Background Report Reference

AP-42 Section Number: 12.15

Background Chapter: 4

Reference Number: 16

Title: Source Sampling Report for Jonson Controls, Inc., Winston-Salem, NC

Environmental Testing

1988

A (C)

EVALUATOR: EBowen EVALUATION DATE: 8/4/92

METHOD 12: SECONDARY EMISSIONS TEST REPORT EVALUATION

STATE: NC FACILITY: Johnson Controls TEST DATE: _____

PROCESS(ES) TESTED: _____

SAMPLING DURATION 3
must have at least 3 runs, each ≥ 1 hour duration, with sampling ≥ 2 minutes at each traverse point, and total sampling volume ≥ 30 dscf

PRODUCTION RATE 3
is process or production rate during testing representative of normal rates

CONTROL DEVICE(S) 3
are devices described, and their efficiencies given

No controls

METHOD 1 3
are calculations accurate, and is figure provided

METHODS 2,3 3
are data and calculations included for gas velocity, cyclonic flow, and molecular weight determination, and is source of barometric pressure noted

METHOD 4 3
are data and calculations included for moisture content determination, and is moisture content realistic (< saturation)

dry wet/bulb method

FIELD DATA 3
is field data on standard forms, and does raw data correspond with printout

ISOKINETICS 3
within 100±10% for all runs

SAMPLING TEMPERATURE 3
both probe and filter must be maintained at 248 ± 25°F or other temperature specified in NSPS; temperature exiting last impinger ≤ 68°F

BACK-HALF 3
nitric acid used in first two impingers, silica gel in fourth
Use low metal glass filter okay for lead

EQUIPMENT 3
were a borosilicate glass probe liner and a quartz fiber filter used

CALIBRATION
were both pre- and post-test calibrations performed for:

meter box 3

pitot tube 3
S

temperature sensor 3

nozzle (3 #) 3

LEAK CHECKS 3
both pre- and post-test

BLANKS 3
were both filter and reagent blanks analyzed, and were any problems addressed

BOILER TESTS —
calculation of F_0 from Orsat accurate

Grid Casting ✓

AP-42 Section: Storage Battery Production (7.15) Ref #: 4

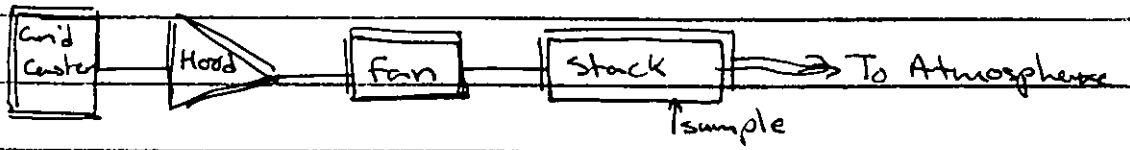
Date: 5/15/92 Rating:

Firm/Company: Johnson Controls, Inc. (Winston Salem, NC)

Tested By: Environmental Testing Inc.

Test Date: 12/10/87

Special Processes: Grid Caster #7 ; #8



Test Conditions: Usual ☒ Unusual ☐

Sampling Method: 17

Sampling Location and Velocity methods: 1 , 2

Calibration Information: Yes ☒ No ☐

Results:

Run	% Isokinetic		Emission Rate (lbs/hr	
1	97.61	99.61	4×10^{-4}	9×10^{-4}
2	96.35	98.11	13×10^{-4}	15×10^{-4}
3	96.12	97.4	6×10^{-4}	10×10^{-4}
4				
Avg:	96.76	98.371	7.67×10^{-4}	11.33×10^{-4}

Production Data: 38 pcs/5.4 hrs. (Line 7) // 72 pcs/7.8 hrs

Source: App. C

Emission Factors: #7 ; $\frac{7.67 \times 10^{-4} \text{ lb/hr}}{\frac{38}{5.4} \frac{\text{pcs}}{\text{hr}}} = 1.09 \times 10^{-4} \text{ lb/pcs} = 2.18 \times 10^{-3} \text{ lb/ton}$

#8 ; $\frac{11.33 \times 10^{-4}}{\frac{72}{7.8} \frac{\text{pcs}}{\text{hr}}} = 1.23 \times 10^{-4} \text{ lb/pcs} = 2.46 \times 10^{-3} \text{ lb/ton}$

* Check production data other data given in grids/day. - by

environmental testing inc.

CASTER #7 & #8

(L1)

SOURCE SAMPLING REPORT

FOR

JOHNSON CONTROLS, INC.

Winston-Salem, North Carolina

Performed by:
ENVIRONMENTAL TESTING, INC.
Charlotte, North Carolina

NORTH CAROLINA PROFESSIONAL SEAL 5178 ENGINEER J. S. McCORMACK

James S. McCormack, P.E.

