



Designation: D5835 – 20

Standard Practice for Sampling Stationary Source Emissions for the Automated Determination of Gas Concentrations¹

This standard is issued under the fixed designation D5835; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice² covers procedures and equipment that will permit representative sampling for the automated determination of gas concentrations of effluent gas streams with limitations as described below. The application is limited to the determination of oxygen (O₂), carbon dioxide (CO₂), carbon monoxide (CO), sulfur dioxide (SO₂), nitric oxide (NO), nitrogen dioxide (NO₂), and total oxides of nitrogen (NO_x).

1.2 Velocity measurements are required to determine the mass flow rates of gases. This is not included in this practice.

1.3 There are some combustion processes and conditions that may limit the applicability of this practice. Where such conditions exist, caution and competent technical judgment are required, especially when dealing with any of the following:

1.3.1 Corrosive or highly reactive components,

1.3.2 High vacuum, high pressure, or high temperature gas streams,

1.3.3 Wet flue gases,

1.3.4 Fluctuations in velocity, temperature, or concentration due to uncontrollable variation in the process,

1.3.5 Gas stratification due to the non-mixing of gas streams,

1.3.6 Measurements made using environmental control devices, and

1.3.7 Low levels of gas concentrations.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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, health, and environmental practices and deter-*

mine the applicability of regulatory limitations prior to use. For more specific safety precautions, refer to 5.1.4.8, 5.2.1.6, and 6.2.2.1.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*³

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D1608 Test Method for Oxides of Nitrogen in Gaseous Combustion Products (Phenol-Disulfonic Acid Procedures)

D3154 Test Method for Average Velocity in a Duct (Pitot Tube Method)

2.2 *Other Document:*

40 CFR Part 60 Standards of Performance for Stationary Sources, Appendix A, Test Methods 2, 3, 3a, 6, 6c, 7, 7e, and 10⁴

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology **D1356**.

4. Summary of Practice

4.1 This practice describes representative duct or stack gas sampling, including both extractive and non-extractive sampling. In extractive sampling, gases are conditioned to remove aerosols, particulate matter, and other interfering substances before being conveyed to instruments. In non-extractive

¹ This practice is under the jurisdiction of ASTM Committee **D22** on Air Quality and is the direct responsibility of Subcommittee **D22.03** on Ambient Atmospheres and Source Emissions.

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² This practice is based on ISO 10396, "Stationary source emissions—Sampling for the automated determination of gas concentrations," available from International Organization for Standardization, Casa Postale 56, CH-1211, Geneva, Switzerland.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

⁴ Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, <http://www.access.gpo.gov>.

sampling, the measurements are made in-situ; therefore, sample conditioning is not necessary beyond filtration.

4.1.1 *Extractive Sampling*—Extractive sampling consists of extraction of the sample, removal of interfering materials, and retention of the analyte concentration without change throughout the sampling system for analysis by appropriate instrumentation (see Fig. 1).

4.2 *Non-extractive Sampling*—Non-extractive sampling does not involve removal of a sample from the duct or stack with sampling confined to the gas stream (see Figs. 2 and 3).

5. Representative Factors

5.1 Nature of the Source:

5.1.1 The representativeness of the gaseous analyte concentration determination in enclosed gas streams depends on several factors:

5.1.1.1 The heterogeneity of the process stream, such as variations in concentration, temperature, or velocity across the duct or stack caused by moisture or gas stratification,

5.1.1.2 Gas leakage or air infiltration and continuous gas reactions, and

5.1.1.3 Random errors due to the finite nature of the sample and the sampling procedure adopted to obtain a representative sample.

