial calibration laboratory or those primary standards maintained by the local agency, State, or EPA region. The greater the number of calibration steps needed to link a measurement to a NIST standard, the greater the degradation of quality of this type of traceability. Thus the “other standard” should be at least as, or even more, accurate and stable than the flow rate standards to be made traceable and should be no more than two traceability steps removed from an actual NIST standard. A calibration relationship for the flow rate standard, such as an equation, curve, or family of curves, should be established that is accurate to within 2% over the expected range of ambient temperatures and pressures at which the flow rate standard is expected to be used. The flow rate standard must be recalibrated or reverified and recertified at least annually. Appendix 12 of EPA’s Quality Assurance Handbook for Air Pollution Measurement Systems, Part I, should be consulted for further information on the calibration of primary and secondary standards for flow measurements and the hierarchy of standards (EPA 1998).

The actual frequency with which this recertification process must be completed depends on the type of flow rate standard—some are likely to be much more stable than others. The best way to determine recertification requirements is to maintain a control chart (a running plot of the difference or percent difference between the flow rate standard and the NIST-traceable primary flow rate or volume standard) for all comparisons. In addition to providing excellent documentation of the certification of the standard, a control chart also gives a good indication of the stability of the standard. If the two standard-deviation control limits are close together, the chart indicates that the standard is very stable and could be recertified less frequently. (The minimum recertification frequency is 1 year.) On the other hand, if the limits are wide, the chart would indicate a less stable standard that should be recertified more often. A particularly unstable standard may be unusable no matter how often it is recertified.

Outline of Generic Flow Rate Calibration Procedure

A fully detailed, EPA-approved flow rate calibration procedure, tailored specifically for each commercially available PM_{2.5} sampler, is contained in the operations manual associated with each sampler that is designated as a reference or equivalent method under 40 CFR Part 53. That sampler-specific procedure should be followed carefully and thoroughly, in conjunction with the guidance in this section, to calibrate the sampler. The following steps outline a general calibration procedure.

1. Before performing a flow rate calibration, be sure to first conduct a leak check and then make sure that the sampler temperature and pressure sensors are displaying reasonable readings (that is, they are calibrated).
2. Equilibrate the selected flow rate calibration device to ambient temperature conditions.
3. Install a filter cassette with an unused 46.2 mm filter in the sampler. This filter should meet all specifications for PM_{2.5} sampling, but it does not need to be pre- or post-weighed. This filter must not be used for sampling but can be used several more times for calibration purposes provided particulate loading on the filter is minimal.
4. Ensure that the sampler is operational and has warmed up. Depending on weather conditions, the sampler should run for a minimum of 10 to 15 minutes before starting the flow rate verification or calibration process. Check the flow rate display to assess stability.
5. Remove the inlet from the sampler. Place the flow calibration device on the sampler downtube using a flow adapter device if necessary. Ensure that any valves in the flow adapter are open so that flow through the sampler is unrestricted.
6. Place the sampler in calibration mode according to the instructions in the manufacturer's operating manual.

7. Follow the instructions in the manufacturer's operating manual for performing the multipoint flow calibration.
8. Once calibration is complete, turn off the sampler pump, remove the filter and filter cassette, remove the flow calibration device (and flow adapter device, if applicable), and replace the sampler inlet. The sampler flow rate is now calibrated.

Calibration of Sampler Temperature Sensors

A fully detailed EPA-approved calibration procedure for temperature sensors, tailored specifically for each commercially available PM_{2.5} sampler, is contained in the operations manual associated with each sampler that is designated as a reference or Class I equivalent method under 40 CFR Part 53. The specific procedure(s) given there should be followed carefully and thoroughly to calibrate the sampler's temperature sensors. It is recommended that a three-point temperature calibration of each temperature sensor be performed each year and that a one-point check of the ambient air temperature sensor be made monthly.

The following discussion provides additional precautions, guidance, and information on temperature standards and calibration that may not be contained in the specific instruction manual procedure. It also presents a generic outline of the general procedure used for calibration of the temperature measurement systems of commercially available samplers. This information should be used to augment the specific instruction manual procedure.

General Requirements and Guidance

1. Multipoint (at least three temperature points) calibration followed by single-point verification of each sampler's temperature sensors must be performed annually to establish traceability of subsequent temperature measurements to an authoritative temperature standard. Calibration with a temperature standard that is traceable to a NIST-traceable primary standard (see Section 6.3.3 regarding NIST traceability) transfers the traceability to the sampler's temperature sensors. Because temperature affects the flow rate, NIST traceability of the sampler's temperature measurements is also required for flow rate measurement traceability.
2. PM_{2.5} sampler manufacturers use various types of temperature sensors. The specific calibration standard and procedure used for calibration or verification of the sampler's temperature sensor may vary depending on the type of sensors used.
3. Multipoint calibration of the sampler's temperature measurement system must consist of at least three separate comparative temperature measurements approximately evenly spaced over the sampler's expected operational ambient temperature range. Both the ambient air and filter temperatures are monitored in order to assess filter temperature deviation from ambient temperature and to set a flag

should the filter temperature rise more than 5°C above ambient temperatures and stay there for 30 consecutive minutes.

4. Section 4.3.5 of the EPA QA Handbook, Volume IV, for Meteorological Measurements (EPA 1995) contains detailed guidance on calibration of temperature sensors/measurement systems, including a reference to the manufacturer's manual for adjustment of signal conditioning circuits. Also covered are required calibration equipment, and methods for calibrating the temperature, a discussion of temperature calibrations, as well as an example of a calibration report.
5. Ideally, temperature calibration would occur in the field to assess temperature sensor responses as they occur in normal operation. However, climate conditions may make this difficult and removal of the sampler to an indoor location may be preferable. Usually the sensor element is removed from the sampler and its connecting wires are left attached to the sampler. The space formerly occupied by the sensor should be plugged with a fitting to prevent any contamination of the sampling system and entry of ambient air.
6. Monthly (once every four weeks) verification of a sampler's temperature sensors' responses should consist of one temperature measurement made at the sampler's current temperature reading. This one-point verification may be substituted for a three-point calibration, provided that a full three-point calibration is carried out upon initial installation of the sampler and at least once per year thereafter, and the temperature measurement system has met the $\pm 2^\circ\text{C}$ accuracy requirement in the previous three-point calibration. A full three-point calibration must be carried out whenever a one-point verification indicates that the sampler's temperature measurement system differs by $\pm 4^\circ\text{C}$ or more from the temperature measured by the temperature standard. A one-point verification of the ambient temperature sensor should be done following the three-point calibration to ensure the sampler has been returned to its normal operating conditions.

Temperature Calibration Standards

The operations manual associated with the sampler should identify one or more types of temperature standards recommended for calibration and provide a detailed calibration procedure for each type that is specifically designed for the particular sampler.

The EPA Quality Assurance Handbook, Volume IV (EPA 1995), Section 4.3.5.1, gives information on calibration equipment and methods for assessing response characteristics of temperature sensors. The ambient air and filter temperature sensors of a reference or Class I equivalent PM_{2.5} sampler are required to be readable to the nearest 0.1°C and have an accuracy of $\pm 1^\circ\text{C}$ over the range of -30 to 45°C. The handbook describes how to prepare three stable thermal mass assemblies whose temperatures can be determined to about 0.1°C.

The thermal mass assemblies can be as simple as insulated vacuum bottles (i.e., thermos bottles) containing pure water or ice, or they may be solid cylinders of aluminum metal. A good ASTM- or NIST-traceable mercury-in-glass thermometer is also needed. The thermometer and the PM_{2.5} sampler sensor are both immersed in the thermal mass and allowed to equilibrate; the temperature readings are compared.

NIST Traceability and Certification of Temperature Standards

The temperature standard used for temperature calibration must have its own certification which shows traceability to a NIST primary standard. A calibration relationship to the temperature standard (an equation or a curve) is established; it is accurate to within 0.5°C over the expected range of ambient temperatures at which the temperature standard is to be used. The temperature standard must be reverified and recertified at least annually.

The actual frequency of recertification depends on the type of temperature standard; some are much more stable than others. The best way to determine recertification requirements is to keep a control chart.

Additional reference sources concerning temperature measurements and calibration are: "Liquid-in-Glass Thermometry" (NIST 1976); "Thermometer Calibration: A Model for State Calibration Laboratories" (NIST 1986); "NIST Measurement Services: Liquid-in-Glass Thermometer Calibration Service" (NIST 1988); and "The Calibration of Thermocouples and Thermocouple Materials" (NIST 1989).

Outline of Generic Temperature Calibration Procedure

Both the ambient air and filter temperature sensors should be calibrated once per year. The ambient air sensor is located inside the shielded fixture on the outside of the PM_{2.5} sampler and is easy to unfasten and remove for comparison to a transfer standard for temperature. It is possible to conduct the three-point calibration of the ambient sensor at the field site, although it may prove easier to remove the sampler to the laboratory to avoid weather problems and for convenience in preparing the temperature standards. On the other hand, the filter temperature sensor of Reference or Class I equivalent PM_{2.5} samplers is located in the open space just below the filter cassette. It is threaded through the wall of the filter assembly section of the sampler and removal of plastic or metal fittings is required to remove the sensor and its associated wiring. It is recommended that this sensor be calibrated in the laboratory. (The temperature sensor housing, the sampler inlet, and the interior of the downtube can also be cleaned in the laboratory.) Be careful when removing the filter temperature sensor—do not disturb the fittings since this could start an internal leak after installation. It is suggested that a sampler leak check be performed after reinstallation of the filter temperature sensor.

Several steps to follow in calibrating ambient air temperature sensors are given below. Make frequent reference to the operator's instruction manual for sampler-specific procedures and instructions.

1. Remove the ambient temperature sensor from the aspirated radiation shield so that it can be placed in a constant temperature bath while it is still connected to the sampler's signal conditioner.
2. Prepare a convenient container (such as an insulated vacuum bottle) for the ambient temperature water bath and the ice slurry bath. See Step 3 below. If complete immersion of the sensor is necessary, wrap it in plastic film so liquid can reach the point where the connecting wire(s) and the sensor interface without wetting them. Use partial immersion when possible, thus keeping the interface dry. If immersion is to be avoided altogether, it will be necessary to use thermal masses of metal rather than those based on water. Refer to Section 4.3.5 of Volume IV of the EPA QA Handbook (EPA 1995). To further insulate the vacuum bottle, it can be positioned inside a larger 2-gal insulated container that has been modified to allow wires or cables to enter the top. Refer to Figure 4.3.5.3 of Volume IV of the EPA handbook.

Keep the temperature changes relatively small and make comparative measurements in this order: AMBIENT, COLD, AMBIENT, HOT, AMBIENT. The range of temperatures need be only as broad as that expected to contain all the ambient temperatures that will be experienced during the upcoming time period, generally a year. The range to be expected is, of course, locale-specific. HOT may have to be 120°F for Phoenix, Arizona, but around 80°F for a location such as Barrow, Alaska.

3. For the ambient bath, use an insulated bottle that was filled with tap or deionized water several hours earlier and allowed to equilibrate to ambient temperature. For the ice slurry, the ice should be made with distilled water and then crushed into pea-sized pieces and mixed with distilled water until an easily penetrable slurry state is reached. As long as ice is present in the slurry and the open end of the bottle is guarded from ambient air temperature fluctuations, the ice slurry temperature will be $0.0 \pm 0.1^\circ\text{C}$.
4. Wrap the sensor(s) and a thermometer together with a rubber band. The thermometer bulb and the temperature sensor active site should be close together. Immerse the sensor and the attached thermometer in the ambient temperature bath. Use a cork or some other device to cover the open end of the insulated bottle and thus keep ambient air from circulating over the top surface of the water (or ice slurry mass). The bath liquid should be stirred to ensure the temperature is uniform; never use the thermometer or temperature sensors to stir the bath. Gentle stirring should continue, if possible, during the measurement process; however, do not stir while readings are being taken as this may

introduce noise into the readings. Wait for the ambient thermal mass and the sensor/thermometer temperatures to equilibrate. Be sure successive temperature readings are stable (indicating equilibration with the ice slurry) before taking comparative readings.

5. For each thermal mass, in the order indicated in Step 2 above, make a series of five measurements, taken about a minute apart. Accurately read the meniscus of the thermometer. Use magnification if necessary to see the meniscus; avoid parallax errors. If the measurements made support the assumption of equilibrium, then average the five readings and record the result as the sensor temperature relative to the thermometer for hot, ambient and for 0.0°C relative to the ice slurry. Record all readings in the sampler notebook.

Calibration of Sampler Pressure Sensor

Each reference or Class I equivalent PM_{2.5} sampler has a built-in atmospheric pressure sensor that produces an output processed to allow control of the actual sampling flow rate to the design value of 16.67 L/min. The following discussion gives information concerning the care of barometers, their principles of operation, and how an aneroid barometer can be made traceable to a mercury column Fortin barometer and then be used to field-check the readings provided by the sampler's pressure sensor. The operation or instruction manual must be consulted for sampler-specific information on how to make adjustments to calibrate the pressure sensor.

General Requirements

1. As required in 40 CFR Part 50, Appendix L, the sampler shall have the capability to measure the barometric pressure of the air surrounding the sampler over a range of 600 to 800 mm Hg. This measurement shall have a resolution of 5 mm Hg and a NIST-traceable accuracy of ± 10 mm Hg.
2. According to ASTM standard D 3631 (ASTM 1977), a barometer can be calibrated by comparing it with a secondary standard traceable to a NIST primary standard.
3. The Fortin mercurial type of barometer works on fundamental principles of length and mass and is therefore more accurate, but is more difficult to read and correct than other types. By comparison, the precision aneroid barometer is an evacuated capsule with a flexible bellows coupled through mechanical, electrical, or optical linkage to an indicator. It is potentially less accurate than the Fortin type but can be transported with less risk to the reliability of its measurements and presents no hazard to personnel from mercury spills. The Fortin type of barometer is best employed as a higher quality laboratory standard which is used to adjust and certify an aneroid barometer in the laboratory. The certified aneroid barometer can then be taken in the

field and used to verify the readouts from the transducer type pressure sensor in the sampler. The sampler sensor can be left in the sampler during the comparison since atmospheric pressures are equivalent within a 100-m horizontal distance and a 0.5 m vertical distance. If there is a discrepancy, the aneroid barometer should be recompared to the Fortin type upon return to the laboratory. A discrepancy with the sampler sensor could indicate an offset in the sampler's pressure sensor adjustment.

4. Protect all barometers from violent mechanical shock and sudden changes in pressure. A barometer subjected to either of these events must be recalibrated. Minimize the vertical and horizontal temperature gradients across the instruments. Locate the instrument to avoid direct sunlight, drafts, and vibration.
5. Multipoint pressure calibrations must be performed on installation and then annually (or when out of specification). Single point pressure verifications should be done every four weeks.

Calibration Procedures

Fortin Type Barometer Readings

1. Read the temperature from the thermometer attached to the barrel to the nearest 0.1°C.
2. Lower the mercury level in the cistern until it clears the index pointer. Raise the level slowly until a barely discernible dimple appears on the surface of the mercury.
3. Tap the barrel near the top of the mercury column.
4. Set the vernier so that the base just cuts off light at the highest point of the meniscus and carefully avoid parallax error.
5. Read the height of the mercury column from the barometer in the manner appropriate to the vernier scale used to the equivalent of the nearest 0.1 mm Hg. Apply appropriate corrections for temperature and gravity as described in the barometer instruction booklet.

Aneroid Type Barometer

1. Always use and read an aneroid barometer when it is in the same position (vertical or horizontal) as it was when calibrated. Locate the portable aneroid barometer next to the laboratory's primary standard to begin the calibration process.
2. Immediately before reading the scale of an aneroid barometer with mechanical linkages, tap its case lightly to overcome bearing drag.

3. Read the aneroid barometer to the nearest 1 mm Hg. If the aneroid barometer is to be taken to the field, compare its readings to the laboratory's primary pressure standard. If possible to do so, adjust the portable barometer to match the reading of the primary standard. If the portable barometer reading cannot be adjusted, note the offset and correct field readings accordingly.

Two types of leak checks are specified for use with PM_{2.5} samplers—an external leak check and an internal filter bypass leak check. The results for both of these procedures should be recorded. Each leak-check procedure is described below.

External Leak Check

The sampler components to be subjected to this leak test include all components and their interconnections in which external air leakage would or could cause an error in the sampler's measurement of the total volume of sample air that passes through the sample filter.

All PM_{2.5} samplers must include external air leak test components, accessory hardware, operator interface controls, a written procedure, and all other items necessary to carry out a leak test of the sampler at a field monitoring site without additional equipment.

Follow these general steps to perform the external leak-check procedure:

1. Remove the sampler inlet and install the flow rate measurement adapter supplied with the sampler (Figure 17-4). Install a leak-check filter in the sampler filter holder.
2. Close the valve on the flow rate measurement adapter and use the sampler air pump to draw a partial vacuum into the sampler, including the impactor, the filter holder assembly (filter in place), the flow measurement device, and the interconnections between these devices. The partial vacuum should be at least 55 mm Hg (75-cm water column), measured at a location downstream of the filter holder assembly.
3. Plug the flow system downstream of these components to isolate the components under vacuum from the pump, such as with a built-in valve.
4. Stop the pump.
5. Measure the trapped vacuum in the sampler with its built-in pressure-measuring device.
6. Measure the vacuum in the sampler with the built-in pressure-measuring device again at least 10 minutes after the first measurement or at the elapsed time specified in the sampler's operations manual.

7. Upon completion of the leak test, slowly open the adapter valve, remove the adapter and plugs, and restore the sampler to the normal operating configuration.

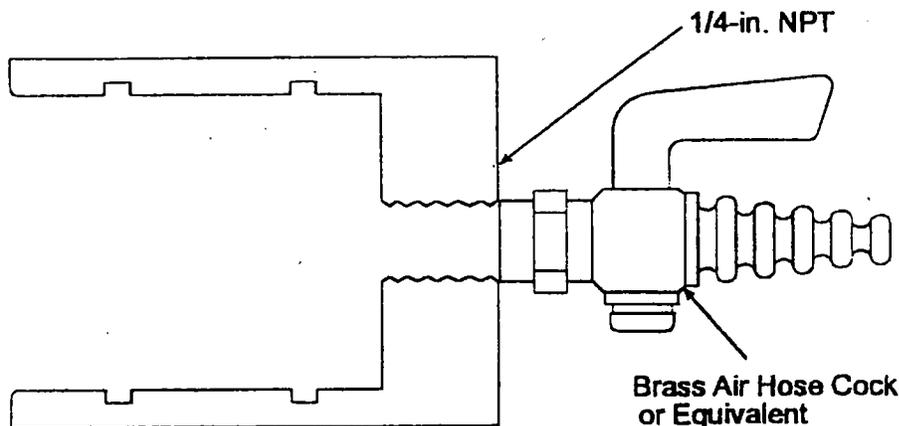


Figure 17-4. Flow adapter.

To pass the external leakage test, the difference between the two pressure measurements should not be greater than the number of millimeters of Hg specified for the sampler by the manufacturer, based on the actual interior volume of the sampler, that indicates a leak of less than 80 mL/min.

Variations of the suggested technique or an alternative external leak test technique may be required for samplers whose design or configuration would make the suggested technique impossible or impractical. Therefore, a manufacturer may propose an alternative procedure to EPA under the reference or equivalency application under 40 CFR Part 53. In such cases, the manufacturer's EPA-approved leak-test procedure should be followed.

Internal Filter Bypass Leak Check

The purpose of this test is to determine if any portion of the sample flow rate that leaks past the sample filter without passing through the filter is significant relative to the design flow rate for the sampler. The suggested technique for the operator to use for this leak test is as follows:

1. Carry out an external leak test as described above.
2. Install a **flow-impervious** membrane material in the filter cassette, either with or without a filter, as appropriate, which effectively prevents air flow through the filter.

3. Use the sampler air pump to draw a partial vacuum in the sampler, downstream of the filter holder assembly, of at least 55 mm Hg (75 cm water column).
4. Plug the flow system downstream of the filter holder to isolate the components under vacuum from the pump, such as with a built-in valve.
5. Stop the pump.
6. Measure the trapped vacuum in the sampler with a built-in pressure-measuring device.
7. Measure the vacuum in the sampler with the built-in pressure-measuring device again several minutes after the first pressure measurement.
8. Remove the flow plug and membrane and restore the sampler to the normal operating configuration.

For successful passage of this test, the difference between the two pressure measurements should not be greater than the number of millimeters of Hg specified for the sampler by the manufacturer. This specification is based on the actual internal volume of the portion of the sampler under vacuum, that indicates a leak of less than 80 mL/min. As with the external leak-check procedure described above, variations of the suggested technique may be used, provided that they were approved as part of the manufacturer's reference or equivalency application for that sampler.

If the leak rate for either of the above procedures is excessive, note the problem on your leak-check information sheet. Check the O-rings on the flow rate adapter for nicks, wear, and excessive flattening. Also check the outside of the intake tube (the downtube) where the device seats for deep scratches or dirt that could allow leakage. Check that the filter holder is well seated. Correct any problems and repeat the leak check.

Multipoint Verification/Calibration Frequency

Multipoint verification of a sampler's flow rate measurement system should take place at least annually or

- following major electrical or mechanical maintenance, such as replacement of a circuit board or rebuilding of the sampling pump assembly, troubleshooting and making repairs to correct leakage, etc.
- when a routine flow rate verification indicates a variation from the set point (16.67 L/min) of more than 4%.

