Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

AP42 Section:	11.3
Reference:	23
Title:	Stationary Source Sampling Report: Chatham Brick And Tile Company, Sanford, NC, Kiln No. 2 Particulate Emissions Compliance Testing, Entropy Environmentalists, Inc., Research Triangle Park, NC, July 1979.

AP-42 Section	11.3
Reference	23
Report Sect.	4
Reference	21

ENTROPY ENVIRONMENTALISTS, INC

SPECIALISTS IN AIR POLLUTION MEASUREMENT & MANAGEMENT

STATIONARY SOURCE SAMPLING REPORT

CHATHAM BRICK AND TILE COMPANY

SANFORD, NORTH CAROLINA

KILN #2

PARTICULATE EMISSIONS COMPLIANCE TESTING

JULY 1979

P.O. Box 12291, Research Triangle Park, North Carolina 27709
Phone 919 781 6550

REPORT CERTIFICATION

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

Date July 27, 1979 Signature Frank J. Phoenix

Frank J. Phoenix

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 27, 1979 Signature D. James Grove

D. James Grove, P. E.

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INTRODUCTION

Stationary source sampling was performed on July 18-19, 1979 at Chatham Brick and Tile Company, Sanford, North Carolina to determine the particulate emissions from kiln #2 which is exhausted by two stacks - the waste heat stack and the dryer stack. Three sets of tests at each site were performed simultaneously.

Immediately following is the "Summary of Results" section, presenting a summary for all the tests. Detailed results of the six particulate tests appear in Appendix A.

A description of the process, including an air flow schematic, is given in the "Process Description and Operation" section.

The last section, "Sampling and Analytical Procedures," briefly describes the sampling strategy used. For a detailed description of the equipment and procedures, see Appendix D. Calibration data is given in Appendix E.

SUMMARY OF RESULTS

Presented in Table 1 below are the emission rates as determined by the six particulate emission tests performed on the waste heat and dryer exhaust stacks.

TABLE 1
PARTICULATE EMISSIONS
pounds per hour

Simultaneous Tests	Waste Heat Stack	Dryer Exhaust	Total
1 & 4	1.35	0.81	2.16
2 & 5	1.12	0.38	1.50
3 & 6	1.80	0.49	2.29
Average	1.42	0.56	1.98

According to North Carolina Regulation 2D.0515, the maximum allowable emission rate is 13.2 pounds per hour. This is based on a process rate of 5.75 tons per hour and includes an estimate of the sawdust being burned. Determination of the process rate is given in the "Process Description and Operation" section.

Tables 2 and 3 on the following pages give the individual test summaries for the tests performed at the waste heat stack and the dryer exhaust.

TABLE 2

PARTICULATE TESTS SUMMARY OF RESULTS

Waste Heat Stack

RUN NUMBER	1	2	3
DATE	7/18/79	7/18/79	7/19/79
STACK TEMPERATURE, DEG. F	341.	344.	323.
STACK FLOW RATE SCFM* DRY	12037.	11888.	12328.
STACK FLOW RATE ACFM, WET	19677.	19577.	19522.
VOLUME OF GAS SAMPLED SCF* DRY	50.91	49.83	52.34
PERCENT ISOKINETIC	102.3	101.3	102.6
PARTICULATES, EPA METHOD 5:			
MILLIGRAMS - CATCH	43.2	35.4	57.8
GRAINS PER DSCF*	.0131	.0110	.0170
POUNDS PER HOUR	1.35	1.12	1.80

* 68 DEG F, 29.92 IN. HG

TABLE 3

PARTICULATE TESTS SUMMARY OF RESULTS

Dryer Outlet Stack

RUN NUMBER	4	5	6
DATE	7/18/79	7/18/79	7/19/79
STACK TEMPERATURE, DEG. F	124.	124.	116.
STACK FLOW RATE SCFM* DRY	16272.	14877.	15246.
STACK FLOW RATE ACFM, WET	18917.	17596.	17527.
VOLUME OF GAS SAMPLED SCF* DRY	50.79	49.21	49.00
PERCENT ISOKINETIC	93.8	99.4	96.5
PARTICULATES, EPA METHOD 5:			
MILLIGRAMS - CATCH	19.1	9.6	12.0
GRAINS PER DSCF*	.0058	.0030	.0038
POUNDS PER HOUR	.81	.38	.49

* 68 DEG F, 29.92 IN. HG

PROCESS DESCRIPTION AND OPERATION

Chatham Brick and Tile Company in Sanford, North Carolina manufactures bricks, which involves the screening and blending of the raw materials and the drying and firing of the final, shaped product. The bricks travel through a tunnel consisting of three zones - brick dryer, firing zone, and cooling zone. The bricks are placed on cars which travel on rails through the kiln. When the car enters and leaves the tunnel, ambient air is allowed to enter uncontrolled. The dryer exhaust stack is located at the beginning of the tunnel.

The car enters the brick dryer where excess water is evaporated off. Hot air used to dry the brick is supplied by the firing zone of the tunnel. The firing zone is located near the middle of the kiln. Natural gas and sawdust are used to heat the firing zone. As shown in Figure 1, ambient air is used to cool the bricks. The beginning of the firing zone is exhausted by a fan.

Potential emissions from the kiln consist mainly of particulate matter in the form of dust generated by the handling of the bricks, and of combustion products from the sawdust. No pollution control equipment is presently in use.

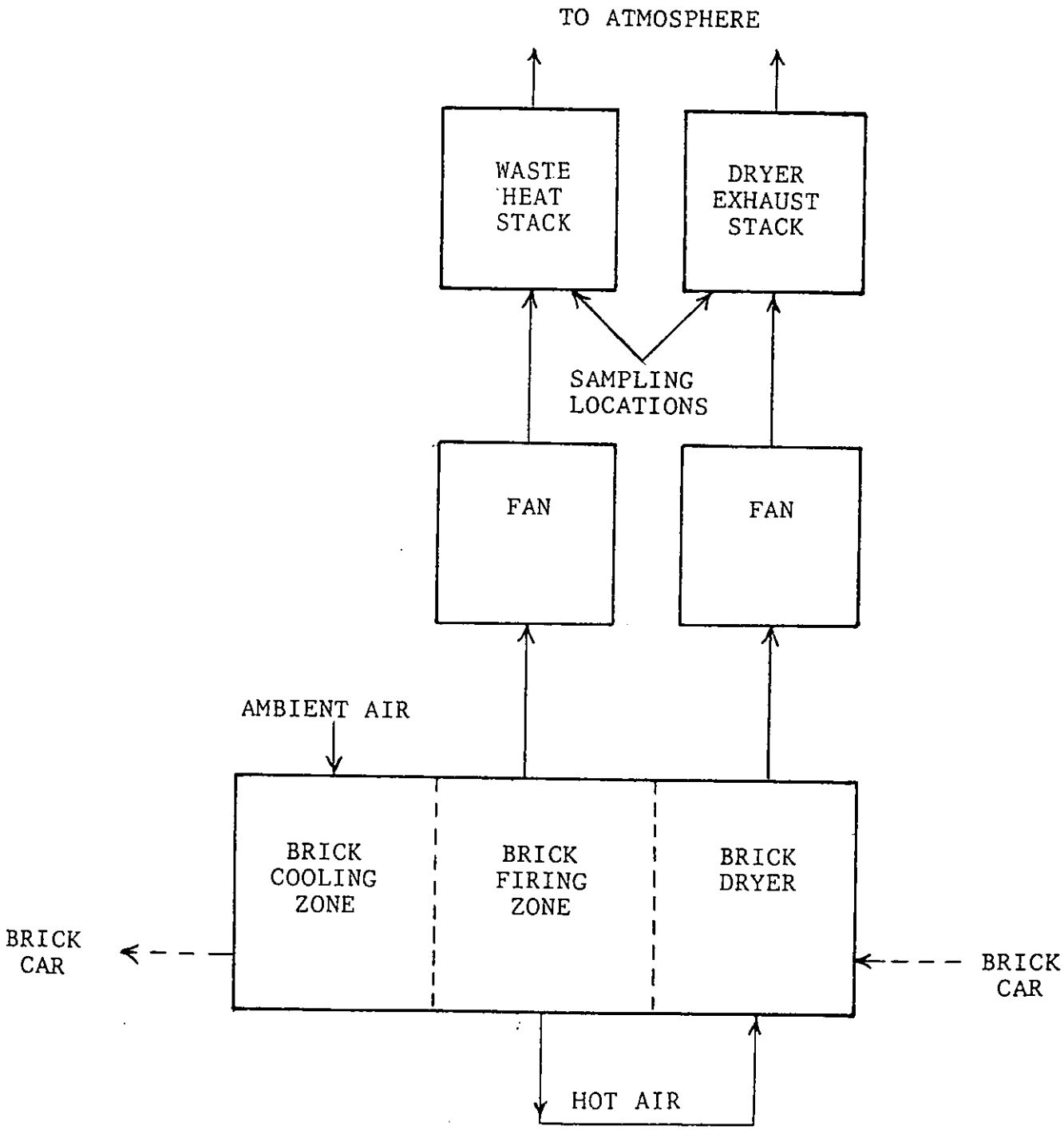


FIGURE 1. PROCESS AIR SCHEMATIC & SAMPLING LOCATIONS

ENTROPY ENVIRONMENTALISTS, INC

During the testing performed at the two stacks, 2263 bricks per hour were being fired in the kiln. With an average brick weight of 4.6 pounds, this converts to a process rate of 5.2 tons of brick per hour. When the estimated sawdust usage rate of 0.55 tons per hour is added, the total process rate is 5.75 tons per hour.

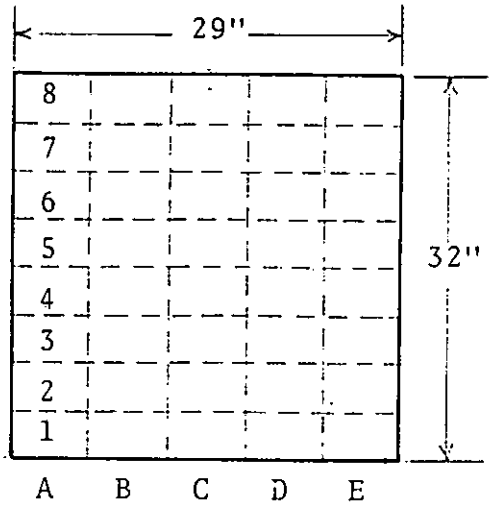
SAMPLING AND ANALYTICAL PROCEDURES

All sampling and analytical procedures used were those recommended by the United States Environmental Protection Agency and the North Carolina Department of Natural Resources and Community Development. Complete details of the equipment and procedures used are described in Appendix D, which is extracted from the Federal Register, August 18, 1977.

Method 1 was used to determine the number and location of the sampling points. A stack extension was added to both stacks. The waste heat stack cross section was divided into 40 equal areas with eight points on each of five traverse axes, as shown in Figure 2. The centroid of each area was sampled for two minutes, resulting in 80 minute tests. The dryer exhaust stack was divided into 36 equal areas, with nine points on each of four traverse axes, as shown in Figure 3. The points were sampled for two minutes each, for a total testing time of 72 minutes for each run.

Velocity measurements were in accordance with Method 2. Molecular weights for the stack gases were determined by Method 3 procedures. Particulate emissions were found using Method 5 analytical and sampling procedures.

All sampling equipment used was manufactured by Nutech Corporation or Entropy Environmentalists, Inc.



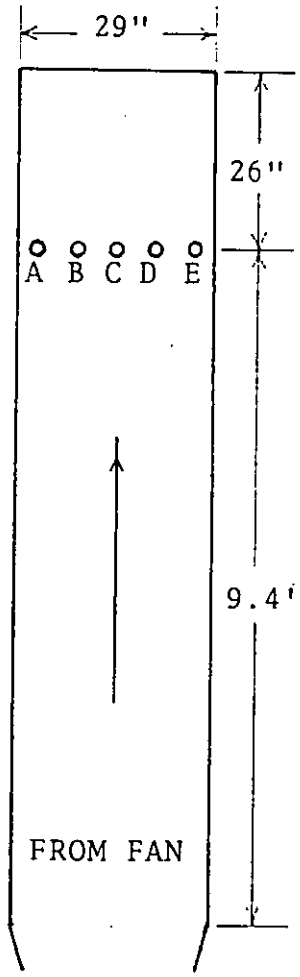
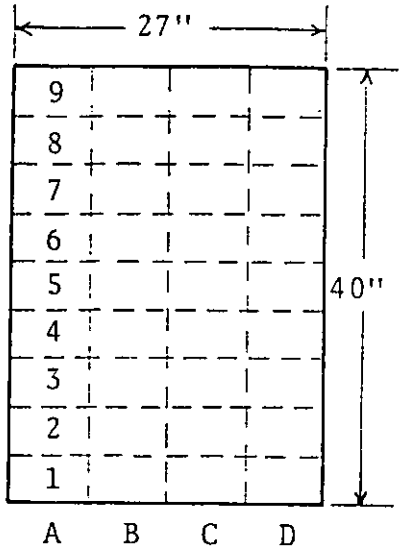


FIGURE 2. WASTE HEAT STACK DIMENSIONS AND SAMPLING POINT LOCATION



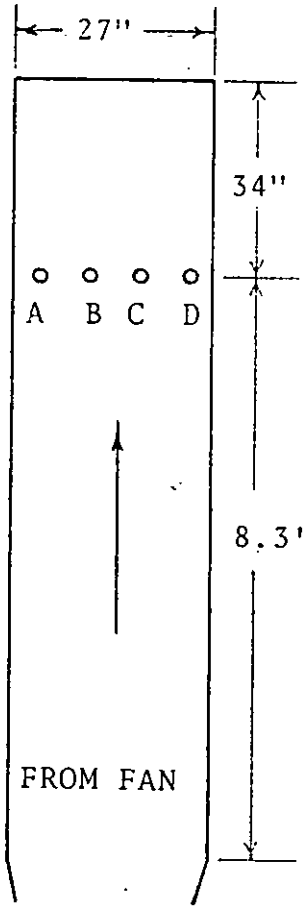


FIGURE 3. DRYER EXHAUST STACK DIMENSION AND SAMPLE POINT LOCATION

APPENDICES

APPENDIX A-1

APPENDIX A

(COMPUTER PRINTED)

PARTICULATE TESTS RESULTS

WITH EXAMPLE CALCULATIONS

EXAMPLE PARTICULATE CALCULATIONS TEST NO. 1

Waste Heat Stack

VOLUME OF DRY GAS SAMPLED AT STANDARD CONDITIONS

VMSTD = 17.64 * VM * Y * (PB+PM/13.6) / (TM+460)

$$VMSTD = \frac{17.64 * 53.956 * 1.006 * (29.77 + 1.520/13.6)}{562.0} = 50.910 \text{ DSCF}$$

VOLUME OF WATER VAPOR AT STANDARD CONDITIONS

VWV = .04707 * VW

VWV = .04707 * 77.0 = 3.624 SCF

PERCENT MOISTURE IN STACK GAS

PMV = (100 * VWV)/(VMSTD+VWV)

$$PMV = \frac{100. * 3.62}{50.910 + 3.62} = 6.6 \text{ PERCENT}$$

MOLE FRACTION OF DRY STACK GAS

MD = (100.-PMV)/100.

$$MD = \frac{100. - 6.6}{100.} = .934$$

AVERAGE MOLECULAR WEIGHT OF DRY STACK GAS

MWD = (PCO2 * .44)+(PO2 * .32)+(PN2+PCO) * .28

MWD = (1.8*0.44)+(18.7*0.32)+((79.5+0.0)*0.28) = 29.04 LB/LB MOLE

MOLECULAR WEIGHT OF STACK GAS

MW = MWD * MD + 18 * (1-MD)

MW = 29.04 * .934 + 18 * (1- .934) = 28.30 LB/LB MOLE

STACK GAS VELOCITY AT STACK CONDITIONS

VS = 85.49 * CP * SQRT[(DPS * (TS+460))/(PS * MW)]

VS = 85.49 * .84 * SQRT[(.528 * 801.)/(29.76 * 28.30)] = 50.9 FPS

STACK GAS VOLUMETRIC FLOW AT STACK CONDITIONS

QA = VS * AS * 60 / 144

QA = 50.9* 928. * 60 / 144 = 19677. ACFM

STACK GAS VOLUMETRIC FLOW AT STANDARD CONDITIONS

QS = (17.64 * QA * PS * MD) / (TS+460)

$$QS = \frac{17.64 * 19677. * 29.76 * .934}{801.0} = 12037. \text{ SCFM}$$

PERCENT ISOKINETIC

PERI = (17.3 * (TS+460) * VMSTD)/(VS * TT * PS * MD * DN * DN)

$$PERI = \frac{17.3 * 801. * 50.910}{50.9 * 80.0 * 29.76 * .934 * .247 * .247} = 102.3 \text{ PERCENT}$$

PARTICULATE LOADING -- EPA METHOD 5
(AT STANDARD CONDITIONS)

CAN = 0.01543 * FMF/VMSTD

CAN = 0.01543 * (43.2/ 50.91) = .0131 GR/DSCF

PARTICULATE LBS/HR--EPA METHOD 5

CAW = 0.00857 * CAN * QS

CAW = 0.00857 * .0131* 12037. = 1.35 LBS/HR

PARTICULATE FIELD DATA & RESULTS TABULATION

PLANT: Chatham Brick & Tile Company, Sanford, N. C.