December 1987

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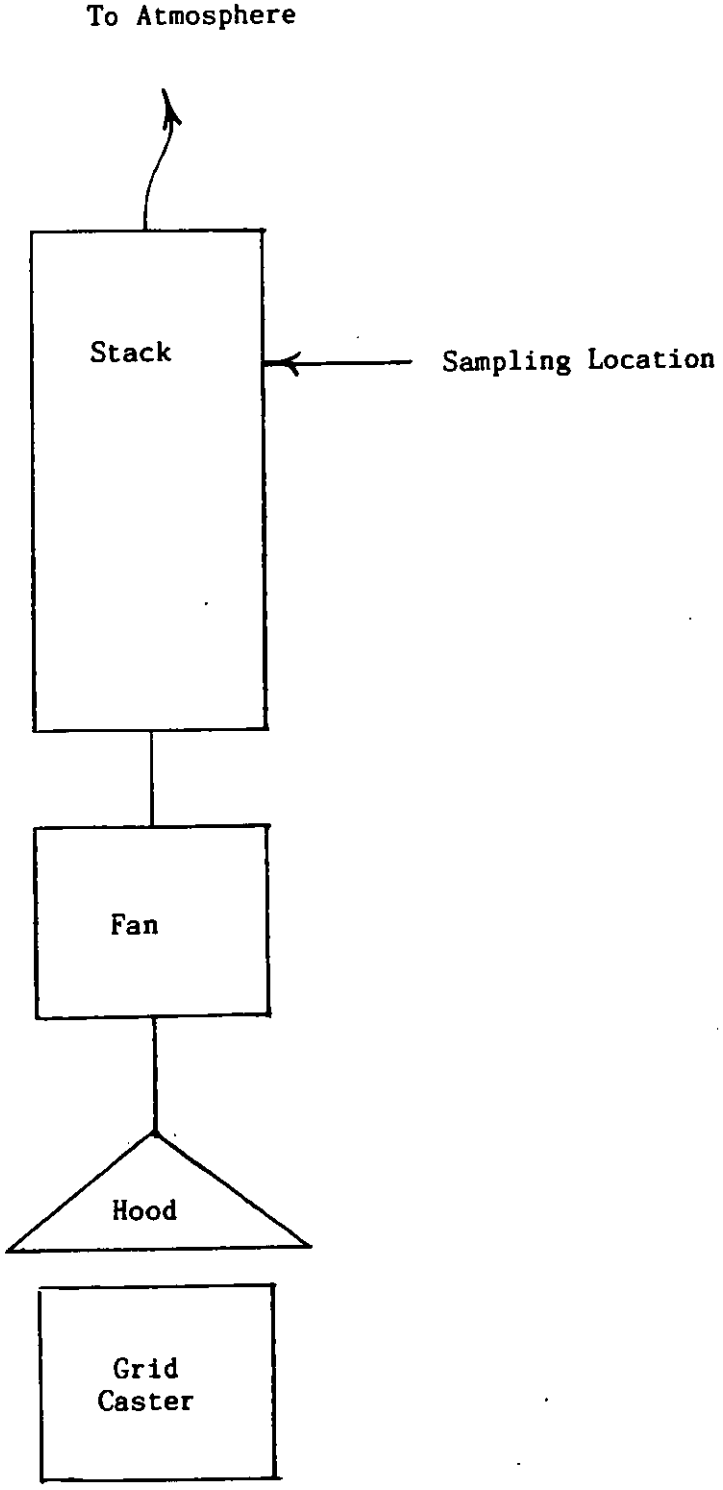
INTRODUCTION

Source sampling was performed for the Johnson Controls, Inc. Winston-Salem, North Carolina, plant to determine lead emissions from Grid Caster Number 7 and Grid Caster Number 8. Both stacks were sampled on December 10, 1987. Three sampling runs were made at each location. A typical sampling location is shown in Figure 1.

The measurements of stack gas flow rate and pollutant concentrations were made according to U.S. Environmental Protection Agency and the Forsyth County Department of Environmental Affairs (FCDEA) recommendations. Ms. Lili Choi, FCDEA, was present as an observer.

The following sections of the report treat the summary of results, the process and its operation, the location of the sampling points and the sampling and analytical procedures used.



FLOW DIAGRAM

NO. 7 and NO. 8 GRID CASTERS (typical)

Figure 1

SUMMARY OF RESULTS

Tables 1 and 2 presents the summary of results from the lead sampling. The mean lead concentration from Grid Caster Number 7 was 0.618×10^{-4} grains per dry standard cubic foot. The mean lead emission rate was 0.0008 pounds per hour. The mean lead concentration from Grid Caster Number 8 was 0.110×10^{-3} grains per dry standard cubic foot. The mean lead emission rate was 0.0011 pounds per hour.

The average visual emissions from each of the two stacks was less than 0.5%. At no time did any observed visual emissions exceed 5%. The field data sheets detailing the opacity readings can be found in Appendix B.

Based on the results of the particulate sampling and the visual emissions, the Johnson Controls, Inc. Winston-Salem, North Carolina plant was in compliance with the allowable emission rate as permitted by FCDEA for Grid Casters Number 7 and 8 which had an allowable emission rate of 0.000176 grains per dry standard cubic foot for each stack based on the regulations in 40CFR60, Subpart KK, "Standards of Performance for Lead-Acid Battery Manufacturing Plants," Section 60.372, Paragraph (1).

