SECTION 2.11

Reference Method for the Determination of Particulate Matter as PM10 in the Atmosphere (High-Volume PM10 Sampler Method)

Outline

2.11.0 INTRODUCTION

PM10 is the designation for particulate matter in the atmosphere that has an aerodynamic diameter of 10 micrometers (μm) or less. A high-volume (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-hour 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 (40 CFR 50, Appendix J), which is reproduced in Subsection 11.12(1).

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. This sampled volume must be corrected to EPA standard conditions (25°C, 760 mm Hg or 101 kPa), and the PM10 measurement is expressed as micrograms per standard cubic meter (μg/std. m^3).

The performance parameters of PM10 samplers are tested in accordance with explicit test procedures that are prescribed in 40 CFR 53(2). 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 System (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 high-volume PM10 samplers (HV PM10) and dichotomous samplers. Only HV PM10 samplers are discussed in this section; dichotomous samplers are discussed in Section 2.10.

An HV PM10 sampler consists of two basic components: a specially designed inlet that transmits only those particles less than 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 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 systems.

Impaction Inlet

Figure 0.1 is a schematic drawing showing the basic elements of an impaction HV PM10 inlet. The symmetrical design of the inlet insures wind-direction insensitivity. Ambient air that is drawn into the inlet is evacuated from the buffer chamber through nine acceleration nozzles into the first impaction chamber, where initial particle separation occurs. The air is then accelerated through an additional 16 jets into a second impaction chamber. The acceleration jets have critical diameters calculated by the manufacturer to provide the necessary changes in velocity to effect correct particle size fractionation within the impaction chambers. The air flow finally exits the inlet through nine vent tubes onto a sample filter. Because air velocities are critical to maintain the correct particle size cutpoint within the inlet, maintaining the correct design flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, the design flow rate for one popular impaction inlet is 1.13 m^3/min.

Cyclonic Inlet

Figure 0.2 is a schematic drawing of a cyclonic HV PM10 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., PM10 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 design volumetric flow rate through the inlet is important. This design 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 design flow rate of 1.13 m^3/min.

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
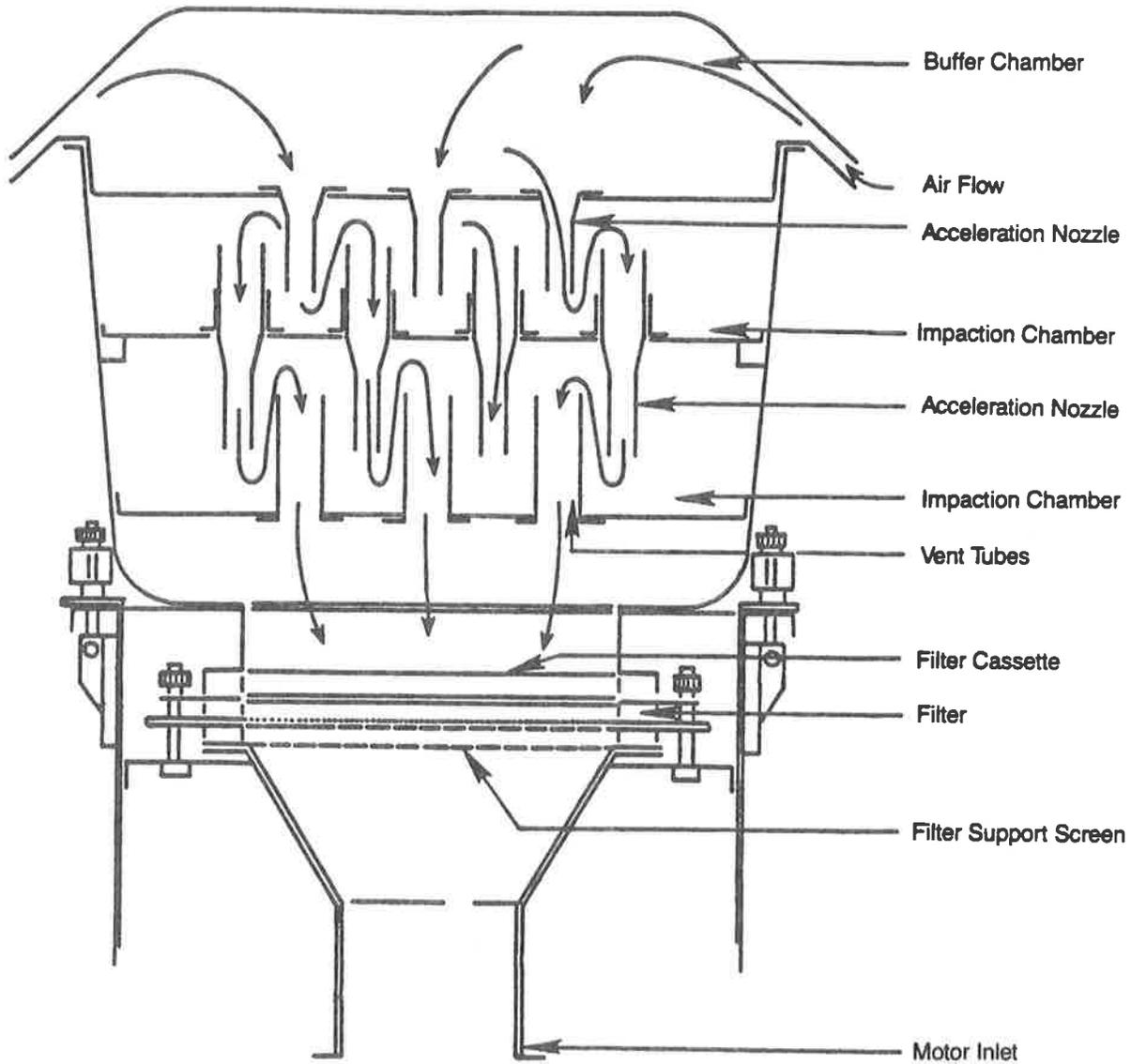
Figure 0.1. Schematic diagram of an impaction inlet.
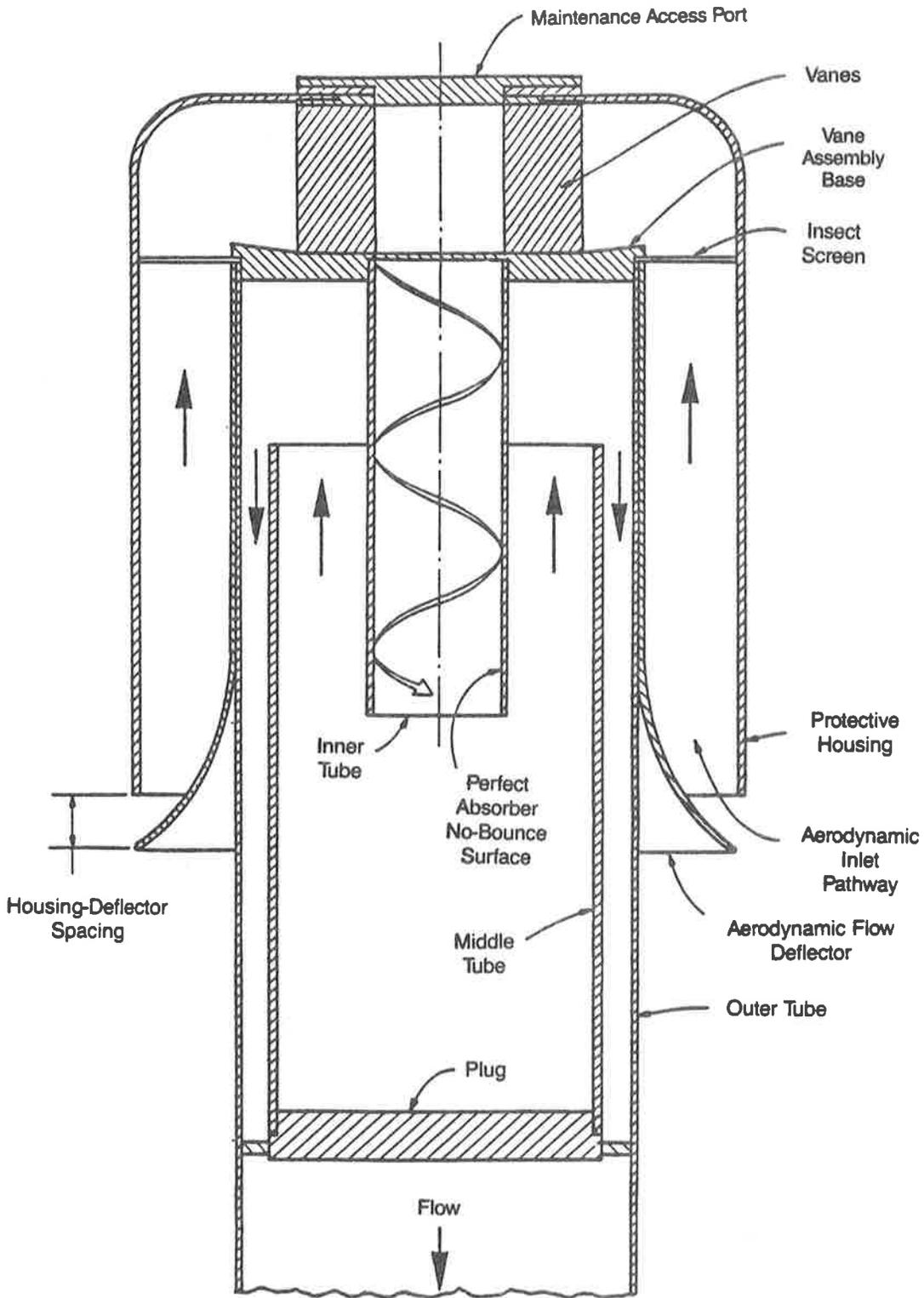
Figure 0.2. Schematic diagram of a cyclonic inlet.

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 set forth 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 blank data forms (see Subsection 12) may be used as they are, or they may serve as guidelines for preparing forms more specific to the needs of the individual monitoring agency. Partially filled-in forms are included at appropriate places in the discussion of the procedures to illustrate their uses.

Tables at the end of some subsections summarize the material covered in those subsections. The material covered in the various subsections of this section is summarized here:

1. Subsection 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.

2. Subsection 2, Calibration Procedures, provides detailed calibration procedures for the HV PM10 sampler. A table at the end of this subsection summarizes acceptance limits and gives references for the calibration procedures of associated monitoring equipment used in a PM10 sampling program.

3. Subsection 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 important to future data validation; particularly important information are any unusual conditions that existed during sample collection. Such conditions should be noted.

4. Subsection 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. Subsection 4 also briefly describes minimum laboratory quality control (QC) procedures. The analytical balance must be calibrated annually, and the filters must be equilibrated in a controlled environment.

5. Subsection 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.

6. Subsection 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.

7. Subsection 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.

8. Subsection 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.

9. Subsection 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.

10. Subsections 10 and 11 contain the PM10 Reference Method and pertinent references used to prepare this document. Subsection 12 provides blank data forms for the convenience of the user.

2.11.1 PROCUREMENT OF EQUIPMENT AND SUPPLIES

The establishment of an ambient PM10 air monitoring network requires the procurement of specialized equipment and supplies for field operations and subsequent filter analysis. Information in this section has been provided to assist the agency in selecting the proper equipment. Subsection 1.1 presents minimum sampling equipment necessary to conduct field operations. Recommended laboratory instrumentation is presented in Subsection 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. Sample blank data sheets are presented in Subsection 12.

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, which is an example of such a 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, at the end of the subsection, 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 PM10 Samplers - An individual sampler must meet U.S. EPA operational standards and be a model designated as a reference or equivalent method. A complete listing of minimum sampler requirements (i.e., 40 CFR 50, Appendix J) is reproduced in Subsection 10. Those HV PM10 samplers not designated as reference or equivalent methods may not be used for reporting data to determine attainment of the National Ambient Air Quality Standards (NAAQS) for particulate matter. The cost of HV PM10 samplers will vary by manufacturer and the options chosen (i.e., continuous flow recorder, timer).

An in-house inventory of general maintenance supplies and replacement parts is recommended. These include various handtools; faceplate, motor, and filter cassette gaskets; general all-purpose cleaner; penetrating oil; distilled water; Kimwipes (or equivalent); 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 temperatures to the nearest ±1°C and referenced to a National Institute of Standards and Technology (NIST) or an American Society for Testing Materials (ASTM) thermometer within ±2°C (NIST is the former National Bureau of Standards [NBS]).

ITEM	Description	Qty	Purchase Order No.	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.

- A barometer capable of accurately measuring barometric pressure over a range of 500 to 800 mm Hg (66 to 106 kPa) to the nearest millimeter of 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 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 H_2O (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 1000-mm H_2O (0- to 36-in. H_2O) 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 an NIST-traceable calibration relationship and be capable of accurately measuring volumetric flows between 1.02 and 1.24 m^3/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 50, Appendix J. These filters may be brittle, which makes them more 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). Subsection 4, Table 4.1, 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 during weighing operations.

1.2.2 <u>Filter Protection</u> - Post-sampling 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 <u>Laboratory Equipment</u> - The analytical balance must be suitable for weighing the type and size of 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°C and controlled within ±3°C. 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°C [283 to 303 K] to the nearest ±1°C) that has been checked against an NIST or ASTM thermometer to within ±2°C.

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 subsection.

TABLE 1.1. ACCEPTANCE TESTS 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 50, Appendix J.	Reject sampler.
Calibration-QC/QA supplies	Check against 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 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.
Laboratory equipment and instrumentation	Check against NIST-traceable standards.	Within accuracy limits presented in text.	Adjust or reject.

2.11.2 CALIBRATION PROCEDURES

Before a PM10 monitoring program commences, it is essential to properly calibrate all sampling and laboratory equipment. 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 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 subsection 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 a table at the end of this subsection (Table 2.1).

Although it concerns TSP samplers rather than HV PM10 samplers, Reference 3 provides useful information concerning flow-rate-calibration procedures that is applicable to PM10 samplers. Reference 4 provides useful information concerning positive-displacement, standard volume meters (e.g., Roots[R] Meters).

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

2.1 A discussion of volumetric and mass flow measurements and their applicability in a PM10 monitoring program.

2.2 A certification procedure for an orifice flow-rate transfer standard.

2.3 Basic calibration procedure specific to an MFC HV PM10 sampler.

2.4 Basic calibration procedure specific to a VFC HV PM10 sampler.

2.5 Calibration frequency requirements.

Table 2.1, at the end of this subsection, presents minimum accuracy requirements for equipment that is used in PM10 sampling. It also references appropriate subsections in Section 2.2 of this volume.

Note: Consistency of temperature and barometric pressure units is required. It is recommended that all temperatures be expressed in kelvin (K = °C + 273). It is also recommended that all barometric pressures be expressed in either mm Hg or kPa

(but do not mix the two units). Take care to avoid calibrating a PM10 sampler using one set of units and then performing sample calculations using another set of units.

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 m^3/min with no tolerance given, the acceptable flow-rate range would be 1.02 to 1.24 m^3/min.

As indicated above, the true or actual flow rate through the sampler inlet must be known and controlled to ensure that only those particles nominally less than 10 μm are being collected. A common source of error in a PM10 monitoring program is confusion of various air volume flow-rate measurement units. Although the sampler's operational flow rate must be monitored in terms of actual volume flow rate units (Qa), sampler flow rates must be corrected to standard volume flow rate units (Qstd) at EPA standard conditions of temperature and pressure to calculate PM10 concentrations as required by EPA. Thus, both Qa and Qstd flow rates are used for PM10 measurements. Before calibration procedures are initiated, the operating agency personnel should review the following flow-rate measurement designations:

- **Qa:** Actual volumetric air flow rates, measured and expressed at existing conditions of temperature and pressure and denoted by Qa (Qactual). Typical units are L/min and m^3/min. Inlet design flow rates are always given in actual volumetric flow rate units.

- **Qstd:** Air flow rates that have been corrected to equivalent standard volume flow rates at EPA standard conditions of temperature and pressure (25 °C or 298 K and 760 mm Hg or 101 kPa) and denoted by Qstd (Qstandard). Typical units are std. L/min and std. m^3/min. Standard volume flow-rate units are often used by engineers and scientists because they are equivalent to mass flow units. Standard volumes (derived from standard volume flow rates) are required for the calculation of PM10 mass concentration (μg/std. m^3) in reporting PM10 measurements.

These Qa and Qstd measurement units must not be confused or interchanged. The flow rate units can be converted as follows, provided the existing temperature and pressure (or in some cases the average temperature and pressure over a sampling period) are known:

$$Qstd = Qa(Pa/Pstd)(Tstd/Ta) \qquad \text{(Eq. 1)}$$

$$\overline{Qstd} = \overline{Qa}(Pav/Pstd)(Tstd/Tav) \qquad \text{(Eq. 1a)}$$

$$Qa = Qstd(Pstd/Pa)(Ta/Tstd) \qquad \text{(Eq. 2)}$$

where:

$Qstd$ = standard volume flow rate, std. m^3/min
Qa = actual volume flow rate, actual m^3/min
Pa = ambient barometric pressure, mm Hg (or kPa)
$Pstd$ = EPA standard barometric pressure, 760 mm Hg (or 101 kPa)
$Tstd$ = EPA standard temperature, 298 K
Ta = ambient temperature, K (K = °C + 273)
$\overline{Qstd}$ = average standard volume flow rate for the sample period, std. m^3/min
$\overline{Qa}$ = average actual volume flow rate for the sample period, m^3/min
Pav = average ambient barometric pressure during the sample period, mm Hg (or kPa)
Tav = average ambient temperature during the sample period, K

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 subsection recommend that individual average temperature (Tav) and pressure (Pav) 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 (Ps) and seasonal average temperature (Ts) 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 subsection provide for calibration of both the sampler and the flow rate transfer standard in actual volumetric flow-rate units (Qa). 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 actual volumetric flow rates of the sampler during sampling are then converted to the equivalent standard volumetric flow rates (Qstd), using Equation 1, for calculation of the PM10 concentration in $\mu g/std.\ m^3$. High-volume samplers for total suspended particulates (TSP) or lead may also be calibrated in this mode, using adaptations of these procedures, if desired for agency consistency. Other modes of calibration (such as calibration in terms of Qstd) are not precluded provided they produce accurate measurements of Qa for comparing the sampler flow rate to its design flow rate, and of Qstd for calculating PM10 concentrations.

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 reference flow [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^R Meter) traceable to the National Institute of Standards and Technology (NIST).

        Note: As they are sold, standard volume meters may not be traceable to NIST. Traceability can be established directly through NIST 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 Reference 4 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.).

    •   Thermometer, capable of accurately measuring temperatures over the range of 0 to 50 °C (273 to 323 K) to the nearest ±1 °C and referenced to an NIST or American Society for Testing and Materials (ASTM) thermometer within ±2 °C at least annually.

- 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 (blank forms appear in Subsection 12).

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 Pa.

4. Read the ambient temperature in the vicinity of the standard volume meter and record it as Ta (K = °C + 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. (See Figure 2.5 of Section 2.2 of this Handbook for an example of the calibration setup.) 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 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 that is described above is one of several alternate procedures which 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

ORIFICE TRANSFER STANDARD CERTIFICATION WORKSHEET

Date: 7/22/88   Roots meter S/N: 7464318   Ta: 22.6   K 295.6

Operator: G. PRATT   Orifice S/N: 2   Pa: 756.2 mm Hg

Plate or Volts AC	Initial Volume	Final Volume	Δ Vol.	ΔTime (min)	ΔHg (mm)	ΔH₂O (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

Vstd	(x-axis) Qstd	(y-axis) $[\Delta H_2O\,(Pa/Ta)]^{1/2}$*	Va	(x-axis) Qa	(y-axis) $[\Delta H_2O\,(Ta/Pa)]^{1/2}$
			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

$Vstd = \Delta Vol\,[(Pa - \Delta Hg)/760]\,(298/Ta)$*

$Qstd = Vstd/\Delta Time$*

$y = mx + b$

$Va = \Delta Vol\,[(Pa - \Delta Hg)/Pa]$

$Qa = Va/\Delta Time$

$y = mx + b$

For subsequent flow rate calculations:

$Qstd = \{[\Delta H_2O\,(Pa/Ta)]^{1/2} - b\}\,\{1/m\}$*

$Qa = \{[\Delta H_2O\,(Ta/Pa)]^{1/2} - b\}\,\{1/m\}$

*NOTE: For PM10 monitoring, a calibration curve corrected to standard conditions is optional.

Figure 2.1. Example Orifice Transfer Standard Certification Worksheet.

the water and mercury manometers by sliding their scales so that their zero lines are even with the bottom of the meniscuses.

