QA Handbook Method 2.2

Reference method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method)

The underlying document was extracted from the *Quality Assurance Handbook for Air Pollution Measurement Systems Volume II- Ambient Air Specific Methods*. EPA-600/4-77/027a, May 1977. Complete digital copies of this volume are available through the EPA National Libraries Network http://www2.epa.gov/libraries (search by document number).

Procedures contained in this document continue to be cited for quality control measures and quality assurance programs administered by EPA and State, local and tribal monitoring agencies. References occur in the most current edition of the *Quality Assurance Handbook for Air Pollution Measurement Systems Volume II- Ambient Air Quality Monitoring Program*. EPA-454/B-13-003 May, 2013. See http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf

Citation and inclusion of this method here in no way impose requirements that supersede more recently promulgated requirements for collecting total suspended particulates by high volume sampling at 40 CFR Part 50 Appendix B, or quality assurance program requirements promulgated at 40 CFR part 58 Appendices A-D.

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EPA

Test Method

Section 2.2
Reference Method for the Determination of Suspended Particulates in the Atmosphere (High-Volume Method)

Outline

Summary

Ambient air drawn into a covered housing and through a filter by a high-flow-rate blower at 1.1 to 1.7 m^3/min (39 to 60 ft^3/min) allows total suspended particulates (TSP) in sizes up to 25 to 50 μm (aerodynamic diameter) to collect on the filter surface. When operated within this range, the high-volume sampler is

capable of collecting TSP samples for 24-hour TSP concentrations ranging from 2 to 750 $\mu g/std\ m^3$ The mass concentration ($\mu g/m^3$)* in ambient air is computed by measuring both the mass of TSP collected and the (standard) volume of air sampled

This method provides a measurement of the mass concentration of total suspended particulate matter (TSP) in ambient air for determination of compliance with the primary and secondary National Ambient Air Quality Standards for Particulate Matter as specified in §50 6 and §50 7 of the Code of Federal Regulations, Title 40 The measurement process is nondestructive, and the size of the sample collected is usually adequate for subsequent chemical analysis Based on collaborative testing, the relative standard deviation (coefficient of variation) for single analyst precision (repeatability) of the method is 3 0 percent. The corresponding value for interlaboratory precision (reproducibility) is 3 7 percent

The absolute accuracy of the method is undefined because of the complex nature of atmospheric particulate matter and the difficulty in determining the "true" particulate matter concentration

This reference method appears in Title 40 of the Code of Federal Regulations, Part 50, Appendix B (as amended on December 6, 1982, (47 FR 54912) A complete copy of the Reference Method is reproduced in Section 2 2 11

Method QA Highlights

In this quality assurance document for the TSP Reference Method (high-volume sampler method), the procedures are designed to serve as guidelines for the development of agency quality assurance programs Because recordkeeping is a critical part of quality assurance activities, several data forms are included to aid in the documentation of necessary data The blank data forms (Section 2.2 13) may be used as they are, or they may serve as guidelines for preparing forms more appropriate to the individual agency, partially filled-in forms are interspersed throughout the text to illustrate their uses Activity matrices at the end of pertinent sections provide a review of the material covered in the text sections The material covered in this section for the TSP method is briefly summarized here.

1. *Procurement of Equipment* Section 2 2.1 describes the selection of equipment and the recommended procurement and calibration checks for the equipment. It also identifies the sections of this part of the Handbook that pertain to specific equipment and supplies. Figure 1.1 provides an example of a permanent procurement record.

2. *Calibration of Equipment* Section 2.2.2 provides detailed calibration procedures for the analytical balance, the relative humidity indicator, the elapsed-time meter, the flow-rate transfer standard, and the high-volume sampler. This section can be removed (along with the corresponding sections for the other methods of this volume of the Handbook) to serve as a calibration handbook. Table 2 2 at the end of the Section summarizes the acceptance limits for equipment calibration.

3. *Filter Selection and Preparation* Section 2.2.3 presents important considerations for the selection, identification, equilibration, weighing check, and handling of filters. The spectro-quality grade filter is recommended for use when additional chemical analyses are anticipated.

4. *Sampling Procedure* Section 2.2.4 details procedures for filter installation, performance of operational checks, sample handling, and data documentation. Several photographs are provided to clarify the installation procedure. Complete documentation of background information during the sampling is one of several quality assurance activities that are important to future data validation; particularly important are any unusual conditions existing during collection of the sample. Any such conditions should be noted.

5. *Analysis of Samples* Section 2.2.5 briefly describes verification of data from the field, sample inspection, filter equilibration, and the gravimetric analysis procedure. The analytical balance must be checked. The filter must be equilibrated in a controlled environment.

6. *Calculation and Data Reporting* Section 2.2 6 describes those activities pertaining to data calculations and reporting. The final data review, the data edit or validation, and the use of standardized reporting procedures are all important parts of a quality assurance program. Independent checks of the data and calculations are recommended to ensure that the reported data are both accurate and precise.

7. *Maintenance* Section 2.2.7 recommends periodic maintenance schedules to ensure that the equipment is capable of performing as specified.

8. *Assessment of Data for Accuracy and Precision* Sections 2.2.8 and 2.2.9 describe the assessment of the data for accuracy and precision, respectively. Independent audit activities provide accuracy checks of flow rate measurements, filter weighings, and data processing. The precision check is performed by using collocated samplers. The expected agreement between two collocated samplers is ±15%.

9. *Reference Information* Section 2.2.10 discusses the traceability of measurements to established standards of higher accuracy, a necessary prerequisite for obtaining accurate data.

Sections 2.2.11 and 2.2.12 contain the Reference Method and pertinent references.

Section 2.2.13 provides blank data forms for the convenience of the user.

*Although TSP is measured in micrograms per standard cubic meter, the "standard" is commonly omitted when reporting TSP measurements, by convention, $\mu g/m^3$ for TSP is understood to mean $\mu g/std\ m^3$

1.0 Procurement of Equipment and Supplies

Specifications for equipment and supplies for monitoring ambient air for total suspended particulates (TSP) are provided in the Reference Method, as reproduced in Section 2.2.11.

Upon receipt of the sampling equipment and supplies, appropriate procurement checks should be conducted to determine their acceptability, and their acceptability or rejection should be recorded in a procurement log. Figure 1.1 is an example of such a log, and Section 2.2.13 provides a blank copy for the Handbook user. This log will serve as a permanent record for future procurements and for any fiscal projections for future programs. It will also help to provide continuity of equipment and supplies Table 1-1 provides a matrix of the activities involved in the procurement of equipment and supplies.

The following list of equipment, apparatus, and supplies provides a reference to sections and subsections within this part of the Handbook to guide the user to specific checkout procedures. Here and throughout the balance of the text, "section" refers to the primary divisions of Section 2.2, "subsection" refers to the subdivisions within these sections

Item	Section	Subsection
Analytical balance	2.2.2	2.1
Relative humidity indicator	2.2.2	2.2
Elapsed-time meter	2.2.2	2.3
Timer	2.2.2	2.4
Flow rate transfer standard	2.2.2	2.5
Sampler	2.2.2	2.6
Filter	2.2.3	3.1, 3.3
Sampler motor	2.2.7	7.1
Faceplate gasket	2.2.7	7.2
Rotameter	2.2.7	7.3
Sampling head	2.2.7	7.4
Motor gasket	2.2.7	7.5
Flow transducer and recorder	2 2.7	7.6

Table 1.1 *Activity Matrix for Procurement of Equipment and Supplies*

Equipment	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Analytical balance	*Indicated weight = standard weight ±0.0005 g for three to five standard weights over sample filter weight range*	*On receipt, check against weights of known accuracy.*	*Request recalibration by manufacturer/supplier.*
Elapsed-time meter	*24 h ±2 min*	*On receipt, check against standard timepiece of known accuracy.*	*Adjust or reject.*
Timer	*24 h ±30 min*	*On receipt, check against elapsed-time meter.*	*Adjust or reject.*
Orifice calibration unit (flow transfer standard)	*Calibration flow rate = actual flow rate ±2%*	*On receipt, check against flow-rate primary standard.*	*Adopt new calibration curve if no evidence of damage; reject if damage is evident.*
Sampler	*Sampler complete; no evidence of damage; flow = 1.1 - 1.7 m^3/min*	*On receipt, observe visually and check operation of all components.*	*Reject or repair.*
Relative humidity indicator	*Indicator reading = psychrometer reading ±6%*	*On receipt, compare with* reading of a wet bulb/dry bulb psychrometer.	*Adjust or replace to attain* acceptance limits.

Item description	Quantity	Purchase order number	Vendor	Date		Cost	Disposition	Comments
				Ordered	Received			
HI-VOL BRUSH SET	12	1782	GEN'L METAL	6-1-75	6-10-75	21	ACC.	
HI-VOL BRUSH SET	100	1782	GEN'L METAL	6-1-75	6-10-75	25	ACC.	

Figure 1.1. Example of a Procurement Log.

2.0 Calibration of Equipment

Before a TSP sampling program is undertaken, a wide variety of sampling and analysis equipment must be calibrated. The calibration activities are summarized in Table 2.2 at the end of this section. Many of these activities will also serve as initial acceptance checks. All data and calculations required for these activities should be recorded in a calibration log book in which a separate section is designated for each apparatus and sampler used in the program.

2.1 Analytical Balance

The calibration should be verified (1) when the analytical balance is first purchased, (2) any time it has been moved or subjected to rough handling, and (3) during routine operations when a standard weight cannot be weighed within ±0.5 mg of its stated weight. A set of three to five standard weights covering the range normally encountered in weighing filters should be weighed. If the weighed value of one or more of the standard weights does not agree within ±0.5 mg of the stated value, the balance should be recalibrated or adjusted by the manufacturer. The results of all balance checks should be recorded in a log book such as the one shown in Figure 2.1.

High-Volume Filter-Weighing Quality Control Log

		Glass-S weights, g			
Date	Time	0.5000	1.0000	2.0000	Technician
7/29/74	11:07	0.5000	1.0002	2.0000	BSM
7/29/74	12:08	0 5002	1.0003	2.0001	DEK
7/29/74	2·40	0 5000	1.0000	1 9999	DEK
7/30/74	4:03	0.4996	0 9999	2.0002	JLK
7/31/74	9.57	0 4997	1.0000	2.0000	DEK
7/31/74	10:56	0.4995	0.9996	1.9996	DEK
7/31/74	11.57	0.4996	0.9998	1.9998	DEK
7/31/74	2.04	0.5001	1.0000	2.0002	DEK
7/31/74	3:05	0.5000	1.0000	2.0000	DEK
8/1/74	9:03	0.4998	0 9997	1.9997	DEK
8/1/74	10·05	0 4999	0.9997	1.9997	DEK
8/1/74	11 10	0.5000	1.0001	2.0001	DEK
8/1/74	12 12	0.4998	0.9997	1.9998	DEK
8/1/74	1:43	0.5000	1.0001	2.0002	DEK
8/1/74	2 42	0 5001	1.0001	2.0001	DEK
8/1/74	3.45	0 5001	1.0000	2.0001	DEK
8/2/74	8:54	0.5000	1.0001	2.0001	DEK
8/2/74	9:56	0.5000	1.0000	2.0001	DEK
8/2/74	10·59	0 5003	0.9999	1.9998	DEK
8/2/74	12·16	0 5001	1.0002	2.0002	DEK
8/2/74	1:55	0 4999	1.0002	2.0001	DEK
8/2/74	3:03	0.5000	0.9999	2.0001	DEK
8/2/74	4:00	0.5000	0.9998	1.9999	DEK
8/3/74	8 41	0 4999	0.9996	1.9998	DEK
8/3/74	11 15	0.5002	1.0002	2.0002	DEK
8/5/74	8.42	0.5001	1.0000	2.0000	DEK
8/5/74	9.45	0 5000	1.0000	2.0000	DEK
8/5/74	10·44	0 5000	1.0000	2.0000	DEK
8/5/74	11·46	0 5000	1.0001	2.0000	DEK
8/5/74	1·16	0.5001	1.0000	2.0000	DEK
8/5/74	2 21	0 5001	1.0000	2.0001	DEK
8/5/74	3.15	0.5000	1.0000	2.0001	DEK
8/6/74	9.37	0.4999	1.0000	2.0000	DEK
8/6/74	11:05	0 5000	0.9998	1.9997	DEK
8/6/74	12.10	0 4999	0 9998	1.9999	DEK
8/6/74	2.10	0 5000	0.9998	2.0000	DEK
8/6/74	3·09	0 5000	1.0000	2.0000	DEK
8/6/74	4:05	0.5000	1.0000	2.0000	DEK
8/7/74	8·50	0.5000	1.0002	2.0003	DEK
8/7/74	9·46	0.4996	0.9998	1.9996	DEK
8/7/74	1·10	0 5001	1.0000	2.0000	DEK
8/7/74	2:20	0.5001	1.0000	2.0000	DEK
8/7/74	3 25	0.5002	1.0001	2.0000	DEK
8/8/74	9:46	0.5000	1.0000	2.0000	DEK
9/24/74	3:50	0 5001	1.0001	2.0001	DEK
9/26/74	3.01	0.5001	1.0001	2.0001	DEK

Figure 2.1. *Example of balance performance record*

2.2 Relative Humidity Indicator

The relative humidity indicator used for monitoring the filter conditioning environment should be checked against a wet bulb/dry psychrometer or the equivalent every 6 months. At least a two-point calibration should be made by comparing readings made in the conditioning environment against those made outdoors or perhaps just outside of the conditioning room. If the difference between the indicator and the corresponding psychrometer readings is within ±6%, it is all right to continue using the relative humidity indicator; if not, the indicator must be calibrated or a new one must be purchased. Record the results of the relative humidity indicator checks in the calibration log book.

2.3 Elapsed-Time Meter

Every 6 months the elapsed-time meter should be checked against a timepiece of known accuracy, either on site or in the laboratory. If the indicator shows any signs of being temperature-sensitive, it should be checked on site during each season of the year. A gain or loss >2 min/24-h period warrants adjustment or replacement of the indicator. The results of these checks should be recorded in the calibration log book.

2.4 On-Off Timer

The on-off timer should be calibrated and adjusted quarterly by using a calibrated elapsed-time meter as the reference. An example calibration procedure for one type is presented below. Figure 2.2 depicts the connection diagram for calibration of a particular kind of timer. The steps in the procedure are

1. Plug a correctly wired timer into an electrical outlet.
2. Set the timer to the correct time.
3. Set the on and off time-trippers for a 24-h test.
4. Plug the test light into one of the output plugs, and plug an elapsed-time meter into the other.
5. Check the system by manually turning the switch on and off.
6. Allow the system to operate for the 24-h test period, and determine the time elapsed on the elapsed-time meter. If the elapsed time is 24 h ±30 min, the timer is acceptable for field use; if not, adjust the tripper switches and repeat the test. Record the calibration data in a timer calibration log such as that shown in Figure 2.3. Section 2.2.13 provides a blank copy for the Handbook user.

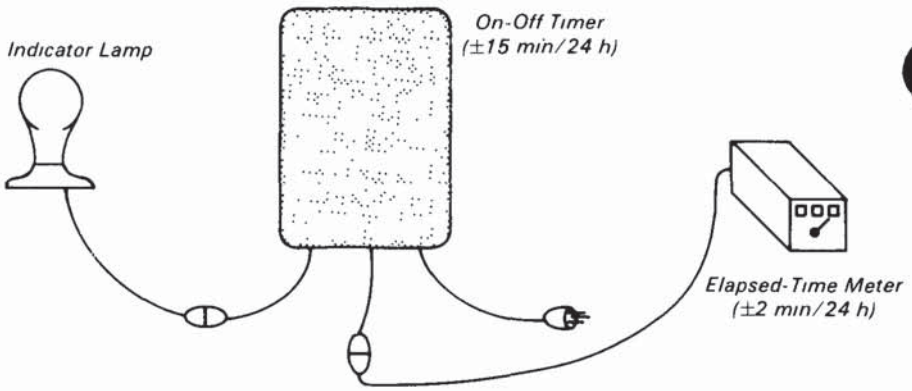


Figure 2.2. Diagram of a timer calibration system.

2.5 Flow Rate Transfer Standard

Calibration of the high-volume sampler's flow indicating or control device is necessary to establish traceability of the field measurement to a primary standard via a flow-rate transfer standard. The calibration procedure provided here applies to a conventional orifice-type flow transfer standard. Other types of transfer standards may be used if the manufacturer or user provides an appropriately modified calibration procedure that has been approved by EPA (see 40 CFR, Part 58, Appendix C, Section 2.8).

Upon receipt and at 1-year intervals, the calibration of the transfer standard orifices should be certified with a positive displacement standard volume meter (such as a Rootsmeter) traceable to the National Bureau of Standards (NBS). Orifice units should be visually inspected for signs of damage before each use, and they should be recalibrated if the inspection reveals any nicks or dents in the orifice.

The following equipment is required for certification of an orifice transfer standard.

1. Positive-displacement, standard volume meter (such as Rootsmeter) traceable to NBS.
2. High-volume air pump (high-volume sampler blower).
3. Resistance plates or variable voltage regulator.
4. Stopwatch
5. Thermometer
6. Barometer
7. Manometers [1 mercury (Hg), 1 water, or equivalent]

The following step-by-step procedure for certification of an orifice transfer standard is adapted from the Reference Method.[1] An orifice transfer standard certification worksheet (Figure 2.4) is provided for documentation of certification data.

1. Record on the certification worksheet the standard volume meter serial number; transfer standard type, model, and serial number; the person performing the certification, and the date.

2. Observe the barometric pressure and record it as P_1 (item 8).

3. Read the ambient temperature in the vicinity of the standard volume meter and record it as T_1 (item 9) (K = °C + 273).

4. 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) manometer to the pressure tap on the orifice transfer standard. Connect a high-volume air pump (such as a high-volume sampler blower) to the outlet side of the standard volume meter. (See Figure 2.5 for an example of the calibration setup.)

5. Check for leaks by temporarily clamping both manometer lines (to avoid fluid loss) and blocking the orifice with a large-diameter rubber stopper, wide cellophane tape, or other suitable means. Start the high-volume air pump and note any change in the standard volume meter reading. 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.

Site location number	Timer number	Date		Elapsed-time indicator serial number	Test period	Elapsed-time indicator reading	Accuracy	Technician (signature)
		Start	Stop					
1141	4321	6-10-75	6-11-75	CW 080G	24 hrs.	23 HRS, 53 MIN	99.5	C. Jones

Figure 2.3. Example of a timer calibration log.

