Appendix 5

Supplementary Material for Chapter 5

Part A
Method P
Appendix A

Method P

AMBIENT AIR ANALYSIS METHOD FOR DETERMINING AMBIENT ATMOSPHERIC CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER NOMINALLY 10 MICROMETERS OR LESS IN AERODYNAMIC DIAMETER (PM10)

1. Principle and Applicability

1.1 Principle

A sampler draws a known quantity of ambient air through an inlet, which is designed to admit specified proportions of particles as a function of their aerodynamic diameter. The inlet is designed to mimic the deposition of particulate matter in the human lung.

The particle collection characteristics of an ideal sampler, one which matches the human lung particle deposition characteristics, are outlined in 5.1.j. The particulate matter collected with such a sampler is referred to as a suspended particulate matter nominally 10 micrometers or less in aerodynamic diameter, or abbreviated as PM10.

As does the human lung, the ideal sampler collects a declining fraction of particles as their diameter increases and an increasing fraction of particles as their diameter decreases. For example, as can be seen in 5.1.j., all particles less than 1.0 $\mu m$ in diameter are collected and no particles of 16 or more $\mu m$ in diameter are collected.

In the ideal sampler, the PM10 passes through the inlet and is collected on a filter. The net weight (mass) of particulate matter deposited on the filter is determined as the difference in filter weight before and after sampling. The concentration of PM10 is reported as mass of particulate collected per cubic meter of air sampled (micrograms per cubic meter) at normal sea level temperature and pressure (760 torr., 25 $^\circ$C).

1.2 Applicability

This method provides for the measurement in ambient air of the concentration of PM10 over a 24-hour period. The measurement process is nondestructive and the sample can be subjected to subsequent physical and chemical analyses.

2. Range

The lower limit of the mass concentration range is limited by the repeatability of filter tare weights, assuming the nominal air sample volume for the sampler. The upper range limit is determined by the point at which the sampler can no longer maintain the required flow. This limit is a complex function of particle type and size distribution which is not readily quantifiable.

3. Interferences

3.1 Loss of Volatile Particles

Volatile particles collected on filter material can be lost during shipment and/or storage of the filters. Filters should therefore be reweighed as soon as possible.
3.2 Artifact Particulate Matter

Filters that meet the alkalinity specifications (Section 6, paragraph 6.4) show little or no artifact sulfate. Loss of true nitrate is dependent on location and temperature, but for most locations, the errors are expected to be small.

4. Precision and Accuracy

4.1 Precision

The reproducibility of PM10 samplers must be within \( \pm 15 \) percent of true value at the 95 percent confidence level, as assessed by collocation of samplers.

4.2 Accuracy

Sample accuracy is dependent on sampling effectiveness, flow measurement, and calibration. Sampling effectiveness is expressed as the ratio of the mass concentration of particles of a given size reaching the sample filter to the mass concentration of particles of the same size approaching the sampler. The particle size for 50 percent effectiveness is required to be \( 10 \pm 1 \) micrometers.

5. Apparatus and Specifications

5.1 PM10 Sampler

The sampler shall be designed to:

a. draw the air sample, via reduced internal pressure, into the sampler inlet and through the filter at a uniform face velocity.

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

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

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

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

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

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

h. provide uniform distribution of particulate matter on the filter media such that the deposition on the four quadrants shall agree within 5 percent.
The sampler shall operate at a controlled flow rate specified by its designer or manufacturer, and it shall have an inlet system that provides particle size discrimination characteristics meeting all of the specifications in this document. The sampler inlet shall show no significant wind direction dependence. This requirement can generally be satisfied by an inlet shape that is circularly symmetrical about a vertical axis.

The sampler shall provide a means to measure the total flow rate during the sampling period. A continuous flow recorder is recommended. The sampler may be equipped with additional flow measurement devices if it is designed to collect more than one particle size fraction.

The sampler shall have an automatic flow control device capable of adjusting and maintaining the sample flow rate within ±10 percent for the sampler inlet over normal variations in line voltage and filter pressure drop. A convenient means must be provided to temporarily disable the automatic flow control device to allow calibration of the sampler’s flow measurement device.

A timing/control device capable of starting and stopping the sampler shall be used to obtain an elapsed run time of 24 ±1 hour (1440 ± 60 minutes). An elapsed time meter, accurate to within 15 minutes, shall be used to measure sampling time. This meter is optional for samplers with continuous flow recorders if the sampling time measurement obtained by means of the recorder meets the ±15-minute accuracy specifications.

The sampler shall have an associated operation or instruction manual.

Since proper service and maintenance is critical to obtaining valid data, the user should adopt adequate and documented standard operating procedures.

5.2 The PM10 sampler shall meet the following criteria for sampling effectiveness at windspeeds from 2 to 24 kilometers per hour:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Particles</td>
<td>Expected mass concentration is within ±10 percent of that predicted by the ideal sampler.</td>
</tr>
<tr>
<td>Solid Particles</td>
<td>Expected mass concentration no more than 5 percent above that obtained for liquid particles of the same size.</td>
</tr>
<tr>
<td>50 Percent Cutpoint</td>
<td>10 ± 1 Fm aerodynamic diameter</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>15 percent coefficient of variation for three collocated samplers.</td>
</tr>
</tbody>
</table>
The sampling effectiveness of the ideal sampler is:

<table>
<thead>
<tr>
<th>Particle Size (Fm)</th>
<th>Sampling Effectiveness</th>
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<tr>
<td>&lt; 1.0</td>
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<td>0.159</td>
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<tr>
<td>15.0</td>
<td>0.041</td>
</tr>
<tr>
<td>≥ 16.0</td>
<td>0.000</td>
</tr>
</tbody>
</table>

6. Filters

6.1 Filter Medium

No commercially available filter medium is ideal in all respects for all samplers. The user's goals in sampling determine the relative importance of various filter evaluation criteria (e.g., cost, ease of handling, physical and chemical characteristics, etc.) and consequently determine the choice among acceptable filters. Furthermore, certain types of filters may not be suitable for use with some samplers, particularly under heavy loading conditions (high mass concentrations), because of high or rapid increase in the filter flow resistance that would exceed the capability of the sampler's automatic flow controller. The specifications given below are minimum requirements to insure acceptability of the filter medium for measurement of PM10 mass concentrations.

6.2 Collection Efficiency

Greater than 99 percent as measured by DOP test (ASTM-2986) with 0.3 Fm particles at the sampler's operating face velocity.

6.3 Integrity

±5 Fg/m³ (assuming sampler's nominal 24-hour air sample volume), measured as the concentration equivalent corresponding to the difference between the initial and final weights of the filter when weighed and handled under simulated sampling conditions (equilibration, initial weighing, placement on inoperative sampler, removal from sampler, re-equilibration, and final weighing).
6.4 Alkalinity

<0.005 milliequivalents/gram of filter as measured by ASTM-D202, following at least two months storage at ambient temperature and relative humidity.

7. Procedure

7.1 The sampler shall be operated in accordance with the general instructions given here and with the specific instructions provided in the sampler manufacturer’s instruction manual.

Note: This procedure assumes that the sampler’s flow rate calibration was performed using flow rates at ambient conditions (Qₐ).

7.2 Inspect each filter for pinholes, particles, and other imperfections; establish a filter information record and assign an identification number to each filter. Careful handling of filters between preweighing and post-sampling is necessary to avoid errors due to damaged filters or loss of particulate.

7.3 Equilibrate each filter in the conditioning environment for at least 24 hours.

Filter Conditioning Environment

a. Temperature range: 15 to 30°C
b. Temperature control: ±3°C
c. Humidity: less than 50 percent relative humidity

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

7.5 Analytical Balance

The analytical balance must be suitable for weighing the type and size of filters required by the sampler. The range and sensitivity required will depend on the filter tare weight and mass loading. Typically, an analytical balance with a sensitivity of 0.1 mg is required for high volume SSI samplers (flow rates > 0.5 m³/min).

7.6 Pre-Run Procedure

a. Air Sample Report – Prior to each run, record on the Air Sample Report: the reporting agency, station address, station name, instrument number and county, site, agency, and project codes. Figure P-1 shows an example of the Air Sample Report form.

b. Clean Filter Installation – the clean particulate filter is placed on the sampler and secured in place.
c. Flow Setting – The actual flow rate must be maintained as specified by the manufacturer in order to maintain the 10 Fm cutpoint of the inlet. This will require special care at elevations greater than 1000 feet above sea level in order to prevent errors due to reduced atmospheric density.

d. Elapsed Time Meter – Record the initial elapsed time meter reading on the Monthly Check Sheet.

7.7 Post-Run Procedure

a. Final Flow Meter Reading – Before removing the filter and flow chart, make sure that the recorder trace shows the final flow. If not, the sampler must be started to determine the final flow.

Remove the flow chart from the recorder and examine the trace for abnormalities. Note and investigate any abrupt changes in air flow. If the start and finish air flows are not representative of your geographic area, note this on the Air Sample Report under “Remarks”.

b. Exposed Filter Removal – Grasp the exposed filter without touching the darkened area. Fold it in half width-wise with the darkened side in. A satisfactory filter is one which has a uniform white border. Dark streaks into the border may indicate an air leak, which invalidates the sample. If there are insects on the filter, remove them carefully. Note on the Air Sample Report if the filter is torn or ruptured, if the start or finish times are not known, or if the flows are outside the specified range.

Note: A removable filter cartridge may be loaded and unloaded at the station operator’s headquarters to avoid contamination and damage to the filter media.

c. Timer and Elapsed Time Meter Check – After each run, check how long the sampler ran by reading the elapsed time meter. Record the final elapsed time meter (ETM) reading. These ETM readings are used in calculating the concentration of collected particulates as they are more accurate than the time or flow chart times. Adjust the timers to meet the timer acceptance limits of 24 hours ± 15 minutes.

7.8 Equilibration

Equilibrate the exposed filter(s) in the conditioning environment for 24 hours and immediately after equilibration reweigh the filter(s) and record the weight(s) with the filter identification number(s).

8. Calibration

The Size Selective Inlet High Volume Sampler (SSI) is calibrated by establishing that the air sample velocity is designed to meet the particle deposition specifications given in Section 5 of this method. The SSI PM10 sampler is calibrated using an orifice transfer standard that has been standardized against a primary standard Roots meter. The orifice transfer standard is
referenced to 25EC and 760 mm Hg. Two different types of orifice calibrators are available. One type uses multihole adapter plates to vary the flow. The second type has an adjustable flow restrictor. In either case, the calibrator is connected to a differential pressure gauge or slack tube manometer. Pressure drops and indicated flow meter readings are recorded and corrected for elevation, as necessary. Using the pressure drops, the standard (true) flowrates are calculated using the certification equation for the transfer standard. Finally, a working sampler calibration curve of standard flowrate vs. indicated flowrate is plotted. The field calibration procedure assumes that:

- elevations below 1,000 feet are equivalent to standard conditions.
- the effect of temperature on the indicated flowrate is negligible and therefore, is not used in the determination of the standard flowrate.

8.1 Apparatus

a. Orifice Calibrator Transfer Standard with certification equation

   (1) A flow rate transfer standard, suitable for the flow rate of the sampler and calibrated against a primary standard that is traceable to NBS, must be used to calibrate the sampler’s flow measurement device.

   (2) The reproducibility and resolution of the transfer standard must be 2 percent or less of the sampler’s operating flow rate.

   (3) The flow rate transfer standard must include a means to vary the sampler flow rate during calibration of the sampler’s flow measurement device.

b. 0-20” differential pressure gauge or slack tube manometer

c. Tygon tubing for static pressure connections

d. Faceplate adapter with “C” clamps

e. Flow charts for continuous recorder

f. Calibration report forms

g. Plastic cap for constant volume sampler sensor

8.2 “As Is” Calibration

Other than routine daily checks, sampler repairs or adjustments (brush changes, motor replacement, flow recorder changes, etc.) should not be made prior to the “as is” calibration. The sampler should be calibrated after each 800 hours of operations, if the sampler is moved to a different site or if the initial flow meter reading falls outside of specified tolerance limits.
**Note:** Some samplers use a closed loop control system to provide constant blower speed and sampler flow. The flow sensor is located in the throat of the filter holder assembly. Before calibrating this type of sampler, first cover the flow sensor with a plastic cap. After calibrating, remove the cap.

a. Open the PM10 sampler shelter and remove the filter holder. Secure the faceplate adaptor and orifice calibrator; then, tighten down the orifice calibrator. If using a variable resistance calibrator, simply secure the calibrator to the faceplate adaptor and turn the restrictor control fully counterclockwise so that the maximum flow will be obtained. Connect a section of tygon tubing from the orifice tap on the calibrator to one leg of the manometer. Open the other leg so that it is open to the atmosphere. A schematic diagram of a typical sampler flow calibration is shown in Figure P-2.

b. After the sampler has warmed up, turn the motor off and then on and allow the static pressure (\(\Delta P\)) and indicated flow reading (Qind) to stabilize. Then, read the static pressure (\(\Delta P\)) and indicated flow readings (Qind). The static pressure is read as the total displacement, in inches, of the manometer water column. Record the static pressure and the indicated flow readings on the PM10 Sampler Calibration Data Sheet (see Figure P-4 as an example). Repeat this step twice so that a total of three test runs are performed.

c. Repeat Step b for each of the remaining four load plates. When using the variable resistance calibrator, select four additional points equally spaced around the setpoint determined in Section 7.6 (two points above and two points below; see example in Figure P-4).

d. Remove the orifice calibrator from the sampler. Measure the indicated flow with a clean filter installed in the PM10 sampler and record this value on the bottom of the Calibration Data Sheet.

e. On the left side of the Calibration Data Sheet, sum the \(\Delta P\) readings for each line (Runs 1-3) and record the sum under “SUM \(\Delta P\)”; then calculate and record the average \(\Delta P\) for each line (Points 1-5). On the right side of the data sheet, sum the Qind readings for each line (Runs 1-3) and record the sum under “SUM Qind”; then, calculate and record the average Qind for each line (Points 1-5).

f. Record the elevation of the sampler on the Calibration Data Sheet. If the elevation is less than 1,000 feet, no altitude correction is required. If the elevation is 1,000 feet or greater, apply an altitude correction factor.

g. Referring to the certification equation and using the corrected \(\Delta P\) values calculated in f., above (or average \(\Delta P\) values for locations less than 1,000 feet elevation), determine and record Qstd (transfer standard) for each point, where:

\[
Q_{std} = \text{Factor Corr} \ \Delta P
\]

h. Using the data from the Calibration Data Sheet, plot a Calibration Graph Qstd (transfer standard) vs. Qind. Draw a straight line through the plotted points, or, if facilities are available, obtain a linear regression computer plot.
This line represents the working sampler calibration graph for the particular sampler elevation. A sample plot is shown in Figure P-5.

i. Using the tabulated values of average Qind, determine Qprev (PM10 Sampler) by referring to the previous sampler calibration curve (Qstd vs. Qind). Find the appropriate value of Qprev from the y-axis corresponding to Qind on the X-axis. Record Qprev on the Calibration Data Sheet for each line (points 1-5).

j. Sum the column Qstd (transfer standard), tabulated on the left side of the Calibration Data Sheet. Record this sum as “S_1”.

k. Sum the Column Qprev (PM10 Sampler), determined in Step I; record this sum as “S_2”.

l. Calculate the percent deviation from previous calibration using the equation listed on the bottom of the Calibration Data Sheet. Record the result.

m. Using the sampler calibration graph, convert the clean filter indicated air flow rate to standard air flow rate and record the result on the bottom of the Calibration Data Sheet.

n. Complete a Calibration Report (see Figure P-3). A copy should be kept at the sampling site and in the operating organization’s headquarters file.

8.3 “Final” Calibration – A final calibration is required after specified maintenance is performed (brush changes, motor replacement, flow recorder changes), including maintenance to correct the average initial flow meter reading being out of tolerance, or to repeat a sampler calibration graph which is non-linear.

8.4 Blank Forms and Assistance – a sample copy of forms such as blank Calibration Data Sheets, as well as assistance in calibration procedures, can be obtained by contacting:

STATE OF CALIFORNIA
Air Resources Board
Aerometric Data Division
Quality Assurance Section
P.O. Box 2815
Sacramento, CA 95812

9. Calculations

9.1 Determine the average flow rate over the sampling period corrected to reference conditions as Q_{std}. 
9.2 Calculate the total volume of air sampled as:

\[ v = Q_{\text{std}} \times t \]

where:

- \( v \) = total air sampled in standard volume units, \( \text{std } m^3 \);
- \( t \) = sampling time, min.

9.3 Calculate the PM10 concentration as:

\[ \text{PM10} = \frac{(w_f - w_i) \times 10^6}{V} \]

Where:

- \( \text{PM10} \) = mass concentration of PM10, \( \text{ug/std } m^3 \);
- \( W_f \) \( W_i \) = final and initial weights of filter(s) Collecting PM10 particles, g;
- \( 10^6 \) = conversion of g to ug.
### 24-Hour Data Air Sample Report

**Station Address:** 7400 Sunrise Blvd  
**Station Name:** Citrus Heights  
**Station Code:** ARB

#### Sampling Conditions
- A: Regular Conditions
- B: Wind-Blown Sand/Dust
- C: Construction Nearby
- D: Ground Fires
- E: Air⑦ (Exposure is Repeated)

<table>
<thead>
<tr>
<th>Date</th>
<th>Flow Rate</th>
<th>Flow CK (CFM)</th>
<th>Filter Paper Weight (G/M2)</th>
<th>Card Col</th>
<th>Elapsed Time Meter (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>7505-75000</td>
<td>30.0</td>
<td>40.5</td>
<td>15-27</td>
<td>69,024.0</td>
</tr>
<tr>
<td>Finish</td>
<td>7505-752400</td>
<td>38.0</td>
<td>40.5</td>
<td>15-27</td>
<td>56,164.0</td>
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</table>

**24-Hour Average:** 38.0 | 40.5

#### Calculations

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<tr>
<th>Pollutant</th>
<th>Analysis Method</th>
<th>Units</th>
<th>Pollutant Code</th>
<th>Method</th>
<th>Analysis Value (mg/l)</th>
<th>Factor</th>
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<tbody>
<tr>
<td>1 PM2.5</td>
<td>SSI</td>
<td>μg/m³</td>
<td>8.1</td>
<td>10.1</td>
<td>0</td>
<td>1/3</td>
</tr>
<tr>
<td>2 Sulfate</td>
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<td>0</td>
<td></td>
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<td></td>
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<td></td>
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#### Notes

**California Air Resources Board**  
**Analysis:** Date 5/4/1975  
**Analyzer:** Date 5/4/1975  
**Lab Analyst:** Date 5/4/1975

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**Figure P-1**  
24-Hour Data Air Sample Report  
5 A-11
Figure P-2
PM10 Sampler Flow Calibration
CALIFORNIA AIR RESOURCES BOARD
CALIBRATION REPORT

TO:   
FROM:

IDENTIFICATION

| Instrument | Site Name |
| Model Number | Site Number |
| Property Number | Site |
| Serial Number | Location |
| Previous Calibration Log Number | Instrument Property of |
| Elevation | Site Temperature °C | Barometric Pressure "Hg |

CALIBRATION STANDARDS

<table>
<thead>
<tr>
<th>Standard</th>
<th>I.D. Number</th>
<th>Certification Date</th>
<th>Certified Value Or Factor</th>
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</table>

CALIBRATION RESULTS

<table>
<thead>
<tr>
<th>Component</th>
<th>Instrument Range, ppm</th>
<th>Initial Zero Setting</th>
<th>Initial Span Setting</th>
<th>Air Flow Rate, SLPM</th>
<th>Air Flow Setting</th>
<th>Reagent Flow Rate, SCLM</th>
<th>Reagent Flow Setting</th>
<th>Converter Efficiency</th>
<th>Best Fit Linear Regression Slope</th>
<th>(x = True; y = Intercept)</th>
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<tr>
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</tr>
</tbody>
</table>

"As is" Deviation from True
"Final" Deviation from True
Change from Previous Calibration, & (date)

Final Zero Setting
Final Span Setting

Comments

Calibrated By ____________________________
Date 12/18/84

Checked By ____________________________

Figure P-3
Calibration Report
Figure P-4
PM10 Sampler Calibration Data Sheet

<table>
<thead>
<tr>
<th>STATIC PRESSURE</th>
<th>SUM AP</th>
<th>AVG AP</th>
<th>COM A</th>
<th>Q3 SD</th>
<th>Q2</th>
<th>Q1</th>
<th>Q0</th>
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<td>2.4</td>
<td>1.8</td>
<td>90.0</td>
<td>84.0</td>
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</table>

Summation of Q3 (transfer standard), $S_3 = 200.0$

Summation of Q2 (sample), $S_2 = 198.5$

1. Corrected AP = Average AP x Altitude Correction Factor.
2. Q3 (transfer standard) is obtained from the certification equation listed above.
3. Q2 (high volume sampler) is obtained from the test sampler calibration curve (Q3 vs. Q2).

% Deviation from Previous Calibration = $\frac{S_2 - S_3}{S_3} \times 100 \times 19.85 = 0.8\%$

* Alt. Cor. Fac. = 1.001 x exp ( -0.000033 x Altitude, Feet) IF Altitude > 1000 Feet, Otherwise = 1.000 (Note: Alt. Cor. Fac. 5.7).

HI-Vol: Clean Filter: Indicated Flowrate = Standard Flowrate = SCFM (Set to 45 SCFM).
SSI: Clean Filter: Indicated Flowrate = 38.5 SCFM, Standard Flowrate = 40.1 SCFM, Actual CFM (Set to 45 Actual CFM).

For SSI Only: Actual CFM = SCFM Altitude Correction Factor.

Comments:

Calibrated by J. Houston
Checked by R. Cleary

ADD-XII (5/95)
Station Name: Citrus Heights
Station Site No.: 34-293
Sampler Property No.: 0597
Sampler Make and Model No.: GMW
Elevation: 250'

Date of Calibration: 2/20/85
"As Is" Calibration:
Final Calibration: ✔

Note: Curve good only for stated altitude of operation <600 feet.

COMMENTS:

Graph prepared by J. Hatson

ADD-43 (5/85)

Figure P-5
PM10 Sampler Calibration Graph
Appendix 5

Supplementary Material for Chapter 5

Part B
Appendix M to 40CFR, Part 50
The measurement process is nondestructive, and the secondary national ambient air quality standards for attainment and maintenance of the primary and secondary national ambient air quality standards for particulate matter specified in §50.6 of this chapter. The measurement process is nondestructive, and the PM₁₀ sample can be subjected to subsequent physical or chemical analyses. Quality assurance procedures and guidance are provided in part 58, Appendices A and B of this chapter and in references 1 and 2 of section 12.0 of this appendix.

2.0 Principle.

2.1 An air sampler draws ambient air at a constant flow rate into a specially shaped inlet where the suspended particulate matter is inertially separated into one or more size fractions within the PM₁₀ size range. Each size fraction in the PM₁₀ size range is then collected on a separate filter over the specified sampling period. The particle size discrimination characteristics (sampling effectiveness and 50 percent cutoff) of the sampler inlet are prescribed as performance specifications in part 53 of this chapter.

2.2 Each filter is weighed (after moisture equilibration) before and after use to determine the net weight (mass) gain due to collected PM₁₀. The total volume of air sampled, measured at the actual ambient temperature and pressure, is determined from the measured flow rate and the sampling time. The mass concentration of PM₁₀ in the ambient air is computed as the total mass of collected particles in the PM₁₀ size range divided by the volume of air sampled, and is expressed in micrograms per actual cubic meter (µg/m³).

2.3 A method based on this principle will be considered a reference method only if the associated sampler meets the requirements specified in this appendix and the requirements in part 53 of this chapter, and the method has been designated as a reference method in accordance with part 53 of this chapter.

3.0 Range.

3.1 The lower limit of the mass concentration range is determined by the repeatability of filter tare weights, assuming the nominal air sample volume for the sampler. For samplers having an automatic filter-changing mechanism, there may be no upper limit. For samplers that do not have an automatic filter-changing mechanism, the upper limit is determined by the filter mass loading beyond which the sampler no longer maintains the operating flow rate within specified limits due to increased pressure drop across the loaded filter. This upper limit cannot be specified precisely because it is a complex function of the ambient particle size distribution and type, humidity, filter type, and perhaps other factors. Nevertheless, all samplers should be capable of measuring 24-hour PM₁₀ mass concentrations of at least 300 µg/m³ while maintaining the operating flow rate within the specified limits.

3.2 Air Volume Determination.

7.0 Apparatus.

7.1 PM₁₀ Sampler.

7.1.1 The sampler shall be designed to:
(a) Draw the air sample into the sampler inlet and through the particle collection filter at a uniform face velocity.
(b) Hold and seal the filter in a horizontal position so that sample air is drawn downward through the filter.
(c) Allow the filter to be installed and removed conveniently.
(d) Protect the filter and sampler from precipitation and prevent insects and other debris from being sampled.
(e) Minimize air leaks that would cause error in the measurement of the air volume passing through the filter.

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

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

7.1.5 A timing/control device capable of starting and stopping the sampler shall be used to obtain a sample collection period of 24 ±1 hr (1,440 ±560 min). An elapsed time meter, accurate to within ±15 minutes, shall be used to measure sampling time. This meter is optional for samplers with continuous flow recorders if the sampling time measurement obtained by means of the recorder meets the ±15 minute accuracy specification.

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

7.2 Filters.

7.2.1 Filter Medium. No commercially available filter medium is ideal in all respects for all samplers. The user’s goals in sampling
determine the relative importance of various filter characteristics, e.g., cost, ease of handling, physical and chemical characteristics, etc., and, consequently, determine the choice among acceptable filters. Furthermore, certain types of filters may not be suitable for use with some sample filters. Flowing conditions (high mass concentrations), because of high or rapid increase in the filter flow resistance that would exceed the capability of the sampler’s flow control device. However, samplers equipped with automatic filter-changing mechanisms may allow use of these types of filters. The specifications given below are minimum requirements to ensure acceptability of the filter medium for measurement of PM10 mass concentrations. Other filter evaluation criteria should be considered to meet individual sampling and analysis objectives.

7.2.2 Collection Efficiency. ≥99 percent, as measured by the DOP test (ASTM–2986) with 0.3 μm particles at the sampler’s operating face velocity.

7.2.3 Integrity. ≤5 ±μg/cm² (assuming sampler’s nominal 24-hour air sample volume). Integrity is measured as the PM10 concentration equivalent corresponding to the average difference between the initial and the final weights of a random sample of test filters that were more or less under actual or simulated sampling conditions, but have no air sample passed through them, i.e., filter blanks. As a minimum, the test procedure must include initial equilibration and weighing, installation on an inoperative sampler, removal from the sampler, and final equilibration and weighing.