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 m^3/min (32 to 46 ft^3/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 that 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 m^3 of air have passed through the standard volume meter. Record the standard volume meter's inlet pressure manometer reading as ΔHg, and the orifice manometer reading as ΔH_2O. Be sure to indicate the correct units of measurement. If ΔH_2O changes significantly during the run, abort the run and start again.

12. When at least 3 m^3 of air have 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 ($\Delta Time$) indicated on the stopwatch.

13. Calculate the volume measured by the standard volume meter ($\Delta Vol.$) using Equation 3 and record.

$$\Delta Vol. = Final\ Volume - Initial\ Volume \qquad (Eq.\ 3)$$

14. Correct. this volume to ambient atmospheric pressure.

$$Va = \Delta Vol.(Pa - \Delta Hg)/Pa \qquad (Eq.\ 4)$$

where:

> Va = actual volume at ambient barometric pressure, m^3
> $\Delta Vol.$ = actual volume measured by the standard volume meter, m^3
> Pa = ambient barometric pressure during calibration, mm Hg (or kPa)
> ΔHg = differential pressure at inlet to volume meter, mm Hg (or kPa).

15. Calculate the actual volumetric flow rate (m^3/min).

$$Qa = Va/\Delta Time \qquad \text{(Eq. 5)}$$

where:

   Qa = actual volumetric flow rate through the orifice, m^3/min
   Va = actual volume at ambient barometric pressure, m^3
   $\Delta Time$ = 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 m^3/min (32 to 46 ft^3/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 m^3/min (36 to 44 ft^3/min)]. Better calibration precision may be obtained by running additional flow rates or repeating the flow rates.

17. For each flow, compute $[(\Delta H_2O)(Ta/Pa)]^{1/2}$, and plot these values against the corresponding values of Qa. Draw the orifice transfer standard's certification curve. For the model $[(\Delta H_2O)(Ta/Pa)]^{1/2} = m(Qa) + b$, 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 m^3/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 Qa from the calibration relationship as:

$$Qa(orifice) = \{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\} \{1/m\} \qquad \text{(Eq. 6)}$$

where:

   Qa(orifice) = actual volumetric flow rate as indicated by the orifice transfer standard, m^3/min
   ΔH_2O = pressure drop across the orifice, mm (or in.) H_2O
   Ta = ambient temperature during use, K (K = °C + 273)
   Pa = 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^R 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 subsection 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 m^3/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 (Qa), and the orifice transfer standard is also calibrated in Qa, as specified in Subsection 2.2.

2.3.1 Calibration Equipment -

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

    Note: The predrilled resistance plates that are 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. Alternately, 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. Thermometer, capable of accurately measuring temperature over the range of 0 to 50 °C (273 to 323 K) to the nearest ±1 °C and referenced to an NIST or ASTM thermometer within ±2 °C at least annually.

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 log book, 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 listed in Subsection 2.3. 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.

   At least three flow rates should be within (or nearly within) the acceptable flow-rate range (i.e., 1.02 to 1.24 m^3/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. Leak Test: Block 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 that is described above is one of several alternate procedures which may be used. Operating agencies may develop their own procedures.
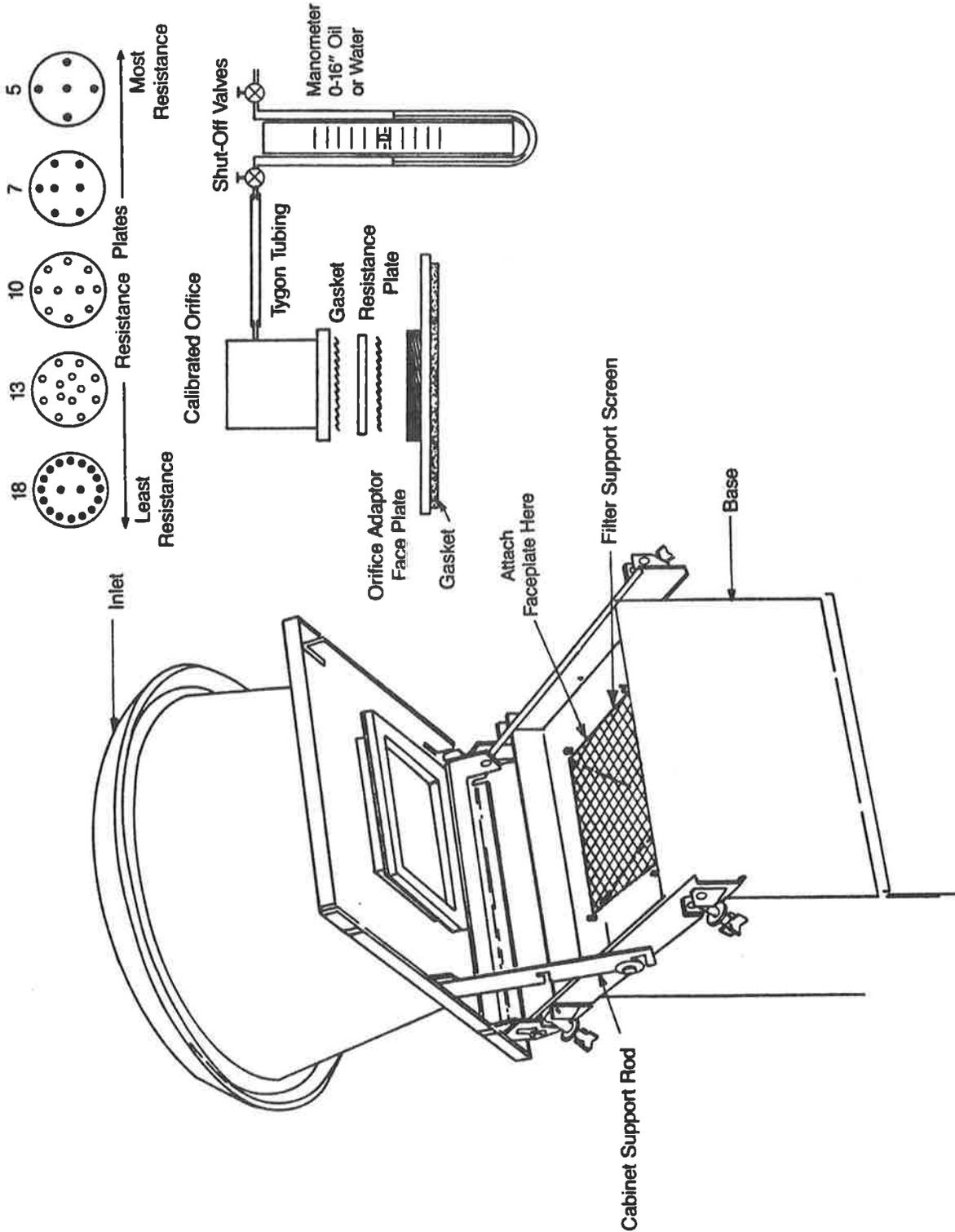
Figure 2.2. MFC sampler calibration equipment.

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 meniscuses. 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 (blank forms appear in Subsection 12).

   • Date, location, and operator's signature.
   • Sampler S/N and model.
   • Ambient barometric pressure (Pa), mm Hg or kPa.
   • Ambient temperature (Ta), K (K = °C + 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 = °C + 273). It is also recommended that all barometric pressures be expressed in either mm Hg or kPa (but do not mix the two units). Take care to avoid calibrating a PM10 sampler using one set of units and then performing sample calculations using another set of units.

   Note: 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 Subsection 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, ΔH_2O (in. H_2O), and the corresponding sampler's manometer deflection, ΔPex [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.

MFC SAMPLER CALIBRATION DATA SHEET

Station Location _MILFORD, NC_ Date _10/15/88_ Time _0900_

Sampler Model _GMW_ S/N _1297_ Operator _D. PALMER_

Pa _762_ mm Hg, Ta _19.4_ °C _292.4_ K, Unusual conditions: _NoNE_

Ps* _743_ mm Hg, Ts* _8.7_ °C _281.7_ K, (*seasonal average Ta and Pa)

Orifice S/N _Z_ Orifice Calibration Date _7/22/88_

Orifice calibration relationship: m = _1.2390_ b = _0.0172_ r = _0.9999_

Plate Number	Total ΔH_2O (in.)	X-Axis = Qa (orifice) flow rate[a] (m^3/min)	Sampler ΔPex (in. H_2O) [or I for flow recorders]	Y-Axis = Sampler $\Delta Pext$[b] [or It for flow recorders][c]
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

[a]$Qa = \{[(\Delta H_2O) (Ta/Pa)]^{1/2} - b\} \{1/m\}$

[b]$\Delta Pext = [\Delta Pex(Ta + 30)/Pa)]^{1/2}$

[c]$It = [I] [(Ta + 30)/Pa]^{1/2}$ if a flow recorder is used

Sampler Calibration Relationship (Qa on x-axis; $\Delta Pext$ or [It] on y-axis):

$\Delta Pext = m[Qa (Orifice)] + b$ or $It = m[Qa(Orifice)] + b$

m = _0.9137_ b = _0.2629_ r = _0.9979_

For subsequent calculation of sampler flow rate:

$\overline{Qa} = \{[mean \Delta Pex (Tav + 30)/Pav]^{1/2} - b\} \{1/m\}$

or $\overline{Qa} = \{mean I[(Tav + 30)/Pav]^{1/2} - b\} \{1/m\}$

Set point flow rate (SFR) _1.14_   Sampler set point (SSP) _4.02_

SFR = 1.13 (Ps/Pa) (Ta/Ts)

$SSP = [Pa/(Ta + 30)] [m(SFR) + b]^2$

or $SSP = [Pa/(Ta + 30)]^{1/2} [m(SFR) + b]$ for flow recorders

Figure 2.3. Example MFC sampler calibration data sheet.

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 of the next subsection.

    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 the following subsection. The data generated will be used to set the mass flow controller (Subsection 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 Qa for each calibration point from the orifice calibration information and Equation 6:

$$Qa(orifice) = \{[\Delta H_2O(Ta/Pa)]^{1/2} - b\}\ \{1/m\} \qquad (Eq.\ 6)$$

where:

   Qa(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
Ta = ambient temperature during use, K (K = °C + 273)
Pa = 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 $\Delta Pext$ for each calibration point as:

$$\Delta Pext = [\Delta Pex(Ta+30)/Pa]^{1/2} \qquad \text{(Eq. 7)}$$

where:

$\Delta Pext$ = transformed manometer reading
ΔPex = sampler manometer reading, mm (or in.) H_2O
Ta = ambient temperature, K (K = °C + 273)
Pa = ambient barometric pressure, mm Hg (or kPa).

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

$$It = I[(Ta+30)/Pa]^{1/2} \qquad \text{(Eq. 7a)}$$

where:

It = 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 7a.

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

Because the determination of the sampler's average operational flow rate (Qa) 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 = $\Delta Pext$ and x = Qa(orifice) so that the model is given by:

$$\Delta Pext = m[Qa(orifice)] + b \qquad \text{(Eq. 8)}$$

[For the flow recorder, the model is:

$$It = m[Qa(orifice)] + b \qquad \text{(Eq. 8a)]}$$

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 ±0.04 m^3/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, $\overline{Qa}$, is calculated from the calibration slope and intercept using Equation 9:

$$\overline{Qa} = \{[\overline{\Delta Pex}(Tav+30)/Pav]^{1/2} - b\}\ \{1/m\} \qquad \text{(Eq. 9)}$$

where:

$\overline{Qa}$ = the sampler's average actual flow rate, m^3/min
$\overline{\Delta Pex}$ = average of initial and final sampler manometer readings, $(\Delta Pex_i + \Delta Pex_f)/2$, mm (or in.) H_2O
Tav = average ambient temperature for the sample period, K (K = °C + 273)
Pav = 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,

$$\overline{Qa} = \{\overline{I}[(Tav+30)/Pav]^{1/2} - b\}\ \{1/m\} \qquad \text{(Eq. 9a)}$$

where:

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

Note: If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for (I) in Equation 9a.

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. The correct volumetric set-point flow rate (SFR) at Ta and Pa has the same mass flow rate as the inlet design volumetric flow rate has at Ts and Ps.

Note: The correct SFR thus may be different from day to day and may be some-what higher or lower than the inlet design flow rate on any particular day.

Set the mass flow controller as follows:

1. Determine the seasonal average temperature (Ts) and seasonal average pressure (Ps) 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 SFR and record on the calibration data sheet:

$$SFR = (1.13) \ (Ps/Pa)(Ta/Ts) \qquad \text{(Eq. 10)}$$

where:

   SFR = set-point actual volumetric flow rate for adjustment of the mass flow controller, based on seasonal average temperature and average pressure at site, m^3/min
   1.13 = inlet design flow rate (as specified by the manufacturer), m^3/min
   Ps, Pa = seasonal average and current ambient barometric pressure at the site, respectively, mm Hg (or kPa)
   Ts, Ta = seasonal average and current ambient temperature, respec-tively, K (K = °C + 273).

3. Calculate and record on the sampler's calibration data sheet the sampler set-point manometer reading [or flow recorder reading] that corresponds to the SFR calculated in Step 2.

$$SSP = [Pa/(Ta + 30)][m(SFR) + b]^2 \qquad \text{(Eq. 11)}$$

where:

   SSP = sampler set-point manometer reading, mm (or in.) H_2O
   Pa = ambient barometric pressure, mm Hg (or kPa)
   Ta = ambient temperature, K (K = °C + 273)
   m = slope of the sampler's calibration relationship
   SFR = set-point flow rate from Equation 10, m^3/min
   b = intercept of the sampler's calibration relationship.

[For the flow recorder,

$$SSP = [m(SFR) + b] \ [Pa/(Ta+30)]^{1/2} \qquad \text{(Eq. 11a)}]$$

4. Visually check to make sure the motor is connected to the mass flow con-troller 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 sampler set point (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 subsection relates known flow rates (Qa, as determined by an orifice transfer standard) to the ratio of the stagnation pressure to the ambient barometric pressure (P1/Pa). The stagnation pressure (P1) 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 Subsection 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 1000-mm (0- to 36-in.) oil or water manometer (to avoid the hazards of a mercury manometer). It is further recommended that each sampler have 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 PM10 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 no means is provided for the user to adjust the operational flow rate. 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 m^3/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 (Qa), and the orifice transfer standard is also calibrated in Qa, as specified in Subsection 2.2.

2.4.1 Calibration Equipment -

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

    Note: The predrilled resistance plates that are 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 1000-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. Thermometer, capable of accurately measuring temperature over the range of 0 to 50 °C (273 to 323 K) to the nearest ±1 °C and referenced to an NIST or ASTM thermometer within ±2 °C at least annually.

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 to a barometer of known accuracy at least annually.

6. Calibration data sheets or the station log book 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 listed in Subsection 2.4. 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 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.

0-400 mm H$_2$O Manometer (0-16 in.)

Resistance Plates

18 13 10 7 5

0-1000 mm H$_2$O Manometer (0-36 in.)

ΔP stg

Calibration Orifice

Orifice Adaptor Plate

Filter Paper Cartridge/Cassette
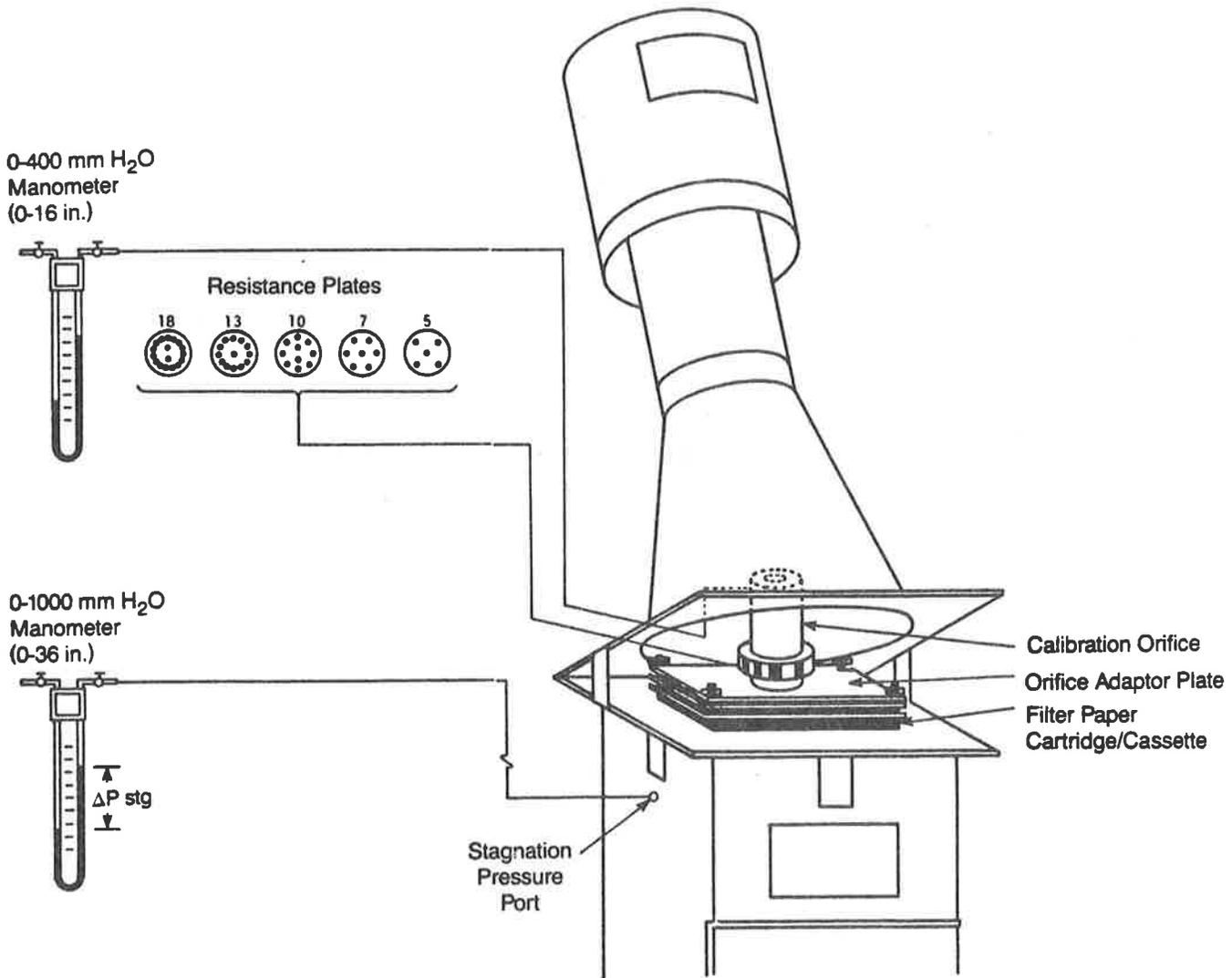
Stagnation Pressure Port

Figure 2.4. Calibration assembly of the VFC sampler.

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 m^3/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.   Leak Test: Block 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 overheat-
     ing 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 stand-
     ard and the faceplate or by crossthreading of the orifice transfer stand-
     ard 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 that is described above is one of many
     alternate procedures which 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 tub-
     ing, watching for the free flow of the fluid.

     Adjust the manometers' sliding scales so that their zero lines are at the
     bottom of the meniscuses. 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
     (blank forms appear in Subsection 12).

     •   Date, location, and operator's signature.
     •   Sampler S/N and model.

VFC SAMPLER CALIBRATION DATA SHEET

Station Location _GLENDORA, CA_   Date _5/1/89_ Time _2:30 AM_

Sampler Model _WEDDING_   S/N _0340870172P_ Operator _I. WISBETH_

Pa _755_ mm Hg, Ta _22.2_ °C _295.2_ K, Unusual Conditions _NONE_

Orifice S/N _2_ ,   Orifice Calibration Date _7/22/88_

Orifice Calibration Relationship: m = _1.2390_ b = _0.0172_ r = _0.9999_

Plate No.	ΔH_2O (in.)	$\Delta Pstg$ (mm Hg)[a]	P1=Pa−$\Delta Pstg$ (mm Hg)	P1/Pa (mm Hg)	Qa (orifice) flow rate[b] (m^3/min)	Qa (orifice) $[Ta]^{1/2}$
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	—		

[a] mm Hg = 25.4 (in. H_2O/13.6)

[b] Qa (orifice) = 1/m {$[(\Delta H_2O)(Ta/Pa)]^{1/2}$ − b}

[c] % Difference = $\left[\dfrac{Qa\ (sampler) - Qa\ (orifice)}{Qa\ (orifice)} \right]$ [100]

Qa (Orifice)	Qa (sampler) (Lookup Table)	% Difference[c]
1.17	1.154	−1.4
1.13	1.115	−1.3

Sampler Calibration Relationship

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

☐ New calibration relationship:

$\left(X = \dfrac{Qa\ (orifice)}{[Ta]^{1/2}},\ Y = (P1/Pa)\right)$

m = _____ b = _____ r = _____

For subsequent calculation of sampler flow rate:

Qa = {$[P1/Pa − b][Ta]^{1/2}$} {1/m}

Operational Flow Rate _1.181_ m^3/min

Figure 2.5. Example VFC sampler calibration data sheet.