If the Multipoint verification fails, then recalibration is required. Before beginning a flow rate calibration, the operator should repeat the flow rate

verification to be certain there were no leaks in the connections between the flow rate verification device and the sampler inlet, and that the flow rate data were reduced and interpreted correctly. In addition, the operator should ensure that the collector's ambient temperature and pressure measurement systems are responding accurately; if not, these systems must be recalibrated (or replaced and calibrated) before performing a flow rate calibration.

Section VII. Filter Preparation and Analysis

Overview

A very critical portion of the PM_{2.5} measurement program is the attention given to filter preparation and handling, and the analytical technique employed in determining the mass of particulate matter collected on the filter. High quality data requires the analytical laboratory staff's attention to detail and their microbalance operation technique. This section offers guidelines to enhance the data quality of the laboratory operation and, hence, the PM_{2.5} mass concentration and any additional qualitative and quantitative determinations. The topics to be discussed in this Section include the microbalance environment, mass reference standards, filter handling, filter conditioning, lot blanks, laboratory blanks, and field blanks. Also addressed are the electrostatic charge neutralization of the filter, presampling weighing, post sampling documentation and inspection, post sampling weighing, calculation of net mass filter loading, chemical speciation, and internal quality control.

Microbalance Environment

Gravimetric analysis of the filters is performed with a microbalance with a readability of 0.001 mg (1 µg) and a repeatability of 1 µg as listed in the microbalance's performance specifications. Because of the greater sensitivity needed for measuring microgram-range weights or weight differences, microbalances are vulnerable to relatively small changes in physical environmental conditions, such as vibration, electrostatic charge buildup, temperature, or relative humidity. Features to offset the effect of these variables on the measurements may be integrated into the design of the microbalances, or they may be offered as options. Additional specific guidance and tips on good microbalance operating procedures are also discussed in Subsection 7 of Section 2.12 in the QA Handbook.

Mass Reference Standards

Mass reference standards should be in the range of 100 to 200 mg, given that the mass range of typical 46.2 mm filter is from 110 to 160 mg. They should be certified as being traceable to NIST mass standards. Additionally, they should have an individual tolerance of no more than 0.025 mg. The mass reference standards should be recalibrated on a regular basis (e.g., yearly). Two separate sets of mass reference standards are recommended. Working calibration standards should be used for routine filter weighing and should be kept next to the microbalance in a protective container. Laboratory primary standards should be handled very carefully and should be kept in a locked compartment. The working standards' masses should be verified against the laboratory primary standards every 3 to 6 months to check for mass shifts associated with handling or contamination.

Filter Handling

Careful handling of the filter during sampling, conditioning, and weighing is necessary to avoid measurement errors due to damaged filters or a gain or loss of collected particles on the filters. Whenever filters are handled, the analyst should wear gloves that are antistatic and powder-free and that act as an effective contamination barrier. If filter loadings are to be speciated chemically, the possibility of contamination from gloves should be considered. Some gloves have been found to be contaminated with sulfate. If antistatic gloves are used, it is important to be sure that ammonium chloride is not a component of the antistatic reagent. Powder-free gloves that are certified to be free of chloride, nitrate, and sulfate are available.

Filter Integrity Check

All filters should be visually inspected for defects before the initial weighing. Use of a light box is suggested. A filter should be discarded if any defects are found. Any lot of filters containing a high number of defects should be returned to the supplier. Specific filter defects to look for are the following: pinholes; separation of ring, chaff, or flashing; loose material; discoloration; filter nonuniformity; and a filter with any imperfection not described above, such as irregular surfaces or other results of poor workmanship.

Filter Conditioning

New filters should be placed in the conditioning environment immediately upon arrival and should be stored there until the presampling weighing. Because it may take several days to reach a stable condition, tests should be conducted on several filters to ensure attainment of stable condition. Filters must be conditioned immediately before both the pre- and post-sampling weighings. Filters must be conditioned for at least 24 hours to allow their weights to stabilize before being weighed. Filters must be conditioned at the same conditions (humidity within $\pm 5\%$ relative humidity) before the pre- and post-sampling weighings. Mean temperature should be held between 20 and 23°C, with a variability of not more than $\pm 2^\circ\text{C}$ over 24 hours.

An air-conditioned room may be used as a conditioning chamber, if relative humidity and temperature can be maintained within the above specifications while filters are conditioning.

Filter Blank

Three types of blank filters should be used: lot blanks, laboratory blanks, and field blanks. Lot blanks are unsampled filters that are used to determine filter weight stability over long periods of time (e.g., 6 weeks) due to the volatilization of material from the filter or to the absorption of gaseous material into the filter from the atmosphere. Laboratory blanks are conditioned, unsampled filters that are used to determine any weight change between pre- and postsampling weighings due to contamination in the microbalance environment. Field blanks are conditioned, unsampled filters that are used to determine whether similar

contamination occurs during sampling.

Electrostatic Charge Neutralization

Electrostatic charge buildup will prevent a microbalance from operating properly. Static charge is the accumulation of electrical charges on the surface of a nonconductive material. Common symptoms of this problem include noisy readout, drift, and sudden readout shifts. To reduce static charge within the balance, it may be necessary to place a radioactive antistatic strip containing a very small amount (i.e., 500 picocuries) of ^{210}Po in the weighing chamber. It may also be necessary to pass each filter near, but not touching, an antistatic strip before it is weighed. ^{210}Po antistatic strips are used to reduce electrostatic buildup in the microbalance's weighing chamber and on individual filters by charge neutralization. They will neutralize electrostatic charges on items brought within an inch of them. These antistatic strips are safe, commonly available, and inexpensive. ^{210}Po has a half-life of 138 days. See Subsection 7.8 of Section 2.12 in the QA Handbook for additional details on charge neutralization.

Presampling Filter Weighing (Tare Weight)

The reference method for $\text{PM}_{2.5}$ requires that the presample filter weighing be conducted within 30 days of the sampling period. The microbalance must be located in the same controlled environment in which the filters are conditioned and the filters must be weighed without intermediate or transient exposure to other conditions or environments. Subsection 7.9 of Section 2.12 in the QA Handbook on $\text{PM}_{2.5}$ Monitoring presents procedures specific to a common commercially available microbalance. The procedures include calibration, QC checks (and acceptance tolerances), and operational procedures. These procedures may have to be adapted for use with other microbalance models.

Researchers have found that the precision of mass measurements for unexposed filters based on replicate weighings is typically 3 to 5 $\mu\text{g}/\text{filter}$ (Desert Research Institute 1994). The precision on exposed filters is typically 5 to 8 $\mu\text{g}/\text{filter}$. Precision for exposed filters with loadings heavier than 1 mg/cm^2 of filter surface area may approach $\pm 2\%$ of the loading. The precision for net mass filter loadings (typically 6 to 9 $\mu\text{g}/\text{filter}$) is defined as the square root of the sum of the squares of the pre- and postsampling precision.

Postsampling Documentation and Inspection

Following sample collection and return of the sample to the laboratory, the analyst would typically follow these steps: thoroughly inspect the sample and document the findings; verify that the temperature of the cooler's interior was maintained at the desired temperature of 4°C; remove the filter cassette from its protective container and examine the container; if particulate matter or debris is found in the protective container after the filter has been removed, record that the sample has been flagged as questionable for the reason specified on the laboratory data form. Save the filter for further inspection and notify appropriate party.

Proceed by matching the filter identification number with the correct laboratory data form on which the original microbalance number, filter number, presampling filter weight, and other information were inscribed. Group filters according to the microbalance used to determine their initial tare weights. Initial separation of filters in this way will eliminate the risk of a measurement error that could result from the use of different microbalances for pre- and post-sampling weighings. Remove the filter from both the protective container and the filter cassette, being careful not to touch or otherwise disturb the filter and its contents. Transfer the filter to a filter-handling container labeled with the corresponding filter number. Place the used filter in the container "dirty-side" up. Keep the particles from contact with the walls of the container. The filter should be handled with clean, smooth forceps and should not be touched by hands. Inspect the filter for any damage that may have occurred during sampling. If any damage is found, note that the sample has been flagged as questionable and include the reason on the laboratory data form. Save the filter for inspection. Notify appropriate party. Finally, transfer the filter in its filter-handling container to the conditioning chamber, and allow the filter to condition for not less than 24 hours.

Postsampling Filter Weighing (Gross Weight and Net Weight)

The postsampling filter weighing should be carried out on the same analytical balance as the one used for the pre-sampling weighing. Different analysts can perform the pre- and post-sampling filter weighings as long as the appropriate standard operating procedures have been followed and as long as the working standard and replicate measurements are within specifications. Use an effective technique to neutralize static charges on the filter. The postsampling conditioning and weighing should be completed within 240 hours (10 days) after the end of the sampling period, unless the filter is maintained at 4 C or less during the entire time between retrieval from the sampler and start of the conditioning, in which case the period shall not exceed 30 days. Specific details of the postsampling filter weighing procedures are provided in Subsection 7.11 of Section 2.12 in the QA Handbook.

Calculation of the net mass filter loading consists of subtracting a filter's pre-sampling mass from its post-sampling mass and recording this value on the laboratory data form. Calculations required to compute and report ambient PM_{2.5} concentrations in $\mu\text{g}/\text{m}^3$ will be discussed in more detail in Lesson 18.

Chemical Speciation

In support of this requirement EPA developed the report, "Particulate Matter (PM_{2.5}) Speciation Guidance Document, Third Draft, January 5, 1999. Plans are to establish a PM_{2.5} chemical speciation network of about 50 trends sites which will provide a basic, long-term record of the characterization of as a minimum trace elements, sulfate, nitrate, ammonium, and carbon constituents. These trend sites will be part of the NAMS network and will serve as a model for other chemical speciation efforts. The full chemical speciation network will include approximately 300 sites. In addition to the 50 NAMS trend sites, another 250 sites will be established to enhance the required network and provide information for developing effective State Implementation Plans (SIPS). These

additional sites will be allowed flexibility in terms of sampling frequency, site selection, site mobility, and target species.

In addition to the routine NAMS trends sites and additional 250 sites for SIP development, the EPA anticipates that special study activities will enhance the information data base for control strategy development and health related studies. Also, EPA anticipates the establishment and operation of the "Super Sites" network. This network is to provide resolved characterizations (time, space, composition) of aerosols and related precursor, intermediate, and sink species that will lead to a greater understanding of PM_{2.5} and ozone formation and loss processes. These latter studies are not to be confused with the PM_{2.5} chemical speciation network and are intended to foster collaborative relationships among State/local agencies, academia and industry

Internal Quality Control

For internal quality control, agencies should keep a laboratory QC notebook or database (with disk backups), which should contain QC data, including the microbalance calibration and maintenance information, routine internal QC checks of mass reference standards and laboratory and field filter blanks, and external QA audits. These data will duplicate data that are already recorded on laboratory data forms but will consolidate them so that long-term trends can be identified. It is recommended that QC charts should be maintained on each microbalance and should be included in this notebook. These charts may allow the discovery of excess drift that could signal an instrument malfunction.

Additional internal quality control guidance is provided in Subsection 7.14 of Section 2.12 in the QA Handbook. This additional guidance covers the weighing of laboratory and field blanks for pre-sampling and post-sampling activities.

Lesson 18

Quality Assurance Guidance for PM_{2.5} Ambient Air Monitoring - Part II

Lesson Goal

Familiarize students with EPA quality assurance regulations and guidance for PM_{2.5} ambient air quality monitoring.

Lesson Objectives

1. List sampling site visit activities that should be conducted at the beginning of a sampling run and at the end of a sampling run.
2. List three criteria that have been established to assist operators in determining whether or not a PM_{2.5} sampler is valid.
3. Recall how frequently the sampler inlet should be dismantled and cleaned and how frequently the impactor well should be cleaned.
4. State the frequency of flow rate verification checks for primary PM_{2.5} samplers used for SLAMS monitoring.
5. Describe at least one quarterly sampler maintenance activity.
6. Recall the minimum number of temperatures that should be used for conducting an audit of the temperature probe of a PM_{2.5} sampler.
7. State the percentage of primary PM_{2.5} samplers at which a reporting organization must locate a permanent duplicate sampler for purposes of assessing precision.
8. Recall that State and local agencies are responsible for conducting the FRM performance evaluations to assess total measurement system bias; however, EPA Regional Offices have agreed to perform this activity.
9. State the recommended frequency for each State or reporting organization to conduct an internal accuracy assessment of each microbalance.
10. List at least five activities included in a system audit.
11. Calculate the PM_{2.5} mass concentration in $\mu\text{g}/\text{m}^3$ given the mass of PM_{2.5} and the total sample volume.
12. Describe at least two situations where manual calculations should be verified.
13. List two methods typically used for keystroke data entry quality control.
14. Recall the primary reasons for doing validation data screening.
15. Describe at least four techniques that may be applicable to PM_{2.5} data validation.

16. State two major reasons why the use of spreadsheets for processing large environmental data sets is strongly discouraged.
17. Recall that the location of information on reporting and interpretation of PM_{2.5} data with respect to the attainment of the PM_{2.5} NAAQS is covered in 40 CFR Part 50 Appendix N.
18. Recall that filter weight data for calculating PM_{2.5} concentrations should be recorded to the full readable precision of the microbalance and that hand-calculated weight differences should be carried to the same number of digits. Rounding should occur after final calculations.
19. Recall that for other hand-recorded data, including calibration and audit data, it is advisable to read and record somewhat more resolution than will be needed and rounding should occur after the final calculation.
20. State the number of filter weight significant figures necessary in order to get adequate precision in net particulate mass.
21. Recall that the 3-year average of the spatially averaged annual means is rounded to the nearest 0.1 µg/m³, that decimals 0.05 and greater are rounded up to the next 0.1, and that any decimal lower than 0.05 is rounded down to the nearest 0.1.
22. Recall that for the 24-hour standard, the 3-year average of the annual 98th percentile values is rounded to the nearest 1 µg/m³, decimals 0.5 and greater are rounded up to the nearest whole number, and any decimal lower than 0.5 is rounded down to the nearest whole number.
23. List at least four reasons for maintaining complete, orderly records, and properly managed PM_{2.5} data.
24. List at least three PM_{2.5} records that should be created and retained.
25. Recall the approach used to assess PM_{2.5} measurement bias and PM_{2.5} measurement precision.

References

U.S. Environmental Protection Agency. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part II, Section 2.12, Monitoring PM_{2.5} in Ambient Air Using Designated Reference or Class I Equivalent Methods*, November 1998.

Revised Requirements for Designation of Reference and Equivalent Methods for PM_{2.5} and Ambient Air Quality Surveillance for Particulate Matter; Final Rule. U.S. Environmental Protection Agency, 40 CFR, Parts 53 and 58, Federal Register, July 18, 1997.

National Ambient Air Quality Standards for Particulate Matter, Appendix K- Interpretation of the National Ambient Air Quality Standards for Particulate Matter, Appendix L-Reference Method for the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere; and Appendix N-Interpretation of the National Ambient Air Quality Standards for Particulate Matter Final Rule. U.S. Environmental Protection Agency, 40 CFR Part 50, Federal Register, July 18, 1997.

U.S. Environmental Protection Agency. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I, Ambient Air Quality Monitoring Program Quality System Development*. EPA 454/R-98-004, August 1998.

U.S. Environmental Protection Agency. *Quality Assurance Guidance Document, Model Quality Assurance Project Plan for the PM_{2.5} Ambient Air Monitoring Program at State and Local Air Monitoring Stations (SLAMS)*. EPA-454/R-98-005, April 1998.

U.S. Environmental Protection Agency. 1994. *Requirements for Quality Assurance Project Plans for Environmental Data Operations*, EPA QA/R-5.

Section I. Field Operations

This Lesson is Part II of two lessons covering QA Guidance for PM_{2.5} monitoring. The material covered is extracted from Subsections 8 through 13 of the QA Handbook, Vol. II, Section 2.12, Monitoring PM_{2.5} in Ambient Air Using Designated Reference or Class I Equivalent Methods.

This Section provides guidance on suggested activities for PM_{2.5} field sampling operations. The guidance is independent of any one type of commercially available PM_{2.5} sampler. Because operational procedures may vary among sampler models, the manufacturer's operations manual must be consulted before the sampler is actually put into service. The discussion presented in this Section of Lesson 18 is extracted from Subsection 8 of the Section 2.12 PM_{2.5} document.

The discussion addresses the following topics:

- Activities to conduct each site visit
- Field operation activities to perform every five operating days
- Field operation activities to perform every four weeks

Activities to Conduct Each Site Visit

Start of Run

The activities conducted during each site visit include preparing for and completing a sample run, validating samples, and proper handling of the filter/cassette assembly. In preparing for the sampling run, care must be taken to ensure that the filter is clean and undamaged before it is installed in the sampler. The filter/cassette assembly should be kept in its protective container until installation and damaged filters must be placed in the protective container and returned to the weighing laboratory where they will be examined and then discarded. All pertinent data must be entered on a data sheet (or in a computer file). The data should include items such as: date and time of sampler setup visit; site designation and location; sampler model, ID number, and filter ID number; sample start date and time; current ambient temperature and barometric pressure indicated by the sampler; unusual conditions that may affect samples (e.g., subjective evaluation of pollution on that day, construction activity, weather conditions); and setup operator's signature or initials.

If the sampler is set to begin operation automatically, ensure that enough time is available to complete the following setup procedures before it starts. Open the filter holder assembly according to the manufacturer's instructions and install the uniquely identified filter cassette containing the preweighed filter. Do not remove

the filter from the cassette. This is done only at the filter weighing facility. Visually inspect the O-rings inside the filter holder to ensure they are present and secure. Proceed with a visual inspection of the maintenance records of the sampler. If it is time for the monthly/every 4 weeks check, measure and record independent measurements (using certified standards) of ambient temperature and pressure, and ensure that the ambient temperature (i.e., inlet temperature) and pressure readings taken by the sampler are $\pm 4^\circ \text{C}$ and 10 mm Hg of the independent readings, respectively. Also check the sampler's display for the filter temperature and ensure that this value is reasonable (within $\pm 5^\circ \text{C}$) as compared to the ambient temperature display.

End of Run

At the end of a run, visually inspect the sampler readouts to ensure that the sampler is operating properly. Sequential samplers will require manipulation of a number of display screens to retrieve all data. Consult the operating manual. Also check the sampler for any other obvious problems, such as a full water collection jar. If problems are identified, describe them on the sample run data sheet and take corrective actions before starting another run. Be sure to record the appropriate information on the sampler run data sheet (or save to a data file). This information includes such items as: date and time of post-sampling site visit, stop time and total elapsed time of the sample run, final flow rate, average flow rate, coefficient of variation of the flow rate, and total volume sampled. A detailed listing of the data to be recorded is included in Subsection 8.2.2 of the Section 2.12 QA Guidance Document.

Sampler Validation

Concerning sample validation, observations made by the site operator about the sampler are most important in deciding if a sample is valid. Never discard a filter/cassette. Field operators are encouraged to use data qualifiers or flags, and record free-form notes on the data sheet, in a site logbook, or on computer data entry screens. The final decision for invalidation will be made after the information provided by the operator and the filter/cassette itself are examined at the office or laboratory. Stringent control of sampler operation is important since too many invalid samples could cause an entire quarter's data set to be lost. The following items should be reviewed as part of the sample validation procedure: sampling period, flow rates, filter quality, filter temperature, and the presence of any exceptional events during the sampling period.

Handling of the sample after collection is also very important. The reference method requires that the sample be removed from the collector within 96 hours of the end date and time of the sample run. Depending on whether the sample is shipped or transported at or near ambient temperatures (25°C) or cooled to 4°C , the laboratory has from 10 to 30 days from the end date and time of the run to determine the sample weight. Package and handle the samples to avoid vibrations

that may dislodge particles. Do not allow the filter surfaces to touch any of the interior surfaces of the protective container. The container must be transported in another insulated container capable of maintaining a temperature of less than 25°C (77°F) unless the transit time to an air-conditioned building or refrigerator is only a few hours. If desired, the sample may be cooled to 4°C by placing leak-proof ice substitutes inside the insulated container. Do not allow the protective container to become wet. Place a min/max thermometer or a liquid crystal temperature sensor strip inside the shipping container to verify that the sample remained cool during its transit to the laboratory. Handle field blank filters in the same manner.

In handling a questionable sample, the operator should complete as much of the run data as possible and explain any omissions. Questionable data should be marked on the run data sheet and comments should be recorded on the data sheet and/or in the site logbook. The questionable filter should not be discarded; rather it should be delivered to the analytical laboratory as if it were a valid sample.

Activities to Perform Every Five Operating Days

Cleaning of the impactor well is strongly recommended after every 5 days of operation. This can be done in the field or as part of the 5 day maintenance procedure described below. Also empty any water from the water trap, clean the sampler interior, inspect the seals, and reinstall the trap. Cleaning of the well is necessary to prevent the sampler from operating with an overloaded PM_{2.5} impactor. When operating in an area with high PM₁₀ concentrations, more frequent cleaning of the well may be necessary. Subsection 9.2.2 of the Section 2.12 document has more information on impactor maintenance.

Impactor wells may be cleaned at the field site. Take care to clean the well thoroughly and to not introduce contaminants. Alternately, it is possible to have spare wells that can be cleaned in a laboratory or other indoor location. The well should be transported to the sampling site in an upright position. During transport, protect the well from excessive vibration, precipitation, direct sunlight, and other harmful environments. Likewise, the used well should be protected in transit back to the laboratory. It is recommended that wells be numbered or otherwise identified and records be kept of their use.

