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STATIONARY SOURCE SAMPLING REPORT

REFERENCE NO. 5867C

ORANGE AND ROCKLAND UTILITIES, INC.
LOVETT GENERATING STATION
TOMKINS COVE, NEW YORK

PARTICULATE EMISSIONS COMPLIANCE TESTING

PYRITE SILO EXHAUST

JUNE 21, 1988

REPORT CERTIFICATION

The sampling and analysis performed for this report was carried out under my direction and supervision.

Date July 19, 1988

Signature Willis S Nesbit

Willis S. Nesbit

I have reviewed all testing details and results in this test report and hereby certify that the test report is authentic and accurate.

Date July 19, 1988

Signature

D. James Grove, P.E.

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INTRODUCTION

1.1 Outline of Test Program. Stationary source sampling was performed for Orange and Rockland Utilities, Inc. at the Lovett Generating Station in Tomkins Cove, New York, on June 21, 1988. Three EPA Method 5 runs were performed at the pyrite silo exhaust to determine the particulate emissions for compliance purposes.

1.2 Test Participants. Table 1-1 lists the personnel present during the test program.

TABLE 1-1

TEST PARTICIPANTS

Orange and Rockland Utilities, Inc.	Ray O'Sullivan Test Coordinator
New York State Department of Environmental Conservation	Rob Martin Test Observer
Entropy Environmentalists, Inc.	Willis S. Nesbit Project Supervisor
	A. Thomas McDonald Sampling Team Leader
	Gary J. Carrara Engineering Technician

SUMMARY OF RESULTS

2.1 Presentation. Table 2-1 presents the particulate emissions for the testing performed June 21, 1988, at the pyrite silo exhaust. Detailed test results are presented in Appendix A; field and analytical data are given in Appendix B.

2.2 Average Emission Rate and Concentration. The average emission rate and concentration were 0.294 pounds per hour and 0.00266 grains per dry standard cubic foot, respectively.

2.3 Aborted Run. Run P1 was aborted due to a sampling train leak. The leak was corrected and the required three runs were conducted. No data from run P1 appears in this report.

TABLE 2-1

PARTICULATE TESTS SUMMARY OF RESULTS

Pyrite Silo Exhaust

	P2	P3	P4
Run Date	6/21/88	6/21/88	6/21/88
<u>Test Train Parameters:</u>			
Volume of Dry Gas Sampled, SCF*	42.511	41.762	41.954
Percent Isokinetic	103.4	103.6	103.4
<u>Flue Gas Parameters:</u>			
Temperature, Degrees F	150	151	156
Volumetric Air Flow Rates SCFM*, Dry	1,301	1,276	1,284
ACFM, Wet	1,525	1,506	1,521
<u>Method 5 Results:</u>			
Catch, Milligrams	8.2	7.6	6.0
Concentration, Grains/DSCF*	0.002977	0.002808	0.002207
Emission Rate, Lbs/Hour	0.03319	0.03071	0.02428

* 68 Degrees F -- 29.92 Inches of Mercury (Hg)

PROCESS DESCCRIPTION AND OPERATION

3.1 General. Orange and Rockland Utilities, Inc. Lovett Generating Station operates coal-fired boilers for the production of steam used in the generation of electricity. Pyrites from the pyrite pulverizers are transferred to the pyrite silo.

3.2 Source Air Flow. Figure 3-1 is an air flow schematic showing the passage of the flue gases exhausted by the pyrite silo.

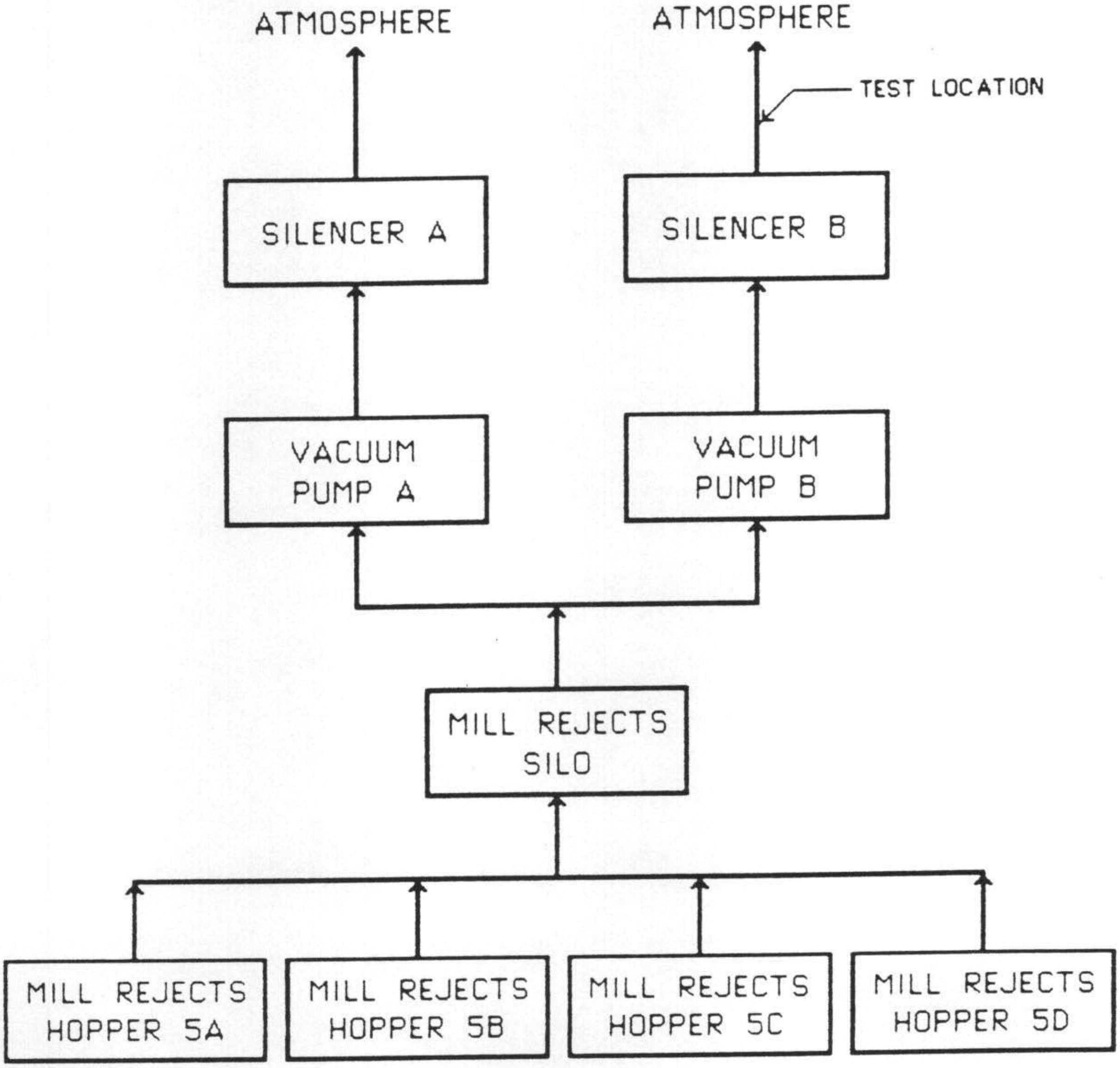


FIGURE 3-1. PYRITE SILO AIR FLOW SCHEMATIC.

SAMPLING AND ANALYTICAL PROCEDURES

4.1 General. All sampling and analytical procedures were those recommended by the United States Environmental Protection Agency and the New York State Department of Environmental Conservation. Descriptions of the sampling equipment and procedures (extracted from 40 CFR 60) are provided in Appendix D.

4.2 Sampling Points. The number and location of the sampling points were determined according to EPA Method 1A. The exhaust cross section was divided into 12 equal areas with six sampling points on each of two traverse axes. The sampling ports were located downstream of the velocity measurement points; refer to Figure 4-1.

4.3 Volumetric Air Flow Rates

4.3.1 Flue Gas Velocity. EPA Method 2 was used to take the velocity measurements during the traverses of the exhaust cross section.

4.3.2 Flue Gas Composition. The flue gas composition and molecular weight were assumed to be that of ambient air.

4.3.3 Flue Gas Moisture. Moisture content was determined by analyzing the sampling train impinger reagents according to the procedures outlined in EPA Method 5.

4.4 Emissions Determinations. EPA Method 5 sampling and analytical procedures were used to determine the particulate emissions. Each of the 12 points was sampled for five minutes, resulting in a net run time of 60 minutes.

4.5 Equipment Calibration. Pertinent calibration data are provided in Appendix C.

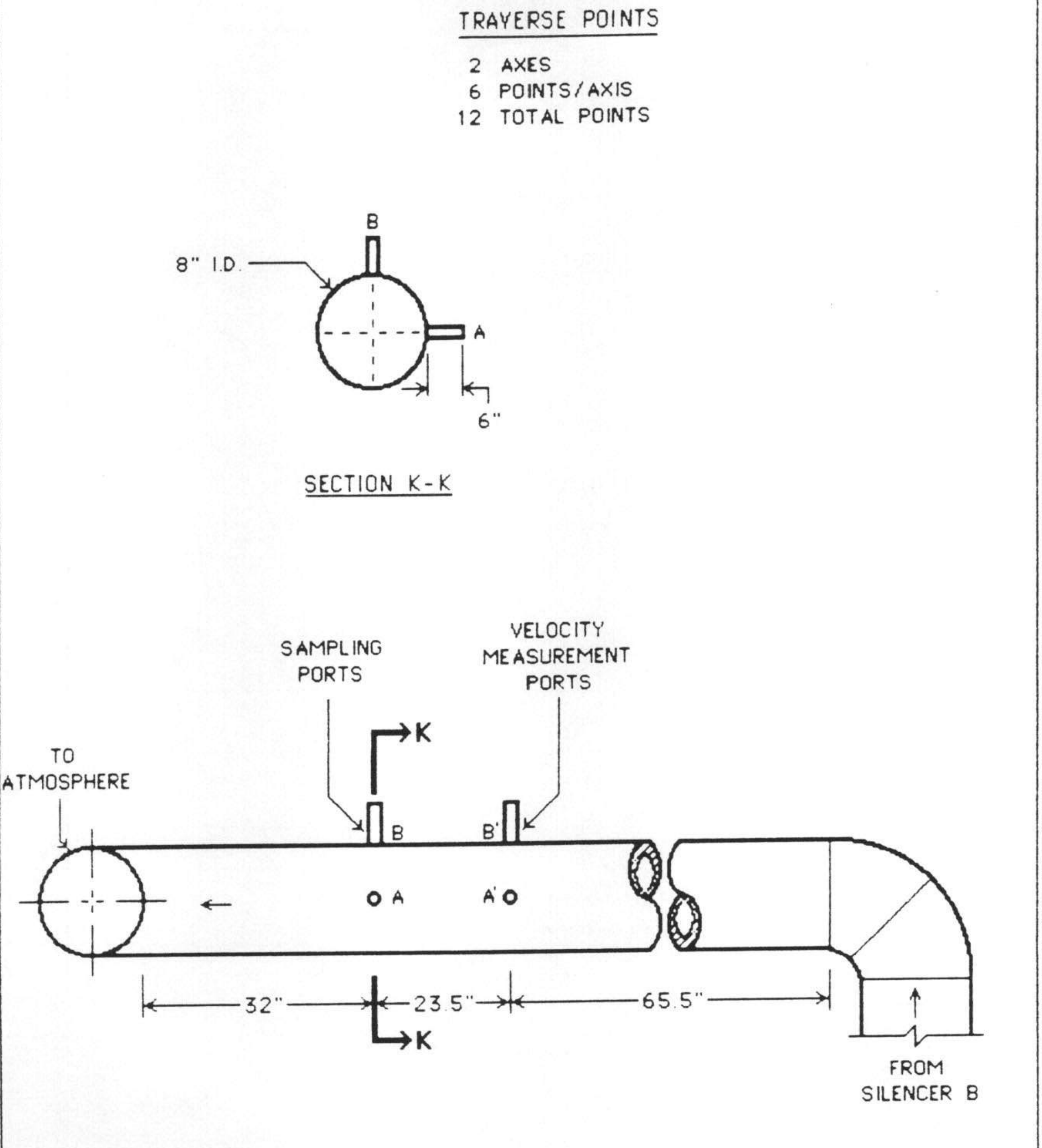


FIGURE 4-1. PYRITE SILO EXHAUST TEST LOCATION.

APPENDIX A

TEST RESULTS AND EXAMPLE CALCULATIONS

ISOKINETIC SAMPLING TRAIN FIELD DATA & RESULTS TABULATION

PLANT: Orange and Rockland Utilities, Inc., Tompkins Cove, New York

RUN #	DATE	SAMPLING LOCATION	OPERATOR
P2	6/21/88	Pyrite Silo Exhaust	A. Thomas McDonald
P3	6/21/88	Pyrite Silo Exhaust	A. Thomas McDonald
P4	6/21/88	Pyrite Silo Exhaust	A. Thomas McDonald

		P2	P3	P4
	Run Start Time	1220	1355	1526
	Run Finish Time	1325	1459	1631
	Net Sampling Points	12	12	12
Theta	Net Run Time, Minutes	60.00	60.00	60.00
Dia	Nozzle Diameter, Inches	0.183	0.183	0.183
Cp	Pitot Tube Coefficient	0.840	0.840	0.840
Y	Dry Gas Meter Calibration Factor	0.989	0.989	0.989
Pbar	Barometric Pressure, Inches Hg	29.80	29.80	29.80
Delta H	Avg. Pressure Differential of Orifice Meter, Inches H2O	1.690	1.640	1.650
Vm	Volume of Metered Gas Sample, Dry ACF	45.519	45.043	45.249
tm	Dry Gas Meter Temperature, Degrees F	99	103	103
Vm(std)	Volume of Metered Gas Sample, Dry SCF*	42.511	41.762	41.954
Vlc	Total Volume of Liquid Collected in Impingers & Silica Gel, mL	12.0	16.0	12.0
Vw(std)	Volume of Water Vapor, SCF*	0.565	0.753	0.565
%H2O	Moisture Content, Percent by Volume	1.3	1.8	1.3
Mfd	Dry Mole Fraction	0.987	0.982	0.987
Md	Estimated Dry Molecular Wt, Lb/Lb-Mole	28.84	28.84	28.84
Ms	Wet Molecular Weight, Lb/Lb-Mole	28.69	28.64	28.69
Pg	Flue Gas Static Pressure, Inches H2O	+1.04	+0.87	+0.92
Ps	Absolute Flue Gas Press., Inches HG	29.88	29.86	29.87
ts	Flue Gas Temperature, Degrees F	150	151	156
Delta p	Average Velocity Head, Inches H2O	1.4610	1.4190	1.4380
vs	Flue Gas Velocity, Feet/Second	73.22	72.30	73.01
A	Stack/Duct Area, Square Inches	50.00	50.00	50.00
Qsd	Volumetric Air Flow Rate, Dry SCFM*	1,301	1,276	1,284
Qaw	Volumetric Air Flow Rate, Wet ACFM	1,525	1,506	1,521
%I	Isokinetic Sampling Rate, Percent	103.4	103.6	103.4
	Method 5 Results:			
mg	Catch, Milligrams	8.2	7.6	6.0
gr/DSCF	Concentration, Grains per DSCF*	0.002977	0.002808	0.002207
Lb/Hr	Emission Rate, Lbs/Hour (PMRc)	0.03319	0.03071	0.02428

* 68 Degrees F -- 29.92 Inches of Mercury (Hg)

