

Introduction

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-h 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 percent (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 document; dichotomous samplers are discussed in *Quality Assurance Guidance Document* 2.10.

An HV PM₁₀ sampler consists of two basic components: a specially designed inlet that transmits only those particles <10 μm in diameter and a flow-control system capable of maintaining a constant flow rate within the design specifications of the inlet. Currently, two types of HV PM₁₀ inlets are available. They are distinguishable by their method 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. Two common types of flow-control systems (base units) are also available. One is equipped with a mass-flow-control (MFC) system; the other is equipped with a volumetric-flow-control (VFC) system. Because the calibration and standard operating procedures differ considerably between these two types of flow-control systems, this document presents procedures that are control-system-specific. Either type of inlet can be used with either the MFC or VFC system.

Impaction Inlet

Figure 1 is a schematic drawing showing the basic elements of an impaction HV PM₁₀ inlet. The symmetrical design of the 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

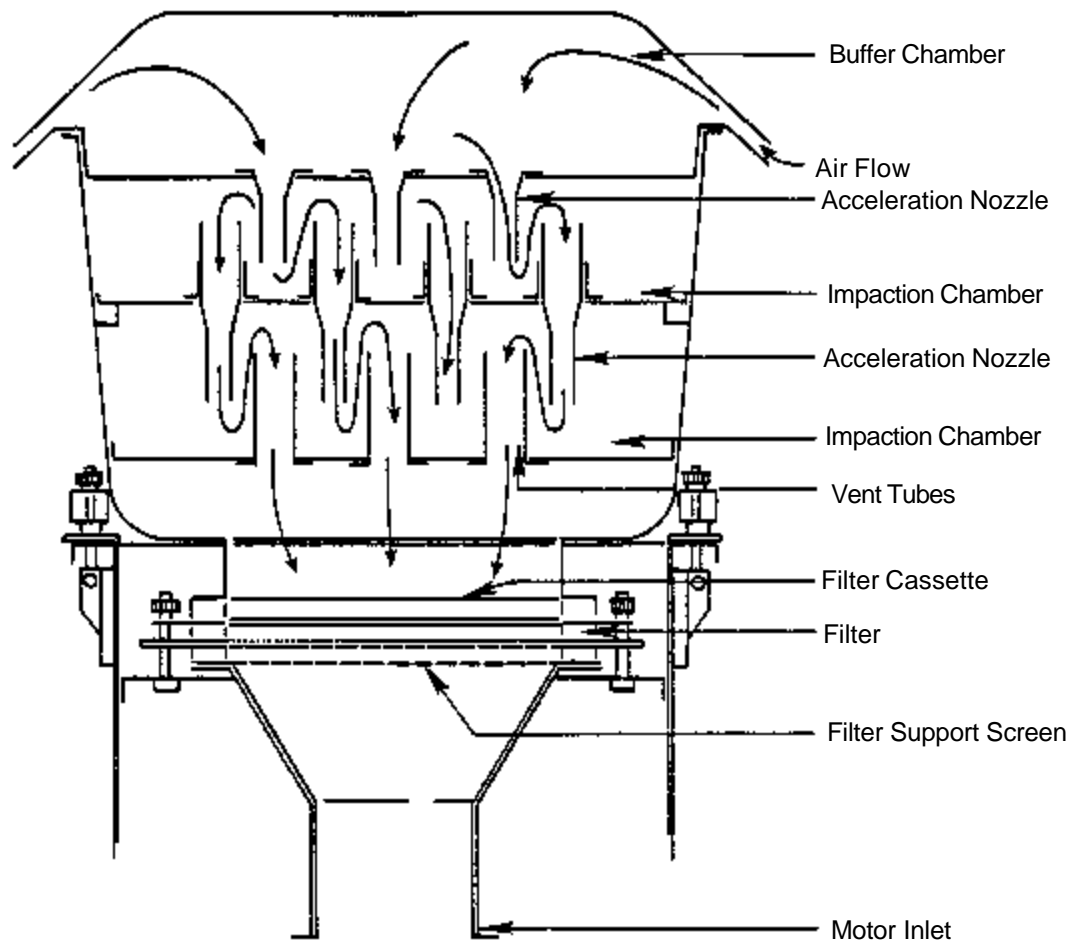


Figure 1. Schematic diagram of an impaction inlet.

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. Because air velocities are critical to maintain the correct particle size cutpoint within the inlet, maintaining the correct flow rate through the inlet is important. This flow rate is specified by the manufacturer in the instruction manual. For example, the flow rate for one popular impaction inlet is $1.13 \text{ m}^3/\text{min}$.

Cyclonic Inlet

Figure 2 is a schematic drawing of a cyclonic HV PM_{10} inlet. The omnidirectional cyclone used for fractionation in this 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., PM_{10} fraction) ultimately to deposit on a filter for subsequent analysis. As with the impaction inlet, control of air velocities in the cyclonic inlet is critical to maintain the correct particle size cutpoint. Maintaining the correct volumetric flow rate through the inlet is important. This flow rate is specified by the manufacturer in the instruction manual. For example, as in the case of the impaction inlet, a popular cyclonic inlet also has a flow rate of $1.13 \text{ m}^3/\text{min}$.

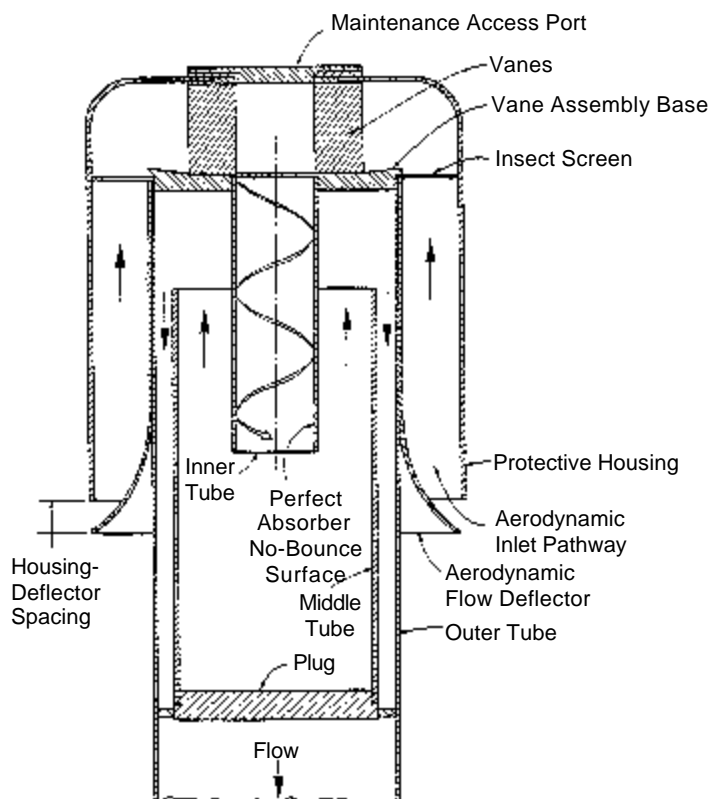


Figure 2. Schematic diagram of a cyclonic inlet.

Mass-Flow-Control (MFC) System

The flow rate in a 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. The controlled flow rate can be changed by an adjustment knob on the flow controller.

Volumetric-Flow-Control (VFC) System

A 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.

Method Highlights

The procedures provided in this document are designed to serve as guidelines for the development of

quality assurance (QA) programs associated with the operation of an HV PM₁₀ sampler. Because recordkeeping is a critical part of QA activities, several data forms are included to aid in the documentation of data.

The tables and figures included in some sections summarize the material covered. The material covered in this document is summarized below:

Section 1, Procurement of Equipment and Supplies, includes recommended procurement procedures, equipment selection criteria, and minimum accuracy requirements. It also provides an example of a permanent procurement record.

Section 2, Calibration Procedures, provides detailed calibration procedures for the HV PM₁₀ sampler. Table 2-1 provided in this section summarizes acceptance limits and gives references for the calibration procedures of associated monitoring equipment used in a PM₁₀ sampling program.

Section 3, Field Operations, provides detailed procedures for filter installation and recovery, sample handling, and data documentation. It also includes procedures for the field flow-rate calibration check. Complete documentation of background information during sampling is one of several QA activities that are important to future data validation; particularly important are any unusual conditions existing during sample collection. Such conditions should be noted.

Section 4, Filter Preparation and Analysis, presents important considerations for the handling, integrity, identification, equilibration, and weighing of filters. A high-quality microquartz filter is recommended. This section also briefly describes minimum laboratory QC procedures. The analytical balance must be calibrated annually, and the filters must be equilibrated in a controlled environment.

Section 5, Calculations, Validations, and Reporting of PM₁₀ Data, presents calculations for determining PM₁₀ mass concentrations and minimum data validation requirements. The final data review and validation, including standardized reporting procedures, are all important parts of a QA program. Independent checks of the data and calculations are required to ensure that the reported data are both accurate and precise.

Section 6, Maintenance, recommends periodic maintenance schedules to ensure that the equipment is capable of performing as specified. The objective of a routine maintenance program is to increase measurement system reliability.

Section 7, Auditing Procedures, presents independent audit activities that provide performance checks of flow-rate measurements and data processing. An analytical process evaluation and a system audit checklist are also provided. Independent audits evaluate data validity.

Section 8, Assessment of Monitoring Data for Precision and Accuracy, describes the assessment procedures for determining the accuracy and precision of the data. The precision check is performed by using collocated samplers.

Section 9, Recommended Standards for Establishing Traceability, discusses the traceability of calibration equipment to established standards of higher accuracy. Such traceability is a prerequisite for obtaining accurate data.

Section 10 contains the pertinent references used to prepare this document.

1.0 Procurement of Equipment and Supplies

The establishment of an ambient PM_{10} air monitoring network requires the procurement of specialized equipment and supplies for field operations and subsequent filter analysis. Information in this section has been provided to assist the agency in selecting the proper equipment. Section 1.1 presents minimum sampling equipment necessary to conduct field operations. Recommended laboratory instrumentation is presented in Section 1.2.

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. Figure 1.1 is an example of such a log. This log will serve as a permanent record for procurements and provide fiscal projections for future programs. It will also help to provide a continuity of equipment and supplies. Table 1-1 lists the major equipment needed, how it should be tested, suggested acceptance limits, and actions to be taken if acceptance limits are not met.

1.1 Procurement Prerequisites—Field Operations

1.1.1 HV PM_{10} 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 PM_{10} 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 PM_{10} . The cost of HV PM_{10} samplers will vary by manufacturer and the options chosen (i.e., continuous flow recorder, timer).

Item	Description	Qty	PO #	Vendor	Date		Cost	Initials	Accept/Reject	Comments
					Ord.	Rec'd				
Gaskets	Motor	5	B549	Lamb	10/1/88	11/3/88	17.35	DBP	A	—
Pens	Record.	15	B550	Dickson	10/1/88	10/25/88	28.95	DBP	A	—

Figure 1.1. Example procurement log.

TABLE 1-1. ACCEPTANCE TEST AND LIMITS FOR PROCUREMENT OF EQUIPMENT AND SUPPLIES

Equipment	Acceptance check	Acceptance limits	Action if requirements are not met
Field operations			
Sampler	Sampler complete; no evidence of damage. Model designated as reference or equivalent method	Specifications outlined in 40 CFR Part 50, Appendix. J	Reject sampler
Calibration quality assurance/quality control (QA/QC) supplies	Check against National Institute of Standards and Technology (NIST)-traceable standards	Within accuracy limits presented in text	Adjust or reject
Laboratory operations			
Filters	Meets requirements. Filter undamaged and suitable for sampling	Specifications outlined in 40 CFR Part 50, Appendix. J. Compatible with individual samplers	Reject filters
Filter handling materials	No evidence of damage	Allows for minimum filter damage and loss of particles	Reject materials or improve method for transporting filters
Lab equipment and instrumentation	Check against American Society for Testing and Materials (ASTM) or NIST-traceable standards	Within accuracy limits presented in text	Adjust or reject

An in-house inventory of general maintenance supplies and replacement parts is recommended. These include various hand tools; faceplate, motor, and filter cassette gaskets; general all-purpose cleaner; penetrating oil; distilled water; **disposable laboratory wipers**; soft brush; and cotton swabs. Spare parts for the sampler may be supplied by the manufacturer or many of them may be purchased locally.

1.1.2 Calibration Equipment

Calibration activities require specialized equipment that will not necessarily be used in routine monitoring. At a minimum, the following equipment is required:

- **A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC 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. For laboratory measurements, a Fortin-type, mercury-column barometer is appropriate. For field measurements, a portable, aneroid barometer (e.g., a climber's or engineer's altimeter) is appropriate.

- 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 ± 2 percent 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.). 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.).
- Spare recorder charts (if the sampler is equipped with a continuous-flow recorder), miscellaneous handtools, and 51-mm (2-in.) duct tape.

1.1.3 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 percent of the NIST-traceable primary standard. This orifice transfer standard may be the same one that is used for calibration.

1.1.4 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.

1.2 Procurement Prerequisites—Laboratory Operations

1.2.1 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). These filters may be brittle, which makes them difficult to handle, and they may be more expensive than glass-fiber filters. The operating agency should determine the relative importance of certain filter evaluation criteria (e.g., physical and chemical characteristics, ease of handling, cost). Table 4-1, Section 4, presents basic criteria that must be met regardless of the filter type selected.

Gloves should be worn during the handling of all filters, and touching should be limited to the edges. Gloves will help to eliminate interference from body oils, hygroscopic particles, and static electricity

buildup during weighing operations.

1.2.2 Filter Protection

Postsampling particle loss and filter damage will occur if proper handling procedures are not followed. 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 storage of exposed filters, however, cassettes may prove to be expensive and unwieldy.

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. The folder can be printed to serve as a data sheet for proper documentation during sampling. A sufficient number of protective envelopes must be available to provide protection for the filters during transportation to and from the monitoring location and for storage of the exposed filters for subsequent gravimetric or chemical analysis.

1.2.3 Laboratory Equipment

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.

Prior to their weighing, filters must be conditioned in an environment where the mean relative humidity (RH) is between 20 and 45 percent and controlled within ± 5 percent, and mean temperature is between 15 and 30 EC and controlled within -3 EC. Temperature and RH readings must be recorded daily, either manually or by hygrothermograph. Among the options available to ensure compliance with the reference method specifications are a sling psychrometer and a calibrated precision thermometer (capable of measuring temperatures over a range of 10 to 30 EC [283 to 303 K] to the nearest **0.1 EC**). **This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.**

It is impossible to present a complete procurement package that would provide for unexpected contingencies in any monitoring network. Each agency must determine the extent of its in-house inventory and the items that should be ordered before sampling can begin. The agency must also be prepared to order any additional equipment required over and above that outlined in this section.

1.2.4 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. The recalibration frequency is to be determined from records of previous recalibrations of these standards.

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. The current masses of the working standards as compared to the laboratory primary standards should be recorded in a laboratory notebook and should be used to check the calibration of the analytical balance.

Always use smooth, nonmetallic forceps for handling mass reference standards. The standards are handled only with these forceps, which are not used for any other purpose. Mark these forceps to distinguish them from the forceps used to handle permeation devices. Handle the standards carefully to avoid damage that may alter their masses.

2.0 Calibration Procedures

Before a PM₁₀ 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 PM₁₀ 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.

Like a total suspended particulate (TSP) sampler, an HV PM₁₀ sampler is essentially a device that pulls a sample of ambient air through a filter during a measured time period and collects particulate mass on the filter. Thus, to establish ambient PM₁₀ concentrations, three independent determinations are made: air volume flow rate, sampling time, and particulate mass. The objective of this section is to provide technically sound flow-rate calibration procedures for both the MFC and VFC HV PM₁₀ samplers.

Note: Calibration procedures for samplers that have been designated as reference methods will also be provided by the manufacturer in the operation or instruction manual. These manufacturer-provided calibration procedures are likely to be more specific and detailed than the more generic procedures presented herein. Also, minimum calibration requirements for the determination of particulate mass and sample time are presented in Table 2-1.

Although it concerns TSP samplers rather than HV PM₁₀ samplers, Smith et al. (1978) provide useful information concerning flow-rate calibration procedures that is applicable to PM₁₀ samplers. The American Gas Association (1992) provides useful information concerning positive displacement, standard volume meters (e.g., Roots[®] Meters).

The following aspects of PM₁₀ monitoring are discussed in this section:

- A discussion of volumetric and mass flow measurements and their applicability in a PM₁₀ monitoring program (Section 2.1)
- A certification procedure for an orifice flow-rate transfer standard (Section 2.2)
- Basic calibration procedure specific to an MFC HV PM₁₀ sampler (Section 2.3)
- Basic calibration procedure specific to a VFC HV PM₁₀ sampler (Section 2.4)
- Calibration frequency requirements (Section 2.5).

Table 2-1 presents minimum accuracy requirements for equipment that is used in PM₁₀ sampling.

Note: Consistency of temperature and barometric pressure units is required. It is recommended that all temperatures be expressed in Kelvin ($K = EC + 273$). It is also recommended that all barometric pressures be expressed in either millimeters (mm) mercury (Hg) or kilopascal (kPa) (but do not mix the two units). Take care to avoid calibrating a PM₁₀ sampler using one set of units and then performing sample calculations using another set of units.

TABLE 2-1. EQUIPMENT CALIBRATION REQUIREMENTS

Equipment	Acceptance limits	Frequency and method of measurement	Action if requirements are not met
Sampler	Indicated flow rate = true flow rate $\pm 4\%$.	Calibrate with certified transfer standard upon receipt, after maintenance on sampler, and any time audits or flow checks deviate more than $\pm 7\%$ from the indicated flow rate or $\pm 10\%$ from the design flow rate.	Recalibrate.
Associated equipment			
Analytical balance	Indicated weight = true weight ± 0.0005 g.	Gravimetrically test-weigh at purchase and during periodic calibration checks; use three to five standard weights covering normal range of filter weights.	Have balance replaced and/or recalibrated.
Mass reference standards	Individual tolerance no greater than 25 μg .	Working standards checked every 3 to 6 months against laboratory primary standard.	Obtain proper standards.
Relative humidity (RH) indicator ^a	Indicator reading = psychrometer reading $\pm 6\%$ RH.	Compare with readings of wet/dry bulb psychrometer on receipt and at 6-month intervals.	Adjust or replace to attain acceptance limits.
On/off timer	± 30 min/24 h.	Check at purchase and routinely on sample recovery days.	Adjust or repair.
Elapsed-time meter ^b	± 2 min/24 h.	Compare with a standard timepiece of known accuracy at receipt and at 6-month intervals.	Adjust or replace time indicator to attain acceptance limits.
Flow rate transfer standard (orifice device)	Indicated flow rate (from previous calibration) = true flow rate $\pm 2\%$.	Check at receipt and at 1-yr intervals against positive-displacement standard volume meter; recalibrate or replace orifice unit if damage is evident.	Adopt new calibration curve.

^aThe RH indicator is required for filter equilibration before weighing (see Section 4.3).

^bOptional with a continuous flow rate recorder.

2.1 Discussion of Flow-Rate Measurement and General Aspects of PM₁₀ Sampler Calibration

An HV PM₁₀ sampler consists of two basic components: a specially designed inlet and a flow-rate controlling system. The particle size discrimination characteristics of both the impaction and cyclonic type inlets depend critically on maintaining certain air velocities within the inlet; a change in velocity will result in a change in the nominal particle size collected. For this reason, it is imperative that the flow rate through the 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 ± 10 percent. For example, if the design flow rate is specified as 1.13 m³/min with no tolerance given, the acceptable flow-rate range would be 1.02 to 1.24 m³/min.

Because it is critical to continually verify that the HV PM₁₀ 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-h 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 to determine the sampler flow rate, provided that actual 24-h average temperatures at the site are not likely to deviate unreasonably from the seasonal average temperature used for the site.

The calibration procedures in this section 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 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 and is expressed in micrograms per actual cubic meter ($\mu\text{g}/\text{m}^3$).**

2.2 Certification of an Orifice Transfer Standard

The following certification procedure 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 PM₁₀ calibration, and other plates may produce flow rates substantially outside the design flow-rate range of the commercially available HV PM₁₀ 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.

2.2.1 Orifice Calibration Procedure

1. Assemble the following equipment:
 - Orifice transfer standard (i.e., top-hat orifice, variable orifice, or ReF device) to be calibrated.

- Water or oil manometer with a 0- to 400-mm (0- to 16-in.) range and minimum scale divisions of 2 mm (0.1 in.). This manometer should be permanently associated with the orifice transfer standard.
- Variable voltage transformer (or a set of resistance plates, if a variable voltage transformer is not available).
- Calibrated positive displacement, standard volume meter (such as a Roots[®] Meter) traceable to NIST.

Note: As they are sold, standard volume meters may not be traceable to NIST. Traceability can be established directly through NIST, a **State weights and measures laboratory, a National Voluntary Laboratory Accreditation Program (NVLAP)-accredited calibration laboratory,** or indirectly through the meter manufacturer's repair department. Periodic recertification is not normally required under clean service conditions unless the meter has been damaged and must be repaired. In general, damage will be indicated by a substantial (e.g., 50-percent) increase in the pressure drop across the meter. The meter's traceability certificate should contain a graph of the pressure drop as a function of flow rate. See American Gas Association (1992) for additional information concerning standard volume meters.

- High-volume air mover (e.g., a blower motor from a HV sampler).
 - Accurate stopwatch.
 - Mercury manometer, with a 0- to 200-mm (0- to 8-in.) range and minimum scale divisions of 2 mm (0.1 in.).
 - **A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.**
 - Barometer, 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 referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.
 - Orifice transfer standard certification worksheet such as shown in Figure 2.1.
2. Record on the certification worksheet the standard volume meter's serial number; orifice transfer standard's type, model, and serial number; the person performing the certification; and the date.
 3. Observe the barometric pressure and record it as P_a .

Orifice Transfer Standard Certification Worksheet						
Date 7/22/97 Standard Volume Meter S/N: 7464318 T _a : 22.6 K 295.6						
Operator: G. Pratt Orifice S/N: 2 P _a : 756.2 mm Hg						
Plate or Volts AC	Initial Volume	Final Volume	ΔVol	ΔTime (min)	ΔHg (mm)	ΔH ₂ O (in.)
1	5692	5695	3.0	3.41	18	3.0
2	5698	5701	3.0	2.75	25	4.5
3	5705	5708	3.0	2.34	32	6.0
4	5712	5715	3.0	2.00	42	8.0
5	5719	5722	3.0	1.88	48	9.0
DATA TABULATION						
V _{std}	(x-axis) Q _{std}	(y-axis) [ΔH ₂ O (P _a /T _a)] ^{1/2*}	V _a	(x-axis) Q _a	(y-axis) [ΔH ₂ O (T _a /P _a)] ^{1/2}	
			2.929	0.859	1.083	
			2.901	1.055	1.327	
			2.873	1.228	1.532	
			2.833	1.417	1.769	
			2.810	1.495	1.876	
m =			m =	1.2390		
b =			b =	0.0172		
r =			r =	0.9999		
CALCULATIONS						
V _{std} = ΔVol [(P _a - ΔHg)/760] (298/T _a)*			V _a = ΔVol [P _a - ΔHg]/P _a			
Q _{std} = V _{std} /ΔTime*			Q _a = V _a /ΔTime			
y = mx + b			y = mx + b			
For subsequent flow rate calculations:						
Q _{std} = {[ΔH ₂ O (P _a /T _a)] ^{1/2} - b} {1/m}*			Q _a = {[ΔH ₂ O (T _a /P _a)] ^{1/2} - b} {1/m}			
*Note: For PM ₁₀ monitoring, a calibration curve corrected to standard conditions is unnecessary .						

Figure 2.1. Example orifice transfer standard certification worksheet.