In the case of sequential samplers in use every day, sampling may be interrupted for up to 1 hour without invalidating the day's sample. Exercise care not to contaminate the filter during the well cleaning or replacement process. It is also suggested that internal and external leak checks be conducted after every 5 days of operation and whenever equipment is replaced or removed.

Activities to Perform Every Four Weeks

Four activities are required to be conducted every four weeks: (1) an external

and internal leak check, (2) a temperature-check, (3) a pressure check, and (4) a flow rate verification check. Control charts presenting flow rate verification check data (indicated vs. measured) should be maintained. These charts provide a reference of instrument flow rate drift patterns and indicate when flow limits ($\pm 4\%$) have been exceeded. The field check is made by installing a measuring device (which is traceable to NIST and is calibrated within the range of the flow rate) on the inlet of the sampler (Figure 18-1). Calibration checks of the sampler flow rate require that the instrument be running. Subsection 8.4.4 of the Section 2.12 Guidance Document contains the procedure for conducting the field flow rate verification check.

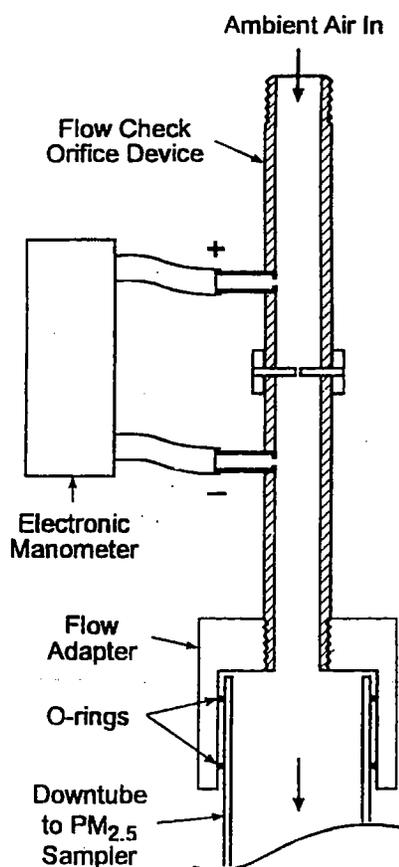


Figure 18-1. Example of installation of sampler flow verification check assembly.

The need for periodic verification of temperature and pressure measurements were addressed in Subsection 6 of Lesson 17.

The following pieces of equipment are required for field calibration checks of temperature, pressure, and flow rate.

- A thermometer, readable to the nearest 0.1°C , and capable of accurately measuring temperature to the nearest $\pm 1^{\circ}\text{C}$. The thermometer must be referenced to a NIST standard or ASTM thermometer within $\pm 0.5^{\circ}\text{C}$ at least annually.
- A barometer, capable of accurately measuring ambient barometric pressure to the nearest ± 1 mm Hg. The barometer must be referenced to a NIST or ASTM barometer within ± 5 mm Hg at least annually.
- An orifice device (or other acceptable flow measurement device) and calibration relationship, along with the sampler's calibration information (equation).
- A clean flow check filter installed in a cassette.
- A flow check data sheet or the sampler's logbook.

Leak checks should be conducted prior to the QC field calibration checks of temperature, pressure, and flow rate. They require insertion of a clean filter, removal of the sampler inlet, and installation of the flow rate adapter on the top of the downtube. Procedures for conducting this leak check were discussed in Section 6 of Lesson 17.

Section II. Sampler Maintenance

Preventive maintenance is defined as a program of planned actions aimed at preventing failure of monitoring and analytical systems. The overall objective of a routine preventive maintenance program is to increase measurement system reliability and to provide for more complete data acquisition. This section addresses only maintenance associated with Reference or Class I Equivalent PM_{2.5} monitoring methods. Maintenance of the laboratory microbalance and support equipment is not covered. Laboratories often employ a balance service representative who services balances on a semi-annual or annual basis.

Some sampler maintenance can be performed at the field site. Major maintenance of the sampler or components, such as the pump, can be performed more conveniently when the equipment is brought to a laboratory or maintenance facility, provided time and labor are available to move the equipment.

A maintenance schedule should be established for each sampler and systematic records should be kept as scheduled and unscheduled maintenance occurs. Files should reflect the history of maintenance, including all replacement parts, suppliers, and cost expenditures, and should include an inventory of on-hand spare equipment for each sampler.

Recommended supplies for all maintenance activities include an alcohol-based general-purpose cleaner that leaves no residue, cotton swabs, a small soft-bristle brush, paper towels, distilled water, and miscellaneous hand tools. Additional supplies may be necessary for specific procedures, as indicated below. Specifications for many of the supplies are given in Section 4.0 of this document. A compressed-air source is also recommended but not required. All activities recommended below are in addition to those specified in the operating manual specific to the sampler and are not intended to replace those in the operating manual.

Five-Day Maintenance Procedures

At least every five sampling days, inspect the water collector bottle. Remove accumulated water, clean the interior of the bottle, inspect the seals, and replace the bottle in the holder. This is part of the 5 day field operating procedure.

In addition, disassemble and clean the impactor well. (See Figure 18-2.) This portion of the procedure is more conveniently done in the laboratory. Separate the upper and lower portions of the well, remove the used filter from the well, wipe the two halves of the well clean with lint-free laboratory tissues or cloth, put a new glass fiber filter in the well's bottom, and add ± 0.1 mL of impactor oil. Check to be sure the oil covers the filter uniformly. Reassemble the well and place it in the impactor. To reduce preparation time, several spare impactor wells should be prepared at one time and stored in a clean, dust-free container until

needed.

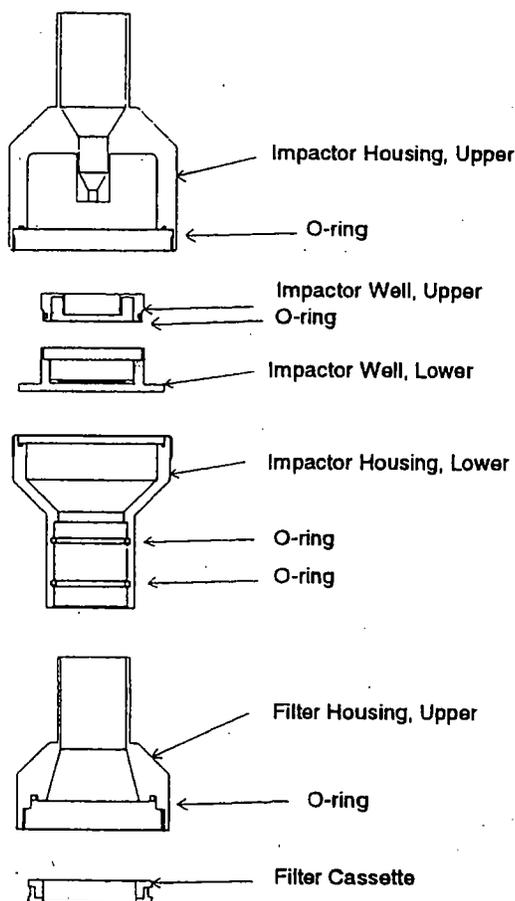


Figure 18-2. Exploded cross-sectional view of design of PM_{2.5} impactor well and filter holder.

Monthly Maintenance Procedures

Monthly maintenance consists of service to the sampling inlet and impactor housing and well. A disassembled sampling inlet is shown in Figure 18-3. The sampling inlet seals to the sampler downtube with two O-rings. In disassembling the sampling inlet, care should be taken during handling not to crack or break the water collector bottle; otherwise the sampler will not maintain adequate vacuum during operation. Detailed procedures for dismantling and cleaning the sampler inlet are provided in Subsection 9.3.2 of the Section 2.12 Guidance Document. Servicing the impactor housing and well consists of disassembling the impactor assembly and inspecting the interior of the impactor housing both above and below the impactor well. The areas need to be clean and dry, so while it is disassembled clean the areas with a lint-free cloth. Also, clean the interior of the impactor jet using a lint-free pipe cleaner or similar tool. The O-rings should also be checked for distortions, cracks, fraying, lack of a light coating of vacuum

grease, or other problems. Any problems must be corrected.

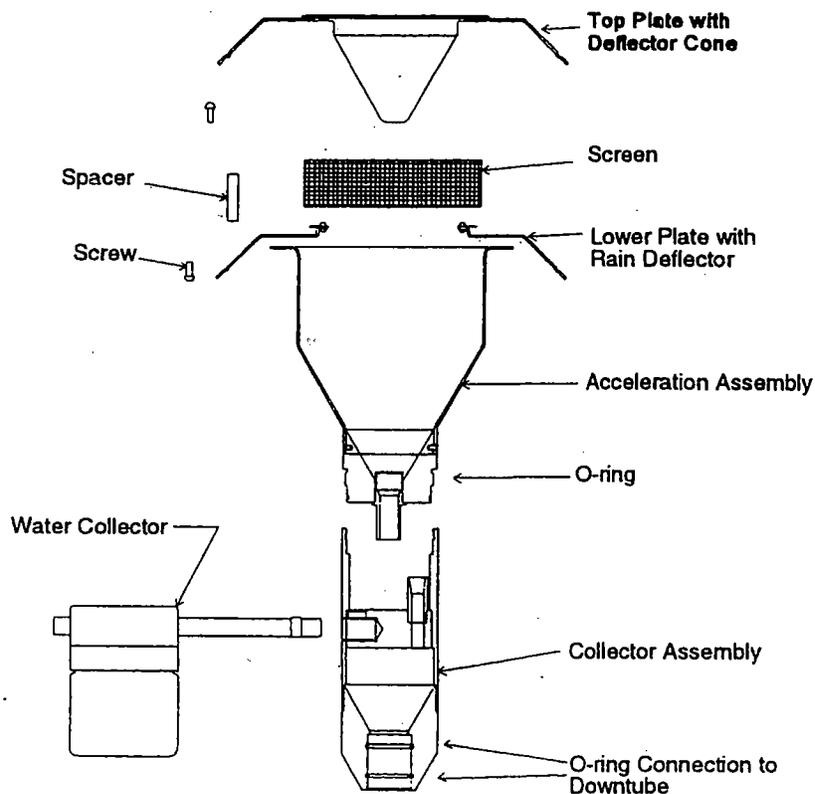


Figure 18-3. Disassembled sampler inlet.

Other Maintenance Procedures

Wipe down the interior of the sampler's case to remove bugs, dirt, and/or water deposits that may have collected inside the case. This procedure may be required more frequently during summer months. Inspect the cooling air intake filter and clean it if necessary.

Check the sampler's internal clock against a timepiece known to be accurate within 1 min/month. Record the value and note whether the sampler's clock has gained or lost time since the previous month's time check. If appropriate, check the integrity of the foam disks inside the containers used to transport the filter cassettes between the laboratory and the field. If pieces are coming loose or if the disks are becoming discolored, replace them. Check the filter cassettes and the backing screens for fractures, cracks, buckling, evidence of wear, or contamination. Clean or replace as necessary.

Quarterly Maintenance

The following activities should be performed once every 3 months at the time of the regular monthly maintenance. Remove the O-rings in the aerosol inlet and condition them with a very light coating of vacuum grease. This will inhibit breakdown and fraying of the O-rings caused by friction on the inlet tube.

Inspect the outer and inner surfaces of the tip (closest to the sampler inlet) of the downtube, and remove any particulate deposits using isopropyl alcohol or water and a soft bristle brush or wads of lint-free lab wipes or cloth. Dry the downtube completely before reinstallation.

Inspect the rubber water seal gasket (located at the point where the downtube enters the sampling case) for cracks or other evidence of leakage. Lubricate or replace the gasket as necessary, according to the sampler's operating manual.

Other Periodic Maintenance

The vacuum pump will need to be rebuilt after a certain period of time (typically a few thousand hours of operation) depending on the pump specifications and the sampling conditions. Because pumps can differ substantially in design and construction, the details of rebuilding them must come from the vendor. Pump rebuilding kits are typically available from the same manufacturer from which the sampler was purchased.

Carry out a leak check and recalibration of the flow system prior to sample collection after performing any pump maintenance, or other repair, replacement, or removal of sampler components.

Refurbishing of PM_{2.5} Samplers

PM_{2.5} samplers that have been operated in the field for extended periods may require major repairs or complete refurbishment. In these cases, the manufacturer's manual must be referred to before work is undertaken. A sampler that has been subject to major repairs or refurbishment must be leak-checked and calibrated prior to sample collection. It is recommended that such a sampler be treated as if it were newly received.

Section III. Performance Evaluation Procedures

Introduction

This section summarizes the performance evaluation procedures for assessing measurement uncertainty, precision, and bias for Reference or Class I Equivalent Methods for PM_{2.5} sampling at SLAMS sites. These requirements are specified in 40 CFR Part 58, Appendix A (EPA 1997). This section also gives suggestions for components of performance and systems evaluations of samplers, balances, and operational procedures that reporting organizations may wish to conduct in addition to those to be provided by the EPA Regional Office.

For the performance evaluation components that are conducted by the State agency or reporting organization, it is expected that the agency or organization will include details in its QA Project Plan (QAPP) and Standard Operating Procedures (SOPs) which describe

- Conducting and reporting of the required quarterly sampler flow rate audits.
- Operation and reporting of data from the required collocated samplers to estimate precision.
- Any additional systems or performance evaluations it wishes to conduct.

In general, any performance evaluation or audit, whether carried out by personnel outside or within the monitoring network organization, should be conducted under the following guidelines:

- Without special preparation or adjustment of the system to be evaluated
- By an individual with a thorough knowledge of the instrument or process being evaluated but not by the routine operator
- With accurate, calibrated, NIST-traceable transfer standards that are completely independent of those used for routine calibration and QC flow checks (although both calibration standards and audit standards may be referenced to the same primary standard for flow rate, volume, temperature, pressure, or mass)
- With complete documentation of audit information. This documentation includes but is not limited to types of instruments evaluated, audit transfer standards and transfer-standard traceability, instrument model and serial numbers, calibration information, and the collected audit data.

Overviews of the procedures for conducting performance and systems evaluations of the PM_{2.5} collection and measurement processes are provided in the

following subsections of the Section 2.12 Guidance Document.

- Subsection 10.2, Performance Evaluations (sample flow rate audit, precision assessment, FRM performance evaluation, balance accuracy, and sampler operation audits)
- Subsection 10.3, Systems Audits (State or reporting organization audits, EPA Regional Office audits)

Performance Evaluations

This section presents performance evaluation procedures specific to reference or Class I equivalent PM_{2.5} samplers that operate on the inertial impaction principle at a sample flow rate of 16.67 L/min. Procedures for evaluating samplers that operate according to other principles (e.g., open-path optical monitors) are not discussed here. 40 CFR Part 58, Appendix A requires that reporting organizations assess, on a calendar quarterly basis, the flow rate accuracy of each primary (data-reporting) PM_{2.5} sampler used in its SLAMS monitoring networks by conducting an evaluation of each sampler's operational flow rate.

Appendix A of 40 CFR Part 58 also requires reporting organizations to permanently collocate samplers at 25% of its sites to assess measurement system precision. Furthermore, the reporting organizations are required to assess total measurement system bias by making quarterly side-by-side comparisons between the site's primary sampler PM_{2.5} concentration results and those of an FRM performance evaluation sampler which is temporarily installed adjacent to the site sampler. This operation may be implemented by the EPA Regional Office.

This section also offers guidance to States or reporting organizations that wish to incorporate internal evaluations into their PM_{2.5} monitoring program. Internal performance evaluations are recommended in addition to the required quarterly flow rate audit (noted above) for sampler flow rate, temperature, and barometric pressure. Balance audits are also suggested. Reporting organizations may elect to include an internal audit of the operational aspects of PM_{2.5} samplers as part of their overall Quality Assurance Project Plan (QAPP). The person conducting these audits should be someone other than the regular site operator. It is also important that the audit devices for the temperature and barometric pressure evaluations not be the ones used for regular site checks and calibrations. However, the audit transfer standards may be traceable to the same primary standards as the working standards.

Sampler Flow Rate Audit

The calibration relationship between the flow rate (in actual L/min) indicated by the flow rate standard and by the sampler's flow rate measurement device should be established or verified in accordance with the sampler's operation or instruction manual prior to the audit; however, no adjustments may be made to the

sampler's flow rate sensors or controls before the audit is performed. For automated data acquisition, a printout may be attached to the audit data sheets. In conducting the sampler flow rate audit (or any audit for that matter) the auditor should consult the manufacturer's operations manual for sampler-specific procedures, suggestions, and precautions.

The audit of the sampler's flow rate consists of one measurement made at the sampler's operational flow rate. The flow rate transfer standard used for the audit must not be the same flow rate standard used to verify or calibrate the sampler, but may have been made traceable to the same primary standard for flow rate or volume. The sampler's operation or instruction manual should provide specific instructions for using the instrument's flow rate readout or display. The audit is carried out by the operator or by personnel from the QA unit of the reporting organization.

Temperature Audit Procedures

Ambient temperature, filter temperature, and ambient pressure sensors on the PM_{2.5} sampler may be audited in conjunction with the flow rate audit. Make no adjustments to the sampler prior to recording all audit results. The recommended procedure for auditing temperature probes is to use a bath of water, oil, or other suitable liquid to provide a stable temperature. A container such as a thermos bottle or Dewar flask should be used to insulate the bath, minimizing heat transfer to and from the fluid in the flask. Temperature sensors and thermometers should never be used to stir the bath. If water is used for the bath, be sure that evaporative cooling does not cause the temperature in the bath to fall during the audit process. A minimum of three temperatures should be used for the audit. Details of temperature calibration procedures are found in Section 6.0 of this document and can be adapted for audit purposes. Record the stabilized temperature reading and report the results on a data sheet or computer file. Any deviation greater than $\pm 2^{\circ}\text{C}$ should be reported for corrective action.

Barometric Pressure Audit Procedures

Ambient pressure is audited using a suitably calibrated sensor at ambient conditions. Subsection 6.0 of the Section 2.12 Guidance Document provides information on establishing traceability and the use of portable barometers. Record all findings on an audit data form or in a bound notebook. Any deviation greater than ± 10 mm Hg should be reported for corrective action.

Assessment of Precision Using Collocated Samplers

Collocated sampler results, where the duplicate sampler is not necessarily a reference method sampler, but a sampler of the same designated method as the primary sampler, are used to assess measurement system precision according to the schedule and procedure specified in 40 CFR Part 58, Appendix A, Section

3.5.2. The regulations require that 25% of a reporting organization's primary samplers for each method designation have another sampler (termed the duplicate sampler) permanently collocated at the same site and collect a sample on at least an every sixth day schedule. The site locations for the duplicate samplers are decided by choosing those sites that are most likely to have concentrations of $PM_{2.5}$ near the NAAQS standard during initial studies. Refer to 40 CFR Part 58, Appendix A, Section 3.5.2 for details. The collocated sampler measurements will be used to calculate quarterly and annual precision estimates for each primary sampler and for each designated method employed by each reporting organization. A data quality objective of 10% coefficient of variation or better has been established for the operational precision of $PM_{2.5}$ monitoring data.

Procedure for Collocated Measurements

The collocated sampler must be kept clean, serviced, and inspected frequently for proper operation, and the calibration of its flow rate, temperature, and pressure measurement systems must be checked and verified at the same intervals as the primary sampler.

The station's primary site collector and the duplicate sampler must be located at least 1 m but no more than 4 m apart, and their inlets should be at the same height above ground and within 1 m of each other as measured in the vertical direction. Space either sampler at least 2 m away from a high-volume sampler. The samplers must be calibrated and operated according to their operations manuals, and the samples must be stored, shipped, and analyzed identically, as described in the sampler's operation or instruction manual and in general accordance with the guidance in this handbook and in the reporting organization's QAPP and Standard Operating Procedures (SOPs). The primary sampler must be operated as it operates during normal sampling or monitoring. Collocated sampling should be conducted during a regularly scheduled sampling period whenever possible.

The concentrations determined from the site's primary sampler and from the collocated, duplicate sampler are to be reported to EPA as directed in 40 CFR Part 58, Appendix A, Section 4. It should be particularly noted that all collocated measurements must be reported, even those that might be considered invalid because of identified malfunctions or other problems that occurred during or following the sample collection period. Although all measurements are to be reported, only those sample pairs having $PM_{2.5}$ concentrations above $6 \mu\text{g}/\text{m}^3$ will be selected for use in precision calculations since at low concentrations agreement between the measurements of collocated samplers may be relatively poor.

FRM Performance Evaluation

State and local reporting organizations are responsible for conducting the FRM performance evaluations to assess total measurement system bias. However, EPA has agreed to implement the program. The reporting organization is responsible for assisting FRM performance evaluation personnel by coordinating schedules and assisting in the setup of the FRM sampler which will be on site for approximately 2 days.

Twenty-five percent of the SLAMS PM_{2.5} primary samplers within each reporting organization will be assessed with an FRM performance evaluation every calendar year so that in a 4-year span all FRM or FEM samplers have been evaluated. Further, every designated FRM or FEM within a reporting organization must

- Have at least 25% of each method designation evaluated, including those at collocated sites (even those with collocated with FRM samplers used in the precision assessment program),
- Have at least one sampler evaluated,
- Be evaluated at a frequency of four evaluations per year.

Details of the schedule for performing collocated measurements with the FRM sampler and guidelines for determining the initial deployment of FRM performance evaluation samplers, based on sites likely to be in violation of the NAAQS, are provided in 40 CFR Part 58, Appendix A, Section 3.5.3. The results from the primary sampler and the duplicate FRM sampler are used by the EPA to calculate the accuracy of the primary sampler on a quarterly basis, the bias of the primary sampler on an annual basis, and the bias of a single reporting organization on an annual basis.

