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STATIONARY SOURCE SAMPLING REPORT

EEI REF. NO. 2988

OSBORNE WASTE WATER TREATMENT PLANT

GREENSBORO, NORTH CAROLINA

PARTICULATE EMISSIONS AND

PARTICLE SIZE DISTRIBUTION TESTING

SLUDGE INCINERATOR SCRUBBER INLET AND SCRUBBER STACK

performed for:

NICHOLS ENGINEERING AND RESEARCH CORPORATION

OCTOBER 1, 2, & 3, 1985

REPORT CERTIFICATION

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

Date October 29, 1985 Signature Neill M Harden

Neill M. Harden

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

Date October 29, 1985 Signature

D. James Grove, P.E.

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INTRODUCTION

1.1 Outline of Test Program. Stationary source sampling was performe for Nichols Engineering and Research Corporation at the Osborne Waste Water Treatment Plant in Greensboro, North Carolina, on October 1-3, 1985. Concurrent testing was performed at the sludge incinerator scrubber inlet a scrubber stack to determine the particulate emissions and particle size distributions. The particulate collection efficiency of the scrubber, the contents of sludge samples taken during each test set, and the results of loss-on-ignition analyses on the Method 5 particulate samples are also reported. Table 1-1 outlines the test program.

TABLE 1-1

SAMPLING LOG

Sludge Incinerator Scrubber

Test Date	Sampling Objective	Sampling Method	Test Set	Concurrent Runs Inlet	Concurrent Runs Stack
10/1	Particulate	EPA 5	1	I-2*	O-1
	Particle Sizing	Cascade Impactor	2	SI-1	SO-1
	Particulate	EPA 5	3	I-3**	O-3**
10/2	Particulate	EPA 5	4	I-4	O-4
	Particle Sizing	Cascade Impactor	5	SI-4	SO-4
10/3	Particulate	EPA 5	6	I-5	O-5
	Particle Sizing	Cascade Impactor	7	SI-5	SO-5

* Run I-2 performed to replace run I-1; for scrubber efficiency calculations runs I-2 and O-1 are considered concurrent runs.

** Aborted due to stoppage of process

SUMMARY OF RESULTS

2.1 Particulate. Table 2-1 summarizes the results of particulate testing performed at the sludge incinerator scrubber inlet and scrubber stack on October 1, 2, and 3, 1985. Run-by-run results are presented in Tables 2-2 and 2-3 for the scrubber inlet and scrubber stack, respectively. Detailed test results are given in Appendix A; field and analytical data are provided in Appendix B.

2.2 Particle Size. The particle size distributions at the scrubber inlet and scrubber stack are tabulated in Table 2-4. Based upon the Method 5 particulate emission rates, emission rates and scrubber collection efficiencies using cumulative emissions greater than each particle size range are also presented. Figure 2-1 summarizes for the three particle sizing test sets the scrubber collection efficiencies by particle size range. Figures 2-2, 2-3, and 2-4 present the particle size distributions for particle sizing test sets 2, 5, and 7, respectively.

2.3 Sludge Analysis. The analytical results of sludge samples collected during each of the seven test sets are presented in Table 2-5.

2.4 Particulate Loss-On-Ignition Analysis. Table 2-6 gives the Method 5 particulate loss-on-ignition results.

1.2 Test Participants. Table 1-2 lists the personnel present during the test program.

TABLE 1-2

TEST PARTICIPANTS

Nichols Engineering and Research Corporation	Rick Leuser Test Coordinator
	Charlie Shaw Test Coordinator
	Bob Eastman Test Coordinator
Entropy, Inc.	Neill M. Harman Entropy Project Director
	Steve Terll Sampling Team Leader
	W. Douglas Biggerstaff Engineering Technician
	Robert Williams Engineering Technician

TABLE 2-1

PARTICULATE EMISSIONS SUMMARY

Sludge Incinerator Scrubber

	Test Set 1	Test Set 4	Test Set 6
Sludge Dry Solids, %	21.2	22.2	20.4
Sludge Feed Rate, Tons/Hr			
Wet	6.81	6.25	5.93
Dry	1.44	1.39	1.21
Emission Rate, Lbs/Hr			
Inlet	31.3	41.8	27.6
Stack	3.88	5.21	4.95
Efficiency, %	87.6*	87.5	82.1
Concentration, Stack			
Gr/DSCF	0.0450	0.0593	0.0575
Gr/DSCF @ 12% CO_2	0.0693	0.0837	0.0784
Lb/Dry Ton of Sludge**	2.69	3.75	4.07

* Runs I-2 and O-1 are treated as concurrent runs used to calculate the collection efficiency

** Calculated by dividing the scrubber stack particulate emission rate (lbs/hr) by the dry sludge feed rate (tons/hr)

TABLE 2-2

PARTICULATE TESTS SUMMARY OF RESULTS

Scrubber Inlet

	I-2	I-4	I-5
RUN DATE	10/01/85	10/02/85	10/03/85
TEST TRAIN PARAMETERS:			
VOLUME OF DRY GAS SAMPLED, SCF*	29.362	20.563	15.765
PERCENT ISOKINETIC	103.0	89.9	108.4
FLUE GAS PARAMETERS:			
TEMPERATURE, DEG. F	826	943	915
GAS FLOW RATES SCFM*, DRY	11,021	11,793	10,956
ACFM, WET	38,558	48,236	47,316
METHOD 5 TEST RESULTS:			
CATCH, MILLIGRAMS	629.7	551.4	300.0
GRAINS PER DSCF*	0.3310	0.4138	0.2937
LBS PER HOUR	31.26	41.83	27.58

* 68 Deg. F. - 29.92 in. Hg.

33,56 Inlet

TABLE 2-3

PARTICULATE TESTS SUMMARY OF RESULTS

Scrubber Stack

	0-1	0-4	0-5	
RUN DATE	10/01/85	10/02/85	10/03/85	
TEST TRAIN PARAMETERS:				
VOLUME OF DRY GAS SAMPLED, SCF*	29.552	38.282	37.032	
PERCENT ISOKINETIC	97.8	100.2	102.2	
FLUE GAS PARAMETERS:				
TEMPERATURE, DEG. F	132	139	139	136.7
GAS FLOW RATES SCFM*, DRY	10,061	10,254	10,051	10,122
ACFM, WET	12,515	13,429	13,102	13,015
PERCENT EXCESS AIR	112.4	96.5	89.3	
METHOD 5 TEST RESULTS:				
CATCH, MILLIGRAMS	86.2	147.1	137.9	
GRAINS PER DSCF*	0.0450	0.0593	0.0575	0.[illegible]
LBS PER HOUR	3.88	5.21	4.95	[illegible]

* 68 Deg. F. - 29.92 in. Hg.

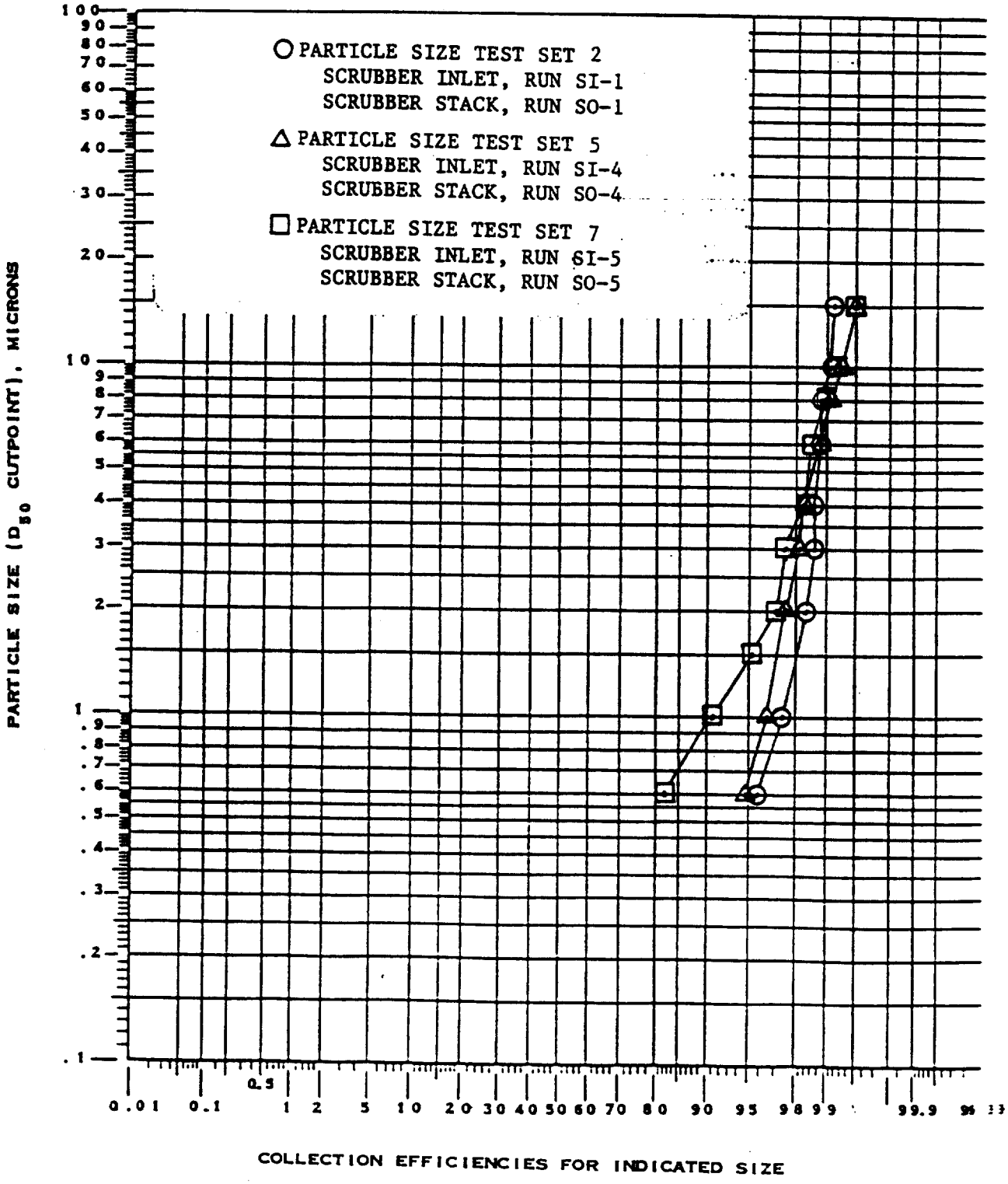


FIGURE 2-1. SLUDGE INCINERATOR SCRUBBER EFFICIENCY VERSUS PARTICLE SIZE DIAMETER

TABLE 2-4

SCRUBBER EFFICIENCY BY PARTICLE DIAMETER

Particle Dia., Microns	Inlet Run SI-1 Cum. % Less Than	Catch, %	Emissions Lbs/Hr*	Cum. > Lb/Hr	Stack Run SO-1 Cum. % Less Than	Catch, %	Emissions Lbs/Hr**	Cum. > Lb/Hr	Collection Efficiency, %
> 15	22.0	78.0	24.4	24.4	95.0	5.0	0.194	0.194	99.2
10	18.5	3.5	1.10	25.5	94.0	1.0	0.039	0.233	99.1
8	18.0	0.5	0.16	25.7	93.0	1.0	0.039	0.272	98.9
6	17.5	0.5	0.16	25.8	92.5	0.5	0.019	0.291	98.9
4	17.0	0.5	0.16	26.0	91.5	1.0	0.039	0.330	98.7
3	16.8	0.2	0.063	26.0	91.0	0.5	0.019	0.349	98.7
2	16.5	0.3	0.094	26.14	89.0	2.0	0.078	0.427	98.4
1	15.2	1.3	0.41	26.55	81.5	7.5	0.291	0.718	97.3
0.6	13.0	2.2	0.69	27.24	70.0	11.5	0.450	1.17	95.7
< 0.6	-	13.0	4.07	31.31	-	70.0	2.72	3.89	87.6

* Based on run I-2 emissions, 31.3 lb/hr

** Based on run O-1 emissions, 3.89 lb/hr

Particle Dia., Microns	Inlet Run SI-4 Cum. % Less Than	Catch, %	Emissions Lbs/Hr*	Cum. > Lb/Hr	Stack Run SO-4 Cum. % Less Than	Catch, %	Emissions Lbs/Hr**	Cum. > Lb/Hr	Collection Efficiency, %
> 15	22.0	78.0	32.6	32.6	97.0	3.0	0.16	0.16	99.5
10	21.0	1.0	0.42	33.0	95.5	1.5	0.078	0.238	99.3
8	19.5	1.5	0.63	33.7	94.0	1.5	0.078	0.316	99.1
6	18.5	1.0	0.42	34.1	92.0	2.0	0.10	0.416	98.8
4	17.8	0.8	0.33	34.4	89.5	2.5	0.13	0.546	98.4
3	17.5	0.3	0.13	34.5	87.5	2.0	0.10	0.646	98.1
2	17.0	0.5	0.21	34.7	84.0	3.5	0.18	0.826	97.6
1	16.5	0.5	0.21	35.0	75.0	9.0	0.47	1.30	96.3
0.6	15.2	1.3	0.54	35.5	65.0	10.0	0.52	1.82	94.9
< 0.6	-	15.2	6.35	41.8	-	65.0	3.39	5.21	87.5

* Based on run I-4 emissions, 41.8 lb/hr

** Based on run O-4 emissions, 5.21 lb/hr

TABLE 2-4

SCRUBBER EFFICIENCY BY PARTICLE DIAMETER

(continued)

Particle Dia., Microns	Inlet Run SI-5 Cum. % Less Than	Inlet Run SI-5 Catch, %	Inlet Run SI-5 Emissions Lbs/Hr*	Inlet Run SI-5 Cum. > Lb/Hr	Stack Run SO-5 Cum. % Less Than	Stack Run SO-5 Catch, %	Stack Run SO-5 Emissions Lbs/Hr**	Stack Run SO-5 Cum. > Lb/Hr	Collection Efficiency, %
> 15	13.8	86.2	23.8	23.8	97.8	2.2	0.11	0.11	99.5
10	13.8	0.0	0.0	23.8	96.2	1.6	0.079	0.189	99.2
8	13.5	0.3	0.083	23.9	95.0	1.2	0.059	0.248	99.0
6	13.0	0.5	0.14	24.0	93.0	2.0	0.099	0.347	98.6
4	12.5	0.5	0.14	24.2	91.0	2.0	0.099	0.446	98.2
3	12.5	0.0	0.0	24.2	88.2	2.8	0.14	0.586	97.6
2	12.0	0.5	0.14	24.3	85.0	3.2	0.16	0.746	96.9
1	10.8	1.2	0.33	24.6	76.0	9.0	0.45	1.20	95.1
0.6	8.0	2.8	0.77	25.4	54.0	22.0	1.09	2.29	91.0
< 0.6	-	8.0	2.21	27.6	-	54.0	2.67	4.95	82.1

* Based on run I-5 emissions, 27.6 lb/hr

** Based on run O-5 emissions, 4.95 lb/hr

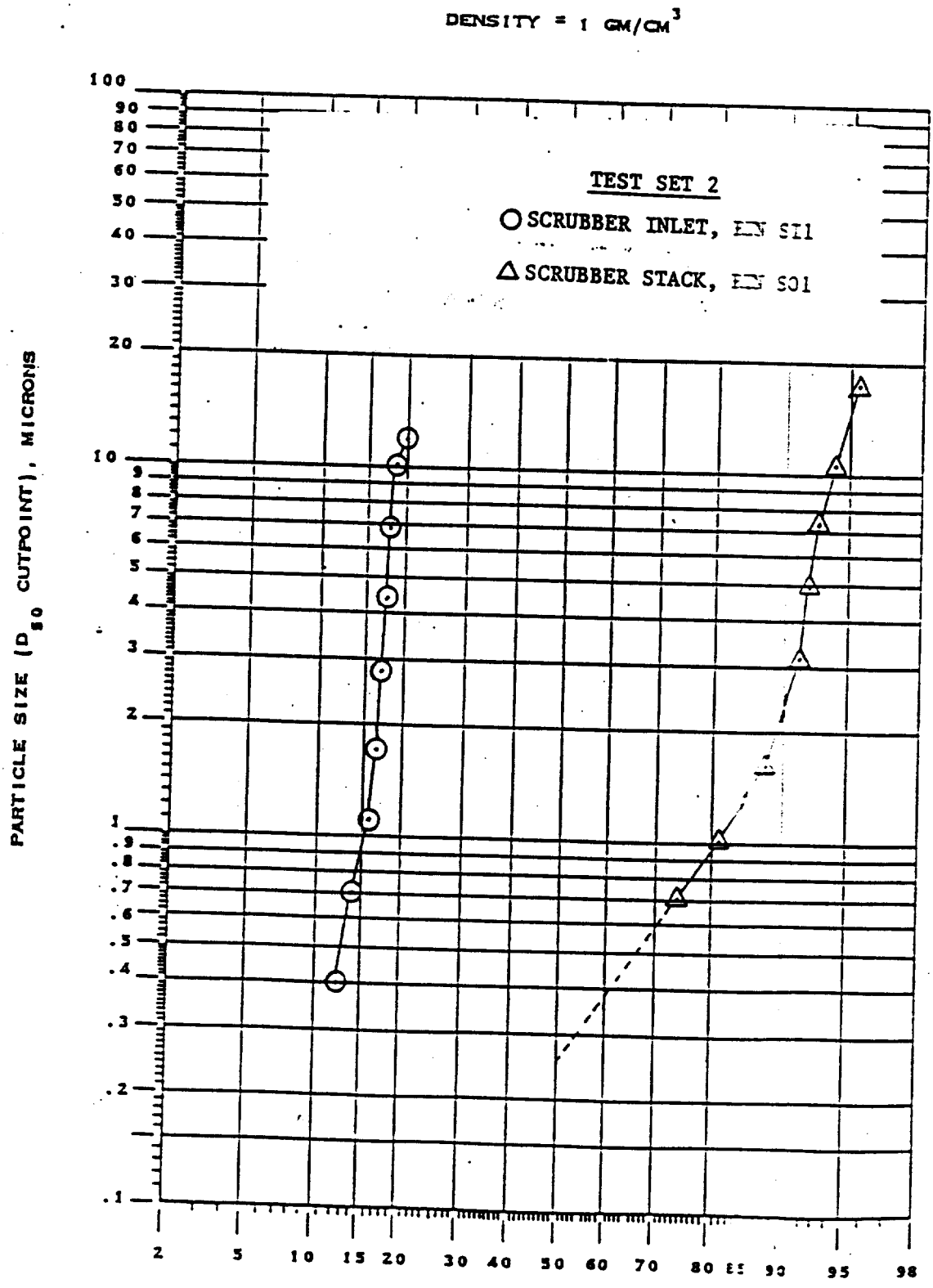


FIGURE 2-2. SLUDGE INCINERATOR PARTICLE SIZE DISTRIBUTION, RUNS SI1 AND SO1

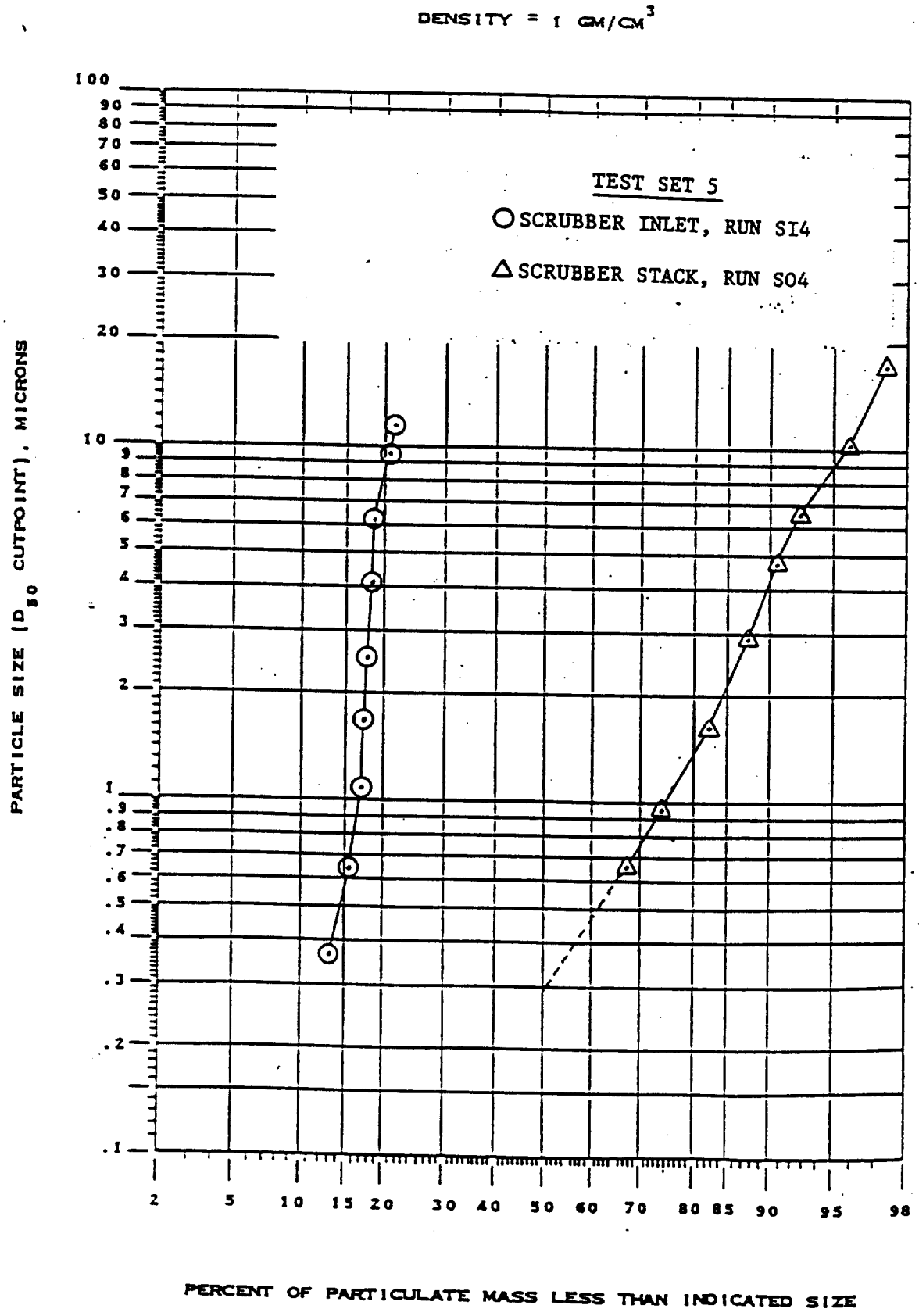


FIGURE 2-3. SLUDGE INCINERATOR PARTICLE SIZE DISTRIBUTION, RUNS SI4 AND SO4

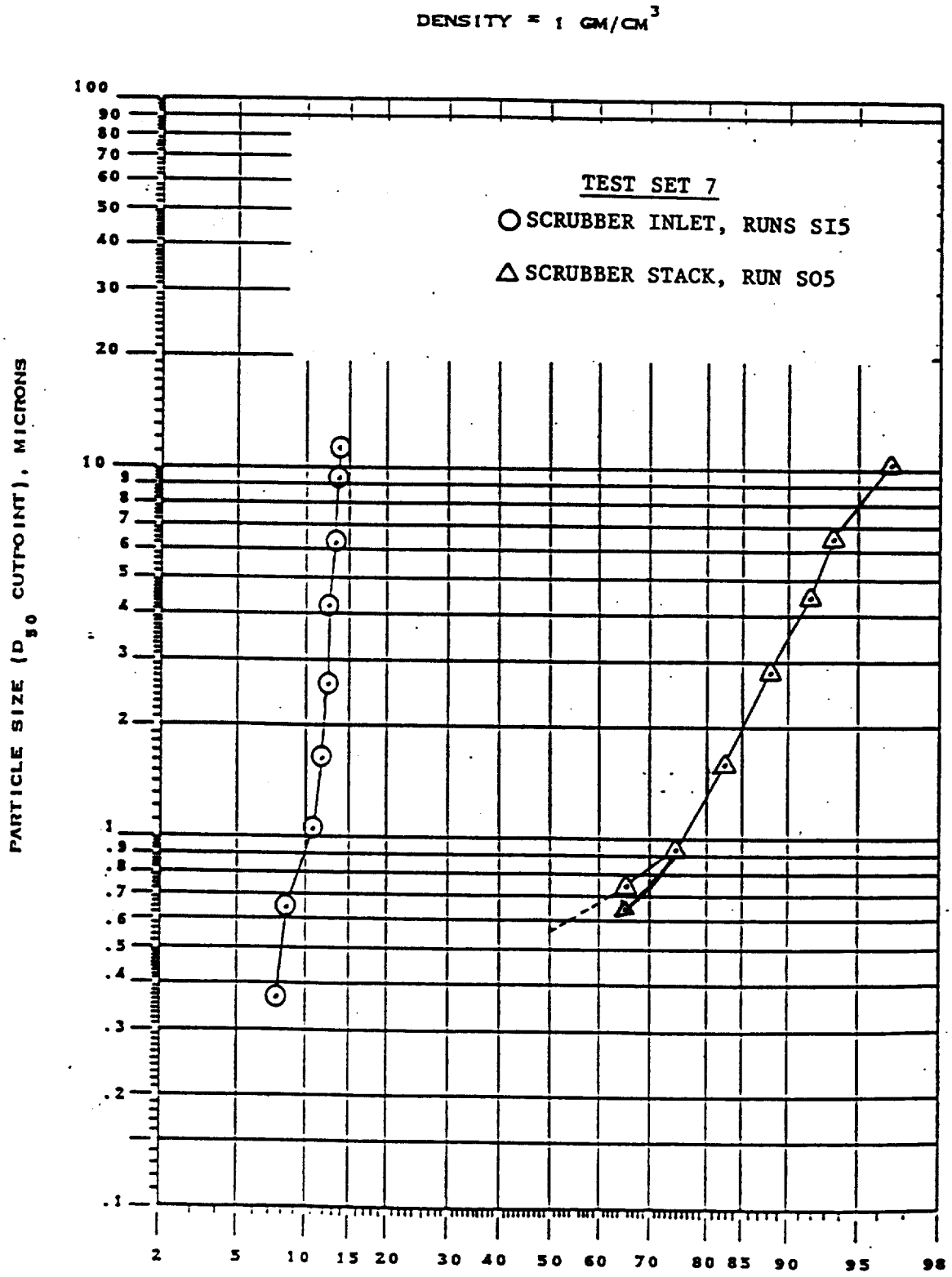


FIGURE 2-4. SLUDGE INCINERATOR PARTICLE SIZE DISTRIBUTION, RUNS SI5 AND SO5

TABLE I-5

SLUDGE ANALYSIS

	Test Sets						
	1	2	3	4	5	6	7
Moisture, Wt.%	78.8	80.9	[illegible]	77.8	79.7	79.6	81.0
Ash, Wt.%, Dry	31.1	31.6	[illegible]	31.3	29.6	28.8	28.7
Silica as Si, Mg/Kg, Dry	4,500	5,300	[illegible]	3,460	5,040	10,800	9,730
Oil & Grease Mg/Kg, as Recvd.	146	112	[illegible]	146	166	186	186

	Composite Sample*
Weight %, Dry	
Hydrogen	3.54
Carbon	43.7
Nitrogen	4.74
Sulfur	1.92
Oxygen	42.9
Heat Content	
Btu/Lb, Dry	7,580

* Composite of all sludge samples taken during each test set

TABLE I-6

METHOD 5 PARTICULATE LOSS-ON-IGNITION ANALYSIS

Weight %

	Test Set			
	1	3	4	6
	I-2	I-3	I-4	I-5
Inlet	12.0	11.3	8.63	12.2
	0-1	0-3	0-4	0-5
Outlet	21.0	21.3	14.4	13.0

PROCESS DESCRIPTION AND OPERATION

3.1 Process Description. The Osborne Waste Water Treatment Plant operates a sludge incinerator system to reduce dewatered sludge to ash by use of combustion. The incinerator consists of seven vertically stacked hearths. Dewatered sludge cake is fed into the top hearth and moved from hearth to hearth by a center shaft with attached arms and teeth which divert the flow of material through the incinerator. The incinerator is equipped with fuel oil-fired burners used to ignite the volatile components of the sludge feed. Combustion air is supplied through auxiliary air fans into hearths 2 through 6. The upper hearths are designed for final drying of the sludge, intermediate hearths are used for combustion, and the bottom hearth is used for ash cooling. Ash is discharged to the ash handling system from a point outside the bottom hearth.