4. Read the ambient temperature in the vicinity of the standard volume meter and record it as T_a ($K = EC + 273$).
5. Connect the orifice transfer standard to the inlet of the standard volume meter. Connect the mercury manometer to measure the pressure at the inlet of the standard volume meter. Connect the orifice (water or oil) manometer to the pressure tap on the orifice transfer standard. Connect a high-volume air mover to the outlet side of the standard volume meter. Make sure that all gaskets are present and are in good condition.
6. Check that the standard volume meter table is level and adjust its legs if necessary.
7. Check for leaks by temporarily clamping both manometer lines (to avoid fluid loss) and blocking the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Start the high-volume air mover and note any change in the standard volume meter's reading.

Caution: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime. It can raise temperatures to the point of defeating the electrical insulation which could result in fire or electric shock to the user.

The **standard volume meter dial** reading should remain constant. If the reading changes, locate any leaks by listening for a whistling sound and/or retightening all connections, making sure that all gaskets are properly installed.

Note: The leak-test procedure described above is one of several alternate procedures that may be used. Operating agencies may develop their own procedures.

8. After satisfactorily completing the leak check, turn off the high-volume air mover, unblock the orifice, and unclamp both manometer lines. Zero the water and mercury manometers by sliding their scales so that their zero lines are even with the bottom of the menisciuses.
9. Turn on the high-volume air mover. Adjust the variable voltage transformer to achieve an appropriate flow rate (i.e., within the approximate range of 0.9 to 1.3 m³/min [32 to 46 ft³/min]). If necessary, use fixed resistance plates or the variable resistance valve to achieve the appropriate flow rate. The use of fixed resistance plates is discouraged (but not prohibited) because the leak check must be repeated each time a plate is installed.
10. After setting a flow rate, allow the system to run for at least 1 min to attain a constant motor speed. Observe the standard volume meter dial reading and simultaneously start the stopwatch. Error in reading the meter dial can be minimized by starting and stopping the stopwatch on whole number dial readings (e.g., 4091.00).
11. Record the initial volume that the meter dial was indicating when the stopwatch was started. Maintain this constant flow rate until at least 3 m³ of air has passed through the standard volume meter. Record the standard volume meter's inlet pressure manometer reading as $\ddot{A}H_g$, and the orifice manometer reading as $\ddot{A}H_2O$. Be sure to indicate the correct units of measurement. If $\ddot{A}H_2O$ changes significantly during the run, abort the run and start again.

12. When at least 3 m³ of air has passed through the system, note the standard volume meter reading and simultaneously stop the stopwatch. Record the final volume that the meter dial was indicating when the stopwatch was stopped. Record the elapsed time ($\ddot{A}Time$) indicated on the stopwatch.
13. Calculate the volume measured by the standard volume meter ($\ddot{A}Vol$) using Equation (1) and record

$$\ddot{A}Vol = \text{Final volume} - \text{Initial volume} \quad (1)$$

14. Correct this volume to ambient atmospheric pressure

$$V_a = \ddot{A}Vol(P_a - \ddot{A}Hg)/P_a \quad (2)$$

where

- V_a = actual volume at ambient barometric pressure, m³
- $\ddot{A}Vol$ = actual volume measured by the standard volume meter, m³
- P_a = ambient barometric pressure during calibration, mm Hg (or kPa)
- $\ddot{A}Hg$ = differential pressure at inlet to volume meter, mm Hg (or kPa).

15. Calculate the actual volumetric flow rate (m³/min)

$$Q_a = V_a/\ddot{A}Time \quad (3)$$

where

- Q_a = actual volumetric flow rate through the orifice, m³/min
- V_a = actual volume at ambient barometric pressure, m³
- $\ddot{A}Time$ = elapsed time, min.

16. Repeat Steps 9 through 15 for at least four additional flow rates within the approximate range of 0.9 to 1.3 m³/min (32 to 46 ft³/min). At least five evenly distributed different flow rates are required, and at least three flow rates must be in the specified inlet flow-rate interval (1.02 to 1.24 m³/min [36 to 44 ft³/min]). Better calibration precision may be obtained by running additional flow rates or repeating the flow rates.
17. For each flow, compute $[(\ddot{A}H_2O)(T_a/P_a)]^{1/2}$, and plot these values against the corresponding values of Q_a . Draw the orifice transfer standard's certification curve. For the model $[(\ddot{A}H_2O)(T_a/P_a)]^{1/2} = m(Q_a) + b$, calculate the linear least-squares regression's slope (m), intercept (b), and correlation coefficient (r) of the certification relationship. Plot the regression line on the same graph as the calibration data. A certification graph should be readable to 0.02 m³/min.
18. If any calibration point does not fall within ± 2 percent of the line, rerun that point, recalculate, and replot.
19. For subsequent use of the orifice transfer standard, calculate Q_a from the calibration relationship as:

$$Q_a (\text{orifice}) = \{[(\ddot{A}H_2O)(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

- Q_a (orifice) = actual volumetric flow rate as indicated by the orifice transfer standard,
m³/min
- ΔH_2O = pressure drop across the orifice, mm (or in.) H₂O
- T_a = ambient temperature during use, K (K = EC + 273)
- P_a = ambient barometric pressure during use, mm Hg (or kPa)
- b = intercept of the orifice calibration relationship
- m = slope of the orifice calibration relationship.

2.2.2 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.

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

The MFC sampler calibration procedure presented in this section relates known flow rates to the pressure in the exit orifice plenum. The known flow rates are determined by an orifice transfer standard that has been certified according to the procedure presented in Section 2.2.1. The exit orifice plenum is the area within the motor housing (below the motor unit) that contains the air flow just before it is exhausted to the atmosphere through the exit orifice. It is recommended that this exit orifice plenum pressure be measured with a 25-cm (10-in.) water or oil manometer. It is further recommended that each sampler should have its own dedicated manometer, which can be conveniently mounted to the side of the sampler housing. Other types of pressure measurement devices may be used provided they have comparable accuracy. However, the 4-in. continuous pressure (flow) recorders of the type often supplied with HV PM₁₀ samplers are generally not sufficiently accurate and are **not recommended** for quantitative sampler pressure or flow measurements. These flow recorders should be used only for nonquantitative determination that the flow was approximately constant and uninterrupted over the sample period. The flow recorder may be connected in parallel with the manometer or other pressure measuring device, using a tee or “Y” tubing connection.

Note: Because flow recorders are still in wide use for quantitative flow measurements, the calibration procedure includes specific instructions for quantitatively calibrating a flow recorder. These flow recorder instructions are enclosed in brackets [] and should be used only when a manometer or other pressure measurement device cannot be used.

For this MFC calibration procedure, the following conditions are assumed:

- The HV PM₁₀ sampler is equipped with a mass flow controller to control its sample flow rate.
- The sampler flow rate is measured by measuring the exit orifice plenum pressure, using a water or oil manometer [or, if necessary, a continuous flow-recording device using square-root-scale chart

paper].

- The sampler inlet is designed to operate at an actual volumetric flow rate of 1.13 m³/min, and the acceptable flow-rate range is ±10 percent of this value.
- The transfer standard for the flow-rate calibration is an orifice device equipped with either a series of resistance plates or an integral variable-resistance valve. The pressure drop across the orifice is measured by an associated water or oil manometer.
- The sampler will be calibrated in actual volumetric flow-rate units (Q_a), and the orifice transfer standard is also calibrated in Q_a , as specified in Section 2.2.

2.3.1 Calibration Equipment

1. Orifice transfer standard with calibration traceable to NIST (see Section 2.2).

Note: The predrilled resistance plates supplied with the orifice transfer standard may have to be modified for the calibration of PM₁₀ samplers. The holes in the plates may have to be enlarged or additional holes may have to be drilled to obtain flow rates within the acceptable range.

Alternatively, new resistance plates could be purchased if they are available.

2. 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.).
3. 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.) for measurement of the sampler exit orifice plenum pressure. This manometer should be associated with the sampler.

Note: Manometers used for field calibration may be subject to damage or malfunction and should thus be checked frequently.

4. **A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.**
5. 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 referenced within ±5 mm Hg of a barometer of known accuracy at least annually.
6. Miscellaneous handtools, calibration data sheets or station logbook, and 51-mm (2-in.) duct tape.

2.3.2 Multipoint Flow-Rate Calibration Procedure—MFC Sampler

The procedure presented here is basic and generic, given the assumptions **for the MFC calibration procedure listed above**. 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.

In-house equipment and personnel, procedural simplicity and uniformity, and subsequent data applications should be considered in establishing the specific, detailed calibration procedure to be implemented.

Caution: Do not attempt to calibrate the MFC sampler under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of the pressure variations.

1. Set up the calibration system as recommended by the manufacturer. Figure 2.2 illustrates the calibration configuration of a typical MFC sampler. MFC samplers are calibrated without a filter or filter cassette installed.
2. Disconnect the motor from the flow controller and plug it directly into a stable line voltage source (i.e., the sampler's on-off timer, if so equipped, or other source of the line voltage).
3. Install the orifice transfer standard and its adapter faceplate on the sampler. Check all gaskets and replace any questionable ones.

Caution: Tighten the faceplate nuts evenly on alternate corners to properly align and seat the gaskets. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

4. Select the first calibration flow rate and install the appropriate resistance plate or adjust the variable orifice valve. At least four flow rates are required to define the calibration relationship.

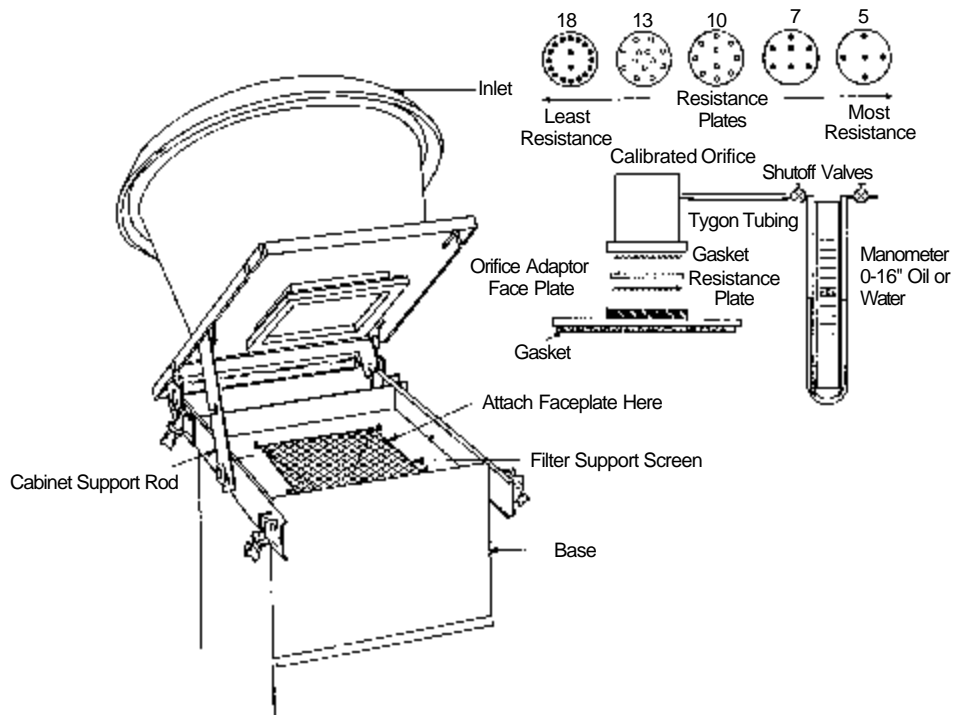


Figure 2.2. MFC sampler calibration equipment.

At least three flow rates should be within (or nearly within) the acceptable flow-rate range (i.e., 1.02 to 1.24 m³/min) for the sampler inlet. For resistance plate orifices, make sure that the orifice and resistance plate gaskets are in place and the orifice is not cross-threaded on the faceplate.

5. **Conduct a leak test by blocking** the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Seal the pressure port with a rubber cap or similar device. Turn on the sampler.

Caution: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime. It can raise temperatures to the point of defeating the electrical insulation, which could result in fire or electric shock to the user.

Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. A leak-free system will not produce an upscale response in the sampler's exit orifice manometer or flow recorder. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by cross-threading of the orifice transfer standard on the faceplate. All leaks must be eliminated before proceeding with the calibration. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

Note: The leak test procedure described above is one of several alternate procedures that may be used. Operating agencies may develop their own procedures.

6. Inspect the connecting tubing of both manometers for crimps or cracks. Open the manometer valves (if present) and blow gently through the tubing, watching for the free flow of the fluid.

Adjust the manometers' sliding scales so that their zero lines are at the bottom of the menisci. Connect the orifice transfer standard manometer to the orifice transfer standard. Connect the sampler's exit orifice manometer [and the continuous flow recorder, if used] to the exit orifice plenum port. Ensure that one side of each manometer is open to atmospheric pressure. Make sure that the tubing fits snugly on the pressure ports and on the manometer.

7. [If a continuous flow recorder is to be used quantitatively in lieu of a manometer, record the site location, sampler S/N, date, and the operator's initials on the blank side of a clean recorder chart. Make sure the chart has a square-root scale. Open the front door of the sampler and install the clean recorder chart.]
8. Read and record the following parameters on the HV PM₁₀ data sheet. Figure 2.3 presents an example calibration data sheet for the MFC sampler.
 - Date, location, and operator's signature
 - Sampler S/N and model

MFC Sampler Calibration Data Sheet				
Station Location	Milford, NC		Date	10/15/97 Time 0900
Sampler Model	GMW	S/N	1297	Operator D. Palmer
P _a	762 mm Hg,	T _a	19.4 EC or 292.4 K,	Unusual conditions: None
P _s ^a	743 mm Hg,	T _s ^a	8.7 EC or 281.7 K,	
Orifice S/N	2		Orifice Calibration Date	7/22/97
Orifice calibration relationship: m = 1.2390 b = 0.0172 r = 0.9999				

Plate Number	Total $\ddot{A}H_2O$ (in.)	X-Axis = Q _a (orifice) flow rate (m ³ /min) ^b	Sampler $\ddot{A}P_{ext}$ (in. H ₂ O) [or I for flow recorders] ^c	Y-Axis = Sampler $\ddot{A}P_{ext}$ ^c [or It for flow recorders] ^d
1	8.34	1.430	5.8	1.57
2	7.55	1.360	5.4	1.51
3	6.59	1.270	4.7	1.41
4	5.80	1.190	4.4	1.36
5	4.61	1.060	3.6	1.23

^aSeasonal average T_a and P_a

^bQ_a (orifice) = {[$\ddot{A}H_2O$ (T_a/P_a)]^{1/2} - b} {1/m}.

^c $\ddot{A}P_{ext}$ = { $\ddot{A}P_{ext}$ (T_a + 30)/P_a]^{1/2}.

^dIt = [I] [(T_a + 30)/P_a]^{1/2} if a flow recorder is used (and square root chart paper).

Sampler Calibration Relationship (Q_a on x-axis; $\ddot{A}P_{ext}$ or [it] on y-axis):

$\ddot{A}P_{ext}$ = m[Q_a(Orifice)] + b or it = m[Q_a(Orifice)] + b

m = **0.9137** b = **0.2629** r = **0.9979**

For subsequent calculation of sampler flow rate:

\overline{Q}_a = {[mean $\ddot{A}P_{ext}$ (T_{av} + 30)/P_{av}]^{1/2} - b} {1/m}

or \overline{Q}_a = {mean I [(T_{av} + 30)/P_{av}]^{1/2} - b} {1/m} if a flow recorder is used (and square root chart paper).

Today's sampler set point (SSP) **3.97** Seasonal SSP **4.00**

SSP = [P/(T + 30)] [m(1.13) + b]²
 or SSP = [P/(T + 30)]^{1/2} [m(1.13) + b] for flow recorders

Figure 2.3. Example MFC sampler calibration data sheet.

- Ambient barometric pressure (P_a), mm Hg or kPa
- Ambient temperature (T_a), K ($K = EC + 273$).
- Orifice S/N and calibration relationship.

Note: Sampler flowrates for subsequent sampling periods may require adjustment for day-to-day variations in T_a and P_a . When such adjustments are necessary, adjustment on an individual or daily basis is preferable. However, the seasonal average temperature (T_s) and the seasonal average pressure (P_s) may be incorporated into the sampler calibration to avoid daily adjustments. Consult the sampler's instruction manual for additional guidance.

Note: Consistency of temperature and barometric pressure units is required. It is recommended that all temperatures be expressed in Kelvin ($K = EC + 273$). 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. Ideally, the temperature of the air in the exit orifice plenum should be measured because it will be somewhat higher than ambient temperature. However, an adequate approximation of this temperature may be obtained by adding 30 K to the ambient temperature. This addition is incorporated in the calculations given in Section 2.3.3.

9. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min). Then, read and record the orifice transfer standard's manometer deflection, $\ddot{A}H_2O$ (in. H_2O), and the corresponding sampler's manometer deflection, $\ddot{A}_{P_{ex}}$ [or flow recorder chart reading, I].

Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 in. of clearance at the bottom for air flow and for the manometer tubing.

10. Install the other resistance plates or adjust the variable orifice value to obtain each of the other calibration flow rates and repeat Step 9 for each. At least four calibration flow rates are required, with at least three in the acceptable flow-rate range (i.e., 1.02 to 1.24 m^3/min).
11. Plot the calibration data on a sheet of graph paper as specified in Step 4 in Section 2.3.3.

Note: The data should be plotted in the field as the calibration is occurring, rather than afterwards back at the laboratory.

Repeat Step 9 for any data that are questionable on the plot. Running additional calibration points at differing flow rates or repeating the calibration points at the same flow rates is encouraged to improve the precision of the calibration.

12. Turn off the sampler and remove the orifice transfer standard.
13. Reconnect the sampler motor to the flow controller.
14. Perform the calibration calculations presented in Section 2.3.3. The data generated will be used to set the mass flow controller (Section 2.3.4) to a value that will result in optimal volumetric flow based on the seasonal average temperature and barometric pressure at the monitoring site.

2.3.3 Calibration Calculations

Gather together all the calibration data, including the orifice calibration information, the sampler calibration data sheet [and, if used, the flow recorder chart, which should graphically display the various calibration flow rates].

Note: These calculations should be done at the time of the calibration, rather than later. This approach will allow additional calibration points to be taken if questions arise about the data that have already been obtained.

1. Verify that the orifice transfer standard calibration relationship is current and traceable to an acceptable primary standard.
2. Calculate and record Q_a for each calibration point from the orifice calibration information and Equation (4):

$$Q_a (\text{orifice}) = \{[\Delta H_2O(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

Q_a (orifice) = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min

ΔH_2O = pressure drop across the orifice, mm (or in.) H_2O

T_a = ambient temperature during use, K ($K = EC + 273$)

P_a = ambient barometric pressure during use, mm Hg (or kPa)

b = intercept of the orifice calibration relationship

m = slope of the orifice calibration relationship.

3. Calculate and record the quantity $\dot{A}P_{\text{ext}}$ for each calibration point as:

$$\dot{A}P_{\text{ext}} = [\dot{A}P_{\text{ex}}(T_a+30)/P_a]^{1/2} \quad (5)$$

where

$\dot{A}P_{\text{ext}}$ = transformed manometer reading

$\dot{A}P_{\text{ex}}$ = sampler manometer reading, mm (or in.) H_2O

T_a = ambient temperature, K ($K = EC + 273$)

P_a = ambient barometric pressure, mm Hg (or kPa).

[If a continuous flow recorder is used quantitatively, calculate and record the quantity I_t as follows:

$$I_t = I[(T_a+30)/P_a]^{1/2} \quad (5a)$$

where

I_t = transformed flow recorder chart reading

I = flow recorder chart reading, arbitrary units on square root scale.]

Note: If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for I in Equation (5a).

4. On a sheet of graph paper, plot the calculated Q_a (orifice) flow rates on the x-axis vs. the transformed sampler manometer response, $\bar{\Delta P}_{ext}$ [or the transformed flow recorder reading, It] on the y-axis.

Because the determination of the sampler's average operational flow rate (Q_a) during a sample period depends on the ambient average temperature and pressure, use of a graphic plot of the calibration relationship is not recommended for subsequent data reduction. This plot is used only to visually assess the calibration points to see if any should be rerun.

Plot the regression line on the same graph paper as the calibration data. For the regression model $y = mx + b$, let $y = \bar{\Delta P}_{ext}$ and $x = Q_a$ (orifice) so that the model is given by:

$$\bar{\Delta P}_{ext} = m[Q_a \text{ (orifice)}] + b \quad (6)$$

[For the flow recorder, the model is:

$$It = m[Q_a \text{ (orifice)}] + b \quad (6a)]$$

Using a programmable calculator or a calculation data form, determine the linear regression slope (m), intercept (b), and correlation coefficient (r) and record them on the data sheet. A five-point calibration should yield a regression equation with a correlation coefficient of $r > 0.990$, with no point deviating more than $\pm 0.04 \text{ m}^3/\text{min}$ from the value predicted by the regression equation. Plot the regression line on the same graph paper that has the individual calibration points.

5. For subsequent sample periods, the sampler's average actual operational flow rate, \bar{Q}_a , is calculated from the calibration slope and intercept using Equation (7):

$$\bar{Q}_a = \frac{1}{m} \left[\bar{\Delta P}_{ex} (T_{av} / 30) / P_{av} \right]^{1/2} + b \quad (7)$$

where

- \bar{Q}_a = the sampler's average actual flow rate, m^3/min
- $\bar{\Delta P}_{ex}$ = average of initial and final sampler manometer readings, $(\Delta P_{ex_i} + \Delta P_{ex_f})/2$, mm (or in.) H_2O
- T_{av} = average ambient temperature for the sample period, K ($K = EC + 273$)
- 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,

$$\bar{Q}_a = \frac{1}{m} \left[\bar{I} (T_{av} / 30) / P_{av} \right]^{1/2} + b \quad (7a)$$

where

\bar{I} = average flow recorder reading for the sample period.]

If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for (I) in Equation (7a).

2.3.4 Mass Flow Controller Adjustment Procedure

Because the controlled flow rate of an MFC sampler is adjustable, it must be set to the proper flow rate for the inlet. The constant mass flow maintained by the MFC causes the actual volumetric flow rate through the inlet to fluctuate as the ambient temperature and barometric pressure change at the monitoring site. Normally, the range of these fluctuations is within the allowable tolerance limits for the inlet. However, the flow-rate set point of the mass flow controller must be correctly adjusted so that the deviations are “centered” with respect to the seasonal average temperature and barometric pressure at the site, not the temperature and pressure prevailing at the time of setting.

Set the mass flow controller as follows:

1. Determine the seasonal average temperature (T_s) and seasonal average pressure (P_s) at the site and record them on the calibration data sheet. (Determination of the number of “seasons,” i.e., the number of different seasonal average temperatures needed for the year, is left to the discretion of the local agency.)
2. Calculate and record on the sampler’s calibration data sheet the sampler set-point (**SSP**) manometer reading [or flow recorder reading].

$$SSP = [P_a/(T_a + 30)][m(1.13) + b]^2 \quad (8)$$

where

SSP = sampler set-point manometer reading, mm (or in.) H₂O
 P_a = ambient barometric pressure, mm Hg (or kPa)
 T_a = ambient temperature, K ($K = EC + 273$)
 m = slope of the sampler’s calibration relationship
1.13 = set-point flow rate (SFR), m³/min
 b = intercept of the sampler’s calibration relationship.

[For the flow recorder,

$$SSP = [m(1.13) + b] [P_a/(T_a+30)]^{1/2} \quad (8a)]$$

3. Repeat this calculation using T_s and P_s to obtain the seasonal SSP.
4. Visually check to make sure the motor is connected to the mass flow controller and the manometer is properly connected.
5. Install a clean filter (in a filter cassette) in the sampler according to the manufacturer’s instructions.

[If the continuous flow recorder is used quantitatively, install a clean chart and verify that the recorder is zeroed (i.e., the pen rests on the innermost circle of the chart).]

6. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min).
7. Following the manufacturer's instructions, adjust the mass flow controller until the manometer reading [or flow recorder response] indicates the SSP as calculated in Step 3.
8. Verify that the flow controller will maintain this flow rate for at least 10 min. Turn off the sampler.
9. The sampler can now be prepared for the next sample run day.

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

The VFC sampler calibration procedure presented in this section 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 (P_1) 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 this case, the sampler flow rate could be measured and calibrated using the exit orifice plenum pressure as described in Section 2.3. However, the use of the stagnation pressure generally provides a more accurate indication of sampler flow rate. Additionally, a continuous flow recorder may be connected to the exit orifice pressure tap for nonquantitative determination that the flow rate was constant and uninterrupted over the sample period.

It is recommended that the stagnation pressure be measured with a 0- to 1,000-mm (0- to 36-in.) oil or water manometer (to avoid the hazards of a mercury manometer).

It is further recommended that each sampler has its own dedicated manometer, which can be conveniently mounted to the side of the sampler housing. Other types of pressure measurement instruments may be used provided they have comparable accuracy. However, the 4-in. continuous pressure (i.e., flow) recorders often supplied with HV PM_{10} samplers are generally not sufficiently accurate and are **not recommended** for quantitative sampler pressure or flow-rate measurements.

The VFC sampler's flow control system is a choked-flow venturi. It must be precisely sized for a given average annual temperature and pressure because the operational flow rate cannot be adjusted by the user. Therefore, the purchasing agency should notify the manufacturer of the **operational** location of the sampler; differences in temperature and pressure between the shipping address and the monitoring site may result in an incorrect operational flow rate. As with the MFC sampler, it will be necessary to determine or estimate both the ambient temperature and barometric pressure readings during the sample period for the subsequent calculation of total sample volume in standard volume units.

For this VFC calibration procedure, the following conditions are assumed:

- The VFC sampler uses a choked-flow venturi to control the actual volumetric flow rate.
- The sampler flow rate is measured by measuring the stagnation pressure ratio, and the sampler is not equipped with a continuous flow recorder.

- The sampler inlet is designed to operate at a constant actual volumetric flow rate of 1.13 m³/min, and the acceptable flow-rate range is ± 10 percent of this value.
- The transfer standard for the flow-rate calibration is an orifice device equipped with either a series of resistance plates or an integral variable-resistance valve. The pressure drop across the orifice is measured by an associated water or oil manometer.
- The sampler will be calibrated in actual volumetric flow-rate units (Q_a), and the orifice transfer standard is also calibrated in Q_a , as specified in Section 2.2.

2.4.1 Calibration Equipment

1. Orifice transfer standard with proper calibration traceable to NIST (see Section 2.2).

Note: The predrilled resistance plates supplied with the orifice transfer standard may have to be modified for the calibration of PM₁₀ samplers. The holes in the plates may have to be enlarged or additional holes may have to be drilled to obtain flow rates within the acceptable range. Alternatively, new resistance plates could be purchased if they are available.

2. An associated water or oil manometer, with a 0- to 400-mm (0- to 16-in.) range and minimum scale divisions of 2 mm (0.1 in.) for measurement of transfer standard pressure.
3. An oil or water manometer, with a 0- to 1,000-mm (0- to 36-in.) range and minimum scale divisions of 2 mm (0.1 in.) or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other pressure instrument) should be associated with the sampler.

Note: Manometers used for field calibration may be subject to damage or malfunction and should thus be checked frequently.

4. A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.
5. 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 millimeters of mercury and referenced within ± 5 mm Hg to a barometer of known accuracy at least annually.
6. Calibration data sheets or the station logbook and 51-mm (2-in.)-wide duct tape.
7. A clean filter.

2.4.2 Multipoint Flow-Rate Calibration Procedure—VFC Sampler

The procedure presented here is basic and intended to be generic, given the assumptions for the VFC calibration procedure listed above. 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.

In-house equipment and personnel, procedural simplicity and uniformity, and subsequent data applications should be considered in establishing the specific, detailed calibration procedure to be implemented.

Note: The calibration of some VFC samplers may be affected by changes in line voltage, particularly if the line voltage is below normal (normal is about 115 VAC). For this reason, VFC samplers should always be calibrated at the monitoring site. Further, if the line voltage at the site is low and likely to fluctuate significantly, a line voltage booster or regulator may be advisable. Also, be sure that replacement blower motors are of the correct type. Avoid the use of lower-amperage blower motors that are intended for use in HV TSP samplers.

Caution: Do not attempt to calibrate the VFC sampler under windy conditions. Short-term velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of the pressure variations.

1. Set up the calibration system as recommended by the manufacturer. Figure 2.4 illustrates the

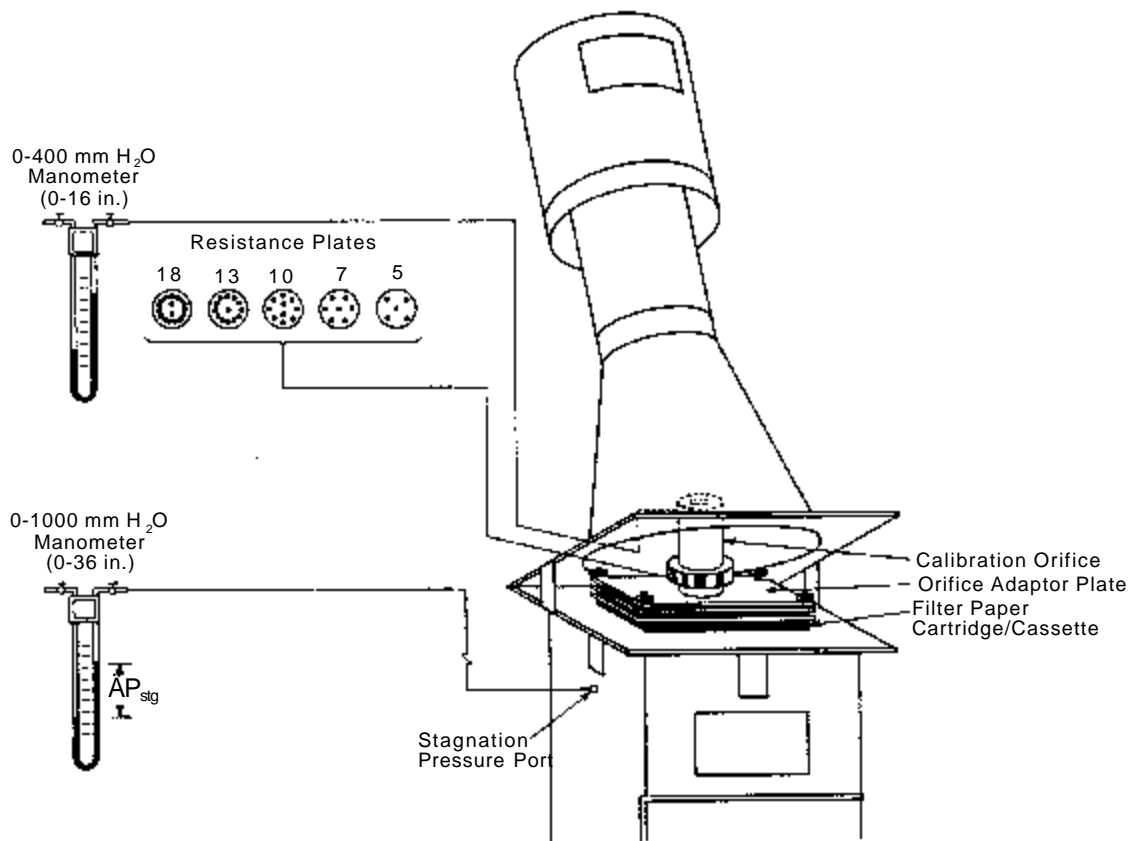


Figure 2.4. Calibration assembly of the VFC sampler.

calibration configuration of a typical VFC sampler. The VFC sampler manufacturer may specify that the sampler be calibrated with a filter installed, which generally precludes calibration flow rates higher than normal operating flow rate. Additional calibration flow rates obtained without a filter may be appropriate, as discussed in Step 8.

2. Install the orifice transfer standard and its adapter faceplate on the sampler; first inspect all gaskets and seals and replace any doubtful ones.

Caution: Tighten the faceplate nuts evenly on alternate corners to properly align and uniformly seat the gaskets. The nuts should be hand-tightened only; too much compression can damage the sealing gasket.

3. Select a calibration flow rate and install the appropriate resistance plate (or no plate) or adjust the variable resistance valve. At least four flow rates are required to define the calibration relationship. At least three flow rates should be within the acceptable flow-rate range (i.e., 1.02 to 1.24 m³/min) for the sampler inlet. For resistance plate orifices, make sure the orifice and resistance plate gaskets are in place and the orifice is not cross-threaded on the faceplate.
4. **Conduct a leak test by blocking** the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Seal both orifice and stagnation pressure ports with rubber caps or similar devices. Turn on the sampler.

Caution: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime. It can raise temperatures to the point of defeating the electrical insulation, which could result in fire or electric shock to the user.

Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by crossthreading of the orifice transfer standard on the faceplate. All leaks must be eliminated before proceeding with the calibration. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

Note: The leak test procedure described above is one of many alternate procedures that may be used. Operating agencies may develop their own procedures.

5. Inspect the connecting tubing of the manometers for crimps or cracks. Open the manometer valves (if present) and blow gently through the tubing, watching for the free flow of the fluid.

Adjust the manometers' sliding scales so that their zero lines are at the bottom of the menisci. Connect the transfer standard manometer to the transfer standard and the sampler stagnation pressure manometer (or other pressure instrument) to the stagnation pressure port. Ensure that one side of each manometer is open to atmospheric pressure. Make sure the tubing fits snugly on the pressure ports and on the manometers.

6. Read and record the following parameters on the VFC Sampler Data Sheet. Figure 2.5 presents an example calibration data sheet for the VFC sampler.

VFC Sampler Calibration Data Sheet						
Station Location	Glendora, CA		Date	9/30/97	Time	2:30 PM
Sampler Model	Wedding		S/N	0340870172P	Operator	T. Wisbeth
P _a	75 mm Hg	T _a	22.2 EC	295.2 K	Unusual Conditions	none
	5					
Orifice S/N	2		Orifice Calibration Date	7/22/97		
Orifice Calibration Relationship:			m =	1.2390	b =	0.0172
			r =	0.9999		

Plate No.	ÄH ₂ O (in.)	ÄP _{stg} (mm Hg) ^a	P ₁ = P _a - ÄP _{stg} (mm Hg)	P ₁ /P _a (mm Hg)	Q _a (orifice) flow rate ^b (m ³ /min)	Q _a (orifice) / [T _a] ^{1/2}
None	5.5	33.34	721.66	0.9558	1.17	
18	5.1	42.86	712.14	0.9432	1.13	
13	4.9	49.40	705.60	0.9346	1.10	
10	4.5	60.79	694.20	0.9195	1.06	
Operational Flow Rate	26.20	728.80	0.953		—	

^amm Hg = 25.4 (in. H₂O/13.6).

^bQ_a (orifice) = 1/m {[(ÄH₂O) (T_a/P_a)]^{1/2} - b}.

^c % Difference = [100] $\left[\frac{Q_a(\text{sampler}) \& Q_a(\text{orifice})}{Q_a(\text{orifice})} \right]$.

Sampler Calibration Relationship

Lookup Table Validated (i.e., % difference # 4)

New calibration relationship

(X = $\frac{Q_a(\text{orifice})}{[T_a]^{1/2}}$, Y = (P₁/P_a))

m = _____ b = _____ c = _____

For subsequent calculation of sampler flow rate:

Q_a = {[(P₁/P_{av}) - b] [T_{ad}]^{1/2}} {1/m}

Operational Flow Rate **1.181** m³/min

Q _a (orifice)	Qa (sampler) (Lookup Table)	% Difference ^c
1.17	1.154	-1.4
1.13	1.115	-1.3

Figure 2.5. Example VFC sampler calibration data sheet.

- Date, location, and operator's signature
- Sampler S/N and model
- Ambient barometric pressure (P_a), mm Hg (or kPa)
- Ambient temperature (T_a), EC and K ($K = EC + 273$)
- Orifice S/N and calibration relationship.

Note: Consistency of temperature and barometric pressure units is required. It is recommended that all temperatures be expressed in Kelvin ($K = EC + 273$). 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.

7. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min).

Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 in. of clearance at the bottom for air flow and for the manometer tubing).

Then, read and record the orifice transfer standard's manometer reading, $\ddot{A}H_2O$, and the corresponding sampler relative stagnation pressure manometer reading, $\ddot{A}P_{stg}$, on the data sheet. (Relative stagnation pressure is a negative pressure [i.e., a vacuum] relative to atmospheric pressure as measured by a manometer with one leg open to the atmosphere.)

Note: Be sure to convert $\ddot{A}P_{stg}$ to millimeters Hg using Equation (9) before recording the reading on the calibration data sheet:

$$\text{mm Hg} = 25.4 (\text{in. H}_2\text{O}/13.6) . \quad (9)$$

8. Install the other resistance plates or adjust the variable orifice value to obtain each of the other calibration flow rates and repeat Step 7 for each. At least four calibration flow rates are required, with at least three in the acceptable flow rate range (i.e., 1.02 to 1.24 m^3/min).

Difficulties may be encountered in obtaining flow rates in the acceptable range. Even with modified resistance plates (or with no plates) installed, it may be impossible to obtain three acceptable flow rates with a filter mounted on the sampler. In this case, either lower flow rate calibration points must be used and the calibration must be extrapolated into the acceptable range, or additional calibration points must be run without a filter installed in the sampler. If additional calibration points are obtained without a filter, they should be examined carefully to make sure they are consistent with the calibration points obtained with a filter (i.e., they fall on a smooth curve through all the calibration points).

9. Plot the calibration data on a sheet of graph paper as specified in Step 5 in Section 2.4.3.

Note: The data should be plotted in the field as the calibration is occurring, rather than afterwards back at the laboratory.

Repeat Step 7 for any data that are questionable on the plot. Running additional calibration points at differing flow rates or repeating the calibration points at the same flow rates is encouraged to improve the precision of the calibration.

10. Turn off the sampler and remove the orifice transfer standard.
11. Install a clean filter on the sampler in the normal sampling mode (use a filter cassette if one is normally used). Turn on the sampler and allow it to warm up to operating temperature.
12. Read the relative stagnation pressure as in Step 7 and record it on the data sheet in the row for the operational flow rate.
13. Perform the calibration calculations presented in Section 2.4.3.

2.4.3 Calibration Calculations

Gather together all the calibration data, including the orifice transfer standard's calibration information and the sampler calibration data sheet.

Note: These calculations should be done at the time of the calibration, rather than later. This approach will allow additional calibration points to be taken if questions arise about the data that have already been obtained.

1. Verify that the orifice transfer standard calibration relationship is current and traceable to an acceptable primary standard.
2. Calculate and record $Q_a(\text{orifice})$ for each calibration point from the orifice calibration information and Equation (4):

$$Q_a(\text{orifice}) = \{[\Delta H_2O(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

$Q_a(\text{orifice})$ = actual volumetric flow rate as indicated by the transfer standard orifice,
m³/min

ΔH_2O = pressure drop across the orifice, mm (or in.) H₂O

T_a = ambient temperature during use, K (K = EC + 273)

P_a = ambient barometric pressure during use, mm Hg (or kPa)

b = intercept of the orifice transfer standard's calibration relationship

m = slope of the orifice transfer standard's calibration relationship.

3. Calculate and record the value of the absolute stagnation pressure, P_1 , for each calibration point:

$$P_1 = P_a - \Delta P_{\text{stg}} \quad (10)$$

where

P_1 = absolute stagnation pressure, mm Hg

P_a = ambient barometric pressure, mm Hg

ΔP_{stg} = relative stagnation pressure, mm Hg.

4. Calculate and record the stagnation pressure ratio:

$$\text{Stagnation pressure ratio} = P_1/P_a . \quad (11)$$

5. On a sheet of graph paper, plot the calculated orifice transfer standard's flow rates, $Q_a(\text{orifice})$, on the x-axis vs. the corresponding stagnation pressure ratios, P_1/P_a , on the y-axis. Draw a smooth curve through the plotted data. If necessary, extrapolate the curve to include the acceptable flow-rate range.
6. If the sampler manufacturer has provided a factory calibration table (i.e., the lookup table) for the sampler, compare $Q_a(\text{orifice})$ for several points on the calibration plot with $Q_a(\text{sampler})$ determined from the factory calibration at T_a . Calculate the percentage difference between $Q_a(\text{orifice})$ and $Q_a(\text{sampler})$ using Equation (12):

$$\% \text{ Difference} = [100] \left[\frac{Q_a(\text{sampler}) - Q_a(\text{orifice})}{Q_a(\text{orifice})} \right] . \quad (12)$$

If the agreement is within a few (i.e., 3 or 4) percent, the factory calibration is validated and may be used for subsequent sample periods. Proceed to Section 2.4.5.

7. If the agreement is not within a few percent, recheck the accuracy of the orifice transfer standard and recheck the calibration procedure. Look for leaks, manometer reading errors, incorrect temperature or pressure data, or miscalculations. Also check for abnormally low line voltage at the site (it should be at least 110 VAC), for the correct blower motor, and for the presence of a gasket between the motor and the choked-flow venturi. A factory calibration is not likely to be substantially incorrect, and any discrepancy of more than a few percent is probably due to some problem with the sampler or with the calibration procedure. However, if no errors or problems with the sampler or with the calibration can be found, or if no factory calibration is provided by the manufacturer, proceed as described in Section 2.4.4.

2.4.4 Generation of Calibration Relationship—VFC Sampler

1. For each calibration point, calculate and record the quantity,

$$Q_a(\text{orifice})/[T_a]^{1/2}$$

where

$Q_a(\text{orifice})$ = actual volumetric flow rate as indicated by the transfer standard orifice,
m³/min

T_a = ambient temperature during sampler calibration, K (K = EC + 273)

2. For the general linear regression model, $y = mx + b$, let $y = P_1/P_a$ and let $x = Q_a(\text{orifice})/[T_a]^{1/2}$, such that the model is given by:

$$P_1/P_a = m[Q_a(\text{orifice})/[T_a]^{1/2}] + b . \quad (13)$$

Calculate the linear regression slope (m), intercept (b), and correlation coefficient (r).

Note: Inspect the plotted calibration curve to determine whether any of the calibration points that are substantially outside of the acceptable flow-rate range need to be eliminated so that they do not cause an inappropriate linear regression line.

- For subsequent sample periods, the sampler's average actual operating flow rate, \overline{Q}_a , is calculated from the calibration slope and intercept using Equation (14):

$$\overline{Q}_a(\text{sampler}) = m \left[\left(\overline{P}_1 / P_{av} \right) + b \right] [T_{av}]^{1/2} \quad (14)$$

where

$$\begin{aligned} \overline{Q}_a(\text{sampler}) &= \text{the sampler's average actual flow rate, m}^3/\text{min} \\ \overline{P}_1 / P_{av} &= \text{average stagnation pressure ratio for the sampling period} \\ T_{av} &= \text{average ambient temperature for the sampling period, K (K = EC + 273)} \\ b &= \text{intercept of the sampler calibration relationship} \\ m &= \text{slope of the sampler calibration relationship.} \end{aligned}$$

Note: The average value for P_1 should be calculated from stagnation pressure measurements taken before and after the sampling period. P_{av} should be estimated from barometric pressure for the sampling period. See also Section 3.3 for additional information.

- If a calibration (lookup) table is desired, evaluate Equation (14) for various appropriate values of P_1/P_a and T_a and list the corresponding values of $Q_a(\text{sampler})$ in tabular form.

Note: A calibration table based on Equation (14) may not match the manufacturer's lookup table exactly because the manufacturer may use a different or more sophisticated model than Equation (13).

2.4.5 Single-Point Operational Flow-Rate Verification

This procedure compares the VFC sampler's normal operating flow rate to the design flow rate of the inlet (e.g., 1.13 m³/min).

- Determine the value of P_1/P_a for the operational flow rate obtained with only the filter cassette installed (Steps 11 and 12 of Section 2.4.2).
- Determine the sampler's operational flow rate, $Q_a(\text{sampler})$, that corresponds to this value of P_1/P_a . Use the manufacturer's calibration table if it has been validated in Step 6 of Section 2.4.3; otherwise, use Equation (14).
- Compare $Q_a(\text{sampler})$ with the inlet design flow rate (e.g., 1.13 m³/min) using Equation (15):

$$\% \text{ Difference} = \left[100 \right] \left[\frac{Q_a(\text{sampler}) - 1.13}{1.13} \right] \quad (15)$$

This design flow rate percentage difference **must** be less than the allowable flow-rate tolerance (i.e., ± 10 , if not otherwise specified by the manufacturer). However, this value **should** be well within ± 7 to allow for some variation with ambient temperature. If this value is not within ± 7 , recheck the calibration procedure and data for errors. Check the sampler for leaks, bad motor brushes, missing gaskets, incorrect motor type, or abnormally low line voltage. Because the VFC flow rate is not adjustable, the VFC manufacturer must be consulted to resolve cases of substantially incorrect VFC flow rates.

2.5 Sampler Calibration Frequency

To ensure accurate measurement of the PM_{10} concentrations, calibrate HV PM_{10} samplers upon installation and recalibrate as follows:

1. 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).
2. After any repairs that might affect sampler calibration (e.g., replacing the motor).
3. After relocation of the sampler to a different site.
4. If the results of a field flow-check exceed quality control limits (e.g., $> \pm 10$ percent from the sampler's indicated flow rate).
5. Whenever a field flow-check or performance audit indicates that the sampler is out (or nearly out) of the acceptable flow-rate range (i.e., 1.02 to 1.24 m^3/min) for the inlet.

Note: Multipoint flow-rate calibrations should be distinguished from single-point, quality control flow checks (see Section 3.5). The latter are done more frequently than calibrations and are intended to check if the sampler flow rate, Q_a (sampler), or the calibration relationship, has changed significantly since the last calibration.

3.0 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.

3.1 Siting Requirements

As with any type of air monitoring study in which sample data are used to draw conclusions about a general population, the validity of the conclusions depends on the representativeness of the sample data. Therefore, the primary goal of a PM₁₀ monitoring project is to select a site or sites where the collected particulate mass is representative of the monitored area.

Table 3-1 presents basic siting criteria for the placement of the HV PM₁₀ sampler. This is not a complete listing of siting requirements; instead, it should be used as an outline by the operating agency to determine a sampler's optimum location. Complete siting criteria are presented in 40 CFR Part 58, Appendix E. Additional information on optimum network design and site exposure criteria is given in Koch and Rector (1987).

Additional factors not specified in the CFR must be considered in determining where the sampler will be deployed. These include accessibility under all weather conditions, availability of adequate electricity, and security of the monitoring personnel and equipment.

The sampler must be situated where the operator can reach it safely despite adverse weather conditions. If the sampler is located on a rooftop, care should be taken that the operator's personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibrations, filter installation and recovery, flow checks, and audits) involves transporting supplies and equipment to and from the monitoring site.

To ensure that adequate power is available, one should consult the manufacturer's instruction manual for the sampler's minimum voltage and power requirements. Lack of a stable power source can result in the loss of many samples because of power interruptions.

The security of the sampler itself depends largely on its location. Rooftop sites with locked access and ground-level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

3.2 Sampler Installation Procedures

1. On receipt of an HV PM₁₀ sampler from the manufacturer, visually inspect it to ensure that all components are accounted for. Compare the equipment delivered with the enclosed packing slip.