TABLE 1

SUMMARY OF RESULTS, LEAD SAMPLING

GRID CASTER NUMBER 7

Run Number	1	2	3
Date	12/10/87	12/10/87	12/10/87
% Isokinetic	97.81	96.35	96.12
Volume of Gas Sampled, SCF * Dry	45.452	46.246	45.528
Stack Gas Flow Rate, SCFM * Dry	1465.1	1513.3	1493.3
Stack Gas Flow Rate, ACFM	1845.7	1902.8	1878.8
Lead:			
Catch, mgrams	0.1050	0.298	0.1500
Concentration, grains/ SCF * Dry	0.0000356	0.0000992	0.0000507
Emission Rate, lbs/hr	0.0004	0.0013	0.0006

*68°F, 29.92 in. Hg
**Nozzle, probe, filter, impingers

TABLE 2

SUMMARY OF RESULTS, LEAD SAMPLING

GRID CASTER NUMBER 8

Run Number	1	2	3
Date	12/10/87	12/10/87	12/10/87
% Isokinetic	99.61	98.11	97.40
Volume of Gas Sampled, SCF • Dry	43.136	39.911	43.231
Stack Gas Flow Rate, SCFM * Dry	1206.0	1146.5	1236.1
Stack Gas Flow Rate, ACFM	1487.9	1412.5	1524.6
Lead:			
Catch, mgrams	0.2490	0.3880	0.2570
Concentration, grains/ SCF • Dry	0.0000889	0.000150	0.0000915
Emission Rate, lbs/hr	0.0009	0.0015	0.0010

*68°F, 29.92 in. Hg
**Nozzle, probe, filter, impingers

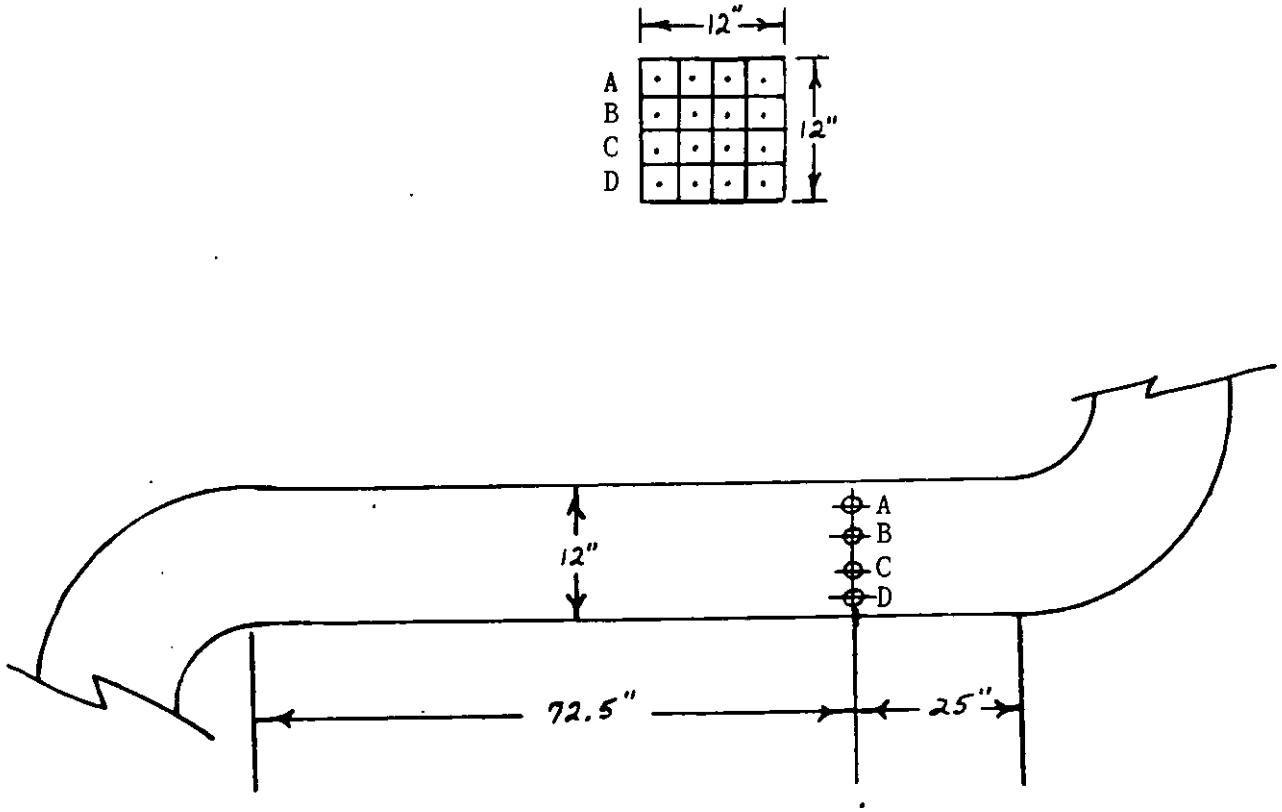
PROCESS DESCRIPTION AND OPERATION

The Johnson Controls, Inc. Winston Salem, North Carolina, plant has a grid casting operation that is typical. For Grid Casters Number 7 and 8 lead is melted in a pot and flows down runners to the grid casting operation. The combustion gases are exhausted to the atmosphere as shown in Figure 1. No control devices are employed in this process.