CONSTANTS, DEFINITIONS, NOMENCLATURE, AND UNITS OF MEASURE FOR ISOKINETIC AND DRY GAS METER CONSTANT RATE SAMPLING

A	Stack cross-sectional area, square feet
avg	Average
$\%CO_2$	Percent carbon dioxide by volume (dry basis)
$\%CO + N_2$	Percent carbon monoxide and nitrogen by volume (dry basis)
Cp	Pitot tube coefficient
Cs	Concentration, pounds per thousand pounds
Cs50	Concentration, pounds per thousand pounds corrected to 50% excess air
Delta H	Average pressure differential of orifice meter, inches H_2O
Delta pavg	Average presure drop encountered during a run
DRE	Destruction and Removal Efficiency for Incineration Devices
%EA	Percent excess air
F	F-factor, dry standard cubic feet per million Btu at 0% oxygen
For. Wt.	Formula weight
F50	Correction Factor for 50% Excess Air
GCV	Gross Caloric Value in Million Btus
Gr/ACF	Concentration, grains per actual cubic foot @ flue gas conditions
Gr/DSCF	Concentration, grains per dry standard cubic foot
Gr@7%02	Concentration, grains per dry standard cubic corrected to 7% oxygen
Gr@12%	Concentration, grains per dry standard cubic corrected to 12% CO_2
Gr@50%	Concentration, grains per dry standard cubic corrected to 50% excess air
Hg	Mercury
H_2O	Water
$\%H_2O$	Percent moisture
%I	Isokinetic sampling rate, percent
Lb/Hr	Emission rate, pounds per hour
Lb/MMBtu	Emission rate, pounds per million Btu
Mfd	Dry mole fraction
Md	Dry molecular weight of flue gas
Ms	Wet molecular weight of flue gas

(continued next page)

CONSTANTS, DEFINITIONS, NOMENCLATURE, AND UNITS OF MEASURE FOR ISOKINETIC AND DRY GAS METER CONSTANT RATE SAMPLING

(continued)

mg	Milligrams
mg/DSCM	Milligrams per dry standard cubic meter
mgGas	Total weight of gas sampled, pounds
$\%O_2$	Percent oxygen by volume (dry basis)
Pbar	Barometric pressure, inches Hg
Pg	Flue gas static pressure, inches H_2O
ppmd	Concentration, parts per million dry by volume
Ps	Absolute flue gas pressure, inches Hg
Pstd	Standard absolute pressure at 29.92 inches of mercury
ps(std)	Sample gas density, pounds per cubic foot
Qsd	Volumetric air flow rate, dry standard cubic feet per min
Theta	Net run time, minutes
tm	Dry gas meter temperature, degrees F
ts	Flue gas temperature, degrees F
Tstd	Standard absolute temperature, 528^{o} Rankin
Vlc	Total volume of liquid collected in impingers & silica gel, mL
Vm	Volume of metered gas sample, dry ACF
Vm(std)	Volume of metered gas sample at dry standard conditions, DSCF
vs	Average flue gas velocity, feet per second
Vw(std)	Volume of water vapor, standard cubic feet
Y	Gamma, dry gas meter calibration factor
0.02832	Cubic meters per cubic foot
0.04707	Standard cubic feet per gram or milliter of H_2O @ standard conditions
0.18	Molecular weight of water divided by 100
0.28	Molecular weight of nitrogen divided by 100
0.32	Molecular weight of oxygen divided by 100
0.44	Molecular weight of carbon dioxide divided by 100
0.264	From Equation 3-1 EPA Method 3
0.5	From Equation 3-1 EPA Method 3
13.6	Specific gravity of mercury (1 inch Hg = 13.6 inch H_2O)

(continued next page)

CONSTANTS, DEFINITIONS, NOMENCLATURE, AND UNITS OF MEASURE FOR ISOKINETIC AND DRY GAS METER CONSTANT RATE SAMPLING

(continued)

17.64	From EPA Method 5, (68 + 460)°R/29.92 in Hg
20.9	Percent O_2 by volume (dry basis) in ambient air
21.0	Percent O_2 by volume (dry basis) in ambient air (from CFR 40, Section 264.343)
24.056	Liters per gram-mole at standard conditions
85.49	Pitot tube coefficient
385.3	Molar volume ft^3/mole @ 68 degrees F & 29.92 in. Hg
453.6	Milligrams per thousand pounds
60	Minutes per hour or seconds per minute
100	Conversion to percent
144	Square inches per square foot
460	0 degrees Fahrenheit in degrees Rankin
7,000	Grains per pound
453,592	Milligrams per pound
453,592,000	Micrograms per pound

CONSTANTS, DEFINITIONS, NOMENCLATURE, AND UNITS OF MEASURE

VOLUMETRIC AIR FLOW RATES

A	Stack/duct area, square inches
ACFM	Actual cubic feet per minute
avg	average
%CO	Percent carbon monoxide by volume (dry basis)
$\%CO_2$	Percent carbon dioxide by volume (dry basis)
Cp	Pitot tube coefficient = 0.84 unless otherwise noted
Delta p	Average velocity head, inches H_2O
%EA	Percent excess air
Hg	Mercury
$\%H_2O$	Percent moisture
Md	Molecular weight, dry
Mfd	Dry mole fraction
MMBtu/Hr	Heat input, million Btu per hour
Ms	Molecular weight, wet
$\%N_2$	Percent nitrogen by volume (dry basis)
$\%O_2$	Percent oxygen by volume (dry basis)
Pbar	Barometric pressure, inches Hg
Pg	Flue gas static pressure, inches H_2O
Ps	Flue gas absolute pressure, inches Hg
Pstd	Standard pressure at 29.92 inches of mercury
Qaw	Volumetric air flow rate, wet ACFM
Qsd	Volumetric air flow rate, dry SCFM
SQRT	Square root
ts	Flue gas temperature, degrees F
Tstd	Standard absolute temperature, 528^{o} Rankin
vs	Flue gas velocity, feet per second
0.18	Molecular weight of water, divided by 100
0.264	Ratio of O_2 to N_2 in air, v/v
0.28	Molecular weight of N_2 or CO, divided by 100
0.32	Molecular weight of O_2, divided by 100
0.44	Molecular weight of CO_2, divided by 100
0.5	Diatomic factor
13.6	Specific gravity of mercury (1 inch Hg = 13.6 inch H_2O)
20.9	Percent O_2 by volume (dry basis) in ambient air
60	minutes/hour or seconds/minute
85.49	Pitot tube constant = $85.49\ \frac{\text{ft.}}{\text{sec.}}\ \frac{(\text{lb/lb-mole})\ (\text{in Hg})}{(^{o}\text{R})\ (\text{in } H_2O)}\ ^{1/2}$
100	Conversion to percent
144	square inches per square foot
460	0 degrees Fahrenheit in degrees Rankin

EXAMPLE TEST CALCULATIONS NO. P2

Pyrite Silo Exhaust

VOLUME OF DRY GAS SAMPLED AT STANDARD CONDITIONS

$$\text{Vm(std)} = 17.64 * \text{Y} * \text{Vm} * \frac{(\text{Pbar} + \text{Delta H}/13.6)}{(460 + \text{tm})}$$

$$\text{Vm(std)} = 17.64 * 0.989 * 45.519 * \frac{(29.80 + 1.690/13.6)}{(460 + 99)} = 42.511 \text{ DSCF}$$

VOLUME OF WATER VAPOR AT STANDARD CONDITIONS

$$\text{Vw(std)} = 0.04707 * \text{Vlc}$$

$$\text{Vw(std)} = 0.04707 * 12.0 = 0.565 \text{ SCF}$$

PERCENT MOISTURE, BY VOLUME, AS MEASURED IN FLUE GAS

$$\%\text{H2O} = 100 * \text{Vw(std)} / (\text{Vw(std)} + \text{Vm(std)})$$

$$\%\text{H2O} = \frac{0.565}{0.565 + 42.511} * 100 = 1.3\ \%$$

DRY MOLE FRACTION OF FLUE GAS

$$\text{Mfd} = 1 - \%\text{H2O}/100$$

$$\text{Mfd} = 1 - 1.3/100 = 0.987$$

WET MOLECULAR WEIGHT OF FLUE GAS

$$\text{Ms} = (\text{Md} * \text{Mfd}) + (0.18 * \%\text{H2O})$$

$$\text{Ms} = 28.84 * 0.987 + (0.18 * 1.3) = 28.69 \text{ LB/LB-MOLE}$$

ABSOLUTE FLUE GAS PRESSURE

$$Ps = Pbar + Pg / 13.6$$

$$Ps = 29.80 + (1.0 / 13.6) = 29.88 \text{ IN. HG.}$$

AVERAGE FLUE GAS VELOCITY [Note: (Delta p)avg is square of avg sq. root]

$$vs = 85.49 * Cp * SQRT\left[\frac{(Delta\ p)avg * (460 + ts)}{Ps * Ms}\right]$$

$$vs = 85.49 * 0.840 * SQRT\left[\frac{1.4610 * (460 + 150)}{29.88 * 28.69}\right] = 73.2 \text{ FT/SEC}$$

DRY VOLUMETRIC FLUE GAS FLOW RATE @ STANDARD CONDITIONS

$$Qsd = \frac{60}{144} * Mfd * vs * A * \frac{Tstd}{ts + 460} * \frac{Ps}{Pstd}$$

$$Qsd = \frac{60}{144} * 0.987 * 73.2 * 50.0 * \frac{528}{150 + 460} * \frac{29.88}{29.92}$$

$$Qsd = 1{,}301 \text{ SCFM}$$

WET VOLUMETRIC STACK GAS FLOW RATE @ FLUE GAS CONDITIONS

$$Qaw = 60 / 144 * vs * A$$

$$Qaw = 60 / 144 * 73.2 * 50.0 = 1{,}525 \text{ ACFM}$$

PERCENT ISOKINETIC OF SAMPLING RATE

$$\%I = \frac{Pstd}{Tstd} * \frac{100}{60} * \frac{(ts + 460) * Vm(std)}{Ps * vs * Mfd * Theta * \text{Area-nozzle, sq.ft.}}$$

$$\%I = \frac{29.92}{528} * \frac{100}{60} * \frac{(150 + 460) * 42.511}{29.88 * 73.2 * 0.987 * 60.00 * 0.0001827}$$

$$\%I = 103.4 \%$$

GRAINS PER DRY STANDARD CUBIC FOOT

$$gr/DSCF = \frac{7000}{453,592} * \frac{mgs}{Vm(std)}$$

$$gr/DSCF = \frac{7000}{453,592} * \frac{8.2}{42.511} = 0.0030 \quad gr/DSCF$$

POUNDS PER HOUR

$$Lb/Hr = 60 / 7000 * gr/DSCF * Qsd$$

$$Lb/Hr = 60/7000 * 0.0030 * 1,301 = 0.03 \quad LB/HR$$

APPENDIX B

FIELD AND ANALYTICAL DATA

Preliminary Field Data

PLANT NAME Orange + Rockland

LOCATION ~~Pyrite Silo~~

SAMPLING LOCATION Pyrite Silo

DUCT DEPTH

FROM INSIDE FAR WALL TO OUTSIDE OF PORT 14"

NIPPLE LENGTH 6"

DEPTH OF DUCT 8"

WIDTH (RECTANGULAR DUCT) ______

EQUIVALENT DIAMETER:

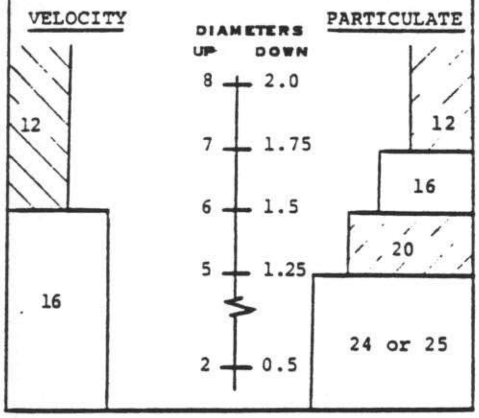
$$D_E = \frac{2 \times \text{DEPTH} \times \text{WIDTH}}{\text{DEPTH} + \text{WIDTH}} = \frac{2(\quad)(\quad)}{(\quad + \quad)} = \_\_\_\_$$

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE	UPSTREAM	DOWNSTREAM
	89" (65½")	32" (47¼)
DIAMETERS	11 (8)	4 (6)

STACK AREA = $\left(8/2\right)^2 \pi$ = 50 IN²

DRAW HORIZONTAL LINE THROUGH DIAMETERS

If more than 8 and 2 diameters and if duct dia. is less than 24", use 8 or 9 points.



Point	% OF DUCT DEPTH	DISTANCE FROM INSIDE WALL	DISTANCE FROM OUTSIDE OF PORT
1	4.4	½"	6½"
2	14.6	1⅛"	7⅛"
3	29.6	2⅜"	8⅜"
4	70.4	5⅝"	11⅝"
5	85.4	6⅞	12⅞
6	95.6	7½	13½
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	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

LOCATION OF TRAVERSE POINTS IN RECTANGULAR STACKS

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	18.8	16.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.8
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.8	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	86.4	79.2
11										95.5	87.5
12											95.8

PARTICULATE FIELD DATA

COMPANY NAME Orange + Rockland
RUN NUMBER P 2
ADDRESS Stoney Point, N.Y.
TIME START 1220
SAMPLING LOCATION Pyrite Silo Exhaust
TIME FINISH 1325
DATE 6-21-88
TEAM LEADER TMS
TECHNICIANS GC
BAROMETRIC PRESSURE, IN. HG 29.8
STATIC PRESSURE, IN. H_2O +1.04
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 5
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.001 0.000

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- — ORSAT SAMPLING SYSTEM
- — TEDLAR BAG
- ✓ THERMOCOUPLE @ 150 °F

IDENTIFICATION NUMBERS

REAGENT BOX 0237
NOZZLE 601
DIAMETER 0.183
METER BOX N4
T/C READOUT 00015
UMBILICAL U2
T/C PROBE 14-1
SAMPLE BOX 4
ORSAT PUMP —
PROBE 2-6
TEDLAR BAG —

FILTER #	TARE
E 7156	.4920

NOMOGRAPH SET-UP

NOMOGRAPH # TMS
ΔH@ 1.78
C FACTOR 1.08-0.05=1.03
METER TEMP 100
STACK TEMP 150
% MOISTURE 2
REF. ΔP 1.60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
B 1	0/0	875.949	1.18	1.36	1.36	92	1	240	60	148	
2	5	879.41	1.44	1.66	1.66	93	1	246	61	151	
3	10	883.17	1.55	1.78	1.78	94	1	251	63	150	
4	15	887.03	1.52	1.75	1.75	96	1	251	64	150	
5	20	890.87	1.57	1.81	1.81	98	1	250	64	151	
6	25	894.78	1.52	1.75	1.75	100	1	253	64	151	
A 1	30/0	898.632	1.15	1.32	1.32	99	1	252	67	149	
2	5	902.06	1.40	1.61	1.61	100	1	252	67	149	
3	10	905.91	1.49	1.71	1.71	102	1	250	65	150	
4	15	909.63	1.55	1.78	1.78	103	1	251	65	150	
5	20	913.54	1.64	1.89	1.89	103	1	251	66	149	
6	25	917.54	1.57	1.81	1.81	104	1	250	65	151	
	60/off	921.468									

