WEST VIRGINIA
SECRETARY OF STATE
KEN HECHLER
ADMINISTRATIVE LAW DIVISION
Form #1

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OFFICE OF WEST VIRGINIA
SECRETARY OF STATE

NOTICE OF PUBLIC HEARING ON A PROPOSED RULE

AGENCY: Division of Environmental Protection Office of Air Quality TITLE NUMBER: 45CSR2

RULE TYPE: Legislative ; CITE AUTHORITY WV Code §§22-5-1 et seq.

AMENDMENT TO AN EXISTING RULE: YES X NO ___

IF YES, SERIES NUMBER OF RULE BEING AMENDED: 45CSR2

TITLE OF RULE BEING AMENDED: "To Prevent and Control Particulate Air Pollution from Combustion of Fuel in Indirect Heat Exchangers"

IF NO, SERIES NUMBER OF NEW RULE BEING PROPOSED: ___

TITLE OF RULE BEING PROPOSED: ___

DATE OF PUBLIC HEARING: November 29, 1994 TIME: 9:00 a.m.

LOCATION OF PUBLIC HEARING:
Office of Air Quality
1558 Washington Street, East
Charleston, WV 25311

COMMENTS LIMITED TO: ORAL ___, WRITTEN ___, BOTH X

COMMENTS MAY ALSO BE MAILED TO THE FOLLOWING ADDRESS: Same as above.

The Department requests that persons wishing to make comments at the hearing make an effort to submit written comments in order to facilitate the review of these comments.

The issues to be heard shall be limited to the proposed rule.

ATTACH A **BRIEF** SUMMARY OF YOUR PROPOSAL

19.50

~~Roger Hall~~ Duoch

45CSR2

TO PREVENT AND CONTROL PARTICULATE AIR POLLUTION FROM COMBUSTION OF FUEL IN INDIRECT HEAT EXCHANGERS

STATEMENT OF CIRCUMSTANCES

The revisions proposed to 45CSR2 were initiated by a petition filed with the West Virginia Division of Environmental Protection on June 3, 1994 on behalf of the West Virginia Manufacturers Association and specific members of that organization. The revisions proposed to 45CSR2 were developed by the staff of the West Virginia Division of Environmental Protection's Office of Air Quality as compromise provisions for public hearing or otherwise incidentally made to reflect enacted changes to the West Virginia Code. The proposed rule consolidates previous rule 45CSR2 and a separate rule, 45CSR2A - "Compliance Test Procdures for Regulation 2 - 'To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers'". Upon authorization of this proposed rule, 45CSR2A will be repealed with the substance of 45CSR2A becoming an appendix of 45CSR2.

APPENDIX B

FISCAL NOTE FOR PROPOSED RULES

Rule Title: 45CSR2 - To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers

Type of Rule: X Legislative ____ Interpretive ____ Procedural

Agency: Office of Air Quality

Address: 1558 Washington Street, East
Charleston, WV 25311-2599

1. Effect of Proposed Rule	Annual		Fiscal Year		
	Increase	Decrease	Current	Next	There-after
Estimated Total Cost	$ -0-	$ -0-	$ -0-	$ -0-	$ -0-
Personal Services	-0-	-0-	-0-	-0-	-0-
Current Expense	-0-	-0-	-0-	-0-	-0-
Repairs and Alterations	-0-	-0-	-0-	-0-	-0-
Equipment	-0-	-0-	-0-	-0-	-0-
Other	-0-	-0-	-0-	-0-	-0-

2. Explanation of above estimates: The proposed revisions to 45CSR2 will have minimal effect upon the costs to the Office of Air Quality of the Division of Environmental Protection implementing this rule.

3. Objectives of these rules: The objective of 45CSR2 is to establish particulate matter emission limitations and enforcement provisions for fuel burning units as a major component of West Virginia's Implementation Plan for attainment and maintenance of the National Ambient Air Quality Standards for particulate matter.

4. Explanation of overall economic impact of proposed rule.

   A. Economic impact on state government.

   There should be minimal impact upon implementation costs to the Division of Environmental Protection associated with the proposed rule amendments.

B. Economic impact on political subdivisions; specific industries; specific groups of citizens.

Industrial facilities, particularly electric utilities in West Virginia allege that compliance with the existing visible emission standards of 45CSR2 has substantial economic impacts resulting from derating or curtailment of power boiler operating rates and retrofit of additional particulate control equipment. The proposed rule changes could reduce these economic impacts.

C. Economic impact on citizens/public at large.

Minimal impacts from rule changes are anticipated.

Date: October 21, 1994

Signature of agency head or authorized representative:

G. Dale Farley
Chief, Office of Air Quality

45CSR2

TO PREVENT AND CONTROL PARTICULATE AIR POLLUTION FROM COMBUSTION OF FUEL IN INDIRECT HEAT EXCHANGERS

SUMMARY

The purpose of 45CSR2, which became effective on September 1, 1994, is to establish particulate matter weight emission standards and visible emission standards for fuel burning units operated in West Virginia.

45CSR2 is a part of the West Virginia State Implementation Plan (SIP) approved by the USEPA to assure attainment and maintenance of attainment with the National Ambient Air Quality Standards for particulate matter. The proposed revisions to 45CSR2 are for the following purposes:

1. To relax the visible emission standards applicable to fuel burning units (including steam generating units and other indirect heat exchangers) to a level essentially the same as those established nationally by USEPA for new or modified fuel burning units;

2. To modify the authority, terminology, and West Virginia Code citations in the rule to conform to revisions enacted by the Legislature in 1994;

3. To update or modernize certain definitions and delete rule provisions no longer applicable;

4. To combine 45CSR2 with the separate rule 45CSR2A which establishes test procedures which must be employed to determine compliance with the weight emission limitations of 45CSR2 and to incorporate by reference USEPA's test method for determining visible emissions from a fuel burning unit; and

5. To replace the variance provisions of the rule with criteria for reporting, establishing, and remediating equipment malfunctions.

45CSR2

TO PREVENT AND CONTROL PARTICULATE AIR POLLUTION FROM COMBUSTION OF FUEL IN INDIRECT HEAT EXCHANGERS

Consultation with the EPAC

This rule was filed prior to the appointment of the Environmental Protection Advisory Council (EPAC). Therefore, no consultation with the EPAC has been possible.

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OFFICE OF WEST VIRGINIA SECRETARY OF STATE

TITLE 45
LEGISLATIVE RULE
~~AIR POLLUTION CONTROL COMMISSION~~
BUREAU OF ENVIRONMENT
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY

SERIES 2
TO PREVENT AND CONTROL PARTICULATE AIR POLLUTION FROM COMBUSTION OF FUEL IN INDIRECT HEAT EXCHANGERS

§45-2-1. General.

1.1. Scope. -- Series 2 establishes emission limitations for smoke and particulate matter which are discharged from fuel burning units. The Appendix to this rule incorporates the compliance determination methods and procedures previously contained in 45CSR2A "Compliance Test Procedures for Rule 2 - 'To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers'".

1.2. Authority. -- W.Va. Code ~~§16-20-5~~§§22-5-1 et seq.

1.3. Filing Date. -- ~~July 31, 1974~~

1.4. Effective Date. -- ~~September 1, 1974~~

1.5. Repeal of Former Rule. -- This legislative rule repeals and replaces 45CSR2A - "Compliance Test Procedures for Rule 2 - 'To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers'" which was filed on September 16, 1988 and became effective on July 14, 1989.

1.6. Incorporation by Reference and Determination of Stringency. -- Compliance test procedures established by USEPA are incorporated by reference in this rule. Since the particulate matter emissions standards and other implementing provisions of this rule were established as major elements of the State Implementation Plan (SIP) to assure attainment with the National Ambient Air Quality Standards for particulate matter there is no counterpart federal rule.

1.7. Constitutional Takings Determination - The Director has determined that this rule will not result in the constitutional taking of real property.

§45-2-2. Definitions.

~~2.1. "Air Pollution", 'statutory air pollution' shall have the meaning ascribed to it in section two, article twenty, chapter sixteen of the Code of West Virginia, as amended.~~

~~2.2. "Air Pollutants" shall mean solids, liquids, or gases which, if discharged into the air, may result in a statutory air pollution.~~

~~2.3. "Commission" shall mean the West Virginia Air Pollution Control Commission.~~

~~2.4. "Director" shall mean the Director of the West Virginia Air Pollution Control Commission.~~

~~2.5. "Person" shall mean any and all persons, natural or artificial, including any municipal, public or private corporation organized or existing under the laws of this or any other state or country, and any firm, partnership, or association of whatever nature.~~

~~2.6. "Fuel Burning Unit" shall mean and include any furnace, boiler apparatus, device, mechanism, stack, or structure used in the process of burning fuel or other combustible material for the primary purpose of producing heat or power by indirect heat transfer. For the purposes of this regulation, all fuel burning units are classified in the following categories:~~

~~(a) Type 'a' shall mean any fuel burning unit which has as its primary purpose the generation of steam or other vapor to produce electric power for sale.~~

~~(b) Type 'b' shall mean any fuel burning unit not classified as a Type 'a' or Type 'c' unit such as industrial pulverized fuel fired furnaces, cyclone furnaces, gas fired and liquid fuel fired units.~~

~~(c) Type 'c' shall mean any hand fired or stoker fired fuel burning unit not classified as a Type 'a' unit.~~

~~2.7. "Similar Unit(s)" shall mean all Type 'a', or all Type 'b', or all Type 'c' fuel burning units located at one plant.~~

~~2.8. "Fuel" shall mean any form of combustible matter (solid, liquid, vapor, or gas) that is used as a source of heat.~~

~~2.9. "Particulate Matter" shall mean any material except uncombined water that exists in a finely divided form as a liquid or solid.~~

~~2.10. "Smoke" shall mean small gasborne and airborne particulate matter arising from a process of combustion in sufficient number to be visible.~~

~~2.11. "Ringelmann Smoke Chart" shall be the Ringelmann's Scale for Grading the Density of Smoke published by the United States Bureau of Mines, or any chart, recorder, indicator, or device which is a standardized method for the measurement of smoke density which is approved by the Commission as the equivalent of said Ringelmann's Scale.~~

~~2.12. "Plant" shall mean and include all fuel burning units, source operations, equipment, and grounds utilized in an integral complex.~~

~~2.13. "Fugitive Particulate Matter" shall mean any and all particulate matter generated by any operation involving or associated with the combustion of fuel in fuel burning units which, if not confined, would be emitted directly into the open air from points other than a stack outlet.~~

~~2.14. "Fugitive Particulate Matter Control System" shall mean any equipment or method used to confine, collect, or dispose of fugitive particulate matter, including, but not limited to, hoods, bins, duct work, fans, and air pollution control equipment.~~

~~2.15. "Air Pollution Control Equipment" shall mean any equipment used for collecting or confining particulate matter for the purpose of preventing or reducing the emission of this air pollutant into the open air.~~

~~2.16. "Stack", for the purposes of this regulation, shall mean, but not be limited to, any duct, control equipment exhaust, or similar apparatus, which vents gases and/or particulate matter into the open air.~~

~~2.17. "Kanawha Valley Air Basin" shall mean that area starting at the junction of the Gauley and New Rivers and terminating at the center of the Winfield Locks and extending a distance of three (3) statute miles, measured horizontally, with no reference to terrain, on each side of the center line of the Kanawha River.~~

2.1. "Air Pollutants" means solids, liquids, or gases which, if discharged into the air, may result in a statutory air pollution.

2.2. "Air Pollution", 'statutory air pollution' shall have the meaning ascribed to it in WV Code §22-5-2.

2.3. "Air Pollution Control Equipment" means any equipment used for collecting or confining particulate matter for the purpose of preventing or reducing the emission of this air pollutant into the open air.

2.4. "ASTM" means American Society for Testing and Material, 1916 Race Street, Philadelphia, Pennsylvania 19103.

2.5. "Control Equipment" means any equipment used for collecting or confining particulate matter for the purpose of preventing or reducing the emission of this air pollutant into the open air.

2.6. "Director" means the Director of the West Virginia Division of Environmental Protection.

2.7. "Discharge Point" means the point at which particulate matter is released from a stack into open air.

2.8. "Fuel" means any form of combustible matter (solid, liquid, vapor, or gas) that is used as a source of heat.

2.9. "Fuel Burning Unit" means and includes any furnace, boiler apparatus, device, mechanism, stack, or structure used in the process of burning fuel or other combustible material for the primary purpose of producing heat or power by indirect heat transfer. For the purposes of this rule, all fuel burning units are classified in the following categories:

(a) Type 'a' means any fuel burning unit which has as its primary purpose the generation of steam or other vapor to produce electric power for sale.

(b) Type 'b' means any fuel burning unit not classified as a Type 'a' or Type 'c' unit such as industrial pulverized-fuel-fired furnaces, cyclone furnaces, gas-fired and liquid-fuel-fired units.

(c) Type 'c' means any hand-fired or stoker-fired fuel burning unit not classified as a Type 'a' unit.

2.10. "Fugitive Particulate Matter" means any and all particulate matter generated by any operation involving or associated with the combustion of fuel in fuel burning units which, if not confined, would be emitted directly into the open air from points other than a stack outlet.

2.11. "Fugitive Particulate Matter Control System" means any equipment or method used to confine, collect, or dispose of fugitive particulate matter, including, but not limited to, hoods, bins, duct work, fans, and air pollution control equipment.

2.12. "Heat Input" means the rate of heat release from all fuels fired in all similar units vented by the test stack during the test run period.

a. 'Design Heat Input (DHI)' means the heat input level (in MM Btu/hr) for which an individual fuel burning unit has been designed to be operated during continuous operation.

b. 'Total Design Heat Input (TDHI)' means the sum of the design heat inputs for all similar units located at one point.

c. 'Normal Maximum Operating Load (NMOL)' means the sum of the Design Heat Input levels (in MM Btu/hr) of the similar unit(s) vented by the test stack, unless the owner/operator has elected to operate one or more of the similar units vented by the test stack at or below a specified percentage of its Design Heat Input level as part of a compliance program, permit, or consent order officially accepted by the Director. In such event, the NMOL is the sum of the Design Heat Input levels or fractions thereof as appropriate (i.e., $\text{NMOL} = 0.75\ \text{DHI}_1 + \text{DHI}_2$).

2.13. "Laboratory Official" means the person, qualified by experience or education, who is charged with overseeing or conducting the laboratory analysis of the collected samples. This person is responsible for ensuring the accuracy and validity of the laboratory results.

2.14. "Malfunction" means any sudden an unavoidable failure of air pollution control equipment or process equipment or of a process to operate in a normal or usual manner. Failures that are caused entirely or in part by poor maintenance, careless operation, or any other preventable upset condition or preventable equipment breakdown shall not be considered malfunctions.

2.15."Normal Operation" when used in the context of fuel quality and combinations fired, means the type, quality, and combination of fuel(s) fired which is representative of the fuel or fuel combination fired, in the unit(s) tested, over a reasonable period prior to the test, and the fuel or fuel combination which might reasonably be expected to continue to be fired in this unit after the test. If the type of fuel, quality or combination used in the unit is variable, use the type, quality, and/or combination fired in day-to-day operation which can reasonably be expected to produce the greatest particulate matter loading to the control equipment (i.e., if coal is fired eight months out of the year and gas is fired four months out of the year, coal is to be burned during the test).

2.16."Owner/Operator" means the person responsible for the compliance of the fuel burning units subject to the provisions of the 45CSR2.

2.17."Particulate Matter" means any material except uncombined water that exists in a finely divided form as a liquid or solid.

2.18. "Person" means any and all persons, natural or artificial, including the State of West Virginia or any other State, the United States of America, any municipal, statutory, public or private corporation organized or existing under the laws of this or any other state or country, and any firm, partnership, or association of whatever nature.

2.19. "Plant" means and include all fuel burning units, source operations, equipment, and grounds utilized in an integral complex.

2.20. "Prefilter" means a filter used in the sampling train prior to the primary filter for the purpose of reducing the particulate matter build-up on the primary filter.

2.21. "Primary Filter" means the last filter used in the sampling train to separate the particulate matter sample from the sampled stack gas.

2.22."Probe" means the part of the pitobe assembly (nozzle, sample tube, pitot tube, filter holder(s), sensor(s)), which precedes the last filter in the sampling train and conveys the sample gas and particulate matter from the nozzle inlet to the last filter disc used for collecting stack particulate matter.

2.23. "Ringelmann Smoke Chart" shall be the Ringelmann's Scale for Grading the Density of Smoke published by the United States Bureau of Mines, or any chart, recorder, indicator, procedure or device which is a standardized method for the measurement of smoke density which is approved by the Director as the equivalent of said Ringelmann's Scale.

2.24. "Sampling Plane" means the imaginary plane located perpendicular to the gas flow in the duct or stack at the place selected for the extraction of the required samples.

2.25. "Shut-down" means the cessation of a facility subject to this rule for any purpose.

2.26. "Similar Unit(s)" means all Type 'a', or all Type 'b', or all Type 'c' fuel burning units located at one plant.

2.27. "Smoke" means small gasborne and airborne particulate matter arising from a process of combustion in sufficient number to be visible.

2.28. "Stack", for the purposes of this rule, means, but not be limited to, any duct, control equipment exhaust, or similar apparatus, which vents gases and/or particulate matter into the open air.

2.29. "Start-up" means the setting in operation of a facility subject to this rule for any purpose.

2.30. "Test Team Supervisor" means the person, qualified by experience or education, who is charged with supervising the stack test. This person is responsible for ensuring the validity and correctness of the submitted test results.

§45-2-3. Visible Emissions of Smoke And/Or Particulate Matter Prohibited And Standards of Measurement.

3.1. ~~Visible emission requirements for fuel burning units not meeting the requirements of section 4, Weight Emission Standards.~~---No person shall cause, suffer, allow, or permit emission of smoke into the open air from any fuel burning unit which is ~~in excess of the Ringelmann limitations specified in the following tables for the designated areas and time periods: (See Table 45-2A at the end of this regulation.)~~ darker in shade or appearance than No. 1 Ringelmann or twenty (20) percent opacity (6-minute average), except for one 6-minute period per hour of not more than twenty-seven (27) percent opacity.

~~3.2.---The provisions of subsection 3.1 of this section shall not apply to smoke emitted during the cleaning of a fire box or soot blowing the shade or appearance of which is less than the Ringelmann number specified in the following table, for a period or periods aggregating no more than eight (8) minutes per fuel burning unit in any eight (8) hour period:~~

~~Subsections~~	~~Ringelmann Number~~
~~3.1(a)~~	~~3~~
~~3.1(b) and (c)~~	~~2~~

~~3.3.---Visible emission requirements for fuel burning units that meet the requirements of section 4, Weight Emission Standards.~~

~~No person shall cause, suffer, allow, or permit emissions of smoke into the open air from any fuel burning unit which is darker in shade or appearance than 0.5 Ringelmann or ten (10) percent opacity.~~

~~3.4. The provisions of subsection 3.3 shall not apply to smoke emitted during the cleaning of a fire box or soot blowing the shade or appearance of which is less than No. 1 Ringelmann or twenty (20) percent opacity for a period or periods aggregating no more than eight (8) minutes per fuel burning unit for any eight (8) hour period.~~

~~3.5. Realizing that with present technology the provisions of this section may, in some cases, be too restrictive to be applied to the building of a new fire in a fuel burning unit, the Commission may, upon specific application by the owner and/or operator of a fuel burning unit(s), grant exemptions to these provisions. However, in no case shall these exemptions exceed the limitations set forth in the following table. (See Table 45-2B at the end of this regulation.)~~

~~If such an exemption to the provisions of this section is desired, an application in writing shall be made to the Director. From time to time the Commission shall review such exemptions to determine if they are still warranted. If the Commission revises or terminates an exemption the owner and/or operator of the affected fuel burning unit(s) shall be notified by certified mail. Such revisions or terminations shall not become effective for at least ninety (90) days after the receipt of notification by the owner and/or operator.~~

3.2. Compliance with the visible emission requirements of subsection 3.1 of this section shall be determined in accordance with 40 CFR Part 60, Appendix A, Method 9 or by using measurements from continuous opacity monitoring systems approved by the Director.

3.3. If the owner or operator of a fuel burning unit can demonstrate to the satisfaction of the Director that compliance with subsection 3.1 cannot practically be achieved with respect to soot blowing operations, the Director may formally approve specific visible emission standards applicable to the fuel burning unit for soot blowing periods; provided that the exception period shall not exceed eight (8) minutes per eight hour period with visible emissions limited to forty percent (40%) opacity.

§45-2-4. Weight Emission Standards.

4.1. (a) No person shall cause, suffer, allow, or permit the discharge of particulate matter into the open air from all fuel burning units located at one plant, measured in terms of pounds per hour in excess of the amount determined as follows:

(1) For Type 'a' fuel burning units, the product of 0.05 and the total design heat inputs for such units in million British Thermal Units (B.T.U.'s) per hour, provided however that no more than twelve hundred (1200) pounds per hour of particulate matter shall be discharged into the open air from all such units;

(2) For Type 'b' fuel burning units, the product of 0.09 and the total design heat inputs for such units in million B.T.U.'s per hour, provided however that no more than six hundred (600) pounds per hour of particulate matter shall be discharged into the open air from all such units; and

(3) For Type 'c' fuel burning units, in excess of the values listed in the following table, provided however that no more than three hundred (300) pounds per hour of particulate matter shall be discharged into the open air from all such units. ~~--(See Table 45-2C at the end of this regulation.)~~

For values between any two corresponding consecutive values listed in this table, linear interpolation is to be used for both columns.

(b) Subject to the provisions of this ~~regulation~~rule, allowable emission rates for individual stacks shall be determined by the owner and/or operator and registered with the ~~Commission~~Director at the request of, and on forms provided by, the Director. Such rates shall be subject to review and approval by the Director.

The approved set of individual stack allowable emission rates shall become an official part of the compliance schedule and/or any permits concerning such source(s), and shall not be changed without the prior written approval of the Director.

(c) If the number of similar fuel burning units located at one plant, each of which is meeting the requirements of this ~~regulation~~rule, is expanded by the addition of a new unit(s), the total allowable emission rate for the new unit(s) shall be determined by the following formula. However, the maximum allowable emission rates given in subsection 4.1(a) are not to be exceeded:

$$R_e = \left(1 - \left(\frac{H_{et} - R_{et}}{H_{et}} \right) \right) H_e$$

Where,

R_e is the total allowable emission rate in pounds per hour for the new fuel burning unit(s);

H_{et} is the total design heat input in million B.T.U.'s per hour of the existing and new similar units;

R_{et} is the total allowable emission rate in pounds per hour corresponding to H_{et}; and

H_e is the total design heat input in million B.T.U.'s per hour for the new fuel burning unit(s).

4.2. ~~Addition of Sulfur Oxides to Combustion Unit Exit Gas Stream. -- No person shall cause, suffer, allow, or permit the addition of sulfur oxides to a combustion unit exit gas stream for the purpose of improving control equipment efficiency. Such action shall constitute a violation of this regulation.~~ No person shall cause, suffer, allow, or permit the addition of sulfur oxides to a combustion unit exit gas stream for the purpose of improving emissions control equipment efficiency unless explicitly written approval for such addition is provided by the Director.

4.3. ~~The provisions of subsection 4.2 of this section shall not apply to combustion units in operation on the effective date of this regulation, September 1, 1974.~~ [RESERVED].

4.4. The Director may approve an alternative particulate matter weight emission standard, not to exceed the product of 0.10 and the design heat input of a fuel burning unit for such unit, upon demonstration by the owner or operator:

a. That it is technologically or economically infeasible to comply with Section 4.1.a;

b. That the affect upon particulate matter ambient air quality concentrations resulting from such emissions increase will be insignificant as defined in 45CSR19;

c. That emissions from the fuel burning unit for which an alternative emission standard is proposed impacts no area in which the National Ambient Air Quality Standards for particulate matter are being exceeded.

d. That all other requirements of law and regulations enforced by the Director will be met.

Any such alternative emission standard shall be embodied in a consent order and subject to approval of the United States Environmental Protection Agency as a revision to the State Implementation Plan.

§45-2-5. Control of Fugitive Particulate Matter.

5.1. No person shall cause, suffer, allow, or permit any source of fugitive particulate matter to operate that is not equipped with a fugitive particulate matter control system. This system shall be operated and maintained in such a manner as to minimize the emission of fugitive particulate matter. Sources of fugitive particulate matter associated with fuel burning units shall include, but not be limited to, the following:

(a) Stockpiling of ash or fuel either in the open or in enclosures such as silos;

(b) Transport of ash in vehicles or on conveying systems, to include spillage, tracking, or blowing of particulate matter from or by such vehicles or equipment; and

(c) Ash or fuel handling systems and ash disposal areas.

§45-2-6. Registration.

6.1. ~~Within thirty (30) days after the effective date of this regulation a~~All persons owning and/or operating ~~existing~~ fuel burning units in existence on September 1, 1974 not previously registered shall have registered such units with the ~~Commission~~Director. The information required for registration shall be determined and provided in the manner specified by the Director. Registration forms should be requested from the Director by the owner and/or operator of fuel burning unit(s) subject to the provisions of this section.

6.2. The owner and/or operator of fuel burning units that ~~are~~were under construction or on which construction ~~is~~was initiated ~~within thirty (30) days after the effective date of this regulation~~as of October 1, 1974 not previously registered shall have registered such fuel burning units ~~within this thirty (30) day period~~with the Director.

§45-2-7. Permits.

7.1. After ~~the effective date of this regulation~~September 1, 1974, no person shall construct or modify any fuel burning unit without first obtaining a permit for such construction or modification. Applications for permits shall be made upon forms available from the Director and ~~shall be filed no less than ninety (90) days prior to the construction or modification. These forms~~ shall include such information as in the judgment of the Director will enable him or her to determine whether such source(s) will be so designed as to operate in conformance with the provisions of this ~~regulation~~rule and other applicable rules, the Code of West Virginia, and will not cause or contribute to the violation of ~~Secondary~~Ambient Air Quality Standards. ~~Within ninety (90) days of the receipt of an application the Director shall issue or deny such permit in accordance with the provisions of section eleven-b, article twenty, chapter sixteen of the Code of West Virginia, as amended.~~

§45-2-8. Reports And Testing.

8.1. At such reasonable times as the Director may designate, the owner or operator of any fuel burning unit(s) may be required to conduct or have conducted tests to determine the compliance of such unit(s) with the emission limitations of section 4. Such tests shall be conducted in accordance with the appropriate method set forth in the appendix to this series. The Director, or his duly authorized representative, may at his option witness or conduct such tests. Should the Director exercise his option to conduct such tests, the operator will provide all the necessary sampling connections and sampling ports to be located in such manner as the Director may require, power for test equipment, and the required safety equipment such as scaffolding, railings, and ladders to comply with generally accepted good safety practices.

~~Within a reasonable tolerance, the individual samples for such emission tests shall be extracted isokinetically, with the probe and filter media maintained at, or about, stack temperatures. Individual measurements shall be made at each of the various extraction points throughout the sampling plane in a manner that yields a composite sample and a distribution of measurements which are representative of the total stack gas flow and pollutant concentrations during the test.~~

~~The primary particulate sample collector shall be a pre-conditioned, fiberglass mat filter, certified as being at least ninety-nine (99) percent efficient in collecting 0.3 micron DOP (Dioctyl Phthalate) smoke, or a filter of equivalent properties and efficiency. The filter used shall be pre-weighed to at least one-tenth (0.1) of a milligram.~~

~~The total sample weight shall include both the particulate collected by the filter and the particulate obtained by appropriate cleaning of all devices preceding this filter in the sampling train. The total sample weight shall be determined to the nearest one-tenth (0.1) of a milligram.~~

Sufficient information on temperatures, velocities, pressures, weights and dimensional values shall be reported to the Director, with such necessary commentary as he may require to allow an accurate evaluation of the reported test results and the conditions under which they were obtained.

8.2. The Director, or his duly authorized representative, may conduct such other tests as he may deem necessary to evaluate air pollution emissions other than those noted in subsection 4.1.

8.3. The operators of fuel burning units shall submit data on operating schedules and the quality of fuel used in such units. Such data shall be reported in the manner the Director may specify, and will include, but not necessarily be limited to, information such as the number of start-ups and shut-downs, the quantity of fuel burned, and the ash, sulfur, moisture, volatile matter, and B.T.U. content.

8.4. Within a reasonable time ~~prior to~~after the start-up or shut-down of a fuel burning unit(s), the owner and/or operator of such unit(s) shall notify the Director of the ~~proposed~~ start-up or shut-down. ~~If such prior notification is not practicable (e.g., if emergency conditions require prompt action, or if the requirement for the start-up and the start-up itself must necessarily occur, in time, outside the Commission's normal working hours) notification should be made within a reasonable time thereafter.~~ This requirement will be deemed to have been satisfied with respect to any unit for which approved continuous opacity monitoring data, including start-up and shut-down dates, are submitted to the Director no less frequently than on a calendar month basis.

8.5. The ~~Commission~~Director may publish, and from time to time revise, detailed test procedures and reporting instructions implementing the provisions of this section.

§45-2-9. ~~Compliance Programs And Schedules~~Start-ups, Shut-downs and Malfunctions.

~~9.1. In the event that a fuel burning unit(s) in existence prior to the adoption of this regulation does not meet the emission limitations, an acceptable program to fully comply with the regulation shall be developed and offered to the Commission by the person responsible for the plant. This program shall be submitted upon the request of, and within such time as shall be fixed by, the Commission. Once this program has been approved by the Commission, the owner and/or operator of such installation shall not be in violation of this regulation so long as the approved or amended program is observed. Compliance programs, schedules, and variances that have previously been issued by the Commission under Series 2 (1972) shall remain in effect until the expiration date of that compliance program, schedule, or variance.~~

~~9.2. In the event that an owner or operator of such a fuel burning unit(s) fails to submit a program or an acceptable program and schedule, the Commission shall, by order, determine the compliance program and schedule.~~

9.1. The opacity standards set forth in Section 3 shall apply at all times except in periods of start-ups, shut-downs and malfunctions.

9.2. At all times, including periods of start-ups, shutdowns, and malfunctions, owners and operators shall, to the extent practicable, maintain and operate any fuel burning unit including associated air pollution control equipment in a manner consistent with good air pollution control practice for minimizing emissions. Determination of whether acceptable operating and maintenance procedures are being used will be based on information available to the Director which may include, but is not limited to, monitoring results, opacity observations, review of operating and maintenance procedures, and inspection of the source.

9.3. Except as provided in subsection 9.4 the owner or operator of a fuel burning unit subject to this rule shall report to the Director, by telephone or telefax, any malfunction of such unit or its air pollution control equipment which results in any excess particulate matter emission rate or excess opacity within twenty-four (24) hours of becoming aware of such condition. The owner or operator shall file a certified written report concerning the malfunction with the Director within ten (10) days providing the following information:

a. A detailed explanation of the factors involved or causes of the malfunction.

b. The date and time of duration (with starting and ending times) of the period of excess emissions.

c. An estimate of the mass of excess emissions discharged during the malfunction period.

d. The maximum opacity measured or observed during the malfunction.

e. Immediate remedial actions taken at the time of the malfunction to correct or mitigate the effects of the malfunction.

f. A detailed explanation of the corrective measures or program that will be implemented to prevent a recurrence of the malfunction and a schedule for such implementation.

9.4. Excess opacity periods meeting the following conditions may be reported on a monthly or quarterly basis as required by the Director:

a. The excess opacity period does not exceed thirty (30) minutes within any 24-hour period.

b. Excess opacity does not exceed 40%, and

c. The excess opacity period is not associated with substantial failure, deactivation or by-pass of particulate matter emissions control equipment.

§45-2-10. Variance.

10.1. Due to unavoidable malfunction of equipment, emissions exceeding those provided for in this ~~regulation~~rule may be permitted by the Director for periods not to exceed ten (10) days upon specific application to the Director. Such application shall be made within twenty-four (24) hours of the malfunction. In cases of major equipment failure, additional time periods may be granted by the ~~Commission~~Director provided a corrective program has been submitted by the owner or operator and approved by the ~~Commission~~Director.

10.2. For the purpose of preventing possible equipment damage during the start-up of a fuel burning unit(s), emissions exceeding those provided for in this ~~regulation~~rule may be permitted by the Director for periods not to exceed twenty-four (24) hours, upon specific application to the Director no less than twenty-four (24) hours prior to the start-up operation.

~~§45-2-11.~~§45-2-10. Exemptions.

~~11.1.~~10.1. All fuel burning units having a heat input under ten (10) million B.T.U.'s per hour will be exempt from sections 4 through ~~9~~10. However, failure to attain acceptable air quality in parts of some urban areas may require the mandatory control of these sources at a later date.

§45-2-11. Inconsistency Between Regulations.

11.1. In the event of any inconsistency between this regulation and Appendix and any other rule of the West Virginia Division of Environmental Protection, such inconsistency shall be resolved by the determination of the Director and such determination shall be based upon the application of the more stringent provision, term, condition, method, rule or regulation.

~~TABLE 45-2A~~

~~(a) From March 15, 1972, until September 1, 1972, smoke which is as dark or darker than:~~

~~Areas of State~~	~~Installation Date of Fuel Burning Unit~~	~~Ringelmann Limitations on Fuel Burning Units~~
~~Kanawha Valley Air Basin~~	~~Before April 4, 1966~~	~~2~~
	~~After April 4, 1966~~	~~1~~
~~Other~~		~~NO LIMITATIONS~~

~~(b) From September 1, 1972, until June 30, 1975, smoke which is as dark as or darker than:~~

~~Areas of State~~	~~Ringelmann Limitation on Fuel Burning Units~~
~~All~~	~~1~~

~~(c) After June 30, 1975, smoke which is darker than:~~

~~Areas of State~~	~~Ringelmann Limitations on Fuel Burning Units~~
~~All~~	~~0.5~~

~~TABLE 45-2B~~

~~Type of Fuel Burning Unit~~	~~Exemptions Allowed for No More than Two (2) Hours Per Start-Up Operation Shall Not be as Dark or Darker in Shade or Appearance As:~~
~~Type 'a' and Type 'b'~~	~~No. 2 Ringelmann~~
~~Type 'c'~~	~~(1) For forty five (45) minutes No. 3 Ringelmann~~ ~~(2) For the remaining seventy-five (75) minutes No. 2 Ringelmann~~

TABLE 45-2C

~~TABLE FOR TYPE 'c' UNITS~~

Total Design Heat Input for All Type 'c' Fuel Burning Units Located at One Plant in Millions of B.T.U.'s Per Hour	Total Allowable Particulate Matter Emission Rate for All Type 'c' Fuel Burning Units Located at One Plant in Pounds Per Hour
10	3.4
20	5.6
40	9.0
60	11.7
80	14.4
100	16.6
200	26.4
400	42.2
600	54.0
3,333	300.0

45~~CSRTP2~~

~~TITLE 45~~
~~PROCEDURAL RULE~~
~~AIR POLLUTION CONTROL COMMISSION~~

~~SERIES TP2~~
~~"COMPLIANCE TEST PROCEDURES FOR REGULATION 2 -~~
~~'TO PREVENT AND CONTROL PARTICULATE AIR~~
~~POLLUTION FROM COMBUSTION OF FUEL IN~~
~~INDIRECT HEAT EXCHANGERS'"~~
45CSR2 APPENDIX
COMPLIANCE TEST PROCEDURES FOR 45CSR2

§45-~~TP2-1.~~Section 1. General.

~~1.1.~~ Scope. -- It is the intent and purpose of this ~~rule~~Appendix to establish stack testing procedures for determination of compliance with the weight emission standards as set forth in ~~the Commission's Regulation 2~~45CSR2 - "To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers". To this end, it is the intent of the ~~Commission~~Division of Environmental Protection Office of Air Quality to adopt by reference, certain of the Reference Methods and other test methods set forth in 40 CFR, Part 60, Appendix A [as of July 1, ~~1988~~1994]. These methods set forth acceptable stack testing, calibration, and laboratory procedures including appropriate apparatus with provisions for certain minor exceptions as delineated in Section 6 of this ~~rule~~Appendix.

~~1.2. Authority. -- W.V. Code §16-20-5, Sections 1 through 13 inclusive~~

~~1.3. Filing Date. -- June 15, 1989~~

~~1.4. Effective Date. -- July 14, 1989~~

§45-~~TP2-2. Definitions.~~Section 2. [RESERVED].

~~2.1. "Commission" means the West Virginia Air Pollution Control Commission.~~

~~2.2. "Director" means the Director of the West Virginia Air Pollution Control Commission.~~

~~2.3. "Person" means any and all persons, natural or artificial, including any municipal, public or private corporation organized or existing under the laws of this or any other state or country, and any firm, partnership, or association of whatever nature.~~

~~2.4. "Owner/Operator" means the person responsible for the compliance of the fuel burning units subject to the provisions of the Commission's Regulation 2.~~

~~2.5. "Test Team Supervisor" means the person, qualified by experience or education, who is charged with supervising the stack test. This person is responsible for ensuring the validity and correctness of the submitted test results.~~

~~2.6. "Laboratory Official" means the person, qualified by experience or education, who is charged with overseeing or conducting the laboratory analysis of the collected samples. This person is responsible for ensuring the accuracy and validity of the laboratory results.~~

~~2.7. "Plant" means and includes all fuel burning units, source operations, equipment, and grounds utilized in an integral complex.~~

~~2.8. "Fuel Burning Unit" means and includes any furnace, boiler apparatus, device, mechanism, stack or structure used in the process of burning fuel or other combustible material for the primary purpose of producing heat or power by indirect heat transfer. For the purposes of this rule, all fuel burning units are classified in the following categories:~~

~~a. Type 'a' means any fuel burning unit which has as its primary purpose the generation of steam or other vapor to produce electric power for sale.~~

~~b. Type 'b' means any fuel burning unit not classified as a Type 'a' or Type 'c' unit such as industrial pulverized fuel fired furnaces, cyclone furnaces, gas fired and liquid fuel fired units.~~

~~c. Type 'c' means any hand fired or stoker fired fuel burning unit not classified as a Type 'a' unit.~~

~~2.9. "Similar Units" means all Type 'a', or all Type 'b', or all Type 'c' fuel burning units located at one plant.~~

~~2.10. "Fuel" means any form of combustible matter (solid, liquid, vapor, or gas) that is used as a source of heat.~~

~~2.11. "Control Equipment" means any equipment used for collecting or confining particulate matter for the purpose of preventing or reducing the emission of this air pollutant into the open air.~~

~~2.12. "Stack" means, but not be limited to, any duct, control equipment exhaust, or similar apparatus, which vents gases and/or particulate matter into the open air.~~

~~2.13. "Particulate Matter" means any material except uncombined water that exists in a finely divided form as a liquid or solid.~~

~~2.14. "Discharge Point" means the point at which particulate matter is released from a stack into open air.~~

~~2.15. "Heat Input" means the rate of heat release from all fuels fired in all similar units vented by the test stack during the test run period.~~

~~a. "Design Heat Input (DHI)" means the heat input level (in MM Btu/hr) for which an individual fuel burning unit has been designed to be operated during continuous operation.~~

~~b. "Total Design Heat Input (TDHI)" means the sum of the design heat inputs for all similar units located at one point.~~

~~c. "Normal Maximum Operating Load (NMOL)" means the sum of the Design Heat Input levels (in MM Btu/hr) of the similar unit(s) vented by the test stack, unless the owner/operator has elected to operate one or more of the similar units vented by the test stack at or below a specified percentage of its Design Heat Input level as part of a compliance program, permit, or consent order officially accepted by the Commission. In such event, the NMOL is the sum of the Design Heat Input levels or fractions thereof as appropriate (i.e., NMOL = 0.75 $DHI_1 + DHI_2$).~~

~~2.16. "Normal Operation" when used in the context of fuel quality and combinations fired, means the type, quality, and combination of fuel(s) fired which is representative of the fuel or fuel combination fired, in the unit(s) tested, over a reasonable period prior to the test, and the fuel or fuel combination which might reasonably be expected to continue to be fired in this unit after the test. If the type of fuel, quality or combination used in the unit is variable, use the type, quality, and/or combination fired in day-to-day operation which can reasonably be expected to produce the greatest particulate matter loading to the control equipment (i.e., if coal is fired eight months out of the year and gas is fired four months out of the year, coal is to be burned during the test).~~

~~2.17. "ASTM" means American Society for Testing and Material, 1916 Race Street, Philadelphia, Pennsylvania 19103.~~

~~2.18. "Sampling Plane" means the imaginary plane located perpendicular to the gas flow in the duct or stack at the place selected for the extraction of the required samples.~~

~~2.19. "Probe" means the part of the pitobe assembly (nozzle, sample tube, pitot tube, filter holder(s), sensor(s)), which precedes the last filter in the sampling train and conveys the sample gas and particulate matter from the nozzle inlet to the last filter disc used for collecting stack particulate matter.~~

~~2.20. "Primary Filter" means the last filter used in the sampling train to separate the particulate matter sample from the sampled stack gas.~~

~~2.21. "Prefilter" means a filter used in the sampling train prior to the primary filter for the purpose of reducing the particulate matter build up on the primary filter.~~

~~§45-TP2-3.~~ Section 3. Symbols.

3.1. Ab = (Sd) x (Va), Ab is the estimate of the weight of residue, prior to use, in the acetone wash volume used (grams)

3.2. An = cross-sectional area of the sample nozzle (ft^2)

3.3. As = cross-sectional area of the sample plane (ft^2)

3.4. ASTM = American Society for Testing and Materials

3.5. B = percent moisture in the sampled gas, by volume, on a wet basis, divided by 100

3.6. BE = the boiler thermal efficiency (percent)

3.7. C = 453.592 grams/pound

3.8. °C = degrees Centrigrade

3.9. cfm = cubic feet per minute

3.10. CEM = continuous emission monitoring equipment

3.11. CO = carbon monoxide

3.12. CO_2 = carbon dioxide

3.13. d = diameter of nozzle (inches)

3.14. DGR = dry gas meter reading: the sample gas volume meter reading at meter conditions (cubic feet)

3.15. ΔDGR = difference between two consecutive DGR's, the volume sampled at each sampling point (cubic feet)

3.16. EA = excess air fraction

3.17. F-factor = a factor representing a ratio of the dry flue gases generated to the calorific value of the fuel combusted ($dscf/10^6$ Btu)

3.18. Fi = quantity of each fuel fired in a fuel burning unit during the total test run period (in appropriate units)

3.19. °F = degrees Fahrenheit

3.20. Fp = combined correction factor for units and pitot tube deviation

3.21. ft^3 = cubic feet

3.22. ft/min = feet per minute

3.23. gm = grams

3.24. hbd = average enthalpy of steam/water leaving boiler as blowdown (Btu/lbm)

3.25. hi = average enthalpy of steam or other working fluid entering the boiler of the fuel burning unit (Btu/lbm)

3.26. ho = average enthalpy of steam or other working fluid leaving the boiler of the fuel burning unit (Btu/lbm)

3.27. ΔH = pitot tube differential reading (inches H_2O)

3.28. ΔHp = indicated differential pressure when the test pitot tube is used at the calibration point

3.29. ΔHs = indicated differential pressure when the standard pitot tube is used at the calibration point

3.30. Hg = mercury

3.31. HI = heat input per fuel burning unit(s) (10^6 Btu per hour)

3.32. H_2S = hydrogen sulfide

3.33. HVf = higher heating value of the fuel on an as fired basis (in Btu/lbm)

3.34. HVi = average Btu value of each fuel used on an as fired basis, in appropriate units (Btu/lbm, Btu/gal, etc.)

3.35. in. Hg = inches of mercury, pressure

3.36. ISKo = overall isokinetic factor, ratio of total actual sample volume (Qm) to the total isokinetic sample volume (Qo), both volumes adjusted to standard conditions

3.37. ISKp = point isokinetic factor, ratio of the actual sample volume to the isokinetic sample volume

3.38. %ISK = 100 (ISKo - 1)

3.39. Kp = coefficient of deviation of the Type S pitot tube used in sampling, determined by calibration

3.40. Ks = coefficient of deviation for a standard pitot tube

3.41. ibf = pounds force

3.42. lbm = pounds mass

3.43. Ma = particulate matter obtained from the evaporation of the acetone washings (grams)

3.44. Mbd = average mass flow rate of blowdown (lbm/hr)

3.45. Mf = particulate matter collected by filter(s) (grams)

3.46. Mg = molecular weight of gas sample on wet basis

3.47. mf = average mass flow rate of steam through the boiler (lbm/hr)

3.48. mg = milligram

3.49. ml = milliliter

3.50. Mn = Mf + Ma - Ab (grams), indicated weight of particulate matter collected by the sampling train

3.51. n = number of items in a set of related items

3.52. N_2 = nitrogen

3.53. O_2 = oxygen

3.54. Θ = sum of all extraction times at all points sampled per run (min.)

