7770246-002-A0

SOUTHWEST SOIL REMEDIATION, INC.
TUCSON, ARIZONA

PORTABLE SOIL THERMAL TREATMENT UNIT EMISSION TEST REPORT

4/15/96
MAYPORT N.S., FLORIDA

BY:

ED WADINGTON

CONFIDENTIAL

RELEASED ONLY BY AUTHORIZED
COMPANY PERSONNEL

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ENERGY AND ENVIRONMENTAL
MEASUREMENT
CORPORATION

FIELD OBSERVATION CHECKLIST

DATE:	4/15/96
PLANT NAME:	SOUTHWEST SOIL REMEDIATION, INC. AT MAYPORT NAVAL STATION, FLORIDA
COMPANY ADDRESS:	3951 E. COLUMBIA STREET TUCSON, ARIZONA 85714
SOURCES TESTED:	4' L.T.T.D. UNIT WITH S.T.U.
PLANT CONTACT:	JAE CHANG
PHONE:	(602) 571-7174
FAX:	(602) 571-7730
OBSERVERS & AFFILIATION:	
	JEFFREY WINTER - DEPT. OF REGULATORY AND ENVIRONMENTAL SERVICES, AIR QUALITY DIV.
EEMC FIELD TEAM:	
TEAM LEADER:	RAFAEL GUILLEN
OTHER MEMBERS:	DAVE WANG

INTRODUCTION

Southwest Soil Remediation (SWSR), Tucson, Arizona contracted with Energy & Environmental Measurement Corporation (EEMC) to conduct a series of emission evaluations on a thermal oxidation system located at SWSR's mobile production facility in Mayport Naval Station, Florida. The purpose of this report is to outline the sampling and analytical methods employed, field/laboratory data and provide test results.

Test Chronolog

4/15/96

Time	Run #	Location	Test Description(s)
0940-1042	1-PT	Outlet	EPA Methods #1-5
1129-1230	2-PT	Outlet	EPA Methods #1-5
1318-1416	3-PT	Outlet	EPA Methods #1-5
0940-1040	1-CO	Outlet	EPA Method #10
1129-1229	2-CO	Outlet	EPA Method #10
1315-1415	3-CO	Outlet	EPA Method #10
1045-1057	1-OP	Outlet	EPA Method #9
1300-1312	2-OP	Outlet	EPA Method #9
1420-1432	3-OP	Outlet	EPA Method #9

PROCESS DESCRIPTION

Process description and diagrams were supplied by SWSR and are included as tabulated.

TEST PROCEDURES

Schematics of the sampling train(s) are included in the Test Methods section as tabulated.

SAMPLING EQUIPMENT & PROCEDURES

Particulate/H2O/Gas Flow Emissions

EPA Methods #1-#5 were utilized for determination of stack particulate emissions. Note Test Methods section for a description of stack parameters (traverse points, etc.).

The sample train consisted of a quartz button hook nozzle followed by a water cooled glass lined pitobe assembly (S-type pitot tube and a type K thermocouple) leading to a heated EPA Type A glass fiber filter. The gases were then pulled through four Greenberg-Smith impingers where flue gas moisture was condensed (1&2-150 ml H_2O, 3- empty, and 4-silica gel). The filtered and dried gases were then pulled, via an umbilical cord, to a RAC type meter box for gas volume metering. A meter box orifice slip stream was utilized for collection of an integrated bag sample and analysis via orsat and a Teledyne oxygen analyzer.

Upon completion of the test run, CO_2 and O_2 was determined by triplicate orsat analysis (integrated bag), and gravimetric analysis of the impinger liquid gain (moisture determination). Resultant particulate samples were then washed from the train, and removed to the EEMC on site mobile laboratory for shipment to the Billings laboratory for analysis.

CO Emissions

EPA Method #10 [1] was utilized for determination of flue gas CO concentration. Location of the sampling points is noted in the stack parameters section. The stack gases were extracted through an inert sampling interface (teflon and/or polypropylene) and conveyed to a TECO 48 NDIR analyzer. Certified calibration gases were employed for instrument span checks. Zero was checked with zero (N_2) gas. A complete description of Method #10 procedures is contained in the Test Methods section of this report. Data was recorded on an integrating computer/logger printing one-minute values.

Opacity

EPA Method #9 [1] was utilized for determination of stack opacity. A certified opacity observer conducted the tests. Results are reported in the Data Summary section. Field data sheets are included in the Field Data and Calculations section.

Units of Reporting

The data is reported with the following units:

Particulates
gr/dscf - grains per dry standard* cubic foot
(*@68 °F & 29.92 "Hg)
PPH - pounds per hour

CO2/O2
% v/v - percent of a volume basis

Gas Flow
FPS - feet per second
SDCFH - Standard (68 °F & 29.92 "Hg) dry cubic feet per hour
AWCFM - Actual wet cubic feet per minute

CO
ppm v/v Dry - parts per million on a volume basis without water
PPH - pounds per hour

RESULTS

This report contains summarizations of all pertinent sampling and analytical results. Field and laboratory data is included as tabulated or indexed.

REFERENCES

[1] Federal Register, 40 CFR, Pt. 60, App. A, Methods #1-5, 9 & 10, 7/1/94

SUMMARY OF SOUTHWEST SOIL REMEDIATION
MAYPORT NAVAL STATION, FLORIDA

4/15/96

OUTLET PARTICULATE EMISSION DATA

TIME	RUN #	GR/DSCF	PPH	AWCFM	SDCFH x10[5]	Ts(oF)	%H2O v/v	%CO2/O2 v/v Dry
0940-1042	1-PT	0.0303	1.15	22,066	2.648	1443	29.16	7.1/9.2
1129-1230	2-PT	0.0488	1.75	20,421	2.510	1445	27.38	8.4/7.9
1318-1416	3-PT	0.0288	1.03	20,504	2.494	1446	27.97	7.4/9.0
	MEAN 1-3	0.0360	1.31	20,997	2.551	1445	28.17	7.6/8.7

OUTLET CO EMISSION DATA

TIME	RUN #	-------- CO	--------
		PPM V/V DRY	PPH
0940-1040	1-CO	3.9	0.08
1129-1229	2-CO	9.4	0.17
1315-1415	3-CO	5.6	0.10
	MEAN 1-3	6.3	0.12

OUTLET OPACITY DATA

TIME	RUN #	% ATTENUATION
1045-1057	1	0.63
1300-1312	2	1.46
1420-1432	3	0.73
	MEAN 1-3	0.94

CALCULATION OF THERMAL OXIDIZER RETENTION TIME

SOUTHWEST SOIL REMEDIATION SYSTEM
@ MAYPORT NAVAL STATION, FLORIDA

A) Volume of Thermal Oxidizer

Diameter = 4.25 ft.
Cross Sectional Area = 14.186 sq.ft.
Length = 41.17 ft.
Volume = (14.186 sq.ft.)(41.17 ft.) = 584.04 cu.ft.

B) Gas Volume/Velocity

20,997 AWCFM or 350 AWCFS
(350 AWCFS)/(14.17 sq.ft.) = 24.67 ft./sec.

C) Retention Time

(41.14 ft)/(24.67 ft./sec.) = 1.67 seconds

COMPLIANCE STATEMENT
SOUTHWEST SOIL REMEDIATION
MAYPORT NAVAL STATION
4/15/96

	EMISSION STANDARD	MEASURED EMISISONS
Particulates	0.04 gr/dscf 2.1 lbs/hr	0.0360 gr/dscf 1.31 lbs/hr
Opacity	5%	0.94%
Carbon Monoxide	100 ppm v/v	6.3 ppm v/v

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

PERMITTEE:
Southwest Soil Remediation, Inc.
3951 E. Columbia St.
Tucson, Arizona 85714-2155

Permit Number: AC 37-276044
Expiration Date: Nov. 15, 1996
County: Mobile Operation

Project: Mobile Soil Thermal Treatment Facility

This permit is issued under the provisions of Chapter 403, Florida Statutes (F.S.), and Chapters 62-212 and 62-4, Florida Administrative Code (F.A.C.). The above named permittee is hereby authorized to perform the work or operate the facility shown on the application and approved drawings, plans, and other documents attached hereto or on file with the Department and made a part hereof and specifically described as follows:

Authorization to construct a Ryan Murphy, Inc. 20 ton per hour (TPH) mobile soil thermal treatment facility/unit (SIC 1629) in Florida. The unit contains a petroleum contaminated soil feed bin, a 7.8 million British thermal unit per hour (MMBtu/hr) 4 feet diameter by 20 feet long rotary drum dryer (kiln), a pulse-jet baghouse with a 4.5 to 1 air to cloth ratio, a catalytic oxidizer, air scrubber, a 4 feet diameter by 25 feet high stack, a Kohler 125 KW diesel generator, and associated equipment. To comply with Florida regulations for soil thermal treatment facilities (Rule 62-296.415, F.A.C.), the unit will be equipped with a 17 MMBtu/hr thermal oxidizer (afterburner) estimated to have a 99.1-percent destruction efficiency. The unit will discharges approximately 20,200 acfm of gases at 1,500 °F to the atmosphere. The kiln and afterburner will use propane (LPG) or natural gas fuels. The diesel engine will use low sulfur diesel fuel (0.05% sulfur max.).

Initial operation is authorized in Duval County only. The facility may be used in any county within the state provided that the public notice requirements have been met in the county and the unit's permit has been amended to authorize operation in that county.

The facility shall be constructed and operated in accordance with the permit applications, plans, documents, amendments, and drawings, except as otherwise noted in the Technical Evaluation and Preliminary Determination, General Conditions, or Specific Conditions.

"Protect, Conserve and Manage Florida's Environment and Natural Resources"

Attachments:

1. Application received August 16, 1995 (contains confidential information).
2. DEP letter dated August 25, 1995.
3. SW Soil Remediation letter received September 11, 1995.
4. SW Soil Remediation letter dated October 23, 1995.
5. List DEP District and county air programs.

GENERAL CONDITIONS:

1. The terms, conditions, requirements, limitations, and restrictions set forth in this permit are "Permit Conditions" and are binding and enforceable pursuant to Sections 403.161, 403.727, or 403.859 through 403.861, Florida Statutes. The permittee is placed on notice that the Department will review this permit periodically and may initiate enforcement action for any violation of these conditions.

2. This permit is valid only for the specific processes and operations applied for and indicated in the approved drawings or exhibits. Any unauthorized deviation from the approved drawings, exhibits, specifications, or conditions of this permit may constitute grounds for revocation and enforcement action by the Department.

3. As provided in Subsections 403.087(6) and 403.722(5), Florida Statutes, the issuance of this permit does not convey any vested rights or any exclusive privileges. Neither does it authorize any injury to public or private property or any invasion of personal rights, nor any infringement of federal, state or local laws or regulations. This permit is not a waiver of or approval of any other Department permit that may be required for other aspects of the total project which are not addressed in the permit.

4. This permit conveys no title to land or water, does not constitute State recognition or acknowledgment of title, and does not constitute authority for the use of submerged lands unless herein provided and the necessary title or leasehold interests have been obtained from the State. Only the Trustees of the Internal Improvement Trust Fund may express State opinion as to title.

5. This permit does not relieve the permittee from liability for harm or injury to human health or welfare, animal, or plant life, or property caused by the construction or operation of this permitted source, or from penalties therefore; nor does it allow the permittee to cause pollution in contravention of Florida Statutes and Department rules, unless specifically authorized by an order from the Department.

GENERAL CONDITIONS:

6. The permittee shall properly operate and maintain the facility and systems of treatment and control (and related appurtenances) that are installed or used by the permittee to achieve compliance with the conditions of this permit, as required by Department rules. This provision includes the operation of backup or auxiliary facilities or similar systems when necessary to achieve compliance with the conditions of the permit and when required by Department rules.

7. The permittee, by accepting this permit, specifically agrees to allow authorized Department personnel, upon presentation of credentials or other documents as may be required by law and at a reasonable time, access to the premises, where the permitted activity is located or conducted to:

   a. Have access to and copy any records that must be kept under the conditions of the permit;

   b. Inspect the facility, equipment, practices, or operations regulated or required under this permit; and

   c. Sample or monitor any substances or parameters at any location reasonably necessary to assure compliance with this permit or Department rules.

Reasonable time may depend on the nature of the concern being investigated.

8. If, for any reason, the permittee does not comply with or will be unable to comply with any condition or limitation specified in this permit, the permittee shall immediately provide the Department with the following information:

   a. a description of and cause of non-compliance; and

   b. the period of noncompliance, including dates and times; or, if not corrected, the anticipated time the non-compliance is expected to continue, and steps being taken to reduce, eliminate, and prevent recurrence of the non-compliance.

The permittee shall be responsible for any and all damages which may result and may be subject to enforcement action by the Department for penalties or for revocation of this permit.

9. In accepting this permit, the permittee understands and agrees that all records, notes, monitoring data and other information relating to the construction or operation of this permitted source which are submitted to the Department may be used by the Department

GENERAL CONDITIONS:

as evidence in any enforcement case involving the permitted source arising under the Florida Statutes or Department rules, except where such use is prescribed by Sections 403.73 and 403.111, Florida Statutes. Such evidence shall only be used to the extent it is consistent with the Florida Rules of Civil Procedure and appropriate evidentiary rules.

10. The permittee agrees to comply with changes in Department rules and Florida Statutes after a reasonable time for compliance, provided, however, the permittee does not waive any other rights granted by Florida Statutes or Department rules.

11. This permit is transferable only upon Department approval in accordance with Florida Administrative Code Rules 62-4.120 and 62-30.300, F.A.C., as applicable. The permittee shall be liable for any non-compliance of the permitted activity until the transfer is approved by the Department.

12. This permit or a copy thereof shall be kept at the work site of the permitted activity.

13. The permittee shall comply with the following:

   a. Upon request, the permittee shall furnish all records and plans required under Department rules. During enforcement actions, the retention period for all records will be extended automatically unless otherwise stipulated by the Department.

   b. The permittee shall hold at the facility or other location designated by this permit records of all monitoring information (including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation) required by the permit, copies of all reports required by this permit, and records of all data used to complete the application for this permit. These materials shall be retained at least three years from the date of the sample, measurement, report, or application unless otherwise specified by Department rule.

   c. Records of monitoring information shall include:

- the date, exact place, and time of sampling or measurements;
- the person responsible for performing the sampling or measurements;
- the dates analyses were performed;
- the person responsible for performing the analyses;
- the analytical techniques or methods used; and
- the results of such analyses.

GENERAL CONDITIONS:

14. When requested by the Department, the permittee shall within a reasonable time furnish any information required by law which is needed to determine compliance with the permit. If the permittee becomes aware that relevant facts were not submitted or were incorrect in the permit application or in any report to the Department, such facts or information shall be corrected promptly.

SPECIFIC CONDITIONS:

CONSTRUCTION REQUIREMENTS

1. The construction of this unit shall reasonably conform to the plan and schedule submitted in the application.

2. The afterburner (thermal oxidizer) for this unit shall be equipped with a stack having a minimum elevation of 25 feet above ground level.

3. The stack sampling facilities must comply with Rule 62-297.345, F.A.C.

4. The unit shall be equipped with means to measure the process feed rate of contaminated soil to the kiln, the pressure drop across the baghouse, and continuous monitors with recorders for the hot zone temperature and the carbon monoxide (CO) concentration (Rule 62-296.415(1)(c), F.A.C.).

5. No alterations shall be made to this unit that has the potential to increase air pollutant emissions without the prior written approval from the Department's Bureau of Air Regulation (BAR).

PLANT OPERATION REQUIREMENTS

6. The facility shall only treat petroleum contaminated soil as defined in Rule 62-775, F.A.C. (Rule 62-296.415, F.A.C.).

7. Hazardous waste as defined in 40 CFR 261.3 shall not be processed by this facility (Rule 62-775, F.A.C.).

8. This facility shall not treat soil contaminated with polychlorobiphenyls (PCB) (Rule 62-775, F.A.C.).

9. Based on data in the application, the total petroleum hydrocarbons (TPHC) contaminates in the soil treated by this facility shall not exceed 15,000 mg/Kg (daily avg.) without prior approval by the Department.

10. The afterburner shall be operated at or above 1,500 °F with a minimum of 1 second retention time (Rule 62-296.415, F.A.C.).

SPECIFIC CONDITIONS:

11. The facility may operate 24 hours per day, 7 days per week, but not more than 5,880 hours during any calendar year. It shall not be operated at a site with another soil thermal treatment facility without prior approval from the Department (combined emissions may make a major facility and the impact of the emissions may exceed the Ambient Reference Concentration).

12. The maximum contaminated soil charging rate to this facility shall not exceed 20 TPH. The permittee shall demonstrate compliance with the PM and visible emission standard of this permit within 45 day of initial operation in Florida at a rate of 18 - 20 TPH.

13. Soil entering the kiln cannot be larger than 2 inches in diameter (Rule 62-775, F.A.C.).

14. As proposed by the permittee, only natural gas or propane (LPG) shall be used as fuel for the kiln and afterburner. Only low sulfur diesel fuel shall be burned by the diesel generator. The maximum permitted fuel consumption is 248 therms per hour of natural gas or 271 gallons per hour (GPH) of propane for the kiln and afterburner. The electrical generator is allowed to burn 10 GPH diesel fuel.

15. The system shall be properly operated and maintained (Rule 62-210.300, F.A.C.). No person shall circumvent any pollution control device or allow the emissions of air pollutants without the applicable air pollution control devices operating properly (Rule 62-210.650, F.A.C.). The permittee's operation of the soil thermal treatment facility in Florida is conditioned upon the baghouse and the afterburner of the facility being fully operational, as demonstrated by monitoring instrumentation on the baghouse and afterburner.

16. The unit shall not be operated at a location or in a manner that may create a nuisance.

EMISSION LIMITS

17. Particulate matter emissions from the afterburner stack shall neither exceed 0.04 grains/dscf, 2.1 lbs/hr, and 6.1 TPY (Rule 62-296.415(2)(b), F.A.C.).

18. Visible emissions from the facility stack shall not exceed 5 percent opacity (Rule 62-296.415(2)(a), F.A.C.).

19. The average carbon monoxide emissions shall not exceed 100 parts per million by volume, dry, during any 60 consecutive minute period (Rule 62-296.415(1)(b), F.A.C.).

SPECIFIC CONDITIONS:

20. The operation of this facility shall not result in the emissions of air pollutants which cause or contribute to an objectionable odor pursuant to Rule 62-296.320, F.A.C.

21. Untreated soil removed from the ground shall be stored under waterproof covers to minimize unconfined emissions of petroleum products (Rule 62-296.310, F.A.C.).

22. Reasonable precautions shall be used to minimize unconfined emissions of particulate matter generated by the operation (Rule 62-296.310, F.A.C.). Reasonable precautions shall be defined as keeping the work areas wet where the soil is being removed, treated, handled, stored, and disposed of.

EMISSION TESTING REQUIREMENTS

23. This facility shall be tested (EPA test methods are specified in 40 CFR 60, Appendix A, revised July 1, 1995) for visible emissions during startup at each new site it is operated at and annually for:

(A) Particulate matter (PM) emissions by EPA Methods 1, 2, 3, 4, and 5.

(B) Visible emissions by EPA Method 9.

(C) Carbon monoxide (CO) emissions by averaging each hour of the readings from the CO continuous emission monitor during the PM test period.

(D) Afterburner temperature by averaging each hour of the temperature readings from the continuous temperature monitor during the PM test.

(E) Afterburner residence time using the test data collected by EPA Methods 1 and 2.

(F) Fuel oil sulfur limits based on analysis referenced in 40 CFR 60.17 or other methods after Department approval. A certified analysis by the fuel oil supplier or documentation that road grade diesel fuel is used in the generator will also be acceptable.

(G) Contaminated soil analysis for volatile organic aromatics (VOA), total recoverable petroleum hydrocarbons (TRPH), polynuclear aromatic hydrocarbons (PAH), volatile organic halocarbons (VOH), and metals as required by Rule 17-775.410, F.A.C. of the soil being treated during the particulate matter compliance test.

SPECIFIC CONDITIONS:

Testing of emissions shall be conducted with the source operating at permitted capacity. Permitted capacity is defined as 90-100 percent of the maximum operating rate allowed by the permit. If it is impracticable to test at permitted capacity, then sources may be tested at less than capacity; in this case subsequent source operation is limited to 110 percent of the test load until a new test is conducted. Once the unit is so limited, then operation at higher capacities is allowed for no more than 15 consecutive days for the purposes of additional compliance testing to regain the permitted capacity in the permit. (Rule 62-297.310, F.A.C.)

24. All compliance tests and test reports shall meet the requirements listed in Rule 62-297, F.A.C.

25. When the Department, after investigation, has good reason (such as complaints, increased visible emissions, or questionable maintenance of control equipment) to believe that any applicable emission standard contained in Rule 62-296.415, F.A.C., or in this permit is being violated, it may require the owner or operator of the unit to conduct compliance tests which identify the nature and quantity of pollutant emissions from the source and to provide a report on the results of said tests to the Department (Rule 17-297.340(2), F.A.C.).

RECORDKEEPING REQUIREMENTS

26. Temperature of the afterburner and CO concentration shall be recorded continuously during operations. The instruments used to obtain these measurements shall be properly calibrated, maintained, and in operation any time the facility is in service.

27. The permittee shall maintain a file of all measurements, including continuous monitoring system, monitoring device, and performance testing measurements, all continuous monitoring system performance evaluations, all continuous monitoring system or monitoring device calibration checks, adjustments and maintenance performed on these systems or devices, all soil analysis required by Rule 62-775, F.A.C., and all other information required by rules and this permit, recorded in a permanent form suitable for inspection. The file shall be retained for at least 3 years following the date of such measurements, maintenance, reports, and records.

28. The permittee shall maintain a daily log that shows the date, location, operation time, pressure drop across the PM control device, processing rate, type and quantity of fuel consumption in the dryer and afterburner, and any operation problems. These records shall be maintained for a minimum of 3 years.

SPECIFIC CONDITIONS:

ADMINISTRATIVE REQUIREMENTS

29. The district and county air program administrators in the counties where the compliance tests will be conducted, shall be notified in writing at least 15 days in advance of any scheduled compliance test to be conducted on this facility (Rule 62-297.340(1)(i), F.A.C.).

30. Compliance test results shall be submitted to the district office and county environmental program (if applicable) that the tests were conducted in within 45 days of the test (Rule 62-297.570(2), F.A.C.).

31. At least 7 days prior to relocating the plant, the permittee shall notify the air program administrator for the Department's district and, if applicable, county air program administrator of the next site where the unit will be operated. The notification shall be on DEP Form 62-210.900(3), F.A.C. The notification shall include the permit number of the facility, a copy of the last stack test results, the date of the proposed move, the new work site for the facility, the amount of contaminated soil at the new site, and the locations and contamination levels of the soils to be treated. Unless notified otherwise by an environmental agency, the unit may be relocated and operated at the new site. The Department will notify the permittee of any new restrictions for the facility that will apply while it is operating at the new site (Rule 62-775.700(1), F.A.C.).

32. The permittee shall submit to the BAR each calendar year, on or before March 1, an Annual Operation Report DEP Form 62-1.202(c) for this facility for the preceding calendar year containing at least the following information pursuant to Subsection 403.061(13), F.S.:

(A) Annual amount of material and/or fuels utilized.

(B) Annual emissions in TPY (note calculation basis).

(C) Annual hours of operation.

(D) Any changes in the information contained in the application.

(E) All compliance tests reports for the preceding year.

(F) Temperature and CO exceedance reports for the year.

SPECIFIC CONDITIONS:

33. An application for an operating permit shall be submitted to the BAR at least 90 days prior to the expiration date of this permit. To apply for an operation permit, the applicant shall submit the appropriate application form, fee, a report on any physical change or major maintenance to the facility, and compliance test reports as required by this permit (Rule 62-4.220, F.A.C.).

STATE OF FLORIDA DEPARTMENT
OF ENVIRONMENTAL PROTECTION

Howard L Rhodes
Howard L. Rhodes
Director
Division of Air Resources
Management

STACK PARAMETERS
SOUTHWEST SOIL REMEDIATION
4' L.T.T.D. PLANT WITH STU

OUTLET

Diameter of Stack @ 3.44 ft.
Area of Stack @ 9.287 sq. ft.

Distance to upstream flow disturbance @ ~6.0 ft.
Distance to downstream flow disturbance @ ~6.0 ft.
Number of diameters upstream @ ~1.7
Number of diameters downstream @ ~1.7
Number of sample ports = 2 at 90 degrees (~3 inch ID)
Number of sample (traverse) points - 24 (12 per traverse)

Location of traverse points: (from inside wall)

1) 0.9 (1.0) inches
2) 2.8 inches
3) 4.9 inches
4) 7.3 inches
5) 10.3 inches
6) 14.7 inches
7) 26.6 inches
8) 30.9 inches
9) 33.9 inches
10) 36.4 inches
11) 38.5 inches
12) 40.4 inches

CO samples were taken from the center of the stack.

Location: Mayport N.S.