V_M	$(\overline{\sqrt{\Delta P}})^2$	ΔH	T_M	T_S
45.519	1.4611	1.69	99	150

ENTROPY

PARTICULATE FIELD DATA

COMPANY NAME ORANGE + Rockland
ADDRESS Stoney Point, N.Y.
SAMPLING LOCATION Pyrite Silo Exhaust
DATE 6-21-88 **TEAM LEADER** (JMC) **TECHNICIANS** S C
BAROMETRIC PRESSURE, IN. HG 29.8 **STATIC PRESSURE, IN. H_2O** +0.87
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 2
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.001 0.000

RUN NUMBER P3
TIME START 1355
TIME FINISH 1459

EQUIPMENT CHECKS

✓ PITOTS, PRE-TEST
✓ PITOTS, POST-TEST
— ORSAT SAMPLING SYSTEM
— TEDLAR BAG
✓ THERMOCOUPLE @ 150 °F

IDENTIFICATION NUMBERS

REAGENT BOX 0237 **NOZZLE** 601 **DIAMETER** .183
METER BOX N4 **T/C READOUT** 00015
UMBILICAL U2 **T/C PROBE** 14-1
SAMPLE BOX 4 **ORSAT PUMP** —
PROBE 2-6 **TEDLAR BAG** —

FILTER #	TARE
E5757	0.5122

NOMOGRAPH SET-UP **NOMOGRAPH #** (JMS)

ΔH@ 1.78 **C FACTOR** 1.08 - 0.05 = 1.03
METER TEMP 100 **STACK TEMP** 150
% MOISTURE 2 **REF. ΔP** 1.60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
B 1	0/0	922.264	1.07	1.23	1.23	97	1	228	60	148	
2	5	925.60	1.38	1.59	1.59	98	1	237	60	149	
3	10	929.25	1.48	1.70	1.70	98	1	248	61	151	
4	15	933.08	1.45	1.67	1.67	100	1	253	61	151	
5	20	936.85	1.56	1.79	1.79	102	1	258	65	150	
6	25	940.75	1.55	1.78	1.78	104	1	257	66	151	
A 1	30/0	944.643	1.21	1.39	1.39	103	1	258	65	148	
2	5	948.17	1.39	1.60	1.60	104	1	255	65	151	
3	10	951.92	1.47	1.69	1.69	106	1	257	68	150	
4	15	955.76	1.50	1.73	1.73	106	1	258	69	156	
5	20	959.60	1.49	1.71	1.71	106	1	256	70	154	
6	25	963.43	1.52	1.75	1.75	106	1	255	70	154	
	60/off	967.307									

V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M	T_S
45.043	1.4188	1.64	103	151

PARTICULATE FIELD DATA

COMPANY NAME Orange & Rockland
RUN NUMBER P4
ADDRESS ~~Stoney Point, N.Y.~~ Tomkins Cove, N.Y.
TIME START 1526
SAMPLING LOCATION Pyrite Silo Exhaust
TIME FINISH 1631
DATE 6-21-88
TEAM LEADER (TMc)
TECHNICIANS GC
BAROMETRIC PRESSURE, IN. HG 29-8
STATIC PRESSURE, IN. H_2O +0.92
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 4
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.002 0.000

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- — ORSAT SAMPLING SYSTEM
- — TEDLAR BAG
- ✓ THERMOCOUPLE @ 150 °F

IDENTIFICATION NUMBERS

REAGENT BOX 0550
NOZZLE 601
DIAMETER .183
METER BOX N4
T/C READOUT 00015
UMBILICAL U2
T/C PROBE 14-1
SAMPLE BOX 4
ORSAT PUMP
PROBE 2-6
TEDLAR BAG —

FILTER #	TARE
E6911	.4770

NOMOGRAPH SET-UP

NOMOGRAPH # (TMc)
$\Delta H_@$ 1.78
C FACTOR 1.08-0.05=1.03
METER TEMP 100
STACK TEMP 150
% MOISTURE 2
REF. ΔP 1.60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
A 1	0/0	968.030	1.17	1.35	1.35	100	1	232	58	155	
2	5	971.48	1.39	1.60	1.60	100	1	246	58	156	
3	10	975.17	1.48	1.70	1.70	101	1	252	64	156	
4	15	978.97	1.62	1.83	1.83	102	1	259	65	160	
5	20	982.90	1.54	1.77	1.77	102	1	259	64	158	
6	25	986.79	1.57	1.81	1.81	103	1	258	65	159	
1	30/0	990.717	1.25	1.44	1.44	103	1	255	66	153	
2	5	994.32	1.32	1.51	1.51	104	1	257	68	157	
3	10	998.06	1.45	1.67	1.67	105	1	257	67	156	
4	15	1001.72	1.52	1.75	1.75	105	1	255	68	157	
5	20	5.62	1.55	1.78	1.78	106	1	255	68	155	
6	25	9.53	1.43	1.64	1.64	106	1	254	68	153	
	60/off	1013.279									

V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M	T_S
45.249	1.4378	1.65	103	156

PARTICULATE SAMPLING LABORATORY RESULTS

Plant Name: ORANGE ROCKLAND

EEI Ref# 5867B

Sampling Location: Pyrite Silo Exhaust

Date Received: 6/24 Date Analyzed: 6/29 Reagent Box ~~(es)~~ Sws: ~~0237~~ 0237, ,0550 as

Run Number	P2	P3	P4
Run Date	6/21	6/21	6/21
Sample ID/Container #	F&R 2480	F&R 2481	F&R 2482
	✓100.1359	✓100.1899	✓104.9347
	100.1363	100.1899	104.9349
	100.1385	100.1909	104.9361
Tare Weight., g.	99.6355	99.6699	104.4514
SAMPLE WT., g.	0.5004	0.5200	0.4833
Sample ID/Container #			
	0.0000	0.0000	0.0000
Tare Wt., g.			
SAMPLE WT., g.	0.0000	0.0000	0.0000
Sum of Particulate, mg.	500.4	520.0	483.3
Total Filter Tare, mg.	492.0	512.2	477.0
Blank Residue, mg.	(100 ml) 0.2	(100 ml) 0.2	(125 ml) 0.3
TOTAL PARTICULATE CATCH, mg.	8.2	7.6	6.0

Blank Beaker #	2003
Final wt., mg.	99546.3
Tare wt., mg.	99545.9
Residue, mg.	0.4
Volume, ml.	200

---Legend---

✓ = Final Weight

L = Loose Particulate

F = Filter D = Dish

R = Rinse P = Pan

Notes and Comments

Concentration, mg/ml 0.002

MOISTURE SAMPLING LABORATORY RESULTS

Plant Name: ORANGE ROCKLAND EEI Ref# 5867B

Sampling Location: Pyrite Silo Exhaust

Date Received: 6/24 Date Analyzed: 6/24 Reagent Box (~~[illegible]~~): ~~0237~~,0550
sws
es 0237,

Run Number	P2	P3	P4
Run Date	6/21	6/21	6/21

ANALYSIS OF MOISTURE CATCH

	P2	P3	P4
Reagent 1 (H2O)			
Final Weight, g.	200.0	205.0	198.0
Tared Weight, g.	200.0	200.0	200.0
	==========	==========	==========
Water Catch,g.	0.0	5.0	-2.0
Reagent 2 ( )			
Final Weight, g.			
Tared Weight, g.			
	==========	==========	==========
Water Catch,g.	0.0	0.0	0.0
Reagent 3 ( )			
Final Weight, g.			
Tared Weight, g.			
	==========	==========	==========
Water Catch,g.	0.0	0.0	0.0
CONDENSED WATER, g.	0.0	5.0	-2.0
Silica Gel:			
Final Weight, g.	212.0	211.0	214.0
Tared Weight, g.	200.0	200.0	200.0
	==========	==========	==========
ADSORBED WATER, g.	12.0	11.0	14.0
TOTAL WATER COLLECTED, g.	12.0	16.0	12.0

CUSTODY SHEET FOR REAGENT BOX # 0237

Date of Makeup 6/13 Initials SAW Locked? ✓

Individual Tare of Reagent: 200 mls. of DI H_2O

Individual Tare of Reagent: mls. of

Individual Silica Gel Tare Weight 200 gms.

PLANT NAME Orange & Rockland

SAMPLING LOCATION Pyrite Silo Exhaust

Run Number	Date Used	Initials	Locked?	Date Cleanup	% S. Gel Spent	Initials	Locked
~~P1~~	~~6-21-88~~	~~TMG~~	~~✓~~	~~6-21-88~~	~~0~~	~~TMG~~	~~✓~~
P2	↓	↓	✓	↓		↓	✓
P3			✓				✓

Received in Lab Date 6/27 Initials MG Locked? ✓

Sampling Method: M5

Remarks:

Zero & Span Balance Initials MG

Filter #	Tare Weight (grams)	Used on Test
INVALIDATED		P1
E7156	.4920	P2
E5757	.5122	P3

ENTROPY ENVIRONMENTALISTS, INC.

CUSTODY SHEET FOR REAGENT BOX # 0550

Date of Makeup 6/17 Initials MEG Locked? ✓

Individual Tare of Reagent: 200 mls. of H_2O

Individual Tare of Reagent: mls. of

Individual Silica Gel Tare Weight 200 gms.

PLANT NAME ORANGE + Rockland

SAMPLING LOCATION Pyrite Silo Exhaust

Run Number	Date Used	Initials	Locked?	Date Cleanup	% S. Gel Spent	Initials	Locked?
P4	6-21-88	JMG	✓	6-21-88	0	JMG	✓

	Date	Initials	Locked?
Received in Lab	6/27	MEG	✓

Sampling Method: M5

Remarks:

Zero & Span Balance Initials MEG

Filter #	Tare Weight (grams)	Used on Test
E6911	.4770	P4

ENTROPY ENVIRONMENTALISTS, INC.

APPENDIX C

CALIBRATION DATA

QUALITY ASSURANCE PROCEDURES

General. Each item of field test equipment purchased or constructed by Entropy is assigned a unique, permanent identification number. New items for which calibration is required are calibrated before initial field use. Equipment whose calibration status may change with use or with time is inspected in the field before testing begins, and again upon return from each field use. When an item of equipment is found to be out of calibration, it is adjusted and recalibrated or retired from service. All equipment is periodically recalibrated in full, regardless of the outcome of these regular inspections.

Calibrations are conducted in a manner and at a frequency which meet or exceed U. S. EPA specifications. Entropy follows the calibration procedures outlined in EPA Reference Methods, and those recommended within the Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III (EPA-600/4-77-027b, August, 1977). When the Reference Methods are inapplicable, Entropy uses methods such as those prescribed by the American Society for Testing and Materials (ASTM).

Data obtained during calibrations are recorded on standardized forms, which are checked for completeness and accuracy by the Quality Assurance Manager or the Quality Assurance Director. Data reduction and subsequent calculations are performed using Entropy's in-house computer facilities. Calculations are generally performed at least twice as a check for accuracy. Copies of calibration data are included in the test or project reports.

Inspection and Maintenance. An effective preventive maintenance program is necessary to ensure data quality. Each item of equipment returning from the field is inspected before it is returned to storage. During the course of these inspections, items are cleaned, repaired, reconditioned, and recalibrated where necessary.

Each item of equipment transported to the field for this test program was inspected again before being packed. Entropy performs these quality assurance activities prior to departure for the job site to detect equipment problems which may originate during periods of storage. This minimizes lost time on site due to equipment failure.

Occasional equipment failure in the field is unavoidable despite the most rigorous inspection and maintenance procedures. For this reason, Entropy routinely transports sufficient backup equipment to the job site to have complete redundancy of all critical sampling train components.

Calibration. Emissions sampling equipment that requires calibration includes the nozzle, pitot tube, pressure gauges, thermometers, flow meters, dry gas meters, and barometers. The following sections elaborate on the calibration procedures followed by Entropy for these items of equipment. Calibration data for the specific items of equipment used for this test program follow the text.

Nozzles. Each probe nozzle is uniquely and permanently identified at the time of purchase, and calibrated before initial field use. The inside diameter of the nozzle is measured to the nearest 0.001 in. using a micrometer. Five measurements are made using different diameters each time. If the difference between the high and the low numbers does not exceed 0.004 inch, the average of the five measurements is used. If the difference exceeds this amount, or when the nozzle becomes nicked, dented, or corroded, the nozzle is reshaped, sharpened, and recalibrated.

Pitot Tubes. All Type S pitot tubes used by Entropy, whether separate or attached to a sampling probe, are constructed in-house or by Nutech Corporation. Each pitot is calibrated when new in accordance with the geometry standards contained in EPA Reference Method 2. A Type S pitot tube, constructed and positioned according to these standards, will have a coefficient of 0.84 ± 0.02. This coefficient should not change as long as the pitot tube is not damaged.

Each pitot tube is inspected visually before it is transported to the field. If this inspection indicates damage or raises doubt that the pitot remains in accordance with the EPA geometry standards, the pitot tube is not used until it has been refurbished and recalibrated.

Differential Pressure Gauges. Some meter consoles used by Entropy are equipped with 10 in. W.C. inclined-vertical manometers. Fluid manometers [illegible] despite the [illegible] own rigorous [illegible] tion and [illegible] For this reason, [illegible] requests sufficient [illegible] of the job site to take samples [illegible] of all [illegible] equipment.

Calibration. [illegible] calibration includes the [illegible] tor tube, pressure [illegible] thermometers. Flow meters [illegible] The [illegible] elements on the calibration [illegible] types of equipment. Calibration [illegible] for this test program [illegible]

Nozzles. [illegible] probe nozzle is [illegible] and permanently identified the size of [illegible] and calibrated before [illegible] field use. The inside diameter of [illegible] is measured [illegible] 0.001 in. using a micrometer. [illegible] measurements are made [illegible] different diameters each one. If the diff[illegible] between the high and the [illegible] diameters does not exceed 0.004 inch, the ave[illegible] have occurred [illegible] If the difference exceeds th[illegible] than the [illegible] and, dented, or corroded, the nozzle is [illegible] reshaped, sharpened, and [illegible]

Pitot Tubes. [illegible] pitot tubes [illegible] whether [illegible] or attached [illegible] thermocouples, are [illegible] in-house or by [illegible] Corporation. [illegible] calibrated [illegible] in accordance with the [illegible] standard [illegible] is [illegible] Type S pitot tube [illegible] mounted and [illegible] according to [illegible] have a coefficient of [illegible] 0.84 [illegible] This [illegible] not [illegible] as long as the pitot tube [illegible] is damaged.

Each pitot tube is [illegible] visually inspected [illegible] in the field [illegible] indicates [illegible] than the [illegible] the [illegible] the pitot tube is not [illegible] and independently [illegible]

Differential Pressure Gauges. [illegible] used by Entropy are [illegible] with [illegible] inclined-vertical [illegible] manometers.

do not require calibration other than leak checks. Manometers are leak-checked in the field prior to each test series, and again upon return from the field.

Most of Entropy's meter consoles are equipped with Magnehelic differential pressure gauges. Each set of gauges is calibrated initially over its full range, 0-10 inches W.C. After each field use, the calibration of the gauge set is checked against an inclined manometer at the average delta p encountered during the test. If the agreement is within ± 5 percent, the calibration is acceptable.

Thermometers

Impinger Thermometer. On site, prior to the start of testing, the thermometer used to monitor the temperature of the gas leaving the last impinger is compared with a mercury-in-glass thermometer which meets ASTM E-1 specifications. The impinger thermometer is adjusted if necessary until it agrees within 2°F of the reference thermometer. (If the thermometer is not adjustable, it is labeled with a correction factor).

Dry Gas Meter Thermometer. The thermometer used to measure the temperature of the metered gas sample is checked prior to each field trip against an ASTM mercury-in-glass thermometer. The dry gas meter thermometer is acceptable if the values agree within 5.4°F. Thermometers not meeting this requirement are adjusted or labeled with a correction factor.