3.55. Pb = atmospheric pressure (in. Hg)

3.56. Pf = ash fraction of the non-metered fuel on an as fired basis

3.57. Pm = absolute pressure of gas at meter (in. Hg)

3.58. Pm = average absolute pressure of the sampled gas at meter conditions for the test run (in. Hg)

3.59. Ps = absolute pressure of gas in stack at sampling plane

3.60. qm = actual sample volume for each sample point adjusted to 68 °F and 29.92 in. Hg (ft^3)

3.61. Qm = sum of all qm for each test run (ft^3)

3.62. qo = volume of sampled gas for each point if isokinetic conditions were maintained, adjusted to 68 °F and 29.92 in. Hg (ft^3)

3.63. Qo = sum of all qo for each test run (ft^3)

3.64. Sd = residue found in acetone blank (gm/ml)

3.65. π = pi, 3.1416

3.66. Δt = elapsed time at each sampling point (minutes)

3.67. Tf = temperature of the primary out-of-stack filter holder, when used (°F)

3.68. Tm = temperature of gas sample at volume meter for each point (°F)

3.69. Tm = average temperature of gas sample at volume meter for test run (°F)

3.70. Ts = stack gas temperature (°F)

3.71. Va = volume of acetone wash (ml)

3.72. Vac = vacuum (inches of mercury)

3.73. Vm = sum of all ΔDGR for the test run (ft^3)

3.74. Vmstd = Vm corrected to standard conditions

3.75. w = 1/(1 - B), ratio of wet gas volume to dry gas volume

3.76. W = Wc + Wd (grams), amount of H_2O removed from the sampled gas

3.77. Wc = amount of water collected in the condenser or impingers (grams)

3.78. Wd = amount of water collected by the drying agent in the absorber (grams)

3.79. % = percent

~~3.80. WVAPCC = West Virginia Air Pollution Control Commission~~

~~§45-TP2-4.~~ Section 4. Adoption of Test Methods.

4.1. For determining compliance with the mass emission rates as delineated in ~~this Commission's Regulation 2~~45CSR2 - "To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers", a person shall utilize those Reference Methods, in particular Method 5, 5B or 17, as contained in 40 CFR, Part 60, Appendix A [as of July 1, ~~1988~~1994] with the following amendments:

a. Primary filter media shall be maintained at, or about, stack temperature. The temperature of the primary filter media shall not exceed that of the stack except that in cases where sampling follows a wet scrubbing device the temperature of the primary filter may be adjusted to a maintained temperature of up to 250 °F.

b. The result of each compliance test is to be the arithmetic average of three (3) complete sampling runs conducted within a seven (7) day period.

c. A complete sampling run shall be one complete determination of the total particulate matter emission rate through the test stack for which:

A. the minimum total sampling time is two (2) hours; and

B. the minimum total sample volume is sixty (60) cubic feet adjusted to 68 °F and 29.92 inches of Hg. Smaller sampling volumes and shorter sampling times may be approved by the Director on a case-by-case basis when necessitated by process variables or other factors.

d. Any and all references in 40 CFR, Part 60, Appendix A, to the "Administrator" is amended to be the "Director".

In carrying out these methods for the purpose of determining mass emission rates, it is understood that other Reference Methods contained in 40 CFR, Part 60, Appendix A are integral parts of Methods 5 and 17 in particular, but not inclusive, Methods 1, 2, 3, and 4.

§45-~~TP2-5.~~Section 5. Unit Load and Fuel Quality Requirements.

5.1. All compliance test runs, which are to be included in the test result for a unit or a specified number of units, shall be conducted while the unit or group of units is operated at or above the normal maximum operating load for the specified unit or group of units; while fuel or combinations of fuel representative of normal operation are being burned; and under such other relevant conditions as the Director may specify based on representative performance of the specified units.

§45-~~TP2-6.~~Section 6. Minor Exceptions.

6.1. In the interest of practicality, the Director or his designee may allow minor exceptions, not related to test site safety, to the specifications of these methods, if the Director or his designee concludes that in a particular case, the granting of such exception would not invalidate the test results. If such exceptions are granted, alternate specifications may be prescribed.

6.2. If an exception as described above is granted, the scope of the exception and any alternative specification prescribed shall be recorded in a letter of exception signed by the authorizing official. A copy of such letter of exception shall be attached to the test report.

§45-~~TP2-7.~~Section 7. Pretest and Post Test General Requirements.

7.1. The owner/operator required to conduct tests and his test consultants shall become familiar with the requirements of ~~Regulation 2~~45CSR2 - "To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers", Reference Methods as contained in 40 CFR, Part 60, Appendix A, and the requirements as delineated in this ~~rule~~Appendix, including all forms, equations, and definitions. Questions of interpretation, applicability, or exception, shall be resolved with the Director or his designee prior to conducting the test.

7.2. When a compliance test conducted in accordance with this ~~rule~~Appendix is required, the owner or operator of the affected unit(s) shall be notified in writing by the Director or his designee. The notice shall prescribe the following:

a. the unit(s) to be tested;

b. the identification number to be assigned to the test;

c. the date by which the test is to be completed and the test report submitted; and

d. the person, if other than the Director, to whom the test report is to be submitted, and with whom questions concerning the test procedure may be resolved. Test report forms (see ~~Appendix~~Attachment) for filing the results of the compliance test are available from the ~~Commission~~Division of Environmental Protection on request.

7.3. At least thirty (30) days prior to each compliance test, a test protocol shall be furnished to the Director for his review and approval and shall include as a minimum, the following information:

a. Identification and description of the unit(s) that are to be tested.

b. A discussion of the manner in which the unit(s) shall be operated during the test periods with respect to operating loads, representativeness of fuel(s) fired, operating temperatures, and other factors which may affect emissions.

c. A description or listing of unit and control equipment data that shall be monitored and recorded during the test runs.

d. A description of test methods and equipment that shall be employed with requests for approval of any variances to test method procedures or sampling equipment designs set forth under ~~these rules~~this Appendix.

e. A drawing of the stack or duct sections where samples shall be taken showing distances to upstream and downstream gas flow disturbances or bends and changes in duct or stack cross sections.

f. A drawing of the test plane(s) showing dimensions and number and location of sampling (traverse) points.

g. The sampling time at each traverse point and total sampling time for each test run. If the sampling time per traverse point is to be less than five (5) minutes, comments shall be included concerning the variability of gas flow and temperatures during the shorter sampling time and how the sampling rate shall be monitored and adjusted to maintain isokinetic conditions.

h. The minimum volume (SCF) of gas that shall be sampled per test run.

i. The name of the person to contact concerning the scheduled tests and affiliation of personnel who shall conduct the tests.

j. A copy of the last individual stack registration approved by the Director in accordance with Sub-Section ~~3~~4.1 (b) of ~~the Commission's Regulation~~ ~~2~~45CSR2.

k. A statement concerning where the laboratory analyses are to be conducted and a description of the chain of custody for collected samples.

l. The anticipated date that subject testing is to be performed.

7.4. Notification of the actual dates upon which compliance testing will be conducted shall be provided to the Director, in writing, no later than fifteen (15) days prior to the date of the first test run so that he may, at his option, have an observer present during the test runs and sample analyses. Such notification may be submitted with the test protocol, however, the actual date of initial testing shall not be less than thirty (30) days from date of protocol submittal. Within constraints imposed by available facilities, copies of test field data sheets, laboratory sheets, unit operating logs and similar relevant data collected during the test runs shall be provided to the ~~WVAPCC~~West Virginia Division of Environmental Protection observer upon request at the conclusion of the tests. Any such data or other information so made available shall be treated as confidential upon request by the operator and shall not be made available to the public. The owner/operator shall place the word "confidential" upon all such information which is gathered and retained by the ~~WVAPCC~~West Virginia Division of Environmental Protection. If facilities and circumstances allow, the ~~WVAPCC~~West Virginia Division of Environmental Protection test observer shall, at his option, observe the laboratory analyses.

7.5. A compliance test report providing the information summarized below and any additional information that the Director may require shall be submitted to the Director within sixty (60) days of the completion of the compliance testing.

a. General Information

A. Plant name and location

B. Units/stacks tested

C. Name and address of company performing the tests

D. Test dates and times

b. Report Certification

The following persons shall certify that the test report contains true and accurate information:

A. Test team supervisor

B. Reviewer of test report (if applicable)

C. If test is performed by source owner, the report shall also be certified by facility owner/operator

c. Test Summary

A. Description of emissions sources/stacks tested

B. Purpose of test

C. Pollutants measured

D. Operating data

(a) Unit(s) configuration and air pollution control equipment flow diagrams.

(b) Summary of operating parameters including steam or electrical production rates and other relevant parameters measured and recorded and/or calculated for test periods shall be attached to the report.

(c) Pertinent control equipment and operating data recorded and/or calculated for the test period should be attached to the report. As each boiler operation and associated control equipment normally presents a unique case, pertinent data shall be determined on a case-by-case basis.

(d) Description of any unusual or non-typical operating mode, fuels, soot blowing, blowdown, etc. occurring or used during the tests.

d. Test Results

A. Mass emission test results with emissions reported in units of the applicable standard and in pounds per hour.

B. Visible emissions test results, if applicable, as measured by observer or transmissometer. If observed by personnel from test company or plant, evidence of observer's certification shall be attached to the report.

C. Description of collected samples (if such information is deemed to be useful).

D. Description and discussion of real or apparent errors involved in test or process measurements, analysis, etc.

e. Test Procedures

A. Description of test equipment including drawing of sampling train.

B. Description of test procedures employed with detailed documentation of any deviations from methods required by this ~~rule~~Appendix.

C. Description of analytical procedures employed with detailed documentation of any deviations from methods required by this ~~rule~~Appendix.

D. Dimensioned drawing of sampling port location showing distances to upstream and downstream gas flow disturbances.

E. Cross-sectional drawing of sampling plane showing location and numbers or other designations of sampling points.

f. Appendix

A. Copies of original field data sheets from test runs.

B. Copies of original log sheets, strip charts and other process or control equipment data recorded during tests. These attachments shall be certified by a responsible plant official. As each boiler operation and associated control equipment normally presents a unique case, pertinent data shall be determined on a case-by-case basis.

C. Laboratory report including chain of custody.

D. Description of test equipment calibration procedures and calibration results for test equipment used.

E. Description of calibration performed on devices recording important operating data during the tests.

F. Copies of strip charts or other original outputs from continuous emission monitoring (CEM) equipment on the tested source and description of CEM system calibration and operation prior to and/or during tests.

G. Originals of any visible emission readings taken during test period.

H. Copies of relevant correspondence such as ~~WVAPCC~~West Virginia Division of Environmental Protection letters approving test method variances.

I. Names and titles of persons involved in the test including sampling team members, company personnel, and outside observers.

7.6. Subject to the provisions of Section 6 of this ~~rule~~Appendix, Minor Exceptions, a complete sampling run is one complete determination of the total particulate matter emission rate through the test stack for which:

a. the composite particulate matter sample is extracted from the duct or stack at a location and from the number of sampling points prescribed in Method 1 of 40 CFR, Part 60, Appendix A [as of July 1, ~~1988~~1994];

b. the sampling equipment and its method of operation for collection of particulate sample meets the criteria and requirements prescribed in Method 5, 5B or Method 17 of 40 CFR, part 60, Appendix A [as of July 1, ~~1988~~1994];

c. the overall sampling rate is within ± 10% of the overall isokinetic sampling rate, as calculated in Method 5, 5B or Method 17 of 40 CFR, Part 60, Appendix A [as of July 1, ~~1988~~1994]; whichever is applicable;

d. the stack gas components data is determined as prescribed by Methods 3 and 4 of 40 CFR, Part 60, Appendix A, [as of July 1, ~~1988~~1994];

e. the other provisions of this ~~rule~~Appendix are met and sufficient heat input and fuel quality data is provided to verify that the requirements of ~~Sub-~~Section ~~7.6., below~~8 are met; and

f. sufficient data and commentary is provided with the submitted test report forms to allow the Director or his designee to evaluate the reported test results and the conditions under which they were obtained.

§45-~~TP2-8.~~Section 8. Heat Input Data Measurements.

8.1. General.

a. The data measurements required to determine the total heat input to the fuel burning unit(s) vented by the test stack during the test run period depends on the computational method applicable.

This ~~rule~~Appendix prescribes three (3) computational methods:

Method 1H - Fuel Use Basis
Method 2H - Steam Balance Basis
Method 3H - Flue Gas Analysis Basis

The test supervisor is to submit data on the heat input(s) based on the Fuel Use Basis (Method 1H) whenever coal scales or other fuel meters, as appropriate, are available.

If the appropriate fuel metering device(s) are not available, Method 2H - Steam Balance Basis is to be used.

For all test runs also submit data on the heat input(s) based on Method 3H - Flue Gas Analysis Basis, in addition to the data required by Method 1H or 2H, whichever is applicable.

b. The following Sub-Sections detail the specific data required for each method and the means of obtaining these data.

8.2. Fuel Use Method (1H).

a. This computational method requires:

A. The measured amount of all fuel(s) fired in the fuel burning units during each test run period, as determined by continuous coal scales or equivalent and/or oil flow and/or gas meter(s). When gas is fired, the temperature and pressure of the gas meter(s) are needed.

B. The average moisture, ash, sulfur, volatile matter, and Btu value(s) of fuels fired in the fuel burning units during the test run period is to be determined and reported as follows:

(a) For coal:

(A) Obtain a representative sample of the coal fired in each fuel burning unit during the test run period. This sample is to be obtained in accordance with the Commercial Sampling Procedure of ASTM: Method D 2234-76 or its latest revision. Consult this ASTM standard for details of the required procedures. Sampling and analysis of coal entering bunkers or silos feeding the fuel burning unit to be tested is also acceptable provided that ASTM requirements are met and that such sampling/analysis properly represents the quality of the coal burned during the test periods.

(B) Prepare the reduced gross sample, obtained above, for laboratory analysis in accordance with ASTM: Method D 2013-72, "Preparing Coal Samples for Analysis" or its later revision. Consult this ASTM standard for details of the required procedure. In this ASTM method, further amplification is given to the methods of reducing the gross sample to a laboratory sample and preparing the laboratory analysis. The laboratory sample is so prepared that 100% of the coal sample shall pass through a No. 60 (250 micron) sieve. The final product is thoroughly mixed prior to extracting analytical samples.

(C) Extract an analytical sample from the laboratory sample and determine the moisture, ash, and volatile matter content of this sample in accordance with ASTM Method D 3173-73 or ASTM Method D 2961-87 (Moisture), ASTM D 3174-82 (Ash), and ASTM D 3175-82 (Volatile Matter) or their latest revisions. Consult these ASTM standards for details of the required procedures. In these ASTM methods, procedures are prescribed for determining the moisture, ash, and volatile content of the sample.

(D) Extract another analytical sample from the laboratory sample and determine the Btu content of the sample in accordance with ASTM: Method D 2015-77 "Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Calorimeter" or its latest revision. Consult this ASTM standard for details of the required procedure.

(E) Extract another analytical sample from the laboratory sample and determine total sulfur content of the sample in accordance with ASTM Method D 3177-75 "Test for Total Sulfur in the Analysis Sample of Coal and Coke" or ASTM Method D 4239-85 or their latest revisions. Consult these ASTM standards for details of the required procedures.

(F) Send a sealed and marked one pint sample of the laboratory sample representative of the gross sample, to the ~~Commission~~Director with the test report. If drying was used in reducing the gross sample to the laboratory sample, indicate the percent loss of moisture during this process. For each container provide the test identification number assigned by the ~~WVAPCC~~West Virginia Division of Environmental Protection in accordance with Sub-Section 7.2.b of this ~~rule~~Appendix and the test run number.

(b) For Fuel Oils:

Determine the supplier's name and address, and the specifications for the oil supplied. Use the supplier's specifications when available for the ash content and Btu value of the oil. When such specifications are not available, determine the grade of oil fired, by referring to any Standard Engineering Handbook. As such the Handbook and appropriate edition should be properly identified, for inclusion as part of any results submitted to the agency for the ash, sulfur and Btu values. Send an eight ounce, sealed and marked, sample of the oil fired during the test to the ~~Commission~~Director with the test report.

(c) For Natural Gas:

Determine the supplier's name and address, and the specification of the natural gas supplied. Use the supplier's specification for the Btu value of the fuel. Ash may be considered negligible.

(d) Other Fuels:

Determine the name and address of the supplier(s) or producer(s) of any other materials fired during the test run period. Determine the source(s) of the fuel(s). Use the supplier(s)'/producer(s)' specifications for the ash, sulfur, and Btu value. When such specifications are not available, resolve with the Director or his designee, the method which shall be used to determine these values, prior to conducting the test. Submit an appropriate small sample of the fuel fired, if other than a gas, to the ~~Commission~~Director in a sealed and marked sample container.

8.3. Steam Balance Method (2H).

This method requires a materials balance and inlet and outlet water/steam or other media pressure and temperature data during the test run period, for the boiler(s) of the fuel burning unit(s) vented by the test stack.

a. Measure the mass flow rate of all water/steam or other media flowing through each boiler, including blowdown.

b. Measure the inlet and outlet pressure and temperature of each water/steam circuit, including blowdown.

c. Construct a flow diagram of the water/steam or other media flow circuit(s) on Form THI-II (2H). Record the measured data on this form, indicating the data points on the diagram.

d. Determine the boiler manufacturer's name and address, and the boiler type and model number. From the manufacturer's specification, determine the boiler(s) thermal efficiencies. If such specifications are not available, describe in detail the basis and method of selecting the value used.

8.4. Flue Gas Analysis Method (3H).

a. This method involves determining the heat input for the boiler(s) of the fuel burning unit(s) vented by the test stack utilizing:

A. appropriate F-factors as contained in 40 CFR, Part 60, Subpart D [as of July 1, ~~1988~~1994]; and

B. total volume of stack gas discharged through the stack during the test run; and

C. the average excess air discharged [O_2% or CO_2%] through the test stack during the test run period.

b. Appropriate F-factors are to be obtained from 40 CFR, Part 60, Subpart D [as of July 1, ~~1988~~1994], unless carbon content of fly ash or bottom ash exceeds five (5) percent on a per weight basis. In these cases, consult the Director or his designee prior to conducting the test to determine and resolve a suitable F-factor adjustment.

c. Total Volume of Stack Gas.

The total volume of stack gas is determined from:

A. volume meter readings obtained during subject test run and recorded on Form TD:-Test Run Data Sheet for each test run.

d. Stack Excess Air.

A. For low nitrogen content fuel(s) (coal, fuel oil, natural gas), the stack excess air can be computed from the data obtained from the Orsat analysis and recorded on Form TOA - Laboratory Data Sheet (Orsat) for each test run. If blast furnace gas, producer gas, or other fuel(s) of high nitrogen content are used, consult the Director or his designee prior to conducting the test to determine and resolve a suitable method of determining the excess air when such fuel(s) is burned.

§45-~~TP2-9.~~Section 9. Computations and Data Analysis.

This section prescribes the computational method to be used in computing the particulate matter stack emission rate for the test and evaluating the supporting test data. Perform the computations and analysis prescribed in this section for the data obtained from each test run which is to be part of the submitted test results. Record the measured data and the appropriate computations on the designated test report forms, a copy of which is in the Appendix. Submit sufficient commentary with the test report data to fully describe the conditions under which the data was obtained and any factors which might affect the evaluation of the test results.

9.1. Particulate Matter Sample Weight Determination. (Form TLP - Laboratory Data Sheet (Particulate)).

Mf = particulate matter (grams) collected by the primary filter, including andy prefilter if used

Ma = particulate matter (grams) obtained from the evaporation of the acetone washings of the internal sampling train surfaces exposed to the particulate sample prior to the primary filter

Ab = particulate matter residue (grams) in the volume (Va) of acetone wash used for Ma above, as determined by the acetone blank analysis [i.e., Ab = (Sd) (Va); where Sd equals the residue found in the acetone blank analysis in gm/ml, and Va equals the volume of acetone used in the acetone wash for Ma above]

Mn = Mf + Ma - Ab = the indicated weight of particulate matter collected, in grams

9.2. Moisture Determination. (Form TLH: Laboratory Data Sheet - Moisture; Forms TD; Test Run Data Sheet).

Record all measured and calculated data on the appropriate forms. Compute and record the following:

Vm = (ft^3) the sum of all ΔDGR for the run, where ΔDGR is equal to the indicated amount of gas sampled at each point during the extraction interval

Tm = (°F) average temperature of the dry gas meter during the test run. Tm = average dry gas meter temperatures (°F) at each sampling point.

Pm = (in. Hg) average absolute pressure at the dry gas meter during the test run. Pm = the average absolute pressure at the dry gas meter for each sample point, where Pm = Pb - Vac; Pb = barometric pressure, Vac = meter vacuum.

Wc = amount of water collected in condenser or impingers (grams)

Wd = amount of water collected by the drying agent used after the condenser or impingers (grams)

W = Wc + Wd (grams)

B = percent moisture in the sampled gas by volume on a wet basis, divided by 100

$$B = W / \frac{374\ Pm\ Vm}{Tm + 460} + W$$

w = moisture correction factor; ratio of the volume of wet sample gas to the volume of dry sample gas

w = 1/ (1 - B)

9.3. Sample Gas Density and Excess Air Determination. (Form TOA - Laboratory Data Sheet (Orsat)).

a. Gas Density.

A. Record the Orsat analysis for all three runs on Form TOA (Laboratory Data Sheet) on lines 1 through 9. Compute and record the average value of CO_2, O_2, CO and N_2 for each run on line 10 or the value of these components of the composite sample, if obtained (optional), on line 11.

B. Transcribe the values of w (moisture correction factor) from Form TLH to Form TOA in blocks 12 for each run. Transcribe the values of B, the percent water (wet basis) from Form TLH to Form TOA in column 13, line 14, for each run.

C. Correct the average component volumetric percentages, dry basis (line 10), to volumetric fractions (wet basis), by dividing by 100w and enter these values on line 14 for each test run.

D. Multiply each of these volumetric fractions (wet basis - line 14) by the corresponding molecular weights on line 15 and enter the values on line 16.

E. Enter the sum of the values on line 16 for each run in the appropriate box on line 17, the apparent molecular weight of the wet gas (Mg).

F. Determine the wet gas density for each run by dividing the molecular weight for the run (on line 17) by the number 29 and enter this quotient in the appropriate box on line 18.

b. Excess Air.

Compute and record the excess air fraction for each run using the average dry gas analysis from line 10 and the formula shown on line 20. Record excess air fraction (EA) in the appropriate box on line 19.

Note: The excess air fraction equation present on line 20 of Form TOA is not applicable when producer gas, blast furnace gas or other fuels high in nitrogen content are used.

9.4. Actual Sample Gas Volume Determination. (Form TD: Test Run Data Sheet).

a. For each point sampled during the run compute the actual volume drown through the sampling nozzle adjusted to standard conditions of 68 °F and 29.92 inches of Hg as indicated below:

qm = Actual sample volume (in cubic feet) drawn through the sampling nozzle for each sampled point adjusted to 68 °F and 29.92 inches of Hg.

$$qm = (\Delta DGR)(w) \cdot \frac{528}{(Tm + 460)} \cdot \frac{Pm}{29.92}$$

WHERE,

ΔDGR, w, Tm, and Pm are defined in Sub-Section 9.2 of this Section and are recorded on Form TD.

b. Record the computed values of qm for each sampled point on the appropriate line of the column labeled qm on Form TD. Sum the values of qm for all points included in the run and enter this value (Qm) in the block so labeled.

9.5. Isokinetic Sample Volume Determination. (Form TD: Test Run Data Sheet).

a. For each point samples during the run, compute the volume of sample gas (adjusted to 68 °F and 29.92 inches of Hg) that would have been drawn through the sampling nozzle if isokinetic conditions were maintained, as indicated below:

qo = Isokinetic sample volume, the volume of sampled gas (in cubic feet) for each sampled point, if isokinetic conditions were maintained, adjusted to standard conditions of 68 °F and 29.92 inches of Hg. For conditions where static pressure in the duct or stack being tested is more than 20 in. H_2O, consult with Director or his designee.

$$qo = \frac{60\ (528)\ (Fp)\ (An)}{\Delta t} \cdot \left[\frac{\Delta H}{Ts + 460}\right]^{.5}$$

WHERE,

Fp = combined correction factor for units and Pitot tube deviation:

Standard tube = 2.90 (units) x 1.00 (deviation) = 2.90

Type S tube = 2.90 (units) x 0.83*(deviation) = 2.41

*Note: The deviation for the Type S tube may vary for different sampling configurations and should be determined by calibration against a standard pitot tube for each Pitobe arrangement per Method 2 of 40 CFR, Part 60, Appendix A [as of July 1, ~~1988~~1994].

An = the cross-sectional area of the sampling nozzle in (ft^2)

ΔH = Pitot tube differential reading** in inches of H_2

**Note: If the particular pitot tube differential indicator used is calibrated to give a reading of the square root of ΔH ($\sqrt{\Delta H}$), change the heading of the "ΔH" column on Form TD to $\sqrt{\Delta H}$ and modify your computations for qo as appropriate.

Ts = Average stack gas temperature (in °F) at each sampled point during the extraction time at that point.

Δt = elapsed time at each sampling point (minutes)

b. Record the computed values of qo for each sampled point on the appropriate line of the column labeled qo on Form TD. Sum the values of qo for all points included in the run and enter this value (Qo) in the block so designated.

9.6. Fractional Isokinetic Rate Determination. (Form TD: Test Run Data Sheet).

a. For each point sampled during the run, compute the point isokinetic factor (ISKp), which indicates the average degree of deviation from isokinetic conditions during the sampling (extraction) time at that point. ISKp is computed as follows:

ISKp = the point isokinetic factor, the ratio of the actual sample volume to the isokinetic sample volume, both volumes adjusted to standard conditions of 68 °F and 29.92 inches of Hg

$$ISKp = \frac{qm}{qo}$$

WHERE,

qm is defined in Sub-Section 9.4 and qo is defined in Sub-Section 9.5 of this ~~rule~~Appendix, both values are recorded for each point on Form TD.

b. Record the computed value of ISKp for each sampled point on the appropriate line of the column labeled ISKp on Form TD. The value of ISKp for each sampled point should not vary greatly from the overall isokinetic factor (ISKo).

c. For each run, compute the overall isokinetic factor (ISKo), which indicates the overall degree of deviation from isokinetic conditions during the run, and which is used in the weight emission rate computations of the next section. ISKo is computed as follows:

ISKo = the overall isokinetic factor, the ratio of the total actual sample volume to the total isokinetic sample volume, both volumes adjusted to standard conditions of 68 °F and 29.92 inches of Hg.

$$ISKo = \frac{Qm}{Qo}$$

WHERE,

Qm is defined in Sub-Section 9.4 and Qo is defined in Sub-Section 9.5 of this ~~rule~~Appendix, both values are recorded for each run on Form TD.

d. Record the computed value of ISKo for each run in the block so designated on Form TD. If the value of ISKo is outside the range of 0.9 to 1.10, reject the run result.

e. Compute the value %ISK as follows: retain the sign and record on Form TR-II: Summary of Test Run Results.

$$\%ISK = 100 \quad (ISKo - 1)$$

9.7. Particulate Matter Emission Rate Determination. (Form TD: Test Run Data Sheet, Form TR-II: Summary of Test Run Results).

The particulate matter emission rate for each run is computed from the following equation:

$$M(P)n = \frac{Mn}{C} \cdot \frac{As}{An} \cdot \frac{60}{\Theta} \cdot \frac{1}{ISKo}$$

WHERE,

M(P)n = the particulate matter emission rate (in pounds per hour) for the test run

Mn = Mf + Ma - Ab indicated weight of particulate matter (in grams) collected by the sampling train.

C = 453.592 grams/pound

As = the cross-sectional area of the sampling plane (ft^2)

An = the cross-sectional area of the sampling nozzle (ft^2)

60 = 60 minutes per hour

Θ = the sum of all extraction times at all points sampled per run (the sum of Δt's). The total sampling time, not including movement time from port to port.

ISKo = Qm/Qo = the overall isokinetic factor for the run. The ratio of total actual volume sampled to the total isokinetic volume, both values adjusted to 68 °F and 29.92 inches of Hg on a wet basis.

The values of Mn, As, An, Θ and ISKo for each run are recorded on Form TD: Test Run Data Sheet.

Record the value of M(P)n for each test run on Form TR-II: Summary of Test Run Results.

9.8. If more than one sampling plane was required to evaluate the total stack emission rate, perform the computation specified in 9.7 of this ~~rule~~Appendix for each sampling plane, then sum the values of M(P)n for all sampling planes used. Record the total emission rate for each run (all sampling planes) on Form TR-II as above, then compute the average stack emission rate for the test. Note the number and designations of the sampling planes used under comments. If more than one sampling train was used simultaneously to sample the required number of sampling points at one sampling plane, the values of Mn, Qm, and Qo are the sum total values for all the sampling trains used for the one sampling plane.

9.9. Heat Input Determinations. (Forms THI-II: Heat Input Data Sheets: Form TOA; Laboratory Data Sheet (Orsat); Form TR-II: Summary of Test Run Results).

a. This Sub-Section prescribes three (3) methods of computing the total heat input to the (similar) fuel burning unit(s) vented by the test stack:

Method 1H - Fuel Use Basis
Method 2H - Steam Balance Basis
Method 3H - Flue Gas Analysis Basis

Submit data and computations on the appropriate forms.

b. Summarize the results of the selected computational methods on From TR-II: Summary of Test Run Results for each run. Record the type units tested (see definitions for type), the total number of similar units associated with the test run results, the two values of the total heat input for all the units associated with the test run results, as computed by the two selected methods, the total design heat input and the total maximum normal operating load for the units associated with the test result (see definitions for the heat input terms).

9.10. Method 1H - Fuel Use Basis.

a. From the data obtained in accordance with Sub-Section 8.2, Heat Input Data Measurements, compute the heat input for each fuel burning unit for which this method is to be used, as follows:

$$HI = \frac{60}{\Theta} \sum_{i=1}^{n} \frac{(Fi \times HVi)}{10^{5}}$$

WHERE,

HI = Heat input per fuel burning unit(s) in 10^6 Btu per hour

Fi = The quantity of each fuel fired in this fuel burning unit during the total test run period (Θ) in appropriate dimension units (e.g., pounds, gallons, SMCF)

HVi = The average Btu value of each fuel used, in appropriate dimensional units related to the Fi units (e.g., Btu/lb, Btu/gal, Btu/SMCF), on an as fired basis

Θ = The total test run period in minutes. The sum of all extraction intervals (Δt)

n = The number of different fuels fired in the fuel burning unit during the test run period

NOTE = When more than one fuel burning unit is vented by the test stack, sum the individual heat input values for all units of the same type vented by the test stack to obtain the total heat input for the test.

b. Record the values used in the computations, and the results on Form THI-II (1H)

9.11. Method 2H - Steam Balance Basis.

a. From the data obtained in accordance with Sub-Section 8.3 of this ~~rule~~Appendix, compute the heat input for each fuel burning unit for which this method is to be used, as follows:

$$HI = \frac{mf\ (ho - hi) + Mbd\ (hbd)}{10^4\ (BE)}$$

WHERE,

HI = Heat input per fuel burning unit in 10^6 Btu per hour

ho = Average enthalpy of steam/water or other media leaving the boiler of the fuel burning unit in Btu/lbm

hi = Average enthalpy of steam/water or other media entering the boiler of the fuel burning unit in Btu/lb

mf = Average mass flow rate of steam/water or other media through the boiler in lbm/hour

Mbd = Average mass flow rate of blowdown in lbm/hour

hbd = Average enthalpy of steam/water or other media leaving the boiler as blowdown in Btu/lbm

BE = The boiler thermal efficiency (percent)

NOTE: The enthalpy values for the above equation can be determined from the inlet and outlet temperatures and pressures of the steam/water or other media flowing through the boiler using appropriate steam tables.

b. Record the steam flow, temperatures, pressures, and enthalpy values on the steam/water or other media circuit flow diagram required on Form THI-II (2H). Also record the necessary calculations and results on Form THI-II (2H) or attached sheet(s). Sum the heat input values of all fuel burning units of the same type vented by the test stack.

9.12. Method 3H - Flue Gas Analysis Basis:

a. From data obtained in accordance with Sub-Section 8.4 of this ~~rule~~Appendix, compute the heat input for each fuel burning unit for which this method is to be used, as follows:

$$HI = \frac{\dfrac{Vmstd}{An} \cdot \dfrac{As}{20.9} \cdot (20.9 - \%O_2)}{\text{F-factor} \cdot \dfrac{\Theta}{60}}$$

WHERE,

HI = Heat input per fuel burning unit in 10^6 Btu per hour

Vmstd = Volume of gas sample measured by the dry gas meter during run corrected to standard conditions of 68 °F and 29.92 inches Hg.

As = Cross-sectional area of the sampling plane (ft^2)

An = Cross-sectional area of the sampling nozzle (ft^2)

$\%O_2$ = Percent oxygen content by volume as taken from Orsat analysis on Form TOA

F-factor = a factor representing a ration of the dry flue gases generated to the calorific value of the fuel combusted ($dscf/10^6$ Btu), See 40 CFR, Part 60, Subpart D

Θ = Sum of all extraction time at all points sampled per run (minutes)

b. Record Vmstd, $\%O_2$, F-factor, and Θ on Form THI-II (3H). Record calculations.

~~§45-TP2-10. Inconsistency Between Regulations.~~

~~10.1. In the event of any inconsistency between this regulation and any other regulation of the Commission, such inconsistency shall be resolved by the determination of the Director and such determination shall be based upon the application of the more stringent provision, term, condition, method, rule or regulation.~~

45CSR2 ATTACHMENTS

STACK TEST REPORT

Facility ______________________________

Unit(s) ______________________________

Stack ______________________________

Conducted by

____

Under Regulation ______________________________

Submitted on ______________________________

to the

STATE OF WEST VIRGINIA
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY

Subject: STACK TEST REPORT

TEST NUMBER ☐

To:

West Virginia Division of Environmental Protection
Office of Air Quality
1558 Washington Street, East
Charleston, WV 25311

(For OAQ Use Only)

IDENTIFICATION

I. Facility

A. Parent Organization ______________________________

B. Facility Name ______________________________

C. Facility Address/Location ______________________________

____

D. Individual to Contact Regarding this Report:

Name ______________________________

Title ______________________________

Address ______________________________

Telephone ______________________________

E. Source Operation Tested ______________________________

____

F. Type of Control Equipment ______________________________

____

G. Stack Designation ______________________________

TEST SUPERVISOR (type)	(Signature)	(Date)

Stack Test Report   Test #

SUMMARY OF TEST RUN RESULTS (TR-II)

	Stack Designation*
Type Units Vented by Stack (circle)	

	Run #1	Run #2	Run #3
Number of Units Vented By Stack			
Total Heat Input (MMBtu/hr) - Method 1H			
Total Heat Input (MMBtu/hr) - Method 2H			
Total Heat Input (MMBtu/hr) - Method 3H			
Normal Max Operating Load (MMBtu/hr)			
Total Design Heat Input (MMBtu/hr)			
Total Coal Fired (pounds)			
Average Percent Ash (coal)			
Average Percent Sulfur (coal)			
Total Oil Fired (gallons) No._____ Oil			
Average Percent Sulfur (oil)			
Total Gas Fired (MCF)			
Other ____________________ ( )			

Date Run Began			
Time Run Began			
Length of Run, minutes ( )			
Number of Points Sampled			

Percent Isokinetic Conditions: %ISK			
Total Sample Volume (Qm) (ft³)			
Percent Moisture: (B x 100)			

Particulate Matter Emission Rate (lbs/hr)			

Test Result	

For WVAPCC Use Only	

Comments:

*As registered with the Commission under Regulation II.

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Stack Test Report Test #

SAMPLING SITE DATA SHEET

Site Identification #

Sampling Plane Schematic: (Show cross-sectional dimensions, port and point locations, deposit buildup, etc.)

Point Sampling time (Δt):

(1) As: ft2

(2) Nearest Upstream Disturbance Dia's

(3)Nearest Downstream Disturbance

(4) For Rect. Ducts: Equal Areas l/w ratio

Minimum Required No. of Points

By Item	No. Points	Ck

Diameter or Equivalent Diameter*:

Sampling Site Layout. (Show dimensions, general arrangement, bends, baffles, disturbances, with respect to the sampling plane.)

*Eq Dia = 2 [(length) (width)/(length + width)] ; for Rectangular Ducts.

Continuation:

Test #

TEST RUN DATA SHEET (Continuation)

Run #

Fp =
θ =
Ps =
Pb =
Mg/29 =
As =
An =
m =
W =

Sampling Train Identification:

TEST		Δ t	Δ H	Ts	DGR	Δ DGR (calc)	Tm	Vac	Tf	Pm (calc)		qm (calc)	qo (calc)	ISKp (calc)
Time*	Point													
						Vm	$\overline{Tm}$			$\overline{Pm}$		Qm	Qo	ISKo

*Local time sampling began at each point.

Test #

TEST RUN DATA SHEET (Continuation)

Run #

TEST		Δt	ΔH	Ts	DGR	ΔDGR (calc)	Tm	Vac	Tf	Pm (calc)		qm (calc)	qo (calc)	ISKp (calc)
Time*	Point													
						Vm	$\overline{Tm}$			$\overline{Pm}$		Qm	Qo	ISKo

*Local time sampling began at each point.

LABORATORY DATA SHEET
(Particulate)

Test #:

ITEM/IDENTIFICATION

WEIGHT (GRAMS)

(1) Prefilter

	R1	R2	R3	B
IDN				

	Run #1	Run #2	Run #3
(1)			

(2) Primary Filter

	R1	R2	R3	B
IDN				

	Run #1	Run #2	Run #3
(2)			

Mf = sum of (1) & (2)

(3) Acetone Wash

	R1	R2	R3	B
IDN				

Sd = (a)/(b)

Sd= gm/ml

	Run #1	Run #2	Run #3		Blank(s)	
						After
						Tare
Ma				(a)		Change
Va=				(b)		Wash Volume (ml)

Ab = (Va)(Sd) =			

Summation

Prefilter	(1) =			
Primary Filter	(2) =			
Acetone Wash	Ma =			
	Subtotal =			
	-Ab =			
	Mn =			

Laboratory Official (type)	(Signature)	(Date)

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Stack Test Report

LABORATORY DATA SHEET
(Moisture)

Test #

ITEMS/IDENTIFICATION

WEIGHT(gms)/VOLUME*(ml)

(1) Impingers/Condensers

	R1	R2	R3
IDN			

	Run #1	Run #2	Run #3	
Wc=				after
				tare
				change

(2) Desiccant Containers

	R1	R2	R3
IDN			

	Run #1	Run #2	Run #3	
Wd=				after
				tare
				change

(3) Summation: W=Wc + Wd =				TOTAL GRAMS

(4) $B = W/ [\{ 374 (\overline{Pm}) (Vm)/(\overline{Tm} + 460) \} + W]$

Run #1: B = (   )/ [{ 374 (   ) (   )/(   )} + (   )] =

Run #2: B = (   )/ [{ 374 (   ) (   )/(   )} + (   )] =

Run #3: B = (   )/ [{ 374 (   ) (   )/(   )} + (   )] =

(5) $w = 1/(1-B)$

	Run #1	Run #2	Run #3
w = moisture correction factor =			

*1 ml equivalent to 1 gram to room temperature

LABORATORY OFFICIAL (type)	(Signature)	(Date)

Stack Test Report

LABORATORY DATA SHEET
(Orsat)

Test #

	Run #1					Run #2					Run #3				
	Date					Date					Date				
	% By Vol., (Dry Basis)					% By Vol., (Dry Basis)					% By Vol., (Dry Basis)				
	Time	CO_2	O_2	CO	N_2	Time	CO_2	O_2	CO	N_2	Time	CO_2	O_2	CO	N_2
1															
2															
3															
4															
5															
6															
7															
8															
9															
10	Avg					Avg					Avg				
11	Comp					Comp					Comp				

	Run #1	Run #2	Run #3
12	w = (13)	w = (13)	w = (13)
	% by vol. (Wet Basis)(B)	% by vol.(Wet Basis)(B)	% by vol. (Wet Basis)(B)

	CO_2	O_2	CO	N_2	H_2O	CO_2	O_2	CO	N_2	H_2O	CO_2	O_2	CO	N_2	H_2O
14															
15	44	32	28	28	18	44	32	28	28	18	44	32	28	28	18
16															

	Run #1	Run #2	Run #3
17	Mol Wt = ☐ =Mg	☐ =Mg	☐ =Mg
18	Mg/29= ☐ =	Mg/29= ☐ =	Mg/29= ☐ =
19	Ex. Air = ☐ = EA	Ex. Air = ☐ =EA	Ex. Air = ☐ = EA

20 WHERE EA* = $\frac{(\%O_2) - (\%CO/2)}{0.264\ (\%N_2) - (\%\ O_2) + (\%CO/2)}$

*Not applicable when procedure gas, blast furnace gas, or other fuels high in N2 are used.

LABORATORY OFFICIAL (Type)	(Signature)	(Date)

LABORATORY DATA SHEET
(Fuels)

TEST #

Sample Number	Fuel Sampling Data			Type Fuel	Fuel Quality Data				
	Gross* Sample lbs	Increments (No.)	Laboratory* Sample lbs		Moisture as rec'd % by Wt.	Ash as rec'd % by Wt.	Sulfur as rec'd % by Wt.	Btu Content as rec'd Btu/lb	Prior* Surface Moisture lost (%)
Run #									
Run #									
Run #									

TEST SUPERVISOR (type)

LABORATORY OFFICIAL (type)

(Signature)

(Signature)

* Note surface moisture lost during reduction of gross coal sample to laboratory sample in percent (%), as applicable.

