



# Standard Practice for Sampling Stationary Source Emissions for the Automated Determination of Gas Concentrations<sup>1</sup>

This standard is issued under the fixed designation D 5835; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice<sup>2</sup> covers procedures and equipment that will permit, within certain limits, representative sampling for the automated determination of gas concentrations of effluent gas streams. The application is limited to the determination of oxygen (O<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>) and total oxides of nitrogen (NO<sub>x</sub>).

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 situations 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 *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.* For more specific safety precautions, refer to 6.2.2.1, Notes 1 and 2.

## 2. Referenced Documents

2.1 *ASTM Standards:*

<sup>1</sup> This practice 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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<sup>2</sup> 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.

D 1356 Terminology Relating to Sampling and Analysis of Atmospheres<sup>3</sup>

D 1608 Test Method for Oxides of Nitrogen in Gaseous Combustion Products (Phenol-Disulfonic Acid Procedure)<sup>3</sup>

D 3154 Test Method for Average Velocity in a Duct (Pitot Tube Method)<sup>3</sup>

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 10<sup>4</sup>

## 3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology D 1356.

## 4. Summary of Practice

4.1 This practice describes representative sampling of gases in a duct, including both extractive and non-extractive sampling. In extractive sampling, these gases are conditioned to remove aerosols, particulate matter, and other interfering substances before being conveyed to the instruments. In non-extractive sampling, the measurements are made in-situ; therefore, no sample conditioning except filtering is required.

4.1.1 *Extractive Sampling*—Extractive sampling includes extraction of the sample, removal of interfering materials, and maintenance of the gas concentration throughout the sampling system for subsequent analysis by appropriate instrumentation (see Fig. 1).

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

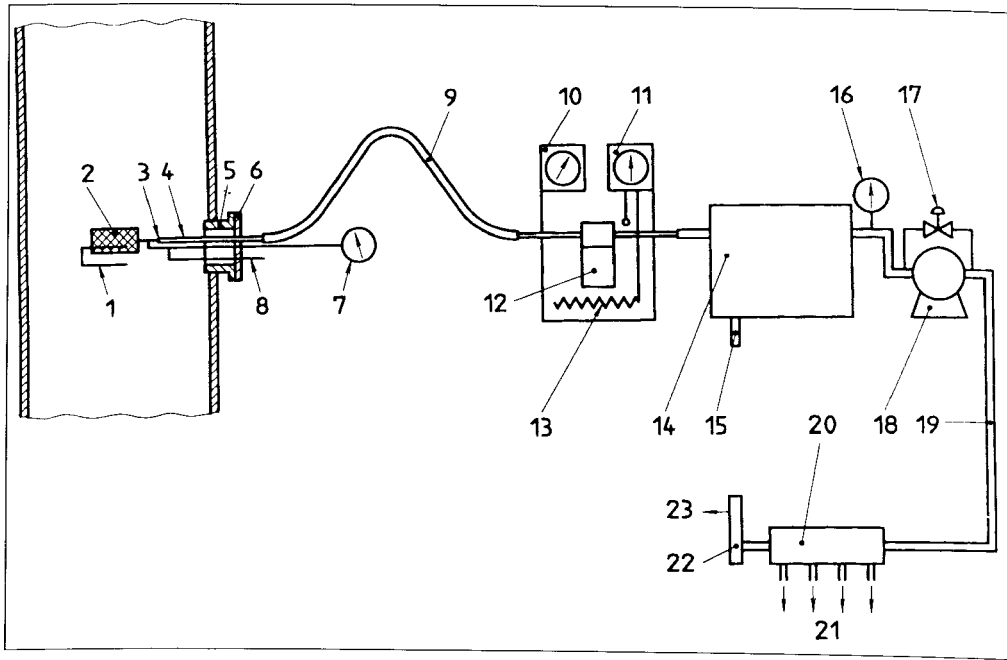
## 5. Representative Factors

5.1 *Nature of the Source:*

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

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 11.03.

<sup>4</sup> Available from Supt. of Documents, U.S. Government Printing Office, Washington, DC 20402.