Balance Accuracy Assessment

It is recommended that each State or reporting organization conduct an internal accuracy assessment of each microbalance on an annual basis. A performance audit of the microbalances used to weigh PM_{2.5} filters will require the use of an independent set of ASTM Class I standard weights traceable to NIST with a tolerance of no more than 0.010 mg. Weights of 100 and 200 mg are suggested. These weights must not be the same ones used as working standards for the day-to-day operation of the microbalance, but may be traceable to the same primary standard used to trace the working standards. Because microbalances are extremely delicate instruments and should not be operated by inexperienced personnel, it is recommended that the performance evaluation of the filter-weighing process be done in cooperation with the laboratory personnel. The person normally performing the weighings for PM_{2.5} monitoring should assist the auditor by preparing the balance as if a series of filter weighings were to be done.

Record all data on data sheets or in the laboratory's balance notebook. The balance display should agree with the designated value of the audit weight to within ± 0.050 mg (twice the tolerance for an ASTM Class 1 weight).

Many laboratories maintain an agreement with a service representative to conduct regular servicing of the balances. It may be instructive to conduct a performance audit prior to the periodic servicing and again immediately after the servicing.

Systems Audits

Reporting organizations should consider conducting systems audits of their PM_{2.5} program. Such audits may be particularly important at the startup of a new monitoring effort and can help recognize and pinpoint problems before they affect too much data. Loss of data could cause a reporting organization's airshed to fall into a nonattainment classification. The EPA Regional Offices are also charged with conducting a systems audit, but only once every 3 years. Systems audits are intended to assess the entire measurement system and data collection activities. These activities include the following:

- Initial equilibration, weighing, and transportation of the filters to the sampler
- Site selection criteria assessment
- Equipment installation
- Site security
- Equipment maintenance
- Calibration procedures
- Handling and placement of the filters
- Proper operation of the sampler and sample collection
- Removal, handling, and transportation of the filter from the sampler to the laboratory
- Weighing, storage, and archival of the sampled filter
- Data analysis and reporting.

EPA specifies that QA and QC programs follow the requirements for QAPPs contained in the EPA document *Requirements for Quality Assurance Project Plans for Environmental Data Operations*, EPA QA/R-5 (EPA 1994). Auditors should develop a checklist based on these guidelines and on the specific

information regarding PM_{2.5} monitoring in this QA handbook.

Effective system auditing requires the auditor to observe the auditee's entire sample acquisition and analysis system and the associated data processing operations. A major portion of the systems audit should be performed while the auditor is at the sampling site. Other locations where the system auditor should observe operations include the laboratory, the shipping and receiving area where field samples are received and logged in, the sample archival area, and the data processing areas.

Data about specific samples obtained during the on-site performance audits may be useful during the system audit. Tracking specific samples and the associated data completely through the system (sample acquisition, shipping, receiving, logging in, weighing, archiving, data processing, and reporting) ensures that every significant operation is examined. This approach also allows the auditor to look at the "interfaces" between different operations—the interactions between field and laboratory tasks—and not just the individual tasks in isolation. Detailed and summary reports and data submitted to EPA databases (e.g., AIRS) for the audited period should be reviewed as a follow up to the audit, if the timing of these reports permits.

Internal Systems Audits by State or Reporting Organizations

State and Reporting Organizations are encouraged to conduct periodic internal audits of their monitoring programs. A checklist for PM_{2.5} auditing is listed in Subsection 10.3.2 of the Section 2.12 Guidance Document. Auditors are encouraged to prepare their own checklists based upon their experience and monitoring program results.

External Systems by the EPA Regional Offices

The EPA Regional Offices are responsible for conducting a systems audit of each reporting organization in their Region at least once every 3 years. Information on these audits and their scheduling may be obtained from the appropriate Regional Office.

Section IV. Calculations, Validations, and Reporting of PM_{2.5} Monitoring Data

This section presents the calculations required to compute and report ambient PM_{2.5} concentrations. The end result of these calculations will be the integrated (average) PM_{2.5} mass concentration during the sampling period, expressed in units of $\mu\text{g}/\text{m}^3$. To obtain this concentration, it is necessary to determine the mass of particles collected by the filter and the total volume of air that was sampled. Unlike many other pollutant measurements, the volumes used to calculate the PM_{2.5} concentration must always be expressed at the actual ambient temperature and pressure used to acquire the sample (40 CFR Part 50.3, as amended 6/28/97). This process represents a change from the convention used to report PM measurements prior to June 1997, in which volumes were adjusted to "EPA-standard" conditions, defined as 25°C (298 K) and 760 mm Hg (101 kPa).

Accurate measurement and control of the sampler's flow rate is needed to determine the total sampled volume and to ensure that the particles trapped by the filter are in the correct particle size range. Reference samplers and Class I equivalent samplers separate PM_{2.5} particles by inertia. Obtaining the correct particle size range by inertial separation requires that the correct air velocity be maintained in the sampler's size separator system (impactor). This velocity will be correct when the specified design flow rate is maintained.

Calculations

Sample Volume Calculations

Both reference and equivalent method samplers are required to provide measurements of the total volume of air sampled (V_a), in m^3 at the actual ambient temperatures and pressures during sampling (40 CFR Part 50, Appendix L, paragraph 7.4.5.2). If the sampler's flow measurement system is properly calibrated, V_a should be accurate, and no further sample volume calculations are required.

Note that in the event the total sample volume measurement from the sampler is not available, the total sample volume may be calculated by multiplying the average flow rate, in actual m^3/min , by the elapsed sample collection time in minutes. Both of these measurements are required to be provided by reference and equivalent method samplers. Use the following formula only if V_a is not available directly from the sampler:

$$V_a = (Q_{\text{avg}} \times t) / 10^3 \quad (18-1)$$

Where:

$$V_a = \text{total sample volume, actual } \text{m}^3$$

Q_{avg} = average sample flow rate over the sample collection period, L/min

t = total elapsed sample collection time, min

10^3 = units conversion

For example, a sampler with an average flow rate of 16.7 L/min (Q_{avg}) for a 1,410-min (23.5-hour) sampling period (t) would have a total sample volume (V_a) of 23.5 m³.

Net PM_{2.5} Mass Calculation

The mass of particulate matter collected on the filter during the sampling period is determined by subtracting the initial (tare) mass of each filter from the final mass of the filter, as

$$M_{2.5} = (M_f - M_i) \times 10^3 \quad (18-2)$$

Where:

$M_{2.5}$ = total mass of PM_{2.5} collected during the sampling period, μg

M_f = final mass of the equilibrated filter after sample collection, mg

M_i = initial (tare) mass of the equilibrated filter before sample collection, mg

10^3 = units conversion ($\mu\text{g}/\text{mg}$)

For example, a filter that weighed 139.293 mg before sampling (M_i) and 139.727 mg after sampling (M_f) would have a PM_{2.5} mass ($M_{2.5}$) of 434 μg .

PM_{2.5} Concentration Calculation

Each PM_{2.5} mass concentration measurement is calculated by dividing the total mass of PM_{2.5} (Equation 18-2) collected during the sampling period ($M_{2.5}$) by the total volume of air sampled (V_a) (taken directly from the sampler readout display or calculated from Equation 18-1), as

$$\text{PM}_{2.5} = M_{2.5} / V_a \quad (18-3)$$

For example, a sample with a mass ($M_{2.5}$) of 434 μg collected from a total sample volume (V_a) of 23.5 m³ corresponds to a PM_{2.5} concentration (PM_{2.5}) of 18.5 $\mu\text{g}/\text{m}^3$. (Procedures for rounding of data are presented later.)

Verification of Manual Calculations and Data Entry

This subsection applies to calculations that are done using manually recorded or transcribed data, and when hand calculators, computerized spreadsheets, or other calculation aids are used by field operators or weighing technicians. This section also describes verification procedures for data that are keyed from handwritten forms into a computer.

Verification of Manual Calculations

Calculations should be verified when new sites are set up, when new personnel are trained, and when calculation aids such as spreadsheets are changed or updated. These should be re-verified periodically as part of the regular audit program. The basic procedure for verifying manual calculations is as follows:

1. Gather the raw data sources to be checked. These might include the analyst's notebook or the field operator's report sheets on which the data were originally recorded.
2. Obtain a copy of the resulting data report. The report should represent the data after they have been entered into the monitoring agency's electronic data system. This will ensure that all sources of human error, including keying errors, are included in the check.
3. Independently verify the results based on the raw data. If calculation aids were used, do not use the same spreadsheet or calculator program that was originally used; the verification calculations should be done as independently as possible.
4. Verify that the correct formulas, conversion constants, and reporting units were used.

The amount of data to be recalculated and verified depends on several factors. If the original calculations are suspect (for example, where mistakes have been found in a certain individual's work), all the questioned results should be recalculated. When there is no reason to suspect widespread errors, as with recalculations done as part of a routine audit, only a percentage of the data set need be checked initially. A commonly used audit guideline is to check 7% of manual calculations, provided that at least one example of each type of calculation is checked. This is a flexible guideline that depends on the amount of data to be checked and other factors. A cross-section of data should be selected for checking, e.g., the first and last values in a data set, extreme values, atypical values. The monitoring agency's QAPP should describe the frequency of these verifications, procedures to be followed, acceptance criteria, and corrective actions.

Verification of Manual Data Entry

Two methods are typically used for keystroke data entry quality control: duplicate keying and proofing. Duplicate keying is defined as data entry by two different operators, followed by resolution of all discrepancies by referring back to the original forms. Proofing refers to manual (visual) comparison of data entered by a single operator against the original forms. The person who proofs the data should not be the person who entered it originally. Duplicate keying is far more likely to eliminate simple keystroke mistakes than proofing. It is also more cost-effective for large data sets, but requires somewhat more work to set up initially.

If a data set has not been entered by the duplicate keying technique, a certain percentage of residual errors is to be expected. Keystroke data entry error rates can be estimated by comparing the original report pages or logbooks to the data reported out of the data system. The end-use of the data should be considered in determining whether the error rate is unacceptably high. For example, if the data are to be used for purposes of compliance or litigation, any avoidable errors may be considered unacceptable. In such a case, the data should be rekeyed as described above.

If a data set has been entered by an effective duplicate keying procedure, simple keystroke errors are expected to be virtually nonexistent (less than 1 in 1,000,000, even with key operators of modest ability). If a check of duplicate-keyed data turns up a significant error rate, the integrity of the duplicate keying procedure should be investigated by examining the SOP for deficiencies. If no procedural problems are found, noncompliance with the SOP or hardware problems should be investigated.

In addition to typographical errors, other potential sources of data entry errors should also be considered while performing an audit of data entry. These include poor handwriting on the original data forms and smears or water damage that renders the writing difficult to read. Hardcopy records must be maintained for a period of time so that audits and verification checks can be performed. The monitoring agency's QAPP should describe the policies regarding verification of manual data entry, audit frequency, and retention policies for original records needed to verify the electronic data.

Data Validation

Validation of monitoring data is an extensive topic that can only be touched on in this section. The general principles are presented in Volume I of the EPA QA Handbook. Validation data screening is done for two primary reasons:

- To verify that the data have been recorded, entered, and calculated correctly. Validation screening can sometimes be used to identify problems such as failing equipment, siting problems, or operator errors.

- To screen for potential outliers (data points that are exceptional in concentration value or in some other way). Data points identified as potential outliers are not necessarily invalid; validation screening simply identifies data points for further investigation.

Data validation can be done in several different ways. A combination of techniques is often the most effective. The exact criteria to be applied and corrective actions taken should be described in the agency's QAPP. Some techniques that may be applicable to PM_{2.5} data validation are the following:

- Graphing and visually examining time-series of operating parameter data such as flow checks (e.g., control charting)
- Graphing and visually examining scatter plots of data (e.g., duplicate sample results)
- Range checking (does the data fall within an expected range of values?)
- Statistical checking (flagging data points outside 3-sigma or other statistically derived limits)
- Evaluation of goodness-of-fit and linearity (applicable to linear regression data such as calibrations)
- Regular review of operators' notes and communication with operators to identify problems
- Review of audit results to identify data potentially impacted by audit findings

Being flagged as a potential outlier by the methods listed above is not *prima facie* evidence that a data point is invalid. Outliers must be thoroughly investigated before they can be excluded. Outliers must be presumed to be correct unless there is documented evidence of an equipment malfunction or other exceptional condition that renders the result unrepresentative. Special flags are available in AIRS indicating when data are suspect.

Identification and investigation of outliers is particularly important with PM_{2.5} monitoring because the 24-hour compliance criterion is based on the upper 98th percentile point of the concentration distribution. Since operational problems can sometimes cause abnormally high readings, potential outliers in the upper tail of the concentration distribution should be validated carefully.

A monitoring agency should provide a detailed description of its data screening procedures in its QAPP or in an approved data validation SOP. Decision rules for data invalidation and for taking corrective actions should be clearly described. Corresponding AIRS data flags should be specified in the

agency's written procedure.

Validation of Software Used to Process PM_{2.5} Data

Software used to process, manage, and report PM_{2.5} data used for compliance purposes must be validated to ensure that it is free of incorrectly coded calculations and errors. The process of validating software is distinct from data validation discussed in the previous section.

A structured approach to software development, testing, and validation is strongly recommended for managing PM_{2.5} compliance data. Information on structured software development, testing and validation can be found in *EPA QA/R-5: EPA Requirements for Quality Assurance Project Plans*, Appendix G, and in many other publications.

A few of the areas that should be tested during the development of PM_{2.5} compliance and reporting software include the following:

- Correctness of calculations
- Correct assignment of input and output values (i.e., verify that the input and output values are correctly identified as to station, sample time period, sampler number, filter number, etc.)
- Correct calculation of statistics, including determination of the correct 98th percentile point for the 24-hour compliance criterion (40 CFR Part 50, Appendix N, Sec. 2.6)
- Correct operation across the turn of the century (year 2000 problem)
- Correct application of validation procedures, range checks, statistical control limits, etc.

Use of spreadsheets for processing and managing large environmental data sets is strongly discouraged. Spreadsheets are difficult to test thoroughly and can develop new problems as more data are added and predefined data ranges overflow. Modern relational database products offer a much more reliable environment for large-scale data processing, although they are somewhat more difficult to learn at first.

Although software does not usually "break" or wear out after it has been written and tested, any change in its runtime environment may potentially cause problems. Therefore, periodic reverification of software is advisable, especially after significant changes to system hardware or software. Whenever individual software modules are changed, it is strongly recommended to run test procedures to detect any unintended consequences of the changes. Software documentation that describes configuration changes and test results should be maintained.

It is strongly encouraged that all monitoring agencies develop and comply with SOPs for software development, testing, maintenance, configuration control, documentation, and data archiving. The QAPP should identify the relevant data processing SOPs, and these should be addressed during periodic audits.

Data Reporting

The primary standards for particulate matter in ambient air are based on the measured mass concentration of PM_{2.5}. Information on reporting and interpretation of PM_{2.5} data with respect to the attainment of these standards is covered in 40 CFR Part 50, Appendix N.

Rounding

Raw data from the samplers are preferably recorded electronically and/or communicated by electronic means to a central computer where they are recorded. Electronically stored data and computerized calculations should not be rounded until final formatting for reports or for delivery to AIRS.

Filter weight data for calculating PM_{2.5} concentrations should be recorded to the full readable precision of the microbalance. Hand-calculated weight differences should be carried to the same number of digits and should not be rounded.

For other hand-recorded data, including calibration and audit data, it is advisable to read and record somewhat more resolution than will be needed for calculating the final result. For example, to make a measurement that will be reported to the nearest 1%, attempt to read the data to at least the nearest 0.5% or better. It is usually not necessary to record more than a factor of 10 for better resolution than that needed in the final result, however.

Special care should be taken when recording data that will be used in a difference calculation: enough significant figures must be recorded so that the result will have the necessary resolution. The most obvious example is the determination of PM_{2.5} mass by difference of two filter weights. Measurement of filter weight to six significant figures is necessary in order to get adequate precision in net particulate mass. All data recording forms should specify the appropriate number of digits, or the necessary resolution in physical units, for each parameter that must be manually recorded.

Rounding Rules for Comparison with NAAQS

For comparing calculated concentration averages to NAAQS levels, it is necessary to use round-off rules defined in Sections 2.5 and 2.6 of 40 CFR Part 50, Appendix N. For the annual PM_{2.5} standard (currently 15 µg/m³), the 3-year average of the spatially averaged annual means is rounded to the nearest 0.1 µg/m³. Decimals 0.05 and greater are rounded up to the next 0.1, and any decimal

lower than 0.05 is rounded down to the nearest 0.1. For the 24-hour $PM_{2.5}$ standard (currently $65 \mu\text{g}/\text{m}^3$), the 3-year average of the annual 98th percentile values is rounded to the nearest $1 \mu\text{g}/\text{m}^3$. Decimals 0.5 and greater are rounded up to the nearest whole number, and any decimal lower than 0.5 is rounded down to the nearest whole number.

A different method is required for determining the annual 98th percentile concentration values used for the 24-hour NAAQS. According to the method described in Section 2.6 of 40 CFR Part 50, Appendix N, the observation number used to represent the 98th percentile value is always rounded up, never down. Refer to 40 CFR Part 50 Appendix N for additional details.

Section V. Data and Records Management

Introduction

It is important to keep good records in any air pollution measurement program. This is particularly true for measurements of PM_{2.5} by reference or Class I equivalent methods because these are manual methods that involve the transfer and handling of samples and data by several persons. Automated methods, on the other hand, present the final, averaged data with much less human intervention and thus limit the possibilities of transcription errors and misplacement of data.

Section 14 of the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Specific Methods, Part I*, gives guidance on data acquisition and information management. Although it emphasizes automated data acquisition, much of the discussion is also applicable to manual methods. There are several reasons for maintaining complete, orderly records and properly managing data. Records can

- Provide information on mechanical problems that occur and document how the problems were corrected.
- Provide a history of warranty repairs.
- Provide a history of in-house repairs and preventive maintenance servicing.
- Document date and site placement details for the primary and collocated samplers as well as the characteristics of the surrounding land areas, sources, and other features.
- Be a useful source of information at the time of the annual network review to show proper sampler installation and operation, performance of QC and QA checks, traceability of equipment and standards, and proof that all systems were kept in control (use of control charts).
- Provide evidence to support the quality of PM_{2.5} data submitted to regional and national databases.

Methodology for Data and Records Management

A systematic approach to maintaining records and managing the data for all reported ambient air pollutant concentrations will usually involve the following considerations:

- Personnel—One or more persons should be identified within the reporting organization to be responsible for maintaining the records and preparing and submitting the required data products. Education, training, and experience are requirements for the position. SOPs will also be required.
- Quality assurance—An individual or group should be assigned to prepare SOPs, to conduct internal systems and performance audits, and to review the data before submission.
- Facilities and equipment—A designated storage location for paper records and computer data files should be established. Using file cabinets that can be locked is suggested. A backup copy of data files should be kept in another location for safety. Computers and data entry stations, as well as connections to centralized databases (such as AIRS), are also required.

PM_{2.5} Records to Create and Retain

A QAPP and SOPs for various aspects of the PM_{2.5} sampling program should be prepared. Much of the required information can be drawn from that given in the applicable sections of the *Code of Federal Regulations*, the sampler's instruction manual, and the Section 2.12 guidance document. Records to maintain are summarized below.

Sampler Siting and Maintenance Records

Documentation regarding siting and maintenance of the PM_{2.5} samplers should be retained in the files. These documents may include the following:

- Site selection criteria checklist; photographs or color slides of the site in a minimum of the four cardinal directions with the PM_{2.5} sampler in the center foreground; site sketch; U.S. Geological Survey (USGS) topographical map of the area; and a copy of the site documentation records that were submitted to the AIRS database when the site was first established and any updates made since that time.
- Procurement log for field equipment. Notes on acceptance/rejection tests.
- Warranty and maintenance records for each PM_{2.5} sampler. It is recommended that a dated maintenance checklist be established for each sampler and that separate maintenance logbooks be used for the PM_{2.5} samplers and the laboratory microbalance(s).

- Manufacturer-supplied calibration and traceability records for the thermometers, flow rate measuring devices, and pressure sensors used for calibrating, checking, or auditing PM_{2.5} samplers. Maintain similar records for calibrations and traceability studies conducted in the reporting organization's laboratory or elsewhere.

Analytical Laboratory Installation Records

Records to keep about the physical setup of the analytical laboratory include the following:

- Equipment inventory (microbalances, conditioning chambers, antistatic devices, calibration and check weights, etc.).
- Procurement log and notes on acceptance/rejection tests.
- Records (e.g., control charts) that demonstrate that the temperature and RH within the weighing laboratory and conditioning chambers were held within specified limits.
- Microbalance logbook.

Field Sampling Operation Records

PM_{2.5} sampling operations generate a number of paper and/or computerized records that need to be reviewed, reported, and filed. Starting with the calibration of the sampler's sensors, these records will include at least the following items:

- Sampler calibration logbooks or data sheets for entering results of temperature, pressure, and flow rate checks, audits, and calibrations. Also include documentation of the devices used to calibrate the sampler(s) and these devices' traceability records or references to the traceability records. A separate section of the logbook should be used for each sampler in the network. Enter results of the sampling procedure checks which include notes on filter inspection, and checks of flow rate and leaks.
- PM_{2.5} Sampler Run Data Sheet. The run data sheet should be prepared at least in duplicate by using carbonless paper or making copies. The original of the data sheet should accompany the filter sample to the laboratory, and a copy should be retained in the field site records files.
- PM_{2.5} Sampler Flow Check Data Sheet
- Computer disks and printouts of data downloaded from the data port of each PM_{2.5} sampler.