3.2 Source Air Flow. After leaving the incinerator, combustion gases pass through a venturi scrubber system and an induced draft fan before exhausting through the stack to the atmosphere. Air is forced through the center shaft and arms to provide protection from the high temperatures in the incinerator. During normal operation, a portion of the exhaust air from the cooling process (now heated to approximately 400°F) is directed back into the incinerator through warm air return ducts in hearths 6 and 7. The remaining hot air is vented through the scrubber outlet stack. The incinerator system is shown schematically in Figure 3-1.

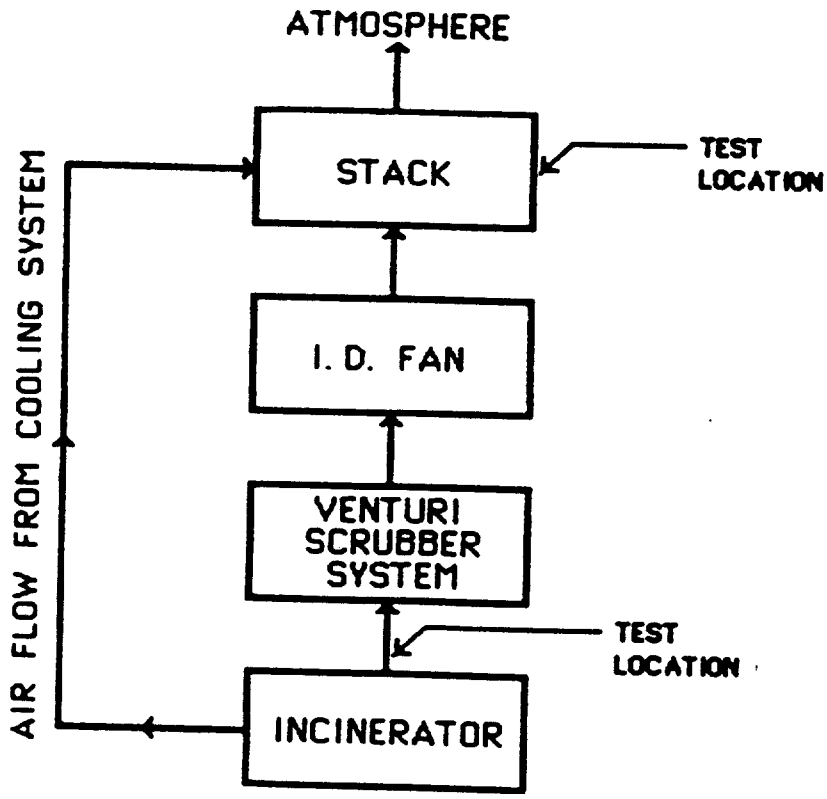


FIGURE 3-1. SLUDGE INCINERATOR AIR FLOW SCHEMATIC SHOWING TEST LOCATIONS

SAMPLING AND ANALYTICAL PROCEDURES

4.1 General. All sampling and analytical procedures were those generally recommended by the United States Environmental Protection Agency and the North Carolina Department of Natural Resources and Community Development. The sampling equipment and procedures are described in Appendix C, which is extracted from 40 CFR (Code of Federal Regulations) Part 60.

4.2 Sampling Points.

4.2.1 Scrubber Stack. The number and location of the sampling points were determined according to procedures outlined in EPA Method 1. As shown in Figure 4-1, the stack cross section was divided into 24 equal areas, with 12 sampling points on each of two traverse axes, labeled A and B.

4.2.2 Scrubber Inlet. Nichols Engineering and Research Corporation and Entropy agreed to divide the inlet duct cross section into 12 equal areas, with four sampling points on each of three traverse axes, labeled A, B, and C. The sampling point configuration is shown in Figure 4-2.

4.3 Flue Gas Velocity and Molecular Weight.

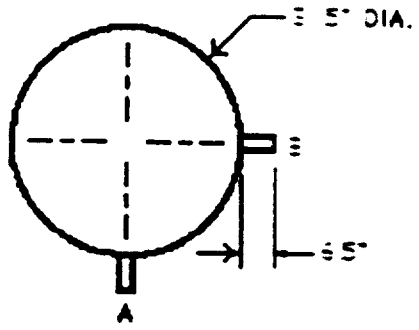
4.3.1 Particulate Tests. Velocity measurements were made according to EPA Method 2. At the scrubber stack, flue gas composition and molecular weight were determined according to EPA Method 3 once during each test day; the Method 3 gas samples were taken during runs 0-1, 0-4, and 0-5 at the scrubber stack. The scrubber inlet particulate test results were calculated using flue gas composition and molecular weight values determined for concurrent runs at the scrubber stack.

4.3.2 Particle Size Tests. Flue gas molecular weight values used to calculate the scrubber inlet and scrubber stack particle size distributions were the values determined at the scrubber stack during particulate testing on the same day.

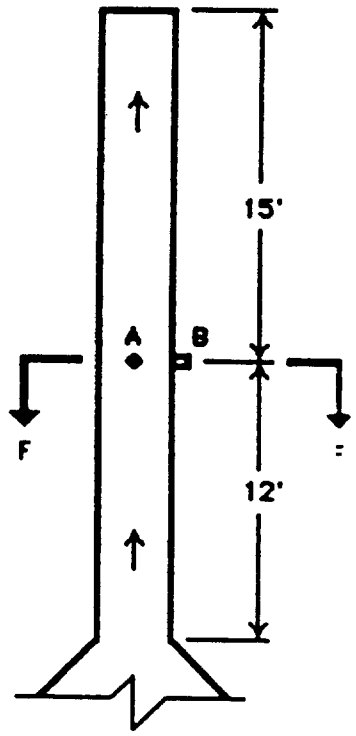
4.4 Particulate Emissions. Particulate emissions were determined according to EPA Method 5.

TRAVERSE POINTS

2 AXIS
12 POINTS/AXIS
24 TOTAL POINTS

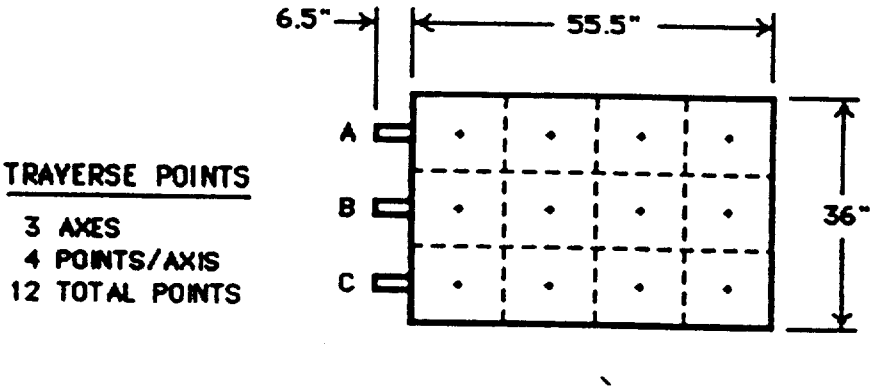


SECTION F-F



ELEVATION VIEW

FIGURE 4-1. SCRUBBER STACK TEST LOCATION



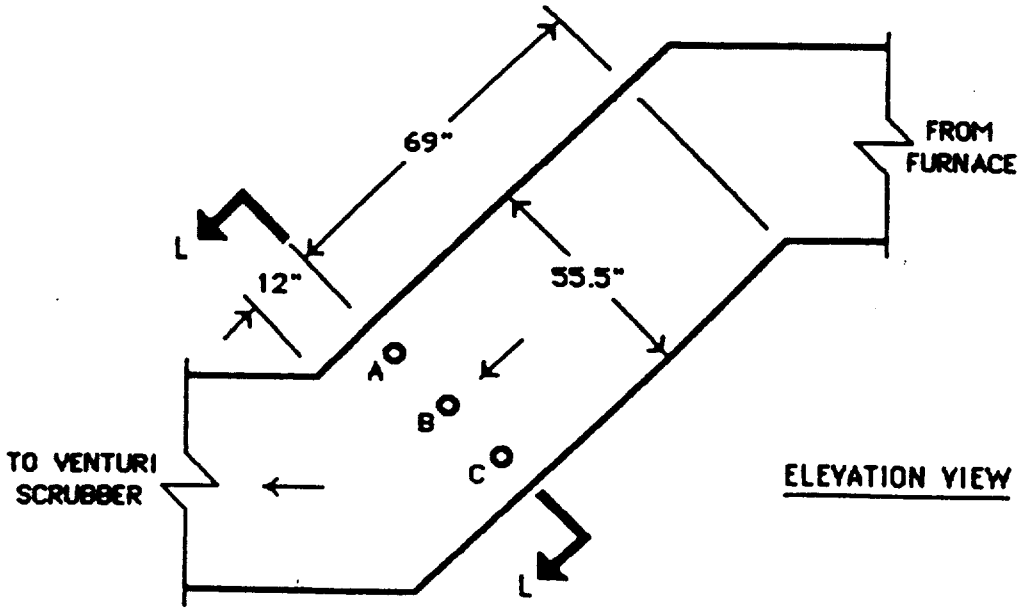


FIGURE 4-2. SCRUBBER INLET TEST LOCATION

4.4.1 Scrubber Stack. Each of the 24 equal areas was sampled for 2.5 minutes, resulting in a net run time of 60 minutes. Run O-1 was only 50 minutes in length due to process outage.

4.4.2 Scrubber Inlet. During Run I-2, each of the 12 equal areas was sampled for four minutes, resulting in a net run time of 48 minutes. During Runs I-4 and I-5, each of the 12 equal areas was sampled for three minutes, resulting in a net run time of 36 minutes.

4.5 Particle Size Distribution. Particle sizing was performed using a cascade impactor attached to a probe on a Method 5 sampling train; the sizing is achieved aerodynamically in the stack. The moisture content value used to calculate the scrubber inlet and scrubber stack particle size distributions was taken from the scrubber stack Method 5 particulate run performed on the same day. Refer to Appendix B for sampling point identities and run times.

4.6 Lab Analyses. All the following laboratory analyses were performed by Industrial & Environmental Analysts, Inc.

4.6.1 Sludge Analysis. The sludge feed samples taken during each test set were subjected to analysis for content of water and dry volatiles, heat content of the dry volatiles, and silica, oil, and grease content in the sludge. A composite of the seven sludge samples was subjected to ultimate analysis.

4.6.2 Method 5 Particulate Loss-On-Ignition. The particulate catch from each Method 5 run was subjected to loss-on-ignition analysis.

4.7 Equipment. All sampling equipment was manufactured by Nutech Corporation or Entropy. Calibration data is provided in Appendix D.

A. TEST RESULTS

1. Particulate Emissions

a. Scrubber Inlet

PARTICULATE FIELD DATA & RESULTS TABULATION

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

RUN	SAMPLING LOCATION	TEST TEAM LEADER
I-2	Scrubber Inlet	Steve Terril
I-4	Scrubber Inlet	Steve Terril
I-5	Scrubber Inlet	Steve Terril

		I-2	I-4	I-5
	RUN DATE	10/01/85	10/02/85	10/03/85
	RUN START TIME	1503	1246	1215
	RUN FINISH TIME	1555	1325	1255
	NET SAMPLING POINTS	12	12	12
Theta	NET RUN TIME, MINUTES	48.00	36.00	36.00
Dia	NOZZLE DIAMETER, INCHES	0.370	0.370	0.306
Cp	PITOT TUBE COEFFICIENT	0.840	0.840	0.840
Y	DRY GAS METER CAL. FACTOR	1.007	1.007	1.007
Pbar	BAROMETRIC PRESSURE, IN. HG.	29.90	29.30	29.30
Delta H	AVG. PRESS. DIFFERENTIAL OF ORIFICE METER, IN. H2O	1.210	1.210	1.701
Vm	VOLUME OF METERED GAS SAMPLE DRY ACTUAL CUBIC FEET	31.142	22.255	18.630
tm	DRY GAS METER TEMP., DEG. F	105	105	90
Vm(std)	VOLUME OF METERED GAS SAMPLE @ DRY STD. COND., DSCF*	29.362	20.563	18.765
Vlc	VOLUME OF WATER CATCH IN IMPINGERS & SIL. GEL.,ML	269.0	219.5	209.5
Vw(std)	VOLUME OF WATER VAPOR, SCF*	12.662	10.332	9.861
%H2O	MOISTURE, PERCENT BY VOLUME	30.1	33.4	33.5
Mfd	DRY MOLE FRACTION	0.699	0.666	0.615

(continued next page)

		I-2	I-4	I-5
%CO2	PERCENT CO2 BY VOLUME, DRY	7.8	8.5	8.8
%O2	PERCENT O2 BY VOLUME, DRY	11.3	10.5	10.1
%CO+N2	PERCENT CO + N2 BY VOLUME	80.9	81.0	81.1
Md	DRY MOLECULAR WT, LB/LB-MOLE	29.70	29.78	29.81
Ms	WET MOLECULAR WT, LB/LB-MOLE	26.17	25.84	25.27
Pg	GAS STATIC PRESS., IN. H2O	-1.1	-1.2	0.5
Ps	ABSOLUTE GAS PRESS., IN. HG.	29.82	29.22	29.34
ts	GAS TEMPERATURE, DEG. F	826	943	915
Delta P	AVG VELOCITY HEAD, IN. H2O	0.2525	0.3503	0.3377
vs	FLUE GAS VELOCITY, FT/SEC	46.3	57.9	56.8
A	STACK/DUCT AREA, SQUARE IN.	1,998.0	1,998.0	1,998.0
Qsd	GAS FLOW RATE, DRY SCFM *	11,021	11,793	10,956
Qaw	GAS FLOW RATE, WET ACFM	38,558	48,236	47,316
%I	PERCENT ISOKINETIC	103.0	89.9	108.4
	METHOD 5 RESULTS:			
mg	CATCH, MILLIGRAMS	629.7	551.4	300.0
gr/DSCF	CONCEN., GRAINS PER DSCF*	0.3310	0.4138	0.2937
Lb/Hr	EMISSION RATE, LBS/HOUR	31.26	41.83	27.58

* 68 Deg. F - 29.92 in. Hg.

A. TEST RESULTS

1. Particulate Emissions

b. Scrubber Stack

PARTICULATE FIELD DATA & RESULTS TABULATION

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

RUN	SAMPLING LOCATION	TEST TEAM LEADER
O-1	Scrubber Stack	Neill M. Harden
O-4	Scrubber Stack	Neill M. Harden
O-5	Scrubber Stack	Neill M. Harden

		O-1	O-4	O-5
	RUN DATE	10/01/85	10/02/85	10/03/85
	RUN START TIME	1130	1228	915
	RUN FINISH TIME	1220	1330	1253
	NET SAMPLING POINTS	24	24	24
Theta	NET RUN TIME, MINUTES	50.00	60.00	60.00
Dia	NOZZLE DIAMETER, INCHES	0.244	0.248	0.244
Cp	PITOT TUBE COEFFICIENT	0.840	0.840	0.840
Y	DRY GAS METER CAL. FACTOR	0.995	0.995	0.995
Pbar	BAROMETRIC PRESSURE, IN. HG.	29.30	29.30	29.30
Delta H	AVG. PRESS. DIFFERENTIAL OF ORIFICE METER, IN. H2O	1.300	1.550	1.400
Vm	VOLUME OF METERED GAS SAMPLE DRY ACTUAL CUBIC FEET	31.800	40.561	38.605
tm	DRY GAS METER TEMP., DEG. F	85	87	78
Vm(std)	VOLUME OF METERED GAS SAMPLE @ DRY STD. COND., DSCF*	29.550	38.282	37.032
Vlc	VOLUME OF WATER CATCH IN IMPINGERS & SIL. GEL.,ML	51.3	105.5	98.0
Vw(std)	VOLUME OF WATER VAPOR, SCF*	2.424	4.966	4.613
%H2O	MOISTURE, PERCENT BY VOLUME	7.5	11.5	11.1
Mfd	DRY MOLE FRACTION	0.924	0.885	0.889

(continued next page)

		O-1	O-4	O-5
%CO2	PERCENT CO2 BY VOLUME, DRY	7.8	8.5	8.8
%O2	PERCENT O2 BY VOLUME, DRY	11.3	10.5	10.1
%CO+N2	PERCENT CO + N2 BY VOLUME	80.9	81.0	81.1
Md	DRY MOLECULAR WT, LB/LB-MOLE	29.70	29.78	29.81
Ms	WET MOLECULAR WT, LB/LB-MOLE	28.81	28.43	28.50
Pg	GAS STATIC PRESS., IN. H2O	-0.1	-0.1	-0.1
Ps	ABSOLUTE GAS PRESS., IN. HG.	29.19	29.29	29.29
ts	GAS TEMPERATURE, DEG. F	132	139	139
Delta P	AVG VELOCITY HEAD, IN. H2O	0.4093	0.4611	0.4401
vs	FLUE GAS VELOCITY, FT/SEC	38.5	41.4	40.4
A	STACK/DUCT AREA, SQUARE IN.	779.3	779.3	779.3
Qsd	GAS FLOW RATE, DRY SCFM *	10,061	10,254	10,051
Qaw	GAS FLOW RATE, WET ACFM	12,515	13,429	13,102
%I	PERCENT ISOKINETIC	97.8	100.2	102.2
%EA	PERCENT EXCESS AIR	112.4	96.5	89.3
	METHOD 5 RESULTS:			
mg	CATCH, MILLIGRAMS	86.2	147.1	137.9
gr/DSCF	CONCEN., GRAINS PER DSCF*	0.0450	0.0593	0.0575
Lb/Hr	EMISSION RATE, LBS/HOUR	3.88	5.21	4.95

* 68 Deg. F - 29.92 in. Hg.

A. TEST RESULTS

2. Particle Size Distributions

a. Scrubber Inlet

PARTICLE SIZING FIELD DATA & RESULTS TABULATION

RUN SI:

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

SAMPLING LOCATION: Scrubber Inlet DATE: 100185

	START-FINISH TIME:	1401-1409		VOLUME METERED, ACF:	2.572
SR)	SAMPLING RATE, ACFM	0.576		NOZZLE DIA., INCHES:	0.248
ST)	SAMPLING TIME, MINUTES:	8.00	Y)	METER CAL. FACTOR:	1.007
PB)	BARO. PRESS., IN.HG.:	29.90	TM)	METER TEMP., DEG F:	104
PSI)	STATIC PRESS., IN. H2O:	-1.00	DH)	DELTA H AVG., IN. H2O:	0.30
TS)	STACK GAS TEMP., DEG F:	216	DEN)	PARTICLE DENSITY, GM/CC:	1.00
PMV)	MOISTURE % BY VOLUME:	32.4	VCF)	VISCOSITY CORR. FACTOR:	1.091
DCF)	DENSITY CORR. FACTOR:	1.000	MD)	MOL WT, DRY LB/LB-MOLE:	29.70
				CONCENT., GR/DSCF:	0.5087

STAGE NO.	- PARTICLE DIAMETER - (microns) FROM GRAPH	AERODYNAMIC	CATCH WEIGHT (mgms)	PERCENT OF TOTAL (%)	CUM. % LESS THAN GIVEN DIA
PreSep	11.19	12.21	64.10	80.2	20.0
PreImp	9.75	10.64	0.70	0.9	19.1
1	6.39	6.97	0.20	0.3	18.8
2	4.08	4.45	0.30	0.4	18.4
3	2.62	2.86	0.90	1.1	17.3
4	1.56	1.70	0.70	0.9	16.4
5	1.03	1.12	0.60	0.8	15.6
6	0.64	0.70	1.10	1.4	14.2
7	0.37	0.40	1.40	1.8	12.4
FILTER	< 0.37	< 0.40	9.90	12.4	
		TOTAL CATCH	79.90		

ENTROPY

PARTICLE SIZING FIELD DATA & RESULTS TABULATION

RUN SI4

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

SAMPLING LOCATION: Scrubber Inlet DATE: 100285

	START-FINISH TIME:	1434-1442		VOLUME METERED, ACF:	3.095
SR)	SAMPLING RATE, ACFM	0.705		NOZZLE DIA., INCHES:	0.248
ST)	SAMPLING TIME, MINUTES:	8.00	Y)	METER CAL. FACTOR:	1.007
PB)	BARO. PRESS., IN.HG.:	29.90	TM)	METER TEMP., DEG F:	103
PSI)	STATIC PRESS., IN. H2O:	1.10	DH)	DELTA H AVG., IN. H2O:	0.49
TS)	STACK GAS TEMP., DEG F:	220	DEN)	PARTICLE DENSITY, GM/CC:	1.00
PMV)	MOISTURE % BY VOLUME:	33.4	VCF)	VISCOSITY CORR. FACTOR:	1.094
DCF)	DENSITY CORR. FACTOR:	1.000	MD)	MOL WT, DRY LB/LB-MOLE:	29.78
				CONCENT., GR/DSCF:	0.4456

STAGE NO.	- PARTICLE DIAMETER - (microns) FROM GRAPH	AERODYNAMIC	CATCH WEIGHT (msms)	PERCENT OF TOTAL (%)	CUM. % LESS THAN GIVEN DIA
PreSep	10.07	11.02	66.30	78.6	21.4
PreImp	8.77	9.59	0.30	0.4	21.0
1	5.75	6.29	1.80	2.1	18.9
2	3.68	4.03	0.60	0.7	18.2
3	2.37	2.59	0.50	0.6	17.6
4	1.41	1.54	0.30	0.4	17.2
5	0.93	1.02	0.20	0.2	17.0
6	0.58	0.63	1.30	1.5	15.5
7	0.33	0.36	1.70	2.0	13.5
FILTER	< 0.33	< 0.36	11.40	13.5	
		TOTAL CATCH	84.40		

ENTROPY

PARTICLE SIZING FIELD DATA & RESULTS TABULATION

RUN SI5

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

SAMPLING LOCATION: Scrubber Inlet DATE: 100385

	START-FINISH TIME:	1321-1329		VOLUME METERED, ACF:	2.751
SR)	SAMPLING RATE, ACFM	0.693		NOZZLE DIA., INCHES:	0.248
ST)	SAMPLING TIME, MINUTES:	8.00	Y)	METER CAL. FACTOR:	1.007
PB)	BARO. PRESS., IN.HG.:	29.30	TM)	METER TEMP., DEG F:	94
PSI)	STATIC PRESS., IN. H2O:	-0.53	DH)	DELTA H AVG., IN. H2O:	0.33
TS)	STACK GAS TEMP., DEG F:	220	DEN)	PARTICLE DENSITY, GM/CC:	1.00
PMV)	MOISTURE % BY VOLUME:	38.5	VCF)	VISCOSITY CORR. FACTOR:	1.094
DCF)	DENSITY CORR. FACTOR:	1.000	MD)	MOL WT, DRY LB/LB-MOLE:	29.81
				CONCENT., GR/DSCF:	0.5531

STAGE NO.	- PARTICLE DIAMETER - (microns) FROM GRAPH	AERODYNAMIC	CATCH WEIGHT (mgms)	PERCENT OF TOTAL (%)	CUM. % LESS THAN GIVEN DIA
PreSep	10.16	11.12	79.40	85.7	14.5
PreImp	8.85	9.68	0.00	0.0	14.5
1	5.80	6.35	0.70	0.8	13.7
2	3.71	4.06	0.50	0.5	13.2
3	2.39	2.61	0.70	0.8	12.4
4	1.42	1.55	0.80	0.9	11.5
5	0.94	1.03	1.30	1.4	10.1
6	0.58	0.63	1.10	1.2	8.9
7	0.34	0.37	1.00	1.1	7.8
FILTER	< 0.34	< 0.37	7.20	7.8	

TOTAL CATCH 92.70

ENTROPY

A. TEST RESULTS

2. Particle Size Distributions

b. Scrubber Stack

PARTICLE SIZING FIELD DATA & RESULTS TABULATION

RUN SO1

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

SAMPLING LOCATION: Scrubber Stack DATE: 100185

	START-FINISH TIME:	1345-1500		VOLUME METERED, ACF:	22.975
SR)	SAMPLING RATE, ACFM	0.348		NOZZLE DIA., INCHES:	0.168
ST)	SAMPLING TIME, MINUTES:	75.00	Y)	METER CAL. FACTOR:	0.998
PB)	BARO. PRESS., IN.HG.:	29.20	TM)	METER TEMP., DEG F:	102
PSI)	STATIC PRESS., IN. H2O:	-0.10	DH)	DELTA H AVG., IN. H2O:	0.28
TS)	STACK GAS TEMP., DEG F:	129	DEN)	PARTICLE DENSITY, GM/CC:	1.00
PMV)	MOISTURE % BY VOLUME:	7.8	VCF)	VISCOSITY CORR. FACTOR:	1.039
DCF)	DENSITY CORR. FACTOR:	1.000	MD)	MOL WT, DRY LB/LB-MOLE:	29.70
				CONCENT., GR/DSCF:	0.0479

STAGE NO.	PARTICLE DIAMETER (microns) FROM GRAPH	PARTICLE DIAMETER (microns) AERODYNAMIC	CATCH WEIGHT (mgms)	PERCENT OF TOTAL (%)	CUM. % LESS THAN GIVEN DIA
0	16.46	17.10	3.20	4.9	95.2
1	10.24	10.64	0.51	0.8	94.4
2	6.90	7.17	0.91	1.4	93.0
3	4.76	4.95	0.41	0.6	92.4
4	3.00	3.12	0.51	0.8	91.6
5	1.55	1.61	2.31	3.5	88.1
6	0.96	1.00	4.81	7.4	80.7
7	0.66	0.69	4.11	6.3	74.4
FILTER	< 0.66	< 0.69	48.61	74.4	
		TOTAL CATCH	65.31		

ENTROPY

PARTICLE SIZING FIELD DATA & RESULTS TABULATION

RUN S04

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

SAMPLING LOCATION: Scrubber Stack DATE: 100285

	START-FINISH TIME:	1410-1515		VOLUME METERED, ACF:	20.618
SR)	SAMPLING RATE, ACFM	0.391		NOZZLE DIA., INCHES:	0.168
ST)	SAMPLING TIME, MINUTES:	65.00	Y)	METER CAL. FACTOR:	0.998
PB)	BARO. PRESS., IN.HG.:	29.30	TM)	METER TEMP., DEG F:	88
PSI)	STATIC PRESS., IN. H2O:	-0.10	DH)	DELTA H AVG., IN. H2O:	0.30
TS)	STACK GAS TEMP., DEG F:	139	DEN)	PARTICLE DENSITY, GM/CC:	1.00
PMV)	MOISTURE % BY VOLUME:	11.5	VCF)	VISCOSITY CORR. FACTOR:	1.045
DCF)	DENSITY CORR. FACTOR:	1.000	MD)	MOL WT, DRY LB/LB-MOLE:	29.78
				CONCENT., GR/DSCF:	0.0543

STAGE NO.	- PARTICLE DIAMETER (microns) - FROM GRAPH	AERODYNAMIC	CATCH WEIGHT (mgms)	PERCENT OF TOTAL (%)	CUM. % LESS THAN GIVEN DIA
0	15.51	16.21	1.60	2.3	97.5
1	9.66	10.09	1.40	2.0	95.5
2	6.50	6.79	1.80	2.6	92.9
3	4.49	4.69	1.60	2.3	90.6
4	2.83	2.96	2.10	3.1	87.5
5	1.46	1.53	3.30	4.8	82.7
6	0.90	0.94	5.30	7.8	74.9
7	0.62	0.65	4.60	6.7	68.2
FILTER	< 0.62	< 0.65	46.60	68.2	
		TOTAL CATCH	68.30		