TABLE 3-1. MINIMUM HV PM₁₀ SAMPLER SITING CRITERIA

Scale	Height above ground (m)	Distance from supporting structure (m)		Other spacing criteria
		Vertical	Horizontal ^a	
Micro	2 to 7		>2	1. Should be >20 m from trees.
Middle, neighborhood, urban, and regional scale	2 to 15		>2	2. Distance from sampler to obstacle, such as buildings, must be twice the height that the obstacle protrudes above the sampler. 3. Must have unrestricted air flow 270E around the sampler inlet. 4. No furnace or incineration flues should be nearby. ^b 5. Spacing from roads varies with traffic (see 40 CFR Part 58, Appendix E). 6. Sampler inlet is at least 2 m but not >4 m from any collocated PM ₁₀ sampler (see 40 CFR Part 58, Appendix A).

^a When inlet is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

^b Distance depends on the height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources.

Notify the manufacturer immediately of any missing or damaged equipment.

2. Perform a laboratory check to determine if the sampler is operational. Turn on the sampler and observe the vacuum motor performance and shift the recorder response (if so equipped).
3. Carefully transport the sampler to the field site. The manufacturers generally ship a HV PM₁₀ inlet in a separate container from the base. To avoid damage, transport the inlet to the site in its shipping carton. If possible, install the HV PM₁₀ sampler in the center of a site platform. This practice will ensure easy access to the sampler's inlet during maintenance procedures and will reduce inlet damage if the sampler should topple over.
4. Following manufacturer's instructions, carefully assemble the base of the HV PM₁₀ sampler. The sampler must be bolted down to a secure mounting surface.
5. Assemble the sampler inlet according to the manufacturer's instructions and carefully install it on the base unit.
6. Check all tubing and power cords for crimps, cracks, or breaks.

7. 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. The use of waterproof interlocking electrical connectors is also recommended to ensure operator safety and to avoid shorts or power interruptions. Do not allow any electrical connections to be submerged during periods of inclement weather.
8. Turn on the sampler and make sure that it is still working properly. Investigate and correct any malfunctions before proceeding. Operate the sampler for approximately 30 min to ensure that the motor brushes are properly seated and that the motor is operating at full performance.
9. Perform a multipoint flow-rate calibration, as described in Section 2.0.

3.3 Sampling Operations

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 following assumptions are made:

- The flow rate through a PM₁₀ sampler that is equipped with a mass-flow controller is indicated by the exit orifice plenum pressure. This pressure is measured with a manometer [or a flow recorder].
- The flow rate through a PM₁₀ sampler that is equipped with a volumetric-flow controller is indicated by the stagnation pressure. This pressure is measured with a manometer.
- The sampler has been calibrated according to procedures presented in Section 2.0.

Sampling procedure checks are summarized in Table 3-2.

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 PM₁₀ samplers are generally not sufficiently accurate and are **not recommended** for quantitative sampler pressure or flow-rate measurements. These flow recorders should be used only for nonquantitative determination that the flow was approximately constant and uninterrupted over the sampling period. The flow recorder may be connected in parallel with the manometer or other pressure measuring device, using a tee or "Y" tubing connector.

Note: Because flow recorders are still in wide use for quantitative flow-rate measurements, the procedures in this section include specific instructions for the use of a flow recorder. These flow recorder instructions are enclosed in brackets [].

The average actual flow rate for VFC samplers is calculated by determining (1) the average of the initial and final relative stagnation pressures ($\dot{A}P_{stg}$), (2) the average ambient temperature (T_{av}), and (3) the average barometric pressure (P_{av}) during the sampling period and then by applying these values to the

calibration relationship.

TABLE 3-2. SAMPLING PROCEDURE CHECKS

Procedure	Frequency and method	Requirements	Action if requirements are not met
Filter installation	Visually check each filter. Inspect gaskets after each sample.	Filters must be undamaged and provided with ID numbers; cassette must be centered on sampler; filter must be centered on cassette screen with edges parallel to edges of screen and to faceplate gasket; gasket must be tightened to prevent leakage.	Void the filter; install substitute filter.
Sample validation and documentation	Visually check each sample and the sample data sheet for completeness.	Record on data sheet must show the sampling date, filter ID, sampler S/N, station location, flow rate, sample time, and any unusual conditions.	Complete or correct the documentation; if unavailable, void the sample.
	Check operational flow rate for conformance with inlet design flow rate for each sample.	Sampler operational flow rate must be within 90 to 110% of the inlet design flow rate.	Readjust operational flow-rate set point or consult manufacturer. Invalidate all samples back to the last acceptable flow check.
Postsample inspection	Visually check each sample for missing pieces or leakage.	There must be no evidence of filter damage or sampler malfunction.	Void the sample; correct the cause of malfunction.
Flow checks	Check flow-rate calibration at least once per month.	The QC-check and design condition percentage differences should be# $\pm 10\%$.	If the percentage differences exceed $\pm 10\%$, invalidate all data collected subsequent to the last calibration or valid flow check. Investigate potential error sources in the sampler, the calibration data, and the calculations. Recalibrate the sampler.

Note: Consistency of temperature and barometric pressure units is required. It is recommended that all temperatures be expressed in Kelvin ($K = EC + 273$). 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.

3.3.1 Presampling Filter Preparation Procedures

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.

Following the manufacturer’s instructions, carefully load the filter in the filter cassette. The filter should be centered on the wire screen so that the gasket will form an airtight seal on the outer edge of the filter when the faceplate is in place. Poorly aligned filters show uneven white borders after exposure. Care should be taken to ensure that the filter cassette is not excessively tightened, as the filter may stick or the gasket may be permanently damaged. Check that the gasket is in good condition and has not deteriorated. **Put a protective cover (if available) over the filter cassette.**

The site operator who is responsible for readying the HV PM_{10} sampler for the next run day can now transport the filter cassette to the monitoring site.

3.3.2 Sampling Procedures—MFC Sampler

3.3.2.1 Filter Installation Procedure

Upon arriving at the monitoring site, the site operator will follow these procedures:

1. Following the manufacturer’s instructions, loosen the nuts that secure the inlet to the base and gently tilt back the inlet to allow access to the filter support screen.
2. Examine the filter support screen. If the screen appears dirty, wipe it clean. If the filter cassette is equipped with a protective cover, remove it and place the loaded cassette in position on the sampler support screen. Tighten the thumb nuts sufficiently to hold the filter cassette securely. Check that the gasket is in good condition and has not deteriorated.

Caution: Tighten the thumb nuts evenly on alternate corners to properly align and seat the gasket. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

3. Lower the sample inlet. Inspect the sample inlet to make sure that it is resting on the filter cassette and not on the PM₁₀ sampler's frame. Secure the sample inlet to the sampler base.
4. [Open the front door of the sampler and examine the flow recorder. Remove any moisture inside by wiping it with a clean cloth. Record the sampler S/N, filter ID number, site location, and sampling date on the back of a clean chart and install the chart in the flow recorder.]

[Note: Charts used for PM₁₀ samplers normally have square-root-function scales; however, linear-function scales may be used. If charts with linear-function scales are used, Equations (5a) and (7a) will have to be modified from their current form by replacing I with $(I)^{1/2}$.]

[While installing the chart, do not bend the pen arm beyond its limits of travel. Raise the pen head by pushing on the very top of the pen arm (or by using the pen lift). Be sure that the chart tab is centered on the slotted drive to ensure full 360E rotation in 24 h. Make sure that the chart edges are properly located beneath the retainers. Lower the pen arm and tap the recorder face lightly to make certain that the pen is free.]

[Note: During periods of inclement weather, the chart tends to stick to the recorder face. Two charts can be installed simultaneously to enable the sample (top, annotated) chart to rotate freely.]

5. [Using a coin or slotted screwdriver, advance the chart and check to see that the pen rests on zero—the smallest circle diameter. If necessary, adjust the zero set screw while gently tapping on the side of the flow recorder. If a chart with a linear-function scale is used, some positive zero offset may be desirable to allow for normal variations in the zero readings.]
6. Turn on the sampler and allow it to equilibrate to operating temperature (3 to 5 min).
7. While the sampler is equilibrating, record the following parameters on the MFC Sampler Field Data Sheet (Figure 3.1):
 - Site location
 - Sample date
 - Filter ID number
 - Sampler model and S/N
 - Operator's initials.
8. Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer while watching for the free flow of the fluid. Adjust the manometer's sliding scale so that its zero line is at the bottom of the menisci.
9. Measure the initial exit orifice plenum pressure ($\ddot{A}P_{ex}$) using an oil or water manometer, with a 0- to 200-mm (0- to 8-in.) range and a minimum scale division of 2 mm (0.1 in.). Record the initial $\ddot{A}P_{ex}$ on the MFC Sampler Field Data Sheet. If $\ddot{A}P_{ex}$ is substantially different than for previous samples or otherwise appears abnormal, carry out a QC flow check as described in Section 3.5.1.

MFC Sampler Field Data Sheet					
Station Location	Milford, NC	Date	10/17/97	AIRS Number	68024550
Sampler Model	GMW	S/N	1297		
Filter ID No.	489929	P_{av}	761	mm Hg, T_{av}	18.5 EC or 291.5 K
Sampler Manometer Readings			Flow Recorder Readings		
Initial $\ddot{A}P_{ex}$	4.3	in. H ₂ O	Mean I	—	
Final $\ddot{A}P_{ex}$	4.0	in. H ₂ O			
Mean $\ddot{A}P_{ex}$	4.15	in. H ₂ O			
Sampler calibration relationship: $m =$ 0.9137 $b =$ 0.2629 $r =$ 0.9979					
\overline{Q}_a	1.162	m ³ /min	Elapsed time (t)	1440	min V_a 1673 m ³
$\overline{Q}_a = \{[\text{mean } \ddot{A}P_{ex} (T_{av} + 30)/P_{av}]^{1/2} - b\} \{1/m\}$					
$\overline{Q}_a = \{\text{mean I } [(T_{av} + 30)/P_{av}]^{1/2} - b\} \{1/m\}$ for flow recorders					
$V_a = (\overline{Q}_a) (t)$					
Operator	D. Palmer				
Comments:	None				
Laboratory Calculations:					
Gross weight (Wg)	3.9714	g			
Tare weight (Wt)	3.9047	g			
Net weight (Wn)	0.0667	g			
PM ₁₀ concentration	39.9	μg/m ³			
PM ₁₀ concentration = (Wn) (10 ⁶)/V _a					

Figure 3.1. Example MFC sampler field data sheet.

10. [Verify that the flow recorder (if used) is operational and that the pen is inking. Note the flow recorder reading. If it is substantially different than for previous samples or otherwise appears abnormal, carry out a QC flow check as described in Section 3.5.1.]
11. Turn the sampler off.
12. [Check the time indicated by the time-set pointer on the flow recorder. If it is in error, rotate the chart clockwise by inserting a screwdriver or coin in the slotted drive in the center of the chart face until the correct time is indicated.]
13. Reset the elapsed time meter to 0000 min and the sampler timer for the next run day. Close the sampler door, taking care not to crimp the vacuum tubing or any power cords. The sampler is now ready to sample ambient air.

3.3.2.2 Filter Recovery Procedure

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.

1. Turn on the sampler and allow it to equilibrate to operating temperature (3 to 5 min).
2. Measure the final \overline{AP}_{ex} and record it on the MFC Sampler Field Data Sheet.
3. Turn off the sampler.
4. [Open the door of the sampler, remove the flow recorder chart, and examine the recorder trace. If the trace indicates extensive flow fluctuations, investigate and correct before the next sampling day.]
5. Record the following parameters on the MFC Sampler Field Data Sheet:
 - Elapsed time of the sampling period, min
 - Average recorder response, arbitrary units
 - Average ambient temperature for the run day (T_{av}), K ($K = EC + 273$)
 - Average ambient barometric pressure for the run day (P_{av}), mm Hg or kPa.

Note: The calculations presented in this section assume that the sampler has been calibrated in terms of actual temperature and barometric pressure. Average sampler flow rate for a sample period is determined from the average exit orifice plenum pressure \overline{AP}_{ex} and the average ambient temperature (T_{av}) and average ambient pressure (P_{av}) for the sample period. T_{av} and P_{av} readings may be recorded or estimated onsite or may be obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport.

Note: If specific T_{av} or P_{av} values for the sample period cannot be obtained, seasonal average temperature for the site (T_s) may be substituted for T_{av} , and average barometric pressure for the site (P_s) may be substituted for P_{av} . Care must be taken, however, that the actual conditions at the

site during the sample period can be reasonably represented by such averages. It is therefore recommended that seasonal values be used to represent actual values only within 20 EC and 40 mm Hg.

- Calculate and record the average actual flow rate (as determined by the sampler's calibration relationship) on the MFC Sampler Field Data Sheet and on the back of the chart. Attach the chart to the data sheet.

$$\overline{Q}_a = b[\overline{AP}_{ex}(T_{av}/30)/P_{av}]^{1/2} + m \quad (7)$$

[or for the flow recorder,

$$\overline{Q}_a = b\overline{I}[(T_{av}/30)/P_{av}]^{1/2} + m \quad (7a)$$

where

\overline{Q}_a = average sampler flow rate, actual m³/min

\overline{AP}_{ex} = average of initial and final sampler manometer readings $(\overline{AP}_{exi} + \overline{AP}_{exf})/2$, mm (or in.) H₂O

\overline{I} = average flow recorder response, arbitrary units]

T_{av} = average ambient temperature for the run day, K

P_{av} = average ambient pressure for the run day, mm Hg or kPa

b = intercept of the MFC sampler calibration relationship

m = slope of the MFC sampler calibration relationship.

[Note: If charts with linear-function scales are used, substitute $(\overline{I})^{1/2}$ for \overline{I} .]

- Observe conditions around the monitoring site; note any activities that may affect filter particle loading (e.g., paving, mowing, fire) and record this information on the MFC Sampler Field Data Sheet.
- Raise the sampler inlet and remove the filter cassette. Replace the cassette protective cover (if so equipped). To avoid particle loss, be careful to keep the cassette as level as possible.
- The sampler may now be readied for the next run day.
- Keeping the filter cassette level, carefully transport it, the data sheet, and the flow recorder chart to the laboratory sample custodian.

3.3.3 Sampling Procedures—VFC Sampler

3.3.3.1 Filter Installation Procedure

Upon arrival at the monitoring site, the operator will follow the procedure presented below:

- Following the manufacturer's instructions, loosen the nuts that secure the inlet to the base and

gently tilt back the inlet to allow access to the filter support screen.

2. Examine the filter support screen. If the screen appears dirty, wipe it clean. If the filter cassette is equipped with a protective cover, remove it and place the loaded cassette in position on the sampler support screen. Tighten the thumb nuts sufficiently to hold the filter cassette securely. Check that the gasket is in good condition and has not deteriorated.

Caution: Tighten the thumb nuts evenly on alternate corners to properly align and seat the gasket. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

3. Lower the sample inlet and secure it to the sampler base. For impaction inlets, inspect the sample inlet to make sure that it is resting on the filter cassette and not on the PM₁₀ sampler's frame. Secure the sampler inlet to the sampler base.
4. Turn on the sampler and allow it to reach a stable operating temperature (3 to 5 min).
5. While the sampler is warming up, record the following parameters on the VFC Sampler Field Data Sheet (Figure 3.2):
 - Site location
 - Sample date
 - Filter ID number
 - Sampler model and S/N
 - Operator's initials.

6. Bring an oil or water manometer to the side of the sampler. This manometer should have a range of 0 to 1,000 mm (0 to 36 in.) and a minimum scale division of 2 mm (0.1 in.).

Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer, while watching for the free flow of the fluid.

Adjust the manometer's sliding scale so that its zero line is at the bottom of the menisciuses.

7. Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the connecting tubing, attach one side of the manometer to the port. Leave the other side of the manometer open to atmospheric pressure. Make sure the tubing snugly fits the port and the manometer.
8. Measure the initial relative stagnation pressure ($\dot{A}P_{stg}$) and record this reading on the VFC Sampler Field Data Sheet.

Note: Be sure to convert the manometer reading to mm Hg using Equation (9) before recording the reading on the VFC Sampler Field Data Sheet.

$$\text{mm Hg} = (25.4) (\text{in. H}_2\text{O}/13.6) . \quad (9)$$

9. Turn off the sampler, disconnect the manometer, and replace the vacuum cap on the stagnation pressure port.

10. Reset the elapsed-time meter to 0000 min and the sampler timer for the next run day.
11. The sampler is now ready to sample ambient air.

VFC Sampler Field Data Sheet					
Station Location	Glendora, CA	Date	9/23/97	AIRS Number	04191949
Sampler Model	Wedding	S/N	0340870172P		
Filter ID No.	67714	P_{av}	750 mm Hg,	T_{av}	28.6 EC 301.6 K
Relative Stagnation Pressure Readings			Absolute Stagnation Pressure		
Initial $\ddot{A}P_{stg}$	29.5 mm Hg	\bar{P}_1	720.3 mm Hg		
Final $\ddot{A}P_{stg}$	29.9 mm Hg	$\bar{P}_1 = P_{av} - \text{Average } \ddot{A}P_{stg}$			
Average $\ddot{A}P_{stg}$	29.7 mm Hg				
Average stagnation pressure ratio (\bar{P}_1/P_{av})		0.960			
Average flow rate (\bar{Q}_a)*		1.162 m ³ /min	Elapsed time (t)	1445 min	V_a 1679 m ³
*Obtained from manufacturer's lookup table (or from alternate calibration relationship)					
$V_a = (\bar{Q}_a) (t)$					
Operator	T. Wisbeth				
Comments:	None				
Laboratory Calculations:					
Gross weight (Wg)	4.4721	g			
Tare weight (Wt)	4.3802	g			
Net weight (Wn)	0.0919	g			
PM ₁₀ concentration	54.7	μg/m ³			
PM ₁₀ concentration = (Wn) (10 ⁶)/V _a					

Figure 3.2. Example VFC sampler field data sheet.

3.3.3.2 Filter Recovery Procedure

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.

1. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min).
2. While the sampler is equilibrating, record the following parameters on the VFC Sampler Field Data Sheet:
 - Elapsed time of the sampling period, min
 - Average ambient temperature for the run day (T_{av}), EC or K
 - Average ambient barometric pressure for the run day (P_{av}), mm Hg or kPa.

Note: T_{av} and P_{av} readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport. If T_{av} and P_{av} readings are not available, seasonal average temperature (T_s) and barometric pressure (P_s) can be substituted. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. It is therefore recommended that seasonal values represent actual values within 20 EC and 40 mm Hg.

3. Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer, while watching for the free flow of the fluid. Adjust the manometer sliding scale so that its zero line is at the bottom of the menisci.
4. Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the connecting tubing, attach one side of the manometer to the port. Make sure that the tubing snugly fits the port and the manometer. Leave the other side open to atmospheric pressure.
5. Record the final $\ddot{A}P_{stg}$ on the VFC Sampler Field Data Sheet. Turn off the sampler and replace the vacuum cap.

Note: Be sure to convert the manometer reading to mm Hg using Equation (9) before recording the reading on the data sheet.

$$\text{mm Hg} = 25.4 (\text{in. H}_2\text{O}/13.6) . \quad (9)$$

6. Calculate the average relative stagnation pressure (\overline{AP}_{ex}) and record it on the data sheet.
7. Calculate the average absolute stagnation pressure (\overline{P}_1) for the sample run day and record it on the data sheet.

$$\overline{P}_1 = P_{av} + \overline{AP}_{stg} \quad (10)$$

where

\overline{P}_1 = average absolute stagnation pressure, mm Hg or kPa.

P_{av} = average ambient barometric pressure for the run day (**not** the retrieval day), mm Hg or kPa.

$\overline{\Delta P}_{stg}$ = average stagnation pressure drop, mm Hg or kPa.

8. Calculate and record the average stagnation pressure ratio:

$$\text{Average stagnation pressure ratio} = \overline{P}_1 / P_{av} \quad (11)$$

where

\overline{P}_1 = average absolute stagnation pressure, mm Hg or kPa

P_{av} = average ambient barometric pressure on the sample run day, mm Hg or kPa.

9. Using the manufacturer's lookup table (or an alternate calibration relationship as described in Section 2.4.4), locate the column and row corresponding to \overline{P}_1 / P_{av} and the T_{av} value for the sample run day. Read and record the indicated \overline{Q}_a value.
10. Observe conditions around the monitoring site; note any activities that may affect filter particle loading (paving, mowing, fire) and record this information on the VFC Sampler Field Data Sheet.
11. Raise the sampler inlet and remove the filter cassette. Replace the cassette protective cover (if so equipped). To avoid particle loss, be careful to keep the cassette as level as possible.
12. The sampler may now be readied for the next sampling period.
13. Keeping the filter cassette level, carefully transport it and the data sheet to the laboratory sample custodian.

3.3.4 Postsampling Filter Handling Procedures

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. Laboratory personnel should adhere to the following procedure:

1. Following the manufacturer's instructions, remove the top frame of the filter cassette.
2. Conduct a secondary check of a sample's validity as presented in "Laboratory Validation Criteria" (Section 3.4).
3. Carefully slip a manila folder underneath the edge of the exposed filter. The filter may stick in the cassette because of overcompression of the filter cassette gasket. Be extremely careful to avoid damage to the brittle quartz filter.

4. Center the filter on the folder. If the filter must be touched, do not touch or jar the deposit. Fold the manila folder lengthwise at the middle with the exposed side of the filter in. If the collected sample is not centered on the filter (i.e., the unexposed border is not uniform around the filter), fold it so that only deposit touches deposit. Do not **crease the folder**—the sample filter may tear. If the filter shears or breaks, ensure that all pieces of the filter are included within the folder.
5. Insert the folder into the protective envelope.
6. Deliver the filter in its protective folder and envelope, accompanied by the completed data sheet, to the analytical laboratory.

3.3.5 Filter Analysis and Calculation of PM₁₀ Concentrations

Postsampling filter analysis is discussed in Sections 4.6 and 4.7. The calculation of PM₁₀ concentrations is discussed in Section 5.1.2.

3.4 Sample Validation and Documentation

3.4.1 Field Validation Criteria

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.

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

After each sampling period, calculate the percentage difference between \bar{Q}_a and the design flow rate (1.13 m³/min) using the following formula:

$$\% \text{ Difference} = [100] \left[\frac{\bar{Q}_a - 1.13}{1.13} \right]. \quad (15)$$

Record this value on a control chart for the field validation of the sampler's actual volumetric flow rate as is shown in Figure 3.3.

\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 percent of 1.13 m³/min (i.e., 1.02 to 1.24 m³/min) expressed in actual volumetric units. If these limits are exceeded, investigate potential error sources immediately. The following criteria should be used as the basis for determining a sample's validity:

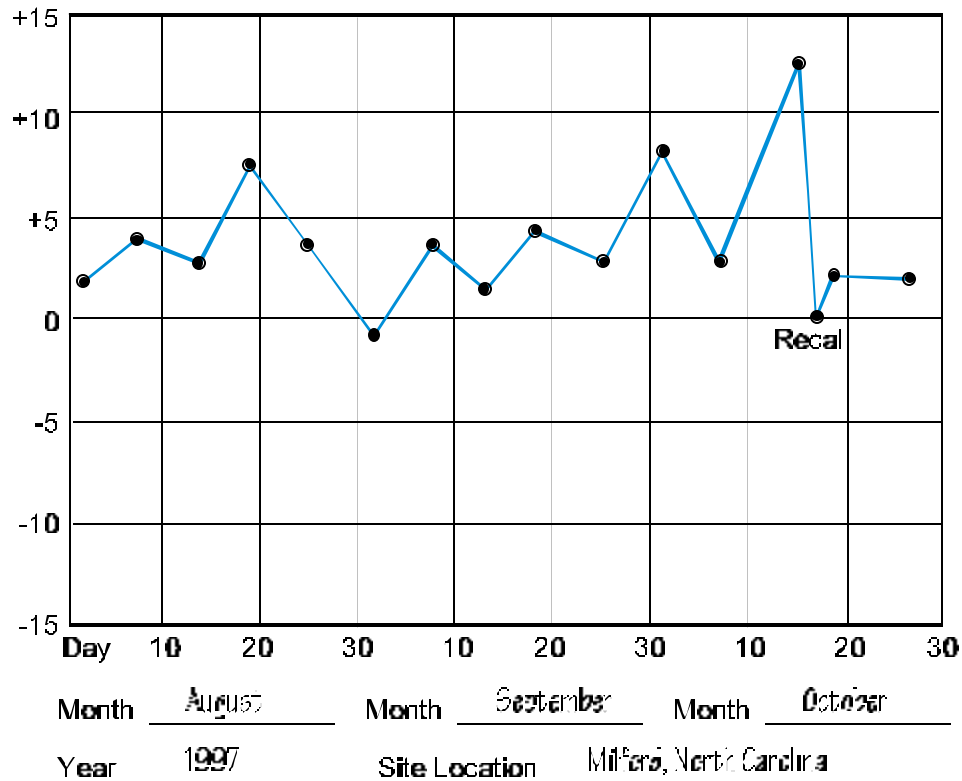


Figure 3.3. Example QC control chart for field validation of flow rates.