NOTE—Key:

1	Baffle	13	Heater
2	In-stack Filter	14	Refrigeration Unit
3	Tee	15	Water Discharge
4	Probe	16	Vacuum Gage
5	Sampling Port	17	Bypass Valve
6	Cap	18	Pump
7	Pressure Gage	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

5.1.1.1 The heterogeneity of the process stream, such as variations in concentration, temperature, or velocity across the duct 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 gas,

5.1.2.3 Size of the source, and

5.1.2.4 Configuration of the duct network where samples are extracted.

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

5.1.3.1 Some sources may have more variability in process (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 pertinent operating characteristics of the process from which emissions are to be sampled and determined. These operating characteristics include, but are not necessarily 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,

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

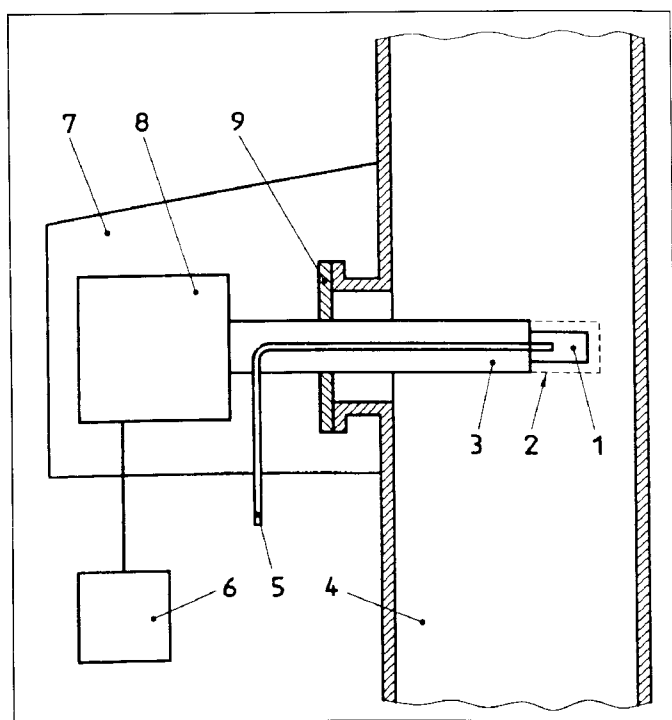
5.1.4.8 Expected gas composition and likely interfering substances.

NOTE 1—**Precaution:** Exercise caution if the duct to be sampled is under pressure or vacuum, or at a 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,



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

- 5.2.1.2 Location of the 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.

NOTE 2—**Precaution:** 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 the extractive sampling of gas may be not as stringent as those for particulate material. It is important that the sampling location be removed from any obstructions that will seriously disturb the gas flow in the duct or stack. 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-section at measurements taken indicates more than  $\pm 15\%$  variation in concentrations, and if an alternative acceptable location is not available, 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. If so, 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, but ensure that the instrument location is representative.

5.3 *Gas Concentration, Velocity, and Temperature Profile*— Before commencing 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 plant is operating under conditions that will be representative of normal operation and determine whether the sampling position is suitable and whether the conditions in the duct are satisfactory (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 D 3154, EPA Test Methods 3 and 3a,

5.3.1.2  $CO_2$ —Test Method D 3154, 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 D 1608, EPA Test Methods 7 and 7e,

5.3.1.6 *Gas Temperature*—Test Method D 3154, EPA Test Method 2, and

5.3.1.7 *Gas Velocity*—Test Method D 3154, EPA Test Method 2.

5.4 *Other Factors*—The principle of operation and the components of the instrument 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 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 that can affect the response time of the measurement section (see Table A1.1).