Flue Gas Temperature Sensor. All thermocouples employed by Entropy for the measurement of flue gas temperatures are calibrated upon receipt. Initial calibrations are performed at three points (ice bath, boiling water, and hot oil). An ASTM mercury-in-glass thermometer is used as a reference. The thermocouple is acceptable if the agreement is within 1.5 percent (absolute) at each of the three calibration points.

On site, prior to the start of testing, the reading from the stack gas thermocouple-potentiometer combination is compared with a mercury-in-glass reference thermometer. If the two agree within 1.5 percent (absolute), the thermocouple and potentiometer are considered to be in proper working order for the test series.

After each field use, the thermocouple-potentiometer system is compared with an ASTM mercury-in-glass reference thermometer at a temperature within 10 percent of the average absolute flue gas temperature. If the absolute temperatures agree within 1.5 percent, the temperature data are considered valid.

Dry Gas Meter and Orifice. The dry gas meter and orifice are calibrated simultaneously. There are two calibration procedures. The full calibration is a complete laboratory procedure used to obtain the calibration factor of the dry gas meter before its first use and periodically thereafter. Full calibrations are performed at three different orifice settings (flow rates). A simpler procedure, the posttest calibration, is designed to check whether the calibration factor has changed. Posttest calibrations are performed after each field test series at an intermediate orifice setting (based on the test data) and at the maximum vacuum reached during the test.

Entropy uses as a transfer standard a dry gas meter that is calibrated annually against a spirometer. During the annual calibration, triplicate calibration runs are performed at seven flow rates ranging from 0.25 to 1.40 cfm.

Dry Gas Meter. Each metering system receives a full calibration at the time of purchase, and a posttest calibration after each field use. If the calibration factor, Y, deviates by less than five percent from the initial value, the test data are acceptable. If Y deviates by more than five percent, the meter is recalibrated and the meter coefficient (initial or recalibrated) that yields the lowest sample volume for the test runs is used.

EPA Reference Method 5 calls for another full calibration anytime the posttest calibration check indicates that Y has changed by more than five percent. Standard practice at Entropy is to recalibrate the dry gas meter anytime Y is found to be outside the range $0.98 \leq Y \leq 1.02$.

Orifice. An orifice calibration factor is calculated for each flow setting during a full calibration. If the range of values does not vary by more than 0.15 in. H_2O over the range of 0.4 to 4.0 in. H_2O, the arithmetic average of the values obtained during the calibration is used.

Barometer. Each field barometer is adjusted before each test series to agree within ± 0.1 inches of a reference aneroid barometer. The reference barometer is checked weekly against the station pressure value (corrected for elevation difference) reported by the National Weather Service station at the Raleigh-Durham airport, approximately 2.5 miles from Entropy's location.

Dry Gas Meter Identification: 6838323 Calibration by: N. Harden

Date: 3-26-86 Barometric Pressure (P_b): 30.12 in. Hg

*Date: ______ *Barometric Pressure (P_b): ______ in. Hg

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Approx. Flow Rate (Q) cfm	Spirometer Gas Volume (V_s) ft3	Spirometer Temp. (t_s) °F	Dry Gas Meter Gas Volume (V_{ds}) ft3	Dry Gas Meter Temp. (t_{ds}) °F	Pressure (Δp) in. H_2O	Time (θ) min.	Flow Rate (Q) cfm	Meter Meter Coeff. (Y_{ds})	Avg. Meter Coeff. ($\bar{Y}_{ds}$)
0.3	2.924	82.4	2.906	81	0.40	10.0	0.2864	1.0026	
	2.969	82.8	2.869	81	0.40	10.0	0.2906	1.0304	
	3.652	83.3	3.501	81	0.40	10.0	0.3571	1.0377	
0.4	4.235	80.6	4.330	~~8~~ 77	0.85	10.0	0.4125	0.9700	
	4.545	80.6	4.370	78	0.85	10.0	0.4427	1.0329	
	4.417	80.6	4.345	79	0.85	10.0	0.4302	1.0114	
0.5	5.328	78.8	5.206	75	1.10	10.0	0.5271	1.0135	
	5.383	79.7	5.212	77	1.15	10.0	0.5299	1.0248	
	5.301	79.7	5.166	78	1.15	10.0	0.529	1.020	
0.8	8.288	81	8.216	79	2.65	10.0	0.8067	0.9985	
	8.397	82	8.214	80	2.65	10.0	0.8158	1.0119	
	8.352	82.4	8.199	80	2.65	10.0	0.8108	1.0076	
1.0	10.638	83.3	10.472	81	4.15	10.0	1.040	1.0014	
	10.656	83.3	10.534	81.5	4.15	10.0	1.042	0.9981	
	10.528	83.3	10.450	81.5	4.15	10.0	1.0296	0.9941	

$$Y_{ds} = \frac{(V_s)\,(t_{ds} + 460)\,(P_b)}{(V_{ds})\,(t_s + 460)\,(P_b + (p / 13.6))}$$

$$Q = (17.64)\,\frac{(P_b)\,(V_s)}{(t_s + 460)\,(\theta)}$$

Dry Gas Meter Identification: 6838323 Calibration by: ______

Date: 3-26-86 Barometric Pressure (P_b): ______ in. Hg

*Date: ______ *Barometric Pressure (P_b): ______ in. Hg

ENTROPY
ENVIRONMENTALISTS, INC.

Approx. Flow Rate (Q) cfm	Spirometer		Dry Gas Meter		Pressure (Δp) in. H_2O	Time (θ) min.	Flow Rate (Q) cfm	Meter Meter Coeff. (Y_{ds})	Avg. Meter Coeff. ($\bar{Y}_{ds}$)
	Gas Volume (V_s) ft^3	Temp. (t_s) °F	Gas Volume (V_{ds}) ft^3	Temp. (t_{ds}) °F					
1.2	12.304	82.4	12.168	80	5.50	10.0	1.1945	0.9932	
	12.177	82.4	12.065	80	5.5	10.0	1.1821	0.9914	
	12.186	82.4	12.100	80	5.5	10.0	1.1830	0.9892	
1.3	13.698	82.4	13.494	79.5	6.85	10.0	1.3418	0.9931	
	13.552	82.4	13.505	80	6.85	10.0	1.3275	0.9826	
	13.752	81.5	13.712	80	7.0	10.0	1.3493	0.9833	

$\bar{Y}_{ds} = 1.0042$

$$Y_{ds} = \frac{(V_s)\ (t_{ds} + 460)\ (P_b)}{(V_{ds})\ (t_s + 460)\ (P_b + (\ p\ /\ 13.6))}$$

$$Q = (17.64)\ \frac{(P_b)\ (V_s)}{(t_s + 460)\ (\theta)}$$

Dry Gas Meter Identification: 6838323 Calibration by: T. McDonald Page 1 of 2

Date: 2-26-88 Barometric Pressure (P_b): 29.26 in. Hg

*Date: 2-29-88 *Barometric Pressure (P_b): 29.74
29.72
29.68 in. Hg

ENTROPY ENVIRONMENTALISTS, INC.

Approx. Flow Rate (Q) cfm	Spirometer		Dry Gas Meter		Pressure (Δp) in. H_2O	Time (O) min.	Flow Rate (Q) cfm	Meter Meter Coeff. (Y_{ds})	Avg. Meter Coeff. ($\bar{Y}_{ds}$)
	Gas Volume (V_s) ft^3	Temp. (t_s) °F	Gas Volume (V_{ds}) ft^3	Temp. (t_{ds}) °F					
	2.404	78.8	2.535	76	0.37	10:00	0.2303	0.9425	
	2.532	78.8	2.523	76.5	0.37	10:00	0.2426	0.9984	
	2.587	78.8	2.527	77	0.38	10:00	0.2478	1.0194	
	4.135	78.8	4.075	75	0.67	10:00	0.4026	1.0059	
	4.171	78.8	4.052	75	0.65	10:00	0.4061	1.0205	
	4.162	78.8	4.019	75.5	0.65	10:00	0.4052	1.0276	
	5.036	78.8	4.887	76	0.95	10:00	0.4824	1.0227	
	5.064	80.0	4.900	76	0.95	10:00	0.4840	1.0234	
	5.027	80.6	4.839	76	0.95	10:00	0.4800	1.0276	
	7.787	78.8	7.711	75	2.04	10:00	0.7582	0.9977	
	7.851	78.8	7.884	75	2.03	10:00	0.7644	1.0095	
	7.814	78.8	7.724	75	2.05	10:00	0.7608	0.9995	
	9.900	78.8	9.845	75	3.17	10:00	0.9639	0.9907	
	9.900	78.8	9.773	75	3.17	10:00	0.9639	0.9980	
	10.018	78.8	9.882	76	3.22	10:00	0.9754	1.0005	

$$Y_{ds} = \frac{(V_s)(t_{ds} + 460)(P_b)}{\quad}$$

$$Q = (17.64)\frac{(P_b)(V_s)}{\quad}$$

Dry Gas Meter Identification: 6838323 Calibration by: T. McDowell Page 2 of 2

Date: 2-26-88 Barometric Pressure (P_b): 29.26 in. Hg

*Date: 2-29-88 *Barometric Pressure (P_b): 29.74
29.72
29.68 in. Hg

ENTROPY ENVIRONMENTALISTS, INC.

Approx. Flow Rate (Q) cfm	Spirometer Gas Volume (V_s) ft^3	Spirometer Temp. (t_s) °F	Dry Gas Meter Gas Volume (V_{ds}) ft^3	Dry Gas Meter Temp. (t_{ds}) °F	Pressure (Δp) in. H_2O	Time (Θ) min.	Flow Rate (Q) cfm	Meter Meter Coeff. (Y_{ds})	Avg. Meter Coeff. ($\bar{Y}_{ds}$)
	11.658	77.9	11.640	76.5	4.20	10:00	1.1362	0.9887	
	11.694	77.9	11.594	77	4.275	10:00	1.1397	0.9964	
	11.548	77.9	11.547	77	4.23	10:00	1.1240	0.9881	
	13.042	77.9	12.946	77	5.25	10:00	1.2694	0.9928	
	12.851	78.8	12.884	77.5	5.23	10:00	1.2487	0.9823	
	12.933	79.7	12.859	78	5.17	10:00	1.2546	0.9899	

$\bar{Y}_{ds}$ = 1.001

Y_{ds} = $(V_s)\ (t_{ds} + 460)\ (P_b)$

Q = (17.64) $(P_b)\ (V_s)$

Meter Box Number: N4

Calibration by: ATM / SWS

Standard Meter Number: 6838323 Standard Meter Gamma: 1.0042

Date: 2-1-88 Barometric Pressure (P_b): 29.95 in. Hg

*Date: ________ *Barometric Pressure (P_b): ________ in. Hg

METERBOX CALIBRATION

Standard Meter			Meter Box Metering System				
Gas Volume (V_{ds}) ft^3	Temp. (t_{ds}) °F	Time (θ) min.	Orifice Setting (ΔH) in. H_2O	Gas Volume (V_d) ft^3	Temp. (t_d) °F	Coeff. (Y_d)	$\Delta H_@$ in. H_2O
3.929	67	10	0.50	4.089	76	.9802	1.762
3.927	67	10	0.50	4.074	77	.9851	1.760
8.061	67	10	2.10	8.327	80	.9910	1.745
7.921	67	10	2.10	8.231	83	.9906	1.797
11.889	68	10	4.80	12.291	86	.9928	1.820
11.911	68	10	4.80	12.347	89	.9955	1.803
					Average	.9892	1.781

$$Y_d = \frac{Y_{ds} * V_{ds} * (t_d + 460) * P_b}{V_d * (t_{ds} + 460) * (P_b + H/13.6)}$$

$$\Delta H_@ = \frac{0.0317 * \Delta H}{P_b * (t_d + 460)} * \left[\frac{(t_{ds} + 460) * \theta}{Y_{ds} * V_{ds}}\right]^2$$

ENTROPY

Meter Box Number: N4

Calibration by: JG

Meter Box Vacuum: 6 in. Hg

Job 5863

O+R

Standard Meter Number: 6838323

Standard Meter Gamma: 1,001

Date: 6-25-88

Barometric Pressure (P_b): 29.7 in. Hg

POST TEST CALIBRATION

Standard Meter			Meter Box Metering System				
Gas Volume (V_{ds}) ft³	Temp. (t_{ds}) °F	Time (θ) min.	Orifice Setting (ΔH) in. H_2O	Gas Volume (V_d) ft³	Temp. (t_d) °F	Coeff. (Y_d)	$\Delta H_@$ in. H_2O
6.880	73	10	1.50	7.072	84	0.990	1.763
6.812	73	10	1.50	7.044	86	0.988	1.791
6.823	73	10	1.50	7.061	89	0.993	1.776
					Average	0.990	1.777

$$Y_d = \frac{Y_{ds} * V_{ds} * (t_d + 460) * P_b}{V_d * (t_{ds} + 460) * (P_b + \Delta H/13.6)}$$

$$\Delta H_@ = \frac{0.0317 * \Delta H}{P_b * (t_d + 460)} * \left[\frac{(t_{ds} + 460) * \theta}{Y_{ds} * V_{ds}}\right]^2$$

NOZZLE NUMBER: 601

Date	Initials	Dia. 1	Dia. 2	Dia. 3	Dia. 4	Dia. 5	Average
12-2-82	ST	.184	.182	.186	.186	.185	0.185
04-07-83	HEC	0.184	0.185	0.188	0.185	0.188	0.186
01-10-84	PLO	.188	.189	.186	.186	.189	0.188
7-6-84	TTM	.188	.187	.187	.187	.188	0.187
7-24-84	NMH	.185	.185	.184	.182	.184	0.184
9-12-85	MH	.178	.179	.179	.181	.179	0.179
10.24.85	GMC	.184	.186	.186	.185	.185	0185
12.9-85	GMC	.184	.185	.185	.184	.186	.185
6-18-86	BB	.181	.183	.184	.181	.183	.182
9-17-86	BB	.184	.184	.186	.185	.187	0.185
11-12-86	BB	.184	.185	.184	.186	.185	0.185
1/12/87	J.E	.189	.190	.189	.191	.192	0.190
5-12 87	J.E	.185	.183	.184	.186	—	.185
7/31/87	J.E	.180	.180	.184	.180	.183	0.181
4/12/88	J.E	.184	.183	.181	.181	.178	0.183

NOTE: All diameters measured in inches.

APPENDIX D

SAMPLING AND ANALYTICAL PROCEDURES

Method 1A—Sample and Velocity Traverses for Stationary Sources with Small Stacks or Ducts

1. *Applicability and Principle*

The applicability and principle of this method are identical to Method 1, except its applicability is limited to 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.

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

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

2. *Procedure*

2.1 Selection of Measurement Site.

2.1.1 Particulate Measurements—Steady or Unsteady Flow. Select a particulate measurement site located preferably at least eight equivalent stack or duct diameters downstream and 10 equivalent diameters upstream from any flow disturbances such as a bends, expansions, or contractions in the stack, or from a visible flame. Next, locate the velocity measurement site eight equivalent diameters downstream of the particulate measurement site. See Figure 1A-1. If such locations are not available, select an alternative particulate measurement location at least two equivalent stack or duct diameters downstream and two and one-half diameters upstream from any flow disturbance. Then, locate the velocity measurement site two equivalent diameters downstream from the particulate measurement site. (See Section 2.1 of Method 1 for calculating equivalent diameters for a rectangular cross-section.)