(Date)

Stack Test Report Test #

HEAT INPUT DATA SHEET - 1H
(Steam Balance Basis)

Run #

Number and Type* Unit	Type Fuel	Ash Pf	Fuel Fired Fi (pounds)	Heating Value (HVi) (Btu/lb)	Heat Input (HI) 10^6 Btu/hr	Sample No.***
Totals**	Pf = ash fractions			1, as fired		
a	▨			▨		▨
b	▨			▨		▨
c	▨			▨		▨

* Type a, b, c; see definitions. List all fuels fired under each unit designation before listing the next unit.

** List the total heat input for each type unit separately. If Method 1H, 2H, or 3H were used in combination to determine the Heat Inputs explain the method of prorating the heat input between the different applicable. (Use additional sheets as necessary.)

*** As listed on Form TAF, Laboratory Data Sheet (Fuels).

θ = min.

PROCESS OBSERVER (type)	(Signature)	(Date)

Stack Test Report Test #

HEAT INPUT DATA SHEET - 2H (Steam Balance Basis)	Run #

Continuation:

$$HI = \frac{Vmstd \cdot \left[\frac{As}{An}\right] \cdot \left[\frac{20.9 - \%O_2}{20.9}\right]}{10^6 \cdot [F\text{-factor}] \cdot 1/60 \cdot \Theta}$$

WHERE,

$\frac{As}{An}$ =

F-factor =

Run #	Vmstd (dscf)	$\%O_2$	Θ (minutes)	HI (10^6 Btu/hr)

HEAT INPUT DATA SHEET - 2H (Steam Balance Basis)	Run #
Heat Input for all fuels fired in this unit during the test run period: 10^6 Btu/hr	BE:
	Type Fuel Burning Unit a b c
Unit Designation:	θ =

Schematic Flow Diagram and Computations:

Note: Use additional blank sheets as necessary. Record the Heat Input for this unit in the appropriate column for Form THI-II (1H).

most recent performance test that demonstrated compliance.

(2) For those affected facilities monitoring both the carbon adsorption system inlet and outlet concentration levels of organic compounds, the periods (during actual coating operations), specified in paragraph (d)(2)(i) or (ii) of this section, as applicable.

(i) For carbon adsorption systems with a common exhaust stack for all the individual adsorber vessels, all periods of three consecutive adsorption cycles of all the individual adsorber vessels during which the average carbon adsorption system efficiency falls below the applicable level as follows:

(A) For those affected facilities demonstrating compliance by the performance test method described in §60.743(a)(1), the value of E determined using Equation (1) during the most recent performance test that demonstrated compliance.

(B) For those affected facilities demonstrating compliance by the performance test described in §60.743(a)(4), the average value of the system efficiency measured with the monitor during the most recent performance test that demonstrated compliance.

(C) For those affected facilities demonstrating compliance pursuant to §60.743(b) or (c), 0.95.

(ii) For carbon adsorption systems with individual exhaust stacks for each adsorber vessel, all 3-day rolling averages for each adsorber vessel during which the average carbon adsorber vessel efficiency falls below the applicable level as follows:

(A) For those affected facilities demonstrating compliance by the performance test method described in §60.743(a)(2), (b), or (c), the value of H_v determined using Equation (3) during the most recent performance test that demonstrated compliance.

(B) For those affected facilities demonstrating compliance by the performance test described in §60.743(a)(4), the average efficiency for that adsorber vessel measured with the monitor during the most recent performance test that demonstrated compliance.

(3) For those affected facilities monitoring condenser exhaust gas temperature, all 3-hour periods (during actual coating operations) during which the average exhaust temperature is 5 or more Celsius degrees above the average temperature measured during the most recent performance test that demonstrated compliance;

(4) For those affected facilities monitoring thermal incinerator combustion gas temperature, all 3-hour periods (during actual coating operations) during which the average combustion temperature of the device is more than 28 Celsius degrees below the average combustion temperature of the device during the most recent performance test that demonstrated compliance;

(5) For those affected facilities monitoring catalytic incinerator catalyst bed temperature, all 3-hour periods (during actual coating operations) during which the average gas temperature immediately before the catalyst bed is more than 28 Celsius degrees below the average gas temperature during the most recent performance test that demonstrated compliance and all 3-hour periods (during actual coating operations) during which the average gas temperature difference across the catalyst bed is less than 80 percent of the average gas temperature difference during the most recent performance test that demonstrated compliance;

(6) For each affected facility monitoring a total enclosure pursuant to §60.744(h) or vapor capture system pursuant to §60.744(g), all 3-hour periods (during actual coating operations) during which the average total enclosure or vapor capture system monitor readings vary by 5 percent or more from the average value measured during the most recent performance test that demonstrated compliance.

(7) Each owner or operator of an affected coating operation not required to submit reports under paragraphs (d)(1) through (6) of this section because no reportable periods have occurred shall submit semiannual statements clarifying this fact.

(e) Each owner or operator of an affected coating operation, demonstrating compliance by the test methods described in §60.743(a)(3) (liquid-liquid material balance) shall submit the following:

(1) For months of compliance, semiannual reports to the Administrator stating that the affected coating operation was in compliance for each 1-month period; and

(2) For months of noncompliance, quarterly reports to the Administrator documenting the 1-month amount of VOC contained in the coatings, the 1-month amount of VOC recovered, and the percent emission reduction for each month.

(f) Each owner or operator of an affected coating operation, either by itself or with associated coating mix preparation equipment, shall submit the following with the reports required under paragraphs (d) and (e) of this section:

(1) All periods during actual mixing or coating operations when a required monitoring device (if any) was malfunctioning or not operating; and

(2) All periods during actual mixing or coating operations when the control device was malfunctioning or not operating.

(g) The reports required under paragraphs (b), (c), (d), and (e) of this section shall be postmarked within 30 days of the end of the reporting period.

(h) Records required in §60.747 must be retained for at least 2 years.

(i) The requirements of this section remain in force until and unless EPA, in delegating enforcement authority to a State under section 111(c) of the Act, approves reporting requirements or an alternative means of compliance surveillance adopted by such States. In this event, affected sources within the State will be relieved of the obligation to comply with this subsection, provided that they comply with the requirements established by the State.

§60.748 Delegation of authority.

(a) In delegating implementation and enforcement authority to a State under section 111(c) of the Act, the authorities contained in paragraph (b) of this section shall be retained by the Administrator and not transferred to a State.

(b) Authorities that will not be delegated to States: §§60.743(a)(3)(v) (A) and (B); 60.743(e); 60.745(a); 60.746.

APPENDIXES TO PART 60

APPENDIX A—TEST METHODS

Method 1—Sample and velocity traverses for stationary sources
Method 1A—Sample and velocity traverses for stationary sources with small stacks or ducts
Method 2—Determination of stack gas velocity and volumetric flow rate (Type S pitot tube)
Method 2A—Direct measurement of gas volume through pipes and small ducts
Method 2B—Determination of exhaust gas volume flow rate from gasoline vapor incinerators
Method 2C—Determination of stack gas velocity and volumetric flow rate in small stacks or ducts (standard pitot tube)
Method 2D—Measurement of gas volumetric flow rates in small pipes and ducts
Method 3—Gas analysis for carbon dioxide, oxygen, excess air, and dry molecular weight
Method 3A—Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedure)
Method 4—Determination of moisture content in stack gases
Method 5—Determination of particulate emissions from stationary sources
Method 5A—Determination of particulate emissions from the asphalt processing and asphalt roofing industry
Method 5B—Determination of nonsulfuric acid particulate matter from stationary sources
Method 5C [Reserved]
Method 5D—Determination of particulate emissions from positive pressure fabric filters
Method 5E—Determination of particulate emissions from the wool fiberglass insulation manufacturing industry
Method 5F—Determination of nonsulfate particulate matter from stationary sources
Method 5G—Determination of particulate emissions from wood heaters from a dilution tunnel sampling location
Method 5H—Determination of particulate emissions from wood heaters from a stack location
Method 6—Determination of sulfur dioxide emissions from stationary sources
Method 6A—Determination of sulfur dioxide, moisture, and carbon dioxide emissions from fossil fuel combustion sources
Method 6B—Determination of sulfur dioxide and carbon dioxide daily average emissions from fossil fuel combustion sources

Method 6C—Determination of Sulfur Dioxide Emissions From Stationary Sources (Instrumental Analyzer Procedure)
Method 7—Determination of nitrogen oxide emissions from stationary sources
Method 7A—Determination of nitrogen oxide emissions from stationary sources—Ion chromatographic method
Method 7B—Determination of nitrogen oxide emissions from stationary sources (Ultraviolet spectrophotometry)
Method 7C—Determination of nitrogen oxide emissions from stationary sources—Alkaline-permanganate/colorimetric method
Method 7D—Determination of nitrogen oxide emissions from stationary sources—Alkaline-permanganate/ion chromatographic method
Method 7E—Determination of Nitrogen Oxides Emissions From Stationary Sources (Instrumental Analyzer Procedure)
Method 8—Determination of sulfuric acid mist and sulfur dioxide emissions from stationary sources
Method 9—Visual determination of the opacity of emissions from stationary sources
Alternate method 1—Determination of the opacity of emissions from stationary sources remotely by lidar
Method 10—Determination of carbon monoxide emissions from stationary sources
Method 10A—Determination of carbon monoxide emissions in certifying continuous emission monitoring systems at petroleum refineries
Method 10B—Determination of carbon monoxide emissions from stationary sources
Method 11—Determination of hydrogen sulfide content of fuel gas streams in petroleum refineries
Method 12—Determination of inorganic lead emissions from stationary sources
Method 13A—Determination of total fluoride emissions from stationary sources—SPADNS zirconium lake method
Method 13B—Determination of total fluoride emissions from stationary sources—Specific ion electrode method
Method 14—Determination of fluoride emissions from potroom roof monitors for primary aluminum plants
Method 15—Determination of hydrogen sulfide, carbonyl sulfide, and carbon disulfide emissions from stationary sources
Method 15A—Determination of total reduced sulfur emissions from sulfur recovery plants in petroleum refineries
Method 16—Semicontinuous determination of sulfur emissions from stationary sources
Method 16A—Determination of total reduced sulfur emissions from stationary sources (impinger technique)
Method 16B—Determination of total reduced sulfur emissions from stationary sources
Method 17—Determination of particulate emissions from stationary sources (instack filtration method)
Method 18—Measurement of gaseous organic compound emissions by gas chromatography
Method 19—Determination of sulfur dioxide removal efficiency and particulate, sulfur dioxide and nitrogen oxides emission rates
Method 20—Determination of nitrogen oxides, sulfur dioxide, and diluent emissions from stationary gas turbines
Method 21—Determination of volatile organic compound leaks
Method 22—Visual determination of fugitive emissions from material sources and smoke emissions from flares
Method 23—Determination of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans From Stationary Sources
Method 24—Determination of volatile matter content, water content, density, volume solids, and weight solids of surface coatings
Method 24A—Determination of volatile matter content and density of printing inks and related coatings
Method 25—Determination of total gaseous nonmethane organic emissions as carbon
Method 25A—Determination of total gaseous organic concentration using a flame ionization analyzer
Method 25B—Determination of total gaseous organic concentration using a nondispersive infrared analyzer
Method 26—Determination of Hydrogen Chloride Emissions From Stationary Sources
Method 27—Determination of vapor tightness of gasoline delivery tank using pressure-vacuum test
Method 28—Certification and auditing of wood heaters
Method 28A—Measurement of air to fuel ratio and minimum achievable burn rates for wood-fired appliances

The test methods in this appendix are referred to in §60.8 (Performance Tests) and §60.11 (Compliance With Standards and Maintenance Requirements) of 40 CFR part 60, subpart A (General Provisions). Specific uses of these test methods are described in the standards of performance contained in the subparts, beginning with Subpart D.

Within each standard of performance, a section title "Test Methods and Procedures" is provided to: (1) Identify the test methods to be used as reference methods to the facility subject to the respective standard and (2) identify any special instructions or conditions to be followed when applying a method to the respective facility. Such instructions (for example, establish sampling rates, volumes, or temperatures) are to be used either in addition to, or as a substitute for procedures in a test method. Similarly, for sources subject to emission monitoring requirements, specific instructions pertaining to any use of a test method as a reference method are provided in the subpart or in Appendix B.

Inclusion of methods in this appendix is not intended as an endorsement or denial of their applicability to sources that are not subject to standards of performance. The methods are potentially applicable to other sources; however, applicability should be confirmed by careful and appropriate evaluation of the conditions prevalent at such sources.

The approach followed in the formulation of the test methods involves specifications for equipment, procedures, and performance. In concept, a performance specification approach would be preferable in all methods because this allows the greatest flexibility to the user. In practice, however, this approach is impractical in most cases because performance specifications cannot be established. Most of the methods described herein, therefore, involve specific equipment specifications and procedures, and only a few methods in this appendix rely on performance criteria.

Minor changes in the test methods should not necessarily affect the validity of the results and it is recognized that alternative and equivalent methods exist. Section 60.8 provides authority for the Administrator to specify or approve (1) equivalent methods, (2) alternative methods, and (3) minor changes in the methodology of the test methods. It should be clearly understood that unless otherwise identified all such methods and changes must have prior approval of the Administrator. An owner employing such methods or deviations from the test methods without obtaining prior approval does so at the risk of subsequent disapproval and retesting with approved methods.

Within the test methods, certain specific equipment or procedures are recognized as being acceptable or potentially acceptable and are specifically identified in the methods. The items identified as acceptable options may be used without approval but must be identified in the test report. The potentially approvable options are cited as "subject to the approval of the Administrator" or as "or equivalent." Such potentially approvable techniques or alternatives may be used at the discretion of the owner without prior approval. However, detailed descriptions for applying these potentially approvable techniques or alternatives are not provided in the test methods. Also, the potentially approvable options are not necessarily acceptable in all applications. Therefore, an owner electing to use such potentially approvable techniques or alternatives is responsible for: (1) assuring that the techniques or alternatives are in fact applicable and are properly executed; (2) including a written description of the alternative method in the test report (the written method must be clear and must be capable of being performed without additional instruction, and the the degree of detail should be similar to the detail contained in the test methods); and (3) providing any rationale or supporting data necessary to show the validity of the alternative in the particular application. Failure to meet these requirements can result in the Administrator's disapproval of the alternative.

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. To aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

1.2 Applicability. This method is applicable to flowing gas streams in ducts, stacks, and flues. The method cannot be used when: (1) flow is cyclonic or swirling (see Section 2.4), (2) a stack is smaller than about 0.30 meter (12 in.) in diameter, or 0.071 m² (113 in.²) cross-sectional area, or (3) the measurement site is less than two stack or duct diameters downstream or less than a half diameter upstream from a flow disturbance.

The requirements of this method must be considered before construction of a new facility from which emissions will be measured; failure to do so may require subsequent alterations to the stack or deviation from the standard procedure. Cases involving variants are subject to approval by the Administrator, U.S. Environmental Protection Agency.

2. *Procedure*

2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected, at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (D_e) shall be calculated from the following equation, to determine the upstream and downstream distances:

$$D_e = \frac{2LW}{(L+W)}$$

where L=length and W=width.

An alternative procedure is available for determining the acceptability of a measurement location not meeting the criteria above. This procedure, determination of gas flow angles at the sampling points and comparing the results with acceptability criteria, is described in Section 2.5.

2.2 Determining the Number of Traverse Points.

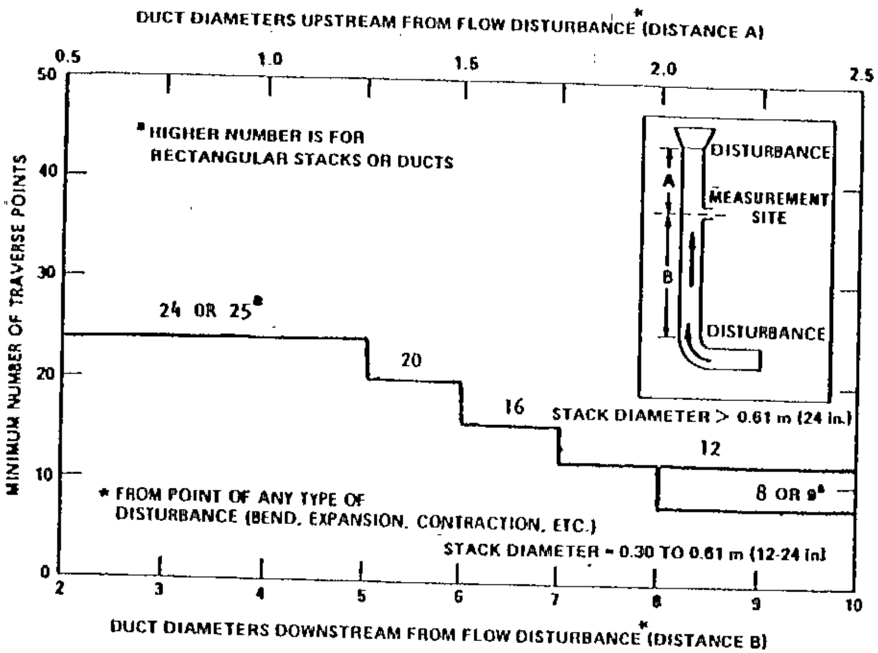

Figure 1-1. Minimum number of traverse points for particulate traverses.

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12–24 in.); (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12–24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1–1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1–1 the minimum number of traverse points that corresponds: (1) to the number of duct diameters upstream; and (2) to the number of diameters downstream. Select the higher of the two minimum numbers of traverse points, or a greater value, so that for circular stacks the number is a multiple of 4, and for rectangular stacks, the number is one of those shown in Table 1–1.

TABLE 1–1. CROSS-SECTION LAYOUT FOR RECTANGULAR STACKS

Number of traverse points	Matrix layout
9	3x3
12	4x3
16	4x4
20	5x4
25	5x5
30	6x5
36	6x6
42	7x6
49	7x7

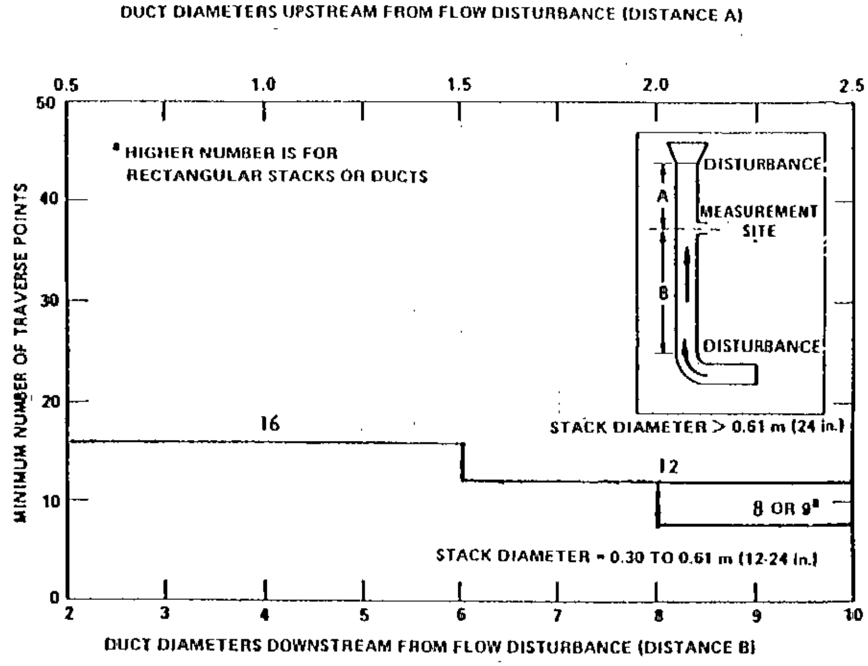

Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

2.2.2 Velocity (Non-Particulate) Traverses. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1–2 may be used instead of Figure 1–1.

2.3 Cross-sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1–2 and the example shown in Figure 1–3. Any equation (for examples, see Citations 2 and 3 in the Bibliography) that gives the same values as those in Table 1–2 may be used in lieu of Table 1–2.

For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation, e.g., after bends, one diameter shall be in the plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls; and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls. To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.). When any of the traverse points as located in Section 2.3.1 fall within 2.5 cm (1.00 in.) of the stack walls, relocate them away from the stack walls to: (1) a distance of 2.5 cm (1.00 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

Whenever two successive traverse points are combined to form a single adjusted traverse point, treat the adjusted point as two separate traverse points, both in the sampling (or velocity measurement) procedure, and in recording the data.

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.7
3	29.5
4	70.5
5	85.3
6	95.6

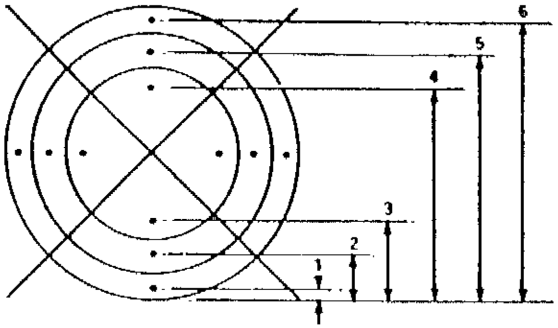

Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

TABLE 1–2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

[Percent of stack diameter from inside wall to traverse point]

Traverse point number on a diameter	Number of traverse points on a diameter—											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	......	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	......	93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5	......	......	85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6	......	......	95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7	......	......	......	89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8	......	......	......	96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9	......	......	......	......	91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10	......	......	......	......	97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11	......	......	......	......	......	93.3	85.4	78.0	70.4	61.2	39.3	32.3
12	......	......	......	......	......	97.9	90.1	83.1	76.4	69.4	60.7	39.8
13	......	......	......	......	......	......	94.3	87.5	81.2	75.0	68.5	60.2
14	......	......	......	......	......	......	98.2	91.5	85.4	79.6	73.8	67.7
15	......	......	......	......	......	......	......	95.1	89.1	83.5	78.2	72.8
16	......	......	......	......	......	......	......	98.4	92.5	87.1	82.0	77.0
17	......	......	......	......	......	......	......	......	95.6	90.3	85.4	80.6
18	......	......	......	......	......	......	......	......	98.6	93.3	88.4	83.9
19	......	......	......	......	......	......	......	......	......	96.1	91.3	86.8
20	......	......	......	......	......	......	......	......	......	98.7	94.0	89.5
21	......	......	......	......	......	......	......	......	......	......	96.5	92.1
22	......	......	......	......	......	......	......	......	......	......	98.9	94.5
23	......	......	......	......	......	......	......	......	......	......	......	96.8
24	......	......	......	......	......	......	......	......	......	......	......	98.9

2.3.1.2 Stacks With Diameters Equal to or Less Than 0.61 m (24 in.). Follow the procedure in Section 2.3.1.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3.2 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one or the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4x3 "minimum number of points" matrix were expanded to 36 points, the final matrix could be 9x4 or 12x3, and would not necessarily have to be 6x6. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.4 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

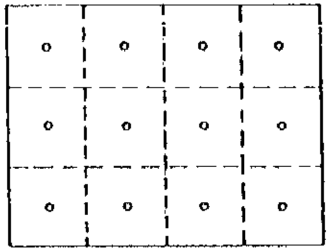

Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of α; assign α values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 20°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

The alternative procedure described in Section 2.5 may be used to determine the rotation angles in lieu of the procedure described above.

2.5 Alternative Measurement Site Selection Procedure. This alternative applies to sources where measurement locations are less than 2 equivalent stack or duct diameters downstream or less than ½ duct diameter upstream from a flow disturbance. The alternative should be limited to ducts larger than 24 in. in diameter where blockage and wall effects are minimal. A directional flow-sensing probe is used to measure pitch and yaw angles of the gas flow at 40 or more traverse points; the resultant angle is calculated and compared with acceptable criteria for mean and standard deviation.

NOTE: Both the pitch and yaw angles are measured from a line passing through the traverse point and parallel to the stack axis. The pitch angle is the angle of the gas flow component in the plane that INCLUDES the traverse line and is parallel to the stack axis. The yaw angle is the angle of the gas flow component in the plane PERPENDICULAR to the traverse line at the traverse point and is measured from the line passing through the traverse point and parallel to the stack axis.

2.5.1 Apparatus.

2.5.1.1 Directional Probe. Any directional probe, such as United Sensor Type DA Three-Dimensional Directional Probe, capable of measuring both the pitch and yaw angles of gas flows is acceptable. (NOTE: Mention of trade name or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.) Assign an identification number to the directional probe, and permanently mark or engrave the number on the body of the probe. The pressure holes of directional probes are susceptible to plugging when used in particulate-laden gas streams. Therefore, a system for cleaning the pressure holes by "back-purging" with pressurized air is required.

2.5.1.2 Differential Pressure Gauges. Inclined manometers, U-tube manometers, or other differential pressure gauges (e.g., magnehelic gauges) that meet the specifications described in Method 2, section 2.2.

NOTE: If the differential pressure gauge produces both negative and positive readings, then both negative and positive pressure readings shall be calibrated at a minimum of three points as specified in Method 2, section 2.2.

2.5.2 Traverse Points. Use a minimum of 40 traverse points for circular ducts and 42 points for rectangular ducts for the gas flow angle determinations. Follow section 2.3 and Table 1-1 or 1-2 for the location and layout of the traverse points. If the measurement location is determined to be acceptable according to the criteria in this alternative procedure, use the same traverse point number and locations for sampling and velocity measurements.

2.5.3 Measurement Procedure.

2.5.3.1 Prepare the directional probe and differential pressure gauges as recommended by the manufacturer. Capillary tubing or surge tanks may be used to dampen pressure fluctuations. It is recommended, but not required, that a pretest leak check be conducted. To perform a leak check, pressurize or use suction on the impact opening until a reading of at least 7.6 cm (3 in.) H_2O registers on the differential pressure gauge, then plug the impact opening. The pressure of a leak-free system will remain stable for at least 15 seconds.

2.5.3.2 Level and zero the manometers. Since the manometer level and zero may drift because of vibrations and temperature changes, periodically check the level and zero during the traverse.

2.5.3.3 Position the probe at the appropriate locations in the gas stream, and rotate until zero deflection is indicated for the yaw angle pressure gauge. Determine and record the yaw angle. Record the pressure gauge readings for the pitch angle, and determine the pitch angle from the calibration curve. Repeat this procedure for each traverse point. Complete a "back-purge" of the pressure lines and the impact openings prior to measurements of each traverse point.

A post-test check as described in section 2.5.3.1 is required. If the criteria for a leak-free system are not met, repair the equipment, and repeat the flow angle measurements.

2.5.4 Calculate the resultant angle at each traverse point, the average resultant angle, and the standard deviation using the following equations. Complete the calculations retaining at least one extra significant figure beyond that of the acquired data. Round the values after the final calculations.

2.5.4.1 Calculate the resultant angle at each traverse point:

$$R_i = \text{arc cosine } [(\text{cosine } Y_i)(\text{cosine } P_i)] \qquad \text{Eq. 1-2}$$

Where:

R_i=Resultant angle at traverse point i, degree.

Y_i=Yaw angle at traverse point i, degree.

P_i=Pitch angle at traverse point i, degree.

2.5.4.2 Calculate the average resultant for the measurements:

$$\bar{R} = \frac{\Sigma R_i}{n} \qquad \text{Eq. 1-3}$$

Where:

$\bar{R}$=Average resultant angle, degree.

n=Total number of traverse points.

2.5.4.3 Calculate the standard deviations:

$$S_d = \sqrt{\frac{\sum_{i=1}^{n}(R_i - \bar{R})^2}{(n-1)}} \qquad \text{Eq. 1-4}$$

Where:

S_d=Standard deviation, degree.

2.5.5 The measurement location is acceptable if $\bar{R} \leq 20°$ and $S_d \leq 10°$.

2.5.6 Calibration. Use a flow system as described in Sections 4.1.2.1 and 4.1.2.2 of Method 2. In addition, the flow system shall have the capacity to generate two test-section velocities: one between 365 and 730 m/min (1200 and 2400 ft/min) and one between 730 and 1100 m/min (2400 and 3600 ft/min).

2.5.6.1 Cut two entry ports in the test section. The axis through the entry ports shall be perpendicular to each other and intersect in the centroid of the test section. The ports should be elongated slots parallel to the axis of the test section and of sufficient length to allow measurement of pitch angles while maintaining the pitot head position at the test-section centroid. To facilitate alignment of the directional probe during calibration, the test section should be constructed of plexiglass or some other transparent material. All calibration measurements should be made at the same point in the test section, preferably at the centroid of the test section.

2.5.6.2 To ensure that the gas flow is parallel to the central axis of the test section, follow the procedure in Section 2.4 for cyclonic flow determination to measure the gas flow angles at the centroid of the test section from two test ports located 90° apart. The gas flow angle measured in each port must be ±2° of 0°. Straightening vanes should be installed, if necessary, to meet this criterion.

2.5.6.3 Pitch Angle Calibration. Perform a calibration traverse according to the manufacturer's recommended protocol in 5° increments for angles from −60° to +60° at one velocity in each of the two ranges specified above. Average the pressure ratio values obtained for each angle in the two flow ranges, and plot a calibration curve with the average values of the pressure ratio (or other suitable measurement factor as recommended by the manufacturer) versus the pitch angle. Draw a smooth line through the data points. Plot also the data values for each traverse point. Determine the differences between the measured data values and the angle from the calibration curve at the same pressure ratio. The difference at each comparison must be within 2° for angles between 0° and 40° and within 3° for angles between 40° and 60°.

2.5.6.4 Yaw Angle Calibration. Mark the three-dimensional probe to allow the determination of the yaw position of the probe. This is usually a line extending the length of the probe and aligned with the impact opening. To determine the accuracy of measurements of the yaw angle, only the zero or null position need be calibrated as follows. Place the directional probe in the test section, and rotate the probe until the zero position is found. With a protractor or other angle measuring device, measure the angle indicated by the yaw angle indicator on the three-dimensional probe. This should be within 2° of 0°. Repeat this measurement for any other points along the length of the pitot where yaw angle measurements could be read in order to account for variations in the pitot markings used to indicate pitot head positions.

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METHOD 1A—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES WITH SMALL STACKS OR DUCTS

1. Applicability and Principle

1.1 The applicability and principle of this method are identical to Method 1, except this method's applicability is limited to stacks or ducts less than about 0.30 meter (12 in.) in diameter or 0.071 m² (113 in.²) in cross-sectional area, but equal to or greater than about 0.10 meter (4 in.) in diameter or 0.0081 m² (12.57 in.²) in cross-sectional area.

1.2 In these small diameter stacks or ducts, the conventional Method 5 stack assembly (consisting of a Type S pitot tube attached to a sampling probe, equipped with a nozzle and thermocouple) blocks a significant portion of the cross section of the duct and causes inaccurate measurements. Therefore, for particulate matter (PM) sampling in small stacks or ducts, the gas velocity is measured using a standard pitot tube downstream of the actual emission sampling site. The straight run of duct between the PM sampling and velocity measurement sites allows the flow profile, temporarily disturbed by the presence of the sampling probe, to redevelop and stabilize.

1.3 The cross-sectional layout and location of traverse points and the verification of the absence of cyclonic flow are the same as in Method 1, Sections 2.3 and 2.4, respectively. Differences from Method 1, except as noted, are given below.

2. Procedure

2.1 Selection of Sampling and Measurement Sites.

2.1.2 PM Sampling (Steady Flow) or only Velocity Measurements. For PM sampling when the volumetric flow rate in a duct is *constant* with respect to time, Section 2.1 of Method 1 may be followed, with the PM sampling and velocity measurement performed at one location. To demonstrate that the flow rate is constant (within 10 percent) when PM measurements are made, perform complete velocity traverses before and after the PM sampling run, and calculate the deviation of the flow rate derived *after the PM* sampling run from the one derived before the PM sampling run. The PM sampling run is acceptable if the deviation does not exceed 10 percent.

2.2 *Determining* the Number of Traverse Points.

2.2.1 PM Sampling. Use Figure 1–1 of Method 1 to determine the number of traverse points to use at both the velocity measurement and PM sampling locations. Before referring to the figure, however, determine the distances between both the velocity *measurement and PM sampling sites* to the nearest upstream and downstream disturbances. Then divide each distance by the stack diameter or equivalent diameter to express the distances in terms of the number of *duct diameters. Next,* determine the number of traverse points from Figure 1–1 of Method 1 corresponding to each of these four distances. Choose the highest of the four numbers of traverse points (or a greater number) so that, for circular ducts, the number is a multiple of four, and for rectangular ducts, the number is one of those shown in Table 1–1 of *Method 1. When the optimum duct diameter* location criteria can be satisfied, the minimum number of traverse points required is eight for circular ducts and nine for rectangular ducts.

2.2.2 *PM Sampling* (Steady Flow) or Velocity Measurements. Use Figure 1–2 of Method 1 to determine the number of traverse points, following the same procedure used for PM sampling traverses as described in Section 2.2.1 of Method 1. When the optimum duct diameter location criteria can be satisfied, the minimum number of traverse points required is eight for circular ducts and nine for rectangular ducts.

3. Bibliography

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METHOD 2—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. *Principle and Applicability*

1.1 Principle. The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

1.2 Applicability. This method is applicable for *measurement of the average velocity* of a gas stream and for quantifying gas flow.

This procedure is not applicable at measurement sites which fail to meet the criteria of Method 1, Section 2.1. Also, the method *cannot be used for direct measurement in* cyclonic or swirling gas streams; Section 2.4 of Method 1 shows how to determine cyclonic or swirling flow conditions. When unacceptable conditions exist, alternative procedures, *subject to the* approval of the Administrator, U.S. Environmental Protection Agency, must be employed to make accurate flow rate determinations; examples of such alternative procedures are: (1) to install straightening vanes; (2) to calculate the total volumetric flow rate stoichiometrically, or (3) to move to another measurement site at which the flow is acceptable.

2. *Apparatus*

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

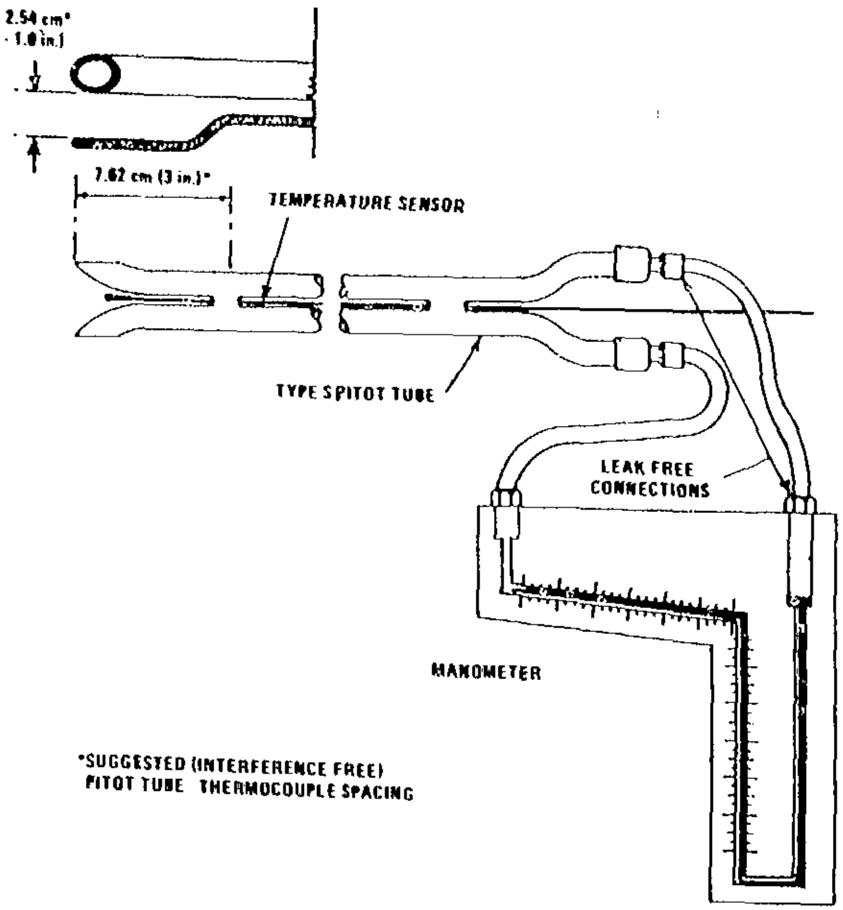


Figure 2-1. Type S pitot tube manometer assembly.

2.1 Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g., stainless steel). It is recommended that the *external tubing diameter (dimension D_t* Figure 2-2b) be between 0.48 and 0.95 centimeter ($\frac{3}{16}$ and $\frac{3}{8}$ inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions P_A and P_B *Figure 2–2b*); it is recommended that this distance be between 1.05 and 1.50 times the external tubing diameter. The face openings of the pitot tube shall, preferably, be aligned as shown in Figure 2-2; however, slight misalignments of the openings are permissible (see Figure 2-3).

The Type S pitot tube shall have a known coefficient, determined as outlined in Section 4. An identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube.

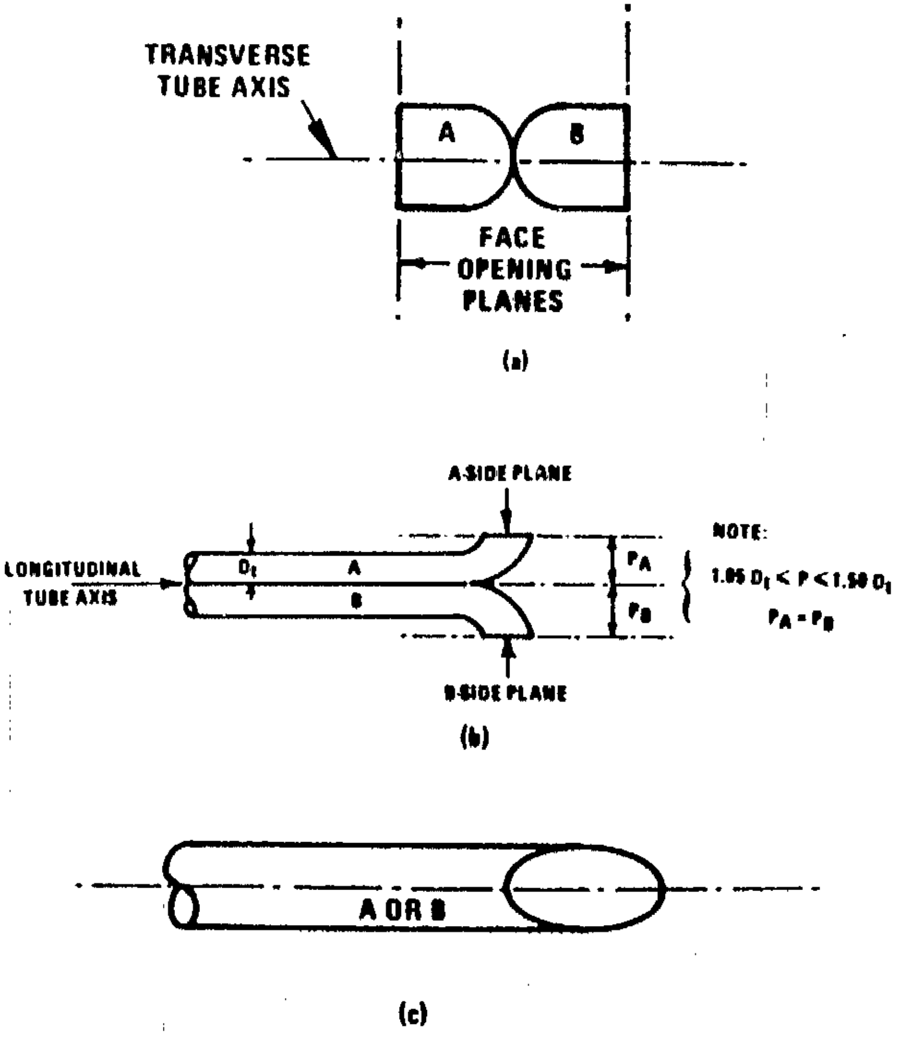


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.

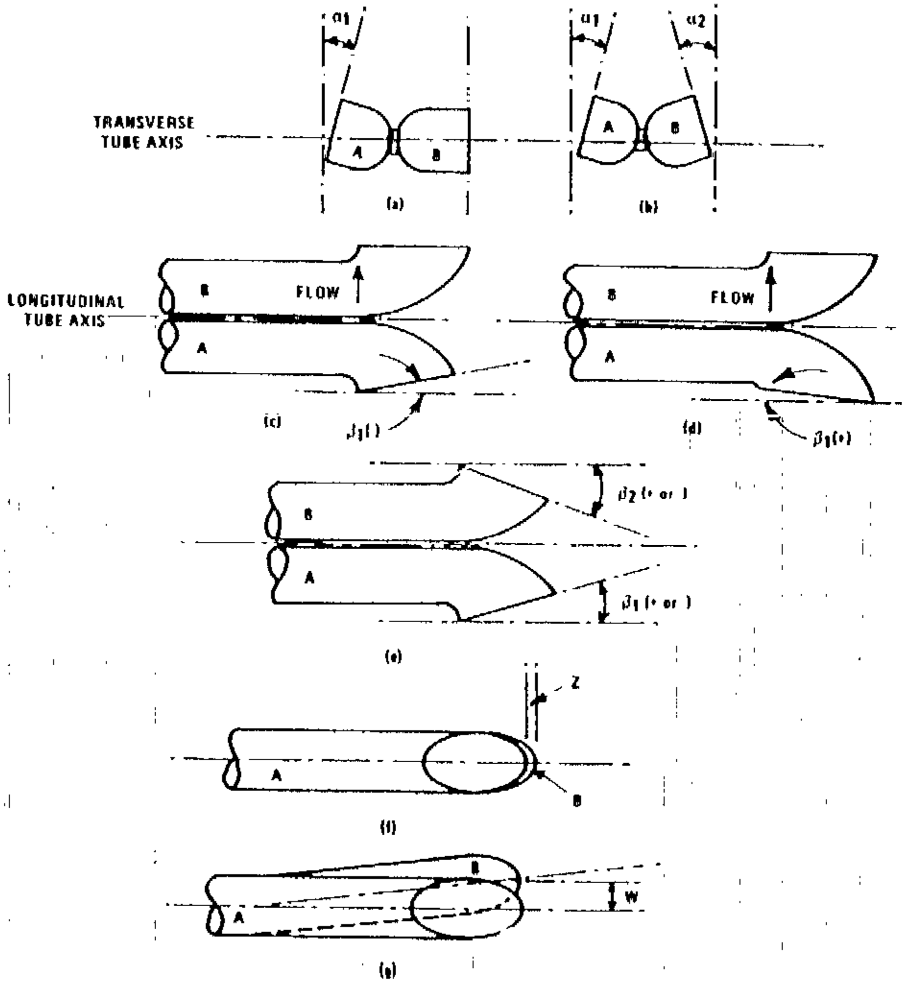


Figure 2–3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as α^1 and $\alpha^2 \leq 10°$, β^1 and $\beta^2 \leq 5°$, $z \leq 0.32$ cm (1/8 in.) and $w \leq 0.08$ cm (1/32 in.) (citation 11 in Bibliography).

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.7 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not plugged up during the traverse period; this can be done by taking a velocity head (Δp) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another Δp reading. If the Δp readings made before and after the air purge are the same (±5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be taken, as above, for the last two back purges at which suitably high Δp readings are observed.