- Decreases in flow rate during sampling (due to mechanical problems) of more than 10 percent from the initial set point result in sample invalidation. Recalibrate the sampler. A sample flow rate may also fluctuate due to heavy filter loading. If a high PM_{10} concentration is suspected, the operator should indicate this on the field data sheet. The laboratory supervisor will make the final decision regarding the sample's validity.
- Changes in flow-rate calibration of more than 10 percent, as determined by a field QC flow-rate check (Section 3.5), will invalidate all samples collected back to the last calibration or valid flow check. Recalibrate the sampler.

3.4.2 Laboratory Validation Criteria

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.

1. Check the filter for signs of air leakage. Leakage may result from a worn or improperly installed faceplate gasket. A gasket generally deteriorates slowly. The custodian should be able to decide well in advance (by the increased fuzziness of the sample outline) when to change the gasket before total gasket failure results. If signs of leakage are observed, void the sample, determine the cause, and instruct the operator to take corrective actions before starting another sampling period.
2. 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. Mark such samples as “void” on the HV PM₁₀ data sheet.
3. 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.

3.4.3 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.

Note: The use of LBs at PM₁₀ monitoring sites is highly encouraged, but not required.

The following information should be recorded on the field DS, sampler recorder chart (RC), in the site LB, and on the flow-rate control chart (CC).

3.4.3.1 Operator Who Starts the Sample

Note: The designation in parentheses indicates where the data must be inscribed):

1. Site designation and location (DS)(RC)(LB). This information should be recorded in the LB only once at the initiation of a monitoring program.
2. Sampler model and S/N (DS)(RC)(LB). This information needs to be recorded in the LB only at the commencement of monitoring, unless there is more than one sampler or a new sampler has been deployed.
3. Filter ID number (DS)(RC)(LB).
4. Sample date (DS)(RC)(LB).
5. Initial $\dot{A}P_{ex}$ for MFC or initial $\dot{A}P_{stg}$ for VFC (DS)(LB).
6. Unusual conditions that may affect the results (e.g., subjective evaluation of pollution that day, construction activity, weather conditions) (DS)(LB).
7. Operator's initials (DS).
8. Signature (LB).

3.4.3.2 Operator Who Removes the Samples

1. Elapsed time of the sample run (DS)(RC)(LB).
2. Final $\ddot{A}P_{ex}$ [or mean I] for MFC or final $\ddot{A}P_{stg}$, \overline{P}_1 , and \overline{P}_1/P_{av} for VFC (DS)(LB)[RC].
3. The calculated average flow rate (\overline{Q}_a) in m^3/min (DS)(LB).
4. The percentage difference between the actual and design flow rates (CC).
5. Average ambient temperature and barometric pressure on the sample run day (DS)(LB).
6. Seasonal average temperature and pressure, if needed (DS/LB). This information needs to be recorded in the logbook once, at the change of each season.
7. Existing conditions that may affect the results (DS)(LB).
8. Explanations for voided or questionable samples (DS)(LB).
9. Operator's initials (DS).
10. Signature (LB).

3.5 Field QC Procedure

For HV PM_{10} 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. A control chart (e.g., Figure 3.4) presenting the percentage difference between a PM_{10} sampler's indicated and measured flow rates should be maintained. This chart provides a quick reference of instrument flow-rate drift problems and is useful for tracking the performance of the sampler. Either the sampler logbook or a data sheet must be used to document flow-check information. This information includes, but is not limited to, instrument and transfer standard model and serial numbers, ambient temperature and pressure conditions, and collected flow-check data.

In this section, the following is assumed:

- The flow rate through a PM_{10} sampler that is equipped with a mass-flow controller is indicated by the exit orifice plenum pressure. This pressure is measured with a manometer [or a flow recorder].
- The flow rate through a PM_{10} sampler that is equipped with a volumetric-flow controller is indicated by the stagnation pressure. This pressure is measured with a manometer.
- Both sampler models are designed to operate at an actual flow rate of $1.13 m^3/min$, with an acceptable flow-rate fluctuation range of 10 percent of this value.
- The transfer standard will be an orifice device equipped with a water or oil manometer.
- The orifice transfer standard's calibration relationship is in terms of the actual volumetric flow rate (Q_a).

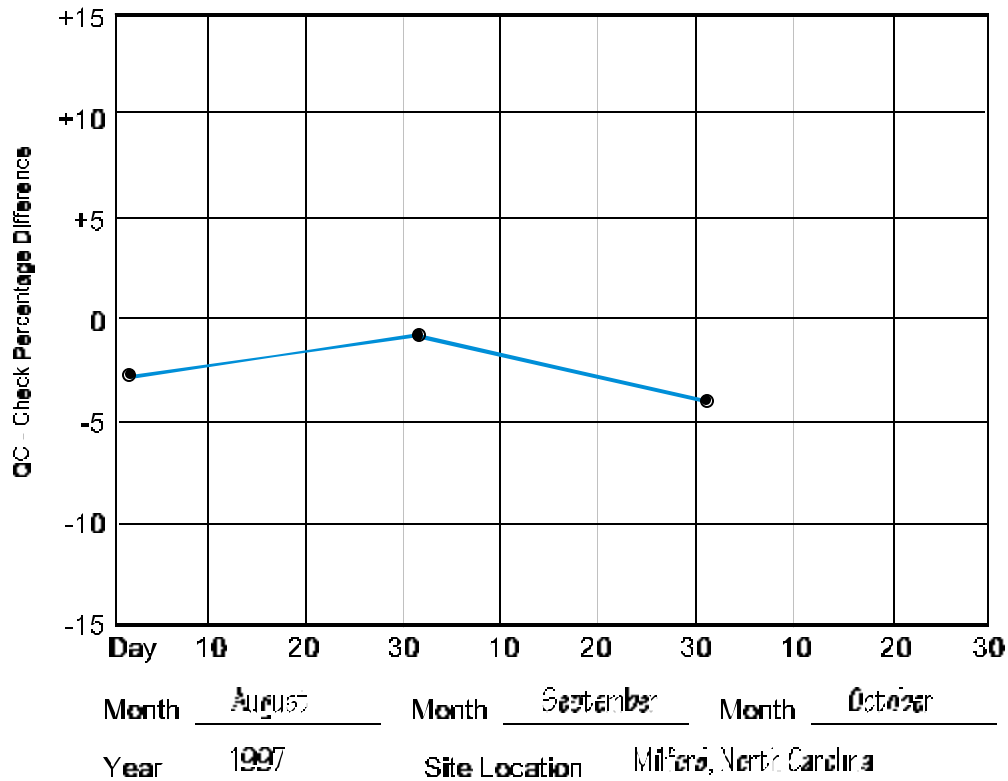


Figure 3.4. Example QC control chart for QC flow checks.

3.5.1 QC Flow-Check Procedure—MFC Sampler

The indicated flow rate (Q_a [sampler]) for MFC samplers is calculated by determining (1) the manometer reading of the exit orifice plenum pressure [or the flow recorder reading], (2) the ambient temperature (T_a), and (3) the barometric pressure (P_a) during the flow check. 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 measurements. The flow recorder may be connected in parallel with the manometer or other pressure measuring device, using a tee or "Y" tubing connector.

Note: Do not attempt to conduct a flow check of PM_{10} samplers under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The flow check will be less precise because of the pressure variations.

An alternate QC flow-check procedure may be presented in the manufacturer's instruction manual. It is recommended that the manual be reviewed and the various methods be evaluated. In-house equipment and procedural simplicity should be considered in determining which method to use.

1. Collect the following equipment and transport it to the monitoring station. This equipment may be the same equipment as used for calibrations.
 - 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.) for measurement of the sampler's exit orifice plenum pressure. This manometer should be the same as that used routinely for sampler flow-rate measurements.
 - An orifice transfer standard and its calibration relationship.
 - 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.) for measurement of the orifice transfer standard.
 - A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.
 - A portable aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient pressure over the range of 500 to 800 mm Hg (66 to 106 kPa) to the nearest millimeter Hg and referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.
 - The sampler's calibration information.
 - Spare recorder charts and a clean flow-check filter.
 - MFC Sampler Flow-Check Data Sheet (Figure 3.5) or site logbook.
2. [Record the site location, sampler S/N, and date on the back of a clean chart and install it in the flow recorder. While installing the chart, do not bend the pen arm beyond its limits of travel. Raise the pen head by pushing on the very top of the pen arm (or by using the pen lift) and simultaneously insert the chart.]
3. [Lower the pen arm and tap the recorder face lightly to make certain that the pen can move freely.]
4. [Using a coin or slotted screwdriver, advance the chart and check to see that the pen head rests on zero (i.e., the smallest diameter circle). If necessary, adjust the zero-set screw while gently tapping on the side of the recorder. A quarter turn of the set screw usually results in large offsets; adjust the set screw carefully.]
5. Set up the flow-check system as previously illustrated in Figure 2.2. MFC samplers are normally flow-checked with a filter in line (i.e., between the orifice transfer standard and the motor). Install a clean filter in the sampler. Place the filter directly on the sampler's filter screen. Do not use a filter cassette. A flow-check filter should never be used for subsequent sampling because particles $>10 \mu\text{m}$ can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both a flow check and subsequent sampling.

MFC Sampler Flow Check Data Sheet					
Station Location	Milford, NC	Date	11/1/97	Time	10:30 AM
Sampler Model	GMW	S/N	1297	Operator	D. Palmer
P _a	763 mm Hg,	T _a	27.0	EC or	300.0 K, Unusual Conditions
					None
Orifice S/N	10387	Orifice Calibration Date	7/22/97		
Orifice Calibration Relationship:	m =	1.2430	b =	-0.0062	r = 0.9999
Sampler Calibration Relationship:	m =	0.9137	b =	0.2629	r = 0.9979
Orifice Pressure Drop (ÄH ₂ O)	4.8	in. H ₂ O	Q _a (orifice) ^a	1.110	m ³ /min
			With Orifice Installed		Without Orifice Installed
Sampler Pressure Drop (ÄP _{ex})	4.0	in. H ₂ O	3.9	in H ₂ O	
Q _a (sampler) ^b	1.152	m ³ /min	1.134	m ³ /min	
QC—Check Percentage Difference ^c	3.9	%			
Q _a (corrected sampler) ^d	1.092	m ³ /min			
Design Flow Rate Percentage Difference ^e	-3.5	%			
<p>^a For calculation of orifice flow rates: $Q_a(\text{orifice}) = \{[\ddot{A}(\text{H}_2\text{O}) (T_a/P_a)]^{1/2} - b\} \{1/m\}$</p> <p>^b For calculation of sampler flow rates: $Q_a(\text{sampler}) = \{[\ddot{A}P_{ex}/P_a) (T_a + 30)]^{1/2} - b\} \{1/m\}$</p> <p>^c QC&check % difference ' [100] $\left[\frac{Q_a(\text{sampler}) \& Q_a(\text{orifice})}{Q_a(\text{orifice})} \right]$ where Q_a(sampler) is measured with the orifice installed.</p> <p>^d Q_a(corrected sampler) ' Q_a(sampler) $\left[\frac{100 \& \text{QC \% difference}}{100} \right]$ where Q_a(sampler) is measured without the orifice installed.</p> <p>^e Design flow rate % difference ' [100] $\left[\frac{Q_a(\text{corrected sampler}) \& 1.13}{1.13} \right]$</p>					

Figure 3.5. Example MFC sampler flow check data sheet.

6. Install the orifice transfer standard and its faceplate on the sampler. Do not restrict the flow rate through the orifice (i.e., by using fixed-resistance plates or closing the variable-resistance valve).

Caution: Tighten the faceplate nuts on alternate corners first to eliminate leaks and to ensure even tightening. The nuts should be hand-tightened; too much compression can damage the sealing gasket. Make sure the orifice transfer standard gasket is in place and the orifice transfer standard is not cross-threaded on the faceplate.
7. Connect the orifice manometer to the pressure port of the orifice transfer standard and the sampler manometer to the sampler's exit orifice plenum. Inspect the manometers' connecting tubing for crimps and cracks. Open the manometer valves and blow gently through the tubing. Watch for the free flow of fluid. Adjust the manometers' scale so that their zero lines are at the bottom of the menisci. Make sure that the connecting tubing snugly fits the manometer and the pressure port.
8. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min).

Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 in. of clearance at the bottom for air flow and for the manometer tubing.
9. Read and record the following parameters on the MFC Sampler Flow-Check Data Sheet:
 - Sampler location and date
 - Sampler model and S/N
 - Ambient temperature (T_a), EC and K.
 - Ambient barometric pressure (P_a), mm Hg or kPa
 - Unusual weather conditions
 - Orifice transfer standard S/N and calibration relationship
 - Operator's signature.
10. Observe the $\ddot{A}H_2O$ across the orifice by reading the manometer deflection. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet.
11. Measure the exit orifice plenum pressure ($\ddot{A}P_{ex}$) by reading the manometer deflection. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet.
12. [Using a coin or small screwdriver, advance the recorder chart to read the sampler's corresponding response (I) and record on the data sheet. A gentle tap on the recorder face is often necessary to ensure that the pen is not sticking to the chart.]
13. Turn off the sampler and remove the orifice transfer standard, but not the filter. Turn on the sampler and repeat Step 11 [or 12] to check the flow rate under normal operating conditions. Turn off the sampler and remove the filter.
14. Calculate and record Q_a (orifice) at actual conditions using the following equation:

$$Q_a(\text{orifice}) = \{[(\ddot{A}H_2O)(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

Q_a (orifice) = actual volumetric flow rate as indicated by the orifice transfer standard,
m³/min

ΔH_2O = pressure drop across the orifice, mm (or in.) H₂O

T_a = ambient temperature during use, K (K = EC + 273)

P_a = ambient barometric pressure during use, mm Hg (or kPa)

b = intercept of the orifice transfer standard calibration relationship

m = slope of the orifice transfer standard calibration relationship.

15. Calculate and record the corresponding sampler flow rate at actual conditions and record.

$$Q_a \text{ (sampler)} = \{[\Delta P_{ex} (T_a + 30)/P_a]^{1/2} - b\} \{1/m\} \quad (7)$$

[or if a flow recorder is being used to measure the exit orifice plenum pressure,

$$Q_a \text{ (sampler)} = \{I[(T_a + 30)/P_a]^{1/2} - b\} \{1/m\} \quad (7a)$$

where

Q_a (sampler) = sampler flow rate, actual m³/min

ΔP_{ex} = exit orifice plenum pressure, mm (or in.) H₂O

[I = recorder response, arbitrary units]

T_a = ambient temperature during the flow check, K (K = EC + 273)

P_a = ambient barometric pressure during flow check, mm Hg (or kPa)

b = intercept of the MFC sampler calibration relationship

m = slope of the orifice calibration relationship.

[**Note:** If charts with linear-function scales are used, substitute (I)^{1/2} for I.]

16. Using this information and the formulas provided on the MFC Sampler Flow-Check Data Sheet, calculate the QC check percentage differences.

$$\text{QC\&check \% difference} = [100] \left[\frac{Q_a \text{ (sampler)} \& Q_a \text{ (orifice)}}{Q_a \text{ (orifice)}} \right] \quad (12)$$

where Q_a (sampler) is measured with the orifice transfer standard being installed.

Record this value on the MFC Sampler Flow-Check Data Sheet and plot on the QC control chart. If the sampler flow rate is within 90 to 110 percent (± 10 percent difference) of the calculated Q_a (orifice) flow rate (in actual volumetric units), the sampler calibration is acceptable. If these limits are exceeded, investigate and correct any malfunction. Recalibrate the sampler before sampling is resumed. Differences exceeding ± 10 percent may result in the invalidation of all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the orifice transfer standard's calibration and all calculations.

17. Calculate the corrected sampler flow rate, Q_a (corrected sampler) using Equation (16):

$$Q_a \text{ (corrected sampler)} = \left[Q_a \text{ (sampler)} \right] \left[\frac{(100 \pm \% \text{ difference})}{100} \right] \quad (16)$$

where Q_a (sampler) is measured without the orifice transfer standard being installed and where the QC-check percentage difference was obtained from Equation (12) above.

Note: Take care to use the correct sign (i.e., positive or negative) for the percent difference when it is used in Equation (16).

18. Calculate and record on the MFC Sampler Flow-Check Data Sheet the percentage difference between the inlet's design flow rate (e.g., 1.13 m³/min) and the corrected sampler flow rate as:

$$\text{Design flow rate \% difference} = \left[100 \right] \left[\frac{Q_a \text{ (corrected sampler)} \pm 1.13}{1.13} \right] \quad (17)$$

It is assumed in this section that the inlet is designed to operate at a flow rate of 1.13 actual m³/min. If the design flow rate percentage difference is less than or equal to ± 10 percent, the sampler calibration is acceptable. If the difference is greater than ± 10 percent, investigate potential error sources and correct any malfunction. Recalibrate the sampler before sampling is resumed. Differences exceeding ± 10 percent may result in the invalidation of all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calculations.

Note: Deviations from the design flow rate may be caused in part by deviations in the site temperature and pressure from the seasonal average conditions. Recalculate the **seasonal SSP** according to Equation (8) in Section 2.3.4 to determine if the flow controller should be adjusted.

19. Set up the sampler for the next sampling period according to the operating procedure in Section 3.3.

3.5.2 QC Flow-Check Procedure—VFC Sampler

The indicated flow rate (Q_a [sampler]) for VFC samplers is calculated by determining (1) the relative stagnation pressure (ΔP_{stg}), (2) the ambient temperature (T_a), and (3) the barometric pressure (P_a) during the flow check. These values are then applied to the sampler's calibration relationship.

Note: Do not attempt to conduct a flow check of PM₁₀ samplers under windy conditions. Short-term wind velocity fluctuations will provide variable pressure readings by the orifice transfer standard's manometer. The flow check will be less precise because of the pressure variations.

Note: An alternative QC flow-check procedure may be presented in the manufacturer's instruction manual. It is recommended that the manual be reviewed and the various methods be evaluated. In-

house equipment and procedural simplicity should be considered in determining which method to use.

1. Collect the following equipment and transport it to the monitoring station:

- An orifice transfer standard and its calibration relationship in actual volumetric flow units (Q_a).
- An associated oil or water manometer, with a 0- to 400-mm (0- to 16-in.) range and minimum scale divisions of 2 mm (0.1 in.).
- An oil or water manometer, with a 0- to 1,000-mm (0- to 36-in.) range and minimum scale divisions of 2 mm (0.1 in.) or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other pressure measurement device) should be associated with the sampler.

Note: Manometers used for QC flow checks may be subject to damage or malfunction and thus should be checked frequently.

- A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.
 - 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 millimeter Hg and referenced within 5 mm Hg of a barometer of known accuracy at least annually.
 - The sampler's calibration relationship (i.e., lookup table or alternative calibration relationship).
 - A clean flow-check filter loaded into a filter cassette.
 - A VFC Sampler Flow-Check Data Sheet (Figure 3.6) or a site logbook.
2. Set up the flow-check system as previously illustrated in Figure 2.4. VFC samplers are normally flow-checked with a loaded filter cassette in line (i.e., between the orifice transfer standard and the motor). The orifice transfer standard should be installed without fixed resistance plates or with the adjustable resistance valve fully open.

A flow-check filter should never be used for subsequent sampling because particles larger than 10 μm can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both a flow check and subsequent sampling.

Caution: Tighten the faceplate nuts on alternate corners first to eliminate leaks and to ensure even tightening. The fittings should be hand-tightened; too much compression can damage the sealing gasket. Make sure the orifice gasket is in place and the orifice transfer standard is not cross-threaded on the faceplate.

3. Turn on the sampler and allow the sampler to warm up to operating temperature (3 to 5 min).

VFC Sampler Flow Check Data Sheet			
Station Location	Glendora, CA	Date	10/3/97 Time 3:25 PM
Sampler Model	Wedding	S/N	0340870172 Operator T. Wisbeth
		P	
P _a 75 mm Hg	T _a 21.3 EC or 294.3 K	Unusual Conditions none	
7			
Orifice S/N	10387	Orifice Calibration Date	7/22/97
Orifice Calibration Relationship: m = 1.2430 b = -0.0062 r = 0.9999			
Orifice Pressure Drop (ÄH ₂ O)	4.65	in. H ₂ O	Q _a (orifice) ^a 1.087 m ³ /min
		With Orifice Installed	Without Orifice Installed
Stagnation Pressure Drop (ÄP _{stg})	37	mm Hg	30 mm Hg
Absolute Stagnation Pressure (P ₁) ^b	720	mm Hg	727 mm Hg
Stagnation Pressure Ratio (P ₁ /P _a)	0.951		0.960
Q _a (sampler) ^c	1.137	m ³ /min	1.164 m ³ /min
QC—Check Percentage Difference ^d	4.6	%	
Q _a (corrected sampler) ^e	1.110	m ³ /min	
Design Flow Rate Percentage Difference ^f	-1.7	%	
<p>^a Q_a (orifice) = {[Ä(H₂O) (T_a/P_a)]^{1/2} - b} {1/m}</p> <p>^b P₁ = P_a - ÄP_{stg}</p> <p>^c Determine Q_a (sampler) from manufacturer's lookup table (or from alternate calibration relationship).</p> <p>^d QC & check % difference = [100] $\left[\frac{Q_a(\text{sampler}) \& Q_a(\text{orifice})}{Q_a(\text{orifice})} \right]$ where Q_a (sampler) is measured with the orifice installed.</p> <p>^e Q_a (corrected sampler) = Q_a (sampler) $\left[\frac{100 \& \text{QC \% difference}}{100} \right]$ where Q_a (sampler) is measured without the orifice installed.</p> <p>^f Design flow rate % difference = [100] $\left[\frac{Q_a(\text{corrected sampler}) \& 1.13}{1.13} \right]$</p>			

Figure 3.6. Example VFC sampler flow check data sheet.

Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 in. of clearance at the bottom for air flow and for the manometer tubing.

4. Read and record the following parameters on the VFC Sampler Flow-Check Data Sheet (Figure 3.6):
 - Sampler location and date
 - Sampler S/N and model
 - Ambient temperature (T_a), EC and K
 - Ambient barometric pressure (P_a), mm Hg or kPa
 - Unusual weather conditions
 - Orifice transfer standard S/N and calibration relationship
 - Operator's signature.

5. Inspect the manometers for crimps or cracks in the connecting tubing. Open the valves and blow gently through the tubing, watching for the free flow of the fluid.

Adjust the manometers' sliding scales so that the zero lines are at the bottom of the menisci.

6. Connect the orifice manometer to the orifice transfer standard, and the sampler manometer to the sampler stagnation pressure port located on the side of the sampler base. Ensure that one side of each manometer is open to atmospheric pressure. Be sure that the connecting tubing snugly fits the pressure ports and the manometers.
7. Read the pressure drop as indicated by the orifice manometer ($\ddot{A}H_2O$) and record on the VFC Sampler Flow-Check Data Sheet. Read the stagnation pressure drop and record as $\ddot{A}P_{stg}$ (mm Hg) on the data sheet.