2.1.2 Particulate (Steady Flow) or Velocity (Steady or Unsteady Flow) Measurements. If the average total volumetric flow rate in a duct is constant with respect to time or if only velocity measurements are required use the same criterion as in Section 2.1 of Method 1.

2.2 Determining the Number of Traverse Points.

2.2.1 Particulate Measurements (Steady or Unsteady Flow). Use Figure 1-1 of Method 1 to determine the number of traverse points. Before referring to the figure, however, determine the distance between the velocity and sampling sites and the distances to the nearest upstream and downstream disturbances and divide each distance by the stack diameter or equivalent diameter to determine the distances in terms of the number of duct diameters. Then, determine the number of traverse points from Figure 1-1 of Method 1 corresponding to each of these three distances. Choose the highest of the three numbers of traverse points (or a greater number) so that for circular ducts the number is a multiple of four; for rectangular ducts use one of those numbers shown in Table 1.1 of Method 1.

2.2.2 Particulate (Steady Flow) and Velocity (Non-Particulate) Measurements. Use Figure 1A-3 to determine number of traverse points, following the same procedure used for particulate traverses as described in Section 2.2.1 of Method 1.

3. *Bibliography*

1. Same as 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, North Carolina. January 1977.

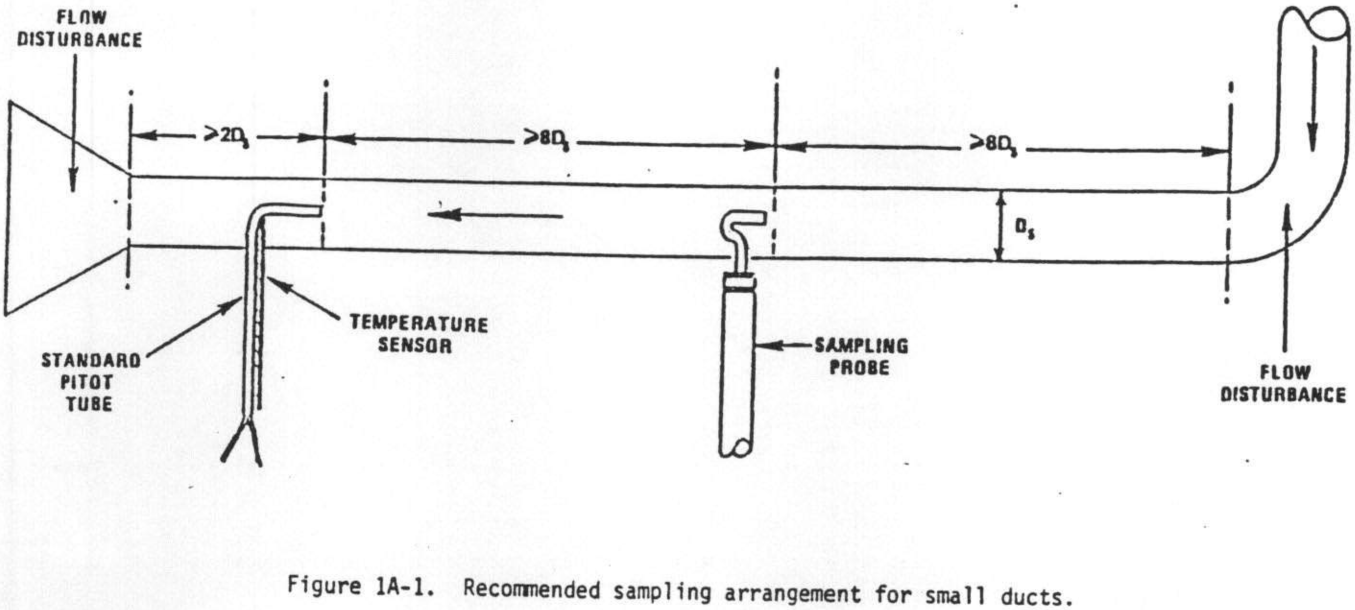


Figure 1A-1. Recommended sampling arrangement for small ducts.

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.

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 centimeters ($^{3}/_{16}$ 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.

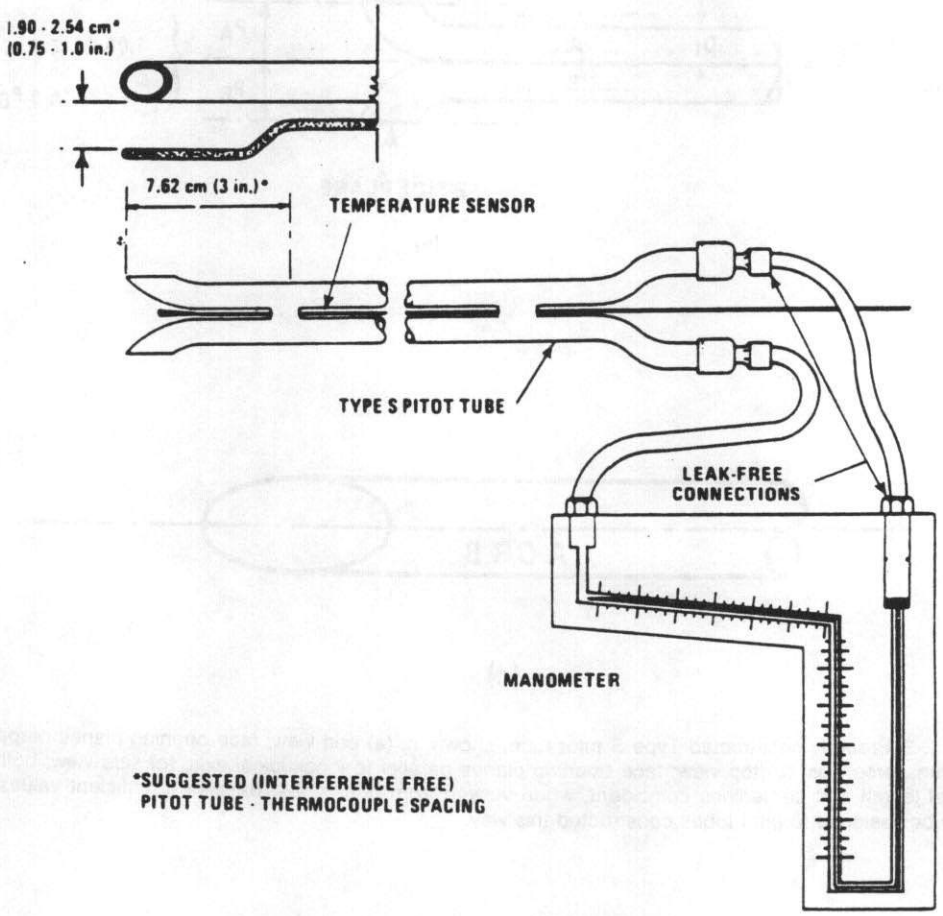


Figure 2-1. Type S pitot tube manometer assembly.

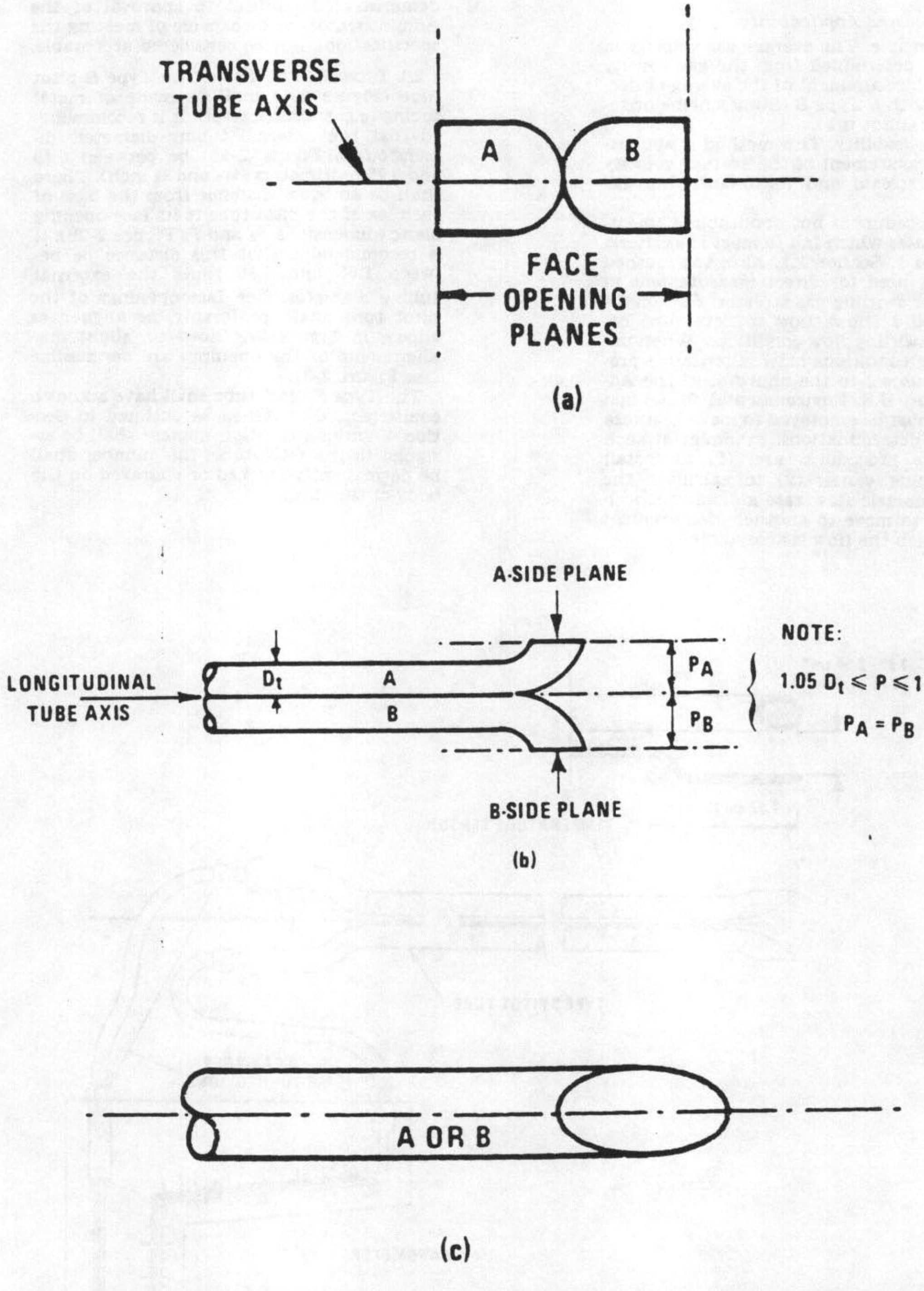


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline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

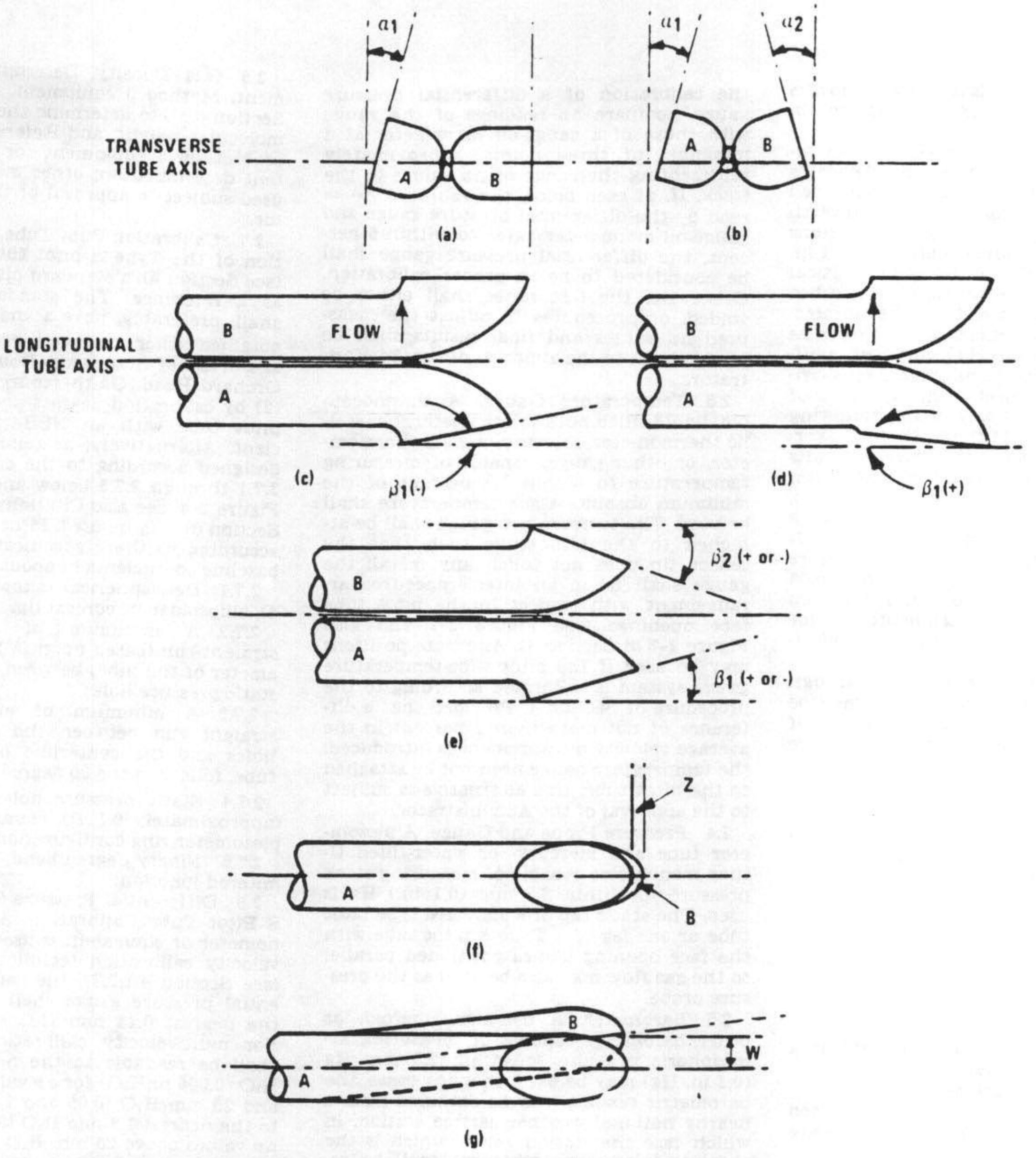


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as α1 and α2 10°, β1 and β2 5°, z 0.32 cm (1/8 in.) and w 0.08 cm (1/32 in.) (citation 11 in Section 6).

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 Section 6 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). Alternate 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 Pilot 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 Section 6) 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 Section 6).

