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       EMISSION MEASUREMENT TECHNICAL INFORMATION CENTER
              CONDITIONAL TEST METHOD

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Determination of Particulate Matter
(Modified High Volume Sampling Procedure)

1. APPLICABILITY AND PRINCIPLE

1.1 Applicability. This method is applicable for the determination of particulate matter (PM) from positive pressure baghouses and other sources that have low concentrations of PM, low humidity, and noncorrosive gases.

1.2 Principle. The PM is withdrawn isokinetically from the source and collected on a glass fiber filter. The PM mass is determined gravimetrically.

2. APPARATUS

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 1. Designs or materials of construction other than that specified may be used subject to the approval of the Administrator. The components of the sampling train are described below:

Figure 1. Modified high-volume sampling train.

2.1.1 Probe and Nozzle. Aluminum with sharp, tapered leading edge. The angle of taper shall be $\leq 30°$, and the taper shall be on the outside to preserve a constant internal diameter. The probe and nozzle shall be constructed of seamless tubing and of the elbow design as shown in Figure 1. A range of nozzle sizes suitable for isokinetic sampling should be available, e.g., 2.54 to 5.08 cm (1.0 to 2.0 in.), with inside diameter nozzles in increments of 0.32 cm (1/8 in.). Each nozzle shall be calibrated according to the procedures outlined in Section 5.1.

2.1.2. Filter Holder. Aluminum with screen and silicone rubber gaskets. The holder shall be attached directly to the outlet of the probe. **Note:** The probe and filter holder must be constructed to be leak free.

2.1.2 Pitot Tube, Differential Pressure Gauge, Barometer, and Gas Density Determination Equipment. Same as in Method 5, Sections 2.1.3, 2.1.4, 2.1.9, and 2.1.10, respectively.

2.1.3 Metering System. A 110-volt blower with a capacity of 0.42 m^3/min (15 cfm) at 7 cm (2.75 in.) H_2O vacuum, thermometers capable of measuring temperature to within 3°C (5.4°F), dry gas meter (DGM) capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 1. Other metering systems capable of maintaining sampling rates within 10 percent of

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isokinetic and determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. This metering system shall be used in conjunction with a pitot tube, to enable checks of isokinetic rates.

2.2 Sample Recovery.

2.2.1 Probe and Probe Nozzle Brushes, Wash Bottles, and Funnel. Same as in Method 5, Sections 2.2.1, 2.2.2, and 2.2.8, respectively.

2.2.2 Filter Shipping Containers.

2.2.3 Acetone-Wash Recovery Bottle. Chemically resistant, borosilicate glass bottle, for acetone washes, 2 to 4 liters. Screw caps shall be constructed to be resistant to chemical attack by acetone. Alternatively, polyethylene bottles may be used. **Note:** Because of the large surface area, extra care must be taken to recover the PM from the probe and nozzle. To allow the probe and nozzle wash samples to be recovered in an efficient way, it is suggested that the probe nozzle and acetone-wash recovery bottle be designed such that the acetone-wash recovery bottle can be attached to the nozzle end of the probe. A flange that allows the lid to be screwed on has been shown to work well. To prevent interference with sampling, the flange must be located at least 1 nozzle diameter from the nozzle opening. The outer edge of the flange must be located 3.8 ± 0.6 cm (1.5 ± 0.25 in.) from the pitot tube to prevent interference with the velocity readings.

2.2.4 Glass Sample Storage Containers. Same as in Method 5, Section 2.2.3.

2.3 Analysis.

2.3.1 Desiccator, Analytical Balance, Hygrometer, Beakers, and Temperature Gauge. Same as in Method 5, Sections 2.3.2, 2.3.3, 2.3.5 to 2.3.7, respectively.