7.2.4 Alkalinity. <25 microequivalents/gram of filter, as measured by the procedure given in reference 13 of section 12.0 of this appendix following at least two months storage in a clean environment (free from contamination by acidic gases) at room temperature and humidity.

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

7.4 Filter Conditioning Environment.

7.4.1 Temperature range. 15 to 30 C.

7.4.2 Temperature control. ±3 C.

7.4.3 Humidity range. 20% to 45% RH.

7.4.4 Humidity control. ±5% RH.

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

8.0 Calibration.

8.1 General Requirements.

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

8.1.2 Particle size discrimination by inertial separation requires that specific air velocities be maintained in the sampler’s air inlet system. Therefore, the flow rate through the sampler’s inlet must be maintained throughout the sampling period within the design flow rate range specified by the manufacturer. Design flow rates are specified as actual volumetric flow rates, measured at existing conditions of temperature and pressure (Qa).

8.2 Flow Rate Calibration Procedure.

8.2.1 PM10 samplers employ various types of flow control and flow measurement devices. The specific procedure used for flow rate calibration or verification will vary depending on the size of the control and the type of flow controller employed. Calibration of Pm10 samplers is in terms of actual volumetric flow rates (Qa) to meet the requirements of section 8.1 of this appendix. The general procedure given here serves to illustrate the steps involved in the calibration. Consult the sampler manufacturer’s instruction manual and reference 2 of section 12.0 of this appendix for specific guidance on calibration.

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

8.2.3 Following the sampler manufacturer’s instruction manual, remove the sampler inlet and connect the flow rate transfer standard to the sampler such that the transfer standard accurately measures the sampler’s flow rate. Make sure there are no leaks between the transfer standard and the sampler.

8.2.4 Choose a minimum of three flow rates (actual m³/min), spaced over the acceptable flow rate range specified for the inlet, under section 7.1.2 of the appendix, that can be obtained by suitable adjustment of the sampler flow rate. In accordance with the sampler manufacturer’s instruction manual, obtain or verify the calibration relationship between the flow rate (actual m³/min) as indicated by the transfer standard and the sampler’s flow rate indicator response. Record the ambient temperature and barometric pressure. Temperature and pressure corrections to subsequent flow indicator readings may be required for certain types of flow measurement devices. When such corrections are necessary, correction on an individual or daily basis is preferable. However, seasonal average temperature and average barometric pressure for the sampling site may be incorporated into the sampler calibration to avoid daily corrections. Consult the sampler manufacturer’s instruction manual and reference 2 in section 12.0 of this appendix for additional guidance.

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

8.2.6 Replace the sampler inlet.

8.2.7 Record the sampler’s flow rate calibration is based on flow rate indicator readings may be required for certain types of flow measurement devices, that would exceed the capability of the sampler’s flow control device. However, samplers equipped with automatic filter-changing mechanisms may allow use of these types of filters. The specifications given below are minimum requirements to ensure acceptability of the filter medium for measurement of PM10 mass concentrations. Other filter evaluation criteria should be considered to meet individual sampling and analysis objectives.

8.2.8 Following calibration, weigh each filter and record the presampling weight with the filter identification number.

9.1 The sampler shall be operated in the conditioning environment (see 7.4) for at least 24 hours.

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

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

9.4 Install a preweighed filter in the sampler following the instructions provided in the sampler manufacturer’s instruction manual.

9.5 Record a flow rate (actual m³/min) in accordance with the instructions provided in the sampler manufacturer’s instruction manual.

Note: No onsite temperature or pressure measurements are necessary if the sampler’s flow indicator does not require temperature or pressure corrections or if seasonal average temperature and average barometric pressure for the sampling site are incorporated into the sampler calibration under section 8.2.4 of this appendix. If individual or daily temperature and pressure corrections are required, ambient temperature and barometric pressure can be obtained on-site measurements or from a nearby weather station. Barometric pressure readings obtained from airports must be station pressure, not corrected to sea level, and may need to be corrected for differences in elevation between the sampling site and the airport.

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

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

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

9.10 Sample for 24±1 hours.

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

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

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

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

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

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

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

10.1 The PM$_{10}$ sampler shall be maintained in strict accordance with the maintenance procedures specified in the sampler manufacturer’s instruction manual.

11.0 Calculations.

11.1 Calculate the total volume of air sampled as:

\[ V = \frac{Q_a t}{10^6} \]

where:

\( V \) = total air sampled, at ambient temperature and pressure, m$^3$;
\( Q_a \) = average sample flow rate at ambient temperature and pressure, m$^3$/min; and
\( t \) = sampling time, min.

11.2 (a) Calculate the PM$_{10}$ concentration as:

\[ \text{PM}_{10} = \frac{(W_f - W_i) \times 10^4}{V} \]

where:

\( W_f \) = final weight of filter;
\( W_i \) = initial weight of filter;
\( W_\text{f} \) = mass concentration of PM$_{10}$, µg/m$^3$;
\( W_\text{i} \) = final and initial weights of filter collecting PM$_{10}$ particles, g; and
\( 10^4 \) = conversion of g to µg.

(b) Note: If more than one size fraction in the PM$_{10}$ size range is collected by the sampler, the sum of the net weight gain by each collection filter \( \Sigma(W_f- W_i) \) is used to calculate the PM$_{10}$ mass concentration.

12.0 References.


8. Appendix N is added to read as follows:

Appendix N to Part 50—Interpretation of the National Ambient Air Quality Standards for Particulate Matter

1.0 General.

(a) This appendix explains the data handling conventions and computations necessary for determining when the annual and 24-hour primary and secondary national ambient air quality standards for PM specified in §50.7 of this chapter are met. Particulate matter is measured in the ambient air as PM$_{10}$ and PM$_{2.5}$ (particles with an aerodynamic diameter less than or equal to a nominal 10 and 2.5 micrometers, respectively) by a reference method based on Appendix M of this part for PM$_{10}$ and on Appendix L of this part for PM$_{2.5}$, as applicable, and designated in accordance with part 53 of this chapter.

(b) Data handling and computation procedures to be used in making comparisons between reported PM$_{10}$ and PM$_{2.5}$ concentrations and the levels of the PM standards are specified in the following sections.

(b) Data resulting from uncontrollable or natural events, for example structural fires or high winds, may require special consideration. In some cases, it may be appropriate to exclude these data because they could result in inappropriate values to compare with the annual PM standards. In other cases, it may be more appropriate to retain the data for comparison with the level of the PM standards and then allow the EPA to formulate the appropriate regulatory response. Whether to exclude, retain, or make adjustments to the data affected by uncontrollable or natural events is subject to the approval of the appropriate Regional Administrator.

(c) Situations may arise in which there are compelling reasons to retain years containing quarters which do not meet the data completeness requirements when at least 75 percent of the scheduled sampling days for each quarter have valid data. However, years with high concentrations and more than a minimal amount of data (at least 11 samples in each quarter) shall not be ignored just because they are comprised of quarters with less than complete data. Thus, in computing annual spatially averaged means, years containing quarters with at least 11 samples but less than 75 percent of data completeness shall be included in the computation if the resulting spatially averaged annual mean concentration (rounded according to the conventions of section 2.3 of this appendix) is greater than the level of the standard.

(d) The equations for calculating the 3-year average annual mean of the PM$_{2.5}$ standard are given in section 2.5 of this appendix.

(d) Sections 2.1 and 2.5 of this appendix contain data handling instructions for the option of using a spatially averaged network of monitors for the annual standard. If spatial averaging is not considered for an area, then the spatial average is equivalent to the annual average of a single site and is treated accordingly in subsequent calculations. For example, paragraph (a)(5) of section 2.1 of this appendix could be eliminated since the spatial average would be equivalent to the annual average.

2.0 Comparisons with the PM$_{2.5}$ Standards.

(a) The annual PM$_{2.5}$ standard is met when the 3-year average of the spatially averaged annual means is less than or equal to 15.0 µg/m$^3$. The 3-year average of the spatially averaged annual means is determined by averaging quarterly means at each monitor to obtain the annual mean PM$_{2.5}$ concentrations at each monitor, then averaging across all designated monitors, and finally averaging for 3 consecutive years. The steps can be summarized as follows:

(1) Average 24-hour measurements to obtain quarterly means at each monitor.
(2) Average quarterly means to obtain annual means at each monitor.
(3) Average across designated monitoring sites to obtain an annual spatial mean for an area (this can be one site in which case the spatial mean is equal to the annual mean).

(4) Average 3 years of annual spatial means to obtain a 3-year average of spatially averaged annual means.

(b) In the case of spatial averaging, 3 years of spatial averages are required to demonstrate that the standard has been met. Designated sites with less than 3 years of data shall be included in spatial averages for those years that data completeness requirements are met. For the annual PM$_{2.5}$ standard, a year meets data completeness requirements when at least 75 percent of the scheduled sampling days for each quarter have valid data. However, years with high concentrations and more than a minimal amount of data (at least 11 samples in each quarter) shall not be ignored just because they are comprised of quarters with less than complete data. Thus, in computing annual spatially averaged means, years containing quarters with at least 11 samples but less than 75 percent of data completeness shall be included in the computation if the resulting spatially averaged annual mean concentration (rounded according to the conventions of section 2.3 of this appendix) is greater than the level of the standard.
Appendix 5

Supplementary Material for Chapter 5

Part C
Table Comparing Method P (State Method) and the Federal Method (40CFR appendix M) for PM10 Samplers
Appendix C. Comparison of Method P (State Method) and the Federal method (40CFR appendix M) for PM10 samplers.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method P</th>
<th>40CFR part 50 Appendix M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Principle</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>1.2 Applicability</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>2.0 Range</td>
<td>The lower limit of the mass concentration range is limited by the repeat-ability of filter tare weights, assuming the nominal air sample volume for the sampler. The upper range limit is determined by the point at which the sampler can no longer maintain the required flow. This limit is a complex function of particle type and size distribution which is not readily quantifiable.</td>
<td>3.0 Should measure 24hr PM10 mass concentration of at least 300 ug/m3 while flow rate is within limits For samplers with auto filter changer, No upper limit.</td>
</tr>
<tr>
<td>3 Interferences</td>
<td>3.1 Loss of Volatile particles Volatile particles collected on filter material can be lost during shipment and/or storage of the filters. Filters should therefore be reweighed as soon as possible. 3.2 Artifact Particulate Matter, negative error, positive error (alkalinity of filters) Filters that meet the alkalinity specifications (Section 6, paragraph 6.4) show little or no artifact sulfate. Loss of true nitrate is dependent on location and temperature but for most locations the errors are expected to be small.</td>
<td>6.1 Volatile particles 6.2 Artifacts, negative and positive error (gas adsorption on PM) 6.3 Humidity 6.4 Filter handling 6.5 Flow rate variation 6.5 Air volume determination</td>
</tr>
<tr>
<td>4.1 Precision</td>
<td>Must be ± 15% of the true value at the 95 percent confidence level (collocated sampler)</td>
<td>4.0 Must be 5 ug/m3 for [PM10] below 80 ug/m3, 7 percent for [PM10] above 80 ug/m3 (collocated samplers)</td>
</tr>
<tr>
<td>4.2 Accuracy</td>
<td>Sample accuracy is dependent on sampling effectiveness, flow measurement and calibration. Sampling effectiveness is expressed as the ratio of the mass concentration of particles of a given size reaching the sample filter to the mass concentration of particles of the same size approaching the sampler. The particle size for 50 percent effectiveness is required to be 10 ± 1 micrometers.</td>
<td>5.0 sampling effectiveness 10 ± 0.5 um 8.2.2 Flow rate accuracy of PM10 sampler: Part 58</td>
</tr>
<tr>
<td>Parameter</td>
<td>Method P</td>
<td>40CFR 50 Appendix M</td>
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<tr>
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</tr>
<tr>
<td><strong>5.1 PM10 sampler shall have</strong></td>
<td>a. draw air sampler, via reduced internal pressure, into the sampler inlet and through the filter at a uniform face velocity&lt;br&gt;b. hold and seal the filter in horizontal position so that sample air drawn downward through the filter&lt;br&gt;c. allow the filter to be installed and removed conveniently&lt;br&gt;d. protect the filter and sampler from precipitation and prevent insect and other debris from being sampled&lt;br&gt;e. minimize leaks&lt;br&gt;f. discharge exhaust air….&lt;br&gt;g. minimize the collection….&lt;br&gt;h. provide uniform distribution …</td>
<td>Section 7.1.1 Identical</td>
</tr>
<tr>
<td><strong>5.2 Sampling effectiveness at wind speeds of 2 to 24 km/hr</strong></td>
<td>Liquid particles ± 10% of that predicted by ideal sampler&lt;br&gt;Solid particles, expected mass concentration no more than 5% above that obtained for liquid particles&lt;br&gt;50% cutpoint <strong>10 ± 1</strong> um aerodynamic diameter&lt;br&gt;<strong>Reproducibility 15% coefficient of variation for three collocated samplers</strong>&lt;br&gt;Wind speed 2 to 24 kph</td>
<td>Part 53.40 Table D-1&lt;br&gt;Expected mass conc. is the same&lt;br&gt;For solids, the same&lt;br&gt;<strong>10 ± 0.5</strong> um (above)&lt;br&gt;<strong>Precision (above)</strong>&lt;br&gt;Wind speed 2 to 24 kph (the same)</td>
</tr>
<tr>
<td><strong>5.2 sampler flow rate and inlet</strong></td>
<td>The sampler shall operate at a controlled flow rate specified by its designed or manufacturer, and it shall have an inlet system that provides particle size discrimination characteristics meeting all of the specifications in this document. The sampler inlet shall show no significant wind direction dependence. This requirement can generally be satisfied by an inlet shape that is circularly symmetrical about a vertical axis.</td>
<td>7.1.2 Identical</td>
</tr>
<tr>
<td><strong>5.3 Total flow control</strong></td>
<td>5.3 The sampler shall provide a means to measure the total flow rate during the sampling period. A continuous flow recorder is recommended. The sampler may be equipped with additional flow measurement devices if it is designed to collect more than one particle size fraction.</td>
<td>7.1.4 Identical</td>
</tr>
<tr>
<td><strong>5.4 Automatic flow control</strong></td>
<td>5.4 The sampler shall have an automatic flow control device capable of adjusting and maintaining the sample flow rate within <strong>±10</strong> percent for the sampler inlet over normal variations in line voltage and filter pressure drop. A convenient means must be provided to temporarily disable the automatic flow control device to allow calibration of the sampler’s flow measurement device.</td>
<td>7.1.3 The sampler shall have automatic flow control device capable of adjusting and maintaining the sample flow rate within the flow rate limits specified for the sampler inlet&lt;br&gt;Table D-1 Part 53.41; The</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
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<tr>
<td>5.5 A timing/control device</td>
<td>A timing/control device capable of starting and stopping the sampler shall be used to obtain an elapsed run time of 24 ± 1 hr (1440 ± 60 minutes). An elapsed time meter, accurate within 15 minutes, shall be used to measure sampling time.</td>
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<tr>
<td>5.6 Manual</td>
<td>The sampler shall have an associated operational or instructional manual</td>
<td></td>
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<tr>
<td>6. Filters</td>
<td>A timing/control device capable of starting and stopping the sampler shall be used to obtain an elapsed run time of 24 ± 1 hr (1440 ± 60 minutes). An elapsed time meter, accurate within 15 minutes, shall be used to measure sampling time.</td>
<td></td>
</tr>
<tr>
<td>5.5 A timing/control device</td>
<td>Within ± 5% of initial flow rate; all measured flow rates over 24 hours within ±10% of initial flow rate</td>
<td></td>
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<tr>
<td>5.6 Manual</td>
<td>7.1.5 Identical</td>
<td></td>
</tr>
<tr>
<td>Filters</td>
<td>7.1.6 Identical</td>
<td></td>
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<tr>
<td>7. Procedure</td>
<td>The sampler shall operate in accordance with the specific guidance provided in the sampler manufacturer's instruction manual. This procedure assumes that the sampler's flow rate calibration was performed using flow rates at ambient conditions (QA).</td>
<td></td>
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<tr>
<td>7.2 Filter inspection</td>
<td>Inspect each filter for pinholes, particles, and other imperfections; establish a filter information record and assign an identification number to each filter. Careful handling of filters between preweighing and post-sampling is necessary to avoid errors due to damaged filters or loss of particulate.</td>
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<tr>
<td>7.3 Filter equilibration</td>
<td>Equilibrate each filter in the conditioning environment for at least 24 hours. Environmental temperature range: 15 to 30°C, b. Temperature control: ±3°C, and c. humidity: less than 50 percent relative humidity RH &lt; 50 percent</td>
<td></td>
</tr>
<tr>
<td>7.4 Filter weighing etc.</td>
<td>Following equilibration, weigh each filter and record the presampling weight with the filter identification number.</td>
<td></td>
</tr>
<tr>
<td>7.5 Analytical Balance</td>
<td>The analytical balance must be suitable for weighing the type and size of filters required by the sampler. The range and sensitivity required will depend on the filter tare weight and mass loading. Typically, an analytical balance with a sensitivity of 0.1 mg is required for high volume SSI samplers (flow rates &gt; 0.5 m³/min).</td>
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<tr>
<td>Parameter</td>
<td>Method P</td>
<td>40CFR 50 Appendix M</td>
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<tr>
<td>7.6 Pre-Run Procedure</td>
<td>a. Air Sample Report – Prior to each run, record on the Air Sample Report: the reporting agency, station address, station name, instrument number and county, site, agency, and project codes.</td>
<td>9.9 Identical</td>
</tr>
<tr>
<td></td>
<td>b. Clean Filter Installation – the clean particulate filter is placed on the sampler and secured in place.</td>
<td>9.5</td>
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<td></td>
<td>c. Flow Setting – The actual flow rate must be maintained as specified by the manufacturer in order to maintain the 10 µm cutpoint of the inlet. This will require special care at elevations greater than 1000 feet above sea level in order to prevent errors due to reduced atmospheric density.</td>
<td>8.2.4 and 9.6 manufacturer’s manual</td>
</tr>
<tr>
<td></td>
<td>d. Elapsed Time Meter – Record the initial elapsed time meter reading on the Monthly Check Sheet.</td>
<td>9.8</td>
</tr>
<tr>
<td>7.7 Post-Run Procedure</td>
<td>a. Final Flow Meter Reading – Before removing the filter and flow chart, make sure that the recorder trace shows the final flow. If not, the sampler must be started to determine the final flow. Remove the flow chart from the recorder and examine the trace for abnormalities. Note and investigate any abrupt changes in air flow. If the start and finish air flows are not representative of your geographic area, note this on the Air Sample Report under “Remarks”.</td>
<td>9.11 and part of 9.6</td>
</tr>
<tr>
<td></td>
<td>b. Exposed Filter Removal – Grasp the exposed filter without touching the darkened area. Fold it in half width-wise with the darkened side in. A satisfactory filter is one which has a uniform white border. Dark streaks into the border may indicate an air leak, which invalidates the sample. If there are insects on the filter, remove them carefully. Note on the Air Sample Report if the filter is torn or ruptured, if the start or finish times are not known, or if the flows are outside the specified range. Note: A removable filter cartridge may be loaded and unloaded at the station operator’s headquarters to avoid contamination and damage to the filter media.</td>
<td>9.12 manufacturer’s manual</td>
</tr>
<tr>
<td>7.7. Post-Run</td>
<td>c. Timer and Elapsed Time Meter Check – After each run, check how long the sampler ran by reading the elapsed time meter. Record the final elapsed time meter (ETM) reading. These ETM readings are used in calculating the concentration of collected particulates as they are more accurate than the time or flow chart times. Adjust the timers to meet the timer acceptance limits of 24 hours ± 15 minutes.</td>
<td>9.11. and part of 7.1.5</td>
</tr>
<tr>
<td>7.8 Equilibration</td>
<td>Equilibrate the exposed filter(s) in the conditioning environment for 24 hours and immediately after equilibration reweigh the filter(s) and record the weight(s) with filter identification number(s).</td>
<td>9.16 and 9.17: Identical (at least 24 hours)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.10 Sample for 24 ± 1 hr</td>
</tr>
<tr>
<td></td>
<td>9.14 Record any factors such as meteorological conditions, construction activity, fires or dust storms, etc. that might be pertinent to the measurement on the filter information record</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.15 Transport the exposed filters to the filter conditioning</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Method P</td>
<td>40CFR 50 Appendix M</td>
</tr>
<tr>
<td>-----------</td>
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</tr>
</tbody>
</table>
| **8. Calibration** | *Calibrated using an **orifice transfer** standard that has been standardized against a primary standard root s meter.*  
*The orifice standard is referenced to 25C and 760 mm Hg.*  
*Two types of orifice standard: multihole adapter plates to vary the flow and an **adjustable flow restrictor.** In both, the calibrator is connected to a differential pressure gauge or slack tube manometer.*  
*Pressure drops and indicated flow meter readings are recorded and corrected for elevation, as necessary.*  
*Using the pressure drops, the standard (true) flow rates are calculated using the certified equation for the transfer standard.*  
*Finally a working sampler calibration curve of standard flow rate vs indicated flow rate is plotted.*  
**Assumptions:**  
Elevation below 1000 feet is equivalent to standard conditions  
The effect of temperature on the indicator flowrate is negligible and therefore is not used in the determination of the standard flow rate. | 8.0 |

<table>
<thead>
<tr>
<th><strong>8.1 Apparatus</strong></th>
<th>7.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a-1</strong></td>
<td>A flow rate transfer standard, suitable for the flow rate of the sampler and calibrated against a primary standard that is traceable to NBS, must be used to calibrate the sampler’s flow measurement device.</td>
</tr>
<tr>
<td><strong>a-2</strong></td>
<td>The reproducibility and resolution of the transfer standard must be 2 percent or less of the sampler’s operating flow rate.</td>
</tr>
<tr>
<td><strong>a-3</strong></td>
<td>The flow rate transfer standard must include a means to vary the sampler flow rate during calibration of the sampler’s flow measurement device.</td>
</tr>
<tr>
<td><strong>b-</strong></td>
<td>0-20” differential pressure gauge or slack tube manometer</td>
</tr>
<tr>
<td><strong>c-</strong></td>
<td>Tygon tubing for static pressure connections</td>
</tr>
<tr>
<td><strong>d-</strong></td>
<td>Faceplate adapter with “C” clamps</td>
</tr>
<tr>
<td><strong>e-</strong></td>
<td>Flow charts for continuous recorder</td>
</tr>
<tr>
<td><strong>f-</strong></td>
<td>Calibration report forms</td>
</tr>
<tr>
<td><strong>g-</strong></td>
<td>Plastic cap for constant volume sampler sensor</td>
</tr>
<tr>
<td>Parameter</td>
<td>Method P</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8.2 “As Is”</td>
<td><strong>Calibration</strong></td>
</tr>
<tr>
<td></td>
<td>Other than routine daily checks, sampler repairs or adjustments (brush changes, motor replacement, flow recorder changes, etc.) should not be made prior to the “as is” calibration. The sampler should be calibrated after each 800 hours (nearly 33 days) of operations, if the sampler is moved to a different site, or if the initial flow meter reading falls outside of specified tolerance limits. Note: Some samplers use a closed loop control system to provide constant blower speed and sampler flow. The flow sensor is located in the throat of the filter holder assembly. Before calibrating this type of sampler, first cover the flow sensor with a plastic cap. After calibrating, remove the cap</td>
</tr>
<tr>
<td>8.2a</td>
<td>Open the PM10 sampler shelters and remove the filter holder. Secure the faceplate adapter and orifice calibrator; then, tighten down the orifice calibrator. If using a variable resistance calibrator, simply secure the calibrator to the faceplate adapter and turn the restrictor control fully counterclockwise so that the maximum flow will be obtained. Connect a section of tygon tubing from the orifice tap on the calibrator to one leg of the manometer. Open the other leg so that it is open to the atmosphere. A schematic diagram of a typical sampler flow calibration is shown in Figure P-2.</td>
</tr>
<tr>
<td>8.2b</td>
<td>After the sampler has warmed up, turn the motor off and then on and allow the static pressure (P) and indicated flow reading (Qing) to stabilize. Then, read the static pressure (ΔP) and indicated flow readings (Qind). The static pressure is read as the total displacement, in inches, of the manometer water column. Record the static pressure and the indicated flow readings on the PM10 Sampler Calibration Data Sheet (see Figure P-4 as an example). Repeat this step twice so that a total of three test runs are performed.</td>
</tr>
<tr>
<td>8.2c</td>
<td>Repeat Step b for each of the remaining four load plates. When using the variable resistance calibrator, select four additional points equally spaced around the setpoint determined in Section 7.6 (two points above and two points below; see example in Figure P-4).</td>
</tr>
<tr>
<td>8.2d</td>
<td>Remove the orifice calibrator from the sampler. Measure the indicated flow with a clean filter installed in the PM10 sampler and record this value on the bottom of the calibration data sheet.</td>
</tr>
<tr>
<td>8.2e</td>
<td>On the left side of the calibration data sheet, sum the ΔP readings for each line (runs 1-3) and record the sum under the sum ΔP for each line (points 1-5). Etc.</td>
</tr>
<tr>
<td>8.2f</td>
<td>Record the elevation of the sampler on the calibration data sheet. If elevation less than 1,000 ft, no correction is required. If the elevation is 1000 ft or greater, apply an altitude correction factor.</td>
</tr>
<tr>
<td>8.2g</td>
<td>Referring to the certification of equation and using the corrected ΔP values calculated in f, above, determine the record Qsts (transfer standard) for each point, where Qstd = factor Corr ΔP</td>
</tr>
<tr>
<td>8.2h</td>
<td>Using the data from the calibration data sheet, plot a calibration graph Qstd vs. Qind. Draw a straight line through the plotted points, or, or obtain a linear regression plot. This line represents the working sampler calibration graph for the particular sampler elevation.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Method P</td>
</tr>
<tr>
<td>-----------</td>
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</tr>
<tr>
<td>8.2i</td>
<td>Using the tabulate values of the average Qind, determine Qprev (PM10 sampler) by referring to the previous sampler calibration curve (Qstd vs Qind). Find the appropriate value of Qprev from the Y-axis corresponding to Qind on the x-axis.</td>
</tr>
<tr>
<td>8.2j</td>
<td>Sum the column Qstd (transfer standard), tabulated on the left side of the calibration data sheet. Record this sum as “S1”.</td>
</tr>
<tr>
<td>8.2k</td>
<td>Sum the column Qprev (PM10 sampler), determine in Step I; record this sum as “S2”.</td>
</tr>
<tr>
<td>8.2l</td>
<td>Calculate the percent deviation from the previous calibration using the equation listed on the bottom the calibration data sheet. Record the result.</td>
</tr>
<tr>
<td>8.3</td>
<td>&quot;Final&quot; Calibration</td>
</tr>
<tr>
<td>8.4</td>
<td>Blank Form and Assistance</td>
</tr>
<tr>
<td>9.1</td>
<td>Determine the average flow rate over the sampling period corrected to reference conditions as Qstd.</td>
</tr>
<tr>
<td>9.2</td>
<td>Calculate the total volume of air sampled as: ( v = Q_{std} \times t ) where: ( v = ) total air sampled in standard volume units, std m(^3); ( t = ) sampling time, min.</td>
</tr>
<tr>
<td>9.3</td>
<td>Calculate the PM10 concentration as: ( PM10 = \frac{(w_f - W_i) \times 10^6}{v} ) Where: ( PM10 = ) mass concentration of PM10, g/ std m(^3); ( W_f W_i = ) final and initial weights of filter(s) Collecting PM10 particles, g; ( 10^6 = ) conversion of g to µg.</td>
</tr>
</tbody>
</table>
Appendix 5

Supplementary Material for Chapter 5

Part D
Appendix L to 40CFR, Part 50
concentrations were 55, 68, 73, 92, 120, and 155 μg/m³. Applying the weighting factors specified in Equation 6, the quarterly mean is:

\[ x_{a} = (1/7) \times [(1/3) \times (202+242+180) + 155+68+73+92+120+155] = 110.1 \mu g/m^3. \]

b. Although 24-hour measurements are rounded to the nearest 10 μg/m³ for determinations of exceedances of the 24-hour standard, note that these values are rounded to the nearest 1 μg/m³ for the calculation of means.