TEST TEAM LEADER: Frank J. Phoenix

TEST 1 Waste Heat Stack

TEST 2 Waste Heat Stack

TEST 3 Waste Heat Stack

RUN NUMBER		1	2	3
TEST DATE		7/18/79	7/18/79	7/19/79
TB	TIME-START	920	1115	1028
TF	TIME-FINISH	1048	1312	1240
TT	NET TIME OF TEST,MIN.	80.0	80.0	80.0
FNP	NET SAMPLING POINTS	40.	40.	40.
DN	SAMPLING NOZZLE DIA., IN.	.247	.247	.247
CP	PITOT TUBE COEFFICIENT	.84	.84	.84
Y	DRY GAS METER CAL. FACTOR	1.006	1.006	1.006
PM	AVERAGE ORIFICE PRESSURE DROP, IN. H20	1.52	1.51	1.54
VM	VOLUME OF DRY GAS SAMPLED CU. FT. AT METER CONDITIONS	53.956	53.466	54.259
TM	AVERAGE GAS METER TEMP. DEGREES F	102.	109.	94.
VMSTD	VOLUME OF DRY GAS SAMPLED AT STANDARD CONDITIONS*, SCF	50.910	49.826	52.338
VW	TOTAL H2O COLLECTED IN IMPINGERS & SILICA GEL, ML.	77.0	79.5	77.5
VWV	VOLUME OF WATER VAPOR AT STANDARD CONDITIONS*, SCF	3.62	3.74	3.65
PMV	PERCENT MOISTURE BY VOL.	6.6	7.0	6.5
MD	MOLE FRACTION DRY GAS	.934	.930	.935
PCO2	PERCENT CO2 BY VOL.,DRY	1.8	1.8	1.8
PO2	PERCENT O2 BY VOL.,DRY	18.7	18.7	18.7

PCO	PERCENT CO BY VOL.,DRY	0.0	0.0	0.0
PN2	PERCENT N2 BY VOL.,DRY	79.5	79.5	79.5
MWD	MOLECULAR WT-DRY STACK GAS	29.04	29.04	29.04
MW	MOLECULAR WT-STACK GAS	28.30	28.27	28.32
PB	BAROMETRIC PRESSURE,IN. HG.	29.77	29.77	30.00
PSI	STATIC PRES OF STACK GAS IN. H2O	-.2	-.2	-.2
PS	STACK PRES,ABS., IN. HG.	29.76	29.76	29.99
TS	AVERAGE STACK TEMP. DEG. F	341.	344.	323.
DPS	AVERAGE VELOCITY HEAD OF STACK GAS,IN. H2O	.528	.520	.536
VS	AVE STACK GAS VELOCITY, FPS	50.9	50.6	50.5
AS	STACK AREA, SQUARE INCHES	928.	928.	928.
QS	STACK FLOW RATE, DRY SCFM*	12037.	11888.	12328.
QA	ACTUAL STACK FLOW RATE, ACFM	19677.	19577.	19522.
PERI	PERCENT ISOKINETIC	102.3	101.3	102.6
	PARTICULATES, EPA METHOD 5:			
FMF	MILLIGRAMS - CATCH	43.2	35.4	57.8
CAN	GRAINS PER DSCF*	.0131	.0110	.0170
CAW	POUNDS PER HOUR	1.35	1.12	1.80

* 68 DEG F, 29.92 IN. HG

APPENDIX A-2

PARTICULATE FIELD DATA & RESULTS TABULATION

PLANT: Chatham Brick & Tile Company, Sanford, N. C.

TEST TEAM LEADER: Chris M. Wrenn

TEST 4 Dryer Outlet Stack

TEST 5 Dryer Outlet Stack

TEST 6 Dryer Outlet Stack

RUN NUMBER		4	5	6
TEST DATE		7/18/79	7/18/79	7/19/79
TB	TIME-START	920	1119	1134
TF	TIME-FINISH	1043	1257	1254
TT	NET TIME OF TEST,MIN.	72.0	72.0	72.0
FNP	NET SAMPLING POINTS	36.	36.	36.
DN	SAMPLING NOZZLE DIA., IN.	.252	.252	.252
CP	PITOT TUBE COEFFICIENT	.84	.84	.84
Y	DRY GAS METER CAL. FACTOR	1.000	1.000	1.000
PM	AVERAGE ORIFICE PRESSURE DROP, IN. H2O	1.79	2.31	1.74
VM	VOLUME OF DRY GAS SAMPLED CU. FT. AT METER CONDITIONS	53.444	52.086	50.800
TM	AVERAGE GAS METER TEMP. DEGREES F	95.	99.	91.
VMSTD	VOLUME OF DRY GAS SAMPLED AT STANDARD CONDITIONS*, SCF	50.792	49.210	48.998
VW	TOTAL H2O COLLECTED IN IMPINGERS & SILICA GEL, ML.	49.5	67.0	59.0
VWV	VOLUME OF WATER VAPOR AT STANDARD CONDITIONS*, SCF	2.33	3.15	2.78
PMV	PERCENT MOISTURE BY VOL.	4.4	6.0	5.4
MD	MOLE FRACTION DRY GAS	.956	.940	.946
PCO2	PERCENT CO2 BY VOL.,DRY	1.8	1.8	1.8
PO2	PERCENT O2 BY VOL.,DRY	18.7	18.7	18.7

PCO	PERCENT CO BY VOL.,DRY	0.0	0.0	0.0
PN2	PERCENT N2 BY VOL.,DRY	79.5	79.5	79.5
MWD	MOLECULAR WT-DRY STACK GAS	29.04	29.04	29.04
MW	MOLECULAR WT-STACK GAS	28.55	28.37	28.44
PB	BAROMETRIC PRESSURE,IN. HG.	29.77	29.77	30.00
PSI	STATIC PRES OF STACK GAS IN. H2O	.2	.2	.2
PS	STACK PRES,ABS., IN. HG.	29.78	29.78	30.01
TS	AVERAGE STACK TEMP. DEG. F	124.	124.	116.
DPS	AVERAGE VELOCITY HEAD OF STACK GAS,IN. H2O	.499	.429	.436
VS	AVE STACK GAS VELOCITY, FPS	42.0	39.1	38.9
AS	STACK AREA, SQUARE INCHES	1080.	1080.	1080.
QS	STACK FLOW RATE, DRY SCFM*	16272.	14877.	15246.
QA	ACTUAL STACK FLOW RATE, ACFM	18917.	17596.	17527.
PERI	PERCENT ISOKINETIC	93.8	99.4	96.5
	PARTICULATES, EPA METHOD 5:			
FMF	MILLIGRAMS - CATCH	19.1	9.6	12.0
CAN	GRAINS PER DSCF*	.0058	.0030	.0038
CAW	POUNDS PER HOUR	.81	.38	.49

* 68 DEG F, 29.92 IN. HG

APPENDIX B-1

Plant Name CHATHAM BRICK & TILE CO.

Sampling Location WASTE HEAT STACK

Run and/or Sample No. _____ Leak Test? ✓ Date 7-19 Operator CW

Time of Sample Collection	Time of Analysis	CO_2 Reading A	O_2 Reading B	CO Reading C	$\%O_2$ B-A	%CO C-B	$\%N_2$ 100-C
11:00 → 12:30	15:00	1.8	20.5	–	18.7	–	—
							—
							—
	Avg.	1.8		Avg.	18.7		79.5

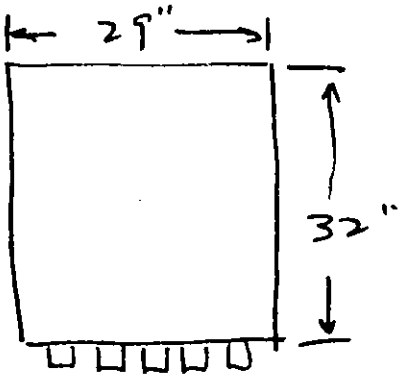
Run and/or Sample No. _____ Leak Test? _____ Date _____ Operator _____

Time of Sample Collection	Time of Analysis	CO_2 Reading A	O_2 Reading B	CO Reading C	$\%O_2$ B-A	%CO C-B	$\%N_2$ 100-C
							—
							—
							—
	Avg.			Avg.			

Run and/or Sample No. _____ Leak Test? _____ Date _____ Operator _____

Time of Sample Collection	Time of Analysis	CO_2 Reading A	O_2 Reading B	CO Reading C	$\%O_2$ B-A	%CO C-B	$\%N_2$ 100-C
							—
							—
							—
	Avg.			Avg.			

PRELIMINARY FIELD DATA



Sketch of stack cross section showing sampling ports.

Stack Geometry

Plant Name CHATHAM BRICK & TILE

Plant Location SANFORD, N.C.

Sampling Location WASTE HEAT STACK

Date(s) 7/17 - 19 /79

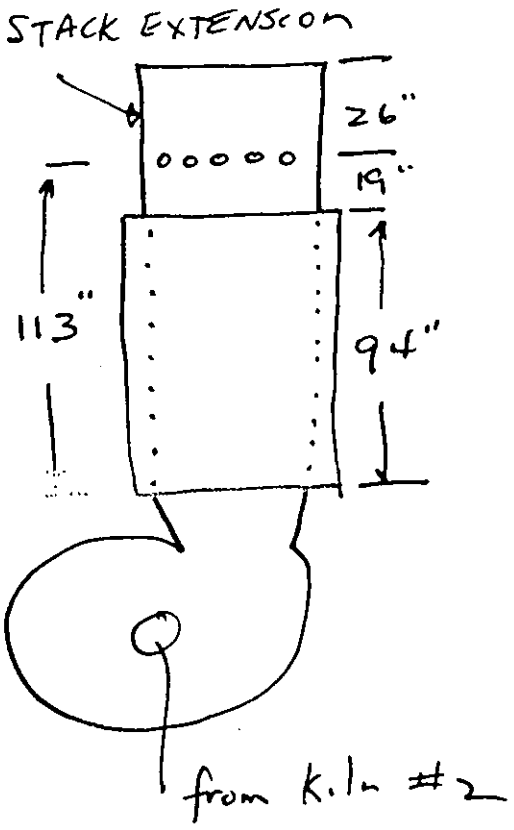
A. Dist. from inside of far wall to outside of near wall: 32" inches

B. Wall thickness: Neg. inches

Inside diameter of stack (A-B): — inches

Stack Area: 928 square inches

Comments: 5 PORTS / 8 points per port



Sketch of stack dimensions and location of sampling ports.

Point	% of Diameter	Distance from inside wall	Distance from outside of port
1	1/16	2	
2	3/16	6	
3	5/16	10	
4	7/16	14	
5	9/16	18	
6	11/16	22	SAME
7	13/16	26	
8	15/16	30	

ENTROPY ENVIRONMENTALISTS, INC.....
SPECIALISTS IN SOURCE SAMPLING

PARTICULATE FIELD DATA

Company/Location CHATHAM BRICK AND TILE CO.

Sampling Location: WASTE HEAT STACK

Date 7-18-79 Test Participants FJP, JN

Bar. Press., in. Hg 29.77 Meter Box # N-4

Static Press., in. H_2O -.15 $\Delta H_@$ 1.87

Ambient Temp, °F 90 C Factor 1.09

Est. Moisture, % 6 Temp. Device T/C

Run # 1

Start: 9:20

Finish: 10.48

$\Delta H/\Delta P = K = 2.83$

Filter # 3947 Tare Wt. .4712

Sample Box # 1 @ Heat Setting 5

Probe # 4' @ Heat Setting 5

Nozzle # 505 with Dia., inches .247

Pitot Leak Tests: Before ✓ After ✓

Sampling Train Leak Test (from nozzle)

Before @ ≥ 15 in. Hg = .003 cfm

After @ 6 in. Hg = .000 cfm

Avg. Δp .65 at ΔH of 1.84

Point	Clock Time	988.445 Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
A 1	0	~~988.350~~	.18	.51	.51	95	1	260	68	310
2	2	989.27	.31	.878	.878	96	1	–	–	321
3	4	990.3	.39	1.10	1.10	97	3	–	–	331
4	6	991.4	.44	1.25	1.25	97	3	255	60	341
5	8	992.7	.43	1.22	1.22	98	3	–	–	345
6	10	993.9	.44	1.25	1.25	99	3	–	–	346
7	12	995.1	.38	1.08	1.08	99	3	250	60	344
8	14	996.3	.35	.96	.96	100	3	–	–	341
B 1	1-0	997.449	.22	.63	.63	98	2	–	–	312
2	2	998.3	.40	1.13	1.13	99	3	255	60	329
3	4	999.5	.48	1.36	1.36	100	3	–	–	340
4	6	000.8	.55	1.56	1.56	100	3	–	–	349
5	8	002.2	.56	1.59	1.59	100	3	260	69	352
6	10	003.6	.60	1.70	1.70	101	3	–	–	354
7	12	005.0	.56	1.59	1.59	101	3	–	–	357
8	14	006.3	.52	1.47	1.47	101	3	260	68	347
C 1	1-0	007.722	.36	1.02	1.02	100	3	–	–	331
2	2	008.	.55	1.55	1.55	101	3	260	68	340
3	4	010.18	.60	1.70	1.70	102	3	260	68	345
4	6	011.61	.75	2.12	2.12	102	4	260	68	348
5	8	013.155	.75	2.12	2.12	102	4	260	68	351

ENTROPY ENVIRONMENTALISTS, INC
SPECIALISTS IN SOURCE

Company CHATHAM BRICK & TILE CO. Run # 1

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
6	10	014.78	.80	2.27	2.27	102	4.5	260	68	349
7	12	016.59	.70	1.98	1.98	102	4.0	260	68	346
8	14	018.06	.55	1.56	1.56	102	3.0	260	67	342
D 1	1-0	019.461	.30	.85	.85	102	2.5	260	68	334
2	2	020.48	.50	1.42	1.42	103	3.0	260	68	343
3	4	021.79	.60	1.70	1.70	103	3.5	260	68	349
4	6	023.21	.75	2.12	2.12	105	4.0	260	68	351
5	8	024.84	.85	2.42	2.42	105	4.5	260	68	353
6	10	026.58	.85	2.42	2.42	106	4.5	260	68	350
7	12	028.36	.75	2.12	2.12	106	4.0	260	68	344
8	14	030.01	.50	1.42	1.42	107	3.5	260	68	334
E 1	1-0	031.356	.25	0.71	0.71	106	2.0	260	68	329
2	2	032.28	.40	1.13	1.13	106	2.5	260	68	334
3	4	033.40	.50	1.42	1.42	107	3.0	260	68	342
4	6	034.71	.65	1.83	1.83	108	3.5	260	68	346
5	8	036.17	.75	2.12	2.12	108	4.0	260	68	345
6	10	037.79	.75	2.12	2.12	108	4.0	260	68	344
7	12	039.41	.75	2.12	2.12	108	4.5	260	68	341
8	14	040.04	.50	1.42	1.42	108	3.0 ~~4.5~~	260	68	326
40	1-0	042.401								
	80									
	diff	53.956								
	avg		.528		1.52	102				341
			(7267)							

CO_2 2%
" 2.5%
" 1.5%

CO2 1%

PARTICULATE FIELD DATA

Company/Location CHATHAM BRICK AND TILE CO.

Run # 2

Sampling Location: WASTE HEAT STACK

Start: 11:15

Date 7-18-79 Test Participants FJP, JTN

Finish: 13:12

Bar. Press., in. Hg 29.77 Meter Box # N-4

K = 2.833

Static Press., in. H_2O -.15 $\Delta H_@$ 1.87

Filter # 3945 Tare Wt. .4625

Ambient Temp, °F 95 C Factor 1.09

Est. Moisture, % 6 Temp. Device T/C 0004

Sample Box # 4 @ Heat Setting 5

Probe # 4' @ Heat Setting 5

Nozzle # 505 with Dia., inches .247

Pitot Leak Tests: Before ✓ After ___

Sampling Train Leak Test (from nozzle)

Before @ ≥ 15 in. Hg = .00 cfm

After @ 10 in. Hg = .00 cfm

Avg. Δp .65 at ΔH of 1.84

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
A1	0	043.427	.28	.79	.79	105	3	300	85	335
2	2	044.4	.35	1.01	1.01	105	3	280	80	336
3	4	045.6	.55	1.56	1.56	105	10	270	65	343
4	6	046.8	.55	1.56	1.56	106	10	260	60	343
5	8	048.1	.70	1.98	1.98	106	10	260	60	344
6	10	052.3	.76	2.16	2.16	108	5	250	60	345
7	12	053.9	.65	1.84	1.84	108	5	251	61	347
8	14	055.5	.50	1.42	1.42	108	4	252	62	329
B1	1-0	056.84	.40	1.13	1.13	108	3	260	62	341
2	2	057.9	.50	1.42	1.42	109	3	260	65	346
3	4	059.3	.57	1.62	1.62	108	4	260	65	352
4	6	060.7	.68	1.93	1.93	109	4	260	65	356
5	8	062.4	.76	2.15	2.15	110	5	260	66	358
6	10	063.8	.84	2.38	2.38	110	5	255	66	356
7	12	065.6	.75	2.11	2.11	110	5	255	62	350
8	14	067.3	.56	1.59	1.59	111	4	250	65	342
C1	1-0	068.75	.34	.96	.96	110	3	250	65	331
2	2	69.8	.50	1.42	1.42	110	3	250	65	340
3	4	71.1	.55	1.56	1.56	110	3	250	65	348
4	6	72.5	.68	1.93	1.93	110	3	250	65	355
5	8	74.0	.76	2.15	2.15	110	4	250	65	356

Impinger SMITH & GREENBERG

051.9
049.2
-2.7

ENTROPY ENVIRONMENTALISTS, INC
SPECIALISTS IN SOURCE

Company CHATHAM BRICK & TILE CO. Run # 2

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
6	10	075.70	.80	2.27	2.27	111	4.0	260	65	354
7	12	077.47	.70	1.98	1.98	111	4.0	260	65	349
8	14	079.01	.60	1.70	1.70	111	3.5	260	65	346
D1	1-0	080.553	.25	0.70	0.70	110	2.0	260	65	319
2	2	081.46	.40	1.13	1.13	111	2.5	260	65	334
3	4	082.58	.49	1.40	1.40	111	3.0	260	65	348
4	6	083.89	.60	1.70	1.70	111	3.0	260	65	354
5	8	085.33	.60	1.70	1.70	111	3.5	260	65	357
6	10	086.77	.60	1.70	1.70	111	3.5	260	68	357
7	12	088.22	.60	1.70	1.70	110	3.5	255	68	354
8	14	089.65	.55	1.56	1.56	110	3.5	255	68	346
E1	1-0	090.688	.20	0.61	0.61	110	2.0	255	68	313
2	2	091.69	.25	0.70	0.70	110	2.0	255	68	328
3	4	092.54	.40	1.13	1.13	110	2.5	255	68	338
4	6	093.68	.45	1.27	1.27	110	3.0	255	68	345
5	8	094.94	.45	1.27	1.27	110	3.0	255	68	347
6	10	096.21	.40	1.13	1.13	110	2.5	255	68	347
7	12	097.38	.40	1.13	1.13	110	2.5	255	68	346
8	14	098.53	.35	0.99	0.99	109	2.5	255	68	341
	1-0	099.653								
40	80									
	diff	53.466								
	avg		.5195 (7208)		1.51	109				344