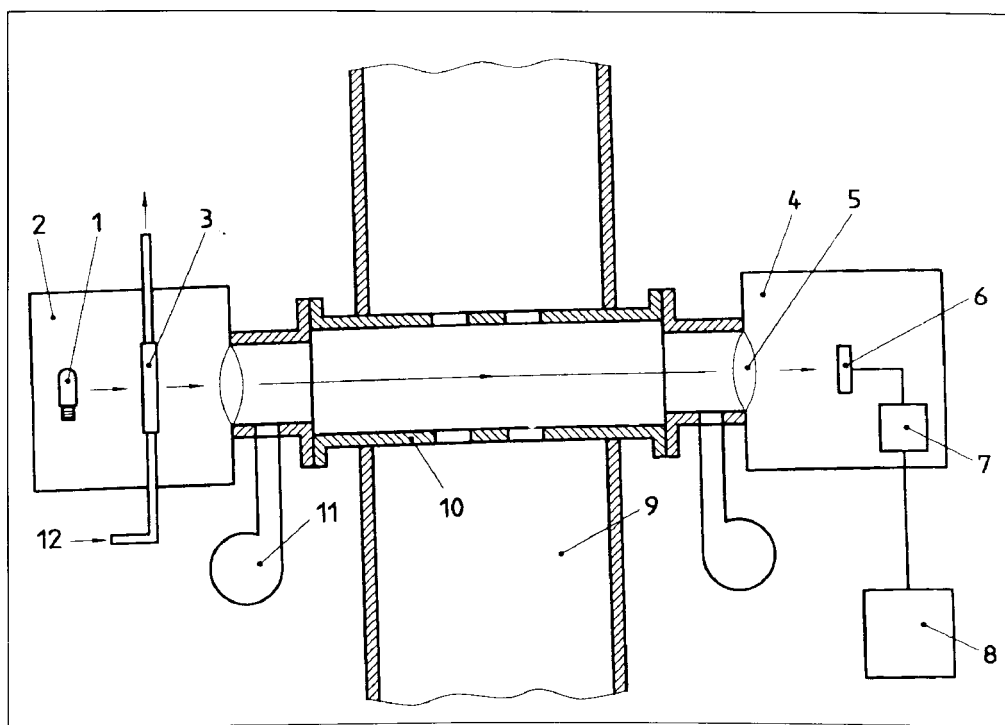
5.4.1 Exercise care to preserve the integrity of the sample taken, by a good selection of equipment, and appropriate heating, drying, and leak testing, etc. In addition, other factors such as corrosion, synergies, reaction with components, decomposition, and adsorption might affect the integrity of a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

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 a specific stainless steel cast alloy), quartz borosilicate, ceramics, or another suitable material. A filter that retains particles greater than 10  $\mu m$  is recommended. A secondary filter might be required as well (see 6.2.4). The filter medium may be located outside the



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

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 erroneous result.

#### 6.2.2 Probe:

6.2.2.1 *Metal Probes*—The choice of the metal depends basically 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 special 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 in 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 employed 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; with the exception of 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 units; 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 the remaining particulate material, in order to protect the pump (6.2.5) and analyzer. It shall follow 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 also be an unheated filter. In this case, it shall immediately follow 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 through the system. This may be a diaphragm pump, a metal bellows pump, or another type of acceptable 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, plus 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 used frequently 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 dew-point. In addition, increased pump maintenance may be anticipated in 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 will be permissible if it does not affect the actual 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 dew-point. When acid is present in the sample, it may be necessary to consider an acid dew-point. The manufacturer's recommendations on the quantity of purge air shall be followed.

6.2.6.3 Dilution may be used to reduce the water concentration to a level where water removal may not be necessary.

#### 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 fed with wet gases; in other cases, it may also be required to avoid 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 damage by high pressure air.

6.2.8 *Gas Manifold*, constructed of an inert material with a separate take-off for each analyzer. It shall be of sufficient size to accommodate the gas flow requirements of all the instruments, yet small enough to keep the gas residence time to a minimum. The exhaust gas must be safely vented.

6.2.9 *Vacuum Gage*—A vacuum gage, 0 to 100 kPa, may be installed on the suction of the sampling pump (6.2.5) to provide an indication of proper operation of the pump and to indicate clogging or leakage when a filter change or cleaning is required. Instead of a vacuum gage, a flow meter, with alarm-point monitoring mounted in the measuring gas line upstream of the analyzer, can be used.

NOTE 3—It is necessary to ensure that an adequate calibration gas pressure be used to provide a sufficient flow rate for all the instruments. The calibration gas flow shall be similar to that used during the 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 a technique for the following (see Fig. 4):

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

(b) reducing the water dew point, by diluting the sample with a dry carrier gas so as to reduce the risk of condensation in the gas circuits,

(c) minimizing the interference of certain components present in the sample, the elimination of which would be particularly difficult, by reducing their relative variations in concentration (for example, dilution with dry air when the variations in O<sub>2</sub> content of the sample falsify the measurement of another constituent), and

(d) 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 the calibration frequency of the measurement unit depends, among other things, on the stability of the dilution ratio.

NOTE 4—In the case of extractive sampling where water is removed, the measured concentrations are based on dry gas.

6.2.10.3 Many types of flow control devices are suitable for use, such as:

(a) Calibrated apertures (capillaries, sonic nozzles, needle valves, etc.),

(b) Flow meters by volume or mass, and

(c) Pressure or flow regulators, or both.