5.1.2 Representativeness may be difficult to achieve for the following reasons:

5.1.2.1 Nature of the source (for example, cyclic, continuous, or batch),

5.1.2.2 Concentration level of the analyte(s),

5.1.2.3 Size of the source, and

5.1.2.4 Configuration of the duct or stack network where samples are extracted.

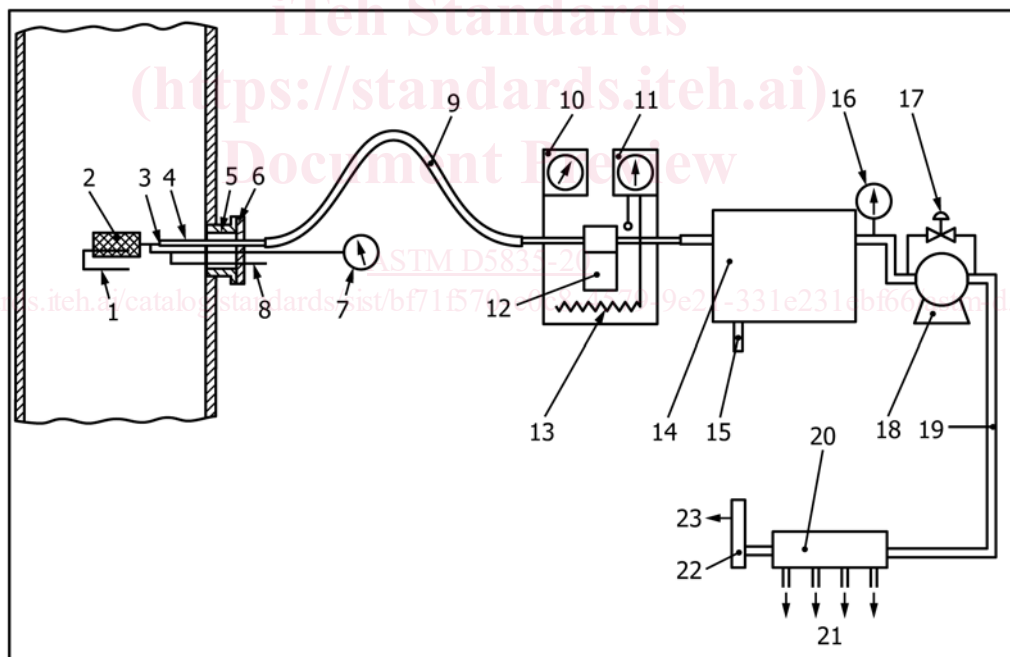
5.1.3 Where there are issues due to the nature of the source as noted in 5.1.2, establish the concentration profile for each operating condition to determine the best sampling location.

5.1.3.1 Some sources may have more variability in their operating processes (for example, cyclic variation) and, consequently, any time dependent measurement may be less representative of the average concentration if a full cycle of variability is not sampled.

5.1.4 Before any measurements are carried out, it is necessary to become familiar with the relevant operating characteristics of the process from which emissions are to be sampled and determined. These operating characteristics include, but are not limited to, the following:

5.1.4.1 Mode of process operation (cyclic, batch charging, or continuous),

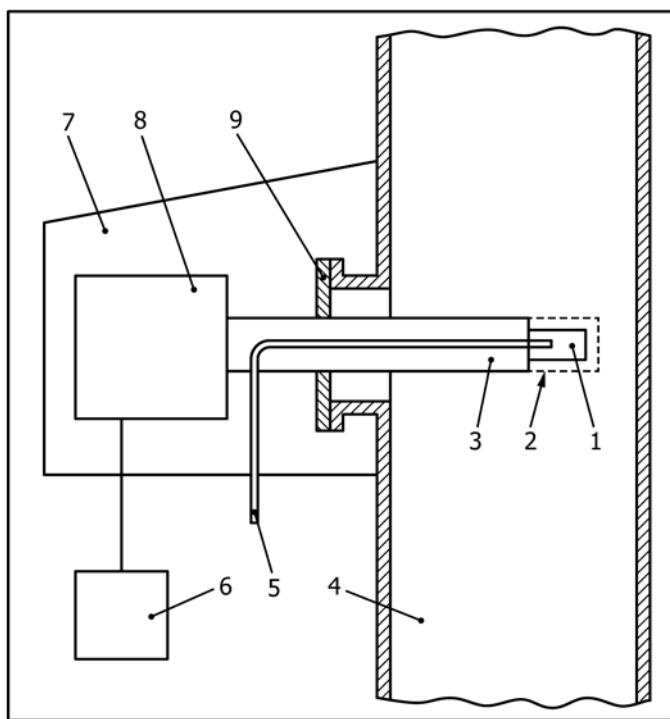
5.1.4.2 Process feed rates and composition,