ENTROPY

PARTICLE SIZING FIELD DATA & RESULTS TABULATION

RUN S05

PLANT: Osborne Waste Water Treatment Plant, Greensboro, North Carolina

SAMPLING LOCATION: Scrubber Stack DATE: 100385

	START-FINISH TIME:	1320-1410		VOLUME METERED, ACF:	16.092
SR)	SAMPLING RATE, ACFM	0.395		NOZZLE DIA., INCHES:	0.168
ST)	SAMPLING TIME, MINUTES:	50.00	Y)	METER CAL. FACTOR:	0.995
PB)	BARO. PRESS.,IN.HG.:	29.30	TM)	METER TEMP., DEG F:	84
PSI)	STATIC PRESS., IN. H2O:	-0.10	DH)	DELTA H AVG., IN. H2O:	0.31
TS)	STACK GAS TEMP., DEG F:	136	DEN)	PARTICLE DENSITY, GM/CC:	1.00
PMV)	MOISTURE % BY VOLUME:	11.1	VCF)	VISCOSITY CORR. FACTOR:	1.043
DCF)	DENSITY CORR. FACTOR:	1.000	MD)	MOL WT, DRY LB/LB-MOLE:	29.81
				CONCENT., GR/DSCF:	0.0568

STAGE NO.	- PARTICLE DIAMETER - (microns) FROM GRAPH	AERODYNAMIC	CATCH WEIGHT (mgms)	PERCENT OF TOTAL (%)	CUM. % LESS THAN GIVEN DIA
0	15.43	16.09	1.00	1.8	98.2
1	9.61	10.02	1.00	1.8	96.4
2	6.46	6.74	1.30	2.3	94.1
3	4.47	4.66	1.40	2.5	91.6
4	2.81	2.93	1.70	3.0	88.6
5	1.45	1.51	3.40	6.1	82.5
6	0.89	0.93	4.70	8.4	74.1
7	0.62	0.65	4.10	7.3	66.8
FILTER	< 0.62	< 0.65	37.40	66.8	
		TOTAL CATCH	56.00		

ENTROPY

A. TEST RESULTS

3. Example Calculations

EXAMPLE PARTICULATE TEST CALCULATIONS NO. I-2

Scrubber Inlet

VOLUME OF DRY GAS SAMPLED AT STANDARD CONDITIONS

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

$$Vm(std) = 17.64 * 1.007 * 31.142 * \frac{(29.90 + 1.210/13.6)}{(460 + 105)} = 29.362\ DS$$

VOLUME OF WATER VAPOR AT STANDARD CONDITIONS

$$Vw(std) = 0.04707 * Vlc$$

$$Vw(std) = 0.04707 * 269.0 = 12.662\ SCF$$

PERCENT MOISTURE, BY VOLUME, AS MEASURED IN FLUE GAS

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

$$\%H2O = \frac{12.662}{12.662 + 29.362} * 100 = 30.1\ \%$$

DRY MOLE FRACTION OF FLUE GAS

$$Mfd = 1 - \%H2O/100$$

$$Mfd = 1 - 30.1/100 = 0.699$$

DRY MOLECULAR WEIGHT OF FLUE GAS

$$Md = \%CO2 * 0.44 + \%O2 * 0.32 + \%CO+\%N2 * 0.28$$

$$Md = 7.8*0.44 + 11.3*0.32 + 80.9*0.28 = 29.70\ LB/LB-MOLE$$

WET MOLECULAR WEIGHT OF FLUE GAS

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

$$Ms = 29.70 * 0.699 + (0.18 * 30.1) = 26.17\ LB/LB-MOLE$$

ABSOLUTE FLUE GAS PRESSURE

$$Ps = Pbar + Ps / 13.6$$

$$Ps = 29.90 + (-1.0 / 13.6) = 29.82 \text{ IN. HG.}$$

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

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

$$vs = 85.49 * 0.840 * SQRT\left[\frac{0.2525 * (460 + 826)}{29.82 * 26.17}\right] = 46.3 \text{ FT/SEC}$$

DRY VOLUMETRIC FLUE GAS FLOW RATE @ STANDARD CONDITIONS

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

$$Qsd = \frac{60}{144} * 0.699 * 46.3 * 1,998.0 * \frac{528}{826 + 460} * \frac{29.82}{29.92}$$

$$Qsd = 11,021 \text{ SCFM}$$

WET VOLUMETRIC STACK GAS FLOW RATE @ FLUE GAS CONDITIONS

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

$$Qaw = 60 / 144 * 46.3 * 1,998.0 = 38,558 \text{ ACFM}$$

PERCENT ISOKINETIC OF SAMPLING RATE

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

$$\%I = \frac{29.92}{528} * \frac{100}{60} * \frac{(826 + 460) * 29.362}{29.82 * 46.3 * 0.699 * 48.00 * 0.0007467}$$

$$\%I = 103.0 \%$$

GRAINS PER DRY STANDARD CUBIC FOOT

$$gr/DSCF = \frac{7000}{453.592} * \frac{mgs}{Vm(std)}$$

$$gr/DSCF = \frac{7000}{453.592} * \frac{629.7}{29.362} = 0.3310 \ gr/DSCF$$

POUNDS PER HOUR

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

$$Lb/Hr = 60/7000 * 0.3310 * 11,021 = 31.26 \ LB/HR$$

B. FIELD AND ANALYTICAL DATA

1. Particulate Emissions

a. Scrubber Inlet

Preliminary Field Data

PLANT NAME Nichols (OSBORNE WATER Treatment)

LOCATION GREENSboro N.C.

SAMPLING LOCATION Incinerator Furnace outlet (Scrubber Inlet)

DUCT DEPTH FROM INSIDE FAR WALL TO OUTSIDE OF PORT 62"

NIPPLE LENGTH 6 1/2"

DEPTH OF DUCT 55 1/2

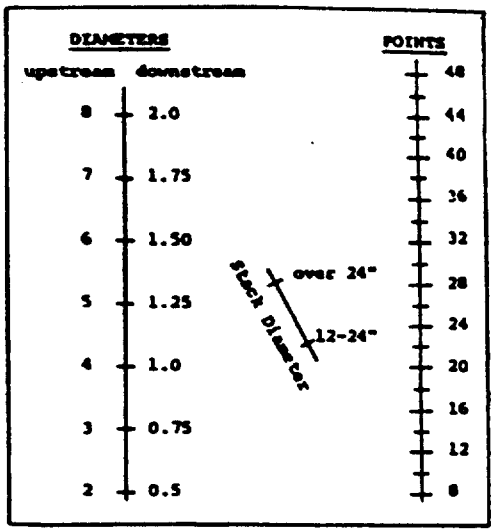
WIDTH (RECTANGULAR DUCT) 36

EQUIVALENT DIAMETER:

$$D_E = \frac{2 \times \text{DEPTH} \times \text{WIDTH}}{\text{DEPTH} + \text{WIDTH}} = \frac{2(55\frac{1}{2})(36)}{(55\frac{1}{2} + 36)} = 43.67$$

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE:	UPSTREAM	DOWNSTREAM
FEET	5.5	1
STACK DIAMETERS	1.5	<1

STACK AREA= $55\frac{1}{2}" \times 36" = 1998$ IN^2



LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.4	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		95.4	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7			89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8			96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9				91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10				97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11					93.3	85.4	78.0	70.4	61.2	39.3	32.3
12					97.9	90.1	83.1	76.4	69.4	60.7	39.8
13						94.3	87.5	81.2	75.0	68.5	60.2
14						98.2	91.5	85.4	79.6	73.8	67.7
15							95.1	89.1	83.5	78.2	72.8
16							98.4	92.5	87.1	82.0	77.0
17								95.6	90.3	85.4	80.6
18								98.6	93.3	88.4	83.9
19									96.1	91.3	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.8
24											98.9

LOCATION OF TRAVERSE POINTS IN RECTANGULAR STACKS

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

Point	% OF DIAMETER	DISTANCE FROM INSIDE WALL	DISTANCE FROM OUTSIDE OF PORT
1	12.5	6.93	13 3/16
2	37.5	20.8	27.0
3	62.5	34.6	41.0
4	87.5	48.5	51.5
5			
6			
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ENTROPY ENVIRONMENTALISTS, INC.

PARTICULATE FIELD DATA

I-4

COMPANY NAME NICHOLS (OSBORNE WATER TREATMENT) RUN NUMBER ~~I-5~~
ADDRESS GREENSBORO NC. TIME START 12:46
SAMPLING LOCATION FURNACE OUTLET (Scrubber Inlet) TIME FINISH 13:25
DATE 10/2/85 TEAM LEADER ST TECHNICIANS DWB
BAROMETRIC PRESSURE, IN. HG 29.3 STATIC PRESSURE, IN. H_2O -1.15
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 17
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.000 0.000

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- = ORSAT SAMPLING SYSTEM
- = TEDLAR BAG
- ✓ THERMOCOUPLE @ 883 °F

IDENTIFICATION NUMBERS

REAGENT BOX 217 NOZZLE 110 DIAMETER .370
METER BOX N-12 T/C READOUT 007
UMBILICAL U-20 T/C PROBE 7-10
SAMPLE BOX 25 ORSAT PUMP —
PROBE 7-2 TEDLAR BAG —

FILTER #	TARE
E 3622	.4967

NOMOGRAPH SET-UP NOMOGRAPH # ST

$\Delta H_@$ 1.64 C FACTOR 0.56
METER TEMP 100 STACK TEMP 800 / 900
% MOISTURE 32 REF. ΔP 0.39 / 0.42
K = 4.7179487

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
A-1	0/0	906.148	0.30	1.41	1.41	94	3	250	63	883	
2	3	908.103	0.33	1.56	1.56	94	6	250	63	903	
3	6	910.125	0.40	1.89	1.89	96	10	250	64	926	
4	9	912.205	0.42	1.98	1.60	100	14	250	65	929	
B-1	12/0	914.378	0.36	1.70	1.70	100	14	250	65	948	
2	3	916.409	0.45	2.12	1.30	108	15	250	65	960	Nomo
3	6	918.408	0.45	1.97	1.10	112	15	250	65	966	K=4.3805
4	9	920.402	0.42	1.84	1.00	114	15	250	65	968	
C-1	24/0	922.258	0.15	0.66	0.66	112	13	250	65	948	
2	3	923.810	0.32	1.40	0.80	111	15	250	65	951	
3	6	925.495	0.35	1.53	0.75	111	15	250	65	960	
4	9	926.905	0.32	1.40	0.75	110	15	250	65	969	
	35/Off	928.703									
			7.021/12								
			.5919								

22.255 .3503 / 1.21 105 943

V_M $(\sqrt{\Delta P})^2$ ΔH T_M T_S

ENTROPY

I-3

COMPANY NAME Nichol's — RUN NUMBER 2
ADDRESS GREENSBORO NC — TIME START 16:32
SAMPLING LOCATION Furnace OUTLET (Scrubber Inlet) — TIME FINISH 17:20
DATE 10/1/85 — TEAM LEADER ST — TECHNICIANS DWB
BAROMETRIC PRESSURE, IN. HG 29.9 — STATIC PRESSURE, IN. H_2O -1.00
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 17
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.000 0.000

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- = ORSAT SAMPLING SYSTEM
- = TEDLAR BAG
- ✓ THERMOCOUPLE @ 800 °F

IDENTIFICATION NUMBERS

REAGENT BOX 237 — NOZZLE 110 — DIAMETER .320
METER BOX N-12 — T/C READOUT 007
UMBILICAL 4-20 — T/C PROBE 7-10
SAMPLE BOX 25 — ORSAT PUMP —
PROBE 7-2 — TEDLAR BAG —

FILTER #	TARE
E3541	.4864

NOMOGRAPH SET-UP — NOMOGRAPH # ST

$\Delta H_@$ 1.64 — C FACTOR 0.56
METER TEMP 100 — STACK TEMP 800
% MOISTURE 32 — REF. ΔP 0.39
K = 4.7179487

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
A-1	0/0	880.005	0.27	1.27	1.27	104	3	250	64	829	
2	4	882.407	0.25	1.18	1.18	103	4	250	64	792	
3	8	884.705	0.30	1.41	1.41	103	6	250	64	776	
4	12	887.305	0.33	1.56	1.56	104	8	250	65	785	
B-1	16/0	889.832	0.24	1.13	1.13	106	8	250	65	869	
2	4	892.104	0.35	1.65	1.65	107	8	250	65	888	
3	8	894.104	0.33	1.56	1.56	107	14	250	65	908	
4	12	896.765	0.27	1.27	1.27	109	14	250	65	842	
C-1	32/0	899.385	0.10	0.47	0.47	109	8	250	65	800	
2	4	900.904	0.20	0.92	0.92	110	15	250	65	781	
3	8	903.107	0.22	1.01	1.01	110	15	250	65	818	17:17 Down
4	12/12	904.935									

V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M	T_S
24.93	.2546	1.22	107	821

ENTROPY

PARTICULATE FIELD DATA

I-2

COMPANY NAME Nichols — RUN NUMBER 1
ADDRESS GREENSBORO NC. — TIME START 3:503
SAMPLING LOCATION FURNACE OUTLET (Scrubber Inlet) — TIME FINISH 15:55
DATE 10/1/85 — TEAM LEADER ST — TECHNICIANS DWB
BAROMETRIC PRESSURE, IN. HG 29.9 — STATIC PRESSURE, IN. H_2O -1.05
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 12
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.000 0.000

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- — ORSAT SAMPLING SYSTEM
- — TEDLAR BAG
- ✓ THERMOCOUPLE @ 800 °F

IDENTIFICATION NUMBERS

REAGENT BOX 237 — NOZZLE 110 — DIAMETER .370
METER BOX N-12 — T/C READOUT 007
UMBILICAL 4-20 — T/C PROBE T-10
SAMPLE BOX 25 — ORSAT PUMP
PROBE T-2 — TEDLAR BAG —

FILTER #	TARE
E2978	4652

NOMOGRAPH SET-UP — NOMOGRAPH # ST

$\Delta H_@$ 1.64 — C FACTOR ~~0.84~~ 0.56
METER TEMP 100 — STACK TEMP 800
% MOISTURE 32 — REF. ΔP ~~0.84~~ 0.39
K=4.3179487

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
A 1	0/0	848.764	0.24	1.13	1.13	102	5	250	63	868	
2	4	851.325	0.26	1.23	1.23	102	8	250	63	834	
3	8	853.708	0.30	1.41	1.41	102	7	250	63	801	
4	12	857.502	0.30	1.41	1.41	103	7	250	63	800	
B-1	16/0	860.075	0.25	1.18	1.18	104	10	250	63	809	
2	4	863.010	0.35	1.65	1.65	106	7	250	63	856	
3	8	865.808	0.33	1.56	1.56	106	8	250	63	892	
4	12	868.606	0.27	1.27	1.27	108	7	250	63	861	
C-1	32/0	871.278	0.11	0.52	0.52	108	4	250	65	791	
2	4	873.010	0.23	1.08	1.08	107	7	250	65	777	
3	8	875.205	0.24	1.13	1.13	108	7	250	65	774	
4	12	877.710	0.20	0.92	0.92	106	7	250	65	831	
	48/FF	879.906									

31.142	.2525	1.21	105	826
V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M	T_S

ENTROPY

PARTICULATE FIELD DATA

I-5

COMPANY NAME Nichols (Osborne Water Treatment) RUN NUMBER I
ADDRESS GREENSBORO NC TIME START 12:5
SAMPLING LOCATION FURNACE OUTPUT (Scrubber Inlet) TIME FINISH 12:55
DATE 10/3/85 TEAM LEADER ST TECHNICIANS DWB
BAROMETRIC PRESSURE, IN. HG 29.3 STATIC PRESSURE, IN. H_2O -.52
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 15
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.007 0.000

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- — ORSAT SAMPLING SYSTEM
- — TEDLAR BAG
- ✓ THERMOCOUPLE @ 892 °F

IDENTIFICATION NUMBERS

REAGENT BOX 237 NOZZLE 109 DIAMETER .30-
METER BOX N-12 T/C READOUT 007
UMBILICAL 420 T/C PROBE 7-10
SAMPLE BOX 25 ORSAT PUMP —
PROBE 7-2 TEDLAR BAG —

FILTER # E3635 **TARE** .4827

NOMOGRAPH SET-UP NOMOGRAPH # 5

$\Delta H_@$ 1.64 C FACTOR 0.56
METER TEMP 100 STACK TEMP 800 / 900
% MOISTURE 32 REF. ΔP .80 .90
K= 2.3

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP °F	LK. CHECK READINGS
A-1	0/0	935.311	0.31	0.71	0.71	86	2	260	62	890	NOMO
2	3	937.003	0.32	0.65	0.65	86	2	260	63	900	K=2.0444
3	6	938.300	0.37	0.76	0.76	86	3	260	63	900	
4	9	939.710	0.39	0.80	0.80	87	5	260	63	890	
B-1	12	941.162	0.35	0.71	0.71	89	5	260	63	900	
2	3	942.610	0.40	0.82	0.82	90	7	260	65	900	
3	6	944.002	0.42	0.86	0.86	91	9	260	65	900	
4	9	945.406	0.38	0.78	0.78	92	9	260	65	920	
C-1	12	946.818	0.23	0.47	0.47	94	7	260	65	900	
2	3	948.005	0.30	0.61	0.61	94	10	260	65	930	
3	6	949.289	0.34	0.69	0.69	94	11	260	65	930	
4	9	950.710	0.27	0.55	0.55	96	13	260	65	900	
	36/42	951.941									

16.63 .3377 .701 90 9:5

V_M $(\sqrt{\Delta P})^2$ ΔH T_M T_S

ENTROPY

PARTICULATE SAMPLING LABORATORY RESULTS

Plant Name NICHOLS — EEI Ref. # 2988

Sampling Location SCRUBBER INLET

Date Received 10/3 — Date Analyzed 10/9 — Reagent Box(es) 0237

Run Number	I2	I3	
Run Date	10/1	10/	10/

SUMMARY OF PARTICULATE ANALYSES

Sum of Particulate, mg.	1095.3	92[illegible].5	
Total Filter Tare mg.	465.2	486.4	
Blank Residue, mg.	(275 ml) 0.4	(275 ml) 0.4	ml)
TOTAL PARTICULATE CATCH, mg.	629.7	434.7	

ANALYSIS OF MOISTURE CATCH

Reagent 1 (H_2O):			
Final Weight, g.	440.0	4[illegible]0.0	
Tared Weight, g.	200.0	200.0	200.0
Water Catch, g.	240.0	240.0	
Reagent 2 ( ):			
Final Weight, g.	—	—	—
Tared Weight, g.	—	—	—
Water Catch, g.	—	—	—
CONDENSED WATER, g.	240.0	240.0	
Silica Gel:			
Final Weight, g.	229.0	224.5	
Tared Weight, g.	200.0	200.0	200.0
ABSORBED WATER, g.	29.0	24.5	
TOTAL WATER COLLECTED, g.	269.0	264.5	

Blank Beaker # 12

Final wt. mg. 49974.2

Tare wt. mg. 49739

Residue, mg. 0.3

Volume, ml. 200

Concen., mg/ml. .0015

--- Legend ---

✓ = Final Weight

L = Loose Particulate

F = Filter D = Dish

R = Rinse P = Pan

Notes and Comments

LABORATORY SAMPLE WEIGHT CALCULATIONS

Plant Name NICHOLS Ref. # 2988

Run Number	1 + 12	2 [illegible]	
Run Date	10/1	10	10/
Sample ID/Container #	FER-268	FER-[illegible]	FER-
	144.1390	147.[illegible]	
	144.1387	147.[illegible]	
	144.1383	147.[illegible]	
	144.1399	147.[illegible]	
Tare Wt., g.	143.0430	146.[illegible]	
SAMPLE WT., g.	1.0953	[illegible]	
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			

PARTICULATE SAMPLING LABORATORY RESULTS

Plant Name NICHOLS EEI Ref. # 2988

Sampling Location SCRUBBER INLET

Date Received 10/3 Date Analyzed 10/8 Reagent Box(es) _____

Run Number	IS	IC	___
Run Date	10/3	___	___

SUMMARY OF PARTICULATE ANALYSES

Sum of Particulate, mg.	783.2	848.4	___
Total Filter Tare mg.	482.7	296.7	___
Blank Residue, mg. (325 ml)	0.5	(200 ml) 0.3	(___ ml) ___
TOTAL PARTICULATE CATCH, mg.	300.0	551.4	

ANALYSIS OF MOISTURE CATCH

Reagent 1 (H_2O):			
Final Weight, g.	398.0	394.0	___
Tared Weight, g.	200.0	200.0	___
Water Catch, g.	198.0	94.0	___
Reagent 2 ( ):			
Final Weight, g.	—	—	___
Tared Weight, g.	—	—	___
Water Catch, g.	—	—	___
CONDENSED WATER, g.	198.0	94.0	___
Silica Gel:			
Final Weight, g.	211.5	225.5	___
Tared Weight, g.	200.0	200.0	___
ABSORBED WATER, g.	11.5	25.5	___
TOTAL WATER COLLECTED, g.	209.5	219.5	

Blank Beaker # 12

Final wt. mg. 49974.2

Tare wt. mg. 49973.9

Residue, mg. 0.3

Volume, ml. 200

Concen., mg/ml. .0015

--- Legend ---

✓ = Final Weight

L = Loose Particulate

F = Filter D = Dish

R = Rinse P = Pan

Notes and Comments

LABORATORY SAMPLE WEIGHT CALCULATIONS

Plant Name NICHOLS EEI Ref. # 2988

Run Number	I5	I-	
Run Date	10/3		
Sample ID/Container #	FOR-312	FOR-2-	
Tare Wt., g.	134.1299 134.1299 133.3467	128.4059 128.4055 128.4069 128.5000 127.35	
SAMPLE WT., g.	.7832	1.0654	
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			

CUSTODY SHEET FOR REAGENT BOX # 0237

Date of Makeup 9/26 Initials VP Locked? ✓

Individual Tare of Reagent: 200 mls. of H_2O

Individual Tare of Reagent: _____ mls. of _____

Individual Silica Gel Tare Weight: 200 gms.

PLANT NAME Nicholas (Greensboro)

SAMPLING LOCATION Furnace outlet

Run Number	Date Used	Initials	Locked?	Date Cleanup	% S. Gel Spent	Initials	Locked?
I2 ✗	10/1/85	ST	yes	10/1/85		ST	yes
I3 ✗	10/1/85	ST	yes	10/1/85		ST	yes

Received in Lab Date 10/2 Initials MG Locked? ✓

Zero & Span Balance Initials MG

Sampling Method: M-5

Filter #	Tare Weight (mgms)	Used on Test
E2970	.4652	✗ I2
E3541	.4864	✗ I3

Remarks:

ENTROPY ENVIRONMENTALISTS, INC.

CUSTODY SHEET FOR REAGENT BOX # 0217

Date of Makeup 9/26 Initials VP Locked? ✓

Individual Tare of Reagent: 200 mls. of H_2O

Individual Tare of Reagent: _____ mls. of _____

Individual Silica Gel Tare Weight 200 gms.

PLANT NAME NICHOLS

SAMPLING LOCATION FURNACE OUTLET

Run Number	Date Used	Initials	Locked?	Date Cleanup	% S. Gel Spent	Initials	Locked?
I-5 ~~I-6~~	10-3	MH	✓	10-3	80	MH	✓
I-55	10-3	MH	✓	10-3	50	MH	✓

Received in Lab Date _____ Initials IS Locked? ✓

Zero & Span Balance Initials VP

Sampling Method: M-5

Filter #	Tare Weight (mgms)	Used on Test
E 3635	.4827	I-5

Remarks:

ENTROPY ENVIRONMENTALISTS, INC.

B. FIELD AND ANALYTICAL DATA

1. Particulate Emissions

b. Scrubber Stack

Preliminary Field Data

PLANT NAME Nichols

LOCATION Greensboro

SAMPLING LOCATION outlet STACK

DUCT DEPTH
FROM INSIDE FAR WALL TO OUTSIDE OF PORT 38"

NIPPLE LENGTH 6 1/2

DEPTH OF DUCT 31 1/2

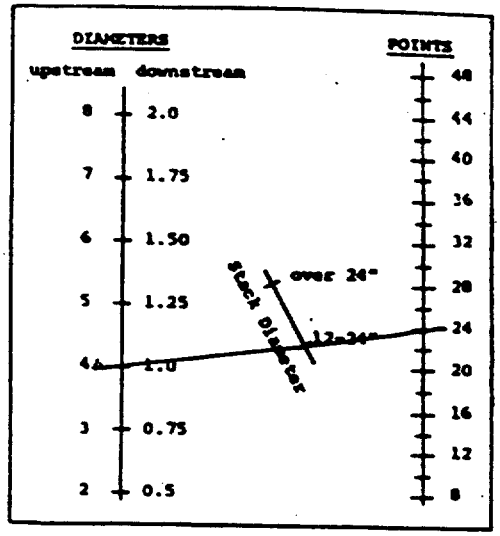
WIDTH (RECTANGULAR DUCT) ____

EQUIVALENT DIAMETER:

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

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE:	UPSTREAM	DOWNSTREAM
FEET	12"	15
STACK DIAMETERS	4	5

STACK AREA = $(31.5/2)^2 \pi$ = 779.3 IN^2



Point	% OF DIAMETER	DISTANCE FROM INSIDE WALL	DISTANCE FROM OUTSIDE OF PORT
1	2.1	1"	7 1/2
2	6.7	2 1/4"	8 3/4
3	11.8	3 3/4	10 1/4
4	17.8	5 1/2	12
5	25.0	7 7/8	14 3/8
6	35.6	11 1/4	17 3/4
7	64.4	20 1/4	26 3/4
8	75.0	23 1/4	30
9	82.3	25 7/8	32 3/8
10	88.2	27 7/8	34 5/8
11	93.3	29 3/4	36 1/4
12	97.9	30 1/8	37 3/8
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5		85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6		95.6	80.6	65.8	35.6	26.9	22.5	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	78.5	70.4	61.2	39.3	32.3
12					97.9	90.1	83.1	76.4	69.4	60.7	39.8
13						94.3	87.5	81.2	75.0	68.5	60.2
14						98.2	91.5	85.4	79.6	73.8	67.7
15							95.1	89.1	83.5	78.2	72.8
16							98.4	92.5	87.1	82.0	77.0
17								95.6	90.3	85.4	80.6
18								98.6	93.3	88.4	83.9
19									96.1	91.3	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.8
24											98.9

LOCATION OF TRAVERSE POINTS IN RECTANGULAR STACKS

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

ENTROPY ENVIRONMENTALISTS, INC.