Orifice Transfer Standard Certification Worksheet

	1	2	3	4	5	6	7	7a
Run No.	Meter reading start V_i (m^3)	Meter reading stop V_f (m^3)	Elapsed time t (min)	Volume measured V_m (m^3)	Differential pressure (at inlet to volume meter) ΔP (mm Hg or in)	(X) Flow rate Q_{std} (std m^3 min)	Pressure drop across orifice ΔH ☒ (in) or ☐ (cm) of water	$\sqrt{\Delta H \left(\frac{(Y)\ P_1}{P_{std}}\right) \frac{298}{T_1}}$
1	4958.00	4968.00	5.441	10.0	26.0	1 77	13.00	3.60
2	4970.00	4980.00	6.200	10.0	33.0	1.54	9.70	3.11
3	4982.00	4992.00	6 788	10.0	40.6	1.39	7 90	2.81
4	4993.00	5003.00	7.597	10.0	48 3	1.23	6.15	2 48
5	5004.00	5014.00	9.057	10 0	58.4	1.02	4.20	2.05
6								

Recorded Calibration Data

Standard volume meter No 462

Transfer standard type ☒ orifice ☐ other

Model No _____ Serial No 142

(8) P_1 750 mm Hg (or in)

(10) P_{std} 760 mm Hg (or 29 92 in)

(9) T_1 295 K

(11) T_{std} 298 K

By GREG MEINERS

Date: 3-28-83

Calculation Equations

(1) $V_m = V_f - V_i$

(2) $V_{std} = V_m \left(\frac{P_1 - \Delta P}{P_{std}}\right)\left(\frac{T_{std}}{T_1}\right)$

(3) $Q_{std} = \frac{V_{std}}{t}$

Least Squares Calculations

linear ($Y = mX + b$) regression equation of $Y = \sqrt{\Delta H\,(P_1/P_{std})\,(298/T_1)}$ on $X = Q_{std}$ for Orifice Calibration Unit (i e , $\sqrt{\Delta H(P_1/P_{std})\,(298/T_1)} = mQ_{std} + b$)

Slope (m) = 2.062 Intercept (b) = −0.056 Correlation coefficient (r) = 0.99995

To use for subsequent calibration: $X = \frac{1}{m}(Y-b)$, $Q_{std} = \frac{1}{m}\left[\sqrt{\Delta H \left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)} - b\right]$

Figure 2.4. *Example of orifice transfer standard certification worksheet.*

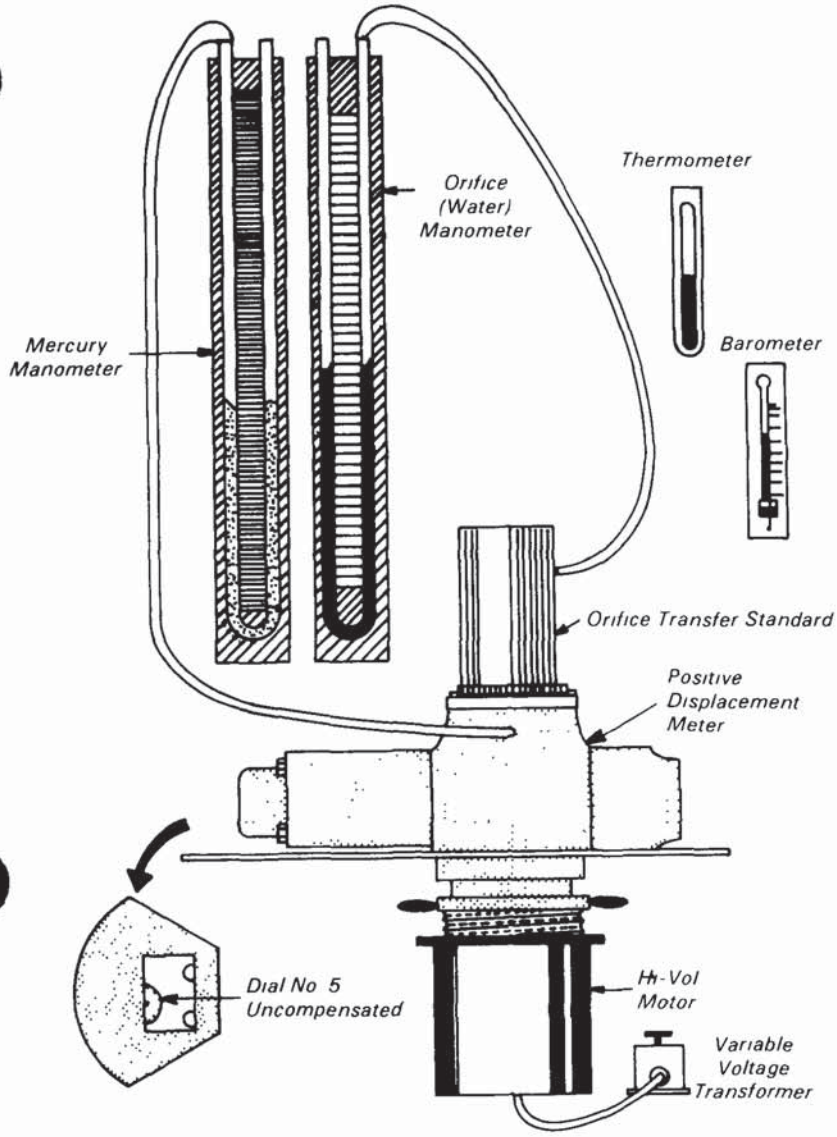


Figure 2.5. *Example of orifice transfer standard calibration setup*

6. Check the level of the positive displacement meter table, and adjust the legs if necessary.

7. After satisfactorily completing the leak check, shut off motor, unclamp both manometer lines, and zero the water and mercury manometers by sliding their scales until the zero is even with the meniscus, as illustrated in Figure 2 6

8. Achieve the appropriate flow rate through the system, either by means of the variable flow resistance in the transfer standard or by varying the voltage to the air pump. (Use of resistance plates is discouraged because the leak check must be repeated each time a new resistance plate is installed) At least five evenly distributed different but constant flow rates are required, at least three of which must be in the specified flow rate interval (1.1 to 1.7 m^3/min [39-60 ft^3/min]).

9 Start the blower motor, adjust the flow, and 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 numbers (e.g , 0046.00)

10 Record the initial meter reading (V_i) in Column 1 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 inlet pressure manometer reading as ΔP (Column 5), and the orifice manometer reading as ΔH (Column 7). Be sure to indicate the correct units of measurement.

11 After 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 meter reading (V_f) in Column 2 and the elapsed time (t) in Column 3

12 Calculate the volume measured by the primary standard volume meter (Vm) at meter conditions of temperature and pressure (using Equation 1 of the work sheet) and record in Column 4

$$V_m = V_f - V_i$$

Equation 2-1

13 Correct this volume to standard volume (std m^3) by using Equation 2 of the work sheet.

$$V_{std} = V_m \left(\frac{P_1 - \Delta P}{P_{std}}\right)\left(\frac{T_{std}}{T_1}\right)$$

Equation 2-2

where:

V_{std} = standard volume, std m^3,
V_m = actual volume measured by the primary standard volume meter, m^3 (Column 4 of work sheet)
P_1 = barometric pressure during calibration, mm (in.) Hg (Item 8 of work sheet)
ΔP = differential pressure at inlet to primary standard volume meter, mm (in) Hg (Column 5 of work sheet)
P_{std} = 760 mm Hg (29 92 in Hg)
T_{std} = 298 K
T_1 = ambient temperature during calibration, K (Item 9 of work sheet).

14. Calculate the standard volumetric flow rate (std m^3/min) by using Equation 3 of the work sheet

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

Equation 2-3

where:

Q_{std} = *standard volumetric flow* rate, std m^3/min at 760 mm Hg and 298 K
t = elapsed time, minutes

15 Record Q_{std} to the nearest 0.01 std m^3/min in column 6 of the work sheet. Repeat steps 9 through 15 for at least four additional constant flow rates evenly spaced over the approximate range of 1.0 to 1.8 std m^3/min (35-64 ft^3/min).

16. For each flow, compute $\sqrt{\Delta H\ (P_1/P_{std})\ (298/T_1)}$ (Column 7a), and plot these values against Q_{std} as shown in Figure 2.7. Be sure to use consistent units (mm or in. Hg) for barometric pressure. Draw the orifice transfer standard certification curve or calculate the linear least squares slope (m) and intercept (b) of the certification curve:

$$\sqrt{\Delta H\ (P_1/P_{std})\ (298/T_1)} = m\ Q_{std} + b.$$

A certification graph should be readable to 0.02 std m^3/min.

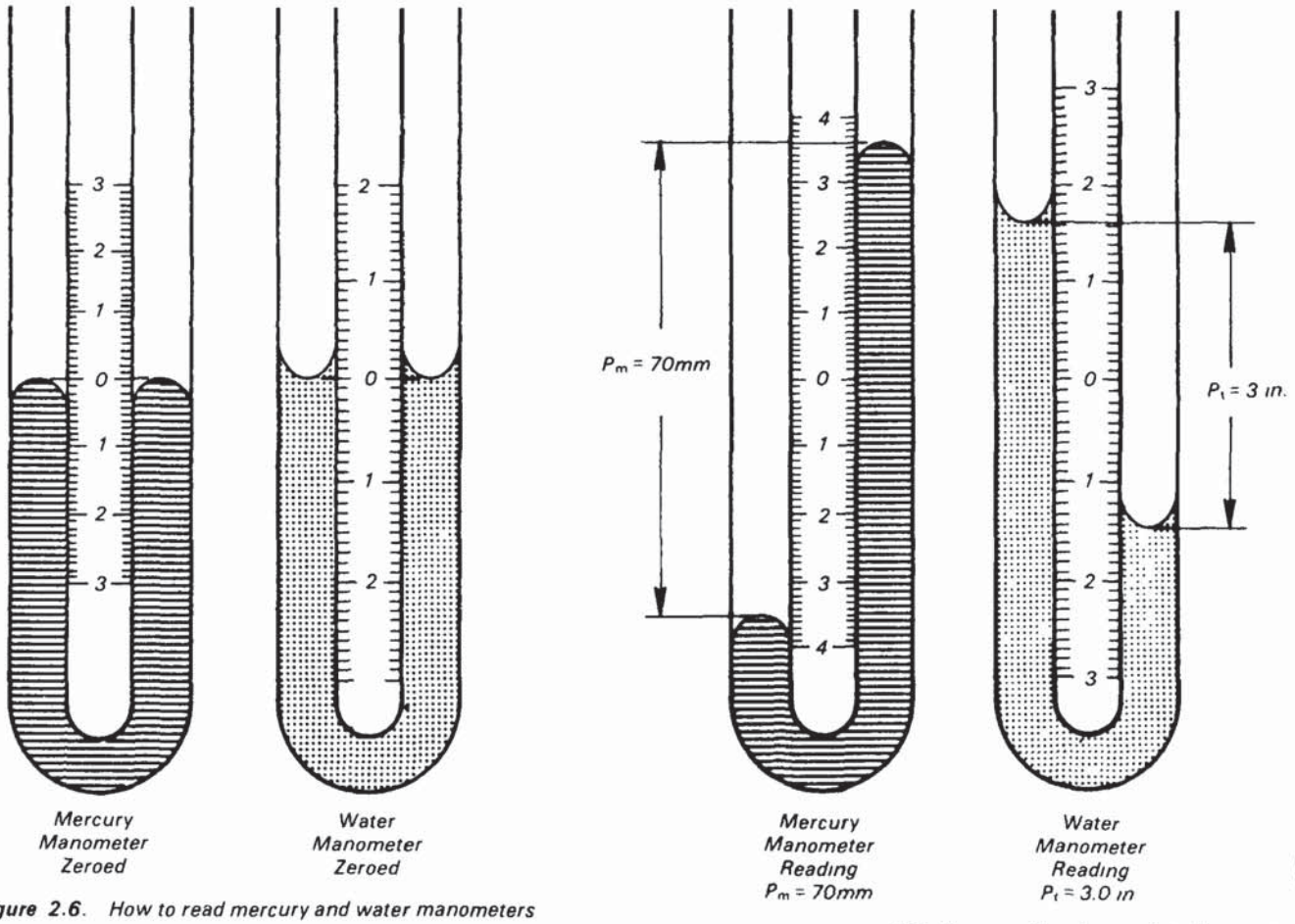


Figure 2.6. How to read mercury and water manometers

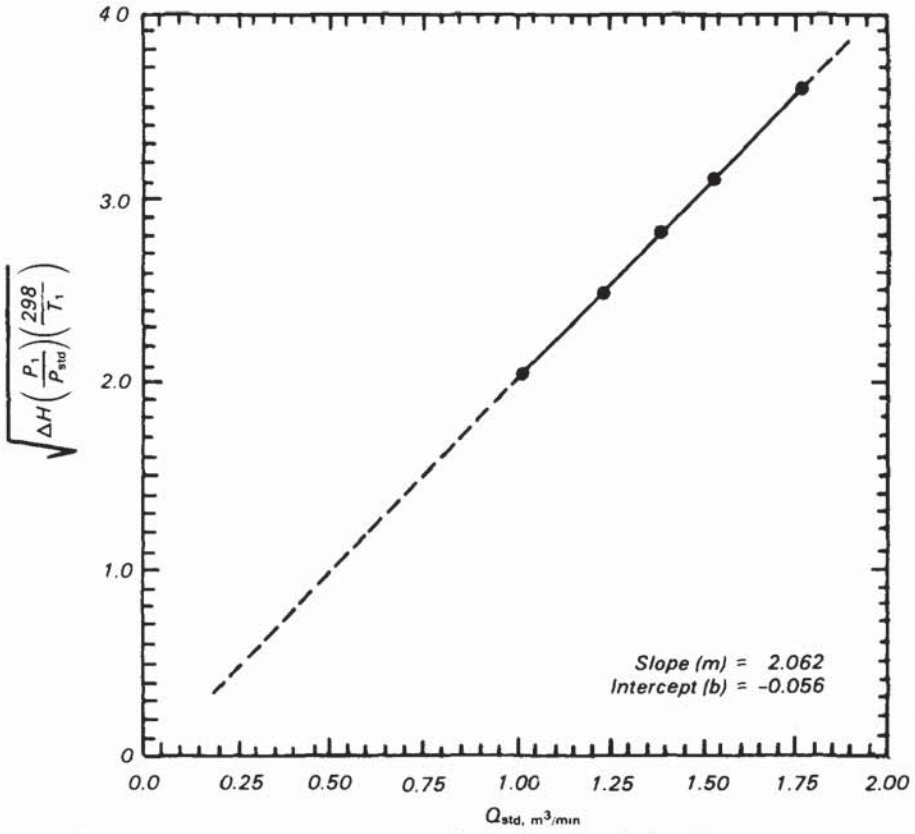


Figure 2.7. Example of orifice transfer standard calibration relationship.

17. If any calibration point does not fall within ±2% of the line, rerun that point, recalculate, and replot. The percent deviation can be calculated by comparing each Y from Column 7a against the corresponding Y_{cal} calculated from the slope and intercept using Equation 2-4.

$$Y_{cal} = m\ Q_{std} + b$$

Equation 2-4

The percent deviation for each point is then calculated using Equation 2-5.

$$\%\ \text{deviation} = \frac{Y - Y_{cal}}{Y_{cal}} \times 100$$

Equation 2-5

18. For subsequent use of the transfer standard, calculate Q_{std} as

$$Q_{std} = \frac{1}{m}\left[\sqrt{\Delta H\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)} - b\right]$$

Equation 2-6

or determine Q_{std} for each value of:

$$\sqrt{\Delta H\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$$

from the certification graph.

where:

P_2 = barometric pressure at time of Hi-Vol calibration

T_2 = temperature at time of Hi-Vol calibration

2.6 Calibration of High-Volume Sampler

Each high-volume sampler must incorporate a flow rate measurement device capable of indicating the total sampler flow rate This device may be an electronic mass flowmeter, an orifice or orifices located in the sample air stream together with a suitable pressure indicator (such as a manometer or an aneroid pressure gauge), or any other type of flow indicator (including a rotameter) having comparable precision and accuracy It must be possible to calibrate the flow rate measurement device to a flow rate that is readable (in corresponding units) to the nearest 0 02 std m^3/min A pressure recorder with an orifice device that provides a continuous record of the flow may be used.

The concentration of TSP in the ambient air is computed as the mass of collected particles, divided by the volume of air sampled, corrected to standard conditions of 760 mm Hg and 298 K, and then expressed in micrograms per standard cubic meter (μg/std m^3). When samples are collected at temperatures and pressures significantly different from standard conditions, the corrected concentrations may differ substantially from actual concentrations (micrograms per actual cubic meter), particularly at high elevations.

Calibration of a high-volume sampler refers to calibration of the sampler's flow rate indicator so that it provides accurate measurements of the sample flow rate from which the volume of the sampled air can be calculated. Details of the calibration procedure vary somewhat depending on (1) the type of flow indicator used, (2) whether the sampler is equipped with an automatic flow controller, and (3) whether the calibration is to incorporate the geographical average barometric pressure and seasonal average temperature at the sampling site. The basic procedure for nonflow-controlled samplers is given in Subsection 2.6 2, whereas the variations in the procedure necessary for flow-controlled samplers are presented in Subsection 2 6.3.

Orifice-type flow indicators are sensitive to changes in both temperature and barometric pressure. Because ambient temperature and barometric pressure vary from day to day, the calibration procedure contains a formula to correct for this variability. Errors resulting from normal daily fluctuation are relatively small, however, compared with barometric differences due to elevation and seasonal temperature changes. Thus, if the modest errors due to daily changes are acceptable, the average barometric pressure for a given elevation and the seasonal average temperature for that location can be incorporated directly into the sampler calibration with little error being introduced in the calculated flow rate.

When this is done, the sampler is calibrated for the average temperature and pressure conditions at the site, and no further temperature or pressure corrections are needed for the flow indicator reading to be used to determine the sampler flow rate. The relationship between the flow indicator reading and the standard volume flow rate then becomes a very simple one. This relationship also can be easily reduced to a simple three-column table (indicator reading, winter flow rate, and summer flow rate) suitable for use even by nontechnically oriented operators

The average barometric pressure for a site can be estimated from the altitude of the site, either by using an altitude-pressure table or by reducing the sea level pressure of 760 mm Hg by 26 mm Hg for each 305 m (1000 ft) of altitude. The average pressure could also be determined by averaging onsite barometer readings or nearby weather station or airport measurements (station pressure, uncorrected) over several months. The seasonal average temperature for a site can be estimated from onsite temperature readings or nearby weather station records over the season. Ideally, the average temperature should reflect the temperature at the time of day at which the flow indicator would normally be read; however, an average determined from 24-hour mean temperature records would be acceptable For most sites, two seasonal average temperatures (summer and winter) are sufficient; for sites where climatic changes are severe, however, four seasonal average temperatures may be needed to accommodate the changes. Where computers are used to process TSP data, monthly average temperatures could be used. Ideally, the seasonal average temperature should generally be within ±15°C of the local ambient temperature at the time the flow indicator is read. If daily temperature changes at the site are too drastic to be represented by a seasonal average (±15°C) actual temperature corrections should be used each time a flow reading is obtained.

Once a decision has been made on whether to incorporate an average barometric pressure and a seasonal average temperature into the calibration, the appropriate expression for plotting or calculating the sampler calibration can be selected from Table 2.1. The use of this expression is explained in Subsection 2.6.2.

2.6.1 *Calibration Schedule* - High-volume-sampler flow-rate devices should be calibrated with a certified flow-rate transfer standard such as an orifice calibration unit (1) upon receipt, (2) after motor maintenance, (3) any time the flow rate device is repaired or replaced, and (4) any time the difference between the sample flow rate and a one-point audit deviates more than ±7 percent.

2.6.2 *Sampler Calibration Procedure* - The procedures for multipoint calibration of a high-volume sampler are specified in 40 CFR 50, Appendix B (reproduced in Section 2.2.11). To facilitate these procedures, calculation data forms have been developed to aid in making the calibrations. These forms also may be used for the calibration of other types of high-volume flow measuring devices,

Table 2.1. *Expressions for Plotting Sampler Calibration Curves*

Type of sampler flow rate measuring device	*For actual pressure and temperature corrections*	*For incorporation of geographic average pressure and seasonal average temperature*
Mass flowmeter	I	I
Orifice and pressure indicator	$\sqrt{I\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	$\sqrt{I\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$
Rotameter, or orifice and pressure recorder having square root scale[a]	$I\sqrt{\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	$I\sqrt{\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$

[a] *This scale is recognizable by its nonuniform divisions; it is the most commonly available for high-volume samplers.*

provided the appropriate equations and procedures are followed

Documentation of all data on the flow-rate transfer standard for the high-volume site sampler, and the calibration procedures are of primary importance The validity of the data collected by the instrument is dependent on the quality of the calibration; thus the calibration must be performed with a transfer standard that meets all conditions specified in Subsection 2 5

The following procedure, which involves the use of the forms shown in Figures 2 8 and 2.9, is given to aid in the collection and documentation of calibration data This procedure applies primarily to a conventional orifice-type flow transfer standard and an orifice-type flow indicator with a flow recorder in the sampler (the most common type), as shown in Figure 2 10

1 Record the official name and address of the station on the form; where appropriate, the name and address should be the same as that appearing on the SAROAD site identification form to eliminate any confusion to persons not familiar with the station.

2 Connect the transfer standard orifice to the inlet of the sampler. Connect the orifice manometer to the orifice pressure tap, as illustrated in Figure 2.10 Make sure there are no leaks between the orifice unit and the sampler.

3. Verify that the flow indicator or recorder is properly connected to the pressure tap on the lower side of the high volume sampler motor housing. Install a clean flow chart in the recorder and adjust the recorder pen to read zero.

4. Operate the sampler for at least 5 minutes to establish thermal equilibrium prior to the calibration

5. Measure and record the barometric pressure (P_2) and ambient temperature (T_2) on the calibration worksheet (Items 1 and 2 on the upper part of the sheet).

6. Adjust the variable resistance of the transfer standard, or if applicable, insert the appropriate resistance plate to achieve the desired flow rate. If samplers have an orifice-type flow indicator downstream of the motor, do not vary the flow rate by adjusting the voltage or power supplied to the sampler

7. Let the sampler run for at least 2 minutes to reestablish the run-temperature conditions Read and record the pressure drop across the transfer standard orifice (ΔH) under Column 1 of the worksheet Read the sampler flow rate indication (I) from the flow recorder and record under column 4 Tap the flow recorder lightly before taking each reading to assure that the pen is not sticking.

8 Calculate $\sqrt{\Delta H\,(P_2/P_{std})\,(298/T_2)}$ and record under column 2.

9 Determine the standard volumetric flow rate (Q_{std}) either graphically from the transfer standard certification curve or by calculating Q_{std} from the least squares slope and intercept of the transfer standard's transposed certification curve

$$Q_{std} = 1/m \left[\sqrt{\Delta H\,(P_2/P_{std})\,(298/T_2)} - b\right]$$

Equation 2-6 (repeated)

Record the value of Q_{std} under Column 3

10. Repeat steps 6 through 9 for at least four additional flow rates distributed over a range that includes 1 1 to 1 7 std m^3/min

11 For each calibration point, calculate a Y value from the appropriate expression selected from Table 2-1 for the flow device being calibrated This should be done whether or not average barometric pressure and seasonal average temperature are to be incorporated into the calibration. Record this value under the appropriate side of Column 5 Calibration Worksheet (Figure 2.8), and mark the box showing which expression was used. For a pressure recorder, use the lower expression for square root function chart paper or middle expression for linear (uniform) chart paper.

12 Determine the calibration relationship by plotting the corresponding values of the Y expression involving I against Q_{std} on a graph similar to that shown in Figure 2.9. The Y expression plotted on the Y axis is from Column 5 of the calibration worksheet; the Q_{std} plotted on the X axis is from Column 3.

13 Draw the sampler calibration curve and/or calculate the linear least squares slope (m), intercept (b), and correlation coefficient of the calibration curve Calibration curves should be readable to 0.02 std m^3/min.