NOTE—Key:

1	Baffle	13	Heater
2	In-stack Filter	14	Refrigeration Unit
3	Tee	15	Water Discharge
4	Probe	16	Vacuum Gauge
5	Sampling Port	17	Bypass Valve
6	Cap	18	Pump
7	Pressure Gauge	19	Sampling Line (Heating Optional)
8	To Zero and Span Gases	20	Manifold
9	Heat-traced Sampling Line	21	To Analyzer(s)
10	Temperature Controller (Line)	22	Rotameter
11	Temperature Controller (Box)	23	Vent
12	Filter		

FIG. 1 Extractive Sampling and Conditioning System



NOTE—Key:

1	Measurement Cell	6	Data Recorder
2	Probe Filter	7	Protective Hood
3	Probe	8	Transceiver
4	Duct or Stack	9	Probe Mounting
5	Gas Calibration Line		

FIG. 2 Non-extractive Point Monitor

- 5.1.4.3 Fuel rates and composition,
- 5.1.4.4 Normal operating gas temperatures and pressures,
- 5.1.4.5 Operating and removal efficiency of the pollution control equipment,
- 5.1.4.6 Configuration of the ducts to be sampled leading to gas stratification,
- 5.1.4.7 Volumetric gas flow rates, and
- 5.1.4.8 Expected gas composition and likely interfering substances. (**Warning**—Exercise caution if the duct to be sampled is under pressure or vacuum, or at high temperature.)

5.2 Location:

5.2.1 *Inspection Parameters*—Perform an inspection of the physical characteristics of the test site to evaluate factors such as:

- 5.2.1.1 Safety of the personnel,
- 5.2.1.2 Location of flow disturbances,
- 5.2.1.3 Accessibility of the sampling site,
- 5.2.1.4 Available space for the sampling equipment and instrumentation and possible scaffolding requirements,
- 5.2.1.5 Availability of suitable electrical power, compressed air, water, steam, etc., and
- 5.2.1.6 Sampling port locations. (**Warning**—Use the electrical equipment in accordance with the local safety requirements. Where a potentially explosive or hazardous atmosphere is suspected, apply particular attention and precautions to ensure the safety of the operations.)

5.2.2 *Sampling Site Location:*

5.2.2.1 It is necessary to ensure that the gas concentrations measured are representative of the average conditions inside the duct or stack. The requirements for extractive sampling of gas may be not as rigorous as those for particulate material. It is important that the sampling location be free of any obstructions that will seriously disturb the gas flow in the duct or stack. Since the pollutant can have cross sectional variation, the concentration at various points of the cross-section shall first be checked, in order to assess the homogeneity of the flow and to detect any infiltration of air or gas stratification, etc. If a preliminary analysis of cross-sectional measurements indicates more than $\pm 15\%$ variation in concentrations, and if an alternative acceptable location is unavailable, multi-point sampling is recommended.

5.2.2.2 Multi-point sampling may be achieved either by moving the probe from point to point or having a probe with multiple access ports. Usually, the cross-sectional concentration of gaseous pollutants is uniform, because of the diffusion and turbulent mixing. In this case, it is only necessary to sample at one point within the stack or duct to determine the average concentration. Extract gas samples near the center of the stack sampling site. When using nonextractive systems, obtain a concentration as representative as possible, and ensure that the instrument location is representative.