No unusual conditions were noted during sampling. The process was continuous and ran in a normal manner.

LOCATION OF SAMPLING POINTS

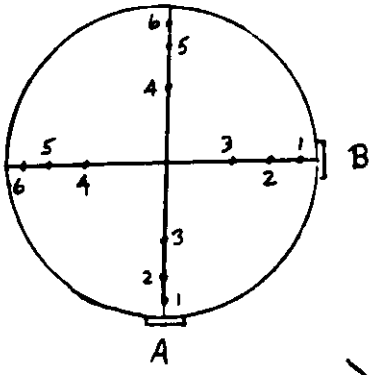
The dimensions of the stacks and the location of the sampling points are shown in Figures 2 and 3. The stack cross section for Grid Caster Number 7 was divided into 16 equal areas. The ports were labeled A,B,C, and D. Each point was sampled for a period of 4 minutes per point which yielded a total test time of 64 minutes per run. The stack cross section for Grid Caster Number 8 was divided into 12 equal areas. The ports were labeled A and B. Each point was sampled for a period of 5 minutes per point which yielded a total test time of 60 minutes per run. The number of sampling points was determined by the distance from the last disturbance in the gas flow as outlined in Method 1, Federal Register, Volume 48, No. 191, 30 September 1983.

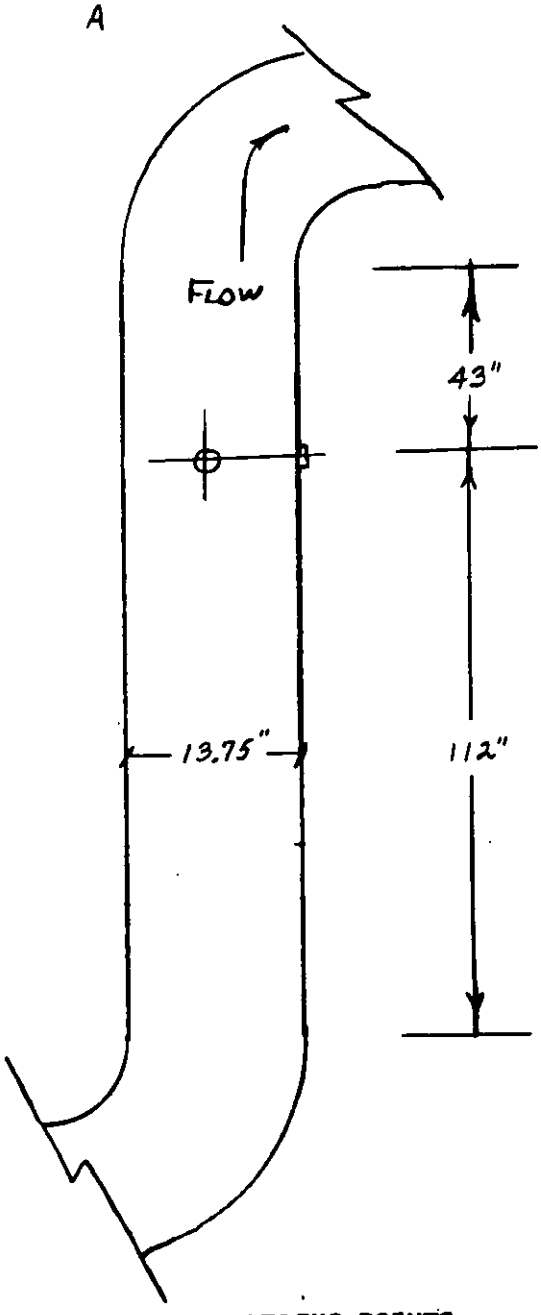


LOCATION OF SAMPLING POINTS

NO. 7 GRID CASTER

Figure 2





LOCATION OF SAMPLING POINTS

GRID CASTER NUMBER 8

Figure 3

SAMPLING AND ANALYTICAL PROCEDURES

All sampling and analytical procedures used were those recommended by the U.S. Environmental Protection Agency and the FCDEA. Complete details are found in Appendix E which is a copy of the Federal Register, Volume 42, Number 160, dated 18 August 1977, the Federal Register, Volume 48, No. 191, 30 September 1983, and the Federal Register, Volume 47, Number 74, 16 April 1982 and the Code of Federal Regulations, 40 CFR Ch. 1, Pt.60, App. A, dated 01 July 1986.

Sample point locations and velocity measurements were made by Methods 1 and 2. Gas composition was determined by Fyrite and Method 3 on continuous bag samples. Method 9 was used for the visual emissions. Method 12 was used for the lead concentration determination.

