



Standard Test Method for High-Volume Sampling for Solid Particulate Matter and Determination of Particulate Emissions¹

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1. Scope

1.1 This test method can be used to estimate the particulate matter concentration in stationary source stacks.

1.2 With the nozzle sizes specified herein, the method can be used for stack stream velocities from approximately 4 to 45 m/s (800 to 8 000 ft/min).

1.3 Particulate matter present in a gaseous phase at the filtration temperature will not be collected. If significant quantities of condensable particulate matter are expected, this test method may not be the method of choice. If the temperature of the sampled gas at the filter is below the stream dewpoint this test method will not work. If moisture is expected to condense between the filter and the orifice, this test method is not applicable unless a moisture collection device is placed immediately upstream of the orifice and the sampling rate is adjusted for the volume of gas that condensed upstream of the orifice.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- D 1071 Test Methods for Volumetric Measurement of Gaseous Fuel Samples²
- D 1356 Terminology Relating to Sampling and Analysis of Atmospheres³
- D 2986 Practice for Evaluation of Air Assay Media by the Monodisperse DOP (Diocetyl Phthalate) Smoke Test³
- D 3154 Test Method for Average Velocity in a Duct (Pitot Tube Method)³

¹ This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres and Source Emissions.

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² Annual Book of ASTM Standards, Vol 05.05.

³ Annual Book of ASTM Standards, Vol 11.03.

D 3464 Test Method for Average Velocity in a Duct Using a Thermal Anemometer³

E 1 Specification for ASTM Thermometers⁴

2.2 Other Documents:

- 40 CFR, Part 60, Environmental Protection Agency Method 2, Appendix A, Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)⁵
- Oregon State Method, Standard Sampling Method, Determination of Particulate Emissions from Cyclones (High Volume Method)⁶

3. Terminology

3.1 For definitions of terms relating to this test method, refer to Terminology D 1356.

3.2 Symbols:

E	= total particulate emission rate: kg/h (lb/h)
F_p	= pitot tube calibration factor (standard-type = 1.0)
I	= percent isokinetic, %
A_a	= area of stack at sampling points, m ² (ft ²)
A_n	= area of nozzle, m ² (ft ²)
C_g	= particulate concentration, g/m ³ (grains/ft ³)
M	= molecular weight of moist gas at stack conditions
M_a	= volume fraction of moisture in stack gas, %
M_o	= 29.0, (molecular weight of air)
P_{std}	= standard atmospheric pressure, 101.32 kPa (29.92 in. Hg)
P_a	= absolute pressure of stack gas kPa (in. Hg)
P_{bar}	= barometric pressure corrected for elevation, kPa (in. Hg)
P_o	= orifice pressure drop, kPa (in. of water)
P_s	= stack velocity pressure, kPa (in. of water)
Q	= stack volumetric flow rate, dry m ³ /s (dry ft ³ /min)
T_s	= stack temperature, degrees K (R)
T_{std}	= standard temperature, 298.2 K (537 R)
T_o	= average orifice meter temperature, degrees K (R)

⁴ Annual Book of ASTM Standards, Vol 14.03.

⁵ Available from Superintendent of Documents, U.S. Printing Office, Washington, DC 20402.

⁶ Available from Oregon Department of Environmental Quality, Control Division, April 1972.

V_{std}	= total volume of gas sampled corrected to dry standard conditions, m^3 (ft^3)
V_s	= average actual stack gas velocity at stack conditions, m/s (ft/min)
$V_{s,std}$	= average actual stack gas velocity corrected to dry standard conditions, m/s (ft/min)
W	= total particulate sample mass, mg
θ	= sampling time of run, (min).

4. Summary of Test Method

4.1 By means of a sampling nozzle, particulate matter as a component of the flowing gas stream is withdrawn from the stack under approximate isokinetic conditions (Fig. 1). Isokinetic conditions are maintained within close limits throughout the sampling period in order to avoid erroneous results caused by mechanical separation of coarse particles (which may result should a velocity change occur at the nozzle).

4.2 The particulate matter in the stream sample is collected on preweighed filters and from rinsings of the collection system ahead of the filter. Particulate mass is determined in the laboratory subsequent to the test.