PARTICULATE FIELD DATA

Company/Location CHATHAM BRICK AND TILE CO. #2 KILN

Sampling Location: WASTE HEAT STACK

Date 7-19-79 Test Participants FSP, JTN

Bar. Press., in. Hg 30.00 Meter Box # N-4

Static Press., in. H_2O -.15 $\Delta H_@$ 1.87

Ambient Temp, °F 85 C Factor 1.07

Est. Moisture, % 6 Temp. Device T/C 0004

Run # 3

Start: 10:28

Finish: 12:40

Filter #	Tare Wt.
3944	.4618

Sample Box # 1 @ Heat Setting 5

Probe # 4' @ Heat Setting 5

Nozzle # 505 with Dia., inches .247

Pitot Leak Tests: Before ✓ After ✓

Sampling Train Leak Test (from nozzle)

Before @ ≥ 15 in. Hg = 0.00 cfm

After @ 4.5 in. Hg = 0.00 cfm

Avg. Δp .65 at ΔH of 1.84

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	
A 1	0	100.203	0.18	0.51	0.51	84	1.0	250	65	295	
2	2	100.91	0.28	0.78	0.78	84	2.0	250	65	305	
3	4	101.95	0.40	1.12	1.12	85	2.0	250	65	317	
4	6	103.04	0.35	0.98	0.98	85	2.0	250	65	325	
5	8	104.21	0.45	1.28	1.28	86	2.0	250	65	331	
6	10	105.34	0.45	1.28	1.28	90	2.0	250	65	329	STOPPED BECAUSE TROUBLE. B-SIDE
7	12	106.58	0.43	1.21	1.21	90	2.5	250	65	328	
8	14	107.77	0.40	1.12	1.12	90	2.5	250	65	324	
B 1	1-0	108.905	0.24	0.68	0.68	91	2.0	250	65	301	BOX NOT HEATING. B-SIDE
2	2	109.83	0.40	1.12	1.12	91	2.0	250	65	314	
3	4	110.95	0.50	1.40	1.40	91	2.5	250	65	325	
4	6	112.24	0.55	1.55	1.55	91	2.5	250	65	331	
5	8	113.59	0.60	1.70	1.70	92	3.0	250	65	333	
6	10	115.01	0.65	1.81	1.81	93	3.0	250	65	329	
7	12	116.47	0.55	1.55	1.55	94	3.0	250	65	327	
8	14	117.84	0.55	1.55	1.55	94	3.0	250	65	326	
C 1	1-0	119.213	0.40	1.12	1.12	94	2.0	250	65	312	
2	2	120.34	0.50	1.40	1.40	94	2.5	250	65	318	
3	4	121.64	0.60	1.70	1.70	95	3.0	250	65	324	
4	6	123.04	0.65	1.81	1.81	95	3.0	250	65	330	
5	8	124.51	0.75	2.10	2.10	95	4.0	250	65	333	

ENTROPY ENVIRONMENTALISTS, INC
SPECIALISTS IN SOURCE

Company CHATHAM BRICK AND TILE CO. Run # 3

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
6	10	126.18	0.85	2.35	2.35	96	4.0	250	65	333
7	12	127.83	0.75	2.10	2.10	96	4.0	250	65	329
8	14	129.60	0.60	1.70	1.70	96	3.5	250	65	326
D1	1-0	131.039	0.35	0.98	0.98	95	2.5	250	65	317
2	2	132.15	0.50	1.40	1.40	96	3.0	250	65	326
3	4	133.44	0.60	1.70	1.70	96	3.0	250	65	331
4	6	134.84	0.75	2.10	2.10	96	4.0	250	65	336
5	8	137.38	0.85	2.35	2.35	97	4.5	250	65	334
6	10	139.11	0.85	2.35	2.35	98	4.5	250	65	330
7	12	140.01	0.75	2.10	2.10	98	4.5	250	65	325
8	14	141.66	0.60	1.70	1.70	99	3.5	250	65	320
E1	1-0	143.101	0.30	0.87	0.87	96	2.0	250	65	313
2	2	144.15	0.40	1.12	1.12	97	2.0	250	65	319
3	4	145.28	0.50	1.40	1.40	97	3.0	250	65	325
4	6	146.59	0.75	2.10	2.10	98	3.5	250	65	327
5	8	148.25	0.70	1.95	1.95	99	4.0	250	65	327
6	10	149.84	0.75	2.10	2.10	99	4.0	250	65	326
7	12	151.49	0.65	1.81	1.81	100	3.5	250	65	320
8	14	152.98	0.55	1.55	1.55	100	3.0	250	65	315
	1-0	154.362								
40	80	54.259								
	diff									
	avg		.536		1.54	94				323
			(.7321)							

PARTICULATE SAMPLING CLEANUP SHEET

Plant Name CHATHAM BRICK

Sampling Location A-Side Waste Heat Stack

Reagent Box # 0210 Date Analyzed 7/25/79

Blank Calculations:	Acetone	Water
Blank Residue	1.4	
Blank Volume	200	
Concentration	.007 mg/mls	mg/mls
Volume Used	100 mls	mls
# 1 Blank Weight	0.7 mgms	mgms
Volume Used	110 mls	mls
# 2 Blank Weight	0.8 mgms	mgms
Volume Used	125 mls	mls
# 3 Blank Weight	0.9 mgms	mgms

Analysis Method: (Zero & Span Balance mg Initials)

EPA-5

Description of Sample:

light catch, black particulate

Remarks:

Date of Test	7/18	7/18	7/18
Test Number	1	2	3
Moisture Collected:			
Impinger water volume	262	264	264
Tared volume	200	200	200
Captured water	62 mls	64 mls	64 mls
Silica Gel weight	240.0	240.5	238.5
Tared weight	225.0	225.0	225.0
Adsorbed water	15.0 gms	15.5 gms	13.5 gms
TOTAL MOISTURE CATCH	77.0 mls	79.5 mls	77.5 mls
Front Half Analysis: (Nozzle, probe, cyclone, filter front half)			
Filter & Particulate	515.1	498.7	520.5
Filter Tare weight	471.2	462.5	461.8
Filter Particulate	-	-	-
Rinsings or Dry Wt.	-	-	-
Particulate catch	43.9 mgms	36.2 mgms	58.7 mgms
Acetone blank	0.7	0.8	0.9
TOTAL FRONT CATCH	43.2 mgms	35.4 mgms	57.8 mgms
Back Half Analysis: (Impingers, filter back half)			
Extractables weight			
Boil Down weight			
Impingers' Catch	mgms	mgms	mgms
Water blank			
TOTAL BACK CATCH	mgms	mgms	mgms
TOTAL TRAIN CATCH	mgms	mgms	mgms

ENTROPY ENVIRONMENTALISTS, INC. SPECIALISTS IN SOURCE

CUSTODY SHEET FOR REAGENT BOX # 0210

Date of Makeup 6/22/79 Individual Water Tare Volume 200 mls

Initials mcg Individual Silica Gel Tare Weight 225 gms

Locked? ✓

Plant Name CHATHAM BRICK

Sampling Location A-SIDE Waste Heat Stack

Box/Test Number	Date Used	Initials	Locked?	Date Cleanup	S. Gel Spent?	Initials	Locked?
1	7-18	JN	✓	7-18	½	FJP	✓
2	"	"	✓	"	½	FJP	✓
3	"	"	✓	"	½	FJP	✓

	Date	Initials	Locked?
Transferred to Lab	7-20	FJP	✓
Received in Lab	7-20	mcg	✓

Zero & Span Balance

Initials mcg

Sampling Method: Method 5

Remarks:

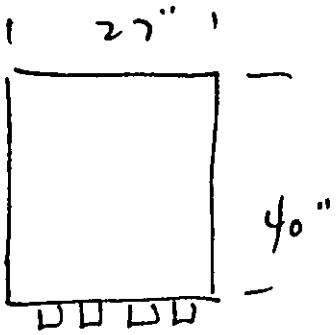
Filter #	Tare Weight (mgms)	Used on Test
3947	.4712	1
3944	.4618	3
3945	.4625	2

ENTROPY ENVIRONMENTALISTS, INC.

SPECIALISTS IN SOURCE SAMPLING

PRELIMINARY FIELD DATA

Stack Geometry



Plant Name CHATHAM BRICK & TILE CO

Plant Location SANFORD, N.C.

Sampling Location DRIER OUTLET STACK

Date(s) 7/17 - 19/79

A. Dist. from inside of far wall to outside of near wall: 40 inches

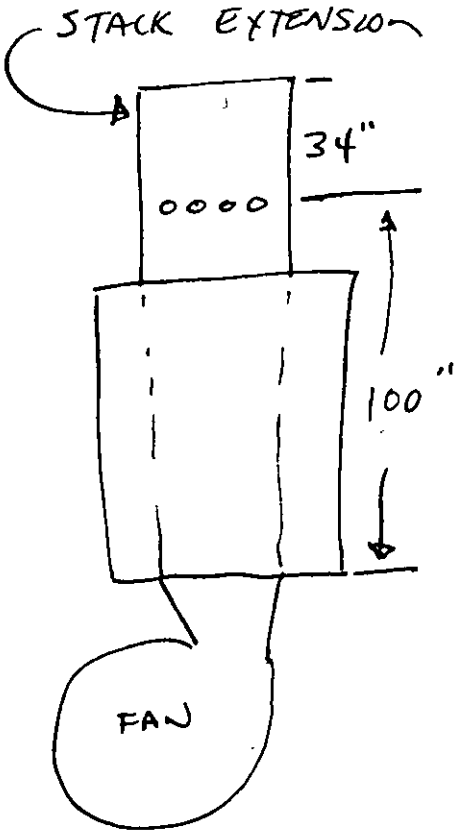
B. Wall thickness: Neg. inches

Inside diameter of stack (A-B): — inches

Stack Area: 1080 square inches

Comments: 4 ports / 9 points per port

Sketch of stack cross section showing sampling ports.



Point	% of Diameter	Distance from inside wall	Distance from outside of port
1	1/18	2 1/4	
2	3/18	6 1/2	
3	5/18	11	
4	7/18	15	
5	9/18	20	
6	11/18	24 1/2	
7	13/18	28 3/4	SAME
8	15/18	33 1/4	
9	17/18	37 3/4	

Sketch of stack dimensions and location of sampling ports.

PARTICULATE FIELD DATA

Company/Location Chatham Brick
Sanford, N.C

Run # 4

Sampling Location: Dryer Outlet Stack

Start: 09:20
Finish: 10:43

Date 7/18 Test Participants CW, CG

Bar. Press., in. Hg 29.77 Meter Box # N-3

Static Press., in. H_2O .20+ $\Delta H_@$ 1.85

Filter # 3814 Tare Wt. .4615

Ambient Temp, °F 81 C Factor 1.00

Est. Moisture, % 7 Temp. Device T/C-1

Sample Box # Bal @ Heat Setting Hi

Probe # S-1 @ Heat Setting 5

Nozzle # 506 with Dia., inches .252

Pitot Leak Tests: Before ✓ After ___

Sampling Train Leak Test (from nozzle)

Before @ ≥ 15 in. Hg = 0.000 cfm

After @ 7 in. Hg = 0.000 cfm

Avg. Δp .47 at ΔH of 1.84

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
A-1	0	269.894	.23	.91	.91	87	3	250	75	109
2	2	271.28	.42	1.65	1.65	88	5	250	75	124
3	4	272.72	.45	1.78	1.78	89	5	250	73	125
4	6	274.18	.48	1.90	1.90	90	5	250	70	125
5	8	275.70	.52	2.0	2.0	90	5	250	70	125
6	10	277.29	.68	2.68	2.68	91	6	250	70	125
7	12	279.05	.65	2.55	2.55	91	7	250	70	126
8	14	280.83	.62	2.45	2.45	93	7	250	70	126
9	16	282.59	.62	2.45	2.45	94	7	250	70	126
B-1	18/0	284.39	.27	1.06	1.06	95	4	245	70	123
2	2	285.69	.42	1.65	1.65	95	5	245	73	126
3	4	286.96	.50	1.98	1.98	95	6	244	75	127
4	6	288.47	.50	1.98	1.98	95	6	240	75	126
5	8	290.02	.51	2.0	2.0	95	6	240	75	126
6	10	291.60	.55	2.15	2.15	95	6	240	75	123
7	12	293.24	.57	2.21	2.21	95	6	240	75	123
8	14	294.90	.60	2.35	2.35	95	6	240	75	123
9	16	296.60	.65	2.53	2.53	95	7	240	75	123
C-1	18/0	298.43	.33	1.30	1.30	95	5	238	73	117
2	2	299.74	.38	1.42	1.42	95	5	235	73	121
3	4	300.99	.35	1.40	1.40	95	5	235	73	123

ENTROPY ENVIRONMENTALISTS, INC
SPECIALISTS IN SOURCE

Company Chatham Brick

Run # 4

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
4	6	302.34	.40	1.58	1.58	95	5	235	73	124
5	8	303.71	.41	1.60	1.60	95	5	235	73	124
6	10	305.10	.43	1.70	1.70	95	5	235	73	124
7	12	306.54	.46	1.82	1.82	95	5	235	73	125
8	14	308.00	.53	2.05	2.05	96	5	235	73	125
9	16	309.65	.57	2.25	2.25	96	5	235	73	125
0-1	18/0	310.43	.22	.86	.86	97	4	240	74	121
2	2	312.55	.36	1.42	1.42	98	5	240	75	122
3	4	313.98	.32	1.29	1.29	98	5	240	75	126
4	6	315.08	.32	1.29	1.29	98	5	240	75	126
5	8	316.35	.34	1.35	1.35	99	5	240	75	126
6	10	317.65	.41	1.60	1.60	99	5	240	75	126
7	12	319.08	.41	1.60	1.60	99	5	240	75	126
8	14	320.43	.43	1.70	1.70	100	5	240	75	126
9	16	321.83	.49	1.94	1.94	100	5	240	75	126
	18/OFF	323.338								
		53.444								
			.499		1.79	95				124
			(.7065)							

PARTICULATE FIELD DATA

Company/Location Chatham Brick
Sanford, N.C.

Sampling Location: Dryer Outlet Stack

Date 7/18 Test Participants CW, CG

Bar. Press., in. Hg 29.77 Meter Box # W-3

Static Press., in. H_2O .21+ $\Delta H_@$ 1.85

Ambient Temp, °F 92 C Factor 1.05

Est. Moisture, % 7 Temp. Device T/C-1

Run # 5

Start: 11:19
Finish: 12:57

Filter #	Tare Wt.
3848	~~.4715~~ .4715

Sample Box # Rod @ Heat Setting 5

Probe # 5-1 @ Heat Setting 5

Nozzle # 506 with Dia., inches .252

Pitot Leak Tests: Before ✓ After ✓

Sampling Train Leak Test (from nozzle)

Before @ ≥ 15 in. Hg = 0.005 cfm

After @ 6 in. Hg = 0.001 cfm

Avg. Δp .46 at ΔH of 1.84

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
A-1	0	323.698	.24	.96	.96	96	3	235	75	110
2	2	324.87	.38	1.52	1.52	97	4	235	75	120
3	4	~~326~~ 326.01	.43	1.72	1.72	97	4	235	75	125
4	6	327.37	.57	2.20	2.20	97	5	235	73	126
5	8	328.98	.57	2.20	2.20	98	5	235	70	126
6	10	330.66	.60	2.40	2.40	98	5	235	70	125
7	12	332.37	.57	2.20	2.20	99	6	235	70	125
8	14	334.07	.57	2.20	2.20	99	6	235	70	124
9	16	335.70	.45	1.80	1.80	99	5	240	70	110
B-1	18/0	337.23	.31	1.25	1.25	99	5	240	70	115
2	2	338.48	.39	1.55	1.55	99	5	240	70	129
3	4	339.83	.46	1.85	1.85	99	5	240	70	127
4	6	341.30	.46	1.85	1.85	99	5	240	70	127
5	8	342.80	.49	1.98	1.98	99	5	240	70	127
6	10	344.36	.55	2.20	2.20	100	5	240	70	127
7	12	346.00	.53	2.11	2.11	100	5	241	70	127
8	14	347.67	.58	2.30	2.30	100	5	243	70	124
9	16	349.36	.60	2.40	2.40	100	5	243	70	124
C-1	18/0	351.16	.32	1.21	1.21	100	4	245	70	109
2	2	352.30	.39	1.55	1.55	100	5	243	70	121
3	4	353.63	.35	1.40	1.40	100	5	240	70	125

ENTROPY ENVIRONMENTALISTS, INC
SPECIALISTS IN SOURCE SAMPLING

Company Chatham Brick

Run # 5

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
4	6	354.95	.38	1.52	1.52	100	5	240	70	125
5	8	356.32	.41	1.65	1.65	100	5	240	70	125
6	10	357.76	.43	1.72	1.72	100	5	238	71	125
7	12	359.19	.47	1.90	1.90	100	5	237	72	125
8	14	360.70	.52	2.10	2.10	100	5	235	74	125
9	16	362.33	.57	2.30	2.30	100	5	235	75	125
0-1	18/0	364.01	.22	.88	.88	100	4	235	75	122
2	2	365.05	.30	1.20	1.20	100	5	235	75	125
3	4	366.25	.34	1.35	1.38	100	5	235	75	125
4	6	367.54	.32	1.20	1.20	100	5	235	75	126
5	8	368.79	.37	1.50	1.50	100	5	239	77	125
6	10	370.13	.37	1.50	1.50	100	5	241	77	125
7	12	371.50	.37	1.50	1.50	101	5	244	77	125
8	14	372.86	.38	1.52	1.52	101	5	245	77	125
9	16	374.24	.43	1.72	1.72	102	5	245	77	126
	18/OFF	375.784								
		52.086								
			.429		2.31	99				124
			(.6553)							

PARTICULATE FIELD DATA

Company/Location Chatham Brick, Sanford, N.C.