Weighing Laboratory Operation Records

Data records from activities in the weighing laboratory are expected to include at least the following items:

- Records of temperature and humidity control in the laboratory and in the filter conditioning environment (if the latter is different from the laboratory). Use of control charts is recommended.
- Laboratory data form(s)
- Laboratory internal QC log(s)
- Results of microbalance calibrations and servicing. This information can be recorded in the microbalance logbook.
- Results of filter integrity checks and determinations of the conditioning periods required for various filter batches
- The completed PM_{2.5} Sampler Run Data Sheet(s)
- Records of sample numbers (identifications) and locations of archived PM_{2.5} samples.
- Maintenance records

QA Records

QA systems and performance audits require complete documentation as well. Records of audits may be similar to the following items:

- Flow rate, temperature, and pressure audit data sheet
- Systems audit questionnaire.

Accuracy and precision audit results are based on comparing the data from the primary sampler (the one used regularly at the site) to data from collocated samplers. These data are reported to the EPA Regional Office and to the AIRS data system. Data that have been invalidated would not be submitted to the AIRS data system.

Data Reporting Requirements

The EPA Regional Office and the AIRS database system require that the following information be reported on a quarterly (generally, calendar-quarter) basis (EPA will calculate measurement uncertainties for the entire calendar year):

- siting documentation (upon installation and any changes thereafter)

- PM_{2.5} concentration data, $\mu\text{g}/\text{m}^3$, or sample weight and volume sampled to allow electronic calculations (entered electronically into the AIRS database system)
- Information calculated and provided by the sampler [Adopted from 40 CFR Part 50, Appendix L, Table L-1]. This information is retrieved from the data port of each sampler. It is generally downloaded in the field to a laptop computer or other data storage device and later processed in the laboratory or office. Data outputs to be provided to the AIRS data bank include such items as: Flow rate 30 second maximum interval; Flow rate average for the sample period; Flow rate coefficient of variation (CV) for the sample period; Flow rate 5 min average out of specifications; and Sample volume total. See 40 CFR Part 50 Appendix L or Table 12-1 of Subsection 12 of the Section 2.12 Guidance Document for a complete listing of the data outputs to be submitted to the AIRS.
- Results of all precision, and all valid bias and accuracy tests carried out during the quarter. See Subsection 10.0 of Section 2.12 Guidance Document for details.

Features can be incorporated into the processing program to detect and correct typographical errors, such as out-of-sequence dates for start and end times, extremely high (or low) filter weights, flow rates, and temperatures.

Section VI. Assessment of Measurement Uncertainty for Monitoring Data

Overview

SLAMS reporting organizations are required to assess the measurement uncertainty of their PM_{2.5} monitoring data according to 40 CFR Part 58 Appendix A. Three different procedures are used in this assessment:

- **Flow rate audit**—The accuracy of the PM_{2.5} sampler's flow rate is assessed by performing a flow rate audit as described in Subsection 10.2.4. of the Section 2.12 Guidance Document. Performance of this audit will be the responsibility of the state and/or the reporting organization. The goal for accuracy of the sampler flow rate is to be within $\pm 2\%$ of the value indicated by the audit device (during multipoint verification/calibration) or $\pm 4\%$ (during one-point verification checks and audits) and to be within $\pm 5\%$ of the sampler's design flow rate (16.67 L/min).
- **Bias**—PM_{2.5} measurement bias is assessed by conducting an FRM performance evaluation. The EPA Regional Offices will conduct this performance evaluation. The bias goal is to have the site's primary sampler's PM_{2.5} concentration value agree within $\pm 10\%$ of the performance evaluation concentration.
- **Precision**—PM_{2.5} measurement precision is assessed by collocating (i.e., locating a second, duplicate, sampler alongside the primary sampler used for measurement) samplers and reporting the results of both the measurement sampler and the collocated sampler. Operation of the duplicate samplers will be the responsibility of the State and/or the reporting organization. The precision goal is to have a CV of less than $\pm 10\%$.

These procedures are very similar to those used in the data quality assessment of PM₁₀ monitoring data. The results of these procedures are used to evaluate individual samplers for bias or excessive imprecision. EPA also uses these results to assess measurement uncertainty for each reporting organization. The results from all SLAMS reporting organizations are used by EPA to assess the measurement uncertainty of data from each PM_{2.5} reference or equivalent method on a national basis.

Flow Rate Audits

Flow rate audits consist of measuring the sampler's normal operating flow rate with a flow rate transfer standard. This procedure is described in Subsection 10.2.1. Manual PM_{2.5} sampler methods must be audited each calendar quarter and

the audits should be scheduled so as to avoid interference with regularly scheduled sampling periods. Where possible, these flow audits should be performed at randomly selected times with respect to time of day and day of week.

Results of the flow rate audit to be reported to EPA are as follows:

- The audit (true) flow rate as determined using the transfer standard.
- The corresponding flow rate as measured by the sampler. This rate should be that used by the sampler to calculate its reported total sampling volume and average flow rate. This information is typically obtained from the sampler's flow rate display or from its data system.

The sampler's flow rate accuracy (A) should be within $\pm 4\%$ of the audit value. Furthermore, the audit measured flow rate accuracy (A_D) should be within $\pm 5\%$ of the sampler's design inlet flow rate (16.67 L/min). The sampler's flow rate accuracies (A and A_D) are calculated as follows:

$$A(\%) = \frac{Q_{\text{Sampler}} - Q_{\text{Audit}}}{Q_{\text{Audit}}} \times 100$$

$$A_D(\%) = 100 \times \frac{(Q_{\text{Sampler}} - 16.67)}{16.67}$$

Where:

A = flow rate accuracy (percent)

A_D = flow rate accuracy (percent) versus design flow rate

Q_{Sampler} = flow rate as measured by sampler (L/min)

Q_{Audit} = flow rate as measured by the flow rate transfer standard (L/min)

16.67 = design flow rate (L/min)

Example

$$Q_a (\text{sampler}) = 17.1 \text{ m}^3/\text{min}.$$

$$Q_a (\text{audit}) = 16.2 \text{ m}^3/\text{min}.$$

$$A(\%) = \frac{17.1 \text{ m}^3/\text{min} - 16.2 \text{ m}^3/\text{min}}{16.2 \text{ m}^3/\text{min}} \times 100 = 5.56\%$$

$$A_D(\%) = \frac{17.1 \text{ m}^3/\text{min} - 16.67 \text{ m}^3/\text{min}}{16.67 \text{ m}^3/\text{min}} \times 100 = 2.58\%$$

Bias Assessment

As noted briefly in the previous discussion of FRM performance evaluations, sampler bias is assessed from the results of an FRM performance evaluation (Subsection 10.2.3) to be administered through the EPA Regional Offices. The goal for acceptable bias is between - 10% and + 10% (i.e., the reporting primary sampler's concentration should agree to within $\pm 10\%$ of the FRM performance evaluation sampler's concentration). Minimum FRM performance evaluation requirements for SLAMS reporting organizations include the following:

- At least one sampler must be evaluated annually.
- At least 25% of each reference and each EPA-designated equivalent method must be evaluated each year (i.e., in most cases, 25% of each make and model of sampler will need to be audited). This percentage includes collocated sites, even those collocated with FRM instruments. Thus, if a reporting organization has three different makes of samplers, each with a different equivalency designation, the reporting organization will have to audit 25% of each make of sampler. If a fractional number of samplers is required, values of 0.5 or greater must be rounded upward to the nearest whole number. For example, a reporting organization with 10 samplers of a given type must evaluate at least three of those samplers.
- Evaluations must occur at least four times a year.
- All samplers must be evaluated at least once every 4 years.

In addition to these requirements, areas that exceed the NAAQS for $\text{PM}_{2.5}$ should place special emphasis on those sites with the highest $\text{PM}_{2.5}$ concentrations as follows:

- Reporting organizations with sites reporting $\text{PM}_{2.5}$ concentrations equal to

or exceeding 90% of the NAAQS (annual or 24-hour, as appropriate):

- 80% of FRM performance evaluations should be performed at those sites reporting PM_{2.5} concentrations equal to or exceeding 90% of the NAAQS (annual or 24-hour, as appropriate).
 - The remaining 20% of FRM performance evaluations should be performed at sites reporting concentrations less than 90% of the NAAQS (annual or 24-hour, as appropriate).
- Reporting organizations without sites reporting PM_{2.5} concentrations equal to or exceeding 90% of the NAAQS (annual or 24-hour, as appropriate):
 - 60% of FRM performance evaluations should be performed at sites that rank in the top 25% of the highest sites for PM_{2.5} concentrations (annual or 24-hour, as appropriate).
 - The remaining 40% of FRM performance evaluations should be performed at the remaining 75% of sites.

The individual sampler and evaluation measurements must be reported to the EPA, which uses them to calculate the single sampler bias (B) and the quarterly average bias for a reporting organization. Reporting organizations may also want to calculate these parameters for their QA use. The single sampler bias (B) calculations are provided in Subsection 13.3.

Precision Assessment

PM_{2.5} precision is assessed by collocating samplers (i.e., locating a second sampler alongside the primary sampler used to report a measurement). The details of the assessment procedure were presented earlier and are not repeated here.

Concentration data must be reported for both the primary and collocated sampler, no matter how low the concentration. Because agreement between the measurements of collocated samplers may be relatively poor at low concentrations, collocated measurement pairs will be used by the EPA to calculate precision only when both PM_{2.5} measurement concentrations are above 6 µg/m³.

Number of Collocated Samplers Required

To assess precision of their sampling data, SLAMS reporting organizations must meet the following collocation requirements:

- At least one primary sampler must have a collocated sampler.
- At least one of the collocated samplers must be an FRM sampler (i.e., not

a designated equivalent method sampler).

- At least 25% of all primary samplers must have collocated samplers. If fractional numbers of collocated samplers are required, values of 0.5 or greater must be rounded upward to the nearest sampler. For example, a reporting organization with 10 primary samplers must provide collocated samplers for at least 3 of those primary samplers.

In addition to these requirements, additional specifications must also be observed with respect to the different makes and models of samplers used as collocated samplers:

- Collocated samplers for FRM-designated primary samplers shall always be of the identical FRM designation (i.e., the collocated and primary samplers are of the same make and model).
- If the primary sampler is an FEM, half of the collocated samplers for the designated equivalent primary samplers have the identical equivalency designation (the same make and model), while the other half are FRM-designated samplers. In cases where odd numbers of collocated samplers are required, the number of collocated FRM samplers should always be rounded upward to the nearest sampler, with the remaining number being samplers of the same equivalent designation (samplers of the same make or model). For example, if five collocated samplers are required, then three should be FRM models and the remaining two should be models of the same equivalency designation.

Location of Collocated Samplers

Collocated samplers should be placed at sites that have the highest $PM_{2.5}$ concentrations, with place special emphasis on sites likely to be in violation of the NAAQS. Data from other particulate measurement methods, such as the PM_{10} samplers, can be helpful in selecting sites for collocation.

SLAMS reporting organizations that have areas in violation of the NAAQS should place their collocated samplers as follows:

- Reporting organizations with sites reporting $PM_{2.5}$ concentrations equal to or exceeding 90% of the NAAQS (annual or 24-hour, as appropriate):
 - 80% of the collocated samplers should be located at those sites that equal or exceed 90% of the NAAQS (annual or 24-hour, as appropriate).
 - The remaining 20% of collocated samplers should be located at sites that report less than 90% of the NAAQS (annual or 24-hour, as appropriate).

- Reporting organizations without sites reporting PM_{2.5} concentrations equal to or exceeding 90% of the NAAQS (annual or 24-hour, as appropriate):
 - 60% of collocated samplers should be located at sites that rank in the top 25% of the highest sites for PM_{2.5} concentrations (annual or 24-hour, as appropriate).
 - The remaining 40% of collocated samplers should be located in the remaining 75% of sites.

Schedule for Operation of Collocated Samplers

Collocated samples should be taken to reflect the normal operation of the primary sampler. The collocated samples should be evenly distributed across the various seasons and days of the week. A recommended simple system to accomplish this is to run the collocated sampler every sixth day. Thus, if the first week's collocated sample was run on Monday, the second week's collocated sample would be run on Sunday, the third week's on Saturday, etc. Remember to start and stop both the collocated and primary samplers at exactly the same time for each sample run.

Lesson 19

Quality Assurance Procedures for Monitoring PM₁₀ in Ambient Air Using a High-Volume Sampler

Lesson Goal

Familiarize students with EPA requirements and guidelines for the development of quality assurance (QA) programs associated with PM₁₀ ambient air quality monitoring using a high-volume (HV) sampler.

Lesson Objectives

1. Identify the two basic components of the HV PM₁₀ sampler.
2. Discuss the two common types of air-flow control systems used with the HV PM₁₀ sampler.
3. Identify the procedures used to properly select and obtain a high-volume sample of particulate matter.
4. Outline the procedures used to calibrate a HV PM₁₀ sampler.
5. Describe the procedures and documentation used for filter installation and recovery, as well as sample handling and data documentation.
6. Describe the procedures for the field flow-rate calibration check.
7. Identify the elements of filter preparation and analysis, including filter handling, integrity, identification, equilibration, and weighing.
8. Identify the minimum necessary laboratory quality control procedures.
9. Calculate PM₁₀ mass concentrations, given the necessary data.
10. Identify the minimum required validation elements for sampling data.
11. Explain the final data review and validation process.
12. Identify the elements of a routine PM₁₀ sampler maintenance program.
13. Identify independent audit activities that provide performance checks of flow-rate measurements and data processing.
14. Describe the assessment procedures for determining the accuracy and precision of sampler data.
15. Discuss the importance of traceability of calibration equipment.

References

U.S. Environmental Protection Agency. September 1997, Second Draft, *Quality Assurance Handbook for Air Pollution Measurement Systems*, Volume II, Part II, Section 2.11, *Monitoring PM₁₀ in Ambient Air Using High-Volume Sampler Method*.

Revised Requirements for Designation of Reference and Equivalent Methods for PM_{2.5} and Ambient Air Quality Surveillance for Particulate Matter; Final Rule. U.S. Environmental Protection Agency, 40 CFR, Parts 53 and 58, Federal Register, July 18, 1997.

National Ambient Air Quality Standards, for Particulate Matter, Appendix K- Interpretation of the National Ambient Air Quality Standards for Particulate Matter, Appendix M-Reference Method for the Determination of Particulate Matter as PM₁₀ in the Atmosphere; and Appendix N-Interpretation of the National Ambient Air Quality Standards for Particulate Matter Final Rule. U.S. Environmental Protection Agency, 40 CFR Part 50, Federal Register, July 18, 1997.

U.S. Environmental Protection Agency. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I, Ambient Air Quality Monitoring Program Quality System Development*. EPA 454/R-98/004, August 1998.

U.S. Environmental Protection Agency. *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations*, EPA QA/R-5. October 1997.

Section K. Introduction

[Note: Lesson 19 and Lesson 20 both address the reference method procedures for monitoring PM₁₀ in ambient air. Lesson 19 covers monitoring PM₁₀ using a high-volume sampler, while Lesson 20 discusses monitoring PM₁₀ using the dichotomous sampler method. Both discussions are based on the Reference Method for PM₁₀ Monitoring found in 40 CFR Part 50 Appendix M and, as such, follow the standard format used in the reference methods. Because of this standard format, some information is the same in both lessons. The two lessons differ significantly, however, due to sampler configurations and unique components.]

PM₁₀ is the designation for particulate matter in the atmosphere that has an aerodynamic diameter of 10 µm or less. A high-volume PM₁₀ (HV PM₁₀) sampler draws a known volume of ambient air at a constant flow rate through a size-selective inlet and through one or more filters. Particles in the PM₁₀ size range are then collected on the filter(s) during the specified 24-hr sampling period. Each sample filter is weighed before and after sampling to determine the net weight (mass) gain of the collected PM₁₀ sample. The reference method for PM₁₀ sampling is given in the *Code of Federal Regulations* (CFR) (40 CFR Part 50, Appendix M) (EPA 1997).

The total volume of air sampled is determined from the measured volumetric flow rate and the sampling time. The concentration of PM₁₀ in the ambient air is computed as the total mass of collected particles in the PM₁₀ size range divided by the volume of air sampled. The PM₁₀ measurement is expressed as micrograms per actual cubic meter (µg/m³).

The performance parameters of PM₁₀ samplers are tested in accordance with explicit test procedures that are prescribed in 40 CFR Part 53 (EPA 1988). One such performance parameter is the particle size discrimination characteristic (i.e., sampler-effectiveness) of the sampler inlet over the PM₁₀ size range. Of particular importance is the particle size at which the sampler effectiveness is 50% (i.e., the particle size cutpoint). Methods for PM₁₀ that meet all requirements in both Parts 50 and 53 are designated as PM₁₀ reference methods for use in State and local air monitoring stations (SLAMS) and prevention of significant deterioration (PSD) monitoring. These designated methods are usually identified by the name of the manufacturer and the model of the sampler.

Two common types of PM₁₀ samplers that meet these designation requirements are HV PM₁₀ samplers and dichotomous samplers. Only HV PM₁₀ samplers are discussed in this lesson; dichotomous samplers are discussed in Lesson 20.

A HV PM₁₀ sampler consists of two basic components: a specially designed inlet, and a flow control system.

Sampler Inlets

Currently, two types of HV PM₁₀ inlets are available. They are distinguishable by their methods of particle discrimination (impaction or cyclonic). Although these two types of inlets differ in their physical size and their principles of operation, they have similar flow-rate requirements.

The symmetrical design of the impaction inlet ensures wind-direction insensitivity. Ambient air that is drawn into the inlet is evacuated from the buffer chamber through nine acceleration nozzles into the first impaction chamber, where initial particle separation occurs. The air is then accelerated through an additional 16 jets into a second impaction chamber. The acceleration jets have critical diameters calculated by the manufacturer to provide the necessary changes in velocity to effect correct particle size fractionation within the impaction chambers. The air flow finally exits the inlet through nine vent tubes onto a sample filter.

The omnidirectional cyclone used for fractionation in a cyclonic inlet allows particles to enter from all angles of approach. An angular velocity component is imparted to the sample air stream and the particles contained in it by a series of evenly spaced vanes. Larger particle removal occurs in an inner collection tube. This tube incorporates a “perfect absorber”—an oil-coated surface to eliminate particle bounce and reentrainment. The sample flow (with the unremoved smaller particles) then enters an intermediate tube, where the trajectory is altered to an upward direction. An additional turn is then made to alter the flow to a downward trajectory to allow the remaining particles (i.e., PM₁₀ fraction) ultimately to deposit on a filter for subsequent analysis.

Flow Control Systems

The flow rate in a Mass Flow Control (MFC) system is actively sensed and controlled at some predetermined set point. Air is pulled through the filter into the intake of a blower and subsequently exits the sampler through an exit orifice, which facilitates measurement of the flow with a manometer or pressure recorder. The flow rate is controlled by an electronic mass-flow controller, which uses a flow sensor installed below the filter holder to monitor the mass flow rate and to control the speed of the motor accordingly.

A Volumetric Flow Control (VFC) system maintains a constant volumetric flow rate (given a fixed temperature) through the inlet, rather than a constant mass flow rate as in the MFC system. In a popular commercial VFC system, a choked-flow venturi is operated such that the air attains sonic velocity in the throat of the device. In this “choked” mode, the flow rate is unaffected by downstream conditions such as motor speed or exit pressure and is a predictable function of upstream conditions, such as the stagnation pressure ratio and temperature. Thus, the volumetric flow is controlled without any moving parts or electronic

components. In this type of flow control system, no means is provided for adjusting the controlled flow rate.

Section II. Procurement of Equipment and Supplies

The establishment of an ambient PM₁₀ air monitoring network requires the procurement of specialized equipment and supplies for field operations and subsequent filter analysis. In addition to field operations and laboratory equipment, a data-handling system (including forms, logs, files, and reporting procedures) must be developed and implemented. It is recommended that each agency establish minimum monitoring equipment requirements and budgetary limits before the procurement procedures are initiated. Upon receipt of the sampling equipment and supplies, appropriate procurement checks should be conducted to determine their acceptability, and whether they are accepted or rejected should be recorded in a procurement log.

HV Samplers

An individual sampler must meet U.S. Environmental Protection Agency (EPA) operational standards and be a model designated as a reference or equivalent method. A complete listing of minimum sampler requirements is in 40 CFR Part 50, Appendix M (EPA 1997). Those HV PM₁₀ samplers not designated as reference or equivalent methods may not be used for reporting data to determine attainment of the National Ambient Air Quality Standards (NAAQS) for PM₁₀. The cost of HV PM₁₀ samplers will vary by manufacturer and the options chosen (i.e., continuous flow recorder, timer).

Calibration QA/QC Supplies

Calibration activities require specialized equipment that will not necessarily be used in routine monitoring. One requirement is a thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50°C to the nearest 0.1°C. This thermometer should be traceable with an accuracy of 0.1°C to a NIST-certified thermometer of an ASTM thermometer.

A barometer capable of accurately measuring barometric pressure over a range of 500 to 800 mm Hg (66 to 106 kilopascal [kPa]) to the nearest millimeter of mercury (Hg) and referenced at least annually to a standard of known accuracy within ± 5 mm Hg is also necessary. Note that for field measurements, a portable, aneroid barometer (e.g., a climber's or engineer's altimeter) is appropriate.