14. After the calibration relationship is determined, recheck each calibration point to determine if it is within the limits of linearity (±5%). This can be done by determining a Y_{cal} for each Q_{std} value recorded under Column 3 of the calibration worksheet. Y_{cal} can be determined from the calibration curve drawn in Figure 2 9 or by using the slope (m) and intercept (b) from the calibration worksheet (Figure 2.8) in the following equation

$$Y_{cal} = m\,Q_{std} + b$$

Equation 2-7

The percent difference for each value (Q_{std}) is determined by comparing each Y_{cal} with the corresponding Y recorded under Column 5 of the worksheet by using the following equation.

$$\%\ \text{difference} = \frac{Y - Y_{cal}}{Y_{cal}} \times 100$$

Equation 2-8

where

Y = Value of appropriate expression as recorded under Column 5 of the calibration worksheet

Y_{cal} = Corresponding Y value for the same Q_{std} as determined from the calibration relationship (Equation 2-7)

Any calibration points that are found to have a greater difference than ±5 percent should be repeated, and a corrected calibration relationship should be recalculated

The use of the calibration relationship determining sampler flow rates and the appropriate expressions to be used are discussed later in Subsection 4.4

2.6.3 *Flow-Controlled Sampler Calibration Procedures* - Samplers equipped with a flow controlling device may be calibrated either by means of a full multipoint calibration of the flow indicator (as described in Subsection 2.6.2 or by a single point calibration of the flow controller, without calibrating the flow indicator.

Multipoint Calibration. The flow controller must be rendered inoperative to allow flow changes to be made during calibration of the flow indicator. Calibration procedures and data forms given in Subsection 2.6.2 can then be used to determine the calibration relationship for the sampler's flow indicator. After calibration, the flow-controlling mechanism should be made operative again and set to a flow near the lower flow limit (1.1 std m^3/min) to allow maximum control range. At this time the sample flow rate should be verified with a clean filter installed. Two or more filters should then be added to the sampler to see if the flow controller maintains a constant flow; this is particularly important at high altitudes where the range of the flow controller may be reduced.

Single-Point Calibration. A flow-controlled sampler may be calibrated solely at its controlled flow rate,

High-Volume Air Sampler Calibration Worksheet

Site location: 114 E. MAIN ST. JONESVILLE OHIO

Date: 4-7-83 (1) Barometric pressure, P_2 mm Hg (or in.): 765

Calibrated by: SONJA FELIX (2) Temperature, T_2 (K): 293

Sampler No: 3 Serial No: 2864

Transfer std type: ORIFICE Serial No: 142

Optional

P_{std} = 760 mm Hg (or 29.92 in.)

Average barometric pressure P_a = _____

Seasonal average temperature T_a = _____

No	1 ΔH Pressure drop across orifice (in) or (cm)	$\sqrt{\Delta H \left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	(X) 3 Q_{std} (from orifice certification std m^3/min	4 I Sampler flow rate indication (arbitrary)	5 (Y) For specific pressure and temperature corrections (see Table 2.1) ☐ I or ☐ $\sqrt{I\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$ or ☐ $I\sqrt{\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	5 (Y) For incorporation of average pressure and seasonal average temperature (see Table 2.1) ☐ I or ☐ $\sqrt{I\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$ or ☐ $I\sqrt{\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$
1	2.2	1.501	0.750	20.0	20.236	
2	3.7	1.946	0.975	28.0	28.330	
3	5.3	2.329	1.155	34.0	34.401	
4	7.1	2.696	1.330	39.0	39.460	
5	8.5	2.950	1.455	43.0	43.507	
6	12.0	3.505	1.725	51.7	52.301	

Least Squares Calculations

Linear regression of Y on X: $Y = mX + b$, Y = appropriate expression from Table 2.1, $X = Q_{std}$

Slope (m) = 32.799 Intercept (b) = 3.951 Correlation Coefficient (r) = 0.9991

To determine subsequent flow rate during use $X = 1/m\,(Y-b)$ $Q_{std} = 1/m$ ([appropriate expression from Table 4.1 of Section 2.2.4] -b)

Figure 2.8. *Example of high volume air sampler calibration worksheet*

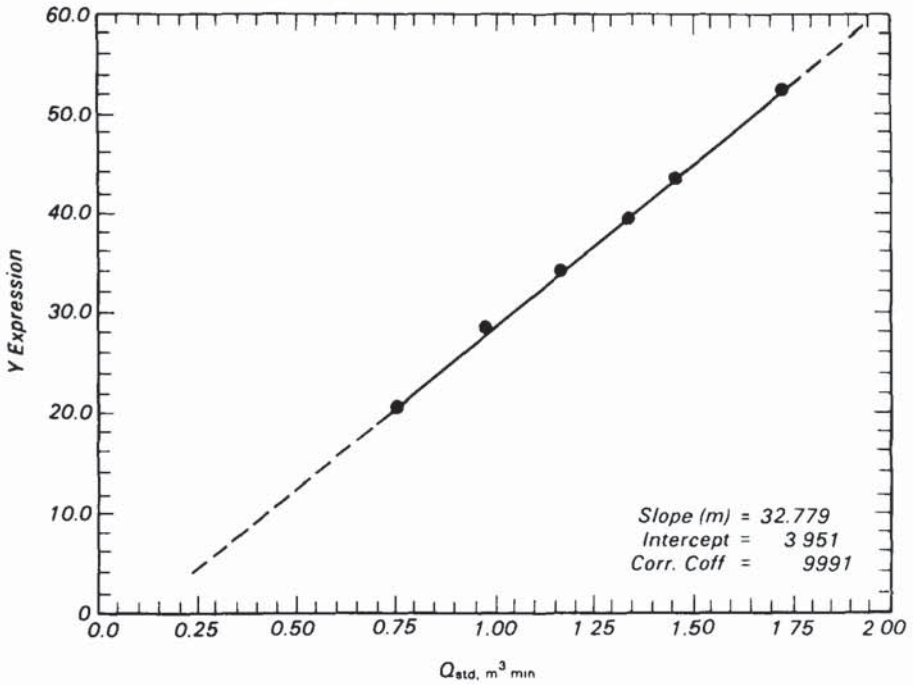


Figure 2.9. *Example of a high-volume sampler calibration relationship.*

provided the previous operating history of the sampler demonstrates that the flow rate is stable and reliable. In this case, the flow indicator may remain uncalibrated, but it should be used to indicate any relative change between initial and final flows, and the sampler should be recalibrated more often to minimize potential loss of samples because of controller malfunction. The following procedures should be used.

1. Set the flow controller for a flow near the lower limit of the flow range (1.1 std m^3/min) to allow maximum control range.
2. Install a clean filter in the sampler and carry out steps 2 through 5 and 7 through 9 of Subsection 2.6.2. No resistance plate should be used with the flow rate transfer standard.
3. Following calibration, add one or two additional clean filters to the sampler, reconnect the transfer standard, and operate the sampler to verify that the controller maintains the same calibrated flow rate; this is particularly important at high altitudes, where the flow control range may be reduced.

2.6.4 *Rotameter Calibration Procedure* - High-volume samplers equipped with rotameters are calibrated by using the same procedures and forms as specified in Subsection 2.6.2. Should adjustment of the rotameter be necessary, the following procedures may be used. (Refer to Figure 2.11, a photographic copy of the rotameter, to identify the working components in this procedural step for adjusting the rotameter.)

1 Attach the rotameter to the high-volume sampler motor.
2. Turn on motor and adjust to selected flow rate.
3 If adjustment is necessary, hold the rotameter vertically and loosen the locking nut by turning it counterclockwise.
4. Turn the adjusting screw to the desired setting (clockwise to lower the ball, or counterclockwise to raise the ball).
5. Be sure the ball continues to read the desired setting after the adjustment is made and as the locking nut is tightened.
6. Seal both the locking nut and the adjustment screw with glue to assure that the setting does not change. Do not cover the exhaust orifice
7. Proceed with calibration of rotameter as specified in Subsection 2.6.2.

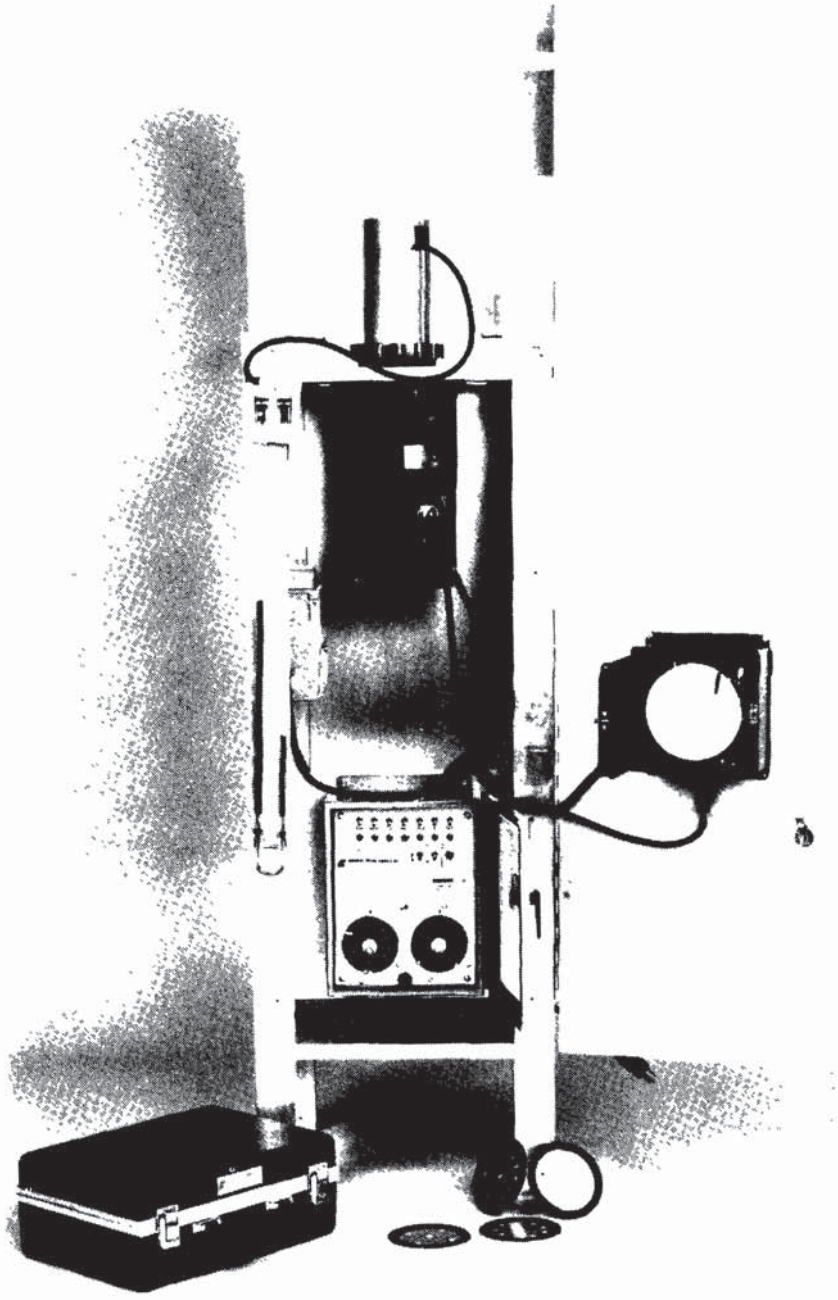


Figure 2.10 *High volume sampler and orifice unit assembled for calibration with flow recorder*

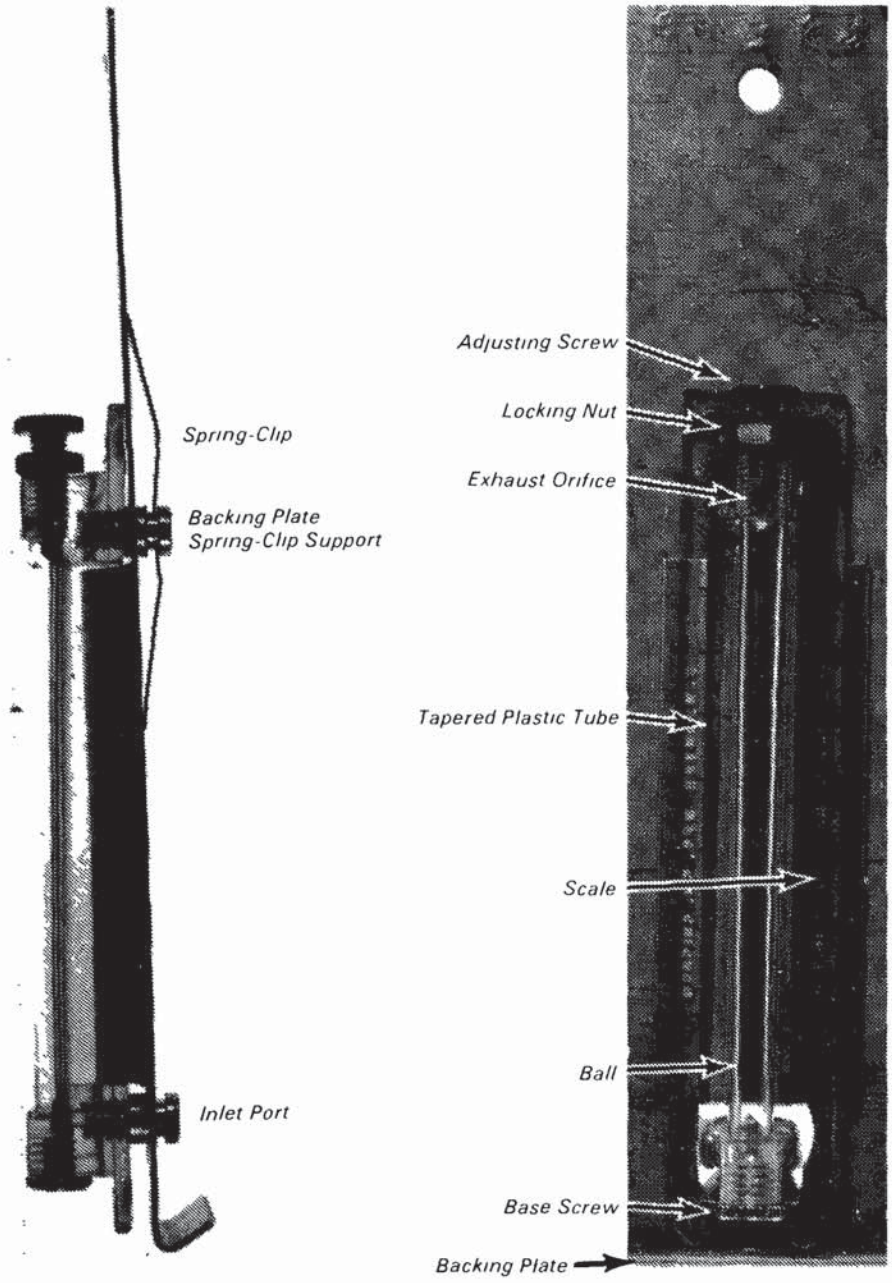


Figure 2.11. *Example of high volume sampler rotameter*

Table 2.2. *Activity Matrix for Calibration of Equipment*

Equipment	Acceptance limits	Frequency and method of measurement	Action if requirements are not met
Analytical balance	Indicated weight = true weight ±0.0005 g	Gravimetvic test-weighing 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
Relative humidity indicator	Indicator reading = psychrometer reading ±6%	Compare with reading of wet bulb/dry bulb psychrometer on receipt and at 6-mo intervals.	Adjust or replace to attain acceptance limits
On-off timer	±30 min/24 h	Check at purchase and quarterly with elapsed-time meter.	Adjust or repair
Elapsed-time meter	±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.
Flow-rate transfer standard	Indicated flow rate (from previous calibration) = actual 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.
Sampler	Indicated flow rate = actual individual calibration points ±5% of linearity	Calibrate with certified transfer standard on receipt, after maintenance on sampler, and any time audit deviates more than ±7%.	Recalibrate.

3.0 Filter Selection and Preparation

Suppliers of glass fiber filters for measurement of TSP have two grades of materials—the standard or traditional grade that has been in use for more than 20 years and a spectro-quality grade. Because the spectro-quality grade contains less organic and inorganic contaminants, it is recommended for use where additional chemical analyses are anticipated. A filter with low surface alkalinity is preferred to avoid positive interferences from absorption of acid gases while sampling. Ideally, surface alkalinity should be between pH 6.5 and 7.5; however, most commercially available glass fiber filters have a pH of >7.5. Filters having a pH of between 6 to 10 are acceptable. An activity matrix for filter selection and preparation is presented as Table 3.1 at the end of this section.

3.1 Selection

Only filters having a collection efficiency of ≥99 percent for particles of 0.3-μm diameter (as measured by the DOP test ASTM-D2986-71) are to be used. The manufacturer should be required to furnish proof of the collection efficiency of a batch of new filters. The collection efficiency should be recorded in the procurement log, Figure 1.1 of Section 2.2.1.

Each filter should be visually inspected using a light table. Loose fibers should be removed with a soft brush. Discard or return to the supplier the filters with pinholes and other defects such as tears, creases, or lumps.

3.2 Identification for Filters Not Numbered by the Supplier

A serial number should be assigned to each filter. The number should be stamped on two diagonally opposite corners—one stamp on each side of the filter. Gentle pressure should be used in application to avoid damaging the filter.

3.3 Equilibration

Each filter should be equilibrated in the conditioning environment for 24 h before weighing to minimize errors in the weight; longer periods of equilibration will not affect accuracy. The conditioning environment temperature should be between 15° and 30°C (59° to 86°F) and should not vary more than ±3°C (5°F); the relative humidity (RH) should be <50% and not vary more than ±5%. A convenient working RH is 40%.

3.4 Weighing

Clean filters are usually processed in lots—that is, several at one time. Clean filters must not be folded or creased prior to their weighing or use. Before the first filter is weighed, the balance should be checked by weighing a standard Class-S weight of between 3 and 5 g. Actual and measured weights, the date, and the operator's initials should be recorded, as shown in Figure 2.1.

If the actual and measured values differ by more than ±0.5 mg (0.0005 g), 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. Each filter should be weighed within 30 seconds after removing it from the equilibration chamber, and the tare weight and the serial number of each filter should be recorded in the laboratory log (Figure 3.1). Section 2.2.13 contains a blank copy of Figure 3.1 for the Handbook user. *Note:* Silicone-treated high volume filters have been found to have a static charge problem. This problem can be eliminated by placing an antistatic device containing a low-level alpha radiation source within the balance chamber. These devices are commercially available.

3.5 Handling

A quantity of filters sufficient for a ≥3-mo period for each sampler should be numbered and weighed at one time. Pack the filters in their original container (or a box of similar size) so that each filter is separated by a sheet of 8½-by-11-in. tracing paper. Be sure the filters are stacked in the box in numerical order so that the operator will use the proper filter first.

In addition to the filters, the field operator should be supplied with preaddressed return envelopes to protect the filters during mailing; these can be printed front and back to serve as a sample record data form, as shown in Figure 3.2. Section 2.2.13 contains a blank copy of Figure 3.2 for the Handbook user.

Laboratory Log for Total Suspended Particulate Data

Notown, Ohio
City Name

600 South Street
Site Address

State Area Site: 37 1

Instrument Last Calibrated 6/4/75
Sampler Identification No 0326

Project Time Year: 75

Project

The Interval

Total Suspended Particulate

Name Parameter Code

Sampling Date Month	Day	ST NR	Conc µg/m³	Filter Number	Average* CFM	Sampling Time	Air m³ Volume	Cross WCT	Tare WCT	Net WCT	Remarks
01	0800		797	10004	49.4	14.37	1993.4	3.301	3.142	0.159	

*From Average Flow Determined from Calibration

Laboratory Functions

Filter Preparation
- Filter must be free of pinholes, tears, creases, lumps, etc
- Filter must be properly equilibrated (20 hrs < time < 28 hrs, humidity < 50%) (Δ Humidity ± 5% Δ Temp ± 3°C)
- Balance must be checked before weighing (STD WGT 3 to 5 g ±0 0005 g)

Sampling Analysis
- Sample must be free or evidence of malfunction, ten or fewer insects in sample
- Filter must be properly equilibrated (see above)
- Balance must be checked before weighing (see above)

All samples were handled in accordance with the above guidelines

A. J. Smith
Signature

Figure 3.1. Laboratory log for total suspended particulate data

Hi-Vol Data Record

Project _____

Station _____

_____

_____

Site and/or Sampler No _____

SAROAD Site Code

Sample Date _____

Filter No _____

Flow Reading initial _____

final _____

Average Flow Rate _____

Running Time Meter initial _____

final _____

Total Sampler Time _____ *min*

Total Air Volume _____ *std m³*

Net TSP Weight _____ *g*

TSP Concentration _____ *µg/std m³*

Optional

	Temperature	*Barometric Pressure*
initial	_____	_____
final	_____	_____
average	_____	_____

Operator _____

Comments _____

_____

_____

_____

_____

_____

Figure 3.2. *Hi-Vol field data form.*

Table 3.1. *Activity Matrix for Filter Selection and Preparation*

Activity	Acceptance limits	Frequency or method of measurement	Action if requirements are not met
Selection and collection efficiency	Efficiency of >99% in 0.3-μm diameter particle collection	Manufacturer's proof of DOP test ASTM-D2986-71	Reject shipment or return to supplier
Integrity	No pinholes, tears, creases, etc.	Visual check of each filter with light table	Discard filter
Identification	Identification number in accordance with specifications	Visual check of each filter	Identify properly or discard filter
Equilbration	Equilibration in controlled environment for ≥24 h; constant humidity chamber with RH of <50% constant within ±5%, temperature between 15° and 30°C with less than ±3°C variation	The room or chamber conditions and the equilibration period are observed for each sample.	Repeat equilibration
Weighing procedure	Indicated filter weight determined to nearest mg within 30 s after removing from the equilibration chamber.	Observation of weighing procedure	Reweigh after re-equilibration
Handling	Filter in protective folder; envelopes undamaged	Visual check of each filter	Replace undamaged filters, discard damaged filters

4.0 Sampling Procedure

The activity matrix presented as Table 4 2 at the end of this section summarizes the sample collection activities and the operational checks

4.1 Filter Installation

Care must be taken to assure that the clean weighed filters are not damaged or soiled prior to installation in the high-volume sampler They should be kept in a protective folder or box and must not be bent or folded The use of filter cassettes (Figure 4 1) that can be loaded and unloaded in the laboratory may be used to minimize damage to the filter Damaged or soiled filters must be discarded

The following procedures are used to install a filter

1 Open the shelter and remove the faceplate of the sampler by loosening the four wingnuts and swinging the bolts outward

2 Wipe all dirt from the support screen and faceplate.

3 Center the filter with the rough side up on the wire screen so that the gasket will form an airtight seal on the outer edge (1 cm) of the filter when the faceplate is in position. When aligned correctly, the edges of the filter will be parallel both to the edges of the screen behind it and to the faceplate gasket above it. Poorly aligned filters show uneven white borders (Figure 4.2) around the filter.