Note: Be sure to convert $\ddot{A}P_{stg}$ to mm Hg using Equation (9) before recording the reading on the data sheet

$$\text{mm Hg} = 25.4 (\text{in. } H_2O/13.6) . \quad (9)$$

8. Turn off the sampler and remove the orifice transfer standard.
9. With only a loaded filter cassette in line, turn on the sampler and allow it to warm up to operating temperature.
10. Read and record the stagnation pressure drop ($\ddot{A}P_{stg}$) for the normal operating flow rate. Turn off the sampler. Replace the vacuum cap on the stagnation pressure port.
11. Calculate and record Q_a (orifice) flow rate for the flow-check point, as in Equation (4), reproduced below:

$$Q_a (\text{orifice}) = \{[(\ddot{A}H_2O)(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

- Q_a (orifice) = actual volumetric flow rate as indicated by the orifice transfer standard,
m³/min
 ΔH_2O = pressure drop across the orifice, mm (or in.) H₂O
 T_a = ambient temperature during use, K (K = EC + 273)
 P_a = ambient barometric pressure during use, mm Hg (or kPa)
 b = intercept of the orifice transfer standard's calibration relationship
 m = slope of the orifice transfer standard's calibration relationship.

12. Calculate and record the value of P_1 (mm Hg) for the measurements with and without the orifice installed

$$P_1 = P_a - \Delta P_{stg} \quad (10)$$

where

- P_1 = stagnation pressure, mm Hg or kPa
 P_a = ambient barometric pressure, mm Hg or kPa
 ΔP_{stg} = stagnation pressure drop, mm Hg or kPa.

13. Calculate and record the stagnation pressure ratio for the measurements with and without the orifice installed.

$$\text{Stagnation pressure ratio} = P_1 / P_a \quad (11)$$

where

- P_1 = stagnation pressure, mm Hg or kPa.
 P_a = ambient barometric pressure, mm Hg or kPa.

14. Refer to the instrument manufacturer's lookup table (or alternative calibration relationship as described in Section 2.4.4) and determine the Q_a (sampler) flow rates (m³/min) for the measurements with and without the orifice installed as indicated for the ratio of P_1/P_a and ambient temperature in EC. Record these values on the VFC Sampler Flow-Check Data Sheet.
15. Using Q_a (orifice) and Q_a (sampler) for the measurements with the orifice installed, calculate the QC-check percentage difference as:

$$\text{QC-check \% difference} = [100] \left[\frac{Q_a(\text{sampler}) \& Q_a(\text{orifice})}{Q_a(\text{orifice})} \right] \quad (12)$$

Record this value on the VFC Sampler Flow-Check Data Sheet and plot it on the control chart for QC flow checks. If the QC-check percentage difference is $\neq \pm 10$ percent, the sampler calibration is acceptable. Those differences exceeding ± 10 percent will require recalibration.

Investigate potential error sources and correct any malfunction. Differences exceeding ± 10 percent

may result in the invalidation of all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calibrations.

16. Using this percentage difference and Q_a (sampler) from the measurements without the orifice installed (i.e., for the normal operating flow rate), calculate the corrected sampler flow rate as:

$$Q_a \text{ (corrected sampler)} = [Q_a \text{ (sampler)}] \left[\frac{(100 \& \% \text{ difference})}{100} \right]. \quad (16)$$

Record Q_a (corrected sampler) on the VFC Sampler Flow-Check Data Sheet.

17. Determine the design flow rate percentage difference between the inlet design flow rate (e.g., 1.13 m³/min) and Q_a (corrected sampler) as:

$$\text{Design flow rate \% difference} = [100] \left[\frac{Q_a \text{ (corrected sampler)} \& 1.13}{1.13} \right]. \quad (15)$$

Record this design flow-rate percentage difference on the VFC Sampler Flow-Check Data Sheet and plot it on the control chart for the field validation of flow rates. When plotting this value, use a different symbol than is normally used for plotting values that are obtained during sampling periods. If the design flow-rate percentage difference is $\neq \pm 10$ percent, the sampler calibration is acceptable. Those differences exceeding ± 10 percent will require recalibration. **Investigate potential error sources and correct any malfunction.** Differences exceeding ± 10 percent may result in the invalidation of all data obtained subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calculations.

4.0 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.

The agency must be aware of two primary sources of error in the handling of HV PM₁₀ filters:

1. Loss of particles during shipment or handling. Section 4.1 presents guidelines to help prevent postsampling particle loss.
2. Artifact formation errors are caused by the retention of sulfur dioxide in the form of sulfate particulate on alkaline filters. The results of experiments involving a variety of filters indicated that sulfate loading errors of the order of 0.3 to 3.0 µg/m³ can be expected with the use of common glass fiber filters under normal hi-vol sampling conditions and that larger sulfate errors are possible under extreme sampling conditions (see Coutant, 1977). A neutral or low-alkalinity filter medium will eliminate excessive artifact formation.

Accuracy, precision, and calibration procedures for the laboratory apparatus are referenced in Section 2, Table 2-1. The recommended filter media and acceptance criteria of 40 CFR Part 50, Appendix M, are summarized in Table 4-1. The specifications given in this table are **minimum** requirements to ensure acceptability of the data for determining the PM₁₀ mass concentration in the atmosphere.

TABLE 4-1. SUMMARY OF FILTER ACCEPTANCE CRITERIA

Criteria	40 CFR 50, Part Appendix M	Explanation
Collection efficiency	>99 percent as measured by the dioctyl phthalate (DOP) test with 0.3-µm particles at the sampler's operating face velocity.	The apparatus needed to perform this test is not available for a typical analytical laboratory. The operating agency must ensure that the filter manufacturer has complied with this guideline (see ASTM 1993).
Integrity	5 µg/m ³ , measured as the concentration equivalent corresponding to the difference between the initial and final weights of the filter, assuming a 24-h sample volume of 1,600 m ³ .	During a simulated sampling test, all sampling procedures are followed except the HV PM ₁₀ sampler is not turned on. The tare weight of the equilibrated filter must agree within ±8 mg of final weight. Refer to Section 3.0, "Field Operations," for recommended HV PM ₁₀ sampling procedures.
Alkalinity	<25 microequivalents/g of filter	A typical analytical laboratory is capable of conducting this test measurement of alkalinity (see Harrell 1985).

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. These filters may be brittle, which makes them more difficult to handle. They may be more expensive than glass fiber filters. The operating agency must evaluate new filter media (as they become available) to ensure that they comply with Federal guidelines. Laboratory activities are summarized in Table 4-2.

4.1 Filter Handling

Quartz filter material may be brittle and subject to shearing and breakage. Laboratory and field personnel must be aware of these characteristics and handle sample filters with care.

For convenience, tare-weighed filters should be packed in groups of 50 or less in their original container or in a box of comparable size. The filters should be separated by a sheet of 8-1/2- × 11-in. tracing paper. Filter inventory can be controlled by stacking the filters in numerical order so that the operator will use the proper filter first. One side of the shipping box can be cut away to allow the operator to remove the filter easily without damaging the corners.

A filter identification number must be assigned to each filter. Because it is extremely difficult to see the “up” side (i.e., the side with the slightly rougher texture) of the quartz filter, consistency in labeling these filters will allow the balance operator easy access to the filter ID number for documentation and cross-referencing of laboratory data forms. This will also eliminate confusion in loading the filter cassettes for subsequent sampling. If the filter ID number is to be embossed by the operating agency, gentle pressure must be used to avoid filter damage, and extreme care must be taken to avoid duplication or missed numbers.

If samples are to be mailed, the field operator should be supplied with reinforced envelopes and manila folders for protection of the exposed filters during their return to the analytical laboratory. These manila folders may be printed to serve as sample data sheets.

4.2 Visual Filter Inspection

All filters must be visually inspected for defects before their initial weighing, and defective filters must be rejected if any are found. Batches of filters containing numerous defects should be returned to the supplier.

Specific defects to look for are:

- Pinhole—A small hole appearing as (1) a distinct and obvious bright point of light when examined over a light table or screen, or (2) a dark spot when viewed over a black surface.
- Loose material—Any extra loose material or dirt particles on the filter that require removal by brushing prior to weighing.
- Discoloration—Any obvious visible discoloration that might be evidence of a contaminant.
- Filter nonuniformity—Any obvious visible nonuniformity in the appearance of the filter when viewed over a light table or black surface that might indicate gradations in porosity across the face

of the filter.

TABLE 4-2. FILTER PREPARATION AND ANALYSIS CHECKS

Activity	Method and frequency	Requirements	Action if requirements are not met
Handling	Observe handling procedure.	Place filters in protective envelopes or boxes and number sequentially.	Improve technique.
Visual check	Visually inspect each filter.	Make sure there are no pinholes, tears, etc.	Discard filter.
Identification	Visually check each filter number assigned.	Make sure the filter ID number is legible and recorded on the laboratory data/coding form and the filter.	Make proper identification.
Equilibration (tare and gross desiccation)	Observe and record the equilibration room or chamber conditions. Observe the minimum equilibration period for each sample.	Equilibrate in controlled environment for 24 h; RH between 20 and 45 percent, with ± 5 prevariation; and temperature between 15 and 30 EC, with ± 3 EC variation.	Repeat equilibration.
Tare weighing procedure	Observe the weighing procedure; perform all internal QC procedures.	Determine filter weight to nearest 0.1 mg. Begin weighing the filter within 30 s after removal from the equilibration chamber.	Reweigh after reequilibration.
Postsampling inspection, documentation, and verification	Visually check all samples and documentation.	Make sure there are no pinholes, tears, etc.; complete documentation; make sure there is no evidence of malfunction or sample loss.	Void the affected samples; report to supervisor.
Gross weighing procedure	Observe the filter weighing procedure; perform all internal QC procedures.	Obtain weight to nearest 0.1 mg; begin weighing the filter within 30 s after removal from equilibration chamber.	Reweigh after equilibration.

- Other—A filter with any imperfection not described above, such as irregular surfaces or other results of poor workmanship.

4.3 Filter Equilibration

Filters must be equilibrated in a conditioning environment for at least 24 h before being weighed. This can be done in an equilibration chamber or in an environmentally controlled weighing room. Relative humidity (RH) should be held constant at a mean value between 20 and 45 percent, with a variability of not more than ± 5 percent. Temperature should be held constant with a mean value between 15 and 30 EC, with a variability of not more than ± 3 EC. An air-conditioned room may be used for equilibration if it can be maintained in this RH and temperature range while the filters are equilibrating. RH and temperature must be checked and recorded on equilibration days (either manually or by a hygrothermograph) to ensure compliance with these guidelines. Equilibration chamber malfunctions, discrepancies, and maintenance activities also should be recorded in the equilibration chamber or laboratory logbook.

4.4 Initial Weighing Procedures (Tare Weight)

Enough filters to last for at least a 1-month sampling period should be numbered and weighed at one time.

Filters must be weighed on an analytical balance with a minimum resolution of 0.1 mg and a precision of 0.5 mg. Each balance used in the weighing procedures must be identified by a balance number. Each balance should be assigned a block of filter numbers to be used sequentially. The procedures follow:

1. Make sure that the balance has been calibrated (at least annually) and maintained according to manufacturer's recommendations. If the balance is out of calibration, have it calibrated according to manufacturer's directions.
2. Zero the balance according to manufacturer's directions.
3. Perform a QC check **using working mass reference standards** on the analytical balance. (Procedures are outlined in Section 4.5.)
4. If filters must be weighed outside the conditioning chamber, take care to avoid interference with ambient hygroscopic particles and begin the weighing procedure within 30 s. Weigh the filter according to manufacturer's instructions, making sure that a stable reading is obtained. At routine intervals, check the zero and calibration of the balance as outlined in Section 4.5.

Note: Be careful when loading and unloading the balance with quartz filters. The corners and edges of the filter should not bump the balance door because the filter may break or filter material may be lost.

5. Place the tared filter, with the filter ID number facing upward, in its original container or a comparably sized box. Place a sheet of 8-1/2- × 11-in. tracing paper between each filter.
6. Record the balance number, the filter ID number, and the tare weight on the Laboratory Data Form (see Figure 4.1) or alternative data recording medium. When bound, these forms serve

Filter Lot Number	9708	Analyst R. Wright				
Balance Number	543201	QC Supervisor R. Shores				
Presampling Filter Weighing	Date	10/11/97	RH	43	Temp	76
Postsampling Filter Weighing	Date	10/17/97	RH	48	Temp	75
Sampler Number	Filter Number ^a	Presampling Mass (g)	Postsampling Mass (g)	Net Mass Filter Loading (g)		
—	zero	0.0000	0.0000	—		
—	std. wt. 1	3.0002	3.0005	—		
—	std. wt. 2	5.0005	5.0001	—		
A4	67143	3.9147	3.9714	0.0567		
B4	67144	3.9089	3.9550	0.0461		
C4	67145	3.9100	3.9973	0.0873		

^aIndicate zero (tare) check or working standard check here.

Figure 4.1. Example laboratory data form.

as a laboratory notebook. Any filter weight outside of the normal range of 3.7 to 4.7 g should be investigated immediately. Sequentially number each form in the upper right corner.

7. Perform the tare and gross weight QC checks as detailed in Section 4.5 and submit all data to the QC supervisor for review. (Minimum QC supervisor activities are also presented in Section 4.5.)

4.5 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 (see Figure 4.2).

4.5.1 "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. If the actual and measured values agree within ± 0.5 mg, each filter should be weighed to the nearest milligram. "Standard filter" checks are not a recommended QC check for HV PM₁₀ filters. With repeated handling, the quartz filter will degrade rapidly and not allow for reproducible data.

4.5.2 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. **A pair of working mass reference standards with weights between 1 and 5 g should be used**. These weights must also agree within ± 0.5 mg. Larger discrepancies should be corrected immediately. When zero and calibration checks exceed acceptable limits, all previously weighed filters must be rechecked.

4.5.3 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. Because of the loss of volatile components, no definitive limits are set for exposed filters; however, if the difference exceeds ± 5.0 mg, the laboratory QC supervisor should investigate immediately.

4.5.4 QC Supervisor Duties

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

Filter Lot Number		9708		Analyst		R. Wright	
Balance Number		543201		QC Supervisor		R. Shores	
Analysis Date		Zero (Tare) Check Weight (mg)		Working Standard 1 Weight (mg)		Working Standard 2 Weight (mg)	
10/11/97		0.0000		3.0002		5.0005	
10/17/97		0.0000		3.0005		5.0001	
First Date	Second Date	Filter Number (Tare or Gross)		First Weighing (g)		Second Weighing (g)	
10/10	10/17	67141 (t)		3.9035		3.9050	
		67142 (t)		3.9153		3.9147	

Figure 4.2. Example laboratory internal QC log.

independent audits. For cross-checking, the supervisor should reference all QC data on the Internal Quality Control Log Sheet to the laboratory QC logbook. Control charts should be maintained on each balance and also included in the logbook. These charts will indicate any excess drift caused by an instrument malfunction.

The QC supervisor must certify the acceptability of all filter weights and recorded QC data daily.

4.6 Postsampling Documentation and Inspection

Upon receipt of exposed filters from the field, the sample custodian should follow this procedure:

1. Examine the field data sheet. Determine whether all data needed to verify sample validity and to calculate mass concentration are provided (e.g., average flow rate, ambient temperature and barometric pressure, and elapsed time). Void the sample if data are missing or unobtainable from a field operator or if a sampler malfunction is evident.
2. If the exposed filter was packaged for shipment, remove the filter from its protective envelope and examine the shipping envelope. If sample material has been dislodged from a filter, recover as much as possible by brushing it from the envelope onto the deposit on the filter with a soft camel-hair brush.
3. Match the filter ID number with the correct laboratory data form on which the original balance ID number, filter ID number, filter tare weight, and other information are inscribed. The sample custodian should group filters according to their recorded balance ID numbers. Initial separation of filters by balance ID number will decrease the probability of a balance error that could result from the use of different balances for tare and gross weights.
4. Remove the filter from the protective manila folder. Should the filter be retained in its filter cassette, loosen the nuts on the top and remove the filter. Overtightening of the nuts may cause the filter to adhere to the cassette gasket. Gently remove it by the extreme corners to avoid damage. Inspect the filters for any damage that may have occurred during sampling. Conduct a secondary check of a sample's validity (as presented in Section 3.3). If insects are embedded in the sample deposit, remove them with Teflon-tipped tweezers and disturb as little of the sample deposit as possible. If more than 10 insects are observed, refer the sample to the supervisor for a decision on acceptance or rejection of the filter for analysis.
5. Place defect-free filters in protective envelopes and forward them to the laboratory for weighing and analysis. File the data sheets for subsequent mass concentration calculations.
6. Place defective filters, with the type of defect(s) listed, in separate clean envelopes, label the envelopes, and submit them to the laboratory supervisor for final approval of filter validity.

4.7 Final Weighing Procedure (Gross Weight)

1. Place the defect-free filter(s) in a conditioning environment and allow them to equilibrate according to procedures outlined in Section 4.3.
2. Repeat Steps 1 through 6 of the HV PM₁₀ filter tare-weighing procedure (Section 4.4). Record

the indicated gross weight on the Laboratory Data Form.

3. Perform the internal QC checks described in Section 4.5 to ensure the validity of reweighing.
4. 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.
5. If the filter is to receive further analysis, place it in a protective covering and note on the envelope or folder what additional analyses are required. Place an asterisk after the gross weight column on the Laboratory Data Form to indicate that the filter requires additional analysis. Carefully transport each packaged filter to the sample custodian, who will forward it to the laboratory responsible for the additional analyses.

4.8 Calculation of PM₁₀ Net 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. Refer to Section 5.0 for information regarding the calculation of PM₁₀ mass concentration.

5.0 Calculations, Validations, and Reporting PM_{10} Data

Measurements of PM_{10} mass concentration in the atmosphere that are used to determine attainment of the NAAQS for particulate matter must be expressed in units of micrograms per actual cubic meter ($\mu\text{g}/\text{m}^3$) of air. This section presents the calculations required to compute and report ambient PM_{10} concentrations. A summary of all calculation formulas and associated symbols presented in [this document](#) is given in Table 5-1.

Particle size discrimination by inertial separation requires that specific air velocities be maintained in the sampler's air inlet system. These design velocities are obtained when a specified "design flow rate" is maintained. The design flow rate is specified as an actual volumetric flow rate (Q_a), measured at existing conditions of temperature (T_a) and pressure (P_a).

The sampler's operational flow rate (i.e., the actual flow rate when the sampler is operating normally to collect a PM_{10} sample) should, of course, be very close to the design flow rate. All PM_{10} samplers have some means for measuring the operational flow rate, and that flow rate measurement system must be calibrated periodically with a certified flow rate transfer standard. Usually, measurements (or estimates) of ambient temperature and barometric pressure are required to get an accurate indication of the operational flow rate. For determining the average sampler flow rate over a sample period, use of average temperature (T_{av}) and average barometric pressure (P_{av}) over the sample period is recommended. However, if average temperature and pressure values (or reasonable estimates) cannot be obtained for each sample period, seasonal average temperature (T_s) and barometric pressure (P_s) for the site may be substituted.

T_{av} and P_{av} readings may be recorded onsite or estimated from data obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from airports or other sources must be at station pressure (i.e., not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport. If individual T_{av} and P_{av} readings cannot be obtained for each sample period and seasonal averages for the site are routinely substituted, care must be taken that the actual temperature and barometric pressure at the site can be reasonably represented by such averages. It is therefore recommended that seasonal average temperature and pressure values (T_s and P_s) for the site be used only when these values are within 20 K and 40 mm Hg (5 kPa) of the actual average temperature and barometric pressure (T_{av} and P_{av}) for the sample period.

The calculations presented in this section assume that the sampler has been calibrated in actual volumetric flow-rate units (Q_a) and that individual average temperature and barometric pressure values are used for each sample period. If seasonal average temperature and pressure values for the site are to be used, T_s may be substituted for T_{av} , and P_s may be substituted for P_{av} in Equations (7), (7a), and (14).

TABLE 5-1. FORMULAS ASSOCIATED WITH PM_{10} MONITORING

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5.1 Calculations

5.1.1. Flow Rate Calculations

Because flow-control methods (and hence, calibration procedures) vary among different sampler models, the calculations necessary to determine the average actual flow rate during a sample run will also differ. The following general procedures are recommended for calculating the average ambient flow rate of the HV PM_{10} sampler. In this section, it is assumed that the samplers have been calibrated according to procedures outlined in Section 2.0.

Note: Consistency in units is required. Adoption of uniform designations of Kelvin for temperature and millimeters Hg (or kPa) for pressure is recommended in all calculations.

5.1.1.1 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 ($\overline{\Delta P_{ex}}$) [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.

Each sampler's flow measurement system should be calibrated periodically, and the calibration should be described by a mathematical expression (e.g., a least-squares linear regression equation) that indicates the slope and intercept of the calibration relationship. Following the procedure in Section 2.0, this expression is in the form of:

$$\overline{Q}_a = b \left[\overline{\Delta P_{ex}} (T_{av} \%30) / P_{av} \right]^{1/2} + m \quad (7)$$

where

- \overline{Q}_a = the sampler's average actual flow rate for the sample period, m^3/min
- $\overline{\Delta P_{ex}}$ = average of initial and final sampler manometer readings, $(\Delta P_{ex_i} + \Delta P_{ex_f})/2$, mm (or in.) H_2O
- T_{av} = average ambient temperature for the sample period, K ($K = EC + 273$)
- 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,

$$\overline{Q}_a = b \left[(T_{av} \%30) / P_{av} \right]^{1/2} + m \quad (7a)$$

where

\bar{I} = average flow recorder reading for the sample period.]

5.1.1.2 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 (\bar{P}_1/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):

$$\bar{P}_1 = P_{av} \& \overline{AP}_{stg} \quad (10)$$

where

\bar{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
 \overline{AP}_{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 Equation (9) before recording the reading on the data sheet:

$$\text{mm Hg} = 25.4 (\text{in. H}_2\text{O}/13.6) . \quad (9)$$

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

$$\text{Average stagnation pressure ratio} = \bar{P}_1/P_{av} . \quad (11)$$

3. Use the manufacturer's lookup table (or alternate calibration relationship; see Section 2.0) to determine \bar{Q}_a from the average stagnation pressure ratio (\bar{P}_1/P_{av}) and T_{av} for the sample period. This value of \bar{Q}_a is the average volumetric flow rate for the sampler period.

5.1.2 Calculation of PM_{10} Concentrations

Accurate reporting of total PM_{10} mass concentration data requires the calculation of the total standard volume of air sampled (Equation [18]) and the final computation of total PM_{10} mass concentration (Equation [19]).

1. Calculate the total standard volume of air sampled:

$$V_a = (\bar{Q}_a)(t) \quad (18)$$

where

V_a = total volume of air sampled in volume units, m^3
 \bar{Q}_a = average sampler flow rate m^3/min
 t = total elapsed sampling time, min.