- Ambient barometric pressure (Pa), mm Hg (or kPa).
- Ambient temperature (Ta), °C and K (K = °C + 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 = °C + 273). It is also recommended that all barometric pressures be expressed in either mm Hg or kPa (but do not mix the two units). Take care to avoid calibrating a PM10 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, ΔH_2O, and the corresponding sampler relative stagnation pressure manometer reading, $\Delta Pstg$, 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 $\Delta Pstg$ to mm Hg using Equation 12 before recording the reading on the calibration data sheet:

$$\text{mm Hg} = 25.4(\text{in. } H_2O/13.6) \qquad \text{(Eq. 12)}$$

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 of the next subsection.

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 the following subsection.

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 Qa(orifice) for each calibration point from the orifice calibration information and Equation 6:

$$Qa(orifice) = \{[\Delta H_2O(Ta/Pa)]^{1/2} - b\}\ \{1/m\} \qquad (Eq.\ 6)$$

where:

$Qa(orifice)$ = 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
Ta = ambient temperature during use, K (K = °C + 273)
Pa = 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, P1, for each calibration point:

$$P1 = Pa - \Delta Pstg \qquad \text{(Eq. 13)}$$

where:

$$P1 = \text{absolute stagnation pressure, mm Hg}$$
$$Pa = \text{ambient barometric pressure, mm Hg}$$
$$\Delta Pstg = \text{relative stagnation pressure, mm Hg.}$$

4. Calculate and record the stagnation pressure ratio:

$$\text{Stagnation pressure ratio} = P1/Pa \qquad \text{(Eq. 14)}$$

5. On a sheet of graph paper, plot the calculated orifice transfer standard's flow rates, Qa(orifice), on the x-axis vs. the corresponding stagnation pressure ratios, P1/Pa, 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 Qa(orifice) for several points on the calibration plot with Qa(sampler) determined from the factory calibration at Ta. Calculate the percentage difference between Qa(orifice) and Qa(sampler) using Equation 17:

$$\% \text{ Difference} = \left[\frac{Qa(sampler) - Qa(orifice)}{Qa(orifice)}\right] \left[100\right] \qquad \text{(Eq. 17)}$$

   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 Subsection 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 Subsection 2.4.4.

2.4.4 <u>Generation of Calibration Relationship - VFC Sampler</u> -

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

$$Qa(orifice)/[Ta]^{1/2}$$

where:

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

Ta = ambient temperature during sampler calibration, K
(K = °C + 273)

2. For the general linear regression model, $y = mx + b$, let $y = P1/Pa$ and
let $x = Qa(orifice)/[Ta]^{1/2}$, such that the model is given by:

$$P1/Pa = m[Qa(orifice)]/[Ta]^{1/2} + b \qquad \text{(Eq. 15)}$$

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.

3. For subsequent sample periods, the sampler's average actual operating
flow rate, $\overline{Qa}$, is calculated from the calibration slope and intercept
using Equation 16:

$$\overline{Qa}(sampler) = \{[(\overline{P1}/Pav)-b][Tav]^{1/2}\}\{1/m\} \qquad \text{(Eq. 16)}$$

where:

$\overline{Qa}$(sampler) = the sampler's average actual flow rate, m^3/min

$\overline{P1}$/Pav = average stagnation pressure ratio for the sampling
period

Tav = average ambient temperature for the sampling period, K
(K = °C + 273)

b = intercept of the sampler calibration relationship

m = slope of the sampler calibration relationship.

Note: The average value for P1 should be calculated from stagnation
pressure measurements taken before and after the sampling period. Pav
should be estimated from barometric pressure for the sampling period.
See also Subsection 3.3 for additional information.

4. If a calibration (lookup) table is desired, evaluate Equation 16 for
various appropriate values of P1/Pa and Ta and list the corresponding
values of Qa(sampler) in tabular form.

Note: A calibration table based on Equation 16 may not match the
manufacturer's lookup table exactly because the manufacturer may use a
different or more sophisticated model than Equation 15.

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 m^3/min).

1.   Determine the value of P1/Pa for the operational flow rate obtained with only the filter cassette installed (Steps 11 and 12 of Subsection 2.4.2).

2.   Determine the sampler's operational flow rate, Qa(sampler), that corresponds to this value of P1/Pa. Use the manufacturer's calibration table if it has been validated in Step 6 of Subsection 2.4.3; otherwise, use Equation 16.

3.   Compare Qa(sampler) with the inlet design flow rate (e.g., 1.13 m^3/min) using Equation 18:

$$\text{Design flow rate \% difference} = \left[\frac{Qa(sampler) - 1.13}{1.13}\right]\left[100\right] \qquad \text{(Eq. 18)}$$

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 PM10 concentrations, calibrate HV PM10 samplers upon installation and recalibrate as follows:

1.   At least quarterly or annually according to the state's quality assurance program (see 40 CFR 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., greater than ±7 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 Subsection 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 have changed significantly since the last calibration.

TABEL 2.1. EQUIPMENT CALIBRATION REQUIREMENTS

Equipment	Acceptance limits	Frequency and method of measurement	Action if requirements are not met	Calibration reference in Volume II, Section 2.2
Sampler	Indicated flow rate = true flow rate ± 4%.	Calibrate with certified transfer standard on receipt, after maintenance on sampler, and any time audits or flow checks deviate more than ±7% from the indicated flow rate or ±10% from the design flow rate.	Recalibrate.	None
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 repaired and/or recalibrated.	Subsection 2.1
Relative humidity indicator[a]	Indicator reading = psychrometer reading ±6% RH.	Compare with reading of wet-bulb/dry-bulb psychrometer on receipt and at 6-mo intervals.	Adjust or replace to attain acceptance limits.	Subsection 2.2
On/off timer	±30 min/24 h.	Check at purchase and routinely on sample-recovery days.	Adjust or repair.	Subsection 2.4
Elapsed-time meter[b]	±2 min/24 h.	Compare with a standard timepiece of known accuracy at receipt and at 6-mo intervals.	Adjust or replace time indicator to attain acceptance limits.	Subsection 2.3
Flow-rate transfer standard (orifice device)	Indicated flow rate (from previous calibration) = true flow rate ±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.	Subsection 2.5

[a]The relative humidity indicator is used in Subsection 4.3.

[b]Optional with a continuous flow-rate recorder.

2.11.3 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 58, Appendix E. Additional information on optimum network design and site exposure criteria is given in Reference 5.

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 mostly 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.

TABLE 3.1. MINIMUM HV PM10 SAMPLER SITING CRITERIA

Scale	Height above ground, meters	Distance from supporting structure, meters		Other spacing criteria
		Vertical	Horizontal[a]	
Micro	2 to 7		>2	1. Should be >20 meters 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 270 degrees around the sampler inlet.
				4. No furnace or incineration flues should be nearby.[b]
				5. Spacing from roads varies with traffic (see 40 CFR 58, Appendix E).
				6. Sampler inlet is at least 2 m but not greater than 4 m from any collocated PM10 sampler. (See 40 CFR 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.

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. 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 2.11.2.

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 in this subsection:

- 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 Subsection 2.

Sampling procedure checks are summarized in Table 3.2 at the end of this section.

The average actual flow rate for MFC samplers is calculated by determining (a) the average of the initial and final manometer readings of the exit orifice plenum pressure [or the average flow recorder reading], (b) the average ambient temperature (Tav), and (c) the average ambient barometric pressure (Pav) 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 <u>not recommended</u> 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.

<u>Note</u>: 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 (a) the average of the initial and final relative stagnation pressures (ΔPstg), (b) the average ambient temperature (Tav), and (c) the average barometric pressure (Pav) during the sampling period and then by applying these values to the calibration relationship.

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

3.3.1 <u>Presampling Filter Preparation Procedures</u> - Most HV PM10 samplers have been designed to accept filter cassettes. Loading these cassettes in the laboratory will minimize damage; however, if extreme 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 at the laboratory.

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 face-plate 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.

The site operator who is responsible for readying the HV PM10 sampler for the next run day can now transport the filter cassette to the monitoring site.

3.3.2 Sampling Procedures--MFC Sampler -

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, re-move 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 deteri-orated.

    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 7a and 9a 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 360-degree 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 meniscuses.

9.   Measure the initial exit orifice plenum pressure (ΔPex) 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 ΔPex on the MFC Sampler Field Data Sheet. If ΔPex is substantially different than for previous samples or otherwise appears abnormal, carry out a QC flow check as described in Subsection 3.5.1.

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 Subsection 3.5.1.]

MFC SAMPLER FIELD DATA SHEET

Station
Location __MILFORD, Nc__ Date _10/17/88_ SAROAD# _68024550_

Sampler Model __GMW__ S/N __1297__

Filter ID No. _439929_ Pav __761__ mm Hg, Tav _18.5_ °C _291.5_ K

Sampler Manometer Readings   Flow Recorder Readings

Initial ΔPex _____4.3_____ in. H$_2$O   Mean I _____

Final ΔPex _____4.0_____ in. H$_2$O

Mean ΔPex _____4.15_____ in. H$_2$O

Sampler Calibration Relationship: m = _0.9137_ b = _0.2629_ r = _0.9979_

$\overline{Qa}$ _____1.162_____ m^3/min   Elapsed Time _____1440_____ min

$\overline{Qa}$ = {[mean ΔPex (Tav + 30)/Pav]$^{1/2}$ – b} {1/m}
$\overline{Qa}$ = {mean I [(Tav + 30)/Pav]$^{1/2}$ – b} {1/m} for flow recorders

Operator __D. PALMER__

Comments: __NONE__

Laboratory Calculations:

$\overline{Qstd}$ _____1.189_____ std m^3/min   Gross weight (Wg) _3.9714_ g

$\overline{Qstd}$ = $\overline{Qa}$ (Pav/Pstd) (Tstd/Tav)   Tare weight (Wt) _3.9047_ g

Vstd _____1712_____ std m^3 Net Weight (Wn) _0.0667_ g

Vstd = ($\overline{Qstd}$) (elapsed time)   PM10 Concentration _39.0_ μg/std m^3

PM10 Concentration = (Wn) (10^6)/Vstd

Figure 3.1. Example MFC sampler field data sheet.

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.

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 ΔPex 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 (Tav), K (K = °C + 273).
   • Average ambient barometric pressure for the run day (Pav), mm Hg or kPa.

   Note: The calculations presented in this subsection 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 (ΔPex) and the average ambient temperature (Tav) and average ambient pressure (Pav) for the sample period. Tav and Pav 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.

Note: If specific Tav or Pav values for the sample period cannot be obtained, seasonal average temperature for the site (Ts) may be substituted for Tav, and average barometric pressure for the site (Ps) may be substituted for Pav. 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°C and 40 mm Hg.

6. 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.

$$\{[\overline{\Delta Pex} \ (Tav + 30)/Pa]^{1/2} - b\} \ \{1/m\} \qquad \text{(Eq. 9)}$$

or for the flow recorder,

$$\overline{Qa} = \{\overline{I} \ [(Tav + 30)/Pa]^{1/2} - b\} \ \{1/m\} \qquad \text{(Eq. 9a)}$$

where

$\overline{Qa}$ = average sampler flow rate, actual m^3/min
$\overline{\Delta Pex}$ = average exit orifice plenum pressure, mm Hg or kPa
$[\overline{I}$ = average flow recorder response, arbitrary units]
Tav = average ambient temperature for the run day, K
Pav = 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 $\overline{I}$.

4. 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.

5. 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.

6. The sampler may now be readied for the next run day.

7. 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 -

Filter Installation Procedure - Upon arriving at the monitoring site, the operator will follow the procedure presented below:

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, re-move 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 deteri-orated.

    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 manom-eter should have a range of 0 to 1000 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 meniscuses.

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.

VFC SAMPLER FIELD DATA SHEET

Station
Location _GLENDORA, CA_ Date _5/7/89_ SAROAD# _04191949_

Sampler Model _WEDDING_ S/N _0340870172P_

Filter ID No. _67714_ Pav _750_ mm Hg, Tav _28.6_ °C _301.6_ K

Relative Stagnation Pressure Readings   ### Absolute Stagnation Pressure

Initial ΔPstg _29.5_ mm Hg $\overline{P1}$ = _720.3_ mm Hg

Final ΔPstg _29.9_ mm Hg $\overline{P1}$ = Pav − Average ΔPstg

Average ΔPstg = _29.7_ mm Hg

Average Stagnation Pressure Ratio ($\overline{P1}$/Pav) _0.960_

Average Flowrate ($\overline{Qa}$)· _1.178_ m³/min   Elapsed Time _1445_ min
·Obtained from manufacturer's lookup table (or
 from alternate calibration relationship)

Operator _T. WISBETH_

Comments: _NONE_

_____

_____

_____

Laboratory Calculations:

$\overline{Qstd}$ _1.149_ Std m³/min   Gross Weight (Wg) _4.4721_ g

$\overline{Qstd}$ = $\overline{Qa}$ (Pav/Pstd) (Tstd/Tav)   Tare Weight (Wt) _4.3802_ g

Vstd _1660_ std m³   Net Weight (Wn) _0.0919_ g

Vstd = ($\overline{Qstd}$) (Elapsed Time)   PM10 Concentration _55.4_ μg/std m³

PM10 Concentration = (Wn) (10^6)/Vstd

Figure 3.2. Example VFC sampler field data sheet.

8. Measure the initial relative stagnation pressure (ΔPstg) and record this
    reading on the VFC Sampler Field Data Sheet.

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

    $$\text{mm Hg} = (25.4) \ (\text{in. } H_2O/13.6) \qquad\qquad \text{(Eq. 12)}$$

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.

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 peri-
ods.

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 (Tav), °C and K.
    •   Average ambient barometric pressure for the run day (Pav), mm Hg or
        kPa.

    Note: Tav and Pav 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 Tav and Pav readings
    are not available, seasonal average temperature (Ts) and barometric pres-
    sure (Ps) can be substituted. Care must be taken, however, that the
    actual conditions at the site can be reasonably represented by such aver-
    ages. It is therefore recommended that seasonal values represent actual
    values within 20°C 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 meniscuses.

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 ΔPstg 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 12 before recording the reading on the data sheet.

$$mm\ Hg = 25.4\ (in.\ H_2O/13.6) \qquad (Eq.\ 12)$$

6. Calculate the average relative stagnation pressure ($\overline{\Delta Pstg}$) and record it on the data sheet.

7. Calculate the average absolute stagnation pressure ($\overline{PI}$) for the sample run day and record it on the data sheet.

$$\overline{PI} = Pav - \overline{\Delta Pstg} \qquad (Eq.\ 13)$$

where

   $\overline{PI}$ = average absolute stagnation pressure, mm Hg or kPa.
   Pav = average ambient barometric pressure for the run day (not the retrieval day), mm Hg or kPa.
   $\overline{\Delta Pstg}$ = average stagnation pressure drop, mm Hg or kPa.

8. Calculate and record the average stagnation pressure ratio:

$$\begin{array}{l}\text{Average stagnation}\\ \text{pressure ratio}\end{array} = \overline{PI}/Pav \qquad (Eq.\ 14a)$$

where

   $\overline{PI}$ = average absolute stagnation pressure, mm Hg or kPa
   Pav = 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 Subsection 2.4.4), locate the column and row corresponding to $\overline{PI}$/Pav and the Tav value for the sample run day. Read and record the indicated $\overline{Qa}$ 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 Post-Sampling 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" (Subsection 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 - Post-sampling filter analysis is discussed in Subsections 4.6 and 4.7. The calculation of PM10 concentrations is discussed in Subsection 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 Qa and the design flow rate (1.13 m³/min) using the following formula:

$$\% \text{ Difference} = 100 \left[\frac{\overline{Qa} - 1.13}{1.13} \right] \qquad \text{(Eq. 18)}$$

   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.

   $\overline{Qa}$ 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:

   - 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 PM10 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 (Subsection 3.5), will invalidate all samples collected back to the last calibration or valid flow check. Recalibrate the sampler.
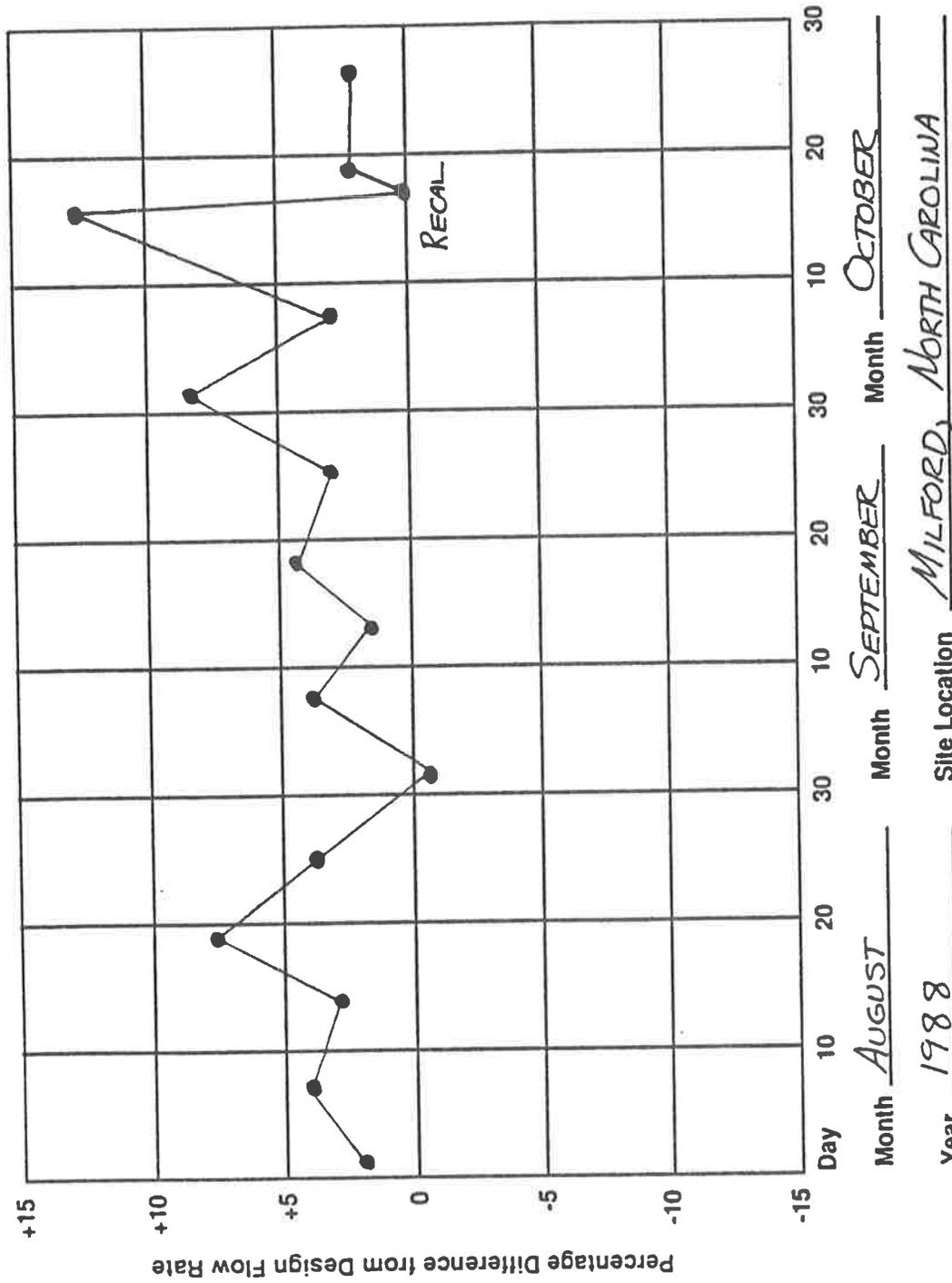
Figure 3.3. Example QC control chart for field validation of flow rates.

3.4.2 <u>Laboratory Validation Criteria</u> - 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 <u>Data Documentation</u> - 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, log books, 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.

<u>Note</u>: The use of log books at PM10 monitoring sites is highly encouraged, but is not required.

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

<u>Operator Who Starts the Sample</u> - (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 log book 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 log book 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 ΔPex for MFC or initial ΔPstg 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).