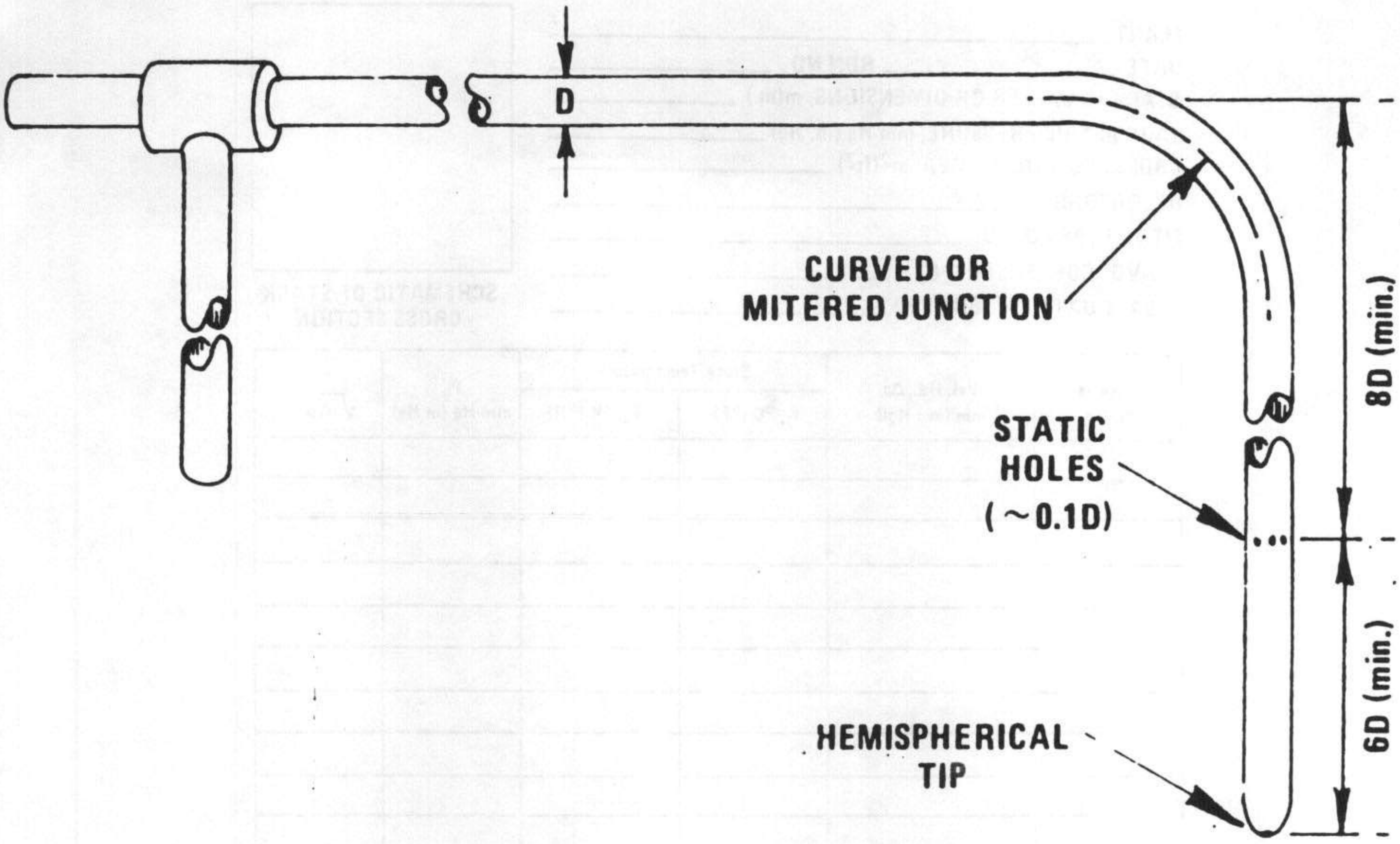


Figure 2-4. Standard pitot tube design specifications.

3. *Procedure*

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

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

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

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

3.5 Determine the atmospheric pressure.

PLANT ______________________

DATE ______________ RUN NO. ______________

STACK DIAMETER OR DIMENSIONS, m(in.) ______________

BAROMETRIC PRESSURE, mm Hg (in. Hg) ______________

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

OPERATORS ______________

PITOT TUBE I.D. NO. ______________

AVG. COEFFICIENT, C_p = ______________

LAST DATE CALIBRATED ______________

SCHEMATIC OF STACK CROSS SECTION

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

Figure 2-5. Velocity traverse data.

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

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

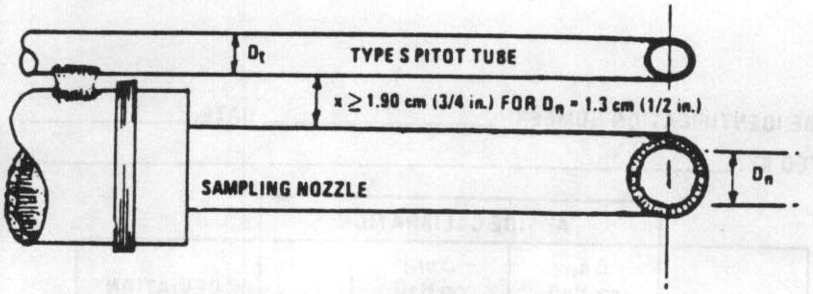
3.8 Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimensions rather than using blueprints.

4. *Calibration*

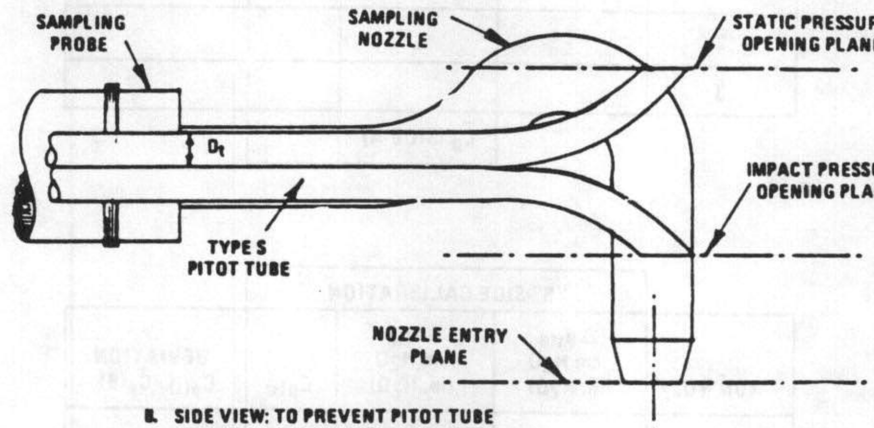
4.1 Type S Pitot Tube. Before its initial use, carefully examine the Type S pitot tube in top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figure 2-2 or 2-3. The pitot tube shall not be used if it fails to meet these alignment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

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

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



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



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

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 Section 6); 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:

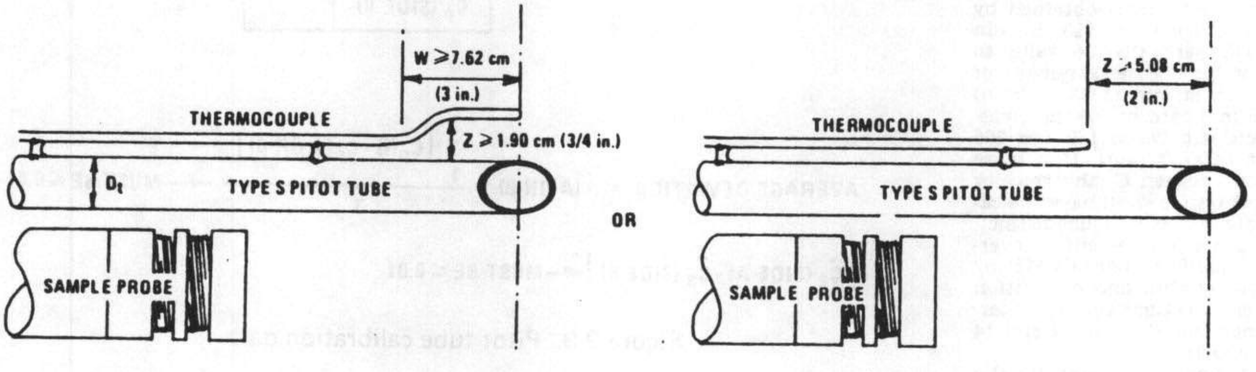


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

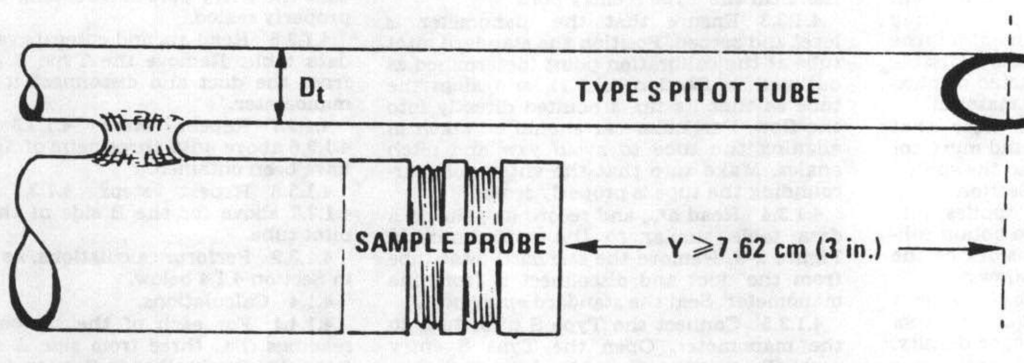


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

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:

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

Equation 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 Section 6 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.

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)		

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

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

Figure 2-9. Pitot tube calibration data.

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 car 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 coeffficient as follows:

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

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 C_p (side A), the mean A-side coefficient, and 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 C_p (side A), and the deviation of each B-side value of $C_{p(s)}$ from C_p C_p (side B). Use the following equation:

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

Equation 2-3

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

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

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of δ (side A) and δ (side B) are less than or equal to 0.01 and if the absolute value of the difference between C_p (A) and C_p (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

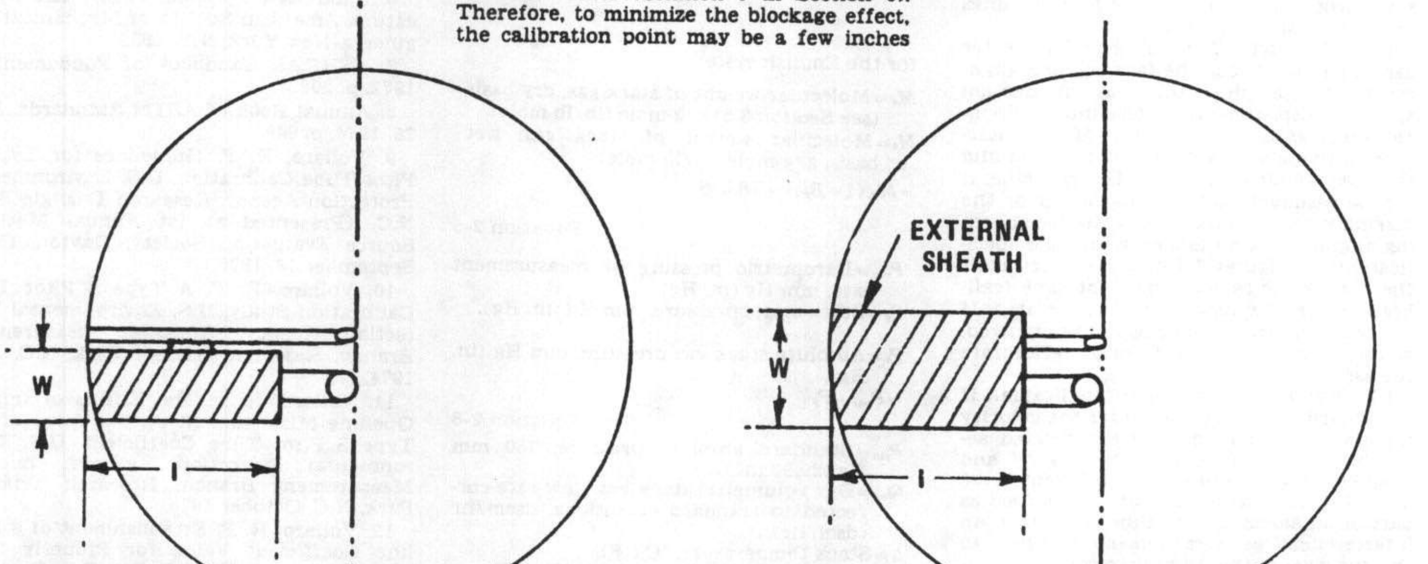
4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., C_p (side A) and C_p (side B), will be valid, so long as either: (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 Section 6). 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 (δ) value of 0.01 or less (see Section 4.1.4.4).



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

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

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 Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Section 6).

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 damanged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

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

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

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

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

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

5. *Calculations*

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

5.1 Nomenclature.

A=Cross-sectional area of stack, m² (ft²).

B_{ws}=Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume.

C_p=Pitot tube coefficient, dimensionless.

K_p=Pitot tube constant,

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

for the metric system and

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

for the English system.

M_d=Molecular weight of stack gas, dry basis (see Section 3.6) g/g-mole (lb/lb-mole).

M_s=Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).

$= M_d\,(1-B_{ws}) + 18.0\ B_{ws}$

Equation 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).

$= P_{bar} + P_g$

Equation 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

Equation 2-7

$= 460 + t_s$ for English

Equation 2-8

T_{std}=Standard absolute temperature, 293 °K (528° R)

v_s=Average stack gas velocity, m/sec (ft/sec).

Δ_p=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.

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

Equation 2-10

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[illegible] Conditions [illegible]
Meeting of the [illegible] Pollution Control
[illegible] Association. [illegible]
[illegible] Toronto, Canada [illegible]

Method 3—Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight

1. *Principle and Applicability*

1.1 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 carbon dioxide (CO_2), percent oxygen (O_2), and, if necessary, percent carbon monoxide (CO). If a dry molecular weight determination is to be made, either an Orsat or a Fyrite [1] analyzer may be used for the analysis; for excess air or emission rate correction factor determination, an Orsat analyzer must be used.

1.2 Applicability. This method is applicable for determining CO_2 and O_2 concentrations, excess air, 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, CO, and nitrogen (n_2) are not present in concentrations sufficient to affect the results.

Other methods, as well as modifications to the procedure described herein, are also applicable for some or all of the above determinations. Examples of specific methods and modifications include: (1) a multi-point sampling method using an Orsat analyzer to analyze individual grab samples obtained at each point; (2) a method using CO_2 or O_2 and stoichiometric calculations to determine dry molecular weight and excess air; (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.

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. The probe should be made of stainless steel or borosilicate glass tubing and should be 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 material are aluminum, copper, quartz glass and Teflon.

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

2.2 Integrated Sampling (Figure 3-2).

2.2.1 Probe. A probe such as that described in Section 2.1.1 is suitable.

2.2.2 Condenser. An air-cooled or water-cooled condenser, or other condenser that will not remove O_2, CO_2, CO, and N_2, may be used to remove excess moisture which would interfere with the operation of the pump and flow meter.

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

2.2.4 Pump. A leak-free, diaphragm-type pump, or equivalent, is used 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. The rotameter, or equivalent rate meter, used should be capable of measuring flow rate to within ±2 percent of the selected flow rate. A flow rate range of 500 to 1000 cm^3/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, may be used. 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 H_2O (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 28 cm (12 in.) is used for the flexible bag leak-check.

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

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

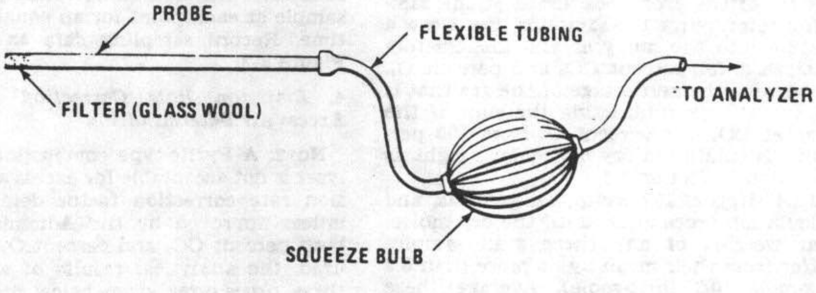

Figure 3-1. Grab-sampling train.