APPENDICES

Summary of Method 12 Lead Results

Johnson Controls Winston-Salem N.C. Grid Caster No. 7

Run Number		1	2	3
Date		12/10/87	12/10/87	12/10/87
DN	Sample nozzle dia., in.	0.302	0.302	0.302
TT	Net time of test	64	64	64
PB	Barometric pressure, in. Hg.	28.96	28.96	28.96
PM	Average orifice pressure drop, in. H20	2.020	2.173	2.134
VM	Volume of dry gas sampled, cu. ft. at meter conditions	50.87	52.67	51.88
TM	Average gas meter temp. in degrees F.	114.69	125.03	125.28
VMSTD	Volume of dry gas sampled at standard conditions*, SCF	45.452	46.246	45.528
VW	Total water collected in impingers + silica gel, ML.	17.6	16.3	16.0
VMV	Volume of water vapor at standard conditions*, SCF	0.829	0.768	0.753
PMV	Percent moisture by volume	1.791	1.633	1.628
MD	Mole fraction dry gas	0.9821	0.9837	0.9837
PCO2	Percent CO2 by volume, dry	0.30	0.23	0.30
PO2	Percent O2 by volume, dry	20.40	20.53	20.40
PCO	Percent CO by volume, dry	0.00	0.00	0.00
PN2	Percent N2 by volume, dry	79.30	79.23	79.30
MWD	Molecular weight-dry stack gas	28.864	28.855	28.864
MW	Molecular weight-stack gas	28.669	28.678	28.687
CP	Pitot tube coefficient	0.84	0.84	0.84
DPS	Average velocity head of stack gas, inches water	0.4890	0.5042	0.4978
TS	Average stack temperature, F	172.13	171.94	172.38

PSI	Static pressure of stack gas, inches Hg.	0.004	0.004	0.004
PS	Stack pressure, absolute	28.964	28.964	28.964
VS	Average stack velocity, FPM	1838.2	1895.0	1871.2
AS	Stack area, inches sqrd.	144.0	144.0	144.0
QS	Stack flow rate, dry, standard conditions, DSCFM	1465.1	1513.3	1493.3
QSW	Stack flow rate, wet, standard conditions, WSCFM	1491.8	1538.4	1518.0
QA	Actual stack flow rate, ACFM	1845.7	1902.8	1878.8
PERI	Percent isokinetic	97.81	96.35	96.12
FMF	Lead, Mg.	0.1050	0.2980	0.1500
CAN	Lead, GR/DSCF	0.356E-04	0.992E-04	0.507E-04
CAM	Lead, GR/WSCF	0.362E-04	0.101E-03	0.516E-04
CAT	Lead, GR/ACF	0.282E-04	0.789E-04	0.403E-04
CAW	Lead, LB/HR	0.0004	0.0013	0.0006
FNP	Net sampling points	16	16	16

*68 Degrees F. 29.92 Inches Hg.

Method 12 Lead Calculations Test Number 1

Johnson Controls Winston-Salem N.C. Grid Caster No. 7

Volume of Dry Gas Sampled at Standard Conditions

$$VMSTD = \frac{17.64 * VM \bullet (PB + PM / 13.6)}{TM + 460} = 45.452$$

Volume of Water Vapor at Standard Conditions

$$VMV = 0.04709 * VW = 0.829$$

Percent Moisture in Stack Gas

$$PMV = \frac{100 * VMV}{VMSTD + VMV} = 1.791$$

Mole Fraction of Dry Gas

$$MD = \frac{100 - PMV}{100} = 0.9821$$

Average Molecular Weight of Dry Stack Gas

$$MWD = 0.44 \bullet PCO2 + 0.32 * PO2 + 0.28 * (PN2+PCO) = 28.864$$

Molecular Weight of Stack Gas

$$MW = MWD \bullet MD + 18 \bullet (1-MD) = 28.669$$

Stack Gas Velocity at Stack Conditions

$$VS = 5129.4 * CP * DPS \bullet SQRT(TS + 460)/(PS * MW) = 1838.2$$

Stack Gas Volumetric Flow at Standard Conditions, Dry

$$QS = \frac{0.123 \bullet VS \bullet AS * PS * MD}{TS + 460} = 1465.1$$

Stack Gas Volumetric Flow at Stack Conditions

$$QA = \frac{QS * (TS + 460)}{17.64 * PS * MD} = 1845.7$$

Percent Isokinetic

$$PERI = \frac{1039 * (TS + 460) * VMSTD}{VS * TT * PS * MD * DN * DN} = 97.81$$

Lead Loading -- Probe, Cyclone, Filter, Impingers
(At Standard Conditions)
CAN = 0.0154 * FMF / VMSTD = 0.356E-04

Lead Loading -- Probe, Cyclone, Filter, Impingers
(At Stack Conditions)

$$CAT = \frac{17.64 * CAN \bullet PS \bullet MD}{TS + 460} = 0.282E-04$$

Lead Lb/Hr -- Probe, Cyclone, Filter, Impingers
(At Standard Conditions)
CAW = 0.00857 • CAN • QS = 0.0004