2.2 Differential Pressure Gauge. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (water column) inclined-vertical manometer, *having 0.01-in. H_2O divisions on the* 0-to 1-in. inclined scale, and 0.1-in. H_2O divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gauge of equivalent sensitivity) is satisfactory for the measurement of Δp values as low as 1.3 mm (0.05 in.) H_2O. However, a differential pressure *gauge of greater sensitivity* shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all Δp readings at the traverse points in the stack is less than 1.3 mm *(0.05 in.) H_2O; (2) for traverses* of 12 or more points, more than 10 percent of the individual Δp readings are below 1.3 mm (0.05 in.) H_2O; (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.3 mm (0.05 in.) H_2O. Citation 18 in Bibliography describes commercially *available instrumentation for the measurement* of low-range gas velocities.

As an alternative to criteria (1) through (3) above, the following calculation may be performed to determine the necessity of using a more sensitive differential pressure gauge:

$$T=\frac{\sum_{i=1}^{n}\sqrt{\Delta p_i+K}}{\sum_{i=1}^{n}\sqrt{\Delta p_i}}$$

Where:

Δp_i=Individual velocity head reading at a traverse point, mm H_2O (in. H_2O).

n=Total number of traverse points.

K=0.13 mm H_2O when metric units are used and 0.005 in. H_2O when English units are used.

If T is greater than 1.05, the velocity head data are unacceptable and a more sensitive differential pressure gauge must be used.

NOTE: If differential pressure gauges other than *inclined manometers are used (e.g.,* magnehelic gauges), their calibration must be checked after each test series. To check the calibration of a differential pressure gauge, compare Δp readings of the gauge with those of a gauge-oil manometer at a minimum of three points, approximately representing *the range of Δp values in the* stack. If, at each point, the values of Δp as read by the differential pressure gauge and gauge-oil manometer agree to within 5 percent, the differential pressure gauge shall be considered to be in proper calibration. Otherwise, the test series shall either be voided, or procedures to adjust *the measured Δp values* and final results shall be used subject to the approval of the Administrator.

2.3 Temperature Gauge. A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer, or other gauge, capable of measuring *temperature to within 1.5 percent of the minimum* absolute stack temperature shall be used. The temperature gauge shall be attached to the pitot tube such that the sensor tip does not touch any metal; the gauge shall be in an interference-free arrangement with respect to the pitot tube face openings (see Figure 2–1 and also Figure 2–7 in Section 4). Alternative positions may be used if the pitot tube-temperature gauge system is calibrated according to the procedure of Section 4. Provided that a difference of not more *than 1 percent in the average velocity measurement* is introduced, the temperature gauge need not be attached to the pitot tube; this alternative is subject to the approval of the Administrator.

2.4 Pressure Probe and Gauge. A piezometer tube and mercury- or water-filled U-tube *manometer capable of measuring stack* pressure to within 2.5 mm (0.1 in.) Hg is used. The static tap of a standard type pitot tube or one leg of a Type S pitot tube with the face opening planes positioned parallel to *the gas flow may also be used as the pressure* probe.

2.5 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby *National Weather Service station, in* which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm (0.1 in.) Hg per 30-meter (100 *foot) elevation increase or vice-versa for* elevation decrease.

2.6 Gas Density Determination Equipment. Method 3 equipment, if needed (see Section 3.6), to determine the stack gas dry molecular weight, and Reference Method 4 or Method 5 equipment for moisture content *determination; other methods may be used* subject to approval of the Administrator.

2.7 Calibration Pitot Tube. When calibration of the Type S pitot tube is necessary (see Section 4), a standard pitot tube is used as a reference. The standard pitot tube shall, preferably, have a known coefficient, *obtained either (1) directly from the* National Bureau of Standards, Route 270, Quince Orchard Road, Gaithersburg, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot *tube designed* according to the criteria given in 2.7.1 *through* 2.7.5 below and illustrated in Figure 2–4 (see also Citations 7, 8, and 17 in Bibliography) may be used. Pitot tubes designed according to these specifications will have baseline coefficients of about 0.99±0.01.

2.7.1 *Hemispherical (shown in Figure 2–4),* ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon *D*, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, *following the 90 degree bend.*

2.7.4 Static pressure holes of equal size (approximately 0.1 *D*), equally spaced in a piezometer ring configuration.

2.7.5 Ninety degree bend, with curved or mitered junction.

2.8 *Differential Pressure Gauge for Type S* Pitot Tube Calibration. An inclined manometer or equivalent is used. If the single-velocity calibration technique is employed (see Section 4.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O). For *multivelocity calibrations, the gauge shall* be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O) for Δp values between 1.3 and 25 mm H_2O (0.05 and 1.0 in. H_2O), and to the nearest 1.3 mm H_2O (0.05 in. H_2O) for Δp values above 25 mm *H_2O (1.0 in. H_2O). A special, more* sensitive gauge will be required to read Δp values below 1.3 mm H_2O [0.05 in. H_2O] (see Citation 18 in Bibliography).

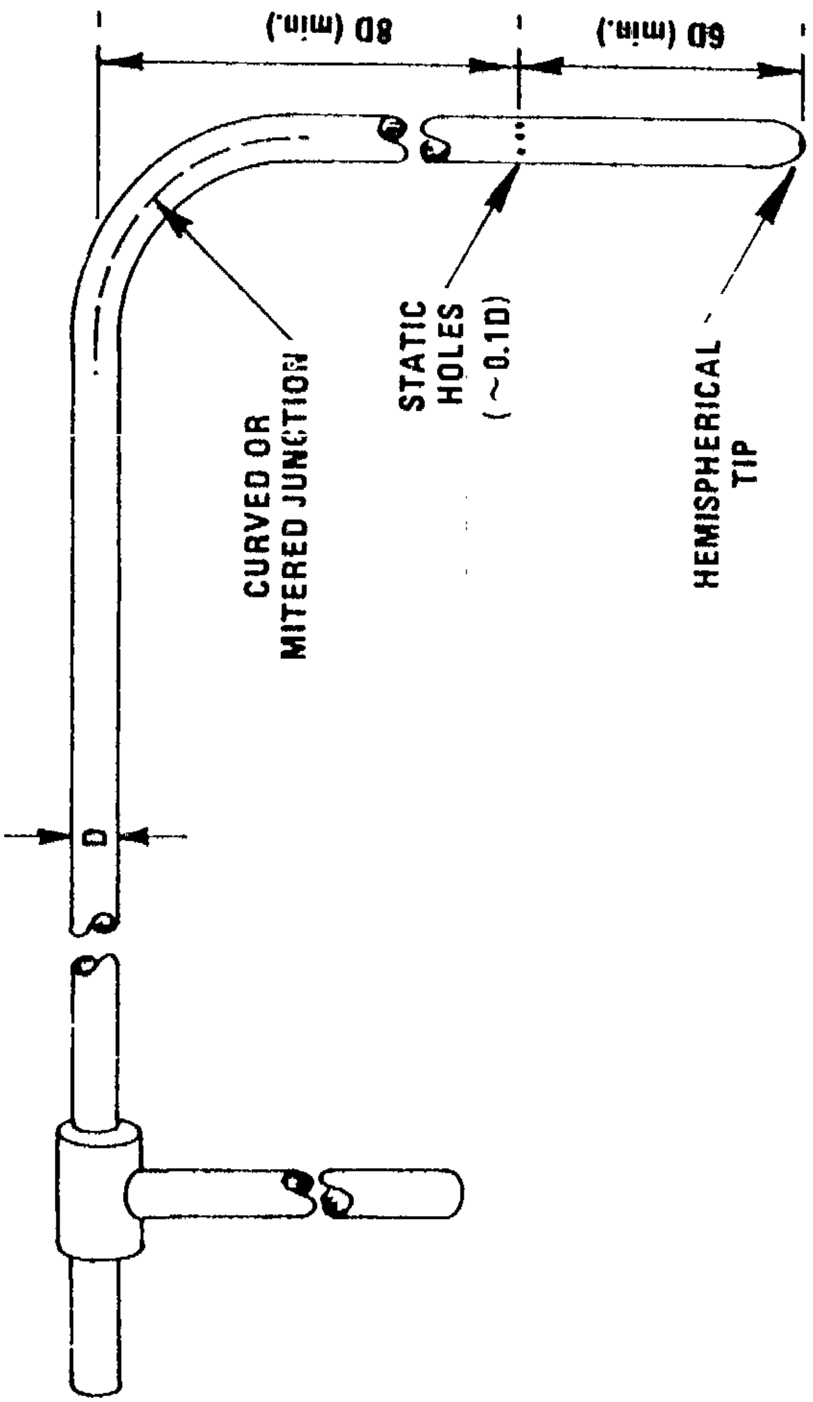


Figure 2-4. Standard pitot tube design specifications.

3. *Procedure*

3.1 Set up the apparatus as shown in Figure 2-1. Capillary tubing or surge tanks installed between the manometer and pitot tube may be used to dampen Δp fluctuations. It is recommended, but not required, that a pretest leak-check be conducted, as follows: (1) blow through the pitot impact opening until at least 7.6 cm (3 in.) H_2O velocity pressure registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (2) do the same for the static pressure side, except using suction to obtain the minimum of 7.6 cm (3 in.) H_2O. Other leak-check procedures, subject to the approval of the Administrator, may be used.

3.2 Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse. Record all necessary data as shown in the example data sheet (Figure 2-5).

3.3 Measure the velocity head and temperature at the traverse points specified by Method 1. Ensure that the proper differential pressure gauge is being used for the range of Δp values encountered (see Section 2.2). If it is necessary to change to a more sensitive gauge, do so, and remeasure the Δp and temperature readings at each traverse point. Conduct a post-test leak-check (mandatory), as described in Section 3.1 above, to validate the traverse run.

3.4 Measure the static pressure in the stack. One reading is usually adequate.

3.5 Determine the atmospheric pressure.

PLANT ____________________

DATE ____________ **RUN NO.** ____________

STACK DIAMETER OR DIMENSIONS, m(in.) ____________

BAROMETRIC PRESSURE, mm Hg (in. Hg) ____________

CROSS SECTIONAL AREA, $m^2(ft^2)$ ____________

OPERATORS ____________

PITOT TUBE I.D. NO. ____________

AVG. COEFFICIENT, C_p = ____________

LAST DATE CALIBRATED ____________

SCHEMATIC OF STACK CROSS SECTION

Traverse Pt. No.	Vel. Hd., Δp mm (in.) H_2O	Stack Temperature		P_g mm Hg (in.Hg)	$\sqrt{\Delta p}$
		t_s, °C (°F)	T_s, °K (°R)		
	Average				

Figure 2-5. Velocity traverse data.

3.6 Determine the stack gas dry molecular weight. For combustion processes or processes that emit essentially CO_2, O_2, CO, and N_2, use Method 3. For processes emitting essentially air, an analysis need not be conducted; use a dry molecular weight of 29.0. For other processes, other methods, subject to the approval of the Administrator, must be used.

3.7 *Obtain the moisture content from Reference Method 4 (or equivalent) or from Method 5.*

3.8 Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimensions rather than using blueprints.

4. Calibration

4.1 Type S Pitot Tube. Before its initial use, carefully examine the Type S pitot tube in top, side, and end views to verify that the face openings of the tube are *aligned within* the specifications illustrated in Figure 2-2 or 2-3. The pitot tube shall not be used if it fails to meet these alignment specifications.

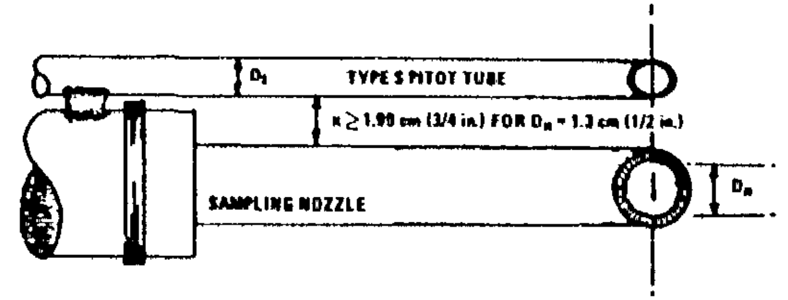
After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8 in.) and if P_A and P_B are equal and between 1.05 and 1.50 D_t, there are two possible options: (1) the pitot tube may be calibrated *according to* the procedure outlined in Sections 4.1.2 through 4.1.5 below, or (2) a baseline (isolated tube) coefficient value of 0.84 may be assigned to the pitot tube. Note, however, that if the pitot tube is part of an assembly, calibration may still be required, despite knowledge of the baseline coefficient value (see Section 4.1.1).

If D_t, P_A, and P_B are outside the specified limits, the pitot tube must be calibrated as outlined in 4.1.2 *through 4.1.5 below.*

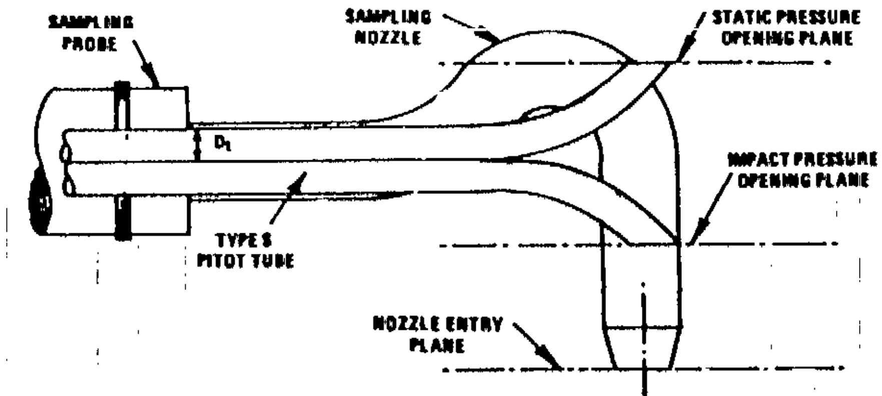
4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Citation 9 in Bibliography); therefore an assigned (or otherwise known) baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. Figures 2-6 through 2-8 illustrate interference-free component *arrangements for Type S pitot tubes* having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

NOTE: Do not use any Type S pitot tube assembly which is constructed such that the *impact pressure opening plane of the pitot* tube is below the entry plane of the nozzle (see Figure 2-6b).

4.1.2 Calibration Setup. If the Type S pitot tube is to be calibrated, one leg of the tube shall be permanently marked A, and the other, B. Calibration shall be done in a flow system having the following essential design features:



A. BOTTOM VIEW; SHOWING MINIMUM PITOT-NOZZLE SEPARATION.



B. SIDE VIEW; TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE, THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

Figure 2-6. Proper pitot tube-sampling nozzle configuration to prevent aerodynamic interference; buttonhook-type nozzle; centers of nozzle and pitot opening aligned; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

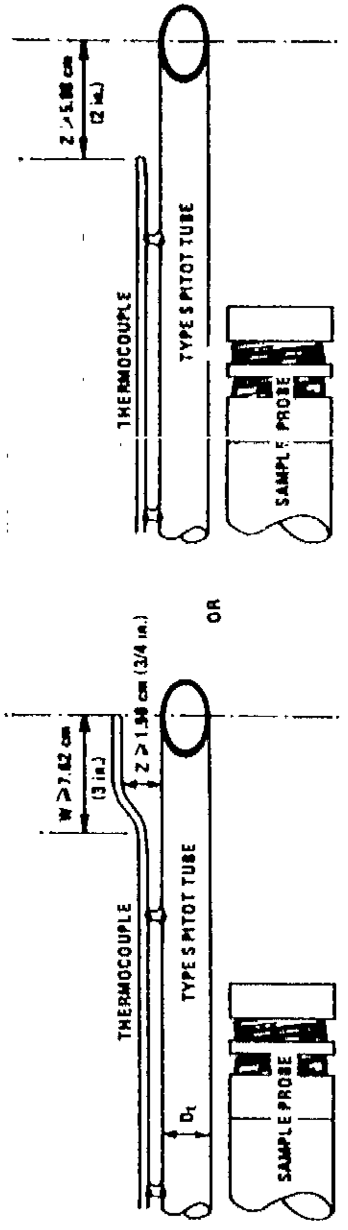


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

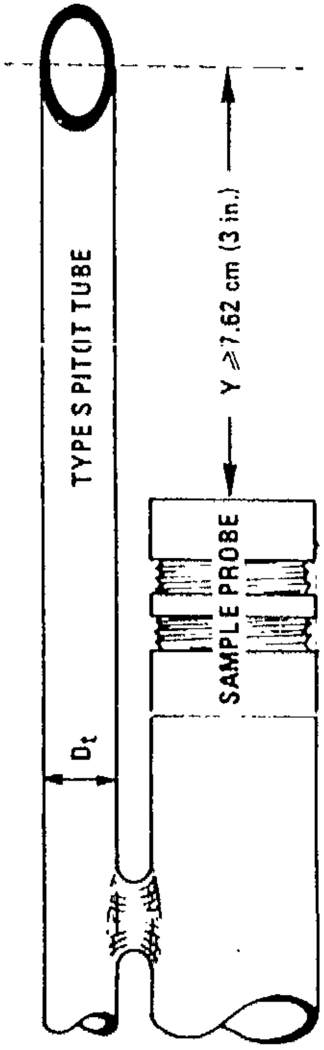


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

4.1.2.1 The flowing gas stream must be confined to a duct of definite cross-sectional area, *either circular or rectangular. For circular* cross-sections, the minimum duct diameter shall be 30.5 cm (12 in.); for rectangular cross-sections, the width (shorter side) shall be at least 25.4 cm (10 in.).

4.1.2.2 The cross-sectional area of the calibration duct must be constant over a distance of 10 or more duct diameters. For a rectangular cross-section, use an equivalent diameter, calculated from the following *equation, to determine the number of duct* diameters:

$$D_e = \frac{2LW}{(L+W)} \qquad \text{Eq. 2-1}$$

Where:
D_e=Equivalent diameter
L=Length
W=Width

To ensure the presence of stable, fully developed flow patterns at the calibration site, or "test section," the site must be located at least eight diameters downstream and two diameters upstream from the nearest disturbances.

NOTE: The eight- and two-diameter criteria are not absolute; other test section locations *may be used (subject to approval of the Administrator)*, provided that the flow at the test site is stable and demonstrably parallel *to the duct axis.*

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min *(1,000 ft/min)* and to within ±5 to 6 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 *ft/min). If a more precise* correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 and 14 in Bibliography for details).

4.1.2.4 Two entry ports, one each for the standard and Type S pitot tubes, shall be cut in the test section; the standard pitot entry *port shall be located slightly downstream of* the Type S port, so that the standard and Type S impact openings will lie in the same cross-sectional plane during calibration. To *facilitate alignment of the pitot tubes during* calibration, it is advisable that the test section be constructed of plexiglas or some other transparent material.

4.1.3 Calibration Procedure. Note that this procedure is a general one and must not be used without first referring to the special considerations presented in Section 4.1.5. Note also that this procedure applies only to single-velocity calibration. To obtain calibration data for the A and B sides of the Type S pitot tube, proceed as follows:

4.1.3.1 Make sure that the manometer is *properly filled and that the oil is free from* contamination and is of the proper density. Inspect and leak-check all pitot lines; repair or replace if necessary.

4.1.3.2 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.3.3 Ensure that the manometer is level and zeroed. Position the standard pitot tube at the calibration point (determined as outlined in Section 4.1.5.1), and align the tube so that its tip is pointed directly into the flow. Particular care should be taken in aligning *the tube to avoid yaw and pitch angles.* Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.4 Read Δp_{std} *and record its value in a* data table similar to the one shown in Figure 2-9. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.5 Connect the Type S pitot tube to the manometer. Open the Type S entry port. Check the manometer level and zero. Insert and align the Type S pitot tube so that its A side impact opening is at the same point as was the standard pitot tube and is pointed directly into the flow. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.6 Read Δp_s and enter its value in the data table. Remove the Type S pitot tube from the duct and disconnect it from the manometer.

4.1.3.7 Repeat steps 4.1.3.3 through 4.1.3.6 above until three pairs of Δp readings have been obtained.

4.1.3.8 Repeat steps 4.1.3.3 through 4.1.3.7 above for the B side of the Type S pitot tube.

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

4.1.4.1 For each of the six pairs of Δp readings (i.e., three from side A and three from side B) obtained in Section 4.1.3 above, *calculate the value of the Type S pitot tube coefficient as follows:*

PITOT TUBE IDENTIFICATION NUMBER: ____________ **DATE:** ________

CALIBRATED BY: ____________

	"A" SIDE CALIBRATION			
RUN NO.	**Δp_{std} cm H_2O (in. H_2O)**	**$\Delta p_{(s)}$ cm H_2O (in. H_2O)**	**$C_{p(s)}$**	**DEVIATION $C_{p(s)} - \bar{C}_p(A)$**
1				
2				
3				
		$\bar{C}_p$ (SIDE A)		

	"B" SIDE CALIBRATION			
RUN NO.	**Δp_{std} cm H_2O (in. H_2O)**	**$\Delta p_{(s)}$ cm H_2O (in. H_2O)**	**$C_{p(s)}$**	**DEVIATION $C_{p(s)} - \bar{C}_p(B)$**
1				
2				
3				
		$\bar{C}_p$ (SIDE B)		

$$\textbf{AVERAGE DEVIATION} = \sigma\,(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} \leq 0.01$$

$$\left| \bar{C}_p\,(\text{SIDE A}) - \bar{C}_p\,(\text{SIDE B}) \right| \longleftarrow \text{MUST BE} \leq 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2–2

Where:

$C_{p(s)}$=Type S pitot tube coefficient

$C_{p(std)}$=Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std}=Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s=Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2–3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} |C_{p(s)} - \bar{C}_p(A \text{ or } B)|}{3}$$

Equation 2–4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

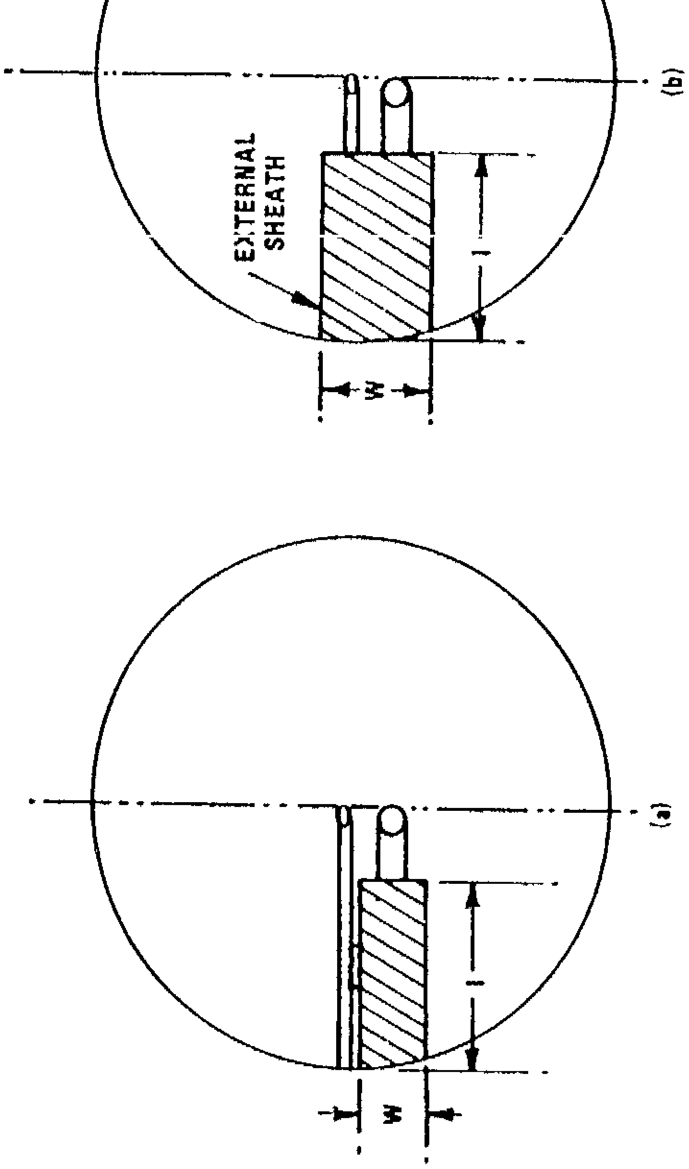
4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2–6 through 2–8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2–6 and 2–8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Bibliography). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2–10a), and 3 percent or less for assemblies with external sheaths (Figure 2–10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specification illustrated in Figure 2–6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2–2 or 2–3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).



$$\text{ESTIMATED SHEATH BLOCKAGE (\%)} = \left[\frac{l \times W}{\text{DUCT AREA}}\right] \times 100$$

Figure 2-10. Projected-area models for typical pitot tube assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

4.1.6.1.1 When a Type S pitot tube (isolated tube or assembly) is used in the field, the appropriate coefficient value (whether assigned or obtained by calibration) shall be used to perform velocity calculations. For calibrated Type S pitot tubes, the A side coefficient shall be used when the A side of the tube faces the flow, and the B side coefficient shall be used when the B side faces the flow; alternatively, the arithmetic average of the A and B side coefficient values may be used, irrespective of which side faces the flow.

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $C_{p(s)}$. Consult Citation 9 in Bibliography for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Bibliography).

4.1.6.2 Recalibration.

4.1.6.2.1 Isolated Pitot Tubes. After each field use, the pitot tube shall be carefully reexamined in top, side, and end views. If the pitot face openings are still aligned within the specifications illustrated in Figure 2-2 or 2-3, it can be assumed that the baseline coefficient of the pitot tube has not changed. If, however, the tube has been damaged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

4.1.6.2.2 Pitot Tube Assemblies. After each field use, check the face opening alignment of the pitot tube, as in Section 4.1.6.2.1; also, remeasure the intercomponent spacings of the assembly. If the intercomponent spacings have not changed and the face opening alignment is acceptable, it can be assumed that the coefficient of the assembly has not changed. If the face opening alignment is no longer within the specifications of Figures 2-2 or 2-3, either repair the damage or replace the pitot tube (calibrating the new assembly, if necessary). If the intercomponent spacings have changed, restore the original spacings or recalibrate the assembly.

4.2 Standard pitot tube (if applicable). If a standard pitot tube is used for the velocity traverse, the tube shall be constructed according to the criteria of Section 2.7 and shall be assigned a baseline coefficient value of 0.99. If the standard pitot tube is used as part of an assembly, the tube shall be in an interference-free arrangement (subject to the approval of the Administrator).

4.3 Temperature Gauges. After each field use, calibrate dial thermometers, liquid-filled bulb thermometers, thermocouple-potentiometer systems, and other gauges at a temperature within 10 percent of the average absolute stack temperature. For temperatures up to 405° C (761° F), use an ASTM mercury-in-glass reference thermometer, or equivalent, as a reference; alternatively, either a reference thermocouple and potentiometer (calibrated by NBS) or thermometric fixed points, e.g., ice bath and boiling water (corrected for barometric pressure) may be used. For temperatures above 405° C (761° F), use an NBS-calibrated reference thermocouple-potentiometer system or an alternate reference, subject to the approval of the Administrator.

If, during calibration, the absolute temperatures measured with the gauge being calibrated and the reference gauge agree within 1.5 percent, the temperature data taken in the field shall be considered valid. Otherwise, the pollutant emission test shall either be considered invalid or adjustments (if appropriate) of the test results shall be made, subject to the approval of the Administrator.

4.4 Barometer. Calibrate the barometer used against a mercury barometer.

5. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

5.1 Nomenclature.

A=Cross-sectional area of stack, m² (ft²).
B_{ws}=Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume.
C_p=Pitot tube coefficient, dimensionless.
K_p=Pitot tube constant,

$$34.97\ \frac{\text{m}}{\text{sec}}\left[\frac{(g/g\text{-mole})(\text{mm Hg})}{(^\circ\text{K})(\text{mm H}_2\text{O})}\right]^{1/2}$$

for the metric system and

$$85.49\ \frac{\text{ft}}{\text{sec}}\left[\frac{(\text{lb/lb-mole})(\text{in. Hg})}{(^\circ\text{R})(\text{in. H}_2\text{O})}\right]^{1/2}$$

for the English system.

M_d=Molecular weight of stack gas, dry basis (see Section 3.6) g/g-mole (lb/lb-mole).
M_s=Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).
$=M_d\,(1-B_{ws})+18.0\,B_{ws}$

Eq. 2-5

P_{bar}=Barometric pressure at measurement site, mm Hg (in. Hg).
P_g=Stack static pressure, mm Hg (in. Hg).
P_s=Absolute stack gas pressure, mm Hg (in. Hg).
$=P_{bar}+P_g$

Eq. 2-6

P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
Q_{sd}=Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).
t_s=Stack temperature, °C (°F).
T_s=Absolute stack temperature, °K, (°R).
$=273+t_s$ for metric.

Eq. 2-7

$=460+t_s$ for English.

Eq. 2-8

T_{std}=Standard absolute temperature, 293 °K (528° R).
v_s=Average stack gas velocity, m/sec (ft/sec).
Δp=Velocity head of stack gas, mm H_2O (in. H_2O).
3,600=Conversion factor, sec/hr.
18.0=Molecular weight of water, g/g-mole (lb/lb-mole).

5.2 Average Stack Gas Velocity.

$$v_s=K_pC_p\left(\sqrt{\Delta p}\right)_{avg}\sqrt{\frac{T_{s(avg)}}{P_sM_s}}$$

Equation 2-9

5.3 Average Stack Gas Dry Volumetric Flow Rate.

$$Q_{sd}=3{,}600(1-B_{ws})v_sA\ \frac{T_{std}}{T_{s\,(avg)}}\ \frac{P_s}{P_{std}}$$

Eq. 2-10

To convert Q_{sd} from dscm/hr (dscf/hr) to dscm/min (dscf/min), divide Q_{sd} by 60.

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3. Procedure

Follow the general procedures in Section 3 of Method 2, except conduct the measurements at the traverse points specified in Method 1A. The static and impact pressure holes of standard pitot tubes are susceptible to plugging in PM-laden gas streams. Therefore, the tester must furnish adequate proof that the openings of the pitot tube have not plugged during the traverse period; this proof can be obtained by first recording the velocity head (Δp) reading at the final traverse point, then cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and finally by recording another Δp reading at the final traverse point. If the Δp reading made after the air purge is within 5 percent of the reading during the traverse, then the traverse is acceptable. Otherwise, reject the run. Note that if the Δp at the final traverse point is so low as to make this determination too difficult, then another traverse point may be selected. If "back purging" at regular intervals is part of the procedure, then take comparative Δp readings, as above, for the last two back purges at which suitable high Δp readings are observed.

METHOD 2D—MEASUREMENT OF GAS VOLUMETRIC FLOW RATES IN SMALL PIPES AND DUCTS

1. Applicability and Principle

1.1 Applicability. This method applies to the measurement of gas flow rates in small pipes and ducts, either before or after emission control devices.

1.2 Principle. To measure flow rate or pressure drop, all the stack gas is directed through a rotameter, orifice plate or similar flow rate measuring device. The measuring device has been previously calibrated in a manner that insures its proper calibration for the gas or gas mixture being measured. Absolute temperature and pressure measurements are also made to calculate volumetric flow rates at standard conditions.

2. Apparatus

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

2.1 Flow Rate Measuring Device. A rotameter, orifice plate, or other flow rate measuring device capable of measuring all the stack flow rate to within 5 percent of its true value. The measuring device shall be equipped with a temperature gauge accurate to within 2 percent of the minimum absolute stack temperature and a pressure gauge accurate to within 5 mm Hg. The capacity of the measuring device shall be sufficient for the expected maximum and minimum flow rates at the stack gas conditions. The magnitude and variability of stack gas flow rate, molecular weight, temperature, pressure, compressibility, dew point, corrosiveness, and pipe or duct size are all factors to consider in choosing a suitable measuring device.

2.2 Barometer. Same as in Method 2, Section 2.5.

2.3 Stopwatch. Capable of incremental time measurement to within 1 second.

3. Procedure

3.1 Installation. Use the procedure in Method 2A, Section 3.1.

3.2 Leak Check. Use the procedure in Method 2A, Section 3.2.

3.3 Flow Rate Measurement.

3.3.1 Continuous, Steady Flow. At least once an hour, record the measuring device flow rate reading, and the measuring device temperature and pressure. Make a minimum of twelve equally spaced readings of each parameter during the test period. Record the barometric pressure at the beginning and end of the test period. Record the data on a table similar to Figure 2D-1.

Plant____________________
Date__________ Run number______
Sample location________________
Barometric pressure, mm (in.) Hg
Start_____, Finish_____
Operators ______________
Measuring device number_____ Calibration coefficient_____
Calibration gas________
Last date calibrated______

Time	Flow rate reading	Static pressure mm (in.) Hg	Temperature	
			°C (°F)	°K (°R)
	Average.			

Figure 2D-1. Flow rate measurement data.

3.3.2 Noncontinuous and Nonsteady Flows. Use flow rate measuring devices with particular caution. Calibration will be affected by variation in stack gas temperature, pressure, compressibility, and molecular weight. Use the procedure in Section 3.3.1. Record all the measuring device parameters on a time interval frequency sufficient to adequately profile each process cyclical or noncontinuous event. A multichannel continuous recorder may be used.

4. Calibration

4.1 Flow Rate Measuring Device. Use the procedure in Method 2A, Section 4, and apply the same performance standards. Calibrate the measuring device with the principal stack gas to be measured (e.g., air, nitrogen) against a standard reference meter. A calibrated dry gas meter is an acceptable reference meter. Ideally, calibrate the measuring device in the field with the actual gas to be measured. For measuring devices that have a volume rate readout, calculate the measuring device calibration coefficient, Y_m, for each run as follows:

$$Y_m = \frac{(Q_r)(T_r)P_{bar}}{(Q_m)(T_m)(P_{bar} + P_g)} \qquad \text{Eq. 2D-1}$$

where:

Q_r=reference meter flow rate reading, m³/min (ft³/min).

Q_m=measuring device flow rate reading, m³/min (ft³/min).

T_r=reference meter average absolute temperature, °K (°R).

T_m=measuring device average absolute temperature, °K (°R).

P_{bar}=barometric pressure, mm Hg (in. Hg).

P_g=measuring device average static pressure, mm Hg (in. Hg).

For measuring devices that do not have a readout as flow rate, refer to the manufacturer's instructions to calculate the Q_m corresponding to each Q_r.

4.2 Temperature Gauge. Use the procedure and specifications in Method 2A, Section 4.2. Perform the calibration at a temperature that approximates field test conditions.

4.3 Barometer. Calibrate the barometer to be used in the field test with a mercury barometer prior to the field test.

5. Gas Flow Rate Calculation

Calculate the stack gas flow rate, Q_s, as follows:

$$Q_s = K_1 Y_m Q_m \frac{(P_{bar} + P_g)}{T_m} \qquad \text{Eq. 2D-2}$$

where:

K_1 = 0.3858 for international system of units (SI); 17.64 for English units.

6. Bibliography

1. Spink, L.K. Principles and Practice of Flowmeter Engineering. The Foxboro Company. Foxboro, MA. 1967.

2. Benedict, Robert P. Fundamentals of Temperature, Pressure, and Flow Measurements. John Wiley and Sons, Inc. New York, NY. 1969.

3. Orifice Metering of Natural Gas. American Gas Association. Arlington, VA. Report No. 3. March 1978. 88 p.

METHOD 3—GAS ANALYSIS FOR THE DETERMINATION OF DRY MOLECULAR WEIGHT

1. APPLICABILITY AND PRINCIPLE

1.1 Applicability.

1.1.1 This method is applicable for determining carbon dioxide (CO_2) and oxygen (O_2) concentrations and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process. The method may also be applicable to other processes where it has been determined that compounds other than CO_2, O_2, carbon monoxide (CO), and nitrogen (N_2) are not present in concentrations sufficient to affect the results.

1.1.2 Other methods, as well as modifications to the procedure described herein, are also applicable for some or all of the above determinations. Examples of specific methods and modifications include: (1) A multipoint sampling method using an Orsat analyzer to analyze individual grab samples obtained at each point; (2) a method using CO_2 or O_2 and stoichiometric calculations to determine dry molecular weight; and (3) assigning a value of 30.0 for dry molecular weight, in lieu of actual measurements, for processes burning natural gas, coal, or oil. These methods and modifications may be used, but are subject to the approval of the Administrator, U.S. Environmental Protection Agency (EPA).

1.1.3 Note. Mention of trade names or specific products does not constitute endorsements by EPA.

1.2 Principle. A gas sample is extracted from a stack by one of the following methods: (1) Single-point, grab sampling; (2) single-point, integrated sampling; or (3) multipoint, integrated sampling. The gas sample is analyzed for pecent CO_2, percent O_2, and if necessary, for percent CO. For dry molecular weight determination, either an Orsat or a Fyrite analyzer may be used for the analysis.

2. APPARATUS

As an alternative to the sampling apparatus and systems described herein, other sampling systems (e.g., liquid displacement) may be used, provided such systems are capable of obtaining a representative sample and maintaining a constant sampling rate, and are, otherwise, capable of yielding acceptable re-

3. Procedure

Follow the general procedures in Section 3 of Method 2, except conduct the measurements at the traverse points specified in Method 1A. The static and impact pressure holes of standard pitot tubes are susceptible to plugging in PM-laden gas streams. Therefore, the tester must furnish adequate proof that the openings of the pitot tube have not plugged during the traverse period; this proof can be obained by first recording the velocity head (Δp) reading at the final traverse point, then cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and finally by recording another Δp reading at the final traverse point. If the Δp reading made after the air purge is within 5 percent of the reading during the traverse, then the traverse is acceptable. Otherwise, reject the run. Note that if the Δp at the final traverse point is so low as to make this determination too difficult, then another traverse point may be selected. If "back purging" at regular intervals is part of the procedure, then take comparative Δp readings, as above, for the last two back purges at which suitable high Δp readings are observed.

METHOD 2D—MEASUREMENT OF GAS VOLUMETRIC FLOW RATES IN SMALL PIPES AND DUCTS

1. Applicability and Principle

1.1 Applicability. This method applies to the measurement of gas flow rates in small pipes and ducts, either before or after emission control devices.

1.2 Principle. To measure flow rate or pressure drop, all the stack gas is directed through a rotameter, orifice plate or similar flow rate measuring device. The measuring device has been previously calibrated in a manner that insures its proper calibration for the gas or gas mixture being measured. Absolute temperature and pressure measurements are also made to calculate volumetric flow rates at standard conditions.

2. Apparatus

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

2.1 Flow Rate Measuring Device. A rotameter, orifice plate, or other flow rate measuring device capable of measuring all the stack flow rate to within 5 percent of its true value. The measuring device shall be equipped with a temperature gauge accurate to within 2 percent of the minimum absolute stack temperature and a pressure gauge accurate to within 5 mm Hg. The capacity of the measuring device shall be sufficient for the expected maximum and minimum flow rates at the stack gas conditions. The magnitude and variability of stack gas flow rate, molecular weight, temperature, pressure, compressibility, dew point, corrosiveness, and pipe or duct size are all factors to consider in choosing a suitable measuring device.

2.2 Barometer. Same as in Method 2, Section 2.5.

2.3 Stopwatch. Capable of incremental time measurement to within 1 second.

3. Procedure

3.1 Installation. Use the procedure in Method 2A, Section 3.1.

3.2 Leak Check. Use the procedure in Method 2A, Section 3.2.

3.3 Flow Rate Measurement.

3.3.1 Continuous, Steady Flow. At least once an hour, record the measuring device flow rate reading, and the measuring device temperature and pressure. Make a minimum of twelve equally spaced readings of each parameter during the test period. Record the barometric pressure at the beginning and end of the test period. Record the data on a table similar to Figure 2D-1.

Plant____________________
Date______________ Run number_______
Sample location____________________
Barometric pressure, mm (in.) Hg
Start_____ Finish_____
Operators____________________
Measuring device number_____ Calibration coefficient_____
Calibration gas_________
Last date calibrated_______

Time	Flow rate reading	Static pressure mm (in.) Hg	Temperature	
			°C (°F)	°K (°R)
	Average.			

Figure 2D-1. Flow rate measurement data.

3.3.2 Noncontinuous and Nonsteady Flows. Use flow rate measuring devices with particular caution. Calibration will be affected by variation in stack gas temperature, pressure, compressibility, and molecular weight. Use the procedure in Section 3.3.1. Record all the measuring device parameters on a time interval frequency sufficient to adequately profile each process cyclical or noncontinuous event. A multichannel continuous recorder may be used.

4. Calibration

4.1 Flow Rate Measuring Device. Use the procedure in Method 2A, Section 4, and apply the same performance standards. Calibrate the measuring device with the principal stack gas to be measured (e.g., air, nitrogen) against a standard reference meter. A calibrated dry gas meter is an acceptable reference meter. Ideally, calibrate the measuring device in the field with the actual gas to be measured. For measuring devices that have a volume rate readout, calculate the measuring device calibration coefficient, Y_m, for each run as follows:

$$Y_m = \frac{(Q_r)\,(T_r)\,P_{bar}}{(Q_m)\,(T_m)\,(P_{bar} + P_g)} \qquad \text{Eq. 2D-1}$$

where:

Q_r=reference meter flow rate reading, m³/min (ft³/min).

Q_m=measuring device flow rate reading, m³/min (ft³/min).

T_r=reference meter average absolute temperature, °K (°R).

T_m=measuring device average absolute temperature, °K (°R).

P_{bar}=barometric pressure, mm Hg (in. Hg).

P_g=measuring device average static pressure, mm Hg (in. Hg).

For measuring devices that do not have a readout as flow rate, refer to the manufacturer's instructions to calculate the Q_m corresponding to each Q_r.

4.2 Temperature Gauge. Use the procedure and specifications in Method 2A, Section 4.2. Perform the calibration at a temperature that approximates field test conditions.

4.3 Barometer. Calibrate the barometer to be used in the field test with a mercury barometer prior to the field test.

5. Gas Flow Rate Calculation

Calculate the stack gas flow rate, Q_s, as follows:

$$Q_s = K_1 Y_m Q_m \frac{(P_{bar} + P_g)}{T_m} \qquad \text{Eq. 2D-2}$$

where:

K_1 = 0.3858 for International system of units (SI); 17.64 for English units.

6. Bibliography

1. Spink, L.K. Principles and Practice of Flowmeter Engineering. The Foxboro Company, Foxboro, MA. 1967.

2. Benedict, Robert P. Fundamentals of Temperature, Pressure, and Flow Measurements. John Wiley and Sons, Inc. New York, NY. 1969.

3. Orifice Metering of Natural Gas. American Gas Association. Arlington, VA. Report No. 3. March 1978. 88 p.

METHOD 3—GAS ANALYSIS FOR THE DETERMINATION OF DRY MOLECULAR WEIGHT

1. APPLICABILITY AND PRINCIPLE

1.1 Applicability.

1.1.1 This method is applicable for determining carbon dioxide (CO_2) and oxygen (O_2) concentrations and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process. The method may also be applicable to other processes where it has been determined that compounds other than CO_2, O_2, carbon monoxide (CO), and nitrogen (N_2) are not present in concentrations sufficient to affect the results.

1.1.2 Other methods, as well as modifications to the procedure described herein, are also applicable for some or all of the above determinations. Examples of specific methods and modifications include: (1) A multi-point sampling method using an Orsat analyzer to analyze individual grab samples obtained at each point; (2) a method using CO_2 or O_2 and stoichiometric calculations to determine dry molecular weight; and (3) assigning a value of 30.0 for dry molecular weight, in lieu of actual measurements, for processes burning natural gas, coal, or oil. These methods and modifications may be used, but are subject to the approval of the Administrator, U.S. Environmental Protection Agency (EPA).