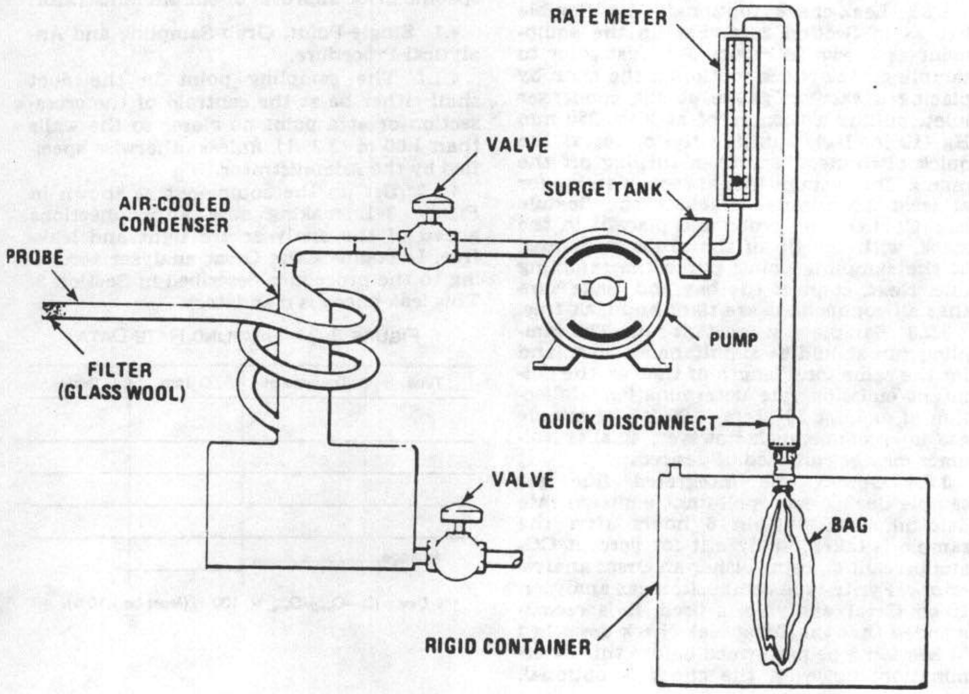

Figure 3-2. Integrated gas-sampling train.

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

2.3.1 Dry Molecular Weight Determination. An Orsat analyzer or Fyrite type combustion gas analyzer may be used.

2.3.2 Emission Rate Correction Factor or Excess Air Determination. An Orsat analyzer must be used. For low CO_2 (less than 4.0 percent) or high O_2 (greater that 15.0 percent) concentrations, the measuring burette of the Orsat must have at least 0.1 percent subdivisions.

3. *Dry Molecular Weight Determination*

Any of the three sampling and analytical procedures described below may be used for determining the dry molecular weight.

3.1 Single-Point, Grab Sampling and Analytical Procedure.

3.1.1 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.

3.1.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight and leak-free. If and Orsat analyzer is used, it is recommended that the analyzer be leaked-checked by following the procedure in Section 5; however, the leak-check is optional.

3.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. 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 O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

3.1.4 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 (lb/lb-mole).

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 (optional) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to 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 and leak free.

3.2.3 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.

3.2.4 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 the Orsat leak-check described in Section 5 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 O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

3.2.5 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).

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

3.3.1 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 twelve 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.

3.3.2 Follow the procedures outlined in sections 3.2.2 throught 3.2.5, 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.

4. *Emission Rate Correction Factor or Excess Air Determination*

NOTE: A Fyrite-type combustion gas analyzer is not acceptable for excess air or emission rate correction factor determination, unless approved by the Administrator. If both percent CO_2 and percent O_2 are measured, the analytical results of any of the three procedures given below may also be used for calculating the dry molecular weight.

Each of the three procedures below shall be used only when specified in an applicable subpart of the standards. The use of these procedures for other purposes must have specific prior approval of the Administrator.

4.1 Single-Point, Grab Sampling and Analytical Procedure.

4.1.1 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.

4.1.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight and leak-free. Leak-check the Orsat analyzer according to the procedure described in Section 5. This leak-check is mandatory.

FIGURE 3-3—SAMPLING RATE DATA

Time	Traverse pt.	Q lpm	% dev.ª
Average..............................			

ª% Dev.=$(Q—Q_{avg})/Q_{avg}$ × 100 (Must be $\leq$10%)

4.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer. For emission rate correction factor determination, immediately analyze the sample, as outlined in Sections 4.1.4 and 4.1.5, for percent CO_2 or percent O_2. If excess air is desired, proceed as follows: (1) immediately analyze the sample, as in Sections 4.1.4 and 4.1.5, 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 6.2.

4.1.4 To insure 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.)

4.1.5 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis.

NOTE: Since this single-point, grab sampling and analytical procedure in 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 4.4 be used to validate the analytical data.

4.2 Single-Point, Integrated Sampling and Analytical Procedure.

4.2.1 The sampling point in the duct shall be located as specified in Section 4.1.1.

4.2.2 Leak-check (mandatory) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to sampling, leak-check (mandatory) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of a least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum shall 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 and leak free.

4.2.3 Sample at a constant rate, or as specified by the Administrator. The sampling run must be simultaneous with, and for the same total lengh 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.

4.2.4 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 4.2.5 through 4.2.7). The Orsat analyzer must be leak-check (see Section 5) before the analysis. If excess air is desired, proceed as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 4.2.5 through 4.2.7) 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; (3) calculate percent excess air, as outlined in Section 6.2.

4.2.5 To insure 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 of four) should be make between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

4.2.6 Repeat the analysis until the following criteria are met:

4.2.6.1 For percent CO_2, repeat the analytical procedure until the results of any three analyses differ by no more that (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 the three acceptable values of percent CO_2 and report the results to the nearest 0.1 percent.

4.2.6.2 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.

4.2.6.3 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.

4.2.7 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before an after the analysis.

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 Citation 5 in the Bibliography be used to validate the analytical data.

4.3 Multi-Point, Integrated Sampling and Analytical Procedure.

4.3.1 Both the minimum number of sampling points and the sampling point location shall be as specified in Section 3.3.1 of this method. The use of fewer points than specified is subject to the approval of the Administrator.

4.3.2 Follow the procedures outlined in Sections 4.2.2 through 4.2.7, 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.

4.4 Quality Control Procedures.

4.4.1 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 the 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.

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

$$F_o = \frac{20.9 - \%O_2}{\%CO_2}$$

Eq. 3-3

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 is 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: %CO = Percent CO by volume (dry basis).

4.4.1.2 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 combination, 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:

$$F_o = \frac{0.209\ F_d}{F_c}$$

Eq. 3-4

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

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.

5. *Leak-Check Procedure for Orsat Analyzers*

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

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

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

5.1.3 Record the meniscus position.

5.1.4 Observe the menicus in the burette and the liquid level in the pipette for movement over the next 4 minutes.

5.1.5 For the Orsat analyzer to pass the leak-check, two conditions must be met.

5.1.5.1 The liquid level in each pipette must not fall below the bottom of the capillary tubing during this 4-minute interval.

5.1.5.2 The meniscus in the burette must not change by more than 0.2 ml during this 4-minute interval.

5.1.6 If the analyzer fails the leak-check procedure, all rubber connections and stopcocks should be checked until the cause of the leak is identified. Leaking stopcocks must be disassembled, cleaned, and regreased. Leaking rubber connections must be replaced. After the analyzer is reassembled, the leak-check procedure must be repeated.

6. *Calculations*

6.1 Nomenclature.

M_d = Dry molecular weight, g/g-mole (lb/lb-mole).

%EA = Percent excess air.

$\%CO_2$ = 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).

0.264 = Ratio of O_2 to N_2 in air, v/v.

0.280 = Molecular weight of N_2 or CO, divided by 100.

0.320 = Molecular weight of O_2 divided by 100.

0.440 = Molecular weight of CO_2 divided by 100.

6.2 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 4.1.3 or 4.2.4) into Equation 3-1.

$$\%\,EA = \frac{\%O_2 - 0.5\%\ CO}{0.264\%\ N_2 - (\%O_2 - 0.5\ \%\ CO)} \times 100$$

Equation 3-1

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, alternate methods, subject to approval of the Administrator, are required.

6.3 Dry Molecular Weight. Use Equation 3-2 to calculate the dry molecular weight of the stack gas

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO)$$

Equation 3-2

NOTE: The above equation does not consider argon in air (about 0.9 percent, moleculars weight of 37.7). A negative error of about 0.4 percent is introduced. The tester may opt to include argon in the analysis using procedures subject to approval of the Administrator.

7. *Bibliography*

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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:

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.

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

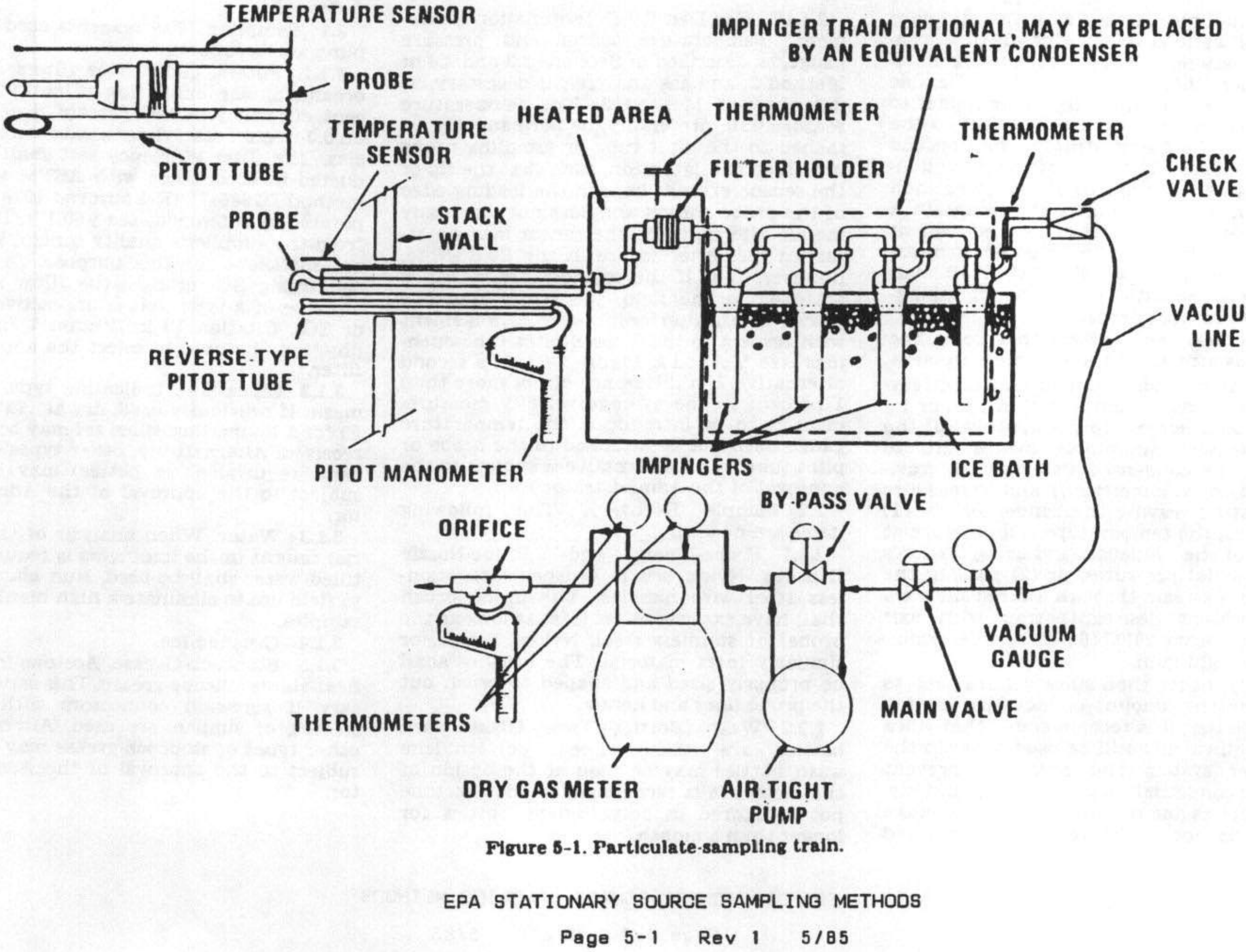

Figure 5-1. Particulate-sampling train.

2.1.4 Differentia 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 differentia 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 temperture 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 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 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. Airtight containers to store silica gel.

2.2.7 Funnel and Rubber Policeman. To aid in transfer of silica gel to container; not

2.2.8 Funnel. Glass or polyethylene, to aid in sample recovery.

2.2 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 Section 7 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, 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 procedures 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 2, Section 3.6; if integrated Method 3 sampling is used for molecular weight determination, the integrated bag sample shall be taken simultaneously with, and for the same total length of time as, the particulate sample run.

Select a nozzle size based on the range of velocity heads, such that it is not necessary to change the nozzle size in order to maintain isokinetic sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads 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 cirumstances, 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 property 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 (cycone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in. Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in. Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with bypass valve fully open and coarse adjust valve, completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of bypass value; 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 get 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 unecessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction will need to be applied to the total volume of dry gas metered;

if, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

Immediately after component changes, leak-checks are optional; if such leak-checks are done, the procedure outlined in Section 4.1.4.1 above shall be used.

4.1.4.3 Post-test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leakcheck 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.

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.

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		
	(e). min.	mm Hg (in. Hg)	(T_s). °C (° F)	(Δ P_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.			

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 be used to 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 levcel 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 volumentrically or gravimetrically. Transfer the acetone to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

NOTE: At the option of the tester, the contents of Container No. 2 as well as the acetone blank container may be evaporated at temperatures higher than ambient. If evaporation is done at an elevated temperature, the temperature must be below the boiling point of the solvent; also, to prevent "bumping," the evaporation process must be closely supervised, and the contents of the beaker must be swirled occasionally to maintain an even temperature. Use extreme care, as acetone is highly flammable and has a low flash point.

4.4 Quality Control Procedures. The following quality control procedures are suggested to check the volume metering system calibration values at the field test site prior to sample collection. These procedures are optional for the tester.

4.4.1 Meter Orifice Check. Using the calibration data obtained during the calibration procedure described in Section 5.3, determine the $\Delta H_{@}$ for the metering system orifice. The $\Delta H_{@}$ is the orifice pressure differential in units of in. H_2O that correlates to 0.75 cfm of air at 528°R and 29.92 in. Hg. The $\Delta H_{@}$ is calculated as follows:

$$\Delta H_{@} = 0.0319\ \Delta H\ \frac{T_m}{P_{bar}}\ \frac{\Theta^2}{Y^2 V_m^2}$$

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 Calibration 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 01.025 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. Before its initial use in the field, the metering system shall be calibrated according to the procedure outlined in APTD-0576. Instead of physically adjusting the dry gas meter dial readings to correspond to the wet test meter readings, calibration factors may be used to mathematically correct the gas meter dial readings to the proper values. Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. for these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.0057 m³/min (0.02 cfm); at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divide the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m³/min (0.02 cfm).

After each field use, the calibration of the metering system shall be checked by performing three calibration runs at a single, intermediate orifice setting (based on the previous field test). With the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the metering system. Calculate the average value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the full range of orifice settings, as outlined in APTD-0576.

Alternative procedures, e.g., using the orifice meter coefficients, maybe used, subject to the approval of the Administrator.