Sampling Location: Dryer Outlet Stack

Date 7/18 Test Participants CW, CG

Bar. Press., in. Hg ____ Meter Box # NV3

Static Press., in. H_2O .27+ $\Delta H_@$ 1.85

Ambient Temp, °F 80 C Factor 1.05

Est. Moisture, % 7 Temp. Device T/C-1

Run # 6

Start: 11:34

Finish: 12:54

Filter #	Tare Wt.
3946	.4679

Sample Box # Red @ Heat Setting 5

Probe # 5-1 @ Heat Setting 5

Nozzle # 506 with Dia., inches .252

Pitot Leak Tests: Before ✓ After ✓

Sampling Train Leak Test (from nozzle)

Before @ ≥ 15 in. Hg = ~~0.005~~ cfm 0.002

After @ 4 in. Hg = 0.003 cfm

Avg. Δp .47 at ΔH of 1.84

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	
A-1	0	377.540	.25	.98	.98	86	2	215	70	112	
2	2	378.66	.40	1.56	1.56	86	2	217	70	116	
3	4	380.04	.52	2.0	2.0	87	2	220	70	117	
4	6	381.66	.55	2.15	2.15	89	3	220	65	117	
5	8	383.31	.57	2.20	2.20	89	4	220	66	116	
6	10	385.00	.62	2.40	2.40	90	4	220	65	116	
7	12	386.71	.52	2.0	2.0	90	4	222	64	116	
8	14	388.32	.52	2.0	2.0	90	4	222	64	116	
9	16	389.92	.42	1.65	1.65	90	4	222	64	116	
B-1	18/0	391.47	.32	1.27	1.27	90	3	220	65	107	
2	2	392.62	.40	1.58	1.58	90	3	220	67	115	
3	4	393.98	.43	1.69	1.69	90	4	220	66	119	
4	6	395.41	.45	1.78	1.78	90	4	220	65	119	
5	8	396.88	.57	2.20	2.20	90	4	220	65	119	
6	10	398.53	.63	2.45	2.45	90	4	220	65	119	
7	12	400.26	.68	2.65	2.65	90	4	220	65	118	
8	14	402.04	.68	2.65	2.65	91	4	220	66	115	
9	16	403.84	.50	1.95	1.95	91	4	220	66	115	
C-1	18/0	405.42	.30	1.18	1.18	92	3	220	66	104	
2	2	406.64	.32	1.27	1.27	92	3	220	66	112	
3	4	407.90	.36	1.42	1.42	92	3	220	66	115	

ENTROPY ENVIRONMENTALISTS, INC
SPECIALISTS IN SOURCE SAMPLING

Company Northern Brick Run # 6

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in. H_2O	Orifice Manometer (ΔH) in. H_2O Desired	Orifice Manometer (ΔH) in. H_2O Actual	Average Meter Temp. °F	Pump Vacuum in. Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F
4	6	409.12	.38	1.49	1.49	92	4	220	66	115
5	8	410.53	.40	1.56	1.56	93	4	220	68	116
6	10	411.92	.44	1.70	1.70	93	4	220	69	116
7	12	413.37	.48	1.89	1.89	93	4	220	70	117
8	14	414.88	.55	2.15	2.15	93	4	220	70	117
9	16	416.53	.60	2.32	2.32	93	4	220	71	117
D-1	18/0	418.22	.20	.79	.79	93	2	225	71	109
2	2	419.22	.30	1.18	1.18	93	2	228	71	118
3	4	420.39	.32	1.27	1.27	93	2	230	71	117
4	6	421.66	.35	1.39	1.39	93	3	231	71	117
5	8	422.96	.33	1.30	1.30	93	3	232	72	117
6	10	424.25	.35	1.39	1.39	93	3	235	72	116
7	12	425.57	.38	1.49	1.49	93	3	235	72	116
8	14	426.92	.42	1.65	1.65	93	3	235	72	115
9	16	428.34	.48	1.89	1.89	93	3	235	72	117
	18/OFF									
	Diff	50.8								
	Avg		.436		1.74	91				116
			(.6602)							

PARTICULATE SAMPLING CLEANUP SHEET

Plant Name CHATHAM BRICK

Sampling Location B-Side Dryer Outlet Stack

Reagent Box # 0203 Date Analyzed 7/25/79

Blank Calculations:	Acetone	Water
Blank Residue	1.4	
Blank Volume	200	
Concentration	.007 mg/mls	mg/mls
Volume Used	200 mls	mls
# 4 Blank Weight	1.4 mgms	mgms
Volume Used	175 mls	mls
# 5 Blank Weight	1.2 mgms	mgms
Volume Used	100 mls	mls
# 6 Blank Weight	0.7 mgms	mgms

Analysis Method: (Zero & Span Balance msg Initials)

EPA-5

Description of Sample:

light catch, white particulate

Remarks:

Date of Test	7/18	7/18	7/19
Test Number	4	5	6
Moisture Collected:			
Impinger water volume	234	254	246
Tared volume	200	200	200
Captured water	34 mls	54 mls	46 mls
Silica Gel weight	240.5	238.0	238.0
Tared weight	225.0	225.0	225.0
Adsorbed water	15.5 gms	13.0 gms	13.0 gms
TOTAL MOISTURE CATCH	49.5 mls	67.0 mls	59.0 mls
Front Half Analysis: (Nozzle, probe, cyclone, filter front half)			
Filter & Particulate	482.0	482.3	480.6
Filter Tare weight	461.5	471.5	467.9
Filter Particulate	–	–	–
Rinsings or Dry Wt.	–	–	–
Particulate catch	20.5 mgms	10.8 mgms	12.7 mgms
Acetone blank	1.4	1.2	0.7
TOTAL FRONT CATCH	19.1 mgms	9.6 mgms	12.0 mgms
Back Half Analysis: (Impingers, filter back half)			
Extractables weight			
Boil Down weight			
Impingers' Catch	mgms	mgms	mgms
Water blank			
TOTAL BACK CATCH	mgms	mgms	mgms
TOTAL TRAIN CATCH	mgms	mgms	mgms

ENTROPY
ENVIRONMENTALISTS, INC.
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SOURCE
SAMPLING

CUSTODY SHEET FOR REAGENT BOX # 0203

Date of Makeup 6/22/79 Individual Water Tare Volume 200 mls

Initials meg Individual Silica Gel Tare Weight 225 gms

Locked? ✓

Plant Name Chatham Brick

Sampling Location B-Side Dryer Outlet Stack

Box/Test Number	Date Used	Initials	Locked?	Date Cleanup	S. Gel Spent?	Initials	Locked?
0203/4	7/18/79	C.G.	✓	7/20	20%	CW	✓
5	7/18	C.W.	✓	7/20	20%	CW	✓
6	7/19	CW	✓	7/20	70%	CW	✓

	Date	Initials	Locked?
Transferred to Lab	7/20	CW	✓
Received in Lab	7/20	meg	✓

Zero & Span Balance

Initials meg

Sampling Method: EPA-5

Remarks:

Filter #	Tare Weight (mgms)	Used on Test
3814	.4615	4
3848	.4715	5
3946	.4679	6

ENTROPY ENVIRONMENTALISTS, INC.

SPECIALISTS IN SOURCE SAMPLING

APPENDIX C

TEST PARTICIPANTS

FRANK J. PHOENIX	PROJECT DIRECTOR
CHRIS M. WRENN	SAMPLING TEAM LEADER
W. CHRIS GOODALL	ENGINEERING TECHNICIAN
JOHN T. NASH	ENGINEERING TECHNICIAN
DONALD J. DEITZ	ENGINEERING TECHNICIAN

APPENDIX D

NOZZLE CALIBRATION DATA

NOZZLE # 506

DATE	INITIALS	DIAMETER, in. 1	2	3	4	AVERAGE
7-15-77	CWN	.254	.254	.254	.254	.254
12-13-78	JLE	.253	.252	.255	.255	.254
3-26-94	MH	.253	.250	.253	.252	.252

NOZZLE CALIBRATION DATA

NOZZLE # 505

DATE	INITIALS	DIAMETER, in. 1	2	3	4	AVERAGE
7-15-77	WN	.250	.247	.250	.248	.249
12-13-78	JLE	.252	.252	.252	.250	.252
3-26-79	MH	.251	.250	.254	.252	.252
6/29/79	C.G.	.246	.249	.247	.247	.247

Date 7-3-79 Box N-4 P_B 29.54 Initials MH

ORIFICE SETTING	TEST METER VOLUME	ROOM TEMP °F	TIME MINUTES	ΔH@	BOX METER VOLUME	BOX METER TEMP	Y
0.3	2	73°	6.60	1.85	2.008	78°	1.005
0.5	3	74°	7.70	1.87	3.030	80°	1.000
0.7	3	73°	6.35	1.79	2.962	74°	1.013
1.0	3	74°	5.40	1.86	3.029	82°	1.003
1.5	5	74°	7.53	1.92	5.043	82°	1.003
2.0	5	73°	6.52	1.93	5.067	76°	0.987
4.0	5	74°	4.55	1.87	5.002	83°	1.006
6.0	5	74°	3.73	1.88	4.984	84°	1.007

$$\Delta H@ = \frac{(0.0317)\Delta H}{P_B(T_{Box} + 460)} \left(\frac{(T_{Room} + 460)\theta}{V_{Test\ Meter}} \right)^2$$

$\Delta H@ = 1.87$

$$Y = \frac{V_{Test}\ (P_B)(T_{Box} + 460)}{V_{Box}(P_B + \frac{\Delta H}{13.6})\ (T_{Room} + 460)}$$

$Y = 1.003$

Date 7-6-79 Box N-3 P_B 29.82 Initials M.C.

ORIFICE SETTING	TEST METER VOLUME	ROOM TEMP °F	TIME MINUTES	ΔH@	BOX METER VOLUME	BOX METER TEMP	Y
0.3	2	72°	6.48	1.74	2.0150	84°	1.014
0.5	3	74°	7.43	1.73	3.018	76°	.996
0.7	3	74°	6.4	1.80	3.017	78°	1.000
1.0	3	72°	5.48	1.86	3.070	84°	.997
1.5	5	74°	7.41	1.86	5.02	78°	.999
2.0	5	74°	6.43	1.85	5.04	83°	.997
4.0	5	74°	4.68	1.95	5.074	84°	.992
6.0	5	72°	3.87	1.98	5.028	84°	1.002

$$\Delta H@ = \frac{(0.0317)\Delta H}{P_B(T_{Box} + 460)} \left(\frac{(T_{Room} + 460)\theta}{V_{Test\ Meter}}\right)^2$$

$$Y = \frac{V_{Test}\ (P_B)(T_{Box} + 460)}{V_{Box}(P_B + \frac{\Delta H}{13.6})\ (T_{Room} + 460)}$$

ΔH @ 1.85 $Y = 1.000$

reading is not within ± 1.5% of the absolute temperature reading of the standard thermometer, the instrument is adjusted until it is in the acceptable range.

MAGNEHELIC GAUGES

After each field use, each magnehelic gauge is calibrated against an inclined manometer at three different settings (low, medium, high) over the range of the individual gauges. If the readings differ more than ± 5% from the manometer readings, the magnehelics are recalibrated.

BAROMETER

After each field use, each barometer is checked against a mercury barometer.

CALIBRATIONS

GENERAL

All measuring equipment Entropy uses is initially calibrated before use. Equipment which can change calibration is both checked upon return from each field use and is also periodically recalibrated in full. When an instrument is found out of calibration, it is so noted in the report and appropriate adjustments are made to the final results. The equipment is then repaired and recalibrated or retired as needed. Specific equipment is handled as follows:

PITOT TUBE

All pitot tubes used by Entropy, whether separate or attached to a sampling probe, are constructed in-house or by Nutech Corporation. Prior to their initial usage, they are calibrated using EPA geometry standards. In general, if a type "S" pitot tube is assembled correctly, and positioned properly in relation to the probe nozzle, it will have an average Cp of 0.84. As long as it is not damaged, it should not change its calibration. The recalibration schedule for pitot tubes is related to the physical condition and usage of the pitot tube, not a fixed time schedule. Each pitot tube is inspected upon return to the laboratory from each field use.

DRY GAS METER AND ORIFICE METER

All Entropy meter boxes are calibrated upon purchase and at least once every six months against a secondary test meter (one calibrated against a wet test meter) according to their usage history. Basic procedures are outlined in the EPA Publication No. APTD-0576. The only differences are in the choice of flow rates used and the volumes metered at each flow rate. After each field use, quick checks are performed to insure $\Delta H@$ changes of less than 5%. These checks compare the orifice against the dry gas meter. If greater than 5% changes occur, recalibration and repair are instituted.

NOZZLES

Each nozzle is calibrated upon purchase, and thereafter whenever it becomes apparent that the nozzle has become damaged. Each nozzle is inspected upon return to laboratory from each field use. The diameter is measured on four different axes, with the high and low readings differing by no more than 0.004 inches as a tolerance.

TEMPERATURE MEASURING INSTRUMENTS

After each field use, the thermocouples or thermometers are calibrated against an ASTM precision mercury-in-glass thermometer across a wide range of temperatures. If the initial

APPENDIX E

METHOD 1 - SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

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

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

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

2. *Procedure*

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

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

where L = length and W = width.

2.2 Determining the Number of Traverse Points.

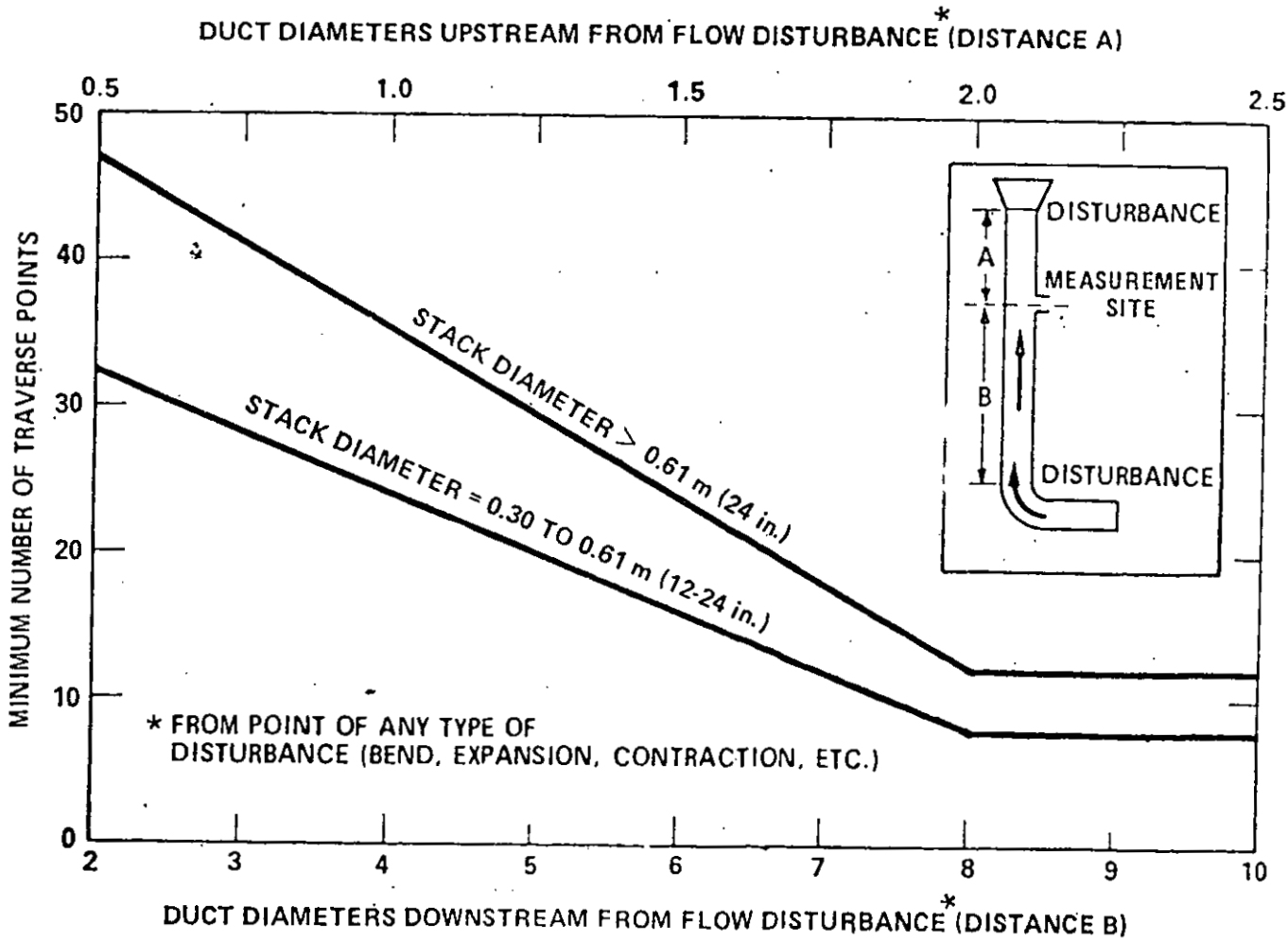
2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between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

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

TABLE 1-1. *Cross-sectional layout for rectangular stacks*

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

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



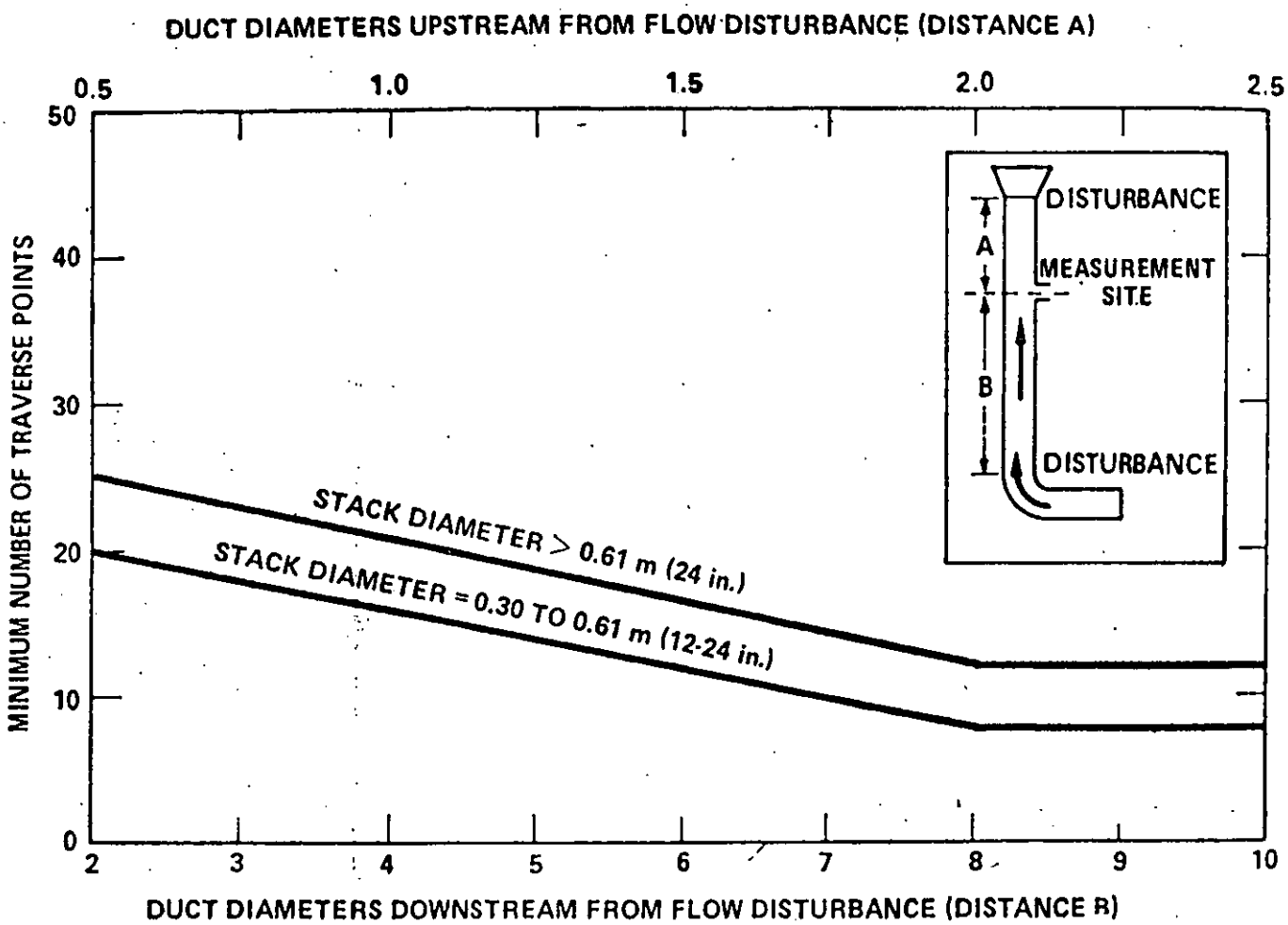


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

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

2.3 Cross-Sectional Layout and Location of Traverse Points.

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

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

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

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

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

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

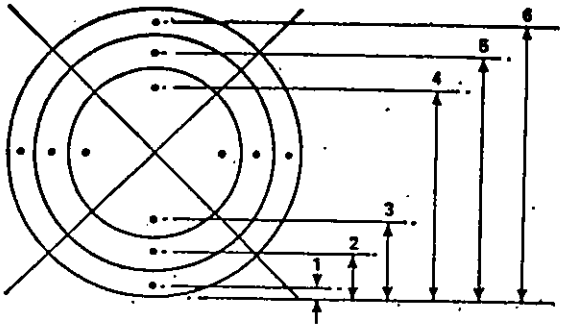


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

Table 1-2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

(Percent of stack diameter from inside wall to traverse point)

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

2.3.1.2 Stacks With Diameters Equal to or Less Tha 0.61 m (24 in.). Follow the procedure in Section 2.3.1. noting only that any "adjusted" points should t relocated away from the stack walls to: (1) a distance 1.3 cm (0.50 in.); or (2) a distance equal to the nozz inside diameter, whichever is larger.