1.1.3 Note. Mention of trade names or specific products does not constitute endorsements by EPA.

1.2 Principle. A gas sample is extracted from a stack by one of the following methods: (1) Single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for pecent CO_2, percent O_2, and if necessary, for percent CO. For dry molecular weight determination, either an Orsat or a Fyrite analyzer may be used for the analysis.

2. APPARATUS

As an alternative to the sampling apparatus and systems described herein, other sampling systems (e.g., liquid displacement) may be used, provided such systems are capable of obtaining a representative sample and maintaining a constant sampling rate, and are, otherwise, capable of yielding acceptable results. Use of such systems is subject to the approval of the Administrator.

2.1 Grab Sampling (Figure 3–1).

2.1.1 Probe. Stainless steel or borosilicate glass tubing equipped with an in-stack or out-stack filter to remove particulate matter (a plug of glass wool is satisfactory for this purpose). Any other materials, inert to O_2, CO_2, CO, and N_2 and resistant to temperature at sampling conditions, may be used for the probe. Examples of such materials are aluminum, copper, quartz glass, and Teflon.

2.1.2 Pump. A one-way squeeze bulb, or equivalent, to transport the gas sample to the analyzer.

2.2 Integrated Sampling (Figure 3-2).

2.2.1 Probe. Same as in Section 2.1.1.

2.2.2 *Condenser.* An air-cooled or water-cooled condenser, or other condenser no greater than 250 ml that will not remove O_2, CO_2, CO, and N_2, to remove excess moisture which would interfere with the operation of the pump and flowmeter.

2.2.3 Valve. A needle valve, to adjust sample gas flow rate.

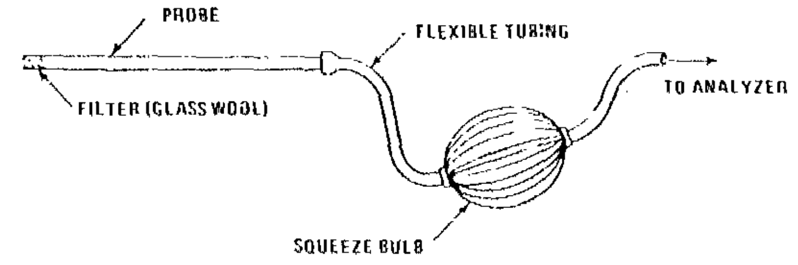

Figure 3-1. Grab-sampling train.

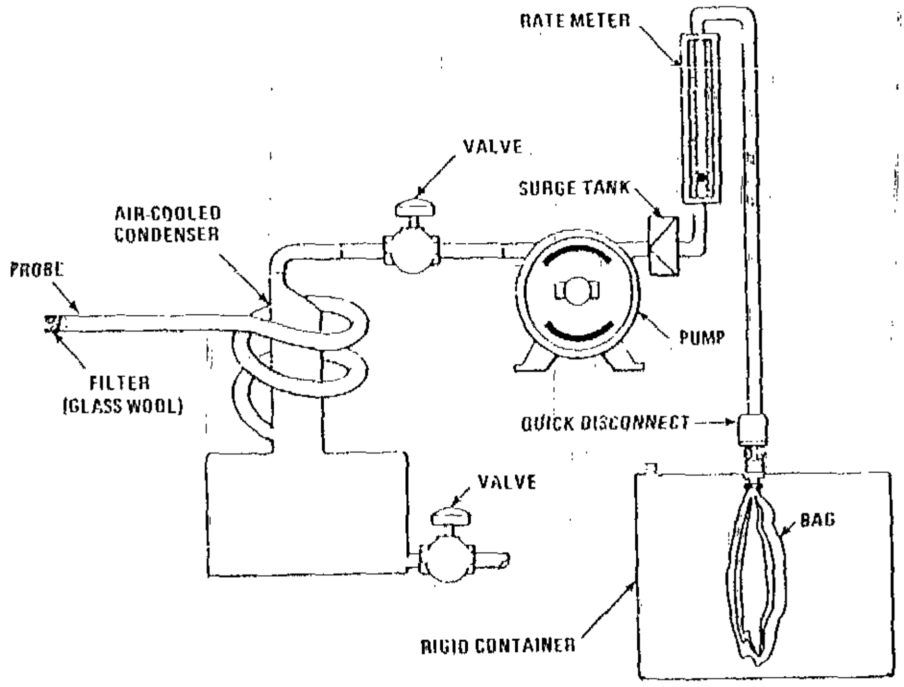

Figure 3-2. Integrated gas-sampling train.

2.2.4 Pump. A leaf-free, diaphragm-type pump, or equivalent, to transport sample gas to the flexible bag. Install a small surge tank between the pump and rate meter to eliminate the pulsation effect of the diaphragm pump on the rotameter.

2.2.5 Rate Meter. A rotameter, or equivalent rate meter, capable of measuring flow rate to within 2 percent of the selected flow rate. A flow rate range of 500 to 1000 cc/min is suggested.

2.2.6 Flexible Bag. Any leak-free plastic (e.g., Tedlar, Mylar, Teflon) or plastic-coated aluminum (e.g., aluminized Mylar) bag, or equivalent, having a capacity consistent with the selected flow rate and time length of the test run. A capacity in the range of 55 to 90 liters is suggested. To leak check the bag, connect it to a water manometer, and pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 minutes. Any displacement in the water manometer indicates a leak. An alternative leak-check method is to pressurize the bag to 5 to 10 cm (2 to 4 in.) H_2O and allow to stand overnight. A deflated bag indicates a leak.

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 30 cm (12 in.), for the flexible bag leak check.

2.2.8 Vacuum Gauge. A mercury manometer, or equivalent, of at least 760 mm (30 in.) Hg, for the sampling train leak check.

2.3 Analysis. An Orsat or Fyrite type combustion gas analyzer. For Orsat and Fyrite analyzer maintenance and operation procedures, follow the instructions recommended by the manufacturer, unless otherwise specified herein.

3. Single-Point, Grab Sampling and Analytical Procedure

3.1 The sampling point in the duct shall either be at the centroid of the cross section or at a point no closer to the walls than 1.00 m (3.3 ft), unless otherwise specified by the Administrator.

3.2 Set up the equipment as shown in Figure 3–1, making sure all connections ahead of the analyzer are tight. If an Orsat analyzer is used, it is recommended that the analyzer be leak checked by following the procedure in Section 6; however, the leak check is optional.

3.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line long enough to allow at least five exchanges. Draw a sample into the analyzer, and immediately analyze it for percent CO_2 and percent O_2. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent 0_2O from 100 percent. Calculate the dry molecular weight as indicated in Section 7.2.

3.4 Repeat the sampling, analysis, and calculation procedures until the dry molecular weights of any three grab samples differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (0.1 lb/lb-mole).

4. Single-Point, Integrated Sampling and Analytical Procedure

4.1 The sampling point in the duct shall be located as specified in Section 3.1.

4.2 Leak check (optional) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3–2. Just before sampling, leak check (optional) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum should remain stable for at least 0.5 minute. Evacuate the flexible bag. Connect the probe, and place it in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Next, connect the bag, and make sure that all connections are tight.

4.3 Sample at a constant rate. The sampling run should be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collection of at least 30 liters (1.00 ft^3) of sample gas is recommended; however, smaller volumes may be collected, if desired.

4.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. Within 8 hours after the sample is taken, analyze it for percent CO_2 and percent O_2 using either an Orsat analyzer or a Fyrite type combustion gas analyzer. If an Orsat analyzer is used, it is recommended that Orsat leak check described in Section 6, be performed before this determination; however, the check is optional. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent 0 from 100 percent. Calculate the dry molecular weight as indicated in Section 7.2.

4.5 Repeat the analysis and calculation procedures until the individual dry molecular weights for any three analyses differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (0.1 lb/lb-mole).

5. Multi-Point, Integrated Sampling and Analytical Procedure

5.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of 12 traverse points shall be used for all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to approval of the Administrator.

5.2 Follow the procedures outlined in Sections 4.2 through 4.5, except for the following: Traverse all sampling points, and sample at each point for an equal length of time. Record sampling data as shown in Figure 3–3.

Time	Traverse pt.	Q, liter/min	% dev.*
Average			

* % dev.=$(Q-Q_{avg})/Q_{avg}$ X 100 (Must be ≤10%)

Figure 3–3. Sampling rate data.

6. Leak-Check Procedure for Orsat Analyzer

Moving an Orsat analyzer frequently causes it to leak. Therefore, an Orsat analyzer should be thoroughly leak checked on site before the flue gas sample is introduced into it. The procedure for leak checking an Orsat analyzer is as follows:

6.1 Bring the liquid level in each pipette up to the reference mark on the capillary tubing, and then close the pipette stopcock.

6.2 Raise the leveling bulb sufficiently to bring the confining liquid meniscus onto the graduated portion of the burette, and then close the manifold stopcock.

6.3 Record the meniscus position.

6.4 Observe the menisus in the burette and the liquid level in the pipette for movement over the next 4 minutes.

6.5 For the Orsat analyzer to pass the leak check, two conditions must be met:

6.5.1 The liquid level in each pipette must not fall below the botton of the capillary tubing during this 4-minute interval.

6.5.2 The menisus in the burette must not change by more than 0.2 ml during this 4-minute interval.

6.6 If the anlyzer fails the leak-check procedure, check all rubber connections and stopcocks to determine whether they might be the cause of the leak. Disassemble, clean, and regrease leaking stopcocks. Replace leaking rubber connections. After the analyzer is reassembled, repeat the lead-check procedure.

7. Calculations

7.1 Nomenclature

M_d = Dry molecular weight, g/g-mole (lb/lb-mole).

$\%CO_2$ = Percent CO_2 by volume, dry basis.

$\%O_2$ = Percent O_2 by volume, dry basis.

%CO = Percent CO by volume, dry basis.

$\%N_2$ = Percent N_2 by volume, dry basis.

0.280 = Molecular weight of N_2 or CO, divided by 100.

0.320 = Molecular wight of O_2 divided by 100.

0.440 = Molecular weight of CO_2 divided by 100.

7.2 Dry Molecular Weight. Use Equation 3–1 to calculate the dry molecular weight of the stack gas.

$$M_d = 0.440(\%CO_2) + 0.320\ (\%O_2) + 0.280(\%N_2 + \%CO) \qquad \text{Eq. 3-1}$$

NOTE. The above equation does not consider argon in air (about 0.9 percent, molecular weight of 39.9). A negative error of about 0.4 percent is introduced. The tester may choose to include argon in the analysis using procedures subject to approval of the Administrator.

8. Bibliography

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Method 3A—Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedure)

1. *Applicability and Principle*

1.1 Applicability. This method is applicable to the determination of oxygen (O_2) and carbon dioxide (CO_2) concentrations in emissions from stationary sources only when specified within the regulations.

1.2 Principle. A sample is continuously extracted from the effluent stream: a portion of the sample stream is conveyed to an instrumental analyzer(s) for determination of O_2 and CO_2 concentration(s). Performance specifications and test procedures are provided to ensure reliable data.

2. *Range and Sensitivity*

Same as Method 6C, Sections 2.1 and 2.2, except that the span of the monitoring system shall be selected such that the average O_2 or CO_2 concentration is not less than 20 percent of the span.

3. *Definitions*

3.1 Measurement System. The total equipment required for the determination of the O_2 or CO_2 concentration. The measurement system consists of the same major sub-

5. BIBLIOGRAPHY

Same as Method 3.

METHOD 4—DETERMINATION OF MOISTURE CONTENT IN STACK GASES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted at a constant rate from the source; moisture is removed from the sample stream and determined either volumetrically or gravimetrically.

1.2 Applicability. This method is applicable for determining the moisture content of stack gas.

Two procedures are given. The first is a reference method, for accurate determinations of moisture content (such as are needed to calculate emission data). The second is an approximation method, which provides estimates of percent moisture to aid in setting isokinetic sampling rates prior to a pollutant emission measurement run. The approximation method described herein is only a suggested approach; alternative means for approximating the moisture content, e.g., drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, previous experience, etc., are also acceptable.

The reference method is often conducted simultaneously with a pollutant emission measurement run; when it is, calculation of percent isokinetic, pollutant emission rate, etc., for the run shall be based upon the results of the reference method or its equivalent; these calculations shall not be based upon the results of the approximation method, unless the approximation method is shown, to the satisfaction of the Administrator, U.S. Environmental Protection Agency, to be capable of yielding results within 1 percent H_2O of the reference method.

NOTE: The reference method may yield questionable results when applied to saturated gas streams or to streams that contain water droplets. Therefore, when these conditions exist or are suspected, a second determination of the moisture content shall be made simultaneously with the reference method, as follows: Assume that the gas stream is saturated. Attach a temperature sensor [capable of measuring to ±1° C (2° F)] to the reference method probe. Measure the stack gas temperature at each traverse point (see Section 2.2.1) during the reference method traverse; calculate the average stack gas temperature. Next, determine the moisture percentage, either by: (1) using a psychrometric chart and making appropriate corrections if stack pressure is different from that of the chart, or (2) using saturation vapor pressure tables. In cases where the pyschrometric chart or the saturation vapor pressure tables are not applicable (based on evaluation of the process), alternative methods, subject to the approval of the Administrator, shall be used.

2. *Reference Method*

The procedure described in Method 5 for determining moisture content is acceptable as a reference method.

2.1 Apparatus. A schematic of the sampling train used in this reference method is shown in Figure 4-1. All components shall be maintained and calibrated according to the procedure outlined in Method 5.

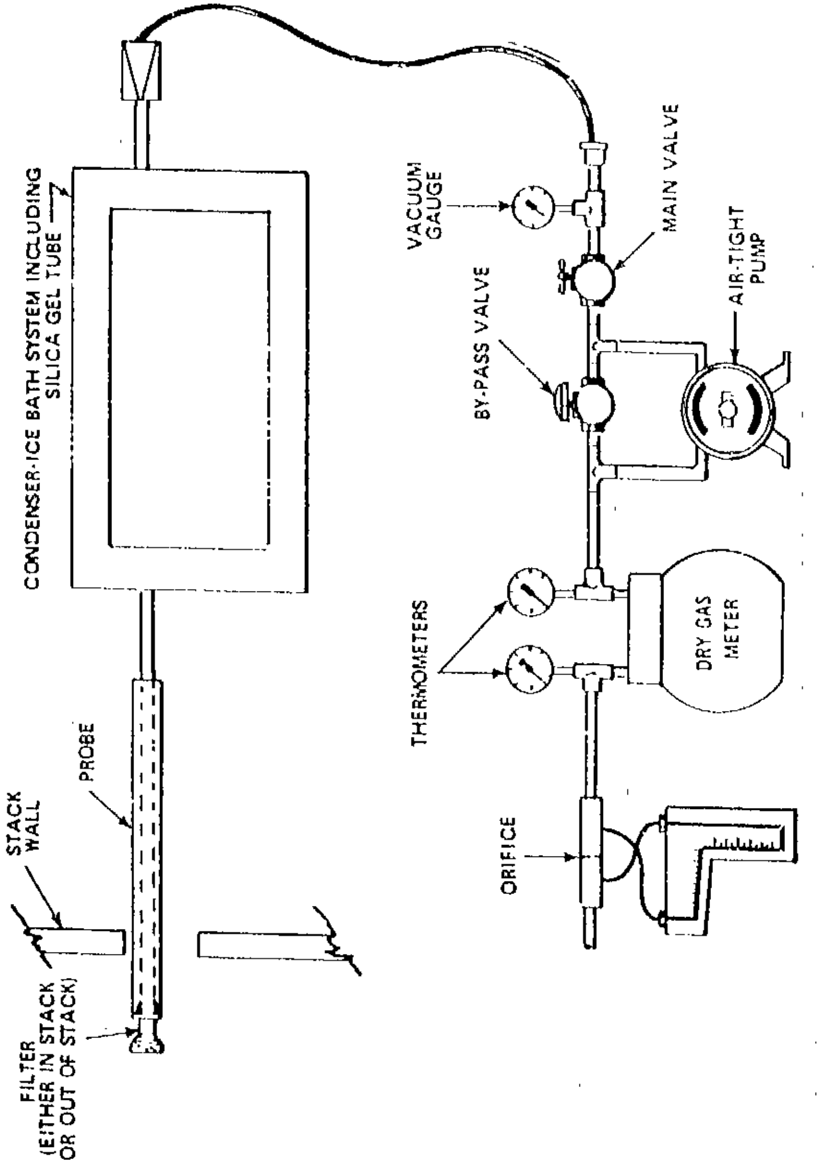

Figure 4-1. Moisture sampling train-reference method.

2.1.1 Probe. The probe is constructed of stainless steel or glass tubing, sufficiently heated to prevent water condensation, and is equipped with a filter, either in-stack (e.g., a plug of glass wool inserted into the end of the probe) or heated out-stack (e.g., as described in Method 5), to remove particular matter.

When stack conditions permit, other metals or plastic tubing may be used for the probe, subject to the approval of the Administrator.

2.1.2 Condenser. The condenser consists of four impingers connected in series with ground glass, leak-free fittings or any similarly leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with a 1.3 centimeter (½ inch) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator.

The first two impingers shall contain known volumes of water, the third shall be empty, and the fourth shall contain a known weight of 6- to 16-mesh indicating type silica gel, or equivalent desiccant. If the silica gel has been previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. A thermometer, capable of measuring temperature to within 1° C (2° F), shall be placed at the outlet of the fourth impinger, for monitoring purposes.

Alternatively, any system may be used (subject to the approval of the Administrator) that cools the sample gas stream and allows measurement of both the water that has been condensed and the moisture leaving the condenser, each to within 1 ml or 1 g. Acceptable means are to measure the condensed water, either gravimetrically or volumetrically, and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures, or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap, with exit gases kept below 20° C (68° F), and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump, to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.3 Cooling System. An ice bath container and crushed ice (or equivalent) are used to aid in condensing moisture.

2.1.4 Metering System. This system includes a vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment as shown in Figure 4-1. Other metering systems, capable of maintaining a constant sampling rate and determining sample gas volume, may be used, subject to the approval of the Administrator.

2.1.5 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby National Weather Service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.6 Graduated Cylinder and/or Balance. These items are used to measure condensed water and moisture caught in the silica gel to within 1 ml or 0.5 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. These balances are suitable for use here.

2.2 Procedure. The following procedure is written for a condenser system (such as the impinger system described in Section 2.1.2) incorporating volumetric analysis to measure the condensed moisture, and silica gel and gravimetric analysis to measure the moisture leaving the condenser.

2.2.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine points shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve traverse points shall be used in all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to the approval of the Administrator. Select a suitable probe and probe length such that all traverse points can be sampled. Consider sampling from opposite sides of the stack (four total sampling ports) for large stacks, to permit use of shorter probe lengths. 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. Place known volumes of water in the first two impingers. Weigh and record the weight of the silica gel to the nearest 0.5 g, and transfer the silica gel to the fourth impinger; alternatively, the silica gel may first be transferred to the impinger, and the weight of the silica gel plus impinger recorded.

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.60 scm (21 scf) will be collected, at a rate no greater than 0.021 m³/min (0.75 cfm). When both moisture content and pollutant emission rate are to be determined, the moisture determination shall be simultaneous with, and for the same total length of time as, the pollutant emission rate run, unless otherwise specified in an applicable subpart of the standards.

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or (if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

2.2.4 During the sampling run, maintain a sampling rate within 10 percent of constant rate, or as specified by the Administrator. For each run, record the data required on the example data sheet shown in Figure 4-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment and whenever sampling is halted. Take other appropriate readings at each sample point, at least once during each time increment.

2.2.5 To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust the flow to the desired rate. Traverse the cross section, sampling at each traverse point for an equal length of time. Add more ice and, if necessary, salt to maintain a temperature of less 20° C (68° F) at the silica gel outlet.

2.2.6 After collecting the sample, disconnect the probe from the filter holder (or from the first impinger) and conduct a leak check (mandatory) as described in Section 2.2.3. Record the leak rate. If the leakage rate exceeds the allowable rate, the tester shall either reject the test results or shall correct the sample volume as in Section 6.3 of Method 5. Next, measure the volume of the moisture condensed to the nearest ml. Determine the increase in weight of the silica gel (or silica gel plus impinger) to the nearest 0.5 g. Record this information (see example data sheet, Figure 4-3) and calculate the moisture percentage, as described in 2.3 below.

2.2.7 A quality control check of the volume metering system at the field site is suggested before collecting the sample following the procedure in Method 5, Section 4.4

2.3 Calculations. Carry out the following calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

FIGURE 4–2—FIELD MOISTURE DETERMINATION REFERENCE METHOD

Plant ....
Location ....
Operator ....
Date ....
Run No. ....
Ambient temperature ....
Barometric pressure ....
Probe length m (ft) ....

SCHEMATIC OF STACK CROSS SECTION

Traverse point number	Sampling time (θ), min.	Stack temperature °C (°F)	Pressure differential across orifice meter ΔH mm (in.) H_2O	Meter reading gas sample volume m³ (ft³)	ΔV_m m³ (ft³)	Gas Sample temperature at dry gas meter Inlet ($T_{m_{in}}$), °C (°F)	Gas Sample temperature at dry gas meter Outlet ($T_{m_{out}}$), °C (°F)	Temperature of gas leaving condenser or last impinger °C (°F)
Total								
Average					Avg.	Avg.	Avg.	

FIGURE 4–3—ANALYTICAL DATA—REFERENCE METHOD

	Impinger volume, ml	Silica gel weight, g
Final		
Initial		
Difference		

2.3.1 Nomenclature.

B_{ws}=Proportion of water vapor, by volume, in the gas stream.

M_w=Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m=Absolute pressure (for this method, same as barometric pressure) at the dry gas meter, mm Hg (in. Hg).

P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R=Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/(lb-mole) (°R) for English units.

T_m=Absolute temperature at meter, °K (°R).

T_{std}=Standard absolute temperature, 293° K (528°R).

V_m=Dry gas volume measured by dry gas meter, dcm (dcf).

ΔV_m=Incremental dry gas volume measured by dry gas meter at each traverse point, dcm (dcf).

$V_{m(std)}$=Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$=Volume of water vapor condensed corrected to standard conditions, scm (scf).

$V_{wsg(std)}$=Volume of water vapor collected in silica gel corrected to standard conditions, scm (scf).

V_f=Final volume of condenser water, ml.

V_i=Initial volume, if any, of condenser water, ml.

W_f=Final weight of silica gel or silica gel plus impinger, g.

W_i=Initial weight of silica gel or silica gel plus impinger, g.

Y=Dry gas meter calibration factor.

ρ_w=Density of water, 0.9982 g/ml (0.002201 lb/ml).

2.3.2 Volume of Water Vapor Condensed.

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w}$$

$$= K_1(V_f - V_i)$$

Eq. 4-1

Where:

K_1=0.001333 m³/ml for metric units
=0.04707 ft³/ml for English units

2.3.3 Volume of Water Vapor Collected in Silica Gel.

$$V_{wsg(std)} = \frac{(W_f - W_i) R T_{std}}{P_{std} M_w}$$

$$= K_2(W_f - W_i)$$

Eq. 4-2

Where:

K_2=0.001335 m³/g for metric units
=0.04715 ft³/g for English units

2.3.4 Sample Gas Volume.

$$V_{m(std)} = V_m Y \frac{(P_m)(T_{std})}{(P_{std})(T_m)}$$

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

Eq. 4-3

Where:

K_3=0.3858 °K/mm Hg for metric units
=17.64 °R/in. Hg for English units

NOTE: If the post-test leak rate (Section 2.2.6) exceeds the allowable rate, correct the value of V_m in Equation 4-3, as described in Section 6.3 of Method 5.

2.3.5 Moisture Content.

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

Eq. 4-4

NOTE: In saturated or moisture droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one using a value based upon the saturated conditions (see Section 1.2), and another based upon the results of the impinger analysis. The lower of these two values of B_{ws} shall be considered correct.

2.3.6 Verification of Constant Sampling Rate. For each time increment, determine the ΔV_m. Calculate the average. If the value for any time increment differs from the average by more than 10 percent, reject the results and repeat the run.

3. *Approximation Method*

The approximation method described below is presented only as a suggested method (see Section 1.2).

3.1 Apparatus.

3.1.1 Probe. Stainless steel glass tubing, sufficiently heated to prevent water condensation and equipped with a filter (either in-stack or heated out-stack) to remove particulate matter. A plug of glass wool, inserted into the end of the probe, is a satisfactory filter.

3.1.2 Impingers. Two midget impingers, each with 30 ml capacity, or equivalent.

3.1.3 Ice Bath. Container and ice, to aid in *condensing moisture in impingers.*

3.1.4 Drying Tube. Tube packed with new or regenerated 6- to 16-mesh indicating-type silica gel (or equivalent desiccant), to dry the sample gas and to protect the meter and pump.

3.1.5 Valve. Needle valve, to regulate the sample gas flow rate.

3.1.6 Pump. Leak-free, diaphragm type, or equivalent, to pull the gas sample through the train.

3.1.7 Volume Meter. Dry gas meter, sufficiently accurate to measure the sample volume within 2%, and calibrated over the range of flow rates and conditions actually encountered during *sampling.*

3.1.8 Rate Meter. Rotameter, to measure the flow range from 0 to 3 lpm (0 to 0.11 cfm).

3.1.9 Graduated Cylinder. 25 ml.

3.1.10 Barometer. Mercury, aneroid, or other barometer, as described in Section 2.1.5 above.

3.1.11 Vacuum Gauge. At least 760 mm Hg *(30 in. Hg) gauge, to be used for the sampling* leak check.

3.2 Procedure.

3.2.1 *Place exactly 5 ml distilled water in* each impinger.

Leak check the sampling train as follows: Temporarily insert a vacuum gauge at or *near the probe inlet; then, plug the probe* inlet and pull a vacuum of at least 250 mm Hg (10 in. Hg). Note the time rate of change of the dry gas meter dial; alternatively, a rotameter (0–40 cc/min) may be temporarily attached to the dry gas meter outlet to determine the leakage rate. A leak rate not in excess of 2 percent of the average sampling *rate is acceptable.*

NOTE: Carefully release the probe inlet plug before turning off the pump.

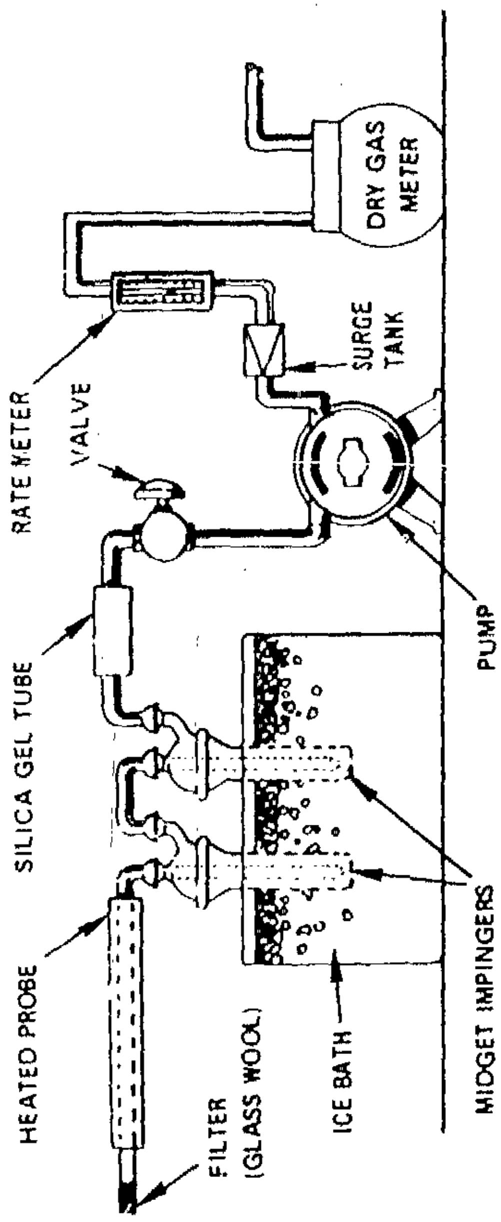

Figure 4-4. Moisture-sampling train - approximation method.

FIGURE 4-5—FIELD MOISTURE DETERMINATION—APPROXIMATION METHOD

Location .... Comments:
Test ....
Date ....
Operator ....
Barometric pressure ....

Clock time	Gas volume through meter, (V_m), m³ (ft³)	Rate meter setting m³/min (ft³/min)	Meter temperature, °C (°F)

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft³) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{wm}=Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.

B_{ws}=Water vapor in the gas stream, proportion by volume.

M_w=Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m=Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.

P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R=Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/lb-mole) (°R) for English units.

T_m=Absolute temperature at meter, °K (°R).

T_{std}=Standard absolute temperature, 293° K (528° R).

V_f=Final volume of impinger contents, ml.

V_i=Initial volume of impinger contents, ml.

V_m=Dry gas volume measured by dry gas meter, dcm (dcf).

$V_{m(std)}$=Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$=Volume of water vapor condensed, corrected to standard conditions, scm (scf).

ρ_w=Density of water, 0.9982 g/ml (0.002201 lb/ml).

Y=Dry gas meter calibration factor.

3.3.2 Volume of Water Vapor Collected.

$$V_{wc} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w}$$

$$= K_1(V_f - V_i)$$

Eq. 4-5

Where:

K_1=0.001333 m³/ml for metric units
=0.04707 ft³/ml for English units.

3.3.3 Gas Volume.

$$V_{m(std)} = V_m\left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right)$$

$$= K_2 \frac{V_m P_m}{T_m}$$

Equation 4-6

where:

K_2=0.3858 °K/mm Hg for metric units
=17.64 °R/in. Hg for English units

3.3.4 Approximate Moisture Content.

$$B_{ws} = \frac{V_{wc}}{V_{wc} + V_{m(std)}} + B_{wm}$$

$$= \frac{V_{wc}}{V_{wc} + V_{m(std)}} + (0.025)$$

Equation 4-7

4. *Calibration*

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. *Bibliography*

1. Air Pollution Engineering Manual (Second Edition). Danielson, J. A. (ed.). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC. Publication No. AP-40. 1973.

2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District, Los Angeles, CA. November, 1963.

3. Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co., Los Angeles, CA. Bulletin WP-50. 1968.

METHOD 5—DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120±14° C (248±25° F) or such other temperature as specified by an applicable subpart of the standards or approved by Administrator, U.S. Environmental Protection Agency, for a particular application. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources.

2. *Apparatus*

2.1 *Sampling Train.* A schematic of the sampling train used in this method is shown in Figure 5-1. Complete construction details are given in APTD-0581 (Citation 2 in Bibliography); commercial models of this train are also available. For changes from APTD-0581 and for allowable modifications of the train shown in Figure 5-1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Bibliography). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

FIGURE 4–5—FIELD MOISTURE DETERMINATION—APPROXIMATION METHOD

Location .... Comments:
Test ....
Date ....
Operator ....
Barometric pressure ....

Clock time	Gas volume through meter, (V_m), m³ (ft³)	Rate meter setting m³/min (ft³/min)	Meter temperature, °C (° F)

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft³) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4–5.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{wm}=Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.

B_{ws}=Water vapor in the gas stream, proportion by volume.

M_w=Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m=Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.

P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R=Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/lb-mole) (°R) for English units.

T_m=Absolute temperature at meter, °K (°R).

T_{std}=Standard absolute temperature, 293° K (528° R).

V_f=Final volume of impinger contents, ml.

V_i=Initial volume of impinger contents, ml.

V_m=Dry gas volume measured by dry gas meter, dcm (dcf).

$V_{m(std)}$=Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$=Volume of water vapor condensed, corrected to standard conditions, scm (scf).

ρ_w=Density of water, 0.9982 g/ml (0.002201 lb/ml).

Y=Dry gas meter calibration factor,

3.3.2 Volume of Water Vapor Collected.

$$V_{wc}=\frac{(V_f-V_i)\rho_w RT_{std}}{P_{std}M_w}$$

$$=K_1(V_f-V_i)$$

Eq. 4–5

Where:

K_1=0.001333 m³/ml for metric units
=0.04707 ft³/ml for English units.

3.3.3 Gas Volume.

$$V_{m(std)}=V_m\left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right)$$

$$=K_2\frac{V_mP_m}{T_m}$$

Equation 4–6

where:

K_2=0.3858 °K/mm Hg for metric units
=17.64 °R/in. Hg for English units

3.3.4 Approximate Moisture Content.

$$B_{ws}=\frac{V_{wc}}{V_{wc}+V_{m(std)}}+B_{wm}$$

$$=\frac{V_{wc}}{V_{wc}+V_{m(std)}}+(0.025)$$

Equation 4–7

4. *Calibration*

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. *Bibliography*

1. Air Pollution Engineering Manual (Second Edition). Danielson, J. A. (ed.). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC. Publication No. AP-40. 1973.

2. Devorkin, Howard. et al. Air Pollution Source Testing Manual. Air Pollution Control District, Los Angeles, CA. November, 1963.

3. Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co., Los Angeles, CA. Bulletin WP-50. 1968.

METHOD 5—DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120±14° C (248±25° F) or such other temperature as specified by an applicable subpart of the standards or approved by Administrator, U.S. Environmental Protection Agency, for a particular application. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources.

2. *Apparatus*

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 5-1. Complete construction details are given in APTD–0581 (Citation 2 in Bibliography); commercial models of this train are also available. For changes from APTD–0581 and for allowable modifications of the train shown in Figure 5–1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Bibliography). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

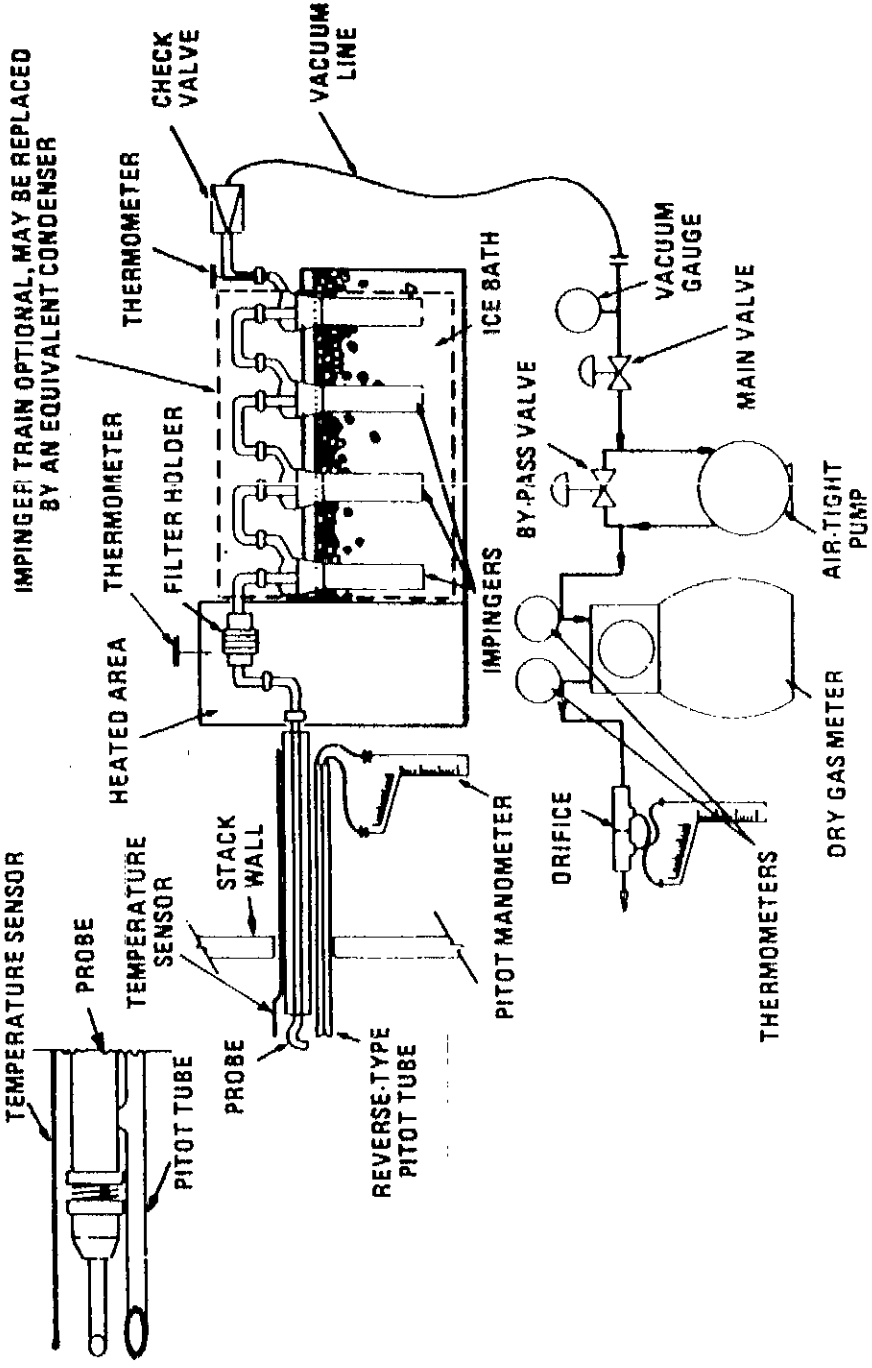

Figure 5-1. Particulate-sampling train.

2.1.1 Probe Nozzle. Stainless steel (316) or glass with sharp, tapered leading edge. The angle of taper shall be ≤30° and the taper shall be on the outside to preserve a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing; other materials of construction may be used, subject to the approval of the Administrator.

A range of nozzle sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1.27 cm (⅛ to ½ in.)—or larger if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (1⁄16 in.). Each nozzle shall be calibrated according to the procedures outlined in Section 5.

2.1.2 Probe Liner. Borosilicate or quartz glass tubing with a heating system capable of maintaining a gas temperature at the exit end during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. (The tester may opt to operate the equipment at a temperature lower than that specified.) Since the actual temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APTD–0581 and utilizing the calibration curves of APTD-0576 (or calibrated according to the procedure outlined in APTD-0576) will be considered acceptable.

Either borosilicate or quartz glass probe liners may be used for stack temperatures up to about 480° C (900° F); quartz liners shall be used for temperatures between 480 and 900° C (900 and 1,650° F). Both types of liners may be used at higher temperatures than specified for short periods of time, subject to the approval of the Administrator. The softening temperature for borosilicate is 820° C (1,508° F), and for quartz it is 1,500° C (2,732° F).

Whenever practical, every effort should be made to use borosilicate or quartz glass probe liners. Alternatively, metal liners (e.g., 316 stainless steel, Incoloy 825,[2] or other corrosion resistant metals) made of seamless tubing may be used, subject to the approval of the Administrator.

2.1.3 Pitot Tube. Type S, as described in Section 2.1 of Method 2, or other device approved by the Administrator. The pitot tube shall be attached to the probe (as shown in Figure 5–1) to allow constant monitoring of the stack gas velocity. The impact (high pressure) opening plane of the pitot tube shall be even with or above the nozzle entry plane (see Method 2, Figure 2–6b) during sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

2.1.4 Differential Pressure Gauge. Inclined manometer or equivalent device (two), as described in Section 2.2 of Method 2. One manometer shall be used or velocity head (Δp) readings, and the other, for orifice differential pressure readings.

2.1.5 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket. Other materials of construction (e.g., stainless steel, Teflon, Viton) may be used, subject to approval of the Administrator. The holder design shall provide a positive seal against leakage from the outside or around the filter. The holder shall be attached immediately at the outlet of the probe (or cyclone, if used).

2.1.6 Filter Heating System. Any heating system capable of maintaining a temperature around the filter holder during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. Alternatively, the tester may opt to operate the equipment at a temperature lower than that specified. A temperature gauge capable of measuring temperature to within 3° C (5.4° F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the one shown in APTD 0581 may be used.

2.1.7 Condenser. The following system shall be used to determine the stack gas moisture content: Four impingers connected in series with leak-free ground glass fittings or any similar leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with 1.3 cm (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator. The first and second impingers shall contain known quantities of water (Section 4.1.3), the third shall be empty, and the fourth shall contain a known weight of silica gel, or equivalent desiccant. A thermometer, capable of measuring temperature to within 1° C (2° F) shall be placed at the outlet of the fourth impinger for monitoring purposes.

Alternatively, any system that cools the sample gas stream and allows measurement of the water condensed and moisture leaving the condenser, each to within 1 ml or 1 g may be used, subject to the approval of the Administrator. Acceptable means are to measure the condensed water either gravi-

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[2] Mention of trade names or specific product does not constitute endorsement by the Environmental Protection Agency.

metrically or volumetrically and to measure the moisture *leaving the condenser by:* (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures; or (2) passing the sample has stream through a tared silica gel *(or equivalent desiccant)* trap with exit gases kept below 20° C (68° F) and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

NOTE: If a determination of the particulate matter collected in the impingers is desired in addition to moisture content, the im*pinger system described* above shall be used, without modification. Individual States or control agencies requiring this information shall be contacted as to the sample recovery and analysis of the impinger contents.

2.1.8 *Metering* System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 5–1. Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that decribed in APTD-0581 or APDT-0576 may be used provided that the specifications of this method are met.

2.1.9 Barometer. *Mercury aneroid,* or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg). In many cases the barometric reading may be obtained from a nearby National *Weather Service station,* in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.10 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3. The temperature sensor shall, preferably, be permanently attached to the pitot tube or sampling probe in a fixed configuration, such that the tip of the sensor extends beyond the leading edge of the probe sheath and does not touch any *metal.* Alternatively, the sensor may be attached just prior to use in the field. Note, however, that if the temperature sensor is attached in the field, the sensor must be placed in an interference-free arrangement with respect to the Type S pitot tube openings (see Method 2, Figure 2–7). As a second alternative, if a difference of not more than 1 percent in the average velocity measurement is to be introduced, the temperature gauge need not be attached to the probe or pitot tube. (This alternative is subject to the approval of the Administrator.)

2.2 Sample Recovery. The following items are needed.

2.2.1 Probe-Liner and Probe-Nozzle Brushes. Nylon bristle brushes with stainless steel wire handles. The probe brush shall have extensions (at least as long as the probe) of stainless steel, Nylon, Teflon, or similarly inert material. The brushes shall be properly sized and shaped to brush out the probe liner and nozzle.

2.2.2 Wash Bottles—Two. Glass wash bottles are *recommended; polyethylene wash* bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 *Glass Sample Storage* Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as *to be leak-free and* resistant to chemical attack by acetone. (Narrow mouth glass bottles have been found to be less prone to leakage.) Alternatively, polyethylene bottles may be used.

2.2.4 Petri Dishes. For filter samples, glass or polyethylene, unless otherwise specified by the Administrator.

2.2.5 Graduated Cylinder and/or Balance. To measure condensed water to within 1 ml or 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances is sultable or use here and in Section 2.3.4.

2.2.6 Plastic Storage Containers. Air-tight containers to store silica gel.

2.2.7 Funnel and Rubber Policeman. To aid in transfer of silica gel to container; not necessary if silica gel is *weighed in the field.*

2.2.8 Funnel, Glass or polyethylene, to aid in sample recovery.

2.3 Analysis. For analysis, the following equipment is needed.

2.3.1 *Glass Weighing Dishes.*

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 *Beakers. 250 ml.*

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature Gauge. To *measure the* temperature of the laboratory environment.