5. Significance and Use

5.1 This test method is useful for estimating total particulate emission rate (see Oregon state method). The average volumetric flow in the stack is determined from velocity traverses of the stack made just prior to and immediately after sampling. The total particulate emission is estimated by multiplying the average volumetric flow by the particulate concentration measured with this test method.

5.2 This test method is not recommended when moisture content of the gas stream or concentration of condensable material, or both, would affect the results obtained by this test method.

NOTE 1—Features of this test method that could affect the results include the following:

- (1) information is not available concerning the proper pitot nozzle orientation required to avoid aerodynamic interference of the nozzle with the pitot measurement and vice-versa;
- (2) the effectiveness of the filter conditioning steps in removing water from the particulate catch is unknown;
- (3) there is no cumulative flow-measuring device on the manual-type systems to give the total volume of gas sampled; and
- (4) except for short duration batch processes and continuous processes that have extremely low-particulate matter concentrations and moisture content, it is unlikely that this test method would be able to sample isokinetically for the amount of time required to cover the complete operating cycle of most processes.

6. Equipment

6.1 Sampling Apparatus: (See Fig. 1)

6.1.1 *Nozzle*—The sampling nozzle, made of metal, with thin walls, a sharp edge entry with a maximum taper of 30°, and a constant diameter bore. It has at least 2 nozzle diameters (based on inside diameter of tubing) of straight section between the leading edge of the nozzle and the beginning of the 90° bend. Nozzle diameters range typically from 20 to 50 mm ($\frac{7}{8}$ to 2 in.) inside diameter. A nozzle diameter is such that isokinetic conditions can be maintained at the flow rates to be used for each test. A typical range of nozzle sizes and flow rates for ambient temperature sources is as follows:

Nozzle Size, ID	Flow Velocity
50 mm ($1\frac{7}{8}$ in.)	4 to 10 m/s (800 to 2000 ft/min)
35 mm ($1\frac{3}{8}$ in.)	10 to 20 m/s (2000 to 4000 ft/min)
25 mm ($1\frac{5}{16}$ in.)	20 to 45 m/s (4000 to 8000 ft/min)

The nozzle is connected to the probe such that deposition of particulate matter in threads or joints is minimized.

6.1.2 *Probe*—The probe is attached to the filter holder either directly or by the shortest possible length of smooth-walled tubing.

6.1.3 *Filter Holder*—Filter holder capable of holding 200 by 250 cm (8 by 10 in.) filters without leaking. A quick disconnect assembly is recommended for ease of changing filters.

6.1.4 *Metering System*—The filter holder is followed by a calibrated orifice, a thermometer or thermocouple, a flow-control valve, and a high-volume blower capable of 0.03 m^3/s (60 ft^3/min) free air capacity. If desired, a total volume measuring device such as a Roots meter may be included in the system.

6.1.5 *Flow-Measuring Device*—A standard-type pitot tube having the dimension specified in Test Method D 3154 is preferred since it is far less sensitive to flow angularity and Reynolds number than the Stauscheibe (S-type) pitot tube. If an S-type pitot is used, it must be calibrated against a standard-type pitot tube or other device of known accuracy. Other flow-measuring devices such as an anemometer may be required for flow rates below 5 m/s (900 ft/min). See Test Method D 3464.

6.1.6 *Flow-Measuring Gages*—The use of an inclined manometer is preferred over a Magnehelic⁷ gage for measuring the velocity head and the pressure drop across the orifice. If a Magnehelic gage is used it must be suitable for the pressure drop that will be encountered, that is, a 0.5 kPa (0 to 2 in. H_2O). A Magnehelic gage is not suitable for a pressure drop of less than 0.025 kPa (0.1 in.). (If a Magnehelic gage is used, check its calibration before each test using an inclined manometer. Use it only in the orientation (vertical, horizontal, etc.) in which it was calibrated).

6.2 Sample Recovery and Mass Analysis:

6.2.1 Probe brush of a length at least equal to the length of the probe.

6.2.2 Wash bottles and storage containers for liquid.

6.2.3 Evaporation equipment.

6.2.4 Analytical balance sensitive to at least 0.1 mg for weighing filters and washings.

6.2.5 Clean manila folders and envelopes for handling and storing filters. Specially constructed, rigid plastic boxes equal in size to that of the filter may be preferred for some applications.