Calibration will also require an orifice transfer standard (e.g., top-hat orifice, variable orifice, or reference flow [ReF] device) capable of accurately measuring the operational flow rate of an HV PM₁₀ sampler at actual conditions. The transfer standard calibration relationship must be referenced annually and be within $\pm 2\%$ of the NIST-traceable primary standard.

Water or oil manometer(s) with a 0- to 400-mm H₂O (0- to 16-in.) range and a minimum scale division of 2 mm (0.1 in.) must also be available for calibration. Note that the VFC sampler calibration procedure requires a second oil or water manometer with a 0- to 1,000-mm H₂O (0- to 36-in. H₂O) range and with a minimum scale division of 2 mm (0.1 in.).

QC Flow Check Device

A QC flow-check device is required for routine operation of the HV PM₁₀ sampler; a calibrated orifice transfer standard is recommended.

The orifice transfer standard must have a NIST-traceable calibration relationship and be capable of accurately measuring volumetric flows between 1.02 and 1.24 m³/min. The calibration relationship must be referenced annually and be within ±2% of the NIST-traceable primary standard. This orifice transfer standard may be the same one that is used for calibration.

Audit Equipment

The equipment needed for auditing is similar to the calibration equipment; however, the audit orifice transfer standard MUST be a different device from the one that is used for routine calibration and flow checks.

Filter Media

The microquartz fiber filter is currently the only commercially available HV PM₁₀ filter that satisfies all criteria specified in 40 CFR Part 50, Appendix M (EPA 1997).

Filter Protection

Filter cassettes are recommended for sampling with most HV PM₁₀ samplers. These may be purchased through the HV PM₁₀ sampler's manufacturer. A sufficient number of cassettes must be purchased to allow insertion and removal of the filters in the laboratory.

For assurance of the integrity of the exposed filter during handling and storage, some type of protective covering is required; a manila folder in a protective envelope is recommended. The folder and envelope should be of comparable size (large enough to allow easy removal of the filter, yet small enough to prevent excess movement within the envelope) and be sealed to preclude damage or loss of particles during transportation to the analytical laboratory.

Analytical Balance

The analytical balance must be suitable for weighing the type and size of the HV PM₁₀ filters used. The range and sensitivity depend on routine tare weights

and expected loadings. The balance must be calibrated at installation and recalibrated at least once a year, as specified by the manufacturer.

Mass Reference Standards

Mass reference standards must be certified as being traceable to NIST mass standards. Additionally, they must have an individual tolerance of no more than 0.025 mg. Examples of mass reference standards that meet these specifications are American National Standards Institute/American Society for Testing and Materials (ANSI/ASTM) Classes 1, 1.1, and 2. The mass reference standards must be recalibrated on a regular basis (e.g., yearly) at a NIST-accredited State weights and measures laboratory or at a calibration laboratory that is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP), which is administered by NIST.

Two separate sets of mass reference standards are recommended. Working standards should be used for routine permeation device weighing and should be kept next to the analytical balance in a protective container. Laboratory primary standards should be handled very carefully and should be kept in a locked compartment. The working standards should be compared to the laboratory primary standards every 3 or 6 months to check for mass shifts associated with handling or contamination.

Section III. Calibration Procedures

Before a PM_{10} monitoring program is undertaken, all sampling and laboratory equipment must be properly calibrated. Calibration is defined as the relationship between an instrumental output and the input of a known reference standard. Data that are traceable to common reference standards are more uniform in character and more readily comparable than data that are not traceable. Because PM_{10} concentration standards are not available for determining calibration relationships, individual components of the sampling method must be calibrated to ensure the integrity of reported data.

Flow Rate Measurement and General Aspects of PM_{10} Sampler Calibration

It is imperative that the flow rate through a PM_{10} sampler's inlet be maintained at a constant value that is as close as possible to the inlet's design flow rate. The design flow rate for a given sampler is specified in the sampler's instruction manual. The manual may also provide tolerance limits (or upper and lower limits) within which the sampler flow must be maintained. If the tolerance is not specified by the manufacturer, it should be assumed to be $\pm 10\%$.

Because it is critical to continually verify that the HV PM_{10} sampler flow rate is being maintained at close to the inlet design flow rate, the procedures in this section recommend that individual average temperature (T_{av}) and pressure (P_{av}) measurements or estimates be used for each 24-hr sample period. However, if

individual pressure and temperature values for each sample period cannot be obtained, seasonal average barometric pressure (P_s) and seasonal average temperature (T_s) for the site may be substituted.

The calibration procedures presented provide for calibration of both the sampler and the flow rate transfer standard in actual volumetric flow-rate units (Q_a). This calibration mode allows convenient monitoring of the flow rate of the sampler against its design flow rate, is consistent with most sampler manufacturers' recommendations, and is in wide use. The mass concentration of PM_{10} in the ambient air is computed as the total mass of collected particles in the PM_{10} size range divided by the volume of air sampled and is expressed in micrograms per actual cubic meter ($\mu\text{g}/\text{m}^3$).

Certification of an Orifice Standard

Chapter 2.2 of the QA Handbook, Part II, Section 2.11 provides a detailed certification procedure that is applicable to an orifice transfer standard such as those that have been used previously in the calibration of TSP samplers. Two common types of orifice devices are available: one equipped with a set of fixed resistance plates (e.g., a ReF device or a top-hat orifice), and the other with an externally variable resistance valve. The series of plates normally provided by the orifice manufacturer includes an 18-, 13-, 10-, 7-, and 5-hole plate. Unfortunately, the 5-hole plate provides too low a flow rate to be useful for HV PM_{10} calibration, and other plates may produce flow rates substantially outside the design flow-rate range of the commercially available HV PM_{10} inlets. Agencies may opt to fabricate or procure a different series of resistance plates that will provide more flow rates within the sampler's design flow-rate range or use the variable-resistance type orifice device.

Orifice Transfer Standard Calibration Frequency

Upon receipt, and at 1-yr intervals, the calibration of the orifice transfer standard should be certified with a standard volume meter (such as a Roots[®] Meter) traceable to NIST. An orifice transfer standard should be visually inspected for signs of damage before each use and should be recalibrated if the inspection reveals any nicks or dents.

Basic Calibration Procedure for a Mass-Flow Controlled (MFC) Sampler Using an Orifice Transfer Standard

The MFC sampler calibration procedure discussed here relates known flow rates to the pressure in the exit orifice plenum of the sampler. The known flow rates are determined by an orifice transfer standard that has been certified using an appropriate certification procedure. The exit orifice plenum of the sampler is the area within the motor housing (below the motor unit) that contains the air flow of the sampler just before it is exhausted to the atmosphere through the exit orifice. It

is recommended that the exit orifice plenum pressure be measured with a 25 cm water or oil manometer and that each sampler should have its own dedicated manometer. Other types of pressure measurement devices may be used provided they have comparable accuracy. (NOTE: the 4 in. continuous pressure (flow) recorders often supplied with HV PM₁₀ samplers are generally not accurate enough and are not recommended for quantitative sampler pressure or flow measurements. Such devices should only be used for approximate flow indications.)

Calibration Equipment

Required calibration equipment includes an orifice transfer standard with calibration traceable to NIST, an associated water or oil manometer with a 0- to 400-mm (0- to 16-in.) range and a minimum scale division of 2 mm (0.1 in.), a water or oil manometer with a 0- to 200-mm (0- to 8-in.) range and a minimum scale division of 2 mm (0.1 in.), a thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50°C to the nearest 0.1°C, a portable aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500 to 800 mm Hg (66 to 106 kPa) to the nearest mm Hg, and miscellaneous handtools, calibration data sheets or station logbooks, and 51-mm (2-in.) duct tape.

Multipoint Flow Rate Calibration Procedure – MFC Sampler

The procedure presented in this section is basic and generic. There may be more detailed calibration procedures, variations, or alternative calibration procedures presented in the manufacturer's instruction manual. It is recommended that the manual be reviewed carefully and that the various calibration variations or alternative procedures be evaluated.

A detailed discussion of this procedure is provided in Chapter 2.3.2 of the QA Handbook, Part II, Section 2.11.

Calibration Calculations

Collect all calibration data, including the orifice calculation information, the sampler calibration data sheet, and the flow recorder chart (if used). Calculate and record Q_a for each calibration point from the orifice calculation information and equation. Next, calculate and record the quantity ΔP_{ext} for each calibration point. If a continuous flow recorder is used quantitatively, calculate and record the quantity. Plot the calculated Q_a (orifice) flow rates on the x-axis versus the transformed sampler manometer response, ΔP_{ext} (or the transformed flow recorder reading) on the y-axis.

Plot the regression line on the same graph paper as the calibration data. Determine the linear regression slope (m), intercept (b), and correlation

coefficient (r) and record them on the data sheet. For subsequent sample periods, the sampler's average actual operational flow rate is calculated from the calibration slope and intercept.

Basic Calibration Procedure for a Volumetric Flow Controlled (VFC) Sampler Using an Orifice Device

The details of calibrating a volumetric flow controlled (VFC) sampler are contained in Section 2.11 of the QA Handbook, Volume II, Part II.

The VFC sampler calibration procedure relates known flow rates (Q_a), as determined by an orifice transfer standard, to the ratio of the stagnation pressure to the ambient barometric pressure (P_1/P_a). The stagnation pressure is the air pressure inside the sampler in the area just under the filter. VFC samplers have a stagnation pressure tap or port through which the stagnation pressure can be measured. A VFC sampler may also have an exit orifice below the motor similar to those in MFC samplers. In such cases, the sampler flow rate could be measured and calibrated using the exit orifice plenum pressure as described above in Section D. The use of the stagnation pressure generally provides a more accurate indication of the sampler flow rate. To provide some measure of whether or not the flow rate was constant and uninterrupted over the sample period, a continuous flow recorder may be connected to the exit orifice pressure tap.

It is recommended that each sampler has its own dedicated manometer; however, other types of pressure measurement instruments may be used provided they have similar accuracy.

The VFC sampler's flow control system is a choked flow venturi. It must be carefully sized for a given annual temperature and pressure because the operating flow rate cannot be adjusted by the user. Consequently, the temperatures and pressures at the operating site must be specified when ordering a sampler.

HV Sampler Calibration Frequency

To ensure accurate measurement of the PM_{10} concentrations, calibrate HV PM_{10} samplers upon installation and recalibrate at least quarterly or annually according to the State's quality assurance program (see 40 CFR Part 58, Appendix A, for a description of the quality assurance requirements). In addition, samplers should also be calibrated after relocation of the sampler to a different site or after any repairs that might affect sampler calibration (e.g., replacing the motor).

HV samplers should also be calibrated if the results of a field flow-check exceed quality control limits or whenever a field flow-check or performance audit indicates that the sampler is out (or nearly out) of the acceptable flow-rate range.

Section IV. Field Operations

This section presents information pertinent to the routine operation of a PM₁₀ monitoring site using an HV PM₁₀ sampler. It covers an array of topics, ranging from initial site selection to final data documentation. The procedures herein are intended to serve as guidelines for the development of a monitoring program that will accurately reflect trends in local or regional air quality. The effectiveness of the monitoring program depends on responsible day-to-day operation of the monitoring site. The operators who conduct sampling activities offer a unique perspective on the sampler's performance, and their awareness and attention to detail will salvage data that may otherwise be lost. It must be stressed, however, that "routine" does not mean "unimportant." The site operator provides cohesiveness in a sampling program.

Siting Requirements

Complete siting requirements for PM₁₀ HV samplers are specified in 40 CFR Part 58, Appendix E. Topics to be considered include spatial scales, temporal scales, accessibility, electrical supply, and security.

Sampler Installation Procedures

On receipt of an HV PM₁₀ sampler from the manufacturer, visually inspect it to ensure that all components are accounted for. Perform a laboratory check to determine if the sampler is operational. Next, carefully transport the sampler to the field site. Following manufacturer's instructions, carefully assemble the base of the HV PM₁₀ sampler. Assemble the sampler inlet according to the manufacturer's instructions and carefully install it on the base unit. Check all tubing and power cords for crimps, cracks, or breaks. Then, plug the power cord into a line voltage outlet. If possible, this outlet should be protected by a ground fault interrupter (GFI) for the operator's safety. Turn on the sampler and make sure that it is still working properly. Operate the sampler for approximately 30 minutes to ensure that the motor brushes are properly seated and that the motor is operating at full performance. Finally, perform a multipoint flow-rate calibration.

Example Sampling Operations for an MFC Sampler

Operational procedures will vary according to the sampler model and options (e.g., the types of flow-rate controller and timer) selected for use in the monitoring program. Consult the instrument manual before putting the sampler into operation. Significant differences exist in the field operation of the two types of flow-controlling systems and, hence, in the determination of operational flow rates.

The average actual flow rate for MFC samplers is calculated by determining (1) the average of the initial and final manometer readings of the exit orifice plenum pressure [or the average flow recorder reading], (2) the average ambient

temperature (T_{av}), and (3) the average ambient barometric pressure (P_{av}) during the sampling period. These values are then applied to the sampler's calibration relationship. The 4-in. pressure (flow) recorders of the type often supplied with HV PM_{10} samplers are generally not sufficiently accurate and are not recommended for quantitative sampler pressure or flow-rate measurements.

Note: Consistency of temperature and barometric pressure units is required. It is recommended that all temperatures be expressed in Kelvin ($K = ^\circ C + 273$). It is also recommended that all barometric pressures be expressed in either mm Hg or kPa (but do not mix the two units). Take care to avoid calibrating a PM_{10} sampler using one set of units and then performing sample calculations using another set of units.

Presampling Filter Preparation

Most HV PM_{10} samplers have been designed to accept filter cassettes. Loading these cassettes in the laboratory will minimize damage; however, if care is exercised, they can be loaded at the site when ambient conditions permit. Workers should wear protective gloves when handling filters to avoid contaminating the filters with body oils and moisture. The filters should be kept in protective folders or boxes. Unexposed filters must never be bent or folded. The analytical laboratory (and/or filter manufacturer) will give each filter an ID number. Because it is extremely difficult to see the "up" side of a quartz filter (i.e., the side with the slightly rougher texture), it is recommended that filters consistently be labeled on one side. When a filter that has been labeled on its "down" side is folded for transport to the laboratory, its sample number will be readily accessible for documentation on laboratory log sheets upon arrival.

Filter Installation

A detailed procedure for filter installation can be found in Chapter 3.3.2.1 of the QA Handbook, Part II, Section 2.11.

Filter Recovery

As soon as possible after sampling, the operator should return to the monitoring site to retrieve the exposed filter. Particle loss or filter damage will result if the filter is left in the sampler for extended periods. A detailed procedure for filter recovery can be found in Chapter 3.3.2.2 of the QA Handbook, Part II, Section 2.11.

Postsampling Filter Handling

If a sample will not be analyzed immediately, the sample custodian should store the filter within a protective covering to minimize the loss of volatile particles. Because filter cassettes often prove too expensive and unwieldy for storage purposes, the use of a manila folder and a protective envelope of

comparable size to that of the filter is recommended.

First, remove the top frame of the filter cassette. Conduct a secondary check of the sample's validity. Next, slip a manila folder underneath the edge of the exposed filter, centering the filter on the folder. Fold the manila folder lengthwise with the exposed side of the filter in. Insert the folder into the protective envelope. Deliver the filter, in its protective folder and envelope, to the analytical laboratory.

Sample Validation and Documentation

The following criteria have been established to assist the operator in initially determining whether a sample is valid. If a sample fails to meet these criteria, do not discard the filter. Document any factors observed that may result in a sample's invalidation on the sample data sheet, and forward the data sheet and the filter to the laboratory supervisor, who will make the final decision regarding the sample's validity.

Field Validation

All samplers must be turned ON and OFF within 1/2 hr of midnight and all samplers must operate for at least 23 but no more than 25 hr (1,380 to 1,500 min).

After each sampling period, calculate the percentage difference between Q_a and the design flow rate (1.13 m³/min). \bar{Q}_a must be within flow-rate limits specified by the inlet manufacturer. The most common impaction and cyclonic inlets have an acceptable flow-rate range of 90 to 110% of 1.13 m³/min (i.e., 1.02 to 1.24 m³/min) expressed in actual volumetric units. Decreases in flow rate during sampling (due to mechanical problems) of more than 10% from the initial set point result in sample invalidation. Also, remember that changes in flow-rate calibration of more than 10%, as determined by a field QC flow-rate check, will invalidate all samples collected back to the last calibration or valid flow check.

Laboratory Validation

The sample custodian at the analytical laboratory is responsible for conducting a secondary check of a sample's validity. Do not discard a sample that fails to meet these criteria; instead, forward it to the laboratory supervisor, who will make the final decision of a sample's validity.

Check the filter for signs of air leakage. Leakage may result from a worn or improperly installed faceplate gasket.

Next, check the exposed filter for physical damage that may have occurred during or after sampling. Physical damage after sampling would not invalidate the sample if all pieces of the filter were put in the folder; however, complete losses of loose particulate after sampling (e.g., loss when folding the filter) would void

the sample.

Finally, check the appearance of the particles. Any changes from normal color may indicate new emission sources or construction activity in the area. Note any change on the data sheet.

Data Documentation

Recordkeeping is a critical part of the QA program. Careful documentation of sampling data will salvage samples that may otherwise be lost. The sheer repetition of recording data may result in errors; however, this cross-referencing between data sheets (DSs), logbooks (LBs), and (for those samplers so equipped) the continuous flow-recorder charts will allow the operator to pinpoint discrepancies that may result in a sample's invalidation.

The QA Handbook, Part II, Section 2.11 provides detailed descriptions of the documentation roles of both the operator who starts the sample and the operator who removes the sample. These can be found in Chapters 3.4.3.1 and 3.4.3.2.

Field QC Flow Check Procedure

For HV PM₁₀ samplers, a field-calibration check of the operational flow rate is recommended at least once per month. The purpose of this check is to track the sampler's calibration stability.

For an MFC sampler, begin by determining the manometer reading of the exit orifice plenum pressure. Record the ambient temperature and pressure. Then, calculate the actual sampler flow rate using the sampler's calibration relationship.

For a VFC sampler, begin by determining the relative stagnation pressure. Record the ambient temperature and pressure. Then, calculate the actual flow rate using the sampler's calibration relationship.

Section V. Filter Preparation and Analysis

The accuracy of a PM₁₀ sampling program depends on several factors. A primary consideration is the analytical laboratory staff's attention to detail and balance technique. This section offers guidelines to enhance the accuracy of the laboratory operation and, hence, the mass concentration determinations of PM₁₀.

Filter Handling

Package tare weighed filters in groups of 50 or less, separating the filters with sheets of tracing paper. Assign a filter number to each filter, and then stack the filters in numerical order. Be sure to ship the filters in reinforced envelopes and manila folders.

Filter Integrity Check

Visually check each filter, looking for pinholes, loose material, nonuniformity, or other filter imperfections.

Filter Equilibration

Let the filters equilibrate for at least 24 hours before weighing, keeping the relative humidity between 20 and 45%, and the temperature between 15 and 30°C, $\pm 3^\circ\text{C}$.

Initial Weighing Procedures

Ensure that the balance has been calibrated at least annually, then allow the balance to warm up for five minutes. Zero the balance, and have the QC supervisor perform the "standard" filter QC check. Weigh the filter, rezeroing and checking balance calibration at routine intervals. Be sure to record the balance number, filter ID number, and tare weight on a laboratory data form.

Internal QC

During the filter weighing process, the following QC checks are recommended. All QC data, including the actual and measured weights, the date, and the operator's initials, should be recorded on an Internal Quality Control Log Sheet.

"Standard Weight" Check

Before the first filter is weighed, the balance should be checked by weighing a pair of working mass reference standards with weights between 1 and 5 g should be used. If the actual and measured values differ by more than ± 0.5 mg, the values should be reported to the supervisor before proceeding.

Zero and Calibration Checks

After every 5 to 10 weighings, the operator should recheck the balance zero and record these check values on the Internal Quality Control Log Sheet. Zero QC checks within ± 0.5 mg of true zero are acceptable.

The calibration of the balance must be checked at least daily and possibly after every 15 filters unless laboratory records indicate that the balance is stable over longer periods of time.

Tare and Gross Weight Checks

On each day of operation, the operator should reweigh five to seven exposed and unexposed filters per balance. Weights of clean filters should be within ± 2.8

mg of original values; if not, troubleshooting and reweighing are in order.

QC Supervisor Responsibilities

The supervisor should keep a bound QC notebook. These notebooks should contain all QC data, including balance calibration and maintenance information, internal routine QC checks, and independent audits.

Post Sampling Documentation and Inspection

Upon receipt of exposed filters from the field, the sample custodian should follow a standard procedure. This procedure is presented in detail in Chapter 4.6 of the QA Handbook, Part II, Section 2.11.

Final Weighing Procedure (Gross Weight)

Place the defect-free filter(s) in a conditioning environment and allow them to equilibrate. Repeat the first six steps of the HV PM₁₀ filter tare-weighing procedure. Then, perform the internal QC checks described in Section 4.5 to ensure the validity of reweighing. If the HV PM₁₀ filter is not to receive additional analysis, place it in a protective envelope or folder. Deliver weighed filters to the sample custodian for archiving.

Calculation of Net Mass Filter Loading

The gross weight minus the tare weight of an HV PM₁₀ filter is the net weight of PM₁₀ for that filter. Each calculation of this process must be independently validated.