3. *Reagents*

3.1 Sampling. The reagents used in sampling are as follows:

3.1.1 Filters. Glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (<0.05 percent penetration) on 0.3-micron dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with ASTM Standard Method D2986–71 (Reapproved 1978) (Incorporated by reference—see §60.17). Test data from the supplier's quality control program are sufficient for this purpose. In *sources* containing SO_2 or SO_3, the filter material must be of a type that is unreactive to SO_2 or SO_3. Citation 10 in Bibliography, may be used to select the appropriate filter.

3.1.2 Silica Gel. Indicating *type, 6 to 16* mesh. If previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccants (equivalent or better) may be used, subject to the *approval of the Adminis*trator.

3.1.3 Water. When analysis of the material caught in the impingers is required, deionized distilled water shall be used. Run blanks prior *to field use to eliminate* a high blank on test samples.

3.1.4 Crushed Ice.

3.1.5 Stopcock Grease. Acetone-insoluble, heat-stable silicone grease. This is not necessary if *screw-on connectors* with Teflon sleeves, or similar, are used. Alternatively, other types of stopcock grease may be used, subject to the approval of the Administrator.

3.2 Sample Recovery. Acetone-reagent *grade, ≤0.001* percent residue, in glass bottles—is required. Acetone from metal containers generally has a high residue blank and should not be used. Sometimes, suppliers transfer acetone to glass bottles from metal containers; thus, acetone blanks shall be run prior to field use and only acetone with low blank values (≤0.001 percent) shall be used. In no case shall a blank value of greater than 0.001 percent of the weight of acetone *used be* subtracted from the sample weight.

3.3 Analysis. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

3.3.2 Desiccant. Anhydrous *calcium sulfate,* indicating type. Alternatively, other types of desiccants may be used, subject to the approval of the Administrator.

4. *Procedure*

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testers should be trained and experienced with the test procedures.

4.1.1 Pretest Preparation. It is suggested that sampling equipment be maintained according to the procedure described in APTD-0576.

Weigh several 200 to 300 g portions of silica gel in air-tight containers to the nearest 0.5 g. Record the total weight of the silica gel plus container, on each container. As an alternative, the silica gel *need not* be preweighed, but may be weighed directly in the impinger or sampling holder just prior to train assembly.

Check filters visually against light for irregularities and flaws *or pinhole leaks.* Label filters of the proper diameter on the back side near the edge using numbering machine ink. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters *in these containers* at all times except during sampling and weighing.

Desiccate the filters at 2015.6° C (68110° 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* above 60 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. Procedures *other than* those described, which account for relative humidity effects, may be used, subject to the approval of the Administrator.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number *of sampling* points according to Method 1 or as specified by the Administrator. Determine the stack pressure, temperature, and the range of velocity heads using Method 2; it is recommended that a leak-check of the pitot *lines* (see Method 2, Section 3.1) be performed. Determine the moisture content using Approximation Method 4 or its alternatives for the purpose of making isokinetic sampling rate settings. Determine the *stack* gas dry molecular weight, as described in Method 2, Section 3.6; if integrated Method 3 sampling is used for molecular weight determination, the integrated bag sample shall be taken simultaneously *with, and for the same* total length of time as, the particulate sample run.

Select a nozzle size based on the range of velocity heads, such that it is not necessary to change the *nozzle size in order* to maintain isokinetic sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads en*countered (see Section* 2.2 of *Method* 2).

Select a suitable probe liner and probe length such that all traverse points can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce *the length of* probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 min (or some greater time interval as specified by the Administrator), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximate average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors. The sampling time at each point shall be the same.

In some circumstances, e.g., batch cycles, it may be necessary to sample for shorter times at the traverse points and to obtain smaller gas sample volumes. In these cases, the Administrator's approval must first be obtained.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

Place 100 ml of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.5 g and recorded.

Using a tweezer or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as to prevent the sample gas stream from circumventing the filter. Check the filter for tears after assembly is completed.

When glass liners are used, install the selected nozzle using a Viton A O-ring when stack temperatures are less than 260° C (500° F) and an asbestos string gasket when temperatures are higher. See APTD-0576 for details. Other connecting systems using either 316 stainless steel or Teflon ferrules may be used. When metal liners are used, install the nozzle as above or by a leak-free direct mechanical connection. 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.

Set up the train as in Figure 5-1, using (if necessary) a very light coat of silicone grease on all ground glass joints, greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Subject to the approval of the Administrator, a glass cyclone may be used between the probe and filter holder when the total particulate catch is expected to exceed 100 mg or when water droplets are present in the stack gas.

Place crushed ice around the impingers.

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 opts to conduct the pretest leak-check, the following procedure shall be used.

After the sampling train has been assembled, turn on and set the filter and probe heating systems at the desired operating temperatures. Allow time for the temperatures to stabilize. If a Viton A O-ring or other leak-free connection is used in assembling the probe nozzle to the probe liner, leak-check the train at the sampling site by plugging the nozzle and pulling a 380 mm Hg (15 in. Hg) vacuum.

NOTE: A lower vacuum may be used, provided that it is not exceeded during the test.

If an asbestos string is used, do not connect the probe to the train during the leak-check. Instead, leak-check the train by first plugging the inlet to the filter holder (cyclone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in. Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in. Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with bypass valve fully open and coarse adjust valve, completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of bypass valve; this will cause water to back up into the filter holder. If the desired vacuum is exceeded, either leak-check at this higher vacuum or end the leak-check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe, filter holder, or cyclone (if applicable) and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced backward into the filter holder and silica gel from being entrained backward into the third impinger.

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction will need to 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 plan to correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

Immediately after component changes, leak-checks are optional; if such leak-checks are done, the procedure outlined in Section 4.1.4.1 above shall be used.

4.1.4.3 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, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 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 6.3 of this method, or shall void the sampling run.

4.1.5 Particulate Train Operation. During the sampling run, maintain an isokinetic sampling rate (within 10 percent of true isokinetic unless otherwise specified by the Administrator) and a temperature around the filter of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator.

For each run, record the data required on a data sheet such as the one shown in Figure 5-2. Be sure to record the initial dry gas meter reading. Record the dry gas meter readings at the beginning and end of each sampling time increment, when changes in flow rates are made, before and after each leak-check, and when sampling is halted. Take other readings required by Figure 5-2 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

Clean the portholes prior to the test run to minimize the chance of sampling deposited material. To begin sampling, remove the nozzle cap, verify that the filter and probe heating systems are up to temperature, and that the pitot tube and probe are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Nomographs are available, which aid in the rapid adjustment of the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85±0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29±4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges do not use the nomographs unless appropriate steps (see Citation 7 in Bibliography) are taken to compensate for the deviations.

FIGURE 5–2—PARTICULATE FIELD DATA

Plant ....
Location ....
Operator ....
Date ....
Run No ....
Sample box No ....
Meter box No ....
Meter ΔH@ ....
C factor ....
Pitot tube coefficient, Cp ....

Ambient temperature ....
Barometric pressure ....
Assumed moisture, % ....
Probe length, m. (ft.) ....
Nozzle identification No. ....
Average calibrated nozzle diameter, cm (in.) ....
Probe heater setting ....
Leak rate, m³/min, (cfm) ....
Probe liner material ....
Static pressure, mm. Hg (in. Hg) ....
Filter No. ....

SCHEMATIC OF STACK CROSS SECTION

Traverse point number	Sampling time	Vacuum	Stack temperature	Velocity head	Pressure differential across orifice meter	Gas sample volume	Gas sample temperature at dry gas meter		Filter holder temperature	Temperature of gas leaving condenser or last impinger
							Inlet	Outlet		
	(θ), min.	mm Hg (in. Hg)	(T_S), °C (°F)	(ΔP_s), mm (in.) H_2O	mm H_2O (in. H_2O)	m³ (ft³)	°C (°F)	°C (°F)	°C (°F)	°C (°F)
Total							Avg.	Avg.		
Average							Avg.			

When the stack is under significant negative pressure (height of impinger stem), take care to close the coarse adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross-section, as required by Method 1 or as specified by the Administrator, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe through the portholes; this minimizes the chance of extracting deposited material.

During the test run, make periodic adjustments to keep the temperature around the filter holder at the proper level; add more ice and, if necessary, salt to maintain a temperature of less than 20° C (68° F) at the condenser/silica gel outlet. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter assembly be used rather than attempting to change the filter itself. Before a new filter assembly is installed, conduct a leak-check (see Section 4.1.4.2). The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Administrator.

Note that when two or more trains are used, separate analyses of the front-half and (if applicable) impinger catches from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case, the front-half catches from the individual trains may be combined (as may the impinger catches) and one analysis of front-half catch and one analysis of impinger catch may be performed. Consult with the Administrator for details concerning the calculation of results when two or more trains are used.

At the end of the sample run, turn off the coarse adjust valve, remove the probe and nozzle from the stack, turn off the pump, record the final dry gas meter reading, and conduct a post-test leak-check, as outlined in Section 4.1.4.3. Also, leak-check the pitot lines as described in Method 2, Section 3.1; the lines must pass this leak-check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Calculations, Section 6) to determine whether the run was valid or another test run should be made. If there was difficulty in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe is removed from the stack at the end of the sampling period. Allow the probe to cool.

When the probe can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, thus drawing water from the impingers into the filter holder.

Before moving the sample train to the cleanup site, remove the probe from the sample train, wipe off the silicone grease, and cap the open outlet of the probe. Be careful not to lose any condensate that might be present. Wipe off the silicone grease from the filter inlet where the probe was fastened and cap it. Remove the umbilical cord from the last impinger and cap the impinger. If a flexible line is used between the first impinger or condenser and the filter holder, disconnect the line at the filter holder and let any condensed water or liquid drain into the impingers or condenser. After wiping off the silicone grease, cap off the filter holder outlet and impinger inlet. Either ground-glass stoppers, plastic caps, or serum caps may be used to close these openings.

Transfer the probe and filter-impinger assembly to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank. Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry Nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container No. 2. Taking care to see that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, probe fitting, probe liner, and front half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Administrator and shall be used when specified by the Administrator; in these cases, save a water blank and follow the Administrator's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a Nylon bristle brush. Brush until the acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone.

Brush and rinse the inside parts of the Swagelok fitting with acetone in a similar way until no visible particles remain.

Rinse the probe liner with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces will be wetted with acetone. Let the acetone drain from the lower end into the sample container. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Follow the acetone rinse with a probe brush. Hold the probe in an inclined position, squirt acetone into the upper end as the probe brush is being pushed with a twisting action through the probe; hold a sample container underneath the lower end of the probe, and catch any acetone and particulate matter which is brushed from the probe. Run the brush through the probe three times or more until no visible particulate matter is carried out with the acetone or until none remains in the probe liner on visual inspection. With stainless steel or other metal probes, run the brush through in the above prescribed manner at least six times since metal probes have small crevices in which particulate matter can be entrapped. Rinse the brush with acetone, and quantitatively collect these washings in the sample container. After the brushing, make a final acetone rinse of the probe as described above.

It is recommended that two people clean the probe to minimize sample losses. Between sampling runs, keep brushes clean and protected from contamination.

After ensuring that all joints have been wiped clean of silicone grease, clean the inside of the front half of the filter holder by rubbing the surfaces with a Nylon bristle brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make a final rinse of the brush and filter holder. Carefully rinse out the glass cyclone, also (if applicable). After all acetone washings and particulate matter have been collected in the sample container, tighten the lid on the sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage occured during transport. Label the container to clearly identify its contents.

Container No. 3. Note the color of the indicating silica gel to determine if it has been completely spent and make a notation of its condition. Transfer the silica gel from the fourth impinger to its original container and seal. A funnel may make it easier to pour the silica gel without spilling. A rubber policeman may be used as an aid in removing the silica gel from the impinger. It is not necessary to remove the small amount of dust particles that may adhere to the impinger wall and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, follow the procedure for container No. 3 in Section 4.3.

Impinger Water. Treat the impingers as follows: Make a notation of any color or film in the liquid catch. Measure the liquid which is in the first three impingers to within ±1 ml by using a graduated cylinder or by weighing it to within ±0.5 g by using a balance (if one is available). Record the volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas.

Discard the liquid after measuring and recording the volume or weight, unless analysis of the impinger catch is required (see Note, Section 2.1.7).

If a different type of condenser is used, measure the amount of moisture condensed either volumetrically or gravimetrically.

Whenever possible, containers should be shipped in such a way that they remain upright at all times.

4.3 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Handle each sample container as follows:

FIGURE 5-3—ANALYTICAL DATA

Plant ________

Date ________

Run No. ________

Filter No. ________

Amount liquid lost during transport ________

Acetone blank volume, ml ________

Acetone wash volume, ml ________

Acetone blank concentration, mg/mg (Equation 5-4) ________

Acetone wash blank, mg (Equation 5-5) ________

Container number	Weight of particulate collected, mg		
	Final weight	Tare weight	Weight gain
1.			

Container number	Weight of particulate collected, mg		
	Final weight	Tare weight	Weight gain
2.			
Total.			
Less acetone blank.			
Weight of particulate matter.			

	Volume of liquid water collected	
	Impinger volume, ml	Silica gel weight, g
Final.		
Initial.		
Liquid collected.		
Total volume collected		g* ml

*Convert weight of water to volume by dividing total weight increase by density of water (1 g/ml).

$$\frac{\text{Increase, g}}{(1\ \text{g/ml})} = \text{Volume water, ml}$$

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, with no less than 6 hours of desiccation time between weighings.

Alternatively, the sample may be oven dried at 105° C (220° F) for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. The tester may also opt to oven dry the sample at 105° C (220° F) for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

Container No. 2. Note the level of liquid in the container and confirm on the analysis sheet whether or not leakage occurred during transport. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results. Measure the liquid in this container either volumetrically to ±1 ml or gravimetrically to ±0.5 g. Transfer the contents to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Container No. 3. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g using a balance. This step may be conducted in the field.

"Acetone Blank" Container. Measure acetone in this container either volumetrically or gravimetrically. Transfer the acetone to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

NOTE: At the option of the tester, the contents of Container No. 2 as well as the acetone blank container may be evaporated at temperatures higher than ambient. If evaporation is done at an elevated temperature, the temperature must be below the boiling point of the solvent; also, to prevent "bumping," the evaporation process must be closely supervised, and the contents of the beaker must be swirled occasionally to maintain an even temperature. Use extreme care, as acetone is highly flammable and has a low flash point.

4.4 Quality Control Procedures. The following quality control procedures are suggested to check the volume metering system calibration values at the field test site prior to sample collection. These procedures are optional for the tester.

4.4.1 Meter Orifice Check. Using the calibration data obtained during the calibration procedure described in Section 5.3, determine the $\Delta H_@$ for the metering system orifice. The $\Delta H_@$ is the orifice pressure differential in units of in. H_2O that correlates to 0.75 cfm of air at 528°R and 29.92 in. Hg. The $\Delta H_@$ is calculated as follows:

$$\Delta H_@ = 0.0319\ \Delta H\ \frac{T_m}{P_{bar}}\ \frac{\Theta^2}{Y^2 V_m^2} \qquad \text{Eq. 5-9}$$

Where:

ΔH=Average pressure differential across the orifice meter, in. H_2O.

T_m=Absolute average dry gas meter temperature, °R.

P_{bar}=Barometric pressure, in. Hg.

Θ=Total sampling time, min.

Y=Dry gas meter calibration factor, dimensionless.

V_m=Volume of gas sample as measured by dry gas meter, dcf.

0.0319=(0.0567 in. Hg/°R) x (0.75 cfm)².

Before beginning the field test (a set of three runs usually constitutes a field test), operate the metering system (i.e., pump, volume meter, and orifice) at the $\Delta H_@$ pressure differential for 10 minutes. Record the volume collected, the dry gas meter temperature, and the barometric pressure. Calculate a dry gas meter calibration check value, Y_c, as follows:

$$Y_c = \frac{10}{V_m}\left[\frac{0.0319\ T_m}{P_{bar}}\right]^{1/2}$$

Eq. 5-10

Where:

Y_c=Dry gas meter calibration check value, dimensionless.

10=10 minutes of run time.

Compare the Y_c value with the dry gas meter calibration factor Y to determine that:

$$0.97Y<Y_c<1.03Y$$

If the Y_c value is not within this range, the volume metering system should be investigated before beginning the test.

4.4.2 Calibrated Critical Orifice. A calibrated critical orifice, calibrated against a wet test meter or spirometer and designed to be inserted at the inlet of the sampling meter box may be used as a quality control check by following the procedure of Section 7.2.

5. *Calibration*

Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of the nozzle to the nearest 0.025 mm (0.001 in.). Make three separate measurements using different diameters each time, and obtain the average of the measurements. The difference between the high and low numbers shall not exceed 0.1 mm (0.004 in.). When nozzles become nicked, dented, or corroded, they shall be reshaped, sharpened, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

5.2 Pitot Tube. The Type S pitot tube assembly shall be calibrated according to the procedure outlined in Section 4 of Method 2.

5.3 Metering System.

5.3.1 Calibration Prior to Use. Before its initial use in the field, the metering system shall be calibrated as follows: Connect the metering system inlet to the outlet of a wet test meter that is accurate to within 1 percent. Refer to Figure 5.5. The wet test meter should have a capacity of 30 liters/rev (1 ft^3/rev). A spirometer of 400 liters (14 ft^3) or more capacity, or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should be periodically calibrated with a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained. Run the metering system pump for about 15 minutes with the orifice manometer indicating a median reading as expected in field use to allow the pump to warm up and to permit the interior surface of the wet test meter to be thoroughly wetted. Then, at each of a minimum of three orifice manometer settings, pass an exact quantity of gas through the wet test meter and note the gas volume indicated by the dry gas meter. Also note the barometric pressure, and the temperatures of the wet test meter, the inlet of the dry gas meter, and the outlet of the dry gas meter. Select the highest and lowest orifice settings to bracket the expected field operating range of the orifice. Use a minimum volume of 0.15 m^3 (5 cf) at all orifice settings. Record all the data on a form similar to Figure 5.6, and calculate Y, the dry gas meter calibration factor, and $\Delta H_{@}$, the orifice calibration factor, at each orifice setting as shown on Figure 5.6. Allowable tolerances for individual Y and $\Delta H_{@}$ values are given in Figure 5.6. Use the average of the Y values in the calculations in Section 6.

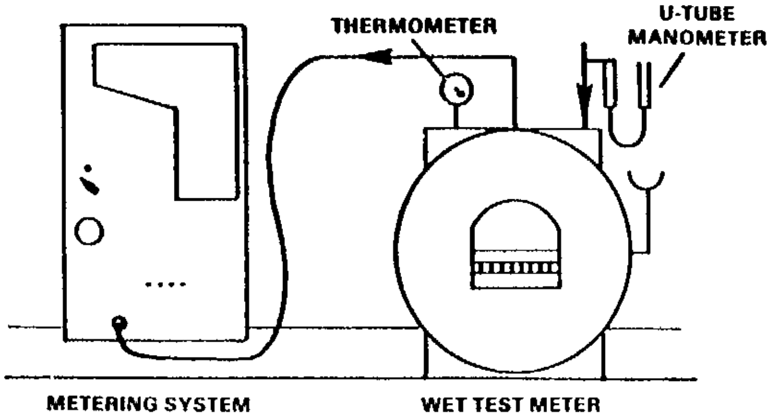

Figure 5.5 Equipment arrangement for metering system calibration.

Date________________ Metering System Identification: ________________

Barometric pressure, P_b = _______ in. Hg

Orifice manometer setting ΔH in. H_2O	Spirometer (wet meter) gas volume V_w ft^3	Dry gas meter volume V_m ft^3	Temperatures				Time Θ min
			Spirometer (wet meter) t_w °F	Dry Gas Meter			
				Inlet t_i °F	Outlet t_o °F	Average t_m °F	

Calculations

ΔH in. H_2O	Y	$\Delta H@$
	$\dfrac{V_w P_b (t_m + 460)}{V_m \left[P_b + \dfrac{\Delta H}{13.6}\right] (t_w + 460)}$	$\dfrac{0.0317 \Delta H}{P_b (t_o + 460)} \left[\dfrac{(t_w + 460)\,\Theta}{V_w}\right]^2$
Average		

Y = Ratio of reading of wet test meter to dry test meter; tolerance for individual values ±0.02 from average.

$\Delta H@$ = Orifice pressure differential that equates to 0.75 cfm of air @ 68°F and 29.92 inches of mercury, in. H_2O; tolerance for individual values ±0.20 from average.

Figure 5.6. Example data sheet for calibration of metering system (English units).

Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057m^3/min (0.02 cfm); at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divide the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m^3/min (0.02 cfm).

5.3.2 Calibration After Use. After each field use, the calibration of the metering system shall be checked by performing three calibration runs at a single, intermediate orifice setting (based on the previous field test), with the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the metering system. Calculate the average value of the dry gas meter calibration factor. If the value has changed by more than 5 percent, recalibrate the meter over the full range of orifice settings, as previously detailed.

Alternative procedures, e.g., rechecking the orifice meter coefficient may be used, subject to the approval of the Administrator.

5.3.3 Acceptable Variation in Calibration. If the dry gas meter 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.

5.4 Probe Heater Calibration. The probe heating system shall be calibrated before its initial use in the field.

Use a heat source to generate air heated to selected temperatures that approximate those expected to occur in the sources to be sampled. Pass this air through the probe at a typical simple flow rate while measuring the probe inlet and outlet temperatures at various probe heater settings. For each air temperature generated, construct a graph of probe heating system setting versus probe outlet temperature. The procedure outlined in APTD–0576 can also be used. Probes constructed according to APTD–0581 need not be calibrated if the calibration curves in APTD–0576 are used. Also, probes with outlet temperature monitoring capabilities do not require calibration.

5.5 Temperature Gauges. Use the procedure in Section 4.3 of Method 2 to calibrate in-stack temperature gauges. Dial thermometers, such as are used for the dry gas meter and condenser outlet, shall be calibrated against mercury-in-glass thermometers.

5.6 Leak Check of Metering System Shown in Figure 5-1. That portion of the sampling train from the pump to the orifice meter should be leak checked prior to initial use and after each shipment. Leakage after the pump will result in less volume being recorded than is actually sampled. The following procedure is suggested (see Figure 5-4): Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing attached into the orifice exhaust pipe. Disconnect and vent the low side of the orifice manometer. Close off the low side orifice tap. Pressurize the system to 13 to 18 cm (5 to 7 in.) water column by blowing into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box; leaks, if present, must be corrected.

5.7 Barometer. Calibrate against a mercury barometer.

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.

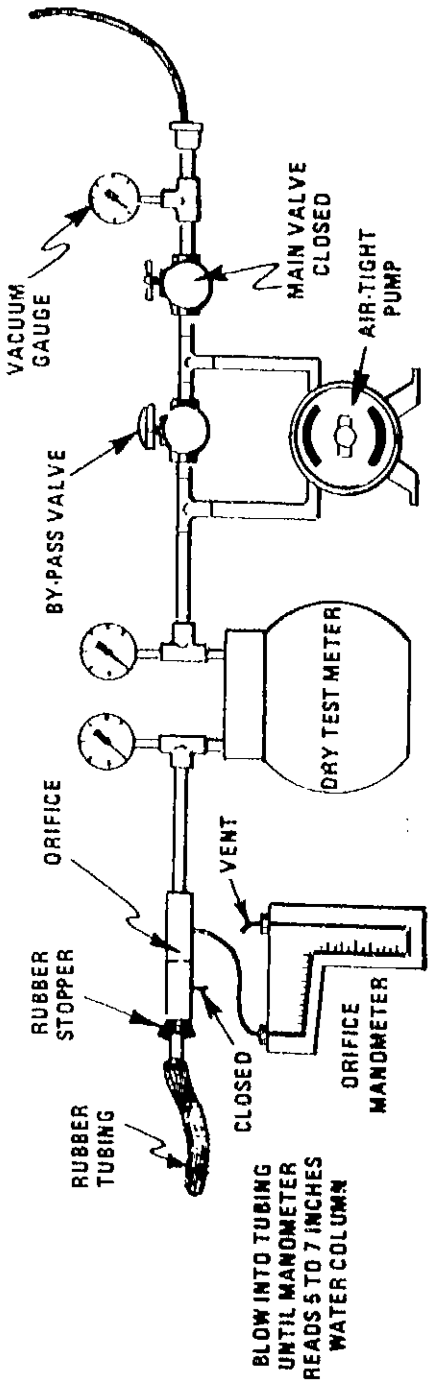

Figure 5–4. Leak check of meter box.

6.1 Nomenclature.

A_n=Cross-sectional area of nozzle, m² (ft²).
B_{ws}=Water vapor in the gas stream, proportion by volume.
C_a=Acetone blank residue concentration, mg/mg.
c_s=Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).
I=Percent of isokinetic sampling.
L_a=Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.
L_i=Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change (i=1, 2, 3....n), m³/min (cfm).
L_p=Leakage rate observed during the post-test leak check, m³/min (cfm).
m_a=Mass of residue of acetone after evaporation, mg.
m_n=Total amount of particulate matter collected, mg.
M_w=Molecular weight of water, 18.0 g/g-mole (18.0lb/lb-mole).
P_{bar}=Barometric pressure at the sampling site, mm Hg (in. Hg).
P_s=Absolute stack gas pressure, mm Hg (in. Hg).
P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
R=Ideal gas constant, 0.06236 mm Hg-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).
T_m=Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).
T_s=Absolute average stack gas temperature (see Figure 5-2), °K (°R).
T_{std}=Standard absolute temperature, 293° K (528° R).
V_a=Volume of acetone blank, ml.
V_{aw}=Volume of acetone used in wash, ml.
V_{lc}=Total volume of liquid collected in impingers and silica gel (see Figure 5–3), ml.
V_m=Volume of gas sample as measured by dry gas meter, dcm (dscf).
$V_{m(std)}$=Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$=Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
v_s=Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).
W_a=Weight of residue in acetone wash, mg.
Y=Dry gas meter calibration factor.
ΔH=Average pressure differential across the orifice meter (see Figure 5–2), mm H_2O (in. H_2O).
ρ_a=Density of acetone, mg/ml (see label on bottle).
ρ_w=Density of water, 0.9982 g/ml (0.002201 lb/ml).
θ=Total sampling time, min.
θ_1=Sampling time interval, from the beginning of a run until the first component change, min.
θ_i=Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.
θ_p=Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.
13.6=Specific gravity of mercury.
60=Sec/min.
100=Conversion to percent.

6.2 Average Dry Gas Meter Temperature and Average Orifice Pressure Drop. See data sheet (Figure 5-2).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C, 760 mm Hg or 68° F, 29.92 in. Hg) by using Equation 5–1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left[\frac{P_{bar}+\frac{\Delta H}{13.6}}{P_{std}}\right]$$

$$= K_1 V_m Y \frac{P_{bar}+(\Delta H/13.6)}{T_m}$$

Equation 5-1

Where;
K_1=0.3858 °K/mm Hg for metric units
=17.64 °R/in. Hg for English units

NOTE: Equation 5-1 can be used as written unless the leakage rate observed during any of the mandatory leak checks (i.e., the post-test leak check or leak checks conducted prior to component changes) exceeds L_a. If L_p or L_i exceeds L_a, Equation 5-1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 5-1 with the expression:

$$[V_m-(L_p-L_a)\theta]$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace V_m in Equation 5–1 by the expression:

$$\left[V_m-(L_1-L_a)\theta_1 - \sum_{i=2}^{n}(L_i-L_a)\theta_i-(L_p-L_a)\theta_p\right]$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of Water Vapor.

$$V_{w(std)} = \frac{V_{lc}\ \rho_w\ R\ T_{std}}{M_w\ P_{std}} = K_2\ V_{lc}$$

Eq. 5-2

Where:

K_2=0.001333 m³/ml for metric units
=0.04707 ft³/ml for English units.

6.5 Moisture Content.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

Eq. 5-3

Note: In saturated or water droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one from the impinger analysis (Equation 5-3), and a second from the assumption of saturated conditions. The lower of the two values of B_{ws} shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the Note of Section 1.2 of Method 4. For the purposes of this method, the average stack gas temperature from Figure 5-2 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is ±1° C (2° F).

6.6 Acetone Blank Concentration.

$$C_a = \frac{m_a}{V_a \rho_a} \qquad \text{Eq. 5-4}$$

6.7 Acetone Wash Blank.

$$W_a = C_a V_{aw} \rho_a \qquad \text{Eq. 5-5}$$

6.8 Total Particulate Weight. Determine the total particulate catch from the sum of the weights obtained from Containers 1 and 2 less the acetone blank (see Figure 5-3).

Note: Refer to Section 4.1.5 to assist in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

$$c_s = (0.001\ g/mg)\ (m_n / V_{m\ (std)})$$

Eq. 5-6

6.10 Conversion Factors:

From	To	Multiply by
scf	m³	0.02832.
g	mg	0.001
g/ft³	gr/ft³	15.43.
g/ft³	lb/ft³	2.205×10⁻³.
g/ft³	g/m³	35.31.

6.11 Isokinetic Variation.

6.11.1 Calculation From Raw Data.

$$I = \frac{100\ T_s[K_3 V_{lc} + (V_m Y / T_m)(P_{bar} + \Delta H/13.6)]}{60 \theta v_s P_s A_n}$$

Eq. 5-7

Where:

K_3=0.003454 mm Hg−m³/ml−°K for metric units.
=0.002669-in. Hg−ft³/ml−°R for English units.

6.11.2 Calculation From Intermediate Values.

$$I = \frac{100\ T_s\ V_{m(std)}\ P_{std}}{60\ T_{std}\ v_s\ \theta\ A_n\ P_s\ (1 - B_{ws})}$$

$$= \frac{K_4\ T_s\ V_{m(std)}}{P_s\ v_s\ A_n\ \theta\ (1 - B_{ws})} \qquad \text{Eq. 5-8}$$

Where:

K_4=4.320 for metric units
=0.09450 for English units.

6.12 Acceptable Results. If 90 percent ≤ I ≤ 110 percent, the results are acceptable. If the particulate results are low in comparison to the standard, and I is over 110 percent or less than 90 percent, the Administrator may accept the results. Citation 4 in the bibliography section can be used to make acceptability judgments. If I is judged to be unacceptable, reject the particulate results and repeat the test.

6.13 Stack Gas Velocity and Volumetric Flow Rate. Calculate the average stack gas velocity and volumetric flow rate, if needed, using data obtained in this method and the equations in Sections 5.2 and 5.3 of Method 2.

7. *Alternative Procedures*

7.1 *Dry Gas Meter as a Calibration Standard*. A dry gas meter may be used as a calibration standard for volume measurements in place of the wet test meter specified in Section 5.3, provided that it is calibrated initially and recalibrated periodically as follows:

7.1.1 Standard Dry Gas Meter Calibration.

7.1.1.1 The dry gas meter to be calibrated and used as a secondary reference meter should be of high quality and have an appropriately sized capacity, e.g., 3 liters/rev (0.1 ft³/rev). A spirometer (400 liters or more capacity), or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should have a capacity of 30 liters/rev (1 ft³/rev) and capable of measuring volume to within ±1.0 percent; wet test meters should be checked against a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained.

7.1.1.2 Set up the components as shown in Figure 5.7. A spirometer, or equivalent, may be used in place of the wet test meter in the system. Run the pump for at least 5 minutes

at a flow rate of about 10 liters/min (0.35 cfm) to condition the interior surface of the wet test meter. The pressure drop indicated by the manometer at the inlet side of the dry gas meter should be minimized [no greater than 100 mm H_2O (4 in. H_2O) at a flow rate of 30 liters/min (1 cfm)]. This can be accomplished by using large diameter tubing connections and straight pipe fittings.

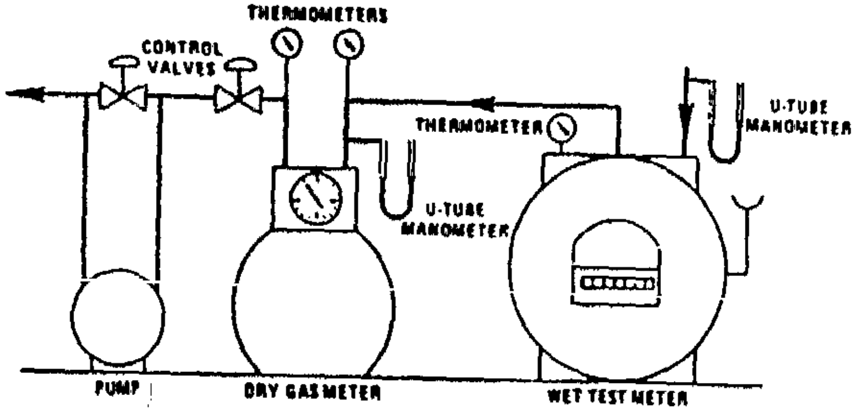

Figure 5.7. Equipment arrangement for dry-gas meter calibration.

7.1.1.3 Collect the data as shown in the example data sheet (see Figure 5-8). Make triplicate runs at each of the flow rates and at no less than five different flow rates. The range of flow rates should be between 10 and 34 liters/min (0.35 and 1.2 cfm) or over the expected operating range.

DATE:__________

DRY GAS METER IDENTIFICATION:__________

BAROMETRIC PRESSURE (P_b):__________ in. Hg

APPROXIMATE FLOW RATE ($\bar{Q}$) cfm	SPIROMETER (WET METER) GAS VOLUME (V_s) ft³	DRY GAS METER VOLUME (V_{dg}) ft³	TEMPERATURES: SPIROMETER (WET METER) (t_s) °F	TEMPERATURES: DRY GAS METER: INLET (t_i) °F	TEMPERATURES: DRY GAS METER: OUTLET (t_o) °F	TEMPERATURES: DRY GAS METER: AVERAGE ($\bar{t}_d$) °F	DRY GAS METER PRESSURE (Δp) in. H₂O	TIME (Θ) min.	FLOW RATE (Q) cfm	METER COEFFICIENT (Y_{ds})	AVERAGE METER COEFFICIENT ($\bar{Y}_{ds}$)
0.40											
0.60											
0.80											
1.00											
1.20											

$$Q = 17.65 \cdot \frac{V_s}{\Theta} \cdot \frac{P_b}{(t_s + 460)} \qquad Y_{ds} = \frac{V_s}{V_{dg}} \cdot \frac{(\bar{t}_d + 460)}{(t_s + 460)} \cdot \frac{P_b}{\left(P_b + \frac{\Delta p}{13.6}\right)}$$

Figure 5.8. Example data sheet for calibration of a standard dry gas meter for method 5 sampling equipment (English units).

7.1.1.4 Calculate flow rate, Q, for each run using the wet test meter gas volume, V_w, and the run time, θ. Calculate the dry gas meter coefficient, Y_{ds}, for each run. These calculations are as follows:

$$Q = K_1 \frac{P_{bar}}{t_w + t_{std}} \frac{V_w}{\theta}$$

$$Y_{ds} = \frac{V_w\ (t_{ds} + t_{std}) \quad P_{bar}}{V_{ds}\ (t_w + t_{std})\ \left(P_{bar} + \frac{\Delta p}{13.6}\right)}$$

Where:

K_1=0.3858 for international system of units (SI); 17.64 for English units.

V_w=Wet test meter volume, liters (ft³).

V_{ds}=Dry gas meter volume, liters (ft³).

t_{ds}=Average dry gas meter temperature, °C (°F).

t_{std}=273° C for SI units; 460° F for English units.

t_w=Average wet test meter temperature, °C (°F).

P_{bar}=Barometric pressure, mm Hg (in. Hg).

Δp=Dry gas meter inlet differential pressure, mm H_2O (in. H_2O).

θ=Run time, min.

7.1.1.5 Compare the three Y_{ds} values at each of the flow rates and determine the maximum and minimum values. The difference between the maximum and minimum values at each flow rate should be no greater than 0.030. Extra sets of triplicate runs may be made in order to complete this requirement. In addition, the meter coefficients should be between 0.95 and 1.05. If these specifications cannot be met in three sets of successive triplicate runs, the meter is not suitable as a calibration standard and should not be used as such. If these specifications are met, average the three Y_{ds} values at each flow rate resulting in five average meter coefficients, Y_{ds}.

7.1.1.6 Prepare a curve of meter coefficient, Y_{ds}, versus flow rate, Q, for the dry gas meter. This curve shall be used as a reference when the meter is used to calibrate other dry gas meters and to determine whether recalibration is required.

7.1.2 Standard Dry Gas Meter Recalibration.

7.1.2.1 Recalibrate the standard dry gas meter against a wet test meter or spirometer annually or after every 200 hours of operation, whichever comes first. This requirement is valid provided the standard dry gas meter is kept in a laboratory and, if transported, cared for as any other laboratory instrument. Abuse to the standard meter may cause a change in the calibration and will require more frequent recalibrations.

7.1.2.2 As an alternative to full recalibration, a two-point calibration check may be made. Follow the same procedure and equipment arrangement as for a full recalibration, but run the meter at only two flow rates [suggested rates are 14 and 28 liters/min (0.5 and 1.0 cfm)]. Calculate the meter coefficients for these two points, and compare the values with the meter calibration curve. If the two coefficients are within ±1.5 percent of the calibration curve values at the same flow rates, the meter need not be recalibrated until the next date for a recalibration check.

7.2 Critical Orifices As Calibration Standards. Critical orifices may be used as calibration standards in place of the wet test meter specified in Section 5.3, provided that they are selected, calibrated, and used as follows:

7.2.1 Section of Critical Orifices.

7.2.1.1 The procedure that follows describes the use of hypodermic needles or stainless steel needle tubings which have been found suitable for use as critical orifices. Other materials and critical orifice designs may be used provided the orifices act as true critical orifices; i.e., a critical vacuum can be obtained, as described in Section 7.2.2.2.3. Select five critical orifices that are appropriately sized to cover the range of flow rates between 10 and 34 liters/min or the expected operating range. Two of the critical orifices should bracket the expected operating range.

A minimum of three critical orifices will be needed to calibrate a Method 5 dry gas meter (DGM); the other two critical orifices can serve as spares and provide better selection for bracketing the range of operating flow rates. The needle sizes and tubing lengths shown below give the following approximate flow rates:

Gauge/cm	Flow rate (liters/min)	Gauge/cm	Flow rate (liters/min)
12/7.6	32.56	14/2.5	19.54
12/10.2	30.02	14/5.1	17.27
13/2.5	25.77	14/7.6	16.14
13/5.1	23.50	15/3.2	14.16
13/7.6	22.37	15/7.6	11.61
13/10.2	20.67	15/10.2	10.48

7.2.1.2 These needles can be adapted to a Method 5 type sampling train as follows: Insert a serum bottle stopper, 13- by 20-mm sleeve type, into a ½-inch Swagelok quick connect. Insert the needle into the stopper as shown in Figure 5-9.

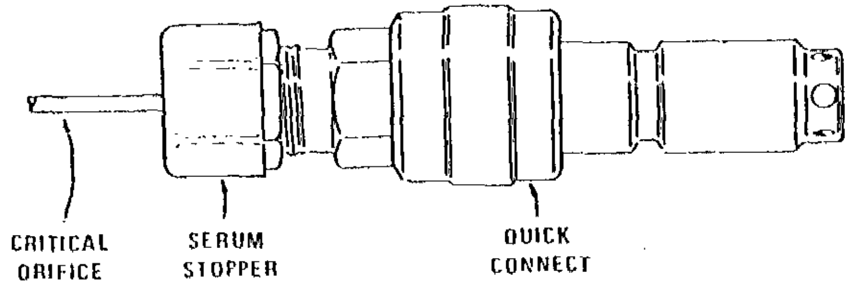

Figure 5-9. Critical orifice adaptation to Method 5 metering system.

7.2.2 Critical Orifice Calibration. The procedure described in this section uses the Method 5 meter box configuration with a DGM as described in Section 2.1.8 to calibrate the critical orifices. Other schemes may be used, subject to the approval of the Administrator.

7.2.2.1 Calibration of Meter Box. The critical orifices must be calibrated in the same configuration as they will be used; i.e., there should be no connections to the inlet of the orifice.

7.2.2.1.1 Before calibrating the meter box, leak check the system as follows: Fully open the coarse adjust valve, and completely close the by-pass valve. Plug the inlet. Then trun on the pump, and determine whether there is any leakage. The leakage rate shall be zero; i.e., no detectable movement of the DGM *dial shall be seen for 1 minute.*

7.2.2.1.2 Check also for leakages in that portion of the sampling train between the pump and the orifice meter. See Section 5.6 *for the procedure; make* any corrections, if necessary. If leakage is detected, check for cracked gaskets, loose fittings, worn O-rings, etc., and make the necessary repairs.

7.2.2.1.3 After determining that the meter box is leakless, calibrate the meter box according to the procedure given in Section 5.3. Make sure that the wet test meter meets the *requirements stated in Section 7.1.1.1.* Check the water level in the wet test meter. Record the DGM calibration factor, Y.

7.2.2.2 Calibration of Critical Orifices. Set up the apparatus as shown in *Figure 5-10.*

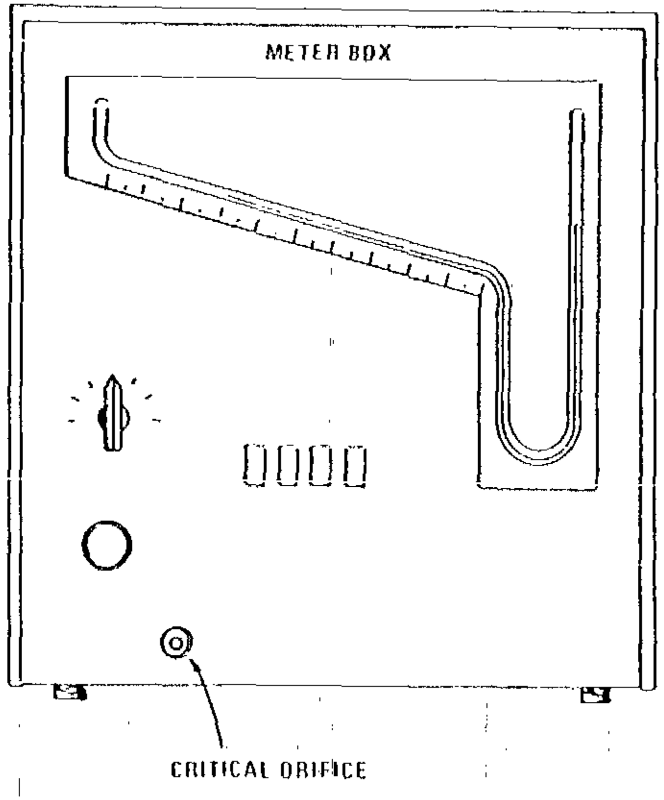

Figure 5-10. Apparatus setup.

7.2.2.2.1 Allow a warm-up time of 15 minutes. *This step is important to equilibrate* the temperature conditions through the DGM.