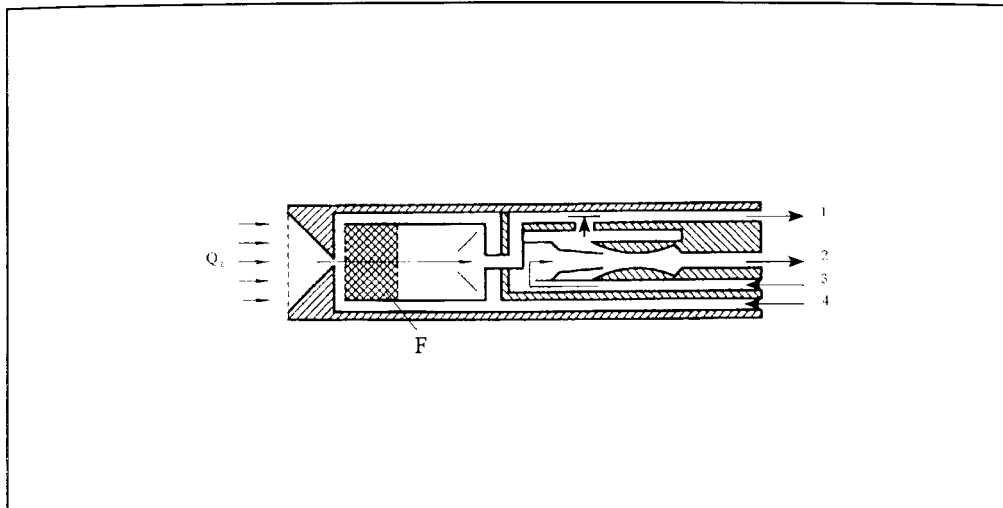
6.2.10.4 The nature and purity of the dilution gas shall be chosen as a function of each application. It is important that the gas being determined is not present in the dilution gas and that the dilution gas does not react with the constituent being analyzed.

6.2.10.5 In addition, large dilution ratios may lead to very low concentrations of the constituent to be determined as a consequence of which adsorption phenomena leading to significant errors in measurement may occur. In this case, choose inert materials to eliminate these phenomena.

#### 6.3 *Components of Non-Extractive Equipment:*

6.3.1 *Point Monitors*, non-extractive point monitors sample the gas stream in the duct at the tip of the probe (6.3.1.2). Gas is monitored at one point or over a short path (less than 100





NOTE 1—Key:

- |       |  |
|-------|--|
| 1     | Probe Vacuum                           |
| 2     | Diluted Sample ( $Q_1 + Q_2$ ), mL/min |
| 3     | Dilution Gas ( $Q_1$ ), mL/min         |
| 4     | Calibration Gas/Air Purge              |
| F     | Removable Glass or Quartz Wool Filter  |
| $Q_2$ | Gas being sampled, mL/min              |

NOTE 2—Dilution Ratio =  $Q_2/(Q_1 + Q_2)$ .

NOTE 3—Source Concentration =  $(Q_1 + Q_2)/Q_2 \times$  measured concentration.

FIG. 4 Dilution Probe

mm), depending upon the principle of measurement (see Fig. 2). Point monitors shall incorporate the components described in 6.3.1.1-6.3.1.7.

6.3.1.1 *Instrument Transceiver*, the component of the instrument that senses the response of the measurement cell (6.3.1.3) and generates an electrical signal that corresponds to the concentration of the gas being measured.

6.3.1.2 *Probe*, a support for the measurement cell, extending from the instrument transceiver (6.3.1.1). Non-extractive point monitor probes shall meet the specifications of 6.3.2.1.

6.3.1.3 *Measurement Cell*, a cell or cavity exposed to the gas stream, for the purpose of producing an electro-optical or chemical response to the gas concentration at the tip of the probe (6.3.1.2).

6.3.1.4 *Probe Filter*, a porous ceramic or sintered metal tube or screen that minimizes the interference of particulate matter with the gas measurement.

6.3.1.5 *Probe Mounting*, a flange installed at the sampling port, used to support the transceiver (6.3.1.1) and probe (6.3.1.2) assembly.

6.3.1.6 *Gas Calibration Line*, a tube used to inject calibration, reference, or zero gas into the measurement cell (6.3.1.3) for the purpose of calibrating the instrument.