Operator Who Removes the Samples -

1. Elapsed time of the sample run (DS)(RC)(LB).
2. Final ΔPex [or mean I] for MFC or final ΔPstg, $\overline{PI}$, and $\overline{PI}$/Pav for VFC (DS)(LB)[RC].
3. The calculated standard average flow rate ($\overline{Qstd}$) in std. 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 PM10 samplers, a field-calibration check of the operational flow rate is recommended at least once per month. The purpose of this check is to track the sampler's calibration stability. A control chart (e.g., Figure 3.4) presenting the percentage difference between a PM10 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 log book 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 subsection, the following is assumed:

• 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.

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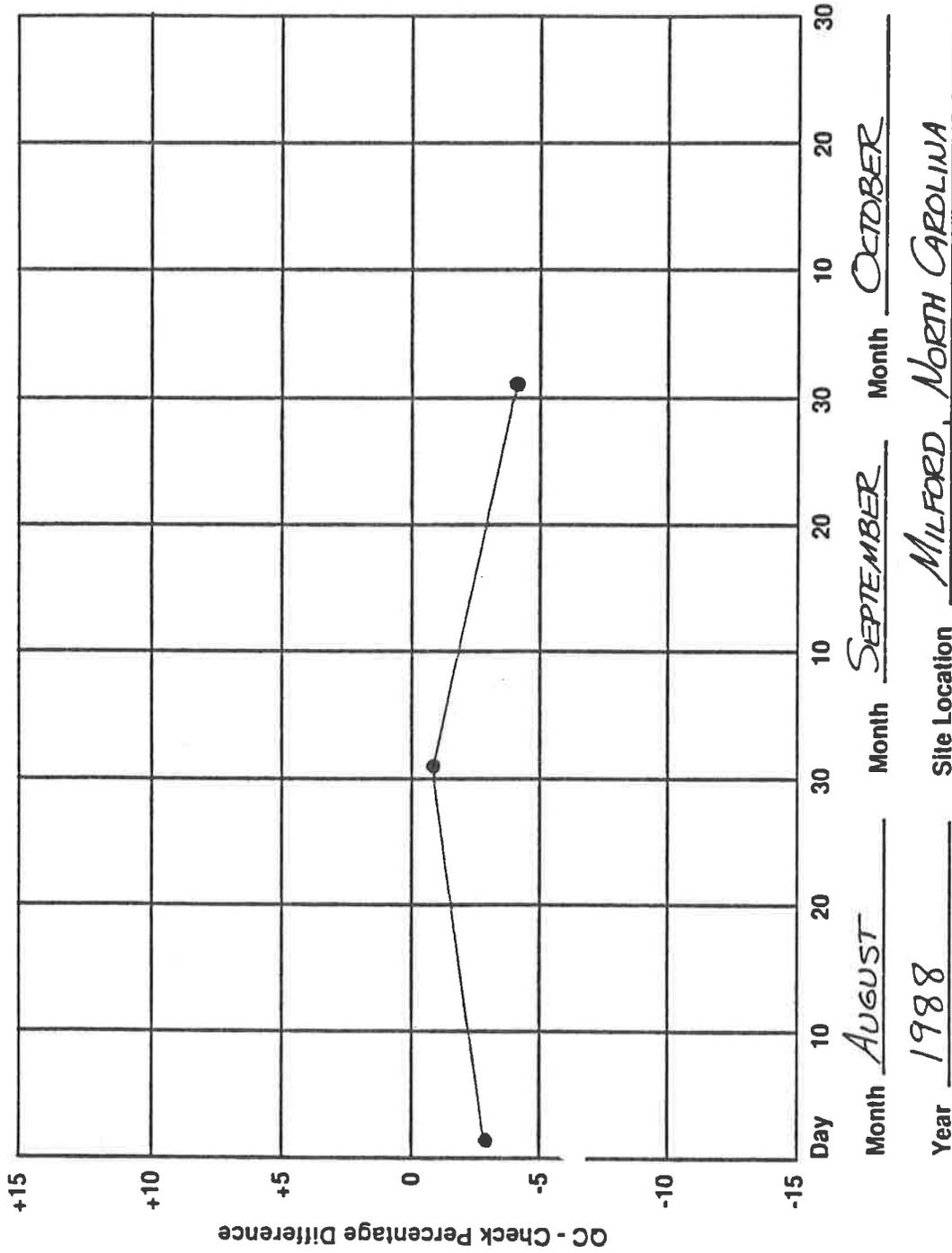
Figure 3.4. Example QC control chart for QC flow checks.

- 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 (Qa).

3.5.1 QC Flow-Check Procedure--MFC Sampler -

The indicated flow rate (Qa (sampler)) for MFC samplers is calculated by determining (a) the manometer reading of the exit orifice plenum pressure [or the flow recorder reading], (b) the ambient temperature (Ta), and (c) the barometric pressure (Pa) 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 PM10 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 PM10 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 is 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 temperature over the range of 0° to 50°C (273 to 323 K) to the nearest ±1°C and referenced to an NIST or ASTM thermometer within ±2°C at least annually.

   - 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 log book.

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 upon the sampler's filter screen. Do not use a filter cassette. 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.

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 meniscuses. Section 2.2 of this volume, Figure 2.6, illustrates the correct method for reading oil or water manometers. Make sure that the connecting tubing snugly fits the manometer and the pressure port.

MFC SAMPLER FLOW CHECK DATA SHEET

Station
Location _MILFORD, NC_   Date _11/1/88_   Time _10:30 AM_

Sampler Model _GMW_   S/N _1297_   Operator _D. PALMER_

Pa _763_ mm Hg, Ta _27.0_ °C _300.0_ K, Unusual Conditions _NONE_

Orifice S/N _10387_ .   Orifice Calibration Date _7/22/88_

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 (ΔH_2O) _4.8_ in. H_2O Qa (Orifice)[a] _1.110_ m³/min

	With Orifice Installed	Without Orifice Installed
Sampler Pressure Drop (ΔPex)	_4.0_ in. H_2O	_3.9_ in. H_2O
Qa (sampler)[b]	_1.152_ m³/min	_1.134_ m³/min
QC—Check Percentage Difference[c]	_3.8_ %	
Qa (corrected sampler)[d]	_1.092_ m³/min	
Design Flow Rate Percentage Difference[e]	_-3.5_ %	

[a]For calculation of orifice flow rates:

$\quad$ Qa (orifice) = $\{[\Delta(H_2O)(Ta/Pa)]^{1/2} - b\}\{1/m\}$

[b]For calculation of sampler flow rates:

$\quad$ Qa (sampler) = $\{[(\Delta Pex/Pa)(Ta + 30)]^{1/2} - b\}\{1/m\}$

[c]QC % Difference = $\left[\dfrac{Qa\ (sampler) - Qa\ (orifice)}{Qa\ (orifice)}\right][100]$ where Qa (sampler) is measured with the orifice installed

[d]Qa (corrected sampler) = Qa (sampler) $\left[\dfrac{100 - QC\ \%\ difference}{100}\right]$ where Qa (sampler) is measured without the orifice installed.

[e]Design Flow Rate % Difference = $\left[\dfrac{Qa\ (corr.\ sampler) - 1.13}{1.13}\right][100]$

Figure 3.5. Example MFC sampler flow check data sheet.

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 trans- fer standard to act as a draft shield (if a shield is not otherwise pro- vided). 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 (Ta), °C and K.
     •   Ambient barometric pressure (Pa), mm Hg or kPa.
     •   Unusual weather conditions.
     •   Orifice transfer standard S/N and calibration relationship.
     •   Operator's signature.

10. Observe the ΔH_2O across the orifice by reading the manometer deflection. Section 2.2 of this volume, Figure 2.6, illustrates the correct way to read a water or oil manometer. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet.

11. Measure the exit orifice plenum pressure (ΔPex) 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 Qa(orifice) at actual conditions using the following equation:

$$Qa(orifice) = \{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\} \{1/m\} \qquad \text{(Eq. 6)}$$

where

        Qa(orifice) = actual volumetric flow rate as indicated by the ori- fice transfer standard, m^3/min
           ΔH_2O = pressure drop across the orifice, mm (or in.) H_2O
               Ta = ambient temperature, K
               Pa = ambient barometric pressure, mm Hg or kPa
                b = intercept of the orifice calibration relationship
                m = slope of the orifice calibration relationship.

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

$$Qa(sampler) = \{[\Delta Pex \ (Ta + 30)/Pa]^{1/2} - b\} \ \{1/m\} \qquad (Eq. \ 9)$$

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

$$Qa(sampler) = \{I[(Ta + 30)/Pa]^{1/2} - b\} \ \{1/m\} \qquad (Eq. \ 9a)$$

where

$Qa(sampler)$ = sampler flow rate, actual m^3/min
ΔPex = exit orifice plenum pressure, mm (or in.) H_2O
I = recorder response, arbitrary units
Ta = ambient temperature during the flow check, K (K = °C + 273)
Pa = ambient barometric pressure during the flow check, 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 $(I)^{1/2}$ for I.

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

$$QC\text{-check \% difference} = \left[\frac{Qa(sampler) - Qa(orifice)}{Qa(orifice)}\right] \left[100\right] \qquad (Eq. \ 17)$$

where $Qa(sampler)$ 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 93 to 107 percent (±7 percent difference) of the calculated $Qa(orifice)$ 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, Qa(corr. sampler) using Equation 23:

$$Qa(corr. \ sampler) = \left[Qa(sampler)\right]\left[\frac{(100 - \% \ difference)}{100}\right] \qquad (Eq. \ 23)$$

where Qa(sampler) is measured without the orifice transfer standard being installed and where the QC-check percentage difference was obtained from Equation 17 above.

Note: Take care to use the correct sign (i.e., positive or negative) for the % difference when it is used in Equation 23.

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 m^3/min) and the corrected sampler flow rate as:

$$\text{Design flow rate \% difference} = \left[\frac{Qa(\text{corr. sampler}) - 1.13}{1.13}\right] \left[100\right] \quad \text{(Eq. 18)}$$

It is assumed in this subsection that the inlet is designed to operate at a flow rate of 1.13 actual m^3/min. If the design flow rate percentage difference is less than or equal to ±7 percent, the sampler calibration is acceptable. If the difference is greater than ±7 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 optimum set-point flow rate (SFR) according to Equation 10 in Subsection 2.3 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 Subsection 3.3.

3.5.2 QC Flow-Check Procedure--VFC Sampler -

The indicated flow rate (Qa (sampler)) for VFC samplers is calculated by determining (a) the relative stagnation pressure (ΔPstg), (b) the ambient temperature (Ta), and (c) the barometric pressure (Pa) 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:

- A orifice transfer standard and its calibration relationship in actual volumetric flow units (Qa).

- 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 1000-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 temperature over the range of 0° to 50°C (273 to 323 K) to the nearest ±1°C and referenced to an NIST or ASTM thermometer within 2°C at least annually. To calculate the orifice flow rates, it will be necessary to convert °C to K.

- 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 log book.

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 value 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).

    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 (Ta), °C and K.
    • Ambient barometric pressure (Pa), 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 meniscuses.

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 (ΔH_2O) and record on the VFC Sampler Flow-Check Data Sheet. Read the stagnation pressure drop and record as $\Delta Pstg$ (mm Hg) on the data sheet.

    Note: Be sure to convert $\Delta Pstg$ to mm Hg using Equation 12 before recording the reading on the data sheet.

    $$mm\ Hg = 25.4(in.\ H_2O/13.6) \qquad\qquad (Eq.\ 12)$$

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 ($\Delta Pstg$) for the normal operating flow rate. Turn off the sampler. Replace the vacuum cap on the stagnation pressure port.

VFC SAMPLER FLOW CHECK DATA SHEET

Station
Location _GLENDORA, CA_ Date _6/1/89_ Time _3:25 PM_

Sampler Model _WEDDING_ S/N _0340870172P_ Operator _T. WISBETH_

Pa _757_ mm Hg, Ta _21.3_ °C _294.3_ K, Unusual Conditions _NONE_

Orifice S/N _10387_ . Orifice Calibration Date _7/22/88_

Orifice Calibration Relationship: m = _1.2430_ b = _−0.0062_ , r = _0.9999_

Orifice Pressure Drop (ΔH_2O) _4.65_ in. H_2O Qa (Orifice)[a] _1.087_ m³/min

	With Orifice Installed	Without Orifice Installed
Stagnation Pressure (ΔPstg)	_37_ mm Hg	_30_ mm Hg
Absolute Stagnation Pressure (P1)[b]	_720_ mm Hg	_727_ mm Hg
Stagnation Pressure Ratio (P1/Pa)	_0.951_	_0.960_
Qa (sampler)[c]	_1.137_ m³/min	_1.164_ m³/min

QC—Check Percentage Difference[d] _4.6_ %

Qa (corrected sampler)[e] _1.110_ m³/min

Design Flow Rate Percentage Difference[f] _−1.7_ %

[a]Qa (orifice) = $\{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\} \{1/m\}$

[b]P1 = Pa − ΔPstg

[c]Determine Qa (sampler) from manufacturer's lookup table (or from alternate calibration relationship)

[d]QC % Difference = $\left[\dfrac{Qa\,(sampler) - Qa\,(orifice)}{Qa\,(orifice)} \right] 100$ where Qa (sampler) is measured with the orifice installed

[e]Qa (corrected sampler) = Qa (sampler) $\left[\dfrac{100 - QC\,\%\,difference}{100} \right]$ where Qa (sampler) is measured without the orifice installed.

[f]Design Flow Rate % Difference = $\left[\dfrac{Qa\,(corr.\,sampler) - 1.13}{1.13} \right] \left[100 \right]$

Figure 3.6. Example VFC sampler flow check data sheet.

11. Calculate and record Qa(orifice) flow rate for the flow-check point, as in Equation (6), reproduced below:

$$Qa(orifice) = \{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\} \{1/m\} \qquad (Eq. 6)$$

where

$Qa(orifice)$ = 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
Ta = ambient temperature, K (K = °C + 273)
Pa = ambient barometric pressure, mm Hg or kPa
b = intercept of the orifice calibration relationship
m = slope of the orifice calibration relationship.

12. Calculate and record the value of P1 (mm Hg) for the measurements with and without the orifice installed.

$$P1 = Pa - \Delta Pstg \qquad (Eq. 13)$$

where

$P1$ = stagnation pressure, mm Hg or kPa
Pa = ambient barometric pressure, mm Hg or kPa
$\Delta Pstg$ = stagnation pressure drop, mm Hg or kPa.

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

$$\text{Stagnation pressure ratio} = P1/Pa \qquad (Eq. 14)$$

where

$P1$ = stagnation pressure, mm Hg or kPa.
Pa = ambient barometric pressure, mm Hg or kPa.

14. Refer to the instrument manufacturer's lookup table (or alternative calibration relationship as described in Subsection 2.4.4) and determine the Qa(sampler) flow rates (m^3/min) for the measurements with and without the orifice installed as indicated for the ratio of P1/Pa and ambient temperature in °C. Record these values on the VFC sampler flow check data sheet.

15. Using Qa(orifice) and Qa(sampler) for the measurements with the orifice installed, calculate the QC-check percentage difference as:

$$QC\text{-check \% difference} = \left[\frac{Qa(sampler) - Qa(orifice)}{Qa(orifice)}\right] \left[100\right] \qquad (Eq. 17)$$

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 differ-

ence is less than or equal to ±7 percent, the sampler calibration is acceptable. Those differences exceeding ±7 percent will require recalibration. 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 Qa (sampler) from the measurements without the orifice installed (i.e., for the normal operating flow rate), calculate the corrected sampler flow rate as:

$$\text{Qa (corr. sampler)} = \left[\text{Qa (sampler)}\right] \left[\frac{100 - \% \text{ difference}}{100}\right] \quad \text{(Eq. 23)}$$

Record Qa (corr. 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 m^3/min) and Qa (corr. sampler) as:

$$\text{Design flow rate } \% \text{ difference} = \left[\frac{\text{Qa (corr. sampler)} - 1.13}{1.13}\right] \quad \text{(Eq. 18)}$$

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 less than or equal to ±7 percent, the sampler calibration is acceptable. Those differences exceeding ±7 percent will require recalibration. 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.

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.
Post-sample 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 less than or equal to ±7 percent.	If the percentage differences exceed ±7 percent, recalibrate the sampler. If they exceed ±10 percent, 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.

2.11.4 FILTER PREPARATION AND ANALYSIS

The accuracy of a PM10 sampling program depends on several factors. A primary factor 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 determination of PM10 mass concentrations.

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. Subsection 4.1 presents guidelines to help prevent post-sampling 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 $\mu g/m^3$ 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 Reference 6.) A neutral or low-alkalinity filter medium will eliminate excessive artifact formation.

Accuracy, precision, and calibration procedures for the laboratory apparatus are referenced in Subsection 2, Table 2.1. The recommended filter media and acceptance criteria of 40 CFR 50, Appendix J, 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.

The microquartz fiber filter is currently the only commercially available HV PM10 filter that satisfies all criteria specified in 40 CFR 50, Appendix J. 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 at the end of this subsection.

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 x 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

TABLE 4.1. SUMMARY OF FILTER ACCEPTANCE CRITERIA

Criteria	40 CFR 50, Appendix J	Explanation
Collection efficiency	Greater than 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 insure that the filter manufacturer has complied with this guideline.
Integrity	5 $\mu g/m^3$, measured as the concentration equivalent corresponding to the difference between the initial and final weights of the filter, assuming a 24-hr sample volume of 1600 m^3.	During a simulated sampling test, all sampling procedures are followed EXCEPT the HV PM10 sampler is not turned on. The tare weight of the equilibrated filter must agree within ±8 mg of final weight. Refer to Subsection 3, Field Operations, for recommended HV PM10 sampling procedures.
Alkalinity	Less than 25 microequivalents/gram of filter.	A typical analytical laboratory is capable of conducting this test measurement of alkalinity (see Reference 8).

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.

The following are specific defects to look for:

1. Pinhole--A small hole appearing as a distinct and obvious bright point of light when examined over a light table or screen, or as a dark spot when viewed over a black surface.

2. Loose material--Any extra loose material or dirt particles on the filter that must be brushed off before the filter is weighed.

3. Discoloration--Any obvious visible discoloration that might be evidence of a contaminant.

4. 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.

5. 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°C, with a variability of not more than ±3°C. 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 assure compliance with these guidelines. Equilibration chamber malfunctions, discrepancies, and maintenance activities also should be recorded in the equilibration chamber or laboratory log book.

4.4 Initial Weighing Procedures (Tare Weight)

Enough filters to last for at least a 3-mo 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. Procedures are as follows:

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 "Standard Weight" check on the analytical balance. (Procedures are outlined in the next subsection.)

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 the next subsection.

    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 upwards, in its original container or a comparably sized box. Place a sheet of 8-1/2 x 11-in. tracing paper between each filter.

6. Record the balance number, the filter ID number, and the tare weight on the Laboratory Data/Coding Form (see Figure 4.1) or alternative data recording medium. When bound, these forms serve 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-hand corner.

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

Balance ID Number	543201				
Balance Operator	R. WRIGHT		Quality Control Supervisor	R. SHORES	
Date	Filter No.	Balance Tare	Tare Wt.	Gross Wt.	Add'l analysis
10/11/88	.67143	0.0000	3.9147	—	—
	67144	0.0000	3.9089	—	—
	67145	0.0001	3.9100	—	—
10/17/88	67143	0.0000	—	3.9714	—
	67144	0.0000	—	3.9550	—
	67145	0.0000	—	3.9973	—

Figure 4.1. Example laboratory data/coding form.

Balance ID Number 543201

Balance Operator R. WRIGHT

Quality Control Supervisor R. SHORES

Date	Standard Weight Checks		Zero Check (± 0.5 mg)		Calibration Check (± 0.5 mg)		Tare and Gross Weight Checks			
	Original Value	Observed Value	Original Value	Observed Value	Original Value	Observed Value	Filter ID	Original Value	Observed Value	T/G[a]
10/11/88	4.0170	4.0173	0.0000	0.0001	5.0007	5.0011	67143	3.9147	3.9144	T
							67145	3.9100	3.9088	T

[a]Tare or Gross Measurement

Figure 4.2. Example internal Quality Control Log Sheet.

4.5.1 "Standard Weight" Check - Before the first filter is weighed, the balance should be checked by weighing a set of "standard weights" between 3 and 5 g. 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 set of standard Class-S Weights (these weights may be the same set used for the initial "standard weight" check) should be used at the 1-, 2-, and 5-g levels. 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 independent audits. For cross-checking, the supervisor should reference all QC data on the Internal Quality Control Log Sheet to the laboratory QC log book. Control charts should be maintained on each balance and also included in the log book. These charts will indicate any excess drift caused by an instrument malfunction.