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

The situation of traverse points being too close to th stack walls is not expected to arise with rectangul stacks. If this problem should ever arise, the Admini trator must be contacted for resolution of the matte.

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

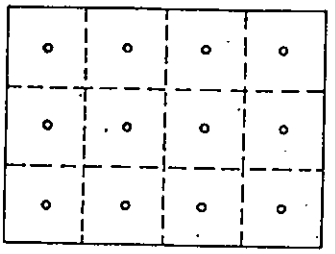


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each travrse point, calculate the average of the absolute values of α; assign α values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 10°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

3. *Bibliography*

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

1. *Principle and Applicability*

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

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

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

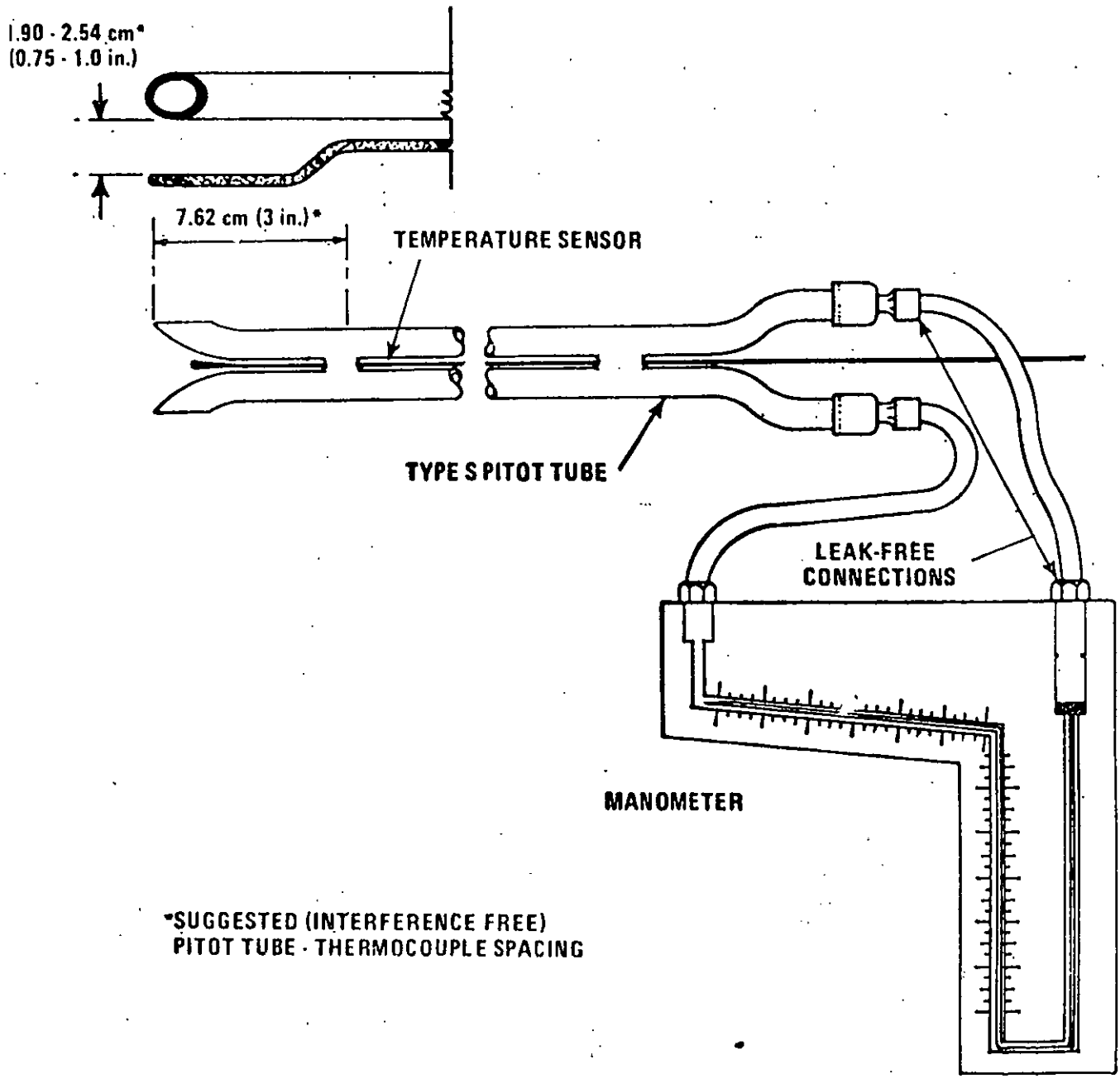
2. *Apparatus*

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

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.



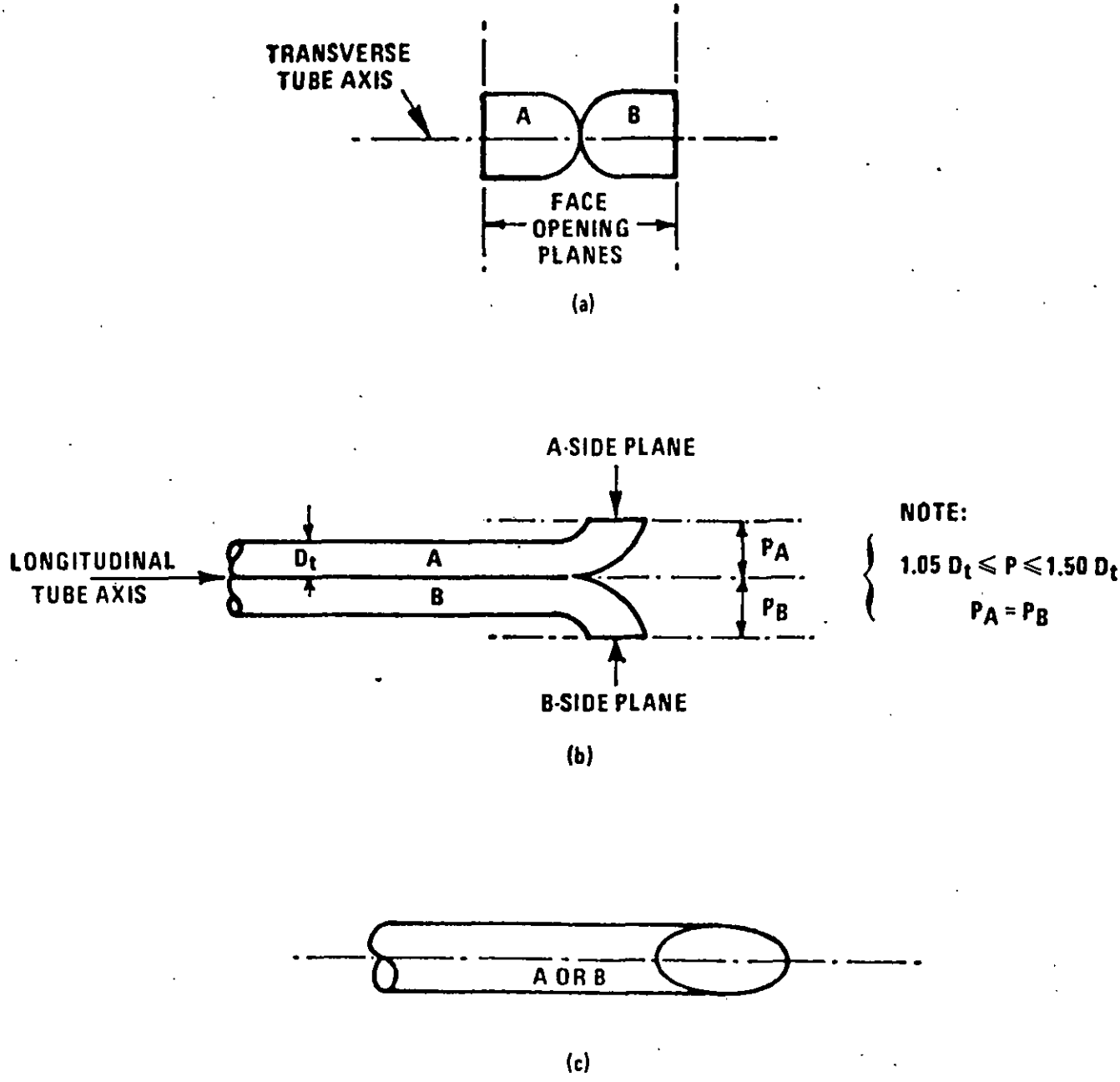


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline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

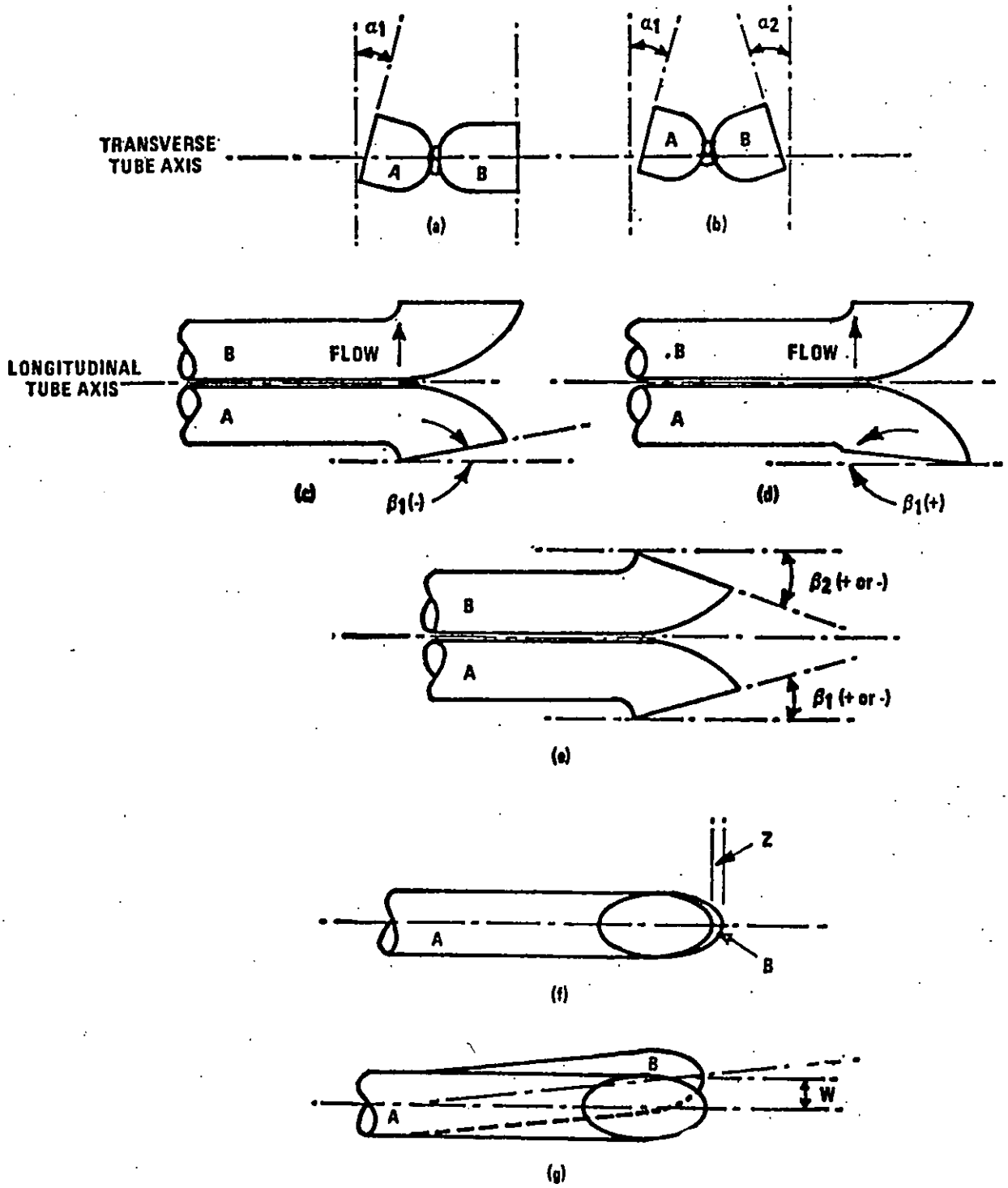


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\bar{C}p(s)$ so long as α_1 and $\alpha_2 < 10^o$, β_1 and $\beta_2 < 5^o$, $z < 0.32$ cm (1/8 in.) and $w <$ 0.08 cm (1/32 in.) (citation 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 X pitot tube with the face opening planes positioned parallel to the gas flow may also be used as the pressure probe.

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

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

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

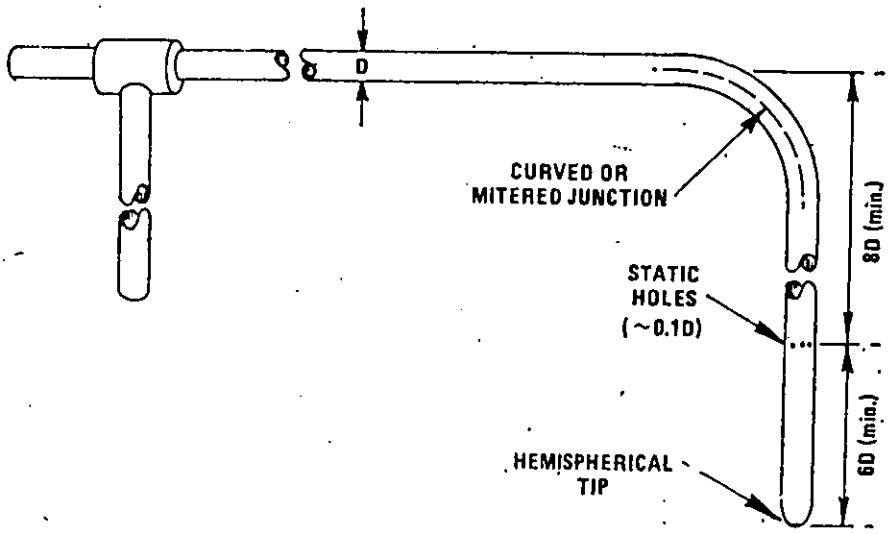


Figure 2-4. Standard pitot tube design specifications.

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.

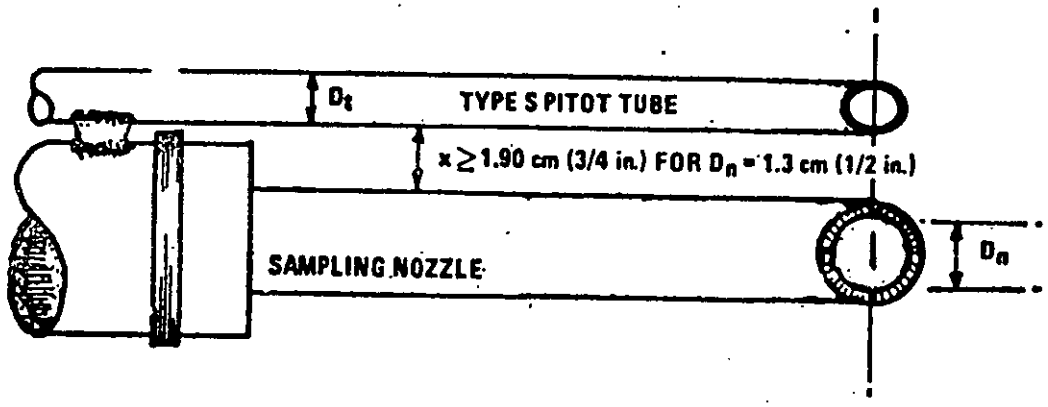
After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8 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.