6. Appendix L is added to read as follows:

**Appendix L to Part 50—Reference Method For the Determination of Fine Particulate Matter as PM\(_{2.5}\) in the Atmosphere**

1.0 Applicability.

1.1 This method provides for the measurement of the mass concentration of fine particulate matter having an aerodynamic diameter less than or equal to a nominal 2.5 micrometers (PM\(_{2.5}\)) in ambient air over a 24-hour period for purposes of determining whether the primary and secondary national ambient air quality standards for fine particulate matter specified in § 50.6 of this part are met. The measurement process is considered to be nondestructive, and the PM\(_{2.5}\) sample obtained can be subjected to subsequent physical or chemical analyses. Quality assessment procedures are provided in Appendix A of this chapter, and quality assurance guidance are provided in references 1, 2, and 3 in section 13.0 of this appendix.

1.2 This method will be considered a reference method for purposes of part 58 of this chapter only if:

(a) The associated sampler meets the requirements specified in this appendix and the applicable requirements in part 53 of this chapter, and

(b) The method and associated sampler have been designated as a reference method in accordance with part 53 of this chapter.

1.3 PM\(_{2.5}\) samplers that meet nearly all specifications set forth in this method but have minor deviations and/or modifications of the reference method requirements for this field sampler audit procedure will be designated as “Class I” equivalent methods for PM\(_{2.5}\) in accordance with part 53 of this chapter.

2.0 Principle.

2.1 An electrically powered air sampler draws ambient air at a constant volumetric flow rate into a specially shaped inlet and through an inertial particle size separator (impactor) where the suspended particulate matter in the PM\(_{2.5}\) size range is separated for collection on a polytetrafluoroethylene (PTFE) filter over the specified sampling period. The air sampler and other aspects of this reference method are specified either explicitly in this appendix or generally with reference to other applicable regulations or quality assurance guidance.

2.2 Each filter is weighed (after moisture and temperature conditioning) before and after sample collection to determine the net gain due to collected PM\(_{2.5}\). The total volume of air sampled is determined by the sampler from the measured flow rate at actual ambient temperature and pressure and the sampling time. The mass concentration of PM\(_{2.5}\) in the ambient air is computed as the total mass of collected particles in the PM\(_{2.5}\) size range divided by the actual volume of air sampled, and is expressed in micrograms per cubic meter of air (μg/m³).

3.0 PM\(_{2.5}\) Measurement Range.

3.1 Lower concentration limit. The lower detection limit of the mass concentration measurement range is estimated to be approximately 2 μg/am³, based on noted mass changes in field blanks in conjunction with the 24 m³ nominal total air sample volume specified for the 24-hour sample.

3.2 Upper concentration limit. The upper limit of the mass concentration range is determined by the filter mass loading beyond which the sampler can no longer maintain the operating flow rate within specified limits due to increased pressure drop across the loaded filter. This upper limit cannot be specified precisely because it is a complex function of the ambient particle size distribution and type, humidity, the individual filter used, the capacity of the sampler flow rate control system, and perhaps other factors. Nevertheless, all samplers are estimated to be capable of measuring 24-hour PM\(_{2.5}\) mass concentrations of at least 200 μg/m³ while maintaining the operating flow rate within the specified limits.

3.3 Sample period. The required sample period for PM\(_{2.5}\) concentration measurements by this method shall be 1,380 to 1500 minutes (23 to 25 hours). However, when a sample period is less than 1,380 minutes, the measurement (as determined by the collected PM\(_{2.5}\) mass divided by the actual sampled air volume), multiplied by the actual number of minutes in the sample period and divided by 1,440, may be used as if it were a valid concentration measurement for the specific purpose of determining a violation of the NAAQS. This value assumes that the PM\(_{2.5}\) concentration is zero for the remaining portion of the sample period and therefore represents the minimum concentration that could have been measured for the full 24-hour sample period. Accordingly, if the value thus calculated is high enough to be an exceedance, such an exceedance is recorded according to the schedule and procedure specified in part 58, Appendix A of this chapter.

3.4 Sample location. The subject sampler and includes both random and systematic (bias) errors. The required sample period

4.0 Accuracy.

4.1 Because the size and volatility of the particles making up ambient particulate matter vary over a wide range and the mass concentration of particles varies with particle size, it is difficult to define the accuracy of PM\(_{2.5}\) measurements in an absolute sense. The accuracy of PM\(_{2.5}\) measurements is therefore defined in a relative sense, referenced to measurements provided by this reference method. Accordingly, accuracy shall be defined as the degree of agreement between a subject field PM\(_{2.5}\) sampler and a collocated PM\(_{2.5}\) reference method audit sampler operating simultaneously at the monitoring site location of the subject sampler and includes both random (precision) and systematic (bias) errors. The requirements for this field sampler audit procedure are set forth in part 58, Appendix A of this chapter.

4.2 Measurement system bias. Results of collocated measurements where the duplicate sampler is not a reference method sampler but is a sampler of the same designated method as the primary sampler, are used to assess measurement system precision according to the schedule and procedure specified in part 58, Appendix A of this chapter.

4.3 Filter for PM\(_{2.5}\) Sample Collection. Any filter manufacturer or vendor who sells or offers to sell filters specifically identified for use with this PM\(_{2.5}\) reference method shall certify that the required number of filters from each lot of filters offered for sale as such have been tested as specified in this section 6.0 and meet all of the following design and performance specifications.

6.1 Size. Circular, 46.2 mm diameter ±0.25 mm. 6.2 Medium. Polytetrafluoroethylene (PTFE) or Polymethylpentene (PMP) or equivalent inert material, 0.38 ±0.04 mm thick, outer diameter 46.2 ±0.25 mm, and width of 3.68 mm (±0.00, ±0.51 mm).

6.3 Pore size. 2 µm as measured by ASTM F 316-94.

6.4 Filter thickness. 30 to 50 µm.

6.5 Maximum pressure drop (clean filter). 30 cm H₂O column @ 16.67 L/min clean air flow.

6.6 Maximum moisture pickup. Not more than 10 µg weight increase after 24-hour exposure to air of 40 percent relative humidity, relative to weight after 24-hour exposure to air of 35 percent relative humidity.

6.7 Collection efficiency. Greater than 99.7 percent, as measured by the DOP test (ASTM D 2986-91) with 0.3 μm particles at the sampler’s operating face velocity.

6.8 Filter weight stability. Filter weight loss shall be less than 20 µg, as measured in each of the following two tests specified in sections 6.9.1 and 6.9.2 of this appendix. The following conditions apply to both of these tests: Filter weight loss shall be the average difference between the initial and the final filter weights of a random sample of test.
filters selected from each lot prior to sale. The number of filters tested shall be not less than 0.1 percent of the filters of each manufacturing lot, or 10 filters, whichever is greater. The filters shall be weighed under laboratory conditions and shall have had no air sample passed through them, i.e., filter blanks. Each test procedure must include initial conditioning and weighing, the test, and final conditioning and weighing. Conditioning and weighing shall be in accordance with sections 8.0 through 8.2 of this appendix and general guidance provided in reference 2 of section 13.0 of this appendix.

6.9.1 Test for loose, surface particle contamination. After the initial weighing, install each test filter, in turn, in a filter cassette (Figures L–27, L–28, and L–29 of this appendix) and drop the cassette from a height of 25 cm to a flat hard surface, such as a particle-free wood bench. Repeat two times, for a total of three drop tests for each test filter. Remove the test filter from the cassette and weigh the filter. The average change in weight shall be less than 20 µg.

6.9.2 Test for temperature stability. After weighing the test filter, place the test filters in a drying oven set at 40 °C ± 2 °C for not less than 48 hours. Remove, condition, and reweigh each test filter. The average change in weight shall be less than 20 µg.

6.10 Alkalinity. Less than 25 microequivalents/gram of filter, as measured by the guidance given in reference 2 in section 13.0 of this appendix.

6.11 Supplemental requirements. Although not required for determination of PM2.5 mass concentration under this reference method, additional specifications for the filter must be developed by users who intend to sample PM2.5 filter samples for time-dependent chemical analysis. These supplemental specifications include background chemical contamination of the filter and any other filter parameters that may be required by the method of chemical analysis. All such supplemental filter specifications must be compatible with and secondary to the primary filter specifications given in this section 6.0 of this appendix.

7.0 PM2.5 Sampler.  
7.1 Configuration. The sampler shall consist of a sample air inlet, downdraft, particle size separator (impactor), filter holder assembly, air pump, and flow rate control system, flow rate measurement device, ambient and filter temperature monitoring system, barometric pressure measurement system, timer, outdoor environmental enclosure, and suitable mechanical, electrical, or electronic control capability to meet or exceed the design and functional performance as specified in this section 7.0 of this appendix. The performance specifications require that the sampler:

(a) Provide automatic control of sample volumetric flow rate and other operational parameters.

(b) Monitor these operational parameters as well as ambient temperature and pressure.

(c) Provide this information to the sampler operator at the end of each sample period in digital form, as specified in Table L–1 of section 7.4.19 of this appendix.

7.2 Mass Flow Specifications. The PM2.5 sampler is specified by a combination of design and performance requirements. The sample inlet, downdraft, particle size discriminator, filter cassette, and the internal configuration of the filter holder assembly are specified explicitly by design figures and associated mechanical dimensions, tolerances, materials, surface finishes, assembly instructions, and other necessary specifications. All other aspects of the sampler are specified by required operational function and performance, and the design of these other aspects (including the design of the lower portion of the filter holder assembly) is optional, subject to acceptable operational performance. Test procedures to demonstrate compliance with both the design and performance requirements are set forth in section E of part 53 of this chapter.

7.3 Design specifications. Except as indicated in this section 7.3 of this appendix, these components must be manufactured or reproduced exactly as specified, in an ISO 9001-registered facility, with registration initially approved and subsequently maintained during the period of manufacture. See §53.1(t) of this chapter for the definition of an ISO-registered facility. Minor modifications or variances to one or more components that clearly would not affect the aerodynamic performance of the inlet, downdraft, impactor, or filter cassette will be considered for specific approval. Any such proposed modifications shall be described and submitted to the EPA for specific individual acceptability. The following shall be part of a reference or equivalent method application under part 53 of this chapter or in writing in advance of such an intended application under part 53 of this chapter.

7.3.1 Sample inlet assembly. The sample inlet assembly, consisting of the inlet, downdraft, and impactor shall be configured and assembled as indicated in Figure L–1 of this appendix and shall meet all associated requirements. A portion of this assembly shall also be subject to the maximum overall sampler leak rate specification under section 7.4.6 of this appendix.

7.3.2 Inlet. The sample inlet shall be fabricated as indicated in Figures L–2 through L–18 of this appendix and shall meet all associated requirements.

7.3.3 Downdraft. The downdraft shall be fabricated as indicated in Figure L–19 of this appendix and shall meet all associated requirements.

7.3.4 Impactor.  
7.3.4.1 The impactor (particle size separator) shall be fabricated as indicated in Figures L–20 through L–24 of this appendix and shall meet all associated requirements. Following the manufacture and finishing of each upper impactor housing (Figure L–21 of this appendix), the dimension of the impaction jet must be verified by the manufacturer using Class ZZ go/no-go plug gauges that are traceable to NIST.

7.3.4.2 Impactor filter specifications:  
(a) Size. Circular, 35 to 37 mm diameter.

(b) Medium. Borosilicate glass fiber, without binder.

(c) Pore size. 1.0 to 1.5 micrometer, as measured by ASTM F 316–80.

(d) Thickness. 300 to 500 micrometers.

7.3.4.3 Impactor oil specifications:  
(a) Composition. Tetrachlorotetraphenylsiloxane, single-component diffusion oil.

(b) Vapor pressure. Maximum 2 x 10^-4 mm Hg at 25 °C.

(c) Viscosity. 36 to 40 centistokes at 25 °C.

(d) Density. 1.06 to 1.07 g/cm^3 at 25 °C.

(e) Quantity. 1 mL ± 0.1 mL.

7.3.5 Filter holder assembly. The sampler shall have a filter holder filter assembly to adapt and seal to the down tube and to hold and seal the specified filter, under section 6.0 of this appendix, in the sample air stream in a horizontal position below the downdraft such that the sample air passes downward through the filter at a uniform face velocity. The upper portion of this assembly shall be fabricated as indicated in Figures L–25 and L–26 of this appendix and shall accept and seal with the filter cassette, which shall be fabricated as indicated in Figures L–27 through L–29 of this appendix.

(a) The lower portion of the filter holder assembly shall be of a design and construction that:  
(1) Mates with the upper portion of the assembly to complete the filter holder assembly,

(2) Completes both the external air seal and the internal filter cassette seal such that all seals are reliable over repeated filter changings, and

(3) Facilitates repeated changing of the filter cassette by the sampler operator.

(b) Leak-test performance requirements for the filter holder assembly are included in section 7.4.6 of this appendix.

(c) If additional or multiple filters are stored in the sampler as part of an automatic sequential sample capability, all such filters, unless they are currently and directly installed in a sampling channel or sampling configuration (either active or inactive) shall be covered or (preferably) sealed in such a way as to:

(1) Preclude significant exposure of the filter to possible contamination or accumulation of dust, insects, or other material that may be present in the ambient air, sampler, or sampler ventilation air during storage periods either before or after sampling; and

(2) To minimize loss of volatile or semi-volatile PM sample components during storage of the filter following the sample period.

7.3.6 Flow rate measurement adapter. A flow rate measurement adapter as specified in Figure L–30 of this appendix shall be furnished with each sampler.

7.3.7 Surface finish. All internal surfaces exposed to sample air prior to the filter shall be treated electrolytically in a sulfuric acid bath to produce a clear, uniform anodized surface finish of not less than 1000 mgft² (1.08 mg/cm²) in accordance with military standard specification (mil. spec.) 8625F, Type II, Class 1 in reference 4 of section 13.0 of this appendix. This anodic surface coating shall not be dyed or pigmented. Following anodization, the surfaces shall be sealed by immersion in boiling deionized water for not less than 15 minutes. Section 53.51(d)(2) of this chapter should also be consulted.

7.3.8 Sampling height. The sampler shall be equipped with legs, a stand, or other means to maintain the sampler in a stable, upright position and such that the center of the sample air entrance to the inlet, during sample collection, is maintained in a horizontal plane and is 2.0 to 2.0 meters above the floor or other horizontal supporting surface. Suitable bolt holes, brackets, tie-downs, or other means should be provided to facilitate mechanically securing the sample to the supporting surface to prevent toppling of the sampler due to wind.

7.4 Performance specifications.  
7.4.1 Sample flow rate. Proper operation of the impactor requires that specific air velocities be maintained through the device. Therefore, the design sampler sample air flow rate through the inlet shall be 16.67 L/min (1.000 ft³/hour) measured as actual volumetric flow rate at the temperature and pressure of the sample air entering the inlet.

7.4.2 Sample air flow rate control system. The sampler shall have a sample air flow rate control system which shall be capable of providing a sample air volumetric flow rate within the specified range, under section 7.4.1 of this appendix, for the
specified filter, under section 6.0 of this appendix, at any atmospheric conditions specified, under section 7.4.7 of this appendix, at a filter pressure drop equal to that of a clean filter plus up to 75 cm water column (55 mm Hg), and over the specified range of supply line voltage, under section 7.4.15.1 of this appendix. This flow control system shall allow for operator adjustment of the operational flow rate of the sampler over a range of at least ±15 percent of the flow rate specified in section 7.4.1 of this appendix.

7.4.3 Sample flow rate regulation. The sample flow rate shall be regulated such that for the specified filter, under section 6.0 of this appendix, at any atmospheric conditions specified, under section 7.4.7 of this appendix, at a filter pressure drop equal to that of a clean filter plus up to 75 cm water column (55 mm Hg), and over the specified range of supply line voltage, under section 7.4.15.1 of this appendix, the flow rate is regulated as follows:

7.4.3.1 (a) The volumetric flow rate, measured or averaged over intervals of not more than 5 minutes over a 24-hour period, shall not vary more than ±5 percent from the specified 16.67 L/min flow rate over the entire sample period.

7.4.3.2 The coefficient of variation (sample standard deviation divided by the mean) of the flow rate, measured over a 24-hour period, shall not be greater than 2 percent.

7.4.3.3 The amplitude of short-term flow rate pulsations, such as may originate from some types of vacuum pumps, shall be attenuated such that they do not cause significant flow measurement errors or affect the collection of particles on the particle collection filter.

7.4.4 Flow rate measurement. The sampler’s sample air flow control system shall terminate sample collection and stop all sample flow for the remainder of the sample period in the event that the sample flow rate deviates by more than 50 percent from the sampler design flow rate specified in section 7.4.1 of this appendix for more than 60 seconds. However, this sampler cut-off provision shall not apply during periods when the sampler is inoperative due to a temporary power interruption, and the manipulated inoperative period shall not be included in the total sample time measured and reported by the sampler, under section 7.4.13 of this appendix.

7.4.5 Flow rate measurement. The sampler shall provide a means to measure and indicate the instantaneous sample air flow rate, which shall be measured as volumetric flow rate at the temperature and pressure of the sample air entering the inlet, with an accuracy of ±2 percent. The measured flow rate shall be available for display to the sampler operator at any time in either sampling or standby modes, and the measurement shall be updated at least every 30 seconds. The sampler shall also provide a simple means by which the sampler operator can manually start the sample flow temporarily during non-sampling modes of operation, for the purpose of checking the sample flow rate or the flow rate measurement system.

7.4.5.2 During each sample period, the sampler’s flow rate measurement system shall automatically monitor the sample volumetric flow rate, obtaining flow rate measurements at intervals of not greater than 30 seconds.

(a) Using these interval flow rate measurements, the sampler shall determine or calculate the following flow-related parameters, scaled in the specified engineering units:

1. The instantaneous or interval-average flow rate, in L/min.

2. The value of the average sample flow rate for the sample period, in L/min.

3. The value of the coefficient of variation (sample standard deviation divided by the average) of the sample flow rate for the sample period, in percent.

4. The occurrence of any time interval during the sample period in which the measured sample flow rate exceeds a range of ±5 percent of the average flow rate for the sample period for more than 5 minutes, in which case a warning flag indicator shall be set.

5. The value of the integrated total sample volume for the sample period, in m³.

(b) Determination or calculation of these values shall properly exclude periods when the sampler is inoperative due to temporary interruption of electrical power, under section 7.4.13 of this appendix, or flow rate cut off, under section 7.4.4 of this appendix.

(c) These parameters shall be accessible to the sampler operator as specified in Table L–1 of section 7.4.19 of this appendix.

7.4.6 Leak test capability.

7.4.6.1 External leakage. The sampler shall include an external air leak-test capability consisting of components, accessory hardware, operator interface controls, a written procedure in the associated Operation/Instruction Manual, and all other necessary functional capability to permit and facilitate the sampler operator to conveniently carry out a leak test of the sampler at a field monitoring site without additional equipment. The purpose of the test is to determine that any portion of the sample flow rate that leaks past the sample filter without passing through the filter is insignificant relative to the design flow rate for the sampler.

(a) The suggested technique for the operator to use for this leak test is as follows:

1. Carry out an external leak test as provided under section 7.4.6.1 of this appendix which indicates successful passage of the prescribed external leak test.

2. Install a flow-impervious membrane material in the filter cassette, either with or without a filter, as appropriate, which effectively prevents air flow through the filter.

3. Use the sampler air pump to draw a partial vacuum in the sampler, downstream of the filter holder assembly, of at least 55 mm Hg (75 cm water column).

4. Plug the flow system downstream of the filter holder to isolate the components under vacuum from the pump, such as with a built-in valve.

5. Stop the pump.

6. Measure the trapped vacuum in the sampler with a built-in pressure measuring device.

7. Measure the vacuum in the sampler with the built-in pressure measuring device again at a later time at least 10 minutes after the first pressure measurement.

8. Remove the flow plug and membrane and restore the sampler to the normal operating configuration.

(b) The associated leak test procedure shall require that for successful passage of this test, the difference between the two pressure measurements shall not be greater than the number of mm of Hg specified for the sampler by the manufacturer, based on the actual internal volume of the sampler, that indicates a leak of less than 80 mL/min.

(c) Variations of the suggested technique or an alternative internal leak test technique may be required for samplers whose design or configuration would make the suggested technique impossible or impractical. The specific proposed internal leak test procedure, or particularly an alternative internal leak test technique proposed for a particular candidate sampler may be described in writing in advance of such an intended application under part 53 of this chapter or in writing in advance of such an intended application under part 53 of this chapter.

7.4.6.2 Internal, filter bypass leak test. The sampler shall include an internal, filter bypass leak-check capability consisting of components, accessory hardware, operator interface controls, a written procedure in the associated Operation/Instruction Manual, and all other necessary functional capability to permit and facilitate the sampler operator to conveniently carry out a test for internal filter bypass leakage in the sampler at a field monitoring site without additional equipment. The purpose of the test is to determine that any portion of the sample flow rate that leaks past the sample filter without passing through the filter is insignificant relative to the design flow rate for the sampler.

(a) The suggested technique for the operator to use for this leak test is as follows:

1. Perform an internal leak test as provided under section 7.4.6.1 of this appendix which indicates successful passage of the prescribed external leak test.

2. Restore the sampler to the normal operating configuration.

3. Close the valve on the flow rate measurement system downstream of these components to isolate the components under vacuum from the pump, such as with a built-in valve.

4. Stop the pump.

5. Measure the trapped vacuum in the sampler as above.

6. Measure the vacuum in the sampler with the built-in pressure measuring device as above.

7. Remove the flow plug and membrane and restore the sampler to the normal operating configuration.

(b) The associated leak test procedure shall require that for successful passage of this test, the difference between the two pressure measurements shall not be greater than the number of mm of Hg specified for the sampler by the manufacturer, based on the actual internal volume of the sampler, that indicates a leak of less than 80 mL/min.

(c) Variations of the suggested technique or an alternative internal, filter bypass leak test technique may be required for samplers whose design or configuration would make the suggested technique impossible or impractical. The specific proposed internal leak test procedure, or particularly an alternative internal leak test technique proposed for a particular candidate sampler may be described in writing in advance of such an intended application under part 53 of this chapter or in writing in advance of such an intended application under part 53 of this chapter.
and submitted to the EPA for specific individual acceptability either as part of a reference or equivalent method application under part 53 of this chapter or in writing in advance of such intended application under part 53 of this chapter.

7.3.5 Filter holder assembly. The sampler shall have a filter holder assembly to adapt and seal to the down tube and to hold and seal the specified filter, under section 6.0 of this appendix, in the sample air stream in a horizontal position below the dust pan such that the sample air passes downward through the filter at a uniform face velocity. The upper portion of this assembly shall be fabricated as indicated in Figures L–25 and L–26 of this appendix and shall accept and seal with the filter cassette, which shall be fabricated as indicated in Figures L–27 through L–29 of this appendix.

(a) The lower portion of the filter holder assembly shall be of a design and construction that:
   (1) Mates with the upper portion of the assembly to complete the filter holder assembly.
   (2) Completes both the external air seal and the internal filter seal such that all seals are reliable over repeated filter changings, and
   (3) Facilitates repeated changing of the filter cassette by the sampler operator.

(b) Leak–test performance requirements for the filter holder assembly are included in section 7.6.6 of this appendix.

(c) If additional or multiple filters are stored in the sampler as part of an automatic sequential sample capability, all such filters, unless they are currently and directly installed in a sampling channel or sampling configuration (either active or inactive), shall be covered or (preferably) sealed in such a way as to:
   (1) Preclude significant exposure of the filter to possible contamination or accumulation of dust, insects, or other material that may be present in the ambient air, sampler, or sampler ventilation air during storage periods either before or after sampling; and
   (2) To minimize loss of volatile or semi-volatile PM sample components during storage of the filter following the sample period.

7.3.6 Flow rate measurement adapter. A flow rate measurement adapter as specified in Figure L–30 of this appendix shall be furnished with each sampler.

7.3.7 Surface finish. All internal surfaces exposed to sample air prior to the filter shall be treated electrolytically in a sulfuric acid bath to produce a clear, uniform anodized surface finish of not less than 1000 mg/m² (1.08 mg/cm²) in accordance with military standard specification (mil. spec.) 8625F, Type II, Class 1 in reference 4 of section 13.0 of this appendix. This anodic surface coating shall not be dyed or pigmented. Following anodization, the surfaces shall be sealed by immersion in boiling deionized water for not less than 15 minutes. Section 53.51(d)(2) of this chapter should also be consulted.

7.3.8 Sampling height. The sampler shall be equipped with legs, a stand, or other means to maintain the sampler in a stable, upright position and such that the center of the sample air entrance to the inlet, during sample collection, is maintained in a horizontal plane and is 2.0 ±0.2 meters above the floor or other supporting surface. Suitable bolt holes, brackets, tie-downs, or other means should be provided to facilitate mechanically securing the sample to the supporting surface to prevent toppling of the sampler due to wind.

7.4 Performance specifications

7.4.1 Sample flow rate. Proper operation of the impactor requires that specific air velocities be maintained through the device. Therefore, the design sample air flow rate through the inlet shall be 16.67 L/min (1.000 m³/hour) measured as actual volumetric flow rate at the temperature and pressure of the sample air entering the inlet.