4 Tighten the four wingnuts just enough to prevent leakage when the filter is aligned and the faceplate is in place. Excessive tightening may cause the filter to stick or permanently damage the gasket.

5 Close the shelter and run the sampler for at least 5 min to establish run-temperature conditions.

6. Record the flow indicator reading and, if needed, the barometric pressure ($P_{3\ initial}$) and the ambient temperature ($T_{3\ initial}$), then stop the sampler. *Note.* No onsite pressure or temperature measurements are necessary if the sampler flow indicator does not require pressure or temperature corrections (e g., a mass flowmeter) or if average barometric pressure and seasonal average temperature for the site have been incorporated into the sampler calibration. For individual pressure and temperature corrections, the ambient pressure and temperature at the time of the flow indicator reading can be obtained by onsite 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 sampler site and the airport. For samplers having flow recorders but not constant flow controllers, the average temperature and pressure at the site *during the sampling period* should be estimated from U S Weather Bureau or other available data.

7. Determine the flow rate from the sampler's calibration relationship (Subsection 4.4) to verify that it is operating within the acceptable range of 1.1 to 1.7 m^3/min (39-60 ft^3/min). If not within this range, use a different filter or adjust the sampler flow rate *Warning:* Substantial flow adjustments may affect the calibration of orifice-type flow indicators and may necessitate their recalibration

8. Record the sample identification information (filter number, site location or identification number, sample date) and the initial flow rate (or flow indicator reading and temperature and barometric pressure if needed) on the Hi-Vol field data form (Figure 4.3). See Subsection 4.7 for proper documentation.

9. Set the timer to start and stop the sampler such that the sampler runs 24 hours, from midnight to midnight local time.

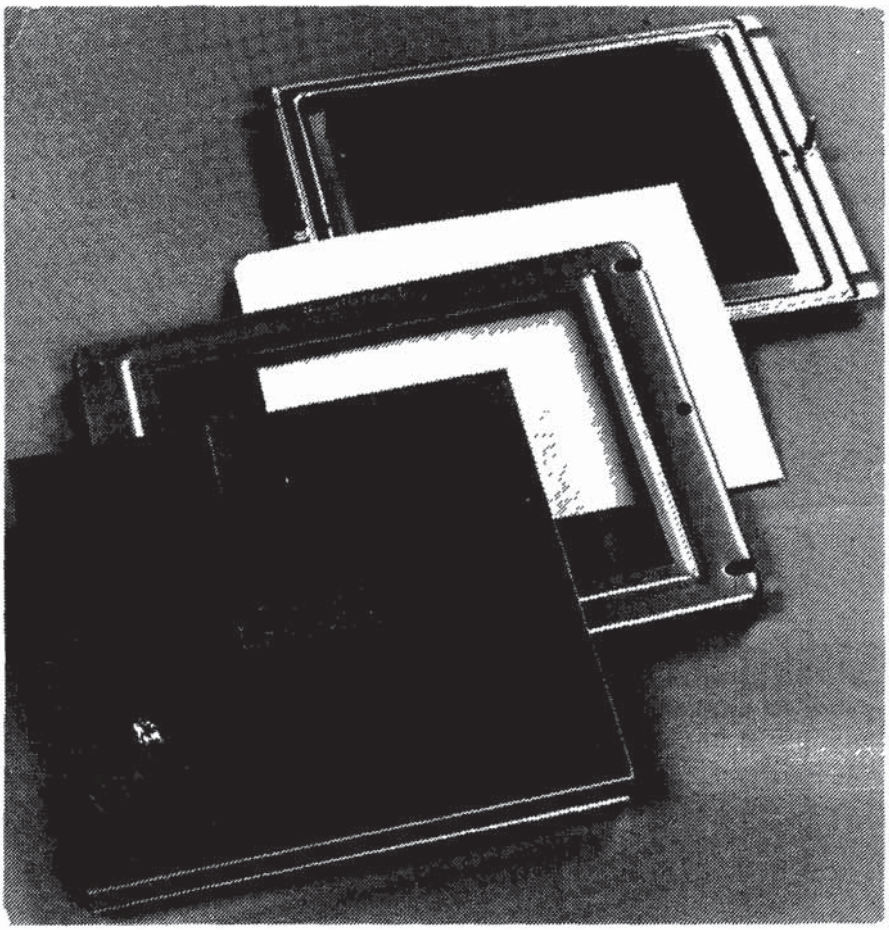


Figure 4.1 *High volume sampler filter cartridge assembly*

Figure 4.2. Nonuniform borders resulting from poorly aligned filters

4.2 Retrieval of Exposed Filter and Post-Sampling Checks

1. As soon as practical following the sampling period, run the sampler for at least 5 min to reestablish run-temperature conditions.

2. Record the flow indicator reading and, if needed, the barometric pressure ($P_{3\ final}$) and the ambient temperature ($T_{3\ final}$)

3. Stop the sampler, remove the faceplate, and lift the exposed filter from the supporting screen by grasping it gently at the ends, not at the corners.

4. Check the filter for signs of air leakage. Leakage may result from a worn faceplate gasket (Figure 4 4) or from an improperly installed gasket. If signs of leakage are observed, void the sampler, determine the cause, and take corrective actions before starting another sampling period A gasket generally deteriorates slowly; thus the operator can decide well in advance (by the increased fuzziness of the sample outline) when to change the gasket before a total failure results

5. Visually inspect the gasket face to see if glass fibers from the filter are being left behind due to overtightening of the faceplate wingnuts and the consequent cutting of the filter along the gasket interface.

6. 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, sample losses due to leakages during the sampling period or losses of loose particulates after sampling (e.g , loss when folding the filter) would invalidate the sample, so mark such samples "void" before forwarding them to the laboratory.

7. Check the appearance of the particulates Any changes from normal color, for example, may indicate new emission sources or construction activity in the area. Note any change on the filter folder along with any obvious reasons for the change.

8. Fold the filter lengthwise at the middle with the exposed side in; if the collected sample is not centered on the filter (i.e , the unexposed border is not uniform around the filter), fold so that only the deposit touches the deposit Results of an improperly folded filter are illustrated in Figure 4 5, where smudge marks from the deposit extend across the borders; this can reduce the value of the sample if the analyses for which the sample was collected need to be divided into equal portions.

9. Place the filter in its numbered folder.

10. Determine the final flow rate from the sampler's calibration relationship (see Subsections 4.3 and 4.4) and record it on the data record along with other pertinent information (see Figure 4.3).

11. Remove the sampler's flow recorder chart and place the chart inside the filter folder with the inked side against the folder and the backside against the filter.

4.3 Flow Readings

4.3.1 *Rotameters* - To obtain a valid measurement, make flow rate

Hi-Vol Data Record

Project SPECIAL STUDY

Station 4278 ELM ST.
SMITHFIELD, CAL

Site and/or (Sampler No) 12

SAROAD Site Code

Comments
CITY CONDUCTED STREET CLEANING ON DAY SAMPLE WAS COLLECTED.

Sample Date 5-23-73

Filter No 14876

Flow Reading initial 1.32 m^3
final 1.28 m^3

Average Flow Rate 1.30 std m^3

Running Time Meter initial 0000
final 1438

Total Sampler Time 1438 min

Total Air Volume 1869.4 std m^3

Net TSP Weight 0.1402 g

TSP Concentration 75 $\mu g/std\ m^3$

Optional

	Temperature	Barometric Pressure
initial		
final		
average (seasonal)	20°C	740 m^3

Operator SONIA FELIX

Figure 4.3. *Example of completed Hi-Vol field data form.*

measurements while the sampler is at normal operating temperature, after a warmup time of ≥5 min.

1. Connect the rotameter to the sampler with the same tubing used during calibration, and place or hold it in a vertical position at eye level.
2. Read the widest part of the float (ball), and use the calibration relationship (see Subsection 4.4) to convert the reading to Q_{std} (m^3/min) and record to the nearest 0.02_{std} m^3/min.
3. Measure the flow rates at the beginning and end of each sampling period. Observe the flow rate for ≥1 min after connecting the rotameter to the sampler before taking a reading. If a gradual change in flow rate is observed, do not take a reading until equilibrium is reached; a gradual change is usually observed when the rotameter is at a substantially different temperature from that of the sampler exhaust air, and thus equilibration may require 2 or 3 min.

4.3.2 *Flow Recorders* - The following procedure is for a high-volume sampler equipped with a flow recorder.

2. Remove any moisture by wiping the inside of the recorder case with a clean cloth. Carefully insert the new chart into the recorder without bending the pen arm beyond its limits of travel. An easy way to do this is to raise the pen head by pushing in on the very top of the pen arm with the right hand while inserting the chart

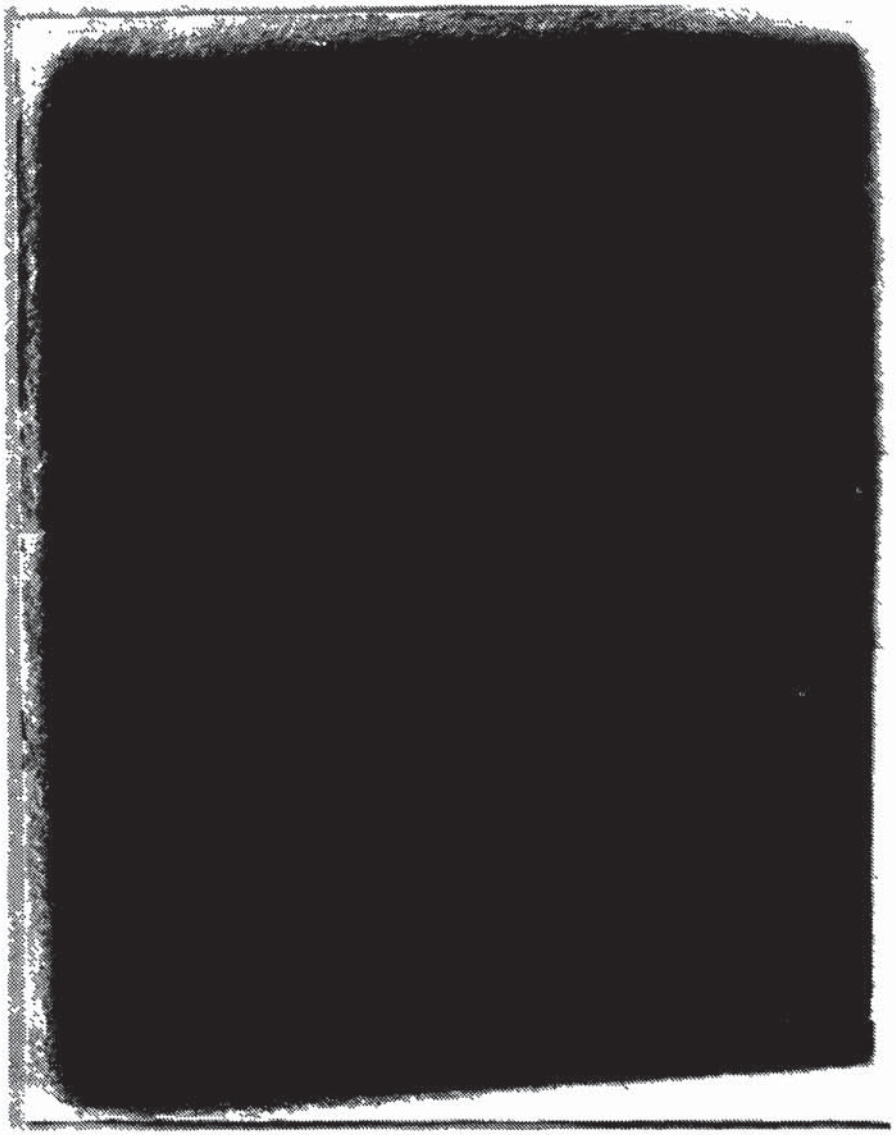


Figure 4.4. Example of air leakage around the filter due to worn faceplate gasket or to improper installation

with the left hand. Be careful not to damage or weaken the center tab on the chart, but be sure the tab is centered on the slotted drive so that the chart will rotate the full 360 degrees in 24 h without binding or slipping. A properly installed chart is shown in Figure 4.6.

3. Check to see that the pen head rests on zero (i.e., the smallest circle diameter on the chart). If not, tap the recorder lightly to make certain that the pen arm is free.

4. Check the time indicated by the pen. If it is in error, rotate the chart clockwise by inserting a screwdriver or coin into the slotted drive in the center of the chart face until the time is correct. If the sampler is started with a timer switch, the correct time is the starting time on the timer (usually midnight).

5. Using an eyedropper, put a small amount of ink into the hole in back of the pen tip. Use of cartridge-type pens will minimize problems with inking.

6. Turn the sampler on (never turn it on until a filter is in place because the transducer and recorder may be damaged), and observe it long enough to know whether the transducer and recorder are operating properly

4.4 Determination of Flow Rates

High-volume sampler flow rate readings must be converted to units of std m^3/min (25°C, 760 mm Hg) for use in calculating TSP concentrations. Expressions for converting sampler flow rate readings (I) to standard conditions are given in Table 4 1 Instructions for the use of this table and the flow measuring device calibration relationships (Figures 2 8 or 2 9) to obtain the sampling flow rate Q_{std} (m^3/min) are given in Subsections 4.4 1 and 4 4 2

No onsite pressure or temperature measurements are necessary if the sampler flow indicator does not require pressure or temperature corrections (e g., a mass flowmeter) of if average barometric pressure and seasonal average temperature for the site have been incorporated into the sampler calibration For individual pressure and temperature corrections, the ambient pressure and temperature at the time of flow indicator reading can be obtained by onsite 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 sampler site and the airport For samplers having flow recorders but not constant flow controllers, the average temperature and pressure at the site during the sampling period should be established from Weather Bureau or other available data

4.4.1 *Samplers Without Continuous Flow Recorders* - For a sampler without a continuous flow recorder, determine the appropriate expression to be used (from Table 4 1) corresponding to the one used in calibration (from Table 2 1) Using this appropriate expression, determine Q_{std} for the initial flow rate from the sampler calibration curve, either graphically or from the transposed regression equation (see Figure 2 8)·

$$Q_{std} = \frac{1}{m}([\text{Appropriate expression from Table 4 1}] - b)$$

Equation 4-1

Similarly, determine Q_{std} from the final flow reading, and calculate the average flow Q_{std} as one-half the sum of the initial and final flow rates.

4.4.2 *Samplers With Continuous Flow Recorders* - For a sampler with a continuous flow recorder, determine the average flow rate reading (I) for the period Determine the appropriate expression from Table 4.1 corresponding to the one used in calibration (from Table 2.1) Then using this expression and the average flow rate reading, determine Q_{std} from the sampler calibration relationship, either graphically or from the

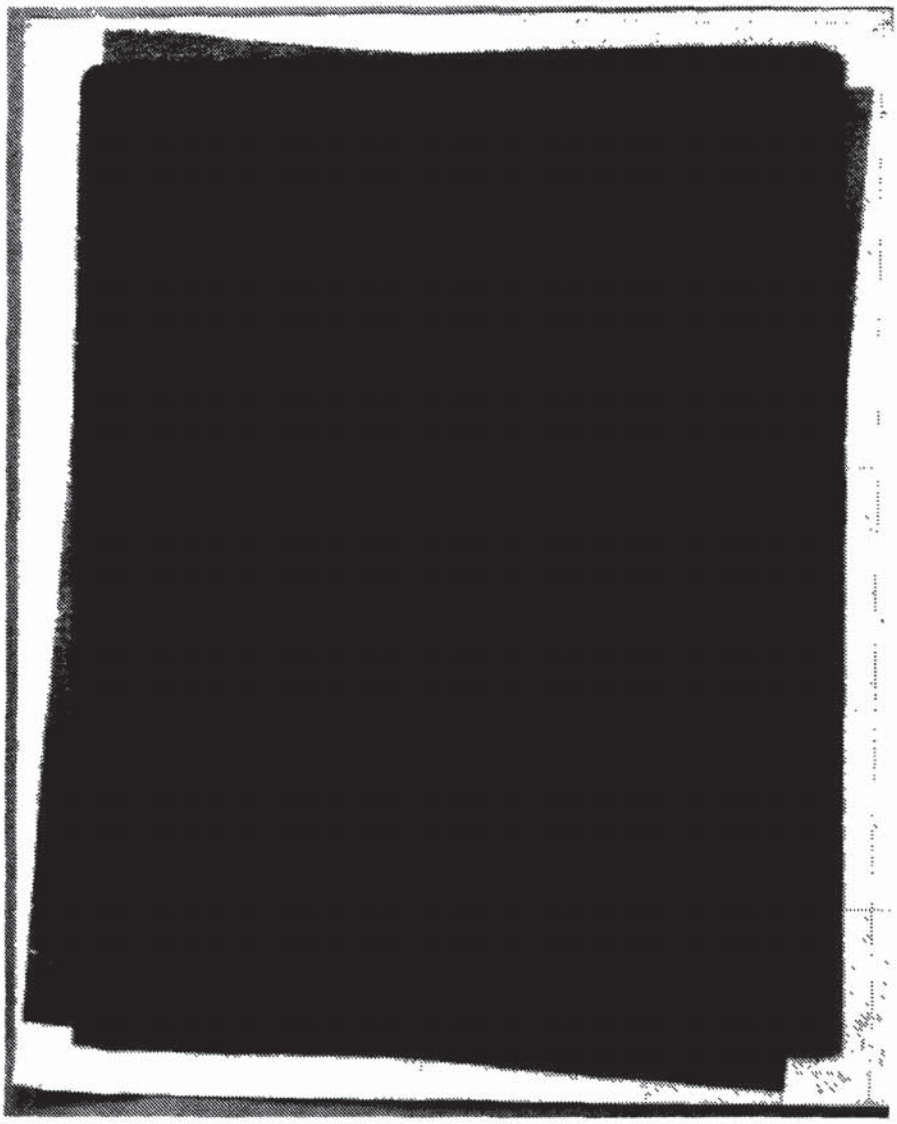


Figure 4.5. *Example of smudged filter border resulting from an improperly folded filter.*

Table 4.1. *Expressions for Determining Flow Rate During Sampler Operation*

	Expression	
Type of sampler flow rate measuring device	*For actual pressure and temperature corrections*	*For use when geographic average pressure and seasonal average temperature have been incorporated into the sampler calibration*
Mass flowmeter	I	I
Orifice and pressure indicator	$\sqrt{I\left(\frac{P_3}{P_{std}}\right)\left(\frac{298}{T_3}\right)}$	$\sqrt{I}$
*Rotameter, or orifice and pressure recorder having square root scale**	$I\sqrt{\left(\frac{P_3}{P_{std}}\right)\left(\frac{298}{T_3}\right)}$	I

**This scale is recognizable by its nonuniform divisions and is the most commonly available for high-volume samplers*

transposed regression equation (see Figure 2.8 and Equation 4-1 above):

If the trace shows substantial flow change during the sampling period, greater accuracy may be achieved by dividing the sampling period into intervals, calculating an average reading for each interval, determining Q_{std} for each interval, and finally computing the average Q_{std} for the whole sampling period.

Calculate the total air volume sampled by the following equation:

$$V = Q_{std}\, t \quad \text{Equation 4-2}$$

where:

V = total air volume sampled, in standard volume units (std m^3);
Q_{std} = average standard flow rate, std m^3/min;
t = sampling time, min.

4.5 Sampling Flow Rate Checks

The two types of sampling flow rate checks recommended are discussed in the following Subsections (4.5.1 and 4.5.2).

4.5.1 *Initial Flow Rate Check* - Initial flow rate measurements should be monitored for each sampler to determine whether corrective action is needed.

1. Record the initial and final flow rates for each sample in the log book maintained with the sampler. A sampler equipped with a continuous recorder should be observed for at least 5 min. before the initial flow rate is recorded.