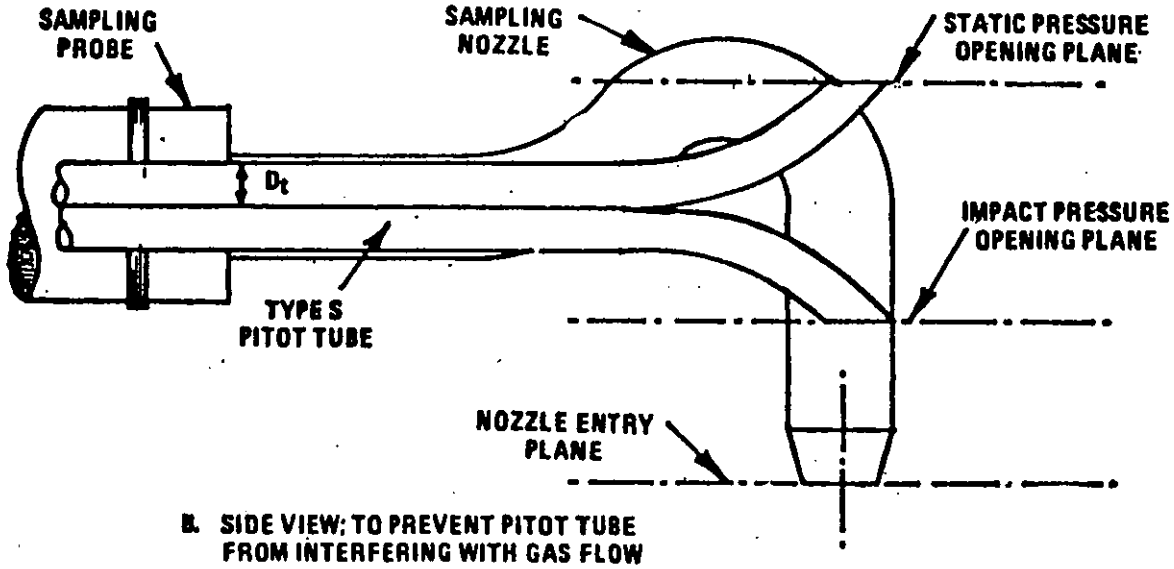
4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of 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 illustrat interference-free component arrangements for Type S pitot tubes having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

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

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



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



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

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

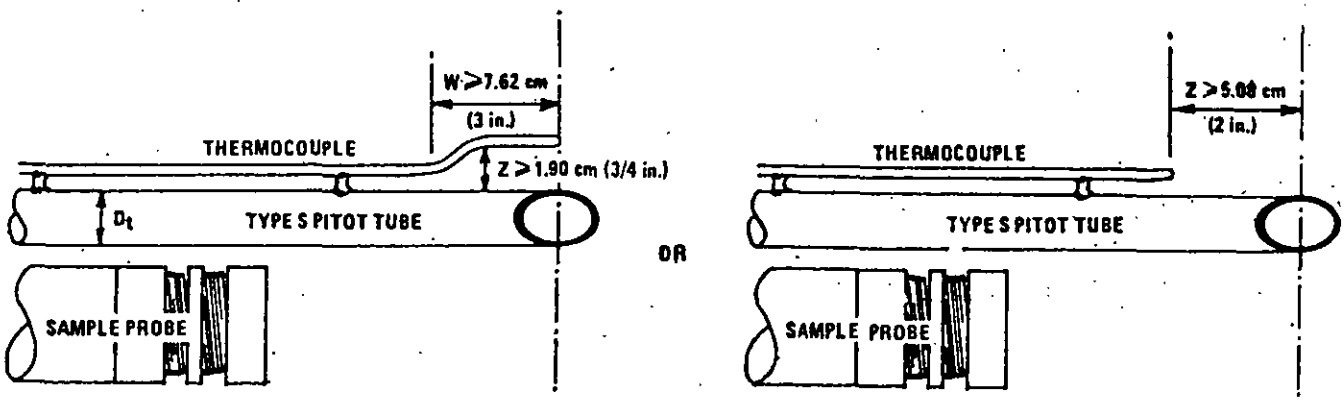


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

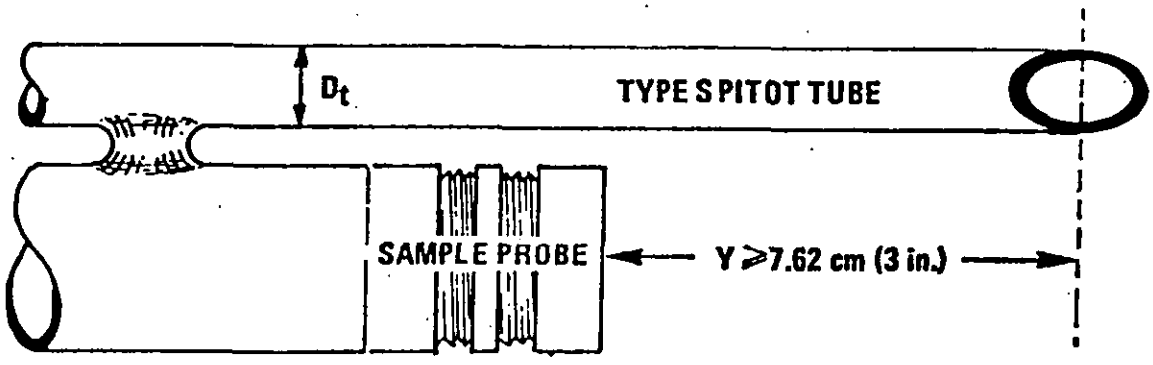


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

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

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

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

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.

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

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

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

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

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

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

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

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

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

PITOT TUBE IDENTIFICATION NUMBER: _____ DATE: _____

CALIBRATED BY: _____

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

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

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

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

Figure 2-9. Pitot tube calibration data.

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

Equation 2-2

where:

$C_{p(s)}$ = Type S pilot 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 pilot tube, cm H_2O (in. H_2O)

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

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

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

Equation 2-3

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

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

Equation 2-4

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

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

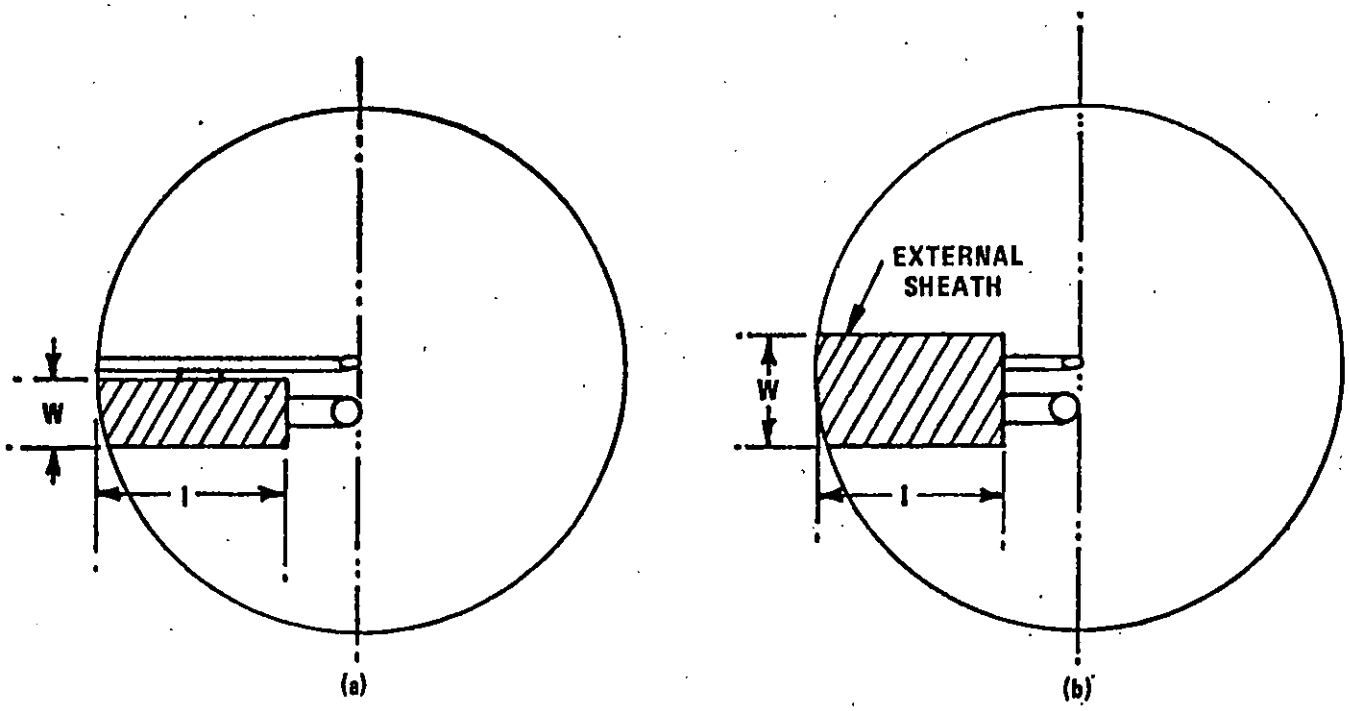
4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid,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

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

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in 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-nozzel separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

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



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

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

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

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

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 30 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $\overline{C}_{p(s)}$. 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 damaged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

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

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

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

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

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

5. *Calculations*

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

5.1 Nomenclature.

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

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

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant,

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

for the metric system and

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

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).

$$= M_d(1-B_{ws}) + 18.0\, B_{ws} \qquad \text{Equation 2-5}$$

P_{bar} = Barometric pressure at measurement site, mm Hg (in. Hg).

P_s = Stack static pressure, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

$$= P_{bar} + P_s \qquad \text{Equation 2-6}$$

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).

$$= 273 + t_s \text{ for metric} \qquad \text{Equation 2-7}$$

$$= 460 + t_s \text{ for English} \qquad \text{Equation 2-8}$$

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

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

Δp = Velocity head of stack gas, mm H_2O (in. H_2O).

3,600 = Conversion factor, sec/hr.

18.0 = Molecular weight of water, g/g-mole (lb-lb-mole).

5.2 Average stack gas velocity.

$$v_s = K_p C_p \left(\sqrt{\Delta p}\right)_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}} \qquad \text{Equation 2-9}$$

5.3 Average stack gas dry volumetric flow rate.

$$Q_{sd} = 3{,}600(1-B_{ws}) v_s A \left(\frac{T_{std}}{T_{s(avg)}}\right)\left(\frac{P_s}{P_{std}}\right) \qquad \text{Equation 2-10}$$

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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.

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 material 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.

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

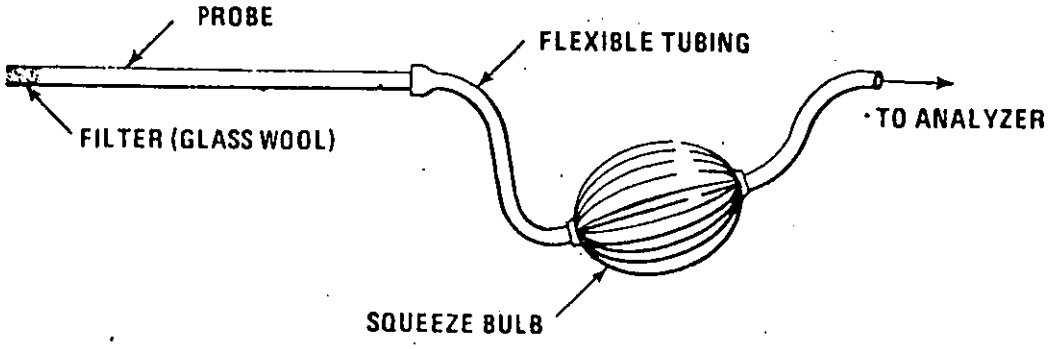

Figure 3-1. Grab-sampling train.

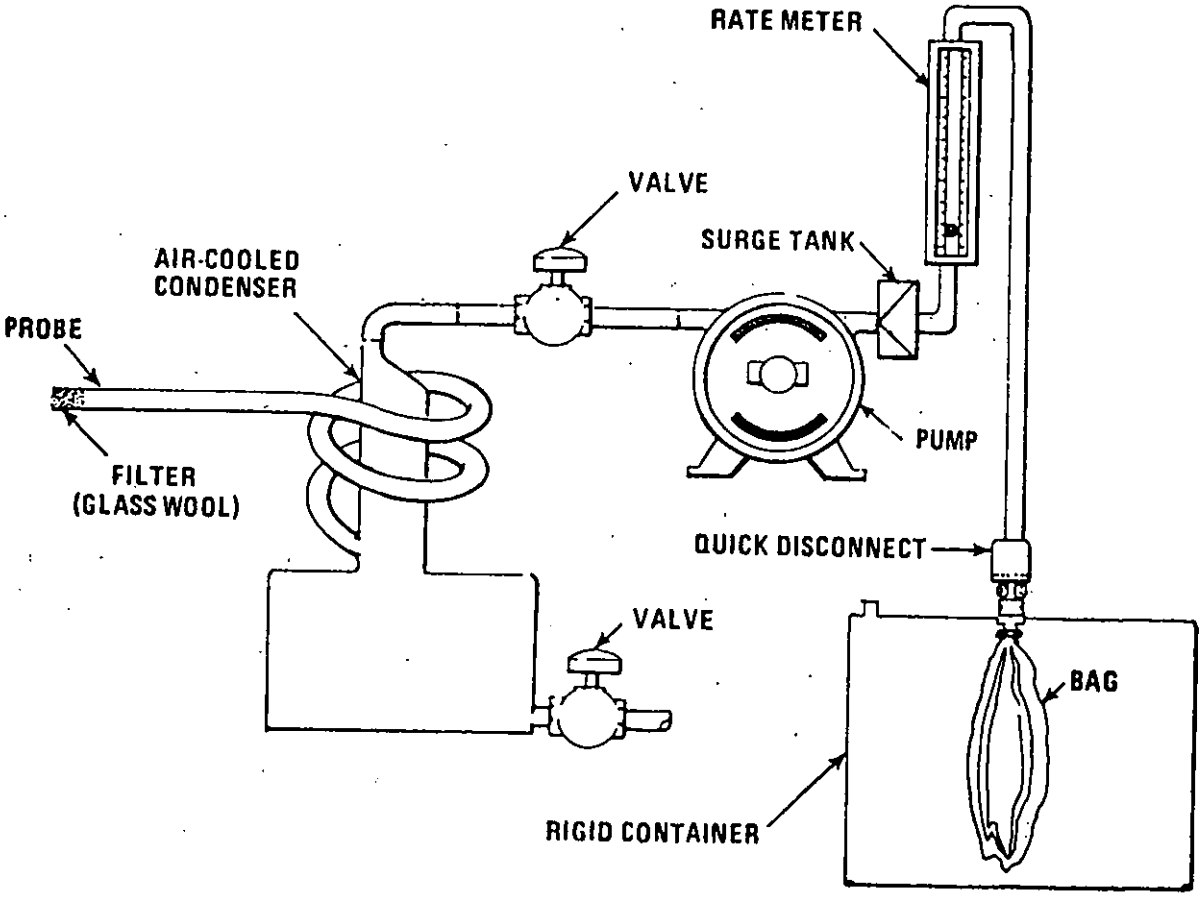

Figure 3-2. Integrated gas-sampling train.

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 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 minute 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 nd 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.

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 than 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 an 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. 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 through 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 no acceptable for excess air or emission rate correction facto 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.

TIME	TRAVERSE PT.	Q 1pm	% DEV.[a]
	AVERAGE		

$$^{a}\%\ DEV = \left(\frac{Q - Q\ avg}{Q\ avg}\right) 100 \qquad (MUST\ BE \leq 10\%)$$

Figure 3-3. Sampling rate data.

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

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 is normally conducted in conjunction with a single-point, grab sampling and analytical procedure for a pollutant, only one analysis is ordinarily conducted. Therefore, great care must be taken to obtain a valid sample and analysis. Although in most cases only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Citation 5 in the Bibliography 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 at 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 length of time as, the pollutant emission rate determination. Collect at least 30 liters (1.00 ft^3) of sample gas. Smaller volumes may be collected, subject to approval of the Administrator.

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

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 than (a) 0.3 percent by volume when CO_2 is greater than 4.0 percent or (b) 0.2 percent by volume when CO_2 is less than or equal to 4.0 percent. Average 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 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 and 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.

5. *Leak-Check Procedure for Orsat Analyzers*

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

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 meniscus 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.

$$\%EA = \left[\frac{\%O_2 - 0.5\%CO}{0.264\,\%N_2(\%O_2 - 0.5\%CO)}\right]100$$

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, molecular 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 4—DETERMINATION OF MOISTURE CONTENT IN STACK GASES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted at a constant rate from the source; moisture is removed from the sample stream and determined either volumetrically or gravimetrically.

1.2 Applicability. This method is applicable for determining the moisture content of stack gas.

Two procedures are given. The first is a reference method, for accurate determinations of moisture content (such as are needed to calculate emission data). The second is an approximation method, which provides estimates of percent moisture to aid in setting isokinetic sampling rates prior to a pollutant emission measurement run. The approximation method described herein is only a suggested approach; alternative means for approximating the moisture content, e.g., drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, previous experience, etc., are also acceptable.

The reference method is often conducted simultaneously with a pollutant emission measurement run; when it is, calculation of percent isokinetic, pollutant emission rate, etc., for the run shall be based upon the results of the reference method or its equivalent; these calculations shall not be based upon the results of the approximation method, unless the approximation method is shown, to the satisfaction of the Administrator, U.S. Environmental Protection Agency, to be capable of yielding results within 1 percent H_2O of the reference method.

NOTE.—The reference method may yield questionable results when applied to saturated gas streams or to streams that contain water droplets. Therefore, when these conditions exist or are suspected, a second determination of the moisture content shall be made simultaneously with the reference method, as follows: Assume that the gas stream is saturated. Attach a temperature sensor [capable of measuring to ±1° C (2° F)] to the reference method probe. Measure the stack gas temperature at each traverse point (see Section 2.2.1) during the reference method traverse; calculate the average stack gas temperature. Next, determine the moisture percentage, either by: (1) using a psychrometric chart and making appropriate corrections if stack pressure is different from that of the chart, or (2) using saturation vapor pressure tables. In cases where the psychrometric chart or the saturation vapor pressure tables are not applicable (based on evaluation of the process), alternate methods, subject to the approval of the Administrator, shall be used.

2. *Reference Method*

The procedure described in Method 5 for determining moisture content is acceptable as a reference method.

2.1 Apparatus. A schematic of the sampling train used in this reference method is shown in Figure 4-1. All components shall be maintained and calibrated according to the procedure outlined in Method 5.

2.1.1 Probe. The probe is constructed of stainless steel or glass tubing, sufficiently heated to prevent water condensation, and is equipped with a filter, either in-stack (e.g., a plug of glass wool inserted into the end of the probe) or heated out-stack (e.g., as described in Method 5), to remove particulate matter.

When stack conditions permit, other metals or plastic tubing may be used for the probe, subject to the approval of the Administrator.

2.1.2 Condenser. The condenser consists of four impingers connected in series with ground glass, leak-free fittings or any similarly leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with a 1.3 centimeter (½ inch) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator.