7.4.2 Sample air flow rate control system. The sampler shall have a flow rate control system which shall be capable of providing a sample air volumetric flow rate within the specified range, under section 7.4.1 of this appendix, for the specified filter, under section 6.0 of this appendix, at any atmospheric conditions specified, under section 7.4.7 of this appendix, at a filter pressure drop equal to that of a clean filter plus up to 75 cm water column (55 mm Hg), and over the specified range of supply line voltage, under section 7.4.15.1 of this appendix. This flow control system shall allow for operator adjustment of the operational flow rate of the sampler over a range of at least ±15 percent of the flow rate specified in section 7.4.1 of this appendix.

7.4.3 Sample flow rate regulation. The sample flow rate shall be regulated such that for the specified filter, under section 6.0 of this appendix, at any atmospheric conditions specified, under section 7.4.7 of this appendix, at a filter pressure drop equal to that of a clean filter plus up to 75 cm water column (55 mm Hg), and over the specified range of supply line voltage, section 7.4.15.1 of this appendix, the flow rate is regulated as follows:

7.4.3.1 The volumetric flow rate, measured or averaged over intervals of not more than 5 minutes between 24-hour period shall not vary more than ±5 percent from the specified 16.67 L/min flow rate over the entire sample period.

7.4.3.2 The coefficient of variation (sample standard deviation divided by the mean) shall be less than 1000 mg/ft² (1.08 mg/cm²) in a horizontal position.

7.4.3.3 The amplitude of short-term flow rate pulsations, such as may originate from some types of vacuum pumps, shall be attenuated such that they do not cause significant flow measurement error or affect the collection of particles on the particle collection filter.

7.4.4 Flow rate cut off. The sampler’s sample air flow rate control system shall terminate sample collection and stop all sample flow for the remainder of the sample period, if the sample flow rate deviates by more than 10 percent from the sampler design flow rate specified in section 7.4.1 of this appendix for more than 60 seconds. However, this sampler cut-off provision shall not apply during periods when the sampler is inoperative due to temporary power interruption, under section 7.4.13 of this appendix, or flow rate cut off, under section 7.4.4 of this appendix.

7.4.5 Flow rate measurement. The sampler shall properly exclude periods when the sampler is inoperative due to a temporary power interruption, under section 7.4.13 of this appendix. In addition, it is strongly encouraged that the flow rate for each 5-minute interval during the sample period be available to the operator following the end of the sample period.

7.4.6 Leak test capability. The sampler shall include an external air leak-test capability consisting of components, accessory hardware, operator interface controls, a written procedure in the associated Operation/Instruction Manual, under section 7.4.18 of this appendix, and all other necessary functional capability to permit and facilitate the sampler operator to conveniently carry out a leak test of the sampler at a field monitoring site without additional equipment. The sampler components to be subjected to this leak test include all components and their interconnections in which external air leakage would or could cause an error in the sampler’s measurement of the total volume of sample air that passes through the sample filter.

(a) The suggested technique for the operator to use for this leak test is as follows:

(1) Remove the sampler inlet and installs the flow rate measurement adapter supplied with the sampler, under section 7.3.6 of this appendix.

(2) Close the valve on the flow rate measurement adapter and use the sampler air pump to draw a partial vacuum in the sampler, including (at least) the impactor, filter holder assembly (filter in place), flow measurement device, and interconnections between these devices, of at least 55 mm Hg (75 cm water column), measured at a location downstream of the filter holder assembly.

(3) Plug the flow system downstream of these components to isolate the components under vacuum from the pump, such as with a built-in valve.

(4) Stop the pump.

(5) Measure the trapped vacuum in the sampler with a built-in pressure measuring device.

(6) (i) Measure the vacuum in the sampler with the built-in pressure measuring device again at a
(ii) Caution: Following completion of the test, the adaptor valve should be opened slowly to limit the flow rate of air into the sampler. Excessive air flow rate may blow oil out of the impacter.

(7) Following completion of the test, open the adaptor valve, remove the adaptor and plugs, and restore the sampler to the normal operating configuration.

(b) The associated leak test procedure shall require that for successful passage of this test, the difference between the two pressure measurements shall not be greater than the number of mm of Hg specified for the sampler by the manufacturer, based on the actual internal volume of the sampler, that indicates a leak of less than 80 mL/min. (c) Variations of the suggested technique or an alternative external leak test technique may be required for samplers whose design or configuration would make the suggested technique impossible or impractical. The specific proposed external leak test procedure, or particularly an alternative internal leak test technique, proposed for a particular candidate sampler may be described and submitted to the EPA for specific individual acceptability either as part of a reference or equivalent method application under part 53 of this chapter or in writing in advance of such an intended application under part 53 of this chapter.

7.4.7.1 Ambient temperature. -30 to +45 °C (Note: Although for practical reasons, the temperature range over which samplers are required to be tested under part 53 of this chapter is -20 to +60 °C, the sampler shall be designed to operate properly over this wider temperature range.)

7.4.7.2 Ambient relative humidity. 0 to 100 percent.

7.4.7.3 Barometric pressure range. 600 to 800 mm Hg.

7.4.8 Ambient temperature sensor. The sampler shall have capability to measure the temperature of the ambient air surrounding the sampler over the range of -30 to +45 °C, with a resolution of 0.1 °C and accuracy of ±2.0 °C, referenced as described in reference 3 in section 13.0 of this appendix, with and without maximum solar insolation.

7.4.8.1 The ambient temperature sensor shall be mounted external to the sampler enclosure and shall have a passive, naturally ventilated sun shield. The sensor shall be located such that the entire sun shield is at least 5 cm above the horizontal plane of the sampler case or enclosure (disregarding the inlet and downtube) and external to the vertical plane of the nearest side or protuberance of the sampler case or enclosure. The maximum temperature measurement error of the ambient temperature measurement system shall be less than 1.6 °C at 1 m/s wind speed and 1000 W/m² solar radiation intensity.

7.4.8.2 The ambient temperature sensor shall be of such a design and mounted in such a way as to facilitate its convenient dismounting and immersion in a liquid for calibration and comparison to the filter temperature sensor, under section 7.4.11 of this appendix.

7.4.8.3 This ambient temperature measurement shall be updated at least every 30 seconds during both sampling and standby (non-sampling) modes of operation. A visual indication of the current (most recent) value of the ambient temperature measurement, updated at least every 30 seconds, shall be available to the sampler operator during both sampling and standby (non-sampling) modes of operation, as specified in Table L±1 of section 7.4.19 of this appendix.

7.4.8.4 Following the end of each sample period, the sampler shall report the maximum, minimum, and average temperature for the sample period, as specified in Table L±1 of section 7.4.19 of this appendix.

7.4.9 Ambient barometric sensor. The sampler shall have capability to measure the barometric pressure of the air surrounding the sampler over a range of 600 to 800 mm Hg referenced as described in reference 3 in section 13.0 of this appendix; also see part 53, subpart E of this chapter. This barometric pressure measurement shall have a resolution of 5 mm Hg and an accuracy of ±10 mm Hg and shall be updated at least every 30 seconds.

A visual indication of the value of the current (most recent) barometric pressure measurement, updated at least every 30 seconds, shall be available to the sampler operator during both sampling and standby (non-sampling) modes of operation, as specified in Table L±1 of section 7.4.19 of this appendix.

7.4.10 Filter temperature control (sampling and post-sampling). The sampler shall provide a means to limit the temperature rise of the sample filter (all sample filters for sequential samplers), from insolation and other sources, to no more than 5 °C above the temperature of the ambient air surrounding the sampler, during both sampling and post-sampling periods of operation. The post-sampling period is the non-sampling period between the end of the sampling period and a predetermined time interval of the sample filter by the sampler operator.

7.4.11 Filter temperature sensor(s). The sampler shall have the capability to monitor the temperature of the sample filter (all sample filters for sequential samplers) over the range of -30 to +45 °C during both sampling and non-sampling periods. While the exact location of this temperature sensor is not explicitly specified, the filter temperature measurement system must demonstrate agreement, within 1 °C, with a test temperature sensor located within 1 cm of the center of the filter downstream of the filter during both sampling and non-sampling modes, as specified in the filter temperature measurement test described in section 53, subpart E of this chapter. This filter temperature measurement shall have a resolution of 0.1 °C and accuracy of ±1.0 °C, referenced as described in reference 3 in section 13.0 of this appendix. This temperature sensor shall be of such a design and mounted in such a way as to facilitate its reasonably convenient dismounting and immersion in a liquid for calibration and comparison to the ambient temperature sensor under section 7.4.8. of this appendix.

7.4.11.2 The filter temperature measurement shall be updated at least every 30 seconds during both sampling and standby (non-sampling) modes of operation. A visual indication of the current (most recent) value of the filter temperature measurement, updated at least every 30 seconds, shall be available to the sampler operator during both sampling and standby (non-sampling) modes of operation, as specified in Table L±1 of section 7.4.19 of this appendix.

7.4.11.3 For sequential samplers, the temperature of each filter shall be measured individually unless it can be shown, as specified in the filter...
temperature measurement test described in § 53.57 of this chapter, that the temperature of each filter can be represented by fewer temperature sensors.

7.4.11.4 The sampler shall also provide a warning flag indicator following any occurrence in which the filter temperature (any filter temperature for sequential samplers) exceeds the ambient temperature by more than 5 °C for more than 30 consecutive minutes during either the sampling or post-sampling periods of operation, as specified in Table L–1 of section 7.4.19 of this appendix, under section 10.12 of this appendix, regarding sample validity when a warning flag occurs. It is further recommended (not required) that the sampler be capable of recording the maximum differential between the measured filter temperature and the ambient temperature and its time and date of occurrence during both sampling and post-sampling (non-sampling) modes of operation and providing for those data to be accessible to the sampler operator following the end of the sample period, as suggested in Table L–1 of section 7.4.19 of this appendix.

7.4.12 Clock/timer system.

(a) The sampler shall have a programmable real-time clock timing/control system that:

(1) Is capable of maintaining local time and date, including year, month, day-of-month, hour, minute, and second to an accuracy of ±1.0 minute per month.

(2) Provides a visual indication of the current system time, including year, month, day-of-month, hour, and minute, updated at least each minute, for operator verification.

(b) Is capable of starting the sample collection period and sample air flow at a specific, operator-settable time and date, and stopping the sample air flow and terminating the sampler collection period 24 hours (1440 minutes) later, or at a specific, operator-settable time and date.

7.4.13 Sample time determination. The sampler shall be capable of determining the elapsed sample collection time for each PM2.5 sample, accurate to within ±1.0 minute, measured as the time between the start of the sampling period, under section 7.4.12 of this appendix and the termination of the sample period, under section 7.4.12 of this appendix or section 7.4.4 of this appendix. This elapsed sample time shall not include periods when the sampler is inoperative due to a temporary interruption of electrical power, under section 7.4.15 of this appendix. In the event that the elapsed sample time determined for the sample period is not within the range specified for the required sample period in section 3.3.5 of this appendix, the sampler shall set a warning flag indicator. The date and time of the start of the sample period, the value of the elapsed sample time for the sample period, and the flag indicator shall be available to the sampler operator following the end of the sample period, as specified in Table L–1 of section 7.4.19 of this appendix.

7.4.14 Outdoor environmental enclosure. The sampler shall have an outdoor enclosure (or enclosures) suitable to protect the filter and other non-weatherproof components of the sampler from precipitation, wind, dust, extremes of temperature and humidity; to help maintain temperature control of the filter (or filters, for sequential samplers); and to provide reasonable security for sampler components and settings.

7.4.15 Electrical power supply.

7.4.15.1 The sampler shall be operable and function as specified herein when operated on an electrical power supply voltage of 105 to 125 volts AC (RMS) at a frequency of 59 to 61 Hz. Optional operation as specified at additional power supply voltages and/or frequencies shall not be precluded by this requirement.

7.4.15.2 The design and construction of the sampler shall comply with all applicable National Electrical Code and Underwriters Laboratories electrical safety requirements.

7.4.15.3 The design of all electrical and electronic controls shall be such as to provide reasonable resistance to interference or malfunction from ordinary or typical levels of stray electromagnetic fields (EMF) as may be found at various monitoring sites and from typical levels of electrical transients or electronic noise as may often or occasionally be present on various electrical power lines.

7.4.15.4 In the event of temporary loss of electrical supply power to the sampler, the sampler shall not be required to sample or provide other specified functions during such loss of power, except that the internal clock/timer system shall maintain its local time and date setting within ±1 minute per week, and the sampler shall retain all other time and programmable settings and all data required to be available to the sampler operator following each sample period for at least 7 days without electrical supply power. When electrical power is absent at the operator-set time for starting a sample period or is interrupted during a sample period, the sampler shall automatically start or resume sampling when electrical power is restored, if such restoration of power occurs before the operator-set stop time for the sample period.

7.4.15.5 The sampler shall have the capability to record and retain a record of the year, month, day-of-month, hour, and minute of the start of each power interruption of more than 1 minute duration, up to 10 such power interruptions per sample period. (More than 10 such power interruptions shall invalidate the sample, except where an exceedance is measured, under section 3.3 of this appendix.) The sampler shall provide for these power interruption data to be available to the sampler operator following the end of the sample period, as specified in Table L–1 of section 7.4.19 of this appendix.

7.4.16 Control devices and operator interface. The sampler shall have mechanical, electrical, or electronic controls, control devices, electrical or electronic circuits as necessary to provide the timing, flow rate measurement and control, temperature control, data storage and computation, operator interface, and other functions specified. Operator-accessible controls, data displays, and interface devices shall be designed to be simple, straightforward, reliable, and easy to learn, read, and operate under field conditions. The sampler shall have provision for operator input and storage of up to 64 characters of numeric (or alphanumeric) data for purposes of site, sampler, and sample identification. This information shall be available to the sampler operator for verification and change and for output via the data output port along with other data following the end of a sample period, as specified in Table L–1 of section 7.4.19 of this appendix. All data required to be available to the operator following a sample collection period or obtained during standby mode in a post-sampling period shall be retained by the sampler until reset, either manually by the operator or automatically by the sampler upon initiation of a new sample collection period.

7.4.17 Data output port requirement. The sampler shall have a standard RS–232C data output connection through which digital data may be exported to an external data storage or transmission device. All information which is required to be available at the end of each sample period shall be accessible through this data output connection. The information that shall be accessible through this output port is summarized in Table L–1 of section 7.4.19 of this appendix. Since no specific format for the output data is provided, the sampler manufacturer or vendor shall make available to sampler purchasers appropriate computer software capable of receiving exported sampler data and correctly translating the data into a standard spreadsheet format and optionally any other formats as may be useful to sampler users. This requirement shall not preclude the sampler from offering other types of output connections in addition to the required RS–232C port.

7.4.18 Operation/instruction manual. The sampler shall include an associated comprehensive operation or instruction manual, as required by part 53 of this chapter, which includes detailed operating instructions on the setup, operation, calibration, and maintenance of the sampler. This manual shall provide complete and detailed descriptions of the operational and calibration procedures prescribed for field use of the sampler and all instruments utilized as part of this reference method. The manual shall include adequate warning of potential safety hazards that may result from normal use or malfunction of the method and a description of necessary safety precautions. The manual shall also include a clear description of all procedures pertaining to installation, operation, periodic and corrective maintenance, troubleshooting, and shall include parts identification diagrams.

7.4.19 Data reporting requirements. The information that the sampler is required to provide and how it is to be provided is summarized in the following Table L–1.
### Table L-1.—Summary of Information To Be Provided by the Sampler

<table>
<thead>
<tr>
<th>Information to be provided</th>
<th>Appendix L section reference</th>
<th>Availability</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate, 30-second maximum interval.</td>
<td>7.4.5.1</td>
<td>✔</td>
<td>XX.X ........................... L/min</td>
</tr>
<tr>
<td>Flow rate, average for the sample period.</td>
<td>7.4.5.2</td>
<td>✔</td>
<td>XX.X ........................... L/min</td>
</tr>
<tr>
<td>Flow rate, CV, for sample period.</td>
<td>7.4.5.2</td>
<td>✔</td>
<td>XX.X ........................... %</td>
</tr>
<tr>
<td>Flow rate, 5-min. average out of spec. (FLAG6).</td>
<td>7.4.5.2</td>
<td>✔</td>
<td>On/Off ........................</td>
</tr>
<tr>
<td>Sample volume, total</td>
<td>7.4.5.2</td>
<td>✔</td>
<td>XX.X ........................... m³</td>
</tr>
<tr>
<td>Temperature, ambient, 30-second interval.</td>
<td>7.4.8</td>
<td>✔</td>
<td>XX.X ........................... °C</td>
</tr>
<tr>
<td>Temperature, ambient, min., max., average for the sample period.</td>
<td>7.4.8</td>
<td>✔</td>
<td>XX.X ........................... °C</td>
</tr>
<tr>
<td>Baro pressure, ambient, 30-second interval.</td>
<td>7.4.9</td>
<td>✔</td>
<td>XXX ............................ mm Hg</td>
</tr>
<tr>
<td>Filter temperature, 30-second interval.</td>
<td>7.4.11</td>
<td>✔</td>
<td>On/Off ........................</td>
</tr>
<tr>
<td>Filter temperature differential, 30-second interval, out of spec. (FLAG6).</td>
<td>7.4.11</td>
<td>✔</td>
<td>XX.X ........................... °C</td>
</tr>
<tr>
<td>Filter temperature, maximum differential from ambient, date, time of occurrence.</td>
<td>7.4.11</td>
<td>✔</td>
<td>XX.X ........................... °C</td>
</tr>
<tr>
<td>Date and time ....................................</td>
<td>7.4.12</td>
<td>✔</td>
<td>YY/MM/DD HH:mm .... Yr./Mon./Day Hrs. min</td>
</tr>
<tr>
<td>Sample start and stop time settings.</td>
<td>7.4.12</td>
<td>✔</td>
<td>YY/MM/DD HH:mm .... Yr./Mon./Day Hrs. min</td>
</tr>
<tr>
<td>Sample period start time.</td>
<td>7.4.12</td>
<td>✔</td>
<td>YYYY/MM/DD HH:mm .... Yr./Mon./Day Hrs. min</td>
</tr>
<tr>
<td>Elapsed sample time</td>
<td>7.4.13</td>
<td>✔</td>
<td>HH:mm ........................... Hrs. min</td>
</tr>
<tr>
<td>Elapsed sample time, out of spec. (FLAG6).</td>
<td>7.4.13</td>
<td>✔</td>
<td>On/Off ........................</td>
</tr>
<tr>
<td>Power interruptions &gt;1 min., start time of first 10.</td>
<td>7.4.15.5</td>
<td>✔</td>
<td>1HH:mm, 2HH:mm, etc .... Hrs. min</td>
</tr>
<tr>
<td>User-entered information, such as sampler and site identification.</td>
<td>7.4.16</td>
<td>✔</td>
<td>As entered ........................</td>
</tr>
</tbody>
</table>

- ✔ Provision of this information is required.
- ✔✔✔ ✔● Provision of this information is optional. If information related to the entire sample period is optionally provided prior to the end of the sample period, the value provided should be the value calculated for the portion of the sample period completed up to the time the information is provided.
- ● Indicates that this information is also required to be provided to the AIRS data bank; see §§ 58.26 and 58.35 of this chapter.
- 1 Information is required to be available to the operator at any time the sampler is operating, whether sampling or not.
- 2 Information relates to the entire sample period and must be provided following the end of the sample period until reset manually by the operator or automatically by the sampler upon the start of a new sample period.
- 3 Information shall be available to the operator visually.
- 4 Information is to be available as digital data at the sampler’s data output port specified in section 7.4.16 of this appendix following the end of the sample period until reset manually by the operator or automatically by the sampler upon the start of a new sample period.
- 5 Digital readings, both visual and data output, shall have not less than the number of significant digits and resolution specified.
- 6 Flag warnings may be displayed to the operator by a single-flag indicator or each flag may be displayed individually. Only a set (on) flag warning must be indicated; an off (unset) flag may be indicated by the absence of a flag warning. Sampler users should refer to section 10.12 of this appendix regarding the validity of samples for which the sampler provided an associated flag warning.

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8.0 Filter Weighing. See reference 2 in section 13.0 of this appendix, for additional, more detailed guidance.

8.1 Analytical balance. The analytical balance used to weigh filters must be suitable for weighing the type and size of filters specified, under section 6.0 of this appendix, and have a readability of ±1 μg. The balance shall be calibrated as specified by the manufacturer at installation and recalibrated immediately prior to each weighing session. See
reference 2 in section 13.0 of this appendix for additional guidance.

8.2 Filter conditioning. All sample filters used shall be conditioned immediately before both the pre- and post-sampling weighings as specified below. See reference 2 in section 13.0 of this appendix for additional guidance.

8.2.1 Mean temperature. 20 - 23 °C.

8.2.2 Temperature control. ±2 °C over 24 hours.

8.2.3 Mean humidity. Generally, 30–40 percent relative humidity; however, where it can be shown that the mean ambient relative humidity during sampling is less than 30 percent, conditioning is permissible at a mean relative humidity within ±5 relative humidity percent of the mean ambient relative humidity during sampling, but not less than 20 percent.

8.2.4 Humidity control. ±5 relative humidity percent over 24 hours.

8.2.5 Conditioning time. Not less than 24 hours.

8.3 Weighing procedure.

8.3.1 New filters should be placed in the conditioning environment immediately upon arrival and stored there until the pre-sampling weighing. See reference 2 in section 13.0 of this appendix for additional guidance.

8.3.2 The analytical balance shall be located in the same controlled environment in which the filters are conditioned. These filters shall be weighed immediately following the conditioning period without intermediate or transient exposure to other conditions or environments.

8.3.3 Filters must be conditioned at the same conditions (humidity within ±5 relative humidity percent) before both the pre- and post-sampling weighings.

8.3.4 Both the pre- and post-sampling weighings should be carried out on the same analytical balance, using an effective technique to neutralize static charges on the filter, under reference 2 in section 13.0 of this appendix. If possible, both weighings should be carried out by the same analyst.

8.3.5 The pre-sampling (tare) weighing shall be within 30 days of the sampling period.

8.3.6 The post-sampling conditioning and weighing shall be completed within 240 hours (10 days) after the end of the sample period, unless the filter sample is maintained at 4 °C or less during the entire time between retrieval from the sampler and the start of the conditioning, in which case the period shall not exceed 30 days. Reference 2 in section 13.0 of this appendix has additional guidance on transport of cooled filters.

8.3.7 Filter blanks.

8.3.7.1 New field blank filters shall be weighed along with the pre-sampling (tare) weighing of each lot of PM2.5 filters. These blank filters shall be transported to the sampling site, installed in the laboratory in protective containers during the field sampling and should be reweighed as a quality control check.

8.3.7.2 New laboratory blank filters shall be weighed along with the pre-sampling (tare) weighing of each set of PM2.5 filters. These laboratory blank filters should remain in the laboratory in protective containers during the field sampling and should be reweighed as a quality control check.

8.3.8 Additional guidance for proper filter weighing and related quality assurance activities is provided in reference 2 in section 13.0 of this appendix.

9.0 Calibration. Reference 2 in section 13.0 of this appendix contains additional guidance.

9.1 General requirements.

9.1.1 Multipoint calibration and single-point verification of the sampler’s flow rate measurement device must be performed periodically to establish and maintain traceability of subsequent flow measurements to a flow rate standard.

9.1.2 An authoritative flow rate standard shall be used for calibrating or verifying the sampler’s flow rate measurement device with an accuracy of ±2 percent. The standard shall be a separate, stand-alone device designed to connect to the flow rate measurement adapter, Figure L–30 of this appendix. This flow rate standard must have its own certification and be traceable to a National Institute of Standards and Technology (NIST) primary standard for volume or flow rate. If adjustments to the sampler’s flow rate measurement system calibration are to be made in conjunction with an audit of the sampler’s flow measurement system, such adjustments shall be made following the audit. Reference 2 in section 13.0 of this appendix contains additional guidance.

9.1.3 The sampler’s flow rate measurement device shall be re-calibrated after electromagnetic maintenance or transport of the sampler.

9.2 Flow rate calibration/verification procedure.

9.2.1 PM2.5 samplers may employ various types of flow control measurement devices. The specific procedure used for calibration or verification of the flow rate measurement device will vary depending on the type of flow rate controller and flow rate measurement employed. Calibration shall be in terms of actual ambient volumetric flow rate (Qa), measured at the sampler’s inlet downtube. The generic procedure given here serves to illustrate the general steps involved in the calibration of a PM2.5 sampler. The sampler operation/instruction manual required by section 7.4.18 of this appendix and the Quality Assurance Handbook listed in reference 2 in section 13.0 of this appendix contains more specific and detailed guidance for calibration.

9.2.2 The flow rate standard used for flow rate calibration shall have its own certification and be traceable to a NIST primary standard for volume or flow rate. A calibration relationship for the flow rate standard and by the sampler’s flow rate measurement device shall have its own certification and be traceable to a NIST primary standard for volume or flow rate. A calibration relationship for the flow rate standard, e.g., an equation, curve, or family of curves relating actual flow rate (Qa) to the flow rate indicator reading, shall be established that is accurate to within 2 percent over the expected range of ambient temperatures and pressures at which the flow rate standard may be used. The flow rate standard must be re-calibrated or re-certified at least annually.

9.2.3 The sampler flow rate measurement device shall be calibrated or verified by removing the sampler inlet and connecting the flow rate standard to the sampler’s downtube in accordance with the operation/instruction manual, such that the flow rate standard accurately measures the sampler’s flow rate. The sampler operator shall first carry out a sampler leak check and confirm that the sampler passes the leak test and then verify that no leaks exist between the flow rate standard and the sampler.

9.2.4 The calibration relationship between the flow rate (in actual L/min) indicated by the flow rate standard and by the sampler’s flow rate measurement device shall be established or verified in accordance with the sampler operation/instruction manual. Temperature and pressure corrections to the flow rate indicated by the flow rate standard may be required for certain types of flow rate standards. Calibration of the sampler’s flow rate measurement device shall consist of at least three separate flow rate measurements (multipoint calibration) evenly spaced within the range of -10 percent to +10 percent of the sampler’s operational flow rate, section 7.4.1 of this appendix. Verification of the sampler’s flow rate shall consist of one flow rate measurement at the sampler’s operational flow rate. The sampler operation/instruction manual and reference 2 in section 13.0 of this appendix provide additional guidance.

9.2.5 If during a flow rate verification the reading of the sampler’s flow rate indicator or measurement device differs by ±2 percent or more from the flow rate measured by the flow rate standard, a new multipoint calibration shall be performed and the flow rate verification must then be repeated.