6.3.1.7 *Protective Hood (optional)*, a shroud that protects the transceiver from the ambient environment.

6.3.2 *Path Monitors*, non-extractive path monitors sample the gas stream in the duct on a line crossing the main part of the duct diameter at the sampling location (see Fig. 3). Path monitors incorporate the components described in 6.3.2.1-6.3.2.7.

6.3.2.1 *Transmitter Assembly*, the component of the monitoring system that houses a light emission source and associ-

ated electro-optical components. The transmitter projects UV, visible or IR radiation through the flue gas to the receiver assembly (6.3.2.2) located on the opposite side of the duct.

6.3.2.2 *Receiver Assembly*, the component of the instrument system that houses a detector and an associated electro-optical component. The detector senses the radiation projected from the transmitter assembly (6.3.2.1) and generates a signal that corresponds to the concentration of the gaseous component monitored. In alternate designs, the receiver assembly is replaced by a retroreflector assembly. A retroreflector projects the light beam back to a transceiver, where a detector responds to the reflected light.

6.3.2.3 *Protective Windows*, windows or lenses at the interface between the flue gas and electro-optical assemblies, used to prevent flue gas from entering the assemblies.

6.3.2.4 *Purge Air Blower*, a device that blows clean air over the protective windows, to minimize particle deposition.

6.3.2.5 *Alignment Calibration Pipe (optional)*, a pipe assembly used for support and for calibration purposes. The monitor system is in a calibration mode when the pipe assembly is flushed with air and closed to prevent entrance of flue gas.

6.3.2.6 *Anti-Vibration System (optional, not shown in Fig. 3)*, a system that isolates the transmitter (6.3.2.1) and receiver (6.3.2.2) assemblies from duct vibrations.

6.3.2.7 *Internal Gas Calibration Cell (Adsorption)*, a cell designed to admit gases for the purpose of calibrating the instrument.

NOTE 5—Some systems may not sample the entire cross-section of the duct. Ensure representativeness, as for example with extractive sampling.

## 7. System Operation

7.1 *Checking for Leaks*—Conduct checks for leaks by disconnecting the sampling line at the probe exit, plugging the line, and adjusting the vacuum to 50 kPa using the bypass valve. If the pressure remains at  $\pm 0.375$  Pa for 15 min, the system may be considered leak free. When liquids or aerosols are present, perform routine checking using reference gases injected at the top of the sampling probe and the instrument inlet.

### 7.2 *Calibration, Function and Set-up:*

7.2.1 Extractive sampling calibration is necessary for both the instrumentation and sampling line. In this case, an appropriate calibration gas insertion port is required. It is often necessary to provide two gas injection points for calibration, one of which is as close as possible to the point at which the sample is taken, and the other at the entry to the instrumentation (see Fig. 1).

7.2.2 Non-extractive sampling systems shall also be calibrated using calibration gases. A calibration cell may be required for path monitors.

7.2.3 Although costly to operate, it is possible to calibrate both extractive and non-extractive systems versus extractive manual (wet chemical) standard methods at the discretion of the user.

7.2.4 The zero gas and the calibration gas are introduced as close as possible to the point at which the sample is taken without excessive pressure. Nitrogen may be used as zero gas.

7.2.5 In order to set the analyzer, zero gas and, subsequently, calibration gas (with a concentration of approximately 70 or 80 % of the full scale) are introduced. This operation is repeated once or twice if necessary.

7.2.6 In order to check the entire scale, for measuring equipment with a linear calibration function, four uniformly distributed calibration gas concentrations (approximately 20, 40, 60 and 80 % of the full scale) are used. The calibration gas used for setting purposes can be diluted gradually. In the case of a non-linear calibration function, at least 10 measuring points are required.

7.2.7 The calibration function of the analyzers can be checked by introducing calibration gases directly to the instruments. The setting of the analyzer shall be checked regularly, for example weekly (period of unattended operation). The calibration function has to be checked at longer intervals (for example yearly) or after repairs to the analyzer.

7.3 *Integrity*—Preserve the integrity of the sample by a good selection of equipment, and appropriate heating, drying, and testing, etc. In addition, other factors such as corrosion, synergies, reaction with components, decomposition, and absorption/adsorption might affect the integrity of a sample.