Company: SWSR

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MASS FLOW CALCULATIONS

Date	Time	Run	PPh(CO)*
			0.08

$$= 60 \times 10^{-6} \times \frac{28}{1364.78} \times 3.9 \times 156$$

$$v/n = 359 \left(\frac{1903.4}{492}\right)\left(\frac{29.92}{30.448}\right) = 1364.$$

$$\text{*PPh} = 60 \times 10^{-6} \times \frac{M/W}{v/n} \times \text{gas flow} \times \text{concentration v/v}$$

M/W = Molecular Weight
Gas Flow = awcfm, sdcfh (compatible with concentration)
Concentration = ppm v/v (Dry or wet - compatible with gas flow units)

$$v/v = 359\left(\frac{Ts(°A)}{492}\right)\left(\frac{29.92}{Ps''Hg}\right)$$

Date	Time	Run	PPh( )*

$$= 60 \times 10^{-6} \times \underline{\quad} \times \underline{\quad} \times \underline{\quad}$$

$$v/n = 359 \left(\frac{\quad}{492}\right)\left(\frac{29.92}{\quad}\right) = \underline{\quad}$$

$$= 60 \times 10^{-6} \times \underline{\quad} \times \underline{\quad} \times \underline{\quad}$$

$$v/n = 359 \left(\frac{\quad}{492}\right)\left(\frac{29.92}{\quad}\right) = \underline{\quad}$$

$$= 60 \times 10^{-6} \times \underline{\quad} \times \underline{\quad} \times \underline{\quad}$$

$$v/n = 359 \left(\frac{\quad}{492}\right)\left(\frac{29.92}{\quad}\right) = \underline{\quad}$$

$$= 60 \times 10^{-6} \times \underline{\quad} \times \underline{\quad} \times \underline{\quad}$$

$$v/n = 359 \left(\frac{\quad}{492}\right)\left(\frac{29.92}{\quad}\right) = \underline{\quad}$$

$$= 60 \times 10^{-6} \times \underline{\quad} \times \underline{\quad} \times \underline{\quad}$$

$$v/n = 359 \left(\frac{\quad}{492}\right)\left(\frac{29.92}{\quad}\right) = \underline{\quad}$$

EPA METHOD #10
FIELD DATA & CALCULATIONS

CLIENT :	**SOUTHWEST SOILS**	**TEST # :**	**1-CO**
SOURCE :	**MAYPORT NAVAL STATION**	**TIME :**	**0940-1040**
	FLORIDA	**DATE :**	**4/15/96**

#	TIME	CO PPM V/V DRY
1	940	2
2	941	2
3	942	2
4	943	2
5	944	3
6	945	3
7	946	3
8	947	2
9	948	2
10	949	2
11	950	2
12	951	3
13	952	3
14	953	3
15	954	4
16	955	4
17	956	3
18	957	3
19	958	3
20	959	3
21	1000	3
22	1001	3
23	1002	3
24	1003	3
25	1004	2
26	1005	2
27	1006	2
28	1007	2
29	1008	3
30	1009	3
31	1010	3
32	1011	3
33	1012	3
34	1013	3
35	1014	3
36	1015	3

CLIENT :	**SOUTHWEST SOILS**		**Page 2 of 4**
SOURCE :	**MAYPORT NAVAL STATION**	**TEST # :**	**1-CO**
	FLORIDA		

#	TIME	CO PPM V/V DRY
37	1016	2
38	1017	3
39	1018	4
40	1019	4
41	1020	4
42	1021	3
43	1022	3
44	1023	4
45	1024	5
46	1025	5
47	1026	5
48	1027	5
49	1028	5
50	1029	6
51	1030	5
52	1031	4
53	1032	3
54	1033	3
55	1034	4
56	1035	6
57	1036	22
58	1037	12
59	1038	9
60	1039	7
61	1040	7

AVERAGE:

CO PPM V/V DRY
3.9

CLIENT :	**SOUTHWEST SOILS**		**Page 3 of 4**
SOURCE :	**MAYPORT NAVAL STATION FLORIDA**	**TEST #:**	**1-CO**

CALIBRATION ERROR CHECK

CO SPAN **200**

CO INITIAL CALIBRATION

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 2% OF SPAN)
827	0	0	0.0
833	75.12	75	0.1
829	149.2	150	-0.4

INITIAL BIAS CHECK

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 5% OF SPAN)
915	0	0	0.0
918	75.13	74	0.6

POST BIAS CHECK

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 5% OF SPAN)
1050	0	0	0.0
1052	75.12	74	0.8

RESPONSE TIM	ZERO:	51 SECONDS
	SPAN:	49 SECONDS

CLIENT : **SOUTHWEST SOILS** **Page 4 of 4**
SOURCE : **MAYPORT NAVAL STATION** **TEST #:** **1-CO**
FLORIDA

MASS FLOW CALCULATIONS

AVG CO
= 3.9 PPM

STATIC PRESS
= -0.03 IN H2O

MOL. WT. USED FOR
CO = 28

AVG TEMP. (FROM CONCURRENT PART. RUN)
= 1443.4 degrees F

BAROMETRIC
PRESS. = 30.45 IN Hg

GAS FLOW
adcfm = 15,631

CU.FT/LB-MOLE
ACT. ft^3/#mole
1364.79

CO
MASS FLOW = 0.08 lbs/hr

EPA METHOD #10
FIELD DATA & CALCULATIONS

CLIENT : SOUTHWEST SOILS
SOURCE : MAYPORT NAVAL STATION
FLORIDA

TEST # : 2-CO
TIME : 1129-1229
DATE : 4/15/96

#	TIME	CO PPM V/V DRY
1	1129	12
2	1130	41
3	1131	12
4	1132	8
5	1133	6
6	1134	4
7	1135	3
8	1136	3
9	1137	5
10	1138	6
11	1139	12
12	1140	11
13	1141	8
14	1142	3
15	1143	1
16	1144	1
17	1145	1
18	1146	2
19	1147	7
20	1148	16
21	1149	10
22	1150	22
23	1151	43
24	1152	18
25	1153	11
26	1154	10
27	1155	10
28	1156	1
29	1157	1
30	1158	1
31	1159	1
32	1200	2
33	1201	2
34	1202	2
35	1203	1
36	1204	1

CLIENT :	**SOUTHWEST SOILS**		**Page 2 of 4**
SOURCE :	**MAYPORT NAVAL STATION**	**TEST # :**	**2-CO**
	FLORIDA		

#	TIME	CO PPM V/V DRY
37	1205	1
38	1206	1
39	1207	1
40	1208	1
41	1209	1
42	1210	1
43	1211	1
44	1212	3
45	1213	69
46	1214	131
47	1215	7
48	1216	3
49	1217	4
50	1218	20
51	1219	15
52	1220	8
53	1221	9
54	1222	2
55	1223	0
56	1224	0
57	1225	0
58	1226	0
59	1227	0
60	1228	0
61	1229	0

AVERAGE:

CO PPM V/V DRY
9.4

CLIENT : **SOUTHWEST SOILS**
SOURCE : **MAYPORT NAVAL STATION** **TEST #:** **2-CO**
FLORIDA

CALIBRATION ERROR CHECK

CO SPAN **200**

CO INITIAL CALIBRATION

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 2% OF SPAN)
827	0	0	0.0
833	75.12	75	0.1
829	149.2	150	-0.4

INITIAL BIAS CHECK

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 5% OF SPAN)
1050	0	0	0.0
1052	75.12	74	0.6

POST BIAS CHECK

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 5% OF SPAN)
1232	0	0	0.0
1235	75.12	74	0.8

RESPONSE TIM ZERO: 51 SECONDS
SPAN: 49 SECONDS

CLIENT : **SOUTHWEST SOILS**
SOURCE : **MAYPORT NAVAL STATION**
FLORIDA
TEST #: **2-CO**

MASS FLOW CALCULATIONS

AVG CO
= 9.4 PPM

AVG TEMP. (FROM CONCURRENT PART. RUN)
= 1444.8 degrees F

CU.FT/LB-MOLE
ACT. ft^3/#mole
1365.79

STATIC PRESS
= -0.03 IN H2O

BAROMETRIC
PRESS. = 30.45 IN Hg

MOL. WT. USED FOR
CO = 28

GAS FLOW
adcfm = 14,830

CO
MASS FLOW 0.17 lbs/hr

EPA METHOD #10
FIELD DATA & CALCULATIONS

CLIENT :	SOUTHWEST SOILS	TEST # :	3-CO
SOURCE :	MAYPORT NAVAL STATION	TIME :	1315-1415
	FLORIDA	DATE :	4/15/96

#	TIME	CO PPM V/V DRY
1	1315	7
2	1316	6
3	1317	1
4	1318	5
5	1319	8
6	1320	7
7	1321	1
8	1322	0
9	1323	0
10	1324	1
11	1325	1
12	1326	4
13	1327	3
14	1328	2
15	1329	1
16	1330	1
17	1331	1
18	1332	7
19	1333	4
20	1334	3
21	1335	1
22	1336	3
23	1337	4
24	1338	1
25	1339	1
26	1340	1
27	1341	0
28	1342	10
29	1343	72
30	1344	4
31	1345	4
32	1346	4
33	1347	5
34	1348	4
35	1349	3
36	1350	1

CLIENT :	**SOUTHWEST SOILS**		**Page 2 of 4**
SOURCE :	**MAYPORT NAVAL STATION**	**TEST # :**	**3–CO**
	FLORIDA		

#	**TIME**	**CO PPM V/V DRY**
37	1351	1
38	1352	0
39	1353	0
40	1354	0
41	1355	0
42	1356	0
43	1357	0
44	1358	6
45	1359	73
46	1400	20
47	1401	2
48	1402	1
49	1403	3
50	1404	37
51	1405	7
52	1406	1
53	1407	1
54	1408	6
55	1409	2
56	1410	1
57	1411	1
58	1412	1
59	1413	0
60	1414	0
61	1415	0

AVERAGE:

CO PPM V/V DRY
5.6

CLIENT :	**SOUTHWEST SOILS**		**Page 3 of 4**
SOURCE :	**MAYPORT NAVAL STATION FLORIDA**	**TEST #:**	**3-CO**

CALIBRATION ERROR CHECK

CO SPAN **200**

CO INITIAL CALIBRATION

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 2% OF SPAN)
827	0	0	0.0
833	75.12	75	0.1
829	149.2	150	-0.4

INITIAL BIAS CHECK

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 5% OF SPAN)
1232	0	0	0.0
1235	75.12	74	0.6

POST BIAS CHECK

TIME	TANK VALUE PPM	INSTRUMENT RESPONSE	% DIFF.(NOT MORE THAN 5% OF SPAN)
1417	0	0	0.0
1420	75.12	75	0.1

RESPONSE TIM	ZERO:	51 SECONDS
	SPAN:	49 SECONDS

CLIENT : **SOUTHWEST SOILS**

SOURCE : **MAYPORT NAVAL STATION** **TEST #:** **3-CO**
FLORIDA

MASS FLOW CALCULATIONS

AVG CO
= 5.6 PPM

STATIC PRESS
= -0.03 IN H2O

MOL. WT. USED FOR

CO = 28

AVG TEMP. (FROM CONCURRENT PART. RUN)
= 1446.1 degrees F

BAROMETRIC
PRESS. = 30.4 IN Hg

GAS FLOW
adcfm = 14,769

CU.FT/LB-MOLE
ACT. ft^3/#mole
1368.97

CO
MASS FLOW 0.1 lbs/hr

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-14-96	14:24:57	1	
04-14-96	14:25:57	0	
04-14-96	14:26:57	20	
04-14-96	14:27:57	130	
04-14-96	14:28:57	147	
04-14-96	14:29:57	150	
04-15-96	08:25:59	11	
04-15-96	08:26:59	1	
04-15-96	08:27:59	0	Start Initial Calibration
04-15-96	08:28:59	62	
04-15-96	08:29:59	150	
04-15-96	08:30:59	152	
04-15-96	08:31:59	148	
04-15-96	08:32:59	100	
04-15-96	08:33:59	75	
04-15-96	08:34:59	122	
04-15-96	09:10:06	0	
04-15-96	09:11:06	125	
04-15-96	09:12:06	149	
04-15-96	09:13:06	122	
04-15-96	09:14:06	1	
04-15-96	09:15:06	0	
04-15-96	09:16:06	22	
04-15-96	09:17:06	58	
04-15-96	09:18:06	74	
04-15-96	09:19:06	21	
04-15-96	09:20:06	18	
04-15-96	09:21:06	14	
04-15-96	09:22:06	12	
04-15-96	09:23:06	10	
04-15-96	09:24:06	9	
04-15-96	09:25:06	7	
04-15-96	09:26:06	9	
04-15-96	09:27:06	38	
04-15-96	09:28:06	54	
04-15-96	09:29:06	27	
04-15-96	09:30:06	13	
04-15-96	09:31:06	6	
04-15-96	09:32:06	4	
04-15-96	09:33:06	2	
04-15-96	09:34:06	1	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-15-96	09:35:06	1	
04-15-96	09:36:06	1	
04-15-96	09:37:06	1	
04-15-96	09:38:06	1	
04-15-96	09:39:06	1	
04-15-96	09:40:06	2	Start Run #1
04-15-96	09:41:06	2	
04-15-96	09:42:06	2	
04-15-96	09:43:06	2	
04-15-96	09:44:06	3	
04-15-96	09:45:06	3	
04-15-96	09:46:06	3	
04-15-96	09:47:06	2	
04-15-96	09:48:06	2	
04-15-96	09:49:06	2	
04-15-96	09:50:06	2	
04-15-96	09:51:06	3	
04-15-96	09:52:06	3	
04-15-96	09:53:06	3	
04-15-96	09:54:06	4	
04-15-96	09:55:06	4	
04-15-96	09:56:06	3	
04-15-96	09:57:06	3	
04-15-96	09:58:06	3	
04-15-96	09:59:06	3	
04-15-96	10:00:06	3	
04-15-96	10:01:06	3	
04-15-96	10:02:06	3	
04-15-96	10:03:06	3	
04-15-96	10:04:06	2	
04-15-96	10:05:06	2	
04-15-96	10:06:06	2	
04-15-96	10:07:06	2	
04-15-96	10:08:06	3	
04-15-96	10:09:06	3	
04-15-96	10:10:06	3	
04-15-96	10:11:06	3	
04-15-96	10:12:06	3	
04-15-96	10:13:06	3	
04-15-96	10:14:06	3	
04-15-96	10:15:06	3	
04-15-96	10:16:06	2	
04-15-96	10:17:06	3	
04-15-96	10:18:06	4	
04-15-96	10:19:06	4	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-15-96	10:20:06	4	
04-15-96	10:21:06	3	
04-15-96	10:22:06	3	
04-15-96	10:23:06	4	
04-15-96	10:24:06	5	
04-15-96	10:25:06	5	
04-15-96	10:26:06	5	
04-15-96	10:27:06	5	
04-15-96	10:28:06	5	
04-15-96	10:29:06	6	
04-15-96	10:30:06	5	
04-15-96	10:31:06	4	
04-15-96	10:32:06	3	
04-15-96	10:33:06	3	
04-15-96	10:34:06	4	
04-15-96	10:35:06	6	
04-15-96	10:36:06	22	
04-15-96	10:37:06	12	
04-15-96	10:38:06	9	
04-15-96	10:39:06	7	
04-15-96	10:40:06	7	End Run #1
04-15-96	10:41:06	5	
04-15-96	10:42:06	4	
04-15-96	10:43:06	4	
04-15-96	10:44:06	20	
04-15-96	10:45:06	9	
04-15-96	10:46:06	4	
04-15-96	10:47:06	3	
04-15-96	10:48:06	3	
04-15-96	10:49:06	2	
04-15-96	10:50:06	0	
04-15-96	10:51:06	35	
04-15-96	10:52:06	74	
04-15-96	10:53:06	62	
04-15-96	10:54:06	1	
04-15-96	10:55:06	0	
04-15-96	10:56:06	0	
04-15-96	10:57:06	128	
04-15-96	10:58:06	142	
04-15-96	10:59:06	146	
04-15-96	11:00:06	150	
04-15-96	11:01:06	87	
04-15-96	11:02:06	4	
04-15-96	11:03:06	2	
04-15-96	11:04:06	2	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-15-96	11:05:06	1	
04-15-96	11:06:06	1	
04-15-96	11:07:06	1	
04-15-96	11:08:06	5	
04-15-96	11:09:06	145	
04-15-96	11:10:06	7	
04-15-96	11:11:06	4	
04-15-96	11:12:06	-10	
04-15-96	11:13:06	78	
04-15-96	11:14:06	12	
04-15-96	11:15:06	4	
04-15-96	11:16:06	3	
04-15-96	11:17:06	3	
04-15-96	11:18:06	3	
04-15-96	11:19:06	9	
04-15-96	11:20:06	23	
04-15-96	11:21:06	686	
04-15-96	11:22:06	26	
04-15-96	11:23:06	12	
04-15-96	11:24:06	83	
04-15-96	11:25:06	11	
04-15-96	11:26:06	3	
04-15-96	11:27:06	2	
04-15-96	11:28:06	2	
04-15-96	11:29:06	12	Start Run #2
04-15-96	11:30:06	41	
04-15-96	11:31:06	12	
04-15-96	11:32:06	8	
04-15-96	11:33:06	6	
04-15-96	11:34:06	4	
04-15-96	11:35:06	3	
04-15-96	11:36:06	3	
04-15-96	11:37:06	5	
04-15-96	11:38:06	6	
04-15-96	11:39:06	12	
04-15-96	11:40:06	11	
04-15-96	11:41:06	8	
04-15-96	11:42:06	3	
04-15-96	11:43:06	1	
04-15-96	11:44:06	1	
04-15-96	11:45:06	1	
04-15-96	11:46:06	2	
04-15-96	11:47:06	7	
04-15-96	11:48:06	16	
04-15-96	11:49:06	10	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-15-96	11:50:06	22	
04-15-96	11:51:06	43	
04-15-96	11:52:06	18	
04-15-96	11:53:06	11	
04-15-96	11:54:06	10	
04-15-96	11:55:06	10	
04-15-96	11:56:06	1	
04-15-96	11:57:06	1	
04-15-96	11:58:06	1	
04-15-96	11:59:06	1	
04-15-96	12:00:06	2	
04-15-96	12:01:06	2	
04-15-96	12:02:06	2	
04-15-96	12:03:06	1	
04-15-96	12:04:06	1	
04-15-96	12:05:06	1	
04-15-96	12:06:06	1	
04-15-96	12:07:06	1	
04-15-96	12:08:06	1	
04-15-96	12:09:06	1	
04-15-96	12:10:06	1	
04-15-96	12:11:06	1	
04-15-96	12:12:06	3	
04-15-96	12:13:06	69	
04-15-96	12:14:06	131	
04-15-96	12:15:06	7	
04-15-96	12:16:06	3	
04-15-96	12:17:06	4	
04-15-96	12:18:06	20	
04-15-96	12:19:06	15	
04-15-96	12:20:06	8	
04-15-96	12:21:06	9	
04-15-96	12:22:06	2	
04-15-96	12:23:06	0	
04-15-96	12:24:06	0	
04-15-96	12:25:06	0	
04-15-96	12:26:06	-1	
04-15-96	12:27:06	-1	
04-15-96	12:28:06	-1	
04-15-96	12:29:06	-1	End Run #2
04-15-96	12:30:06	-1	
04-15-96	12:31:06	0	
04-15-96	12:32:06	0	
04-15-96	12:33:06	0	
04-15-96	12:34:06	5	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-15-96	12:35:06	74	
04-15-96	12:36:06	65	
04-15-96	12:37:06	3	
04-15-96	12:38:06	41	
04-15-96	12:39:06	14	
04-15-96	12:40:06	2	
04-15-96	12:41:06	1	
04-15-96	12:42:06	1	
04-15-96	12:43:06	1	
04-15-96	12:44:06	3	
04-15-96	12:45:06	10	
04-15-96	12:46:06	158	
04-15-96	12:47:06	89	
04-15-96	12:48:06	79	
04-15-96	12:49:06	6	
04-15-96	12:50:06	3	
04-15-96	12:51:06	3	
04-15-96	12:52:06	8	
04-15-96	12:53:06	11	
04-15-96	12:54:06	10	
04-15-96	12:55:06	4	
04-15-96	12:56:06	3	
04-15-96	12:57:06	1	
04-15-96	12:58:06	1	
04-15-96	12:59:06	1	
04-15-96	13:00:06	1	
04-15-96	13:01:06	2	
04-15-96	13:02:06	3	
04-15-96	13:03:06	13	
04-15-96	13:04:06	38	
04-15-96	13:05:06	59	
04-15-96	13:06:06	6	
04-15-96	13:07:06	35	
04-15-96	13:08:06	26	
04-15-96	13:09:06	13	
04-15-96	13:10:06	5	
04-15-96	13:11:06	2	
04-15-96	13:12:06	5	
04-15-96	13:13:06	23	
04-15-96	13:14:06	11	
04-15-96	13:15:06	7	Start Run #3
04-15-96	13:16:06	6	
04-15-96	13:17:06	1	
04-15-96	13:18:06	5	
04-15-96	13:19:06	8	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)
04-15-96	13:20:06	7
04-15-96	13:21:06	1
04-15-96	13:22:06	0
04-15-96	13:23:06	0
04-15-96	13:24:06	1
04-15-96	13:25:06	1
04-15-96	13:26:06	4
04-15-96	13:27:06	3
04-15-96	13:28:06	2
04-15-96	13:29:06	1
04-15-96	13:30:06	1
04-15-96	13:31:06	1
04-15-96	13:32:06	7
04-15-96	13:33:06	4
04-15-96	13:34:06	3
04-15-96	13:35:06	1
04-15-96	13:36:06	3
04-15-96	13:37:06	4
04-15-96	13:38:06	1
04-15-96	13:39:06	1
04-15-96	13:40:06	1
04-15-96	13:41:06	0
04-15-96	13:42:06	10
04-15-96	13:43:06	72
04-15-96	13:44:06	4
04-15-96	13:45:06	4
04-15-96	13:46:06	4
04-15-96	13:47:06	5
04-15-96	13:48:06	4
04-15-96	13:49:06	3
04-15-96	13:50:06	1
04-15-96	13:51:06	1
04-15-96	13:52:06	0
04-15-96	13:53:06	0
04-15-96	13:54:06	0
04-15-96	13:55:06	0
04-15-96	13:56:06	0
04-15-96	13:57:06	0
04-15-96	13:58:06	6
04-15-96	13:59:06	73
04-15-96	14:00:06	20
04-15-96	14:01:06	2
04-15-96	14:02:06	1
04-15-96	14:03:06	3
04-15-96	14:04:06	37

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)	
04-15-96	14:05:06	7	
04-15-96	14:06:06	1	
04-15-96	14:07:06	1	
04-15-96	14:08:06	6	
04-15-96	14:09:06	2	
04-15-96	14:10:06	1	
04-15-96	14:11:06	1	
04-15-96	14:12:06	1	
04-15-96	14:13:06	0	
04-15-96	14:14:06	-1	
04-15-96	14:15:06	-1	End Run #3
04-15-96	14:16:06	0	
04-15-96	14:17:06	0	
04-15-96	14:18:06	-1	
04-15-96	14:19:06	52	
04-15-96	14:20:06	75	
04-15-96	14:21:06	61	
04-15-96	14:22:06	-1	
04-15-96	14:23:06	-1	
04-15-96	14:24:06	-1	
04-15-96	14:25:06	0	
04-15-96	14:26:06	0	
04-15-96	14:27:06	101	
04-15-96	14:28:06	149	
04-15-96	14:29:06	150	
04-15-96	14:30:06	149	
04-15-96	14:31:06	89	
04-15-96	14:32:06	-1	
04-15-96	14:33:06	0	
04-15-96	14:34:06	-2	
04-15-96	14:35:06	-2	
04-15-96	14:36:06	-2	
04-15-96	14:37:06	-1	
04-15-96	14:38:06	-1	
04-15-96	14:39:06	-2	
04-15-96	14:40:06	-2	
04-15-96	14:41:06	-2	
04-15-96	14:42:06	-1	
04-15-96	14:43:06	-1	
04-15-96	14:44:06	-1	
04-15-96	14:45:06	0	
04-15-96	14:46:06	0	
04-15-96	14:47:06	0	
04-15-96	14:48:06	0	
04-15-96	14:49:06	0	

SWSR CO COMPLIANCE
MAYPORT,FLORIDA

		CO PPM (DRY)
04-15-96	14:50:06	0
04-15-96	14:51:06	0
04-15-96	14:52:06	0
04-15-96	14:53:06	0
04-15-96	14:54:06	0
04-15-96	14:55:06	51
04-15-96	14:56:06	49
04-15-96	14:57:06	146
04-15-96	14:58:06	149
04-15-96	14:59:06	24
04-15-96	15:00:06	2
04-15-96	15:01:06	1
04-15-96	15:02:06	1

EPA METHODS #1-5
GAS FLOW / MOISTURE
PARTICULATE

TEST 1R1 @ SWDK
DATE 4/15/96 Mayport N.S PAGE 1 OF 2

$$\text{Pm"Hg} = \underline{30.45}\ \text{Pb"Hg} + \left(\frac{\underline{1.50}\ \Delta\text{H"H2O}}{13.6}\right) = \underline{30.56}\ \text{Pm"Hg}$$

$$\text{Ps"Hg} = \underline{30.45}\ \text{Pb"Hg} + \left(\frac{\underline{-0.03}\ \text{Static"H2O}}{13.6}\right) = \underline{30.448}\ \text{Ps"Hg}$$

$$\text{1) Vm(std)} = (\underset{③}{\underline{41.46}}\ \text{Vm})(17.65)(\underset{②}{\underline{.938}}\ \text{mcf})\left(\frac{\underline{30.56}\ \text{Pm"Hg}}{\underset{①}{\underline{5477}\ \text{Tm°A}}}\right) = \underset{③}{\underline{38.299}}\ \text{dscf}$$

$$\text{2) Vw(std)} = .04707(\underline{335}\ \text{ml.}) = \underset{③}{\underline{15.768}}\ \text{scf}$$

$$\text{3) Bsw} = \frac{(\underline{15.768}\ \text{scf})}{(\underline{15.768}\ \text{scf} + \underline{38.299}\ \text{dscf})} = \underset{③}{\underline{0.2916}}\ \text{Bws} \times 100 = \underset{②}{\underline{29.16}}\ \text{%H2O}$$

$$\text{4) Vm(actual)} = \frac{(\underline{.938}\ \text{mcf})(\underline{41.46}\ \text{Vm})}{1-\underline{.2916}\ \text{Bws}}\ \ \frac{(\underline{1903.4}\ \text{Ts°A})}{\underset{①}{(\underline{547.7}\ \text{Tm°A})}}\ \ \frac{(\underline{30.56}\ \text{Pm"Hg})}{\underset{③}{(\underline{30.448}\ \text{Ps"Hg})}} = \underset{③}{\underline{191.485}}\ \text{aw}$$

0.7084

$$\text{5) Md} = 0.44(\underset{①}{\underline{7.1}}\ \text{%CO2}) + 0.32(\underset{①}{\underline{9.2}}\ \text{%O2}) + 0.28(\underset{①}{\underline{83.7}}\ \text{%N2 + %CO}) = \underset{②}{\underline{29.50}}\ \text{lb./lb.}$$

$$\text{6) Ms} = (\underline{29.50}\ \text{lb./lb. mole})(1-\underline{.2916}\ \text{Bsw}) + (18 \times \underline{.2916}\ \text{Bws}) = \underset{②}{\underline{26.15}}\ \text{lb./lb. mc}$$

$$\text{7a) A} = (3.1416)(\underset{\text{dia ③}}{\underline{3.44}}\ \text{ft} / 2)\hat{}2 = \underset{③}{\underline{9.294}}\ \text{sq.ft.}\ ○$$

$$\text{7b) A} = (\underset{③}{\underline{\qquad}}\ \text{ft})(\underset{③}{\underline{\qquad}}\ \text{ft}) = \underset{③}{\underline{\qquad}}\ \text{sq.ft.}\ ☐$$

$$\text{8) Vs} = (85.49)(\underline{.84}\ \text{cp})\left(\sqrt{\underset{②}{\underline{0.127}}\ \Delta\text{P"H2O}}\right)\left(\sqrt{\frac{\underline{1903.4}\ \text{Ts°A}}{\underline{30.448}\ \text{Ps"Hg}(\underline{26.15}\ \text{lb./lb. mole})}}\right) = \underset{②}{\underline{39.57}}$$

$$\text{9a) Qsw} = 3600(\underline{39.57}\ \text{fps})(\underline{9.294}\ \text{ft}\hat{}2)\left(\frac{528°\text{A}}{\underline{1903.4}\ \text{Ts°A}}\right)\left(\frac{\underline{30.448}\ \text{Ps"Hg}}{29.92\ \text{"Hg}}\right) = \underset{①}{\underline{373,742.3}}\ \text{wscf}$$

$$\text{9b) Qsd} = (1-\underline{.2916}\ \text{Bsw})(\underline{373742.3}\ \text{wscf/hr}) = \underset{①}{\underline{264,759.0}}\ \text{dscf/hr}$$

$$\text{10) ADCFM} = \frac{\left(\frac{\underline{1903.4}\ \text{Ts°A}}{528°\text{A}}\right)\left(\frac{29.92\ \text{"Hg}}{\underline{30.448}\ \text{Ps"Hg}}\right)(\underline{264759}\ \text{dscf/hr})}{60} = \underset{①}{\underline{15631.4}}\ \text{ADCFM}$$

$$\text{10) AWCFM} = \left(\frac{1}{1-\underline{.2916}\ \text{Bsw}}\right)(\underline{15631.4}\ \text{ADCFM}) = \underline{32065.8}\ \text{AWCFM}$$