2. Average the initial flow rate measurements for the first four samples after each calibration. Check future initial flow rates that deviate more than ±10% from this average for samplers on which a manometer or a flow recorder is used and ±15 percent for samplers on which a rotameter is used. If the change has been gradual over time, recalibrate. If large deviations occur between successive samples, repeat the flow reading after 5 minutes. If the second reading is within the above limits, continue normal operations; if not, check the line voltage and/or replace the filter

3. Perform a calibration check if neither of the above checks identifies the trouble. If the calibration check is satisfactory, continue normal operations; if not, perform a complete calibration

4.5.2 *Operational Flow Rate Check* - It is recommended that a one-point operational flow check be made on each sampler at least once every 2 weeks. The purpose of this check is to

Figure 4 6 Flow rate recorder with chart installed

track the in-control conditions of the sampler calibration The same flow rate transfer standard used to calibrate the high-volume sampler may be used for the operational flow check

1 Operate the sampler at its normal flow rate with flow check device in place Determine Q_{std} for the check point from the calibration of the flow check device, and determine the measured flow rate from the sampler's calibration (see Subsections 4 3 and 4 4) Use the following procedure for plotting the check data

2 Calculate the percentage difference (% D) between the known check flow measurement and the flow measured by the sampler's normal flow indicator (Equation 4-1) Let Q_a represent the known flow rate and Q_m the measured flow rate for the flow check

$$\% D = \left(\frac{Q_m - Q_a}{Q_a}\right) 100$$

Equation 4-3

Thus if Q_m = 1.48 m³/min and Q_a = 1 42 m³/mm
then

$$\% D = \left(\frac{1.48 - 1.42}{1.42}\right) 100 = +4\%$$

If the % D is not within ±7 percent for any one check, recalibrate before resuming the sampling

3 Record the Q_m, the Q_a, and the % D on an $\bar{X}$-and-R chart (Figure 4 7) under "Measurement Result, Items 1 and 2 " Record the % D in the cells preceded by the "Range R " The % D can be positive or negative, so retain the sign of the difference, since it may indicate trends and/or consistent biases More information on the construction of a quality control chart and the interpretation of the results are in Appendix H, Volume I of this Handbook [2]

4. Repeat the above for each operational flow rate check, plot all points on the chart, and connect the points by drawing connecting lines Tentative limits are ±4 7 percent (warning lines) and ±7 percent (out-of-control lines) Out-of-control points indicate possible problems in calibration or instrument errors When out-of-control results are obtained, recalibrate the sampler prior to further sampling After 15 to 20 points are plotted, new control and warning limits may be derived, as described in Appendix H of Volume I of this Handbook.[2] Do not increase the control and warning limits, however, more stringent limits may be established

5 Forward the $\bar{X}$-and-R chart to the QA supervisor for review

4.6 Time Measurements

Start and stop times for samplers not equipped with a timer switch or an elapsed-time meter are recorded by the operator who starts and stops the sampler If more than one operator is involved, each should set his/her watch to a common reference to achieve accurate times, such a reference could be an office clock that is checked daily or the local telephone company, which gives the time of day The time measurement procedure is as follows

1 Take the start and stop times for samplers equipped with timer switches from the timers' start and stop settings

2 Check the timer clock, and set it, if necessary, for the correct times at each filter change

3 Use an elapsed-time meter to determine the number of minutes sampled because timers cannot be set or read to within less than ±30 min

4.7 Documentation

The following information should be recorded on the filter folder or on a field data record form (Figure 4 3) by the persons indicated, and it should be verified with a signature

4.7.1 *The Operator Who Starts the Sample*

1 Station location
2 Project number
3 Site number
4 Sampler ID number
5 Filter number

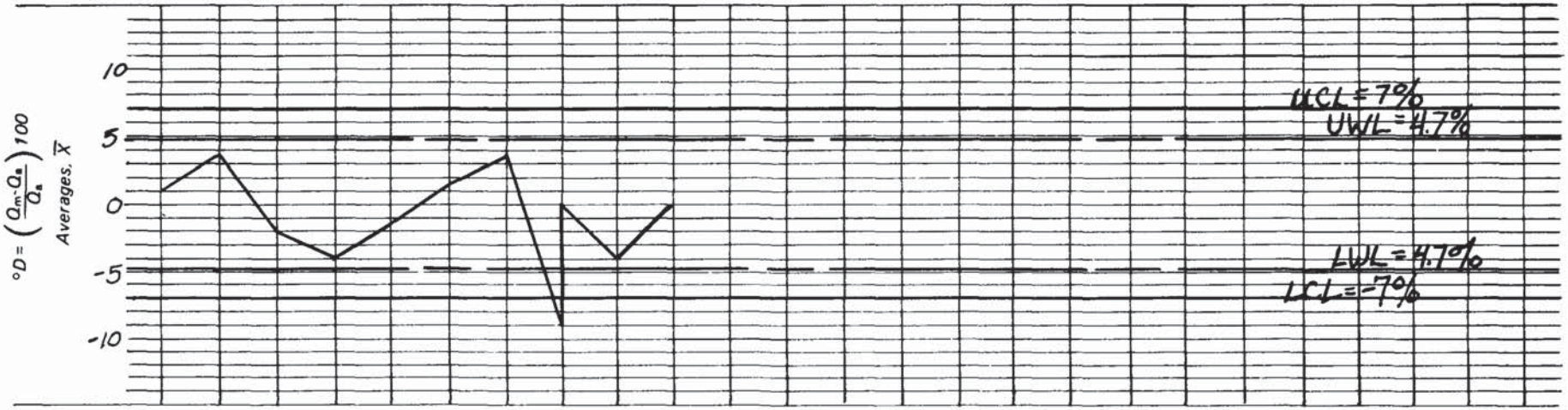
Project Name: Operational Flow Rate Check

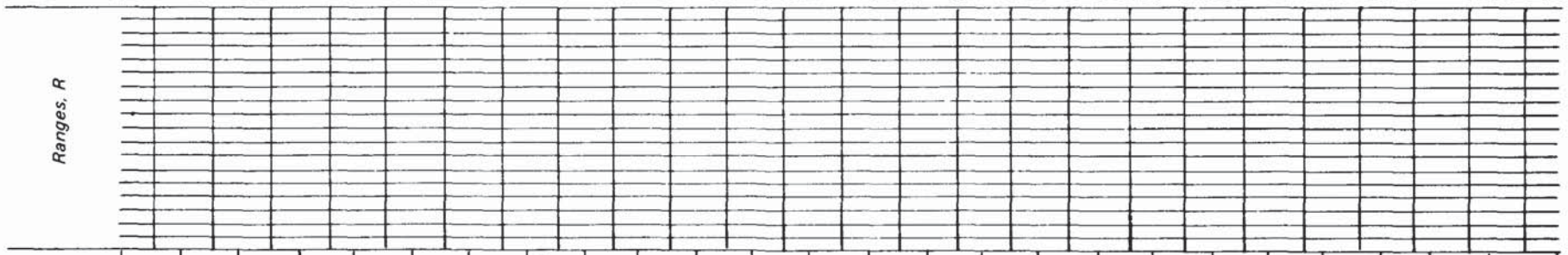
Measurement: $\bar{X}$, %D = 100(Qm − Qa)/Qa

Performed: % accuracy in routine and audited measurements

Measurement Units: Qm, Qa in cfm,

			Date	2/4	2/26	3/10	3/25	4/7	4/22	5/6	5/29	6/9	6/30		
Measured Actual	Measurement	Code	1												
			2												
			3												
		Result	1	60	55	54	54	58	60	56	50	53	56	Qm	
			2	59	53	55	56	59	59	54	55	55	56	Qa	
			3												
Sum															
Average, $\bar{X}$															
Range, R			%D	1.7	3.8	-1.8	-3.6	-1.7	1.7	3.7	-9.1	-3.6	0		





Comments (Correct Action, etc.): Recalibration done

Figure 4.7. Quality control chart for operational flow check

6 Sample date
7 Initial flow reading (if using rotameter) and/or initial temperature and barometric pressure if required
8. Unusual conditions that may affect the results (e.g., subjective evaluation of pollution that day, construction activity, meteorology)
9 Signature.

4.7.2 *The Operator Who Removes the Sample*
1 Elapsed time
2. Final flow reading (or be sure that the flow rate chart accompanies the sample) and final temperature and barometric pressure if required
3. Existing conditions that may affect the results
4. Signature

4.7.3 *The Operator Who Transfers the Sample to the Laboratory Record*
1. Receiving date initialed
2. Shipping date initialed

Table 4.2. *Activity Matrix for Sampling Procedure*

Activity	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Filter installation	*Filter rough side up, centered on screen, edges parallel to edges of screen and to faceplate gasket, gasket tightened to prevent leakage*	*Visually check each exposed filter.*	*Void the filter; install substitute filter*
Flow checks	*1) Sampler flow rate within acceptable range of 1 1 to 1.7 m^3/min (39-60 ft^3/min) 2) Stabilized initial flow rate = established initial flow rate ±10% for pressure transducer or ±15% for rotameter*	*Check flow rate at each filter change*	*1) Determine cause of flow problem and correct; measure line voltage, change the filter, check calibration and calibrate sampler.*
Elapsed time	*3) Sampling time 24 ±1 h*	*Check on and off settings of timers*	*Reset timer*
Sample handling	*No evidence of malfunction in post-sampling check*	*Visually check each sample for tears, missing pieces, or leakage*	*Void the sample; correct the cause of malfunction.*
Documentation	*Names, sampling dates, times; sample, filter, and station numbers; unusual conditions, flow rates, and handling dates recorded on sample envelope*	*Visually check each sample data record*	*Complete or correct the documentation; if unavailable, void the sample.*

5.0 Analysis of Samples

A matrix summarizing the major quality assurance activities for sample analyses is presented as Table 5.1 at the end of this section.

5.1 Sample Documentation and Inspection

Upon receipt of the sample from the field the following procedure should be followed:

1. Remove the filter folder from its shipping envelope and examine the Hi-vol Field Data Record (Figure 4.3) to determine whether all data needed to verify the sample and to calculate the concentration have been provided. Void the sample if data are missing and unobtainable from the field operator or if a sampler malfunction (e.g., faceplate gasket leakage) is evident.
2. Record the filter number on the Hi-vol Field Data Record and on the Laboratory Data Log (Figure 3.1).
3. Examine the shipping envelope. If sample material has been dislodged from the 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.
4. Examine the filter. If insects are embedded in the sample deposit, remove them with Teflon-tipped tweezers, but 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 to accept or reject it
5. Record the data verification, the sample inspection, and removal of insects under "Remarks" in the Laboratory Data Log

5.2 Filter Equilibration

The following procedure should be used to equilibrate the exposed filters in a conditioning environment for 24 h; up to 48 h may be needed for very damp filters.

1 Use an eqilibration chamber with a desiccant or an environmentally controlled weighing room to maintain an RH of <50 percent at 15° and 30°C (59° to 86°F) An air-conditioned room may be used for equilibration if it can be maintained at an RH of <50% that is constant within ±5% and an air temperature between 15° and 30°C that is constant within ±3°C (5°F) while the filters are equilibrating A convenient working RH is 40 percent. Keep a hygrometer in the room

2. Check the RH daily
3 Record the hygrometer readings and any equilibration chamber malfunctions, discrepancies, or maintenance in the Laboratory Data Log.

5.3 Gravimetric Analysis

A balance check should be performed as specified in Subsection 2 1

1 Weigh the exposed filters to the nearest milligram (mg) on the analytical balance.

2 Weigh the filters in the conditioning environment if practical; if not, be sure that the analytical balance is as close as possible to the conditioning chamber where it is relatively free of air currents and where it is at or near the temperature of the chamber. Weighing should take place within 30 seconds after removing filters from the equilibration chamber

3. Record the weight in the Laboratory Data Log and on the High Volume Field Data Record.

Table 5.1. *Activity Matrix for Analysis of Samples*

Activity	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Documentation verification and sample inspection	*Complete documentation; no evidence of malfunction or sample loss; ≤10 insects in sample*	*Visually check all samples and documentation.*	*Void the sample*
Filter equilibration	*Controlled environment for ≥24 h; RH <50% within ±5%; temperature constant within ±3°C at 15° to 30°C (59° to 86°F)*	*For each sample, observe room or chamber conditions and equilibration period.*	*Repeat equilibration for 24 h at properly controlled conditions*
Gravimetric analysis	*Indicated weight obtained to nearest milligram within 30 s after removal from equilibration chamber*	*Observe filter weighing*	*Report to supervisor; reweigh after equilibration for 24 h at controlled conditions.*

6.0 Calculations of TSP Concentrations and Data Reporting

A matrix summarizing the quality control activities for the calculations and the data-reporting requirements is presented in Table 6 1

6.1 TSP Concentration

Equation 6-1 should be used to calculate the total air volume sampled

$$V = Q_{std}\, t \quad \text{Equation 6-1}$$

where

V = Total air volume sampled, in standard volume units, std m^3;
Q_{std} = average standard flow rate, std m^3/min;
t = sampling time, min

Equation 6-2 should be used to calculate the TSP sample concentration.

$$TSP = \frac{(W_f - W_i)10^6}{V} \quad \text{Equation 6-2}$$

where

TSP = concentration of TSP, μg/std m^3,
W_f = weight of exposed filter, g
W_i = tare weight of filter, g

All original calculations should be recorded in the Laboratory Data Log (Figure 3.1).

6.2 Data Documentation and Reporting

All daily concentration levels should be recorded in micrograms per standard cubic meter (μg/std m^3), with the required identifying information, on the SAROAD Daily Data form (Figure 6.1). See AEROS User's Manual, OAQPS No. 1.2-039, for detailed instructions.

Table 6.1. *Activity Matrix for Calculations and Data Reporting*

Activity	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Sample volume and concentration	*All needed data available*	*Visually check data records for each sample.*	*Void the sample.*
Data documentation and reporting	*Complete documentation for calculation of concentration; all sample and data identification numbers matched; no evidence of malfunction or sample loss; all needed data available*	*Visually check data record and data log for each sample.*	*Void the sample.*

24-Hour or Greater Sampling Interval

2 Smelter Town Pollution Control
1 Agency

Smelter Town
City Name

400 North Street
Site Address

TSP 24 hour
Project Time Interval

State		Area					Site	
4	6	0	9	0	0	0	0	1
2	3	4	5	6	7	8	9	10

Agency	Project	Time	Year	Month
P	0 2	7	7 6	0 2
11	12 13	14	15 16	17 18

TSP			
Name PARAMETER Code	Name PARAMETER Code	Name PARAMETER Code	Name PARAMETER Code
1 1 1 0 1			
23 24 25 26 27	37 38 39 40 41	51 52 53 54 55	65 66 67 68 69
0 1 0 1 0			
28 29 30 31 32	42 43 44 45 46	56 57 58 59 60	70 71 72 73 74

Day 19 20	St Hr 21 22	33 34 35 36	47 48 49 50	61 62 63 64	75 76 77 78
	0 0	0 0 7 8			
	0 0	0 0 9 5			
DP→		4 3 2 1 0	4 3 2 1 0	4 3 2 1 0	4 3 2 1 0

Figure 6.1. SAROAD daily data form.

7.0 Maintenance

Scheduled or preventive maintenance of the sampling equipment reduces voided samples, downtime, and remedial maintenance Because the sampling equipment is operated only intermittently, the frequency of maintenance is a function of the actual hours of use. Normally, two or three preventive maintenance activities are required each year When possible, maintenance is best performed in the laboratory rather than in the field. Motors on which maintenance has been performed can then be carried to the field for installation and calibration. Table 7 1 at the end of this section summarizes the quality assurance activities of major maintenance checks. All maintenance activities should be recorded in a log book

7.1 Sampler Motor

Motor brushes usually require replacement after 400 to 500 h of operation at normal line voltage (115 V) The procedure is as follows.

1. Replace the brushes before they are worn to the point that damage can occur to the commutator of the Hi-Vol motor The optimum replacement interval must be determined from experience
2. Follow the manufacturer's instructions for replacing the brushes.
3. Recalibrate the high-volume sampler after the brushes are replaced Do not recalibrate the motor until after an initial break-in period for the proper seating of the brushes against the armature; this period usually requires running the sampler for several hours against a resistance equivalent to a clean filter or a No. 18 calibration plate.
4. Refer to the flow diagram in Figure 7.1 for the various steps required for motor maintenance
5. Record all sampler maintenance operations (with dates performed and the operator's initials) in the sampler log book and on a gummed label (Figure 7 2) attached to the sampler

7.2 Faceplate Gasket

A worn faceplate gasket is characterized by a gradual blending of the interface between the collected particulates and the clean filter border Any decrease in the sharpness of this interface indicates the need for a new gasket.

1 Remove the old gasket with a knife.

2. Clean the surface properly.

3 Seal a new gasket to the faceplate with rubber cement or double-sided adhesive tape.

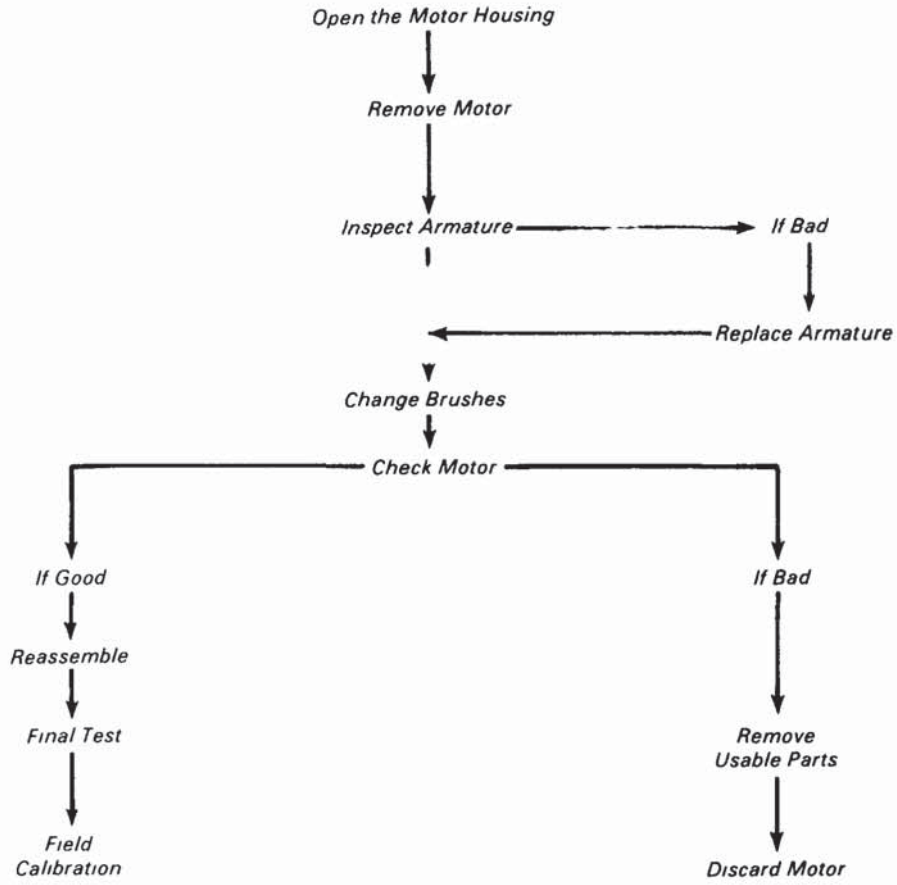


Figure 7.1. Flow diagram for high volume sampler motor maintenance

Hi-vol motor number _____

Site location _____

Last maintenance _____

Last calibration _____

Checked by _____

Next maintenance due _____

Next calibration due _____

Figure 7.2. Example of a gummed label for a high-volume sampler.

4. Record all gasket replacements with dates and operator's initials in the sampler log book

7.3 Rotameter

1. Clean and recalibrate the rotameter of a sampler when the float behaves erratically or when moisture or foreign matter is detected in the rotameter.

2. Clean the rotameter prior to routine calibration (alcohol is a satisfactory cleaning solvent).

3. Refer to the flow diagram (Figure 7.3) for the required maintenance steps.

7.4 Sampling Head

Leaks in the sampling head occur infrequently. The welded seams and the condition of the guide pins on the top surface of the head should be visually checked initially. Should a

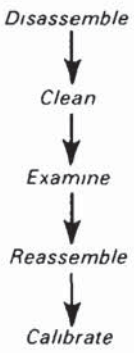


Figure 7.3. Maintenance sequence for rotameter

defect be suspected, the following procedure should be followed:

1 Assemble the sampling head to the motor
2 Install a filter for resistance
3 Apply a soap solution to the suspect problem area
4 Disassemble the sampling head.
5 Examine the inside of the head for soap bubbles
6 Repair or discard the sampling head if a leak is indicated by soap solution being inside of the head

7.5 Motor Gaskets

Two gaskets are used with each sampler motor. The top rubber gasket is approximately 3/16-in. thick and the bottom foam rubber gasket is approximately 3/4-in. thick.

1 Inspect both gaskets for wear or deterioration
2. Replace if necessary.

7.6 Flow Transducer and Recorder

Routine maintenance is not required for this device. Should a malfunction occur, replace the old recorder with a new one.