Section VI. Calculation, Validation, and Reporting

Units of mass concentration for purposes of comparisons to NAAQS for particulate matter must be in micrograms per actual cubic meter ($\mu\text{g}/\text{m}^3$) of air.

Flow Rate Calculations for MFC Sampler

The average actual flow rate for the sample period is calculated by determining (a) the average of the initial and final manometer readings (ΔP_{ex}) [or the average flow recorder trace], (b) the average ambient temperature (T_{av}), and (c) the average ambient barometric pressure (P_{av}) during the sampling period and applying these values to the calibration relationship. The equation for calculating the sampler's average actual operation is:

$$Q_a = \{ [\Delta P_{ex} (T_{av} + 30) / P_{av}]^{1/2} - b \} \{ l/m \}$$

Where:

Q_a = the sampler's average actual flow rate, m^3/min

ΔP_{ex} = average of initial and final sampler manometer readings,
 $(\Delta P_{exi} + (\Delta P_{exf})/2$ mm or inches of H_2O

T_{av} = average ambient temperature for the sample period, K

P_{av} = average ambient pressure for the sample period, mm Hg (or kPa)

b = intercept of the sampler calibration relationship

m = slope of the sampler calibration relationship

For the flow recorder, the equation is:

$$Q_a = \{ I [(T_{av} + 30) / P_{av}]^{1/2} - b \} \{ l/m \}$$

Where:

I = average flow recorder reading for the sample period

If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for (I) in the flow recorder equation.

Flow Rate Calculations for VFC Sampler

The average actual flow rate for the sample period is calculated by determining the ratio of the average absolute stagnation pressure to the average ambient barometric pressure (P_i / P_{av}) and the ambient average temperature (T_{av}) for the sampler period.

1. Calculate the value of P_1 in millimeters Hg (or kPa):

$$\overline{P_1} = P_{av} - \overline{\Delta P_{stg}}$$

where

- P_1 = average absolute stagnation pressure for the sample period, mm Hg or kPa
 P_{av} = average barometric pressure for the sample period, mm Hg or kPa
 ΔP_{stg} = average of initial and final relative stagnation pressure readings, mm Hg or kPa.

Note: Be sure to convert a water manometer reading to mm Hg using the following equation before recording the reading on the data sheet:

$$\text{mm Hg} = 25.4 (\text{in. H}_2\text{O}/13.6)$$

2. Calculate and record the value of the average stagnation pressure ratio:

$$\text{Average stagnation pressure ratio} = \overline{P_1} / P_{av}$$

3. Use the manufacturer's lookup table to determine Q_a from the average stagnation pressure ratio ($\overline{P_1} / P_{av}$) and T_{av} for the sample period. This value of Q_a is the average volumetric flow rate for the sampler period.

PM₁₀ Concentration Calculation

Accurate reporting of total PM₁₀ mass concentration data requires the calculation of the total standard volume of air sampled and the final computation of total PM₁₀ mass concentration. First, calculate the total standard volume of air sampled. Then, calculate total PM₁₀ mass concentration in $\mu\text{g}/\text{m}^3$.

Calculation Validation

Data necessary to compute the mass concentration of PM₁₀ originate from two main sources: field operations and laboratory operations. These data must be validated to ensure that all reported PM₁₀ measurements are accurate relative to the overall scope of the QA program. When the final mass concentration of PM₁₀ in a sample has been computed, the validation procedure will not only check on these computations, but will also aid in flagging questionable mass concentrations (i.e., extremely high or low values).

First, collect total sampling time data, average actual flow rate data, and tare and gross weights. Recalculate the total mass concentration for seven samples per 100, and compare each validated PM₁₀ concentration with the originally reported value. If calculation errors are found, all values in that sample lot should be recalculated. Investigate and recalculate all total mass concentration values that are either exceedingly high or exceedingly low. Correct any errors that are found. Finally, if all mass concentration computations appear correct, and high or low values are still found, review all raw data for completeness and correctness.

Data Reporting and Interpretation

Detailed information on reporting and interpretation of PM₁₀ data with respect to the attainment of the NAAQS is fully covered in 40 CFR Part 50, Appendix K, and will not be addressed here.

Section VII. Maintenance

Preventive maintenance is defined as a program of positive actions aimed to prevent failure of monitoring and analytical systems. The overall objective of a routine preventive maintenance program is to increase measurement system reliability and to provide for more complete data acquisition.

Maintenance Procedures

The HV PM₁₀ sampler is comprised of two basic components: the inlet and the flow control system. Because of the differences between sampler models, it will be necessary to refer to the manufacturer's instruction manual for specific, step-by-step maintenance guidelines and necessary supplies.

Impaction Inlet

The impaction inlet should be dismantled and cleaned at intervals specified by the manufacturer to preclude problems with particle bounce. It is recommended that scribe marks be etched on the inlet to ensure proper alignment during reassembly.

Cyclonic Inlet

The cyclonic inlet should be cleaned at intervals specified by the manufacturer. The inlet is constructed to allow easy access to the fractionating element through a maintenance access port.

Caution: Prolonged positioning of the cyclonic inlet at angles exceeding 90° from vertical (during maintenance activities) may result in residual leakage of oil from the middle tube onto the inside surfaces of the outer tube. If this occurs, the outer tube will require wiping with a disposable laboratory wipe to prevent the oil from contaminating the filter substrate.

MFC Base

Check tubing and power lines for crimps, cracks, and obstructions every sample recovery day. Inspect the filter screen every sampler recovery day. Inspect the filter cassette gaskets each time a cassette is loaded. Check the motor and housing gaskets every three months. Replace blower motor brushes before they become worn. Replace the motor and recorder as needed. Replace the recorder pens every 30 recording days.

VFC Base

Check tubing and power lines for crimps, cracks, and obstructions every sample recovery day. Inspect filter screen and throat of the choked flow venturi every sampler recovery day. Inspect the filter cassette gaskets each time a cassette is loaded. Check the motor and housing gaskets every three months. Replace blower motor brushes before they become worn. Replace the motor as needed.

Refurbishment of HV PM₁₀ Samplers

If operated in the field for extended periods, HV PM₁₀ samplers may require major repairs or complete refurbishment. If so, refer to the manufacturer's instrument manual before work is undertaken. A sampler that has undergone major repairs or refurbishment must be leak-checked and calibrated prior to sample collection.

Section VIII. Auditing Procedures

The operating agency must perform QA audits and process evaluations to determine the accuracy of the PM₁₀ monitoring system and, hence, the data it produces. The primary goal of an auditing program is to identify system errors that may result in suspect or invalid data. The efficiency of the monitoring system (i.e., labor input vs. valid data output) is contingent upon effective QA activities.

Flow Rate Performance Audit for MFC PM₁₀ Sampler

A detailed description of the flow rate performance audit procedure for an MFC PM₁₀ sampler is provided in Chapter 7.1 of the QA Handbook, Part II, Section 2.11.

Audit Data Reporting

Preliminary audit results should be given to the operating agency at the completion of the audit and discussed as necessary. These data should not be used to make monitoring system modifications. Mistakes may have been made and calibration curves may have shifted, so a post-audit verification of the audit equipment and data is essential before decisions can be made on the sampler's performance.

Final audit results should be submitted to the operating agency as soon as possible to avoid data loss and the use of invalidated data.

Flow Rate Performance Audit Frequency

The frequency of flow-rate audits depends on the use of the data (e.g., for PSD air monitoring or for SLAMS). For PSD monitoring, the flow rate of each sampler must be audited at least once per sampling quarter. For SLAMS, flow-rate audits should be conducted on at least 25% of the operational samplers in the monitoring network each quarter, such that each sampler is audited at least once a year. If a reporting organization has fewer than four PM₁₀ samplers, one or more randomly selected samplers should be reaudited so that at least one sampler is audited each calendar quarter.

Systems Audit

A system audit is an onsite inspection and review of the quality of the total measurement system (i.e., sample collection, sample analysis, data processing, etc.). This audit is normally conducted at the startup of a new monitoring system and as appropriate thereafter.

Data Processing

Data processing should be audited soon after the original calculations have been performed to allow corrections to be made immediately and to allow for possible retrieval of additional explanatory data from field personnel. A minimum frequency of seven samples per 100 (or a minimum of four samples per lot) is recommended.

Analytical Process System

This system presents an analytical evaluation of the filter-weighing process. In addition to observing the balance operator's technique, the auditor should conduct an independent audit of exposed filter reweighing.

Section IX. Assessment of Monitoring Data for Precision and Accuracy

Precision

One or more monitoring sites within the reporting organization are selected for duplicate, collocated sampling as follows: for a network of 1 to 5 sites, 1 site is selected; for a network of 6 to 20 sites, 2 sites are selected; and for a network of more than 20 sites, 3 sites are selected. Sites must be selected on the basis of having annual mean PM₁₀ concentrations that are among the highest 25% of the annual mean PM₁₀ concentrations for all the sites in the network.

Collocated PM₁₀ samplers being used for assessment of precision should gen-

erally be of the same type. That is, they should have similar flow rates (e.g., high, medium, or low), similar inlet types (e.g., impaction or cyclonic), and similar flow controller types (e.g., MFC or VFC). Where a PM₁₀ network contains more than one type of sampler, each type should be represented by at least one collocated sampler pair, if possible.

The two collocated samplers must be within 4 m of each other, but at least 2 m apart to preclude air flow interference. Calibration, sampling, and analysis must be the same for both collocated samplers and all other samplers in the network. One of each pair of collocated samplers is designated as the primary sampler from which samples will be used to report air quality for the site; the other is designated as the duplicate sampler. The measurements from both samplers at each collocated sampling site are reported. The percentage differences in measured concentrations (micrograms/cubic meter) between the two collocated samplers are used to calculate precision as described in 40 CFR Part 58, Appendix A.

Accuracy

Each calendar quarter, audit the flow rate of at least 25% of the PM₁₀ samplers such that each PM₁₀ sampler is audited at least once per year. If there are fewer than four PM₁₀ samplers within a reporting organization, randomly reaudit one or more samplers so that one sampler is audited each calendar quarter.

The accuracy of the HV PM₁₀ sampler method in the measurement of PM₁₀ is assessed by auditing the performance of the sampler (at its specified flow rate). Both the audit flow rate and the corresponding sampler flow rate are reported. The percentage differences between these flow rates are used to calculate accuracy as described in 40 CFR Part 58, Appendix A.

Section X. Recommended Standards for Establishing Traceability

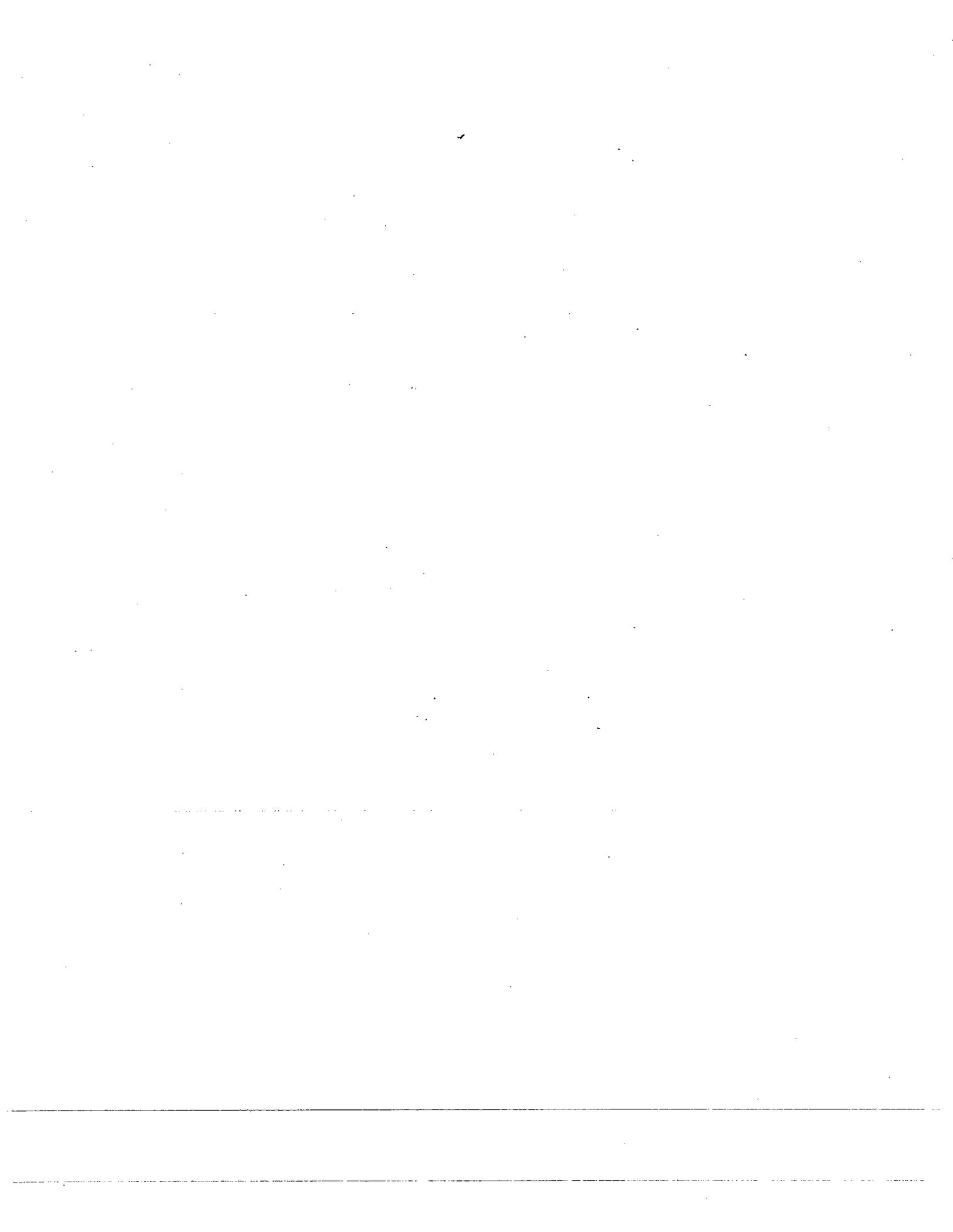
Two factors are essential for attaining accurate data: (1) the measurement process must be under statistical control at the time of the measurement, and (2) the combination of systematic errors and random variation (i.e., measurement errors) must yield a suitably small uncertainty. The attainment of accurate data requires the performance of QC checks, independent audits of the flow measurement process, careful documentation of monitoring data, and the use of equipment and standards that can be traced to appropriate primary standards.

ANSI/ASTM Class 1, 1.1, or 2 mass reference standards are recommended for the laboratory balance calibration. See Section 4.5 of Chapter 4, QA Handbook Section 2.11 for details on balance calibration checks.

Use of a positive-displacement standard volume meter (e.g., a Roots[®] Meter) is recommended for calibrating the flow-rate transfer standards that are used to calibrate and audit the HV PM₁₀ sampler.

The elapsed-time meter should be checked upon initial receipt and referenced at least annually against an accurate timepiece, and it must be accurate within 15 min/day.

The accuracy of associated monitoring equipment (i.e., thermometers, barometers, stop watches, etc.) should be checked at routine intervals, but no less than once per year, against standards of known accuracy and traceable to NIST.



Lesson 20

Monitoring PM₁₀ in Ambient Air Using a Dichotomous Sampler

Lesson Goal

Familiarize students with EPA guidelines for the development of quality assurance programs associated with the operation of dichotomous samplers.

Lesson Objectives

1. Describe equipment selection criteria and minimum accuracy requirements.
2. Describe the calibration procedures for a dichotomous sampler, including flow rate transfer standards and other monitoring equipment.
3. Describe proper field operations procedures, including filter installation, performance of operational quality control (QC) checks, sample handling, and data documentation.
4. Identify and describe the important considerations for the handling, integrity, equilibration, and weighing of filters.
5. Calculate PM₁₀ mass concentrations, given filter weights, flow rate, and sampling time.
6. Describe minimum data validation requirements.
7. Describe minimum maintenance requirements and procedures to increase measurement system reliability.
8. Identify and describe independent audit activities and laboratory evaluations that provide performance checks of flow rate measurements and data processing.
9. Identify and describe filter weighing procedures and balance operation procedures that evaluate data validity.
10. Describe assessment procedures utilizing collocated samplers for determining the accuracy and precision of PM₁₀ data.
11. Identify and describe the importance of the traceability of monitoring equipment.

References

U.S. Environmental Protection Agency. September 1997, Second Draft, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part II, Section 2.10, Monitoring PM₁₀ in Ambient Air Using a Dichotomous Sampler.*

Revised Requirements for Designation of Reference and Equivalent Methods for PM_{2.5} and Ambient Air Quality Surveillance for Particulate Matter; Final Rule.

U.S. Environmental Protection Agency, 40 CFR, Parts 53 and 58, Federal Register, July 18, 1997.

National Ambient Air Quality Standards, for Particulate Matter, Appendix K- Interpretation of the National Ambient Air Quality Standards for Particulate Matter, Appendix M-Reference Method for the Determination of Particulate Matter as PM₁₀ in the Atmosphere; and Appendix N-Interpretation of the National Ambient Air Quality Standards for Particulate Matter Final Rule. U.S. Environmental Protection Agency, 40 CFR Part 50, Federal Register, July 18, 1997.

U.S. Environmental Protection Agency. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I, Ambient Air Quality Monitoring Program Quality System Development.* EPA 454/R-98-004, August 1998.

U.S. Environmental Protection Agency. *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, EPA QA/R-5.* October, 1997.

Section I. Introduction

PM₁₀ is particulate matter with an aerodynamic diameter less than or equal to 10 μm. A PM₁₀ sampler draws a measured quantity of ambient air through a specially designed particle size discrimination inlet at a constant flow rate. PM₁₀ particles are collected on one or more filters during a 24-hr sampling period. Each filter is weighed before and after sampling to calculate the net weight (mass) gain of the collected PM₁₀ sample. Two types of samplers meet EPA reference method designation requirements for PM₁₀. They are the high-volume (HV) PM₁₀ sampler and the dichotomous sampler. Only the dichotomous sampler is discussed in this lesson. The PM₁₀ high-volume sampler is discussed in Lesson 19. Figure 20-1 shows the PM₁₀ dichotomous sampler inlet.

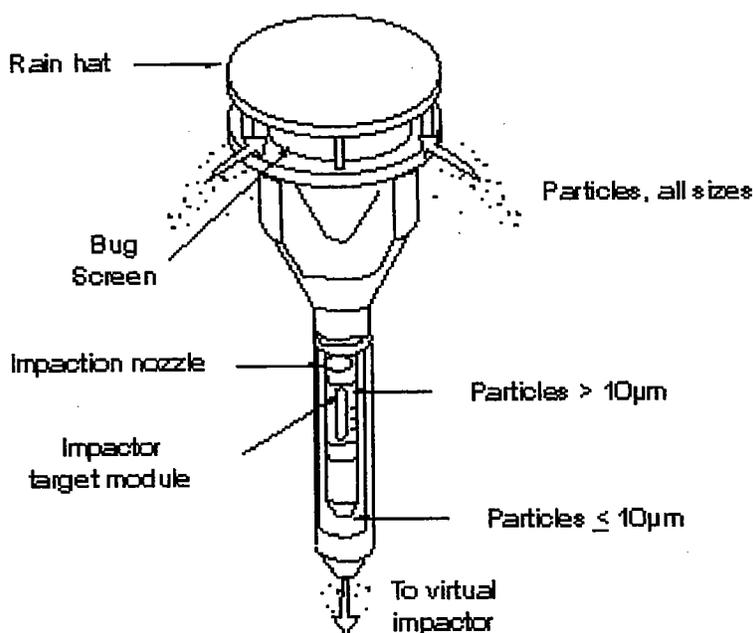


Figure 20-1. PM₁₀ Dichotomous Sampler Inlet.

Figure 20-2 illustrates the particle size separation mechanism occurring in the sampler.

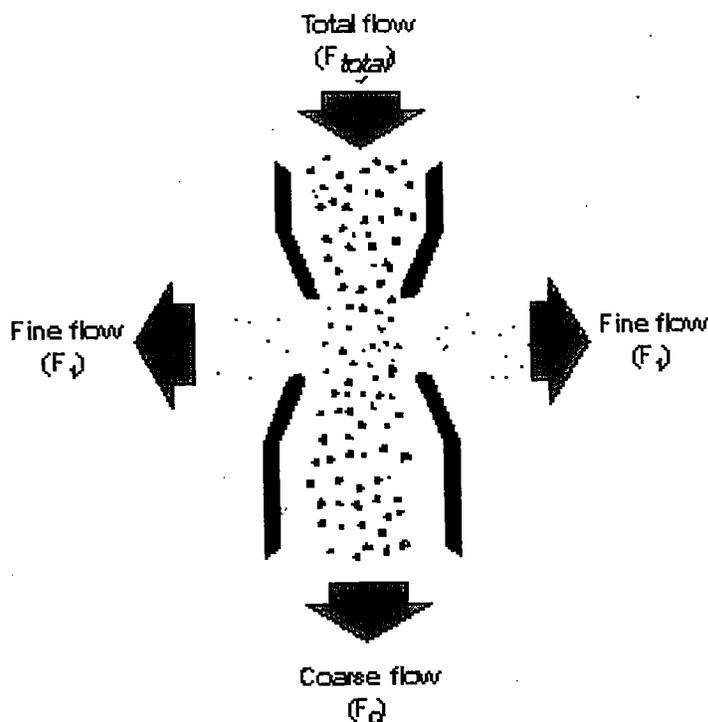


Figure 20-2. Particle Size Separation in a Dichotomous Sampler Using Virtual Impactation.