### 7.4 *Maintenance of Sampling Systems:*

7.4.1 The maintenance of the sampling system consists of performing the following operations:

7.4.1.1 Verify the compliance with the safety regulations,

7.4.1.2 Verify the operation of the safety devices,

7.4.1.3 Replace the consumed components of the treatment unit (filter, drier, etc.), and

7.4.1.4 Adjust the operating parameter.

7.4.2 Perform the sampling line maintenance frequently.

## 8. Keywords

8.1 automated stack sampling; dilution extraction; in-situ sampling; stack emissions; stack sampling

## ANNEX

### (Mandatory Information)

#### A1. CONSTRUCTION MATERIALS USED FOR EQUIPMENT

##### A1.1 Sample Components

A1.1.1 The choice of proper construction materials is a very important part of designing a sampling interface. Acceptable construction materials must meet three criteria:

A1.1.1.1 Materials must have sufficient chemical resistance to withstand the corrosive constituents of the sample.

A1.1.1.2 Materials must not exhibit excessive interaction (reaction, absorption, adsorption) with the sample gases.

A1.1.1.3 Materials used in or near the stack must be heat resistant.

A1.1.2 For a sampling system of minimum design, the above criteria must be examined in light of material costs, consistent with the quality of the information required.

##### A1.2 Chemical Resistance

A1.2.1 The corrosive constituents encountered in monitoring sources are nitrogen dioxide, sulfur dioxide, dilute nitric acid, dilute sulfurous acid, diluted or concentrated sulfuric acid

(wet sulfur trioxide (SO<sub>3</sub>) or acid mist). The chemical resistances of various materials to these constituents have been collected from a number (8 to 12) of sources and are summarized in Table A1.1. All the materials are evaluated at room temperature and may be considerably less resistant at higher temperatures.

A1.2.2 Of the metals, Carpenter 20 SS stainless steel is the most resistant, followed by 316 SS, 304 SS, and finally aluminum. Glass and PTFE are quite resistant to all components of the sample. Polyvinyl chloride (PVC) and vinyl are somewhat less resistant to all constituents except concentrated nitric acid which is not anticipated to be present in the sampling interface. PVC and vinyl are resistant to corrosiveness but may react with corrosive constituents. For measurements of nitrogen dioxide and sulfur dioxide at low concentrations in wet samples, PTFE and glass are recommended. Polyethylene and polypropylene have very nearly the same chemical resistance and are acceptable for use except where

**TABLE A1.1 Chemical Resistance of Various Materials**

NOTE 1—Key: S = Satisfactory; Q = Questionable; U = Unsatisfactory.

NOTE 2—Recommendation—If corrosivity plays a role, PTFE can be used for dry SO<sub>2</sub> and dry NO<sub>2</sub>.

Material	Dry SO <sub>2</sub>	Dry NO <sub>2</sub>	Diluted HNO <sub>3</sub>	Diluted H <sub>2</sub> SO <sub>3</sub>	Diluted H <sub>2</sub> SO <sub>4</sub>	Concentrated <sup>A</sup> HNO <sub>3</sub>	Concentrated H <sub>2</sub> SO <sub>4</sub>
Type 304 SS	S (some pitting observed)	S	S	Q	U	S	U
Type 316 SS	S	S	S (< 0.051) <sup>B</sup>	S	S or Q (< 0.508)	S (< 0.508)	U (> 1.27)
Carpenter 20 SS	S	S	S	S	S or Q	S	S
Aluminum	S	—	S (0.127 to 0.508)	S (0.127 to 0.508)	S (0.127 to 0.508)	Q (0.508 to 1.27)	U (> 1.27)
Glass	S	S	S (< 0.127)	—	S (< 0.127)	S (< 0.127)	S (< 0.127)
PTFE	S	S	S	S	S	S	S
PVC	S	S	S	S	Q	U	S or Q
Vinyl	S	S	S	S or Q	S	Q or U	S or Q
Polyethylene	S	S	S or Q	S	S	U	Q or U
Polypropylene	S	S	S	S	S	U	Q or U
Nylon	—	S	S	U	U	U	U
Viton	S to U	S	S	S	S	S to U	S to U

<sup>A</sup> High concentrations of HNO<sub>3</sub> are not anticipated in the sampling interface.

<sup>B</sup> Quantities in parentheses indicate corrosion rates, in millimetres per year.

concentrated nitric acid is encountered. Nylon is a material of apparent limited usefulness in sampling systems, while sources differ on the performance of Viton during resistance tests.

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