7.2.2.2.2 Leak check the system as in Section 7.2.2.1.1. *The leakage rate shall be zero.*

7.2.2.2.3 Before calibrating the critical orifice, determine its suitability and the appropriate operating vacuum as follows: Turn on the pump, fully open the coarse adjust valve, and adjust the by-pass valve to give a vacuum reading corresponding to about half of atmospheric pressure. Observe the meter box orifice manometer reading, H. Slowly increase the vacuum reading until a stable reading is obtained on the meter box orifice manometer. Record the critical vacuum for each orifice. Orifices that do not reach a critical value *shall not be used.*

7.2.2.2.4 Obtain the barometric pressure using a barometer as described in Section 2.1.9. Record the barometric pressure, P_{bar}, in *mm Hg (in. Hg).*

7.2.2.2.5 Conduct duplicate runs at a vacuum of 25 to 50 mm Hg (1 to 2 in. Hg) above the critical vacuum. The runs shall be at least 5 minutes each. The DGM volume readings shall be in increments of 0.00283 m³ (0.1 ft³) or in increments of complete revolutions of the DGM. As a guideline, the times should not differ by more than 3.0 seconds (this includes allowance for changes in the DGM temperatures) to achieve ± 0.5 percent in K′. Record the information listed in Figure 5-11.

7.2.2.2.6 Calculate K′ using Equation 5-9.

$$K' = \frac{K_1 V_m Y (P_{bar}+\Delta H/13.6)\sqrt{T_{amb}}}{P_{bar} T_m \Theta}$$ Eq. 5-9

Where:

$$K' = \text{Critical orifice coefficient, } \frac{(m^3)(°K)^{1/2}}{(mm.\ Hg)(min)}\left[\frac{(ft^3)(°R)^{1/2}}{(in.\ Hg)(min)}\right]$$

$\sqrt{T_{amb}}$=Absolute ambient temperature, °K (°R).

Average the K′ values. The individual K′ values should not differ by more than ±0.5 percent from the average.

7.2.3 Using the Critical Orifices as Calibration Standards.

7.2.3.1 Record the barometric pressure.

Date ______ Train ID ______ DGM cal. factor ______ Critical orifice ID ______

Dry gas meter		Run number 1	Run number 2
Final reading	m³ (ft³)	....	....
Initial reading	m³ (ft³)	....	....
Difference, V_m	m³ (ft³)	....	....
Inlet/Outlet temperatures:			
Initial	°C (°F)	/	/
Final	°C (°F)	/	/
Avg. Temperature, t_m.	°C (°F)	....	....
Time, Θ	min/sec	/	/
	min	....	....
Orifice man. rdg., ΔH	mm (in.) H_2O	....	....
Bar. pressure, P_{bar}	mm (in.) Hg	....	....
Ambient temperature, t_{amb}.	°C (°F)	....	....
Pump vacuum	mm (in.) Hg	....	....
K′ factor	....	....	....
Average	....	....	....

Figure 5-11. Data sheet for determining K′ factor.

7.2.3.2 Calibrate the metering system according to the procedure outlined in Sections 7.2.2.1 to 7.2.2.5. Record the information listed in Figure 5.12.

7.2.3.3 Calculate the standard volumes of air passed through the DGM and the critical orifices, and calculate the DGM calibration factor, Y, using the equations below:

$$V_m(std) = K_1 V_m \frac{P_{bar}+(\Delta H/13.6)}{T_m}$$ Eq. 5-10

$$V_{cr}(std)=K'\frac{P_{bar}\Theta}{\sqrt{T_{amb}}}$$ Eq. 5-11

$$Y=\frac{V_{cr(std)}}{V_{m(std)}}$$ Eq. 5-12

where:

$V_{cr(std)}$=Volume of gas sample passed through the critical orifice, corrected to standard conditions, dsm³ (dscf).

K_1=0.3858 °K/mm Hg for metric units
=17.64 °R/in. Hg for English units.

7.2.3.4 Average the DGM calibration values for each of the flow rates. The calibration factor, Y, at each of the flow rates should not differ by more than ±2 percent from the average.

7.2.3.5 To determine the need for recalibrating the critical orifices, compare the DGM Y factors obtained from two adjacent orifices each time a DGM is calibrated; for example, when checking 13/2.5, use orifices 12/10.2 and 13/5.1. If any critical orifice yields a DGM Y factor differing by more than 2 percent from the others, recalibrate the critical orifice according to Section 7.2.2.2.

Date ______ Train ID ______ Critical orifice ID ______ Critical orifice K′ factor ______

Dry gas meter		Run number 1	Run number 2
Final reading	m³ (ft³)	....	....
Initial reading	m³ (ft³)	....	....
Difference, V_m	m³ (ft³)	....	....
Inlet/outlet temperatures:			
Initial	°C (°F)	/	/
Final	°C (°F)	/	/
Avg. Temperature, t_m	°C (°F)	....	....
Time, Θ	min/sec	/	/
	min	....	....
Orifice man. rdg., ΔH	mm (in.) H_2O	....	....
Bar. pressure, P_{bar}	mm (in.) Hg .	....	....
Ambient temperature, t_{amb} ...	°C (°F)	....	....
Pump vacuum	mm (in.) Hg .	....	....
$V_{m(std)}$	m³ (ft³)	....	....
$V_{cr(std)}$	m³ (ft³)	....	....
DGM cal. factor, Y	....	....	....

Figure 5-12. Data sheet for determining DGM Y factor.

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METHOD 5A—DETERMINATION OF PARTICULATE EMISSIONS FROM THE ASPHALT PROCESSING AND ASPHALT ROOFING INDUSTRY

1. *Applicability and Principle*

1.1 Applicability. This method applies to the determination of particulate emissions from asphalt roofing industry process saturators, blowing stills, and other sources as specified in the regulations.

1.2 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass filter fiber maintained at a temperature of 42°±10°C (108°±18°F). The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

2. *Apparatus*

2.1 Sampling Train. The sampling train configuration is the same as shown in Figure 5-1 of Method 5. The sampling train consists of the following components:

2.1.1 Probe Nozzle, Pitot Tube, Differential Pressure Gauge, Filter Holder, Condenser, Metering System, Barometer, and Gas Density Determination Equipment. Same as Method 5, Sections 2.1.1, 2.1.3 to 2.1.5, and 2.1.7 to 2.1.10, respectively.

2.1.2 Probe Liner. Same as in Method 5, Section 2.1.2, with the note that at high stack gas temperatures (greater than 250°C (480°F)), water-cooled probes may be required to control the probe exit temperature to 42°±10°C (108±18°F).

2.1.3 Precollector Cyclone. Borosilicate glass following the construction details shown in Air Pollution Technical Document-0581, "Construction Details of Isokinetic Source-Sampling Equipment".

NOTE: The tester shall use the cyclone when the stack gas moisture is greater than 10 percent. The tester shall not use the precollector cyclone under other, less severe conditions.

2.1.4 Filter Heating System. Any heating (or cooling) system capable of maintaining a sample gas temperature at the exit end of the filter holder during sampling at 42°±10°C (108°±18°F). Install a temperature gauge capable of measuring temperature within 3°C (5.4°F) at the exit side of the filter holder so that the sensing tip of the temperature gauge is in direct contact with the sample gas, and the sample gas temperature can be regulated and monitored during sampling. The temperature gauge shall comply with the calibration specifications defined in Section 5. The tester may use systems other than the one shown in APTD-0581.

2.2 Sample Recovery. The equipment required for sample recovery is as follows:

2.2.1 Probe-Liner and Probe-Nozzle Brushes, Graduated Cylinder and/or Balance, Plastic Storage Containers, and Funnel and Rubber Policeman. Same as Method 5, Sections 2.2.1, 2.2.5, 2.2.6, and 2.2.7, respectively.

2.2.2 Wash Bottles. Glass.

2.2.3 Sample Storage Containers. Chemically resistant, borosilicate glass bottles, with rubber-backed Teflon screw cap liners or caps that are constructed so as to be leak-free and resistant to chemical attack by 1,1,1-trichloroethane (TCE), 500-ml or 1000-ml. (Narrow mouth glass bottles have been found to be less prone to leakage.)

2.2.4 Petri Dishes. Glass, unless otherwise specified by the Administrator.

2.2.5 Funnel. Glass.

2.3 Analysis. For analysis, the following equipment is needed:

one from the impinger and precollector analysis (Equations 5A–1 and 5A–2) and a second from the assumption of saturated conditions. The lower of the two values of moisture content shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the note of Section 1.2 of Method 4. For the purpose of this method, the average stack gas temperature from Figure 5–2 of Method 5 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is within ±1°C (2°F).

6.6 TCE Blank Concentration.

$$C_t = m_t/V_t\rho_t \qquad \text{Eq. 5A-3}$$

6.7 TCE Wash Blank.

$$W_t = C_t V_{tw}\rho_t \qquad \text{Eq. 5A-4}$$

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

6.9 Particulate Concentration.

$$c_s = K_2 m_n/V_{m(std)} \qquad \text{Eq. 5A-5}$$

Where:

K_2=0.001 g/mg.

6.10 Isokinetic Variation and Acceptable Results. Same as in Method 5, Sections 6.11 and 6.12, respectively.

7. *Bibliography*

The bibliography for Method 6A is the same as that for Method 5.

METHOD 5B—DETERMINATION OF NONSULFURIC ACID PARTICULATE MATTER FROM STATIONARY SOURCES

1. *Applicability and Principle.*

1.1 Applicability. This method is to be used for determining nonsulfuric acid particulate matter from stationary sources. Use of this method must be specified by an applicable subpart, or approved by the Administrator, U.S. Environmental Protection Agency, for a particular application.

1.2 Principle. Particulate matter is withdrawn isokinetically from the source using the Method 5 train at 160°C (320°F). The collected sample is then heated in the oven at 160°C (320°F) for 6 hours to volatilize any condensed sulfuric acid that may have been collected, and the nonsulfuric acid particulate mass is determined gravimetrically.

2. *Procedure.*

The procedure is identical to EPA Method 5 except for the following:

2.1 Initial Filter Tare. Oven dry the filter at 160±5°C (320 ±10°F) for 2 to 3 hours, cool in a desiccator for 2 hours, and weigh. Desiccate to constant weight to obtain the initial tare. Use the applicable specifications and techniques of Section 4.1.1 of Method 5 for this determination.

2.2 Probe and Filter Temperatures. Maintain the probe outlet and filter temperatures at 160±14°C (320±25°F).

2.3 Analysis. Dry the probe sample at ambient temperature. Then oven-dry the probe and filter samples at a temperature of 160±5°C (320±10°F) for 6 hours. Cool in a desiccator for 2 hours, and weigh to constant weight. Use the applicable specifications and techniques of Section 4.3 of Method 5 for this determination.

METHOD 5C—[RESERVED]

METHOD 5D—DETERMINATION OF PARTICULATE MATTER EMISSIONS FROM POSITIVE PRESSURE FABRIC FILTERS

1. *Applicability and Principle*

1.1 Applicability. This method applies to the determination of particulate matter emissions from positive pressure fabric filters. Emissions are determined in terms of concentration (mg/m³) and emission rate (kg/h).

The General Provisions of 40 CFR Part 60, §60.8(e), require that the owner or operator of an affected facility shall provide performance testing facilities. Such performance testing facilities include sampling ports, safe sampling platforms, safe access to sampling sites, and utilities for testing. It is intended that affected facilities also provide sampling locations that meet the specification for adequate stack length and minimal flow disturbances as described in Method 1. Provisions for testing are often overlooked factors in designing fabric filters or are extremely costly. The purpose of this procedure is to identify appropriate alternative locations and procedures for sampling the emissions from positive pressure fabric filters. The requirements that the affected facility owner or operator provide adequate access to performance testing facilities remain in effect.

1.2 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature at or above the exhaust gas temperature up to a nominal 120°C (120±14°C or 248±25°F). The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

2. *Apparatus*

The equipment requirements for the sampling train, sample recovery, and analysis are the same as specified in Sections 2.1, 2.2, and 2.3, respectively, of Method 5 or Method 17.

3. *Reagents*

The reagents used in sampling, sample recovery, and analysis are the same as specified in Sections 3.1, 3.2, and 3.3, respectively, of Method 5 or Method 17.

4. *Procedure*

4.1 Determination of Measurement Site. The configurations of positive pressure fabric filter structures frequently are not amenable to emission testing according to the requirements of Method 1. Following are several alternatives for determining measurement sites for positive pressure fabric filters.

4.1.1 Stacks Meeting Method 1 Criteria. Use a measurement site as specified in Method 1, Section 2.1.

4.1.2 Short Stacks Not Meeting Method 1 Criteria. Use stack extensions and the procedures in Method 1. Alternatively, use flow straightening vanes of the "egg-crate" type (see Figure 5D–1). Locate the measurement site downstream of the straightening vanes at a distance equal to or greater than two times the average equivalent diameter of the vane openings and at least one-half of the overall stack diameter upstream of the stack outlet.

4.1.3 Roof Monitor or Monovent. (See Figure 5D–2.) For a positive pressure fabric filter equipped with a peaked roof monitor, ridge vent, or other type of monovent, use a measurement site at the base of the monovent. Examples of such locations are shown in Figure 5D–2. The measurement site must be upstream of any exhaust point (e.g., louvered vent).

4.1.4 Compartment Housing. Sample immediately downstream of the filter bags directly above the tops of the bags as shown in the examples in Figure 5D–2. Depending on the housing design, use sampling ports in the housing walls or locate the sampling equipment within the compartment housing.

4.2 Determination of Number and Location of Traverse Points. Locate the traverse points according to Method 1, Section 2.3. Because a performance test consists of at least three test runs and because of the varied configurations of positive pressure fabric filters, there are several schemes by which the number of traverse points can be determined and the three test runs can be conducted.

4.2.1 Single Stacks Meeting Method 1 Criteria. Select the number of traverse points according to Method 1. Sample all traverse points for each test run.

4.2.2 Other Single Measurement Sites. For a roof monitor or monovent, single compartment housing, or other stack not meeting Method 1 criteria, use at least 24 traverse points. For example, for a rectangular measurement site, such as a monovent, use a balanced 5 x 5 traverse point matrix. Sample all traverse points for each test run.

4.2.3 Multiple Measurement Sites. Sampling from two or more stacks or measurement sites may be combined for a test run, provided the following guidelines are met:

(a) All measurement sites up to 12 must be sampled. For more than 12 measurement sites, conduct sampling on at least 12 sites or 50 percent of the sites, whichever is greater. The measurement sites sampled should be evenly, or nearly evenly, distributed among the available sites; if not, all sites are to be sampled.

(b) The same number of measurement sites must be sampled for each test run.

(c) The minimum number of traverse points per test run is 24. An exception to the 24-point minimum would be a test combining the sampling from two stacks meeting Method 1 criteria for acceptable stack length, and Method 1 specifies fewer than 12 points per site.

(d) As long as the 24 traverse points per test run criterion is met, the number of traverse points per measurement site may be reduced to eight.

Alternatively, conduct a test run for each measurement site individually using the criteria in Section 4.2.1 or 4.2.2 for number of traverse points. Each test run shall count toward the total of three required for a performance test. If more than three measurement sites are sampled, the number of traverse points per measurement site may be reduced to eight as long as at least 72 traverse points are sampled for all the tests.

The following examples demonstrate the procedures for sampling multiple measurement sites.

Example 1: A source with nine circular measurement sites of equal areas may be tested as follows: For each test run, traverse three measurement sites using four points per diameter (eight points per measurement site). In this manner, test run number 1 will include sampling from sites 1, 2, and 3; run 2 will include samples from sites 4, 5, and 6; and run 3 will include sites 7, 8, and 9. Each test area may consist of a separate test of each measurement site using eight points. Use the results from all nine tests in determining the emission average.

Example 2: A source with 30 rectangular measurement sites of equal areas may be tested as follows: For each of three test runs, traverse five measurement sites using a 3 x 3 matrix of traverse points for each site. In order to distribute the sampling evenly over all the available measurement sites while sampling only 50 percent of the sites, number the sites consecutively from 1 to 30 and sample all the even numbered (or odd numbered) sites. Alternatively, conduct a separate test of each of 15 measurement sites using Section 4.2.1 or 4.2.2 to determine the number and location of traverse points, as appropriate.

Example 3: A source with two measurement sites of equal areas may be tested as follows: For each test of three test runs, traverse both measurement sites using Section 4.2.3 in determining number of traverse

P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
T_m=Average absolute dry gas meter temperature (see Figure 8–2), °K (°R).
T_s=Average absolute stack gas temperature (see Figure 8-2), °K (°R).
T_{std}=Standard absolute temperature, 293° K (528° R).
V_a=Volume of sample aliquot titrated, 100 ml for H_2SO_4 and 10 ml for SO_2.
V_{lc}=Total volume of liquid collected in impingers and silica gel, ml.
V_m=Volume of gas sample as measured by dry gas meter, dcm (dcf).
$V_{m(std)}$=Volume of gas sample measured by the dry gas meter corrected to standard conditions, dscm (dscf).
v_s=Average stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 8, m/sec (ft/sec).
V_{soln}=Total volume of solution in which the sulfuric acid or sulfur dioxide sample is contained, 250 ml or 1,000 ml, respectively.
V_t=Volume of barium perchlorate titrant used for the sample, ml.
V_{tb}=Volume of barium perchlorate titrant used for the blank, ml.
Y=Dry gas meter calibration factor.
ΔH=Average pressure drop across orifice meter, mm (in.) H_2O.
θ=Total sampling time, min.
13.6=Specific gravity of mercury.
60=sec/min.
100=Conversion to percent.

6.2 Average Dry Gas Meter Temperature and Average Orifice Pressure Drop. See data sheet (Figure 8-2).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C and 760 mm Hg or 68° F and 29.92 in. Hg) by using Equation 8-1.

$$V_{m(std)}=V_mY\left(\frac{T_{std}}{T_m}\right)\frac{P_{bar}+\left(\frac{\Delta H}{13.6}\right)}{P_{std}}$$

$$=K_1V_mY\,\frac{P_{bar}+(\Delta H/13.6)}{T_m}$$

Equation 8–1

Where:
K_1=0.3858 °K/mm Hg for metric units.
=17.64 °R/in., Hg for English units.

NOTE: If the leak rate observed during any mandatory leak-checks exceeds the specified acceptable rate, the tester shall either correct the value of V_m in Equation 8-1 (as described in Section 6.3 of Method 5), or shall invalidate the test run.

6.4 Volume of Water Vapor and Moisture Content. Calculate the volume of water vapor using Equation 5-2 of Method 5; the weight of water collected in the impingers and silica gel can be directly converted to milliliters (the specific gravity of water is 1 g/ml). Calculate the moisture content of the stack gas, using Equation 5-3 of Method 5. The "Note" in Section 6.5 of Method 5 also applies to this method. Note that if the effluent gas stream can be considered dry, the volume of water vapor and moisture content need not be calculated.

6.5 Sulfuric Acid Mist (including SO_3) Concentration.

$$C_{H_2SO_4}=K_2\,\frac{N(V_t-V_{tb})\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 8–2

Where:
K_2=0.04904 g/milliequivalent for metric units.
=1.081×10^{-4} lb/meq for English units.

6.6 Sulfur Dioxide Concentration.

$$C_{SO_2}=K_3\,\frac{N(V_t-V_{tb})\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 8-3

Where:
K_3=0.03203 g/meq for metric units.
=7.061×10^{-5} lb/meq for English units.

6.7 Isokinetic Variation.

6.7.1 Calculation from Raw Data.

$$I=\frac{100T_s[K_4V_{lc}+(V_mY/T_m)(P_{bar}+\Delta H/13.6)]}{60\theta v_sP_sA_n}\qquad\text{Eq. 8–4}$$

Where:
K_4=0.003464 mm Hg-m³/ml-°K for metric units.
=0.002676 in. Hg-ft³/ml-°R for English units.

6.7.2 Calculation from Intermediate Values.

$$I=\frac{T_sV_{m(std)}P_{std}100}{T_{std}v_s\theta A_nP_s60(1-B_{ws})}$$

$$=K_5\,\frac{T_sV_{m(std)}}{P_sv_sA_n\theta(1-B_{ws})}$$

Equation 8–5

where:
K_5=4.320 for metric units.
=0.09450 for English units

6.8 Acceptable Results. If 90 percent <I <110 percent, the results are acceptable. If the results are low in comparison to the standards and I is beyond the acceptable range, the Administrator may opt to accept the results. Use Citation 4 in the Bibliography of Method 5 to make judgments. Otherwise, reject the results and repeat the test.

6.9 Stack Gas Velocity and Volumetric Flow Rate. Calculate the average stack gas velocity and volumetric flow rate, if needed, using data obtained in this method and equations in Sections 5.2 and 5.3 of Method 2.

6.10 Relative Error (RE) for QA Audit Samples. Same as in Method 6, Section 6.4.

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METHOD 9—VISUAL DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES

Many stationary sources discharge visible emissions into the atmosphere; these emissions are usually in the shape of a plume. This method involves the determination of plume opacity by qualified observers. The method includes procedures for the training and certification of observers, and procedures to be used in the field for determination of plume opacity. The appearance of a plume as viewed by an observer depends upon a number of variables, some of which may be controllable and some of which may not be controllable in the field. Variables which can be controlled to an extent to which they no longer exert a significant influence upon plume appearance include: Angle of the observer with respect to the plume; angle of the observer with respect to the sun; point of observation of attached and detached steam plume; and angle of the observer with respect to a plume emitted from a rectangular stack with a large length to width ratio. The method includes specific criteria applicable to these variables.

Other variables which may not be controllable in the field are luminescence and color contrast between the plume and the background against which the plume is viewed. These variables exert an influence upon the appearance of a plume as viewed by an observer, and can affect the ability of the observer to accurately assign opacity values to the observed plume. Studies of the theory of plume opacity and field studies have demonstrated that a plume is most visible and presents the greatest apparent opacity when viewed against a contrasting background. It follows from this, and is confirmed by field trials, that the opacity of a plume, viewed under conditions where a contrasting background is present can be assigned with the greatest degree of accuracy. However, the potential for a positive error is also the greatest when a plume is viewed under such contrasting conditions. Under conditions presenting a less contrasting background, the apparent opacity of a plume is less and approaches zero as the color and luminescence contrast decrease toward zero. As a result, significant negative bias and negative errors can be made when a plume is viewed under less contrasting conditions. A negative bias decreases rather than increases the possibility that a plant operator will be cited for a violation of opacity standards due to observer error.

Studies have been undertaken to determine the magnitude of positive errors which can be made by qualified observers while reading plumes under contrasting conditions and using the procedures set forth in this method. The results of these studies (field trials) which involve a total of 769 sets of 25 readings each are as follows:

(1) For black plumes (133 sets at a smoke generator), 100 percent of the sets were read with a positive error[1] of less than 7.5 percent opacity; 99 percent were read with a positive error of less than 5 percent opacity.

(2) For white plumes (170 sets at a smoke generator, 168 sets at a coal-fired power plant, 298 sets at a sulfuric acid plant), 99 percent of the sets were read with a positive error of less than 7.5 percent opacity; 95 percent were read with a positive error of less than 5 percent opacity.

The positive observational error associated with an average of twenty-five readings is therefore established. The accuracy of the method must be taken into account when determining possible violations of applicable opacity standards.

1. *Principle and Applicability*

1.1 Principle. The opacity of emissions from stationary sources is determined visually by a qualified observer.

1.2 Applicability. This method is applicable for the determination of the opacity of emissions from stationary sources pursuant to §60.11(b) and for qualifying observers for visually determining opacity of emissions.

2. *Procedures*

The observer qualified in accordance with section 3 of this method shall use the following procedures for visually determining the opacity of emissions:

2.1 Position. The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140° sector to his back. Consistent with maintaining the above requirement, the observer shall, as much as possible, make his observations from a position such that his line of vision is approximately perpendicular to the plume direction, and when observing opacity of emissions from rectangular outlets (e.g., roof monitors, open baghouses, noncircular stacks), approximately perpendicular to the longer axis of the outlet. The observer's line of sight should not include more than one plume at a time when multiple stacks are involved, and in any case the observer should make his observations with his line of sight perpendicular to the longer axis of such a set of multiple stacks (e.g., stub stacks on baghouses).

2.2 Field Records. The observer shall record the name of the plant, emission location, type facility, observer's name and affiliation, a sketch of the observer's position relative to the source, and the date on a field data sheet (Figure 9-1). The time, estimated distance to the emission location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds), and plume background are recorded on a field data sheet at the time opacity readings are initiated and completed.

2.3 Observations. Opacity observations shall be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present. The observer shall not look continuously at the plume, but instead shall observe the plume momentarily at 15-second intervals.

2.3.1 Attached Steam Plumes. When condensed water vapor is present within the plume as it emerges from the emission outlet, opacity observations shall be made beyond the point in the plume at which condensed water vapor is no longer visible. The observer shall record the approximate distance from the emission outlet to the point in the plume at which the observations are made.

2.3.2 Detached Steam Plume. When water vapor in the plume condenses and becomes visible at a distinct distance from the emission outlet, the opacity of emissions should be evaluated at the emission outlet prior to the condensation of water vapor and the formation of the steam plume.

2.4 Recording Observations. Opacity observations shall be recorded to the nearest 5 percent at 15-second intervals on an observational record sheet. (See Figure 9-2 for an example.) A minimum of 24 observations shall be recorded. Each momentary observation recorded shall be deemed to represent the average opacity of emissions for a 15-second period.

2.5 Data Reduction. Opacity shall be determined as an average of 24 consecutive observations recorded at 15-second intervals. Divide the observations recorded on the record sheet into sets of 24 consecutive observations. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and in no case shall two sets overlap. For each set of 24 observations, calculate the average by summing the opacity of the 24 observations and dividing this sum by 24. If an applicable standard specifies an averaging time requiring more than 24 observations, calculate the average for all observations made during the specified time period. Record the average opacity on a record sheet. (See Figure 9-1 for an example.)

3. *Qualifications and Testing*

3.1 Certification Requirements. To receive certification as a qualified observer, a candidate must be tested and demonstrate the ability to assign opacity readings in 5 percent increments to 25 different black plumes and 25 different white plumes, with an error not to exceed 15 percent opacity on any one reading and an average error not to exceed 7.5 percent opacity in each category. Candidates shall be tested according to the procedures described in section 3.2. Smoke generators used pursuant to section 3.2 shall be equipped with a smoke meter which meets the requirements of section 3.3.

The certification shall be valid for a period of 6 months, at which time the qualification procedure must be repeated by any observer in order to retain certification.

3.2 Certification Procedure. The certification test consists of showing the candidate a complete run of 50 plumes—25 black plumes and 25 white plumes—generated by a smoke generator. Plumes within each set of 25 black and 25 white runs shall be presented in random order. The candidate assigns an opacity value to each plume and records his observation on a suitable form. At the completion of each run of 50 readings, the score of the candidate is determined. If a candidate fails to qualify, the complete run of 50 readings must be repeated in any retest. The smoke test may be administered as part of a smoke school or training program, and may be preceded by training or familiarization runs of the smoke generator during which candidates are shown black and white plumes of known opacity.

3.3 Smoke Generator Specifications. Any smoke generator used for the purposes of section 3.2 shall be equipped with a smoke meter installed to measure opacity across the diameter of the smoke generator stack. The smoke meter output shall display instack opacity based upon a pathlength equal to the stack exit diameter, on a full 0 to 100 percent chart recorder scale. The smoke meter optical design and performance shall meet the specifications shown in Table 9-1. The smoke meter shall be calibrated as prescribed in section 3.3.1 prior to the conduct of each smoke reading test. At the completion of each test, the zero and span drift shall be checked and if the drift exceeds ±1 percent opacity, the condition shall be corrected prior to conducting any subsequent test runs. The smoke meter shall be demonstrated, at the time of installation, to meet the specifications listed in Table 9-1. This demonstration shall be repeated following any subsequent repair or replacement of the photocell or associated electronic circuitry including the chart recorder or output meter, or every 6 months, whichever occurs first.

TABLE 9-1—SMOKE METER DESIGN AND PERFORMANCE SPECIFICATIONS

Parameter	Specification
a. Light source	Incandescent lamp operated at nominal rated voltage.
b. Spectral response of photocell.	Photopic (daylight spectral response of the human eye—Citation 3).
c. Angle of view	15° maximum total angle.
d. Angle of projection	15° maximum total angle.
e. Calibration error	±3% opacity, maximum.
f. Zero and span drift	±1% opacity, 30 minutes
g. Response time	5 seconds.

3.3.1 Calibration. The smoke meter is calibrated after allowing a minimum of 30 minutes warmup by alternately producing simulated opacity of 0 percent and 100 percent. When stable response at 0 percent or 100 percent is noted, the smoke meter is adjusted to produce an output of 0 percent or 100 percent, as appropriate. This calibration shall be repeated until stable 0 percent and 100 percent readings are produced without adjustment. Simulated 0 percent and 100 percent opacity values may be produced by alternately switching the power to the light source on and off while the smoke generator is not producing smoke.

3.3.2 Smoke Meter Evaluation. The smoke meter design and performance are to be evaluated as follows:

3.3.2.1 Light Source. Verify from manufacturer's data and from voltage measurements made at the lamp, as installed, that the lamp is operated within ±5 percent of the nominal rated voltage.

3.3.2.2 Spectral Response of Photocell. Verify from manufacturer's data that the photocell has a photopic response; i.e., the spectral sensitivity of the cell shall closely approximate the standard spectral-luminosity curve for photopic vision which is referenced in (b) of Table 9-1.

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[1] For a set, positive error = average opacity determined by observers' 25 observations—average opacity determined from transmissometer's 25 recordings.

FIGURE 9-1
RECORD OF VISUAL DETERMINATION OF OPACITY

PAGE____of____

COMPANY____________________
LOCATION____________________
TEST NUMBER____________________
DATE____________________
TYPE FACILITY____________________
CONTROL DEVICE____________________

HOURS OF OBSERVATION____________________
OBSERVER____________________
OBSERVER CERTIFICATION DATE____________________
OBSERVER AFFILIATION____________________
POINT OF EMISSIONS____________________
HEIGHT OF DISCHARGE POINT____________________

	Initial			Final
CLOCK TIME				
OBSERVER LOCATION Distance to Discharge				
Direction from Discharge				
Height of Observation Point				
BACKGROUND DESCRIPTION				
WEATHER CONDITIONS Wind Direction				
Wind Speed				
Ambient Temperature				
SKY CONDITIONS (clear, overcast, % clouds, etc.)				
PLUME DESCRIPTION Color				
Distance Visible				
OTHER INFORMATION				

SUMMARY OF AVERAGE OPACITY

Set Number	Time	Opacity	
	Start--End	Sum	Average

Readings ranged from ____ to ____ % opacity

The source was/was not in compliance with ____ at the time evaluation was made.

FIGURE 9–2—OBSERVATION RECORD

Company ....
Location ....
Test Number ....
Date ....

Page ___ of ___
Observer ....
Type facility ....
Point of emissions ....

Hr.	Min.	Seconds				Steam plume (check if applicable)		Comments
		0	15	30	45	Attached	Detached	
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
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	19							
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	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							

FIGURE 9-2—OBSERVATION RECORD—(CONTINUED)

Page ___ of ___

Company ....
Location ....
Test Number ....
Date ....

Observer ....
Type facility ....
Point of emissions ....

Hr.	Min.	Seconds				Steam plume (check if applicable)		Comments
		0	15	30	45	Attached	Detached	
	30							
	31							
	32							
	33							
	34							
	35							
	36							
	37							
	38							
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	59							

3.3.2.3 Angle of View. Check construction geometry to ensure that the total angle of view of the smoke plume, as seen by the photocell, does not exceed 15°. The total angle of view may be calculated from: $\theta = 2 \tan^{-1} d/2L$, where θ=total angle of view; d=the sum of the photocell diameter+the diameter of the limiting aperture; and L=the distance from the photocell to the limiting aperture. The limiting aperture is the point in the path between the photocell and the smoke plume where the angle of view is most restricted. In smoke generator smoke meters this is normally an orifice plate.

3.3.2.4 Angle of Projection. Check construction geometry to ensure that the total angle of projection of the lamp on the smoke plume does not exceed 15°. The total angle of projection may be calculated from: $\theta = 2 \tan^{-1} d/2L$, where θ= total angle of projection; d= the sum of the length of the lamp filament + the diameter of the limiting aperture; and L= the distance from the lamp to the limiting aperture.

3.3.2.5 Calibration Error. Using neutral-density filters of known opacity, check the error between the actual response and the theoretical linear response of the smoke meter. This check is accomplished by first calibrating the smoke meter according to 3.3.1 and then inserting a series of three neutral-density filters of nominal opacity of 20, 50, and 75 percent in the smoke meter pathlength. Filters calibrated within ±2 percent shall be used. Care should be taken when inserting the filters to prevent stray light from affecting the meter. Make a total of five nonconsecutive readings for each filter. The maximum error on any one reading shall be 3 percent opacity.

3.3.2.6 Zero and Span Drift. Determine the zero and span drift by calibrating and operating the smoke generator in a normal manner over a 1-hour period. The drift is measured by checking the zero and span at the end of this period.

3.3.2.7 Response Time. Determine the response time by producing the series of five simulated 0 percent and 100 percent opacity values and observing the time required to reach stable response. Opacity values of 0 percent and 100 percent may be simulated by alternately switching the power to the light source off and on while the smoke generator is not operating.

4. *Bibliography.*

1. Air Pollution Control District Rules and Regulations, Los Angeles County Air Pollution Control District, Regulation IV, Prohibitions, Rule 50.

2. Weisburd, Melvin I., Field Operations and Enforcement Manual for Air, U.S. Environmental Protection Agency, Research Triangle Park, NC. APTD-1100, August 1972, pp. 4.1-4.36.

3. Condon, E.U., and Odishaw, H., Handbook of Physics, McGraw-Hill Co., New York, NY, 1958, Table 3.1, p. 6-52.

ALTERNATE METHOD 1—DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES REMOTELY BY LIDAR

This alternate method provides the quantitative determination of the opacity of an emissions plume remotely by a mobile lidar system (laser radar; Light Detection and Ranging). The method includes procedures for the calibration of the lidar and procedures to be used in the field for the lidar determination of plume opacity. The lidar is used to measure plume opacity during either day or nighttime hours because it contains its own pulsed light source or transmitter. The operation of the lidar is not dependent upon ambient lighting conditions (light, dark, sunny or cloudy).

The lidar mechanism or technique is applicable to measuring plume opacity at numerous wavelengths of laser radiation. However, the performance evaluation and calibration test results given in support of this method apply only to a lidar that employs a ruby (red light) laser (Reference 5.1).

1. *Principle and Applicability*

1.1 Principle. The opacity of visible emissions from stationary sources (stacks, roof vents, etc.) is measured remotely by a mobile lidar (laser radar).

1.2 Applicability. This method is applicable for the remote measurement of the opacity of visible emissions from stationary sources during both nighttime and daylight conditions, pursuant to 40 CFR §60.11(b). It is also applicable for the calibration and performance verification of the mobile lidar for the measurement of the opacity of emissions. A performance/design specification for a basic lidar system is also incorporated into this method.

1.3 Definitions.

Azimuth angle: The angle in the horizontal plane that designates where the laser beam is pointed. It is measured from an arbitrary fixed reference line in that plane.

Backscatter: The scattering of laser light in a direction opposite to that of the incident laser beam due to reflection from particulates along the beam's atmospheric path which may include a smoke plume.

Backscatter signal: The general term for the lidar return signal which results from laser light being backscattered by atmospheric and smoke plume particulates.

Convergence distance: The distance from the lidar to the point of overlap of the lidar receiver's field-of-view and the laser beam.

Elevation angle: The angle of inclination of the laser beam referenced to the horizontal plane.

Far region: The region of the atmosphere's path along the lidar line-of-sight beyond or behind the plume being measured.

Lidar: Acronym for Light Detection and Ranging.

Lidar range: The range or distance from the lidar to a point of interest along the lidar line-of-sight.

Near region: The region of the atmospheric path along the lidar line-of-sight between the lidar's convergence distance and the plume being measured.

Opacity: One minus the optical transmittance of a smoke plume, screen target, etc.

Pick interval: The time or range intervals in the lidar backscatter signal whose minimum average amplitude is used to calculate opacity. Two pick intervals are required, one in the near region and one in the far region.

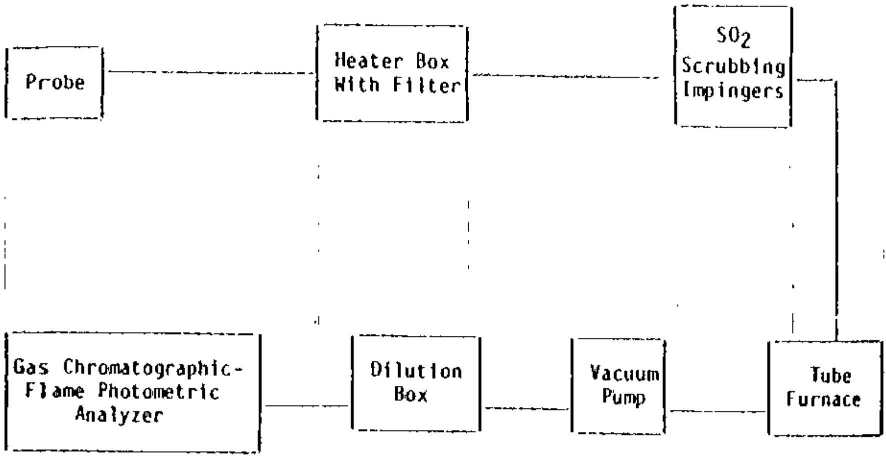

Figure 16B-1. Sampling train.

2.1.1 *Probe, Probe Brush, Particulate Filter, SO_2 Scrubber, Combustion Tube, and Furnace.* Same as in Method 16A, Sections 2.1.1 to 2.1.6.

2.1.2 *Sampling Pump.* Leakless Teflon-coated diaphragm type or equivalent.

2.2 *Analysis.*

2.2.1 *Dilution System (optional), Gas Chromatograph, Oven, Temperature Gauges, Flow System, Flame Photometric Detector, Electrometer, Power Supply, Recorder, Calibration System, Tube Chamber, Flow System, and Constant Temperature Bath.* Same as in Method 16, Sections 5.2, 5.4, and 5.5.

2.2.2 *Gas Chromatograph Columns.* Same as in Method 16, Section 12.1.4.1.1. Other columns with demonstrated ability to resolve SO_2 and be free from known interferences are acceptable alternatives.

3. *Reagents*

Same as in Method 16, Section 6, except the following:

3.1 *Calibration Gas.* SO_2 permeation tube gravimetrically calibrated and certified at some convenient operating temperature. These tubes consist of hermetically sealed FEP Teflon tubing in which a liquefied gaseous substance is enclosed. The enclosed gas permeates through the tubing wall at a constant rate. When the temperature is constant, calibration gases covering a wide range of known concentrations can be generated by varying and accurately measuring the flow rate of diluent gas passing over the tubes. In place of SO_2 permeation tubes, National Bureau of Standards traceable cylinder gases containing SO_2 in nitrogen may be used for calibration. The calibration gas is used to calibrate the GC/FPD system and the dilution system.

3.2 *Recovery Check Gas.* Hydrogen sulfide (100 ppm or less) in nitrogen, stored in aluminum cylinders. Verify the concentration by Method 11, the procedure discussed in Section 7.1 of Method 16A, or gas chromatography where the instrument is calibrated with an H_2S permeation tube as described below. For the wet-chemical methods, the standard deviation should not exceed 5 percent on at least three 20-minute runs.

Hydrogen sulfide recovery gas generated from a permeation device gravimetrically calibrated and certified at some convenient operation temperature may be used. The permeation rate of the device must be such that at a dilution gas flow rate of 3 liters/min, an H_2S concentration in the range of the stack gas or within 20 percent of the standard can be generated.

3.3 *Combustion Gas.* Gas containing less than 50 ppb reduced sulfur compounds and less than 10 ppm total hydrocarbons. The gas may be generated from a clean-air system that purifies ambient air and consists of the following components: diaphragm pump, silica gel drying tube, activated charcoal tube, and flow rate measuring device. Gas from a compressed air cylinder is also acceptable.

4. *Pretest Procedures*

Same as in Method 16, Section 7.

5. *Calibration*

Same as in Method 16, Section 8, except SO_2 is used instead of H_2S.

6. *Sampling and Analysis Procedure*

6.1 *Sampling.* Before any source sampling is done, conduct a system performance check as detailed in Section 7.1 to validate the sampling train components and procedures. Although this test is optional, it would significantly reduce the possibility of rejecting tests as a result of failing the post-test performance check. At the completion of the pretest system performance check, insert the sampling probe into the test port making certain that no dilution air enters the stack through the port. Condition the entire system with sample for a minimum of 15 minutes before beginning analysis. If the sample is diluted, determine the precise dilution factor as in Section 8.5 of Method 16.

6.2 *Analysis.* Pass aliquots of diluted sample through the SO_2 scrubber and oxidation furnace, and then inject into the GC/FPD analyzer for analysis. The rest of the analysis is the same as in Method 16, Sections 9.2.1 and 9.2.2.

7. Post-Test Procedures

7.1 *System Performance Check.* Same as in Method 16A, Section 4.3. Sufficient numbers of sample injections should be made so that the precision requirements of Section 4.1 of Method 16 are satisfied.

7.2 *Recalibration.* Same as in Method 16, Section 10.2.

7.3 *Determination of Calibration Drift.* Same as in Method 16, Section 10.3.

8. Calculations

8.1 *Nomenclature.*

C_{SO_2} = Sulfur dioxide concentration, ppm.

C_{TRS} = Total reduced sulfur concentration as determined by Equation 16B-1, ppm.

d = Dilution factor, dimensionless.

N = Number of samples.

8.2 *SO_2 Concentration.* Determine the concentration of SO_2 (C_{SO_2}) directly from the calibration curves. Alternatively, the concentration may be calculated using the equation for the least-squares line.

8.3 *TRS Concentration.*

$$C_{TRS} = (C_{SO_2})\,(d) \qquad \text{Eq. 16B-1}$$

8.4 *Average TRS Concentration.*

$$\text{Avg. } C_{TRS} = \frac{\sum_{i=1}^{n} C_{TRS}}{N} \qquad \text{Eq. 16B-2}$$

9. *Example System*

Same as in Method 16, Section 12. Single column systems using the column in Section 12.1.4.1.1 of Method 16 or a 7-ft Carbosorb B HT 100 column have been found satisfactory in resolving SO_2 from CO_2.

10. *Bibliography*

1. Same as in Method 16, Sections 13.1 to 13.6.

2. National Council of the Paper Industry for Air and Stream Improvement, Inc. A Study of TRS Measurement Methods. Technical Bulletin No. 434. New York, NY. May 1984. 12 p.

3. Margeson, J.H., J.E. Knoll, and M.R. Midgett. A Manual Method for TRS Determination. Draft available from the authors. Source Branch, Quality Assurance Division, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

METHOD 17—DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES (IN-STACK FILTRATION METHOD)

Introduction

Particulate matter is not an absolute quantity; rather, it is a function of temperature and pressure. Therefore, to prevent variability in particulate matter emission regulations and/or associated test methods, the temperature and pressure at which particulate matter is to be measured must be carefully defined. Of the two variables (i.e., temperature and pressure), temperature has the greater effect upon the amount of particulate matter in an effluent gas stream; in most stationary source categories, the effect of pressure appears to be negligible.

In Method 5, 250° F is established as a nominal reference temperature. Thus, where Method 5 is specified in an applicable subpart of the standards, particulate matter is defined with respect to temperature. In order to maintain a collection temperature of 250° F, Method 5 employs a heated glass sample probe and a heated filter holder. This equipment is somewhat cumbersome and requires care in its operation. Therefore, where particulate matter concentrations (over the normal range of temperature associated with a specified source category) are known to be independent of temperature, it is desirable to eliminate the glass probe and heating systems, and sample at stack temperature.