EEMC

EPA METHODS #1-5
GAS FLOW / MOISTURE
PARTICULATE

TEST 1PT @ SWSR
DATE 4/15/96 Mayport N.S.
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$$\text{11a) Cs} = \frac{\underset{④}{\underline{0.0752}}\text{ g.}}{\underline{38.299}\text{ dscf}}(15.43) = \underset{③}{\underline{0.0303}}\text{ gr/dscf}$$

$$\text{11b) Cs} = \frac{\underset{④}{\underline{0.0752}}\text{ g.}}{\underline{191.485}\text{ awcf}}(15.43) = \underset{③}{\underline{0.0061}}\text{ gr/awcf}$$

$$\text{12) lbs./10^6 BTU} = \left(\frac{\underline{\quad\quad}\text{ gr/dscf}}{7000}\right)(\underline{\quad\quad}\text{ Fd})\left(\frac{20.9}{20.9-\underline{\quad\quad}\text{ \%O2}}\right) = \underset{②\text{or}③}{\underline{\quad\quad}}\text{ lbs./10^6}$$

$$\text{13a) ME} = \frac{(\underline{.0303}\text{ gr/dscf})(\underline{264759}\text{ dscf/hr})}{7000} = \underset{①}{\underline{1.15}}\text{ lbs./hr}$$

$$\text{13b) MEa} = \frac{(\underline{.0061}\text{ gr/awcf})(\underline{220658}\text{ awcfm})(60)}{7000} = \underset{①}{\underline{1.15}}\text{ lbs./hr}$$

$$\text{Nozzle} = (3.1416)(\underset{\text{Nozzle dia ④}}{\underline{.0429}}\text{ ft} / 2)\text{^}2 = \underset{⑥}{\underline{.001445}}\text{ ft^2}$$

$$\text{14) I} = \frac{(0.0945)(\underline{1903.4}\text{ Ts°A})(\underline{38.299}\text{ dscf})}{(\underline{30.448}\text{ Ps"Hg})(\underline{39.57}\text{ fps})(\underset{⑥}{\underline{.001445}}\text{ ft^2})(\underline{60}\text{ min})(1-\underline{.2916}\text{ Bws})} = \underset{①}{\underline{93.1}}\text{ \%Isokinet}$$

EPA METHODS #1-5
FIELD DATA
PARTICULATES

CLIENT :	**SOUTHWEST SOILS**	**TEST # :**	**1-PT**
SOURCE :	**MAYPORT BASE FLORIDA**	**TIME :**	**0940-1042**
		DATE :	**4/15/96**

#	METER READING (C F)	DELTA P IN. H2O	DELTA H IN. H2O	METER TEMP DEG. F	STACK TEMP DEG. F	SQRT DELTA P
1	505.800	0.12	1.17	78	1484	0.35
2	507.540	0.10	1.00	80	1456	0.32
3	508.990	0.14	1.55	82	1461	0.37
4	510.650	0.15	1.71	83	1400	0.39
5	512.640	0.15	1.84	86	1440	0.39
6	514.540	0.15	1.78	86	1470	0.39
7	516.360	0.14	1.64	85	1487	0.37
8	518.180	0.14	1.68	86	1452	0.37
9	520.000	0.13	1.53	84	1473	0.36
10	521.700	0.11	1.33	85	1444	0.33
11	523.300	0.11	1.30	86	1445	0.33
12	524.900	0.12	1.32	87	1451	0.35
1	526.570	0.12	1.45	86	1424	0.35
2	528.270	0.13	1.60	87	1424	0.36
3	530.000	0.11	1.36	88	1398	0.33
4	531.650	0.11	1.32	86	1452	0.33
5	533.200	0.11	1.35	87	1440	0.33
6	534.860	0.12	1.43	91	1440	0.35
7	536.560	0.11	1.34	91	1432	0.33
8	538.190	0.12	1.52	95	1420	0.35
9	539.900	0.12	1.52	95	1435	0.35
10	541.620	0.13	1.60	96	1432	0.36
11	543.410	0.15	1.88	97	1434	0.39
12	545.330	0.15	1.84	98	1447	0.39
	547.260					

FIELD DATA

CLIENT : **SOUTHWEST SOILS** **TEST #:** **1-PT**
SOURCE : **MAYPORT BASE**
DATE : **4/15/96**

METER CAL. FACTOR (Mcf)	0.938 Y	CO2 AVG.	7.1 %
BAROMETRIC PRESS. (PB)	30.45 in. Hg	O2 AVG.	9.2 %
METER VOLUME (Vm)	41.460 cfm	STACK DIAMETER	3.44 ft
WATER VOLUME (Ml)	335.0 Ml	STACK WIDTH	0.00 ft
TOTAL TEST TIME	60.0 min	STACK LENGTH	0.00 ft
SAMPLE TIME INTERVAL	2.5 min	STATIC PRESS.	-0.03 in. H2O
NOZZLE DIAMETER (Nz)	0.515	Wt. PART. COLLECTED	0.0752 GRAMS
PITOT FACTOR (cp)	0.84	F FACTOR BASIS %O2	Fd

FIELD DATA AVERAGES

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**1-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

AVG DELTA H	1.50 in. H2O	AVG DELTA P	0.127 in. H2O
AVG METER TEMP (Tm)	87.7 deg F	AVG STACK TEMP (Ts)	1443.4 deg F
AVG METER TEMP (Tm)	547.7 deg A	AVG STACK TEMP (Ts)	1903.4 deg A
PRESSURE METER (Pm)	30.56 in. Hg	PRESSURE STACK (Ps)	30.448 in. Hg
NOZZLE OPENING AREA (Nz.Sq)	0.00145 sq. ft	MOISTURE (Bws)	0.2916

CALCULATIONS

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**1-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

STD SAMPLE VOL. Vm(std)	38.299 dscf
VOL. WATER VAPOR Vw(std)	15.768 scf
PERCENT MOISTURE	29.16 %
ACTUAL METER VOL.	191.485 awcf
GAS DENSITY DRY Md	29.5 lb/lb mole
GAS DENSITY WET Ms	26.15 lb/lb mole
STACK AREA (ft.2)	9.294 sft

STACK GAS VEL. Vs	39.57 fps
STACK GAS FLOW DRY	2.648E+05 dscf/hr 15631.4 adcfm
STACK GAS FLOW WET	22065.8 awcfm
PARTICULATE CONC. Cs	0.0303 gr/dscf
PARTICULATE CONC. AWCF	0.0061 gr/awcf
MASS FLOW DRY	1.15 lb/hr
MASS FLOW WET	1.15 lb/hr
PERCENT ISOK. I	93.0 %

EEMC

PARTICULATE FIELD DATA

RUN # 4

COMPANY NAME S S R

TIME START 940

SAMPLING LOCATION Mayport Base site florida

TIME FINISH 1042

DATE 4/15/96 TEAM LEADER R.G. TECHNICIANS DW

BAROMETRIC PRESSURE, "Hg. 30.45 STATIC PRESSURE, "H2O -.03

SAMPLING TRAIN LEAK TEST VACUUM, "Hg. 15 10

SAMPLING TRAIN LEAK RATE, cu. ft./min. 0.000 0.002

EQUIPMENT CHECKS

✓ PITOTS, PRE-TEST

✓ PITOTS, POST-TEST

_ ORSAT SAMPLING SYSTEM

_ TEDLAR BAG

5 THERMOCOUPLE @ ✓ °F

PITOT 027 NOZZLE .515

METER BOX 217 T/C READOUT N-2

Y FACTOR .938

STACK DIAMETER 3.44 ft

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING Cu. Ft.	PITOT READING (ΔP) IN. H2O	$\sqrt{\Delta P}$	ΔH	GAS METER TEMP. °F	PUMP VACUUM " Hg. GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	%CO2	%O2
1	2.5	505.800	.12		1.77	78	2	230	62	1480		
2	5	507.45	.1		1.0	80	2	230	65	1450	0	9.5
3	7.5	508.99	.14		1.55	82	2	250	65	1460		
4	10	510.60	.15		1.71	83	2	250	65	1400		
5	12.5	512.6	.15		1.54	86	2	250	60	1400		
6	15	514.50	.15		1.78	86	2	250	58	1470		
7	17.5	516.36	.14		1.64	85	2	250	50	1457		
8	20	518.18	.14		1.68	86	2	250	50	1452		
9	22.5	520.0	.13		1.33	84	2	250	50	1473		
10	25	521.7	.11		1.33	85	2	250	50	1400		
11	27.5	523.3	.11		1.30	86	2	250	50	1445		
12	30	524.9	.12		1.32	87	2	248	52	1451		
1	2.5	526.570	.12		1.45	86	2	250	52	1424		9.3
2	5	528.27	.13		1.6	87	2	230	52	1424		
3	7.5	530.0	.11		1.36	88	2	235	52	1399		
4	10	531.65	.11		1.32	86	2	235	52	1452		
5	12.5	533.26	.11		1.35	87	2	240	52	1440		
6	15	534.86	.12		1.43	91	2	240	55	1440		
7	17.5	536.56	.11		1.34	91	2	240	55	1432		
8	20	538.19	.12		1.57	95	2	240	55	1420		
9	22.5	539.90	.12		1.50	95	2	240	55	1435		
0	25	541.62	.13		1.6	96	2	240	53	1432		9.0
1	27.5	543.01	.15		1.78	97	2	242	53	1434		
2	30	545.33	.15		1.84	98	2	245	58	1441		
		547.260				99						
		41.460										

EEMC

TEST # 1

@ Mayport

Lab #

TEST DATE 4/15/96

SOURCE Mayport N.S.

WEIGHED BY ____ APPROVED BY ____

MOISTURE DETERMINATION

Balance level ✓ Balance zeroed ✓

GRAMS

IMPINGER # 1

Final Weight 820

Initial Weight 597

Increase 223

IMPINGER # 2

Final Weight 686

Initial Weight 595

Increase 91

IMPINGER #3

Final Weight 488

Initial Weight 482

Increase 6

SILICA GEL IMPINGER

Final Weight 822

Initial Weight 807

Increase 15

WATER WEIGHT GAIN, GRAMS

Impinger # 1 ____

Impinger # 2 ____

Impinger # 3 ____

Silica Gel ____

TOTAL MASS OF WATER CAPTURED 335 GR

NOTES

EEMC ENERGY AND ENVIRONMENTAL MEASUREMENT CORPORATION

Plant SWS

Date 4-15-96 Run # 1

PARTICULATE CATCH

A. Beaker # DD

Description Wash

Final Wt. 103.8163 103.8164

Tare Wt. 103.7835

Net Wt. .0328 ✓

B. Beaker #

Description

Final Wt.

Tare Wt.

Net Wt.

C. Beaker #

Description

Final Wt.

Tare Wt.

Net Wt.

D. Beaker #

Description

Final Wt.

Tare Wt.

Net Wt.

FILTER CATCH

Filter # 250

Final Wt. .3213 .3215

Tare Wt. .2783

Net Wt. .0430 ✓

PM-10 CAPTURE

Filter Wt.

Post Cyclone

PM-10 Capture

Probe and Cyclone Residue .0328 g. - .0006 g. Blank = .0322 g.

Impinger Residue ___ g. - ___ g. Blank = ___ g.

EPA Method ---------- Filter, Probe, & Cyclone Residue = .0752 g. ✓

TOTAL PARTICULATE WEIGHT (Includes Impingers) = ___ g.

NOTES:

EPA METHODS #1-5
FIELD DATA
PARTICULATES

CLIENT :	**SOUTHWEST SOILS**	**TEST # :**	**2-PT**
SOURCE :	**MAYPORT BASE**	**TIME :**	**1129-1230**
	FLORIDA	**DATE :**	**4/15/96**

#	METER READING (C F)	DELTA P IN. H2O	DELTA H IN. H2O	METER TEMP DEG. F	STACK TEMP DEG. F	SQRT DELTA P
1	548.509	0.08	1.15	88	1402	0.28
2	550.020	0.10	1.44	90	1424	0.32
3	551.730	0.11	1.59	94	1428	0.33
4	553.510	0.12	1.81	96	1374	0.35
5	555.420	0.13	1.88	98	1458	0.36
6	557.370	0.13	1.89	97	1450	0.36
7	559.300	0.14	2.04	98	1444	0.37
8	561.320	0.14	2.05	99	1433	0.37
9	563.340	0.12	1.75	100	1445	0.35
10	565.230	0.10	1.46	100	1439	0.32
11	566.870	0.08	1.17	101	1445	0.28
12	568.470	0.09	1.30	101	1465	0.30
1	570.076	0.10	1.45	98	1451	0.32
2	571.740	0.11	1.56	99	1473	0.33
3	573.520	0.12	1.71	96	1471	0.35
4	575.350	0.11	1.60	97	1442	0.33
5	577.190	0.09	1.30	97	1458	0.30
6	578.800	0.09	1.29	97	1464	0.30
7	580.400	0.10	1.43	97	1449	0.32
8	582.100	0.10	1.49	97	1402	0.32
9	583.800	0.12	1.75	97	1435	0.35
10	585.700	0.15	2.12	98	1484	0.39
11	587.700	0.12	1.70	97	1491	0.35
12	589.600	0.10	1.60	98	1447	0.32
	591.390					

FIELD DATA

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**2-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

METER CAL. FACTOR (Mcf)	0.938 Y	CO2 AVG.	8.4 %
BAROMETRIC PRESS. (PB)	30.45 in. Hg	O2 AVG.	7.9 %
METER VOLUME (Vm)	42.881 cfm	STACK DIAMETER	3.44 ft
WATER VOLUME (Ml)	312.0 Ml	STACK WIDTH	0.00 ft
TOTAL TEST TIME	60.0 min	STACK LENGTH	0.00 ft
SAMPLE TIME INTERVAL	2.5 min	STATIC PRESS.	-0.03 in. H2O
NOZZLE DIAMETER (Nz)	0.515	Wt. PART. COLLECTED	0.1232 GRAMS
PITOT FACTOR (cp)	0.84	F FACTOR BASIS %O2	Fd

FIELD DATA AVERAGES

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**2-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

AVG DELTA H	1.61 in. H2O	AVG DELTA P	0.110 in. H2O
AVG METER TEMP (Tm)	97.1 deg F	AVG STACK TEMP (Ts)	1444.8 deg F
AVG METER TEMP (Tm)	557.1 deg A	AVG STACK TEMP (Ts)	1904.8 deg A
PRESSURE METER (Pm)	30.568 in. Hg	PRESSURE STACK (Ps)	30.448 in. Hg
NOZZLE OPENING AREA (Nz.Sq)	0.00145 sq. ft	MOISTURE (Bws)	0.2738

CALCULATIONS

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**2-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

STD SAMPLE VOL. Vm(std)	38.953	dscf
VOL. WATER VAPOR Vw(std)	14.686	scf
PERCENT MOISTURE	27.38	%
ACTUAL METER VOL.	190.124	awcf
GAS DENSITY DRY Md	29.66	lb/lb mole
GAS DENSITY WET Ms	26.47	lb/lb mole
STACK AREA (ft.2)	9.294	sft

STACK GAS VEL. Vs	36.62	fps
STACK GAS FLOW DRY	2.510E+05 14829.6	dscf/hr adcfm
STACK GAS FLOW WET	20420.8	awcfm
PARTICULATE CONC. Cs	0.0488	gr/dscf
PARTICULATE CONC. AWCF	0.0100	gr/awcf
MASS FLOW DRY	1.75	lb/hr
MASS FLOW WET	1.75	lb/hr
PERCENT ISOK. I	99.7	%

EEMC

PARTICULATE FIELD DATA

RUN # 2

COMPANY NAME SSR
TIME START 1129
SAMPLING LOCATION Mayport Naval Station
TIME FINISH 1230
DATE 4/15/96 TEAM LEADER R O
TECHNICIANS D W
BAROMETRIC PRESSURE, "Hg. 30.45
STATIC PRESSURE, "H2O -.03
SAMPLING TRAIN LEAK TEST VACUUM, "Hg. 15 7
SAMPLING TRAIN LEAK RATE, cu. ft./min. 0.003 0.01

EQUIPMENT CHECKS
✓ PITOTS, PRE-TEST
✓ PITOTS, POST-TEST
_ ORSAT SAMPLING SYSTEM
_ TEDLAR BAG
_ THERMOCOUPLE @ Sic °F

PITOT 027 NOZZLE .515
METER BOX 2K T/C READOUT N-L
Y FACTOR .938
STACK DIAMETER

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING Cu. Ft.	PITOT READING (ΔP) IN. H2O	$\sqrt{\Delta P}$	ΔH	GAS METER TEMP. °F	PUMP VACUUM " Hg. GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	%CO2	%O2
1	2.5	548.509	.08		1.15	86	1	230	52	1402		8.8
2	5	550.02	.1		1.40	90	1	230	55	1424		
3	7.5	551.73	.11		1.59	94	1	240	56	1424		
4	10	553.51	.12		1.88	96	1	240	53	1374		
5	12.5	555.42	.13		1.85	98	1	240	53	1458		
6	15	557.37	.13		1.89	97	1	245	55	1450		
7	17.5	559.3	.14		2.04	98	1	248	58	1461		
8	20	561.32	.14		2.05	99	1	250	56	1433	8.0	7.5
9	22.5	563.34	.12		1.75	100	1	251	58	1445		
10	25	565.23	.10		1.46	100	1	256	58	1439		
11	27	566.87	.08		1.17	101	1	258	58	1445		
12	30	568.47	.09		1.30	101	1	260	80	1465		
1	2.5	570.076	.1		1.45	98	1	255	58	1451		7.2
2	5	571.74	.11		1.56	99	1	256	58	1473		
3	7.5	573.52	.12		1.71	96	1	260	60	1471		
4	10	575.35	.11		1.60	97	1	260	60	1442		
5	12.5	577.19	.09		1.30	97	1	260	60	1458		
6	15	578.8	.09		1.24	97	1	260	60	1464		
7	17.5	580.4	.1		1.43	97	1	260	60	1449		
8	20	582.1	.1		1.49	97	1	260	60	1402		
9	22.5	583.4	.12		1.75	97	1	260	60	1435		
10	25	885.7	.15		2.12	98	1	240	60	1484		
11	27.5	587.7	.12		1.7	97	1	240	60	1491		
12	30	589.6	.1		1.6	98	1	240	60	1447		
		591.390										
		42.881										

EEMC

TEST # 2
@ S.S.R.

Lab #
TEST DATE 4/10/96
SOURCE Mayport
WEIGHED BY _____ APPROVED BY _____

MOISTURE DETERMINATION

Balance level ✓ Balance zeroed ✓

GRAMS

IMPINGER # 1
Final Weight 832
Initial Weight 609
Increase 223

IMPINGER # 2
Final Weight 705
Initial Weight 623
Increase 82

IMPINGER #3
Final Weight 438
Initial Weight 488
Increase 0

SILICA GEL IMPINGER
Final Weight 829.
Initial Weight 822
Increase 7

WATER WEIGHT GAIN, GRAMS

Impinger # 1 _____

Impinger # 2 _____

Impinger # 3 _____

Silica Gel _____

TOTAL MASS OF WATER CAPTURED 312. GR

NOTES

EEMC **ENERGY AND ENVIRONMENTAL MEASUREMENT CORPORATION**

Plant SWS

Date 4-15-96 Run # 2

PARTICULATE CATCH

A. Beaker # 94

Description wash

Final Wt. 101.4606 101.4605 ____

Tare Wt. 101.4381

Net Wt. .0225 ✓

B. Beaker # ____

Description ____

Final Wt. ____ ____ ____

Tare Wt. ____

Net Wt. ____

C. Beaker # ____

Description ____

Final Wt. ____ ____ ____

Tare Wt. ____

Net Wt. ____

D. Beaker # ____

Description ____

Final Wt. ____ ____ ____

Tare Wt. ____

Net Wt. ____

FILTER CATCH

Filter # 247

Final Wt. .3804 .3804 ____

Tare Wt. .2791

Net Wt. .1013 ✓

PM-10 CAPTURE

Filter Wt. ____

Post Cyclone ____

PM-10 Capture ____

Probe and Cyclone Residue .0225 g. - .0006 g. Blank = .0219 ✓ g.

Impinger Residue ____ g. - ____ g. Blank = ____ g.

EPA Method ---------- Filter, Probe, & Cyclone Residue = .1232 ✓ g.

TOTAL PARTICULATE WEIGHT (Includes Impingers) = ____ g.

NOTES: ____

✓

EPA METHODS #1-5
FIELD DATA
PARTICULATES

CLIENT : SOUTHWEST SOILS
SOURCE : MAYPORT BASE
FLORIDA

TEST # : 3-PT
TIME : 1318-1416
DATE : 4/15/96

#	METER READING (C F)	DELTA P IN. H2O	DELTA H IN. H2O	METER TEMP DEG. F	STACK TEMP DEG. F	SQRT DELTA P
1	591.772	0.10	1.46	83	1450	0.32
2	593.430	0.09	1.29	85	1460	0.30
3	595.030	0.11	1.56	87	1453	0.33
4	596.790	0.12	1.81	86	1451	0.35
5	598.620	0.11	1.57	87	1445	0.33
6	600.370	0.12	1.74	88	1428	0.35
7	602.210	0.12	1.75	89	1406	0.35
8	604.040	0.12	1.75	90	1461	0.35
9	605.890	0.11	1.58	92	1450	0.33
10	607.640	0.10	1.44	91	1458	0.32
11	609.310	0.09	1.29	90	1448	0.30
12	610.910	0.09	1.28	91	1471	0.30
1	612.495	0.11	1.58	89	1440	0.33
2	614.260	0.13	1.85	90	1458	0.36
3	616.170	0.12	1.74	92	1426	0.35
4	618.030	0.12	1.75	93	1428	0.35
5	619.900	0.10	1.44	95	1458	0.32
6	621.600	0.09	1.29	96	1461	0.30
7	623.190	0.09	1.32	98	1435	0.30
8	624.820	0.09	1.34	98	1435	0.30
9	626.460	0.12	1.76	99	1435	0.35
10	628.310	0.15	2.20	99	1449	0.39
11	630.410	0.13	1.89	99	1452	0.36
12	632.350	0.11	1.60	99	1449	0.33
	634.150					

FIELD DATA

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**3-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

METER CAL. FACTOR (Mcf)	0.938 Y	CO2 AVG.	7.4 %
BAROMETRIC PRESS. (PB)	30.40 in. Hg	O2 AVG.	9.0 %
METER VOLUME (Vm)	42.378 cfm	STACK DIAMETER	3.44 ft
WATER VOLUME (Ml)	320.0 Ml	STACK WIDTH	0.00 ft
TOTAL TEST TIME	60.0 min	STACK LENGTH	0.00 ft
SAMPLE TIME INTERVAL	2.5 min	STATIC PRESS.	-0.03 in. H2O
NOZZLE DIAMETER (Nz)	0.515	Wt. PART. COLLECTED	0.0724 GRAMS
PITOT FACTOR (cp)	0.84	F FACTOR BASIS %O2	Fd

FIELD DATA AVERAGES

CLIENT :	**SOUTHWEST SOILS**	**TEST #:**	**3-PT**
SOURCE :	**MAYPORT BASE**		
		DATE :	**4/15/96**

AVG DELTA H	1.60 in. H2O	AVG DELTA P	0.110 in. H2O
AVG METER TEMP (Tm)	91.9 deg F	AVG STACK TEMP (Ts)	1446.1 deg F
AVG METER TEMP (Tm)	551.9 deg A	AVG STACK TEMP (Ts)	1906.1 deg A
PRESSURE METER (Pm)	30.518 in. Hg	PRESSURE STACK (Ps)	30.398 in. Hg
NOZZLE OPENING AREA (Nz.Sq)	0.00145 sq. ft	MOISTURE (Bws)	0.2797

CALCULATIONS

CLIENT : **SOUTHWEST SOILS** **TEST #:** **3-PT**
SOURCE : **MAYPORT BASE**
DATE : **4/15/96**

STD SAMPLE VOL. Vm(std)	38.796 dscf	STACK GAS VEL. Vs	36.77 fps
VOL. WATER VAPOR Vw(std)	15.062 scf	STACK GAS FLOW DRY	2.494E+05 dscf/hr 14769.3 adcfm
PERCENT MOISTURE	27.97 %	STACK GAS FLOW WET	20504.4 awcfm
ACTUAL METER VOL.	191.349 awcf	PARTICULATE CONC. Cs	0.0288 gr/dscf
GAS DENSITY DRY Md	29.54 lb/lb mole	PARTICULATE CONC. AWCF	0.0058 gr/awcf
GAS DENSITY WET Ms	26.31 lb/lb mole	MASS FLOW DRY	1.03 lb/hr
STACK AREA (ft.2)	9.294 sft	MASS FLOW WET	1.02 lb/hr
		PERCENT ISOK. I	100.0 %

EEMC

PARTICULATE FIELD DATA

RUN # 3

COMPANY NAME S S R

TIME START 1318

SAMPLING LOCATION Mayport

TIME FINISH 1418

DATE 4/18/96 TEAM LEADER K.G. TECHNICIANS DW

BAROMETRIC PRESSURE, "Hg. 30.40 STATIC PRESSURE, "H2O -.03

SAMPLING TRAIN LEAK TEST VACUUM, "Hg. 15 7

SAMPLING TRAIN LEAK RATE, cu. ft./min. 0.003 0.009

✓ EQUIPMENT CHECKS
✓ PITOTS, PRE-TEST
✓ PITOTS, POST-TEST
__ORSAT SAMPLING SYSTEM
__TEDLAR BAG
__THERMOCOUPLE @ [illegible] °F