NOTE: If the dry gas meter coefficient values obtained before and after a test series differ by more than 5 percent, the test series shall either be voided, or calculations for test series shall be performed using whichever meter coefficient value (i.e., before or after) gives the lower value of total sample volume.

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 ft³/rev). A spirometer of 400 liters (14 ft³) 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 m³ (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 ΔH@, the orifice calibration factor, at each orifice setting as shown on Figure 5.6. Allowable tolerances for individual Y and ΔH@, values are given in Figure 5.6. Use the average of the Y values in the calculations in Section 6.

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 0.00057m³/min (0.02 cfm); at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divided the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m³/min (0.02 cfm).

5.3.2 Calibration After Use. After each filed 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, inset 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 follow-

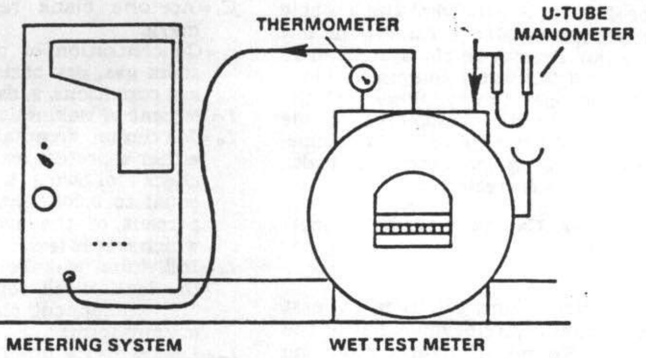

Figure 5.5 Equipment arrangement for metering system calibration.

Date________________

Metering System Identification: ________________

Barometric pressure, P_b = ______ in. Hg

Orifice manometer setting ΔH in. H_2O	Spirometer (wet meter) gas volume (V_w) ft³	Dry gas meter volume (V_m) ft³	Temperatures				Time (θ) min
			Spirometer (wet meter) (t_w) °F	Dry Gas Meter			
				Inlet (t_o) °F	Outlet (t_i) °F	Average (t_m) °F	

Calculations

ΔH in. H_2O	Y	$\Delta H_@$
	$\frac{V_w\, P_b\, (t_m + 460)}{V_m (P_b + \frac{\Delta H}{13.6})\, (t_w + 460)}$	$\frac{0.0317\ \Delta H}{P_b\, (t_o + 460)} \left[\frac{(t_w + 460)\, \theta}{V_w}\right]^2$,
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).

ing procedure is suggested (see Figure 5-4): Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing atached 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.

6.1 Nomenclature

A_n=Cross-sectional area of nozzle, m^2 (ft^2).
B_{ws}=Water vapor in the gas stream, proportion by volume.
C_a=Acetone blank residue concentration, mg/g.
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 0.0057 m^3/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 ($i=1, 2, 3....n$), m^3/min (cfm).
L_p=Leakage rate observed during the post-test leak check, m^3/min (cfm).
m_n=Total amount of particulate matter collected, mg.
M_w=Molecular weight of water, 18.0 g/g-mole (18.0lb/lb-mole).
m_a=Mass of residue of acteone after evaporation, mg.
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-m^3/°K-g-mole (21.85 in. Hg-ft^3/°R-lb-mole).
T_m=Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).
T_s=Absolute average stack gas temperature (see Figure 5-2), °K (°R).
T_{std}=Standard absolute temperature, 293° K (528° R).
V_a=Volume of acetone blank, ml.
V_{aw}=Volume of acetone used in wash, ml.
V_{lc}=Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.
V_m=Volume of gas sample as measured by dry gas meter, dcm (dscf).
$V_{m(std)}$=Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$=Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
v_s=Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).
W_a=Weight of residue in acetone wash, mg.
Y=Dry gas meter calibration factor.
ΔH=Average pressure differential across the orifice meter (see Figure 5-2), mm H_2O (in. H_2O).
ρ_a=Density of acetone, mg/ml (see label on bottle).

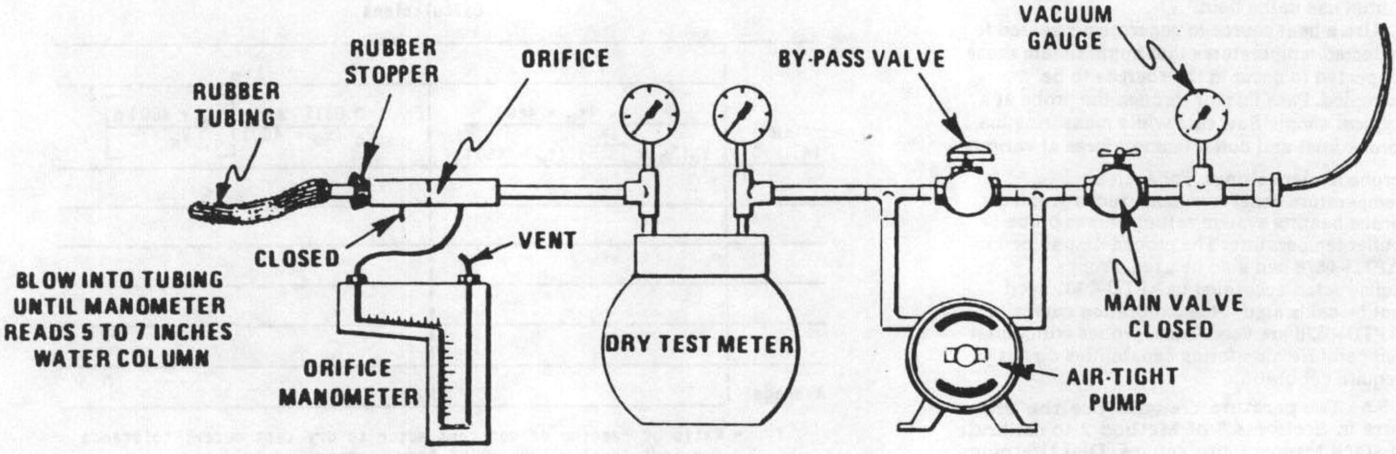

Figure 5-4. Leak check of meter box.

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.

Equation 5-2

$$V_{w(std)} = V_{1c}\left(\frac{\rho_w}{M_w}\right)\left(\frac{RT_{std}}{P_{std}}\right) = K_2 V_{1c}$$

where:

K_2=0.001333 m³/ml for metric units
=0.04707 ft³/ml for English units.

6.5 Moisture Content.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)}+V_{w(std)}}$$

Equation 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_w 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.

Equation 5-4

$$C_a = \frac{m_a}{V_a \rho_a}$$

6.7 Acetone Wash Blank.

$W_a = C_a V_{aw} \rho_a$ Equation 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) ($m_n / V_{m(std)}$) Equation 5-6

6.10 Conversion Factors:

From	To	Multiply by
scf	m³	0.02832.
g/ft³	gr/ft³	15.43.
g/ft³	lb/ft³	2.205×10⁻³.
g/ft³	g/m³	35.31.

6.11 Isokinetic Varition.

6.11.1 Calculation From Raw Data.

$$I = \frac{100\ T_s[K_3 V_{1c}+(P_m/T_m)(P_{bar}+\Delta H/13.6)]}{60\theta_{vs}\ P_s\ A_n}$$

Equation 5-7

where:

K_3=0.003454 mm Hg−m³/ml−°K for metric units.
=0.002669-in. Hg−ft³/ml−°R for English units.

6.11.2 Calculation From Intermediate Values.

$$I = \frac{T_s V_{m(std)} P_{std} 100}{T_{std} v_s \theta A_n P_s 60(1-B_{ws})}$$

$$= K_4 \frac{T_s V_{m(std)}}{P_s V_s A_n \theta (1-B_{ws})}$$

Equation 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 judeged to be unacceptable, reject the particulate results and repeat the test.

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 H₂O (4 in. H₂O) at a flow rate of 30 liters/min (1 cfm)]. This can be accomplished by using large diameter tubing connections and straight pipe fittings.

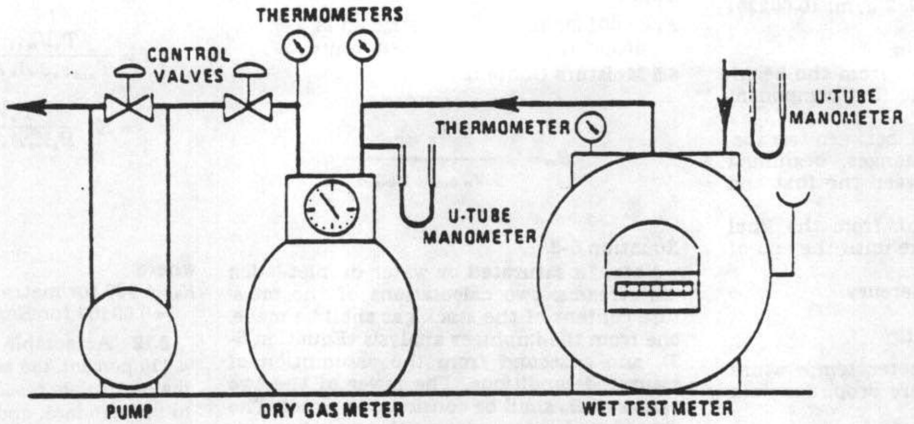

Figure 5.7 . Equipment arrangement for dry-gas meter calibration.

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

			TEMPERATURES								
				DRY GAS METER							
APPROXIMATE FLOW RATE ($\tilde{Q}$) cfm	SPIROMETER (WET METER) GAS VOLUME (V_s) ft^3	DRY GAS METER VOLUME (V_{dg}) ft^3	SPIROMETER (WET METER) (t_s) °F	INLET (t_i) °F	OUTLET (t_o) °F	AVERAGE ($\bar{t}_d$) °F	DRY GAS METER PRESSURE (Δp) in. H$_2$O	TIME (Θ) min.	FLOW RATE (Q) cfm	METER METER COEFFICIENT (Y_{ds})	AVERAGE METER COEFFICIENT ($\bar{Y}_{ds}$)
0.40											
0.60											
0.80											
1.00											
1.20											

$$Q = 17.65 \cdot \frac{V_s}{\Theta} \cdot \frac{P_b}{(t_s + 460)} \qquad Y_{ds} = \frac{V_s}{V_{dg}} \cdot \frac{(\bar{t}_d + 460)}{(t_s + 460)} \cdot \frac{P_b}{\left(P_b + \frac{\Delta p}{13.6}\right)}$$

Figure 5.8. Example data sheet for calibration of a standard dry gas meter for method 5 sampling equipment (English units).

7.1.1.4 Calculate flow rate, Q, for each run using the wet test meter gas volume, V_w, and the run time, θ. Calculate the dry gas meter coefficient, Y_{ds}, for each run. These calculations are as follows:

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

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

Where:

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

V_w=Wet test meter volume, liters (ft ^{3}).

V_{ds}=Dry gas meter volume, liters (ft ^{3}).

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, $\overline{Y}_{ds}$.

7.1.1.6 Prepare a curve of meter coefficient, $\overline{Y}_{ds}$, 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.

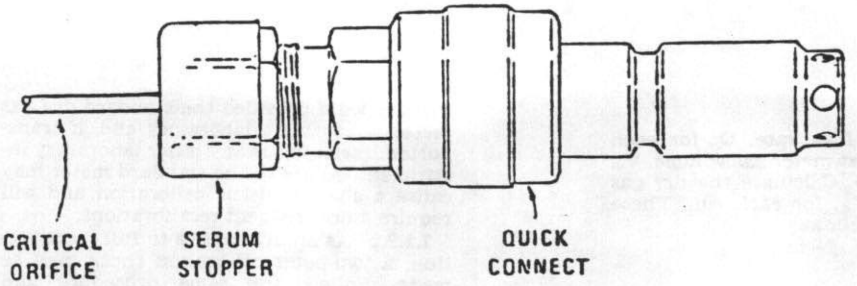

Figure 5-9. Critical orifice adaptation to Method 5 metering system.

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.

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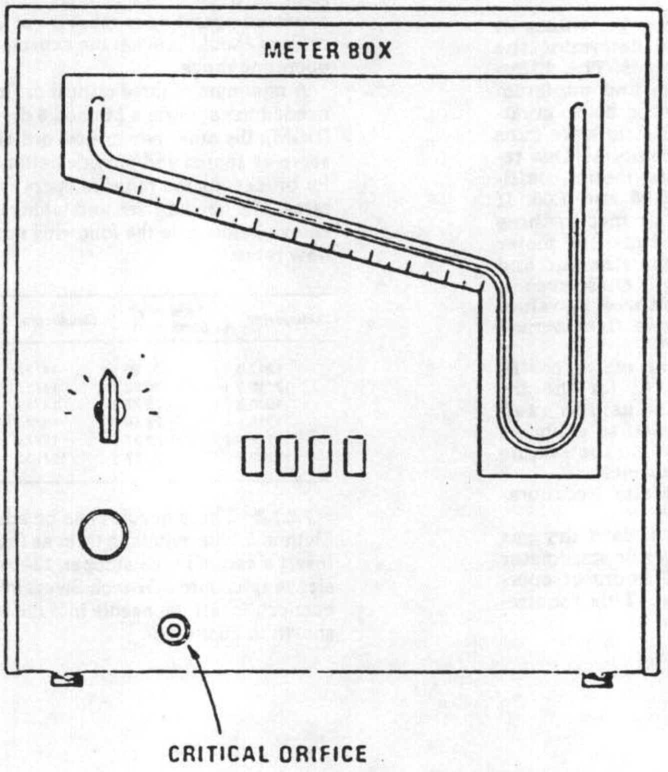

Figure 5-10. Apparatus setup.

7.2.2.2.1 Allow a warm-up time of 15 minutes. This step is important to equilibrate the temperature conditions through the DGM.

7.2.2.2.2 Leak check the system as in Section 7.2.2.1.1. The leakage rate shall be zero.

7.2.2.2.3 Before calibrating the critical orifice, determine its suitability and the appropriate operating vacuum as follows: Turn on the pump, fully open the coarse adjust valve, and adjust the by-pass valve to give a vacuum reading corresponding to about half of atmospheric pressure. Observe the meter box orifice manometer reading, H. Slowly increase the vacuum reading until a stable reading is obtained on the meter box orifice manometer. Record the critical vacuum for each orifice.

Orifices that do not reach a critical value shall not be used.

7.2.2.2.4 Obtain the barometric pressure using a barometer as described in Section 2.1.9. Record the barometric pressure, P_{bar}, in mm Hg (in. Hg).

7.2.2.2.5 Conduct duplicate runs at a vacuum of 25 to 50 mm Hg (1 to 2 in. Hg) above the critical vacuum. The runs shall be at least 5 minutes each. The DGM volume readings shall be in increments of 0.00283 m³ (0.1 ft³) or in increments of complete revolutions of the DGM. As a guideline, the times should not differ by more than 3.0 seconds (this includes allowance for changes in the DGM temperatures) to achieve ± 0.5 percent in K'. Record the information listed in Figure 5–11.

7.2.2.2.6 Calculate K' using Equation 5–9.

K' = Critical orifice coefficient,

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.

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

$$\frac{(m^3)(°K)^{1/2}}{(mm.\ Hg)\ (min)} \left[\frac{(ft^3)(°R)^{1/2}}{(in.\ Hg)\ (min)} \right]$$

Sections 7.2.2.2.1 to 7.2.2.2.5. Record the information listed in Figure 5.12.

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 No.	
		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.) H₂O.		
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

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:"

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

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

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

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 cheching 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 No.	
		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.) H₂O.		
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.

8. *Bibliography*

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[FR Doc. 87-6551 Filed 3-25-87; 8:45 am]