Summary of Method 12 Lead Results

Johnson Controls Winston-Salem N.C. Grid Caster No. 8

Run Number		1	2	3
Date		12/10/87	12/10/87	12/10/87
DN	Sample nozzle dia., in.	0.337	0.335	0.337
TT	Net time of test	60	60	60
PB	Barometric pressure, in. Hg.	28.96	28.96	28.96
PM	Average orifice pressure drop, in. H20	1.898	1.667	1.945
VM	Volume of dry gas sampled, cu. ft. at meter conditions	46.88	44.26	47.81
TM	Average gas meter temp. in degrees F.	97.88	108.92	107.75
VMSTD	Volume of dry gas sampled at standard conditions*, SCF	43.136	39.911	43.231
VW	Total water collected in impingers + silica gel, ML.	15.9	11.8	13.3
VMV	Volume of water vapor at standard conditions*, SCF	0.749	0.556	0.626
PMV	Percent moisture by volume	1.706	1.373	1.428
MD	Mole fraction dry gas	0.9829	0.9863	0.9857
PC02	Percent C02 by volume, dry	0.17	0.17	0.17
P02	Percent 02 by volume, dry	20.57	20.60	20.60
PCO	Percent CO by volume, dry	0.00	0.00	0.00
PN2	Percent N2 by volume, dry	79.27	79.23	79.23
MWD	Molecular weight-dry stack gas	28.853	28.851	28.851
MW	Molecular weight-stack gas	28.668	28.702	28.696
CP	Pitot tube coefficient	0.84	0.84	0.84
DPS	Average velocity head of stack gas, inches water	0.3861	0.3664	0.3953
TS	Average stack temperature, F	159.50	160.75	161.08

PSI	Static pressure of stack gas, inches Hg.	-0.007	-0.007	-0.007
PS	Stack pressure, absolute	28.959	28.959	28.959
VS	Average stack velocity, FPM	1437.0	1364.3	1472.5
AS	Stack area, inches sqrd.	148.5	148.5	148.5
QS	Stack flow rate, dry, standard conditions, DSCFM	1206.0	1146.5	1236.1
QSW	Stack flow rate, wet, standard conditions, WSCFM	1226.9	1162.4	1254.0
QA	Actual stack flow rate, ACFM	1487.9	1412.5	1524.6
PERI	Percent isokinetic	99.61	98.11	97.40
FMF	Lead, Mg.	0.2490	0.3880	0.2570
CAN	Lead, GR/DSCF	0.889E-04	0.150E-03	0.915E-04
CAM	Lead, GR/WSCF	0.904E-04	0.152E-03	0.929E-04
CAT	Lead, GR/ACF	0.721E-04	0.122E-03	0.742E-04
CAW	Lead, LB/HR	0.0009	0.0015	0.0010
FNP	Net sampling points	12	12	12

*68 Degrees F. 29.92 Inches Hg.

Method 12 Lead Calculations Test Number 1

Johnson Controls Winston-Salem N.C. Grid Caster No. 8

Volume of Dry Gas Sampled at Standard Conditions

$$VMSTD = \frac{17.64 \bullet VM * (PB + PM / 13.6)}{TM + 460} = 43.136$$

Volume of Water Vapor at Standard Conditions

$$VMV = 0.04709 \bullet VW = 0.749$$

Percent Moisture in Stack Gas

$$PMV = \frac{100 * VMV}{VMSTD + VMV} = 1.706$$

Mole Fraction of Dry Gas

$$MD = \frac{100 - PMV}{100} = 0.9829$$

Average Molecular Weight of Dry Stack Gas

$$MWD = 0.44 * PCO2 + 0.32 * PO2 + 0.28 * (PN2+PCO) = 28.853$$

Molecular Weight of Stack Gas

$$MW = MWD \bullet MD + 18 * (1-MD) = 28.668$$

Stack Gas Velocity at Stack Conditions

$$VS = 5129.4 \bullet CP * DPS * SQRT(TS + 460)/(PS \bullet MW) = 1437.0$$

Stack Gas Volumetric Flow at Standard Conditions, Dry

$$QS = \frac{0.123 \bullet VS * AS * PS \bullet MD}{TS + 460} = 1206.0$$

Stack Gas Volumetric Flow at Stack Conditions

$$QA = \frac{QS \bullet (TS + 460)}{17.64 * PS \bullet MD} = 1487.9$$

Percent Isokinetic

$$PERI = \frac{1039 \bullet (TS + 460) \bullet VMSTD}{VS * TT * PS \bullet MD \bullet DN * DN} = 99.61$$

Lead Loading -- Probe, Cyclone, Filter, Impingers
(At Standard Conditions)
CAN = 0.0154 • FMF / VMSTD = 0.889E-04

Lead Loading -- Probe, Cyclone, Filter, Impingers
(At Stack Conditions)

$$CAT = \frac{17.64 * CAN \bullet PS \bullet MD}{TS + 460} = 0.721E-04$$

Lead Lb/Hr -- Probe, Cyclone, Filter, Impingers
(At Standard Conditions)
CAW = 0.00857 * CAN * QS = 0.0009

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

APPENDIX B

Plant Johnson Controls

Date 12-10-87

Sampling location Grid Caster #7

Inside of far wall to outside of nipple (X) 13"

Inside of near wall to outside of nipple (nipple length) (Y) 1"

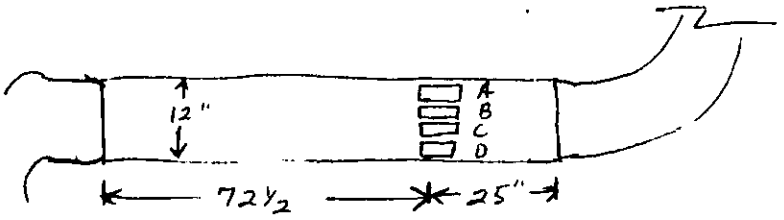
Stack I.D. (X-Y) 12"