9.2.6 Following the calibration or verification, the flow rate standard shall be removed from the sampler and the sampler inlet shall be reinstalled. Then the sampler’s normal operating flow rate (in L/min) shall be determined with a clean filter in place. If the flow rate indicated by the sampler differs by ±2 percent or more from the required sampler flow rate, the sampler flow rate must be adjusted to the required flow rate, under section 7.4.1 of this appendix.

9.3 Periodic calibration or verification of the calibration of the sampler’s ambient temperature, filter temperature, and barometric pressure measurement systems is also required. Reference 3 of section 13.0 of this appendix contains additional guidance.

10.0 PM2.5 Measurement Procedure The detailed procedure for obtaining valid PM2.5 measurements with each specific sampler designated as part of a reference method for PM2.5 under part 53 of this chapter shall be provided in the sampler-specific operation or instruction manual required by section 7.4.18 of this appendix. Supplemental guidance is provided in section 2.12 of the Quality Assurance Handbook listed in reference 2 in section 13.0 of this appendix. The generic procedure given here serves to illustrate the general steps involved in the PM2.5 sample collection and measurement, using a PM2.5 reference method sampler.

10.1 The sampler shall be set up, calibrated, and operated in accordance with the specific, detailed guidance provided in the specific sampler’s operation or instruction manual and in accordance with a specific quality assurance program developed and established by the user, based on applicable supplementary guidance provided in section 2 in section 13.0 of this appendix.

10.2 Each new sample filter shall be inspected for correct type and size and for pinholes, particles, and other imperfections. Unacceptable filters should be discarded. A unique identification number shall be assigned to each filter, and an information record shall be established for each filter. If the filter identification number is not or cannot be marked directly on the filter, alternative means, such as a number-identified storage container, must be established to maintain positive filter identification.

10.3 Each filter shall be conditioned in the conditioning environment in accordance with the requirements specified in section 8.2 of this appendix.

10.4 Following conditioning, each filter shall be weighed in accordance with the requirements specified in section 8.0 of this appendix and the preweighing weight recorded with the filter identification number.

10.5 A numbered and preweighed filter shall be installed in the sampler following the instructions provided in the sampler operation or instruction manual.

10.6 The sampler shall be checked and prepared for sample collection in accordance with
instructions provided in the sampler operation or instruction manual and with the specific quality assurance program established for the sampler by the user.

10.7 The sampler’s timer shall be set to start the sample collection at the beginning of the desired sample period and stop the sample collection 24 hours later.

10.8 Information related to the sample collection (site location or identification number, sample date, filter identification number, and sampler model and serial number) shall be recorded and, if appropriate, entered into the sampler.

10.9 The sampler shall be allowed to collect the PM$_{2.5}$ sample during the set 24-hour time period.

10.10 Within 96 hours of the end of the sample collection period, the filter, while still contained in the filter cassette, shall be carefully removed from the sampler, following the procedure provided in the sampler operation or instruction manual and the quality assurance program, and placed in a protective container. This protective container shall be made of metal and contain no loose material that could be transferred to the filter. The protective container shall hold the filter cassette securely such that the cover shall not come in contact with the filter’s surfaces. Reference 2 in section 13.0 of this appendix contains additional information.

10.11 The total sample volume in actual m$^3$ for the sampling period and the elapsed sample time shall be obtained from the sampler and recorded in accordance with the instructions provided in the sampler operation or instruction manual. All sampler warning flag indications and other information required by the local quality assurance program shall also be recorded.

10.12 All factors related to the validity or representativeness of the sample, such as sampler tampering or malfunctions, unusual meteorological conditions, construction activity, fires or dust storms, etc. shall be recorded as required by the local quality assurance program. The occurrence of a flag warning during a sample period shall not necessarily indicate an invalid sample but rather shall indicate the need for specific review of the QC data by a quality assurance officer to determine sample validity.

10.13 After retrieval from the sampler, the exposed filter containing the PM$_{2.5}$ sample should be transported to the filter conditioning environment as soon as possible ideally to arrive at the conditioning environment within 24 hours for conditioning and subsequent weighing. During the period between filter retrieval from the sampler and the start of the conditioning, the filter shall be maintained as cool as practical and continuously protected from exposure to temperatures over 25 °C. See section 8.3.6 of this appendix regarding time limits for completing the post-sampling weighing. See reference 2 in section 13.0 of this appendix for additional guidance on transporting filter samplers to the conditioning and weighing laboratory.

10.14. The exposed filter containing the PM$_{2.5}$ sample shall be re-conditioned in the conditioning environment in accordance with the requirements specified in section 8.2 of this appendix.

10.15. The filter shall be reweighed immediately after conditioning in accordance with the requirements specified in section 8.0 of this appendix, and the post-sampling weight shall be recorded with the filter identification number.

10.16 The PM$_{2.5}$ concentration shall be calculated as specified in section 12.0 of this appendix.

11.0 Sampler Maintenance

11.1 The sampler shall be maintained as described by the sampler’s manufacturer in the sampler-specific operation or instruction manual required under section 7.4.18 of this appendix and in accordance with the specific quality assurance program developed and established by the user based on applicable supplementary guidance provided in reference 2 in section 13.0 of this appendix.

12.0 Calculations

12.1 (a) The PM$_{2.5}$ concentration is calculated as:

$$PM_{2.5} = \frac{(W_f - W_i)V_a}{V_a}$$

where:

- $PM_{2.5}$ = mass concentration of PM$_{2.5}$, µg/m$^3$;
- $W_f$, $W_i$ = final and initial weights, respectively, of the filter used to collect the PM$_{2.5}$ particle sample, µg;
- $V_a$ = total air volume sampled in actual volume units, as provided by the sampler, m$^3$.

(b) Note: Total sample time must be between 1,380 and 1,500 minutes (23 and 25 hrs) for a fully valid PM$_{2.5}$ sample; however, see also section 3.3 of this appendix.

13.0 References


14.0 Figures L–1 through L–30 to Appendix L.
FIGURE L-1. PM2.5 SAMPLER, ASSEMBLY

ATTACH WATER COLLECTOR HARDWARE

(FOR EXAMPLE: 1/4" NPT GLASS JAR
BRASS, LONG NIPPLE, 1/4" MNPT X 2" LONG
BRASS, BUSHING, 1/4" FNPT X 3/8" MNPT
BRASS, PLUG, 1/4" MNPT)

DOTTED LINE INDICATES
TOP OF SAMPLER CASE

<table>
<thead>
<tr>
<th>TOLERANCES</th>
<th>ALL DIMENSIONS ARE INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 PLCS</td>
<td>+/- 0.010</td>
</tr>
<tr>
<td>3 PLCS</td>
<td>+/- 0.005</td>
</tr>
<tr>
<td>FRAC.</td>
<td>+/- 1/64</td>
</tr>
<tr>
<td>ANGLE</td>
<td>+/- 15'</td>
</tr>
</tbody>
</table>
FIGURE L-3. 10-MICRON INLET, TOP

NOTES:

1. COMMERCIAL SPINNING TOLERANCES ARE ACCEPTABLE
2. MATERIAL IS SPUN 6061-T6 ALUMINUM, POST-HEAT TREATED TO-T4
3. CLEAR ANODIZE

0.149 DIA. 4 PLCS
EQUALY SPACED ON
A 0.500 DIA. R.
SYMMETRICAL
ABOUT CIL
0.03 MAX
0.20 MAX
5.00
7.20
9.70
45°
BEAD ROLL 1/4" FROM EDGE
0.093 STOCK
TOP VIEW
(1) MATERIAL: 0.031 THK. SCE-41 CSN PSA. 2 SIDES

0.031 STOCK

3.5 ID

4.980 OD

NOTES:

TOLERANCES

SPACING: +/- 0.010

MAX: +/- 0.025

MIN: +/- 0.025

ANGLE: +/- 15°

ALL DIMENSIONS ARE INCHES
FIGURE L-9, 10-MICRON SPACER

NOTES:
1. BREAK ALL SHARP EDGES
2. MATERIAL IS ALUMINUM TUBING
3. CLEAR ANODIZE
4. 4 REQUIRED PER UNIT

6-32 UNC-2B X 1/2 DEEP BOTH ENDS

1/4

TOP VIEW
FIGURE L-11. 10-MICRON INLET, LOWER

0.03 MAX.

0.20 MAX.

0.145 IDIA 4 PLCS.
A 0.950 IDIA IDIA.

0.136 IDIA 6 PLCS.
EQUALY SPACED ON
A 3.855 IDIA IDIA.

0.125 IDIA IDIA FOR A
0.083 STOCK.

BEAD ROLL 1/4" FROM EDGE

45°

NOTES:

1. BEND RADIUS: MINIMUM PER COMMERCIAL SPINNING OR STAMPING STANDARDS.
2. MATERIALS: SPIN ALUMINUM 6061-T6, POST-HEAT TREATED TO -74.
3. CLEAR ANODIZE.
NOTES:
(1) BREAK ALL SHARP EDGES
(2) CLEAR ANODIZE
(3) TUBING 2.75 O.D. x 2.38 I.D.
(4) FINISH #83

2.625-16 UN X 0.25 +/- 0.020 LG. THD. - LOOSE FIT

3/8 NPT (AFTER ASSEMBLY)

TOLERANCES

<table>
<thead>
<tr>
<th>TOLG</th>
<th>TOLG</th>
<th>FRAC</th>
<th>ANGLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/-0.010</td>
<td>+/-0.005</td>
<td>+/-1/64</td>
<td>+/-15'</td>
</tr>
</tbody>
</table>

ALL DIMENSIONS ARE INCHES
FIGURE L-18. 10-MICRON EXIT ADAPTOR

NOTES:
1. BREAK ALL SHARP EDGES
2. MATERIAL IS ALUMINUM 6061-T6
3. CLEAR ANODIZE
4. 2.75 O.D. RD. STK.

DIMENSIONS ARE INCHES

TOLERANCES:
+/- 0.005
+/- 0.010
+/- 0.005
+/- 0.125
+/- 0.184
FIGURE L-22. 2.5-MICRON IMPACTOR WELL, UPPER SECTION

NOTES:
(1) FINISH: CLEAR ANODIZE
(2) 32 RMS FINISH ALL OVER
(3) MATERIAL IS ALUMINUM 6061-T6

<table>
<thead>
<tr>
<th>TOLERANCES</th>
<th>2 PCS</th>
<th>3 PCS</th>
<th>FRAC.</th>
<th>ANGLE</th>
</tr>
</thead>
</table>
| +/- 0.010  | +/- 0.005 | +/- 1/64 | +/- 15' |}

ALL DIMENSIONS ARE INCHES
Figure L-23. 2.5-micron impactor well, lower section.

NOTES:
(1) CLEAR ANODIZE
(2) 32 RMS FINISH ALL OVER
(3) MATERIAL ALUMINUM 6061-T6

TOLERANCES
RMS +/-.010
+/- .005
+/- .020
FIGURE L-24. 2.5-MICRON IMPACTOR HOUSING, LOWER

NOTES:
(1) MATERIAL IS ALUMINUM 6061-T6
(2) CLEAR ANODIZE
(3) BOXED DIMENSIONS ARE OPTIONAL
(4) THIS PART AND FILTER HOLDER, TOP (FIGURE L-26) MAY BE MACHINED AS ONE PIECE; INTERNAL SURFACES AND DIMENSIONS MUST BE AS SHOWN

<table>
<thead>
<tr>
<th>TOLERANCES</th>
<th>ALL DIMENSIONS ARE INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOL.</td>
<td>TOL.</td>
</tr>
<tr>
<td>+/- 0.010</td>
<td>+/- 0.005</td>
</tr>
</tbody>
</table>
**FIGURE L-27. FILTER CASSETTE, UPPER SECTION**

**NOTES:**

(1) MATERIAL IS WHITE DELRIN®

---

**TOLERANCES**

<table>
<thead>
<tr>
<th>2 PLCS</th>
<th>3 PLCS</th>
<th>FRACT.</th>
<th>ANGLE</th>
<th>ALL DIMENSIONS ARE INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 0.010</td>
<td>+/- 0.005</td>
<td>+/- 1/64</td>
<td>+/- 15'</td>
<td></td>
</tr>
</tbody>
</table>

DELRIN® IS A TRADEMARK OF DUPONT ENGINEERING POLYMERS.
USE OF THIS NAME DOES NOT CONSTITUTE AN ENDORSEMENT OF EPA.
NOTES:
(1) MATERIAL IS 302 OR 304 STAINLESS
    (FULL OR HALF HARD)  
(2) HOLES ARE FORGED IN STRESS RELIEF AREA SHOWN

HOLES PATTERN
FIGURE L-29. FILTER CASSETTE, LOWER SECTION

NOTES:
(1) MATERIAL IS WHITE DELRIN®

DELRIN® IS A TRADEMARK OF DUPONT ENGINEERING POLYMERS. USE OF THIS NAME DOES NOT CONSTITUTE AN ENDORSEMENT OF EPA.

<table>
<thead>
<tr>
<th>TOLERANCES</th>
<th>2 PLCS</th>
<th>3 PLCS</th>
<th>FRAC</th>
<th>ANGLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 0.010</td>
<td>+/- 0.005</td>
<td>+/- 1/64</td>
<td>+/- 15'</td>
<td></td>
</tr>
</tbody>
</table>

ALL DIMENSIONS ARE INCHES
FIGURE L-30. FLOW RATE MEASUREMENT ADAPTER

NOTES:
1) MATERIAL IS ALUMINUM 6061-T6

TOLERANCES

<table>
<thead>
<tr>
<th>TOLERANCES</th>
<th>PLUS</th>
<th>MINUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8&quot;</td>
<td>+0.008</td>
<td>-0.010</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>+0.006</td>
<td>-0.015</td>
</tr>
</tbody>
</table>

ALL DIMENSIONS ARE INCHES
Appendix 5

Supplementary Material for Chapter 5

Part E
40CFR, Part 53, Subpart E
The accuracy of flow rate meters shall be verified at the highest and lowest pressures and temperatures used in the tests and shall be checked at zero and at least one flow rate within ±3 percent of 16.7 L/min within 7 days prior to use for this test. Where an instrument’s measurements are to be recorded with an analog recording device, the accuracy of the entire instrument-recorder system shall be calibrated or verified. (e) Test setup. (1) The candidate test sampler shall have its inlet and impactor or impactors removed. The lower end of the downstream tube shall be reconnected to the filter holder, using an extension of the downtube, if necessary. If the candidate sampler has a separate impactor for each channel, then for this test, the filter holder assemblies must be connected to the physical location on the sampler where the impactors would normally connect.

(2) The test particle delivery system shall be connected to the sampler downtube so that the test aerosol is introduced at the top of the downtube. (f) Test procedure. (1) All surfaces of the added or modified component or components which come in contact with the aerosol flow shall be thoroughly washed with 0.01 N NaOH and then dried.

(2) Generate aerosol. (i) Generate aerosol composed of oleic acid with a uranine fluorometric tag of 3 ± 0.25 µm aerodynamic diameter using a vibrating orifice aerosol generator according to conventions specified in § 53.61(g).

(ii) Check for the presence of satellites and adjust the generator to minimize their production.

(iii) Calculate the aerodynamic particle size using the operating parameters of the vibrating orifice aerosol generator. The calculated aerodynamic diameter must be 3 ± 0.25 µm aerodynamic diameter.

(3) Verify the particle size according to procedures specified in § 53.62(d)(4)(i).

(4) Collect particles on filters for a time period such that the relative error of the resulting measured fluorometric concentration for the active filter is less than 5 percent.

(5) Determine the quantity of material collected on the active filter using a calibrated fluorometer. Record the mass of fluorometric material for the active filter as \( M_{\text{active}} \) for each channel, making each calculation for each channel separately.

\[
T_i = \frac{M_{\text{active}}}{M_{\text{active}} + M_{\text{wash}} + M_{\text{no-flow}}} \times 100\% 
\]

where:

\( T_i \) = the active channel number.

(9) Repeat paragraphs (f)(1) through (8) of this section for each channel, making each channel in turn the exclusive active channel.

(g) Test results. The candidate Class I sampler passes the aerosol transport test if \( T_i \) is at least 97 percent for each channel.

<table>
<thead>
<tr>
<th>Subpart E Procedure</th>
<th>Performance Test</th>
<th>Performance Specification</th>
<th>Test Conditions</th>
<th>Part 50, Appendix L Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>§ 53.52 Sampler leak check test</td>
<td>Sampler leak check facility</td>
<td>External leakage: 80 mL/min, max Internal leakage: 80 mL/min, max</td>
<td>Controlled leak flow rate of 80 mL/min</td>
<td>Sec. 7.4.6</td>
</tr>
<tr>
<td>§ 53.53 Base flow rate test</td>
<td>Sample flow rate: 1. Mean 2. Regulation 3. Meas. accuracy 4. CV accuracy 5. Cut-off 6. Proper operation</td>
<td>1. 16.67 ± 5%, L/min 2. 2%, max 3. 2%, max 4. 0.3%, max 5. Flow rate cut-off if flow rate deviates more than 10% from design flow rate for &gt;60 + 30 seconds</td>
<td>(a) 6-hour normal operational test plus flow rate cut-off test (b) Nominal conditions (c) Additional 55 mm Hg pressure drop to simulate loaded filter (d) Variable flow restriction used for cut-off test</td>
<td>Sec. 7.4.1 Sec. 7.4.2 Sec. 7.4.3 Sec. 7.4.4 Sec. 7.4.5</td>
</tr>
<tr>
<td>§ 53.54 Power interruption test</td>
<td>Sample flow rate: 1. Mean 2. Regulation 3. Meas. accuracy 4. CV accuracy 5. Occurrence time of power interruptions 6. Elapsed sample time 7. Sample volume</td>
<td>1. 16.67 ± 5%, L/min 2. 2%, max 3. 2%, max 4. 0.3%, max 5. &gt;2 min if &gt;60 seconds 6. &gt;20 seconds 7. &gt;2%, max</td>
<td>(a) 6-hour normal operational test (b) Nominal conditions (c) Additional 55 mm Hg pressure drop to simulate loaded filter (d) 6 power interruptions of various durations</td>
<td>Sec. 7.4.1 Sec. 7.4.2 Sec. 7.4.3 Sec. 7.4.4 Sec. 7.4.5 Sec. 7.4.13 Sec. 7.4.14 Sec. 7.4.15.4 Sec. 7.4.15.5</td>
</tr>
<tr>
<td>§ 53.55 Temperature and line voltage effect test</td>
<td>Sample flow rate: 1. Mean 2. Regulation 3. Meas. accuracy 4. CV accuracy 5. Temperature meas. accuracy 6. Proper operation</td>
<td>1. 16.67 ± 5%, L/min 2. 2%, max 3. 2%, max 4. 0.3%, max 5. 2° C</td>
<td>(a) 6-hour normal operational test (b) Nominal conditions (c) Additional 55 mm Hg pressure drop to simulate loaded filter (d) Ambient temperature at -20 and +40 °C (e) Line voltage: 105 Vac to 125 Vac</td>
<td>Sec. 7.4.1 Sec. 7.4.2 Sec. 7.4.3 Sec. 7.4.4 Sec. 7.4.5 Sec. 7.4.6 Sec. 7.4.15.1</td>
</tr>
</tbody>
</table>
Table E-1.—Summary of Test Requirements for Reference and Class I Equivalent Methods for PM$_{2.5}$—Continued

<table>
<thead>
<tr>
<th>Subpart E Procedure</th>
<th>Performance Test</th>
<th>Performance Specification</th>
<th>Test Conditions</th>
<th>Part 50, Appendix L Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>§ 53.56 Barometric pressure effect test</td>
<td>Sample flow rate: 1. Mean 2. Regulation 3. Meas. accuracy 4. CV accuracy 5. Pressure meas. accuracy 6. Proper operation</td>
<td>1. 16.67 ± 5%, L/min 2. 2%, max 3. 2%, max 4. 0.3%, max 5. 10 mm Hg</td>
<td>(a) 6-hour normal operational test (b) Nominal conditions (c) Additional 55 mm Hg pressure drop to simulate loaded filter (d) Barometric pressure at 600 and 800 mm Hg.</td>
<td>Sec. 7.4.1 Sec. 7.4.2 Sec. 7.4.3 Sec. 7.4.5 Sec. 7.4.9</td>
</tr>
<tr>
<td>§ 53.57 Filter temperature control test</td>
<td>1. Filter temp meas. accuracy 2. Ambient temp. meas. accuracy 3. Filter temp control accuracy, sampling and non-sampling</td>
<td>1. 2 °C 2. 2 °C 3. Not more than 5 °C above ambient temp. for more than 30 min</td>
<td>(a) 4-hour simulated solar radiation, sampling (b) 4-hour simulated solar radiation, non-sampling (c) Solar flux of 1000 W/m$^2$</td>
<td>Sec. 7.4.8 Sec. 7.4.10 Sec. 7.4.11</td>
</tr>
<tr>
<td>§ 53.58 Field precision test</td>
<td>1. Measurement precision 2. Storage deposition test for sequential samplers</td>
<td>1. $P_j &lt; 2$ µg/m$^3$ for conc. &lt;40 µg/m$^3$ (24-hr) or &lt;30 µg/m$^3$ (48-hr); or $RP_j &lt; 5%$ for conc. &gt;40 µg/m$^3$ (24-hr) or &gt;30 µg/m$^3$ (48-hr) 2. 50 µg, max weight gain</td>
<td>(a) 3 collocated samplers at 1 site for at least 10 days (b) PM$_{2.5}$ conc. ≤10 µg/m$^3$ (c) 24- or 48-hour samples (d) 5- or 10-day storage period for inactive stored filters</td>
<td>Sec. 5.1 Sec. 7.3.5 Sec. 8 Sec. 10</td>
</tr>
</tbody>
</table>

The Following Requirement is Applicable to Candidate Equivalent Methods Only

§ 53.59 Aerosol transport test | Aerosol transport | 97%, min, for all channels | Determine aerosol transport through any new or modified components with respect to the reference method sampler before the filter for each channel. |

**Table E-2.—Spectral Energy Distribution and Permitted Tolerance for Conducting Radiative Tests**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Ultraviolet</th>
<th>Visible</th>
<th>Infrared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (µm)</td>
<td>0.28 to 0.32</td>
<td>10.32 to 0.40</td>
<td>0.40 to 0.78</td>
</tr>
<tr>
<td>Irradiance (W/m$^2$)</td>
<td>5</td>
<td>56</td>
<td>450 to 550</td>
</tr>
<tr>
<td>Allowed Tolerance</td>
<td>±15%</td>
<td>±25%</td>
<td>±10%</td>
</tr>
</tbody>
</table>
### DESIGNATION TESTING CHECKLIST

<table>
<thead>
<tr>
<th>Verification</th>
<th>Compliance Status: Y = Yes</th>
<th>N = No</th>
<th>NA = Not applicable/Not available</th>
<th>Verification Comments (Includes documentation of who, what, where, when, why) (Doc. #, Rev. #, Rev. Date)</th>
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</thead>
<tbody>
<tr>
<td>Performance Specification Tests</td>
<td>Sample flow rate coefficient of variation (§ 53.53) (L 7.4.3)</td>
<td>Verified by Direct Observation of Process or of Documented Evidence: Performance, Design or Application Spec. Corresponding to Sections of 40 CFR Part 53 or 40 CFR Part 50, Appendix L</td>
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<tr>
<td>Filter temperature control (sampling) (§ 53.57) (L 7.4.10)</td>
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<tr>
<td>Elapsed sample time accuracy (§ 53.54) (L 7.4.13)</td>
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<td>Filter temperature control (post sampling) (§ 53.57) (L 7.4.10)</td>
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<tr>
<td>Application Specification Tests</td>
<td>Field Precision (§ 53.58) (L 5.1)</td>
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</tr>
<tr>
<td>Meets all Appendix L requirements (part 53, subpart A, § 53.2(a)(3)) (part 53, subpart E, § 53.51(a),(d))</td>
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<td>Filter Weighing (L-8)</td>
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<td>Field Sampling Procedure (§ 53.30, .31, .34)</td>
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<td>Design Specification Tests</td>
<td>Filter (L-6)</td>
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<td>Range of Operational Conditions (L-7.4.7)</td>
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<tr>
<td>The Following Requirements Apply Only to Class I Candidate Equivalent Methods</td>
<td>Aerosol Transport (§ 53.59)</td>
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### Figure E-2—Product Manufacturing Checklist

**PRODUCT MANUFACTURING CHECKLIST**

<table>
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<th>NA = Not applicable/Not available</th>
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<tbody>
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</table>

*Verification Comments (Includes documentation of who, what, where, when, why) (Doc. #, Rev. #, Rev. Date)*

**Performance Specification Tests**

- Assembled operational performance (Burn-in test) (§ 53.53)
- Sample flow rate (§ 53.53) (L 7.4.1, L 7.4.2)
- Sample flow rate regulation (§ 53.53) (L 7.4.3)
- Flow rate and average flow rate measurement accuracy (§ 53.53) (L 7.4.5)
- Ambient air temperature measurement accuracy (§ 53.55) (L 7.4.8)
- Ambient barometric pressure measurement accuracy (§ 53.56) (L 7.4.9)
- Sample flow rate cut-off (§ 53.53) (L 7.4.4)
- Sampler leak check facility (§ 53.52) (L 7.4.6)

**Application Specification Tests**

- Flow rate calibration transfer standard (L-9.2)
- Operational /Instructional manual (L-7.4.18)

**Design Specification Tests**

- Impactor (jet width) (§ 53.51(d)(1)) (L-7.3.4.1)
- Surface finish (§ 53.51(d)(2)) (L-7.3.7)
Appendix A to Subpart E of Part 53—

References


e. Subpart F is added to read as follows:

Subpart F—Procedures for Testing Performance Characteristics of Class II Equivalent Methods for PM$_{2.5}$

§53.60 General provisions.

(a) This subpart sets forth the specific requirements that a PM$_{2.5}$ sampler associated with a candidate Class II equivalent method must meet to be designated as an equivalent method for PM$_{2.5}$. This subpart also sets forth the explicit test procedures that must be carried out and the test results, evidence, documentation, and other materials that must be provided to EPA to demonstrate that a sampler meets all specified requirements for designation as an equivalent method.

(b) A candidate method described in an application for a reference or equivalent method application submitted under §53.4 shall be determined by the EPA to be a Class II candidate equivalent method on the basis of the definition of a Class II equivalent method given in §53.1.

(c) Any sampler associated with a Class II candidate equivalent method (Class II sampler) must meet all requirements for reference method samplers and Class I equivalent method samplers specified in subpart E of this part, as appropriate. In addition, a Class II sampler must meet the additional requirements as specified in paragraph (d) of this section.