PITOT 027 NOZZLE .515

METER BOX 2K T/C READOUT N-2

Y FACTOR .938

STACK DIAMETER

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING Cu. Ft.	PITOT READING (ΔP) IN. H2O	$\sqrt{\Delta P}$	ΔH	GAS METER TEMP. °F	PUMP VACUUM " Hg. GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	%CO2	%O2
1	2.5	591.772	.1		1.46	83	1	228	58	1450		
2	5	593.43	.09		1.29	85	1	235	58	1460		
3	7.5	595.03	.11		1.56	87	1	240	55	1453		
4	10	596.79	.12		1.81	86	1	240	55	1451		
5	12.5	598.62	.11		1.57	87	1	240	55	1445		
6	15	600.37	.12		1.74	88	1	246	55	1428		
7	17.5	602.21	.12		1.75	89	1	250	58	1406		
8	20	604.04	.12		1.75	90	1	252	57	1461		
9	22.5	605.89	.11		1.58	92	1	250	57	1450		
10	25	607.64	.1		1.44	91	1	250	55	1458		
11	27.5	609.31	.09		1.29	90	1	256	55	1448		
12	30	610.91	.09		1.28	91	1	255	55	1471		
1	2.5	612.495	.11		1.58	89	1	250	50	1440		
2	5	614.26	.13		1.85	90	1	250	50	1458		
3	7.5	616.17	.12		1.74	92	1	249	50	1426		
4	10	618.03	.12		1.75	93	1	240	50	1428		
5	12.5	619.9	.1		1.44	95	1	240	50	1458		
6	15	621.6	.09		1.29	96	1	245	50	1461		
7	17.5	623.19	.09		1.32	98	1	243	50	1435		
8	20	624.82	.09		1.34	98	1	245	52	1435		
9	22.5	626.46	.12		1.76	99	1	240	53	1435		
10	25	628.31	.10		2.2	99	1	240	50	1449		
11	27.5	630.41	.13		1.89	99	1	245	50	1452		
12	30	632.35	.11		1.60	99	1	245	50	1449		
		634.150				99						
			[illegible]									

EEMC

TEST # 3
@ 55R

Lab #
TEST DATE 4/15/96
SOURCE Mayport
WEIGHED BY RG APPROVED BY

MOISTURE DETERMINATION

Balance level ✓ Balance zeroed ✓

	GRAMS
IMPINGER # 1	
Final Weight	783
Initial Weight	566
Increase	217
IMPINGER # 2	
Final Weight	643
Initial Weight	567
Increase	76
IMPINGER #3	
Final Weight	490
Initial Weight	488
Increase	2
SILICA GEL IMPINGER	
Final Weight	854.0
Initial Weight	829.0
Increase	25.0

WATER WEIGHT GAIN, GRAMS

Impinger # 1

Impinger # 2

Impinger # 3

Silica Gel

TOTAL MASS OF WATER CAPTURED 320. GI

NOTES

EEMC ENERGY AND ENVIRONMENTAL MEASUREMENT CORPORATION

Plant SWS
Date 4-15-96 Run # 3

PARTICULATE CATCH

A. Beaker # 123
Description wash
Final Wt. 97.5333 97.5332 ____
Tare Wt. 97.4834
Net Wt. .0499 ✓

B. Beaker # ____
Description ____
Final Wt. ____ ____ ____
Tare Wt. ____
Net Wt. ____

C. Beaker # ____
Description ____
Final Wt. ____ ____ ____
Tare Wt. ____
Net Wt. ____

D. Beaker # ____
Description ____
Final Wt. ____ ____ ____
Tare Wt. ____
Net Wt. ____

FILTER CATCH

Filter # 246
Final Wt. .3027 .3027 ____
Tare Wt. .2796
Net Wt. .0231 ✓

PM-10 CAPTURE

Filter Wt. ____
Post Cyclone ____
PM-10 Capture ____

Probe and Cyclone Residue .0499 g. - .0006 g. Blank = .0493 ✓ g.
Impinger Residue ____ g. - ____ g. Blank = ____ g.
EPA Method ---------- Filter, Probe, & Cyclone Residue = .0724 ✓ g.
TOTAL PARTICULATE WEIGHT (Includes Impingers) = ____ g.
NOTES: ____

EEMC ENERGY AND ENVIRONMENTAL MEASUREMENT CORPORATION

Plant SWS

Date 4-15-96 Run # Blan

PARTICULATE CATCH

A. Beaker # 204

Description 200 ml DD H_2O

Final Wt. 101.1642 101.1643 ____

Tare Wt. 101.1636

Net Wt. .0006 ✓

B. Beaker # ____

Description ____

Final Wt. ____ ____ ____

Tare Wt. ____

Net Wt. ____

C. Beaker # ____

Description ____

Final Wt. ____ ____ ____

Tare Wt. ____

Net Wt. ____

D. Beaker # ____

Description ____

Final Wt. ____ ____ ____

Tare Wt. ____

Net Wt. ____

FILTER CATCH

Filter # 261

Final Wt. .2795 .2795 ____

Tare Wt. .2795

Net Wt. .0000

PM-10 CAPTURE

Filter Wt. ____

Post Cyclone ____

PM-10 Capture ____

Probe and Cyclone Residue ____ g. - ____ g. Blank = ____ g.

Impinger Residue ____ g. - ____ g. Blank = ____ g.

EPA Method ---------- Filter, Probe, & Cyclone Residue = ____ g.

TOTAL PARTICULATE WEIGHT (Includes Impingers) = ____ g.

NOTES: ____

EEMC

Orsat Analysis for 5 5 R
Lab No. ____ Date 4/16/96 *
Source Mayport @ Stack
STU

TEST NO.	GAS	1	2	3	4	5	AVERAGE
1	TOTAL/CO	16.3	16.2	16.3			
	CO_2	7.0	7.0	7.2			7.1
	O_2	9.3	9.2	9.1			9.2
2	TOTAL/CO	16.3	16.3	16.4			
	CO_2	8.4	8.4	8.5			8.4
	O_2	7.9	7.9	7.9			7.9
3	TOTAL/CO	16.3	16.4	16.3			
	CO_2	7.3	7.4	7.4			7.4
	O_2	9.0	9.0	8.9			9.0
4	TOTAL/CO						
	CO_2						
	O_2						
5	TOTAL/CO						
	CO_2						
	O_2						
6	TOTAL/CO						
	CO_2						
	02						
7	TOTAL/CO						
	CO_2						
	O_2						
8	TOTAL/CO						
	CO_2						
	O_2						
9	TOTAL/CO						
	CO_2						
	O_2						
10	TOTAL/CO						
	CO_2						
	O_2						
11	TOTAL/CO						
	CO_2						
	O_2						

NOTES: * bags shipped to Tucson for Analyzes

EEMC

Run 1

Visible Emissions Field Sheet

Firm Name SW Soil Date 4-15-96 Observer DJ Wang

Address Mayport NAS Source Description Soil Remediation

Stack Height 20' Stack Diameter 3' Start Time 1045 Stop Time 1057

Distance from Stack 80' Direction from Stack SSE

Observation Point SE of testing trailer

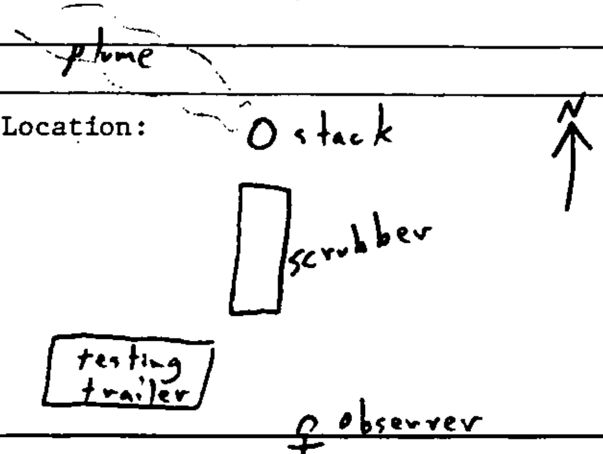
Plume Characteristics Mainly heat waves

Sky Conditions and Color cloudy - white Ambient Air Temp. 75

Est. Wind Speed 5 Direction SE Est. Relative Humidity 80%

Notes:

Sketch of Observer Location:



PLUME DENSITY READINGS: IN RINGELMANN IF BLACK, IN OPACITY IF ANY OTHER COLOR

MIN \ SEC	0	15	30	45	REMARKS	MIN \ SEC	0	15	30	45	REMARKS
0	0	0	0	0		30					
1	0	0	0	0		31					
2	0	5	0	0		32					
3	0	0	0	5		33					
4	0	0	0	0		34					
5	0	0	0	5		35					
6	5	0	0	0		36					
7	0	0	0	0		37					
8	0	0	5	5		38					
9	0	0	0	0		39					
10	0	0	0	0		40					
11	0	0	0	0		41					
12						42					
13						43					
14						44					
15						45					
16						46					
17						47					
18						48					
19						49					
20						50					
21						51					
22						52					
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					

AVERAGE DENSITY .63

EEMC

Run 2

Visible Emissions Field Sheet

Firm Name SW Soil Date 4-15-96 Observer D J Wang

Address Mayport Source Description Soil Remediation

Stack Height 20' Stack Diameter 3' Start Time 1300 Stop Time 1312

Distance from Stack 80' Direction from Stack S

Observation Point SE of testing trailer

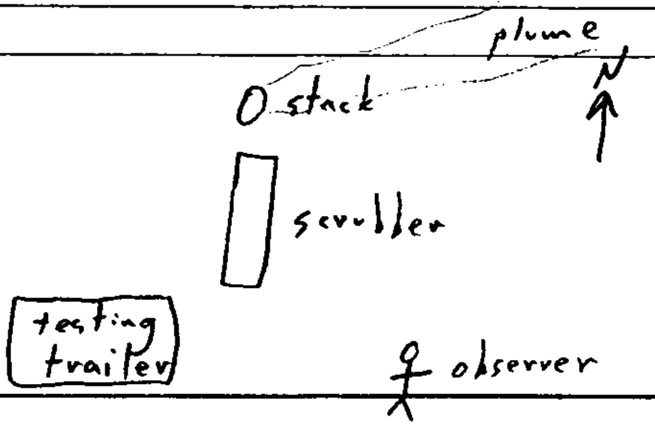
Plume Characteristics Mainly heat waves

Sky Conditions and Color cloudy - Gray Ambient Air Temp. 75

Est. Wind Speed 15 Direction W Est. Relative Humidity 85%

Notes:

Sketch of Observer Location:



PLUME DENSITY READINGS: IN RINGELMANN IF BLACK, IN OPACITY IF ANY OTHER COLOR

MIN \ SEC	0	15	30	45	REMARKS	MIN \ SEC	0	15	30	45	REMARKS
0	0	5	5	0		30					
1	0	0	0	5		31					
2	5	0	0	0		32					
3	0	5	5	0		33					
4	0	0	0	0		34					
5	5	0	0	5		35					
6	0	0	0	5		36					
7	0	0	0	5		37					
8	0	5	0	0		38					
9	0	5	0	0		39					
10	0	0	0	0		40					
11	5	0	0	5		41					
12						42					
13						43					
14						44					
15						45					
16						46					
17						47					
18						48					
19						49					
20						50					
21						51					
22						52					
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					

AVERAGE DENSITY 1.46

Run 3

EEMC

Visible Emissions Field Sheet

Firm Name SW Soil Date 4-15-96 Observer D.J. Wang

Address Mayport Source Description Soil Remediation

Stack Height 20' Stack Diameter 3' Start Time 1420 Stop Time 1432

Distance from Stack 80' Direction from Stack S

Observation Point SE of testing trailer

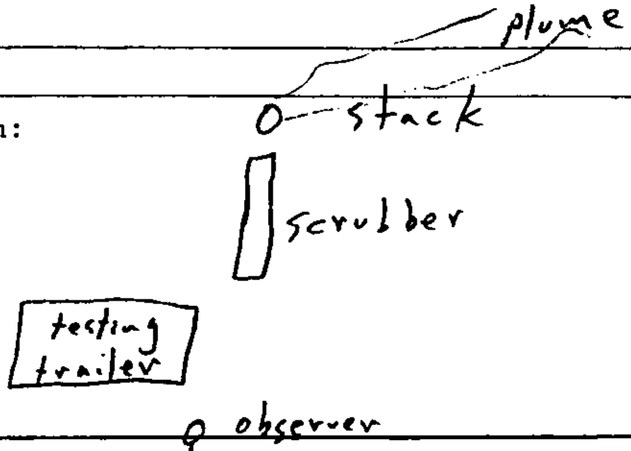
Plume Characteristics Mainly heat waves

Sky Conditions and Color cloudy gray Ambient Air Temp. 69°

Est. Wind Speed 15 Direction W Est. Relative Humidity 100% - rain

Notes:

Sketch of Observer Location:



PLUME DENSITY READINGS: IN RINGELMANN IF BLACK, IN OPACITY IF ANY OTHER COLOR

MIN \ SEC	0	15	30	45	REMARKS	MIN \ SEC	0	15	30	45	REMARKS
0	5	0	0	0		30					
1	0	0	0	5		31					
2	0	0	0	0		32					
3	0	0	0	0		33					
4	0	0	0	5		34					
5	0	0	0	0		35					
6	0	0	0	0		36					
7	5	0	0	0		37					
8	5	0	0	0		38					
9	0	0	5	0		39					
10	0	0	0	0		40					
11	0	0	0	5		41					
12						42					
13						43					
14						44					
15						45					
16						46					
17						47					
18						48					
19						49					
20						50					
21						51					
22						52					
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					

AVERAGE DENSITY .73

EQUIPMENT CALIBRATION
SOUTHWEST SOIL REMEDIATION
4/15/96

1) Meter Boxes

<u>2-K</u>

12/27/95 @ 0.938 (Full Profile)

4/28/96 @ 0.992 (@ 1.60 "H2O Delta H and 2 "Hg Vacuum)

2) Thermocouple (N-2) & Dial Thermometer

Note attached data sheets.

3) Pitot tubes (S-type, #027)

Manufactured by EEMC to meet 0.84 pitot coefficient requirements. Note attached data sheet.

4) Barometer (aneroid)

The aneroid barometer was calibrated with a mercury wall barometer prior to and after the test series. See attached data sheet.

5) Nozzle (particulate emissions)

The stack particulate button hook nozzle was measured on site by a Precise Starrett expanding micrometer and micro-calipers.

6) CO Calibration Gases

EPA Protocol tanks of CO in N2 span gases were utilized to zero and span the FID stack instrument. N2 zero gas was employed. Copies of the span gas certifications are included in this section. Please note Q.C. sheets for a description of calibration procedures.

METER BOX CALIBRATION

Date : 12/27/95
Calibrated By : J.C.
Dry Gas Meterbox ID : 2K

Barometric Pressure, Pb = 27.53 in. Hg
Vacuum = 0.0 in. Hg

Orifice Manometer Setting, Delta H in. H20	0.50	1.00	2.00	3.00	4.00	5.00
Gas Volume Wet Test Meter Vw, cu. ft.	11.367	11.238	11.771	10.815	13.020	18.772
Gas Volume Dry Gas Meter						
M Final	430.679	443.132	456.565	468.857	483.268	504.045
M Initial	418.420	430.930	443.805	457.112	469.174	483.662
Vd, cu. ft.	12.259	12.202	12.760	11.745	14.094	20.383
Wet Test Meter						
tw Deg F	62	63	64	64	65	65
tw Deg A	522	523	524	524	525	525
Dry Gas Meter Outlet, tmo 1)	67	70	71	73	73	73
2)	68	70	71	73	73	73
3)	70	79	71	73	73	73
Dry Gas Meter Inlet tmi 1)	73	74	79	83	81	82
2)	73	78	82	86	85	87
3)	75	70	85	86	87	89
Mean tm, Deg F	71	74	77	79	79	80
Mean tm, Deg A	531	534	537	539	539	540
Time, Minutes	29.36	20.18	15.26	11.56	12.10	15.71
Results :						
Y =	0.942	0.937	0.939	0.940	0.938	0.934
Delta H @ =	1.97	1.90	1.98	2.01	2.04	2.06

Averages :

Y = **0.938**

Delta H = **1.993**

METER BOX CALIBRATION

Date : 4/28/96
Calibrated By : J.C.
Dry Gas Meterbox ID : 2K

Barometric Pressure, Pb = 27.70 in. Hg
Vacuum = 2.0 in. Hg

Orifice Manometer Setting, Delta H in. H20		1.60	1.60	1.60
Gas Volume Wet Test Meter Vw, cu. ft.		5.005	5.015	5.000
Gas Volume Dry Gas Meter				
M Final		640.045	645.658	654.058
M Initial		635.000	640.589	648.981
Vd, cu. ft.		5.045	5.069	5.077
Wet Test Meter				
twDeg F		80	81	82
twDeg A		540	541	542
Dry Gas Meter Outlet, tmo	**1)**	80	81	84
	2)	81	83	85
	3)	82	84	87
Dry Gas Meter Inlet tmi	**1)**	81	86	88
	2)	84	88	90
	3)	87	90	93
Mean tm, Deg F		83	85	88
Mean tm, Deg A		543	545	548
Results :				
	Y =	0.992	0.993	0.991

Averages :

Y = **0.992**

1744 Mullowney Lane
Billings, MT 59101

EEMC

3730 N. Pelligrino Drive
Tucson, AZ 85749

Date: 4/1/96
Thermocouple No.: N-2
Ambient Temperature: 79 °F
Barometric Pressure: 27.60 "Hg
Calibrator: R.C
Reference: Mercury-in-glass: ✓
Other:

Pre test

Reference Point No.[a]	Source[b] (specify)	Reference thermometer temperature, °F	Thermocouple potentiometer temperature, °F	Difference,[c] %
200	water	200	199	0.2
210	"	210	209	0.1
250	furnace	250	248	0.3
350	"	350	349	0.1
450	"	450	448	0.2
550	"	550	549	0.1
650	"	650	650	0
850	"	850	850	0
1100	"	1100	1101	-.01
1200	"	1200	1201	-.01
1300	"	1300	1302	-.01
1400	"	1400	1402	-.01
1500	"	1500	1503	-.02

[a] Every 30°C (50°F) for each reference point

[b] Type of Calibration system used

[c] $$\frac{(\text{Ref. temp: °C} + 273) - (\text{Test therm. temp. °C} + 273}{\text{Ref. Temp. °C} + 273} \times 100 \leq 1.5\%$$

Stack Temperature Sensor Calibration Data Sheet

1744 Mullowney Lane
Billings, MT 59101

EEMC

3730 N. Pelligrino Drive
Tucson, AZ 85749

Date: 4/18/96 Thermocouple No.: N-2

Ambient Temperature: 82 °F Barometric Pressure: 27.68 "Hg

Calibrator: R. G. Reference: Mercury-in-glass: ✓

Other:

Post test

Reference Point No.[a]	Source[b] (specify)	Reference thermometer temperature, °F	Thermocouple potentiometer temperature, °F	Difference,[c] %
200	water	200	200	
210	"	210	210	
300	furnace	300	301	
400	"	400	401	
500	"	500	501	
600	"	600	601	
700	"	700	702	
800	"	800	802	
900	"	900	903	
1000	"	1000	1003	
1100	"	1100	1103	
1200	"	1200	1203	
1300	"	1300	1302	
1500	"	1500	1502	

[a] Every 30°C (50°F) for each reference point

[b] Type of Calibration system used

[c] $\frac{(\text{Ref. temp: °C} + 273) - (\text{Test therm. temp. °C} + 273}{\text{Ref. Temp. °C} + 273} \times 100 \leq 1.5\%$

Stack Temperature Sensor Calibration Data Sheet

SAMPLE TRAIN TEMPERATURE CALIBRATION DATA

DIAL THERMOMETERS

DATE: 4/18/96 post

STANDARD: Glass Thermometer ✓
Thermistor ____

PRETEST pre 2/5/96

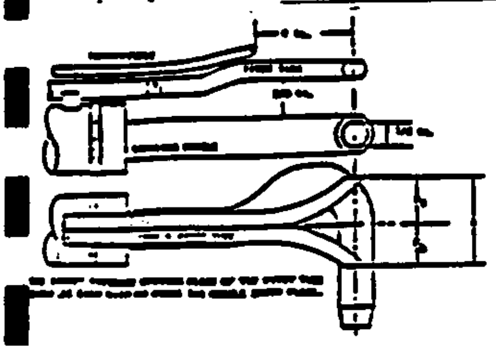
THERMOMETER	BOILING WATER	AMBIENT	ACCEPTABLE RANGE
Impinger	210 / 211	70 / 69	+/- 2°F
Meter 1	210 / 211	70 / 69	
Meter 2			
Collection Box	210 / 210	70 / 70	

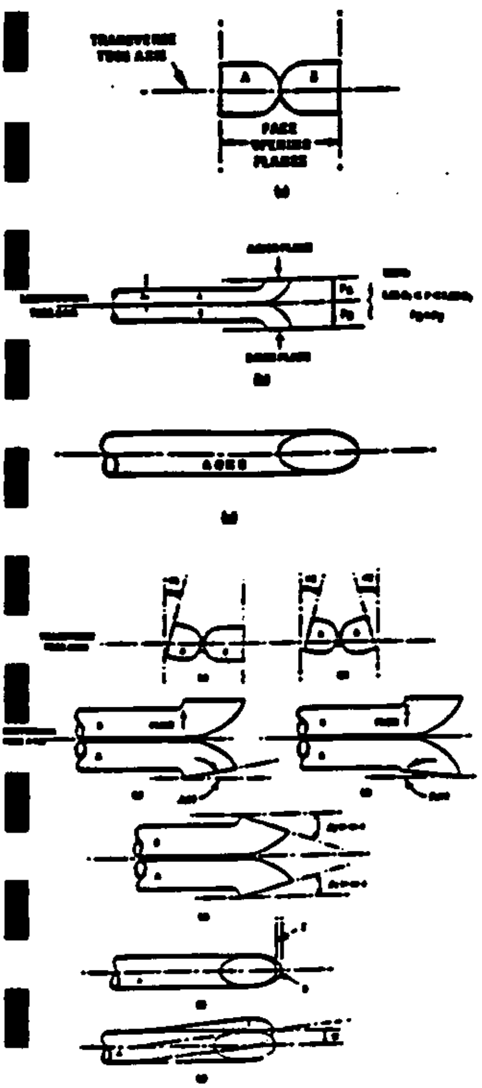
POSTTEST

THERMOMETER	BOILING WATER	AMBIENT	ACCEPTABLE RANGE
Impinger	209 / 210	82/81	+/- 2°F
Meter 1	209 / 210	82/ 81	
Meter 2			
Collection Box	209 / 211	82/ 80	

J

Company Name: S.S.R.





Pre-sample Date 4/1/96		Post Sample 4/18/96
yes	level?	yes
NO	obstructions?	NO
None	damaged?	NO
0	$-10° < \alpha_1 < +10°$	0
0	$-10° < \alpha_2 < +10°$	0
1	$-5° < \beta_1 < +5°$	2
1	$-5° < \beta_2 < +5°$	2
.05	$Z \leq 1/8"$	.05
0.0	$W \leq 1/32"$	0.0
.3625	$1.05\ D_t < P_a < 1.5D_t$	.3625
.3670	$1.05\ D_t < P_b < 1.5D_t$	.3670
.253	$3/16" \leq D_t \leq 3/8"$	.253
yes	$P_a = P_b \pm 0.063"$	yes

Comments:

Pitot tube/probe number 027 meets or exceeds all specifications criteria and/or applicable design features* and is hereby assigned a pitot tube calibration factor of 0.084.

Signature R. Guiller

Date 4/18/96

*See 40 CRF 60, Vol. 40, Appendix A, Method 2 (7-1-93). Verify the minimum 2 inch setback of the thermocouple and minimum 3/4 inch separation between the pitot tube and the nozzle as shown at the top of this page.

1744 Mullowney Lane
Billings, MT 59101

EEMC

3730 N. Pelligrino Drive
Tucson, AZ 35749

BAROMETER CALIBRATION

Date	Hg Barometer Reading	Aneroid Barometer	Difference
Pre 4/1/96	27.48	27.59	.11
Post 4/18/96	27.68	27.60	0.08

EEMC

NOZZLE CALIBRATION

S.S.K.

NOZZLE I.D. NUMBER	NOMINAL SIZE, INCHES	MEASURED	AVERAGE	DATE
1/2 inch Nozzle Glass	1/2	.514 .517 .515	.515	4/15/96

Nozzles measured by Precise Starrett expanding micrometer and micro-calipers.

Scott Specialty Gases, Inc.
1290 COMBERMERE STREET, TROY, MI 48083 (810) 589-2950 FAX:(810) 589-2134

CERTIFICATE OF ANALYSIS: EPA PROTOCOL GAS

Customer	Assay Laboratory		
C A E INSTRUMENT RENTAL 246 WOODWORK LANE PALATINE, IL 60067	Scott Specialty Gases, Inc 1290 Combermere Troy, MI 48083	**Purchase Order :** **Scott Project # :**	13845-71500 583416

ANALYTICAL INFORMATION

This certification was performed according to EPA Traceability Protocol For Assay and Certification of Gaseous Calibration Standards; Procedure G1; September, 1993.

Cylinder Number : ALM024967 **Certificate Date :** 7/20/95 **Expiration Date :** 7/20/98

Cylinder Pressure + : 2000 psig **Previous Certificate Date :** None

ANALYZED CYLINDER

Components	Certified Concentration	Analytical Uncertainty*
Carbon Monoxide	75.12 ppm	±1% NIST Directly Traceable

Balance Gas: Nitrogen

+Do not use when cylinder pressure is below 150 psig.
*Analytical accuracy is inclusive of usual known error sources which at least include precision of the measurement processes.

REFERENCE STANDARD

Type	Expiration Date	Cylinder Number	Concentration
NTRM1679	8/11/96	ALM-041534	97.1 ppm Carbon Monoxide in Nitrogen

INSTRUMENTATION

Instrument/Model/Serial #	Last Date Calibrated	Analytical Principle
Beckman/867/0100157	6/28/95	Non-Dispersive Infrared

ANALYZER READINGS (Z=Zero Gas R=Reference Gas T=Test Gas r=Correlation Coefficient)

Components

Carbon Monoxide

First Triad Analysis

Date: 7/13/95	Response Units: mv	
Z1=0.00	R1=120.00	T1=94.10
R2=120.00	Z2=0.00	T2=94.10
Z3=0.00	T3=93.90	R3=120.00
Avg. Conc. of Cust. Cyl 75.14 ppm		

Second Triad Analysis

Date: 7/20/95	Response Units: mv	
Z1=0.00	R1=120.00	T1=94.00
R2=120.00	Z2=0.00	T2=94.00
Z3=0.00	T3=94.00	R3=120.00
Avg Conc. of Cust Cyl. 75.11 ppm		

Calibration Curve

Concentration=$A+Bx+Cx^2+Dx^3+Ex^4$	
r=1.00000	NTRM1679
Constants:	A=0.004324870
B=0.815704500	C=-0.000638036
D=0.000004831	E=0.000000000

Special Notes

Cylinder

Analyst

Scott Specialty Gases, Inc.