Plant Name NICHOLS

Sampling Location SCRUBBER STACK Fuel Type _____

Run and/or Sample No. 30-1 Leak Test? ✓ Date 10-1-85 Operator MH

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
1130	1230	7.8	19.0	—	11.2	—	
TO		7.7	19.0		11.3		
1222							
	Avg.	7.8		Avg.	11.3		80.9

Run and/or Sample No. 0-4 Leak Test? ✓ Date 10-2 Operator MH

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
1228	1345	8.5	19.0	—	10.5	—	
TO		8.5	19.0		10.5		
1330							
	Avg.	8.5		Avg.	10.5		81.0

Run and/or Sample No. 0-5 Leak Test? ✓ Date 10-3 Operator MH

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
~~0915~~ 1040	1315	8.7	18.8	—	10.1	—	
TO		8.8	18.8		10.0		
1253							
	Avg.	8.8		Avg.	10.1		81.1

PARTICULATE FIELD DATA

0-1

COMPANY NAME NICHOLS
ADDRESS GREENSBORO, NC
SAMPLING LOCATION SCRUBBER STACK
DATE 10-1-85 TEAM LEADER MH TECHNICIANS RW
BAROMETRIC PRESSURE, IN. HG 29.2 STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 6(F)
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.010 0.012

RUN NUMBER 5
TIME START 1100
TIME FINISH 1222

Restarted (1130)

EQUIPMENT CHECKS

- V PITOTS, PRE-TEST
- V PITOTS, POST-TEST
- V ORSAT SAMPLING SYSTEM
- V TEDLAR BAG
- V THERMOCOUPLE @ ____ °F

IDENTIFICATION NUMBERS

REAGENT BOX 277 NOZZLE 304 DIAMETER .244
METER BOX N8 T/C READOUT
UMBILICAL T/C PROBE —
SAMPLE BOX ORSAT PUMP 05
PROBE 4-3 TEDLAR BAG 20

FILTER #	TARE
E3856	.4846

NOMOGRAPH SET-UP

NOMOGRAPH # MH
$\Delta H_@$ 1.61 C FACTOR .90
METER TEMP 95 STACK TEMP 140
% MOISTURE 6 REF. ΔP .60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
A 1	0	269.670	.35	1.10	1.10	84	1	250	60	132	
2	2½	271.22	.47	1.46	1.46	86	1	250	60	133	
3	5	272.78	.48	1.48	1.48	88	1	250	60	133	
4	7½	274.49	.49	1.50	1.50	89	2	250	60	133	
5	10	276.20	.45	1.40	1.40	91	2	250	60	133	
6	12½	277.90	.40	1.23	1.23	92	2	250	60	133	
7	15	279.51	.37	1.14	1.14	93	2	250	60	133	
8	17½	280.88	.34	1.04	1.04	94	2	250	60	133	
9	20	282.37	.35	1.10	1.10	95	2	250	60	133	
10	22½	283.92	.37	1.14	1.14	97	2	250	60	133	
11	25	285.36	.39	1.25	1.25	97	2	250	60	133	
12	27½	287.00	.42	1.37	1.37	99	3	250	60	128	
B 1	30/0	288.627	.40	1.23	1.23	99	3	250	60	129	
2	2½	290.25	.43	1.38	1.38	101	3	250	60	129	
3	5	291.66	.45	1.40	1.40	101	4	250	60	129	
4	7½	293.48	.42	1.37	1.37	101	4	250	60	130	
5	10	295.08	.40	1.23	1.23	101	5	250	60	130	
6	12½	296.74	.36	1.20	1.20	100	5	250	60	130	
7	15	298.22	.43	1.38	1.38	100	6	250	60	135	
8	17½	300.15	.44	1.48	1.48	101	6	250	60	145	
9	50/20	301.472									
10	~~22½~~										
11	~~25~~	process down									
12	~~27½~~										
	65/OFF										

31.802 / .4093 (= $(\sqrt{\Delta P})^2$) 1.30 (= ΔH) 95 (= T_M) 132 (= T_S)

V_M

ENTROPY

PARTICULATE FIELD DATA

0-3

COMPANY NAME NICHOLS — RUN NUMBER 4
ADDRESS GREENSBORO, NC — TIME START 1628
SAMPLING LOCATION SCRUBBER STACK — TIME FINISH 1701
DATE 10-1-86 — TEAM LEADER MH — TECHNICIANS RW
BAROMETRIC PRESSURE, IN. HG 29.2 — STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.003

EQUIPMENT CHECKS

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

IDENTIFICATION NUMBERS

REAGENT BOX 277 — NOZZLE 304 — DIAMETER .244
METER BOX N8 — T/C READOUT ___
UMBILICAL ___ — T/C PROBE ___
SAMPLE BOX ___ — ORSAT PUMP on
PROBE 4- — TEDLAR BAG ___

FILTER #	TARE
E3706	.5004

NOMOGRAPH SET-UP — NOMOGRAPH # MH

$\Delta H_@$ 1.61 — C FACTOR .90
METER TEMP 95 — STACK TEMP 130
% MOISTURE 4 — REF. ΔP .60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
B 1	0	324.838	.36	1.00	1.10	87	1	250	60	135	
2	2½	326.30	.40	1.23	1.23	88	2	250	60	136	
3	5	327.78	.43	1.32	1.32	88	2	250	60	135	
4	7½	329.35	.46	1.41	1.41	89	2	250	60	134	
5	10	331.00	.46	1.41	1.41	90	3	250	60	133	
6	12½	332.74	.44	1.35	1.35	90	3	250	60	132	
7	15	334.41	.46	1.41	1.41	90	3	250	60	132	
8	17½	336.06	.50	1.52	1.53	91	4	250	60	133	
9	20	337.84	.50	1.53	1.53	92	5	250	60	134	
10	22½	339.59	.50	1.53	1.53	93	5	250	60	134	
11	25	341.27	.45	1.38	1.38	93	5	250	60	144	
12	27½	342.69	.42	1.29	1.29	94	6	250	60	144	
A 1	30	344.532	.38	1.20	1.20	94	6	250	60	144	
2	32½	345.780									
3	35										
4	37½										
5	40										
6	42½										
7	45										
8	47½										
9	50										
10	52½										
11	55										
12	57½										
	60										

20.942 — .4420 — 1.36 — 91 — 136

V_M — $(\sqrt{\Delta P})^2$ — ΔH — T_M — T_S

ENTROPY

PARTICULATE FIELD DATA

0.4

COMPANY NAME NICHOLS — RUN NUMBER ~~0-5~~
ADDRESS GREENSBORO, NC — TIME START 1228
SAMPLING LOCATION SCRUBBER STACK — TIME FINISH 1330
DATE 10-2-85 — TEAM LEADER MH — TECHNICIANS RW
BAROMETRIC PRESSURE, IN. HG 29.3 — STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 10(F)
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.005 0.004

TOTAL MOISTURE 10.5.5

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- ✓ ORSAT SAMPLING SYSTEM
- ✓ TEDLAR BAG
- ✓ THERMOCOUPLE @ 132 °F

IDENTIFICATION NUMBERS

REAGENT BOX 218 — NOZZLE 304 — DIAMETER .248
METER BOX ~~AAC1~~ — T/C READOUT 01
UMBILICAL — T/C PROBE 5-11
SAMPLE BOX — ORSAT PUMP 05
PROBE 4-3 — TEDLAR BAG 20

FILTER # / TARE

E3632 / .4888

NOMOGRAPH SET-UP — NOMOGRAPH # MH

$\Delta H_@$ ~~1.76~~ — C FACTOR ~~.96~~ .97
METER TEMP ~~95~~ 90 — STACK TEMP 130
% MOISTURE 6 — REF. ΔP ~~.59~~ .55

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
A 1	0	346.367	.48	1.52	1.52	82	2	250	60	132	
2	2½	347.88	.49	1.57	1.57	83	2	250	60	132	
3	5	349.49	.53	1.70	1.70	82	3	250	60	132	— NOMO
4	7½	351.02	.53	1.80	1.80	82	4	250	60	133	
5	10	353.27	.53	1.80	1.80	82	4	250	60	133	
6	12½	354.86	.51	1.73	1.73	82	4	250	60	134	
7	15	356.86	.44	1.50	1.50	83	4	250	60	135	
8	17½	358.42	.43	1.45	1.45	84	4	250	60	136	
9	20	360.06	.42	1.42	1.42	85	5	250	60	136	
10	22½	361.69	.41	1.38	1.38	86	5	250	60	137	
11	25	363.75	.42	1.42	1.42	86	6	250	60	138	
12	27½	364.88	.41	1.38	1.38	86	6	250	60	139	
B 1	30	366.530	.40	1.35	1.35	87	6	250	60	138	
2	2½	368.28	.40	1.35	1.35	87	6	250	60	138	
3	5	369.63	.44	1.50	1.50	88	7	250	60	138	
4	7½	371.45	.45	1.52	1.52	89	7	250	60	141	
5	10	373.12	.45	1.52	1.52	89	7	250	60	145	
6	12½	374.71	.44	1.50	1.50	90	8	250	60	145	
7	15	376.37	.44	1.50	1.50	90	8	250	60	145	
8	17½	378.00	.47	1.60	1.60	92	9	250	60	144	
9	20	379.83	.50	1.70	1.70	93	9	250	60	144	
10	22½	381.69	.50	1.70	1.70	93	9	250	60	144	
11	25	383.31	.50	1.70	1.70	95	10	250	60	144	
12	27½	385.027	.50	1.70	1.70	96	10	250	60	143	
	60/OFF	386.628	16.2974								

(.4791)

40.561 ✓ — .4611 ✓ — 1.55 ✓ — 87 ✓ — 138.6 — 139 ✓

V_M — $(\sqrt{\Delta P})^2$ — ΔH — T_M — T_S

ENTROPY

PARTICULATE FIELD DATA

0-5

COMPANY NAME NICHOLS
ADDRESS GREENSBORO, NC
SAMPLING LOCATION SCRUBBED STACK
DATE 10-3-85 TEAM LEADER MH TECHNICIANS RW
BAROMETRIC PRESSURE, IN. HG 29.3 STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 10(E)
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.006 0.017

RUN NUMBER ~~A-6~~
TIME START 0915
TIME FINISH 1253

Restarted (1040)

EQUIPMENT CHECKS

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

IDENTIFICATION NUMBERS

REAGENT BOX ___ NOZZLE 304 DIAMETER .244
METER BOX RAC 1 T/C READOUT 01
UMBILICAL ___ T/C PROBE 5-11
SAMPLE BOX ___ ORSAT PUMP 05
PROBE 4-3 TEDLAR BAG 20

FILTER # **TARE**

NOMOGRAPH SET-UP NOMOGRAPH # MH

$\Delta H_@$ 1.76 C FACTOR .95
METER TEMP 80 STACK TEMP 140
% MOISTURE 7 REF. ΔP .58

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
B 1	0	408.697	.39 (.42)	1.2 (1.33)	1.33	71	2	250	60	138	
2	2½	410.340	.46	1.45	1.45	71	2	250	60	134	
3	5	411.84	.47	1.49	1.49	74	2	250	60	134	
4	7½	413.57	.50	1.58	1.58	75	2	250	60	139	
5	10	415.03	.50	1.58	1.58	79	4	250	60	140	
6	12½	416.68	.47	1.49	1.49	82	4	250	60	141	
7	15	418.25	.46	1.42	1.42	81	5	250	60	141	
8	17½	419.97	.46	1.45	1.45	79	5	250	60	141	
9	20	421.54	.47	1.49	1.49	80	5	250	60	141	
10	22½	423.15	.45	1.42	1.42	81	6	250	60	142	
11	26	424.90	.48	1.52	1.52	80	6	250	60	142	STOP TEST 1107
12	27½	426.85	.47	1.49	1.49	73	6	250	60	139	
A 1	30/0	428.308	.42	1.33	1.33	74	6	250	60	132	STARTED 1220
2	2½	429.30	.44	1.40	1.40	75	6	250	60	132	
3	5	431.55	.44	1.40	1.40	76	7	250	60	135	
4	7½	433.16	.46	1.45	1.45	77	8	250	60	139	
5	10	434.87	.45	1.42	1.42	77	8	250	60	140	
6	12½	436.53	.43	1.36	1.36	78	8	250	60	140	
7	15	438.02	.40	1.27	1.27	78	8	250	60	140	
8	17½	439.58	.37	1.17	1.17	80	8	250	60	140	
9	20	441.03	.40	1.27	1.27	81	8	250	60	141	
10	22½	442.66	.39	1.24	1.24	82	8	250	60	141	
11	25	444.15	.40	1.27	1.27	82	8	250	60	141	
12	27½	445.68	.38	1.21	1.21	83	8	250	60	141	
	60/OFF	447.202									

38.605 / .4401 / 1.40 / 78 / 139

V_M / $(\sqrt{\Delta P})^2$ / ΔH / T_M / T_S

PARTICULATE SAMPLING LABORATORY RESULTS

Plant Name NICHOLS EEI Ref. # 2988

Sampling Location SCRUBBER STACK

Date Received 10/2 Date Analyzed 10/8 Reagent Box(es) 0277

Run Number	0-1 3	0-3 4	
Run Date	10/1	10/1	

SUMMARY OF PARTICULATE ANALYSES

Sum of Particulate, mg.	571.0	565.7	
Total Filter Tare mg.	484.6	500.4	
Blank Residue, mg.	(100 ml) 0.2	(100 ml) 0.2	(ml)
TOTAL PARTICULATE CATCH, mg.	86.2	65.1	

ANALYSIS OF MOISTURE CATCH

Reagent 1 (H_2O):			
Final Weight, g.	236.0	223.0	
Tared Weight, g.	200.0	200.0	200.0
Water Catch, g.	36.0	23.0	
Reagent 2 ( ):			
Final Weight, g.	–	–	–
Tared Weight, g.	–	–	–
Water Catch, g.	–	–	–
CONDENSED WATER, g.	36.0	23.0	
Silica Gel:			
Final Weight, g.	215.5	213.0	
Tared Weight, g.	200.0	200.0	200.0
ABSORBED WATER, g.	15.5	13.0	
TOTAL WATER COLLECTED, g.	51.5	36.0	

Blank Beaker # 12

Final wt. mg. 49974.2

Tare wt. mg. 49973.9

Residue, mg. 0.3

Volume, ml. 200

Concen., mg/ml. .0015

--- Legend ---

✓ = Final Weight

L = Loose Particulate

F = Filter D = Dish

R = Rinse P = Pan

Notes and Comments

LABORATORY SAMPLE WEIGHT CALCULATIONS

Plant Name NICHOLS EEI Ref. # 2988

Run Number	3 0-1	4 0-3	
Run Date	10/1	10/1	
Sample ID/Container #	F8R-271	F8R-272	
	141.7241	148.0609	
	141.7233	148.0604	
	141.7257	148.0613	
	141.7268	148.0625	
Tare Wt., g.	141.1523	147.4947	
SAMPLE WT., g.	.5710	.5657	
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			

PARTICULATE SAMPLING LABORATORY RESULTS

Plant Name NICHOLS EEI Ref. # 2988

Sampling Location SCRUBBER STACK

Date Received 10/3 Date Analyzed 10/9 Reagent Box(es) ____

Run Number	0-5	0-4	___
Run Date	10/3	___	___

SUMMARY OF PARTICULATE ANALYSES

Sum of Particulate, mg.	632.3	636.1	___
Total Filter Tare mg.	494.2	488.8	___
Blank Residue, mg.	(140 ml) 0.2	(150 ml) 0.2	(ml) ___
TOTAL PARTICULATE CATCH, mg.	137.9	147.1	

ANALYSIS OF MOISTURE CATCH

Reagent 1 (H_2O):			
Final Weight, g.	282.0	285.0	___
Tared Weight, g.	200.0	200.0	___
Water Catch, g.	82.0	85.0	___
Reagent 2 ( ):			
Final Weight, g.	—	—	___
Tared Weight, g.	—	—	___
Water Catch, g.	—	—	___
CONDENSED WATER, g.	82.0	85.0	___
Silica Gel:			
Final Weight, g.	216.0	220.5	___
Tared Weight, g.	200.0	200.0	___
ABSORBED WATER, g.	16.0	20.5	___
TOTAL WATER COLLECTED, g.	98.0	105.5	

Blank Beaker # 12

Final wt. mg. 49974.2

Tare wt. mg. 49973.9

Residue, mg. 0.3

Volume, ml. 200

Concen., mg/ml. .0015

--- Legend ---

✓ = Final Weight

L = Loose Particulate

F = Filter D = Dish

R = Rinse P = Pan

Notes and Comments

LABORATORY SAMPLE WEIGHT CALCULATIONS

Plant Name NICHOLS EEI Ref. # 298E

Run Number	0-5	0-4	
Run Date	10/3		
Sample ID/Container #	F8R-315	F8R-298	
Tare Wt., g.	133.3115 ✓133.3111 132.6788	146.4589 ✓146.4586 146.4591 146.4643 145.8225	
SAMPLE WT., g.	.6323	.6361	
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			
Sample ID/Container #			
Tare Wt., g.			
SAMPLE WT., g.			

CUSTODY SHEET FOR REAGENT BOX # 0277

Date of Makeup 9/25/85 Initials MLD Locked ✓

Individual Tare of Reagent: 200 mls. of H_2O

Individual Tare of Reagent: _____ mls. of _____

Individual Silica Gel Tare Weight 200 gms.

PLANT NAME NICHOLS

SAMPLING LOCATION SCRUBBER STACK

Run Number	Date Used	Initials	Locked?	Date Cleanup	% S. Gel Spent	Initials	Locked?
0-1 ~~B~~	10-1-85	MK	✓	10-1	50	MK	✓
0-3 ~~A~~	10-1	MK	✓				

Received in Lab Date 10/2 Initials MEG Locked? ✓

Zero & Span Balance Initials MEC

Sampling Method: M-5

Filter #	Tare Weight (mgms	Used on Test
E3856	.484	30-1
E3706	.500	~~A~~ 0-3

Remarks:

ENTROPY ENVIRONMENTALISTS, INC.

CUSTODY SHEET FOR REAGENT BOX # 0218

Date of Makeup 9/13 Initials MCJ Locked? ✓

Individual Tare of Reagent: 200 mls. of H_2O

Individual Tare of Reagent: _____ mls. of _____

Individual Silica Gel Tare Weight 200 gms.

PLANT NAME NICHOLS

SAMPLING LOCATION SCRUBBER STACK

Run Number	Date Used	Initials	Locked?	Date Cleanup	% S. Gel Spent	Initials	Locked
0-4 ~~1-5~~	10-2	MK	✓	10-2	70	MK	✓
0-5 ~~0-6~~	10-3	MK	✓	10-3	~~70~~	MK	✓

Received in Lab Date 10/2 Initials MCJ Locked? ✓

Zero & Span Balance Initials VC

Sampling Method: _____

Filter #	Tare Weight (mgms)	Used on Test
E 3632	.4888	0-4
E 3631	.4942	0-5

Remarks:

ENTROPY ENVIRONMENTALISTS, INC.

B. FIELD AND ANALYTICAL DATA

2. Particle Size Distribution

a. Scrubber Inlet

PARTICULATE FIELD DATA

SI-1

COMPANY NAME Nichols — RUN NUMBER ST
ADDRESS GREENSBORO, NC. — TIME START 14:05 — 14C
SAMPLING LOCATION FURNACE OUTLET (Scrubber Inlet) — TIME FINISH 14:09
DATE 10/1/85 — TEAM LEADER ST — TECHNICIANS DWB
BAROMETRIC PRESSURE, IN. HG 29.9 — STATIC PRESSURE, IN. H_2O -1.00
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 5
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.000 0.000

EQUIPMENT CHECKS

- = PITOTS, PRE-TEST
- = PITOTS, POST-TEST
- = ORSAT SAMPLING SYSTEM
- = TEDLAR BAG
- ___ THERMOCOUPLE @ ___ °F

IDENTIFICATION NUMBERS

REAGENT BOX 237 — NOZZLE 104 — DIAMETER .248
METER BOX N2 — T/C READOUT 007
UMBILICAL U-30 — T/C PROBE SP-132
SAMPLE BOX 22 — ORSAT PUMP —
PROBE — TEDLAR BAG —

FILTER # / **TARE**

457-463 / 323

NOMOGRAPH SET-UP — NOMOGRAPH # ST

$\Delta H_@$ 1.64 — C FACTOR 0.66
METER TEMP 100 — STACK TEMP 800
% MOISTURE 25 — REF. ΔP 1.68
K = 1.0952391

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	Hill Heat EXIT TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHEX READING
B-3	0/0	845.558	.27	.30	.30	104	1	213	65	765	
4	4	846.808	.27	.30	.30	104	1	219	65	769	
	B/FF	848.110									

2.552 — .27 — .30 — 104 — 216 — 767

V_M — $(\sqrt{\Delta P})^2$ — ΔH — T_M — T_S

ENTROPY

PARTICULATE FIELD DATA

SI-4

COMPANY NAME Nichols
ADDRESS GREENSBORO NC
SAMPLING LOCATION FURNACE Outlet (Cyclone Inlet)
DATE 10-2-85 TEAM LEADER [illegible] TECHNICIANS PWB
BAROMETRIC PRESSURE, IN. HG 29.9 STATIC PRESSURE, IN. H_2O +1.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 [illegible]
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.00 [illegible]

RUN NUMBER SI-2
TIME START 14:34
TIME FINISH 14:42

EQUIPMENT CHECKS

- ✓ PITOTS, PRE-TEST
- ✓ PITOTS, POST-TEST
- — ORSAT SAMPLING SYSTEM
- — TEDLAR BAG
- ✓ THERMOCOUPLE @ 950 °F

IDENTIFICATION NUMBERS

REAGENT BOX 237 NOZZLE 104 DIAMETER .248
METER BOX N-12 T/C READOUT 007
UMBILICAL U-20 T/C PROBE SP-132
SAMPLE BOX 2 ORSAT PUMP —
PROBE [illegible] TEDLAR BAG —

FILTER #	TARE
450	SF 322
456	

NOMOGRAPH SET-UP NOMOGRAPH # ST

$\Delta H_@$ 1.64 C FACTOR 0.66
METER TEMP 100 STACK TEMP 800
% MOISTURE 25 REF. ΔP 1.68
K=1.0 52381

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	[illegible] BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
3	0	928.983	.45	.49	0.49	≈	1		65	950	
4	4	930.602	.45	.49	0.49	≈	1		65	963	
	8/end	932 078									

V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M		T_S
3.095	.45	.49	103	—	957

ENTROPY

PARTICULATE FIELD DATA

SI-5

COMPANY NAME Nichols (Osborne Water Treatment) RUN NUMBER I-5
ADDRESS Greensboro NC TIME START 13:21
SAMPLING LOCATION FURNACE OUTLET (Scrubber Inlet) TIME FINISH 13:29
DATE 10-3-96 TEAM LEADER ST TECHNICIANS DWB
BAROMETRIC PRESSURE, IN. HG 29.3 STATIC PRESSURE, IN. H_2O -0.53
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 5
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.000 0.000

EQUIPMENT CHECKS

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

IDENTIFICATION NUMBERS

REAGENT BOX ____ NOZZLE 104 DIAMETER .248
METER BOX N12 T/C READOUT 007
UMBILICAL 4-20 T/C PROBE ____
SAMPLE BOX 22 ORSAT PUMP —
PROBE ____ TEDLAR BAG —

FILTER # **TARE**

415 ____
42[illegible] ____
SF-31[illegible] ____

NOMOGRAPH SET-UP NOMOGRAPH # ST

$\Delta H_@$ 1.64 C FACTOR 0.66
METER TEMP 1 STACK TEMP 300
% MOISTURE 32 REF. ΔP 1.68
K=1.0 S52381

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	[illegible] TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
C	0	952.702	.30	.33	.33	94	1	—	60	935	
	4	953.625	.30	.33	.33	94	1	—	60	930	
	8/OFF	954.954									

2.751 / V_M .30 / $(\sqrt{\Delta P})^2$ .33 / ΔH 94 / T_M 933 / T_S

ENTROPY

PARTICLE SIZING LABORATORY DATA

CUSTOMER Nichols JOB # 2988 SAMPLING LOCATION Scrubber Inlet

DATE 10/1-2-3 ANALYST ME Jackson

	RUN SI1				RUN SI4				RUN SI5			
STAGE	FILTER NUMBER	PARTICULATE AND FILTER WEIGHT (mg)	FILTER TARE (mg)	CATCH (mg)	FILTER NUMBER	PARTICULATE AND FILTER WEIGHT (mg)	FILTER TARE (mg)	CATCH (mg)	FILTER NUMBER	PARTICULATE AND FILTER WEIGHT (mg)	FILTER TARE (mg)	CATCH (mg)
P&N	—	—	—	64.1	P&N	—	—	66.3	P&N	—	—	79.4
0	PI			0.7	PI	—	—	0.3	PI	—	—	0.0
1	457	209.9	209.7	0.2	450	211.7	209.9	1.8	415	207.9	207.2	0.7
2	458	206.5	206.2	0.3	451	208.1	207.5	0.6	416	207.4	206.9	0.5
3	459	207.9	207.0	0.9	452	209.1	208.6	0.5	417	207.3	206.6	0.7
4	460	208.8	208.1	0.7	453	208.6	208.3	0.3	418	210.2	209.4	0.8
5	461	205.7	205.1	0.6	454	208.5	208.3	0.2	419	208.6	207.3	1.3
6	462	207.5	206.4	1.1	455	209.3	208.0	1.3	420	207.8	206.7	1.1
7	463	208.1	206.7	1.4	456	209.5	207.8	1.7	421	207.5	206.5	1.0
BU	SF323	219.1	209.2	9.9	SF322	220.0	208.6	11.4	SF317	216.4	209.2	7.2

PI = Pre-impactor P&N = PROBE AND NOZZLE

BU = Back-up Filter

B. FIELD AND ANALYTICAL DATA

2. Particle Size Distributions

b. Scrubber Stack

PARTICULATE FIELD DATA

SO-

COMPANY NAME NICHOLS — RUN NUMBER #3
ADDRESS GREENSBORO, NC — TIME START 1345
SAMPLING LOCATION SCRUBBER STACK — TIME FINISH 1505
DATE 10-1-86 — TEAM LEADER MH — TECHNICIANS RW
BAROMETRIC PRESSURE, IN. HG 29.2 — STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 30 ___ ___ ___ ___
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.005 0.002 ___ ___ ___ ___

EQUIPMENT CHECKS

___ PITOTS, PRE-TEST
___ PITOTS, POST-TEST
___ ORSAT SAMPLING SYSTEM
___ TEDLAR BAG
___ THERMOCOUPLE @ ___ °F

IDENTIFICATION NUMBERS

REAGENT BOX 722 — NOZZLE 303 — DIAMETER .168
METER BOX N8 — T/C READOUT ___
UMBILICAL ___ — T/C PROBE ___
SAMPLE BOX ___ — ORSAT PUMP ___
PROBE ___ — TEDLAR BAG ___

FILTER # / **TARE**

B568 ___
A561 ___
SF 213 ___

NOMOGRAPH SET-UP — NOMOGRAPH # MH

$\Delta H_@$ 1.61 — C FACTOR .91-.05=.8
METER TEMP 100 — STACK TEMP 130
% MOISTURE 6 — REF. ΔP 2.8

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	FILTER BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP C_T	BK. CHECK READINGS
B2	0	301.573	.43	.28	.28	103	1	—	65	12	
	5	302.69			.28	106	1		65	12	
	10	304.86			.26	107	1		65	12	
	15	306.15			.28	106	2		65	12	
	20	307.65			.28	105	2		65	12	
	25	309.27			.28	105	2		65	12	
	30	310.72			.28	104	2		65	12	
B4	35	312.28			.28	103	2		65	12	
	40	313.8			.28	102	2		65	12	
	45	315.35			.28	101	3		65	12	
	50	316.84			.26	100	3		65	12	
	55	318.41			.28	98	3		65	12	
	60	319.98			.28	97	3		65	12	
	65	321.52			.28	97	3		65	12	
	70 OFF	323.06			.28	99	3		65	12	
	75 OFF	324.548									

32.975	.43	.28	102	12
V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M	T_S

ENTROPY

PARTICULATE FIELD DATA

SD-4

COMPANY NAME NICHOLS — RUN NUMBER 4
ADDRESS GREENSBORO — TIME START 1410
SAMPLING LOCATION SCRUBBER STACK — TIME FINISH 1515
DATE 10-2-85 — TEAM LEADER MH — TECHNICIANS RW
BAROMETRIC PRESSURE, IN. HG 29.3 — STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.010

EQUIPMENT CHECKS

___ PITOTS, PRE-TEST
___ PITOTS, POST-TEST
___ ORSAT SAMPLING SYSTEM
___ TEDLAR BAG
___ THERMOCOUPLE @ ___ °F

IDENTIFICATION NUMBERS

REAGENT BOX 222 — NOZZLE 303 — DIAMETER .168
METER BOX N8 — T/C READOUT 01
UMBILICAL ___ — T/C PROBE ___
SAMPLE BOX ___ — ORSAT PUMP ___
PROBE ___ — TEDLAR BAG ___