Table 7.1. Activity Matrix for Maintenance

Equipment	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Sampler motor	*400-500 h of motor brush operation; no malfunction*	*Visually check upon receipt and after each 400 h of operation.*	*Replace motor brushes; perform other maintenance as indicated.*
Faceplate gasket	*No leaks at the filter seal*	*Visually check after each sampling period.*	*Replace the gasket.*
Rotameter	*No foreign materials; stable operation*	*Visually check at each reading.*	*Clean; replace if damaged.*
Motor gaskets	*Leak-free fit*	*Visually check after each 400 h of operation.*	*Replace gaskets.*
Sampling head	*No leaks*	*Visually check after each 400 h of operation.*	*Replace sampling head.*

8.0 Auditing Procedure

An audit is an independent assessment of the accuracy of data *Independence is achieved by having the audit made by an operator other than the one conducting the routine measurements and by using audit standards and equipment different from those routinely used in monitoring.* The audit should be a true assessment of the accuracy of the measurement process under normal operation—that is, without any special preparation or adjustment of the system Routine quality assurance checks by the operator are necessary for obtaining good quality data, but they are not part of the auditing procedure.

Three performance audits and one systems audit are detailed in Subsections 8.1 and 8.2. These audits are summarized in Table 8 2 at the end of this section. See Sections 2.0.11 and 2 0 12 of this volume for detailed procedures for systems audits and performance audits, respectively

Proper implementation of an auditing program serves a two-fold purpose: to ensure the integrity of the data and to assess the accuracy of the data A technique for estimating the accuracy of the data is given in section 2.0 8 of this volume

8.1 Performance Audits

Performance audits conducted by another operator/analyst provide a quantitative evaluation of the quality of the data produced by the total measurement system (sample collection, sample analysis, and data processing). Performance audits of three individual portions of the total measurement system are recommended

1. Flow rate calibration
2. Exposed filter reweighing
3. Data processing.

8.1.1 *Audit of Flow Rate Calibration* - The frequency of audits of the flow rate depends on the use of the data (e.g., for PSD[3] air monitoring or for SLAMS[4]). It is recommended that the flow rate of each high-volume sampler be audited each quarter. Any type flow-rate transfer device acceptable for use in calibration of high-volume samplers may be used as the audit flow-rate reference standard, however, the audit standard must be different from the standard used to calibrate the high-volume samplers. The audit standard must be calibrated with a positive-displacement standard volume meter (i.e , Roots meter) traceable to the National Bureau of Standards See Subsection 2 2 for procedures used to certify flow rate transfer standards

With the audit device in place, the high-volume sampler should be operated at its normal flow rate The differences in flow rate (in std m^3/min) between the audit flow measurement (X) and the flow indicated by the sampler's normal flow indicator (Y) are used to calculate accuracy as described in Section 2 0 8 of this volume

Great care must be taken in auditing high-volume samplers having flow regulators because the introduction of the audit device can cause abnormal flow patterns at the point of flow sensing. For this reason, the orifice of the flow audit device must be used with a normal glass fiber filter in place (and without resistance plates) in auditing flow-regulated high-volume samplers, or other steps should be taken to assure that flow patterns are not disturbed at the point of flow sensing

Detailed procedures and forms used to perform flow rate audits are given in Section 2 0.12 of this volume

8.1.2 *Audit of Exposed Filter Reweighing* - To avoid possible loss of volatile components, exposed filters should be weighed, including any necessary reweighing, as soon after collection and equilibration as practical. Thus, it may be impossible to have lot sizes of more than 10 or 20 exposed filters. The procedure is as follows.

1 Select randomly and reweigh four re-equilibrated filters out of every group of 50 or less. (This would mean 100 percent checking if four or fewer exposed filters were weighed at one time). For groups of 50 to 100, reweigh 7 from each group These suggested starting frequencies may be altered, based on experience and data quality Decrease the frequency if past experience indicates that the data are of good quality, or increase it if the data are of poor quality. It is more important to be sure that the sample is representative of the various conditions that may influence data quality than to adhere to a fixed frequency
2 Reweigh all filters in a lot if any audit weight differs by more than ±5 0 mg from the original weight.
3 Accept the lot with no change if all audits are within ±5 0 mg of the originals
4 Record the original and the audit weights in milligrams (mg) on an $\bar{X}$-and-R chart (Figure 8 1). Plot the difference (d), defined as

$$d = \text{original weight} - \text{audit weight}. \qquad \text{Equation 8-1}$$

Tentative warning and control limits of ±3 3 and ±5 0 mg, respectively, are recommended until sufficient data are obtained to support an alteration of these limits Out-of-control points indicate the need for recalibration of the balance and/or improved operator technique Do not increase the limits, however, more stringent limits may be established if experience warrants
5 Forward the $\bar{X}$-and-R chart to the supervisor for review
6. Reweigh all of the remaining exposed filters in the lot if the balance requires recalibration or the operation technique is changed

8.1.3 *Audit of Data Processing* - For convenience, the data processing should be audited soon after the original calculations have been performed This allows corrections to be made immediately. This also allows for possible retrieval of additional explanatory data from field personnel when necessary The procedure is as follows

1. Use the audit rate of Subsection 8 1 2
2. Starting with the raw data on the data form or on the flow rate recorder chart, independently compute the concentration (in μg TSP/m^3) and compare it with the corresponding concentration reported on the SAROAD form. If the mass concentration computed by the audit check $(\mu g\ TSP/m^3)_a$ does not agree (within round-off error) with the original

$\bar{X}$ and R Chart

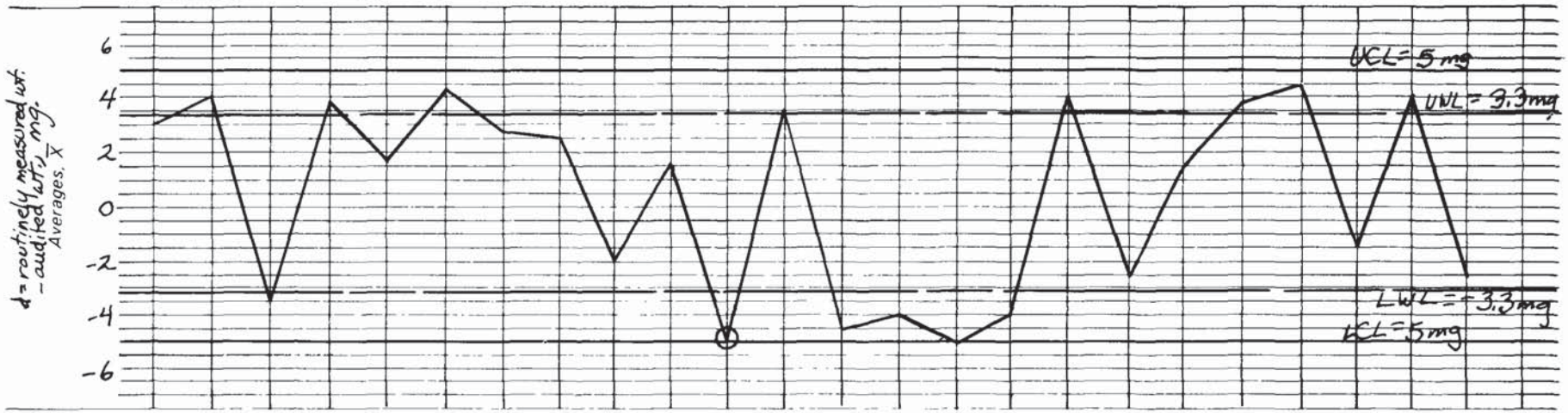
Project Name: Audits of weights of exposed filters

Measurement Performed: d = routinely measured weight − audited weight (mg)

Measurement Units: mg

original weight
audit weight

Data	T6	1/1	1/8	1/15	1/22	1/29	2/5	2/12	2/19	2/26	3/4	3/11	3/18	3/25	4/1	4/8	4/15	4/22	4/29	5/6	5/13	5/20	5/27	6/3	6/10
Measurement Code 1		LOT 1 →								LOT 2 →								LOT 3 →							
Measurement Result 1		3812.7	3710.2	3873.9	3744.7	3971.5	3804.0	3867.0	3740.7	3903.0	3763.6	3798.6	4253.7	4089.9	3868.0	3709.8	3962.9	3799.9	4275.4	4225.2	3905.9	3755.1	3982.4	3788.2	4255.1
Measurement Result 2		3815.5	3706.9	3877.7	3741.0	3969.7	3799.6	3864.1	3738.0	3905.1	3762.0	3804.6	4257.3	4094.3	3864.0	3704.9	3946.7	3795.6	4279.2	4223.9	3902.2	3758.9	3983.9	3784.0	4258.2
Measurement Result 3																									
Sum																									
Average, $\bar{X}$																									
d ~~Range, R~~		3.2	3.8	-3.8	3.7	1.8	4.4	2.9	2.7	-2.1	1.6	-5.4	3.6	-4.4	4.0	4.9	-3.9	4.3	-2.8	1.3	3.7	4.5	-1.5	4.2	-3.1



Ranges, R

Comments (Correct Action etc.)

Reweigh all filters in LOT 2

Figure 8.1 Quality control chart for audit of weights of exposed filters.

value (μg TSP/m^3)$_m$, recheck all samples in the lot and correct them as necessary.

3. Record the audit values in the data log, 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.

8.2 Systems Audit

A systems audit is an on-site inspection and review of the quality of the total measurement system (sample collection, sample analysis, data processing, etc.), and it is normally a qualitative appraisal. The procedure is as follows:

1. Conduct a systems audit on receipt of a new monitoring system and as appropriate thereafter to audit possible degradation or significant changes in system operation.
2. Use the preliminary checklist given in Figure 8.2. Check the questions for applicability to the particular local, State, or Federal agency.

See Sections 2.0.11 and 2.0.12 of this volume for detailed procedures and forms for systems audits and performance audits, respectively.

Table 8.2. *Activity Matrix for Auditing Procedure*

Audit	*Acceptance limits*	*Frequency and method of measurement*	*Action if requirements are not met*
Flow rate	*Percentage difference,* $d = \frac{Y - X}{X} 100$ *within* $\pm 7\%$	*Once each quarter*	*Recalibrate before resuming sampling.*
Exposed filter reweighing	*Audit weight = original weight* ± 5 *mg*	*Perform 7 audits/100 filters, or 4 audits/*$\leq$*50 filters; use analytical balance, condition filters for 24 h before weighing.*	*Reweigh all filters in the lot*
Data processing	*Audit concentration agrees with original reported concentration within round-off error*	*Independently repeat calculation of TSP concentration from data record for 7 samples per 100 (minimum of 4 per lot)*	*Recheck all calculations.*
Systems	*Method described in this section of the Handbook*	*At beginning of a new monitoring system and periodically as appropriate, observe procedures and use checklist.*	*Initiate improved methods and/or training programs.*

Checklist for Use by Auditor for Hi-Vol Method

1 *What type of hi-vol samplers are used in the network?* _____

_____

2 *How often are the samplers run? (a) daily (b) once every 6 days (c) once every 12 days (d) other* _____

3 *What type of filter and how many are being used?* _____

_____

4 *Are there any preexposure checks for pin holes or imperfections run on the filters?* _____

5 *What is the collection efficiency for your filters?* _____

6 *What is the calibration procedure for the hi-vol sampler?* _____

_____

7 *Which statement most closely estimates the frequency of flow rate calibration? (a) once when purchased (b) once when purchased, then after every sampler modification (c) when purchased, then at regular intervals thereafter* _____

8 *Are flow rates measured before and after the sampling period?*

Yes _____ *No* _____

9 *Is there a log book for each sampler for recording flows and times? Yes* _____ *No* _____

10 *Are filters conditioned before initial and final weighings?* _____ *If so, for how long?* _____ *At what percentage humidity?* _____

11 *Is the balance checked periodically?* _____ *If so, how often?* _____ *With which standard weights?* _____

12 *How often are the hi-vol filters weighed?* _____

How are the data from these weighings handled? _____

_____

13 *Are all weighings and serial numbers of filters kept in a log book at the laboratory?* _____

14 *What is the approximate time delay between sample collection and the final weighing?* _____ *days*

Figure 8.2. *Example of simplified checklist for use by auditor for hi-vol method*

9.0 Assessment of Monitoring Data for Precision and Accuracy

9.1 Precision

For each monitoring network, collocate an additional sampler at a minimum of one site (two sites are required for SLAMS[4]) as follows

1 Select a site with the highest expected geometric mean concentrations.
2 Locate the two high volume samplers within 4 m of each other, but at least 2 m apart to preclude air flow interference.
3 Identify one of the two samplers at the time of installation as the sampler for normal routine monitoring, identify the other as the duplicate sampler
4. Be sure that the calibration, sampling, and analysis procedure are the same for the collocated sampler as for all other samplers in the network
5 Operate a collocated sampler whenever its associated routine sampler is operated.
6 Use the differences in the concentrations (+g TSP/std m^3) between the routine and duplicate samplers to calculate the precision as described in Section 2 0 8 of this Handbook.

Based on the results of a collaborative test,[5] percent difference (Equation 8-1 of Section 2 0 8) should not exceed ³15% * An example calculation is given in Section 2.0 8 of this Handbook

9.2 Accuracy

The accuracy of the high-volume method for measurement of TSP is assessed by auditing certain portions of the measurement process, as described in Section 2.2.8 The calculation procedure for single instrument accuracy is given in Section 2.0 8 of this volume of the Handbook

*This ³15% is calculated at the 99 7 probability interval This means that if the two samplers do agree, chances are less than 3 out of 1000 that a difference larger than 15% will be observed

10.0 Recommended Standards for Establishing Traceability

For data of the desired quality to be achieved, two considerations are essential: (1) the measurement process must be in a state of statistical control at the time of the measurement, and (2) the combination of systematic errors and random variation (measurement errors) must yield a suitably small uncertainty. Evidence of good-quality data requires the performance of quality control checks and independent audits of the measurement process; documentation of the data on a quality control chart; and the use of materials, instruments, and measurement procedures that can be traced to an appropriate performance standard

Data must be routinely obtained by repeating measurements of Standard Reference samples (primary, secondary, and/or working standards), and a condition of process control must be established. The working calibration standards should be traceable to standards of higher accuracy, such as those listed here.

10.1 Recommended Standards for Establishing Traceability

1 Class-S weights of NBS specifications are recommended for the analytical balance calibration. See Subsection 2.1 for details on balance calibration checks.

2. A positive displacement rootsmeter is recommended for calibrating the flow rate transfer standard that is used to calibrate the high-volume sampler. See Subsection 2.6 for details on high-volume sampler calibration.

3. A positive displacement rootsmeter (including a resistance plate) is recommended for calibrating the device used to audit the high-volume-sampler flow-rate calibration. See Subsection 8.1 for details on flow-rate calibration audits.

4. The elapsed-time meter, checked semiannually against an accurate timepiece, must be within ± 2 min/day.

11.0 Reference Method*

Appendix B—Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)

1.0 Applicability.

1.1 This method provides a measurement of the mass concentration of total suspended particulate matter (TSP) in ambient air for determining compliance with the primary and secondary national ambient air quality standards for particulate matter as specified in § 50 6 and § 50.7 of this chapter. The measurement process is nondestructive, and the size of the sample collected is usually adequate for subsequent chemical analysis Quality assurance procedures and guidance are provided in Part 58, Appendixes A and B, of this chapter and in References 1 and 2

2.0 Principle.

2.1 An air sampler, properly located at the measurement site, draws a measured quantity of ambient air into a covered housing and through a filter during a 24-hr (nominal) sampling period The sampler flow rate and the geometry of the shelter favor the collection of particles up to 25-50 +m (aerodynamic diameter), depending on wind speed and direction (3) The filters used are specified to have a minimum collection efficiency of 99 percent for 0 3 +m (DOP) particles (see Section 7 1 4)

2.2 The filter is weighed (after moisture equilibration) before and after use to determine the net weight (mass) gain The total volume of air sampled, corrected to EPA standard conditions (25°C, 760 mm Hg [101 kPa]), is determined from the measured flow rate and the sampling time. The concentration of total suspended particulate matter in the ambient air is computed as the mass of collected particles divided by the volume of air sampled, corrected to standard conditions, and is expressed in micrograms per standard cubic meter (+g/std m³) For samples collected at temperatures and pressures significantly different than standard conditions, these corrected concentrations may differ substantially from actual concentrations (micrograms per actual cubic meter), particularly at high elevations The actual particulate matter concentration can be calculated from the corrected concentration using the actual temperature and pressure during the sampling period

3.0 Range.

3.1 The approximate concentration range of the method is 2 to 750 +g/std m³ The upper limit is determined by the point at which the sampler can no longer maintain the specified flow rate due to the increased pressure drop of the loaded filter This point is affected by particle size distribution, moisture content of the collected particles, and variability from filter to filter, among other things The lower limit is determined by the sensitivity of the balance (see Section 7 10) and by inherent sources of error (see Section 6)

3.2 At wind speeds between 1 3 and 4 5 m/sec (3 and 10 mph), the high-volume air sampler has been found to collect particles up to 25 to 50 +m, depending on wind speed and direction (3) For the filter specified in Section 7 1, there is effectively no lower limit on the particle size collected

4.0 Precision.

4.1 Based upon collaborative testing the relative standard deviation (coefficient of variation) for single analyst precision (repeatability) of the method is 3 0 percent. The corresponding value for interlaboratory precision (reproducibility) is 3 7 percent. (4)

5.0 Accuracy.

5.1 The absolute accuracy of the method is undefined because of the complex nature of atmospheric particulate matter and the difficulty in determining the "true" particulate matter concentration This method provides a measure of particulate matter concentration suitable for the purpose specified under Section 1 0. Applicability.

6.0 Inherent Sources of Error.

6.1 *Airflow variation.* The weight of material collected on the filter represents the (integrated) sum of the product of the instantaneous flow rate times the instantaneous particle concentration Therefore, dividing this weight by the average flow rate over the sampling period yields the true particulate matter concentration only when the flow rate is constant over the period The error resulting from a nonconstant flow rate depends on the magnitude of the instantaneous changes in the flow rate and in the particulate matter concentration Normally, such errors are not large, but they can be greatly reduced by equipping the sampler with an automatic flow controlling mechanism that maintains constant flow during the sampling period Use of a constant flow controller is recommended *

6.2 *Air volume measurement* If the flow rate changes substantially or nonuniformly during the sampling period, appreciable error in the estimated air volume may result from using the average of the presampling and postsampling flow rates Greater air volume measurement accuracy may be achieved by (1) equipping the sampler with a flow controlling mechanism that maintains constant air flow during the sampling period,* (2) using a calibrated, continuous flow rate recording device to record the actual flow rate during the sampling period and integrating the flow rate over the period, or (3) any other means that will accurately measure the total air volume sampled during the sampling period. Use of a continuous flow recorder is recommended, particularly if the sampler is not equipped with a constant flow controller

6.3 *Loss of volatiles.* Volatile particles collected on the filter may be lost during subsequent sampling or during shipment and/or storage of the filter prior to the postsampling weighing (5) Although such losses are largely unavoidable, the filter should be reweighed as soon after sampling as practical.

6.4 *Artifact particulate matter.* Artifact particulate matter can be

*Reproduced from 40 CFR 50, Appendix B, as amended, December 6, 1982 (47 FR 54912)

formed on the surface of alkaline glass fiber filters by oxidation of acid gases in the sample air, resulting in a higher than true TSP determination. (6, 7) This effect usually occurs early in the sample period and is a function of the filter pH and the presence of acid gases It is generally believed to account for only a small percentage of the filter weight gain, but the effect may become more significant where relatively small particulate weights are collected.

6.5 *Humidity.* Glass fiber filters are comparatively insensitive to changes in relative humidity, but collected particulate matter can be hygroscopic. (8) The moisture conditioning procedure minimizes but may not completely eliminate error due to moisture.

6.6 *Filter handling.* Careful handling of the filter between the presampling and postsampling weighings is necessary to avoid errors due to loss of fibers or particles from the filter. A filter paper cartridge or cassette used to protect the filter can minimize handling errors. (See Reference 2, Section 2).

6.7 *Nonsampled particulate matter.* Particulate matter may be deposited on the filter by wind during periods when the sampler is inoperative. (9) It is recommended that errors from this source be minimized by an automatic mechanical device that keeps the filter covered during nonsampling periods, or by timely installation and retrieval of filters to minimize the nonsampling periods prior to and following operation.

6.8 *Timing errors.* Samplers are normally controlled by clock timers set to start and stop the sampler at midnight. Errors in the nominal 1,440-min sampling period may result from a power interruption during the sampling period or from a discrepancy between the start or stop time recorded on the filter information record and the actual start or stop time of the sampler. Such discrepancies may be caused by (1) poor resolution of the timer set-points, (2) timer error due to power interruption, (3) missetting of the timer, or (4) timer malfunction. In general, digital electronic timers have much better set-point resolution than mechanical timers, but require a battery backup system to maintain continuity of operation after a power interruption. A continuous flow recorder or elapsed time meter provides an indication of the sampler run-time, as well as indication of any power interruption during the sampling period and is therefore recommended.

6.9 *Recirculation of sampler exhaust.* Under stagnant wind conditions, sampler exhaust air can be resampled. This effect does not appear to affect the TSP measurement substantially, but may result in increased carbon and copper in the collected sample. (10) This problem can be reduced by ducting the exhaust air well away, preferably downwind, from the sampler.

7.0 Apparatus.

(See References 1 and 2 for quality assurance information.)

Note.—Samplers purchased prior to the effective date of this amendment are not subject to specifications preceded by (†).

7.1 *Filter.* (Filters supplied by the Environmental Protection Agency can be assumed to meet the following criteria. Additional specifications are required if the sample is to be analyzed chemically.)