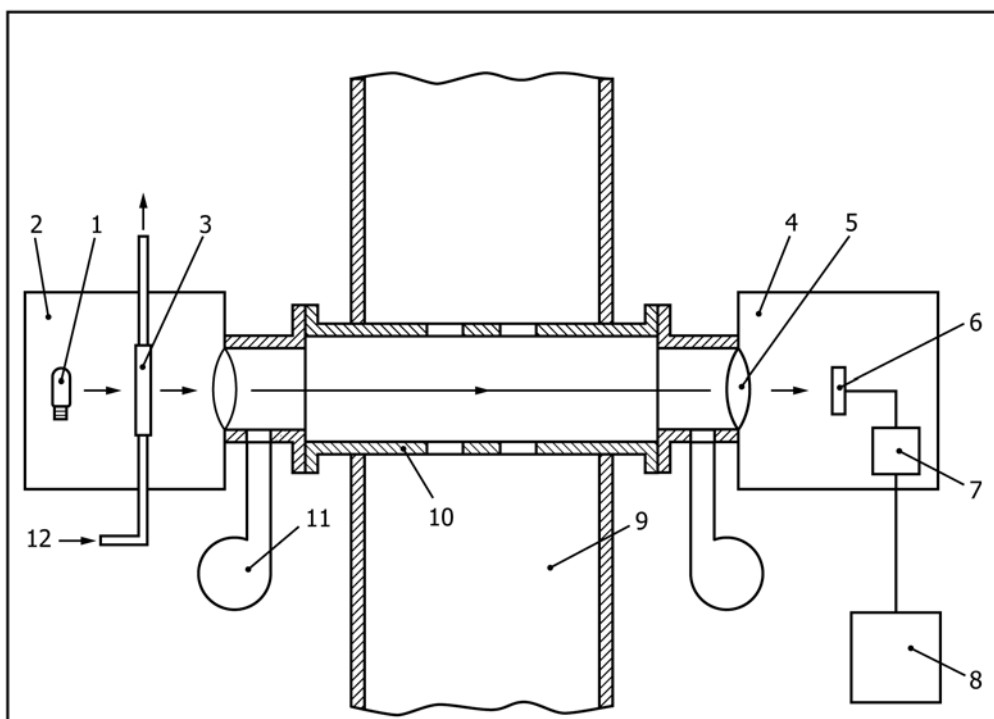
5.3 *Gas Concentration, Velocity, and Temperature Profile*—

Before sampling, determine if there are any spatial or temporal fluctuations in the gas concentrations by conducting a preliminary survey of the gas concentration, temperature, and velocity. Measure the concentration, temperature, and velocity at the sampling points several times to obtain their spatial and temporal profiles. Conduct this survey when the facility is operating under conditions that are representative of normal operation and determine whether the sampling position is suitable and whether the conditions in the duct are acceptable for ensuring representative sampling (see 5.1.2).

5.3.1 The following test methods may be used to determine gas concentration, temperature, and velocity:

- 5.3.1.1 O_2 —Test Method D3154, EPA Test Methods 3 and 3a,
- 5.3.1.2 CO_2 —Test Method D3154, EPA Test Methods 3 and 3a,
- 5.3.1.3 CO —EPA Test Method 10,
- 5.3.1.4 SO_2 —EPA Test Methods 6 and 6c,
- 5.3.1.5 NO_x —Test Method D1608, EPA Test Methods 7 and 7e,
- 5.3.1.6 *Gas Temperature*—Test Method D3154, EPA Test Method 2, and
- 5.3.1.7 *Gas Velocity*—Test Method D3154, EPA Test Method 2.

5.4 *Other Factors*—The operational principle and the components of instrumental systems can significantly affect the degree to which a collected sample is representative of the measured gas in the source. For example, a point sampling extractive system requires more attention to the sampling site location than an across-the-stack in-situ sampling system. Furthermore, sampling lines should not be composed of materials that have gas adsorbing properties (see Table A1.1).