FILTER # / **TARE**

3424
A427
SF180

NOMOGRAPH SET-UP — NOMOGRAPH # MH

$\Delta H_@$ 1.61 — C FACTOR .97-.05=.92
METER TEMP 85 — STACK TEMP 140
% MOISTURE 67 — REF. ΔP 2.60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	ANDERSEN FILTER EXIT ~~BOX~~ TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READINGS
B3	0	387.232	.44	.30	.30	84	2	115	60	138	
	5	388.85			.30	85	2	115	60	139	
	10	390.41			.30	86	2	117	60	139	
	15	392.05			.30	87	3	119	60	139	
	20	393.69			.30	87	3	122	60	139	
	25	395.21			.30	88	4	124	60	139	
B7	30	396.69			.30	88	4	133	60	139	
	35	398.40			.30	89	4	143	60	139	
	40	399.99			.30	89	4	144	60	139	
	45	401.48			.30	90	5	145	60	139	
	50	403.06			.30	90	5	145	60	139	
	55	404.77			.30	91	5	145	60	139	
	60	406.28			.30	91	5	145	60	139	
	65/OFF	407.850									

20.618	.44	.30	88	139
V_M	$(\sqrt{\Delta P})^2$	ΔH	T_M	T_S

ENTROPY

PARTICULATE FIELD DATA

SD-5

COMPANY NAME NICHOLS
ADDRESS GREENSBORO, NC
SAMPLING LOCATION SCRUBBER STACK
DATE 10-3-85 TEAM LEADER MH TECHNICIANS RV
BAROMETRIC PRESSURE, IN. HG 29.3 STATIC PRESSURE, IN. H_2O -.10
SAMPLING TRAIN LEAK TEST VACUUM, IN. HG 15 5(E)
SAMPLING TRAIN LEAK RATE, CU. FT./MIN. 0.010 0.005

RUN NUMBER ~~0-56~~
TIME START 1320
TIME FINISH 1410

EQUIPMENT CHECKS

___ PITOTS, PRE-TEST
___ PITOTS, POST-TEST
___ ORSAT SAMPLING SYSTEM
___ TEDLAR BAG
___ THERMOCOUPLE @ ___ °F

IDENTIFICATION NUMBERS

REAGENT BOX ___ NOZZLE .305 DIAMETER .1168
METER BOX RAC 1 T/C READOUT 01
UMBILICAL ___ T/C PROBE ___
SAMPLE BOX ___ ORSAT PUMP ___
PROBE ___ TEDLAR BAG ___

FILTER # / **TARE**

3420 ___
A423 ___
SF179 ___

NOMOGRAPH SET-UP

NOMOGRAPH # MH
$\Delta H_@$ 1.76 C FACTOR .96-.05=.91
METER TEMP 80 STACK TEMP 140
% MOISTURE 8 REF. ΔP 2.60

SAMPLE POINT	CLOCK TIME, MIN.	DRY GAS METER READING, CU. FT.	PITOT READING (ΔP), IN. H_2O	ORIFICE SETTING (ΔH), IN. H_2O IDEAL	ORIFICE SETTING (ΔH), IN. H_2O ACTUAL	GAS METER TEMP. °F	PUMP VACUUM IN. HG GAUGE	ANDERSON FILTER EXIT BOX TEMP. °F	IMP. EXIT TEMP. °F	STACK TEMP. °F	LK. CHECK READING
A3	0	447.363	.44	.31	.31	79	3	107	60	135	
	5	448.92		.31	.31	81	3	107	60	135	
	10	450.50			.31	82	3	107	60	136	
	15	452.15			.31	84	3	111	60	136	
	20	453.73			.31	85	3	108	60	136	
A6	25	455.33			.31	86	3	113	60	136	
	30	456.95			.31	86	4	113	60	136	
	35	458.56			.31	87	4	113	60	136	
	40	460.22			.31	87	4	112	60	136	
	45	461.85			.31	87	5	110	60	136	
	50/AF	463.445									

16.092 .44 .31 84 136

V_M $(\sqrt{\Delta P})^2$ ΔH T_M T_S

ENTROPY

PARTICLE SIZING LABORATORY DATA

CUSTOMER Nichols JOB # 2988 SAMPLING LOCATION Scrubber Stack

DATE 10/1-2-3 ANALYST ME Jackson

STAGE	RUN S01 FILTER NUMBER	RUN S01 PARTICULATE AND FILTER WEIGHT (mg)	RUN S01 FILTER TARE (mg)	RUN S01 CATCH (mg)	RUN S02 FILTER NUMBER	RUN S02 PARTICULATE AND FILTER WEIGHT (mg)	RUN S02 FILTER TARE (mg)	RUN S02 CATCH (mg)	RUN S03 FILTER NUMBER	RUN S03 PARTICULATE AND FILTER WEIGHT (mg)	RUN S03 FILTER TARE (mg)	RUN S03 CATCH (mg)
Nozzle	—	—	—	2.4	Nozzle	—	—	0.4				
0	illegible	illegible	illegible	illegible	illegible	illegible	illegible	illegible	illegible	illegible	illegible	illegible
1	A 558	148.0	147.5	0.5	A 424	129.5	128.1	1.4	A 420	127.4	126.4	1.0
2	B 569	165.4	164.5	0.9	B 425	143.8	142.0	1.8	B 421	154.0	152.7	1.3
3	A 559	148.5	148.1	0.4	A 425	128.5	126.9	1.6	A 421	129.3	127.9	1.4
4	B 560	165.9	165.4	0.5	B 426	145.0	142.9	2.1	B 422	145.2	143.5	1.7
5	A 560	150.1	147.8	2.3	A 426	149.9	146.6	3.3	A 422	129.9	126.5	3.4
6	B 561	169.0	164.2	4.8	B 427	167.6	162.3	5.3	B 423	148.9	144.2	4.7
7	A 561	151.9	147.8	4.1	A 427	150.0	145.4	4.6	A 423	150.5	146.4	4.1
BU	SF 213	320.7	272.1	48.6	SF180	313.9	267.3	46.6	SF 179	303.6	266.2	37.4

PI = Pre-impactor

BU = Back-up Filter

APPENDIX C

SAMPLING AND ANALYTICAL PROCEDURES

3.3 END-TO-END CALIBRATION

Before actual sampling is begun, it is strongly recommended that an end-to-end calibration be performed at ambient conditions with a dry gas meter which has already been calibrated against a primary standard. As is, the flowmeter provides 95% accuracy for full scale reading; however, this accuracy will decrease at lower flow rates. For this reason, an end-to-end calibration at 3 or 4 points with a dry gas meter will provide extremely accurate flow information at any desired flow rate and can be accomplished in 10 - 15 minutes. Simply plot Flow Rate (as determined with the dry gas meter and stop watch) vs. flowmeter reading. Draw a line through the points and in this manner accurate, instantaneous flow measurements at any rate can be accomplished with only the flowmeter during actual stack sampling. The above calibration to be performed as quickly as possible to avoid any collection in stack head.

4.0 STACK SAMPLING PROCEDURE

Stack Sampling is simple in principle, but in practice it is complicated by the need to ensure that the collected particulates are representative of the particulates flowing at any one sampling point and also at all possible points in the cross section of the flue at the sampling position. The first requirement is satisfied by isokinetic sampling in which the inlet sampling nozzle velocity is equal and in the same direction as the flue gas velocity. The weight of particulates collected is then equal to the weight of particulates flowing through an area in the flue equal to the area of the sampling nozzle. If sampling is not isokinetic, the gas flow lines are disturbed by the presence of the nozzle and either too few or too many particles are collected.

The second requirement, ensuring that the sample is representative of the average particle flow past the sampling position, presents no problem when the distribution of solids flow is uniform over the area of the flue. Samples taken at all points will be identical and any chosen point will give a representative sample. The weight of solids E passing through the flue per unit time is then found by multiplying the weight w/t collected per unit time at the sampling point (w being the weight collected during the time t) by the ratio of the area A of the flue to the area a of the nozzle:

$$E = \frac{w}{t} \cdot \frac{A}{a}$$

However, the particulates are not usually distributed uniformly over the cross-sectional area of the flue and it is necessary to collect the sample in increments taken separately at each point and the average weight calculated from the separate observations, which is called incremental sampling. Or a single gross sample may be collected by moving the sampling nozzle from point to point which is called cumulative sampling. The incremental method is recommended for the beginner because it is easier to spot mistakes. Also, it is preferred by research investigators and is recommended for those who require the best accuracy because it gives information on the reliability of the average. The cumulative method may be slightly quicker and may be preferred by those doing routine testing not requiring the highest degree of accuracy. Incremental sampling is recommended when using the Andersen Stack Sampler. The cumulative method may be used on occasion and will be discussed later.

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

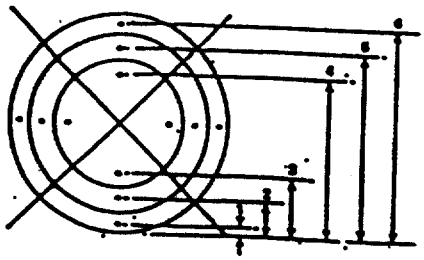


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

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	89.5	65.8	35.6	25.9	22.0	18.8	16.5	14.6	13.2
7				96.8	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
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	23.8
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	38.3	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									96.4	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

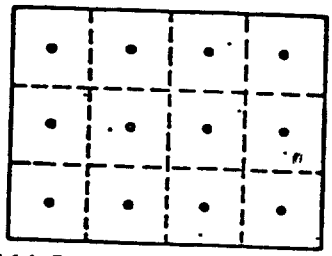


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

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

2. Bibliography

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PROPOSED REVISION - OCTOBER 29, 1984

SEE ATTACHED

42 FR 41754 08/18/77
43 FR 11984 03/23/78
48 FR 45034 9/30/83

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.

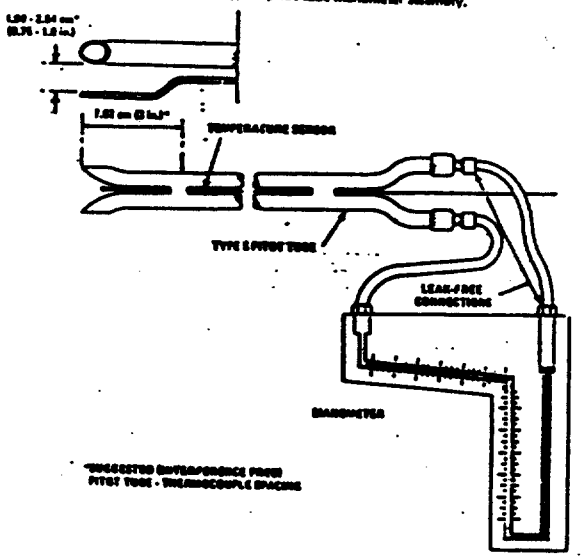
2. *Apparatus*

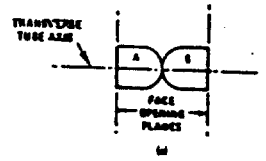
Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

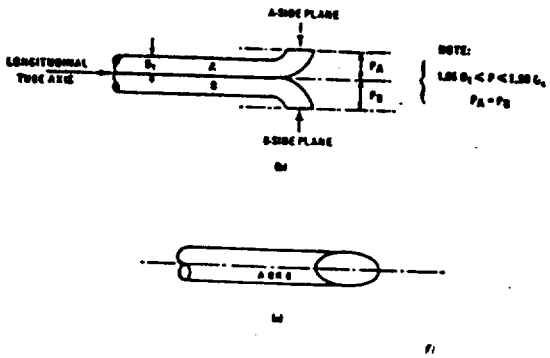
2.1 Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g., stainless steel). It is recommended that the external tubing diameter (dimension D_t, Figure 2-2b) be between 0.48 and 0.95 centimeter (3/16 and 3/8 inch). There shall be an equal distance from the base of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

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

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







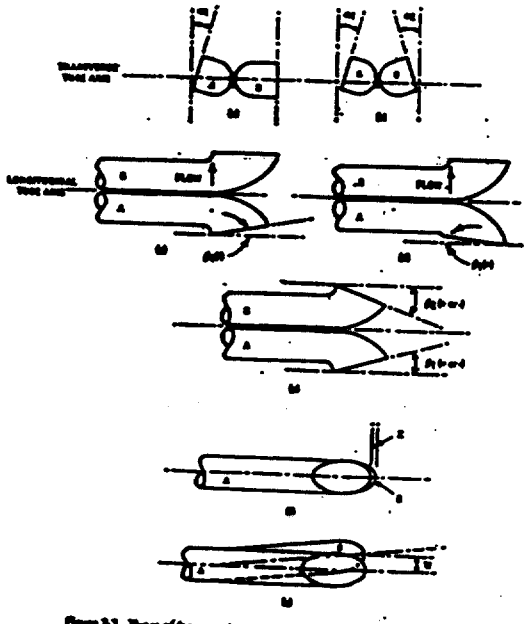


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and contortions coincident, when viewed from both sides. Baseline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

Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as α_1 and $\alpha_2 < 10°$, β_1 and $\beta_2 < 5°$, $z < 0.32$ cm (1/8 in.) and $w <$ 0.08 cm (1/32 in.) (shown 11 in Section 4).

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 ($\pm$5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be taken, as above, for the last two back purges at which suitably high Δp readings are observed.

2.2 Differential Pressure Gauge. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (water column) inclined-vertical manometer, having 0.01-in. H_2O divisions on the 0- to 1-in. inclined scale, and 0.1-in. H_2O divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gauge of equivalent sensitivity) is satisfactory for the measurement of Δp values as low as 1.3 mm (0.05 in.) H_2O. However, a differential pressure gauge of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all Δp readings at the traverse points in the stack is less than 1.3 mm (0.05 in.) H_2O; (2) for traverses of 12 or more points, more than 10 percent of the individual Δp readings are below 1.3 mm (0.05 in.) H_2O; (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.3 mm (0.05 in.) H_2O. Citation 18 in Section 6 describes commercially available instrumentation for the measurement of low-range gas velocities.

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

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

where:

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

n = Total number of traverse points.

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

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

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

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

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

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

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

2.7 Calibration 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).

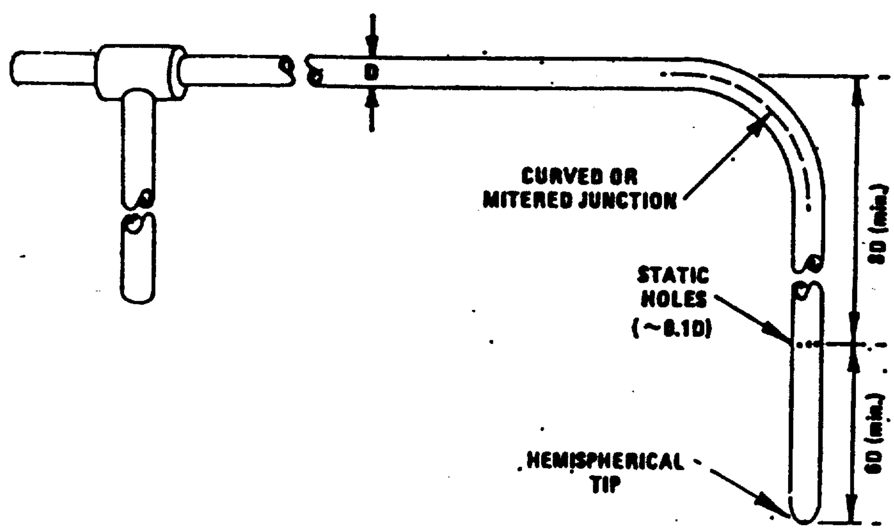


Figure 2-4. Standard pitot tube design specifications.

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.

2.6 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.

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

2.8 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, 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 illustrate interference-free 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:

PLANT _____

DATE _____ RUN NO. _____

STACK DIAMETER OR EQUIVALENT, cm (in.) _____

BAROMETRIC PRESSURE, mm Hg (in. Hg) _____

CROSS SECTIONAL AREA, m^2 (ft^2) _____

OPERATORS _____

PITOT TUBE I.D. NO. _____

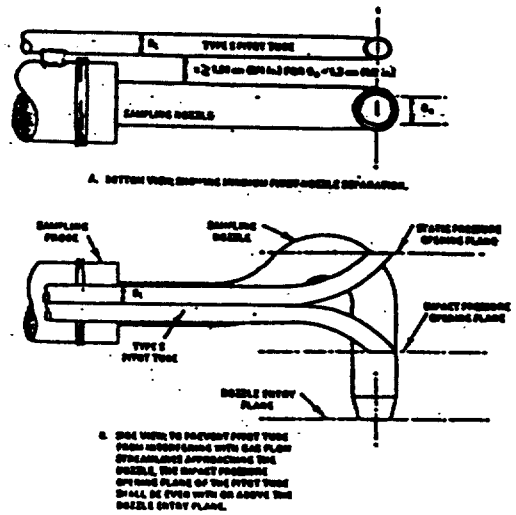
AVG. COEFFICIENT, C_p = _____

LAST DATE CALIBRATED _____

SCHEMATIC OF STACK CROSS SECTION

Traverse Pt. No.	Velocity Head, Δp, cm H_2O (in. H_2O)	Stack Temperature		P_s, mm Hg (in. Hg)	$\sqrt{\Delta p}$
		°C (°F)	°C (°F)		
		Average			

Figure 2-5. Velocity traverse data.



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

B. SIDE VIEW TO PREVENT PITOT TUBE FROM MISREADING 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; concave nozzle and pitot opening aligned; 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 in 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 test section must be constant over a distance of 10 or more stack diameters. For a rectangular cross-section, use an equivalent diameter, calculated from the following equation, to determine the number of duct diameters:

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

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 test site must be located at least eight diameters downstream and two diameters upstream from the nearest disturbance.

NOTE.—The eight- and two-diameter criteria are minimums; 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 maintain 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 ±4 percent for the measurement of velocities between 183 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 183 to 1,525 m/min (600 to 5,000 ft/min), and calibration data must 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 be 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 has 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 4.1.4.1), and align the tube so that its tip is pointed directly into the flow. Particular care should be taken in aligning the tube to ensure yaw and pitch angles of zero. 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 that 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, 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.

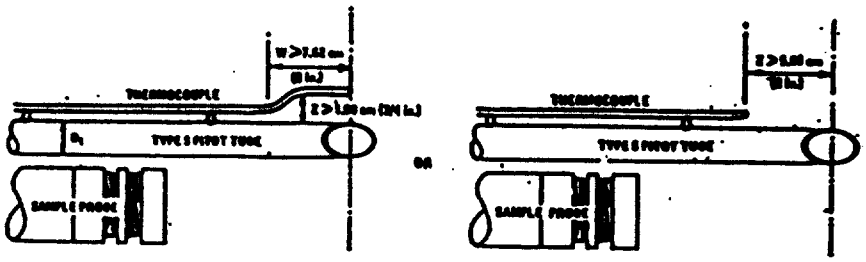


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

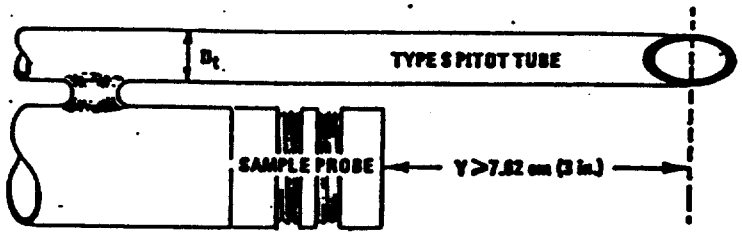


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

PITOT TUBE IDENTIFICATION NUMBER: _____ DATE: _____

CALIBRATED BY: _____

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

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

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

$$\left| \bar{C}_{p \text{ (SIDE A)}} - \bar{C}_{p \text{ (SIDE B)}} \right| \leftarrow \text{MUST BE} < 0.01$$

Figure 2-9. Pitot tube calibration data.

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

Equation 2-2

where:

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

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

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

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

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

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

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

Equation 2-3

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

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

Equation 2-4

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

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

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

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

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

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

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

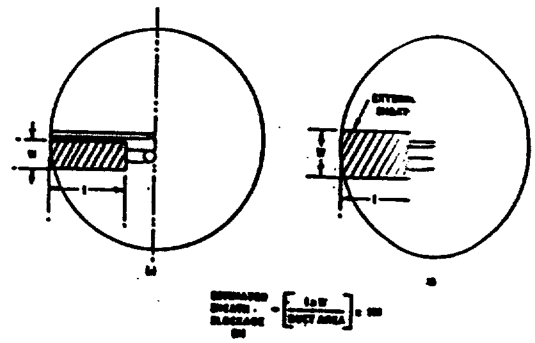


Figure 2-10. Projected-area models for typical pitot assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

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

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $\bar{C}_{p(s)}$. 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, m^2 (ft^2).

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

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant,

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

for the metric system and

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

for the English system.

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

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

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

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

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

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

$= P_{bar} + P_g$ Equation 2-6

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

Q_{sd} = Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).

t_s = Stack temperature, °C (°F).

T_s = Absolute stack temperature, °K (°R).

$= 273 + t_s$ for metric Equation 2-7

$= 460 + t_s$ for English Equation 2-8

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

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

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

3,600 = Conversion factor, sec/hr.

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

5.2 Average stack gas velocity.

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

Equation 2-9

5.3 Average stack gas dry volumetric flow rate.

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

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 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 transfer the gas sample to the analyzer.

2.2 Integrated Sampling (Figure 3-2).

2.2.1 Probe. Same 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.

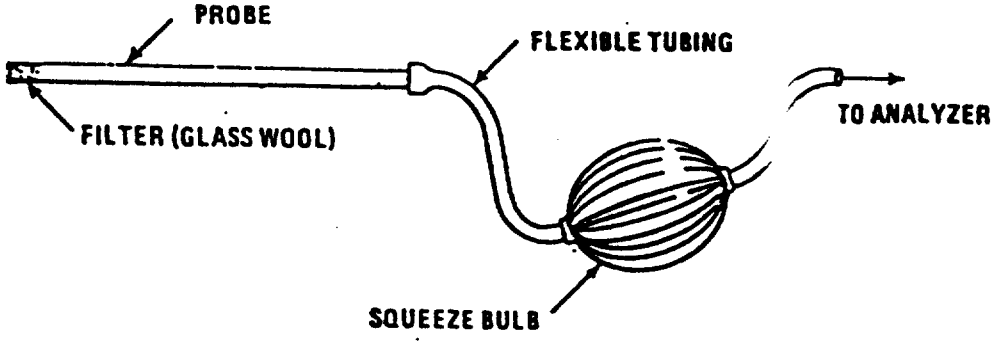

Figure 3-1. Grab-sampling train.

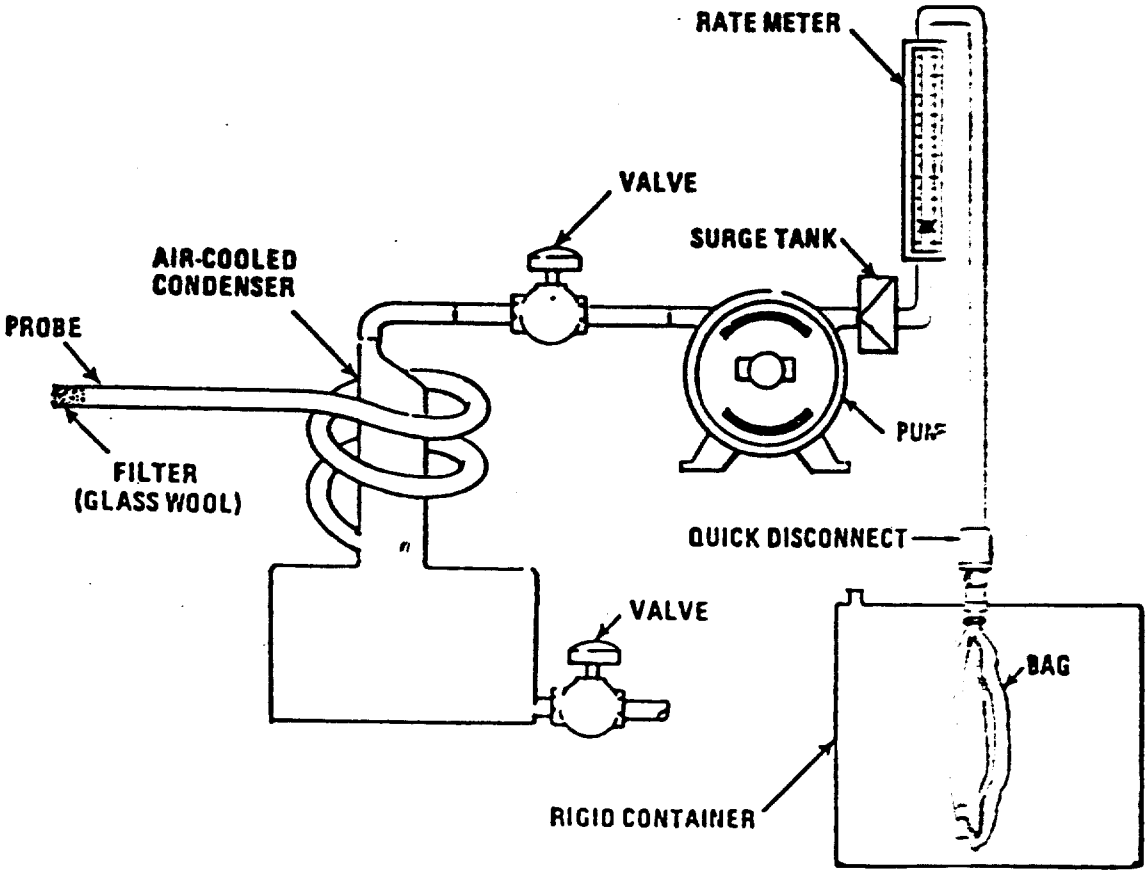

Figure 3-2. Integrated gas-sampling train.

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 cm³/min is suggested.

2.2.6 Flexible Bag. Any leak-free plastic (e.g., Tedlar, Mylar, Teflon) or plastic-coated aluminum (e.g., aluminized Mylar) bag, or equivalent, having a capacity consistent with the selected flow rate and time length of the test run, may be used. A capacity in the range of 55 to 90 liters is suggested.

To leak-check the bag, connect it to a water manometer and pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 minutes. Any displacement in the water manometer indicates a leak. An alternative leak-check method is to pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O) and allow to stand overnight. A deflated bag indicates a leak.

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 30 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 leak-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 6.2.

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 ft³) of sample gas is recommended; however, smaller volumes may be collected, if desired.

3.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. Within 8 hours after the sample is taken, analyze it for percent CO_2 and percent O_2 using either an Orsat analyzer or a Fyrite-type combustion gas analyzer. If an Orsat analyzer is used, it is recommended that the Orsat leak-check described in Section 5 be performed before this determination; however, the check is optional. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.2.

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 not acceptable for excess air or emission rate correction factor determination, unless approved by the Administrator. If both percent CO_2 and percent O_2 are measured, the analytical results of any of the three procedures given below may also be used for calculating the dry molecular weight. "Each of the three procedures below plus the quality assurance procedures in Section 4.4 shall be used when specified in the applicable subpart of the regulation." 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] $\%\ DEV = \left(\frac{Q - Q\ avg}{Q\ avg}\right) 100$ (MUST BE < 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 percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air as outlined in Section 6.2.

4.1.4 To 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 Section 4.4 be used to validate the analytical data.

4.2 Single-Point, Integrated Sampling and Analytical Procedure.

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

4.2.2 Leak-check (mandatory) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to sampling, leak-check (mandatory) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of 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 ft³) 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 Section 4.4 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 3.2.1 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 3-2.

4.4 Quality Control Procedures.

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

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

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

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

Where:

$\%O_2$ = Percent O_2 by volume (dry basis).

$\%CO_2$ = Percent CO_2 by volume (dry basis).

20.9 = Percent O_2 by volume in ambient air.

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

$$\%CO_2(adj) = \%CO_2 + \%CO$$

$$\%O_2(adj) = \%O_2 - 0.5\ \%CO$$

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

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

$$F_o = \frac{0.209\ F_c}{F_c} \qquad \text{Eq. 3-4}$$

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

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

5. *Leak-Check Procedure for Orsat Analyzers*

Moving an Orsat analyzer frequently causes it to leak. Therefore, an Orsat analyzer should be 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 4.2.3 or 4.2.4) into Equation 3-1.

$$\%EA = \left[\frac{\%O_2 - 0.5\%CO}{0.264\ \%N_2 - (\%O_2 - 0.5\%CO)}\right] 100 \qquad \text{Equation 3-1}$$ [57]

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.