(d) Except as provided in paragraphs (d)(1), (2), and (3) of this section, all Class II samplers are subject to the additional tests and performance requirements specified in §53.62 (full wind tunnel test), §53.65 (loading test), and §53.66 (volatility test). Alternative tests and performance requirements, as described in paragraphs (d)(1), (2), and (3) of this section, are optionally available for certain Class II samplers which meet the requirements for reference method or Class I samplers given in 40 CFR part 50, Appendix L, and in subpart E of this part, except for specific deviations of the inlet, fractionator, or filter.

(1) Inlet deviation. A sampler which has been determined to be a Class II sampler solely because the design or construction of its inlet deviates from the design or construction of the inlet of a reference method sampler shall not be subject to the requirements of §53.62 (full wind tunnel test), provided that it meets all requirements of §53.63 (wind tunnel inlet aspiration test), §53.65 (loading test), and §53.66 (volatility test).

(2) Fractionator deviation. A sampler which has been determined to be a Class II sampler solely because construction or design of its particle size fractionator deviates from the design or construction of the particle size fractionator specified in 40 CFR part 50, Appendix L for reference method samplers shall not be subject to the requirements of §53.62 (full wind tunnel test), provided that it meets all requirements of §53.64 (static fractionator test), §53.65 (loading test), and §53.66 (volatility test).

(3) Filter size deviation. A sampler which has been determined to be a Class II sampler solely because its effective filtration area deviates from that of the reference method sampler specified in 40 CFR part 50, Appendix L, for reference method samplers shall not be subject to the requirements of §53.62 (full wind tunnel test) nor §53.65 (loading test), provided it meets all requirements of §53.66 (volatility test).

(e) The test specifications and acceptance criteria for each test are summarized in Table F-1 of this subpart. The candidate sampler must demonstrate performance that meets the acceptance criteria for each applicable test to be designated as an equivalent method.

(1) Overview of various test procedures for Class II samplers—(1) Full wind tunnel test. This test procedure is designed to ensure that the candidate sampler’s effectiveness (aspiration of an ambient aerosol and penetration of the sub 2.5-micron fraction to its sample filter) will be comparable to that of a reference method sampler. The candidate sampler is challenged at wind speeds of 2 and 24 km/hr with monodisperse aerosols of the size specified in Table F-2 of this subpart. The experimental test results are then integrated with three idealized ambient distributions (typical, fine, and coarse) to yield the expected mass concentration measurement for each. The acceptance criteria are based on the results of this numerical analysis and the particle diameter for which the sampler effectiveness is 50 percent.

(2) Wind tunnel inlet aspiration test. The wind tunnel inlet aspiration test directly compares the inlet of the candidate sampler to the inlet of a reference method sampler with the single-sized, liquid, monodisperse challenge aerosol specified in Table F-2 of this subpart at wind speeds of 2 km/hr and 24 km/hr. The acceptance criteria, presented in Table F-1 of this subpart, is based on the relative aspiration between the candidate inlet and the reference method inlet.

(3) Static fractionator test. The static fractionator test determines the effectiveness of the candidate sampler’s 2.5-micron fractionator under static conditions for aerosols of the size specified in Table F-2 of this subpart. The numerical analysis procedures and acceptance criteria are identical to those in the full wind tunnel test.

(4) Loading test. The loading test is conducted to ensure that the performance of a candidate sampler is not significantly affected by the amount of particulate deposited on its interior surfaces between periodic cleanings. The candidate sampler is artificially loaded by sampling a test...
Appendix 5

Supplementary Material for Chapter 5

Part F
Appendix A to 40CFR, Part 58
(c) Each PM$_{2.5}$ station in the SLAMS network must be in operation in accordance with the minimum requirements of Appendix D of this part, be sited in accordance with the criteria in Appendix E of this part, and be located as described on the station’s AIRS site identification form, according to the following schedule:

1. Within 1 year after September 16, 1997, at least one required core PM$_{2.5}$ SLAMS site in each MSA with population greater than 500,000, plus one site in each PAMS area, (plus at least two additional SLAMS sites per State) must be in operation.

2. Within 2 years after September 16, 1997, all other required SLAMS, including all required core SLAMS, required regional background and regional transport SLAMS, continuous PM monitors in areas with greater than 1 million population, and all additional required PM$_{2.5}$ SLAMS must be in operation.

3. Within 3 years after September 16, 1997, all additional sites (e.g., sites classified as SLAMS/SPM to complete the mature network) must be in operation.

§ 58.26 Annual state air monitoring report.

(b) The SLAMS annual data summary report must contain:

(d) For PM monitoring and data—(1) The State shall submit a summary to the appropriate Regional Office (for SLAMS) or Administrator (through the Regional Office) (for NAMS) that details proposed changes to the PM Monitoring Network Description and to be in accordance with the annual network review requirements in § 58.25. This shall discuss the existing PM networks, including modifications to the number, size or boundaries of monitoring planning areas and optional community monitoring zones; number and location of PM$_{10}$ and PM$_{2.5}$ SLAMS; number and location of core PM$_{2.5}$ SLAMS; alternative sampling frequencies proposed for PM$_{2.5}$ SLAMS (including core PM$_{2.5}$ SLAMS and PM$_{2.5}$ NAMS), core PM$_{2.5}$ SLAMS to be designated PM$_{2.5}$ NAMS; and PM$_{10}$ and PM$_{2.5}$ SLAMS to be designated PM$_{10}$ and PM$_{2.5}$ NAMS respectively.

(2) The State shall submit an annual summary to the appropriate Regional Office of all the ambient air quality monitoring PM data from all special purpose monitors that are described in the State’s PM monitoring network description and are intended for SIP purposes. These include those population-oriented SPMs that are eligible for comparison to the PM NAAQS. The State shall certify the data in accordance with paragraph (c) of this section.

(e) The Annual State Air Monitoring Report shall be submitted to the Regional Administrator by July 1 or by an alternative annual date to be negotiated between the State and Regional Administrator. The Region shall provide review and approval/disapproval within 60 days. After 3 years following September 16, 1997, the schedule for submitting the required annual revised PM$_{2.5}$ monitoring network description may be altered based on a new schedule determined by the Regional Administrator. States may submit an alternative PM monitoring network description in which it requests exemptions from specific required elements of the network design (e.g., required number of core sites, other SLAMS, sampling frequency, etc.). After 3 years following September 16, 1997 or once a CMZ monitoring area has been determined to violate the NAAQS, then changes to an MPA monitoring network affecting the violating locations shall require public review and notification.

h. Section 58.30 is amended by revising the introductory text of paragraph (a) to read as follows:

§ 58.30 NAMS network establishment.

(a) By January 1, 1980, with the exception of PM$_{10}$ and PM$_{2.5}$ samplers, which shall be by July 1, 1998, the State shall: * * * * *

j. In § 58.31, paragraph (f) is revised to read as follows:

§ 58.31 NAMS network description.

(f) The monitoring objective, spatial scale of representativeness, and for PM$_{2.5}$, the monitoring planning area and community monitoring zone, as defined in Appendix D of this part.

§ 58.34 NAMS network completion.

With the exception of PM$_{10}$ samplers, which shall be by 1 year after September 16, 1997, and PM$_{2.5}$, which shall be by 3 years after September 16, 1997:

k. In § 58.35, the first sentence of paragraph (b) is revised to read as follows:

§ 58.35 NAMS data submittal.

(b) The State shall report to the Administrator all ambient air quality data for SO$_2$, CO, O$_3$, NO$_2$, Pb, PM$_{10}$, and PM$_{2.5}$, and information specified by the AIRS Users Guide (Volume II, Air Quality Data Coding, and Volume III, Air Quality Data Storage) to be coded into the AIRS-AQS format. * * *

l. Revise Appendix A of part 58 to read as follows:

 Appendix A—Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS)

1. General Information.
Agency requirements (Reference 4 of this Appendix), and approved by the appropriate Regional Administrator, or the Regional Administrator’s designee. The Quality Assurance Program will be reviewed during the systems audits described in section 2.5 of this Appendix.

2.2.1 Common factors that should be considered by reporting organizations include:

(a) Precision. A measurement of mutual agreement among individual measurements of the same property usually under prescribed similar conditions, expressed generally in terms of the standard deviation;

(b) Accuracy. The degree of agreement between an observed value and an accepted reference value, accuracy includes a combination of random error (precision) and systematic error (bias) components which are due to sampling and analytical operations;

(c) Bias. The systematic or persistent distortion of a measurement process which causes errors in one direction. The individual results of these tests for each method shall be reported to EPA as specified in section 4 of this Appendix. EPA will then calculate quarterly assessments of measurement uncertainty applicable to the SLAMS data as described in section 5 of this Appendix. Data assessment results should be reported to EPA only for methods and analyzers approved for use in SLAMS monitoring under Appendix C of this part.

3.0.3 Each reporting organization shall be defined as a State, subordinate organization within a State, or other organization that is responsible for a set of stations that monitors the same pollutant and for which data quality assessments can be pooled. States must define one or more reporting organizations for each pollutant such that each monitoring station in the State SLAMS network is included in one, and only one, reporting organization.

3.0.4 Assessment results shall be reported as specified in section 4 of this Appendix. Table A-1 of this Appendix provides a summary of the minimum data quality assessment requirements, which are described in more detail in the following sections.

3.1 Precision of Automated Methods Excluding PM2.5.

3.1.1 Methods for SO2, NO2, O3, and CO. A one-point precision check must be performed at least once every 2 weeks on each automated analyzer used to measure SO2, NO2, and O3. The precision check is made by having the analyzer with a precision check gas of known concentration (effective concentration for open path analyzers) between 0.08 and 10 ppm for SO2, NO2, and O3, and between 8 and 10 ppm for CO analyzers. To check the precision of SLAMS analyzers operating on ranges higher than 0.1 ppm, SO2, NO2, and O3, or 0 to 100 ppm for CO, use precision check gases of appropriately higher concentration as approved by the appropriate Regional Administrator or their designee. However, the results of precision checks at concentration levels other than those specified above need not be reported to EPA. The standards from which precision check test concentrations are obtained must meet the specifications of section 2.3 of this Appendix.

3.1.1.1 Except for certain CO analyzers described below, point analyzers that operate in their normal sampling mode during the precision check, and the test atmosphere must pass through all filters, scrubbers, conditioners and other components used during normal ambient sampling and as much of the ambient air inlet system as is practicable. If permitted by the associated operation or instruction manual, a CO point analyzer may be temporarily modified during the precision check to reduce vent or purge flows, or the test atmosphere may enter the analyzer at a point other than the normal sample inlet, provided that the analyzer’s response is not likely to be altered by these deviations from the normal operation mode. If a precision check is made in conjunction with a zero or span adjustment, it must be made prior to such zero or span adjustments. Randomization of the precision check with respect to time of day, day of week, and routine service and adjustments is encouraged wherever possible.

3.1.1.2 Open path analyzers are tested by inserting a test cell containing a precision check gas concentration into the optical measurement beam of the instrument. If possible, the normally used transmitter, receiver, and as appropriate, reflecting dome should be used during the test, and the sample inlet, provided that the analyzer’s response is not likely to be altered by these deviations from the normal operation mode. If a precision check is made in conjunction with a zero or span adjustment, it must be made prior to such zero or span adjustments. Randomization of the precision check with respect to time of day, day of week, and routine service and adjustments is encouraged wherever possible. If permitted by the associated operation or instruction manual, an alternate local light source or an alternate optical path that does not include the normal atmospheric monitoring path may be used. The actual concentration of the precision check gas in the test cell must be selected to produce an effective concentration in the range specified in section 3.1.1. Generally, the precision test concentration measurement will be the sum of the atmospheric pollutant concentration and the precision test concentration. If so, the result must be corrected to remove the atmospheric concentration contribution. The corrected concentration is obtained by subtracting the average of the atmospheric concentrations measured by the open path instrument under the same conditions before and immediately after the precision check test from the precision test concentration measurement. If the difference between these before and after measurements is greater than 20 percent of the effective concentration of the test gas, discard the test result and repeat the test. If possible, open path analyzers should be tested during periods when the
3.1.1.3 Report the actual concentration (effective concentration for open path analyzers) of the precision check gas and the corresponding concentration measurement (corrected concentration, if applicable, for open path analyzers) indicated by the analyzer. The percent differences between these concentrations are used to assess the precision of the monitoring data as described in section 5.1 of this Appendix.

3.1.2 Methods for Particulate Matter Excluding PM10. A one-point precision check must be performed at least once every 2 weeks on each automated analyzer used to measure PM10. The precision check is made by checking the operational flow rate of the analyzer. If a precision flow rate check is made in conjunction with a flow rate adjustment, it must be made prior to such flow rate adjustment. Randomization of the precision check with respect to time of day, day of week, and routine service and adjustments is encouraged where possible.

3.1.2.1 Standard procedure: Use a flow rate transfer standard certified in accordance with section 2.3.3 of this Appendix to check the analyzer’s normal flow rate. Care should be used in selecting and using the flow rate measurement device such that it does not alter the normal operating flow rate of the analyzer. Report the actual analyzer flow rate measured by the transfer standard and the corresponding flow rate measured, indicated, or assumed by the analyzer.

3.1.2.2 Alternative procedure: If it is permissible to obtain the precision check flow rate data from the analyzer’s internal flow meter without the use of an external flow rate transfer standard, provided:

3.1.2.2.1 The flow meter is audited with an external flow rate transfer standard at least every 6 months.

3.1.2.2.2 Records of at least the three most recent flow audits of the instrument’s internal flow meter over at least several weeks confirm that the flow meter is stable, verifiable, and accurate to ±4%.

3.1.2.2.3 The instrument and flow meter give no indication of improper operation.

3.1.2.2.4 With suitable communication capability, the precision check may thus be carried out remotely. For this procedure, report the set-point flow rate as the actual flow rate along with the flow rate measured or indicated by the analyzer flow meter.

3.1.2.2.5 For either procedure, the percent differences between the actual and indicated flow rates are used to assess the precision of the monitoring data as described in section 5.1 of this Appendix (using flow rates in lieu of concentrations). The percent differences between these concentrations are used to assess the precision of the monitoring data as described in section 5.1 of this Appendix.

3.2 Accuracy of Automated Methods Excluding PM10.

3.2.1 Methods for SO2, NO2, O3, or CO.

3.2.1.1 Each calendar quarter (during which analyzers are operated), audit at least 25 percent of the SLAMS analyzers that monitor for SO2, NO2, O3, or CO such that each analyzer is audited at least once per year. If there are fewer than four analyzers for a pollutant within a reporting organization, randomly reaudit one or more analyzers so that at least one analyzer for that pollutant is audited each calendar quarter. Where possible, EPA strongly encourages more frequent auditing, up to an audit frequency of once per quarter for each SLAMS analyzer.

3.2.1.2 (a) The audit is made by challenging the analyzer with at least one audit gas of known concentration (effective concentration for open path analyzers) from each of the following ranges applicable to the analyzer being audited:

<table>
<thead>
<tr>
<th>Audit Level</th>
<th>SO2, O3</th>
<th>NO2</th>
<th>CO</th>
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<tr>
<td>1</td>
<td>0.03–0.08</td>
<td>0.03–0.08</td>
<td>3–8</td>
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<tr>
<td>2</td>
<td>0.15–0.20</td>
<td>0.15–0.20</td>
<td>15–20</td>
</tr>
<tr>
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<td>0.35–0.45</td>
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<tr>
<td>4</td>
<td>0.80–0.90</td>
<td>...</td>
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</tr>
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</table>

(b) NO2 audit gas for chemiluminescence-type NO2 analyzers must also contain at least 0.08 ppm NO.

3.2.1.3 NO concentrations substantially higher than 0.08 ppm, as may occur when using some gas phase titration (GPT) techniques, may lead to audit errors in chemiluminescence analyzers due to inevitable minor NO-NO2 channel imbalance. Such errors may be atypical of routine monitoring errors to the extent that such NO concentrations exceed typical ambient NO concentrations at the site. These errors may be minimized by modifying the GPT technique to lower the NO concentrations remaining in the NO2 audit gas to levels closer to typical ambient NO concentrations at the site.

3.2.1.4 To audit SLAMS analyzers operating on ranges higher than 0 to 1.0 ppm for SO2, NO2, and O3, or 0 to 100 ppm for CO, use audit gases of appropriately higher concentration as approved by the appropriate Regional Administrator or the Administrator’s designee. The results of audits at concentration levels other than those shown in the above table need not be reported to EPA.

3.2.1.5 The standards from which audit gas test concentrations are obtained must meet the specifications of section 2.3 of this Appendix. The gas standards and equipment used for auditing must not be the same as the standards and equipment used for calibration or calibration span adjustments. The auditor should not be the operator or analyst who conducts the routine monitoring, calibration, and analysis.

3.2.1.6 For point analyzers, the audit shall be carried out by allowing the analyzer to analyze the audit test atmosphere in its normal sampling mode such that the test atmosphere passes through all filters, scrubbers, conditioners, and other sample inlet components used during normal ambient sampling and as much of the ambient air inlet system as is practicable. The exception provided in section 3.1 of this Appendix for certain CO analyzers does not apply for audits.

3.2.1.7 Open path analyzers are audited by inserting a test cell containing the various audit gas concentrations into the optical measurement beam of the instrument. If possible, the normally used transmitter, receiver, and, as appropriate, reflecting devices should be used during the audit, and the normal monitoring configuration of the instrument should be modified as little as possible to accommodate the test cell for the audit. However, if permitted by the associated operation or instruction manual, an alternate local light source or an alternate optical path that does not include the normal atmospheric monitoring path may be used. The actual concentrations of the audit gas in the test cell must be selected to produce effective concentrations in the ranges specified in this section 3.2 of this Appendix. Generally, each audit concentration measurement result will be the sum of the atmospheric pollutant concentration and the audit test concentration. If so, the result must be corrected to remove the atmospheric concentration contribution. The corrected concentration is obtained by subtracting the average of the atmospheric concentrations measured by the open path instrument under test immediately before and immediately after the audit test (or preferably before and after each audit concentration level) from the audit concentration measurement. If the difference between the before and after measurements is greater than 20 percent of the effective concentration of the test gas standard, discard the test result for that concentration level and repeat the test for that level. If possible, open path analyzers should be audited during periods when the atmospheric pollutant concentrations are relatively low and steady. Also, the monitoring path length must be reverified to within ±3 percent to validate the audit, since the monitoring path length is critical to the determination of the effective concentration.

3.2.1.8 Report both the actual concentrations (effective concentrations for open path analyzers) of the audit gases and the corresponding concentration measurements (corrected concentrations, if applicable, for open path analyzers) indicated or produced by the analyzer being tested. The percent differences between these concentrations are used to assess the accuracy of the monitoring data as described in section 5.2 of this Appendix.

3.2.2 Methods for Particulate Matter Excluding PM10.

3.2.2.1 Each calendar quarter, audit the flow rate of at least 25 percent of the SLAMS PM10 analyzers such that each PM10 analyzer is audited at least once per year. If there are fewer than four PM10 analyzers within a reporting organization, randomly re-audit one or more analyzers so that at least one analyzer is audited each calendar quarter. Where possible, EPA strongly encourages more frequent auditing, up to an audit frequency of once per quarter for each SLAMS analyzer.

3.2.2.2 The audit is made by measuring the analyzer’s normal operating flow rate, using a flow rate transfer standard certified in accordance with section 2.3.3 of this Appendix. The flow rate standard used for auditing must not be the same flow rate standard used to calibrate the analyzer. However, both the calibration standard and the
auditing must not be the same flow rate standard used to calibrate the sampler. However, both the calibration standard and the audit standard may be referenced to the same primary flow rate standard. The flow audit should be scheduled so as to avoid interference with a scheduled sampling period. Report the audit (actual) flow rate and the corresponding flow rate indicated by the sampler’s normally used flow indicator. The percent differences between these flow rates are used to calculate accuracy and bias as described in section 5.4.1 of this Appendix.

3.4.2 SO₂ Methods.

3.4.2.1 Prepare audit solutions from a working sulfite-tetrachloromericurate (TCM) solution as described in section 10.2 of the SO₂ Reference Method (40 CFR part 50, Appendix A). These audit samples must be prepared independently from the standardized sulfite solutions used in the routine calibration procedure. Sulfite-TCM audit samples must be stored between 0 and 5 °C and expire 30 days after preparation.

3.4.2.2 Prepare audit samples in each of the concentration ranges of 0.2-0.3, 0.5-0.6, and 0.8-0.9 µg SO₂/ml. Analyze an audit sample in each of the three ranges at least once each day that samples are analyzed and at least twice per calendar quarter. Report the audit concentrations (in µg SO₂/ml) and the corresponding indicated concentrations (in µg SO₂/ml). The percent differences between these concentrations are used to calculate accuracy as described in section 5.4.2 of this Appendix.

3.4.3 NO₂ Methods. Prepare audit solutions from a working sodium nitrite solution as described in the appropriate equivalent method (see Reference 8 of this Appendix). These audit samples must be prepared independently from the standardized nitrite solutions used in the routine calibration procedure. Sodium nitrite audit samples expire in 3 months after preparation. Prepare audit samples in each of the concentration ranges of 0.5-0.6, and 0.8-0.9 µg NO₂/ml. Analyze an audit sample in each of the three ranges at least once each day that samples are analyzed and at least twice per calendar quarter. Report the audit concentrations (in µg NO₂/ml) and the corresponding indicated concentrations (in µg NO₂/ml). The percent differences between these concentrations are used to calculate accuracy as described in section 5.4.2 of this Appendix.

3.4.4 Pb Methods.

3.4.4.1 For the Pb Reference Method (40 CFR part 50, Appendix G), the flow rates of the high-volume Pb samplers shall be audited as part of the TSP network using the same procedures described in section 3.4.1 of this Appendix. For agencies operating high-volume Pb networks, 25 percent of the total number of high-volume samplers are to be audited each quarter.

3.4.4.2 Each calendar quarter, audit the Pb Reference Method analytical procedure using glass fiber filter strips containing a known quantity of Pb. These audit sample strips are prepared by depositing a Pb solution on unexposed glass fiber filter strips of dimensions 1.9 cm by 20.3 cm (3/4 inch by 8 inch) and allowing them to dry thoroughly. The audit samples must be prepared using batches of reagents different from those used to calibrate the Pb analytical equipment being audited. Prepare audit samples in the following concentration ranges:

<table>
<thead>
<tr>
<th>Range</th>
<th>Pb Concentration, µg/Strip</th>
<th>Equivalent Ambient Pb Concentration, µg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100-300</td>
<td>0.5-1.5</td>
</tr>
<tr>
<td>2</td>
<td>600-1000</td>
<td>3.0-5.0</td>
</tr>
</tbody>
</table>

¹ Equivalent ambient Pb concentration in µg/m² is based on sampling at 1.7 m³/min for 24 hours on a 20.3 cm x 25.4 cm (8 inch x 10 inch) glass fiber filter.

3.4.4.3 Audit samples must be extracted using the same extraction procedure used for exposed filters.

3.4.4.4 Analyze three audit samples in each of the two ranges each quarter samples are analyzed. The audit sample analyses shall be distributed as much as possible over the entire calendar quarter. Report the audit concentrations (in µg Pb/strip) and the corresponding measured concentrations (in µg Pb/strip) using unit code 77. The percent differences between the concentrations are used to calculate analytical accuracy as described in section 5.4.2 of this Appendix.

3.4.4.5 The accuracy of an equivalent Pb method is assessed in the same manner as for the reference method. The flow auditing device and Pb analysis audit samples must be compatible with the specific requirements of the equivalent method.

3.5 Measurement Uncertainty for Automated and Manual PM₁₀ Methods. The goal for acceptable measurement uncertainty has been defined as ± 10 percent coefficient of variation (CV) for total precision and ± 10 percent for total bias (Reference 14 of this Appendix).

3.5.1 Flow Rate Audits.

3.5.1.1 Automated methods for PM₁₀. A one-point precision check must be performed at least once every 2 weeks on each automated analyzer used to measure PM₁₀. The precision check is made by checking the operational flow rate of the analyzer. If a precision flow rate check is made in conjunction with a flow rate adjustment, it must be made prior to such flow rate adjustment. Randomization of the precision check with respect to time of day, day of week, and routine service and adjustments is encouraged where possible.

3.5.1.1.1 Standard procedure: Use a flow rate transfer standard certified in accordance with section 2.3.3 of this Appendix to check the analyzer’s normal flow rate. Care should be used in selecting and using the flow rate measurement device such that it does not alter the normal operating flow rate of the analyzer. Report the actual analyzer flow rate measured by the transfer standard and the corresponding flow rate measured, indicated, or assumed by the analyzer.

3.5.1.1.2 Alternative procedure: It is permissible to obtain the precision check flow rate data from the analyzer’s internal flow meter without the use of an external flow rate transfer standard, provided that the flow meter is audited with an external flow rate transfer standard at least every 6 months; records of at least the three most recent flow audits of the instrument’s internal flow meter over at least several weeks confirm that the flow meter is stable, verifiable and accurate to ± 5%; and the instrument and flow meter give no indication of improper
operation. With suitable communication capability, the precision check may thus be carried out remotely. For this procedure, report the set-point flow rate as the actual flow rate along with the flow rate measured or indicated by the analyzer flow meter.

3.5.1.1.3 For either procedure, the differences between the actual and indicated flow rates are used to assess the precision of the monitoring data as described in section 5.5 of this Appendix.

3.5.1.2 Manual methods for PM$_{2.5}$.

Each calendar quarter, audit the flow rate of each SLAMS PM$_{2.5}$ analyzer. The audit is made by measuring the analyzer’s normal operating flow rate, using a flow rate transfer standard certified in accordance with section 2.3.3 of this Appendix. The flow rate standard used for auditing must not be the same flow rate standard used to calibrate the analyzer. However, both the calibration standard and the audit standard may be referenced to the same primary flow rate or volume standard. Great care must be used in auditing the flow rate to be certain that the flow measurement device does not alter the normal operating flow rate of the analyzer.

Report the audit (actual) flow rate and the corresponding flow rate indicated or assumed by the sampler. The procedures used to calculate measurement uncertainty PM$_{2.5}$ are described in section 5.5 of this Appendix.

3.5.2 Measurement of Precision using Collocated Procedures for Automated and Manual Methods of PM$_{2.5}$.

(a) For PM$_{2.5}$ sites within a reporting organization each EPA designated Federal reference method (FRM) or Federal equivalent method (FEM) must:

(1) Have 25 percent of the monitors collocated (values of .5 and greater round up).

(2) Have at least 1 collocated monitor (if the total number of monitors is less than 4). The first collocated monitor must be a designated FRM monitor.