2. Calculate total PM_{10} mass concentration in $\mu\text{g}/m^3$:

$$PM_{10} = (10^6)(W_g - W_t)/V_a \quad (19)$$

where

$$\begin{aligned} PM_{10} &= PM_{10} \text{ mass concentration, } \mu\text{g}/\text{m}^3 \\ 10^6 &= \text{conversion factor, } \mu\text{g}/\text{g} \\ W_g, W_t &= \text{gross and tare weights of the HV } PM_{10} \text{ filter, respectively, g} \\ V_a &= \text{total sample volume in volume units, } \text{m}^3/\text{min}. \end{aligned}$$

5.2 Calculation Validation

Data necessary to compute the mass concentration of PM_{10} originate from two main sources: field operations and laboratory operations. These data must be validated to ensure that all reported PM_{10} measurements are accurate relative to the overall scope of the QA program. When the final mass concentration of PM_{10} 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). Therefore, should a mass concentration approach the primary or secondary ambient air quality standard, this validation procedure will provide checks for all preliminary field and laboratory operations. The steps of the calculation validation procedure are as follows:

1. Gather the following data for each sample:
 - Total sampling time, min
 - Average actual volumetric flow rate, \overline{Q}_a , m^3/min
 - Tare and gross weights, W_t and W_g , of the HV PM_{10} filter, g.
2. Recalculate the total mass concentration of PM_{10} for seven samples per 100 (minimum of four per lot) as specified in Sections 5.1.1 or 5.1.2. These suggested frequencies may be adjusted subsequently, based on accumulated experience and level of data quality. Decrease the frequency if experience indicates that data are of good quality, or increase it if data are of marginal or poor quality. It is more important to be sure that the validation check is representative of the various conditions that may influence data quality than to adhere to a fixed frequency.
3. Compare each validated PM_{10} concentration with the originally reported value. Correct any errors that are found, initial them, and indicate the date of correction. If a high percentage of errors is found, check additional calculated values. If consistent errors are found, check all values in the block of data and investigate and correct the cause.
4. Scan all total mass concentration values; note those that appear excessively high or low and investigate. Repeat Steps 2 and 3 for these samples.
5. If all mass concentration computations appear correct and questionably high or low values still exist, review all raw data (i.e., sample time, average actual volumetric flow rate, and its subsequent correction to standard conditions) for completeness and correctness.

5.3 Data Reporting

Attainment of the standards for particulate matter in the ambient air is based on the measured mass concentration of PM_{10} . Information on reporting and interpretation of PM_{10} data with respect to the attainment of these standards is covered in 40 CFR **Part 50**, Appendix K.

6.0 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.

This section outlines general maintenance procedures for HV PM₁₀ samplers. For more complete information on a particular sampler, or on laboratory equipment maintenance, refer to the manufacturer's instruction manual for the individual instrument. Table 6-1 summarizes maintenance activities for the HV PM₁₀ sampler.

Records should be maintained for the maintenance schedule of each HV PM₁₀ sampler. Files should reflect the history of maintenance, including all replacement parts, suppliers, costs, expenditures, and an inventory of on-hand spare equipment for each sampler. Check sheets should be used to record preventive and/or corrective maintenance activities and the subsequent sampler calibration curve.

6.1 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.

6.2 Recommended Maintenance Schedules

Although no maintenance schedule is explicitly prescribed in the Reference Method (40 CFR **Part 50**, Appendix **M**), field testing of the most common HV PM₁₀ samplers determined the following maintenance frequencies.

6.2.1 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.

Note: Bees often use this inlet as a hive, so be very careful during disassembly. A screen can be installed around the "lip" of the sampler inlet to prohibit larger insects from entering.

6.2.2 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 wiper** to prevent the oil from contaminating the filter substrate.

TABLE 6-1. ROUTINE MAINTENANCE ACTIVITIES

Equipment	Frequency and/or method	Acceptance limits	Action if requirements are not met
Sampler inlet	Dismantle and clean at manufacturer-specified intervals.	No obvious particulate deposits or damage.	Clean, replace damaged equipment before sampling.
Sampler base			
Power lines	Check for crimps or cracks.	No obvious damage.	Replace as necessary.
Filter screen and throat	Visually check on sample-recovery days.	No obvious deposits; clean with wire brush.	Clean.
Gaskets	At 3-mo intervals, inspect all gaskets in the sampler.	No leaks; no compression; damage evident	Replace as necessary.
Brushes	Replace after 600 to 1,000 h of operation.	Stable flow rate.	Replace as necessary.
Motor	Replace if needed.	Correct model must be used.	Obtain correct model.
Flow controller	Check when flow-rate changes are evident.	Stable flow rate throughout sample run.	Replace or repair if possible.
Recording device	Inspect when experiencing difficulty in zeroing, or when large changes in flow rates occur.	Recorder stays zeroed; chart advances; pen inks.	Replace or repair if possible.
Tubing, fittings	Visually inspect on sample-recovery days.	No crimps, cracks, or obstructions; no cross-threading.	Replace as necessary.

6.2.3 MFC Base

The MFC base is equipped with the following items:

1. Connecting tubing and power lines, which must be checked for crimps, cracks, or obstructions on sample recovery days. Fittings should be inspected periodically for cross-threading and tightness.
2. A filter screen, which should be inspected on sample recovery days for any impacted deposits.
3. Filter cassette gaskets, which need to be inspected each time a cassette is loaded. A worn cassette gasket is characterized on exposed filters by a gradual blending of the boundary between the collected particulates and the filter border.
4. Motor and housing gaskets, which should be checked at 3-mo intervals and replaced as necessary.
5. Blower motor brushes, which should be replaced before they become worn to the point that damage may occur. Although motor brushes usually require replacement after 600 to 1,000 h of operation, the optimum replacement interval must be determined by experience. A pumice stone can be used against the motor's contacts to ensure high conductivity. Change the brushes according to manufacturer's instructions, and perform the operator's field-calibration check as presented in Section 3.5. If the sampler's indicated flow rate exceeds the manufacturer-specified design flow-rate range, adjust the sampler before the next run day.

To achieve the best performance, new brushes should be properly seated on the motor's commutator before full voltage is applied to them. After the brushes have been changed, operate the sampler at 50 to 75 percent of normal line voltage for approximately 30 min. The motor should return to full performance after an additional 30 to 45 min at normal line voltage.

Caution: The motors that are used for HV PM₁₀ samplers are higher-current versions of the motors that have been used for HV total suspended particulate samplers. The brushes for the two types of motor are different. Make sure that the correct replacement brushes are used for the maintenance of HV PM₁₀ samplers.

6. If a motor needs to be replaced, be sure to use the higher-current versions that are needed for HV PM₁₀ sampling. When lower-current motors are installed in HV PM₁₀ samplers, the flow rate has been found to vary with changes in the line voltage.
7. A flow controller, which should be replaced if the flow recorder indicates no flow, low flow, excessive flow, or erratic flow. Minor adjustments can be made to alter sampling flow rates; however, the controller generally cannot be repaired in the field.
8. A flow recorder, which requires very little maintenance, but does deteriorate with age. Difficulty in zeroing the recorder and/or significant differences (i.e., >0.3 m³/min) in average flow rates obtained from consecutive sampling periods usually indicate a faulty recorder. The recorder pens should be replaced every 30 recording days. In dry climates, a more frequent replacement schedule may be required.

6.2.4 VFC Base

The VFC base is equipped with the following items:

1. Power lines, which must be checked for crimps or cracks on sample recovery days. Fittings should be inspected periodically for cross-threading and tightness.
2. A filter screen and the throat of the choked-flow venturi, which should be inspected on sample recovery days for any impacted deposits.
3. Filter cassette gaskets, which should be checked each time a filter is installed. A worn cassette gasket is characterized on exposed filters by a gradual blending of the boundary between the collected particulates and the filter border.
4. Motor and housing gaskets, which should be checked at 3-mo intervals and replaced as necessary.
5. Blower motor brushes, which should be replaced before they become worn to the point that damage may occur. Although motor brushes usually require replacement after 600 to 1,000 h of operation, the optimum replacement interval must be determined by experience. A pumice stone can be used against the motor's contacts to ensure high conductivity. Change the brushes according to manufacturer's instructions, and perform the operator's field-calibration check as presented in Section 3.5. If the sampler's indicated flow rate exceeds the manufacturer-specified design flow-rate range, recalibrate the sampler before the next run day.

To achieve the best performance, new brushes should be properly seated on the motor's commutator before full voltage is applied to them. After the brushes have been changed, operate the sampler at 50 to 75 percent of normal line voltage for approximately 30 min. The motor should return to full performance after an additional 30 to 45 min at normal line voltage.

Caution: The motors that are used for HV PM₁₀ samplers are higher-current versions of the motors that have been used for HV total suspended particulate samplers. The brushes for the two types of motor are different. Make sure that the correct replacement brushes are used for the maintenance of HV PM₁₀ samplers.

6. If a motor needs to be replaced, be sure to use the higher-current versions that are needed for HV PM₁₀ sampling. When lower-current motors are installed in HV PM₁₀ samplers, the flow rate has been found to vary with changes in the line voltage.

6.3 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.

7.0 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. This true assessment of the accuracy and efficiency of the PM₁₀ measurement system can only be achieved by conducting an audit under the following guidelines:

- Without special preparation or adjustment of the system to be audited.
- 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.
- With complete documentation of audit information for submission to the operating agency. The audit information includes, but is not limited to, types of instruments and audit transfer standards, instrument model and serial numbers, transfer-standard traceability, calibration information, and collected audit data.

The audit procedures described in this section produce two quantitative estimates of a PM₁₀ sampler's performance: the audit flow-rate percentage difference and the design flow-rate percentage difference. The audit flow-rate percentage difference determines the accuracy of the sampler's indicated flow rate by comparing it with a flow rate from the audit transfer standard. The design flow-rate percentage difference determines how closely the sampler's flow rate matches the inlet design flow rate under normal operational conditions.

An independent observer should be present for the audit, preferably the routine operator of the sampling equipment. This practice not only contributes to the integrity of the audit, but also allows the operator to offer any explanations and information that will help the auditor to determine the possible causes of discrepancies between audit-standard values and the sampling equipment values.

Audit techniques may vary among different models of samplers because of differences in required flow rates, flow-controlling devices, options utilized (i.e., continuous flow recorder), and the configuration of the samplers. The audit procedures provided in this section are specific to HV PM₁₀ samplers that are equipped with PM₁₀ inlets requiring an actual flow rate of 1.13 m³/min. Basic procedures for performance audits for both the MFC and VFC samplers are given here. Other procedures or other types of audit equipment may be acceptable if they provide equivalent results. System audits are also discussed. The requirements for these audits and evaluations are summarized Table 7-1. Refer to Method 12 of this volume for additional requirements for basic performance audits. **Refer to Part 1, Section 15, of this volume for detailed procedures for performance evaluations and technical systems audits.**

TABLE 7-1. AUDITING REQUIREMENTS

Procedure	Frequency and/or method	Acceptance limits	Action if requirements are not met
Flow-rate audit	Once each quarter for PSD monitoring, once per year for SLAMS.	<ol style="list-style-type: none"> 1. Percentage difference between the sampler-indicated flow rates and the audit-measured flow rate is within 10%. 2. $\pm 10\%$ of inlet design flow rate. 	Recalibrate before resuming sampling; if difference exceeds $\pm 10\%$, double-check calculations. If difference still exceeds $\pm 10\%$, invalidate data since last calibration or valid flow check. Readjust flow controller if necessary (MFC sampler) or contact manufacturer (VFC sampler). Recalibrate.
Systems audit	At beginning of a new monitoring system and periodically as appropriate; observe procedures and use checklist.	Method described in this section and Part 1, Section 15 , of this volume.	Initiate improved methods and/or training programs.
Data processing	Independently repeat calculation of PM_{10} concentration from data record for 7 samples per 100 (minimum of 4 per lot).	Audit concentration agrees with original report concentration within roundoff error.	Recheck all calculations.
Filter weighing	Perform 7 audits/100 filters, or 4 audits/#50 filters; use analytical balance; condition filters for at least 24 h before weighing.	Audit weight = original weight ± 5 mg unexposed filters.	Reweigh all filters in the lot.
Balance	Observe weighing technique; review balance maintenance and calibration log.	Balance is maintained and calibrated at least annually.	Reweigh all filters; calibrate balance.

7.1 Flow-Rate Performance Audit Procedure for Mass-Flow-Controlled (MFC) HV PM₁₀ Samplers

For this MFC procedure, the following conditions are assumed:

- The MFC sampler utilizes an electronic mass-flow controller for flow-rate control.
- The sampler's flow rate is measured by a water or oil manometer connected to the exit orifice plenum pressure port [or, if necessary, by a continuous flow recorder connected to the exit orifice port and equipped with square-root-scale chart paper].
- The sampler inlet is designed to operate at a flow rate of 1.13 m³/min at actual conditions; the acceptable flow-rate fluctuation range is ±10 percent of this value (i.e., 1.02 to 1.24 m³/min).
- The calibrated NIST-traceable audit transfer standard is an orifice device with an associated water or oil manometer.
- The audit orifice transfer standard's calibration relationship is expressed in actual volumetric flow-rate units (Q_a) as described in Section 2.2.

Note: Do not attempt to audit HV PM₁₀ samplers under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the audit orifice transfer standard's manometer. The audit will be less precise because of the pressure variations.

The auditor should adhere to the following procedures during an audit of the MFC sampler:

1. Transport the following equipment to the monitoring site:
 - Audit orifice transfer standard with calibration relationship in actual volumetric flow-rate (i.e., Q_a) units and traceable to NIST (see Section 2.2). This orifice transfer standard should not be the same one that is used for routine calibrations and QC flow checks.
 - An associated water or oil manometer, with a 0- to 400-mm (0- to 16-in.) range and minimum scale divisions of 2 mm (0.1 in.).
 - **A thermometer capable of accurately measuring ambient air temperatures over a range of 0 to 50 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.**
 - A portable aneroid barometer (e.g., a climber's or engineer's altimeter), capable of accurately measuring ambient barometric pressure over the range of approximately 500 to 800 mm Hg (66 to 106 kPa) to the nearest millimeter Hg and referenced within ±5 mm Hg to a barometer of known accuracy at least annually.
 - MFC Sampler Audit Data Sheet such as shown in Figure 7.1.
 - Clean filter [and clean recorder chart, if a flow recorder is used to quantitatively measure the flow rate].

Note: The site operator is responsible for providing the manometer (or other device) that is normally used for measuring the sampler's flow rate, the sampler calibration relationship

MFC Sampler Audit Data Sheet					
Station Location	Milford, NC	Date	11/1/97	Time	10:15 AM
Sampler Model	GMW	S/N	1297	Operator	D. Palmer
P _a 75 mm Hg	T _a 6 EC or	279 K	Unusual Conditions None		
7					
Audit Orifice S/N	10387	Orifice Calibration Date		7/22/97	
Orifice Calibration Relationship:	m =	1.2430	b =	-0.0062	r = 0.9999
Sampler Calibration Relationship:	m =	0.9137	b =	0.2629	r = 0.9979
Orifice Pressure Drop (ÄH ₂ O)	5.4	in. H ₂ O	Q _a (orifice) ^a	1.144	m ³ /min
			With Orifice Installed		Without Orifice Installed
Sampler Pressure Drop (ÄP _{ex})	4.0	in. H ₂ O	4.0	in. H ₂ O	4.2 in H ₂ O
Q _a (sampler) ^b	1.116	m ³ /min	1.116	m ³ /min	1.151 m ³ /min
Audit Flow Rate Percentage Difference ^c	-2.4	%			
Q _a (corrected sampler) ^d	1.179	m ³ /min			
Design Flow Rate Percentage Difference ^e	4.3	%			
<p>^a For calculation of audit orifice standard flow rates: $Q_a(\text{audit}) = \{[\ddot{A}(\text{H}_2\text{O}) (T_a/P_a)]^{1/2} - b\} \{1/m\}$</p> <p>^b For calculation of sampler flow rates: $Q_a(\text{sampler}) = \{[\ddot{A}P_{\text{ex}}/P_a) (T_a + 30)]^{1/2} - b\} \{1/m\}$</p> <p>^c Audit % difference ' $[100] \left[\frac{Q_a(\text{sampler}) \& Q_a(\text{orifice})}{Q_a(\text{orifice})} \right]$ where Q_a (sampler) is measured with the orifice installed</p> <p>^d Q_a (corrected sampler) ' Q_a (sampler) $\left[\frac{100 \& \text{Audit \% difference}}{100} \right]$ where Q_a (sampler) is measured without the orifice installed.</p> <p>^e Design flow rate % difference ' $[100] \left[\frac{Q_a(\text{corrected sampler}) \& 1.13}{1.13} \right]$</p>					
Auditor	F. McElroy		Observer	D. Palmer	

Figure 7.1. Example MFC sampler audit data sheet.

that is currently in effect for determining the flow rate for sample periods, and any other information or equipment that is normally used to determine the sampler's indicated flow rate.

2. [If a continuous flow recorder is being used quantitatively in lieu of a manometer to measure sampler flow rate, record the site location, sampler S/N, date, and the auditor's initials on the blank side of a clean recorder chart. Open the front door of the sampler and install the clean recorder chart. If the MFC sampler was calibrated by using square-root-scale chart paper, the audit must be conducted with the same type of chart paper. Observe the recorder zero setting. If necessary, instruct the operator to adjust the pen to indicate true zero.]
3. Instruct the operator to install a clean filter in the HV PM₁₀. **DO NOT** use a filter cassette; place the filter directly on the sampler filter screen. An audit filter should never be used for subsequent sampling because particles >10 µm can be collected on the filter while the inlet is raised. The sampler mass will be biased as a result of using a filter for both an audit and subsequent sampling.
4. Install the audit orifice transfer standard's faceplate on the sampler. Check that the gaskets are in good condition and have not deteriorated.

Caution: Tighten the faceplate nuts evenly on alternate corners to properly align and uniformly seat the gaskets. The nuts should be hand-tightened only; too much compression can damage the sealing gaskets.

5. Install the audit orifice transfer standard with **no resistance plate**, or fully open the valve of a variable-resistance orifice. For resistance plate orifices, make sure the orifice gasket is present and the audit orifice transfer standard is not cross-threaded on the faceplate. Seal the audit orifice transfer standard's pressure port with a rubber cap or similar device.
6. Leak-test the audit system (refer to Section 2.3.2, Step 5). Identify and correct any leaks before continuing.
7. Inspect the audit orifice manometer connecting tubing for crimps or cracks. Open the manometer valves fully and blow gently through the tubing, watching for the free flow of the fluid. Adjust the manometer sliding scale so that the zero line is at the bottom of the menisci. Connect the audit manometer to the pressure port on the orifice. Make sure the unconnected side of the manometer is open to the atmosphere. Make sure that the tubing fits snugly on the pressure port and on the manometer.
8. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min).

Note: The sampler inlet may be partially lowered over the audit orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 in. of clearance at the bottom for air flow and for the manometer tubing.

9. Observe and record the following parameters on the MFC Sampler Audit Data Sheet:
 - Sampler location, date, time
 - Sampler model and S/N, and calibration relationship
 - Ambient temperature (T_a), K (K = EC + 273)

- Ambient barometric pressure (P_a), mm Hg or kPa
 - Unusual weather conditions
 - Audit orifice transfer standard S/N and calibration information.
10. When the sampler has warmed up to operating temperature, observe the pressure drop across the orifice by reading the total manometer deflection, and record as ΔH_2O on the audit data sheet.
 11. Instruct the operator to read the sampler exit orifice manometer reading, ΔP_{ex} [or the continuous flow recorder response, I], and record it on the data sheet.
 12. Turn off the sampler and remove the audit orifice transfer standard, but do not remove the filter. Turn the sampler on again and repeat Step 11 for the normal operating flow rate.
 13. Gather together all audit data, including the audit orifice transfer standard's calibration information, the MFC sampler's calibration data [and the recorder chart that graphically displays the sampler response].
 14. Verify that the correct readings have been inscribed on the data sheet.
 15. Determine the flow rate through the audit orifice transfer standard, as presented in Equation (4):

$$Q_a(\text{audit}) = \{[\Delta H_2O(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

$Q_a(\text{audit})$ = actual volumetric flow rate as indicated by the audit orifice transfer standard,
m³/min

ΔH_2O = pressure drop across the orifice, mm (or in.) H₂O

T_a = ambient temperature, K (K = EC + 273)

P_a = ambient barometric pressure, mm Hg (or kPa)

b = intercept of the audit orifice transfer standard's calibration relationship.

m = slope of the audit orifice transfer standard's calibration relationship

16. Instruct the operator to calculate the sampler's indicated flow rate, $Q_a(\text{sampler})$ with and without the orifice installed, as it is normally done, using the sampler's calibration relationship (Equation 7 [or 7a], Section 2.3.3) and record both $Q_a(\text{sampler})$ values on the data sheet.
17. Calculate the percentage difference between the sampler's indicated flow rate, $Q_a(\text{sampler})$ with the orifice installed, and the corresponding audit flow rate, $Q_a(\text{audit})$, determined from the audit orifice transfer standard as:

$$\text{Audit flow rate \% difference} = [100] \left[\frac{Q_a(\text{sampler}) \& Q_a(\text{audit})}{Q_a(\text{audit})} \right]. \quad (12)$$

18. Record the audit flow rate percentage difference on the data sheet. If the audit flow rate percentage difference is $\neq \pm 10$ percent, the sampler calibration is acceptable. Differences exceeding ± 10 percent require sampler recalibration and may result in invalidation of all data

subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the audit orifice transfer standard's certification, and all calculations.

19. Calculate the corrected sampler flow rate, Q_a (corrected sampler), using Equation (16):

$$Q_a \text{ (corrected sampler)} = \left[Q_a \text{ (sampler)} \right] \left[\frac{(100 \pm \text{audit \% difference})}{100} \right] \quad (16)$$

where Q_a (sampler) is for the measurement without the audit orifice transfer standard installed. Be sure to carry over the sign of the audit percent difference from Step 17.

Calculate the design flow-rate percentage difference between the corrected sampler flow rate, Q_a (corrected sampler), and the inlet design flow rate of 1.13 m³/min as:

$$\text{Design flow\&rate \% difference} = \left[100 \right] \left[\frac{Q_a \text{ (corrected sampler)} - 1.13}{1.13} \right]. \quad (15)$$

20. Record the design flow-rate percentage difference. If the design flow-rate percentage difference is ± 10 percent, the sampler calibration is acceptable. Differences exceeding ± 10 percent should be investigated and may result in invalidation of all data obtained subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the audit orifice transfer standard's certification and all calculations.

Note: Deviations from the inlet design flow rate may be caused in part by deviations in the ambient temperature and pressure from the seasonal average conditions. Calculate the **sampler set point** according to Equation (8) in Section 2.3.4 to determine if the sample set point should be adjusted.

7.2 Flow-Rate Performance Audit Procedure for Volumetric-Flow-Controlled (VFC) HV PM₁₀ Sampler

For this VFC procedure, the following conditions are assumed:

- The VFC sampler utilizes a choked-flow venturi for flow-rate control.
- The sampler's flow rate is measured by a manometer (or other pressure measuring instrument) connected to measure the stagnation pressure via a stagnation pressure port. (This procedure does not provide an audit of a continuous flow recorder that may be connected to the exit orifice port.)
- The sampler inlet is designed to operate at a flow rate of 1.13 m³/min at actual conditions; the acceptable flow-rate fluctuation range is ± 10 percent of this value (i.e., 1.02 to 1.24 m³/min).
- The calibrated, NIST-traceable transfer standard is an orifice type with an associated water or oil manometer.

- The audit orifice transfer standard's calibration relationship is expressed in actual volumetric flow-rate (Q_a) units as described in Section 2.2.

Note: Do not attempt to audit HV PM₁₀ samplers under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the audit orifice transfer standard's manometer. The audit will be less precise because of the pressure variations.

The auditor should adhere to the following procedures during an audit of the VFC sampler. A flowchart of the audit procedures is given in Figure 7.2.

1. Transport the following equipment to the monitoring site:
 - Audit orifice transfer standard with calibration relationship in actual volumetric flow-rate (Q_a) units and traceable to NIST. The audit orifice transfer standard's faceplate or filter cassette may require modification to ensure a good seal during the performance audit. The audit orifice transfer standard should not be the same one that is used for routine calibrations and QC flow checks.
 - An associated water or oil manometer, with a 0- to 400-mm (0- to 16-in.) range and 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 EC to the nearest 0.1 EC. This thermometer should be traceable with an accuracy of 0.1 EC to a NIST-certified thermometer or an ASTM thermometer.**
 - A portable aneroid barometer (e.g., a climber's or engineer's altimeter), capable of accurately measuring ambient barometric pressure over the range of approximately 500 to 800 mm Hg (66 to 106 kPa) to the nearest millimeter Hg and referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.
 - VFC Sampler Audit Data Sheet such as shown in Figure 7.3.
 - A clean filter.