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO) \qquad \text{Equation 3-2}$$

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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48 FR 49458 10/25/83

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, psychrometric 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. Those 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.

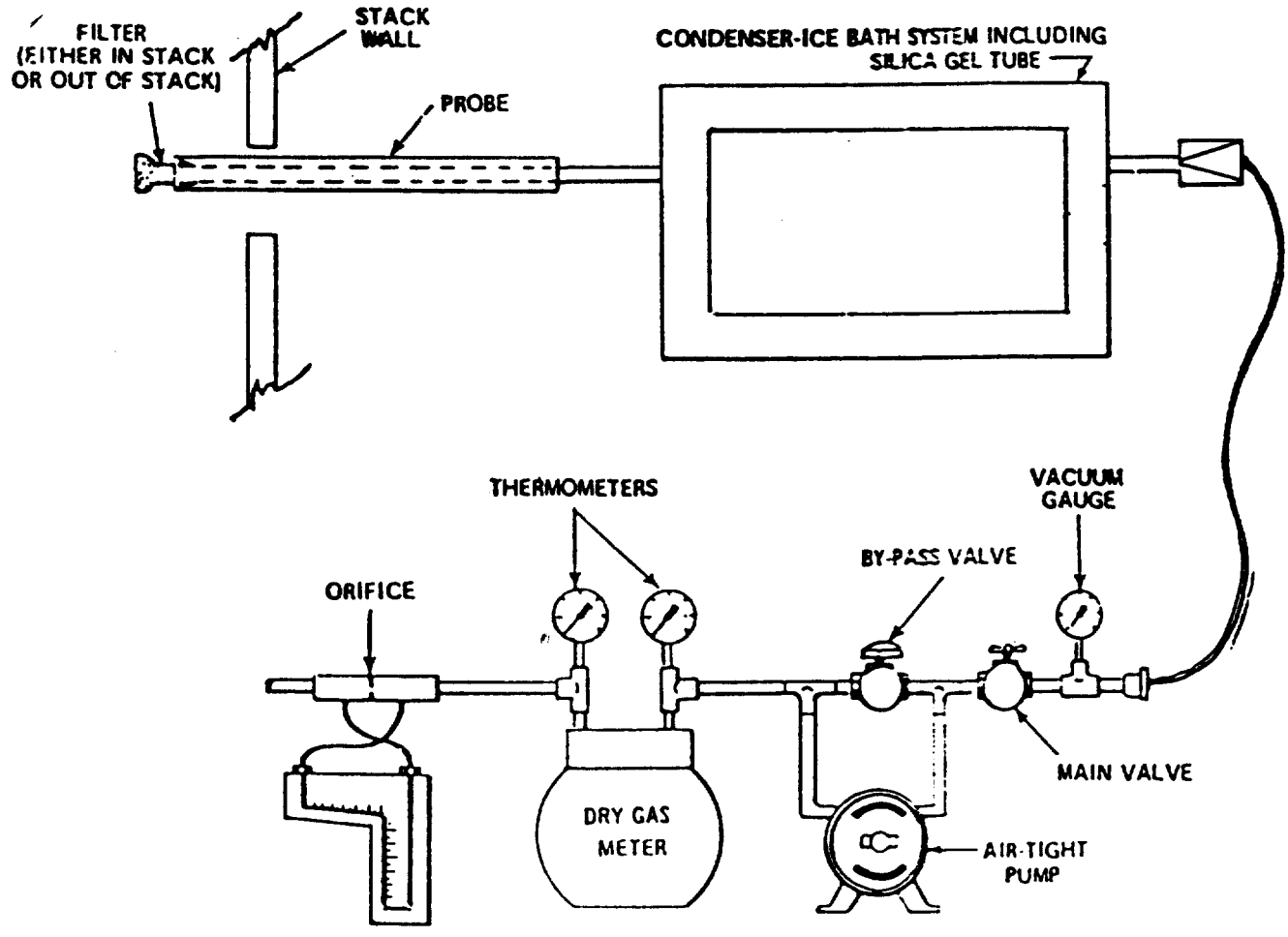

Figure 4-1. Moisture sampling train-reference method.

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

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.85 scm (30 scf) will be collected, at a rate no greater than 0.028 m³/min (1.25 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 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 repeat the test run 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 for example data sheet, Figure 4-2) and calculate the moisture percentage, as described in 2.3 below.

2.2.7 A quality control check of the volume metering system at the field site is suggested before collecting the sample following the procedure in Method 5, Section 4.4.

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

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 ($T_{m_{in}}$), °C (°F)	OUTLET ($T_{m_{out}}$), °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, dcm (dscf).

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

$V_{wg(std)}$ = 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.

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

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 = 0.3846 °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.

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

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/gm (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 2.1.3 above.

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

3.2 Procedure.

3.2.1 Place exactly 5 ml distilled water in each impinger.

Leak check the sampling train as follows: Temporarily insert a vacuum gauge at or near the probe inlet; then, plug the probe inlet and pull a vacuum of at least 250 mm Hg (10 in. Hg). Note the time rate of change of the dry gas meter dial; alternatively, a rotameter (0-40 cc/min) may be temporarily attached to the dry gas meter outlet to determine the leakage rate. A leak rate not in excess of 2 percent of the average sampling rate is acceptable.

NOTE.—Carefully release the probe inlet plug before turning off the pump.

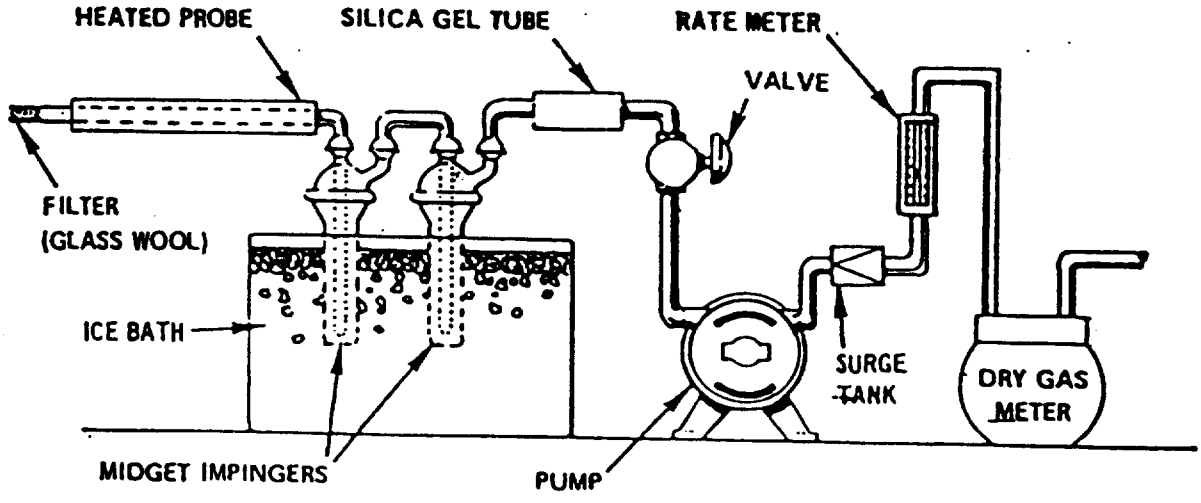

Figure 4-4. Moisture-sampling train - approximation method.

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 Bibliography); commercial models of this train are also available. For changes from APTD-0581 and for allowable modifications of the train shown in Figure 5-1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Bibliography). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

2.1.1 Probe Nozzle. Stainless steel (316) or glass with sharp, tapered leading edge. The angle of taper shall be 30° and the taper shall be on the outside to preserve a constant internal diameter. The probe nozzle shall be of the buttonhook 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 [illegible] 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 [illegible].

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 exact temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APTD-0581 and utilizing the calibration curve of APTD-0576 (or calibrated according to the procedure outlined in APTD-0576) will be considered adequate.

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 [illegible]° 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, Inconel[1] or other corrosion resistant metals) made to commercial 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 1-6b) during sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

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

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 4.1.2), the third shall be empty, and the fourth shall contain a known weight of silica gel, or equivalent desiccant. A thermometer, capable of measur-

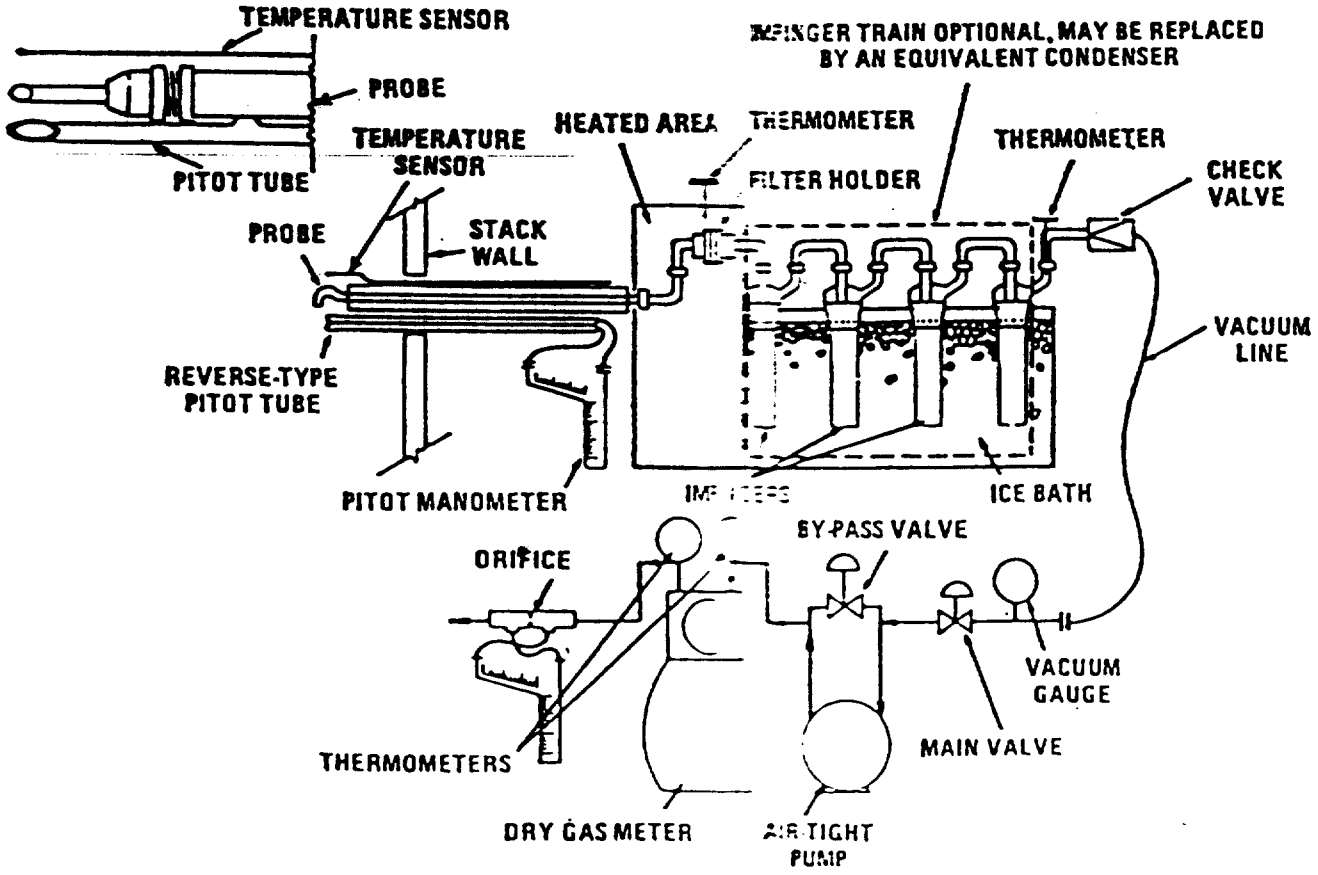

Figure 5-1. Particulate sampling train.

ing 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 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. 8/

2.2.5 Graduated Cylinder and/or Balance. To measure condensed water to within 1 ml or 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances is suitable for use here and in Section 2.3.4.

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

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

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

2.3 Analysis. 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

3.1.1 Filters. Glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (<0.05 percent penetration) on 0.3-micron dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with ASTM standard method D2986-71 (Reapproved 1978) (incorporated by reference—see § 60.17). Test data from the supplier's quality control program are sufficient for this purpose. In sources containing SO_2 or SO_3, the filter material must be of a type that is unreactive to SO_2 or SO_3. Citation 10 in Section 7 Bibliography, may be used to select the appropriate filter.

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

3.1.3 Water. When analysis of the material caught in the impingers is required, distilled water shall be used. Run blanks prior to field use to eliminate a high blank on test samples.

3.1.4 Crushed Ice.

3.1.5 Stopcock Grease. Acetone-insoluble, heat-stable silicone grease. This is not necessary if screw-on connectors with Teflon sleeves, or similar, are used. Alternatively, other types of stopcock grease may be used, subject to the approval of the Administrator.

3.2 Sample Recovery. Acetone—reagent grade, ≤0.001 percent residue, in glass bottles—is required. Acetone from metal containers generally has a high residue blank and should not be used. Sometimes, suppliers transfer acetone to glass bottles from metal containers; thus, acetone blanks shall be run prior to field use and only acetone with low blank values (≤0.001 percent) shall be used. In no case shall a blank value of greater than 0.001 percent of the weight of acetone used be subtracted from the sample weight.

3.3 Analysis. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

3.3.2 Desiccant. Anhydrous calcium sulfate, indicating type. Alternatively, other types of desiccants may be used, subject to the approval of the Administrator.

4. Procedure

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testers should be trained and experienced with the test procedures.

4.1.1 Pretest Preparation. 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. The sampling time at each point shall be the same. 8/

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 200° C (400° 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.

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, m³/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.

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

Clean the portholes prior to the test run to minimize he chance of sampling deposited material. To begin sampling, remove the nozzle cap, verify that the filter nd probe heating systems are up to temperature, and hat the pitot tube and probe are properly positioned. osition the nozzle at the first traverse point with the tip ointing directly into the gas stream. Immediately start he 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 he stack gas equivalent density (dry molecular weight) s equal to 29±4. APTD-0576 details the procedure for using the nomographs. If C_p and M_s are outside the above stated ranges do not use the nomographs unless appropriate steps (see Citation 7 in Bibliography) are taken o compensate for the deviations.

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

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

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

During the test run, make periodic adjustments to eep the temperature around the filter holder at the roper 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 he 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 s recommended that another complete filter assembly e used rather than attempting to change the filter itself. efore a new filter assembly is installed, conduct a leak-heck (see Section 4.1.4.2). The total particulate weight hall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, xcept in cases where simultaneous sampling is required a two or more separate ducts or at two or more different ocations 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 he 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 4.1.4.2. 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.

4.1.8 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Calculations, Section 5) 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. 87

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. 87

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. 87

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' desiccation time between weighings.

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

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

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

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

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

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

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

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

Eq. 5-9

Where:

ΔH = Average pressure differential across the orifice meter, in. H_2O.

T_m = Absolute average dry gas meter temperature, °R.

P_m = Barometric pressure, in. Hg.

Θ = Total sampling time, min.

Y = Dry gas meter calibration factor, dimensionless.

V_m = Volume of gas sample as measured by dry gas meter, dcf.

0.0319 = (0.0567 in. Hg/°R) x (0.75 cfm)

Before beginning the field test (a set of three runs usually constitutes a field test), operate the metering system (i.e., pump, volume meter, and orifice) at the $\Delta H_@$ pressure differential for 10 minutes. Record the volume collected, the dry gas meter temperature, and the barometric pressure. Calculate a dry gas meter calibration check value, Y_c, as follows:

$$Y_c = \frac{10}{V_m}\left[\frac{0.0319\ T_m}{P_m}\right]\Delta H \qquad \text{Eq. 5-10}$$

Where:

Y_c = Dry gas meter calibration check value, dimensionless.

10 = 10 minutes of run time.

Compare the Y_c value with the dry gas meter calibration factor Y to determine that:

$0.97Y < Y_c < 1.03Y$

If the Y_c value is not within this range, the volume metering system should be investigated before beginning the test.

4.4.2 Calibrated Critical Orifice. A calibrated critical orifice, calibrated against a wet test meter or spirometer and designed to be inserted at the inlet of the sampling meter box, may be used as a quality control check, such procedure being subject to approval by the Administrator.

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 16 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.

Plant _____

Date _____

Run No. _____

Filter No. _____

Amount liquid lost during transport _____

Acetone blank volume, ml _____

Acetone wash volume, ml _____

Acetone blank concentration, mg/mg (equation 5-4) _____

Acetone wash blank, mg (equation 5-5) _____

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED, mg		
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN
1			
2			
TOTAL			
Less acetone blank			
Weight of particulate matter			

	VOLUME OF LIQUID WATER COLLECTED	
	IMPINGER VOLUME, ml	SILICA GEL WEIGHT, g
FINAL		
INITIAL		
LIQUID COLLECTED		
TOTAL VOLUME COLLECTED		g* ml

* CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1 g/ml).

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

Figure 5-3. Analytical data.

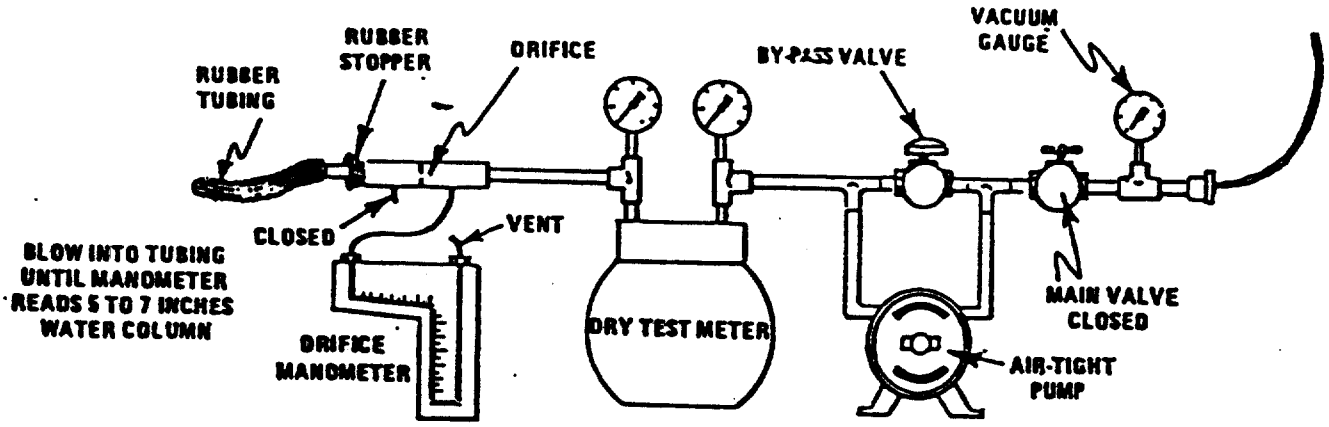

Figure 5-4. Leak check of meter box.

6.1 Nomenclature.

A_n = Cross-sectional area of nozzle, m² (ft²).

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

C_a = Acetone blank residue concentration, mg/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_g = 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 5-3), °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 Equation 2-9, using data obtained from Method 4, 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 5-3), mm H₂O (in. H₂O).

ρ_a = Density of acetone, mg/ml (see label on bottle).

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

θ = Total sampling time, min.

θ_i = Sampling time interval, from the beginning of a run until the first component change, min.

θ_i = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.

θ_p = Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.

13.6 = Specific gravity of mercury.

60 = Seconds/min.

100 = Conversion to percent.

6.2 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 5-3).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C, 760 mm Hg or 68° F, 29.92 in. Hg) by using Equation 5-1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right]$$

$$= K_1 V_m Y \frac{P_{bar} + \left(\frac{\Delta H}{13.6}\right)}{T_m}$$

Equation 5-1

where:

K_1 = 0.3858 °K/mm Hg for metric units

= 17.64 °R/in. Hg for English units

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

$$V_{w(std)} = V_{lc}\left(\frac{\rho_w}{M_w}\right)\left(\frac{RT_{std}}{P_{std}}\right) = K_2 V_{lc} \qquad \text{Equation 5-2}$$

where:

K_2 = 0.001333 m³/ml for metric units

= 0.0472 ft³/ml for English units.

6.5 Moisture Content.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}} \qquad \text{Equation 5-3}$$

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 5-8). 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	m^3	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.

$$I = \frac{100\, T_s [K_4 V_{lc} + (V_m/T_m)(P_{bar} + \Delta H/13.6)]}{60\, \theta v_s P_s A_n}$$

Equation 5-7

where:

K_4=0.003454 mm Hg−m³/ml−°K for metric units.
=0.002669 in. Hg−ft³/ml−°R for English units.

6.11.2 Calculation From Intermediate Values.

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

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

Equation 5-8

where:

K_4=4.320 for metric units
=0.09450 for English units.

6.12 Acceptable Results. If 90 percent ≤ I ≤ 110 percent, the results are acceptable. If the 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. Alternative Procedures

7.1 Dry Gas Meter as a Calibration Standard. A dry gas meter may be used as a calibration standard for volume measurements in place of the wet test meter specified in Section 5.3, provided that it is calibrated initially and recalibrated periodically as follows:

7.1.1 Standard Dry Gas Meter Calibration.

7.1.1.1 The dry gas meter to be calibrated and used as a secondary reference meter should be of high quality and have an appropriately sized capacity, e.g., 3 liters/rev (0.1 ft³/rev). A spirometer (400 liters or more capacity), or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should have a capacity of 30 liters/rev (1 ft³/rev) and capable of measuring volume to within ±1.0 percent; wet test meters should be checked against a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained.

7.1.1.2 Set up the components as shown in Figure 5-7. A spirometer, or equivalent, may be used in place of the wet test meter in the system. Run the pump for at least 5 minutes at a flow rate of about 10 liters/min (0.35 cfm) to condition the interior surface of the wet test meter. The pressure drop indicated by the manometer at the inlet side of the dry gas meter should be minimized [no greater than 100 mm H_2O (4 in. H_2O) at a flow rate of 30 liters/min (1 cfm)]. This can be accomplished by using large diameter tubing connections and straight pipe fittings.

7.1.1.3 Collect the data as shown in the example data sheet (see Figure 5-8). Make triplicate runs at each of the flow rates and at no less than five different flow rates. The range of flow rates should be between 10 and 34 liters/min (0.35 and 1.2 cfm) or over the expected operating range.

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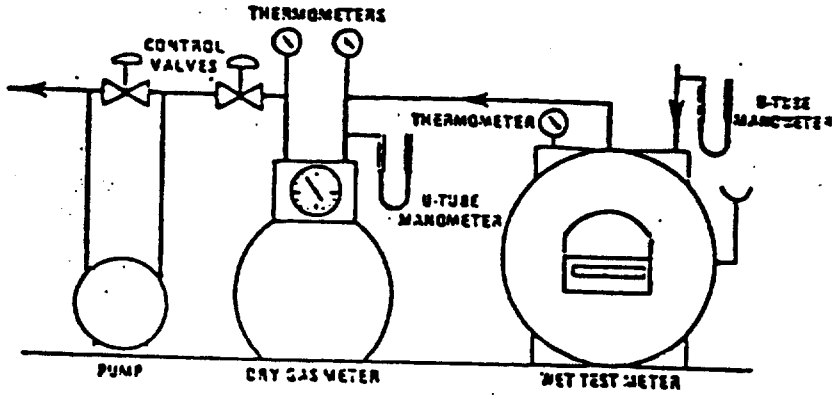


Figure 5.7 . Equipment arrangement for dry-gas meter calibration.

OPERATING INSTRUCTIONS
FOR ANDERSEN STACK SAMPLING EQUIPMENT

1.0 INTRODUCTION

In the past, an accurate evaluation of the particulate sample collected from a stack has been difficult because the collection devices were designed mainly to be used exterior to the stack. In addition, there has been a lack of instrumentation capable of giving meaningful particle sizing information.

Now, however, the Andersen Stack Sampler is available which provides a reliable particulate sample that is collected and sized aerodynamically in the stack at isokinetic conditions simultaneously with the collection of gaseous samples. Isokinetic sampling requires that the stack gases are drawn into the sampling nozzle at the same velocity and in the same direction as they occur in the stack. This method of stack effluent analysis is easier and more economical for the simultaneous determination of grain loading, particle sizing, and gaseous content than any other technique.

There are two types or classes of stack sampling equipment. One class (external probe) has the solids-collecting device mounted outside the flue at the exit end of the probe tube and usually requires heating the probe tube and collection device to prevent condensation of water vapor. The other class (internal probe) has the solids-collecting device mounted inside the flue to provide sample collection done under actual stack conditions. The Andersen Stack Sampler is an internal collector and differs from more conventional devices in that it does not operate by means of filtration or impingement, but rather by means of inertial impaction.

A brief description of general stack sampling procedures follows. The unique characteristics and points to be considered when using the Andersen Stack Sampler will be covered in detail.

The particulate matter in stack gases is seldom distributed uniformly over the cross section of a flue; however, by a proper selection of sampling points, a representative sample can be obtained. Also, the quantity seldom remains steady over a substantial period of time because of the difficulty of maintaining uniform plant operating conditions. Therefore, it is necessary to know the operating cycles and cycle conditions in order to obtain representative samples during steady plant conditions. Peak loading times, temperatures, and humidity will all affect the sampl

It should be clearly understood that the result of a test can give only an average value of emission during the period of sampling and can be representative only of the conditions during that period. Therefore, it is recommended that duplicate samples be taken whenever sampling flues.

Since it is not possible to collect all of the material emitted from a stack, it i necessary to obtain a representative sample. This requires the selection of a suitable sampling position, the collection of several samples and the conversion of the data obtained into a reliable estimate of total emission.

Sampling points in the stack should be selected to avoid gas turbulence as much as possible. When selecting a site, the general rule is for measurements to be made

eight to ten diameters downstream or three to five diameters upstream from a disturbance. Disturbances are usually caused by inlets, outlets, bends, constrictions, dampers, etc. Often, it is physically impossible to sample in a uniform gas mixture and compromises must be made. Whenever this occurs, all measurements and techniques must be carefully applied to ensure ressonable accuracy.

After the selection of a suitable sampling site, one is ready to make a preliminary survey including gas velocity, temperature, and combustion efficiency determinations. A preliminary traverse is made with a pitot tube connected to an inclined/vertical manometer.

The S pitot tube measures velocity head at the point in the gas stream where it is placed. Temperature, pressure, and humidity determinations must also be made on the sampling plane since these parameters may affect the stack gas density significantly. When making this traverse, the process cycle must be kept in mind because the stack gas velocity is dependent upon the cycle fluctuations. Also, at this time, an Orsat Analyzer is normally used to determine the efficiency of combustion. The acceptable level of CO_2 is 12 percent. It may be necessary to make several preliminary traverses in order to find an area which will conform to the previously discussed requirements. With the velocity information obtained, it is now possible to select a nozzle and flow rate that will be required for isokinetic sampling.