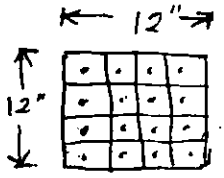
Nearest upstream disturbance 2.08 dd

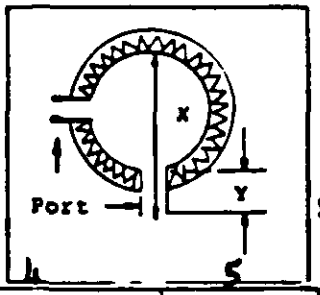
Nearest downstream disturbance 6.04 dd

Calculated by PRJ

Eq. Dia. = 12"







SCHEMATIC OF SAMPLING LOCATION

1	2	3	4	5
TRAVERSE POINT NUMBER	FRACTION OF STACK I D	STACK I D	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	NIPPLE LENGTH	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1			1.5	1.0	2.5
2			4.5	1.0	5.5
3			7.5	1.0	8.5
4			10.5	1.0	11.5

METHOD 2 GAS VELOCITY AND CYCLONIC FLOW DETERMINATION

Plant and City Johnson Controls - Winston Salem NC Run Date 12-10-87

Sampling Location Grid Caster #7 Clock Time 0810

Run Number 1 Operator PRS-JAF Amb. Temp., °F 96

Bar. Press., in. Hg 28.96 Static Press., in. H_2O +0.05

Stack Press., in. Hg 28.964 Static Press., in. Hg +0.004

Stack Dimension, in. - Diam. or side 1 12.0 side 2 12.0

Pitot Tube (C_p) 0.84 Pitot Tube Leak Check <0.1 @ 4.0 in. H_2O

Field data — Square Duct with straightening vanes

Traverse point number	Position, in.	Velocity head (Δp_s), in. H_2O	Stack temp., °F	Cyclonic flow determination: Δp_s at 0° reference	Cyclonic flow determination: Angle (α) which yields a null Δp
A 1	2.5	0.40	165		
2	5.5	0.35			
3	8.5	0.31			
4	11.5	0.23			
B 1	2.5	0.30			
2	5.5	0.10			
3	8.5	0.12			
4	11.5	0.27			
C 1	2.5	0.24			
2	5.5	0.17			
3	8.5	0.21			
4	11.5	0.24			
D 1	2.5	0.24			
2	5.5	0.27			
3	8.5	0.29			
4	11.5	0.24	165		
		0.25			
				Average angle (α)[a]	

[a] Average of (α) must be < 10 degrees to be acceptable.

RAC

NOMAGRAPH DATA

$\Delta H_@$ 1.89 T_m 115 %M 2% P_s/P_m 1.0 C 1.15 D_b 165

$\overline{\Delta p}$ 0.25 T_s 170 DN_c 0.295 DN_a 0.302 (0.302, 0.302) Ref. Δp 0.225 W_b 85 (Δ80)

METHOD 5 PARTICULATE FIELD DATA

Plant Johnson Controls - Winston Salem, NC
Run No. 1
Location Grid Caster #7
Date 12-10-87
Operator FHH
Sample Box No. 1
Meter Box No. 14/01
Filter No. M12 1
Probe No. 1
Pitot Tube Cp 0.84

Very Important — Fill In All Blanks
Leak Checks: Beg. @ 15" 0.001
End @ 7' 0.0005
Pitot Tube: ⊕<0.1 @ 4.8 "H2O
⊖<0.1 @ 4.8 "H2O
Static Pressure: +0.05 "H2O
Start: 0830
Finish: 0943
Observer L. Chai Agency FCDEA

Bar. Press. "Hg 28.96
Meter Box ΔH@ 1.89 Y = 1.00
Assumed Tm, °F 115
Dry Bulb, °F 173
Wet Bulb, °F 87
Db - Wb, °F 86
Assumed Moisture % 2%
Ps/Pm 1.0
C Factor 1.15

Ambient Temp., °F 96
Heater Box Setting, °F 250°
Probe Tip Dia., in. 0.302
Probe Length 4' glass lined
Probe Heater Setting 85%
Average Δp 0.25 Δp 0.225
Average ΔH 2.05 ΔH Rel
Process Weight
Steam Load NA
Steam Pressure NA

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in H_2O	Orifice Manometer (ΔH) in H_2O Desired	Orifice Manometer (ΔH) in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum in Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	% CO_2	% O_2
A 1	0	944.20	0.35	2.88	2.88	100	96	5.0	265	58	173		
2	4	947.96	0.32	2.61	2.61	108	96	5.0	275	55	172		
3	8	951.57	0.34	2.80	2.80	116	96	5.4	270	57	170		
4	12	955.34	0.24	1.99	1.99	121	97	4.5	245	62	171		
B 1	16/0	958.51	0.31	2.55	2.55	121	99	5.2	240	60	174		
2	4	962.05	0.12	1.02	1.02	124	100	3.0	245	58	174		
3	8	964.36	0.29	2.39	2.39	127	102	4.8	250	59	172		
4	12	967.79	0.28	2.30	2.30	131	103	4.8	250	60	171		
C 1	16/0	971.22	0.13	1.10	1.10	128	106	3.6	260	59	174		
2	4	973.67	0.17	1.43	1.43	130	107	4.2	250	58	173		
3	8	976.34	0.19	1.60	1.60	132	108	4.4	245	58	172		
4	12	979.23	0.28	2.30	2.30	134	108	5.0	245	58	171		
D 1	16/0	982.65	0.23	1.90	1.90	130	110	4.6	250	57	172		
2	4	985.83	0.19	1.60	1.60	133	111	4.4	265	59	172		
3	8	988.74	0.22	1.80	1.80	134	112	4.5	260	60	172		
4	12	991.83	0.25	2.05	2.05	137	113	5.0	255	61	171		
	16	995.07											