7. Reagents and Materials

7.1 *Purity of Reagents*—All reagents shall conform to the specifications of the Committee on Analytical Reagents of the

⁷ Magnehelic is a registered trademark of Dwyer Instruments Inc., Michigan City, IN.

TABLE 1 Calibration Data

Plant Name and Location _____
 Dates Tested _____ By _____

Equipment	Calibration Date	Place of Calibration	Method
Pitot Tube			
Orifice Meter			
Velocity Pressure Meter			
Orifice Pressure Meter			
Thermometer/Thermocouple			
Other (List)			

American Chemical Society, where such specifications are available.⁸

7.2 Filters—Glass fiber filters, 200 by 250 cm (8 by 10 in.) rectangular, without organic binder exhibiting at least 99.95 % efficiency (0.05 % penetration) using 0.3- μ m dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with Practice D 2986. Test data from the supplier's quality control program is sufficient for this purpose.

7.3 Sample Recovery—Reagent grade acetone or other suitable solvent, <0.001 % residue, in glass bottles. Solvent blanks should be run prior to field use and only solvent with low blank values (<0.001 %) should be used.

8. Sampling Strategy

8.1 The ideal sampling location is one at least 8 stack diameters downstream and 2 stack diameters upstream from the nearest obstruction or bend in the stack. If the ideal sampling location is unavailable because of design or construction, collect the sample from the location giving the most representative sample. Do not sample at any site less than 2 diameters downstream of or $\frac{1}{2}$ diameter upstream of a flow disturbance. Conduct sampling in a vertical stack rather than in a horizontal run if at all possible. Operational considerations are safety, access holes, power availability, weather protection, etc.

8.2 The period during which the sample is collected depends whether the process is steady state or cyclic, and the process operating capacity. If the process is steady state, conduct the tests at a time when process conditions are stabilized or arrangements are made with operating personnel to hold conditions constant. If the process is cyclic, define the portion of the cycle over which sampling is conducted. In all cases, record the percentage of operating capacity of the process at the time of sampling.

8.3 In order to provide a representative sample, it is standard procedure in source testing to divide the stack into segments of equal area using criteria delineated in Test Method D 3154.

Then each segment is sampled for an equal period of time. However, if this technique is employed with the high-volume stack sampling train, instances will occur where the diameter of the nozzle will be larger than the width of the stack segment being sampled. In other words, the use of Test Method D 3154 could result in segment overlapping, that is, sampling two segments of the stack simultaneously. To prevent this, refer to Test Method D 3154 to select the desired number of sampling points, but if overlap still occurs, combine these overlapping segments into one segment at least 2.5 cm (1 in.) from the stack wall.

8.4 Conduct sampling with the nozzle velocity adjusted to within ± 10 % of the isokinetic rate.

8.5 Select the sampling time so that at least 100 mg is collected.

8.6 Determine stack gas moisture content using previous test results, a wet bulb/dry bulb measurement or, if applicable, process feed data.

8.7 Take at least three samples from a process in order to obtain an average particulate concentration along with the standard deviation of the samples.

9. Calibration and Pretest Preparation

9.1 Calibration—Calibrate the pitot tube, orifice flowmeter, pressure gages, and temperature measurement devices against a primary standard. Note the date, place, and method of calibration of these devices on Table 1. Perform a complete calibration at least once a year, but perform spot checks to identify leaks or significant calibration changes after every test.

9.1.1 Probe Nozzle—Using a micrometer, measure the inside diameter of the nozzle to the nearest 0.1 mm (0.005 in.). Make three separate measurements using different diameters each time and obtain the average of the measurements. The differences between the high and low numbers should not exceed 0.3 mm (0.01 in.). Repair, sharpen and recalibrate nozzles when they become nicked or dented.

9.1.2 Pitot Tube—Standard-type pitot tubes meeting the specifications in Test Method D 3154 can be used as received from the manufacturer. Calibrate the S-type pitot tube prior to use and at least after every fifth field test using the procedure specified in Test Method D 3154 or U.S. Environmental Protection Agency Method 2 (40 CFR 60 Appendix A).

9.1.3 Pressure Gages—Inclined manometers do not have to be calibrated unless the manometer has been damaged or a

⁸ Reagent Chemicals, American Chemical Society Specifications, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.