1290 COMBERMERE STREET, TROY, MI 48083 (810) 589-2950 FAX:(810) 589-2134

CERTIFICATE OF ANALYSIS: EPA PROTOCOL GAS

Customer	Assay Laboratory		
C A E INSTRUMENT RENTAL 246 WOODWORK LANE PALATINE, IL 60067	Scott Specialty Gases, Inc 1290 Combermere Troy, MI 48083	Purchase Order : Scott Project # :	13845-71500 583416

ANALYTICAL INFORMATION

This certification was performed according to EPA Traceability Protocol For Assay and Certification of Gaseous Calibration Standards; Procedure G1: September, 1993.

Cylinder Number : ALM028270 **Certificate Date :** 7/20/95 **Expiration Date :** 7/20/98

Cylinder Pressure + : 1950 psig **Previous Certificate Date :** None

ANALYZED CYLINDER

Components	Certified Concentration	Analytical Uncertainty*
Carbon Monoxide	149.2 ppm	±1% NIST Directly Traceable

Balance Gas: Nitrogen

+Do not use when cylinder pressure is below 150 psig.

*Analytical accuracy is inclusive of usual known error sources which at least include precision of the measurement processes.

REFERENCE STANDARD

Type	Expiration Date	Cylinder Number	Concentration
NTRM 2636	8/11/96	ALM034181	244.2 ppm Carbon Monoxide in Nitrogen

INSTRUMENTATION

Instrument/Model/Serial #	Last Date Calibrated	Analytical Principle
CO: Beckman/864/102528	7/20/95	Non-Dispersive Infrared

ANALYZER READINGS (Z=Zero Gas R=Reference Gas T=Test Gas r=Correlation Coefficient)

Components	First Triad Analysis	Second Triad Analysis	Calibration Curve
Carbon Monoxide	Date: 7/13/95 Response Units: mv Z1=0.00 R1=100.00 T1=62.00 R2=100.00 Z2=0.00 T2=62.10 Z3=0.00 T3=62.00 R3=100.00 Avg. Conc. of Cust. Cyl. 149.2 ppm	Date: 7/20/95 Response Units: mv Z1=0.00 R1=100.00 T1=62.10 R2=100.00 Z2=0.00 T2=62.10 Z3=0.00 T3=62.00 R3=100.00 Avg. Conc. of Cust. Cyl. 149.3 ppm	Concentration=A+Bx+Cx^2+Dx^3+Ex^4 r=0.99999 NTRM 2636 Constants: A=0.312350000 B=2.336400000 C=0.001024300 D=0.000000000 E=0.000000000

Special Notes

Mail

Analyst

VISIBLE EMISSIONS EVALUATOR

This is to certify that

David Q. Wang

met the specifications of Federal Reference Method 9 and qualified as a visible emissions evaluator. Maximum deviation on white and black smoke did not exceed 7.5% opacity and no single error exceeding 15% opacity was incurred during the certification test conducted by Eastern Technical Associates of Raleigh, North Carolina. This certificate is valid for six months from date of issue.

President

250998
Certificate Number

Vice President

Nelema
Location

David B. Savage, Jr.
Program Manager

October 18, 1995
Date of Issue

Listing of Quality Control Procedures
EPA #1-#6, #8, #17, & #201A Testing Methodology

I. Calibration of Equipment

A. Meter box (meter)

The meter box is calibrated with a wet test meter or standard dry gas meter prior to and after the test series. In addition the initial test includes a profile covering pertinent Delta H values (completed at least every six months).

The post meter box calibration includes a triplicate calibration at the mean Delta H at the maximum meter vacuum experienced during the test series.*

*If an orifice slip stream is utilized the meter calibration is conducted at the maximum slip stream flow rate encountered during testing.

B. Thermometers

1) Dry gas meter (2)

2) Silica gel impinger effluent (1)

These dial thermometers are checked at ambient and water boiling conditions prior to and after the test series. If they are off more than +/- 5.4 °F for the Dry Gas Meter thermometer or Collection Box thermometer or +/-2.0 °F for the Impinger thermometer they are adjusted or replaced (if not correctable). In addition all thermometers in the field are daily checked prior to sampling utilizing ambient temperatures (reference glass thermometers and/or an Omega Simulator (thermocouple)).

3) Thermocouple (stack gas) or
Thermistor ($\leq$250 degrees F)

The temperature sensor system is compared to standard glass thermometers in solutions of water and/or oil. An Omega thermocouple simulator (calibrator CL-30) is utilized for high temperature thermocouple calibration performance. The thermistor is NBS traceable (as per manufacturer).

C. Manometer (vertical/inclined)

This device is a primary standard. It is leak checked prior to and during field utilization. During use it is operated at level conditions (bubble indicator).

I. Calibration of Equipment - (continued)

D. Vacuum Gauge

The vacuum gauge is an indicator of train vacuum - it does not affect the sample. Performance is checked each time the unit is utilized. If it is suspect it is discarded and replaced.

E. Meter Box Leak Integrity

The meter box is placed under positive pressure just prior to field testing to determine if a leak exists. This procedure is repeated prior to each meter calibration.

F. Impinger Weight

The Greenberg/Smith impingers are weighed in the field utilizing an Ohaus Dial-a-gram balance. A set of Ohaus standard weights are used to ensure field accuracy.

G. Orsat (CO2 & O2)

The orsat analyzer is rebuilt after each test series. The scrubber flasks are removed and cleaned. The solutions are replaced, and the unit is leak checked. In the field the unit is checked again for leaks prior to use.

It is known that the orsat is not always a reliable field apparatus. In order to validate orsat results a portable real time electrochemical analyzer is used for oxygen measurement. In some cases CO2 is measured with a NDIR portable analyzer. The O2 monitor is calibrated with ambient air, while the NDIR is calibrated with tank gases validated with an orsat analysis.

H. Gas Flow

An S-type pitot is used for measurement of stack gas dynamic and static pressure. The geometry of the pitot head is measured to ensure compatibility with EPA specifications at 0.84 (+/- 0.02) pitot coefficient.

I. Barometer (aneroid)

A mercury wall barometer is utilized to determine and set the aneroid prior to field testing. It is rechecked after the test series.

J. Nozzle Diameter

A digital Vernier caliper is utilized for at least a triplicate determination of nozzle diameter.

II. Laboratory Analysis

A. Balance (calibration)

The laboratory balance is calibrated (with S weights) <u>just prior to each act of weighing</u>. Standard interim weights are utilized to determine if the calibration has been successful (+/- 0.2mg).

B. Sample Weighing

1. Filters (initial - tare)
The desiccated filters are tared to a constant weight (+/- 0.5 mg).

2. Wash - beakers - tare
Beakers are tared to a constant weight (+/- 0.5 mg).

3. Filters (final - sample)
Each desiccated sample filter is weighed until a final weight (requires at least two weighings.)
A blank filter is weighed concurrently with the sample filter.
4. Wash/Beakers (250 ml) - sample
Each desiccated beaker is reweighed until a constant weight is achieved.

A blank acetone wash beaker is weighed concurrently with the sample filter.

In order to ensure a representative wash blank the wash and blank solutions are brought up to a common volume (200 ml). Acetone residues would thus be at a common volume.

No control charts are maintained for the balance since it is recalibrated for <u>each</u> weighing sequence.

III. Sampling

A. Sampling train

A pre and post leak check of the sampling train is conducted for each test.

B. Gas Flow

A pitot system leak check is conducted prior to and after the test series.

C. Temperature (Thermocouple)

An electronic simulator is utilized for field determination of response accuracy at the stack temperature.

III. Sampling - continued

D. Temperature
Dial - Train Thermometers are checked against ambient air to determine continued field integrity.

E. Orsat
Ambient air is analyzed in the field to assess orsat performance.

F. Impinger balance
The balance is zeroed and checked for accuracy with standard weights.

G. Probe cleaning
After triple wash probe clean out the probe is visually inspected.

H. Sample Removal
The samples are placed into glass or inert plastic bottles for removal to the laboratory. Labeling includes (minimum):

a) Date
b) Run #
c) Level mark
d) sample description
e) source I.D.

I. Post Purge
Upon completion of Method #8 sampling a 15 minute post purge is conducted utilizing carbon filtered ambient air or tank N2.

IV. Laboratory Analysis (SO2)

The impingers (H_2O_2) are washed with distilled water from the train, and placed in inert sample bottles (properly labeled). The samples are removed to the laboratory for analysis. Standard Method #6 analysis is employed. Standardization of the Barium Perchlorate Solution is conducted in the field (0.1 N H_2SO_4 or as appropriate). Audit samples are run to ensure chemical accuracy. Field blanks are integrated into the samples and audit results. Since the chemicals for each analysis are reestablished for each test series, no control charts are maintained.

It is sometimes necessary to determine the SO_2 collection efficiency of the sampling train. This is done by titrating each impinger separately. No other analytical deviations from standard Method #6 procedures are taken.

This document is not designed to be a redundant dissertation of EPA methods. Instead, it is a brief commentary on general practices as routinely employed and almost all of which are described in EPA reference methods and quality control manuals.

Listing of Quality Control Procedures
for
EPA Method #10 Testing Methodology

I. Calibration of Equipment (CO in N2)

A) Zero and Span

Gases certified by the manufacturer to be within ±2% of the specified concentration are to be utilized. The instrument is then zeroed and calibrated by inputing at least three span gas concentrations (~0% of scale, ~30% of scale and one at high span ~60-90% of scale). A dilution system is sometimes utilized for span evaluation. Dilution is achieved utilizing a air or nitrogen diluent measured with mass flow meters calibrated with bubble tubes.

The instrument is calibrated just prior to and each hour of testing.

B) Interferences (CO2)

The TECO Monitor #48 and the Horiba MEXA NDIR Monitor do not respond significantly to CO2. A high concentration of CO2 (~12%) when injected into the CO NDIR Monitors does not indicate any interference (<0.1% of scale or 5 ppm v/v @ 0-5000 ppm v/v span). Ascarite as a result is not normally utilized in the sample train.

C) Sample Flow

Both monitors pump their own gas sample. The flow rate is maintained during the sample run.

D) Sample Interface

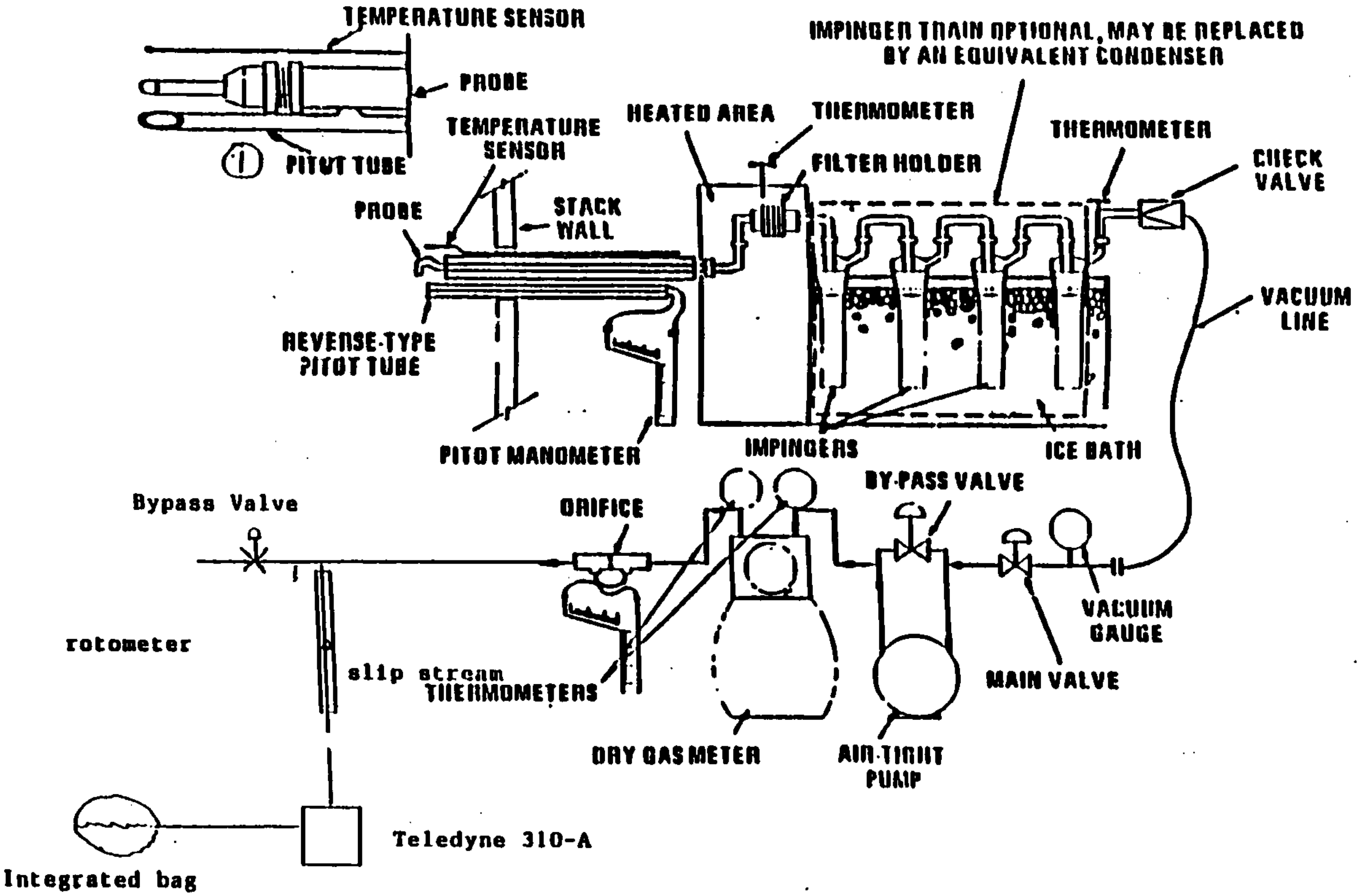
The interface is checked prior to and after each sampling session.

II. Sampling (CO)

CO instrument data is logged automatically utilizing one minute integrations.

PARTICULATE SAMPLING TRAIN

EPA Methods #1-5



EPA METHODS #1-4

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 m^2 (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:

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.

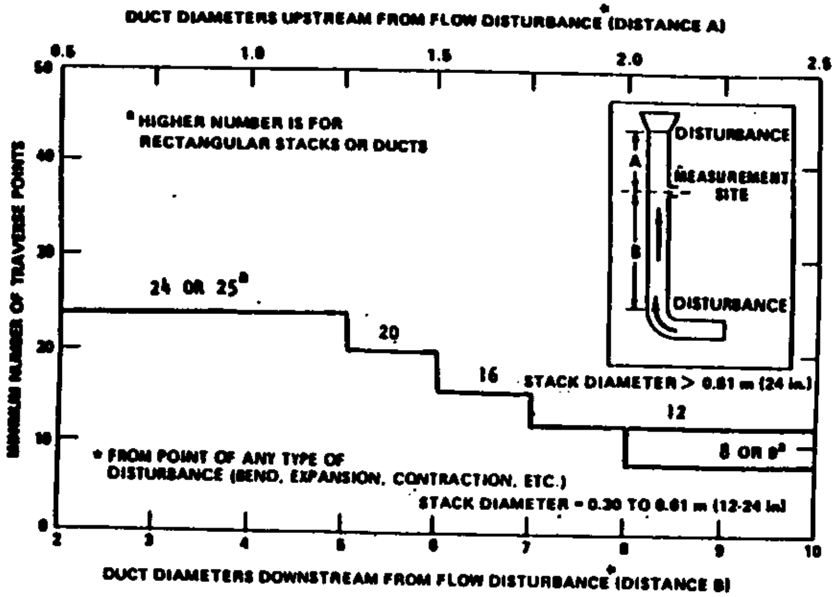


Figure 1-1. Minimum number of traverse points for particulate traverses.

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

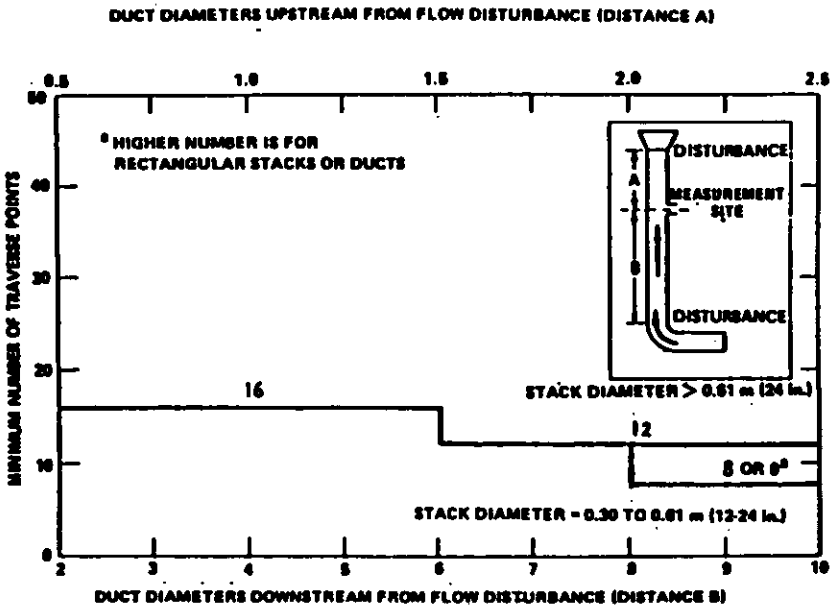


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

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

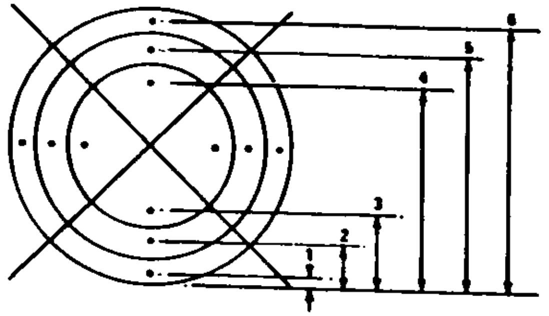


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

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.

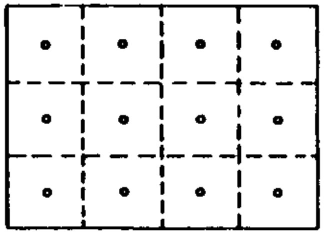


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

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:

$$R_i = \text{arc cosine}\ [(\text{cosine}\ Y_i)(\text{cosine}\ P_i)]$$

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:

$$\bar{R} = \frac{\Sigma R_i}{n}$$

Eq. 1–3

Where:

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

n=Total number of traverse points.

2.5.4.3 Calculate the standard deviations:

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

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.

3. *Bibliography*

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5. Hanson, H.A., et al. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. USEPA, ORD, ESRL, Research Triangle Park, NC. EPA–600/2–76–170, June 1976.

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13. Smith, W.S. and D.J. Grove. A Proposed Extension of EPA Method 1 Criteria. "Pollution Engineering." *XV* (8):36–37. August 1983.

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15. Smith, W.S. and D.J. Grove. A New Look at Isokinetic Sampling—Theory and Applications. "Source Evaluation Society Newsletter." *VIII* (3):19–24. August 1983.

2.1.1 **PM Measurements.** Select a PM sampling site located preferably at least 8 equivalent stack or duct diameters downstream and 10 equivalent diameters upstream from any flow disturbances such as bends, expansions, or contractions in the stack, or from a visible flame. Next, locate the velocity measurement site 8 equivalent diameters downstream of the PM sampling site. See Figure 1A–1. If such locations are not available, select an alternative PM sampling site that is at least 2 equivalent stack or duct diameters downstream and 2½ diameters upstream from any flow disturbance. Then, locate the velocity measurement site 2 equivalent diameters downstream from the PM sampling site. Follow Section 2.1 of Method 1 for calculating equivalent diameters for a rectangular cross section.

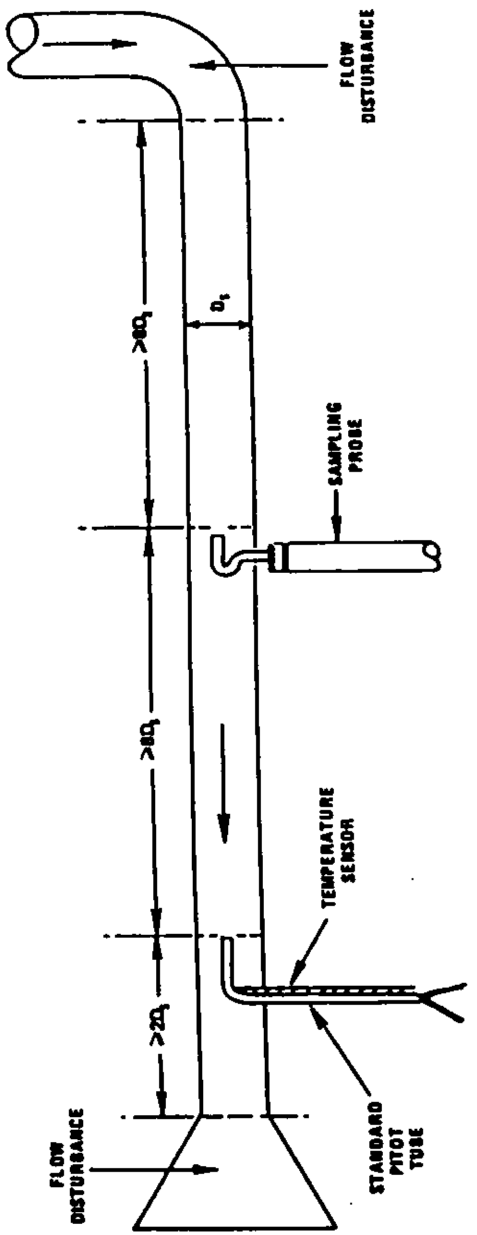

Figure 1A-1. Recommended sampling arrangement for small ducts.

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

1. Same as in Method 1, Section 3, Citations 1 through 6.

2. Vollaro, Robert F. Recommended Procedure for Sample Traverses in Ducts Smaller Than 12 Inches in Diameter. U.S. Environmental Protection Agency, Emission Measurement Branch, Research Triangle Park, NC. January 1977.

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.

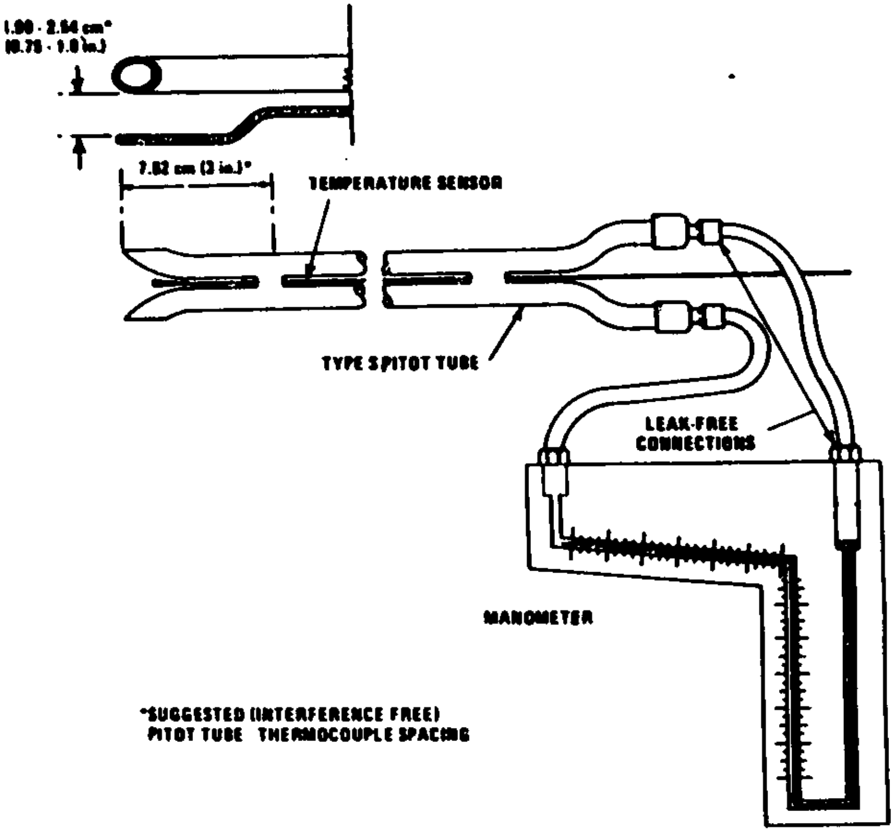

Figure 2-1. Type S pitot tube manometer assembly.

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 (3/16 and 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.