(b) In addition, monitors selected must also meet the following requirements:

(1) A monitor designated as an EPA FRM shall be collocated with a monitor having the same EPA FRM designation.

(2) For each monitor designated as an EPA FEM, 50 percent of the designated monitors shall be collocated with a monitor having the same method designation and 50 percent of the monitors shall be collocated with an FRM monitor. If there are an odd number of collocated monitors required, the additional monitor shall be an FRM. An example of this procedure is found in Table A-2 of this Appendix.

(c) For PM$_{2.5}$ sites during the initial deployment of the SLAMS network, special emphasis should be placed on those sites in areas likely to be in violation of the NAAQS. Once areas are initially designated FRM or FEM within a reporting organization, report this change to the Regional organization.

4. Reporting Requirements.

For each pollutant, prepare a list of all monitoring sites and their AIRS site identification codes in each reporting organization and submit the list to the appropriate EPA Regional Office, with a copy to AIRS-AQS. Whenever there is a change in this list of monitoring sites in a reporting organization, report this change to the Regional Office and to AIRS-AQS.

4.1 Quarterly Reports. For each quarter, each reporting organization shall report to AIRS-AQS directly (or via the appropriate EPA Regional Office for organizations not direct users of AIRS) the results of all valid precision, bias and accuracy tests it has carried out during the quarter. Quarterly reports of precision, bias and accuracy must be submitted consistent with the data reporting requirements specified for air quality data as set forth in § 58.35(c). EPA strongly encourages early submittal of the QA data in order to assist the State and Local agencies in controlling and evaluating the quality of the ambient air SLAMS data. Each organization shall report all QA/QC measurements. Report results from invalid tests, from tests carried out during a time period for which ambient data immediately prior to or subsequent to the tests were invalid for appropriate reasons, and from tests of methods or analyzers not approved for use in SLAMS monitoring networks under Appendix C of this part. Such data should be flagged so that it will not be utilized for quantitative assessment of precision, bias and accuracy.

4.2 Annual Reports.

4.2.1 When precision, bias and accuracy estimates for a reporting organization have been calculated for all four quarters of the calendar year, EPA will calculate and report the measurement uncertainty for the entire calendar year. These limits will then be associated with the data submitted in the annual SLAMS report required by § 58.26.

4.2.2 Each reporting organization shall submit, along with its annual SLAMS report, a listing by pollutant of all monitoring sites in the reporting organization.

5. Calculations for Data Quality Assessment.

(a) Calculations of measurement uncertainty are carried out by EPA according to the following procedures. Reporting organizations should report the data for individual precision, bias and accuracy tests as specified in sections 3 and 4 of this Appendix even though they may elect to perform...
some or all of the calculations in this section on their own.

5.1 Precision of Automated Methods Excluding PM$_{2.5}$. Estimates of the precision of automated methods are calculated from the results of biweekly precision checks as specified in section 3.1 of this Appendix. At the end of each calendar quarter, an integrated precision probability interval for all SLAMS analyzers in the organization is calculated for each pollutant.

5.1.1 Single Analyzer Precision.

5.1.1.1 The percent difference (d$_i$) for each precision check is calculated using equation 1, where $Y_i$ is the concentration indicated by the analyzer for the I-th precision check and $X_i$ is the known concentration for the I-th precision check, as follows:

$$d_i = \frac{Y_i - X_i}{X_i} \times 100$$

5.1.1.2 For each analyzer, the quarterly average ($\overline{d}_i$) is calculated using equation 2, and the standard deviation ($S_a$) with equation 3, as follows:

$$\overline{d}_i = \frac{1}{n} \sum_{i=1}^{n} d_i$$

$$S_a = \sqrt{\frac{(n-1)S_j^2 + (n_1 - 1)S_j^2 + \ldots + (n_k - 1)S_j^2}{n_1 + n_2 + \ldots + n_j + \ldots + n_k - k}}$$

5.1.2 Precision for Reporting Organization.

5.1.2.1 For each pollutant, the average ($\overline{D}$) of the individual percentage differences ($d_i$) for all n analyzers audited during the quarter is calculated using equation 8, as follows:

$$\overline{D} = \frac{n \sum_{i=1}^{n} d_i}{n}$$

5.1.2.2 For each concentration level of a particular pollutant, the standard deviation ($S_a$) are calculated, using equations 4 and 5 or 4a and 5a, where $k$ is the number of analyzers audited within the reporting organization for a single pollutant, as follows:

$$D = \frac{1}{k} \sum_{j=1}^{k} d_j$$

Equation 4

$$D = \frac{n_1 d_1 + n_2 d_2 + \ldots + n_j d_j + \ldots + n_k d_k}{n_1 + n_2 + \ldots + n_j + \ldots + n_k}$$

Equation 5

$$S_a = \sqrt{\frac{1}{k} \sum_{j=1}^{k} S_j^2}$$

Equation 5a

5.2 Accuracy of Automated Methods Excluding PM$_{2.5}$. Estimates of the accuracy of automated methods are calculated from the results of independent audits as described in section 3.2 of this Appendix. At the end of each calendar quarter, an integrated accuracy probability interval for all SLAMS analyzers audited in the reporting organization is calculated for each pollutant. Separate accuracy probability limits are calculated for each audit concentration level in section 3.2 of this Appendix.

5.2.1 Single Analyzer Accuracy. The percentage difference (d$_j$) for each audit concentration is calculated using equation 1, where $Y_i$ is the auditor’s indication of the concentration measurement from the I-th audit check and $X_i$ is the actual concentration of the audit gas used for the I-th audit check.

5.2.2 Accuracy for Reporting Organization.

5.2.2.1 For each audit concentration level of a particular pollutant, the average (D) of the individual percentage differences (d$_j$) for all n analyzers audited during the quarter is calculated using equation 9, as follows:

$$D = \frac{1}{n} \sum_{i=1}^{n} d_i$$

Equation 6

$$S_a = \sqrt{\frac{1}{n-1} \left( \sum_{i=1}^{n} d_i^2 - \frac{1}{n} \left( \sum_{i=1}^{n} d_i \right)^2 \right)}$$

Equation 7

5.2.2.2 For reporting organizations having four or fewer analyzers for a particular pollutant, only one audit is required each quarter. For such reporting organizations, the audit results of two consecutive quarters are required to calculate an average and a standard deviation, using equations 8 and 9. Therefore, the reporting of probability limits shall be on a semiannual (instead of a quarterly) basis.

5.2.2.3 For each pollutant, the 95 Percent Probability Limits for the precision of a reporting organization are calculated using equations 6 and 7, as follows:

$$\text{Upper 95 Percent Probability Limit} = \bar{D} + 1.96 S_a$$

Equation 8

$$\text{Lower 95 Percent Probability Limit} = \bar{D} - 1.96 S_a$$

Equation 9

5.3 Accuracy of Manual Methods Excluding PM$_{2.5}$. Estimates of the accuracy of manual methods are calculated using equations 3, where $n$ is the number of precision checks made for each pollutant. Equation 2 and 3 follow:

$$d_j = Y_j - X_j$$

Equation 3

$$D = \frac{n_1 d_1 + n_2 d_2 + \ldots + n_j d_j + \ldots + n_k d_k}{n_1 + n_2 + \ldots + n_j + \ldots + n_k}$$

Equation 6

$$S_a = \sqrt{\frac{1}{k} \sum_{j=1}^{k} S_j^2}$$

Equation 5a

5.3.1 Single Sampler Precision.

5.3.1.1 At low concentrations, agreement between the measurements of collocated samplers, expressed as percent differences, may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are above the following limits:

(a) TSP: 20 $\mu g/m^3$.
(b) SO$_2$: 45 $\mu g/m^3$.
(c) NO$_2$: 30 $\mu g/m^3$.
(d) Pb: 0.15 $\mu g/m^3$.
(e) PM$_{10}$: 20 $\mu g/m^3$.

5.3.1.2 For each selected measurement pair, the percent difference ($d_i$) is calculated, using equation 10, as follows:

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100$$

where:

- $Y_i$ is the pollutant concentration measurement obtained from the duplicate sampler;
- $X_i$ is the concentration measurement obtained from the primary sampler designated for reporting air quality for the site.

(a) For each site, the quarterly average percent difference ($d_i$) is calculated from equation 2 and the standard deviation ($S_i$) is calculated from equation 3, where $n$ is the number of selected measurement pairs at the site.

5.3.2 Precision for Reporting Organization.

5.3.2.1 For each pollutant, the average percentage difference (D) and the pooled standard deviation ($S_a$) are calculated, using equations 4 and 5, or using equations 4a and 5a if different numbers of paired measurements are obtained at the collocated sites. For these calculations, the k of equations 4, 4a, 5 and 5a is the number of collocated sites.
5.3.2.2 The 95 Percent Probability Limits for the integrated precision for a reporting organization are calculated using equations 11 and 12, as follows:

**Equation 11**

Upper 95 Percent Probability Limit = \( D + 1.96 S_a \)

**Equation 12**

Lower 95 Percent Probability Limit = \( D - 1.96 S_a \)

5.4 Accuracy of Manual Methods Excluding PM\(_{2.5}\). Estimates of the accuracy of manual methods are calculated from the results of independent audits as described in section 3.4 of this Appendix. At the end of each calendar quarter, an integrated accuracy probability interval is calculated for each manual method network operated by the reporting organizations.

5.4.1 Particulate Matter Samplers other than PM\(_{2.5}\) (including reference method Pb samplers). For the flow rate audit described in section 3.4.1 of this Appendix, the percentage difference (\( d_i \)) for each audit is calculated using equation 1, where \( X_i \) represents the known flow rate and \( Y_i \) represents the flow rate indicated by the sampler.

5.4.1.2 Accuracy for Reporting Organization. For each type of particulate matter measured (e.g., TSP/Pb), the average (\( D \)) of the individual percent differences for all similar particulate matter samplers audited during the calendar quarter is calculated using equation 8. The standard deviation (\( S_a \)) of the percentage differences for all of the similar particulate matter samplers audited during the calendar quarter is calculated using equation 9. The 95 Percent Probability Limits for the integrated accuracy for the reporting organization are calculated using equations 6 and 7. For reporting organizations having four or fewer particulate matter samplers of one type, only one audit is required each quarter, and the audit results of two consecutive quarters are required to calculate an average and a standard deviation. In that case, probability limits shall be reported semi-annually rather than quarterly.

5.4.2 Analytical Methods for SO\(_2\), NO\(_2\), and Pb. 5.4.2.1 Single Analysis-Day Accuracy. For each of the audits of the analytical methods for SO\(_2\), NO\(_2\), and Pb described in sections 3.4.2, 3.4.3, and 3.4.4 of this Appendix, the percentage difference (\( d_i \)) at each concentration level is calculated using equation 1, where \( X_i \) represents the known value of the audit sample and \( Y_i \) represents the value of SO\(_2\), NO\(_2\), or Pb indicated by the analytical method.

5.4.2.2 Accuracy for Reporting Organization. For each analytical method, the average (\( D \)) of the individual percent differences at each concentration level for all audits during the calendar quarter is calculated using equation 8. The standard deviation (\( S_a \)) of the percentage differences at each concentration level for all audits during the calendar quarter is calculated using equation 9. The 95 Percent Probability Limits for the accuracy for the reporting organization are calculated using equations 6 and 7.

5.5 Precision, Accuracy and Bias for Automated and Manual PM\(_{2.5}\) Methods.

(a) Reporting organizations are required to report the data that will allow assessments of the following individual quality control checks and audits:

- (1) Flow rate audit.
- (2) Collocated samplers, where the duplicate sampler is not an FRM device.
- (3) Collocated samplers, where the duplicate sampler is an FRM device.
- (4) FRM audits.

(b) EPA uses the reported results to derive precision, accuracy and bias estimates according to the following procedures.

5.5.1 Flow Rate Audits. The reporting organization shall report both the audit standard flow rate and the flow rate indicated by the sampling instrument. These results are used by EPA to calculate flow rate accuracy and bias estimates.

5.5.1.1 Accuracy of a Single Sampler - Single Check (Quarterly) Basis (\( d_i \)). The percentage difference (\( d_i \)) for a single flow rate audit \( d_i \) is calculated using Equation 13, where \( X_i \) represents the audit standard flow rate (known) and \( Y_i \) represents the indicated flow rate, as follows:

**Equation 13**

\[
D_i = \frac{1}{n_j} \sum_{i=1}^{n_i} d_i = Y_i - X_i \times 100
\]

5.5.1.2 Bias of a Single Sampler - Annual Basis (\( D \)). For an individual particulate sampler \( j \), the average (\( D_j \)) of the individual percentage differences (\( d_i \)) during the calendar year is calculated using Equation 14, where \( n_j \) is the number of individual percentage differences produced for sampler \( j \) during the calendar year, as follows:

**Equation 14**

\[
D_j = \frac{1}{n_j} \sum_{i=1}^{n_i} d_i
\]

5.5.1.3 Bias for Each EPA Federal Reference and Equivalent Method Designation Employed by Each Reporting Organization - Quarterly Basis (\( D_{k,q} \)). For method designation \( k \) used by the reporting organization, quarter \( q \)’s single sampler percentage differences (\( d_i \)) are averaged using Equation 15, where \( n_{k,q} \) is the number of individual percentage differences produced for method designation \( k \) in quarter \( q \), as follows:

**Equation 15**

\[
D_{k,q} = \frac{1}{n_{k,q}} \sum_{i=1}^{n_{k,q}} d_i
\]

5.5.1.4 Bias for Each Reporting Organization - Quarterly Basis (\( D_k \)). For each reporting organization, quarter \( q \)’s single sampler percentage differences (\( d_i \)) are averaged using Equation 15, to produce a single average for each reporting organization, where \( n_k \) is the total number of single sampler percentage differences for all federal reference or equivalent methods of samplers in quarter \( q \), as follows:

**Equation 16**

\[
D_k = \frac{1}{n_k} \sum_{i=1}^{n_k} d_i
\]

5.5.1.5 Bias for Each EPA Federal Reference and Equivalent Method Designation Employed by Each Reporting Organization - Annual Basis (\( D_k \)). For method designation \( k \) used by the reporting organization, the annual average percentage difference, \( D_k \), is derived using Equation 17, where \( D_{k,q} \) is the average reported for method designation \( k \) during the \( q \)th quarter, and \( n_{k,q} \) is the number of the method designation \( k \)’s monitors that were deployed during the \( q \)th quarter, as follows:

**Equation 17**

\[
D_k = \frac{\sum_{q=1}^{4} n_{k,q} D_{k,q}}{4 n_{k,q}}
\]

5.5.1.6 Bias for Each Reporting Organization - Annual Basis (\( D \)). For each reporting organization, the annual average percentage difference, \( D \), is derived using Equation 18, where \( D_i \) is the average reported for the reporting organization during the \( q \)th quarter and \( n_q \) is the total number monitors that were deployed during the \( q \)th quarter. A single annual average is produced for each reporting organization.

**Equation 18**

\[
D = \frac{\sum_{q=1}^{4} n_q D_q}{4 n_q}
\]

5.5.2 Collocated Samplers, Where the Duplicate Sampler is not an FRM Device.

(a) At low concentrations, agreement between the measurements of collocated samplers may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are above the following limits:

\[\text{PM}_{2.5} \geq 6 \text{ mg/m}^3\]

(b) Collocated sampler results are used to assess measurement system precision. A collocated sampler pair consists of a primary sampler (used for routine monitoring) and a duplicate sampler (used as a quality control check). Quarterly precision estimates are calculated by EPA for each pair of collocated samplers and for each method designation employed by each reporting organization. Annual precision estimates are calculated by EPA for each primary sampler, for each EPA Federal reference method and equivalent method designation employed by each reporting organization, and nationally for each EPA Federal reference method and equivalent method designation.

5.5.2.1 Percent Difference for a Single Check (\( d_i \)). The percentage difference, \( d_i \), for each check is calculated by EPA using Equation 19, where \( X_i \) represents the concentration produced from the primary sampler and \( Y_i \) represents concentration reported for the duplicate sampler, as follows:

**Equation 19**

\[
d_i = \frac{Y_i - X_i}{Y_i + X_i} \times 100
\]

5.5.2.2 Coefficient of Variation (CV) for a Single Check (CV). The coefficient of variation, \( CV_i \), for each check is calculated by EPA by dividing the absolute value of the percentage difference, \( d_i \), by the square root of two as shown in Equation 20, as follows:

**Equation 20**

\[
CV_i = \frac{d_i}{\sqrt{2}}
\]
5.5.2.3 Precision of a Single Sampler - Quarterly Basis (CV_{j,q}).

For particulate sampler j, the individual coefficients of variation (CV_{j,q}) during the quarter are pooled using Equation 21, where n_{j,q} is the number of pairs of measurements from collocated samplers during the quarter, as follows:

\[
CV_{j,q} = \sqrt{\frac{1}{n_{j,q}} \sum_{i=1}^{n_{j,q}} CV_i^2}
\]

(b) The 90 percent confidence limits for the single sampler’s CV are calculated by EPA using Equations 22 and 23, where X^2_{0.05,df} and X^2_{0.95,df} are the 0.05 and 0.95 quantiles of the chi-square (X^2) distribution with n_{j,q} degrees of freedom, as follows:

\[
\text{Lower Confidence Limit} = CV_{j,q} \left( 1 - \frac{X^2_{0.95, n_{j,q}}}{n_{j,q}} \right)
\]

\[
\text{Upper Confidence Limit} = CV_{j,q} \left( 1 + \frac{X^2_{0.95, n_{j,q}}}{n_{j,q}} \right)
\]

5.5.2.4 Precision of a Single Sampler - Annual Basis.

For particulate sampler j, the individual coefficients of variation, CV_i, produced during the calendar year are pooled using Equation 21, where n is the number of checks made during the calendar year. The 90 percent confidence limits for the single sampler’s CV are calculated by EPA using Equations 22 and 23, where X^2_{0.05,df} and X^2_{0.95,df} are the 0.05 and 0.95 quantiles of the chi-square (X^2) distribution with n degrees of freedom. 5.5.2.5 Precision for Each EPA Federal Reference Method and Equivalent Method Designation Employed by Each Reporting Organization - Quarterly Basis (CV_{k,q}).

(a) For particulate sampler j, the individual coefficients of variation, CV_{j,q}, obtained from Equation 21, are pooled using Equation 24, where n_{k,q} is the number of collocated primary monitors for the designated method (but not collocated with FRM samplers) and n_{j,q} is the number of degrees of freedom associated with CV_{j,q}, as follows:

\[
CV_{k,q} = \sqrt{\frac{1}{n_{k,q}} \sum_{j=1}^{n_{k,q}} (CV_{j,q}^2 n_{j,q})}
\]

(b) The number of method CVs produced for a reporting organization will equal the number of different method designations having more than one primary monitor employed by the organization during the quarter. (When exactly one monitor of a specified designation is used by a reporting organization, it will be collocated with an FRM sampler.)

5.5.2.6 Precision for Each Method Designation Employed by Each Reporting Organization - Annual Basis (CV_k).

For each method designation k used by the reporting organization, the quarter’s single sampler coefficients of variation, CV_{j,q}, as follows:

\[
CV_k = \sqrt{\frac{1}{n_{k,q}} \sum_{q=1}^{n_{k,q}} CV_{k,q}^2}
\]

5.5.3 Collocated Samplers, Where the Duplicate Sampler is an FRM Device. At low concentrations, agreement between the measurements of collocated samplers may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are above the following limits:

PM_{2.5} ≤ 6 μg/m^3. These duplicate sampler results are used to assess measurement system bias. Quarterly bias estimates are calculated by EPA for each primary sampler and for each method designation employed by each reporting organization. Annual precision estimates are calculated by EPA for each primary monitor, for each method designation employed by each reporting organization, and nationally for each method designation.

5.5.3.1 Accuracy for a Single Check (d_i). The percentage difference, d_i, for each check is calculated by EPA using Equation 26, where X_i represents the concentration produced from the FRM sampler taken as the true value and Y represents concentration reported for the primary sampler, as follows:

\[
d_i = \frac{Y_i - X_i}{X_i} \times 100\%
\]

5.5.3.2 Bias of a Single Sampler - Quarterly Basis (D_j,q).

(a) For particulate sampler j, the mean bias for the year is derived from the quarterly bias estimates, D_j,q, using Equation 31, where the variables are as defined for Equations 27 and 28, as follows:

\[
D_j = \frac{\sum_{q=1}^{4} \left( n_{j,q} D_{j,q} \right)}{\sum_{q=1}^{4} n_{j,q}}
\]

(b) The standard error of the above estimate, se_j, is calculated using Equation 32, as follows:
5.5.3.4 Bias for a Single Reporting Organization (D') - Annual Basis. The reporting organizations mean bias is calculated using Equation 35, where variables are as defined in Equations 31 and 32, as follows:

\[
se_j' = \sqrt{\frac{1}{n_j} \sum_{q=1}^{4} \left[ \frac{1}{n_{j,q}} - 1 \right] \sum_{q=1}^{4} \left( n_{j,q} - 1 \right) \left( n_{j,q} - \bar{X}_{j,q} - \bar{X}_{j,q} \right)}
\]

\[
D_j = \frac{1}{n_j} \sum_{q=1}^{n_j} D_{j,q} = \frac{1}{n_j} \sum_{q=1}^{n_j} \frac{1}{n_{j,q}} \sum_{q=1}^{n_j} \left( n_{j,q} - 1 \right) \left( n_{j,q} - \bar{X}_{j,q} - \bar{X}_{j,q} \right)
\]

5.5.4 FRM Audits. FRM Audits are performed once per quarter for selected samplers. The reporting organization reports concentration data from the primary sampler. Calculations for FRM Audits are similar to those for collocated samplers having FRM samplers as duplicates. The calculations differ because only one check is performed per quarter.

5.5.4.1 Accuracy for a Single Sampler, Quarterly Basis (d). The percentage difference, d, for each check is calculated using Equation 26, where \( X_i \) represents the concentration produced from the FRM sampler and \( \bar{X}_i \) represents the concentration reported for the primary sampler. For quarter q, the bias estimate for sampler j is denoted \( D_{j,q} \).

5.5.4.2 Bias of a Single Sampler - Annual Basis (D'). For particulate sampler j, the mean bias for the year is derived from the quarterly bias estimates, \( D_{j,q} \), using Equation 31, where \( n_{j,q} \) equals 1 because one FRM audit is performed per quarter.

5.5.4.3 Bias for a Single Reporting Organization - Annual Basis (D'). The reporting organizations mean bias is calculated using Equation 35, where variables are as defined in Equations 31 and 32.

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(7a) Copies of section 2.12 of the Quality Assurance Handbook for Air Pollution Measurement Systems, are available from Department E (MD-77B); U.S. EPA, Research Triangle Park, NC 27711.
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<td>Response check at .03–.08 ppm, .15–.20 ppm, .35–.45 ppm, 80–90 ppm (if applicable)</td>
<td>1. Each analyzer 2. 25% of analyzers (at least 1)</td>
<td>1. Once per year 2. Each calendar quarter</td>
<td>Actual concentration² and measured (indicated) concentration³ for each level</td>
</tr>
<tr>
<td>Manual Methods for SO₂ and NO₂</td>
<td>Check of analytical procedure with audit standard solutions</td>
<td>Analytical system</td>
<td>Each day samples are analyzed, at least twice per quarter</td>
<td>Actual concentration and measured (indicated) concentration for each audit solution</td>
</tr>
<tr>
<td>TSP, PM₁₀</td>
<td>Check of sampler flow rate</td>
<td>1. Each sampler 2. 25% of samplers (at least 1)</td>
<td>1. Once per year 2. Each calendar quarter</td>
<td>Actual flow rate and flow rate indicated by the sampler</td>
</tr>
<tr>
<td>Lead</td>
<td>1. Check of sample flow rate as for TSP 2. Check of analytical system with Pb audit strips</td>
<td>1. Each sampler 2. Analytical system</td>
<td>1. Include with TSP 2. Each quarter</td>
<td>2. Actual concentration and measured (indicated) concentration of audit samples (µg Pb/strip)</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>Collocated samplers</td>
<td>25% of SLAMS (monitors with Conc affecting NAAQS violation status)</td>
<td>Once every six days</td>
<td>1. Particle mass concentration indicated by sampler and by collocated sampler 2. 24-hour value for automated methods 1. Actual flow rate and flow rate indicated by the sampler 2. Particle mass concentration indicated by sampler and by audit reference sampler</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>Collocated samplers</td>
<td>25% of SLAMS (monitors with Conc affecting NAAQS violation status)</td>
<td>Once every six days</td>
<td>1. Particle mass concentration indicated by sampler and by collocated sampler 2. 24-hour value for automated methods 1. Actual flow rate and flow rate indicated by the sampler 2. Particle mass concentration indicated by sampler and by audit reference sampler</td>
</tr>
<tr>
<td>Manual and Automated Methods-Precision.</td>
<td>Collocated samplers</td>
<td>25% of SLAMS (monitors with Conc affecting NAAQS violation status)</td>
<td>Once every six days</td>
<td>1. Particle mass concentration indicated by sampler and by collocated sampler 2. 24-hour value for automated methods 1. Actual flow rate and flow rate indicated by the sampler 2. Particle mass concentration indicated by sampler and by audit reference sampler</td>
</tr>
<tr>
<td>Manual and Automated Methods-Accuracy and Bias</td>
<td>Check of sampler flow rate 2. Audit with reference method</td>
<td>25% of SLAMS (monitors with Conc affecting NAAQS violation status)</td>
<td>1. Minimum of every calendar quarter, 4 checks per year 2. Minimum 4 measurements per year</td>
<td>1. Particle mass concentration indicated by sampler and by collocated sampler 2. 24-hour value for automated methods 1. Actual flow rate and flow rate indicated by the sampler 2. Particle mass concentration indicated by sampler and by audit reference sampler</td>
</tr>
</tbody>
</table>

¹ Concentration times 100 for CO.
² Effective concentration for open path analyzers.
³ Corrected concentration, if applicable, for open path analyzers.

### Table A-2.—Summary of PM₂.₅ Collocation and Audits Procedures As An Example Of A Typical Reporting Organization Needing 43 Monitors, Having Procured FRMs and Three Other Equivalent Method Types

<table>
<thead>
<tr>
<th>Method Designation</th>
<th>Total # of Monitors</th>
<th>Total # Collocated</th>
<th># of Collocated FRMs</th>
<th># of Collocated Monitors of Same Type</th>
<th># of Independent FRM Audits</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRM</td>
<td>25</td>
<td>6</td>
<td>6</td>
<td>n/a</td>
<td>6</td>
</tr>
<tr>
<td>Type A</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Type C</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Type D</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

m. Appendix C is amended by revising section 2.2 and adding sections 2.2.1 and 2.2.2, adding sections 2.4 through 2.5, revising section 2.7.1, and adding section 2.9 and references 4 through 6 to section 6.0 to read as follows:

Appendix C—Ambient Air Quality Monitoring Methodology

* * * * *

2.2 Substitute PM₁₀ samplers.

2.2.1 For purposes of showing compliance with the NAAQS for particulate matter, a high volume TSP sampler described in 40 CFR part 50.