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

4.6 Post-Sampling Documentation and Inspection

Upon receipt of exposed filters from the field, the sample custodian should adhere to the following 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's-hair brush.

3. Match the filter ID number with the correct laboratory data/coding 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 Subsection 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 Subsection 4.3.

2. Repeat Steps 1 through 6 of the HV PM10 filter tare-weighing procedure (Subsection 4.4). Record the indicated gross weight on the Laboratory Data/Coding Form.

3. Perform the internal QC checks described in Subsection 4.5 to ensure the validity of reweighing.

4. If the HV PM10 filter is not to receive additional analysis, place it into 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 Labora-
    tory Data/Coding Form to indicate that the filter requires additional
    analysis. Carefully transport each packaged filter to the sample custo-
    dian, who will forward it to the laboratory responsible for the addition-
    al 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. Subsection 5 presents information regarding the calculation of PM10
mass concentration.

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 less than ±5 percent variation; and temperature between 15 and 30°C, with less than ±3°C 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.
Post-sampling 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.

2.11.5 CALCULATIONS, VALIDATIONS, AND REPORTING OF PM10 DATA

Measurements of PM10 mass concentration in the atmosphere that are used to determine attainment of the National Ambient Air Quality Standards for particulate matter must be expressed in units of micrograms per standard cubic meter (μg/std. m^3) of air. For these measurements, "standard" means EPA-standard conditions of temperature and pressure, which are 25 °C (298 K) and 760 mm Hg (101 kPa), respectively. This section presents the calculations required to compute and report ambient PM10 concentrations. A summary of all calculation formulas and associated symbols presented in Section 2.11 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 (Qa), measured at existing conditions of temperature (Ta) and pressure (Pa).

The sampler's operational flow rate (i.e., the actual flow rate when the sampler is operating normally to collect a PM10 sample) should, of course, be very close to the design flow rate. All PM10 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 (Tav) and average barometric pressure (Pav) over the sample period are recommended. However, if average temperature and pressure values (or reasonable estimates) cannot be obtained for each sample period, seasonal average temperature (Ts) and barometric pressure (Ps) for the site may be substituted.

Tav and Pav readings may be recorded on site 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 Tav and Pav 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 (Ts and Ps) 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 (Tav and Pav) for the sample period.

The calculations presented in this subsection assume that the sampler has been calibrated in actual volumetric flow rate units (Qa) 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, Ts may be substituted for Tav, and Ps may be substituted for Pav in Equations 1a, 9, 9a, 14a, and 16.

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 PM10 sampler. In this subsection, it is assumed that the samplers have been calibrated according to procedures outlined in Subsection 2.

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

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 (ΔPex) [or the average flow recorder trace], (b) the average ambient temperature (Tav), and (c) the average ambient barometric pressure (Pav) 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 Subsection 2, this expression is in the form of:

$$\overline{Qa} = \{[\overline{\Delta Pex}(Tav+30)/Pav]^{1/2} - b\} \{1/m\} \qquad \text{(Eq. 9)}$$

where:

$\overline{Qa}$ = the sampler's average actual flow rate for the sample period, m^3/min

$\overline{\Delta Pex}$ = average of initial and final sampler manometer readings, (ΔPex_i + ΔPex_f)/2, mm (or in.) H_2O

Tav = average ambient temperature for the sample period, K (K = °C + 273)

Pav = average barometric 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,

$$\overline{Qa} = \{\overline{I}[(Tav+30)/Pav]^{1/2} - b\} \{1/m\} \qquad \text{(Eq. 9a)}$$

where:

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

The average actual flow rate is then corrected to EPA-standard conditions, calculated as:

$$\overline{Qstd} = \overline{Qa}(Pav/Pstd)(Tstd/Tav) \qquad\qquad \text{(Eq. 1a)}$$

where:

$\overline{Qstd}$ = average sampler flow rate corrected to EPA-standard volume flow rate units, std. m^3/min

$\overline{Qa}$ = average actual sampler flow rate for the sample period, m^3/min

Pstd = standard barometric pressure, 760 mm Hg (or 101 kPa)

Tstd = standard temperature, 288 K

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 ($\overline{P1}$/Pav) and the ambient average temperature (Tav) for the sampler period.

1.   Calculate the value of P1 in mm Hg (or kPa):

$$\overline{P1} = Pav - \overline{\Delta Pstg} \qquad\qquad \text{(Eq. 13)}$$

where:

$\overline{P1}$ = average absolute stagnation pressure for the sample period, mm Hg (or kPa)

Pav = average barometric pressure for the sample period, mm Hg (or kPa)

$\overline{\Delta Pstg}$ = 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 12 before recording the reading on the data sheet:

$$mm\ Hg = 25.4\ (in.\ H_2O/13.6) \qquad\qquad \text{(Eq. 12)}$$

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

$$\text{Average stagnation pressure ratio} = (\overline{P1}/Pav) \qquad\qquad \text{(Eq. 14a)}$$

3.   Use the manufacturer's lookup table (or alternate calibration relationship; see Subsection 2) to determine $\overline{Qa}$ from the average stagnation pressure ratio ($\overline{P1}$/Pav) and Tav for the sample period. This value of $\overline{Qa}$ is the average volumetric flow rate for the sampler period.

4.   The average actual flow rate is then corrected to EPA standard conditions:

$$\overline{Qstd} = \overline{Qa}(Pav/Pstd)(Tstd/Tav) \qquad\qquad \text{(Eq. 1a)}$$

where:

$\overline{Qstd}$ = average sampler flow rate corrected to EPA-standard volume flow rate units, std. m^3/min

$\overline{Qa}$ = average actual sampler flow rate for the sample period, m^3/min

Pstd = standard barometric pressure, 760 mm Hg (or 101 kPa)

Tstd = standard temperature, 298 K

5.1.2 <u>Calculation of PM10 Concentrations</u> - Accurate reporting of total PM10 mass concentration data requires the calculation of the total standard volume of air sampled (Equation 21) and the final computation of total PM10 mass concentration (Equation 22).

1.   Calculate the total standard volume of air sampled:

$$Vstd = (\overline{Qstd})(t) \qquad \text{(Eq. 21)}$$

where:

Vstd = total volume of air sampled in standard volume units, std. m^3

$\overline{Qstd}$ = average sampler flow rate corrected to EPA-standard conditions, std. m^3/min

t = total elapsed sampling time, min.

2.   Calculate total PM10 mass concentration in μg/std. m^3:

$$PM10 = (10^6)(Wg - Wt)/Vstd \qquad \text{(Eq. 22)}$$

where:

PM10 = PM10 mass concentration, μg/std. m^3

10^6 = conversion factor, μg/g

Wg, Wt = gross and tare weights of the HV PM10 filter, respectively, g

Vstd = total sample volume in standard volume units, std. m^3

5.2 Calculation Validation

Data that are needed to compute the mass concentration of PM10 originate from two main sources: field operations and laboratory operations. These data must be validated to ensure that all reported PM10 measurements are accurate relative to the overall scope of the quality assurance program. When the final mass concentration of PM10 in a sample has been computed, the validation procedure not only will check on these computations, but also will aid in the flagging of 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, $\overline{Qa}$ (m^3/min)
   •   Tare and gross weights, Wt and Wg, of the HV PM10 filter (g)

2. Recalculate the total mass concentration of PM10 for 7 samples per 100 (minimum of 4 per lot) as specified in Subsections 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 PM10 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 PM10. Information on reporting and interpretation of PM10 data with respect to the attainment of these standards is covered in 40 CFR 50, Appendix K.

TABLE 5.1.   FORMULAS ASSOCIATED WITH PM10 MONITORING

Calculation	Formula	Equation
Conversion of flow rate from actual to standard volume units	$Qstd = Qa(Pa/Pstd)(Tstd/Ta)$	(Eq. 1)
Conversion of average flow rate from actual to standard volume units	$\overline{Qstd} = \overline{Qa}(Pav/Pstd)(Tstd/Tav)$	(Eq. 1a)
Conversion of flow rate from standard to actual volume units	$Qa = Qstd(Pstd/Pa)(Ta/Tstd)$	(Eq. 2)
Uncorrected air volume measured by standard volume meter	$\Delta Vol. = $ Final Volume $-$ Initial Volume	(Eq. 3)
Correction of air volume measured by std. vol. meter to ambient baro. pressure	$Va = \Delta Vol.(Pa - \Delta Hg)/Pa$	(Eq. 4)
Actual volumetric flow rate measured by standard volume meter	$Qa = Va/\Delta Time$	(Eq. 5)
Actual volumetric flow rate measured by orifice transfer standard	$Qa(orifice) = \{[\Delta H_2O(Ta/Pa)]^{1/2} - b\}\ \{1/m\}$	(Eq. 6)
Transformed exit orifice pressure for MFC sampler calibration relationship	$\Delta Pext = [\Delta Pex(Ta+30)/Pa]^{1/2}$	(Eq. 7)
Transformed flow recorder reading for MFC sampler calibration relationship	$It = I[(Ta+30)/Pa]^{1/2}$	(Eq. 7a)
Regression model (y=mx+b) for calibration of MFC sampler	$\Delta Pext = m[Qa(orifice)] + b$	(Eq. 8)
Regression model (y=mx+b) for calibration of MFC sampler using flow recorder	$It = m[Qa(orifice)] + b$	(Eq. 8a)

(continued)

TABLE 5.1.   FORMULAS ASSOCIATED WITH PM10 MONITORING (Cont'd)

Calculation	Formula	Equation
Calibration relationship for MFC sampler	$\overline{Qa} = \{[\overline{\Delta Pex}(Tav+30)/Pav)]^{1/2} - b\} \{1/m\}$	(Eq. 9)
Calibration relationship for MFC sampler using flow recorder	$\overline{Qa} = \{\overline{I}[(Tav+30)/Pav]^{1/2} - b\} \{1/m\}$	(Eq. 9a)
Set-point flow rate for MFC sampler	$SFR = (1.13)(Ps/Pa)(Ta/Ts)$	(Eq. 10)
Set-point manometer reading for MFC sampler	$SSP = [Pa/(Ta + 30)][m(SFR) + b]^2$	(Eq. 11)
Set-point reading for MFC sampler using flow recorder	$SSP = [m(SFR) + b][Pa/(Ta+30)]^{1/2}$	(Eq. 11a)
Conversion of manometer reading in inches of H_2O to mm Hg	$mm\ Hg = 25.4(in.\ H_2O/13.6)$	(Eq. 12)
Absolute stagnation pressure	$P1 = Pa - \Delta Pstg, \overline{P1} = Pa - \overline{\Delta Pstg}$	(Eq. 13)
Stagnation press. ratio	Stagnation press. ratio $= P1/Pa$	(Eq. 14)
Avg. stagnation press. ratio	Avg. stag. press. ratio $= \overline{P1}/Pav$	(Eq. 14a)
Regression model (y=mx+b) for calibration of VFC sampler	$P1/Pa = m[Qa(orifice)]/[Ta]^{1/2} + b$	(Eq. 15)
Calibration relationship for VFC sampler	$\overline{Qa}(sampler) = \{[(\overline{P1}/Pav) - b][Tav]^{1/2}\}\{1/m\}$	(Eq. 16)
Audit or QC flow check of sampler calibration	$\%\ diff. = \left[\dfrac{Qa(sampler) - Qa(audit)}{Qa(audit)}\right][100]$	(Eq. 17)
Audit or QC flow check of sampler operational flow rate	$\%\ difference = \left[\dfrac{Qa(audit) - 1.13}{1.13}\right][100]$	(Eq. 18)
Regression model (y=mx+b) for provisional calibration of VFC sampler for audit	$(P1/Pa) = m'[Qa(audit)] + b'$	(Eq. 19)

(continued)

TABLE 5.1. FORMULAS ASSOCIATED WITH PM10 MONITORING (Cont'd)

Calculation	Formula	Equation
Provisional calibration of VFC sampler for audit	$Qa(audit) = [(P1/Pa) - b']/m'$	(Eq. 20)
Total air volume sampled	$Vstd = (\overline{Qstd})(t)$	(Eq. 21)
PM10 mass concentration	$PM10 = (10^6)(Wg - Wt)/Vstd$	(Eq. 22)
Corrected sampler flow rate under normal operating conditions during audits and QC flow checks	$Qa(corr.\ sampler)$ $= \left[Qa(sampler\right] \left[\dfrac{100 - \%\ difference}{100}\right]$	(Eq. 23)

SYMBOLS

b   Intercept of linear regression calibration relationship

b'   Intercept of linear regression for provisional calibration for audit of VFC sampler

ΔH_2O Pressure drop across a transfer standard orifice, mm (or in.) of water column

ΔHg Differential pressure at inlet to standard volume meter, mm Hg (or kPa)

I   Flow recorder chart reading, arbitrary units on square-root-function scale

$\overline{I}$ Average flow recorder chart reading over the sample period, arbitrary units on square-root-function scale

It   Transformed flow recorder reading, for calibration relationship

m   Slope of linear regression calibration relationship

m'   Slope of linear regression for provisional calibration for audit of VFC sampler

Pa   Current ambient barometric pressure, mm Hg (or kPa)

Pav   Average ambient barometric pressure for the sample period, mm Hg (or kPa)

ΔPex Pressure in exit orifice plenum of sampler, measured with respect to atmospheric pressure, mm (or in.) water column

$\overline{\Delta Pex}$ Average of initial and final ΔPex readings, mm (or in.) H_2O

TABLE 5.1. FORMULAS ASSOCIATED WITH PM10 MONITORING (Cont'd)

SYMBOLS (cont'd)

ΔPext   Transformed exit orifice plenum pressure, for calibration relationship, mm (or in.) water column

PM10   PM10 mass concentration, μg/std. m^3

Pstd   EPA-standard atmospheric pressure, 760 mm Hg (or 101 kPa)

ΔPstg   Relative stagnation pressure, measured with respect to atmospheric pressure, mm Hg

$\overline{\Delta\text{Pstg}}$ Average of initial and final ΔPstg readings, mm Hg

P1   Absolute stagnation pressure, mm Hg

$\overline{\text{P1}}$ Average absolute stagnation pressure for the sample period, mm Hg

P1/Pa   Ratio of absolute stagnation pressure to current barometric pressure

$\overline{\text{P1}}$/Pav   Average ratio of absolute stagnation pressure to barometric pressure for the sampler period

Qa   Sampler flow rate measured in actual volumetric units, m^3/min

$\overline{\text{Qa}}$ Average sampler flow rate for the sample period measured in actual volumetric units, m^3/min

Qa(audit)   Sampler flow rate in actual volumetric units determined by a flow rate audit, m^3/min

Qa(orifice)   Flow rate measured by an orifice transfer standard in actual volumetric units, m^3/min

Qa(sampler)   Flow rate in actual volumetric units indicated by sampler's calibration relationship during flow rate audit or QC flow check, m^3/min

Qstd   Flow rate measured in EPA-standard volumetric units, std. m^3/min

$\overline{\text{Qstd}}$ Average sampler flow rate for the sample period in standard volumetric units, std. m^3/min

SFR   Set-point flow rate in actual volumetric units for MFC sampler, m^3/min

SSP   Sampler set point manometer reading [or flow recorder reading] for MFC sampler needed to obtain SFR, mm Hg [or I]

t   Total elapsed sampling time, min

Ta   Current ambient temperature, K (K = °C + 273)

Tav   Average ambient temperature during the sample period, K

(continued)

TABLE 5.1. FORMULAS ASSOCIATED WITH PM10 MONITORING (Cont'd)

SYMBOLS (cont'd)

ΔTime	Elapsed time during which a flow rate is measured by a standard volume meter, min
Tstd	EPA-standard temperature, 298 K
Va	Actual air volume measured by standard volume meter at ambient temperature and barometric pressure, m^3
ΔVol	Uncorrected air volume measured by standard volume meter, m^3
Vstd	Total sample volume measured in standard volume units, m^3
Wg, Wt	Gross and tare weights of the HV PM10 filter, respectively, g

2.11.6 MAINTENANCE

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

This section 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 at the end of this section 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 50, Appendix J), 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 degrees 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 Kimwipe to prevent the oil from contaminating the filter substrate.

6.2.3 <u>MFC Base</u> - 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 Subsection 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.

     <u>Caution</u>: 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., greater than 0.3 m^3/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 Subsection 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.

TABLE 8.1. 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 800 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 through-out 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.

2.11.7 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 subsection 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 high-volume (HV) PM10 samplers that are equipped with PM10 inlets requiring an actual flow rate of 1.13 m^3/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 in a table at the end of this section (Table 7.1). Refer to Section 2.0.12 of this Handbook for additional requirements for basic performance audits. Refer to Section 2.0.11 of this Handbook for detailed procedures for systems audits.

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

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 m^3/min at actual conditions; the acceptable flow-rate fluctuation range is ±10 percent of this value (i.e., 1.02 to 1.24 m^3/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 (Qa) as described in Subsection 2.2.

<u>Note</u>: 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., Qa) units and traceable to NIST (see Subsection 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 temperature over an appropriate range to the nearest ±1 °C and referenced to an NIST or ASTM thermometer within ±2 °C at least annually.

- 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 mm 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 (blank forms appear in Subsection 12).

- 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 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 larger than 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 open the valve of a variable-resistance orifice wide open. 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.

MFC SAMPLER AUDIT DATA SHEET

Station Location _MILFORD, NC_ Date _1/11/89_ Time _10:15 AM_

Sampler Model _GMW_ S/N _1297_

Pa _751_ mm Hg, Ta _6_ °C _279_ K, Unusual Conditions _NONE_

Audit Orifice S/N _10387_ , Orifice Calibration Date _12/15/88_

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 (ΔH_2O) _5.4_ in. H_2O Qa (audit)[a] _1.144_ m^3/min

	With Orifice Installed	**Without Orifice Installed**
Sampler Pressure Drop (ΔPex)	_4.0_ in. H_2O	_4.2_ in. H_2O
Qa (sampler)[b]	_1.116_ m^3/min	_1.151_ m^3/min

Audit Flow Rate Percentage Difference[c] _-2.4_ %

Qa (corrected sampler)[d] _1.179_ m^3/min

Design Flow Rate Percentage Difference[e] _4.3_ %

---

[a]For calculation of audit orifice standard flow rates:

$$Qa \ (audit) = \{[\Delta(H_2O) \ (Ta/Pa)]^{1/2} - b\} \ \{1/m\}$$

[b]For calculation of sampler flow rates:

$$Qa \ (sampler) = \{[(\Delta Pex/Pa) \ (Ta + 30)]^{1/2} - b\} \ \{1/m\}$$

[c]Audit % Difference = $\left[\dfrac{Qa \ (sampler) - Qa \ (orifice)}{Qa \ (orifice)}\right] \left[100\right]$ where Qa (sampler) is measured with the orifice installed.

[d]Qa (corrected sampler) = Qa (sampler) $\left[\dfrac{100 - Audit \ \% \ Difference}{100}\right]$ where Qa (sampler) is measured without the orifice installed

[e]Design Flow Rate % Difference = $\left[\dfrac{Qa \ (corrected \ sampler) - 1.13}{1.13}\right] \left[100\right]$

Auditor _F. McELROY_ Observer _D. PALMER_

Figure 7.1. Example MFC sampler audit data sheet.

6. Leak test the audit system (refer to Subsection 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 meniscuses. 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 (Ta), K (K = °C + 273).
    *   Ambient barometric pressure (Pa), 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, ΔPex [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 6:

$$Qa(audit) = \{[\Delta H_2O(Ta/Pa)]^{1/2} - b\} \{1/m\} \qquad \text{(Eq. 6)}$$

where:

$Qa(audit)$ = actual volumetric flow rate as indicated by the audit orifice transfer standard, m^3/min
ΔH_2O = pressure drop across the orifice, mm (or in.) H_2O
Ta = ambient temperature, K (K = °C + 273)
Pa = 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, $Qa(sampler)$ with and without the orifice installed, as it is normally done, using the sampler's calibration relationship (Equation 9 [or 9a], Subsection 2.3.3) and record both $Qa(sampler)$ values on the data sheet.