Note: The site operator is responsible for providing the manometer (or other pressure measuring device) that is normally used for measuring the sampler's stagnation pressure, the sampler lookup table or alternative calibration relationship that is currently in effect for determining the flow rate for sampling periods, and any other information or equipment that is normally used to determine the sampler's indicated flow rate.

2. Instruct the operator to install a clean filter in the VFC sampler. A filter cassette may be used if the audit orifice transfer standard can be properly mounted on top of the cassette. Otherwise, install the filter without the cassette. An audit filter should never be used for subsequent sampling because particles $>10 \mu\text{m}$ can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both an audit and subsequent sampling.
3. Install the audit orifice transfer standard's faceplate on the sampler. Check that the gaskets are in good condition and have not deteriorated.

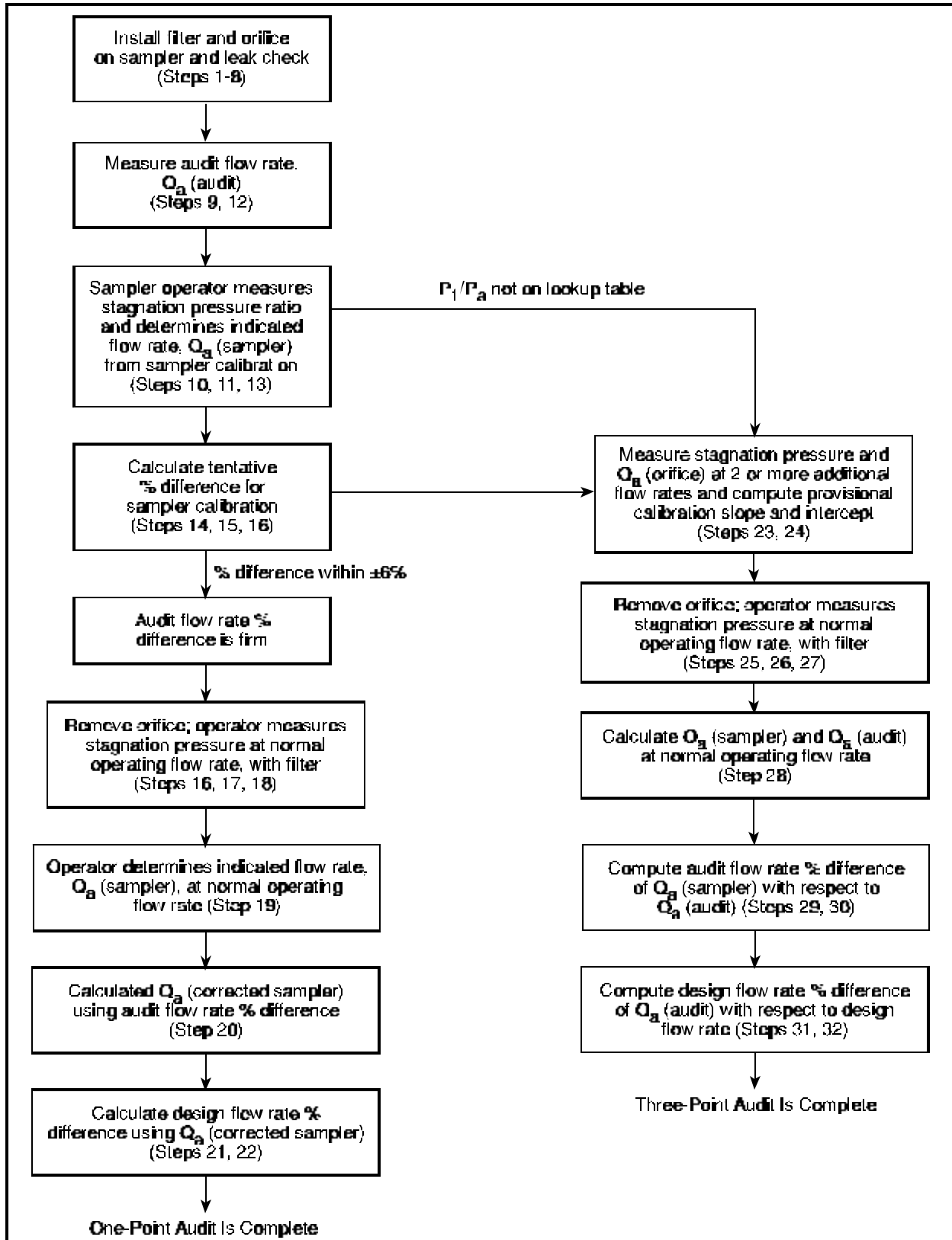


Figure 7.2. Flow chart of performance audit procedures for volumetric-flow-controlled PM₁₀ samplers.

VFC Sampler Audit Data Sheet (Part 1)				
Station Location	Indianapolis	Date	11/24/97	Time 2:15 PM
Sampler Model	Wedding	S/N	1040870285C	
P _a 73 mm Hg	T _a 11 EC or 284 K	Unusual Conditions None		
9				
Audit Orifice S/N	10387	Orifice Calibration Date	7/22/97	
Orifice Calibration Relationship:	m = 1.2430	b = -0.0062	r = 0.9999	
Sampler Calibration Relationship:	m = Lookup	b = Table	r = Used	
Orifice Pressure Drop (ÄH ₂ O)	4.5	in. H ₂ O	Q _a (orifice) ^a	1.063 m ³ /min
			With Orifice Installed	Without Orifice Installed
Stagnation Pressure (ÄP _{stg})	39.37	mm Hg	33.02	mm Hg
Absolute Stagnation Pressure (P ₁) ^b	699.63	mm Hg	705.98	mm Hg
Stagnation Pressure Ratio (P ₁ /P _a)	0.9467	(see note)	0.960	(see note)
Q _a (sampler) ^c	1.121	m ³ /min	1.146	m ³ /min
Audit Flow Rate Percentage Difference ^d	5.5	% (see note)		
Q _a (corrected sampler) ^e	1.083	m ³ /min		
Design Flow Rate Percentage Difference ^f	-4.2	%		
<p>Note: If P₁/P_a is less than the values that are listed in the manufacturer's lookup table or if audit flow rate percentage difference is greater than ±10 percent, proceed to Part 2 of the VFC Sampler Audit Data Sheet. Otherwise, complete this part.</p>				
<p>^a Q_a(orifice) = {[Ä(H₂O) (T_a/P_a)]^{1/2} - b} {1/m}</p> <p>^b P₁ = P_a - ÄP_{stg}</p> <p>^c Determine Q_a(sampler) from manufacturer's lookup table (or from alternate calibration relationship).</p> <p>^d Audit % difference = [100] $\left[\frac{Q_a(\text{sampler}) \& Q_a(\text{audit})}{Q_a(\text{audit})} \right]$ where Q_a(sampler) is measured with the orifice installed.</p> <p>^e Q_a(corrected sampler) = Q_a(sampler) $\left[\frac{100 \& \text{Audit \% difference}}{100} \right]$ where Q_a(sampler) is measured without the orifice installed.</p> <p>^f Design flow rate % difference = [100] $\left[\frac{Q_a(\text{corrected sampler}) \& 1.13}{1.13} \right]$</p>				
Auditor	R. Wright	Observer	K. McDaniel	

Figure 7.3. Example VFC sampler audit data sheet.

VFC Sampler Audit Data Sheet (Part 2)								
Station Location		Indianapolis		Date	11/24/97	Time	2:15 PM	
Sampler Model		Wedding		S/N	1040870285C			
P_a	73	mm Hg	T_a	11	EC or	284	K Unusual Conditions	None
	9							
Audit Orifice S/N		10387		Orifice Calibration Date		7/22/97		
Orifice Calibration Relationship:			$m =$	1.2430	$b =$	-0.0062	$r =$	0.9999

Plate No.	$\ddot{A}H_2O$ (in.)	$\ddot{A}P_{stg}$ (mm Hg)	P_1 (mm Hg)	P_1/P_a (mm Hg)	$(P_1/P_a)^{1/2}$	Q_a (Orifice) (m ³ /min)
1	4.5	39.37	699.63	0.9467	0.9730	1.063
2	4.35	44.45	694.55	0.9399	0.9695	1.045
3	4.1	52.07	686.93	0.9295	0.9641	1.015

Provisional Sampler Calibration Relationship: ($X = Q_a$ (Orifice), $Y = (P_1/P_a)^{1/2}$)

$m_{ll} =$ 0.1849 $b_{ll} =$ 0.7764 $r_{ll} =$ 0.9998

Measurements with filter installed and Audit Orifice Transfer Standard removed:

$\ddot{A}P_{stg}$	33.02	mm Hg	P_1^a	705.98	mm Hg
P_1/P_a	0.9553		$(P_1/P_a)^{1/2}$	0.9774	
Q_a (audit) ^b	1.087	m ³ /min	Q_a (sampler) ^c	1.146	m ³ /min
Audit Flow Rate Percentage Difference ^d				5.4	%
Design Flow Rate Percentage Difference ^e				-3.8	%

^a $P_1 = P_a - \ddot{A}P_{stg}$.

^b Q_a (audit) is determined from the provisional sampler calibration relationship.

^c Q_a (sampler) is determined from the lookup table or alternative calibration relationship.

^d Audit flow rate % difference = $[100] \left[\frac{Q_a \text{ (sampler)} \& Q_a \text{ (audit)}}{Q_a \text{ (audit)}} \right]$

^e Design flow rate % difference = $[100] \left[\frac{Q_a \text{ (audit)} \& 1.13}{1.13} \right]$

Auditor R. Wright	Observer K. McDaniel
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Figure 7.3 (continued)

Caution: Tighten the faceplate nuts evenly on alternate corners to properly align and uniformly seat the gaskets. The nuts should be hand-tightened only; too much compression can damage the sealing gaskets.

4. Install the audit orifice transfer standard with **no resistance plate**, or fully open the valve of a variable-resistance orifice. For resistance plate-type orifices, make sure the orifice gasket is present and that the audit orifice transfer standard is not cross-threaded on the faceplate. Seal the audit orifice transfer standard's pressure port and the stagnation pressure port with rubber caps or similar devices.
5. Leak-test the audit system (refer to Section 2.4.2, Step 4). Identify and correct any leaks before proceeding.
6. Inspect the audit manometer connecting tubing for crimps or cracks. Fully open the valves and blow gently through the tubing, watching for the free flow of the fluid. Adjust the manometer sliding scale so that the zero line is at the bottom of the meniscuses. Connect the audit manometer to the pressure port on the audit orifice transfer standard. Make sure the unconnected side of the manometer is open to the atmosphere. Make sure that the tubing fits snugly on the pressure port and on the manometer.
7. Read and record the following parameters on the VFC Sampler Audit Data Sheet:
 - Sampler location, date, time
 - Sampler model and S/N
 - Ambient temperature (T_a), EC and K ($K = EC + 273$)
 - Ambient barometric pressure (P_a), mm Hg (or kPa)
 - Unusual weather conditions
 - Audit orifice transfer standard's S/N and calibration relationship
 - Sampler lookup table number or other calibration relationship currently in effect.
8. Turn on the sampler and allow it to warm up to operating temperature (3 to 5 min).

Note: The sampler inlet may be partially lowered over the audit orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 in. of clearance at the bottom for air flow and for the manometer tubing.
9. When the sampler has warmed up to operating temperature, observe the pressure drop across the orifice by reading the total manometer deflection and record as ΔH_2O on the audit data sheet.
10. Instruct the operator to measure the sampler's relative stagnation pressure (i.e., relative to atmospheric pressure) with the manometer (or other pressure measurement instrument) normally used to measure stagnation pressure. Record the relative stagnation pressure as ΔP_{stg} on the data sheet. If ΔP_{stg} is measured in inches of water, convert the reading to millimeters Hg using Equation (9):

$$\text{mm Hg} = 25.4 (\text{in. H}_2\text{O})/13.6 . \quad (9)$$

11. Compute the absolute stagnation pressure, P_1 , as:

$$P_1 = P_a - \Delta P_{\text{stg}} \quad (10)$$

and the absolute stagnation pressure ratio as:

$$\text{Stagnation pressure ratio} = P_1/P_a \quad (11)$$

Record the P_1/P_a ratio on the audit data sheet.

12. Determine the flow rate through the audit orifice transfer standard, Q_a (audit), using Equation (4):

$$Q_a (\text{audit}) = \{[\Delta H_2O(T_a/P_a)]^{1/2} - b\} \{1/m\} \quad (4)$$

where

Q_a (audit) = actual volumetric flow rate as indicated by the audit orifice transfer standard,
m³/min

ΔH_2O = pressure drop across the orifice, mm (or in.) H₂O

T_a = ambient temperature, K (K = EC + 273)

P_a = ambient barometric pressure, mm Hg (or kPa)

b = intercept of the audit orifice transfer standard's calibration relationship

m = slope of the audit orifice transfer standard's calibration relationship.

13. Instruct the operator to determine the sampler's indicated flow rate, Q_a (sampler), using the P_1/P_a value obtained in Step 11 and the sampler's lookup table or alternative calibration relationship. Record this flow rate on the audit data sheet. If P_1/P_a is below the range covered by the lookup table or alternative calibration relationship, proceed to Step 23.
14. Calculate the audit flow rate percentage difference between the sampler's indicated flow rate, Q_a (sampler), and the corresponding audit flow rate, Q_a (audit), determined from the audit orifice transfer standard as:

$$\text{Audit flow\&rate \% difference} = \left[100 \left| \frac{Q_a (\text{sampler}) \& Q_a (\text{audit})}{Q_a (\text{audit})} \right| \right] \quad (12)$$

For the moment, this value should be considered as tentative. Record this value on the audit data sheet.

15. If the audit flow rate percentage difference is within ± 10 , the value may be considered as firm and may be recorded on Part 1 of the audit data sheet. Proceed to Step 16. If the value is **not** within ± 10 , or if a more comprehensive three-point audit is desired, skip to Step 23.
16. Turn off the sampler and remove the audit orifice transfer standard.
17. With a filter installed on the sampler in the normal sampling configuration (i.e., with a filter cassette, if normally used), turn on the sampler and allow it to warm up to operating temperature.

18. Instruct the operator to measure the sampler's relative stagnation pressure, $\ddot{A}P_{stg}$, and to calculate the absolute stagnation pressure ratio, P_1/P_a , as specified in Steps 10 and 11. Record these data on Part 1 of the audit data sheet. Turn off the sampler and replace the vacuum cap on the stagnation pressure port.
19. Calculate the sampler's indicated operational flow rate, Q_a (sampler), using the P_1/P_a value obtained in Step 18 and the sampler's lookup table or alternative calibration relationship. Record this flow rate on Part 1 of the audit data sheet.
20. Calculate the corrected sampler flow rate using Equation (16):

$$Q_a \text{ (corrected sampler)} = \left[Q_a \text{ (sampler)} \right] \left[\frac{(100 \text{ \& audit \% difference})}{100} \right] \quad (16)$$

where Q_a (sampler) is obtained from Step 19 and the audit flow rate percentage difference is obtained from Step 14. Record this value on Part 1 of the audit data sheet.

21. Calculate the design flow rate percentage difference between the corrected sampler flow rate from Step 20 and the inlet design flow rate of $1.13 \text{ m}^3/\text{min}$ as:

$$\text{Design flow\&rate \% difference} = \left[100 \right] \left[\frac{Q_a \text{ (audit) \& } 1.13}{1.13} \right]. \quad (15)$$

Record this value on Part 1 of the audit data sheet.

22. If the design flow rate percentage difference is within ± 10 percent, the sampler calibration is acceptable. Differences exceeding ± 10 percent should be investigated and may result in the invalidation of all data obtained subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the audit orifice transfer standard's certification, and all calculations.

This completes the one-point audit. Return the sampler to its normal operating configuration.

23. Repeat Steps 8 through 12 for at least two additional audit flow rates, obtained with resistance plates or by adjusting the variable resistance valve. These additional flow rates should be within or only slightly below the acceptable flow rate range (i.e., 1.02 to $1.24 \text{ m}^3/\text{min}$) of the sampler inlet, if possible. Record the data from all three points on Part 2 of the audit data sheet.

Note: Resistance plates supplied by the manufacturer of the audit orifice transfer standard may have to be modified (i.e., holes enlarged or additional holes drilled) to obtain appropriate flow rates.

24. For each calibration point, calculate and record the quantities (P_1/P_a) and Q_a (orifice). For the linear regression model,

$$(P_1/P_a) = m\mathbb{N}[Q_a (\text{orifice})] + b\mathbb{N}. \quad (20)$$

Calculate the linear regression slope ($m\mathbb{N}$), intercept ($b\mathbb{N}$) and correlation coefficient ($r\mathbb{N}$). Be sure to include the data obtained for the first flow rate in Steps 11 and 12 in the calculation of the linear regression. The regression calculations require a total of at least three points. Record these values on Part 2 of the audit data sheet.

Note: This is a temporary, provisional calibration relationship that is valid only during the audit because no temperature term is included in the calculations.

25. Turn off the sampler and remove the audit orifice transfer standard.
26. With a filter installed on the sampler in the normal sampling configuration (i.e., with a filter cassette, if normally used), turn on the sampler and allow it to warm up to operating temperature.
27. Instruct the operator to measure the sampler's relative stagnation pressure, $\dot{A}P_{\text{stg}}$, and to calculate the absolute stagnation pressure ratio, P_1/P_a as specified in Steps 10 and 11. Record these data on Part 2 of the audit data sheet. Turn off the sampler and replace the vacuum cap on the stagnation pressure port.
28. Calculate the sampler's indicated operational flow rate, Q_a (sampler), using the P_1/P_a value obtained in Step 27 and the sampler's lookup table or alternative calibration relationship. Calculate the audit value for the sampler's operational flow rate, Q_a (audit), using the (P_1/P_a) value obtained in Step 27 and the slope ($m\mathbb{N}$) and intercept ($b\mathbb{N}$) of the provisional sampler calibration relationship obtained in Step 24. Record these two flow rates on Part 2 of the audit data sheet.
29. Calculate the audit flow rate percentage difference between Q_a (sampler) and Q_a (audit) obtained in Step 28 as:

$$\text{Audit flow\&rate \% difference} = [100] \left[\frac{Q_a (\text{sampler}) \& Q_a (\text{audit})}{Q_a (\text{audit})} \right]. \quad (12)$$

Record this value on Part 2 of the audit data sheet.

30. If the audit flow rate percentage difference is within ± 10 percent, the sampler calibration is acceptable. Differences exceeding ± 10 percent will require recalibration and may result in the invalidation of all data subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the audit orifice transfer standard's certification, and all calculations.
31. Calculate the design flow-rate percentage difference between the Q_a (audit) obtained from Step 28 and the inlet design flow rate of $1.13 \text{ m}^3/\text{min}$ as:

$$\text{Design flow\&rate \% difference} = [100] \left[\frac{Q_a (\text{audit}) \& 1.13}{1.13} \right]. \quad (15)$$

Record this value on Part 2 of the audit data sheet.

32. If the design flow rate percentage difference is within ± 10 percent, the sampler calibration is acceptable. Differences exceeding ± 10 percent should be investigated and may result in the invalidation of all data obtained subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the audit orifice transfer standard's certification and all calculations.

This completes the three-point audit. Return the sampler to its normal operating configuration.

7.3 Audit Data Reporting

The operating agency should be given a copy of the audit preliminary results at the completion of the audit. The audit data sheet should be signed by both the auditor and the observer, and the results should be discussed. These preliminary data should never be used to make monitoring system adjustments. Auditors may make mistakes, and calibration curves may shift. A postaudit verification of audit equipment and data is essential before inferences can be drawn regarding the sampler's performance. An auditor should be able to support audit data with complete pre- or postaudit equipment verification documentation.

Final verified audit data should be submitted to the operating agency as soon as possible. Delays may result in data loss; a sampler out of audit limits is also out of calibration limits, and the data collected may be invalid. If a sampler exhibits unsatisfactory agreement with the verified audit results (i.e., audit flow-rate percentage differences exceeding ± 10 percent), a calibration should be performed immediately, certainly before the next run day.

7.4 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 percent 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 PM_{10} samplers, one or more randomly selected samplers should be reaudited so that at least one sampler is audited each calendar quarter.

7.5 System 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. Sections 7.5.1 and 7.5.2 present system audit procedures to evaluate data processing and laboratory operations.

Part 1, Section 15, of this volume provides additional detailed procedures and forms for system audits.

7.5.1 System Audit of 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. The following procedure is suggested:

1. Use the operational flow rates as reported on the sample data sheets.
2. Beginning with the raw data on the HV PM₁₀ sample data sheet and the filter net and tare weights, independently compute the PM₁₀ concentration (micrograms per cubic meter) and compare it with the corresponding concentration originally reported. If the mass concentration computed by the audit check does not agree with the original value within roundoff error, recheck the calculations for all samples in the lot.
3. Record the audit values on a data sheet and report them, along with the original values, to the supervisor for review. The audit value is always given as the correct value, based on the assumption that a discrepancy between the two values is always double-checked by the auditor.

7.5.2 Analytical Process System Evaluation

This section 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. The performance evaluation of the HV PM₁₀ filter-weighing process should be conducted in the following manner:

1. Instruct the operator to weigh a set of three to five **ASTM Class 1, 1.1, or 2 mass reference standards** covering the range normally encountered during gravimetric analysis. The weighed value should agree within ± 0.5 mg of the stated values.
2. Observe the balance operator's technique and review the laboratory weighing procedure for determining both the tare and gross weights of the sampling filters.
3. Review the maintenance and calibration log for each balance. Routine balance maintenance and calibrations must be performed by the manufacturer's service representative at manufacturer-specified scheduled intervals. In no case should the interval between calibrations exceed 1 year.
4. Review QC data records for the filter-weighing process. Ensure that the following QC activities have been performed and documented:
 - Standard weight check every day of balance operation.
 - Zero checks after every 5 to 10 filter weighings, calibration checks after every 15, unless longer-term stability of the balance has been established by records (at least 1 calibration check per day).
 - At least five filters reweighed each day.

If any of these QC checks are out of limits, note what action was taken.

8.0 Assessment of Monitoring Data for Precision and Accuracy

8.1 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. Where possible, additional collocated sampling is encouraged. **Sites must be selected on the basis of having annual mean PM_{10} concentrations that are** among the highest 25 percent of the annual mean PM_{10} concentrations for all the sites in the network. If such sites are impractical, however, alternate sites approved by the Regional Administrator may be selected.

Collocated PM_{10} samplers being used for assessment of precision should generally 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 PM_{10} 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. Each duplicate sampler must be operated concurrently with its associated **primary** sampler at least once a week. The operation schedule should be selected so that the sampling days are distributed evenly over the year and over the 7 days of the week. The every-6th-day schedule used by many monitoring agencies is **required**. The measurements from both samplers at each collocated sampling site are reported. An example precision data reporting form is presented in Figure 8.1. 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.

8.2 Accuracy

Each calendar quarter, audit the flow rate of at least 25 percent 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 HV PM_{10} 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 Section 7.0. Both the audit flow rate and the corresponding sampler flow rate are reported. An example accuracy data reporting form is presented in Figure 8.2. The percentage differences between these flow rates are used to calculate accuracy as described in 40 CFR **Part 58**, Appendix A.

9.0 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.

9.1 Recommended Standards for Establishing Traceability

1. **ANSI/ASTM Class 1, 1.1, or 2 mass reference standards** are recommended for the laboratory balance calibration. See Section 4.5 for details on balance calibration checks.
2. 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.

Note: As they are sold, standard volume meters may not be traceable to NIST. Traceability can be established through NIST or through the meter manufacturer's repair department. Periodic recertification is not normally required under clean service conditions unless the meter has been damaged and must be repaired. Section 2.0 presents details on HV PM₁₀ sampler calibration, and Section 7.0 presents details on the flow-rate performance audits.

3. 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.
4. 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.

10.0 References

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