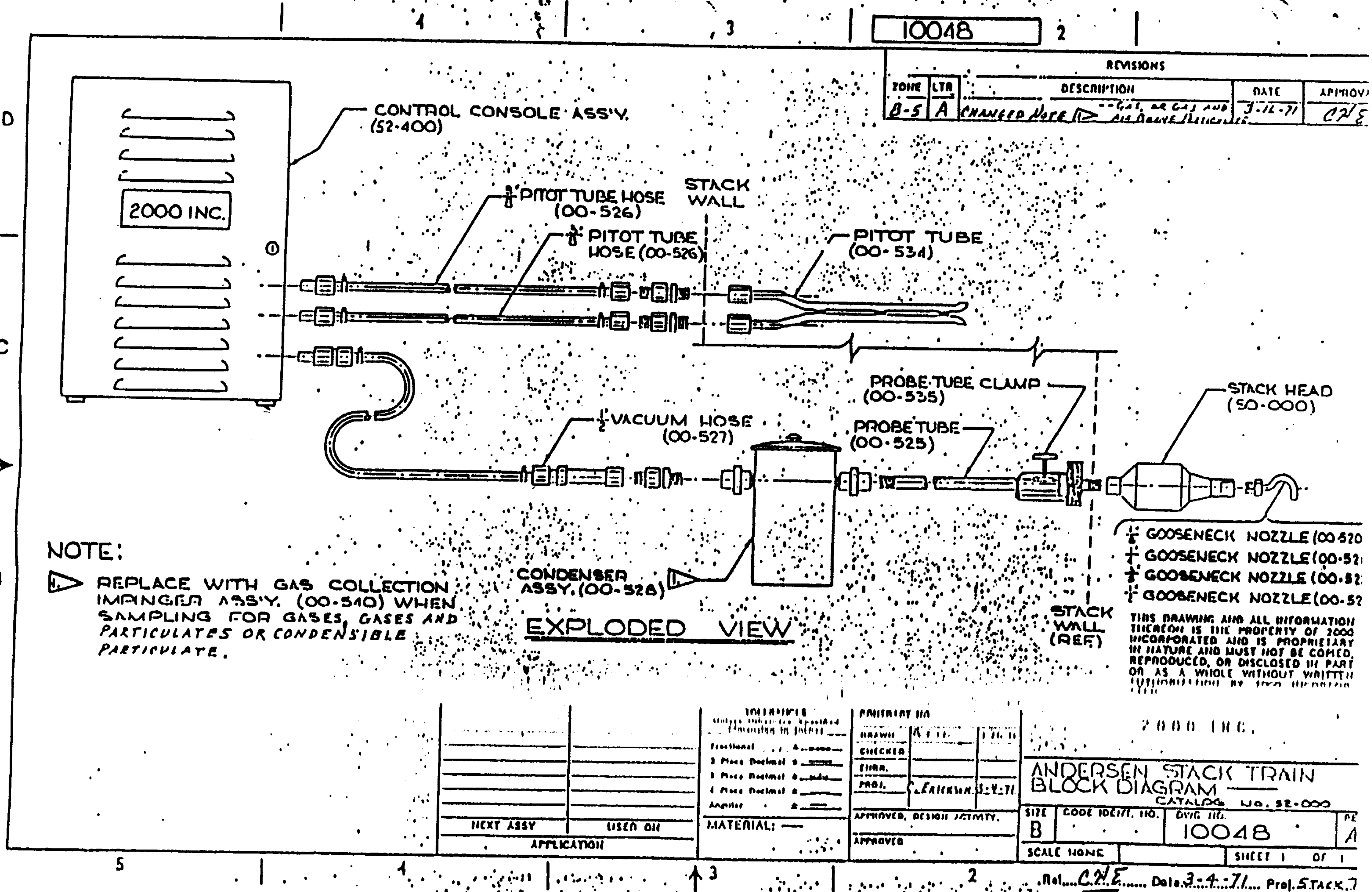
The sampling site selected must be able to safely accommodate two men during the taking of velocity, temperature, and humidity measurements in addition to collecting the samples. A probe tube clamp is provided in the Andersen Sampling Train to hold the stack head, probe tube, and condenser in place. The clamp has a standard 3 inch pipe thread for easy insertion into the access hole. When sampling for non-condensible particulates only, the probe tube may be screwed into the condenser for the removal of entrapped water. In this manner, the impinger may be eliminated entirely from the sampling apparatus. Whenever sampling for particulates and gases simultaneously, four Greenburg-Smith impingers in an ice bath will replace the condenser. Provisions are made so that the impinger case may be used with a rail. If a rail is not used to support the impinger case, a teflon-lined heated hose connecting the probe tube to the inlet part of the impinger case so that the case can be placed on the platform or ground could be used. In this manner, the temperature of the sample gases would be maintained above the dew point to prevent condensation upstream from the impinger case. The impinger case will replace the condenser also whenever one is concerned with collecting condensible particulates.

2.0 EQUIPMENT (SEE DRAWING 10048)

2.1 ANDERSEN STACK SAMPLING HEAD

The Andersen Stack Sampling Head consists of a stainless steel case and 1/2" female pipe fittings. It is designed to be inserted directly into the stack (standard 3 inch opening) where high temperature and/or corrosive conditions may exist.

The Sampler contains nine jet plates each having a pattern of precision-drilled orifices. The nine plates, separated by 2.5 millimeter stainless steel spacers, divide the sample into eight fractions or particle size ranges. The jets on each plate are arranged in concentric circles which are offset on each succeeding plate. The size of the orifices is the same on a given plate, but is smaller for each succeeding downstream plate. Therefore, as the sample is drawn through the Sampler


10048
REVISIONS
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CHANGED NOTE
CONTROL CONSOLE ASS'Y. (52-400)
2000 INC.
3/8 PITOT TUBE HOSE (00-526)
3/8 PITOT TUBE HOSE (00-526)
STACK WALL
PITOT TUBE (00-534)
PROBE TUBE CLAMP (00-535)
PROBE TUBE (00-525)
1/2 VACUUM HOSE (00-527)
STACK HEAD (50-000)
GOOSENECK NOZZLE
GOOSENECK NOZZLE
GOOSENECK NOZZLE
GOOSENECK NOZZLE
CONDENSER ASSY. (00-528)
STACK WALL (REF)
EXPLODED VIEW
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at a constant flow rate, the jets of air flowing through any particluar plate direct the particulates toward the collection area on the downstream plate directly below the circles of jets on the plate above. Since the jet diameters decrease from plate to plate, the velocities increase such that whenever the velocity imparted to a particle is sufficiently great, its inertia will overcome the aerodynamic drag of the turning airstream and the particle will be impacted on the collection surface. Otherwise, the particle remains in the airstream and proceeds to the next plate. Since the particle deposit areas are directly below the jets, seven of the plates act as both a jet stage and a collection plate. Thus, No. 0 plate is only a jet stage and No. 8 plate is only a collection plate. The types of plates available are stainless steel and nickel-plated brass. The case is made of 304 stainless steel. The temperature limitation of the Sampler is approximately 1500 degrees fahrenheit with the stainless steel plates.

The Andersen Stack Sampler has been calibrated by several independent laboratories in order to arrive at the current respective size cuts for each stage. The calibrations were referenced to unit density (1 g/cc), spherical particles so that the aerodynamically equivalent sized particles collected on each stage are always identical for any given flow rate. For this reason, a stack sample containing a mixture of shapes and densities is fractionated and collected according to its aerodynamic characteristics and is aerodynamically equivalent in size to the unit density spheres collected on each specific stage during calibration. For example, consider a golf ball and ping-pong ball of identical shape and physical size. Undoubtedly, they will not behave similarly in any environment because of the large differences in density. In other words, the aerodynamic size of a particle gives information relating to the physical size, shape, and density of the particle and indicates how the particle will behave in any environment. If the aerodynamic size distribution of the particulates in a stack sample is known, then the following pertinent information can be determined:

1. Particle behavior after leaving the stack.
2. Approximate area of environmental deposition.
3. Probable point of respiratory deposition.
4. Type of control equipment needed to collect the particles.

This type of information is impossible to obtain with only physical sizing data which is normally obtained by means of microscopic sizing or wet and/or dry screening.

Figure 1 is a plot of D_p' versus flow rate through the Stack Sampler at 70° F. D_p' is the effective aerodynamic diameter of a spherical, unit density particle. The efficiency of collection for polydisperse material as encountered under actual stack sampling conditions for any given effective cutoff diameter (ECD) is 95 plus percent.*

Figure 2 shows the correction factor for determining the physical diameter of spherical particles having other than unit density. Extreme caution should be exercised

*In Figure 1 it can be seen that the ECD for Stage 4 at 0.8 cfm is 2.0 microns (μ). For data presentation purposes, this means that essentially all of the 2.0 μ particles are separated by Stage 4 and collected on Stage 5. In reality, however, a small amount of the 2.1 μ particles that should be on Stage 5 pass on through to Stage 6. Likewise, a compensating small amount of the 1.9 μ particles that should be on Stage 6 land on Stage 5. The same correlation applies to the 2.2 μ and 1.8 μ particles, etc. In other words, the amount of overlapping on each stage is self-compensating.

Figure 1. Aerodynamic Diameter V[illegible]w Rate through Andersen Stack Sampler

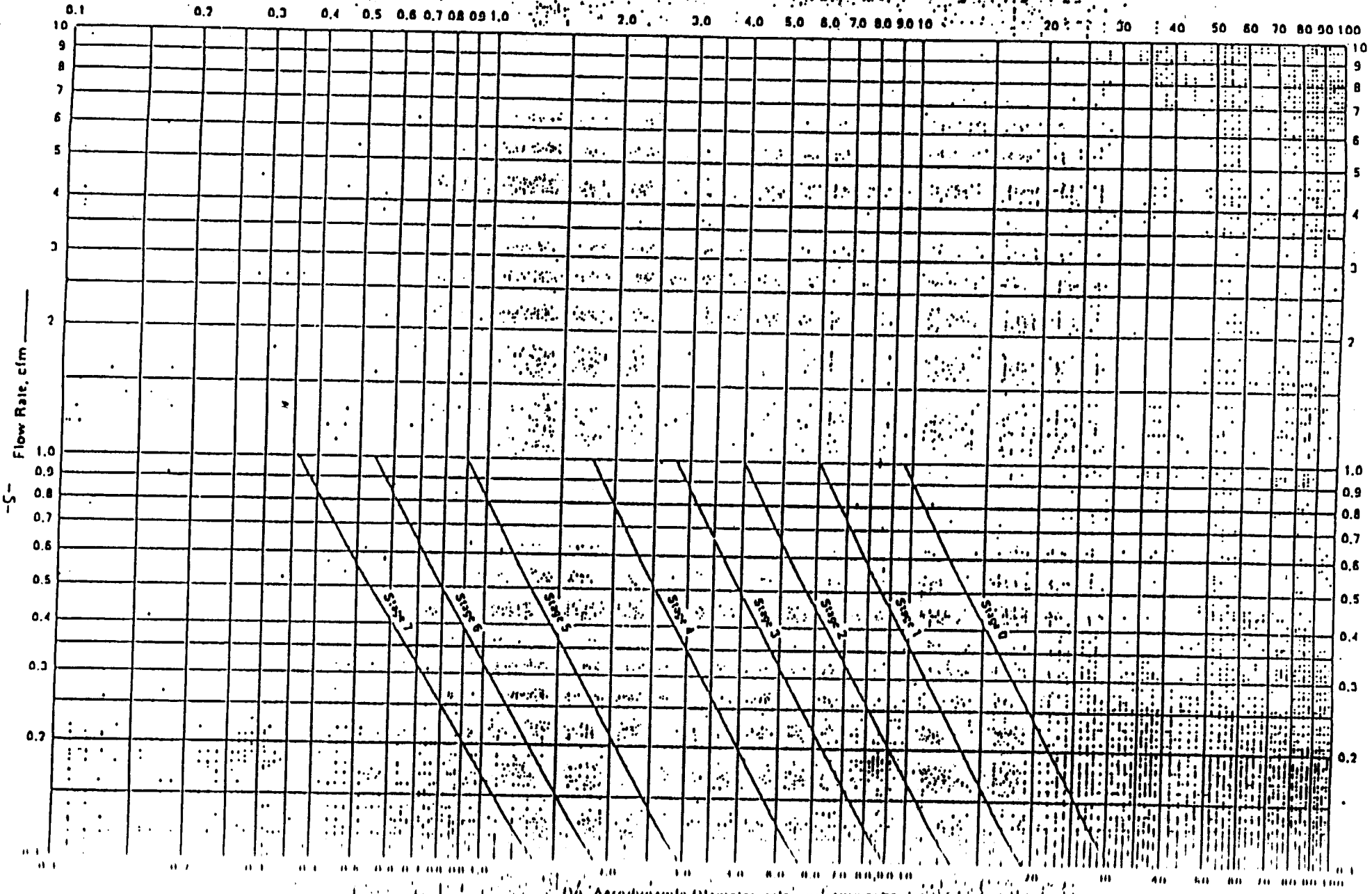


Figure 2. Density Correction Factor for Physical Size of Particles Captured in Andersen Stack Sampler

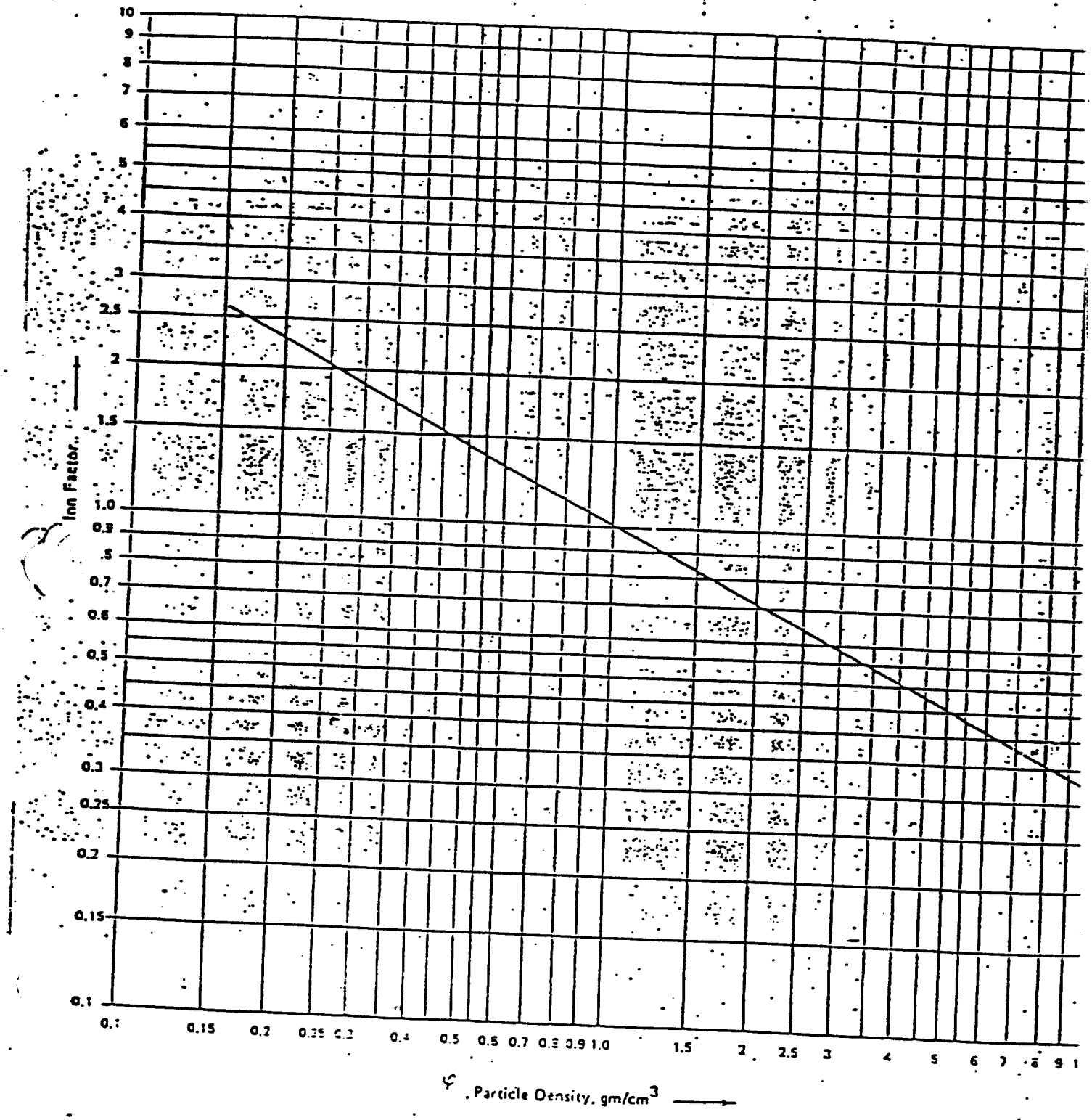
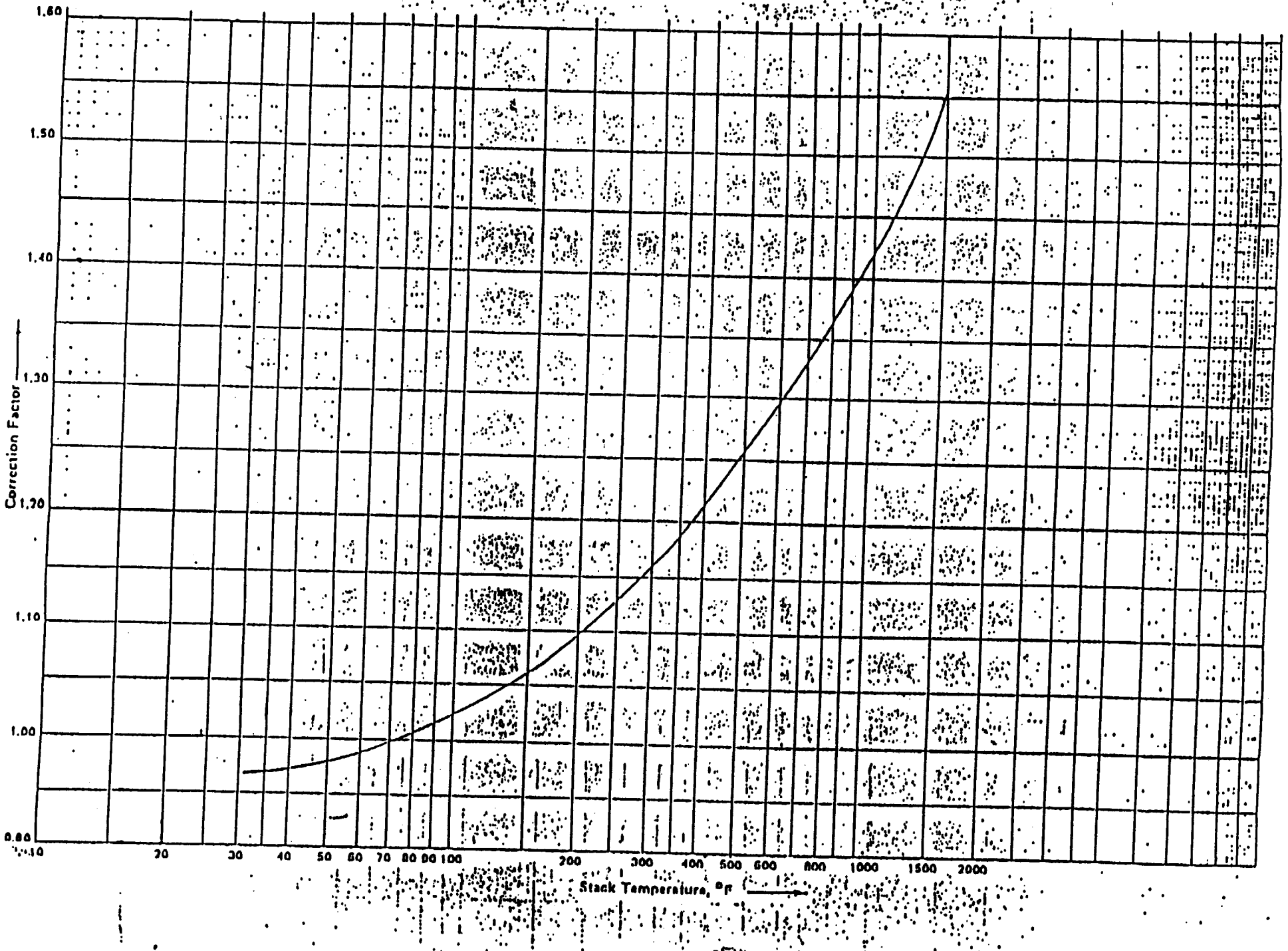


Figure 9. Temperature ... Factor for Aerodynamic
Size of Particles Capt... ...ndersen Stack Sampler



when using Figure 2 because it is valid only if the assumption is made that the particles are spherical in shape. Normally this assumption is not valid. Multiply the effective aerodynamic diameter as determined from Figure 1 by the correction factor from Figure 2 to determine the physical diameter for that density.

Figure 3 shows the correction factor for determining the effective aerodynamic particle diameter for elevated temperatures. Multiply the effective aerodynamic diameter as determined from Figure 1 by the correction factor from Figure 3 to determine the diameter for that temperature.

3.3 END-TO-END CALIBRATION

Before actual sampling is begun, it is strongly recommended that an end-to-end calibration be performed at ambient conditions with a dry gas meter which has already been calibrated against a primary standard. As is, the flowmeter provides 95% accuracy for full scale reading; however, this accuracy will decrease at lower flow rates. For this reason, an end-to-end calibration at 3 or 4 points with a dry gas meter will provide extremely accurate flow information at any desired flow rate and can be accomplished in 10 - 15 minutes. Simply plot Flow Rate (as determined with the dry gas meter and stop watch) vs. flowmeter reading. Draw a line through the points and in this manner accurate, instantaneous flow measurements at any rate can be accomplished with only the flowmeter during actual stack sampling. The above calibration to be performed as quickly as possible to avoid any collection in stack head.

4.0 STACK SAMPLING PROCEDURE

Stack Sampling is simple in principle, but in practice it is complicated by the need to ensure that the collected particulates are representative of the particulates flowing at any one sampling point and also at all possible points in the cross section of the flue at the sampling position. The first requirement is satisfied by isokinetic sampling in which the inlet sampling nozzle velocity is equal and in the same direction as the flue gas velocity. The weight of particulates collected is then equal to the weight of particulates flowing through an area in the flue equal to the area of the sampling nozzle. If sampling is not isokinetic, the gas flow lines are disturbed by the presence of the nozzle and either too few or too many particles are collected.

The second requirement, ensuring that the sample is representative of the average particle flow past the sampling position, presents no problem when the distribution of solids flow is uniform over the area of the flue. Samples taken at all points will be identical and any chosen point will give a representative sample. The weight of solids E passing through the flue per unit time is then found by multiplying the weight w/t collected per unit time at the sampling point (w being the weight collected during the time t) by the ratio of the area A of the flue to the area a of the nozzle:

$$E = \frac{w}{t} \cdot \frac{A}{a}$$

However, the particulates are not usually distributed uniformly over the cross-sectional area of the flue and it is necessary to collect the sample in increments taken separately at each point and the average weight calculated from the separate observations, which is called incremental sampling. Or a single gross sample may be collected by moving the sampling nozzle from point to point which is called cumulative sampling. The incremental method is recommended for the beginner because it is easier to spot mistakes. Also, it is preferred by research investigators and is recommended for those who require the best accuracy because it gives information on the reliability of the average. The cumulative method may be slightly quicker and may be preferred by those doing routine testing not requiring the highest degree of accuracy. Incremental sampling is recommended when using the Andersen Stack Sampler. The cumulative method may be used on occasion and will be discussed later.

The accuracy of the measurements is dependent upon the proper choice of sampling points. The area of the flue is divided into a number of imaginary equal areas and the sample is made up of increments taken from the center point of each area. The greater the number of areas (greater number of sampling points) the more accurate the measurement will be.

In a circular duct, a traverse is made by dividing the duct into equal concentric areas and sampling in the center of each area on four sides of center. No sample is taken in the exact center. The number of equal areas chosen depends on the size of the duct and the accuracy desired. In a rectangular duct, a sample traverse is made by dividing the duct into equal areas and sampling at the center of each area. The number of areas used depends on the flow pattern and size of the duct. See Figure 4 for drawings and tables.

The Andersen Stack Head should be kept clean and assembled when not in use. Before using, examine the jet plates by holding them up to the light. If any hole is plugged, blow out with air or wash with a detergent-water solution and sponge. Rubbing back and forth across the holes usually suffices. The quickest and most economical way for cleaning the jet plates is to place the plates in an inexpensive ultrasonic cleaner with a solvent for a few seconds after each use to insure that the orifices are clean.

Under normal conditions, the orifices do not become plugged if proper sampling and handling techniques are followed. After the plates are cleaned, avoid touching the orifices to prevent oil and/or dirt from plugging the jet holes. If this precaution is taken, there are only two other causes of hole plugage: (1) collecting too much sample and (2) collecting a sample when the stack head temperature is below the dew point of the flue gases so that condensation occurs. These problems are easily eliminated by taking a sample of proper size and ensuring that the stack head temperature is maintained above the dew point during the sampling period.

With the jet plates in proper sequence, the sampler is ready to operate on the end of the probe tube. The appropriate nozzle is attached to the inlet end of the sampler to achieve the desire isokinetic sampling rate. The zero numbered plate is on the upstream end of the stack head followed by plates 1 through 8 respectively. Downstream from Stage 8 a backup filter and filter holder may be inserted if there is sub-micron material in the stack sample below the lower limit of the last collection stage. Glass fiber webs are recommended as backup filters if elevated stack gas temperatures are encountered.

The sampling head will operate efficiently in any position such as vertical or horizontal. Ideally, the collection head should be used with a straight inlet nozzle and an elbow on the downstream end connecting to the probe tube. This arrangement will work with any thin-walled stack (such as metal) and eliminates the possibility of particles being impinged in any bends or probe lines. If it is necessary to sample a thick-walled stack (such as brick) it will be impossible to insert the right angled elbow through a three inch sampling hole. In this case, the stack head will have to be connected in line with the probe tube and a standard gooseneck nozzle used.

After determining the average velocity pressure along the sampling line, the stack gas temperature is measured and the gas density is calculated. If the stack gases contain an appreciable amount of water vapor, a significant error will result if

not taken into consideration. With this data, the flue gas velocity is determined which also is the required inlet nozzle velocity. Choose the appropriate nozzle size to give the approximate velocity required for the flow range that is available. Then calculate the needed flow rate through the stack head at stack conditions (temperature and pressure) to give the correct nozzle velocity. $Q = AV$

Where: Q = actual flow rate in cubic feet per minute.
A = Area of the nozzle in square feet.
V = Velocity in feet per minute.

Next, determine what flow rate is needed through the flowmeter at flowmeter conditions to give the required flow rate through the stack head at stack conditions.

EXAMPLE:

Cross Section Traverse

VP	$\sqrt{VP}$
.20	.448
.18	.424
.17	.413
.23	.480
.25	.500
.24	.491
.28	.530
.17	.413
.25	.500
.26	.510
.26	.510
.25	.510
.26	.510
.24	.491
.24	.491
.22	.470
.21	.459
	8.150

Stack Temperature = 1115° F
Barometric Pressure = 26.0" Hg
Stack gases are dry.
Stack gas density at 32° F and 29.92" Hg = 0.0807 lbs/cu. ft.
VP = velocity pressure in inches of water
W = stack gas density in lbs/ft^3

$$\text{Average } \sqrt{VP} = \left(\frac{8.150}{17}\right)^2 = 0.230$$

$$\text{Stack gas density} = 0.0807 \times \frac{26.0}{29.9} \times \frac{460 + 32}{460 + 1115} = 0.0310 \text{ lbs/cu. ft.}$$

$$\text{Stack gas velocity} = 18.27 \sqrt{\frac{VP}{W}} = 18.27 \sqrt{\frac{.230}{.0310}} = 49.8 \text{ feet per second}$$

$$= 49.8 \times 60 = 2988 \text{ feet per minute (fpm)}$$

Therefore, we need 2988 fpm inlet nozzle velocity.
1/4 inch nozzle area = 0.000341 ft^2

$$Q = AV = (0.000341)\ (2988) = 1.02 \text{ cfm}$$

We need 1.02 cfm through the stack head at 1115° F and 26.0 inches Hg. At the flowmeter the pressure is 26.0" Hg since it is downstream from the vacuum pump and exposed to the atmosphere. The flowmeter temperature is 85° F. Therefore, we need

$$Q \times \frac{460 + 85}{460 + 1115} = 0.353 \text{ cfm}$$ at the flowmeter to give the desired inlet nozzle velocity for isokinetic sampling.

If the velocity profile along the sample line is relatively flat (<15%) or if all of the particulates are 5 microns or less in size, then cumulative sampling may be performed without introducing significant errors (see Figure 5 for correcting to isokinetic rate). However, if the velocity profile is not uniform or if the particle size spectrum goes above 5 microns, then incremental sampling is recommended. This requires a clean set of plates at each point with a different flow rate to maintain isokinetic sampling. An alternate technique is to change nozzle diameters at the various sampling points while keeping the flow constant to adjust the inlet nozzle velocity. It is imperative that the flow rate does not change significantly while collecting a sample on a particular set of plates; otherwise, the particle size range collected on each plate will shift an unacceptably large amount with the changing flow rate.