Section I of the lesson identifies the basic components of the dichotomous sampler. Section II covers the procurement of equipment and supplies for field and laboratory equipment including dichotomous samplers, calibration equipment, flow-check devices, audit equipment, filter media, filter cassettes, filter handling containers, the analytical balance, and mass reference standards. Section III discusses calibration procedures including flow rate measurement systems; recommended standards; total, fine, and coarse flow rate calibration procedures; calibration of total and coarse rotameters; and calibrations calculations.

Section IV addresses sampler field operations including siting requirements spatial and temporal scales; safety, electrical, and security considerations; sampler installation procedures; calibration check procedures; and documentation. Section V addresses filter preparation and analysis, including the microbalance, mass reference standards, filter handling, and filter integrity checks. Section VI examines the various calculations, validations, and reporting requirements necessary to ensure valid sampling data. Section VII discusses the maintenance procedures for the dichotomous sampler, including maintenance supplies, identifying components which require routine or special maintenance, and considerations for using refurbished samplers. Section VIII addresses auditing procedures to including audit guidelines, types of audits, and specific auditing procedures. Section IX discusses the various procedures for ensuring precision and accuracy of monitoring data. Finally, Section X will identify some

recommended standards for establishing traceability.

Section II. Procurement of Equipment and Supplies

In this Section the focus of the material is on procuring and acceptance testing of the proper equipment for PM_{10} monitoring. A detailed description of field operating equipment and laboratory equipment is provided. Also, data handling systems including forms, logs, files, and reporting procedures must be developed and properly documented in order to ensure effective collection and reporting of quality data.

Prior to purchasing equipment and supplies, a listing of the required monitoring requirements must be established and budgetary limits formulated. In addition, performance specifications and acceptance criteria must be prepared. When the equipment is received, acceptance testing should be conducted and all results of the tests should be properly documented, including whether the equipment was accepted or rejected. The procurement log will serve as the permanent record for procurement and acceptance testing and will provide a useful tool for future monitoring equipment projections.

Procurement Prerequisites –Field Operations

Items to be discussed for field operation equipment include dichotomous samplers and special calibration equipment to calibrate the sampler for temperature, barometric pressure, and volumetric flow measurements. In addition, for QC procedures a flow verification check device is discussed because it is needed to verify sampler operation at the correct flow rate. Audit equipment is similar to the calibration equipment, except all equipment used for audits must be separate from those used for calibrations.

Procurement Prerequisites –Laboratory Operations

For laboratory operations, the discussion features such items as filter media, filter support cassettes, filter cassette protective containers, filter handling containers, and analytical balance. In addition, the use of mass reference standards is discussed.

Section III. Calibration Procedures

Overview

Before commencing a sampling program, all sampling and analysis equipment must be properly calibrated. All data and calculations should be recorded in a calibration logbook, on calculation data sheets, or appropriate recording files.

Flow Rate Measurement and General Aspects of PM_{10} Sampler Calibration

Because the particle size discrimination characteristics of the dichotomous sampler are significantly impacted by air velocities, it is critical that the flow rate through the sampler be maintained as closely as possible to the sampler's design flow rates. These values, along with appropriate upper and lower limits, are contained in the instruction manual for the sampler. If they are not specified, the limits should be within $\pm 10\%$.

Sampler Calibration

The following material contains information for sampler calibration. A section on equipment calibration requirements provides information on necessary calibration equipment such as the flow-rate transfer standard, On/off timer, elapsed-time meter, analytical balance, relative humidity indicator, and mass reference standards.

Recommended standards and associated equipment suggestions are provided for total and fine flow rates as well as coarse flow rates. Recommended standards for total and fine flow rates include laminar flow element, mass flowmeter, dry gas meter, and critical orifice. For coarse flow rate standards, suggested equipment includes laminar flow element, mass flowmeter, dry gas meter, critical orifice, and soap film flowmeter.

The following segment provides procedures for the precalibration system check. During this check, it is important to remember several things:

- Filters used for flow rate calibrations should not be used for subsequent sampling.
- Allow sampler to warm up for at least 5 minutes before calibrating.
- A sampler equipped with an overload feature should shut down when approximately 15 in. of vacuum is reached.
- Maximum indication should be read from the total vacuum gauge only.
- Note that leak-free systems should indicate a vacuum of 10 to 15 in. or more, and the rate of decline to 0 in. indication should require 60 seconds or more.

Procedures for total rotameter calibration are presented in this section as well. Remember that the total flow control valve must be adjusted to a setting which represents an acceptable flow rate as specified for the inlet (i.e., 12 to 19 L/min.). Note that, while rotameter settings for subsequent sampling periods may need to be adjusted to account for day-to-day variations in ambient temperature and pressure, it is possible to use seasonal averages to avoid daily adjustments. Be sure to repeat the calibration procedure for at least three different settings within

the acceptable flow rate range.

For coarse rotameter calibration, be sure that the flow-control valve is set to an approximate value of 90% of the rotameter scale. Adjust the total flow control valve to indicate a nominal flow of 16.7 L/min. Repeat the procedure for rotameter settings representing flow rates of 75%, 60%, 40%, and 20% of the established operating range (1.4 to 1.9 L/min).

Suggested calibration calculations include verifying that the transfer standard calibration equation is current and traceable to an acceptable primary standard, calculating flow rate (Q_a), calculating and recording total and actual coarse rotameter actual corrections, obtaining the total flow rate calibration relationship, and calculating the sampler's average actual operational flow rate.

Sampler Calibration Frequency

The sampler should be calibrated when initially installed, and then at least annually thereafter. It is also important that the sampler be calibrated after any repairs that might affect calibration. In addition, the sampler should be calibrated whenever a field calibration flow check exceeds quality control limits, or when an audit shows the sampler to be out of calibration.

Section IV. Field Operations

Spatial and temporal scale considerations are important in dichotomous sampler siting. Spatial scales may range from a small (0.1- to 0.5-km²) area to large regional areas exceeding tens of hundreds of square kilometers.

With regard to the temporal scale, interest focuses on either an annual geometric mean concentration or a 24-hr average concentration. Because siting of a dichotomous sampler requires that consideration be given to prevailing wind direction, a sampler sited for monitoring trends in air quality over a period of a year will not necessarily be ideal for measuring 24-hr concentrations. Thus, the choice of temporal scale will also affect the sampler location.

Although spatial and temporal scales must be considered in site selection, the following guidelines should be observed regardless of the scale:

- The dichotomous sampler must have unobstructed air flow for a minimum of 2 m in all directions.
- The sampler inlet should be placed at a height of 2 to 15 m above ground level.
- If a dichotomous sampler is collocated with any other particulate sampler, the minimum spacing between sampler inlets must be 2 m and the

maximum spacing must be 4 m. All inlet heights should be within 1 vertical meter of one another.

Additional factors must be considered in determining where the actual sampler will be deployed. These include accessibility under all weather conditions (a dichotomous sampler used for routine sampling must be situated where the operator can reach it safely regardless of weather conditions), availability of adequate electricity (a dichotomous sampler will require a minimum continuous operating current of 3 to 5 A at 120 V a.c. and 60 Hz and may require a higher startup current, which necessitates a slow-blow fuse), and security of the monitoring equipment (the security of the operating personnel as well as the sampler should be considered).

Sampler Installation Procedures

When a sampler is received from the manufacturer, it is important to visually inspect the sampler to ensure that all components are accounted for. Next, perform an operational check in the laboratory. Carefully transport the monitor to the sampling site. Install the control module and connect the vacuum lines, checking all tubing for crimps, cracks, or breaks. Plug in the power cord, and then perform a multipoint flow rate calibration.

Example Sampling Operations

Sampling operations are specific to the particular model of dichotomous sampler. Since operational procedures will vary between various models, consult the instruction manual prior to sampling. Each dichotomous sampler is equipped with two filter holders, one for coarse particle sampling (6.35 mm o.d. tubing), the other for fine particle sampling.

A detailed generic sampling procedure is provided in Chapter 3.3 of the QA Handbook, Section 2.10. It includes specific procedural guidance on pre-sampling procedures, filter installation, filter recovery, sample validation and documentation, and sample handling.

Field Calibration Check Procedure

For dichotomous samplers, a field calibration check of the total and coarse flow rates is recommended after each month of operation. The purpose of this check is to track the sampler calibration stability. Control charts presenting flow check data (indicated vs. observed) should be maintained. These charts provide a quick reference of instrument flow rate drift patterns and will indicate when flow limits ($\pm 10\%$ variation from the indicated or design condition flow rate) have been exceeded. The field check is made by installing a measuring device (which is traceable to NIST and is calibrated within the range of the total or coarse flow rate) on the inlet of the sampler.

Calibration checks of the sampler flow rate require that the instrument be running. The following flow check procedures are specific to an orifice device. A variety of transfer standards may be used with this same procedure; however, necessary apparatus and subsequent calculations to determine the sampler's flow rates will vary.

A detailed description of the field calibration check procedure is located in Chapter 3.4 of the QA Handbook, Section 2.10.

Section V. Filter Preparation and Analysis

The following discussion addresses the details of analytical balance determination of the mass of sample collected.

Filter Handling

Filter handling requirements include using only nonserrated, nonmetallic forceps and nylon gloves. In addition, all filters should be placed in petri dishes for convenience, and all dishes should be labeled with sequential numbers to facilitate identification and analysis.

Filter Integrity Check

All filters must be visually inspected for defects before the initial weighing. When inspecting filters, check for pinholes, separation of the filter ring, chaff or flashing, loose materials, discoloration, or other imperfections. Batches containing high numbers of defects should be returned to the manufacturer.

Filter Equilibration

Filters must be equilibrated in a conditioning environment for at least 24 h before being weighed. Relative humidity (RH) should be held constant at a mean value between 20 and 45%, with a variability of not more than $\pm 5\%$. Temperature should be held constant with a mean value between 15 and 30°C, with a variability of not more than $\pm 3^\circ\text{C}$. Filters should be conditioned in their protective petri dishes with the lids (on which the filter ID is recorded) removed and placed beneath the bottom half of the petri dish.

Initial Weighing Procedures

This section presents procedures specific for a common commercially available analytical balance. Calibration, QC checks (and acceptable tolerances) and operational procedures may have to be adapted to other analytical balance models. Allow the balance to warm up for five minutes, and always zero the balance. Have the QC supervisor perform the "standard" filter check. Weigh the filter, place it in a petri dish, and record the assigned filter ID number on the petri

dish, including the size fraction code.

Internal Quality Control

Internal quality control responsibilities lie with both the analyst and the QC supervisor.

After every tenth weighing, the analyst should recheck the zero and calibration of the balance and record these check values on the Laboratory Internal Quality Control Log (Figure 4.2).

Keep a bound QC notebook. These notebooks must contain all QC data, including the balance calibration and maintenance information, internal routine QC checks, and independent audits. It is recommended that control charts be maintained on each balance and included in this notebook. These charts may indicate any excess drift that could flag an instrument malfunction.

At the beginning of each weighing day, after the analyst has completed the zeroing and calibration checks of the balances, tare weigh one arbitrarily selected filter from a set of “standard” filters (10% of the total number of filters to be weighed). In addition, reweigh five to seven exposed and unexposed filters per balance each day of operation.

Post Sampling Documentation and Inspection

Upon receipt of the sample from the field, the analyst should follow this procedure, documented in detail in Chapter 4.6 of the QA Handbook, Section 2.10:

First, examine the data sheet and check for completion of entries. Remove the filter from the petri dish and examine the dish for dislodged material. Be sure to recover any material dislodged from the filter. Match the filter ID number with the correct laboratory coding form, and then group filters according to recorded balance ID numbers.

Next, remove the filter from the petri dish and cassette and examine filters for any damage. If defects are found, return defective filters to original petri dish and label defect by type for submission to laboratory QC supervisor.

Final Weighing Procedure (Gross Weight)

For final weighing, the analyst should follow this procedure, documented in detail in Chapter 4.7 of the QA Handbook, Section 2.10:

Group the filters according to their recorded balance numbers. Open the petri dish and place the lid beneath the bottom of the dish to avoid filter mix-ups. Cover open dish with a clean laboratory paper towel and allow the filter to

equilibrate. Then, repeat steps in tare weight weighing procedure.

Calculation of Net Mass Filter Loading

Gross weight minus the tare weight is the net mass of the particulate. Each calculation must be independently validated.

Section VI. Calculation, Validations, and Reporting

Units of mass concentration for purposes of comparisons to the National Ambient Air Quality Standards (NAAQS) for particulate matter must be in micrograms per actual cubic meter ($\mu\text{g}/\text{m}^3$) of air.

Calculations Using a Dichotomous Sampler

Flow rate calculations are performed as follows:

Determine average total or coarse rotameter response by averaging initial rotameter set points and final rotameter readings.

$$\bar{I} = (\text{TSP or CSP} + \text{IF}) / 2$$

Where:

\bar{I}	= average total or coarse rotameter response, arbitrary units
TSP, CSP	= total or coarse rotameter set points, arbitrary units
IF	= indicated final total or coarse rotameter response, arbitrary units

Determine total or coarse flow rate by applying average rotameter readings to the sampler's total or coarse calibration relationship.

$$\overline{TQ_a} \text{ or } \overline{CQ_a} = 1/m \left[\bar{I} (T_{av}/P_{av})^{1/2} - b \right]$$

Where:

$\overline{TQ_a}, \overline{CQ_a}$	= sampler total or coarse average flow rate, actual L/min
\bar{I}	= average total or coarse rotameter response, arbitrary units
T_{av}	= average ambient temperature for the day, K
P_{av}	= average ambient pressure for the day, mm Hg or kPa
m	= slope of the total or coarse flow rate calibration relationship
b	= intercept of the total or coarse flow rate calibration relationship

For PM_{10} concentration calculation, follow these steps:

- a. Determine total volume sampled in m^3 by multiplying total flow rate in m^3/min by the elapsed total sampling time in minutes.

$$V = (\overline{TQ_a})t$$

Where:

- V = total sample volume in standard volume units, m^3/min
 $\overline{TQ_a}$ = total flow rate corrected to standard conditions, m^3/min
 t = elapsed total sampling time, min

- b. Determine mass concentration in $\mu\text{g}/m^3$ of the fine filter by dividing net mass of particulate of the fine filter in μg by the total sample volume in liters (L).

$$PM_{10} = \frac{(Mf + Mc)10^6}{V}$$

Where:

- PM_{10} = mass concentration of PM_{10} , $\mu\text{g}/m^3$
 Mf = net mass of particulate of the fine filter, mg
 Mc = net mass of particulate of the course filter, mg
 10^6 = conversion factor for mg to μg and L to m^3
 V = total sample volume in standard volume units, m^3/min

Calculation Validation

Data necessary to compute the mass concentration of PM_{10} originate from two main sources—field operations and laboratory operations—and must be validated. The validation procedure ensures that all reported data are accurate relative to the overall scope of the QA program.

In order to validate calculations, first collect total sampling time and average total flow rate data. Compute the total mass concentration for seven samples per 100 and check to see if errors are found; if errors are located, all values in that sample lot should be recalculated. Investigate any total mass concentration values that are exceedingly high or low.

Data Reporting and Interpretation

Detailed information on reporting and interpretation of PM₁₀ data with respect to the attainment of the NAAQS are fully covered in 40 CFR Part 50, Appendix K.

Section VII. Maintenance

Preventive maintenance is defined as a program of positive actions aimed to prevent failure of monitoring and analytical systems. The overall objective of a routine preventive maintenance program is to increase measurement system reliability and to provide for more complete data acquisition.

Maintenance Procedures

An alcohol-based general-purpose cleaner, cotton swabs, a small soft-bristle brush, paper towels, distilled water, and miscellaneous hand tools are required maintenance supplies for dichotomous samplers. A compressed air source is recommended, but not required.

The sampling module of the dichotomous sampler consists of the sampler inlet and the virtual impaction assembly. Detailed instructions for disassembling and maintaining the sampler inlet and virtual impaction assembly are provided in Chapter 6.1.2 of the QA Handbook, Section 2.10.

It is also important to clean and maintain the control module. Be sure to unplug the power cord from its receptacle before removing or opening the front panel of the dichotomous control module. Detailed instructions for disassembling and maintaining the control module are provided in Chapter 6.1.3 of the QA Handbook, Section 2.10.

Refurbishing Dichotomous Samplers

Dichotomous samplers that have been operated in the field for extended periods may require major repairs or complete refurbishment. In these cases, the manufacturer's instrument manual must be referred to before work is undertaken. A dichotomous sampler that has been subject to major repairs or refurbishment must be leak-checked and calibrated prior to sample collection.

Section VIII. Auditing Procedures

The operating agency must perform QA audits and process evaluations to determine the accuracy of the PM₁₀ monitoring system and, hence, the data it produces. The primary goal of an auditing program is to identify system errors that may result in suspect or invalid data. The efficiency of the monitoring system (i.e., labor input vs. valid data output) is contingent upon effective QA activities.

Audit Guidelines

There can be no special preparation or adjustment of the system to be audited. The audit must be conducted by an individual with a thorough knowledge of the instrument or process being evaluated who is NOT the routine operator. Accurate, calibrated, NIST-traceable standards must be used. Audit documentation information, including calibration information and collected audit data, must be used.

Types of Audits

The following section presents audit procedures specific to commercially available dichotomous samplers that operate at an actual total flow of 16.7 L/min and a coarse flow of 1.67 L/min. Audit techniques may vary between different models of samplers due to differences in required flow rates and the sampler's sampling configuration.

A detailed description of the flow rate performance audit is presented in Chapter 7.1 of the QA Handbook, Section 2.10.

A systems audit is an onsite inspection and review of the quality of the total measurement system (sample collection, sample analysis, data processing, etc.). This audit is normally conducted at the startup of a new monitoring system and as appropriate thereafter. Chapters 7.2.1 and 7.2.2 of the QA Handbook, Section 2.10, present systems audit procedures for evaluating data processing and laboratory operations.

It is recommended that data processing be audited soon after the original calculations have been performed. This allows corrections to be made immediately and also allows for possible retrieval of additional explanatory data from field personnel when necessary. A minimum frequency of seven samples per 100 (minimum of four per lot) is recommended.

A performance audit of the microbalances used to weigh dichotomous filters would require the use of ASTM Class 1 standard weights. Note that microbalances are extremely delicate instruments and should not be operated by inexperienced personnel.

To perform a performance evaluation of the filter weighing process, first review the maintenance and calibration log for each balance. Review QC data records for the filter-weighing process and ensure that appropriate QC activities have been performed and documented. Then, randomly select and have the balance operator reweigh several filters (number dependent on group size) from the group. Record the original values and the audit weights for these filters on the audit form. Calculate the weight difference for each filter, then forward the audit data to the laboratory supervisor for review.

Note that, for unexposed filters, the difference should be less than $\pm 20 \mu\text{g}$ (0.020 mg).

Section IX. Assessment of Monitoring Data for Precision and Accuracy

Precision

One or more monitoring sites within the reporting organization are selected for duplicate collocated sampling as follows: for a network of 1 to 5 sites, 1 site is selected; for a network of 6 to 20 sites, 2 sites are selected; and for a network of more than 20 sites, 3 sites are selected. Collocated PM_{10} samplers being used for assessment of precision should generally be of the same type. The two collocated samplers must be within 4 m of each other, but at least 2 m apart to preclude air flow interference. Each duplicate sampler must be operated concurrently with its associated primary sampler at least once a week. The measurements from both samplers at each collocated sampling site are reported. The percentage differences in measured concentrations ($\mu\text{g}/\text{m}^3$) between the two collocated samplers are used to calculate precision as described in 40 CFR Part 58, Appendix A.

Accuracy

Each calendar quarter, audit the flow rate of at least 25% of the PM_{10} samplers such that each PM_{10} sampler is audited at least once per year. If there are fewer than four PM_{10} samplers within a reporting organization, randomly reaudit one or more samplers so that one sampler is audited each calendar quarter.

The accuracy of the dichotomous sampler method in the measurement of PM_{10} is assessed by auditing the performance of the sampler (at its specified flow rate) as described in Chapter 7.1 of the QA Handbook, Section 2.10. Both the audit flow rate and the corresponding sampler flow rate are reported. The percentage differences between these flow rates are used to calculate accuracy as described in 40 CFR Part 58, Appendix A.

Section X. Recommended Standards for Establishing Traceability

Two factors are essential for attainment of data of the desired quality: (1) the measurement process must be under statistical control at the time of the measurement, and (2) the combination of systematic errors and random variation (measurement errors) must yield a suitably small uncertainty. Evidence of good quality data requires the performance of QC checks, independent audits of the measurement process, careful documentation of data, and the use of equipment and instrumentation that can be traced to an appropriate primary standard.

Laboratory Microbalance

ASTM Class 1, 1.1, or 2 weights are recommended for the laboratory microbalance calibration.

Flow Rate Transfer Standard

A positive-displacement primary standard or laminar flow element is recommended for calibrating the flow rate transfer standard that is used to calibrate the dichotomous sampler.

Transfer Standard Used to Audit Dichotomous Flow Rate Calibration

A positive-displacement primary standard is recommended for calibrating the transfer standard used to audit the dichotomous flow rate calibration.

In addition, an elapsed time meter should be checked semiannually against a timepiece accurate to within 15 min/day, and accuracy checks of thermometers, barometers, stopwatches, and similar equipment should be conducted at regular intervals against standards of known accuracy and NIST traceability.