17. Calculate the percentage difference between the sampler's indicated flow rate, $Qa(sampler)$ with the orifice installed, and the corresponding audit flow rate, $Qa(audit)$, determined from the audit orifice transfer standard as:

$$\text{Audit flow rate \% difference} = \left[\frac{Qa(sampler) - Qa(audit)}{Qa(audit)}\right] \left[100\right] \qquad \text{(Eq. 17)}$$

18. Record the audit flow rate percentage difference on the data sheet. If the audit flow rate percentage difference is less than or equal to ±7 percent, the sampler calibration is acceptable. Differences exceeding ±7 percent require sampler recalibration. Differences exceeding ±10 percent 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, $Qa(corrected sampler)$, using Equation 23:

$$Qa(\text{corr. sampler}) = \left[Qa(sampler)\right] \left[\frac{100 - \text{audit \% difference}}{100}\right] \qquad \text{(Eq. 23)}$$

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

Calculate the design flow rate percentage difference between the corrected sampler flow rate, $Qa(corr. sampler)$, and the inlet design flow rate of 1.13 m^3/min as:

$$\text{Design flow rate} \atop \text{\% difference} = \left[\frac{Qa(\text{corr. sampler}) - 1.13}{1.13}\right] \left[100\right] \qquad \text{(Eq. 18)}$$

20. Record the design flow rate percentage difference. If the design flow rate percentage difference is less than or equal to ±7 percent, the sampler calibration is acceptable. Differences exceeding ±7 percent should be investigated, and deviations exceeding ±10 percent (or the acceptable design flow-rate range specified by the inlet manufacturer) 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 optimum set-point flow rate (SFR) according to Equation 10 in Subsection 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 m^3/min at actual conditions; the acceptable flow-rate fluctuation range is ±10 percent of this value (i.e., 1.02 to 1.24 m^3/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 (Qa) units as described in Subsection 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.
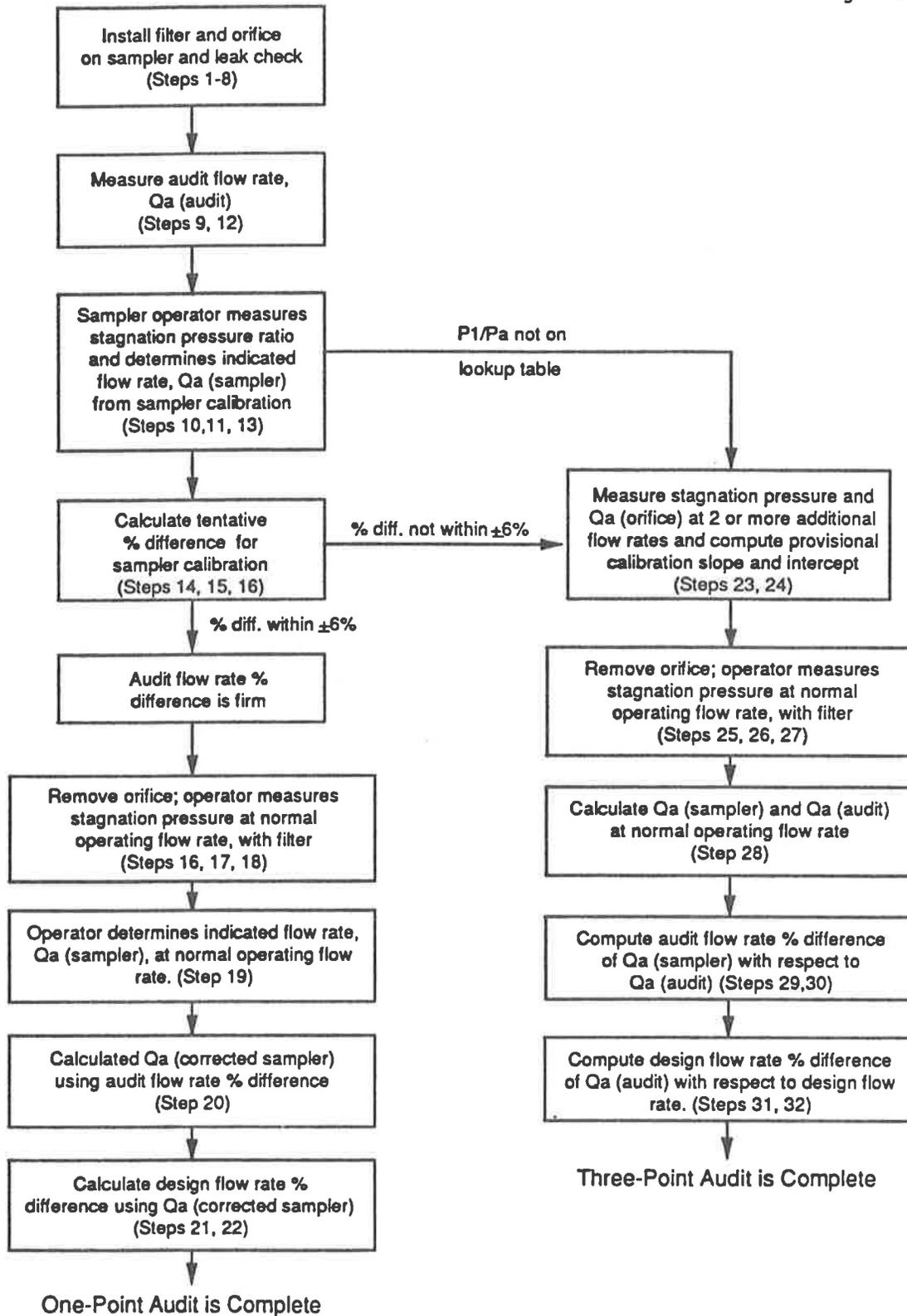
Figure 7.2. Flow chart of performance audit procedures for volumetric-flow-controlled PM10 samplers.

1.   Transport the following equipment to the monitoring site:

  •   Audit orifice transfer standard with calibration relationship in
      actual volumetric flow-rate (Qa) 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 temperature over an
      appropriate range to the nearest ±1 °C and referenced to an NIST or
      ASTM thermometer within ±2 °C at least annually.

  •   A portable aneroid barometer (e.g., a climber's or engineer's altim-
      eter), capable of accurately measuring ambient barometric pressure
      over the range of approximately 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.

  •   VFC Sampler Audit Data Sheet such as shown in Figure 7.3 (blank
      forms appear in Subsection 12).

  •   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 subse-
     quent 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 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.

     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.

VFC SAMPLER AUDIT DATA SHEET (Part 1)

Station Location _INDIANAPOLIS_ Date _1/23/89_ Time _2:15PM_

Sampler Model _WEDDING_ S/N _10408 70285C_

Pa _739_ mm Hg, Ta _11_ °C _284_ K, Unusual Conditions _NONE_

Audit Orifice S/N _10387_ , Orifice Calibration Date _12/15/88_

Orifice Calibration Relationship: m = _1.2430_ b = _-0.0062_ r = _0.9999_

Sampler Calibration Relationship: m = _Lookup_ b = _TABLE_ r = _Used_

Orifice Pressure Drop (ΔH_2O) _4.5_ in. H_2O Qa (audit)[a] _1.063_ m^3/min

	With Orifice Installed	Without Orifice Installed
Stagnation Pressure (ΔPstg)	_39.37_ mm Hg	_33.02_ mm Hg
Absolute Stagnation Pressure (P1)[b]	_699.63_ mm Hg	_705.98_ mm Hg
Stagnation Pressure Ratio (P1/Pa)	_0.9467_ (see Note)	_0.9553_ (see Note)
Qa (sampler)[c]	_1.121_ m^3/min	_1.146_ m^3/min

Audit Flow Rate Percentage Difference[d] _5.5_ % (see Note)

Qa (corrected sampler)[e] _1.083_ m^3/min

Design Flow Rate Percentage Difference[f] _-4.2_ %

Note: If P1/Pa is less than the values that are listed in the manufacturer's lookup table or if audit flow rate percentage difference is greater than ±6 percent, proceed to Part 2 of the VFC Sampler Audit Data Sheet. Otherwise, complete this part.

---

[a]Qa (orifice) = $\{[\Delta(H_2O)\,(Ta/Pa)]^{1/2} - b\}\,\{1/m\}$

[b]P1 = Pa − ΔPstg

[c]Determine Qa (sampler) from manufacturer's lookup table (or from alternate calibration relationship)

[d]Audit % Difference = $\left[\dfrac{(Qa\ (sampler) - Qa\ (audit)}{Qa\ (audit)}\right][100]$ where Qa (sample) is measured with the orifice installed.

[e]Qa (corrected sampler) = Qa (sampler) $\left[\dfrac{100 - Audit\ \%\ Difference}{100}\right]$ where Qa (sampler) is measured without the orifice installed

[f]Design Flow Rate % Difference = $\left[\dfrac{Qa\ (corrected\ sampler) - 1.13}{1.13}\right][100]$

Auditor _R. WRIGHT_ Observer _K. MᶜDANIEL_

(continued)

Figure 7.3. Example VFC sampler audit data sheet. (Part 1 of 2)

VFC SAMPLER AUDIT DATA SHEET (Part 2)

(continued from Part 1 of this form)

Station Location __INDIANAPOLIS__ Date __1/23/89__ Time __2:15 PM__
Sampler Model __WEDDING__ S/N __1040870285C__
Pa __739__ mm Hg, Ta __11__ °C __284__ K, Unusual Conditions __NONE__
Audit Orifice S/N __10387__, Orifice Calibration Date __12/15/88__
Orifice Calibration Relationship: m = __1.2430__ b = __-0.0062__ r = __0.9999__

Plate No.	ΔH₂O (in.)	ΔPstg (mm Hg)	P1[a] (mm Hg)	P1/Pa (mm Hg)	Qa (Orifice)[b] (m³/min)
1	4.5	39.37	699.63	0.9467	1.063
2	4.35	44.45	694.55	0.9399	1.045
3	4.1	52.07	686.93	0.9295	1.015

Provisional Sampler Calibration Relationship: X = Qa (Orifice), Y = (P1/Pa)
m' = __0.3571__ b' = __0.5669__ r' = __0.9997__

Measurements with filter installed and Audit Orifice Transfer Standard removed:
ΔPstg __33.02__ mm Hg P1[a] __705.98__ mm Hg
P1/Pa __0.9553__
Qa (audit)[c] __1.085__ m³/min Qa (sampler)[d] __1.146__ m³/min

Audit Flow Rate Percentage Difference[e] __5.6__ %
Design Flow Rate Percentage Difference[f] __-4.0__ %

[a]$P1 = Pa - \Delta Pstg$

[b]$Qa \text{ (orifice)} = \{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\}\{1/m\}$

[c]$Qa \text{ (audit)} = [(P1/Pa) - b']/m'$

[d]Qa (sampler) is determined from the lookup table or alternative calibration relationship

[e]$\text{Audit Flow Rate \% Difference} = \left[\frac{(Qa \text{ (sampler)} - Qa \text{ (audit)})}{Qa \text{ (audit)}}\right][100]$

[f]$\text{Design Flow Rate \% Difference} = \left[\frac{Qa \text{ (audit)} - 1.13}{1.13}\right][100]$

Auditor __R. WRIGHT__ Observer __K. McDANIEL__

Figure 7.3. Example VFC sampler audit data sheet. (Part 2 of 2)

4. Install the audit orifice transfer standard with <u>no resistance plate</u>, or open the valve of a variable-resistance orifice wide open. 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 Subsection 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 (Ta), °C and K (K = °C + 273).
   - Ambient barometric pressure (Pa), 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 $\Delta Pstg$ on the data sheet. If $\Delta Pstg$ is measured in inches of water, convert the reading to mm Hg using Equation 12:

$$mm\ Hg = 25.4\ (in.\ H_2O)/13.6 \qquad (Eq.\ 12)$$

11. Compute the absolute stagnation pressure, P1, as:

$$P1 = Pa - \Delta Pstg \qquad (Eq.\ 13)$$

and the absolute stagnation pressure ratio as:

$$Stagnation\ pressure\ ratio = P1/Pa \qquad (Eq.\ 14)$$

Record the P1/Pa ratio on the audit data sheet.

12. Determine the flow rate through the audit orifice transfer standard, Qa(audit), using Equation 6:

$$Qa(audit) = \{[\Delta H_2O(Ta/Pa)]^{1/2} - b\}\ \{1/m\} \qquad (Eq.\ 6)$$

where:

Qa(audit) = actual volumetric flow rate as indicated by the audit orifice transfer standard, m^3/min
ΔH_2O = pressure drop across the orifice, mm (or in.) H_2O
Ta = ambient temperature, K (K = °C + 273)
Pa = 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, Qa(sampler), using the P1/Pa 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 P1/Pa 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, Qa(sampler), and the corresponding audit flow rate, Qa(audit), determined from the audit orifice transfer standard as:

$$\begin{array}{l} \text{Audit flow rate} \\ \text{\% difference} \end{array} = \left[\frac{Qa(sampler) - Qa(audit)}{Qa(audit)}\right] \left[100\right] \qquad (Eq.\ 17)$$

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 ±6, 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 ±6, 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, ΔPstg, and to calculate the absolute stagnation pressure ratio, P1/Pa, 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, Qa(sampler), using the P1/Pa 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 23:

$$Qa(\text{corrected sampler}) = \left[Qa(\text{sampler})\right] \left[\frac{100 - \text{Audit \% difference}}{100}\right] \quad (Eq. 23)$$

where Qa(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 m^3/min as:

$$\frac{\text{Design flow rate}}{\text{\% difference}} = \left[\frac{Qa(\text{corrected sampler}) - 1.13}{1.13}\right] \left[100\right] \quad (Eq. 18)$$

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

22. If the design flow rate percentage difference is within ±7 percent, the sampler calibration is acceptable. Differences exceeding ±7 percent should be investigated. Differences exceeding ±10 percent (or the acceptable flow-rate range specified by the inlet manufacturer) 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 m^3/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 (P1/Pa) and Qa(orifice). For the linear regression model,

$$(P1/Pa) = m'[Qa(orifice)] + b' \qquad \text{(Eq. 19)}$$

Calculate the linear regression slope (m'), intercept (b') and correlation coefficient (r'). 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, ΔPstg, and to calculate the absolute stagnation pressure ratio, P1/Pa 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, Qa(sampler), using the P1/Pa 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, Qa(audit), using the (P1/Pa) value obtained in Step 27 and the slope (m') and intercept (b') 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 Qa(sampler) and Qa(audit) obtained in Step 28 as:

$$\text{Audit flow rate \% difference} = \left[\frac{Qa(sampler) - Qa(audit)}{Qa(audit)}\right]\left[100\right] \qquad \text{(Eq. 17)}$$

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

30. If the audit flow rate percentage difference is within ±7 percent, the sampler calibration is acceptable. Differences exceeding ±7 percent will require recalibration. Differences exceeding ±10 percent 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 Qa(audit) obtained from Step 28 and the inlet design flow rate of 1.13 m^3/min as:

$$\text{Design flow rate} \atop \text{\% difference} = \left[\frac{Qa(audit) - 1.13}{1.13}\right] \left[100\right] \qquad \text{(Eq. 18)}$$

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

32. If the design flow rate percentage difference is within ±7 percent, the sampler calibration is acceptable. Differences exceeding ±7 percent should be investigated. Differences exceeding ±10 percent (or the acceptable flow-rate range specified by the inlet manufacturer) 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 post-audit 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 post-audit 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 ±7 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 PM10 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.

Section 2.0.11 of this Handbook 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 7 samples per 100 (or a minimum of 4 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 standard 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 subsection 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 as discussed in Section 2.2.8 of this volume. 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 Class S standard weights 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.

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.	1. Percentage difference between the sampler-indicated flow rates and the audit-measured flow rate is within 7%.	Recalibrate before resuming sampling; if difference exceeds ±10%, double-check calculations. If difference still exceeds ±10%, invalidate data since last calibration or valid flow check.
		2. ±10% of inlet design flow rate.	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 subsection and Section 2.0.11 of this Handbook.	Initiate improved methods and/or training programs.
Data processing	Independently repeat calculation of PM10 concentration from data record for 7 samples per 100 (minimum of 4 per lot).	Audit concentration agrees with original report concentration within round-off 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 for 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.

2.11.8 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. Annual mean particulate matter concentrations of the selected sites should be among the highest 25 percent of the annual mean PM10 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 PM10 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 PM10 network contains more than one type of sampler, each type should be represented by at least one collocated sampler pair, if possible.

The two collocated samplers must be within 4 m of each other, but at least 2 m apart to preclude air flow interference. Calibration, sampling, and analysis must be the same for both collocated samplers and all other samplers in the network. One of each pair of collocated samplers is designated as the primary sampler from which samples will be used to report air quality for the site; the other is designated as the duplicate sampler. Each duplicate sampler must be operated concurrently with its associated routine 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-6-day schedule used by many monitoring agencies is recommended. 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/standard cubic meter) between the two collocated samplers are used to calculate precision as described in 40 CFR 58, Appendix A.

8.2 Accuracy

The accuracy of the HV PM10 sampler method in the measurement of PM10 is assessed by auditing the performance of the sampler (at its specified flow rate) as described in Subsection 7. 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 58, Appendix A.

DATA QUALITY ASSESSMENT REPORTING FORM

PRECISION

Check box and complete only if all entries are for a single site and/or method

STATE — REPORTING ORGANIZATION (1 2 3 4 5) — YEAR (6 7) — QUARTER (8)

1 : ORIGINAL
2 : REVISION
3 : DELETION

NAME OF REPORTING ORGANIZATION

DATE SUBMITTED — MO/DAY/YR — PREPARED BY

SAROAD SITE CODE 10-18 — SITE

POLLUTANT — METHOD CODE 21-23 — METHOD

UNIT CODES
µg/m³ 01
ppm 07
mg/ml 64
L/M 73
m³/min 83
µg 77

Column headings:

- SAROAD SITE CODE 10-18
- POLLUTANT
- METHOD CODE 21-23
- 24 (P)
- DATE — MON. 25-26 / DAY 27-28
- UNIT
- UNIT CODE 31-32
- ACTUAL OR DESIGNATED 34-37 / 38-40
- INDICATED OR COLLOCATED 41-44 / 45-47

DATA QUALITY ASSESSMENT REPORTING FORM — ACCURACY

2.11.9   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.   Class-S weights of NIST specifications are recommended for the laboratory balance calibration. See Subsection 4.5 for details on balance calibration checks.

2.   Use of a positive-displacement standard volume meter (e.g., a Roots[R] 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. Subsection 2 presents details on HV PM10 sampler calibration, and Subsection 7 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 to 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.

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APPENDIX J—REFERENCE METHOD FOR
THE DETERMINATION OF PARTICULATE
MATTER AS PM_{10} IN THE ATMOSPHERE

1.0 *Applicability.*

1.1 This method provides for the measurement of the mass concentration of particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM_{10}) in ambient air over a 24-hour period for purposes of determining attainment and maintenance of the primary and secondary national ambient air quality standards for particulate matter specified in § 50.6 of this chapter. The measurement process is nondestructive, and the PM_{10} sample can be subjected to subsequent physical or chemical analyses. Quality assurance procedures and guidance are provided in Part 58, Appendices A and B, of this chapter and in References 1 and 2.

2.0 *Principle.*

2.1 An air sampler draws ambient air at a constant flow rate into a specially shaped inlet where the suspended particulate matter is inertially separated into one or more size fractions within the PM_{10} size range. Each size fraction in the PM_{10} size range is then collected on a separate filter over the specified sampling period. The particle size discrimination characteristics (sampling effectiveness and 50 percent cutpoint) of the sampler inlet are prescribed as performance specifications in Part 53 of this chapter.

2.2 Each filter is weighed (after moisture equilibration) before and after use to determine the net weight (mass) gain due to collected PM_{10}. The total volume of air sampled, corrected to EPA reference conditions (25° C, 101.3 kPa), is determined from the measured flow rate and the sampling time. The mass concentration of PM_{10} in the ambient air is computed as the total mass of collected particles in the PM_{10} size range divided by the volume of air sampled, and is expressed in micrograms per standard cubic meter (μg/std m³). For PM_{10} samples collected at temperatures and pressures significantly different from EPA reference conditions, these corrected concentrations sometimes differ substantially from actual concentrations (in micrograms per actual cubic meter), particularly at high elevations. Although not required, the actual PM_{10} concentration can be calculated from the corrected concentration, using the average ambient temperature and barometric pressure during the sampling period.

2.3 A method based on this principle will be considered a reference method only if (a)

the associated sampler meets the requirements specified in this appendix and the requirements in Part 53 of this chapter, and (b) the method has been designated as a reference method in accordance with Part 53 of this chapter.

3.0 *Range.*

3.1 The lower limit of the mass concentration range is determined by the repeatability of filter tare weights, assuming the nominal air sample volume for the sampler. For samplers having an automatic filter-changing mechanism, there may be no upper limit. For samplers that do not have an automatic filter-changing mechanism, the upper limit is determined by the filter mass loading beyond which the sampler no longer maintains the operating flow rate within specified limits due to increased pressure drop across the loaded filter. This upper limit cannot be specified precisely because it is a complex function of the ambient particle size distribution and type, humidity, filter type, and perhaps other factors. Nevertheless, all samplers should be capable of measuring 24-hour PM_{10} mass concentrations of at least 300 μg/std m³ while maintaining the operating flow rate within the specified limits.