3. REAGENTS

3.1 Sampling.

3.1.1 Filters. Same as in Method 5, Section 3.1.1.

3.2 Sample Recovery. Same as in Method 5, Section 3.2.

3.3 Analysis.

3.3.1 Acetone and Desiccant. Same as in Method 5, Sections 3.3.1 and 3.3.2, respectively.

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4. PROCEDURE

4.1 Sampling.

4.1.1 Pretest Preparations.

4.1.1.1 Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper size on the back side near the edge using numbering machine ink. As an alternative, label the shipping containers and keep each filter in its own container at all times except during sampling and weighing.

4.1.1.2 Desiccate the filters at $20 \pm 5.6°C$ ($68 \pm 10°F$) and ambient pressure for at least 24 hours, and weigh at intervals of at least 6 hours to a constant weight, i.e., ≤ 0.5 mg change from previous weighing; record results to the nearest 0.1 mg. During each weighing, the filter must not be exposed to the laboratory atmosphere for a period greater than 2 minutes and a relative humidity greater than 50 percent. Alternatively (unless otherwise specified by the Administrator), the filters may be oven dried at $105°C$ ($220°F$) for 2 to 3 hours, desiccated for 2 hours, and weighed to a constant weight. Procedures other than those described, that account for relative humidity effects, may be used (subject to the approval of the Administrator).

4.1.2 Preliminary Determinations. Follow the procedure given in Method 5, Section 4.1.2, except select a suitable probe length such that all traverse points can be sampled. The approximate moisture content is not needed to set the sampling rate.

4.1.3 Preparation of Collection Train. Set up the train as in Figure 1. Prepare the filter holder as specified in Method 5, Section 4.1.3. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

4.1.4 Leak-Check Procedures.

4.1.4.1 Pretest Leak-Check. A pretest leak-check is recommended, but not required. If the tester chooses to conduct the pretest leak-check, use the following procedure: When assembling the sampling train, do not connect the probe and filter to the train during the leak check. Instead, leak check the train by first plugging the inlet to the DGM and then pulling a 127 mm (5 in.) Hg vacuum. Leakage rates in excess of 0.0057 m^3/min (0.2 cfm) or

4 percent of the average sampling rate, whichever is less, are unacceptable.

4.1.4.2 Post-Test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leak-check shall be done in accordance with the procedures outlined in Section 4.1.4.1. If the leakage rate is found to be no greater than 0.0057 m^3/min (0.2 cfm) or 4 percent of the average sampling rate, whichever is less, the results are acceptable, and no correction need be applied to the total volume of dry gas metered. If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.5 of this method or void the sampling run.

4.1.5 Particulate Train Operation. Operate the sampling train using the procedure described in Method 5, Section 4.1.5 with the following exceptions:

4.1.5.1 For each run, record the data required on a data sheet such as the one shown in Figure 2. Record the pressure drop across the DGM once during each sampling interval.

Figure 2. Particulate field data.

Plant _____
Location _____
Operator _____
Date _____
Run No. _____
Meter box no. _____
Pitot tube coefficient, C_p _____

Ambient temperature, °C (°F) _____
Barometric pressure, mm Hg (in. Hg) _____
Moisture, % _____
Probe length, m (ft) _____
Average calibration nozzle diameter, cm (in.) _____
Leak rate, m³/min (cfm) _____
Static pressure, mm Hg (in. Hg) _____
Filter no. _____

Traverse point number	Sampling θ min	DGM vacuum cm H_2O (in. H_2O)	Stack temperature t_s °C (°F)	Velocity head Δp mm H_2O (in. H_2O)	Pressure differential across orifice meter mm H_2O (in. H_2O)	Gas sample volume V_m m³ (ft³)	DGM temperature °C (°F)
Total							
Average							

4.1.5.2 The filter does not need to be heated. Determine the orifice settings for each run using Equation 1.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic, using Equation 4, to determine whether the run was valid or another test run should be made.