7.1.1 Size. 20.3 ± 0 2 x 25.4 ± 0.2 cm (nominal 8 x10 in).

7.1.2 Nominal exposed area: 406.5 cm^3 (63 in^2).

7.1.3 Material Glass fiber or other relatively inert, nonhygroscopic material. (8)

7.1.4 Collection efficiency: 99 percent minimum as measured by the DOP test (ASTM-2986) for particles of 0.3 μm diameter.

7.1.5 Recommended pressure drop range· 42-54 mm Hg (5.6-7.2 kPa) at a flow rate of 1.5 std m^3/min through the nominal exposed area.

7.1.6 pH: 6 to 10. (11)

7.1.7 Integrity: 2.4 mg maximum weight loss. (11)

7.1.8 Pinholes: None.

7.1.9 Tear strength: 500 g minimum for 20 mm wide strip cut from filter in weakest dimension. (See ASTM Test D828-60).

7.1.10 Brittleness: No cracks or material separations after single lengthwise crease.

7.2 *Sampler.* The air sampler shall provide means for drawing the air sample, via reduced pressure, through the filter at a uniform face velocity.

7.2.1 The sampler shall have suitable means to:

a. Hold and seal the filter to the sampler housing.
b. Allow the filter to be changed conveniently.
c. Preclude leaks that would cause error in the measurement of the air volume passing through the filter.
d. (†)Manually adjust the flow rate to accommodate variations in filter pressure drop and site line voltage and altitude The adjustment may be accomplished by an automatic flow controller or by a manual flow adjustment device Any manual adjustment device must be designed with positive detents or other means to avoid unintentional changes in the setting.

7.2.2 *Minimum sample flow rate, heavily loaded filter:* 1.1 m^3/min (39 ft^3/min).††

7.2.3 *Maximum sample flow rate, clean filter:* 1.7 m^3/min (60 ft^3/min).††

7.2.4 Blower Motor: The motor must be capable of continuous operation for 24-hr periods.

7.3 *Sampler shelter.*

7.3.1 The sampler shelter shall·

a. Maintain the filter in a horizontal position at least 1 m above the sampler supporting surface so that sample air is drawn downward through the filter.
b. Be rectangular in shape with a gabled roof, similar to the design shown in Figure 1.
c. Cover and protect the filter and sampler from precipitation and other weather.
d. Discharge exhaust air at least 40 cm from the sample air inlet.
e. Be designed to minimize the collection of dust from the supporting surface by incorporating a baffle between the exhaust outlet and the supporting surface.

*At elevated altitudes, the effectiveness of automatic flow controllers may be reduced because of a reduction in the maximum sampler flow

(†) See note at beginning of Section 7

††These specifications are in actual air volume units to convert to EPA standard air volume units, multiply the specifications by (P_b/P_{std}) $(298/T)$ where P_b and T are the barometric pressure in mm Hg (or kPa) and the temperature in K at the sampler, and P_{std} is 760 mm Hg (or 101 kPa)

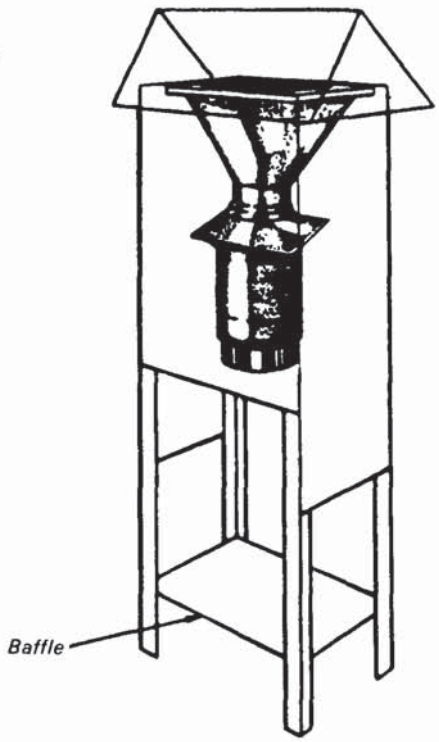


Figure 1. *High-volume sampler in shelter*

7.3.2 The sampler cover or roof shall overhang the sampler housing somewhat, as shown in Figure 1, and shall be mounted so as to form an air inlet gap between the cover and the sampler housing walls †This sample air inlet should be approximately uniform on all sides of the sampler. †The area of the sample air inlet must be sized to provide an effective particle capture air velocity of between 20 and 35 cm/sec at the recommended operational flow rate. The capture velocity is the sample air flow rate divided by the inlet area measured in a horizontal plane at the lower edge of the cover. †Ideally, the inlet area and operational flow rate should be selected to obtain a capture air velocity of 25 ±2 cm/sec

7.4 *Flow rate measurement devices.*

7.4.1 The sampler shall incorporate a flow rate measurement device capable of indicating the total sampler flow rate. Two common types of flow indicators covered in the calibration procedure are (1) an electronic mass flowmeter and (2) an orifice or orifices located in the sample air stream together with a suitable pressure indicator such as a manometer, or aneroid pressure gauge. A pressure recorder may be used with an orifice to provide a continuous record of the flow Other types of flow indicators (including rotameters) having comparable precision and accuracy are also acceptable.

7.4.2 †The flow rate measurement device must be capable of being calibrated and read in units corresponding to a flow rate which is readable to the nearest 0.02 std m^3/min over the range 1.0 to 1.8 std m^3/min

7.5 *Thermometer,* to indicate the approximate air temperature at the flow rate measurement orifice, when temperature corrections are used.

7.5.1 Range: -40° to +50°C (223-323 K).

7.5.2 Resolution: 2° C (2 K).

7.6 *Barometer,* to indicate barometric pressure at the flow rate measurement orifice, when pressure corrections are used

7.6.1 Range: 500 to 800 mm Hg (66-106 kPa).

7.6.2 Resolution: ±5 mm Hg (0.67 kPa).

7.7 *Timing/control device.*

7.7.1 The timing device must be capable of starting and stopping the sampler to obtain an elapsed run-time of 24 hr ±1 hr (1,440 ±60 min).

7.7.2 Accuracy of time setting: ±30 min, or better. (See Section 6 8).

7.8 *Flow rate transfer standard,* traceable to a primary standard. (See Section 9.2).

7.8.1 Approximate range: 1.0 to 1.8 m^3/min.

7.8.2 Resolution: 0.02 m^3/min.

7.8.3 Reproducibility: ±2 percent (2 times coefficient of variation) over normal ranges of ambient temperature and pressure for the stated flow rate range. (See Reference 2, Section 2.)

7.8.4 Maximum pressure drop at 1.7 std m^3/min; 50 cm H_2O (5 kPa).

7.8.5 The flow rate transfer standard must connect without leaks to the inlet of the sampler and measure the flow rate of the total air sample

[Corrected by 48 FR 17355, April 22, 1983]

7.8.6 The flow rate transfer standard must include a means to vary the sampler flow rate over the range of 1.0 to 1.8 m^3/min (35-64 ft^3/min) by introducing various levels of flow resistance between the sampler and the transfer standard inlet.

7.8.7 The Conventional type of flow transfer standard consists of: An orifice unit with adapter that connects to the inlet of the sampler, a manometer or other device to measure orifice pressure drop, a means to vary the flow through the sampler unit, a thermometer to measure the ambient temperature, and a barometer to measure ambient pressure Two such devices are shown in Figures 2a and 2b. Figure 2a shows multiple fixed resistance plates, which necessitate disassembly of the unit each time the flow resistance is changed. A preferable design, illustrated in Figure 2b, has a variable flow restriction that can be adjusted externally without disassembly of the unit. Use of conventional, orifice-type transfer standard is assumed in the calibration procedure (Section 9). However, the use of other types of transfer standards meeting the above specifications, such as the one shown in Figure 2c, may be approved; see the note following Section 9.1.

7.9 *Filter conditioning environment*

7.9.1 Controlled temperature: between 15° and 30° C with less than ±3° C variation during equilibration period.
[Corrected by 48 FR 17355, April 22, 1983]

7.9.2 Controlled humidity: Less than 50 percent relative humidity, constant within ±5 percent.

7.10 *Analytical balance.*

7.10.1 Sensitivity: 0.1 mg.

7.10.2 Weighing chamber designed to accept an unfolded 20.3 x 25.4 cm (8 x 10 in) filter.

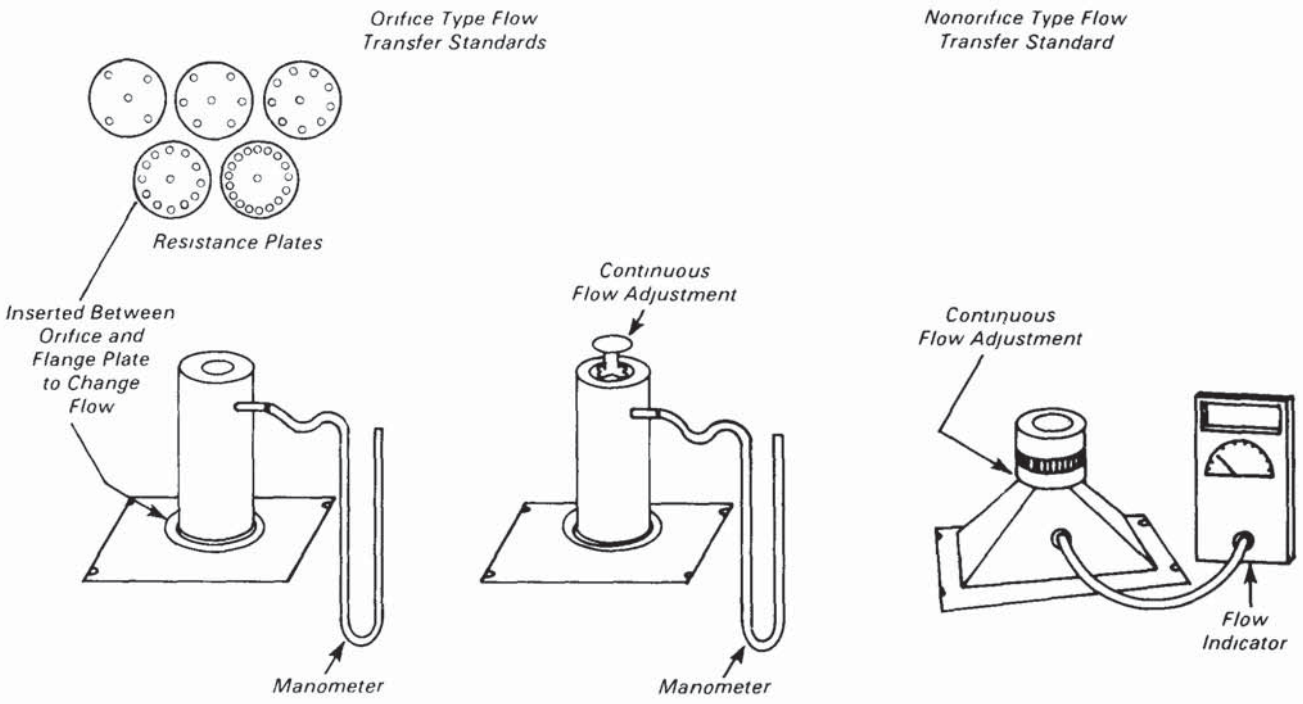
7.11 *Area light source,* similar to X-ray film viewer, to backlight filters for visual inspection.

7.12 *Numbering device,* capable of printing identification numbers on the filters before they are placed in the filter conditioning environment, if not numbered by the supplier.

8.0 Procedure.

(See References 1 and 2 for quality assurance information.)

8.1 Number each filter, if not already numbered, near its edge with a unique identification number.



2a Orifice Unit Using Fixed Resistance Plates

2b Preferable Orifice Unit with Externally Adjustable Resistance.

2c Electronic Flowmeter with Externally Adjustable Resistance.

Figure 2. *Various types of flow transfer standards Note that all devices are designed to mount to the filter inlet area of the sampler*

8.2 Backlight each filter and inspect for pinholes, particles, and other imperfections; filters with visible imperfections must not be used.

8.3 Equilibrate each filter in the conditioning environment for at least 24-hr

8.4 Following equilibration, weigh each filter to the nearest milligram and record this tare weight (W_i) with the filter identification number

8.5 Do not bend or fold the filter before collection of the sample

8.6 Open the shelter and install a numbered, preweighted filter in the sampler, following the sampler manufacturer's instructions During inclement weather, precautions must be taken while changing filters to prevent damage to the clean filter and loss of sample from or damage to the exposed filter Filter cassettes that can be loaded and unloaded in the laboratory may be used to minimize this problem (See Section 6.6). [Corrected by 48 FR 17355, April 22, 1983]

8.7 Close the shelter and run the sampler for at least 5 min to establish run-temperature conditions.

8.8 Record the flow indicator reading and, if needed, the barometric pressure (P_3) and the ambient temperature (T_a) see NOTE following step 8 12). Stop the sampler Determine the sampler flow rate (see Section 10 1); if it is outside the acceptable range (1.1 to 1.7 m^3/min [39-60 ft^3/min]), use a different filter, or adjust the sampler flow rate Warning Substantial flow adjustments may affect the calibration of the orifice-type flow indicators and may necessitate recalibration.

8.9 Record the sampler identification information (filter number, site location or identification number, sample date, and starting time)

8.10 Set the timer to start and stop the sampler such that the sampler runs 24-hrs from midnight to midnight (local time).

8.11 As soon as practical following the sampling period, run the sampler for at least 5 min to again establish run-temperature conditions.

8.12 Record the flow indicator reading and, if needed, the barometric Pressure (P_a) and the ambient temperature (T_a).

Note.—No onsite pressure or temperature measurements are necessary if the sampler flow indicator does not require pressure or temperature corrections (e.g., a mass flowmeter) or if average barometric pressure and seasonal average temperature for the site are incorporated into the sampler calibration (see step 9.3.9). For individual pressure and temperature corrections, the ambient pressure and temperature can be obtained by onsite 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 sampler site and the airport. For samplers having flow recorders but not constant flow controllers, the average temperature and pressure at the site during the sampling period should be estimated from weather bureau or other available data.

8.13 Stop the sampler and carefully remove the filter, following the sampler manufacturer's instructions.

Touch only the outer edges of the filter. See the precautions in step 8.6.

8.14 Fold the filter in half lengthwise so that only surfaces with collected particulate matter are in contact and place it in the filter holder (glassine envelope or manila folder).

8.15 Record the ending time or elapsed time on the filter information record, either from the stop set-point time, from an elapsed time indicator, or from a continuous flow record. The sample period must be 1,440 ± 60 min. for a valid sample.

8.16 Record on the filter information record any other factors, such as meteorological conditions, construction activity, fires or dust storms, etc., that might be pertinent to the measurement. If the sample is known to be defective, void it at this time.

8.17 Equilibrate the exposed filter in the conditioning environment for at least 24-hrs.

8.18 Immediately after equilibration, reweigh the filter to the nearest milligram and record the gross weight with the filter identification number. See Section 10 for TSP concentration calculations.

9.0 Calibration.

9.1 Calibration of the high volume sampler's flow indicating or control device is necessary to establish traceability of the field measurement to a primary standard via a flow rate transfer standard. Figure 3a illustrates the certification of the flow rate transfer standard and Figure 3b illustrates its use in calibrating a sampler flow indicator. Determination of the corrected flow rate from the sampler flow indicator, illustrated in Figure 3c, is addressed in Section 10.1.

Note.—The following calibration procedure applies to a conventional orifice-type flow transfer standard and an orifice-type flow indicator in the sampler (the most common types). For samplers using a pressure recorder having a square-root scale, 3 other acceptable calibration procedures are provided in Reference 12. Other types of transfer standards may be used if the manufacturer or user provides an appropriately modified calibration procedure that has been approved by EPA under Section 2.8 of Appendix C to Part 58 of this chapter.

9.2 *Certification of the flow rate transfer standard.*

9.2.1 *Equipment required:* Positive displacement standard volume meter traceable to the National Bureau of Standards (such as a Roots meter or equivalent), stop-watch, manometer, thermometer, and barometer

9.2.2 Connect the flow rate transfer standard to the inlet of the standard volume meter. Connect the manometer to measure the pressure at the inlet of the standard volume meter. Connect the orifice manometer to the pressure tap on the transfer standard. Connect a high-volume air pump (such as a high-volume sampler blower) to the outlet side of the standard volume meter. See Figure 3a.

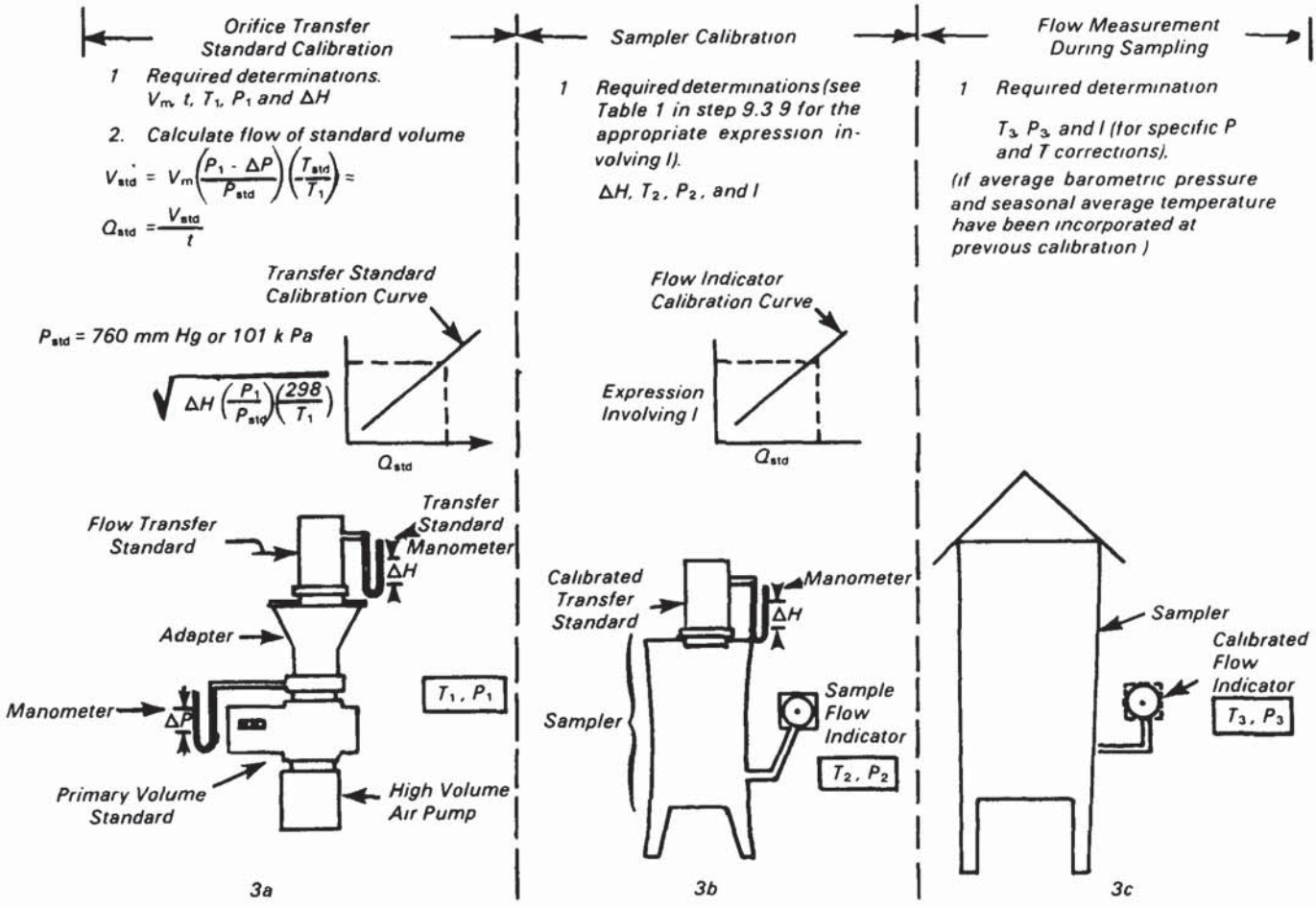


Figure 3. *Illustration of the 3 steps in the flow measurement process.*

9.2.3 Check for leaks by temporarily clamping both manometer lines (to avoid fluid loss) and blocking the orifice with a large-diameter rubber stopper, wide cellophane tape, or other suitable means. Start the high-volume air pump and note any change in the standard volume meter reading. 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.

9.2.4 After satisfactorily completing the leak check as described above, unclamp both manometer lines and zero both manometers.

9.2.5. Achieve the appropriate flow rate through the system, either by means of the variable flow resistance in the transfer standard or by varying the voltage to the air pump. (Use of resistance plates as shown in Figure 1a is discouraged because the above leak check must be repeated each time a new resistance plate is installed.) At least five different but constant flow rates, even distributed, with at least three in the specified flow rate interval (1.1 to 1.7 m^3/min [39-60 ft^3/min]), are required.

9.2.6 Measure and record the certification data on a form similar to the one illustrated in Figure 4 according to the following steps.

9.2.7 Observe the barometric pressure and record as P_1 (item 8 in Figure 4).

9.2.8 Read the ambient temperature in the vicinity of the standard volume meter and record it as T_1 (item 9 in Figure 4).

9.2.9 Start the blower motor, adjust the flow, and allow the system to run for at least 1 min for a constant motor speed to be attained.

9.2.10 Observe the standard volume meter reading and simultaneously start a stopwatch. Record the initial meter reading (V_i) in column 1 of Figure 4.