4.0 *Precision.*

4.1 The precision of PM_{10} samplers must be 5 μg/m³ for PM_{10} concentrations below 80 μg/m³ and 7 percent for PM_{10} concentrations above 80 μg/m³, as required by Part 53 of this chapter, which prescribes a test procedure that determines the variation in the PM_{10} concentration measurements of identical samplers under typical sampling conditions. Continual assessment of precision via collocated samplers is required by Part 58 of this chapter for PM_{10} samplers used in certain monitoring networks.

5.0 *Accuracy.*

5.1 Because the size of the particles making up ambient particulate matter varies over a wide range and the concentration of particles varies with particle size, it is difficult to define the absolute accuracy of PM_{10} samplers. Part 53 of this chapter provides a specification for the sampling effectiveness of PM_{10} samplers. This specification requires that the expected mass concentration calculated for a candidate PM_{10} sampler, when sampling a specified particle size distribution, be within ±10 percent of that calculated for an ideal sampler whose sampling effectiveness is explicitly specified. Also, the particle size for 50 percent sampling effectivensss is required to be 10±0.5 micrometers. Other specifications related to accuracy apply to flow measurement and calibration, filter media, analytical (weighing) procedures, and artifact. The flow rate accuracy of PM_{10} samplers used in certain monitoring networks is required by Part 58

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of this chapter to be assessed periodically via flow rate audits.

6.0 *Potential Sources of Error.*

6.1 *Volatile Particles.* Volatile particles collected on filters are often lost during shipment and/or storage of the filters prior to the post-sampling weighing[3]. Although shipment or storage of loaded filters is sometimes unavoidable, filters should be reweighed as soon as practical to minimize these losses.

6.2 *Artifacts.* Positive errors in PM$_{10}$ concentration measurements may result from retention of gaseous species on filters[4,5]. Such errors include the retention of sulfur dioxide and nitric acid. Retention of sulfur dioxide on filters, followed by oxidation to sulfate, is referred to as artifact sulfate formation, a phenomenon which increases with increasing filter alkalinity[6]. Little or no artifact sulfate formation should occur using filters that meet the alkalinity specification in section 7.2.4. Artifact nitrate formation, resulting primarily from retention of nitric acid, occurs to varying degrees on many filter types, including glass fiber, cellulose ester, and many quartz fiber filters[5,7,8,9,10]. Loss of true atmospheric particulate nitrate during or following sampling may also occur due to dissociation or chemical reaction. This phenomenon has been observed on Teflon[5] filters[3] and inferred for quartz fiber filters[11,12]. The magnitude of nitrate artifact errors in PM$_{10}$ mass concentration measurements will vary with location and ambient temperature; however, for most sampling locations, these errors are expected to be small.

6.3 *Humidity.* The effects of ambient humidity on the sample are unavoidable. The filter equilibration procedure in section 9.0 is designed to minimize the effects of moisture on the filter medium.

6.4 *Filter Handling.* Careful handling of filters between presampling and postsampling weighings is necessary to avoid errors due to damaged filters or loss of collected particles from the filters. Use of a filter cartridge or cassette may reduce the magnitude of these errors. Filters must also meet the integrity specification in section 7.2.3.

6.5 *Flow Rate Variation.* Variations in the sampler's operating flow rate may alter the particle size discrimination characteristics of the sampler inlet. The magnitude of this error will depend on the sensitivity of the inlet to variations in flow rate and on the particle distribution in the atmosphere during the sampling period. The use of a flow control device (section 7.1.3) is required to minimize this error.

6.6 *Air Volume Determination.* Errors in the air volume determination may result from errors in the flow rate and/or sampling time measurements. The flow control device serves to minimize errors in the flow rate determination, and an elapsed time meter (section 7.1.5) is required to minimize the error in the sampling time measurement.

7.0 *Apparatus.*

7.1 *PM$_{10}$ Sampler.*

7.1.1 The sampler shall be designed to:

a. Draw the air sample into the sampler inlet and through the particle collection filter at a uniform face velocity.

b. Hold and seal the filter in a horizontal position so that sample air is drawn downward through the filter.

c. Allow the filter to be installed and removed conveniently.

d. Protect the filter and sampler from precipitation and prevent insects and other debris from being sampled.

e. Minimize air leaks that would cause error in the measurement of the air volume passing through the filter.

f. Discharge exhaust air at a sufficient distance from the sampler inlet to minimize the sampling of exhaust air.

g. Minimize the collection of dust from the supporting surface.

7.1.2 The sampler shall have a sample air inlet system that, when operated within a specified flow rate range, provides particle size discrimination characteristics meeting all of the applicable performance specifications prescribed in Part 53 of this chapter. The sampler inlet shall show no significant wind direction dependence. The latter requirement can generally be satisfied by an inlet shape that is circularly symmetrical about a vertical axis.

7.1.3 The sampler shall have a flow control device capable of maintaining the sampler's operating flow rate within the flow rate limits specified for the sampler inlet over normal variations in line voltage and filter pressure drop.

7.1.4 The sampler shall provide a means to measure the total flow rate during the sampling period. A continuous flow recorder is recommended but not required. The flow measurement device shall be accurate to ±2 percent.

7.1.5 A timing/control device capable of starting and stopping the sampler shall be used to obtain a sample collection period of 24 ±1 hr (1,440 ±60 min). An elapsed time meter, accurate to within ±15 minutes, shall be used to measure sampling time. This meter is optional for samplers with continuous flow recorders if the sampling time measurement obtained by means of the recorder meets the ±15 minute accuracy specification.

7.1.6 The sampler shall have an associated operation or instruction manual as required by Part 53 of this chapter which includes detailed instructions on the calibration, operation, and maintenance of the sampler.

7.2 *Filters.*

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7.2.1 *Filter Medium.* No commercially available filter medium is ideal in all respects for all samplers. The user's goals in sampling determine the relative importance of various filter characteristics (e.g., cost, ease of handling, physical and chemical characteristics, etc.) and, consequently, determine the choice among acceptable filters. Furthermore, certain types of filters may not be suitable for use with some samplers, particularly under heavy loading conditions (high mass concentrations), because of high or rapid increase in the filter flow resistance that would exceed the capability of the sampler's flow control device. However, samplers equipped with automatic filter-changing mechanisms may allow use of these types of filters. The specifications given below are minimum requirements to ensure acceptability of the filter medium for measurement of PM_{10} mass concentrations. Other filter evaluation criteria should be considered to meet individual sampling and analysis objectives.

7.2.2 *Collection Efficiency.* >99 percent, as measured by the DOP test (ASTM-2986) with 0.3 μm particles at the sampler's operating face velocity.

7.2.3 *Integrity.* ±5 μg/m³ (assuming sampler's nominal 24-hour air sample volume). Integrity is measured as the PM_{10} concentration equivalent corresponding to the average difference between the initial and the final weights of a random sample of test filters that are weighed and handled under actual or simulated sampling conditions, but have no air sample passed through them (i.e., filter blanks). As a minimum, the test procedure must include initial equilibration and weighing, installation on an inoperative sampler, removal from the sampler, and final equilibration and weighing.

7.2.4 *Alkalinity.* <25 microequivalents/ gram of filter, as measured by the procedure given in Reference 13 following at least two months storage in a clean environment (free from contamination by acidic gases) at room temperature and humidity.

7.3 *Flow Rate Transfer Standard.* The flow rate transfer standard must be suitable for the sampler's operating flow rate and must be calibrated against a primary flow or volume standard that is traceable to the National Bureau of Standards (NBS). The flow rate transfer standard must be capable of measuring the sampler's operating flow rate with an accuracy of ±2 percent.

7.4 *Filter Conditioning Environment.*

7.4.1　Temperature range: 15° to 30° C.

7.4.2　Temperature control: ±3° C.

7.4.3　Humidity range: 20% to 45% RH.

7.4.4　Humidity control: ±5% RH.

7.5 *Analytical Balance.* The analytical balance must be suitable for weighing the type and size of filters required by the sampler. The range and sensitivity required will depend on the filter tare weights and mass loadings. Typically, an analytical balance with a sensitivity of 0.1 mg is required for high volume samplers (flow rates >0.5 m³/ min). Lower volume samplers (flow rates <0.5 m³/min) will require a more sensitive balance.

8.0 *Calibration.*

8.1 *General Requirements.*

8.1.1　Calibration of the sampler's flow measurement device is required to establish traceability of subsequent flow measurements to a primary standard. A flow rate transfer standard calibrated against a primary flow or volume standard shall be used to calibrate or verify the accuracy of the sampler's flow measurement device.

8.1.2　Particle size discrimination by inertial separation requires that specific air velocities be maintained in the sampler's air inlet system. Therefore, the flow rate through the sampler's inlet must be maintained throughout the sampling period within the design flow rate range specified by the manufacturer. Design flow rates are specified as actual volumetric flow rates, measured at existing conditions of temperature and pressure (Q_a). In contrast, mass concentrations of PM_{10} are computed using flow rates corrected to EPA reference conditions of temperature and pressure (Q_{std}).

8.2 *Flow Rate Calibration Procedure.*

8.2.1　PM_{10} samplers employ various types of flow control and flow measurement devices. The specific procedure used for flow rate calibration or verification will vary depending on the type of flow controller and flow indicator employed. Calibration in terms of actual volumetric flow rates (Q_a) is generally recommended, but other measures of flow rate (e.g., Q_{std}) may be used provided the requirements of section 8.1 are met. The general procedure given here is based on actual volumetric flow units (Q_a) and serves to illustrate the steps involved in the calibration of a PM_{10} sampler. Consult the sampler manufacturer's instruction manual and Reference 2 for specific guidance on calibration. Reference 14 provides additional information on the use of the commonly used measures of flow rate and their interrelationships.

8.2.2　Calibrate the flow rate transfer standard against a primary flow or volume standard traceable to NBS. Establish a calibration relationship (e.g., an equation or family of curves) such that traceability to the primary standard is accurate to within 2 percent over the expected range of ambient conditions (i.e., temperatures and pressures) under which the transfer standard will be used. Recalibrate the transfer standard periodically.

8.2.3　Following the sampler manufacturer's instruction manual, remove the sampler inlet and connect the flow rate transfer standard to the sampler such that the trans-

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fer standard accurately measures the sampler's flow rate. Make sure there are no leaks between the transfer standard and the sampler.

8.2.4 Choose a minimum of three flow rates (actual m³/min), spaced over the acceptable flow rate range specified for the inlet (see 7.1.2) that can be obtained by suitable adjustment of the sampler flow rate. In accordance with the sampler manufacturer's instruction manual, obtain or verify the calibration relationship between the flow rate (actual m³/min) as indicated by the transfer standard and the sampler's flow indicator response. Record the ambient temperature and barometric pressure. Temperature and pressure corrections to subsequent flow indicator readings may be required for certain types of flow measurement devices. When such corrections are necessary, correction on an individual or daily basis is preferable. However, seasonal average temperature and average barometric pressure for the sampling site may be incorporated into the sampler calibration to avoid daily corrections. Consult the sampler manufacturer's instruction manual and Reference 2 for additional guidance.

8.2.5 Following calibration, verify that the sampler is operating at its design flow rate (actual m³/min) with a clean filter in place.

8.2.6 Replace the sampler inlet.

9.0 *Procedure.*

9.1 The sampler shall be operated in accordance with the specific guidance provided in the sampler manufacturer's instruction manual and in Reference 2. The general procedure given here assumes that the sampler's flow rate calibration is based on flow rates at ambient conditions (Q_a) and serves to illustrate the steps involved in the operation of a PM₁₀ sampler.

9.2 Inspect each filter for pinholes, particles, and other imperfections. Establish a filter information record and assign an identification number to each filter.

9.3 Equilibrate each filter in the conditioning environment (see 7.4) for at least 24 hours.

9.4 Following equilibration, weigh each filter and record the presampling weight with the filter identification number.

9.5 Install a preweighed filter in the sampler following the instructions provided in the sampler manufacturer's instruction manual.

9.6 Turn on the sampler and allow it to establish run-temperature conditions. Record the flow indicator reading and, if needed, the ambient temperature and barometric pressure. Determine the sampler flow rate (actual m³/min) in accordance with the instructions provided in the sampler manufacturer's instruction manual. NOTE.—No onsite temperature or pressure measurements are necessary if the sampler's

flow indicator does not require temperature or pressure corrections or if seasonal average temperature and average barometric pressure for the sampling site are incorporated into the sampler calibration (see step 8.2.4). If individual or daily temperature and pressure corrections are required, ambient temperature and barometric pressure can be obtained by on-site measurements or from a nearby weather station. Barometric pressure readings obtained from airports must be station pressure, not corrected to sea level, and may need to be corrected for differences in elevation between the sampling site and the airport.

9.7 If the flow rate is outside the acceptable range specified by the manufacturer, check for leaks, and if necessary, adjust the flow rate to the specified setpoint. Stop the sampler.

9.8 Set the timer to start and stop the sampler at appropriate times. Set the elapsed time meter to zero or record the initial meter reading.

9.9 Record the sample information (site location or identification number, sample date, filter identification number, and sampler model and serial number).

9.10 Sample for 24±1 hours.

9.11 Determine and record the average flow rate (Q_a) in actual m³/min for the sampling period in accordance with the instructions provided in the sampler manufacturer's instruction manual. Record the elapsed time meter final reading and, if needed, the average ambient temperature and barometric pressure for the sampling period (see note following step 9.6).

9.12 Carefully remove the filter from the sampler, following the sampler manufacturer's instruction manual. Touch only the outer edges of the filter.

9.13 Place the filter in a protective holder or container (e.g., petri dish, glassine envelope, or manila folder).

9.14 Record any factors such as meteorological conditions, construction activity, fires or dust storms, etc., that might be pertinent to the measurement on the filter information record.

9.15 Transport the exposed sample filter to the filter conditioning environment as soon as possible for equilibration and subsequent weighing.

9.16 Equilibrate the exposed filter in the conditioning environment for at least 24 hours under the same temperature and humidity conditions used for presampling filter equilibration (see 9.3).

9.17 Immediately after equilibration, reweigh the filter and record the postsampling weight with the filter identification number.

10.0 *Sampler Maintenance.*

10.1 The PM₁₀ sampler shall be maintained in strict accordance with the mainte-

Environmental Protection Agency

nance procedures specified in the sampler manufacturer's instruction manual.

11.0 *Calculations.*

11.1 Calculate the average flow rate over the sampling period corrected to EPA reference conditions as Q_{std}. When the sampler's flow indicator is calibrated in actual volumetric units (Q_a), Q_{std} is calculated as:

$$Q_{std} = Q_a \times (P_{av}/T_{av})(T_{std}/P_{std})$$

where

Q_{std}=average flow rate at EPA reference conditions, std m³/min;

Q_a=average flow rate at ambient conditions, m³/min;

P_{av}=average barometric pressure during the sampling period or average barometric pressure for the sampling site, kPa (or mm Hg);

T_{av}=average ambient temperature during the sampling period or seasonal average ambient temperature for the sampling site, K;

T_{std}=standard temperature, defined as 298 K;

P_{std}=standard pressure, defined as 101.3 kPa (or 760 mm Hg).

11.2 Calculate the total volume of air sampled as:

$$V_{std} = Q_{std} \times t$$

where

V_{std}=total air sampled in standard volume units, std m³;

t=sampling time, min.

11.3 Calculate the PM₁₀ concentration as:

$$PM_{10} = (W_f - W_i) \times 10^6/V_{std}$$

where

PM_{10}=mass concentration of PM₁₀, μg/std m³;

W_f, W_i=final and initial weights of filter collecting PM₁₀ particles, g;

10^6=conversion of g to μg.

NOTE: If more than one size fraction in the PM₁₀ size range is collected by the sampler, the sum of the net weight gain by each collection filter [$\Sigma(W_f - W_i)$] is used to calculate the PM₁₀ mass concentration.

12.0 *References.*

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[52 FR 24664, July 1, 1987; 52 FR 29467, Aug. 7, 1987]

2.11.11 REFERENCES

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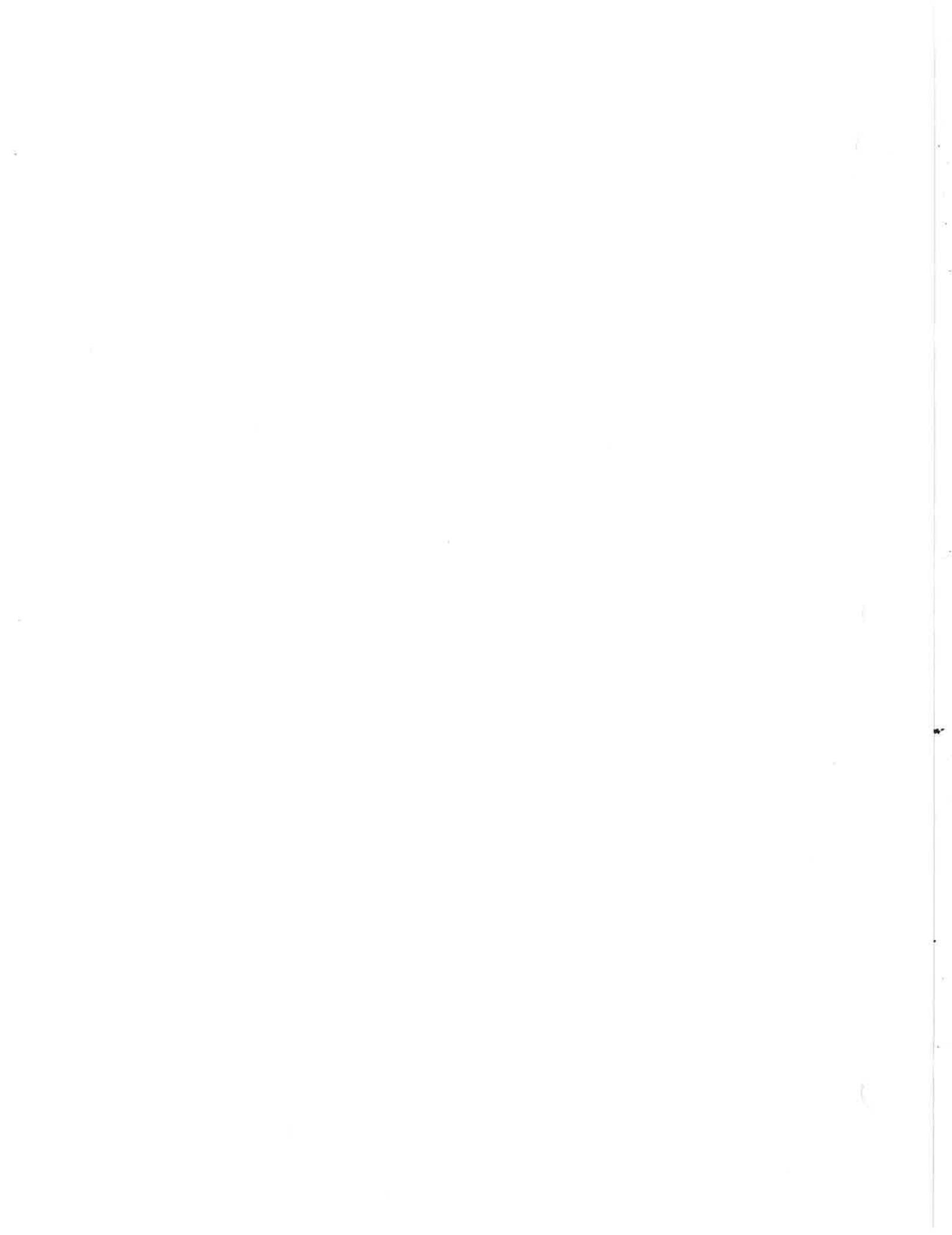| ITEM	Description	Qty	Purchase Order No.	VENDOR	DATE		COST	Initials	Accept/ Reject	COMMENTS
					Ord.	Rec'd.				

Figure 1.1. Example procurement log.