4.2 Sample Recovery. Transfer the probe filter assembly to the cleanup area as described in Method 5, Section 4.2.

4.2.1 Container No. 1 (Filter). Treat the filter as outlined in Method 5, Section 4.2.

4.2.2 Container No. 2 (Acetone Rinse). Attach the acetone-wash recovery bottle to the nozzle end of the probe to collect the probe and filter holder rinses. Brush and rinse the probe and the front half of the filter holder three times with acetone. After the brushing, make a final rinse of the probe and the front half of the filter holder. Rinse the brush with acetone and transfer the washings from the acetone-wash recovery bottle to the sample storage bottle. Rinse the acetone-wash recovery bottle, and quantitatively collect these washings in the sample storage bottle. **Note:** Two people are required to clean the probe. Between sampling runs, keep brushes clean and protected from contamination.

4.2.3 Container No. 3 (Acetone Rinse). Conduct a second probe wash using the same procedure described in Section 4.2.2.

4.3 Analysis. For analysis, follow the procedure described in Method 5, Section 4.3, except omit the paragraph dealing with Container No. 3 (Method 5), and analyze Container No. 3 from this method using the same procedure as Container No. 2. **Note:** Containers 2 and 3 may be combined for analysis.

5. CALIBRATION

Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle and Pitot Tube. Same as in Method 5, Sections 5.1 and 5.2, respectively.

5.2 Metering System.

5.2.1 Before its initial use in the field, the metering system shall be calibrated as follows: Run the metering system pump for about 15 minutes with
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the orifice manometer indicating a median reading as expected in field use to allow the pump to warmup. Connect the metering system inlet to the outlet of a spirometer. The spirometer should have a capacity of 600 liters (21 ft^3) or greater. Then, at a minimum of three orifice manometer settings, pass an exact quantity of gas through the spirometer and note the gas volume indicated by the DGM.   Also note the barometric pressure, temperature of the spirometer, temperature of the DGM, temperature of the orifice, and sampling time for the calibration run. Select the highest and lowest orifice settings to bracket the expected field operating range of the orifice. Use a minimum of 370 liters (13 ft^3) at all orifice settings. Record all the data and calculate Y, the DGM calibration factor using Equation 1. Use the average of the Y values in Section 6.5. Calculate the volumetric flow rate, Q, of the spirometer during each calibration run and plot a calibration curve of $\sqrt{}$)H verses Q. From the calibration curve obtain the slope, a, and the y-intercept, b, which shall be used in the calculation in Section 6.3. **Note:** Before calibrating the metering system, it is suggested that a leak-check be conducted.

5.2.2 After each field use, check the calibration of the metering system by performing three calibration runs at the average rheostat setting reached during the test series. If the calibration factor has changed by more than 5 percent, recalibrate the DGM over the full range of rheostat settings.

5.2.3 If the DGM coefficient values obtained before and after a test series differ by more than 5 percent, the test series shall either be voided, or calculations for the test series shall be performed using whichever meter coefficient value (i.e., before or after) gives the lower value of total sample volume.

5.3   Temperature Gauges and Barometer. Same as in Method 5, Sections 5.5 and 5.7, respectively.

5.4 Leak-Check of Metering System. Follow the procedure described in Section 4.1.4.1.

6.   CALCULATIONS

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

6.1   Nomenclature. Same as in Method 5, Section 6.1 except:

a = Slope of meter box calibration curve, flow rate versus ΔH.

b = y intercept of meter box calibration curve.

C_p = Pitot tube coefficient.

L_a = Maximum acceptable leakage rate for a pretest leak check equal to 0.0057 m^3/min (0.2 ft^3/min).

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M_w = Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).

P_g = Gauge pressure of dry gas meter, cm H_2O (in. H_2O).

P_m = Meter pressure (P_{bar} corrected for P_g), cm H_2O (in. H_2O).

T_s = Temperature of the spirometer, $^\circ$R ($^\circ$F).

$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter corrected for standard conditions, scm (scf).

V_s = Volume of gas measured by the spirometer, scm (scf).

Δp = Velocity head pressure, mm H_2O (in. H_2O).

θ = Sampling time, min.