The first two impingers shall contain known volumes of water, the third shall be empty, and the fourth shall contain a known weight of 6- to 16-mesh indicating type silica gel, or equivalent desiccant. If the silica gel has been previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. A thermometer, capable of measuring temperature to within 1° C (2° F), shall be placed at the outlet of the fourth impinger, for monitoring purposes.

Alternatively, any system may be used (subject to the approval of the Administrator) that cools the sample gas stream and allows measurement of both the water that has been condensed and the moisture leaving the condenser, each to within 1 ml or 1 g. Acceptable means are to measure the condensed water, either gravimetrically or volumetrically, and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures, or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap, with exit gases kept below 20° C (68° F), and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump, to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.3 Cooling System. An ice bath container and crushed ice (or equivalent) are used to aid in condensing moisture.

2.1.4 Metering System. This system includes a vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment as shown in Figure 4-1. Other metering systems, capable of maintaining a constant sampling rate and determining sample gas volume, may be used, subject to the approval of the Administrator.

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

2.1.6 Graduated Cylinder and/or Balance. These items are used to measure condensed water and moisture caught in the silica gel to within 1 ml or 0.5 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. These balances are suitable for use here.

2.2 Procedure. The following procedure is written for a condenser system (such as the impinger system described in Section 2.1.2) incorporating volumetric analysis to measure the condensed moisture, and silica gel and gravimetric analysis to measure the moisture leaving the condenser.

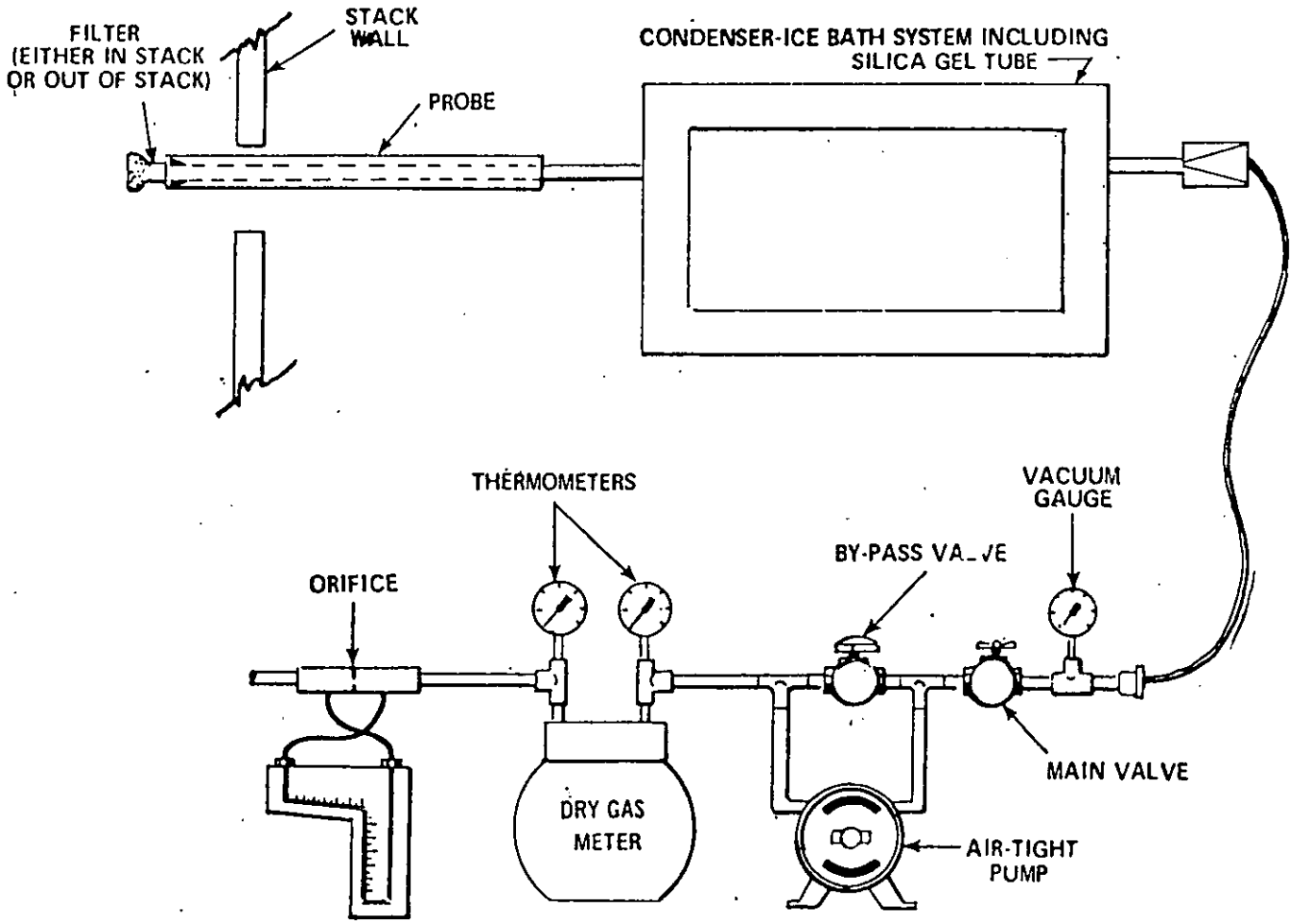

Figure 4-1. Moisture sampling train-reference method.

2.2.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine points shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve travers points shall be used in all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to the approval of the Administrator. Select a suitable probe and probe length such that all traverse points can be sampled. Consider sampling from opposite sides of the stack (four total sampling ports) for large stacks, to permit use of shorter probe lengths. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point. Place known volumes of water in the first two impingers. Weigh and record the weight of the silica gel to the nearest 0.5 g, and transfer the silica gel to the fourth impinger; alternatively, the silica gel may first be transferred to the impinger, and the weight of the silica gel plus impinger recorded.

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.60 m³ (21 scf) will be collected, at a rate no greater than 0.021 m³/min (0.75 cfm). When both moisture content and pollutant emission rate are to be determined, the moisture determination shall be simultaneous with, and for the same total length of time as, the pollutant emission rate run, unless otherwise specified in an applicable subpart of the standards.

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° °C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or (if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

2.2.4 During the sampling run, maintain a sampling rate within 10 percent of constant rate, or as specified by the Administrator. For each run, record the data required on the example data sheet shown in Figure 4-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment and whenever sampling is halted. Take other appropriate readings at each sample point, at least once during each time increment.

2.2.5 To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust the flow to the desired rate. Traverse the cross section, sampling at each traverse point for an equal length of time. Add more ice and, if necessary, salt to maintain a temperature of less than 20° C (68° F) at the silica gel outlet.

2.2.6 After collecting the sample, disconnect the probe from the filter holder (or from the first impinger) and conduct a leak check (mandatory) as described in Section 2.2.3. Record the leak rate. If the leakage rate exceeds the allowable rate, the tester shall either reject the test results or shall correct the sample volume as in Section 6.3 of Method 5. Next, measure the volume of the moisture condensed to the nearest ml. Determine the increase in weight of the silica gel (or silica gel plus impinger) to the nearest 0.5 g. Record this information (see example data sheet, Figure 4-3) and calculate the moisture percentage, as described in 2.3 below.

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

PLANT _____

LOCATION _____

OPERATOR _____

DATE _____

RUN NO. _____

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

PROBE LENGTH m(ft) _____

SCHEMATIC OF STACK CROSS SECTION

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STACK TEMPERATURE °C (°F)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH), mm(in.) H_2O	METER READING GAS SAMPLE VOLUME m^3 (ft^3)	ΔV_m m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
						INLET (Tm_{in}), °C (°F)	OUTLET (Tm_{out}), °C (°F)	
TOTAL						Avg.	Avg.	
AVERAGE						Avg.		

Figure 4-2. Field moisture determination-reference method.

	IMPINGER VOLUME, ml	SILICA GEL WEIGHT, g
FINAL		
INITIAL		
DIFFERENCE		

Figure 4-3. Analytical data - reference method.

2.3.1 Nomenclature.

B_{ws} = Proportion of water vapor, by volume, in the gas stream.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m^3)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft^3)/(lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R).

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

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

ΔV_m = Incremental dry gas volume measured by dry gas meter at each traverse point, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed corrected to standard conditions, scm (scf).

$V_{wsi(std)}$ = Volume of water vapor collected in silica gel corrected to standard conditions, scm (scf).

V_f = Final volume of condenser water, ml.

V_i = Initial volume, if any, of condenser water, ml.

W_f = Final weight of silica gel or silica gel plus impinger, g.

W_i = Initial weight of silica gel or silica gel plus impinger, g.

Y = Dry gas meter calibration factor.

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

2.3.2 Volume of water vapor condensed.

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w} = K_1 (V_f - V_i)$$

Equation 4-1

where:

K_1 = 0.001333 m^3/ml for metric units
= 0.04707 ft^3/ml for English units

2.3.3 Volume of water vapor collected in silica gel.

$$V_{wsi(std)} = \frac{(W_f - W_i) R T_{std}}{P_{std} M_w} = K_2 (W_f - W_i)$$

Equation 4-2

where:

K_2 = 0.001336 m^3/g for metric units
= 0.04715 ft^3/g for English units

2.3.4 Sample gas volume.

$$V_{m(std)} = V_m Y \frac{(P_m)(T_{std})}{(P_{std})(T_m)} = K_3 Y \frac{V_m P_m}{T_m}$$

Equation 4-3

where:

K_3 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

NOTE.—If the post-test leak rate (Section 2.2.6) exceeds the allowable rate, correct the value of V_m in Equation 4-3, as described in Section 6.3 of Method 5.

2.3.5 Moisture Content.

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

Equation 4-4

NOTE.—In saturated or moisture droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one using a value based upon the saturated conditions (see Section 1.2), and another based upon the results of the impinger analysis. The lower of these two values of B_{ws} shall be considered correct.

2.3.6 Verification of constant sampling rate. For each time increment, determine the ΔV_m. Calculate the average. If the value for any time increment differs from the average by more than 10 percent, reject the results and repeat the run.

3. *Approximation Method*

The approximation method described below is presented only as a suggested method (see Section 1.2).

3.1 Apparatus.

3.1.1 Probe. Stainless steel or glass tubing, sufficiently heated to prevent water condensation and equipped with a filter (either in-stack or heated out-stack) to remove particulate matter. A plug of glass wool, inserted into the end of the probe, is a satisfactory filter.

3.1.2 Impingers. Two midget impingers, each with 30 ml capacity, or equivalent.

3.1.3 Ice Bath. Container and ice, to aid in condensing moisture in impingers.

3.1.4 Drying Tube. Tube packed with new or regenerated 6- to 16-mesh indicating-type silica gel (or equivalent desiccant), to dry the sample gas and to protect the meter and pump.

3.1.5 Valve. Needle valve, to regulate the sample gas flow rate.

3.1.6 Pump. Leak-free, diaphragm type, or equivalent, to pull the gas sample through the train.

3.1.7 Volume meter. Dry gas meter, sufficiently accurate to measure the sample volume within 2%, and calibrated over the range of flow rates and conditions actually encountered during sampling.

3.1.8 Rate Meter. Rotameter, to measure the flow range from 0 to 3 l pm (0 to 0.11 cfm).

3.1.9 Graduated Cylinder. 25 ml.

3.1.10 Barometer. Mercury, aneroid, or other barometer, as described in Section 2.1.5 above.

3.1.11 Vacuum Gauge. At least 760 mm Hg (30 in. Hg) gauge, to be used for the sampling leak check.

3.2 Procedure.

3.2.1 Place exactly 5 ml distilled water in each impinger. Assemble the apparatus without the probe as shown in Figure 4-4. Leak check the train by placing a vacuum gauge at the inlet to the first impinger and drawing a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet of the rotameter, and then turning off the pump. The vacuum shall remain constant for at east one minute. Carefully release the vacuum gauge before unplugging the rotameter end.

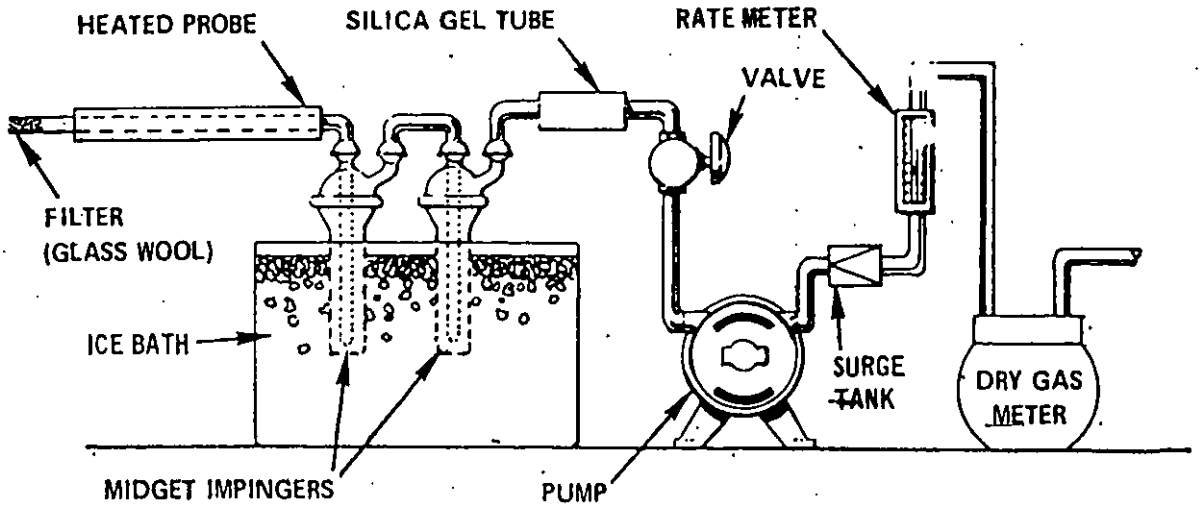

Figure 4-4. Moisture-sampling train - approximation method.

LOCATION _____ COMMENTS

TEST _____

DATE _____

OPERATOR _____

BAROMETRIC PRESSURE _____

CLOCK TIME	GAS VOLUME THROUGH METER, (Vm), m^3 (ft^3)	RATE METER SETTING m^3/min. (ft^3/min.)	METER TEMPERATURE, °C (°F)

Figure 4-5. Field moisture determination - approximation method.

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft^3) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{wm} = Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.

B_{we} = Water vapor in the gas stream, proportion by volume.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole)

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m^3)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft^3)/lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R)

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

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed, corrected to standard conditions, scm (scf).

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

3.3.2 Volume of water vapor collected.

$$V_{wc} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w}$$
$$= K_1 (V_f - V_i)$$

Equation 4-5

where:

K_1 = 0.001333 m^3/ml for metric units
= 0.04707 ft^3/ml for English units.

3.3.3 Gas volume.

$$V_{m(std)} = V_m \left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right)$$
$$= K_2 \frac{V_m P_m}{T_m}$$

Equation 4-6

where:

K_2 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

3.3.4 Approximate moisture content.

$$B_{we} = \frac{V_{wc}}{V_{wc} + V_{m(std)}} + B_{wm}$$
$$= \frac{V_{wc}}{V_{wc} + V_{m(std)}} + (0.025)$$

Equation 4-7

4. *Calibration*

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. *Bibliography*

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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 the 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 Section 7); 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 Section 7). 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,[1] or other corrosion resistant metals) made of seamless tubing may be used, subject to the approval of the Administrator.

2.1.3 Pitot Tube. Type S, as described in Section 2.1 of Method 2, or other device approved by the Administrator. The pitot tube shall be attached to the probe (as shown in Figure 5-1) to allow constant monitoring of the stack gas velocity. The impact (high pressure) opening plane of the pitot tube shall be even with or above the nozzle entry plane (see Method 2, Figure 2-6b) during sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

2.1.4 Differential Pressure Gauge. Inclined manometer or equivalent device (two), as described in Section 2.2 of Method 2. One manometer shall be used for velocity head (Δp) readings, and the other, for orifice differential pressure readings.

2.1.5 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket. Other materials of construction (e.g., stainless steel, Teflon, Viton) may be used, subject to approval of the Administrator. The holder design shall provide a positive seal against leakage from the outside or around the filter. The holder shall be attached immediately at the outlet of the probe (or cyclone, if used).

2.1.6 Filter Heating System. Any heating system capable of maintaining a temperature around the filter holder during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. Alternatively, the tester may opt to operate the equipment at a temperature lower than that specified. A temperature gauge capable of measuring temperature to within 3° C (5.4° F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the one shown in APTD-0581 may be used.

2.1.7 Condenser. The following system shall be used to determine the stack gas moisture content: Four impingers connected in series with leak-free ground glass fittings or any similar leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with 1.3 cm (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator. The first and second impingers shall contain known quantities of water (Section 4.1.3), the third shall be empty, and the fourth shall contain a known weight of silica gel, or equivalent desiccant. A thermometer, capable of measuring temperature to within 1° C (2° F) shall be placed at the outlet of the fourth impinger for monitoring purposes.