9.2.11 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 inlet pressure manometer reading as ΔP (column 5 in Figure 4), and the orifice manometer reading as ΔH (column 7 in Figure 4). Be sure to indicate the correct units of measurement.

9.2.12 After at least 3 m^3 of air have passed through the system, observe the standard volume meter reading while simultaneously stopping the stopwatch. Record the final meter reading (V_f) in column 2 and the elapsed time (t) in column 3 of Figure 4.

9.2.13 Calculate the volume measured by the standard volume meter at meter conditions of temperature and pressures as $V_m = V_f - V_i$. Record in column 4 of Figure 4.

9.2.14 Correct this volume to standard volume (std m^3) as follows:

$$V_{std} = V_m \frac{P_1 - \Delta P}{P_{std}} \frac{T_{std}}{T_1}$$

where:

V_{std} = standard volume, std m^2;
V_m = actual volume measured by the standard volume meter;
P_1 = barometric pressure during calibration, mm Hg or kPa;
ΔP = differential pressure at inlet to volume meter, mm Hg or kPa;
P_{std} = 760 mm Hg or 101 kPa;
T_{std} = 298 K;
T_1 = ambient temperature during calibration, K.

Calculate the standard flow rate (std m^3/min) as follows:

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

where:

Q_{std} = standard volumetric flow rate, std m^3/min
t = elapsed time, minutes.

Record Q_{std} to the nearest 0.01 std m^3/min in column 6 of Figure 4.

9.2.15 Repeat steps 9.2.9 through 9.2.14 for at least four additional constant flow rates, evenly spaced over the approximate range of 1.0 to 1.8 std m^3/min (35-64 ft^3/min).

9.2.16 For each flow, compute

$$\sqrt{\Delta H\,(P_1/P_{std})\,(298/T_1)}$$

(column 7a of Figure 4) and plot these values against Q_{std} as shown in Figure 3a. Be sure to use consistent units (mm Hg or kPa) for barometric pressure. Draw the orifice transfer standard certification curve or calculate the linear least squares slope (m) and intercept (b) of the certification curve:

$$\sqrt{\Delta H\,(P_1/P_{std})\,(298/T_1)}$$

$= m\,Q_{std} + b$. See Figures 3 and 4. A certification graph should be readable to 0.02 std m^3/min.

9.2.17 Recalibrate the transfer standard annually or as required by applicable quality control procedures. (See Reference 2.)

9.3 *Calibration of sampler flow indicator.*

Note.—For samplers equipped with a flow controlling device, the flow controller must be disabled to allow flow changes during calibration of the sampler's flow indicator, or the alternate calibration of the flow controller given in 9.4 may be used. For samplers using an orifice-type flow indicator downstream of the motor, do not vary the flow rate by adjusting the voltage or power supplied to the sampler.

9.3.1 A form similar to the one illustrated in Figure 5 should be used to record the calibration data

9.3.2 Connect the transfer standard to the inlet of the sampler. Connect the orifice manometer to the orifice pressure tap, as illustrated in Figure 3b. Make sure there are no leaks between the orifice unit and the sampler.

9.3.3 Operate the sampler for at least 5 minutes to establish thermal equilibrium prior to the calibration.

9.3.4 Measure and record the ambient temperature, T_2, and the barometric pressure, P_2, during calibration.

9.3.5 Adjust the variable resistance or, if applicable, insert the appropriate resistance plate (or no plate) to achieve the desired flow rate.

9.3.6 Let the sampler run for at least 2 min to re-establish the run-temperature conditions. Read and record the pressure drop across the orifice (ΔH) and the sampler flow rate indication (I) in the appropriate columns of Figure 5.

9.3.7 Calculate

$$\sqrt{\Delta H(P_2/P_{std})\,(298/T_2)}$$

and determine the flow rate at standard conditions (Q_{std}) either graphically from the certification curve or by calculating Q_{std} from the least square slope and intercept of the transfer standard's transposed certification curve:

$$Q_{std} = 1/m\,\sqrt{\Delta H(P_2/P_{std})\,(298/T_2)} - b.$$

Record the value of Q_{std} on Figure 5. [Corrected by 48 FR 17355, April 22, 1983]

9.3.8 Repeat steps 9.3.5, 9.3.6, and 9.3.7 for several additional flow rates distributed over a range that includes 1.1 to 1.7 std m^3/min.

9.3.9 Determine the calibration curve by plotting values of the

Orifice Transfer Standard Certification Worksheet

	1	2	3	4	5	6	7	7a
Run No	Meter reading start V_i (m^3)	Meter reading stop V_f (m^3)	Elapsed time t (min)	Volume measured V_m (m^3)	Differential pressure (at inlet to volume meter) ΔP (mm Hg or in.)	(X) Flow rate Q_{std} (std m^3 min)	Pressure drop across orifice ΔH ☐ (in) or ☐ (cm) of water	$\Delta H \left(\frac{(Y)}{\frac{P_1}{P_{std}}}\right) \frac{298}{T_1}$
1								
2								
3								
4								
5								
6								

Recorded Calibration Data

Standard volume meter No _____

Transfer standard type ☐ orifice ☐ other

Model No _____ Serial No _____

(8) P_1 _____ mm Hg (or in.) (10) P_{std} 760 mm Hg (or 29.92 in.)

(9) T_1 _____ K (11) T_{std} 298 K

By _____

Date _____

Calculation Equations

(1) $V_m = V_f - V_i$

(2) $V_{std} = V_m \left(\frac{P_1 - \Delta P}{P_{std}}\right)\left(\frac{T_{std}}{T_1}\right)$

(3) $Q_{std} = \frac{V_{std}}{t}$

Least Squares Calculations

linear ($Y = mX + b$) regression equation of $Y = \sqrt{\Delta H (P_1/P_{std})(298/T_1)}$ on $X = Q_{std}$ for Orifice Calibration Unit (i.e., $\sqrt{\Delta H(P_1/P_{std})(298/T_1)} = mQ_{std} + b$)

Slope (m) = _____ Intercept (b) = _____ Correlation coefficient (r) = _____

To use for subsequent calibration $X = \frac{1}{m}(Y - b)$, $Q_{std} = \frac{1}{m}\left[\sqrt{\Delta H \left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)} - b\right]$

Figure 4. Example of orifice transfer standard certification worksheet

High-Volume Air Sampler Calibration Worksheet

Site location: _____

Date: _____ *(1) Barometric pressure, P_2 mm Hg (or in.)* _____

Calibrated by: _____ *(2) Temperature, T_2 (K)* _____

Sampler No. _____ *Serial No.* _____

Transfer std. type _____ *Serial No* _____

Optional. P_{std} = 760 mm Hg (or 29.92 in.) *Average barometric pressure* P_a = _____ *Seasonal average temperature* T_a = _____					5 (Y)	
					For specific pressure and temperature corrections (see Table 2-1)	*For incorporation of average pressure and seasonal average temperature (see Table 2-1)*
					☐ 1 or ☐ $\sqrt{1\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$ or ☐ $1/\sqrt{\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	☐ 1 or ☐ $\sqrt{1\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$ or ☐ $1/\sqrt{\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$
No	*1 ΔH Pressure drop across orifice (in) or (cm)*	$\sqrt{\Delta H\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	*(X) 3 Q_{std} (from orifice certification std m^3/min*	*4 I Sampler flow rate indication (arbitrary)*		
1	2.2	1.501	0.750	20.0	20.236	
2	3.7	1.946	0.975	28.0	28.330	
3	5.3	2.329	1.155	34.0	34.401	
4	7.1	2.696	1.330	39.0	39.460	
5	8.5	2.950	1.455	43.0	43.507	
6	12.0	3.505	1.725	51.7	52.301	

Least Aquares Calculations

Linear regression of Y on X $Y = mX + b$, *Y = appropriate expression from Table 2-1,* $X = Q_{std}$

Slope (m) = _____ *Intercept (b) =* _____ *Correlation Coefficient (r) =* _____

To determine subsequent flow rate during use $X = 1/m\,(Y-b)$ | $Q_{std} = 1/m$ ([appropriate expression from Table 2] - b)

Figure 5. *Example of high-volume air sampler calibration worksheet.*

appropriate expression involving I, selected from Table 1, against Q_{std}. The choice of expression from Table 1 depends on the flow rate measurement device used (see Section 7.4.1) and also on whether the calibration curve is to incorporate geographic average barometric pressure (P_a) and seasonal average temperature (T_a) for the site to approximate actual pressure and temperature. Where P_a and T_a can be determined for a site for a seasonal period such that the actual barometric pressure and temperature at the site do not vary by more than ±60 mm Hg (8 kPa) from P_a or ±15° C from T_a respectively, then using P_a and T_a avoids the need for subsequent pressure and temperature calculation when the sampler is used. The geographic average barometric pressure (P_a) may be estimated from an altitude-pressure table or by making an (approximate) elevation correction of — 26 mm Hg (— 3.46 kPa) for each 305 m (1,000 ft) above sea level (760 mm Hg or 101 kPa). The seasonal average temperature (T_a) may be estimated from weather station or other records. Be sure to use consistent units (mm Hg or kPa) for barometric pressure.
[Corrected by 48 FR 17355, April 22, 1983]

9.3.10 Draw the sampler calibration curve or calculate the linear least squares slope (m), intercept (b), and correlation coefficient of the calibration curve: [Expression from Table 1] = m Q_{std} + b. See Figures 3 and 5. Calibration curves should be readable to 0.02 std m^3/min

9.3.11 For a sampler equipped with a flow controller, the flow controlling mechanism should be re-enabled and set to a flow near the lower flow limit to allow maximum control range. The sample flow rate should be verified at this time with a clean filter installed. Then add two or more filters to the sampler to see if the flow controller maintains a constant flow; this is particularly important at high altitudes where the range of the flow controller may be reduced

9.4 Alternate calibration of flow-controlled samplers. A flow-controlled sampler may be calibrated solely at its controlled flow rate, provided that previous operating history of the sampler demonstrates that the flow rate is stable and reliable In this case, the flow indicator may remain uncalibrated but should be used to indicate any relative change between initial and final flows, and the sampler should be recalibrated more often to minimize potential loss of samples because of controller malfunction

9.4.1 Set the flow controller for a flow near the lower limit of the flow range to allow maximum control range

9.4.2 Install a clean filter in the sampler and carry out steps 9.3.2, 9.3.3, 9.3.4, 9.3.6, and 9 3.7.

9.4.3 Following calibration, add one or two additional clean filters to the sampler, reconnect the transfer standard, and operate the sampler to verify that the controller maintains the same calibrated flow rate; this is particularly important at high altitudes where the flow control range may be reduced

10.0 Calculations of TSP Concentration

10.1 Determine the average sampler flow rate during the sampling period according to either 10.1.1 or 10 1 2 below.

10.1.1 For a sampler without a continuous flow recorder, determine the appropriate expression to be used from Table 2 corresponding to the one from Table 1 used in step 9.3 9 Using this appropriate expression, determine Q_{std} for the initial flow rate from the sampler calibration curve either graphically or from the transposed regression equation

$Q_{std} = \frac{1}{m}$ ([Appropriate expression from Table 2]—b)

Similarly, determine Q_{std} from the final flow reading and calculate the average flow Q_{std} as one-half the sum of the initial and final flow rates.

10.1.2 For a sampler with a continuous flow recorder, determine the average flow rate device reading, I, for the period. Determine the appropriate expression from Table 2 corresponding to the one from Table 1 used in step 9.3.9 Then using this expression and the average flow rate reading, determine Q_{std} from the sampler calibration curve, either graphically or from the transposed regression equation

$Q_{std} = \frac{1}{m}$ ([Appropriate expression from Table 2]—b)

If the trace shows substantial flow change during the sampling period, greater accuracy may be achieved by dividing the sampling period into intervals and calculating an average reading before determining Q_{std}.

10.2 Calculate the total air volume sampled as.

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

where:

V = total air volume sampled, in standard volume units, std m^3/;
Q_{std} = average standard flow rate, std m^3/min,
t = sampling time, min.

[Corrected by 48 FR 17355, April 22, 1983]

10.3 Calculate and report the particulate matter concentration as:

$$TSP = \frac{(W_f - W_i) \times 10^6}{V}$$

where:

TSP = mass concentration of total suspended particulate matter, μg/std m^3;
W_i = initial weight of clean filter, g;
W_f = final weight of exposed filter, g
V = air volume sampled, converted to standard conditions, std m^3
10^6 = conversion of g to μg

10.4 If desired, the actual particulate matter concentration (see Section 2.2) can be calculated as follows:

$$(TSP)_a = TSP\ (P_3/P_{std})\ (298/T_3)$$

Table 1. *Expressions for Plotting Sampler Calibration Curves*

Type of sampler flow rate measuring device	*Expression*	
	For actual pressure and temperature corrections	*For incorporation of geographic average pressure and seasonal average temperature*
Mass flowmeter	I	I
*Orifice and *pressure indicator*	$\sqrt{I\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	$\sqrt{I\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$
Rotameter, or orifice and pressure recorder having square root scale[a]	$I\sqrt{\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	$I\sqrt{\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$

**This scale is recognizable by its nonuniform divisions and is the most commonly available for high-volume samplers.*

Table 2. *Expressions for Determining Flow Rate During Sampler Operation*

Type of sampler flow rate measuring device	Expression: For actual pressure and temperature corrections	Expression: For use when geographic average pressure and seasonal average temperature have been incorporated into the sampler calibration
Mass flowmeter	I	I
Orifice and pressure indicator	$\sqrt{I\left(\frac{P_3}{P_{std}}\right)\left(\frac{298}{T_3}\right)}$	I
Rotameter, or orifice and pressure recorder having square root scale*	$I\sqrt{\left(\frac{P_3}{P_{std}}\right)\left(\frac{298}{T_3}\right)}$	I

*This scale is recognizable by its nonuniform divisions and is the most commonly available for high-volume samplers.

where

$(TSP)_a$ = actual concentration at field conditions, $\mu g/m^3$;

TSP = concentration at standard conditions, $\mu g/std\ m^3$;

P_3 = average barometric pressure during sampling period, mm Hg;

P_{std} = 760 mm Hg (or 101 kPa);

T_3 = average ambient temperature during sampling period, K.

11.0 References.

1. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I. Principles. EPA-600/9-76-005. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1976.

2. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Specific Methods. EPA-600/4-77-027a. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1977.

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12.0 References

1. 40 CFR 50, Appendix B, as amended December 6, 1982 (47 FR 54912).
2. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume I, Principles. EPA-600/9-76-005, March 1976.
3. 40 CFR 58, Appendix B.
4. 40 CFR 58, Appendix A.
5. McKee, H.C., et al. Collaborative Study of Reference Method for the Determination of Suspended Particulates in the Atmosphere (Hi-Vol Method). PB 205-891, June 1971.

13.0 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, but the usual section-page documentation in the top right-hand corner of each page has been replaced with a number in the lower right-hand corner that will enable the user to identify and refer to a similar filled-in form in a text section For example, Form TSP-1 1 indicates that the form is Figure 1.1 of the TSP method description. Any future revisions of these forms can be documented as 1.1A, 1.1B, etc The following data forms are included in this section·

Form	Title
1.1	Procurement Log
2.3	Timer Calibration Log
2.4	Orifice Transfer Standard Certification Work Sheet
2 8	High-Volume Sampler Calibration Work Sheet
3.1	Laboratory Log for Total Suspended Particulate Data
3.2	Hi-Vol Field Data Form
4.6	Quality Control Chart
6.1	SAROAD Daily Data Form
8.2	Checklist for Use by Auditor for Hi-Vol Method

Procurement Log

Item description	Quantity	Purchase order number	Vendor	Date		Cost	Disposition	Comments
				Ordered	Received			

Time Calibration Log

Site location number	Timer number	Date		Elapsed-time indicator serial number	Test period	Elapsed-time indicator reading	Accuracy	Technician (signature)
		Start	Stop					

Orifice Transfer Standard Certification Worksheet

	1	2	3	4	5	6	7	7a
Run No	Meter reading start V_i (m^3)	Meter reading stop V_f (m^3)	Elapsed time t (min)	Volume measured V_m (m^3)	Differential pressure (at inlet to volume meter) ΔP (mm Hg or in.)	(X) Flow rate Q_{std} (std m^3 min)	Pressure drop across orifice ΔH ☐ (in) or ☐ (cm) of water	$\Delta H \left(\frac{(Y)}{\frac{P_1}{P_{std}}}\right) \frac{298}{T_1}$
1								
2								
3								
4								
5								
6								

Recorded Calibration Data

Standard volume meter No _____

Transfer standard type ☐ orifice ☐ other

Model No _____ Serial No _____

(8) P_1 _____ mm Hg (or in.) (10) P_{std} 760 mm Hg (or 29.92 in.)

(9) T_1 _____ K (11) T_{std} 298 K

By. _____

Date _____

Calculation Equations

(1) $V_m = V_f - V_i$

(2) $V_{std} = V_m \left(\frac{P_1 - \Delta P}{P_{std}}\right)\left(\frac{T_{std}}{T_1}\right)$

(3) $Q_{std} = \frac{V_{std}}{t}$

Least Squares Calculations

linear ($Y = mX + b$) regression equation of $Y = \sqrt{\Delta H (P_1/P_{std})(298/T_1)}$ on $X = Q_{std}$ for Orifice Calibration Unit (i.e., $\sqrt{\Delta H(P_1/P_{std})(298/T_1)} = mQ_{std} + b$)

Slope (m) = _____ Intercept (b) = _____ Correlation coefficient (r) = _____

To use for subsequent calibration $X = \frac{1}{m}(Y-b)$,

$$Q_{std} = \frac{1}{m}\left[\sqrt{\Delta H \left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)} - b\right]$$

High-Volume Air Sampler Calibration Worksheet

Site location: _____

Date: _____ (1) Barometric pressure, P_2 mm Hg (or in.) _____

Calibrated by _____ (2) Temperature, T_2 (K) _____

Sampler No. _____ Serial No. _____

Transfer std. type. _____ Serial No. _____

Optional: P_{std} = 760 mm Hg (or 29.92 in.)

Average barometric pressure: P_a = _____

Seasonal average temperature: T_a = _____

No	1 ΔH Pressure drop across orifice (in) or (cm)	$\sqrt{\Delta H \left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	(X) 3 Q_{std} (from orifice certification std m^3/min	4 I Sampler flow rate indication (arbitrary)	5 (Y) For specific pressure and temperature corrections (see Table 2 1) ☐ I or ☐ $\sqrt{I\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$ or ☐ $I\sqrt{\left(\frac{P_2}{P_{std}}\right)\left(\frac{298}{T_2}\right)}$	5 (Y) For incorporation of average pressure and seasonal average temperature (see Table 2 1) ☐ I or ☐ $\sqrt{I\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$ or ☐ $I\sqrt{\left(\frac{P_2}{P_a}\right)\left(\frac{T_a}{T_2}\right)}$
1						
2						
3						
4						
5						
6						

Least Aquares Calculations

Linear regression of Y on X: $Y = mX + b$, Y = appropriate expression from Table 2 1, $X = Q_{std}$

Slope (m) = _____ Intercept (b) = _____ Correlation Coefficient (r) = _____

To determine subsequent flow rate during use: $X = 1/m\,(Y-b)$ | $Q_{std} = 1/m$ [appropriate expression from Table 2] - b]

Laboratory Log for Total Suspended Particulate Data

City Name _____

Site Address _____ State Area Site

Project _____ The Interval _____ Project Time Year

Instrument Last Calibrated _____
Sampler Identification No _____

Total Suspended Particulate

Name Parameter Code

Sampling Date Month	Day	ST NR	Conc µg/m³	Filter Number	Average* CFM	Sampling Time	Air m³ Volume	Cross WCT	Tare WCT	Net WCT.	Remarks

*From Average Flow Determined from Calibration

Laboratory Functions

Filter Preparation

- Filter must be free of pinholes, tears, creases, lumps, etc
- Filter must be properly equilibrated (20 hrs <time<28 hrs, humidity <50%)
  (Δ Humidity ± 5% Δ Temp ± 3°C)
- Balance must be checked before weighing (STD. WGT 3 to 5 g ±0 0005 g)

Sampling Analysis

- Sample must be free or evidence of malfunction, ten or fewer insects in sample
- Filter must be properly equilibrated (see above)
- Balance must be checked before weighing (see above)

All samples were handled in accordance with the above guidelines

_____
Signature

Hi-Vol Data Record

Project _____

Station _____

_____

_____

Site and/or Sampler No _____

Saroad Site Code

Sample Date _____

Filter No. _____

Flow Reading initial _____

final _____

Average Flow Rate _____

Running Time Meter initial _____

final _____

Total Sampler Time _____ *min*

Total Air Volume _____ *std m³*

Net TSP Weight _____ *g*

TSP Concentration _____ *µg/std m³*

Optional

	Temperature	*Barometric Pressure*
initial	_____	_____
final	_____	_____
average	_____	_____

Operator _____

Comments _____

_____

_____

_____

_____

_____

$\overline{X}$ and R Chart

Project Name _____ Measurement _____ Measurement Performed _____ Measurement Units _____

Data																										
Measurement	Code	1																								
		2																								
		3																								
	Result	1																								
		2																								
		3																								
Sum																										
Average, $\overline{X}$																										
Range, R																										

Averages, $\overline{X}$

Ranges, R

Comments (Correct Action, etc.)