6.2 DGM Calibration Factor.

Eq. 1
$$Y = \frac{V_s \, T_m}{V_m \, T_s}$$

6.3 Orifice Pressure Drop Setting During Sampling.

$$\text{Eq. 2} \qquad \Delta H^{1/2} = \frac{K_1\, A_n\, C_p\, T_{std}}{\Delta P_{std}}\left[\frac{(P_{bar} + K_2\, P_g)\, \Delta p}{T_s\, M_w}\right]^{1/2}$$

where:

$$K_1 = 34.97 \;\; \frac{m}{sec}\;\; \frac{(g/g\text{-mole})(mm\ Hg)^{1/2}}{(^\circ K)(mm\ H_2O)}$$

$$= 85.49 \;\; \frac{ft}{sec}\;\; \frac{(lb/lb\text{-mole})(in.\ Hg)^{1/2}}{(^\circ R)(in.\ H_2O)}$$

$$K_2 = 0.736 \text{ mm Hg/cm } H_2O \quad (0.0736 \text{ in. Hg/in. } H_2O).$$

6.4 Average DGM Temperature. Same as in Method 5, Section 6.2.

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6.5 Gas Volume. Correct the sample volume measured by the DGM to standard conditions (20°C, 760 mm Hg or 68°F, 29.92 in. Hg) using Equation 3.

$$\text{Eq. 3} \qquad V_{m(std)} = V_m\, Y\, \frac{T_{std}}{T_m}\; \frac{P_m}{P_{std}}$$

$$= K_3\, V_m\, \frac{P_m}{T_m}$$

where:

$$K_3 = 0.3858\,^\circ K/mm\ Hg\ (17.64\,^\circ R/in.\ Hg).$$

Note: Equation 2 can be used as written unless the leakage rate observed during any of the mandatory leak-checks exceeds L_a. If L_p exceeds L_a, the procedure in Method 5, Section 6.3 shall be used.

6.6 Moisture Content. Determine the stack moisture content using the wet bulb-dry bulb temperatures or Method 4.

6.7 Acetone Blank Concentrations, Acetone Wash Blank, and Conversion Factors. Same as in Method 5, Sections 6.6, 6.7, and 6.10, respectively.

6.8 Particulate Concentration.

$$\text{Eq. 4} \qquad c_s = 0.001 \; \frac{m_n}{V_{m(std)} \; (1-B_{ws})}$$

where:

   $0.001 = $ g/mg.

6.9 Total Particulate Weight. Determine the total particulate catch from the sum of the weights obtained from Containers 1, 2, and 3, less the acetone blank.

6.10 Percent Isokinetic Rate.

$$\text{Eq. 5} \qquad I = K_4 \; \frac{T_s \; V_{m(std)}}{P_s \; v_s \; A_n \; 2 \; (1-B_{ws})}$$

where:

   $K_4 = 4.3204 \; [(\text{mm Hg})(\text{sec})(\%)]/[(°K)(\text{min})]$

      $= 0.0945 \; [(\text{in. Hg})(\text{sec})(\%)]/[(°R)(\text{min})].$

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6.11 Acceptable Results. Same as Method 5, Section 6.12.

7. BIBLIOGRAPHY

Same as in Bibliography of Method 5.

Figure 2. Particulate field data.

Plant _____   Ambient   temperature,   °C
(°F)_____   Location _____
                                                  Barometric pressure, mm Hg (in.
Hg)_____   Operator   _____
                                                  M o i s t u r e ,   %
_____ Date _____
                                                  P r o b e   l e n g t h ,   m   (f t)
_____
Run No. _____   Average calibration nozzle diameter, cm
(in.)_____
Meter box no. _____   L e a k   r a t e ,   m ^{3} / m i n
(cfm)_____ Pitot   tube coefficient, Cp _____
                                                  Static   pressure,   mm   Hg   (in.
Hg)_____   F   i   l   t   e   r
no._____

Traverse sample point number	Sampling DGM **2** temperature min °C (°F)	DGM vacuum cm H₂O (in. H₂O)	Stack temperature t_s °C (°F)	Velocity head Δp_s mm H₂O (in. H₂O)	Pressure differential across orifice meter mm H₂O (in. H₂O)	Gas volume m³ (ft³)

Total

Average