Whenever collecting a sample, always turn the inlet nozzle away from the oncoming gas stream until the vacuum source is applied. At the same instant the pump is turned on, the sample nozzle may be turned into the oncoming flue gases. Also turn the inlet nozzle away from the oncoming gases as the pump is turned off. If the pump is turned on or off with the inlet nozzle facing the oncoming particulates, an error in collected sizes on each stage will be introduced. Before sampling, however, the pump should be turned on with the stack head out of the flue and the flow rate adjusted to the desired valve as read on the flowmeter.

A unique feature of the Andersen Stack Sampler is that there is always a constant pressure drop across the entire system. Therefore, once the proper flow rate is adjusted, it will not change during the sampling period. This is particularly useful when sampling wet plumes. The Andersen Stack Sampler may be inserted directly into plumes saturated with water. The only point to keep in mind is that the stack head temperature must be maintained above the dew point to allow collection of dry samples on the plates with the vaporized water condensing out downstream in the condenser or impingers. An easy way to effect this is to wrap a constant temperature heat tape around the stack head and probe line. It will take 5 - 10 minutes for the stack head temperature to reach equilibrium. Of course, the gas temperature in the stack head must be monitored for flow rate determinations.

Good weighing accuracy is of primary concern during gravimetric analyses and is determined by the ratio of the quantity of sample collected to the sensitivity of the balance being used. A balance with four decimal place reading and sensitivity of 0.10 milligram is recommended. Normal samples vary from one to 10 milligrams per plate. Stage loadings in excess of 10 milligrams are not recommended because of re-entrainment problems.

Only with experience can an operator determine the optimum sampling time for a specific grain loading situation. The deposit areas should be discrete and there should be no material deposited between the sample piles which would indicate oversampling.

It is also suggested that tare weights be made on the plates after chemical and/or physical analyses and the plates have been cleaned. This eliminates the possibility of a change in tare weight taking place during the sampling period whenever sampling in hot and corrosive gases.

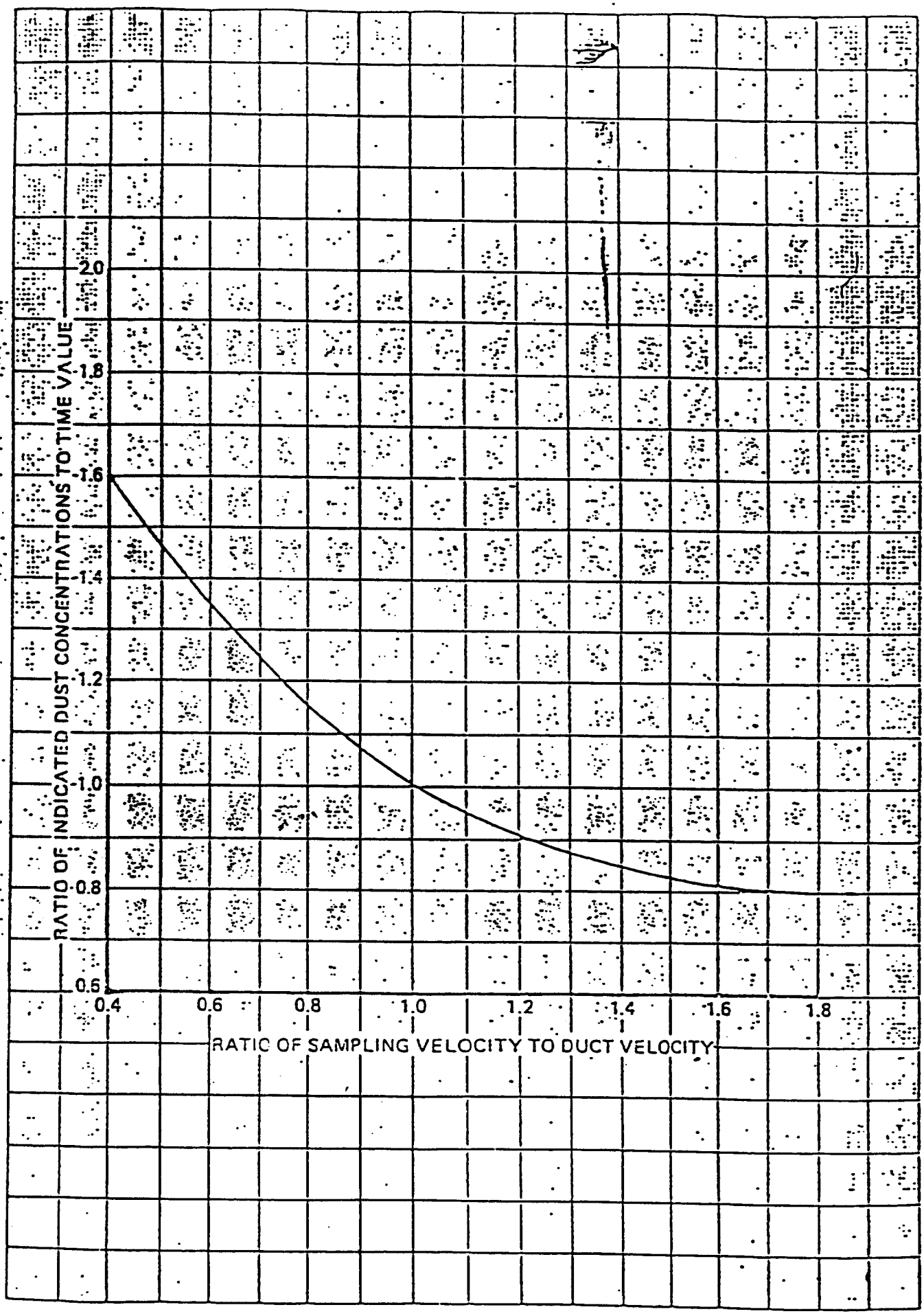

RATIO OF INDICATED DUST CONCENTRATIONS TO TIME VALUE
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
RATIC OF SAMPLING VELOCITY TO DUCT VELOCITY

FIGURE 5

Some types of material become charged when passing through the orifices on the lower stages resulting in part of the sample adhering to the bottom side of the plates. This problem is easily remedied simply by grounding the probe line.

Whenever sampling for gases and/or condensible particulates, it is necessary to rinse the sampling train after the sampling is complete. Distilled water may be used as a wash for inorganic material. Organic constituents may be rinsed with acetone or another suitable organic solvent. The rinsing material should be poured into a beaker and retained for analysis.

When sampling for particulates only, the first two impingers are filled with exactly 250 and 150 ml of deionized water respectively. The quantity of water vapor in the stack can be determined by subtracting these initial volumes from the final volume. When sampling for a specific gas, the first impinger is left dry and the second is filled with 150 ml of the appropriate reagent. A precise volume is critical since condensation may occur in this impinger.

The third and fourth impingers trap any moisture leaving the first two impingers. The silica gel must be precisely weighed, as the difference in its weight after sampling will have to be taken into account.

To determine the weight of soluble and insoluble solids from the liquid impingers it is necessary to evaporate the liquid in a tarred beaker. Then re-weigh the beaker to find total solids. If volatile organic particulate matter is collected, an extraction in some organic reagent such as chloroform or carbon tetrachloride is required. This reagent is then evaporated with a stream of dry air in a pre-weighed beaker and the difference in beaker weight before and after evaporation is the organic's weight.

The total weight of particulate matter collected is the sum of the aqueous and solvent residues.

5.0 DATA PRESENTATION

To determine the concentration of particulates for any specific size or size range first calculate the percentage of total particles for each stage. Then the cumulative percentage is determined beginning with either end of the impactor. Thus, if one starts with the first stage, 100% of the particles will be above 0 microns, some lesser percentage above the last stage, a lesser percentage yet above the next to last stage and so on.

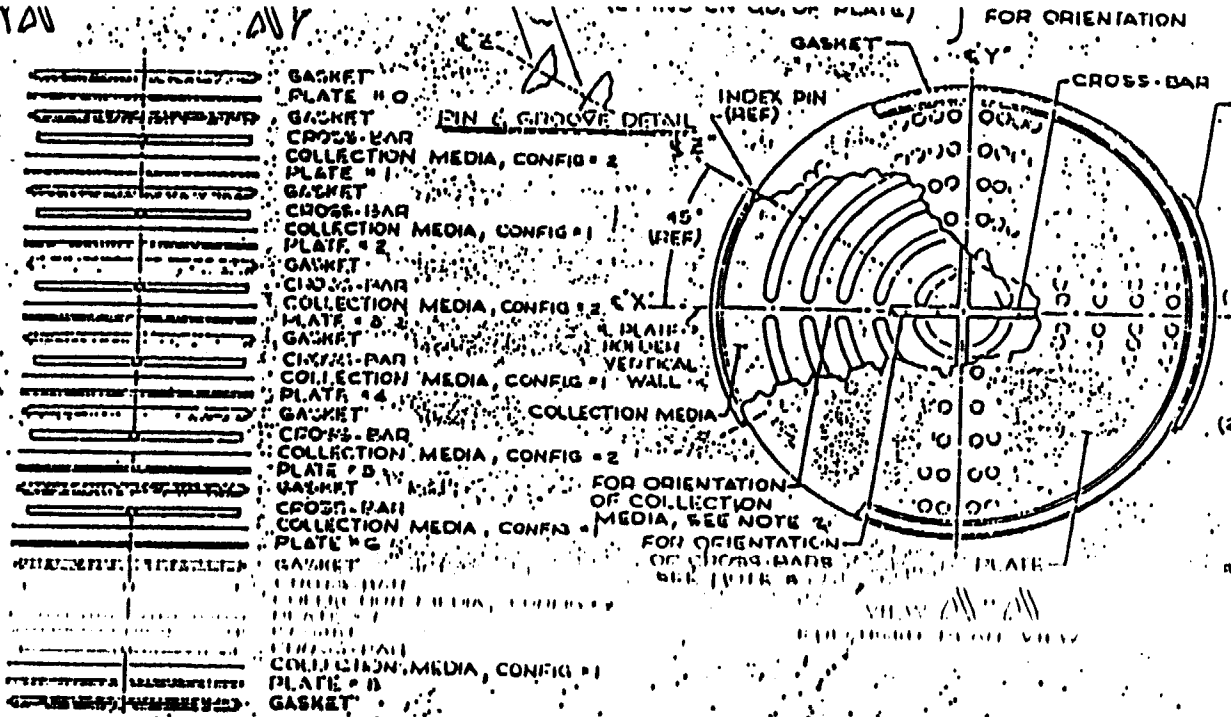
Plot the cumulative percentage determined above against the corrected aerodynamic diameter of the particles corresponding to the same stage. Draw a smooth curve connecting the points. The curve will be hyperbolic in shape if standard arithmetic graph paper is used or a straight line will result if probability logrithmic graph paper is used. It is not uncommon for the curves to contain bulges whenever abnormal distributions occur. From the graph the particle concentration for any size range can be determined. Following in Table No. 1 and Figure 6 data from an actual sample is shown. Approximately 55% of the particles are below 0.59 microns. 100% of the particles are below 15.0 microns.

1. Personal communication, Dr. Andrew McFarland, University of Notre Dame, South Bend, Indiana - 1971.

Particle Diameter - Microns
KEUFFEL & ESSER CO.

TABLE 1

Plate	Tare (g)	Final (g)	Net (mg)	%	Cum. %	ECD (Microns)
1	20.48484	20.48628	1.34	13.4	100.0	15.0
2	21.38338	21.38394	.56	5.6	86.7	9.5
3	21.92025	21.92066	.41	4.1	81.1	6.3
4	21.55775	21.55817	.42	4.2	77.0	4.4
5	11.40815	11.40854	.39	3.9	72.8	2.86
6	11.61862	11.61961	.99	9.9	68.9	1.43
7	11.76540	11.76664	1.24	12.4	59.0	.87
8	20.99617	20.99737	1.20	12.0	46.6	.59
Back Up Filter	0.20810	0.21156	3.46	34.6	34.6	
		Total	10.01			



NOTES:

ORIENTION OF ALL PLATES No. 0 THRU 8, CROSS-BARS AND COLLECTION MEDIAE MUST BE AS SHOWN IN VIEW A-A & AS NOTED BELOW

(1) INDEX PIN IN PLATE No. 0, AND INDEX GROOVE IN PLATE No. 1 THRU 8 MUST ALL BE ORIENTED ON SAME ℄ ℄

(2) COLLECTION MEDIA MUST BE ORIENTED WITH RADIAL SPOKES CENTERED ON ℄"X" AND ℄"Y", TYPICAL FOR ALL COLLECTION MEDIAE.

NEXT ASSY	USED ON	APPLICATION	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES Fractional ± 2 Place Decimal ± 3 Place Decimal ± 4 Place Decimal ± Angular ±		MATERIAL: STAINLESS STEEL	
CONTRACT NO.			
DRAWN			
CHECKED			
ENGR.			
PROJ.			
APPROVED, DESIGN ACTIVITY			
APPROVED			

2000 INC.

Salt Lake City, Utah

STACK SAMPLER - HI-VOL PLATES INSTRUCTION DRAWING

SIZE	CODE IDENT. NO.	DWG NO.	REV.
C	51125	10	S

SCALE: | SHEET 1 OF 1

APPENDIX D

CALIBRATION DATA

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

For the calibration of Entropy's dry gas metering systems, the protocol proposed in the Federal Register Vol. 47 No. 195, Thursday, October 7, 1982 is followed. Standard transfer meter number 1017057 (standard meter used for calibrating field metering systems) was calibrated with a spirometer at seven different flow rates between 0.25 and 1.40 cfm. Triplicate calibration runs were performed at each flow rate.

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 five 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 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.

Dry Gas Meter Identification: 1017057 Calibration by: Bruce Hawks

Date: 8/10/84 Barometric Pressure (P_b): 29.70 in. Hg

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

ENTROPY ENVIRONMENTALISTS, INC.

Approx. Flow Rate (Q) cfm	Spirometer #2502 Gas Volume (V_s) ft^3	Spirometer #2502 Temp. (t_s) °F	Dry Gas Meter Gas Volume (V_{ds}) ft^3	Dry Gas Meter Temp. (t_{ds}) °F	Pressure (Δp) in. H_2O	Time (θ) min.	Flow Rate (Q) cfm	Meter Meter Coeff. (Y_{ds})	Avg. Meter Coeff. ($\bar{Y}_{ds}$)
0.25	2.550	73.4	2.554	76	-0.23	9.657	0.2594	1.0039	
	2.368	73.4	2.371	76	-0.22	9.170	0.2536	1.0041	
	2.468	77	2.486	77	-0.20	10.008	0.2406	0.9933	
0.40	3.962	73.4	3.999	75	-0.43	9.958	0.3908	0.9948	
	4.071	73.4	4.104	75	-0.43	10.033	0.3985	0.9960	
	4.089	73.4	4.118	76	-0.43	10.099	0.3977	0.9989	
0.60	5.993	75.2	6.090	77	-0.90	9.995	0.5869	0.9896	
	6.330	75.2	6.438	77	-0.95	10.001	0.6196	0.9889	
	6.330	76.2	6.435	77	-1.00	10.005	0.6193	0.9894	
0.80	7.933	73.4	8.046	76	-1.5	10.000	0.7792	0.9945	
	8.151	73.4	8.260	76	-1.6	10.001	0.8005	0.9956	
	8.188	73.4	8.302	76	-1.5	10.055	0.7998	0.9948	
1.00	9.153	75.2	9.298	76	-2.0	9.436	0.9495	0.9908	
	9.171	75.2	9.326	76	-2.0	9.460	0.9490	0.9898	
	9.126	75.2	9.304	76	-2.1	9.435	0.9468	0.9875	

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

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

Dry Gas Meter Identification: 1017057 Calibration by: Bruce Hawks

Date: 8/10/84 Barometric Pressure (P_b): 29.70 in. Hg

ENTROPY ENVIRONMENTALISTS, INC.

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

Approx. Flow Rate (Q) cfm	Spirometer		Dry Gas Meter		Pressure (Δp) in. H_2O	Time (θ) min.	Flow Rate (Q) cfm	Meter Meter Coeff. (Y_{ds})	Avg. Meter Coeff. ($\bar{Y}_{ds}$)
	Gas Volume (V_s) ft^3	Temp. (t_s) °F	Gas Volume (V_{ds}) ft^3	Temp. (t_{ds}) °F					
1.20	9.281	77	9.446	78	-2.7	8.239	1.0990	0.9910	
	9.608	77	9.807	78	-2.9	8.085	1.1594	0.9886	
	9.144	77	9.344	78	-3.1	7.636	1.1683	0.9880	
1.40	9.098	73.4	9.228	76	-3.7	6.831	1.3082	0.9999	
	9.135	73.4	9.267	76	-3.8	6.775	1.3243	1.0000	
	9.126	73.4	9.277	76	-3.9	6.776	1.3228	0.9982	
			$\bar{Y}_{DS} = 0.9942$						

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

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

CALIBRATION BY: MH

METER BOX NUMBER: N8

DATE: 7-27-85 BAROMETRIC PRESSURE (P_B): 29.64 IN. HG

*DATE: ________ *BAROMETRIC PRESSURE (P_B): ________ IN. HG

STANDARD METER NUMBER: [illegible]17057 COEFFICIENT (Y_{DS}): 0.9942

NOMINAL FLOW RATE ($\tilde{Q}$) CFM	STANDARD DRY GAS METER			METER BOX METERING SYSTEM		
	GAS VOLUME (V_{DS}) FT^3	TEMP. (T_{DS}) °F	TIME (θ) MIN.	ORIFICE SETTING (ΔH) $IN. H_2O$	GAS VOLUME (V_D) FT^3	TEMP. (T_D) °F
0.4	[illegible].165	69	10:00	0.50	4.248	89
	[illegible].238	69	10:00	.5	4.324	87
0.8	8.443	69	10:00	~~2~~.10	8.700	88
	8.475	69	10:00	2.1	8.742	90
1.2	2.765	69	10:00	4.80	13.107	86
	2.702	69	10:00	4.8	13.079	89

NOMINAL FLOW RATE ($\tilde{Q}$) CFM	METER BOX METERING SYSTEM			
	FLOW RATE (Q_D) CFM	ORIFICE FACTOR (OF)	COEFF. (Y_D)	$\Delta H@$ $IN. H_2O$
0.4	0.4093	3.043	1.0104	1.590
	.4164	3.038	1.0063	1.541
0.8	.8296	6.231	0.9943	1.628
	.8328	6.242	.9969	1.610
1.2	1.2543	9.403	.9876	1.634
	1.2482	9.429	.9904	1.641
	AVERAGE		0.998	1.61

$$\Delta H_{@} = \frac{0.0317 \cdot \Delta H}{P_b \cdot (t_d + 460)} \cdot \left[\frac{(t_{ds} + 4[illegible] \cdot \theta}{Y_{ds} \cdot [illegible]}\right]^2$$

$$Y_d = \frac{Y_{ds} \cdot V_{ds} \cdot (t_d + 460 [illegible]}{V_d \cdot (t_{ds} + 460) \cdot (P_b + [illegible].6)}$$

ENTROPY

CALIBRATION BY: MH

METER BOX NUMBER: N 12

DATE: 11-7-84 BAROMETRIC PRESSURE (P_B): 29.89 IN. HG

*DATE: _____ *BAROMETRIC PRESSURE (P_B): _____ IN. HG

STANDARD METER NUMBER: 1017057 COEFFICIENT (Y_{DS}): 0.9947

NOMINAL FLOW RATE ($\tilde{Q}$) CFM	STANDARD DRY GAS METER			METER BOX METERING SYSTEM		
	GAS VOLUME (V_{DS}) FT³	TEMP. (T_{DS}) °F	TIME (θ) MIN.	ORIFICE SETTING (ΔH) IN. H_2O	GAS VOLUME (V_D) FT³	TEMP. (T_{DS}) °F
0.4	4.128	66	10.0	.5	4.163	79
	4.109	67	10.0	.5	4.226	91
0.8	8.286	67	10.0	2.1	8.531	92
	8.296	67	10.0	2.1	8.515	93
1.2	13.717	66	11.0	4.8	13.959	86
	12.460	66	10.0	4.8	12.744	91

NOMINAL FLOW RATE ($\tilde{Q}$) CFM	METER BOX METERING SYSTEM			
	FLOW RATE (Q_D) CFM	ORIFICE FACTOR (OF)	COEFF. (Y_D)	ΔH@ IN. H_2O
0.4	.4114	3.003	1.0090	1.616
	.4087	3.036	1.0095	1.602
0.8	.8242	6.238	1.0063	1.651
	.8252	6.233	1.0112	1.644
1.2	1.2427	9.364	1.0023	1.678
	1.2417	9.407	1.0064	1.666
	AVERAGE		1.007	1.64

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

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

CALIBRATION BY: FREDDY JONES | METER BOX NUMBER: N-12

DATE: 10/6/85 | BAROMETRIC PRESSURE (P_B): 29.55 IN. HG

*DATE: _____ | *BAROMETRIC PRESSURE (P_B): _____ IN. HG

STANDARD METER NUMBER: 1017067 | COEFFICIENT (Y_{DS}): 0.9924

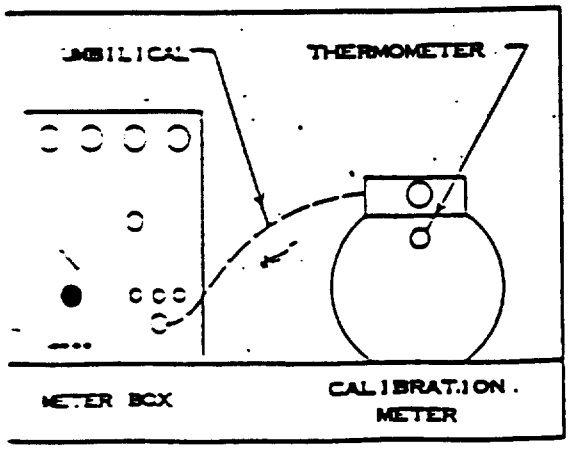
POST-TEST METER BOX CALIBRATION

	STANDARD DRY GAS METER			METER BOX METERING SYSTEM		
NOMINAL FLOW RATE ($\tilde{Q}$) CFM	GAS VOLUME (V_{DS}) FT^3	TEMP. (T_{DS}) °F	TIME (θ) MIN.	ORIFICE SETTING (ΔH) IN. H_2O	GAS VOLUME (V_D) FT^3	TEMP. (T_D) °F
	6.894	71	10.0	1.4	6.704	74
	6.893	71	10.0	1.4	6.777	79
	6.870	71	10.0	1.4	6.781	83
				VACUUM = 150 IN. Hg		

	METER BOX METERING SYSTEM			
NOMINAL FLOW RATE ($\tilde{Q}$) CFM	FLOW RATE (Q_d) CFM	ORIFICE FACTOR (OF)	COEFF. (Y_D)	ΔH@ IN. H_2O
	6.728	5.030	1.0256	1.688
	6.727	5.053	1.0229	1.673
	6.705	5.072	1.0264	1.672
	AVERAGE		1.024	1.68

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

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



SCHEMATIC OF EQUIPMENT SET-UP FOR FULL AND POST-TEST METER BOX CALIBRATIONS

CALIBRATION BY: MH

METER BOX NUMBER: RAC 1

DATE: 11-8-84 BAROMETRIC PRESSURE (P_B): 29.95 IN. HG

*DATE: _____ *BAROMETRIC PRESSURE (P_B): _____ IN. HG

STANDARD METER NUMBER: 1017057 COEFFICIENT (Y_{DS}): 0.9942

NOMINAL FLOW RATE ($\tilde{Q}$) CFM	STANDARD DRY GAS METER			METER BOX METERING SYSTEM		
	GAS VOLUME (V_{DS}) FT^3	TEMP. (T_{DS}) ^oF	TIME (θ) MIN.	ORIFICE SETTING (ΔH) IN. H_2O	GAS VOLUME (V_D) FT^3	TEMP. (T_{DS}) ^oF
0.4	4.023	66	10.0	.5	4.089	72
	4.004	66	10.0	.5	4.184	90
0.8	7.978	66	10.0	2.1	8.318	91
	9.607	66	12.0	2.1	10.040	96
1.2	11.933	66	10.0	4.8	12.175	84
	11.927	66	10.0	4.8	12.251	89

NOMINAL FLOW RATE ($\tilde{Q}$) CFM	METER BOX METERING SYSTEM			
	FLOW RATE (Q_D) CFM	ORIFICE FACTOR (OF)	COEFF. (Y_D)	$\Delta H@$ IN. H_2O
0.4	0.4017	2.980	0.9881	1.720
	0.3998	3.030	0.9936	1.680
0.8	0.7967	6.216	0.9936	1.774
	0.7994	6.244	1.0004	1.746
1.2	1.1916	9.337	0.9960	1.836
	1.1910	9.380	0.9985	1.821
	AVERAGE		0.995	1.76

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

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

ENTROPY

NOZZLE NUMBER: 104

Date	Initials	Dia. 1	Dia. 2	Dia. 3	Dia. 4	Dia. 5	Average
11-30-82	TWA	.243	.240	.241	.24	.242	0.241"
2-2-83	PLO	.244	.245	.246	.24	.244	0.245"
8-31-83	ST	.243	.244	.243	.243	.244	0.243"
3-8-84	JNC	.244	.245	.244	.245	.246	0.245"
7-5-84	TTM	.244	.244	.241	.24	.245	0.244"
3-28-85	JDE	.256	.257	.258	.25	.254	0.256"
7-30-85	JFJ	.249	.248	.248	.24	.249	0.248

NOZZLE NUMBER: 109

Date	Initials	Dia. 1	Dia. 2	Dia. 3	Dia. 4	Dia. 5	Average
11-30-82	TWA	.307	.307	.304	.305	.308	0.306"
8-31-83	ST	.302	.302	.305	.304	.303	0.303"
3-8-84	JNC	.307	.309	.307	.309	.309	0.308"
7-5-84	TTM	.310	.312	.312	.309	.310	0.311
3-26-85	JSE	.305	.307	.305	.309	.306	0.306"

NOZZLE NUMBER: 110

Date	Initials	Dia. 1	Dia. 2	Dia. 3	Dia. 4	Dia. 5	Average
11-30-82	TWA	.370	.372	.372	.370	.371	0.371"
8-31-83	ST	.371	.371	.370	.369	.370	0.370"
11-15-83	PLO	.374	.374	.372	.373	.375	0.374"
3/8/84	JNC	.370	.370	.372	.372	.371	0.371"
7-5-84	TTM	.374	.376	.374	.373	.374	0.374"
3-28-85	JOE	.372	.371	.369	.368	.370	0.370"

ENTROPY ENVIRONMENTALISTS, INC.

NOZZLE NUMBER: 303

Date	Initials	Dia. 1	Dia. 2	Dia. 3	Dia. 4	Dia. 5	Average
12-2-92	ST	.174	.170	.172	.171	.174	0.172
04-07-83	HEC	0.172	0.175	0.174	0.172	0.172	0.173
7-6-84	TTM	.173	.172	.173	.173	.172	0.173
10-23-84	ATM	.166	.167	.166	.169	.168	0.167
2-1-85	JSH	.169	.167	.169	.167	.166	0.168

NOTE: All diameters measured in inches.

ENTROPY ENVIRONMENTALISTS, INC.

NOZZLE NUMBER: 304

Date	Initials	Dia. 1	Dia. 2	Dia. 3	Dia. 4	Dia. 5	Average
12-2-82	ST	.244	.243	.242	.246	.244	0.244
04-07-83	MEC	0.244	0.247	0.244	0.245	0.243	0.245
4-26-83	PLO	.247	.247	.247	.248	.250	0.248
05-10-83	JNC	.249	.250	.250	.249	.249	0.249
7-6-84	TTM	.248	.250	.248	.249	.248	0.249
10-23-84	ATM	.242	.245	.244	.244	.243	0.244

NOTE: All diameters measured in inches.

ENTROPY ENVIRONMENTALISTS, INC.