NOTE—Key:

1	Lamp	7	Electronic Module
2	Transmitter Assembly	8	Data Recorder
3	Internal Gas Calibration Cell	9	Stack or Duct
4	Receiver Assembly	10	Alignment/Calibration Pipe
5	Protective Windows	11	Purge Air Blower
6	Detector	12	Gas Calibration Line

FIG. 3 Non-extractive Path Monitor

5.4.1 Exercise care to preserve the integrity of the sample taken, by selection of suitable equipment and appropriate heating, drying, and leak testing, etc. In addition, other factors such as corrosion, synergies, reaction with components, decomposition, and adsorption that might affect the integrity of a sample should be considered.

6. Equipment

6.1 Recommended construction materials are described in Annex A1.

6.2 Components of Extractive Sampling Equipment:

6.2.1 *Primary Filter*—The filter medium shall be constructed of an appropriate alloy such as stainless steel cast alloy, quartz borosilicate, ceramics, or another suitable material. A filter that traps particles greater than 10 µm in size is recommended. A secondary filter might be required as well (see 6.2.4). The filter may be placed outside the duct or at the tip of the sample probe (6.2.2). If placed at the tip of the probe, a deflector plate may be added to prevent particle build-up on the leading edge of the filter. This will prevent blockage of the filter. Avoid contamination of the filter with particulate matter where condensate may react with gases, resulting in compromised results.

6.2.2 Probe:

6.2.2.1 *Metal Probes*—The choice of probe metal depends on the physical and chemical properties of the sample and on the nature of the gas to be determined. Mild steel is subject to corrosion by oxidizing gases and may be porous to hydrogen. Thus, it is preferable to have stainless steel or chromium steels that can be used up to 900°C. Other specialized steels or alloys can be used above this temperature. Heat the probe if condensation occurs in its interior and cool it with an air or water jacket when sampling very hot gases. Electrically ground metal probes since high voltages are easily generated in dry gas streams, causing particulate matter to be collected on the probe surface. Grounding is particularly important when sampling in an explosive atmosphere.

6.2.2.2 *Refractory Probes* (see Annex A1), generally made of vitreous silica, porcelain, mullite or recrystallized alumina. They are fragile and may warp at high temperatures; except for silica, they may also crack from thermal shock. Borosilicate glass probes can withstand temperatures up to 500°C and vitreous silica probes up to 1000°C. Some refractors of advanced ceramic materials can withstand temperatures higher than 1000°C.

6.2.3 Heated Sampling Line Connected to Moisture Removal Assembly:

6.2.3.1 The sampling line shall be made of stainless steel, or Polytetrafluoroethylene (PTFE).

6.2.3.2 The tube diameter shall be adequate to provide a flow rate that is sufficient to feed the monitors, bearing in mind the sampling line length and the pressure characteristics of the sampling pump (6.2.5) used.

6.2.3.3 Maintain the sampling line at a temperature of at least 15°C above the water and acid dew-point temperature of the sampled gas. Monitor the temperature.

6.2.3.4 In order to reduce the residence time in the sampling line and the risk of physico-chemical transformation of the sample, the gas flow can be greater than that required for the analytical instruments; only part of the sample is then analyzed and the excess flow discarded through a bypass valve (see Fig. 1). It may be necessary to heat the transport line to avoid condensation.

6.2.4 Secondary Filter:

6.2.4.1 A secondary filter may be needed to remove remaining particulate material and protect both the sampling pump (6.2.5) and analyzer. It shall be placed in the sampling line (6.2.3) immediately downstream of the probe. A filter that retains particles greater than 1 µm is recommended. Acceptable materials are PTFE or quartz borosilicate. The size of the filter shall be determined from the required sample flow and the manufacturer's data on the flow rate per unit area.

6.2.4.2 Maintain the filter temperature not less than 15°C above the water and acid dew-point of the sampled gas. The secondary filter may be an unheated filter. In this case, it shall be placed immediately after the water vapor removal (cooler) device.