Appendix B, may be used in a SLAMS in lieu of a PM₁₀ monitor as long as the ambient concentrations of particles measured by the TSP sampler are below the PM₁₀ NAAQS. If the TSP sampler measures a single value that is higher than the PM₁₀ 24–hour standard, or if the annual average of its measurements is greater than the PM₁₀ annual standard, the TSP sampler operating as a substitute PM₁₀ sampler must be replaced with
Appendix 5

Supplementary Material for Chapter 5

Part G
Table of Relationship of Filter-based FRM PM10 and PM2.5 to Continuous Method
Appendix G. Relationship of filter-based FRM PM10 and PM2.5 to continuous methods for various sampling sites.

<table>
<thead>
<tr>
<th>Samplers</th>
<th>Y = ax + b</th>
<th>$R^2$</th>
<th># samples</th>
<th>study Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fresno Supersite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSI$^1$ - TEOM$^{10}$</td>
<td>$Y = 0.83x - 9.8$</td>
<td>0.95</td>
<td>10</td>
<td>1999 - 2000</td>
</tr>
<tr>
<td>SSI - BAM$^{3}$10</td>
<td>$Y = 1.108x - 23.24$</td>
<td>0.76</td>
<td>10</td>
<td>1999 - 2000</td>
</tr>
<tr>
<td><strong>RAAS$^4$ - BAM2.5</strong></td>
<td>$Y = 1.067x + 7.06$</td>
<td>0.97</td>
<td>27</td>
<td>1999 - 2000</td>
</tr>
<tr>
<td>RAAS - TEOM2.5</td>
<td>$Y = 0.418x + 3.17$</td>
<td>0.31</td>
<td>27</td>
<td>1999 - 2000</td>
</tr>
</tbody>
</table>

**Bakersfield, CA (Dutcher et al, 1999)**

<table>
<thead>
<tr>
<th>Samplers</th>
<th>Y = ax + b</th>
<th>$R^2$</th>
<th># samples</th>
<th>study Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSI - BAM10</td>
<td>$Y = 1.009x + 1.90$</td>
<td>0.98</td>
<td>8</td>
<td>1998-1999</td>
</tr>
<tr>
<td>SSI - TEOM10</td>
<td>$Y = 0.368x + 6.92$</td>
<td>0.95</td>
<td>20</td>
<td>1998-1999</td>
</tr>
<tr>
<td>RAAS - BAM2.5win$^5$</td>
<td>$Y = 0.912x + 0.80$</td>
<td>0.99</td>
<td>24</td>
<td>1998-1999</td>
</tr>
<tr>
<td>RAAS - BAM2.5scc$^6$</td>
<td>$Y = 0.97x + 3.25$</td>
<td>0.99</td>
<td>24</td>
<td>1998-1999</td>
</tr>
</tbody>
</table>

1 Size selective inlet, federal reference method
2 Tapered element oscillating microbalance model 1400a operated @ 50°C.
3 Beta attenuation monitor model 1020
4 Reference ambient air monitor for, federal reference method
5 PM2.5 BAM with WINS impactor
6 PM2.5 BAM with cyclone separator

**Reference:**

Appendix 5
Supplementary Material for Chapter 5

Part H
Summary of PM Sampler Comparison Study at the Bakersfield Monitoring Station
The purpose of this study was to compare the performance of PM2.5 and PM10 continuous measurement methods to reference methods. Our intent was to identify PM2.5 and PM10 continuous analyzer(s) that can be used to determine compliance with the State ambient air quality standards (AAQS).

In response to a request by the Air Resources Board (a Board), the Office of Environmental Health and Hazard Assessment (OEHHA) and the ARB staff are reviewing the State PM standard. OEHHA has recommended retaining the current PM10 standard, revising the 24-hr and annual average values, and has proposed PM2.5 24-hr and annual standards. As a part of the PM standard review, ARB must describe the method by which particles will be measured and used to determine compliance with the AAQS. That activity resulted in staff reviewing the current PM10 State method (Method P), and identifying methods to measure PM2.5.

In the Board draft staff report, prepared for the Air Quality Advisory Committee, dated November 26, 2001, staff recommended the State adopt the PM10 and the PM2.5 Federal reference method (FRM) samplers that employ inertial impactors as methods suitable for determining compliance with the State standard. Staff also recommended the use of continuous PM10 and PM2.5 analyzers, if possible, that were being evaluated in Bakersfield, CA. Additional testing was necessary to capture the atmospheric conditions in the two areas with the most persistent particulate problems in California, the San Joaquin Valley and the South Coast Air Basin. The testing in Bakersfield adequately represents the conditions in both areas. Moreover, findings for this report needed to be based on a well-controlled study that eliminated vendor involvement, and that used an existing station with agency monitoring staff to operate the equipment. Other rigorous elements incorporated into the study included duplicate instrumentation for all instruments, extensive sample collection, multiple reference samplers, and audits by an outside entity of the candidate and reference devices.

**Objectives**

The study was conducted to compare the performance of advanced, commercially available continuous PM10 and PM2.5 analyzers to the performance of federal reference methods. These reference methods included duplicate hi-volume SSI and low-volume Partisol samplers for PM10, and the lo-volume RAAS for PM2.5. The resulting data were used to:

1) Determine whether any specific continuous monitoring method(s) is (are) acceptable for measuring PM10 and PM2.5 in California for the State Ambient Air Quality Standard.

2) Compare the common attributes of a lo-vol and hi-vol PM10. This objective was selected to evaluate the effect of using a hi-vol versus the lo-vol sampler as the ‘subtractant’ if one needed to calculate course mass (PM10-PM2.5).
Location of the Study

The study was conducted at the Air Resources Board monitoring station at 5558 California Avenue in Bakersfield, California. Located at the southern end of the Central Valley, the station is situated in a basin created by surrounding mountain ranges. Major activities in the region include oil productions, agricultural operations, and motor vehicle traffic. Bakersfield contains major roadways connecting Northern and Southern California.

Historical air quality data at Bakersfield shows that the winter season in the area sees high levels of air pollution due to emissions, topography, and meteorological conditions. Historically, during the winter months, this region is dominated by high PM concentrations. A large component of this PM consists of volatile compounds (nitrates and moisture).

Conducting the study in fall and winter in this location provided a wide range of meteorological and air quality conditions under which to test the instruments.

Instruments evaluated

Three types of PM10 and four types of PM2.5 continuous samplers were evaluated. Two of each type and size cut were operated for a total of 14 samplers.

The data from the continuous PM10 samplers were compared to two types of reference method, one hi-vol and one lo-vol. The PM2.5 continuous data were compared to the PM2.5 lo-vol reference method.

Reference method samplers

PM10
The Partisol model 2000 (Rupprecht and Patashnick [R&P] Partisol 2000; lo-vol) and the SSI model SA1200 (Thermo Andersen Inc; hi-vol) were the Federal Reference Method (FRM) samplers against which the PM10 continuous samplers were compared. A pair of Partisol PM10 FRMs were provided by R&P for the period of the study. The SSI was also operated in tandem at the site. It is currently the State method for PM10. These samplers are permanently placed at many stations by the ARB and local air districts. The mass of the PM in either instance is determined by pre- and post-weighing the sample filter. The mass concentration of PM is determined by dividing the collected mass by the total amount of air sampled.

PM2.5
The reference ambient air sampler (RAAS 2.5-300, Thermo Andersen Instruments), an FRM for PM2.5, was used to evaluate the accuracy of the
continuous PM2.5 samplers. This sampler consists of a PM10 inlet and a Wells Impactor Ninety-Six (WINS impactor), followed by a Teflon filter. The RAAS operates at 16.7 lpm. The WINS impactor is used to eliminate particles between PM10 and PM2.5 before they are collected on a 47-mm Teflon filter. The concentration of the PM is determined in the same manner as PM10, however using criteria contained in federal regulations specific to PM2.5.

Both lo-vol PM10 and PM2.5 FRMs used louvered PM10 inlets.

Continuous samplers

Four types of continuous samplers were evaluated in the study. All were lo-volume (16.67 lpm). Four samplers were provided by each vendor, two were configured to sample PM10, and two to sampler PM2.5. The participating samplers were the Thermo Andersen Beta Attenuation Monitor (BAM, model FH 62 C-14, here after called And-BAM), the Met One BAM (model 1020, here after called Met-BAM), and the Rupprecht and Patashnick (R&P) Filter Dynamics Measurement Systems (R&P FDMS series 8500). Also two PM2.5 Continuous Ambient Mass Monitor (CAMM) were provided by Thermo Andersen. Each PM10 device was equipped with louvered PM10 inlets and an inertial impactor. The instrument manufacturers assumed the responsibility for installing and calibrating their samplers. ARB staff provided space to the vendors at the air monitoring station. The representatives trained ARB staff and departed the site after they were confident the sampler was performing properly and the staff were suitably trained. The manufacturers’ representatives handed over all aspects of the operation of the samplers to ARB staff for the duration of the study.

The PM2.5 samplers were equipped with a PM2.5 sharp cut cyclone (scc) to separate the PM2.5 fraction from the PM10. The cyclone is well suited for continuous operation.

Beta Attenuation Monitors (BAM)

A beta attenuation monitor (BAM) consists of a lo-vol size selective inlet, a filter tape, a beta source, a beta ray detector, a lo-vol flow controller, and a timer. The sampler uses a source of beta radiation ($^{14}$C) and a detector to measure the beta absorption from PM accumulated on the filter tape. The filter material is a roll or cassette that advances automatically on a timed sequence. When particles are placed between the beta source and the detector, the beta rays are attenuated or absorbed by particles in their path. The difference in attenuation before and after the segment of the tape used to collect PM is attributed to the PM deposited on the filter. The reduction in beta ray intensity passing through the collected PM is a function of the mass of material between the source and the detector. The degree of beta radiation attenuation is converted to a PM concentration.
Thermo Andersen BAM (Model FH 62 C14)

The Thermo Andersen BAM (And-BAM) was equipped with an optional intermittent tube heater to reduce the relative humidity so that moisture does not condense on the filter. It performs simultaneous mass collection and measurement with continuous display of the current concentration. The single spot remains in the chamber for particle collection and measurement for 24-hr or until it is full (typ1500 µg/m³), although the sampler has the ability of advancing the tape at a preset time. Calibration is accomplished with two calibration foils. It performs auto-zero check and is equipped with temperature sensor. It can measure PM mass as high as 5000 µg/m³.

Met One BAM (Model 1020)

The Met One BAM (Met-BAM) was also configured to eliminate water vapor from condensing on the filter. It automatically warmed the incoming air to 3°C above ambient. It has a sample time of 50 minutes per hour. The first and last five minutes of the sampling hour are used to calibrate, measure, and calculate the concentration of PM. The tape is automatically moved every hour. The sampler performs auto-zero/span check and is equipped with pressure and temperature sensors. It can measure PM mass as high as 1,000 mg/m³.

Continuous Ambient Mass Monitor

The continuous ambient mass monitor (CAMM) based on a measure of pressure drop increase across a membrane filter with increasing particle loading on the filter. The analyzer consists of a diffusion dryer to remove particle-bound water and a filter tape to collect PM.

Filter Dynamics Measurement System (Series 8500)

The series 8500 Filter Dynamics Measurement System (FDMS) manufactured by R&P consists of an inlet, a sample filter, a dryer (sample equilibration system or SES), a microbalance, a purge filter conditioning unit, and a control unit. It uses a tapered oscillating microbalance that operates at 30°C to measure the PM mass. It measures the PM mass and corrects for the volatile PM due to the elevated sampler temperature (30°C), and reports the sum of non-volatile and non-volatile PM mass.

Study Period and Sampling Frequency

The study began on October 15, 2001, and ended January 31, 2002. During this period, the PM10 (SSI and Partisol) samplers and one of the PM2.5 (RAAS) filter-based samplers were operated one-in-three day schedule. The second RAAS was operated every day. All continuous analyzers were operated 24 hours a day, 7 days a week.
Data completeness

Data completeness (DC) is a measure of the number of available useable data to the total number of data possible for a single pollutant for a single site. Mathematically it is defined as:

\[
\%DC = \left( \frac{\text{total number samples possible} - \text{samples lost due to calibration and downtime}}{\text{total number of samples}} \right) \times 100
\]

For continuous data, there should be at least 18 or more hourly data of the maximum 24 and no more than 2 hours of consecutive hours data missing. The ARB strives for at least 85% DC. Data completeness was determined for both samplers not each one.

Using the above formula, the And-BAM PM10 and PM2.5 provided 86% and 96% DC (Table 1) respectively. The 4% incompleteness rate for PM2.5 was attributed to a wet filter due to roof leak at the sampler tube inlet. The collocated PM10 And-BAM sampler failed an audit on January 29, 2002. Because of this the data generated in January were discarded resulting in 86% DC. The CAMM had 96% DC, most of the 4% incompleteness was attributed to operator error.

The Met-BAM PM10 and PM2.5 samplers provided 90% and 97% DC respectively. Most of the data loss was because of pump problem and the samplers ran out of filter tapes during the weekend.

The FDMS PM10 and PM2.5 provided 92% and 87% DC respectively. The lower %DC of the PM2.5 FDMS (87%) and of the PM10 (92%) were attributed to either the clogging of the sample equilibration systems (dryers) or to the non-zero status provide by the samplers status output. Each of the FDMS samplers had had its dryer replaced once, the instrument provides an hourly status report (non-zero status code) whether the corresponding data is useable or not. Per manufacturer’s protocol, the data were considered valid only when the status values are zero. In addition to dryer replacement, data were invalidated due to non-zero status codes.

All samplers achieved the ARB goal for data completeness.
Table 1. Data completeness for samplers used at the Bakersfield sampler comparison study, 10/15/01 to 01/31/02

<table>
<thead>
<tr>
<th>Samplers</th>
<th>hrs lost to cal</th>
<th>hrs lost to down time</th>
<th>%DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermo Andersen BAM-PM10</td>
<td>4</td>
<td>744</td>
<td>86</td>
</tr>
<tr>
<td>Thermo Andersen BAM-PM2.5</td>
<td>4</td>
<td>216</td>
<td>96</td>
</tr>
<tr>
<td>Thermo Andersen CAMM PM2.5</td>
<td>4</td>
<td>216</td>
<td>96</td>
</tr>
<tr>
<td>Met One BAM-PM10</td>
<td>5</td>
<td>144</td>
<td>90</td>
</tr>
<tr>
<td>Met One BAM-PM2.5</td>
<td>13</td>
<td>144</td>
<td>97</td>
</tr>
<tr>
<td>FDMS PM10</td>
<td>4</td>
<td>408</td>
<td>92</td>
</tr>
<tr>
<td>FDMS PM2.5</td>
<td>11</td>
<td>648</td>
<td>87</td>
</tr>
</tbody>
</table>

1 includes instrument malfunction, environmental factors (e.g. roof leak), operator error, and others

Methods of Data Analysis

To compare the performance of continuous samplers with the FRMs, first 24-hr averages were calculated for each continuous sampler. Then the average of the collocated samplers was compared with the average of the collocated FRMs. When one of the collocated continuous samplers did not produce enough data to produce 24-hr average, the 24-hr average of a single sampler was used for comparison. For precision, daily averages of collocated samplers were compared.

Precision of the FRMs was determined using the equations described in 40CFR Part 58 (Federal Register, 1997). The equations are given below. First the percent difference of each pair of 24-hr average data was calculated using equation 1.

**Equation 1**

\[ d_i = \left( \frac{sampler_1 - sampler_2}{Average \ of \ (sampler_1 \ and \ sampler_2)} \right) \times 100 \]

For a given sampler j, the average of the individual percentage difference during the study can be calculated using.

**Equation 2**

\[ D_{j,q} = \frac{1}{n_{j,q}} \sum_{i=1}^{n_{j,q}} d_i \]

Where \(n_{j,q}\) the number of sample pairs measured during the study. Also, regression analysis of collocated samplers was determined to evaluate the extent of agreement of the two.
To assess the accuracy of the continuous samplers, the averages of continuous PM10 samplers’ data were compared with the averages of PM10 Partisol and SSI FRMs. Because of the similarity of flow rate and filter size, the daily averages of the PM10 continuous samplers were compared with the averages of Partisol sampler for accuracy. The averages of continuous PM2.5 samplers’ data were compared with the averages of PM2.5 RAAS FRM. A regression analysis of the FRM to each continuous sampler was used to determine a slope, intercept, and correlation.

**PM10 sampler comparison**

Results of comparisons of PM10 samplers are given in Table 2. The FRMs are the lo-vol Partisol and the hi-vol SSI. Each was evaluated for precision using collocated samplers. The average of collocated Partisol was used to compare with average of collocated continuous samplers for accuracy.

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Intercept (ug/m3)</th>
<th>slope</th>
<th>r (^1)</th>
<th># samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partisol(^2)</td>
<td>Partisol</td>
<td>0.26</td>
<td>0.99</td>
<td>1.0</td>
<td>32</td>
</tr>
<tr>
<td>SSI(^2)</td>
<td>SSI</td>
<td>0.18</td>
<td>1.01</td>
<td>1.0</td>
<td>32</td>
</tr>
<tr>
<td>And-BAM(^3)</td>
<td>And-BAM</td>
<td>0.86</td>
<td>1.0</td>
<td>0.98</td>
<td>108</td>
</tr>
<tr>
<td>Met-BAM(^4)</td>
<td>Met BAM</td>
<td>-1.63</td>
<td>0.97</td>
<td>1.0</td>
<td>97</td>
</tr>
<tr>
<td>FDMS(^5)</td>
<td>FDMS</td>
<td>17.14</td>
<td>1.04</td>
<td>0.93</td>
<td>91</td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partisol</td>
<td>SSI</td>
<td>2.57</td>
<td>0.96</td>
<td>1.0</td>
<td>32</td>
</tr>
<tr>
<td>Partisol</td>
<td>And-BAM</td>
<td>-2.50</td>
<td>1.04</td>
<td>0.99</td>
<td>34</td>
</tr>
<tr>
<td>Partisol</td>
<td>Met BAM</td>
<td>-1.65</td>
<td>1.13</td>
<td>1.0</td>
<td>32</td>
</tr>
<tr>
<td>Partisol</td>
<td>FDMS</td>
<td>1.08</td>
<td>1.05</td>
<td>0.97</td>
<td>30</td>
</tr>
</tbody>
</table>

\(r = \text{correlation}\)

\(^2\) Partisol and SSI (size selective inlet) are Federal Reference Methods for PM10 manufactured by Rupprecht and Patashnick Co., Inc. and Thermo Andersen respectively.

\(^3\) And- BAM = Thermo Andersen BAM model FH 62 C14 manufactured by Thermo Andersen, Inc.

\(^4\) Met BAM = Met One BAM model 1020 manufactured by Met One Instruments, Inc.

\(^5\) FDMS = Filter Dynamics Measurement Systems series 8500 manufactured by Rupprecht and Patashnick Co.,

FRMs

The precision of the samplers, two Partisols (slope = 0.99, correlation 1.0, and intercept 0.26) and the two SSIs (slope = 1.01, correlation 1.0, and intercept 0.18) was excellent. Calculating the precision of each sampler type using equations 1 and 2 above, the Partisol and SSI have precision values of 0.7% and 1% respectively (Table 3).
The agreement of the lo-vol Partisol with the high-vol SSI also shows excellent agreement \((r = 1.0)\) with the slope and intercept of 0.96 and 2.57 respectively. Continuous samplers

Regression analysis of the collocated continuous And-BAM (slope 1.0, intercept 0.86, and correlation 0.98), Met-BAM (slope 0.97, intercept -1.63, and correlation 1.0), and the FDMS (slope 1.04, intercept 17.14, and correlation 0.93) yielded good agreement between pairs.

Table 3. Daily precision for both PM2.5 and PM10 samplers.

<table>
<thead>
<tr>
<th></th>
<th>PM10</th>
<th>PM2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSI</td>
<td>1</td>
<td>_</td>
</tr>
<tr>
<td>Partisol</td>
<td>0.7</td>
<td>_</td>
</tr>
<tr>
<td>RAAS</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Comparison of the Partisol to the And-BAM, Met-BAM, and the FDMS resulted in slope values of \((1.04, 1.13, \text{ and } 1.05 \text{ respectively})\), correlation values \((0.99, 1.0, \text{ and } 0.97, \text{ respectively})\), and intercepts \((-2.50, -1.65, \text{ and } 1.08, \text{ respectively})\) which indicate agreement between the continuous sampler and the FRM within the criteria for a California Approved Sampler. (Table 2). Thirty or more data pairs were used for comparison.

**PM2.5 sampler comparison**

The comparison of RAAS PM2.5 FRM to continuous PM2.5 shown in Table 4 indicates excellent inter and intra sampler agreement for the PM2.5 samplers.

Regression analysis of the collocated RAAS yielded a slope of 0.98, correlation of 1.0, and an intercept of -0.57 showing very good agreement between pairs. Similarly the collocated And-BAM (slope 0.98, correlation 0.98, and intercept 0.69), the Met-BAM (slope 0.98, correlation 1.0, and intercept -1.19), the FDMS (slope 1.04, correlation 0.99, and intercept, 0.88), and the CAMM (slope 0.97, correlation 0.91, and intercept 2.32) (Table 4) agree well with each other. When calculated using equations 1 and 2, the RAAS has precision value of 4% (Table 3).
Table 4. PM2.5 samplers comparison

<table>
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<tr>
<th>X</th>
<th>Y</th>
<th>Intercept</th>
<th>slope</th>
<th>r(^1)</th>
<th># samples</th>
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<td><strong>Precision</strong></td>
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<tr>
<td>RAAS(^2)</td>
<td>RAAS</td>
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<td>And-BAM(^3)</td>
<td>And-BAM</td>
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<tr>
<td>Met-BAM(^4)</td>
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<tr>
<td>FDMS(^5)</td>
<td>FDMS</td>
<td>0.88</td>
<td>1.04</td>
<td>0.99</td>
<td>55</td>
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<tr>
<td>CAMM(^6)</td>
<td>CAMM</td>
<td>2.32</td>
<td>0.97</td>
<td>0.91</td>
<td>96</td>
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</table>

| **Accuracy** |          |           |       |         |           |
| RAAS        | And-BAM  | -1.32     | 1.02  | 0.98    | 102       |
| RAAS        | Met-BAM  | -1.58     | 1.03  | 1.0     | 102       |
| RAAS        | FDMS     | 3.73      | 1.01  | 0.99    | 102       |
| RAAS        | CAMM     | 9.79      | 0.68  | 0.87    | 93        |

\(^1\) r = correlation
\(^2\) RAAS = Reference Ambient Air Monitor is a Federal reference method for PM2.5
\(^3\) And-BAM = Thermo Andersen BAM model FH 62 C14 manufactured by Thermo Andersen Inc.
\(^4\) Met BAM = Met One BAM model 1020 manufactured by Met One Instruments, Inc.
\(^5\) FDMS = Filter Dynamic Measurement Systems, series 8500 manufactured by Rupprecht and Patashnick Co.
\(^6\) CAMM = Continuous Ambient Mass Monitor manufactured by the Thermo Andersen Inc.

Continuous Samplers

The accuracy of a PM2.5 continuous sampler was determined by comparing 24-hr average data with the RAAS PM2.5 FRM (Table 4). The values of the slopes (1.02, 1.03, and 1.01 respectively), correlation (0.98, 1.0, and 0.99 respectively), and intercepts (-1.32, -1.58, and 3.73 respectively) indicate good accuracy for the And-BAM, the Met-BAM, and the FDMS respectively. For CAMM, slope of 0.68, correlation of 0.87, and intercept of 9.79 indicate poor agreement with the FRM.
Criteria for Acceptability as California Approved Samplers

The criteria used by the U.S. EPA for determining acceptability of PM10 equivalent samplers, seen below as PM10 Class II, were adopted by staff as the criteria for selecting California Approved Samplers. The criteria have been used successfully by the U.S EPA to approve a large number of samplers that are used throughout the country. We find the criteria suitable provided the tests are conducted in California and under conditions typical of areas with large populations and with persistent PM problems.

The U.S. EPA promulgated more stringent criteria in the PM2.5 regulations for PM2.5 equivalency. The new levels have been seen as quite stringent, to the point that the PM2.5 reference sampler, when compared to itself, often fails the test. They have been characterized as unnecessarily stringent, particularly in light of the increased number of data values available from continuous instruments. That feature is discussed below. It is interesting to note, however, that all samplers in the California Approved Sampler Study, except one, would have passed the more stringent PM2.5 criteria. The one that did not pass, failed only slightly with a slightly elevated y-intercept.

The U.S. EPA is developing other techniques for inter-sampler comparisons that are designed to take full advantage of the power of the increased sampling frequency of continuous samplers versus the intermittent schedule of filter based measurements. The EPA has found that the increased sampling frequency from continuous samplers would allow them to relax the nominal level of the acceptance criteria without lessening the effectiveness of the current comparative test.

Staff are following the evolving developments being discussed by the U.S.EPA, however, have selected a more stringent criteria for the California Approved Sampler at this time. The criteria have a history of being accepted by the measurement community and reliable if sampling conditions are regulated.

Table 5. Criteria for PM10 and PM2.5 (40CFR 53 Table C-1)

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<th>PM2.5 Class II</th>
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<td>Precision of replicate reference</td>
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<td>2 µg/m³ or 5%</td>
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<td>Slope</td>
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<td>± 0.05</td>
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<td>Intercept (µg/m³)</td>
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<tr>
<td>Correlation (r)</td>
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<td>≥0.97</td>
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Conclusions

The staff proposes to use the accuracy and precision criteria stated in federal regulation as the U.S. EPA PM10 class II test specifications as the State’s criteria
for determining acceptability of a California Acceptable Sampler for PM10 and PM2.5.

For both PM2.5 and PM10, three of the four samplers evaluated in the study--the Thermo Andersen BAM (model FH 62 C14), the Met One BAM (model 1020), and the R&P FDMS (series 8500) satisfy the criteria. Consequently, staff recommends that these samplers be approved for use to measure PM mass for determining compliance with the existing and proposed State AAQS.
Appendix 5

Supplementary Material for Chapter 5

Part I
Table of the State of California PM10 and PM2.5 Monitoring List
<table>
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<th>SITE</th>
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**Note:** R&P = Regional Particulate, H = High Range, RAAS = RAAS.
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