Alternatively, any system that cools the sample gas stream and allows measurement of the water condensed and moisture leaving the condenser, each to within 1 ml or 1 g may be used, subject to the approval of the Administrator. Acceptable means are to measure the condensed water either gravimetrically or volumetrically and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures; or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap with exit gases kept below 20° C (68° F) and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

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 described in APTD-0581 or APTD-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

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

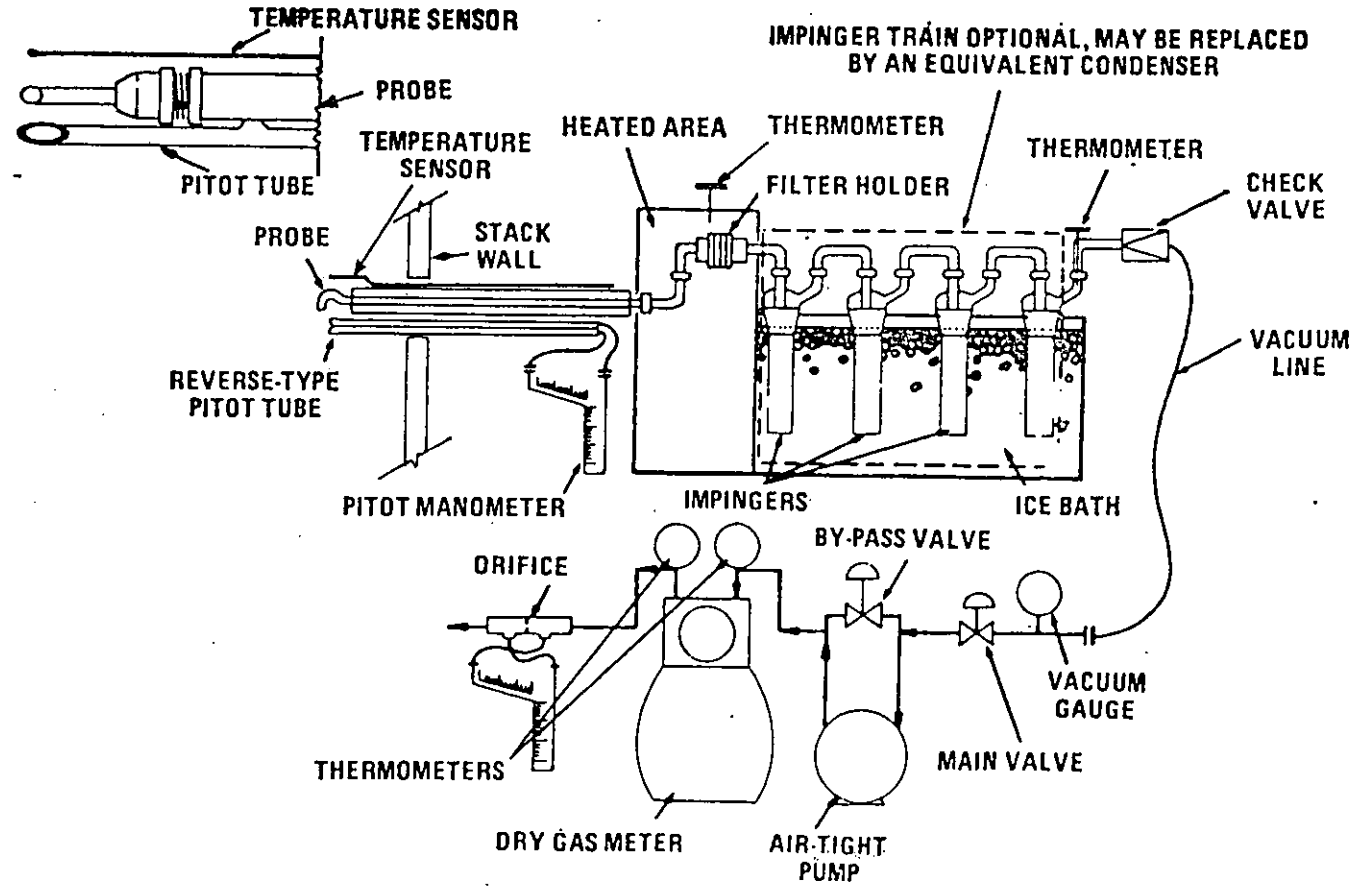

Figure 5-1. Particulate-sampling train.

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 for use here and in Section 2.3.4.

2.2.6 Plastic Storage Containers. Air-tight containers to store silica gel.

2.2.7 Funnel and Rubber Policeman. To aid in transfer of silica gel to container; not necessary if silica gel is weighed in the field.

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

2.3 Analysis. For analysis, the following equipment is needed.

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 Beakers. 250 ml.

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature Gauge. To measure the temperature of the laboratory environment.

3. *Reagents*

3.1 Sampling. The reagents used in sampling are as follows:

3.1.1 Filters. Glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (≤0.05 percent penetration) on 0.3-micron dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with ASTM standard method D 2986-71. Test data from the supplier's quality control program are sufficient for this purpose.

3.1.2. Silica Gel. Indicating type, 6 to 16 mesh. If previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccants (equivalent or better) may be used, subject to the approval of the Administrator.

3.1.3 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. All the components shall be maintained and calibrated according to the procedure described in APTD-0576, unless otherwise specified herein.

Weigh several 200 to 300 g portions of silica gel in air-tight containers to the nearest 0.5 g. Record the total weight of the silica gel plus container, on each container. As an alternative, the silica gel need not be preweighed, but may be weighed directly in its impinger or sampling holder just prior to train assembly.

Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper 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.

In some circumstances, e.g., batch cycles, it may be necessary to sample for shorter times at the traverse points and to obtain smaller gas sample volumes. In these cases, the Administrator's approval must first be obtained.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

Place 100 ml of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.5 g and recorded.

Using a tweezer or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as to prevent the sample gas stream from circumventing the filter. Check the filter for tears after assembly is completed.

When glass liners are used, install the selected nozzle using a Viton A O-ring when stack temperatures are less than 240° C (500° F) and an asbestos string gasket when temperatures are higher. See APTD-0576 for details. Other connecting systems using either 316 stainless steel or Teflon ferrules may be used. When metal liners are used, install the nozzle as above or by a leak-free direct mechanical connection. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

Set up the train as in Figure 5-1, using (if necessary) a very light coat of silicone grease on all ground glass joints, greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Subject to the approval of the Administrator, a glass cyclone may be used between the probe and filter holder when the total particulate catch is expected to exceed 100 mg or when water droplets are present in the stack gas.

Place crushed ice around the impingers.

4.1.4 Leak-Check Procedures.

4.1.4.1 Pretest Leak-Check. A pretest leak-check is recommended, but not required. If the tester opts to conduct the pretest leak-check, the following procedure shall be used.

After the sampling train has been assembled, turn on and set the filter and probe heating systems at the desired operating temperatures. Allow time for the temperatures to stabilize. If a Viton A O-ring or other leak-free connection is used in assembling the probe nozzle to the probe liner, leak-check the train at the sampling site by plugging the nozzle and pulling a 380 mm Hg (15 in. Hg) vacuum.

NOTE.—A lower vacuum may be used, provided that it is not exceeded during the test.

If an asbestos string is used, do not connect the probe to the train during the leak-check. Instead, leak-check the train by first plugging the inlet to the filter holder (cyclone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in. Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in. Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, are unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with bypass valve fully open and coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of bypass valve; this will cause water to back up into the filter holder. If the desired vacuum is exceeded, either leak-check at this higher vacuum or end the leak check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe, filter holder, or cyclone (if applicable) and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced backward into the filter holder and silica gel from being entrained backward into the third impinger.

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction will need to be applied to the total volume of dry gas metered; if, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

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

4.1.4.3 Post-test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leak-check shall be done in accordance with the procedures outlined in Section 4.1.4.1, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction need be applied to the total volume of dry gas metered. If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

4.1.5 Particulate Train Operation. During the sampling run, maintain an isokinetic sampling rate (within 10 percent of true isokinetic unless otherwise specified by the Administrator) and a temperature around the filter of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator.

For each run, record the data required on a data sheet such as the one shown in Figure 5-2. Be sure to record the initial dry gas meter reading. Record the dry gas meter readings at the beginning and end of each sampling time increment, when changes in flow rates are made, before and after each leak check, and when sampling is halted.

Take other readings required by Figure 5-2 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

Clean the portholes prior to the test run to minimize the chance of sampling deposited material. To begin sampling, remove the nozzle cap, verify that the filter and probe heating systems are up to temperature, and that the pitot tube and probe are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Nomographs are available, which aid in the rapid adjustment of the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85 ± 0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29 ± 4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges do not use the nomographs unless appropriate steps (see Citation 7 in Section 7) are taken to compensate for the deviations.

PLANT _____

LOCATION _____

OPERATOR _____

DATE _____

RUN NO. _____

SAMPLE BOX NO. _____

METER BOX NO. _____

METER $\Delta H@$ _____

C FACTOR _____

PITOT TUBE COEFFICIENT, C_p _____

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, m^3/min. (cfm) _____

PROBE LINER MATERIAL _____

STATIC PRESSURE, mm Hg (in. Hg) _____

FILTER NO. _____

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	VACUUM mm Hg (in. Hg)	STACK TEMPERATURE (T_s) °C (°F)	VELOCITY HEAD (ΔP_s), mm(in.)H_2O	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER mm H_2O (in. H_2O)	GAS SAMPLE VOLUME m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		FILTER HOLDER TEMPERATURE, °C (°F)	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
							INLET °C (°F)	OUTLET °C (°F)		
TOTAL							Avg.	Avg.		
AVERAGE							Avg.			

Figure 5-2. Particulate field data.

When the stack is under significant negative pressure (height of impinger stem), take care to close the coarse adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross-section, as required by Method 1 or as specified by the Administrator, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe through the portholes; this minimizes the chance of extracting deposited material.

During the test run, make periodic adjustments to keep the temperature around the filter holder at the proper level; add more ice and, if necessary, salt to maintain a temperature of less than 20° C (68° F) at the condenser/silica gel outlet. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter assembly be used rather than attempting to change the filter itself. Before a new filter assembly is installed, conduct a leak-check (see Section 4.1.4.2). The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Administrator.

Note that when two or more trains are used, separate analyses of the front-half and (if applicable) impinger catches from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case, the front-half catches from the individual trains may be combined (as may the impinger catches) and one analysis of front-half catch and one analysis of impinger catch may be performed. Consult with the Administrator for details concerning the calculation of results when two or more trains are used.

At the end of the sample run, turn off the coarse adjust valve, remove the probe and nozzle from the stack, turn off the pump, record the final dry gas meter reading, and conduct a post-test leak-check, as outlined in Section 4.1.4.3. Also, leak-check the pitot lines as described in Method 2, Section 3.1; the lines must pass this leak-check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Calculations, Section 6) to determine whether the run was valid or another test run should be made. If there was difficulty in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe is removed from the stack at the end of the sampling period. Allow the probe to cool.

When the probe can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, thus drawing water from the impingers into the filter holder.

Before moving the sample train to the cleanup site, remove the probe from the sample train, wipe off the silicone grease, and cap the open outlet of the probe. Be careful not to lose any condensate that might be present. Wipe off the silicone grease from the filter inlet where the probe was fastened and cap it. Remove the umbilical cord from the last impinger and cap the impinger. If a flexible line is used between the first impinger or condenser and the filter holder, disconnect the line at the filter holder and let any condensed water or liquid drain into the impingers or condenser. After wiping off the silicone grease, cap off the filter holder outlet and impinger inlet. Either ground-glass stoppers, plastic caps, or serum caps may be used to close these openings.

Transfer the probe and filter-impinger assembly to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank. Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container No. 2. Taking care to see that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, probe

fitting, probe liner, and front half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Administrator and shall be used when specified by the Administrator; in these cases, save a water blank and follow the Administrator's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a nylon bristle brush. Brush until the acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone.

Brush and rinse the inside parts of the Swagelok fitting with acetone in a similar way until no visible particles remain.

Rinse the probe liner with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces will be wetted with acetone. Let the acetone drain from the lower end into the sample container. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Follow the acetone rinse with a probe brush. Hold the probe in an inclined position, squirt acetone into the upper end as the probe brush is being pushed with a twisting action through the probe; hold a sample container underneath the lower end of the probe, and catch any acetone and particulate matter which is brushed from the probe. Run the brush through the probe three times or more until no visible particulate matter is carried out with the acetone or until none remains in the probe liner on visual inspection. With stainless steel or other metal probes, run the brush through in the above prescribed manner at least six times since metal probes have small crevices in which particulate matter can be entrapped. Rinse the brush with acetone, and quantitatively collect these washings in the sample container. After the brushing, make a final acetone rinse of the probe as described above.

It is recommended that two people be used to clean the probe to minimize sample losses. Between sampling runs, keep brushes clean and protected from contamination.

After ensuring that all joints have been wiped clean of silicone grease, clean the inside of the front half of the filter holder by rubbing the surfaces with a nylon bristle brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make a final rinse of the brush and filter holder. Carefully rinse out the glass cyclone, also (if applicable). After all acetone washings and particulate matter have been collected in the sample container, tighten the lid on the sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage occurred 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:

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.

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 (1g/ml):

$$\frac{\text{INCREASE, g}}{\text{1 g/ml}} = \text{VOLUME WATER, ml}$$

Figure 5-3. Analytical data.

Alternatively, the sample may be oven dried at 105° C (220° F) for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. The tester may also opt to oven dry the sample at 105° C (220° F) for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

Container No. 2. Note the level of liquid in the container and confirm on the analysis sheet whether or not leakage occurred during transport. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results. Measure the liquid in this container either volumetrically to ±1 ml or gravimetrically to ±0.5 g. Transfer the contents to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Container No. 3. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g using a balance. This step may be conducted in the field.

"Acetone Blank" Container. Measure acetone in this container either volumetrically or gravimetrically. Transfer the acetone to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

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

5. *Calibration*

Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of the nozzle to the nearest 0.025 mm (0.001 in.). Make three separate measurements using different diameters each time, and obtain the average of the measurements. The difference between the high and low numbers shall not exceed 0.1 mm (0.004 in.). When nozzles become nicked, dented, or corroded, they shall be reshaped, sharpened, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

5.2 Pitot Tube. The Type S pitot tube assembly shall be calibrated according to the procedure outlined in Section 4 of Method 2.

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

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

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

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

5.4 Probe Heater Calibration. The probe heating system shall be calibrated before its initial use in the field according to the procedure outlined in APTD-0576. Probes constructed according to APTD-0581 need not be calibrated if the calibration curves in APTD-0576 are used.

5.5 Temperature Gauges. Use the procedure in Section 4.3 of Method 2 to calibrate in-stack temperature gauges. Dial thermometers, such as are used for the dry gas meter and condenser outlet, shall be calibrated against mercury-in-glass thermometers.

5.6 Leak Check of Metering System Shown in Figure 5-1. That portion of the sampling train from the pump to the orifice meter should be leak checked prior to initial use and after each shipment. Leakage after the pump will result in less volume being recorded than is actually sampled. The following procedure is suggested (see Figure 5-4): Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing attached into the orifice exhaust pipe. Disconnect and vent the low side of the orifice manometer. Close off the low side orifice tap. Pressurize the system to 13 to 18 cm (5 to 7 in.) water column by blowing into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box; leaks, if present, must be corrected.

5.7 Barometer. Calibrate against a mercury barometer.

6. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

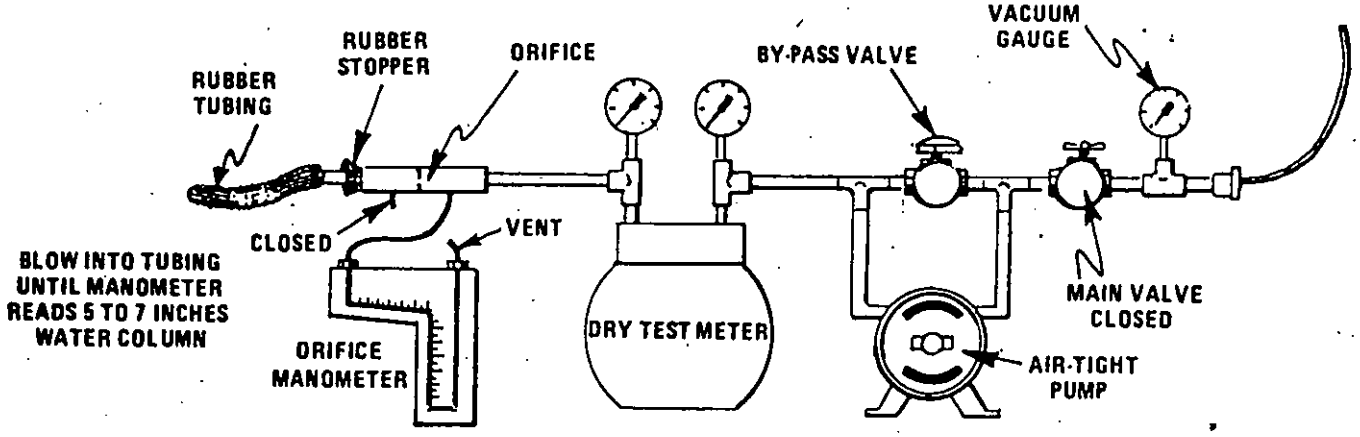

Figure 5-4. Leak check of meter box.

6.1 Nomenclature

A_n = Cross-sectional area of nozzle, m² (ft²).
B_{ws} = Water vapor in the gas stream, proportion by volume.
C_a = Acetone blank residue concentrations, 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 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.
L_i = Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change, (i=1, 2, 3 . . . n), m³/min (cfm).
L_p = Leakage rate observed during the post-test leak check, m³/min (cfm).
m_a = Total amount of particulate matter collected, mg.
M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).
m_n = Mass of residue of acetone 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-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).
T_m = Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).
T_s = Absolute average stack gas temperature (see Figure 5-2), °K (°R).
T_{std} = Standard absolute temperature, 293° K (528° R).
V_a = Volume of acetone blank, ml.
V_{aw} = Volume of acetone used in wash, ml.
V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.
V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).
$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
V_s = Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).
W_a = Weight of residue in acetone wash, mg.
Y = Dry gas meter calibration factor.
ΔH = Average pressure differential across the orifice meter (see Figure 5-2), mm H_2O (in. H_2O).
ρ_a = Density of acetone, mg/ml (see label on bottle).
ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).
θ = Total sampling time, min.
θ_i = Sampling time interval, from the beginning of a run until the first component change, min.
θ_n = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.
θ = 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:
$m_1 = 0.3858$ °K/mm Hg for metric units
$= 17.64$ °R/in. Hg for English units

NOTE.—Equation 5-1 can be used as written unless the leakage rate observed during any of the mandatory leak checks (i.e., the post-test leak check or leak checks conducted prior to component changes) exceeds L_a. If L_p or L_i exceeds L_a, Equation 5-1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 5-1 with the expression:

$$V_m - (L_p - L_a)\theta]$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace V_m in Equation 5-1 by the expression:

$$\left[V_m - (L_1 - L_a)\theta_1 - \sum_{i=2}^{n} (L_i - L_a)\theta_i - (L_p - L_a)\theta_p\right]$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of water vapor.

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

Equation 5-2

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

6.5 Moisture Content.

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

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_{ws} shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the Note of Section 1.2 of Method 4. For the purposes of this method, the average stack gas temperature from Figure 5-2 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is ± 1° C (2° F).

6.6 Acetone Blank Concentration.

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

Equation 5-4

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 Variation.

6.11.1 Calculation From Raw Data.

$$I = \frac{100\, T_s [K_3 V_{lc} + (V_m / T_m)(P_{bar} + \Delta H/13.6)]}{60\, \theta\, v_s P_s A_n}$$

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 $\leq I \leq 110$ percent, the results are acceptable. If the results are low in comparison to the standard and I is beyond the acceptable range, or, if I is less than 90 percent, the Administrator may opt to accept the results. Use Citation 4 to make judgments. Otherwise, reject the results and repeat the test.

7. *Bibliography*

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