This method describes an in-stack sampling system and sampling procedures for use in such cases. It is intended to be used only when specified by an applicable subpart of the standards, and only within the applicable temperature limits (if specified), or when *otherwise approved by the Administrator.*

1. *Principle and Applicability*

1.1 Principle. Particulate matter is withdrawn *isokinetically from the source and* collected on a glass fiber filter maintained at stack temperature. The particulate mass is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method applies to the determination of particulate emissions from stationary sources for determining compliance with new source performance standards, only when specifically provided for in an applicable subpart of the standards. This method is not applicable to stacks that contain liquid droplets or are saturated with water vapor. In addition, this method shall not be used as written if the projected cross-sectional area of the probe extension-filter holder assembly covers more than 5 percent of the stack cross-sectional area (see Section 4.1.2).

2. *Apparatus*

2.1 *Sampling Train. A schematic of the* sampling train used in this method is shown in Figure 17-1. Construction details for many, but not all, of the train components are given in APTD-0581 (Citation 2 in Bibliography); for changes from the APTD-0581 document and for allowable modifications to *Figure 17-1, consult with the Administrator.*

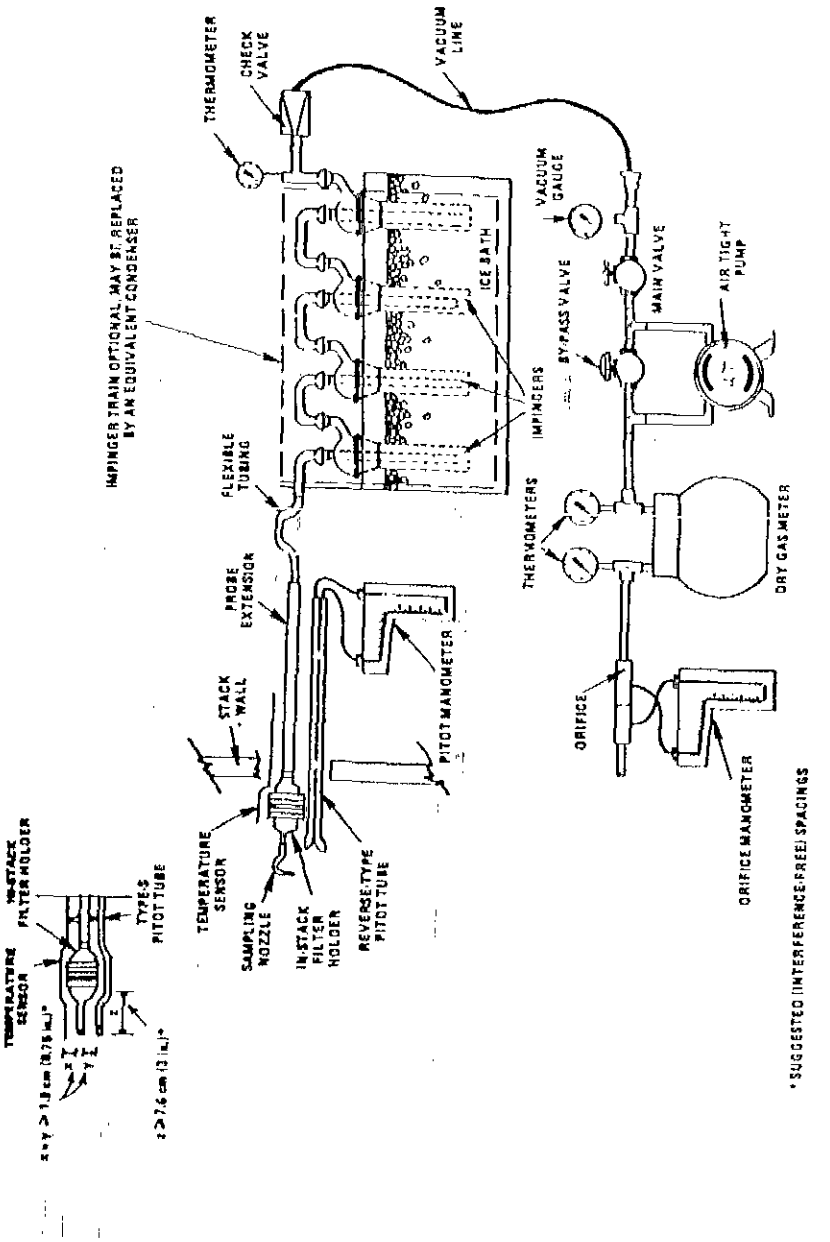

Figure 17-1. Particulate-Sampling Train, Equipped with In-Stack Filter.

The operating and maintenance procedures for many of the sampling train components are described in APTD-0576 (Citation 3 in Bibliography). Since correct usage is important in obtaining valid results, all users should read the APTD-0576 document and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

2.1.1 Probe Nozzle. Stainless steel (316) or glass, with sharp, tapered leading edge. The angle of taper shall be 30° and the taper shall be on the outside to preserve a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing. Other materials of construction may be used subject to the approval of the Administrator.

A range of sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1.27 cm (⅛ to ½ in.)—or larger if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (1/16 in.). Each nozzle shall be calibrated according to the procedures outlined in Section 5.1.

2.1.2 Filter Holder. The in-stack filter holder shall be constructed of borosilicate or quartz glass, or stainless steel; if a gasket is used, it shall be made of silicone rubber, Teflon, or stainless steel. Other holder and gasket materials may be used subject to the approval of the Administrator. The filter holder shall be designed to provide a positive seal against leakage from the outside or around the filter.

2.1.3 Probe Extension. Any suitable rigid probe extension may be used after the filter holder.

2.1.4 Pitot Tube. Type S, as described in Section 2.1 of Method 2, or other device approved by the Administrator; the pitot tube shall be attached to the probe extension to allow constant monitoring of the stack gas velocity (see Figure 17-1). The impact (high pressure) opening plane of the pitot tube shall be even with or above the nozzle entry plane during sampling (see Method 2, Figure 2–6b). It is recommended: (1) that the pitot tube have a known baseline coefficient, determined as outlined in Section 4 of Method 2; and (2) that this known coefficient be preserved by placing the pitot tube in an interference-free arrangement with respect to the sampling nozzle, filter holder, and temperature sensor (see Figure 17-1). Note that the 1.9 cm (0.75 in.) free-space between the nozzle and pitot tube shown in Figure 17-1, is based on a 1.3 cm (0.5 in.) ID nozzle. If the sampling train is designed for sampling at higher flow rates than that described in APTD-0581, thus necessitating the use of larger sized nozzles, the free-space shall be 1.9 cm (0.75 in.) with the largest sized nozzle in place.

Source-sampling assemblies that do not meet the minimum spacing requirements of Figure 17-1 (or the equivalent of these requirements, e.g., Figure 2-7 of Method 2) may be used; however, the pitot tube coefficients of such assemblies shall be determined by calibration, using methods subject to the approval of the Administrator.

2.1.5 Differential Pressure Gauge. Inclined manometer or equivalent device (two), as described in Section 2.2 of Method 2. One manometer shall be used for velocity head (Δp) readings, and the other, for orifice differential pressure readings.

2.1.6 Condenser. It is recommended that the impinger system described in Method 5 be used to determine the moisture content of the stack gas. Alternatively, any system that allows measurement of both the water condensed and the moisture leaving the condenser, each to within 1 ml or 1 g, may be used. The moisture leaving the condenser can be measured either by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures; or (2) passing the sample gas stream through a silica gel trap with exit gases kept below 20° C (68° F) and determining the weight gain.

Flexible tubing may be used between the probe extension and condenser. If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel still be used between the condenser system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.7 Metering System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 17-1. Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that described in APTD-0581 or APTD-0576 may be used provided that the specifications of this method are met.

2.1.8 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg). In many cases, the barometric reading may be obtained from a nearby National Weather Service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.9 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3.

The temperature sensor shall be attached to either the pitot tube or to the probe extension, in a fixed configuration. If the temperature sensor is attached in the field, the sensor shall be placed in an interference-free arrangement with respect to the Type S pitot tube openings (as shown in Figure 17-1 or in Figure 2–7 of Method 2). Alternatively, the temperature sensor need not be attached to either the probe extension or pitot tube during sampling, provided that a difference of not more than 1 percent in the average velocity measurement is introduced. This alternative is subject to the approval of the Administrator.

2.2 Sample Recovery.

2.2.1 Probe Nozzle Brush. Nylon bristle brush with stainless steel wire handle. The brush shall be properly sized and shaped to brush out the probe nozzle.

2.2.2 Wash Bottles—Two. Glass wash bottles are recommended; polyethylene wash bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as to be leak-free and resistant to chemical attack by acetone. (Narrow mouth glass bottles have been found to be less prone to leakage.) Alternatively, polyethylene bottles may be used.

2.2.4 Petri Dishes. For filter samples; glass or polyethylene, unless otherwise specified by the Administrator.

2.2.5 Graduated Cylinder and/or Balance. To measure condensed water to within 1 ml or 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances is suitable for use here and in Section 2.3.4.

2.2.6 Plastic Storage Containers. Air tight containers to store silica gel.

2.2.7 Funnel and Rubber Policeman. To aid in transfer of silica gel to container; not necessary if silica gel is weighed in the field.

2.2.8 Funnel. Glass or polyethylene, to aid in sample recovery.

2.3 Analysis.

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 mg.

2.3.5 Beakers, 250 ml.

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature Gauge. To measure the temperature of the laboratory environment.

3. *Reagents*

3.1 Sampling.

3.1.1 Filters. The in-stack filters shall be glass mats or thimble fiber filters, without organic binders, and shall exhibit at least 99.95 percent efficiency (0.05 percent penetration) on 0.3 micron dioctyl phthalate smoke particles. The filter efficiency tests shall be conducted in accordance with ASTM Standard Method D2986–71 (Reapproved 1978) (incorporated by reference—see §60.17). Test data from the supplier's quality control program are sufficient for this purpose.

3.1.2 Silica Gel. Indicating type, 6- to 16-mesh. If previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccants (equivalent or better) may be used, subject to the approval of the Administrator.

3.1.3 Crushed Ice.

3.1.4 Stopcock Grease. Acetone-insoluble, heat-stable silicone grease. This is not necessary if screw-on connectors with Teflon sleeves, or similar, are used. Alternatively, other types of stopcock grease may be used, subject to the approval of the Administrator.

3.1.5 Water. Same as in Method 5, section 3.1.3.

3.2 Sample Recovery. Acetone, reagent grade, 0.001 percent residue, in glass bottles. Acetone from metal containers generally has a high residue blank and should not be used. Sometimes, suppliers transfer acetone to glass bottles from metal containers. Thus, acetone blanks shall be run prior to field use and only acetone with low blank values (0.001 percent) shall be used. In no case shall a blank value of greater than 0.001 percent of the weight of acetone used be subtracted from the sample weight.

3.3 Analysis.

3.3.1 Acetone. Same as 3.2.

3.3.2 Desiccant. Anhydrous calcium sulfate, indicating type. Alternatively, other types of desiccants may be used, subject to the approval of the Administrator.

4. *Procedure*

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testers should be trained and experienced with the test procedures.

4.1.1 Pretest Preparation. All components shall be maintained and calibrated according to the procedure described in APTD-0576, unless otherwise specified herein.

Weigh several 200 to 300 g portions of silica gel in air-tight containers to the nearest 0.5 g. Record the total weight of the silica gel plus container, on each container. As an alternative, the silica gel need not be preweighed, but may be weighed directly in its impinger or sampling holder just prior to train assembly.

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 (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccate the filters at 20±5.6° C (68±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 above 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. Procedures other than those described, which account for relative humidity effects, may be used, subject to the approval of the Administrator.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number of sampling points according to Method 1 or as specified by the Administrator. Make a projected-area model of the probe extension-filter holder assembly, with the pitot tube face openings positioned along the centerline of the stack, as shown in Figure 17-2. Calculate the estimated cross-section blockage, as shown in Figure 17-2. If the blockage exceeds 5 percent of the duct cross sectional area, the tester has the following options: (1) a suitable out-of-stack filtration method may be used instead of in-stack filtration; or (2) a special in-stack arrangement, in which the sampling and velocity measurement sites are separate, may be used; for details concerning this approach, consult with the Administrator (see also Citation 10 in Bibliography). Determine the stack pressure, temperature, and the range of velocity heads using Method 2; it is recommended that a leak-check of the pitot lines (see Method 2, Section 3.1) be performed. Determine the moisture content using Approximation Method 4 or its alternatives for the purpose of making isokinetic sampling rate settings. Determine the stack gas dry molecular weight, as described in Method 2, Section 3.6; if Integrated Method 3 sampling is used for molecular weight determination, the integrated bag sample shall be taken simultaneously with, and for the same total length of time as, the particulate sample run.

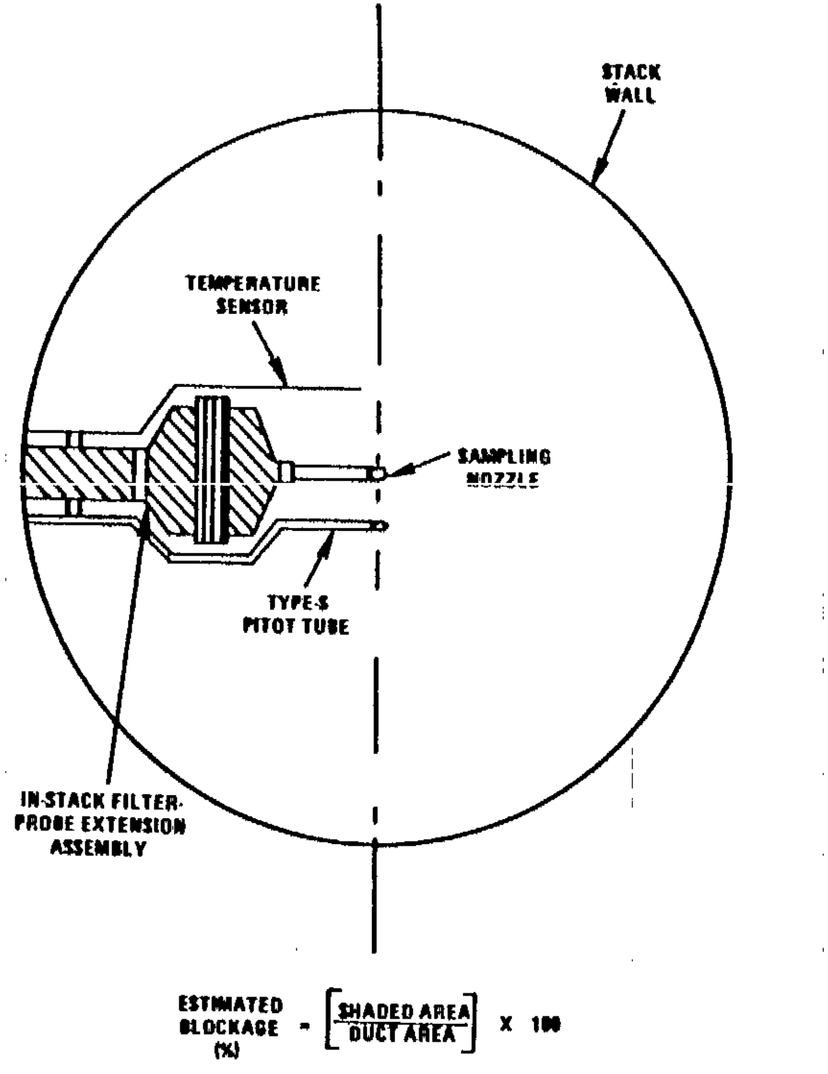

Figure 17-2. Projected-area model of cross-section blockage (approximate average for a sample traverse) caused by an in-stack filter holder-probe extension assembly.

Select a nozzle size based on the range of *velocity heads, such that it is not necessary* to change the nozzle size in order to maintain isokinetic sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads encountered (see Section 2.2 of Method 2).

Select a probe extension length such that all traverse points can be sampled. For large *stacks, consider sampling from opposite* sides of the stack to reduce the length of probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 minutes (or some greater time interval if specified by the Administrator), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximate average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors.

In some circumstances, e.g., batch cycles, it may be necessary to sample for shorter times at the traverse points and to obtain smaller gas sample volumes. In these cases, the Administrator's approval must first be obtained.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

If impingers are used to condense stack gas moisture, prepare them as follows: place 100 ml of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.5 g and recorded.

If some means other than impingers is used to condense moisture, prepare the condenser *(and, if appropriate, silica gel for condenser* outlet) for use.

Using a tweezer or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as not to allow the sample gas stream to circumvent the filter. Check filter for tears after assembly is completed. *Mark the probe extension with heat* resistant tape or by some other method to denote the proper distance into the stack or *duct for each sampling point.*

Assemble the train as in Figure 17–1, using a very light coat of silicone grease on all ground glass joints and greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Place crushed ice around the impingers.

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 opts to conduct the pretest leak-check, the following procedure shall be used.

After the sampling train has been assembled, plug the inlet to the probe nozzle with a material that will be able to withstand the stack temperature. Insert the filter holder into the stack and wait approximately 5 minutes (or longer, if necessary) to allow the system to come to equilibrium with the temperature of the stack gas stream. Turn on the pump and draw a vacuum of at least 380 *mm Hg (15 in. Hg); note that a lower vacuum* may be used, provided that it is not exceeded during the test. Determine the leakage rate. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m³/min. (0.02 cfm), whichever is less, is unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with by-pass valve fully open and coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the by-pass valve until the desired vacuum is reached. Do not reverse direction of by-pass valve. If the desired vacuum is exceeded, either leak-check at this higher vacuum or end the leak-check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe nozzle and immediately turn off the vacuum pump. This prevents water from being forced backward and keeps silica gel *from being entrained backward.*

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at *a vacuum equal to or greater than the maximum* value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction will need to 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 plan* to correct the sample volume as shown in

Section 6.3 of this method, or shall void the *sampling run.*

Immediately after component changes, leak-checks are optional; if such leak-checks are done, the procedure outlined in Section 4.1.4.1 above shall be used.

4.1.4.3 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*, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than 0.00057 m³/min (0.02 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 6.3 of this method, or shall void the sampling run.

4.1.5 Particulate Train Operation. During the sampling run, maintain a sampling rate such that sampling is within 10 percent of true isokinetic, unless otherwise specified by the Administrator.

For each run, record the data required on the example data sheet shown in Figure 17–3. Be sure to record the initial dry gas meter reading. Record the dry gas meter readings *at the beginning* and end of each sampling time increment, when changes in flow rates are made, before and after each leak check, and when sampling is halted. Take other readings required by Figure 17–3 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional *adjustments in flow rate.* Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

FIGURE 17-3—PARTICULATE FIELD DATA

Plant ....
Location ....
Operator ....
Date ....
Run No ....
Sample box No ....
Meter box No ....
Meter ΔH@ ....
C factor. ....
Pitot tube coefficient, Cp. ....

SCHEMATIC OF STACK CROSS SECTION

Barometric pressure ....
Assumed moisture, % ....
Probe extension length, m (ft.) ....
Nozzle identification No. ....
Average calibrated nozzle diameter cm (in.) ....
Filter No. ....
Leak rate, m³/min, (cfm) ....
Static pressure, mm Hg (in. Hg) ....

Traverse point number	Sampling time	Vacuum	Stack temperature (Ts)	Velocity head (ΔP)	Pressure differential across orifice meter	Gas sample volume	Gas sample temperature at dry gas meter		Temperature of gas leaving condenser or last impinger
							Inlet	Outlet	
	(θ), min.	mm Hg (in. Hg)	°C (°F)	mm H_2O (in H_2O)	mm H_2O (in H_2O)	m³ (ft³)	°C (°F)	°C (°F)	°C (°F)
Total							Avg.	Avg.	
Average							Avg.		

Clean the portholes prior to the test run to minimize the chance of sampling the deposited material. To begin sampling, remove the nozzle cap and verify that the pitot tube and probe extension are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Nomographs are available, which aid in the rapid adjustment to the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85±0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29±4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges, do not use the nomographs unless appropriate steps (see Citation 7 in Bibliography) are taken to compensate for the deviations.

When the stack is under significant negative pressure (height of impinger stem), take care to close the coarse adjust valve before inserting the probe extension assembly into the stack to prevent water from being forced backward. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross section, as required by Method 1 or as specified by the Administrator, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe extension through the portholes, to minimize chance of extracting deposited material.

During the test run, take appropriate steps (e.g., adding crushed ice to the impinger ice bath) to maintain a temperature of less than 20° C (68° F) at the condenser outlet; this will prevent excessive moisture losses. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter holder assembly be used rather than attempting to change the filter itself. Before a new filter holder is installed, conduct a leak check, as outlined in Section 4.1.4.2. The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Administrator. Note that when two or more trains are used, a separate analysis of the collected particulate from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case the particulate catches from the individual trains may be combined and a single analysis performed.

At the end of the sample run, turn off the pump, remove the probe extension assembly from the stack, and record the final dry gas meter reading. Perform a leak-check, as outlined in Section 4.1.4.3. Also, leak-check the pitot lines as described in Section 3.1 of Method 2; the lines must pass this leak-check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Section 6.11) to determine whether another test run should be made. If there is difficulty in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe extension assembly is removed from the stack at the end of the sampling period. Allow the assembly to cool.

When the assembly can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, forcing condenser water backward.

Before moving the sample train to the cleanup site, disconnect the filter holder-probe nozzle assembly from the probe extension; cap the open inlet of the probe extension. Be careful not to lose any condensate, if present. Remove the umbilical cord from the condenser outlet and cap the outlet. If a flexible line is used between the first impinger (or condenser) and the probe extension, disconnect the line at the probe extension and let any condensed water or liquid drain into the impingers or condenser. Disconnect the probe extension from the condenser; cap the probe extension outlet. After wiping off the silicone grease, cap off the condenser inlet. Ground glass stoppers, plastic caps, or serum caps (whichever are appropriate) may be used to close these openings.

Transfer both the filter holder-probe nozzle assembly and the condenser to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank. Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry Nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container No. 2. Taking care to see that dust on the outside of the probe nozzle or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, fitting, and front half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Administrator and shall be used when specified by the Administrator; in these cases, save a water blank and follow Administrator's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a Nylon bristle brush. Brush until acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone.

Brush and rinse with acetone the inside parts of the fitting in a similar way until no visible particles remain. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Rinse the brush with acetone and quantitatively collect these washings in the sample container. Between sampling runs, keep brushes clean and protected from contamination.

After ensuring that all joints are wiped clean of silicone grease (if applicable), clean the inside of the front half of the filter holder by rubbing the surfaces with a Nylon bristle brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make final rinse of the brush and filter holder. After all acetone washings and particulate matter are collected in the sample container, tighten the lid on the sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage occurred during transport. Label the container to clearly identify its contents.

Container No. 3. If silica gel is used in the condenser system for mositure content determine if it has been completely spent; make a notation of its condition. Transfer the silica gel back to its original container and seal. A funnel may make it easier to pour the silica gel without spilling, and a rubber policeman may be used as an aid in removing the silica gel. It is not necessary to remove the small amount of dust particles that may adhere to the walls and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, follow the procedure for Container No. 3 under "Analysis."

Condenser Water. Treat the condenser or impinger water as follows: make a notation of any color or film in the liquid catch. Measure the liquid volume to within ±1 ml by using a graduated cylinder or, if a balance is available, determine the liquid weight to within ±0.5 g. Record the total volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas. Discard the liquid after measuring and recording the volume or weight.

4.3 Analysis. Record the data required on the example sheet shown in Figure 17-4. Handle each sample container as follows:

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, with no less than 6 hours of desiccation time between weighings.

Alternatively, the sample may be oven dried at the average stack temperature or 105° C (220° F), whichever is less, for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. The tester may also opt to oven dry the sample at the average stack temperature or 105° C (220° F), whichever is less, for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

FIGURE 17-4—ANALYTICAL DATA

Plant ______
Date ______
Run No. ______
Filter No. ______
Amount liquid lost during transport ______
Acetone blank volume, ml ______
Acetone wash volume, ml ______
Acetone blank concentration, mg/mg (Equation 17-4) ______
Acetone wash blank, mg (Equation 17-5) ______

Container number	Weight of particulate collected, mg		
	Final weight	Tare weight	Weight gain
1.			
2.			
Total.			
Less acetone blank.			
Weight of particulate matter.			

	Volume of liquid water collected	
	Impinger volume, ml	Silica gel weight, g
Final.		
Initial.		
Liquid collected.		
Total volume collected		g* ml

*Convert weight of water to volume by dividing total weight increase by density of water (1 g/ml).

$$\frac{\text{Increase, g}}{(1\ \text{g/ml})} = \text{Volume water, ml}$$

Container No. 2. Note the level of liquid in the container and confirm on the analysis sheet whether or not leakage occurred during transport. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results. Measure the liquid in this container either volumetrically to ±1 ml or gravimetrically to ±0.5 g. Transfer the contents to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Container No. 3. This step may be conducted in the field. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g using a balance.

"Acetone Blank" Container. Measure acetone in this container either volumetrically or gravimetrically. Transfer the acetone to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

NOTE: At the option of the tester, the contents of Container No. 2 as well as the acetone blank container may be evaporated at temperatures higher than ambient. If evaporation is done at an elevated temperature, the temperature must be below the boiling point of the solvent; also, to prevent "bumping," the evaporation process must be closely supervised, and the contents of the beaker must be swirled occasionally to maintain an even temperature. Use extreme care, as acetone is highly flammable and has a low flash point.

5. *Calibration*

Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of the nozzle to the nearest 0.025 mm (0.001 in.). Make three separate measurements using different diameters each time, and obtain the average of the measurements. The difference between the high and low numbers shall not exceed 0.1 mm (0.004 in.). When nozzles become nicked, dented, or corroded, they shall be reshaped, sharpened, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

5.2 Pitot Tube. If the pitot tube is placed in an interference-free arrangement with respect to the other probe assembly components, its baseline (isolated tube) coefficient shall be determined as outlined in Section 4 of Method 2. If the probe assembly is not interference-free, the pitot tube assembly coefficient shall be determined by calibration, using methods subject to the approval of the Administrator.

5.3 Metering System. Before its initial use in the field, the metering system shall be calibrated according to the procedure outlined in APTD-0576. Instead of physically adjusting the dry gas meter dial readings to correspond to the wet test meter readings, calibration factors may be used to mathematically correct the gas meter dial readings to the proper values.

Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057 m³/min (0.02 cfm); at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divide the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m³/min (0.02 cfm).

After each field use, the calibration of the metering system shall be checked by performing three calibration runs at a single, intermediate orifice setting (based on the previous field test), with the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the metering system. Calculate the average value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the full range of orifice settings, as outlined in APTD-0576.

Alternative procedures, e.g., using the orifice meter coefficients, may be used, subject to the approval of the Administrator.

NOTE: If the dry gas meter 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.

5.4 Temperature Gauges. Use the procedure in Section 4.3 of Method 2 to calibrate in-stack temperature gauges. Dial thermometers, such as are used for the dry gas meter and condenser outlet, shall be calibrated against mercury-in-glass thermometers.

5.5 Leak Check of Metering System Shown in Figure 17-1. That portion of the sampling train from the pump to the orifice meter should be leak checked prior to initial use and after each shipment. Leakage after the pump will result in less volume being recorded than is actually sampled. The following procedure is suggested (see Figure 17-5). Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing attached into the orifice exhaust pipe. Disconnect and vent the low side of the orifice manometer. Close off the low side orifice tap. Pressurize the system to 13 to 18 cm (5 to 7 in.) water column by blowing into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box; leaks, if present, must be corrected.

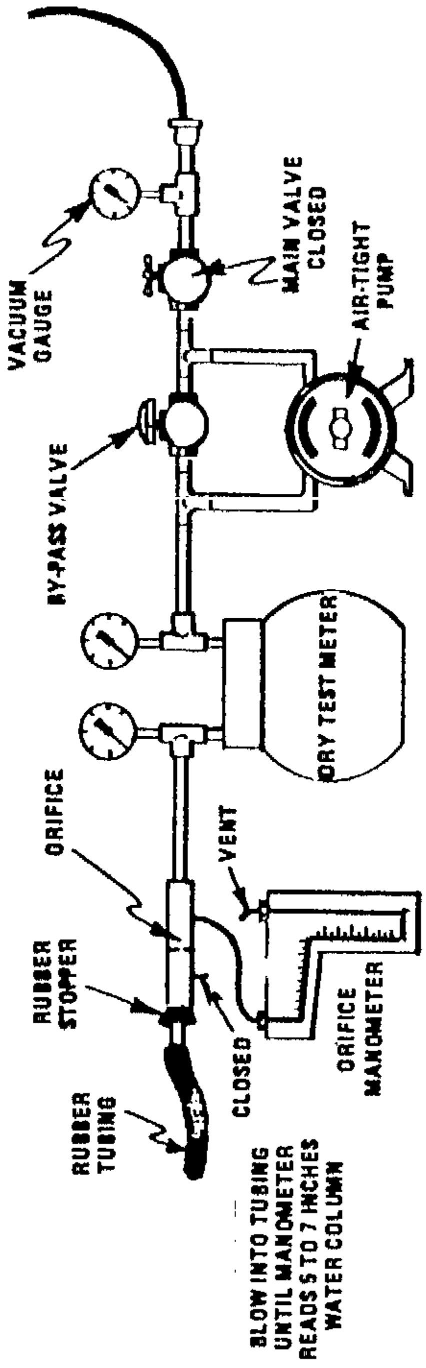

Figure 17-5. Leak check of meter box.

5.6 Barometer. Calibrate against a mercury barometer.

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.

A_n=Cross-sectional area of nozzle, m² (ft²).
B_{ws}=Water vapor in the gas stream, proportion by volume.
C_a=Acetone blank residue concentration, mg/mg.
c_s=Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).
I=Percent of isokinetic sampling.
L_a=Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.
L_i=Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change (i=1, 2, 3 . . . n), m³/min (cfm).
L_p=Leakage rate observed during the post-test leak check, m³/min (cfm).
m_a=Mass of residue of acetone after evaporation, mg.
m_n=Total amount of particulate matter collected, mg.
M_w=Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).
P_{bar}=Barometric pressure at the sampling site, mm Hg (in. Hg).
P_s=Absolute stack gas pressure, mm Hg (in. Hg).
P_{std}=Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
R=Ideal gas constant, 0.06236 mm Hg-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).
T_m=Absolute average dry gas meter temperature (see Figure 17–3), °K (°R).
T_s=Absolute average stack gas temperature (see Figure 17–3), °K (°R).
T_{std}=Standard absolute temperature, 293°K (528°R).
V_a=Volume of acetone blank, ml.
V_{aw}=Volume of acetone used in wash, ml.
V_{lc}=Total volume of liquid collected in impingers and silica gel (see Figure 17–4), ml.
V_m=Volume of gas sample as measured by dry gas meter, dcm (dcf).
$V_{m(std)}$=Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$=Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
v_s=Stack gas velocity, calculated by Method 2, Equation 2–9, using data obtained from Method 17, m/sec (ft/sec).
W_a=Weight of residue in acetone wash, mg.
Y=Dry gas meter calibration coefficient.
ΔH=Average pressure differential across the orifice meter (see Figure 17–3), mm H₂O (in. H₂O).
ρ_a=Density of acetone, mg/ml (see label on bottle).
ρ_w=Density of water, 0.9982 g/ml (0.002201 lb/ml).
θ=Total sampling time, min.
θ_1=Sampling time interval, from the beginning of a run until the first component change, min.
θ_i=Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.
θ_p=Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.
13.6=Specific gravity of mercury.
60=Sec/min.
100=Conversion to percent.

6.2 Average Dry Gas Meter Temperature and Average Orifice Pressure Drop. See data sheet (Figure 17–3).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C, 760 mm Hg or 68° F, 29.92 in. Hg) by using Equation 17–1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right]$$

$$= K_1 V_m Y \frac{P_{bar} + (\Delta H/13.6)}{T_m}$$

Eq. 17-1

Where:

K_1=0.3858° K/mm Hg for metric units; 17.64° R/in. Hg for English units.

NOTE: Equation 17–1 can be used as written unless the leakage rate observed during any of the mandatory leak checks (i.e., the post-test leak check or leak checks conducted prior to component changes) exceeds L_a. If L_p or L_i exceeds L_a, Equation 17–1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 17–1 with the expression:

$$[V_m - (L_p - L_a)\theta]$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace V_m in Equation 17–1 by the expression:

$$\left[V_m - (L_1 - L_a)\,\theta_1 - \sum_{i=2}^{n} (L_i - L_a)\,\theta_i - (L_p - L_a)\,\theta_p\right]$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of Water Vapor.

$$V_{w(std)} = V_{lc}\left(\frac{\rho_w}{M_w}\right)\left(\frac{RT_{std}}{P_{std}}\right) = K_2 V_{lc}$$

Eq. 17–2

Where:

K_2=0.001333 m³/ml for metric units; 0.04707 ft³/ml for English units.

6.5 Moisture Content.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

Eq. 17–3

6.6 Acetone Blank Concentration.

$$C_a = \frac{m_a}{V_a \rho_a}$$

Eq. 17–4

6.7 Acetone Wash Blank.

$$W_a = C_a V_{aw} \rho_a$$

Eq. 17–5

6.8 Total Particulate Weight. Determine the total particulate catch from the sum of the weights obtained from Containers 1 and 2 less the acetone blank (see Figure 17–4).

NOTE: Refer to Section 4.1.5 to assist in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

$$c_s = (0.001\ \text{g/mg})\ (m_n/V_{m(std)})$$

Eq. 17–6

6.10 Conversion Factors:

From	To	Multiply by
scf	m³	0.02832
g/ft³	gr/ft³	15.43
g/ft³	lb/ft³	2.205×10⁻³
g/ft³	g/m³	35.31

6.11 Isokinetic Variation.

6.11.1 Calculation from Raw Data.

$$I = \frac{100\, T_s\, [K_3 V_{lc} + (V_m Y/T_m)\,(P_{bar} + \Delta H/13.6)]}{60\, \theta v_s\, P_s\, A_n}$$

Eq. 17–7

Where:

K_3=0.003454 mm Hg-m³/ml-°K for metric units; 0.002669 in. Hg-ft³/ml-°R for English units.

6.11.2 Calculation from Intermediate Values.

$$I = \frac{T_s\, V_{m(std)}\, P_{std}\, 100}{T_{std}\, v_s\, \theta\, A_n\, P_s\, 60\, (1-B_{ws})}$$

$$= K_4 \frac{T_s\, V_{m(std)}}{P_s\, v_s\, A_n\, \theta\, (1-B_{ws})}$$

Eq. 17–8

Where:

K_4=4.320 for metric units; 0.09450 for English units.

6.12 Acceptable Results. If 90 percent <I <110 percent, the results are acceptable. If the results are low in comparison to the standard and I is beyond the acceptable range, or, if I is less than 90 percent, the Administrator may opt to accept the results. Use Citation 4 in Bibliography to make judgments. Otherwise, reject the results and repeat the test.

7. *Bibliography*

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METHOD 18—MEASUREMENT OF GASEOUS ORGANIC COMPOUND EMISSIONS BY GAS CHROMATOGRAPHY

Introduction

This method should not be attempted by persons unfamiliar with the performance characteristics of gas chromatography, nor by those persons who are unfamiliar with source sampling. Particular care should be exercised in the area of safety concerning choice of equipment and operation in potentially explosive atmospheres.

1. *Applicability and Principle*

1.1 Applicability. This method applies to the analysis of approximately 90 percent of the total gaseous organics emitted from an industrial source. It does not include techniques to identify and measure trace amounts of organic compounds, such as those found in building air and fugitive emission sources.

This method will not determine compounds that (1) are polymeric (high molecular weight), (2) can polymerize before analysis, or (3) have very low vapor pressures at stack or instrument conditions.

1.2 Principle.

The major organic components of a gas mixture are separated by gas chromatography (GC) and individually quantified by flame ionization, photoionization, electron capture, or other appropriate detection principles.

The retention times of each separated component are compared with those of known compounds under identical conditions. Therefore, the analyst confirms the identity and approximate concentrations of the organic emission components beforehand. With this information, the analyst then prepares or purchases commercially available standard mixtures to calibrate the GC under conditions identical to those of the samples. The analyst also determines the need for sample dilution to avoid detector saturation, gas stream filtration to eliminate particulate matter, and prevention of moisture condensation.

2. *Range and Sensitivity*

2.1 Range. The range of this method is from about 1 part per million (ppm) to the upper limit governed by GC detector saturation or column overloading. The upper limit can be extended by diluting the stack gases with an inert gas or by using smaller gas sampling loops.

2.2 Sensitivity. The sensitivity limit for a compound is defined as the minimum detectable concentration of that compound, or the concentration that produces a signal-to-noise ratio of three to one. The minimum detectable concentration is determined during the presurvey calibration for each compound.

3. *Precision and Accuracy*

Gas chromatographic techniques typically provide a precision of 5 to 10 percent relative standard deviation (RSD), but an experienced GC operator with a reliable instrument can readily achieve 5 percent RSD. For this method, the following combined GC/operator values are required.

(a) Precision. Duplicate analyses are within 5 percent of their mean value.

(b) Accuracy. Analysis results of prepared audit samples are within 10 percent of preparation values.

4. *Interferences*

Resolution interferences that may occur can be eliminated by appropriate GC column and detector choice or by shifting the retention times through changes in the column flow rate and the use of temperature programming.

The analytical system is demonstrated to be essentially free from contaminants by periodically analyzing blanks that consist of hydrocarbon-free air or nitrogen.

Sample cross-contamination that occurs when high-level and low-level samples or standards are analyzed alternately, is best dealt with by thorough purging of the GC sample loop between samples.

To assure consistent detector response, calibration gases are contained in dry air. To adjust gaseous organic concentrations when water vapor is present in the sample, water vapor concentrations are determined for those samples, and a correction factor is applied.

5. *Presurvey and Presurvey Sampling.*

Perform a presurvey for each source to be tested. Refer to Figure 18-1. Some of the information can be collected from literature surveys and source personnel. Collect gas samples that can be analyzed to confirm the identities and approximate concentrations of the organic emissions.

5.1 Apparatus. This apparatus list also applies to Sections 6 and 7.

5.1.1 Teflon Tubing. (Mention of trade names or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.) Diameter and length determined by connection requirements of cylinder regulators and the GC. Additional tubing is necessary to connect the GC sample loop to the sample.

5.1.2 Gas Chromatograph. GC with suitable detector, columns, temperature-controlled sample loop and valve assembly, and temperature programable oven, if necessary. The GC shall achieve sensitivity requirements for the compounds under study.

5.1.3 Pump. Capable of pumping 100 ml/min. For flushing sample loop.

5.1.4 Flowmeters. To measure flow rates.

5.1.5 Regulators. Used on gas cylinders for GC and for cylinder standards.

5.1.6 Recorder. Recorder with linear strip chart is minimum acceptable. Integrator (optional) is recommended.

5.1.7 Syringes, 0.5-ml, 1.0- and 10-microliter sizes, calibrated, maximum accuracy (gas tight), for preparing calibration standards. Other appropriate sizes can be used.

5.1.8 Tubing Fittings. To plumb GC and gas cylinders.

5.1.9 Septums. For syringe injections.

5.1.10 Glass Jars. If necessary, clean-colored glass jars with Teflon-lined lids for condensate sample collection. Size depends on volume of condensate.

5.1.11 Soap Film Flow Meter. To determine flow rates.

5.1.12 Tedlar Bags. 10- and 50-liter capacity, for preparation of standards.

5.1.13 Dry Gas Meter with Temperature and Pressure Gauges. Accurate to ±2 percent, for perparation of gas standards.

5.1.14 Midget Impinger/Hot Plate Assembly. For preparation of gas standards.

5.1.15 Sample Flasks. For presurvey samples, must have gas-tight seals.

5.1.16 Adsorption Tubes. If necessary, blank tubes filled with necessary adsorbent (charcoal, Tenax, XAD-2, etc.) for presurvey samples.

5.1.17 Personnel Sampling Pump. Calibrated, for collecting adsorbent tube presurvey samples.

5.1.18 Dilution System. Calibrated, the dilution system is to be constructed following the specifications of an acceptable method.

5.1.19 Sample Probes. Pyrex or stainless steel, of sufficient length to reach centroid of stack, or a point no closer to the walls than 1 m.

5.1.20 Barometer. To measure barometric pressure.

5.2 Reagents.

5.2.1 Deionized Distilled Water.

5.2.2 Methylene Dichloride.

5.2.3 Calibration Gases. A series of standards prepared for every compound of interest.

5.2.4 Organic Compound Solutions. Pure (99.9 percent), or as pure as can reasonably be obtained, liquid samples of all the organic compounds needed to prepare calibration standards.

5.2.5 Extraction Solvents. For extraction of adsorbent tube samples in preparation for analysis.

5.2.6 Fuel. As recommended by the manufacturer for operation of the GC.

5.2.7 Carrier Gas. Hydrocarbon free, as recommended by the manufacturer for operation of the detector and compatability with the column.

5.2.8 Zero Gas. Hydrocarbon free air or nitrogen, to be used for dilutions, blank preparation, and standard preparation.

5.3 Sampling.

5.3.1 Collection of Samples with Glass Sampling Flasks. Presurvey samples can be collected in precleaned 250-ml double-ended glass sampling flasks. Teflon stopcocks, without grease, are preferred. Flasks should be cleaned as follows: Remove the stopcocks from both ends of the flasks, and wipe the parts to remove any grease. Clean the stopcocks, barrels, and receivers with methylene dichloride. Clean all glass ports with a soap solution, then rinse with tap and deionized distilled water. Place the flask in a cool glass annealing furnace and apply heat up to 500° C. Maintain at this temperature for 1 hour. After this time period, shut off and open the furnace to allow the flask to cool. Grease the stopcocks with stopcock grease and return them to the flask receivers. Purge the assembly with high-purity nitrogen for 2 to 5 minutes. Close off the stopcocks after purging to maintain a slight positive nitrogen pressure. Secure the stopcocks with tape.

Presurvey samples can be obtained either by drawing the gases into the previously evacuated flask or by drawing the gases into and purging the flask with a rubber suction bulb.

5.3.1.1 Evacuated Flask Procedure. Use a high-vacuum pump to evacuate the flask to the capacity of the pump; then close off the stopcock leading to the pump. Attach a 6-mm outside diameter (OD) glass tee to the flask inlet with a short piece of Teflon tubing. Select a 6-mm OD borosilicate sampling probe, enlarged at one end to a 12-mm OD and of sufficient length to reach the centroid of the duct to be sampled. Insert a glass wool plug in the enlarged end of the probe to remove particulate matter. Attach the other end of the probe to the tee with a short piece of Teflon tubing. Connect a rubber suction bulb to the third leg of the tee. Place the filter end of the probe at the centroid of the duct, or at a point no closer to the walls than 1 m, and purge the probe with the rub-

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RE: 45CSR2 - To Prevent and Control Particulate Air Pollution from Combustion of Fuel in Indirect Heat Exchangers

Dear Ms. Cooper:

This is to advise you that I am giving approval for the filing of the above-captioned rule with your Office and the Legislative Rule-Making Review Committee as an agency-approved rule.

Your cooperation in this regard is very much appreciated. If you have any questions or require additional information, please feel free to contact Roger T. Hall at 759-0515.

Sincerely yours,

David C. Callaghan
Commissioner
Bureau of Environment

DCC/GDF-tlm

Attachments