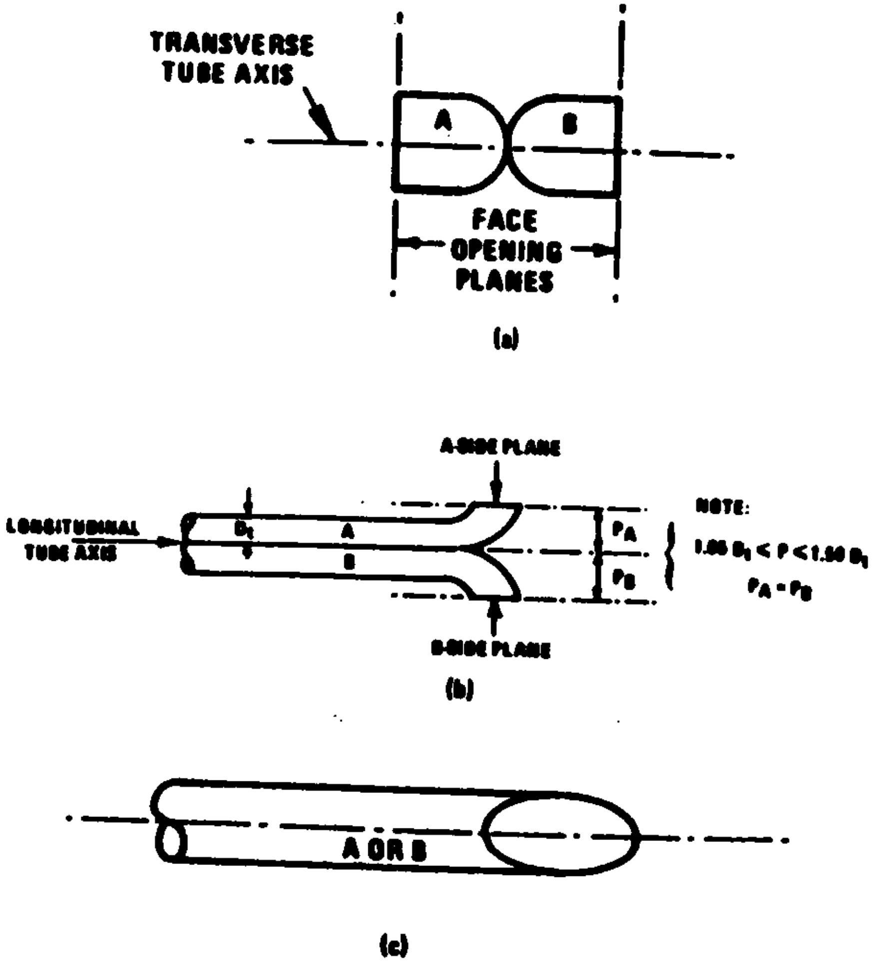

Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline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

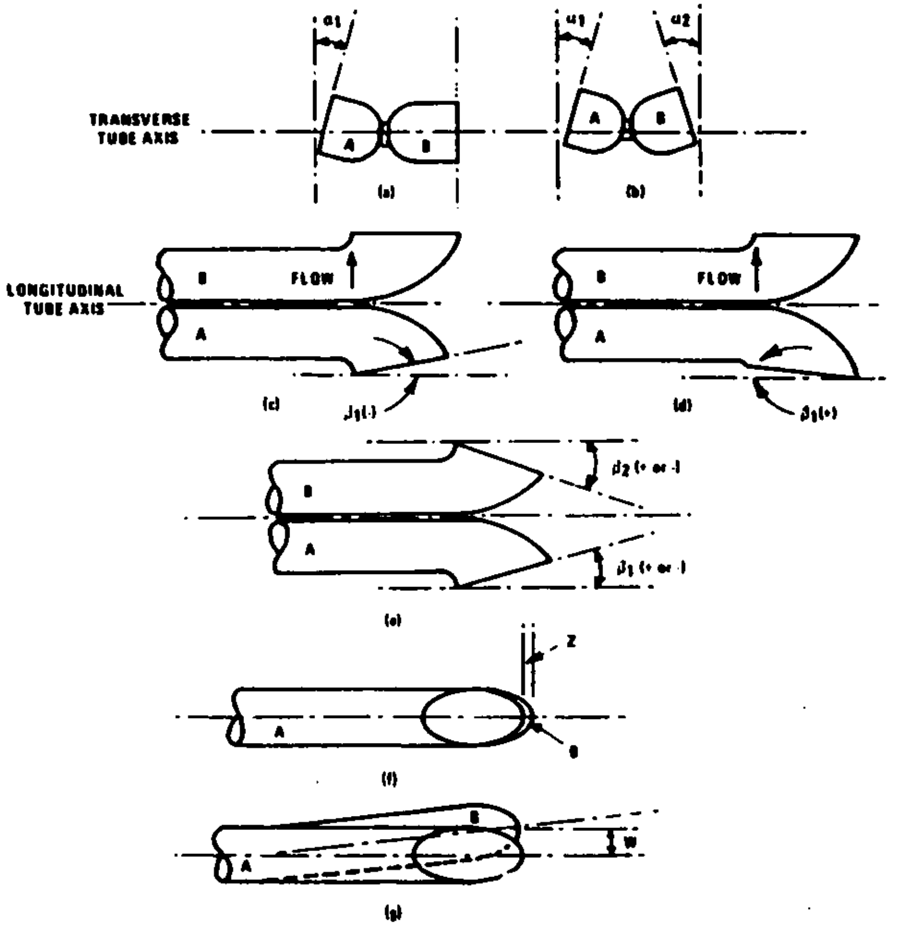

Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as α^1 and $\alpha^2 \leq 10°$, β^1 and $\beta^2 \leq 5°$, $z \leq 0.32$ cm (1/8 in.) and $w \leq 0.08$ cm (1/32 in.)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

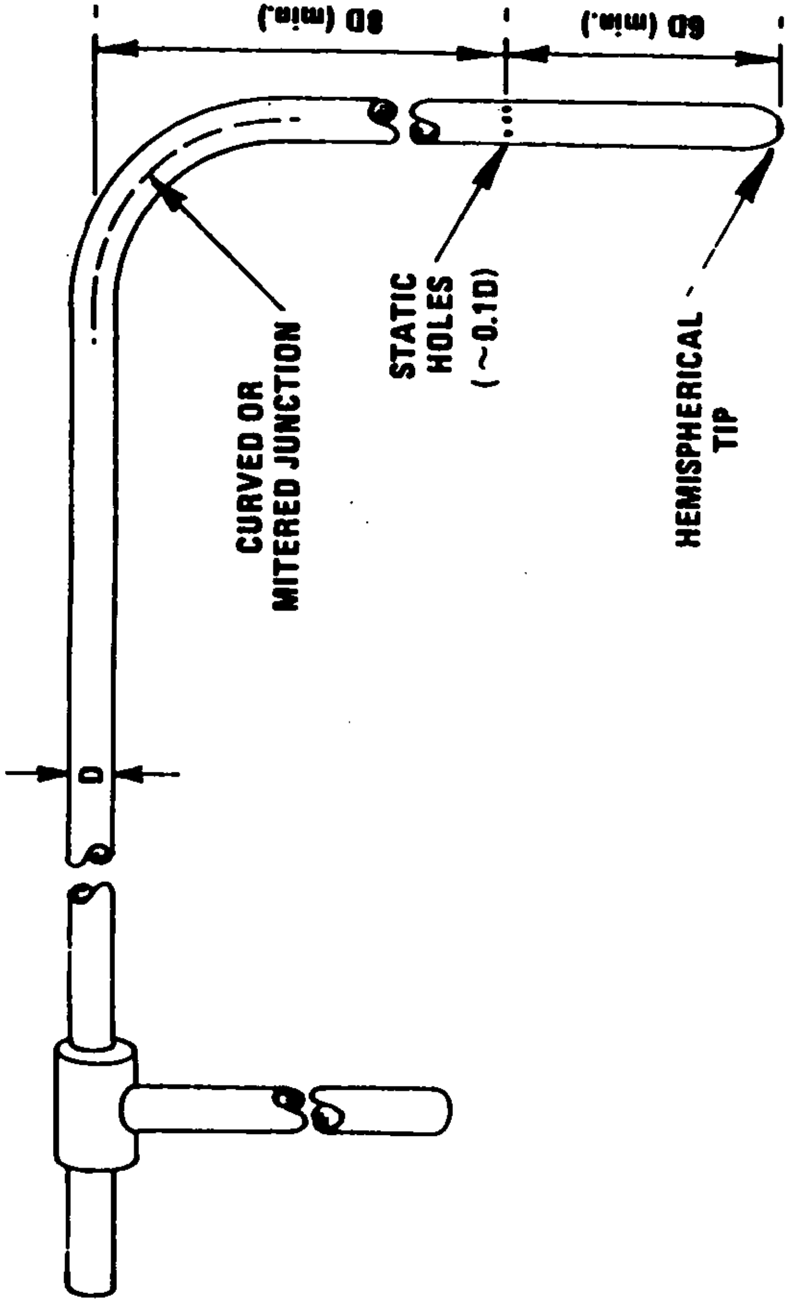

Figure 2-4. Standard pitot tube design specifications.

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_s 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:

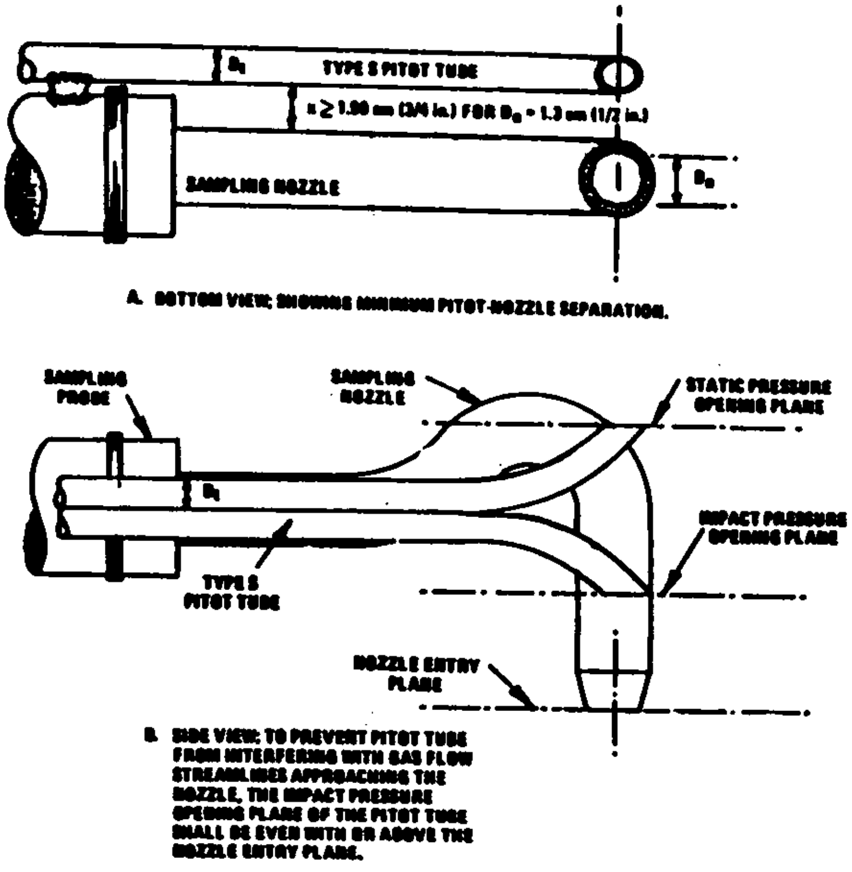

Figure 2-6. Proper pitot tube-sampling nozzle configuration to prevent aerodynamic interference; buttonhook-type nozzle; centers of nozzle and pitot opening aligned; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

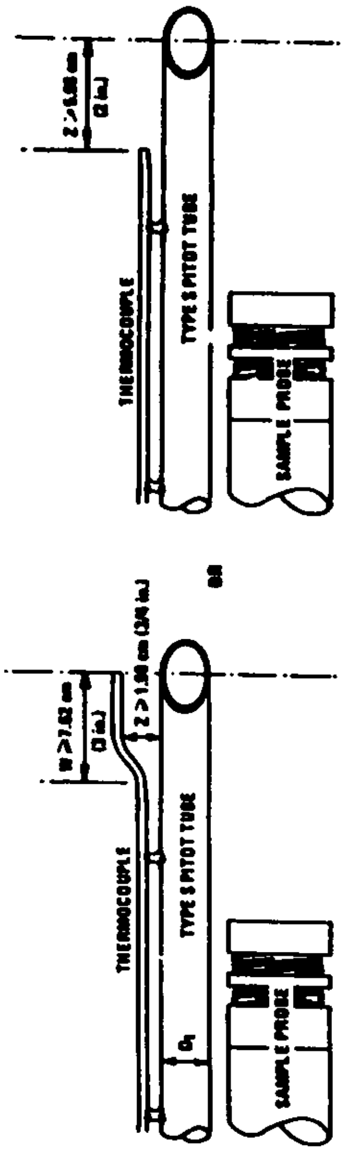

Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

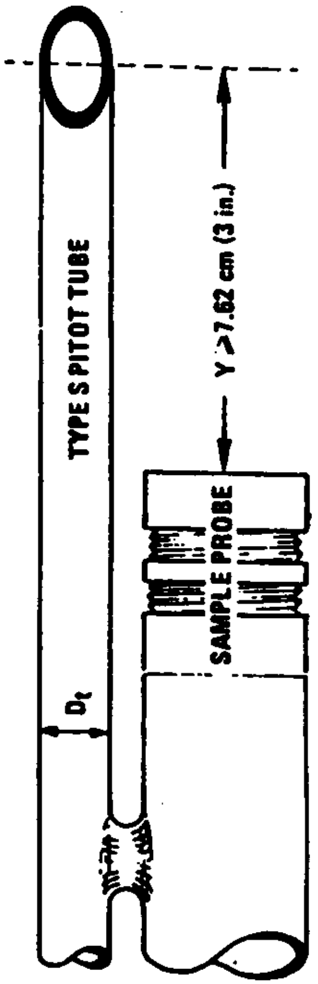

Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

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)		

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

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

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:

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

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).

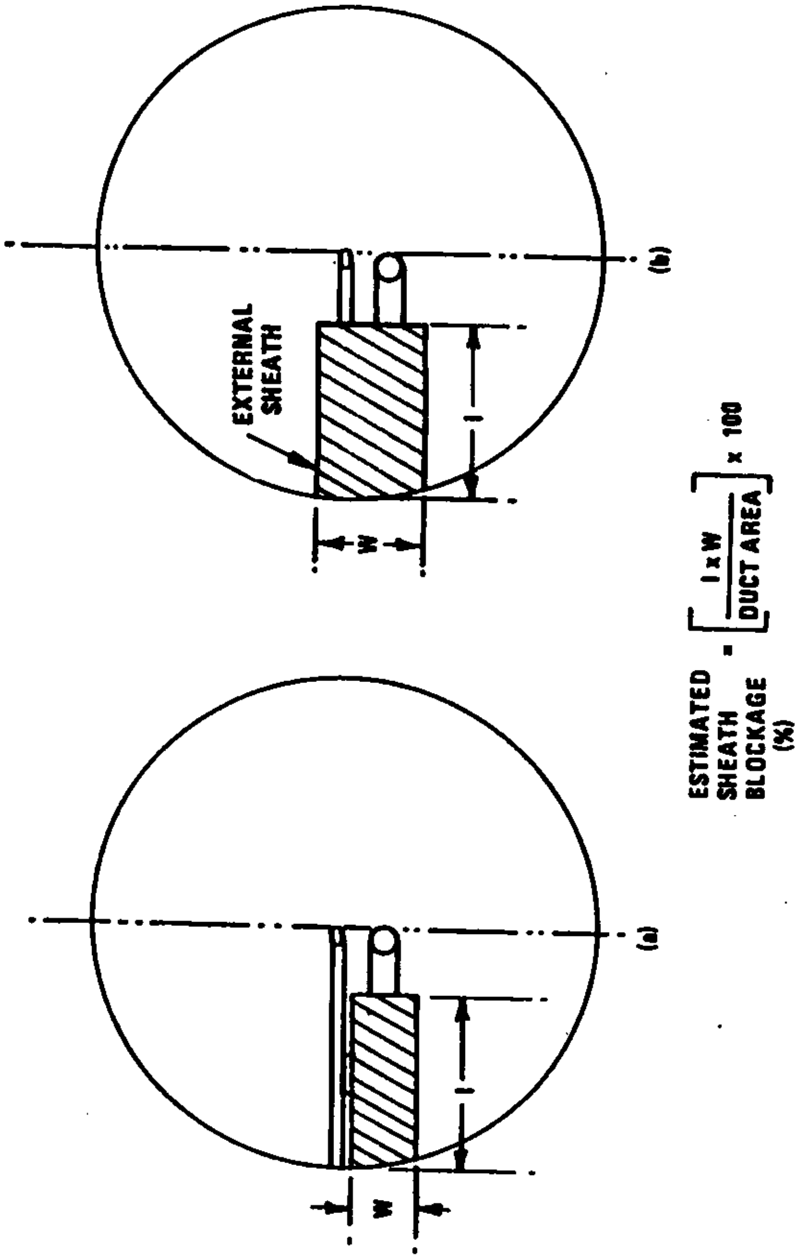

Figure 2-10. Projected-area models for typical pitot tube assemblies.

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,

$$34.97 \frac{m}{sec} \left[\frac{(g/g\text{-mole})(mm\ Hg)}{(°K)(mm\ H_2O)}\right]^{1/2}$$

for the metric system and

$$85.49 \frac{ft}{sec} \left[\frac{(lb/lb\text{-mole})(in.\ Hg)}{(°R)(in.\ H_2O)}\right]^{1/2}$$

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.

$$v_s = K_p C_p (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$

Equation 2-9

5.3 Average Stack Gas Dry Volumetric Flow Rate.

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

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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METHOD 2A—DIRECT MEASUREMENT OF GAS VOLUME THROUGH PIPES AND SMALL DUCTS

1. *Applicability and Principle*

1.1 Applicability. This method applies to the measurement of gas flow rates in pipes and small ducts, either in-line or at exhaust positions, within the temperature range of 0 to 50°C.

1.2 Principle. A gas volume meter is used to measure gas volume directly. Temperature and pressure measurements are made to correct the volume to 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 Gas Volume Meter. A positive displacement meter, turbine meter, or other direct volume measuring device capable of measuring volume to within 2 percent. The meter shall be equipped with a temperature gauge (±2 percent of the minimum absolute temperature) and a pressure gauge (±2.5 mm Hg). The manufacturer's recommended capacity of the meter shall be sufficient for the expected maximum and minimum flow rates at the sampling conditions. Temperature, pressure, corrosive characteristics, and pipe size are factors necessary to consider in choosing a suitable gas meter.

2.2 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm 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 the sampling point shall be applied at a rate of minus 2.5 mm Hg per 30-meter elevation increase, or vice-versa for elevation decrease.

2.3 Stopwatch. Capable of measurement to within 1 second.

3. *Procedure*

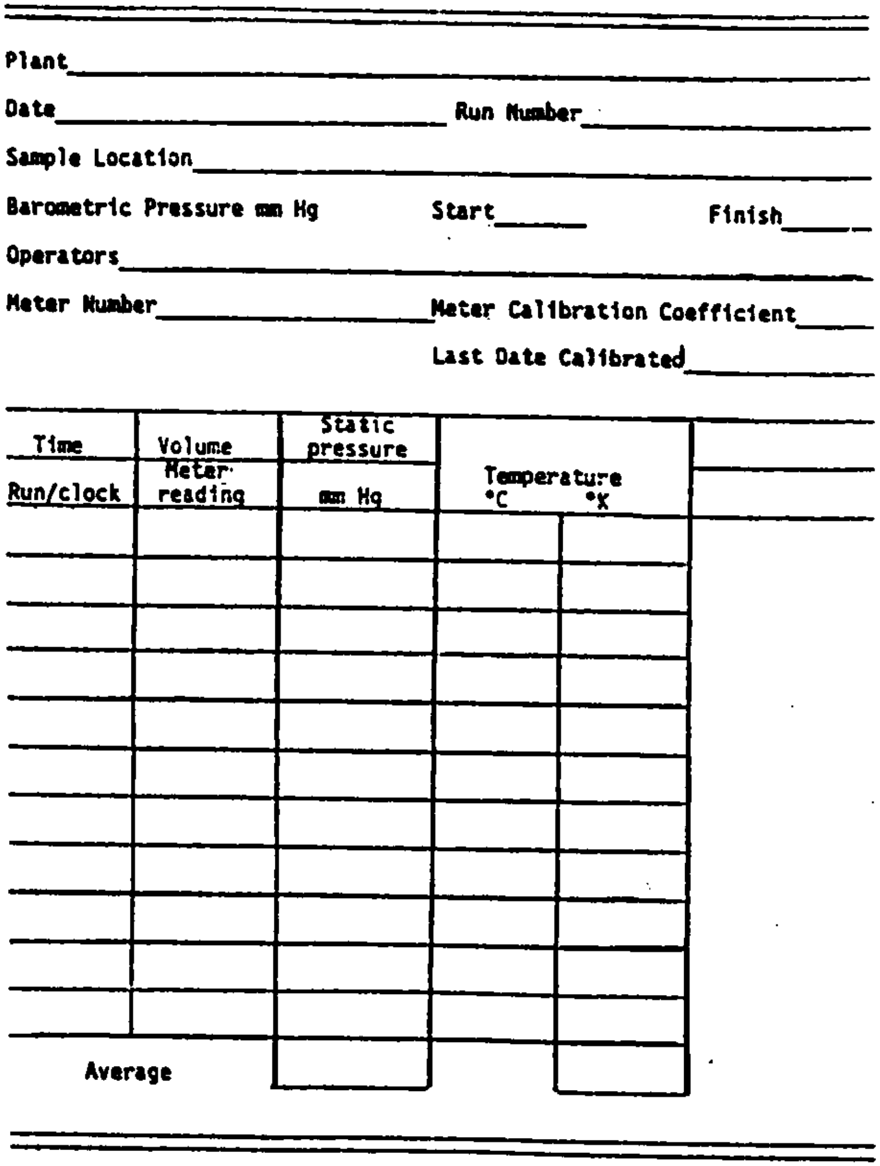
3.1 Installation. As there are numerous types of pipes and small ducts that may be subject to volume measurement, it would be difficult to describe all possible installation schemes. In general, flange fittings should be used for all connections wherever possible. Gaskets or other seal materials should be used to assure leak-tight connections. The volume meter should be located so as to avoid severe vibrations and other factors that may affect the meter calibration.

3.2 Leak Test. A volume meter installed at a location under positive pressure may be leak-checked at the meter connections by using a liquid leak detector solution containing a surfactant. Apply a small amount of the solution to the connections. If a leak exists, bubbles will form, and the leak must be corrected.

A volume meter installed at a location under negative pressure is very difficult to test for leaks without blocking flow at the inlet of the line and watching for meter movement. If this procedure is not possible, visually check all connections and assure tight seals.

3.3 Volume Measurement.

3.3.1 For sources with continuous, steady emission flow rates, record the initial meter volume reading, meter temperature(s), meter pressure, and start the stopwatch. Throughout the test period, record the meter temperature(s) and pressure so that average values can be determined. At the end of the test, stop the timer and record the elapsed time, the final volume reading, meter temperature(s), and pressure. Record the barometric pressure at the beginning and end of the test run. Record the data on a table similar to Figure 2A-1.



Plant____________________

Date____________________ Run Number____________

Sample Location____________________

Barometric Pressure mm Hg Start______ Finish______

Operators____________________

Meter Number____________ Meter Calibration Coefficient______

Last Date Calibrated____________

Time Run/clock	Volume Meter reading	Static pressure mm Hg	Temperature °C	 °K
Average				

Figure 2A-1. Volume flow rate measurement data.

3.3.2 For sources with noncontinuous, non-steady emission flow rates, use the procedure in 3.3.1 with the addition of the following: Record all the meter parameters and the start and stop times corresponding to each process cyclical or noncontinuous event.

4. *Calibration*

4.1 Volume Meter. The volume meter is calibrated against a standard reference meter prior to its initial use in the field. The reference meter is a spirometer or liquid displacement meter with a capacity consistent with that of the test meter.

Alternatively, a calibrated, standard pitot may be used as the reference meter in conjunction with a wind tunnel assembly. Attach the test meter to the wind tunnel so that the total flow passes through the test meter. For each calibration run, conduct a 4-point traverse along one stack diameter at a position at least eight diameters of straight tunnel downstream and two diameters upstream of any bend, inlet, or air mover. Determine the traverse point locations as specified in Method 1. Calculate the reference volume using the velocity values following the procedure in Method 2, the wind tunnel cross-sectional area, and the run time.

Set up the test meter in a configuration similar to that used in the field installation (i.e., in relation to the flow moving device). Connect the temperature and pressure gauges as they are to be used in the field. Connect the reference meter at the inlet of the flow line, if appropriate for the meter, and begin gas flow through the system to condition the meters. During this conditioning operation, check the system for leaks.

The calibration shall be run over at least three different flow rates. The calibration flow rates shall be about 0.3, 0.6, and 0.9 times the test meter's rated maximum flow rate.

For each calibration run, the data to be collected include: reference meter initial and final volume readings, the test meter initial and final volume reading, meter average temperature and pressure, barometric pressure, and run time. Repeat the runs at each flow rate at least three times.

Calculate the test meter calibration coefficient, Y_m, for each run as follows:

$$Y_m = \frac{(V_{rf} - V_{ri})\,(t_r + 273)}{(V_{mf} - V_{mi})(t_m + 273)} \quad \frac{P_b}{(P_b + P_g)}$$

Eq. 2A–1

Where:

Y_m=Test volume meter calibration coefficient, dimensionless.
V_r=Reference meter volume reading, m³.
V_m=Test meter volume reading, m³.
t_r=Reference meter average temperature, °C.
t_m=Test meter average temperature, °C.
P_b=Barometric pressure, mm Hg.
P_g=Test meter average static pressure, mm Hg.
f=Final reading for run.
i=Initial reading for run.

Compare the three Y_m values at each of the flow rates tested 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 runs may be required to complete this requirement. If this specification cannot be met in six successive runs, the test meter is not suitable for use. In addition, the meter coefficients should be between 0.95 and 1.05. If these specifications are met at all the flow rates, average all the Y_m values from runs meeting the specifications to obtain an average meter calibration coefficient, Y_m.

The procedure above shall be performed at least once for each volume meter. Thereafter, an abbreviated calibration check shall be completed following each field test. The calibration of the volume meter shall be checked by performing three calibration runs at a single, intermediate flow rate (based on the previous field test) with the meter pressure set at the average value encountered in the field test. 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 flow as described above.

NOTE.—If the volume meter calibration 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 greater value of pollutant emission rate.

4.2 Temperature Gauge. After each test series, check the temperature gauge at ambient temperature. Use an American Society for Testing and Materials (ASTM) mercury-in-glass reference thermometer, or equivalent, as a reference. If the gauge being checked agrees within 2 percent (absolute temperature) of the reference, the temperature data collected in the field shall be considered valid. Otherwise, the test data shall be considered invalid or adjustments of the test results shall be made, subject to the approval of the Administrator.

4.3 Barometer. Calibrate the barometer used against a mercury barometer prior to the field test.

5. *Calculations*

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

tions throughout the test. During periods of process interruption and halting of gas flow, stop the timer and mark the recorder strip charts so that data from this interruption are not included in the calculations. At the end of the test period, record the final parameters for the inlet volume meter and mark the end on all of the recorder strip charts.

3.6 Post Test Calibrations. At the conclusion of the sampling period, introduce the calibration gases as specified in the respective reference methods. If an analyzer output does not meet the specifications of the method, invalidate the test data for the period. Alternatively, calculate the volume results using initial calibration data and using final calibration data and report both resulting volumes. Then, for emissions calculations, use the volume measurement resulting in the greatest emission rate or concentration.

4. *Calculations*

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

4.1 Nomenclature.

CO_e=Mean carbon monoxide concentration in system exhaust, ppm.

CO_{2e}=Mean carbon dioxide concentration in system exhaust, ppm.

HC_e=Mean organic concentration in system exhaust as defined by the calibration gas, ppm.

HC_i=Mean organic concentration in system inlet as defined by the calibration gas, ppm.

K=Calibration gas factor

=2 for ethane calibration gas.