2.11.12 DATA FORMS

Blank data forms are provided on the following pages for the convenience of the Handbook user. Each blank form has the customary descriptive title centered at the top of the page and has retained its original figure number designation. The following data forms are included in this section:

Form	Title
1.1	Example Procurement Log
2.1	Example Orifice Transfer Standard Certification Worksheet
2.3	Example MFC Sampler Calibration Data Sheet
2.5	Example VFC Sampler Calibration Data Sheet
3.1	Example MFC Sampler Field Data Sheet
3.2	Example VFC Sampler Field Data Sheet
3.5	Example MFC Sampler Flow Check Data Sheet
3.6	Example VFC Sampler Flow Check Data Sheet
4.1	Example Laboratory Data/Coding Form
4.2	Example Internal Quality Control Log Sheet
7.1	Example MFC Sampler Audit Data Sheet
7.3	Example VFC Sampler Audit Data Sheet
8.1	Precision Data Quality Assessment Form
8.2	Accuracy Data Quality Assessment Form

ORIFICE TRANSFER STANDARD CERTIFICATION WORKSHEET

| Date: | Roots meter S/N: | Ta: | K |
| Operator: | Orifice S/N: | Pa: | mm Hg |

Plate or Volts AC	Initial Volume	Final Volume	Δ Vol.	ΔTime (min)	ΔHg (mm)	ΔH_2O (in.)

DATA TABULATION

Vstd	(x-axis) Qstd	(y-axis) $[\Delta H_2O (Pa/Ta)]^{1/2}$ *	Va	(x-axis) Qa	(y-axis) $[\Delta H_2O (Ta/Pa)]^{1/2}$
	m =			m =	
	b =			b =	
	r =			r =	

CALCULATIONS

Vstd = Δ Vol [(Pa − ΔHg)/760] (298/Ta)'
Qstd = Vstd/ΔTime'
y = mx + b

Va = ΔVol [(Pa − ΔHg)/Pa]
Qa = Va/ΔTime
y = mx + b

For subsequent flow rate calculations:

Qstd = {$[\Delta H_2O (Pa/Ta)]^{1/2}$ − b} {1/m}

Qa = {$[\Delta H_2O (Ta/Pa)]^{1/2}$ − b} {1/m}

NOTE: For PM10 monitoring, a calibration curve corrected to standard conditions is optional.

Figure 2.1. Example Orifice Transfer Standard Certification Worksheet.

MFC SAMPLER CALIBRATION DATA SHEET

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____ Operator _____

Pa _____ mm Hg, Ta _____ °C _____K, Unusual conditions: _____

Ps· _____ mm Hg, Ts· _____ °C _____K, (·seasonal average Ta and Pa)

Orifice S/N _____ Orifice Calibration Date _____

Orifice calibration relationship: m = _____ b = _____ r = _____

Plate Number	Total ΔH_2O (in.)	X-Axis = Qa (orifice) flow rate[a] (m^3/min)	Sampler ΔPex (in. H_2O) [or I for flow recorders]	Y-Axis = Sampler $\Delta Pext$[b] [or It for flow recorders][c]

[a]$Qa = \{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\}\{1/m\}$

[b]$\Delta Pext = [\Delta Pex(Ta + 30)/Pa)]^{1/2}$

[c]$It = [I][(Ta + 30)/Pa]^{1/2}$ if a flow recorder is used

Sampler Calibration Relationship (Qa on x-axis; $\Delta Pext$ or [It] on y-axis):
$\Delta Pext = m[Qa (Orifice)] + b$ or $It = m[Qa(Orifice)] + b$

m = _____ b = _____ r = _____

For subsequent calculation of sampler flow rate:
$\overline{Qa} = \{[\text{mean } \Delta Pex\ (Tav + 30)/Pav]^{1/2} - b\}\{1/m\}$
or $\overline{Qa} = \{\text{mean } I[(Tav + 30)/Pav]^{1/2} - b\}\{1/m\}$

Set point flow rate (SFR) _____   Sampler set point (SSP) _____
$SFR = 1.13\ (Ps/Pa)\ (Ta/Ts)$ $SSP = [Pa/(Ta + 30)][m(SFR) + b]^2$
or $SSP = [Pa/(Ta + 30)]^{1/2}[m(SFR) + b]$ for flow recorders

Figure 2.3. Example MFC sampler calibration data sheet.

MFC SAMPLER FIELD DATA SHEET

Station
Location _____ Date _____ SAROAD# _____

Sampler Model _____ S/N _____

Filter ID No. _____ Pav _____ mm Hg, Tav _____ °C _____ K

Sampler Manometer Readings   **Flow Recorder Readings**

Initial ΔPex _____ in. H_2O Mean I _____

Final ΔPex _____ in. H_2O

Mean ΔPex _____ in. H_2O

Sampler Calibration Relationship: m = _____ b = _____ r = _____

$\overline{Qa}$ _____ m^3/min   Elapsed Time _____ min

$\overline{Qa}$ = {[mean ΔPex (Tav + 30)/Pav]$^{1/2}$ − b} {1/m}
$\overline{Qa}$ = {mean I [(Tav + 30)/Pav]$^{1/2}$ − b} {1/m} for flow recorders

Operator _____

Comments: _____
_____
_____
_____

Laboratory Calculations:

$\overline{Qstd}$ _____ std m^3/min   Gross weight (Wg) _____ g
$\overline{Qstd}$ = $\overline{Qa}$ (Pav/Pstd) (Tstd/Tav)   Tare weight (Wt) _____ g

Vstd _____ std m^3 Net Weight (Wn) _____ g
Vstd = ($\overline{Qstd}$) (elapsed time)   PM10 Concentration _____ μg/std m^3
                                          PM10 Concentration = (Wn) (10^6)/Vstd

Figure 3.1. Example MFC sampler field data sheet.

VFC SAMPLER CALIBRATION DATA SHEET

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____ Operator _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Orifice S/N _____ , Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Plate No.	ΔH_2O (in.)	$\Delta Pstg$ (mm Hg)[a]	P1=Pa–$\Delta Pstg$ (mm Hg)	P1/Pa (mm Hg)	Qa (orifice) flow rate[b] (m^3/min)	$\dfrac{Qa \text{ (orifice)}}{[Ta]^{1/2}}$
Operational Flow Rate						

[a] mm Hg = 25.4 (in. H_2O/13.6)

[b] Qa (orifice) = 1/m {[(ΔH_2O) (Ta/Pa)]$^{1/2}$ – b}

[c] % Difference = $\left[\dfrac{Qa \text{ (sampler)} - Qa \text{ (orifice)}}{Qa \text{ (orifice)}} \right]$ [100]

Qa (Orifice)	Qa (sampler) (Lookup Table)	% Difference[c]

Sampler Calibration Relationship
☐ Lookup Table Validated (i.e., % difference ≤ 4)
☐ New calibration relationship:

(X = $\dfrac{Qa \text{ (orifice)}}{[Ta]^{1/2}}$, Y = (P1/Pa)

m = _____ b = _____ r = _____

For subsequent calculation of sampler flow rate:

Qa = {[P1/Pa – b][Ta]$^{1/2}$} {1/m}

Operational Flow Rate _____ m^3/min

Figure 2.5. Example VFC sampler calibration data sheet.

VFC SAMPLER FIELD DATA SHEET

Station
Location _____ Date _____ SAROAD# _____

Sampler Model _____ S/N _____

Filter ID No. _____ Pav _____ mm Hg, Tav _____ °C _____ K

Relative Stagnation Pressure Readings   ### Absolute Stagnation Pressure

Initial ΔPstg _____ mm Hg $\overline{P1} =$ _____ mm Hg

Final ΔPstg _____ mm Hg $\overline{P1} =$ Pav − Average ΔPstg

Average ΔPstg = _____ mm Hg

Average Stagnation Pressure Ratio ($\overline{P1}$/Pav) _____

Average Flowrate ($\overline{Qa}$)* _____ m³/min   Elapsed Time _____ min
*Obtained from manufacturer's lookup table (or
 from alternate calibration relationship)

Operator _____

Comments: _____
_____
_____
_____
_____

Laboratory Calculations:

$\overline{Qstd}$ _____ Std m³/min   Gross Weight (Wg) _____ g
$\overline{Qstd} = \overline{Qa}$ (Pav/Pstd) (Tstd/Tav)   Tare Weight (Wt) _____ g

Vstd _____ std m³   Net Weight (Wn) _____ g
Vstd = ($\overline{Qstd}$) (Elapsed Time)   PM10 Concentration _____ μg/std m³
                                          PM10 Concentration = (Wn) (10⁶)/Vstd

Figure 3.2. Example VFC sampler field data sheet.

MFC SAMPLER FLOW CHECK DATA SHEET

Station
Location _____ Date _____ Time _____

Sampler Model _____ S/N _____ Operator _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Orifice S/N _____ . Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Sampler Calibration Relationship: m = _____ b = _____ r = _____

Orifice Pressure Drop (ΔH_2O) _____ in. H_2O Qa (Orifice)[a] _____ m^3/min

	With Orifice Installed	**Without Orifice Installed**
Sampler Pressure Drop (ΔPex)	_____ in. H_2O	_____ in. H_2O
Qa (sampler)[b]	_____ m^3/min	_____ m^3/min

QC—Check Percentage Difference[c] _____ %

Qa (corrected sampler)[d] _____ m^3/min

Design Flow Rate Percentage Difference[e] _____ %

---

[a]For calculation of orifice flow rates:

$Qa \text{ (orifice)} = \{[\Delta(H_2O)\,(Ta/Pa)]^{1/2} - b\}\,\{1/m\}$

[b]For calculation of sampler flow rates:

$Qa \text{ (sampler)} = \{[(\Delta Pex/Pa)\,(Ta + 30)]^{1/2} - b\}\,\{1/m\}$

[c]$QC \text{ % Difference} = \left[\dfrac{Qa \text{ (sampler)} - Qa \text{ (orifice)}}{Qa \text{ (orifice)}}\right]\left[100\right]$ where Qa (sampler) is measured with the orifice installed

[d]$Qa \text{ (corrected sampler)} = Qa \text{ (sampler)}\left[\dfrac{100 - QC \text{ % difference}}{100}\right]$ where Qa (sampler) is measured without the orifice installed.

[e]$\text{Design Flow Rate % Difference} = \left[\dfrac{Qa \text{ (corr. sampler)} - 1.13}{1.13}\right]\left[100\right]$

Figure 3.5. Example MFC sampler flow check data sheet.

VFC SAMPLER FLOW CHECK DATA SHEET

Station)
Location _____ Date _____ Time _____

Sampler Model _____ S/N _____ Operator _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Orifice S/N _____ . Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Orifice Pressure Drop (ΔH_2O) _____ in. H_2O Qa (Orifice)[a] _____ m^3/min

	With Orifice Installed	Without Orifice Installed
Stagnation Pressure ($\Delta Pstg$)	_____ mm Hg	_____ mm Hg
Absolute Stagnation Pressure (P1)[b]	_____ mm Hg	_____ mm Hg
Stagnation Pressure Ratio (P1/Pa)	_____	_____
Qa (sampler)[c]	_____ m^3/min	_____ m^3/min

QC—Check Percentage Difference[d] _____ %

Qa (corrected sampler)[e] _____ m^3/min

Design Flow Rate Percentage Difference[f] _____ %

---

[a]Qa (orifice) = $\{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\}\{1/m\}$

[b]P1 = Pa − ΔPstg

[c]Determine Qa (sampler) from manufacturer's lookup table (or from alternate calibration relationship)

[d]QC % Difference = $\left[\dfrac{Qa\ (sampler) - Qa\ (orifice)}{Qa\ (orifice)}\right]$ 100   where Qa (sampler) is measured with the orifice installed

[e]Qa (corrected sampler) = Qa (sampler) $\left[\dfrac{100 - QC\ \%\ difference}{100}\right]$ where Qa (sampler) is measured without the orifice installed.

[f]Design Flow Rate % Difference = $\left[\dfrac{Qa\ (corr.\ sampler) - 1.13}{1.13}\right]\left[100\right]$

Figure 3.6. Example VFC sampler flow check data sheet.

Balance ID Number					
Balance Operator			**Quality Control Supervisor**		
Date	Filter No.	Balance Tare	Tare Wt.	Gross Wt.	Add'l analysis

Figure 4.1. Example laboratory data/coding form.

Balance ID Number

Balance Operator

Quality Control Supervisor

Date	Standard Weight Checks		Zero Check (± 0.5 mg)		Calibration Check (± 0.5 mg)		Tare and Gross Weight Checks			
	Original Value	Observed Value	Original Value	Observed Value	Original Value	Observed Value	Filter ID	Original Value	Observed Value	T/G[a]

[a]Tare or Gross Measurement

Figure 4.2. Example internal Quality Control Log Sheet.

DATA QUALITY ASSESSMENT REPORTING FORM

ACCURACY

Check box and complete only if all entries are for a single site and/or method

UNIT CODES	
ng m3	01
ppm	02
µg/mL	64
CFM	72
L/min	73
m³/min	83
µg	77

SAROAD SITE CODE

10 18

SITE

POLLUTANT **METHOD CODE**

21 23

METHOD

STATE	REPORTING ORGANIZATION	YEAR	QUARTER	
	1 2 3 4 5	6 7	8	9

1 - ORIGINAL
2 - REVISION
3 - DELETION

NAME OF REPORTING ORGANIZATION

PREPARED BY

DATE SUBMITTED ___ MO /DAY/YR

SAROAD SITE CODE	POLLU TANT	METHOD CODE		DATE MON DAY	T¹ S²	UNIT	UNIT CODE	ACTUAL	LEVEL 1	INDICATED	ACTUAL	LEVEL 2	INDICATED
10 18		21-23	A 24	26 28	29 30		31-32 0 33	34 37	38 40	41-44 45-47	48 51	52 54	55 58 59 61
			A				1 33	34 37 LEVEL 3	38 40	41-44 45-47 LEVEL 4	48 51	52 54	55 58 59 61
			A				0		LEVEL 1			LEVEL 2	
									LEVEL 3			LEVEL 4	
			A				0		LEVEL 1			LEVEL 2	
							1		LEVEL 3			LEVEL 4	
			A				0		LEVEL 1			LEVEL 2	
							1		LEVEL 3			LEVEL 4	

¹ Type of audit
1. Audit conducted by reporting organization, audit standard certified by reporting organization
2. Audit conducted by reporting organization, audit standard certified by another organization
3. Audit conducted by other than reporting organization

² Source of test piece standard

GAS STANDARDS
A NBS Site
B NBS reference gas
C Commercial Gas
D Permeation, standard
E Other
F Prestandard, verified by comparison to an Site

FLOW STANDARDS
1 Laminar flow element
2 Rootmeter, certified <1 pt.
3 Rootmeter, set cert <1 pt.
4 Certified orifice device
5 Wet test meter
6 Dry gas meter
7 Bubble flow meter
U Other

CHECK STANDARDS
W Recept grade chemical supplied with battery
X Other

SEND COMPLETED FORM TO REGIONAL OFFICE

DATA QUALITY ASSESSMENT REPORTING FORM

Check box and complete only if all entries are for a single site and or method

UNIT CODES
µg/m³ 01
ppm 07
µg/ml 64
CFM 72
L/min 73
m³/min 83
µg 77

STATE   REPORTING ORGANIZATION   YEAR   QUARTER
1 2 3 4 6
6 7
8
9

1 - ORIGINAL
2 - REVISION
3 - DELETION

NAME OF REPORTING ORGANIZATION

DATE SUBMITTED   PREPARED BY

MO./DAY/YR

SAROAD SITE CODE
10 18

SITE

POLLUTANT   METHOD CODE
21 23

METHOD

SAROAD SITE CODE 10-18	POLLU-TANT	METHOD CODE 21-23	24	DATE MON. 25-26	DAY 27-28	UNIT	UNIT CODE 31-32	ACTUAL OR DESIGNATED 34-37 38-40	INDICATED OR COLLOCATED 41-44 45-47

P P P P

P P P P

P P P P

P P P P

P P P P

MFC SAMPLER AUDIT DATA SHEET

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Audit Orifice S/N _____ , Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Sampler Calibration Relationship: m = _____ b = _____ r = _____

Orifice Pressure Drop (ΔH_2O) _____ in. H_2O Qa (audit)[a] _____ m^3/min

	With Orifice Installed	**Without Orifice Installed**
Sampler Pressure Drop (ΔPex)	_____ in. H_2O	_____ in. H_2O
Qa (sampler)[b]	_____ m^3/min	_____ m^3/min

Audit Flow Rate Percentage Difference[c] _____ %

Qa (corrected sampler)[d] _____ m^3/min

Design Flow Rate Percentage Difference[e] _____ %

---

[a]For calculation of audit orifice standard flow rates:

$Qa \, (audit) = \{[\Delta(H_2O)\,(Ta/Pa)]^{1/2} - b\}\,\{1/m\}$

[b]For calculation of sampler flow rates:

$Qa \, (sampler) = \{[(\Delta Pex/Pa)\,(Ta + 30)]^{1/2} - b\}\,\{1/m\}$

[c]Audit % Difference $= \left[\dfrac{Qa \, (sampler) - Qa \, (orifice)}{Qa \, (orifice)}\right]\left[100\right]$ where Qa (sampler) is measured with the orifice installed.

[d]Qa (corrected sampler) $= Qa \, (sampler)\left[\dfrac{100 - Audit \; \% \; Difference}{100}\right]$ where Qa (sampler) is measured without the orifice installed

[e]Design Flow Rate % Difference $= \left[\dfrac{Qa \, (corrected \; sampler) - 1.13}{1.13}\right]\left[100\right]$

Auditor _____   Observer _____

Figure 7.1. Example MFC sampler audit data sheet.

VFC SAMPLER AUDIT DATA SHEET (Part 1)

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Audit Orifice S/N _____ , Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Sampler Calibration Relationship: m = _____ b = _____ r = _____

Orifice Pressure Drop (ΔH_2O) _____ in. H_2O Qa (audit)[a] _____ m^3/min

	With Orifice Installed	**Without Orifice Installed**
Stagnation Pressure ($\Delta Pstg$)	_____ mm Hg	_____ mm Hg
Absolute Stagnation Pressure (P1)[b]	_____ mm Hg	_____ mm Hg
Stagnation Pressure Ratio (P1/Pa)	_____ (see Note)	_____ (see Note)
Qa (sampler)[c]	_____ m^3/min	_____ m^3/min

Audit Flow Rate Percentage Difference[d] _____ % (see Note)

Qa (corrected sampler)[e] _____ m^3/min

Design Flow Rate Percentage Difference[f] _____ %

Note: If P1/Pa is less than the values that are listed in the manufacturer's lookup table or if audit flow rate percentage difference is greater than ±6 percent, proceed to Part 2 of the VFC Sampler Audit Data Sheet. Otherwise, complete this part.

---

[a]Qa (orifice) = $\{[\Delta(H_2O)(Ta/Pa)]^{1/2} - b\} \{1/m\}$

[b]P1 = Pa − ΔPstg

[c]Determine Qa (sampler) from manufacturer's lookup table (or from alternate calibration relationship)

[d]Audit % Difference = $\left[\dfrac{(Qa\,(sampler) - Qa\,(audit)}{Qa\,(audit)} \right] [100]$ where Qa (sample) is measured with the orifice installed.

[e]Qa (corrected sampler) = Qa (sampler) $\left[\dfrac{100 - Audit\,\%\,Difference}{100} \right]$ where Qa (sampler) is measured without the orifice installed

[f]Design Flow Rate % Difference = $\left[\dfrac{Qa\,(corrected\,sampler) - 1.13}{1.13} \right] [100]$

Auditor _____ Observer _____

(continued)

Figure 7.3. Example VFC sampler audit data sheet. (Part 1 of 2)

VFC SAMPLER AUDIT DATA SHEET (Part 2)

(continued from Part 1 of this form)

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Audit Orifice S/N _____ , Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Plate No.	ΔH_2O (in.)	$\Delta Pstg$ (mm Hg)	P1[a] (mm Hg)	P1/Pa (mm Hg)	Qa (Orifice)[b] (m^3/min)

Provisional Sampler Calibration Relationship: X = Qa (Orifice), Y = (P1/Pa)

m' = _____ b' = _____ r' = _____

Measurements with filter installed and Audit Orifice Transfer Standard removed:

$\Delta Pstg$ _____ mm Hg   P1[a] _____ mm Hg

P1/Pa _____

Qa (audit)[c] _____ m^3/min   Qa (sampler)[d] _____ m^3/min

Audit Flow Rate Percentage Difference[e] _____ %

Design Flow Rate Percentage Difference[f] _____ %

[a]P1 = Pa − $\Delta Pstg$

[b]Qa (orifice) = $\{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\}\{1/m\}$

[c]Qa (audit) = [(P1/Pa) − b']/m'

[d]Qa (sampler) is determined from the lookup table or alternative calibration relationship

[e]Audit Flow Rate % Difference = $\left[\dfrac{(Qa\,(sampler) - Qa\,(audit))}{Qa\,(audit)}\right][100]$

[f]Design Flow Rate % Difference = $\left[\dfrac{Qa\,(audit) - 1.13}{1.13}\right][100]$

Auditor _____   Observer _____

Figure 7.3. Example VFC sampler audit data sheet. (Part 2 of 2)