6.2.5 Sampling Pump:

6.2.5.1 Use a gas-tight pump to withdraw a continuous sample from the duct or stack through the sampling system. This may be a diaphragm pump, a metal bellows pump, or another suitable pump that is constructed of corrosion-resistant material.

6.2.5.2 The capacity of the pump shall be such that it can supply all the analyzers with their required flows, with a 10 % excess flow margin. Place a bypass valve across the pump to control the flow rate. This valve will lengthen the life of the pump if it is frequently used at lower flow rates. Note that some commercially available conditioning modules may be supplied with the pump upstream of the refrigeration permeation drier. In such cases, when high acidity and moisture are present in the gas stream, the pump should be operated at a temperature of at least 15°C above the acid dewpoint. In addition, increased pump maintenance may be necessary under such conditions.

6.2.6 Removal of Water Vapor—If a water removal procedure is employed, it shall be either a condensation/refrigeration or permeation drying method, or a combination of both. Use of a desiccant is permissible if it does not change the concentration of gases such as CO. Each method has its own merits subject to the following considerations:

6.2.6.1 When the condensation refrigeration method is employed, the removal shall take place outside the heated box.

6.2.6.2 Where permeation drying is employed, half of the dryer tube (wet end) shall be heated to a temperature of at least 15°C above the gas dewpoint. When acid is present in the sample, it may be necessary to consider the acid dewpoint. The manufacturer's recommendations on the quantity of purge air shall be followed.

6.2.6.3 Dilution may be used to reduce water content to a level where water removal may be unnecessary.

6.2.7 Analyzer Sampling Line:

6.2.7.1 The part of the sampling line associated with the analyzer shall be made of an inert material and of sufficient size to accommodate the requirements of the instrumentation.

6.2.7.2 Depending on whether a drying technique or dilution is used, heat tracing is required where the monitor is supplied with wet gases; in other cases, it may be necessary to eliminate condensation upstream of the condenser, where the system extracts hot gases. If back flushing is used to clean the in-stack filter, a pressure-regulated valve shall be installed upstream of the conditioner to protect the equipment from high pressure air damage.

6.2.8 Gas Manifold, constructed of an inert material with separate ports for each analyzer. It shall be sized to accommodate the gas flow requirements of all instruments, but small enough to minimize gas residence time. The exhaust gas must be safely vented.

6.2.9 Vacuum Gauge—A vacuum gauge, 0 to 100 kPa, may be installed on the negative pressure side of the sampling pump (6.2.5) to provide an indication of satisfactory pump operation and to indicate the need to change or clean a filter due to clogging or leakage. Instead of a vacuum gauge, a flow meter, with alarm set-point monitoring mounted in the measuring gas line upstream of the analyzer, can be used.

NOTE 1—It is necessary to ensure that an adequate calibration gas pressure is available so that a sufficient flow is provided to all instruments to ensure valid calibrations. The calibration gas flow shall be similar to that used for continuous sample analysis. Avoid excessive pressurization of the analyzers. Vent the excess gaseous discharges from the manifold and instruments away from the working area.

6.2.10 Dilution:

6.2.10.1 The dilution technique is an alternative to hot gas monitoring or to sample gas drying. Sample dilution is performed for (see Fig. 4):

(1) Reducing the concentration of the constituent of the gas to be measured to a level compatible with the range of the analytical unit,

(2) Reducing the water dew point, by diluting the sample with a dry carrier gas to reduce the risk of condensation in the gas sampling lines and associated filters,

(3) Minimizing the interference of certain components present in the sample, the elimination of which may be particularly difficult, by reducing their relative variations in concentration (for example, dilution with dry air when variation in O₂ content of the sample interferes with the measurement of another constituent), and

(4) Retarding the physico-chemical transformation of the sample because of the reduced reaction rates at low concentrations and low temperatures.

6.2.10.2 Choose the dilution ratio according to the objectives of the measurement. It should remain constant because