=3 for propane calibration gas.

=4 for butane calibration gas.

=Appropriate response factor for other calibration gas.

V_{es}=Exhaust gas volume, m^3.

V_{is}=Inlet gas volume, m^3.

Q_{es}=Exhaust gas volume flow rate, m^3/min.

Q_{is}=Inlet gas volume flow rate, m^3/min.

Θ=Sample run time, min.

s=Standard conditions: 20°C, 760 mm Hg.

300=Estimated concentration of ambient CO_2, ppm. (CO_2 concentration in the ambient air may be measured during the test period using an NDIR).

4.2 Concentrations. Determine mean concentrations of inlet organics, outlet CO_2, outlet CO, and outlet organics according to the procedures in the respective methods and the analyzers' calibration curves, and for the time intervals specified in the applicable regulations. Concentrations should be determined on a parts per million by volume (ppm) basis.

4.3 Exhaust Gas Volume. Calculate the exhaust gas volume as follows:

$$V_{es} = V_{is} \frac{K(HC_i)}{K(HC_e)+CO_{2e}+CO_e-300}$$

Eq. 2B-1

4.4 Exhaust Gas Volume Flow Rate. Calculate the exhaust gas volume flow rate as follows:

$$Q_{es}=V_{es}/\theta$$

Eq. 2B-2

5. *Bibliography*

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METHOD 2C—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE IN SMALL STACKS OR DUCTS (STANDARD PITOT TUBE)

1. Applicability and Principle

1.1 Applicability.

1.1.1 The applicability of this method is identical to Method 2, except this method is limited to stationery source stacks or ducts less than about 0.30 meter (12 in.) in diameter or 0.071 m^2 (113 $in.^2$) in cross-sectional area, but equal to or greater than about 0.10 meter (4 in.) in diameter or 0.0081 m^2 (12.57 $in.^2$) in cross-sectional area.

1.1.2 The apparatus, procedure, calibration, calculations, and bibliography are the same as in Method 2, Sections 2, 3, 4, 5, and 6, except as noted in the following sections.

1.2 Principle. The average gas velocity in a stack or duct is determined from the gas density and from measurement of velocity heads with a standard pitot tube.

2. Apparatus

2.1 Standard Pitot Tube (instead of Type S). Use a standard pitot tube that meets the specifications of Section 2.7 of Method 2. Use a coefficient value of 0.99 unless it is calibrated against another standard pitot tube with an NBS-traceable coefficient.

2.2 Alternative Pitot Tube. A modified hemispherical-nosed pitot tube (see Figure 2C-1), which features a shortened stem and enlarged impact and static pressure holes, may be used. This pitot tube is useful in liquid drop-laden gas streams when a pitot "back purge" is ineffective. Use a coefficient value of 0.99 unless the pitot is calibrated as mentioned in Section 2.1 above.

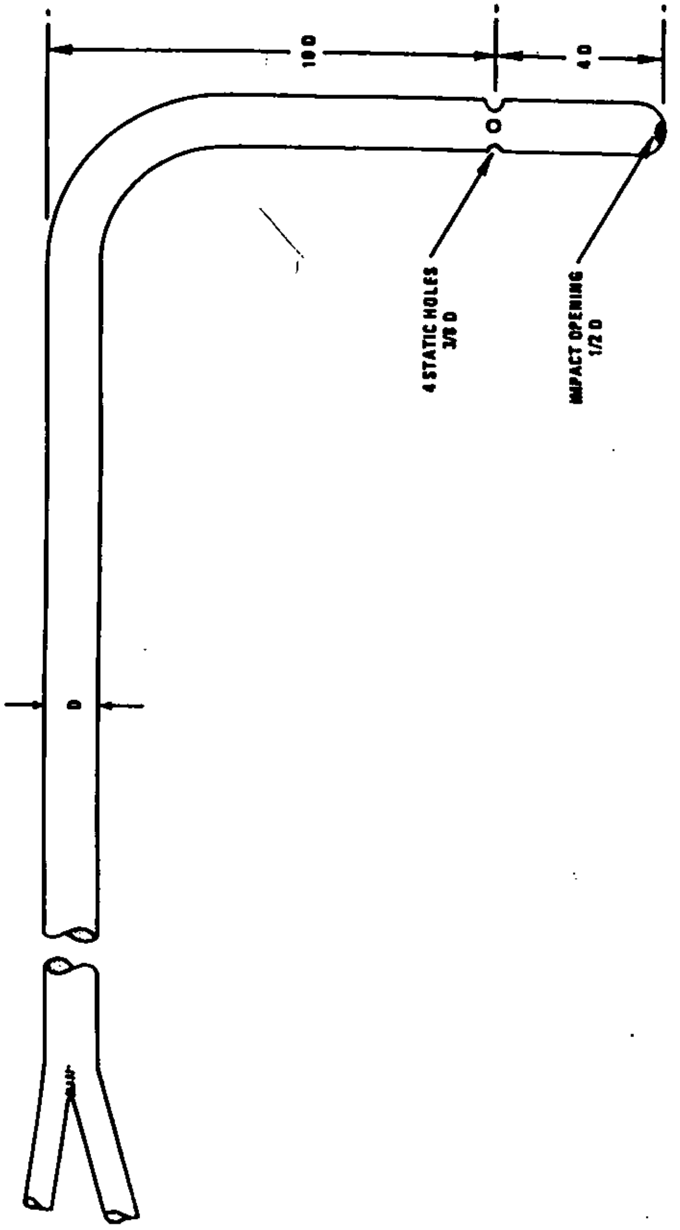

Figure 2C-1. Modified hemispherical-nosed pitot tube.

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.

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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 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.

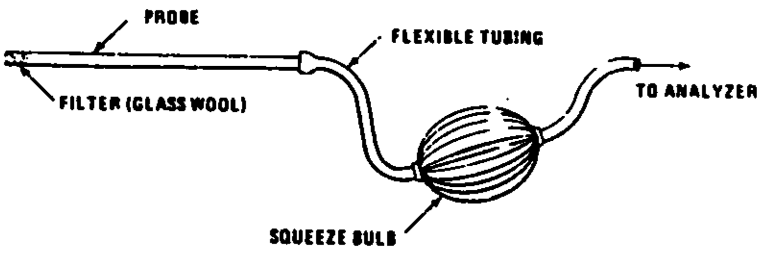

Figure 3-1. Grab-sampling train.

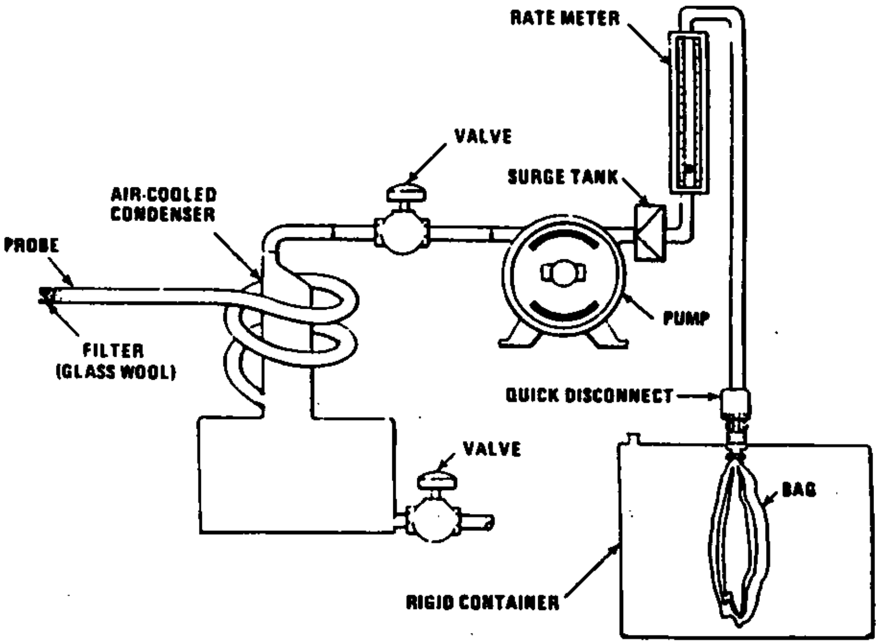

Figure 3-2. Integrated gas-sampling train.

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.[a]
Average			

[a] % 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.

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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 i emissions from stationary sources only whe specified within the regulations.

1.2 Principle. A sample is continuousl extracted from the effluent stream: a portio of the sample stream is conveyed to an instrumental analyzer(s) for determination o O_2 and CO_2 concentration(s). Performanc 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 averag O_2 or CO_2 concentration is not less than 2 percent of the span.

3. *Definitions*

3.1 Measurement System. The total equipment required for the determination of th

O_2 or CO_2 concentration. The measurement system consists of the same major subsystems as defined in Method 6C, Sections 3.1.1, 3.1.2, and 3.1.3.

3.2 Span, Calibration Gas, Analyzer Calibration Error, Sampling System Bias, Zero Drift, Calibration Drift, Response Time, and Calibration Curve. Same as Method 6C, Sections 3.2 through 3.8, and 3.10.

3.3 Interference Response. The output response of the measurement system to a component in the sample gas, other than the gas component being measured.

4. *Measurement System Performance Specifications*

Same as Method 6C, Sections 4.1 through 4.4.

5. *Apparatus and Reagents*

5.1 Measurement System. Any measurement system for O_2 or CO_2 that meets the specifications of this method. A schematic of an acceptable measurement system is shown in Figure 6C–1 of Method 6C. The essential components of the measurement system are described below:

5.1.1 Sample Probe. A leak-free probe, of sufficient length to traverse the sample points.

5.1.2 Sample Line. Tubing, to transport the sample gas from the probe to the moisture removal system. A heated sample line is not required for systems that measure the O_2 or CO_2 concentration on a dry basis, or transport dry gases.

5.1.3 Sample Transport Line, Calibration Value Assembly, Moisture Removal System, Particulate Filter, Sample Pump, Sample Flow Rate Control, Sample Gas Manifold, and Data Recorder. Same as Method 6C, Sections 5.1.3 through 5.1.9, and 5.1.11, except that the requirements to use stainless steel, Teflon, and nonreactive glass filters do not apply.

5.1.4 Gas Analyzer. An analyzer to determine continuously the O_2 or CO_2 concentration in the sample gas stream. The analyzer shall meet the applicable performance specifications of Section 4. A means of controlling the analyzer flow rate and a device for determining proper sample flow rate (e.g., precision rotameter, pressure gauge downstream of all flow controls, etc.) shall be provided at the analyzer. The requirements for measuring and controlling the analyzer flow rate are not applicable if data are presented that demonstrate the analyzer is insensitive to flow variations over the range encountered during the test.

5.2 Calibration Gases. The calibration gases for CO_2 analyzers shall be CO_2 in N_2 or CO_2 in air. Alternatively, CO_2/SO_2, O_2/SO_2, or $O_2/CO_2/SO_2$ gas mixtures in N_2 may be used. Three calibration gases, as specified Section 5.3.1 through 5.3.3 of Method 6C, shall be used. For O_2 monitors that cannot analyze zero gas, a calibration gas concentration equivalent to less than 10 percent of the span may be used in place of zero gas.

6. *Measurement System Performance Test Procedures*

Perform the following procedures before measurement of emissions (Section 7).

6.1 Calibration Concentration Verification. Follow Section 6.1 of Method 6C, except if calibration gas analysis is required, use Method 3 and change the acceptance criteria for agreement among Method 3 results to 5 percent (or 0.2 percent by volume, whichever is greater).

6.2 Interference Response. Conduct an interference response test of the analyzer prior to its initial use in the field. Thereafter, recheck the measurement system if changes are made in the instrumentation that could alter the interference response (e.g., changes in the type of gas detector). Conduct the interference response in accordance with Section 5.4 of Method 20.

6.3 Measurement System Preparation, Analyzer Calibration Error, and Sampling System Bias Check. Follow Sections 6.2 through 6.4 of Method 6C.

7. *Emission Test Procedure*

7.1 Selection of Sampling Site and Sampling Points. Select a measurement site and sampling points using the same criteria that are applicable to tests performed using Method 3.

7.2 Sample Collection. Position the sampling probe at the first measurement point, and begin sampling at the same rate as used during the sampling system bias check. Maintain constant rate sampling (i.e., ±10 percent) during the entire run. The sampling time per run shall be the same as for tests conducted using Method 3 plus twice the system response time. For each run, use only those measurements obtained after twice the response time of the measurement system has elapsed to determine the average effluent concentration.

7.3 Zero and Calibration Drift Test. Follow Section 7.4 of Method 6C.

8. *Quality Control Procedures*

The following quality control procedures are recommended when the results of this method are used for an emission rate correction factor, or excess air determination. The tester should select one of the following options for validating measurement results:

8.1 If both O_2 and CO_2 are measured using Method 3A, the procedures described in Section 4.4 of Method 3 should be followed to validate the O_2 and CO_2 measurement results.

8.2 If only O_2 is measured using Method 3A, measurements of the sample stream CO_2 concentration should be obtained at the sample by-pass vent discharge using an Orsat or Fyrite analyzer, or equivalent. Duplicate samples should be obtained concurrent with

at least one run. Average the duplicate Orsat or Fyrite analysis results for each run. Use the average CO_2 values for comparison with the O_2 measurements in accordance with the procedures described in Section 4.4 of Method 3.

8.3 If only CO_2 is measured using Method 3A, concurrent measurements of the sample stream CO_2 concentration should be obtained using an Orsat or Fyrite analyzer as described in Section 8.2. For each run, differences greater than 0.5 percent between the Method 3A results and the average of the duplicate Fyrite analysis should be investigated.

9. *Emission Calculation*

For all CO_2 analyzers, and for O_2 analyzers that can be calibrated with zero gas, follow Section 8 of Method 6C, except express all concentrations as percent, rather than ppm.

For O_2 analyzers that use a low-level calibration gas in place of a zero gas, calculate the effluent gas concentration using Equation 3A–1.

$$C_{gas} = \frac{C_{ma} - C_{oa}}{C_m - C_o} (\check{C} - C_m) + C_{ma}$$

Eq. 3A–1

Where:

C_{gas}=Effluent gas concentration, dry basis, percent.

C_{ma}=Actual concentration of the upscale calibration gas, percent.

C_{oa}=Actual concentration of the low-level calibration gas, percent.

C_m=Average of initial and final system calibration bias check responses for the upscale calibration gas, percent.

C_o=Average of initial and final system calibration bias check responses for the low-level gas, percent.

$\check{C}$=Average gas concentration indicated by the gas analyzer, dry basis, percent.

10. *Bibliography*

Same as bibliography of Method 6C.

METHOD 3B—GAS ANALYSIS FOR THE DETERMINATION OF EMISSION RATE CORRECTION FACTOR OR EXCESS AIR

1. APPLICABILITY AND PRINCIPLE

1.1 Applicability

1.1.1 This method is applicable for determining carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) concentrations of a sample from a gas stream of a fossil-fuel combustion provess for excess air or emission rate correction factor calculations.

1.1.2 Other methods, as well as modifications to the procedure described herein, are also applicable for 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, and (2) a method using CO_2 or O_2 and stoichiometric calculations to determine excess air. These methods and modifications may be used, but are subject to the approval of the Administrator, U.S. Environmental Protection Agency (FPA).

1.1.3 Note. Mention of trade names or specific products does not constitute endorsement 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 percent CO_2 percent O_2, and, if necessary, percent CO. An Orsat analyzer must be used for excess air or emission rate correction factor determinations.

2. APPARATUS

The alternative sampling systems are the same as those mentioned in Section 2 of Method 3.

2.1 Grab Sampling and Integrated Sampling. Same as in Sections 2.1 and 2.2, respectively, of Method 3.

2.2 Analysis. An Orsat analyzer only. Fo low CO_2 (less than 4.0 percent) or high O (greater than 15.0 percent) concentrations the measuring burette of the Orsat mus have at least 0.1 percent subdivisions. Fo Orsat maintenance and operation procedures, follow the instructions recommende by the manufacturer, unless otherwise specified herein.

3. PROCEDURES

Each of the three procedures below shall b used only when specified in an applicabl subpart of the standards. The use of thes procedures for other purposes must have specific prior approval of the Adminsitrator.

NOTE.—A Fyrite-type combustion gas analyzer is not acceptable for excess air or emis sion rate correction factor determination unless approved by the Administrator. I both percent CO_2 and percent O_2 are meas ured, the analytical results of any of th three procedures given below may be used fo calculating the dry molecular weight (se Method 3).

3.1 Single-Point, Grab Sampling and Analytic Procedure.

3.1.1 The sampling point in the duct sho be as described in Section 3.1 of Method 3.

3.1.2 Set up the equipment as shown in Fi ure 3–1 of Method 3, making sure all conne tions ahead of the analyzer are tight. Lea check the Orsat analyzer according to th procedure described in Section 6 of Method This leak check is mandatory.

3.1.3 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. For emission rate correction factor determinations, immediately analyze the sample, as outlined in Sections 3.1.4 and 3.1.5, for percent CO_2 or percent O_2. If excess air is desired, proceed as follows: (1) immediately analyze the sample, as in Sections 3.1.4 and 3.1.5, for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent, and (3) calculate percent excess air as outlined in Section 4.2.

3.1.4 To ensure complete absorption of the CO_2, O_2, or if applicable, CO, make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three or four) should be made between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

NOTE.—Since this single-point, grab sampling and analytical procedure is normally conducted in conjunction with a single-point, grab sampling and analytical procedure for a pollutant, only one analysis is ordinarily conducted. Therefore, great care must be taken to obtain a valid sample and analysis. Although in most cases, only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 3.4 be used to validate the analytical data.

3.1.5 After the analysis is completed, leak check (mandatory) the Orsat analyzer once again, as described in Section 6 of Method 3. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis.

3.2 Single-Point, Integrated Sampling and Analytical Procedure.

3.2.1 The sampling point in the duct shall be located as specified in Section 3.1.1.

3.2.2 Leak check (mandatory) the flexible bag as in Section 2.2.6 of Method 3. Set up the equipment as shown in Figure 3–2 of Method 3. Just before sampling, leak check (mandatory) the train as described in Section 4.2 of Method 3.

3.2.3 Sample at a constant rate, or as specified by the Administrator. The sampling run must be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collect at least 30 liters (1.00 ft^3) of sample gas. Smaller volumes may be collected, subject to approval of the Administrator.

3.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. For emission rate correction factor determination, analyze the sample within 4 hours after it is taken for percent CO_2 or percent O_2 (as outlined in Sections 3.2.5 through 3.2.7). The Orsat analyzer must be leak checked (see Section 6 of Method 3) before the analysis. If excess air is desired, procede as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 3.2.5 through 3.2.7) for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air, as outlined in Section 4.2.

3.2.5 To ensure complete absorption of the CO_2, O_2, or if applicable, CO, follow the procedure described in Section 3.1.4.

NOTE.—Although in most instances only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 3.4.1 be used to validate the analytical data.

3.2.6 Repeat the analysis until the following criteria are met:

3.2.6.1 For percent CO_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when CO_2 is greater than 4.0 percent or (b) 0.2 percent by volume when CO_2 is less than or equal to 4.0 percent. Average three acceptable values of percent CO_2, and report the results to the nearest 0.2 percent.

3.2.6.2 For percent O_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when O_2 is less than 15.0 percent or (b) 0.2 percent by volume when O_2 is greater than or equal to 15.0 percent. Average the three acceptable values of percent O_2, and report the results to the nearest 0.1 percent.

3.2.6.3 For percent CO, repeat the analytical procedure until the results of any three analyses differ by no more than 0.3 percent. Average the three acceptable values of percent CO, and report the results to the nearest 0.1 percent.

3.2.7 After the analysis is completed, leak check (mandatory) the Orsat analyzer once again, as described in Section 6 of Method 3. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis.

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

3.3.1 The sampling points shall be determined as specified in Section 5.3 of Method 3.

3.3.2 Follow the procedures outlined in Sections 3.2.2 through 3.2.7, 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 of Method 3.

3.4 Quality Control Procedure.

3.4.1 Data Validation When Both CO_2 and O_2 Are Measured. Although in most instances, only CO_2 or O_2 measurement is required, it is recommended that both CO_2 and O_2 be measured to provide a check on the quality of the data. The following quality control procedure is suggested.

NOTE.—Since the method for validating the CO_2 and O_2 analyses is based on combustion of organic and fossil fuels and dilution of the gas stream with air, this method does not apply to sources that (1) remove CO_2 or O_2 through processes other than combustion, (2) add O_2 (e.g., oxygen enrichment) and N_2 in proportions different from that of air, (3) add CO_2 (e.g., cement or lime kilns) or (4) have no fuel factor, F_o, values obtainable (e.g., extremely variable waste mixtures). This method validates the measured proportions of CO_2 and O_2 for fuel type, but the method does not detect sample dilution resulting from leaks during or after sample collection. The method is applicable for samples collected downstream of most lime or limestone flue-gas desulfurization units as the CO_2 added or removed from the gas stream is not significant in relation to the total CO_2 concentration. The CO_2 concentrations from other types of scrubbers using only water or basic slurry can be significantly affected and would render the F_o check minimally useful.

3.4.1.1 Calculate a fuel factor, F_o, using the following equation:

$$F_o = \frac{20.9 - \%O_2}{\%CO_2} \qquad \text{Eq. 3B–1}$$

where:

$\%O_2$=Percent O_2 by volume, dry basis.
$\%CO_2$=Percent CO_2 by volume, dry basis.
20.9=Percent O_2 by volume in ambient air.

If CO present in quantities measurable by this method, adjust the O_2 and CO_2 values before performing the calculation for F_o as follows:

$\%CO_2\ (adj) = \%CO_2 + \%CO$
$\%O_2\ (adj) = \%O_2 - 0.5\ \%CO$
where:

%5CO = Percent CO by volume, dry basis.

3.4.1.2 Compare the calculated F_o factor with the expected F_o values. The following table may be used in establishing acceptable ranges for the expected F_o if the fuel being burned is known. When fuels are burned in combinations, calculate the combined fuel F_d and F_c factors (as defined in Method 19) according to the procedure in Method 19, Section 5.2.3. Then calculate the F_o factor as follows:

$$F_o = \frac{0.209\ F_d}{F_c} \qquad \text{Eq. 3B–2}$$

Fuel type	F_o range
Coal:	
Anthracite and lignite	1.016–1.130
Bituminous	1.083–1.230
Oil:	
Distillate	1.260–1.413
Residual	1.210–1.370
Gas:	
Natural	1.600–1.836
Propane	1.434–1.586
Butane	1.405–1.553
Wood	1.000–1.120
Wood bark	1.003–1.130

3.4.1.3 Calculated F_o values, beyond the acceptable ranges shown in this table, should be investigated before accepting the test results. For example, the strength of the solutions in the gas analyzer and the analyzing technique should be checked by sampling and analyzing a known concentration, such as air; the fuel factor should be reviewed and verified. An acceptability range of ±12 percent is appropriate for the F_o factor of mixed fuels with variable fuel ratios. The level of the emission rate relative to the compliance level should be considered in determining if a retest is appropriate, i.e., if the measured emissions are much lower or much greater than the compliance limit, repetition of the test would not significantly change the compliance status of the source and would be unnecessarily time consuming and costly.

4. CALCULATIONS

4.1 Nomenclature. Same as Section 5 of Method 3 with the addition of the following:

%EA = Percent excess air.
0.264 = Ratio of O_2 to N_2 in air, v/v.

4.2 Percent Excess Air. Calculate the percent excess air (if applicable) by substituting the appropriate values of percent O_2, CO, and N_2 (obtained from Section 3.1.3 or 3.2.4) into Equation 3B–3.

$$\%EA = \frac{\%O_2 - 0.5\ \%CO}{0.264\ \%N_2 - (\%O_2 - 0.5\ \%CO)} \times 100 \qquad \text{Eq. 3B–3}$$

NOTE.—The equation above assumes that ambient air is used as the source of O_2 and that the fuel does not contain appreciable amounts of N_2 (as do coke oven or blast furnace gases). For those cases when appreciable amounts of N_2 are present (coal, oil and natural gas do not contain appreciable amounts of N_2) or when oxygen enrichment is used, alternative methods, subject to approval of the Administrator, are required.

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.

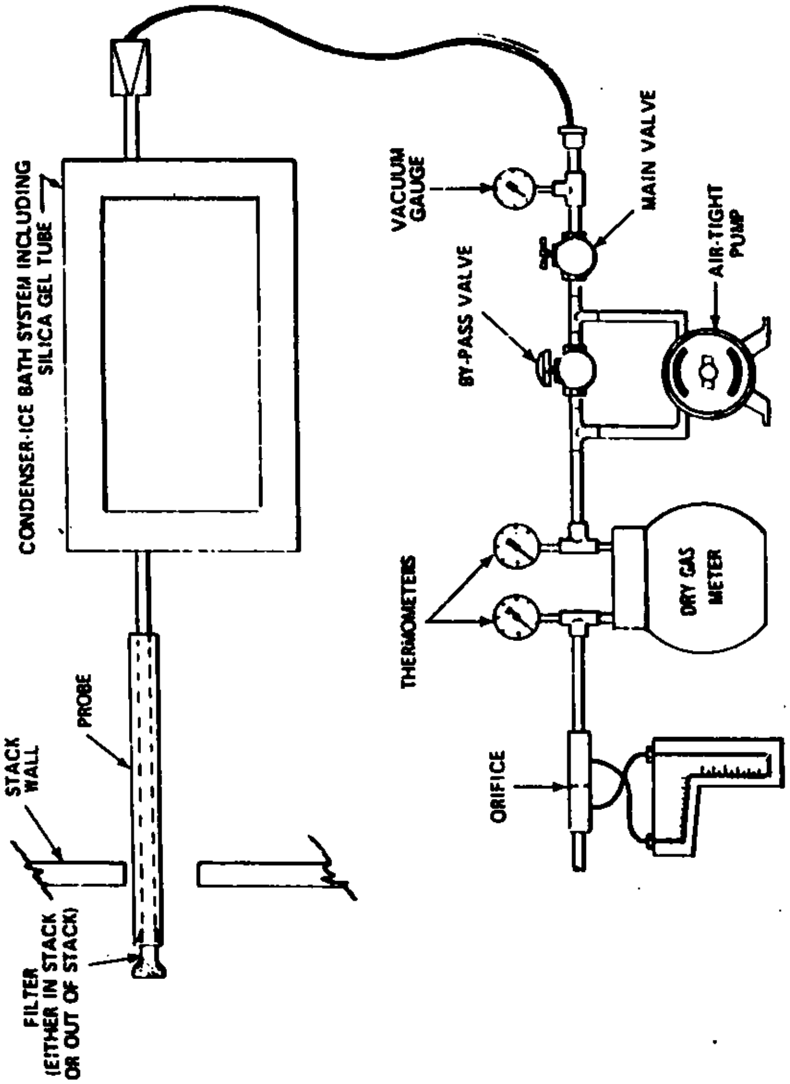

Figure 4-1. Moisture sampling train-reference method.

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 m^3/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 m^3/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.

EPA METHOD #5

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:

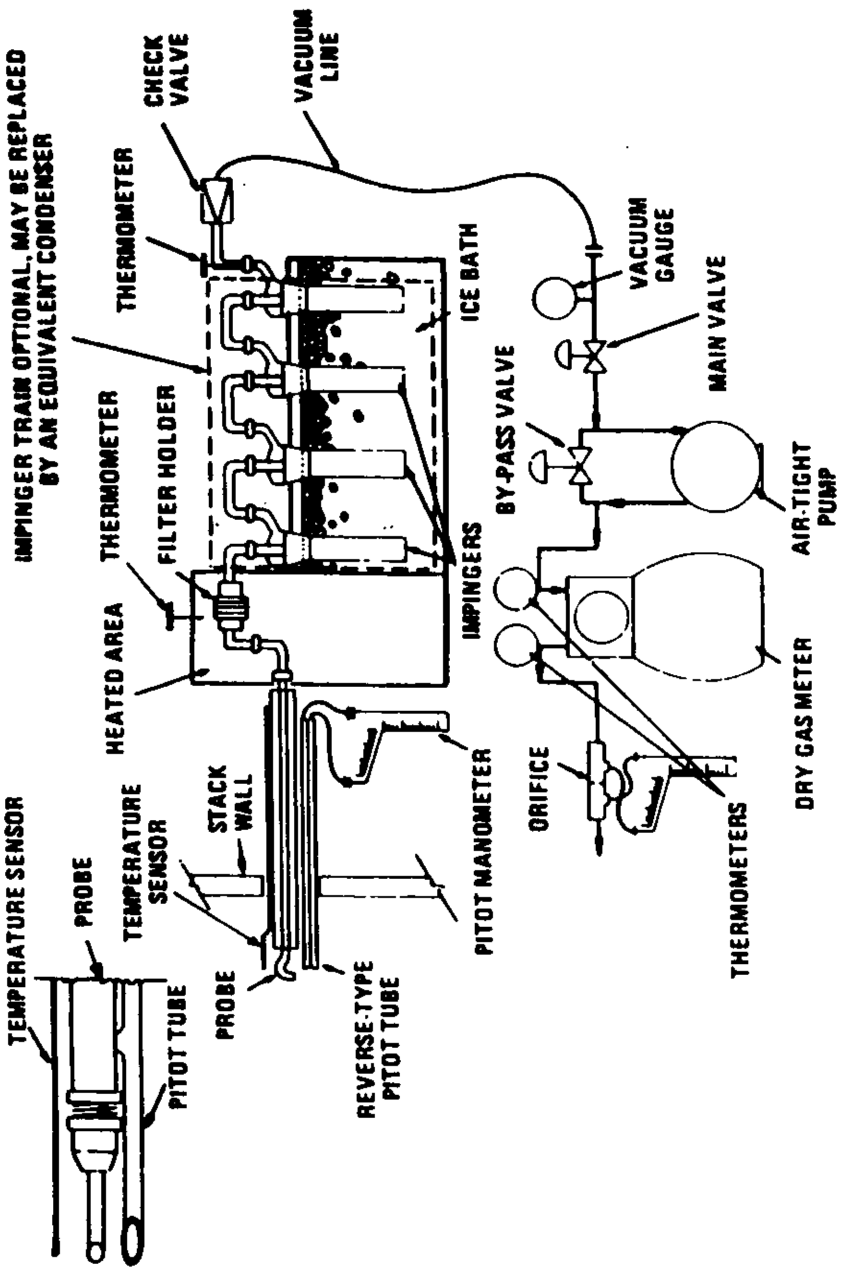

Figure 5-1. Particulate-sampling train.

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, it 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 impinger 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 suitable 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 Administrator.

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 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. 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 3, 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 encountered (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 m³/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 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 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 ____

SCHEMATIC OF STACK CROSS SECTION

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. ____

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 on 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 contaminations.

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.			
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:

$$\Delta H_@ = 0.0319\ \Delta H \quad \frac{T_m}{P_{bar}} \quad \frac{\Theta^2}{Y^2 V^2_m} \qquad \text{Eq. 5–9}$$

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.
$0.0319=(0.0567\ \text{in. Hg/°R}) \times (0.75\ \text{cfm})^2$.

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.

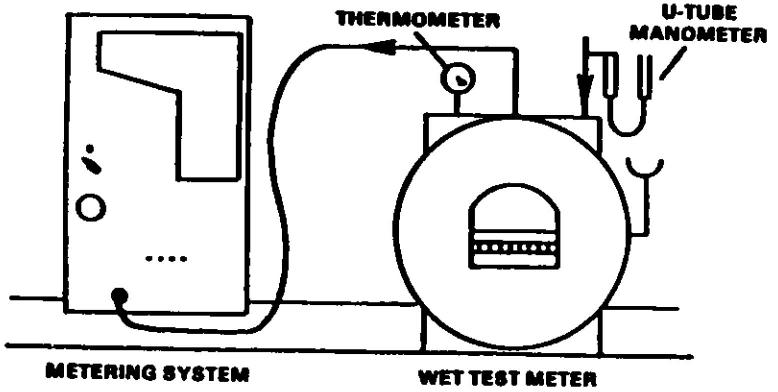

Figure 5.5 Equipment arrangement for metering system calibration.

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	$\Delta H@$
	$\frac{V_w P_b (t_m + 460)}{V_m \left[P_b + \frac{\Delta H}{13.6}\right] (t_w + 460)}$	$\frac{0.0317\ \Delta H}{P_b (t_o + 460)} \left[\frac{(t_w + 460)\ \theta}{V_w}\right]^2$
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 tne 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.

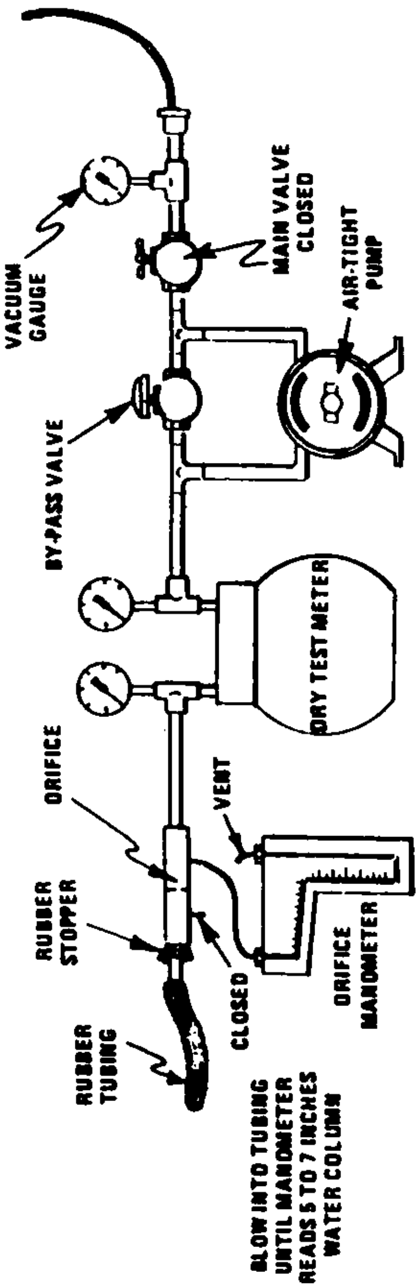

Figure 5–4. Leak check of meter box.

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 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 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 $_i$ 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_3=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_5=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.

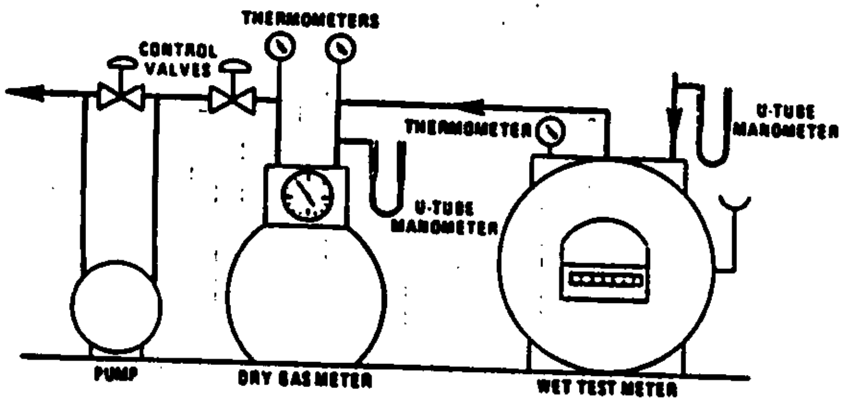

Figure 5.7 . Equipment arrangement for dry-gas meter calibration.

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_{ds}) 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 (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											

$$Q = 17.65 \cdot \frac{V_s}{\theta} \cdot \frac{P_b}{(t_s + 460)}$$

$$Y_{ds} = \frac{V_s}{V_{ds}} \cdot \frac{(t_d + 460)}{(t_s + 460)} \cdot \frac{P_b}{\left(P_b + \frac{\Delta p}{13.6}\right)}$$

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:

$$Q = K_1 \frac{P_{bar}}{t_w + t_{std}} \frac{V_w}{\theta}$$

$$Y_{ds} = \frac{V_w\,(t_{ds}+t_{std})\;P_{bar}}{V_{ds}\,(t_w+t_{std})\;\left(P_{bar}+\frac{\Delta p}{13.6}\right)}$$

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.

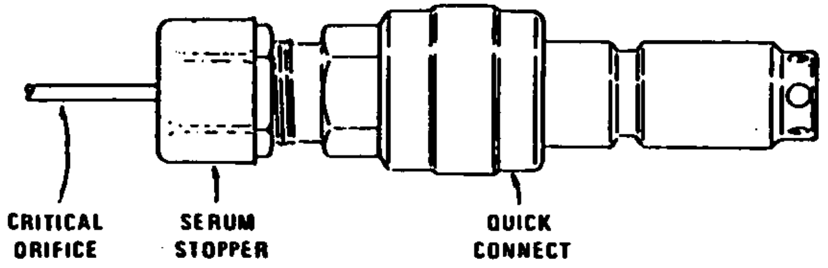

Figure 5-9. Critical orifice adaptation to Method 5 metering system.

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.

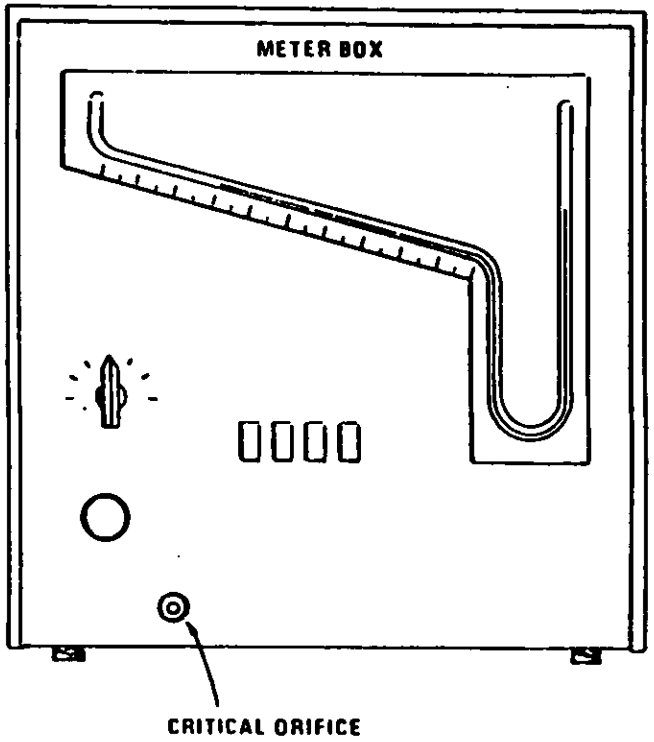

Figure 5-10. Apparatus setup.

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 m^3 (0.1 ft^3) 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.

$$K' = \frac{K_1 V_m Y (P_{bar} + \Delta H/13.6) \sqrt{T_{amb}}}{P_{bar} T_m \Theta} \qquad \text{Eq. 5-9}$$

Where:

$$K' = \text{Critical orifice coefficient, } \frac{(m^3)(°K)^{1/2}}{(mm.\ Hg)(min)} \left[\frac{(ft^3)(°R)^{1/2}}{(in.\ Hg)(min)} \right]$$

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	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 7.2.2.2.1 to 7.2.2.2.5. 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:

$$V_m(std) = K_1 V_m \frac{P_{bar} + (\Delta H/13.6)}{T_m} \qquad \text{Eq. 5-10}$$

$$V_{cr}(std) = K' \frac{P_{bar} \Theta}{\sqrt{T_{amb}}} \qquad \text{Eq. 5-11}$$

$$Y = \frac{V_{cr(std)}}{V_{m(std)}} \qquad \text{Eq. 5-12}$$

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	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 mate-

EPA METHOD #9

American Society for Testing and Materials. Philadelphia, Pa. 1974.

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 Start--End	Opacity Sum	Opacity 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

Page ___ of ___

Company ....
Location ....
Test Number ....
Date.

Observer ....
Type facility ....
Point of emissions ....

Hr.	Min.	Seconds 0	Seconds 15	Seconds 30	Seconds 45	Steam plume (check if applicable) Attached	Steam plume (check if applicable) Detached	Comments
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
	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							
	39							
	40							
	41							
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	56							
	57							
	58							
	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.

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CO MONITORING TRAIN

EPA Method #10

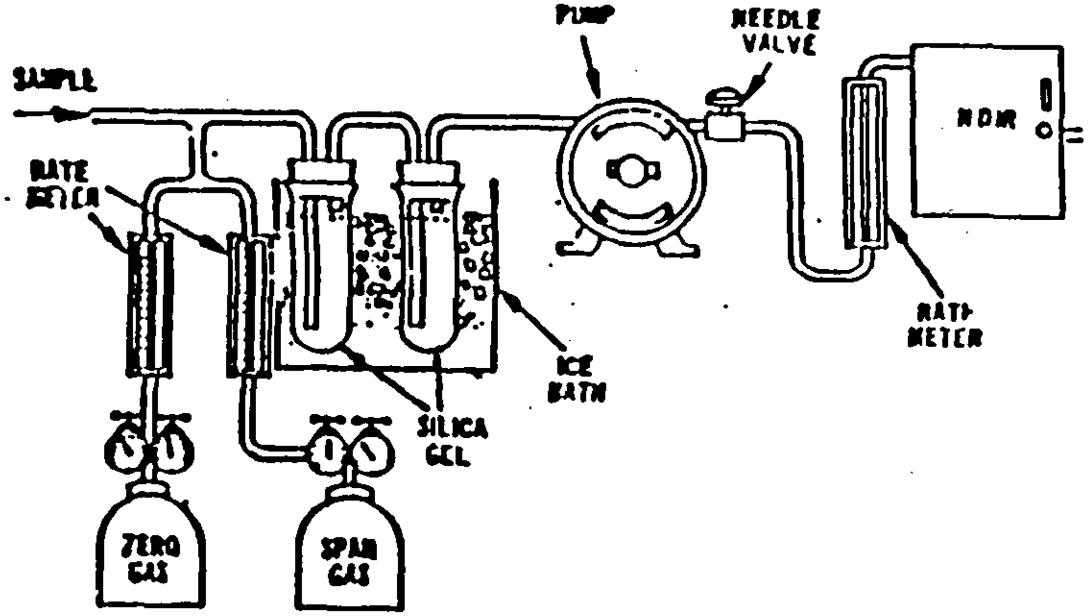

Figure 10-3. Analytical equipment.

EPA METHOD #10

METHOD 10—DETERMINATION OF CARBON MONOXIDE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. An integrated or continuous gas sample is extracted from a sampling point and analyzed for carbon monoxide (CO) content using a Luft-type nondispersive infrared analyzer (NDIR) or equivalent.

1.2 Applicability. This method is applicable for the determination of carbon monoxide emissions from stationary sources only when specified by the test procedures for determining compliance with new source performance standards. The test procedure will indicate whether a continuous or an integrated sample is to be used.

2. *Range and Sensitivity*

2.1 Range. 0 to 1,000 ppm.

2.2 Sensitivity. Minimum detectable concentration is 20 ppm for a 0 to 1,000 ppm span.

3. *Interferences*

Any substance having a strong absorption of infrared energy will interfere to some extent. For example, discrimination ratios for water (H_2O) and carbon dioxide (CO_2) are 3.5 percent H_2O per 7 ppm CO and 10 percent CO_2 per 10 ppm CO, respectively, for devices measuring in the 1,500 to 3,000 ppm range. For devices measuring in the 0 to 100 ppm range, interference ratios can be as high as 3.5 percent H_2O per 25 ppm CO and 10 percent CO_2 per 50 ppm CO. The use of silica gel and ascarite traps will alleviate the major interference problems. The measured gas volume must be corrected if these traps are used.

4. *Precision and Accuracy*

4.1 Precision. The precision of most NDIR analyzers is approximately ±2 percent of span.

4.2 Accuracy. The accuracy of most NDIR analyzers is approximately ±5 percent of span after calibration.

5. *Apparatus*

5.1 Continuous Sample (Figure 10-1).

5.1.1 Probe. Stainless steel or sheathed Pyrex[1] glass, equipped with a filter to remove particulate matter.

5.1.2 Air-Cooled Condenser or Equivalent. To remove any excess moisture.

5.2 Integrated Sample (Figure 10-2).

5.2.1 Probe. Stainless steel or sheathed Pyrex glass, equipped with a filter to remove particulate matter.

5.2.2 Air-Cooled Condenser or Equivalent. To remove any excess moisture.

5.2.3 Valve. Needle valve, or equivalent, to adjust flow rate.

5.2.4 Pump. Leak-free diaphragm type, or equivalent, to transport gas.

5.2.5 Rate Meter. Rotameter, or equivalent, to measure a flow range from 0 to 1.0 liter per min (0.035 cfm).

5.2.6 Flexible Bag. Tedlar, or equivalent, with a capacity of 60 to 90 liters (2 to 3 ft^3). Leak-test the bag in the laboratory before using by evacuating bag with a pump followed by a dry gas meter. When evacuation is complete, there should be no flow through the meter.

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[1] Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

5.2.7 Pitot Tube. Type S, or equivalent, attached to the probe so that the sampling rate can be regulated proportional to the stack gas velocity when velocity is varying with the time or a sample traverse is conducted.

5.3 Analysis (Figure 10–3).

5.3.1 Carbon Monoxide Analyzer. Nondispersive infrared spectrometer, or equivalent. This instrument should be demonstrated, preferably by the manufacturer, to meet or exceed manufacturer's specifications and those described in this method.

5.3.2 Drying Tube. To contain approximately 200 g of silica gel.

5.3.3 Calibration Gas. Refer to section 6.1.

5.3.4 Filter. As recommended by NDIR manufacturer.

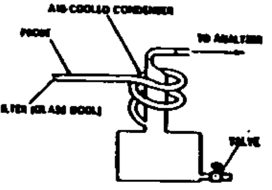

Figure 10-1. Continuous sampling train.

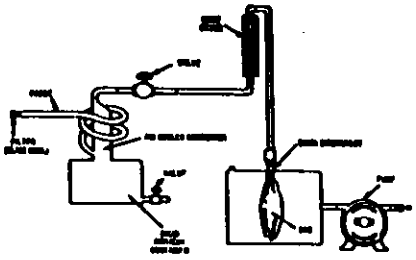

Figure 10-2. Integrated gas sampling train.

5.3.5 CO_2 Removal Tube. To contain approximately 500 g of ascarite.

5.3.6 Ice Water Bath. For ascarite and silica gel tubes.

5.3.7 Valve. Needle valve, or equivalent, to adjust flow rate

5.3.8 Rate Meter. Rotameter or equivalent to measure gas flow rate of 0 to 1.0 liter per min (0.035 cfm) through NDIR.

5.3.9 Recorder *(optional)*. To provide permanent record of NDIR readings.

6. *Reagents*

6.1 Calibration Gases. Known concentration of CO in nitrogen (N_2) for instrument span, prepurified grade of N_2 for zero, and two additional concentrations corresponding approximately to 60 percent and 30 percent span. The span concentration shall not exceed 1.5 times the applicable source performance standard. The calibration gases shall be certified by the manufacturer to be within ±2 percent of the specified concentration.

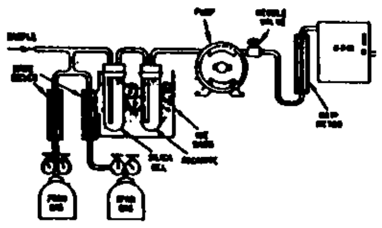

Figure 10-3. Analytical equipment.

6.2 Silica Gel. Indicating type, 6 to 16 mesh, dried at 175° C (347° F) for 2 hours.

6.3 Ascarite. Commercially available.

7. *Procedure*

7.1 Sampling.

7.1.1 Continuous Sampling. Set up the equipment as shown in Figure 10–1 making sure all connections are leak free. Place the probe in the stack at a sampling point and purge the sampling line. Connect the analyzer and begin drawing sample into the analyzer. Allow 5 minutes for the system to stabilize, then record the analyzer reading as required by the test procedure. (See section 7.2 and 8). CO_2 content of the gas may be determined by using the Method 3 integrated sample procedure, or by weighing the ascarite CO_2 removal tube and computing CO_2 concentration from the gas volume sampled and the weight gain of the tube.

7.1.2 Integrated Sampling. Evacuate the flexible bag. Set up the equipment as shown in Figure 10–2 with the bag disconnected. Place the probe in the stack and purge the sampling line. Connect the bag, making sure that all connections are leak free. Sample at a rate proportional to the stack velocity. CO_2 content of the gas may be determined by using the Method 3 integrated sample procedures, or by weighing the ascarite CO_2 removal tube and computing CO_2 concentration from the gas volume sampled and the weight gain of the tube.

7.2 CO Analysis. Assemble the apparatus as shown in Figure 10–3, calibrate the instrument, and perform other required operations as described in section 8. Purge analyzer with N_2 prior to introduction of each sample. Direct the sample stream through the instrument for the test period, recording the readings. Check the zero and span again after the test to assure that any drift or malfunction is detected. Record the sample data on Table 10–1.

8. *Calibration*

Assemble the apparatus according to Figure 10–3. Generally an instrument requires a warm-up period before stability is obtained. Follow the manufacturer's instructions for specific procedure. Allow a minimum time of 1 hour for warm-up. During this time check the sample conditioning apparatus, i.e., filter, condenser, drying tube, and CO_2 removal tube, to ensure that each component is in good operating condition. Zero and calibrate the instrument according to the manufacturer's procedures using, respectively, nitrogen and the calibration gases.

TABLE 10–1—FIELD DATA

	Comments
Location	
Test	
Date	
Operator	
Clock time	Rotameter setting, liters per minute (cubic feet per minute)

9. *Calculation*

Calculate the concentration of carbon monoxide in the stack using Equation 10–1.

$$C_{CO\,stack}=C_{CO\,NDIR}(1-F_{CO_2})$$

Eq. 10–1

Where:

$C_{CO\,stack}$=Concentration of CO in stack, ppm by volume (dry basis).

$C_{CO\,NDIR}$=Concentration of CO measured by NDIR analyzer, ppm by volume (dry basis).

F_{CO_2}=Volume fraction of CO_2 in sample, i.e., percent CO_2 from Orsat analysis divided by 100.

10. Alternative Procedures

10.1 Interference Trap. The sample conditioning system described in Method 10A, sections 2.1.2 and 4.2, may be used as an alternative to the silica gel and ascarite traps.

11. *Bibliography*

1. McElroy, Frank, The Intertech NDIR–CO Analyzer, Presented at 11th Methods Conference on Air Pollution, University of California, Berkeley, CA. April 1, 1970.
2. Jacobs, M. B., et al., Continuous Determination of Carbon Monoxide and Hydrocarbons in Air by a Modified Infrared Analyzer, J. Air Pollution Control Association, 9(2): 110–114. August 1959.
3. MSA LIRA Infrared Gas and Liquid Analyzer Instruction Book, Mine Safety Appliances Co., Technical Products Division, Pittsburgh, PA.
4. Models 215A, 315A, and 415A Infrared Analyzers, Beckman Instruments, Inc., Beckman Instructions 1635-B, Fullerton, CA. October 1967.
5. Continuous CO Monitoring System, Model A5611, Intertech Corp., Princeton, NJ.
6. UNOR Infrared Gas Analyzers, Bendix Corp., Ronceverte, WV

ADDENDA

A. PERFORMANCE SPECIFICATIONS FOR NDIR CARBON MONOXIDE ANALYZERS

Range (minimum)	0–1000 ppm.
Output (minimum)	0–10mV.
Minimum detectable sensitivity.	20 ppm.
Rise time, 90 percent (maximum).	30 seconds.
Fall time, 90 percent (maximum).	30 seconds.
Zero drift (maximum)	10% in 8 hours.
Span drift (maximum)	10% in 8 hours.
Precision (minimum)	±2% of full scale.
Noise (maximum)	±1% of full scale.
Linearity (maximum deviation)	2% of full scale.
Interference rejection ratio	CO_2—1000 to 1, H_2O—500 to 1.

B. *Definitions of Performance Specifications.*

Range—The minimum and maximum measurement limits.

Output—Electrical signal which is proportional to the measurement; intended for connection to readout or data processing devices. Usually expressed as millivolts or milliamps full scale at a given impedance.

Full scale—The maximum measuring limit for a given range.

Minimum detectable sensitivity—The smallest amount of input concentration that can be detected as the concentration approaches zero.

Accuracy—The degree of agreement between a measured value and the true value; usually expressed as ± percent of full scale.

Time to 90 percent response—The time interval from a step change in the input concentration at the instrument inlet to a reading of 90 percent of the ultimate recorded concentration.

Rise Time (90 percent)—The interval between initial response time and time to 90 percent response after a step increase in the inlet concentration.

Fall Time (90 percent)—The interval between initial response time and time to 90 percent response after a step decrease in the inlet concentration.

Zero Drift—The change in instrument output over a stated time period, usually 24 hours, of unadjusted continuous operation when the input concentration is zero; usually expressed as percent full scale.

Span Drift—The change in instrument output over a stated time period, usually 24 hours, of unadjusted continuous operation when the input concentration is a stated upscale value; usually expressed as percent full scale.

Precision—The degree of agreement between repeated measurements of the same concentration, expressed as the average deviation of the single results from the mean.

Noise—Spontaneous deviations from a mean output not caused by input concentration changes.

Linearity—The maximum deviation between an actual instrument reading and the reading predicted by a straight line drawn between upper and lower calibration points.