METHOD 5 PARTICULATE FIELD DATA

Plant Johnson Controls · Winston-Salem, NC
Run No. 2
Location Grand Caster #7
Date 12-10-87
Operator FHH
Sample Box No. 2
Meter Box No. 1401
Filter No. M12 2
Probe No. 2
Pilot Tube Cp 0.84

Very Important — Fill In All Blanks
Leak Checks: Beg. @ 15" 0.0025
End @ " 0.001
Pilot Tube: ⊕ <0.1 @ 6.1 "H₂O
⊖ <0.1 @ 6.1 "H₂O
Static Pressure: +0.05 "H₂O
Start: 1000
Finish: 1113
Observer L. Choi Agency FCDEA

Bar. Press. "Hg 28.96
Meter Box ΔH@ 1.89 Y = 1.00
Assumed Tm, °F 115
Dry Bulb, °F 173
Wet Bulb, °F 87
Db - Wb, °F 86
Assumed Moisture % 2%
Ps/Pm 1.0
C Factor 1.15

Ambient Temp., °F 96
Heater Box Setting, °F 250°
Probe Tip Dia., in. 0.302
Probe Length 4' glass lined
Probe Heater Setting 857.
Average Δp 0.25 Δp 0.225
Average ΔH 2.05 ΔH Ref
Process Weight
Steam Load NA
Steam Pressure NA

Point	Clock Time	Dry Gas Meter, Cu. Ft	Pitot Manometer (Δp) in H_2O	Orifice Manometer (ΔH) in H_2O Desired	Orifice Manometer (ΔH) in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum in Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	% CO_2	% O_2
A 1	0	995.30	0.40	3.29	3.29	120	112	5.0	225	64	172		
2	4	999.42	0.41	3.38	3.38	131	112	5.2	230	60	172		
3	8	1003.58	0.38	3.10	3.10	136	113	4.8	235	60	172		
4	12	1007.59	0.30	2.45	2.45	138	114	4.1	240	62	170		
B 1	16/0	1011.17	0.35	2.88	2.88	134	114	4.9	240	58	173		
2	4	1014.98	0.11	0.93	0.93	134	115	3.0	245	56	173		
3	8	1017.23	0.26	2.12	2.12	136	115	4.0	245	56	171		
4	12	1020.43	0.35	2.88	2.88	138	116	5.0	250	55	169		
C 1	16/0	1024.27	0.16	1.34	1.34	135	116	3.6	255	55	173		
2	4	1027.07	0.12	1.02	1.02	136	116	3.2	260	52	173		
3	8	1029.41	0.18	1.50	1.50	136	116	3.9	265	53	172		
4	12	1032.16	0.27	2.20	2.20	137	117	4.8	270	52	171		
D 1	16/0	1035.41	0.21	1.73	1.73	134	117	4.5	260	56	173		
2	4	1038.43	0.17	1.43	1.43	136	117	3.8	240	54	173		
3	8	1041.18	0.23	1.90	1.90	137	117	4.6	245	58	172		
4	12	1044.30	0.32	2.61	2.61	139	117	5.2	250	59	172		
	16	1047.97											

METHOD 5 PARTICULATE FIELD DATA

Plant Johnson Controls - Winston-Salem, NC
Run No. 3
Location Grid Coster #7
Date 12-10-87
Operator FLH
Sample Box No. 3
Meter Box No. 1401
Filter No. M12 3
Probe No. 3
Pitot Tube Cp 0.84

Very Important — Fill In All Blanks
Leak Checks: Beg. @ 15" 0.001
End @ 12"
Pitot Tube: ⓐ <0.1 @ 5.3 "H₂O
ⓑ <0.1 @ 5.3 "H₂O
Static Pressure: +0.05 "H₂O
Start: 1145
Finish: 1256
Observer L. Choi Agency FCDEA

Bar. Press. "Hg 28.96
Meter Box ΔH@ 1.89 Y = 1.00
Assumed Tm, °F 115
Dry Bulb, °F 73
Wet Bulb, °F 87
Db - Wb, °F 86
Assumed Moisture % 2%
Ps/Pm 1.0
C Factor 1.15

Ambient Temp., °F 96
Heater Box Setting, °F 250°
Probe Tip Dia., in. 0.302
Probe Length 4' glass lined
Probe Heater Setting 85%
Average Δp 0.25 Δp 0.225
Average ΔH 2.05 ΔH Rel
Process Weight
Steam Load NA
Steam Pressure NA

Point	Clock Time	Dry Gas Meter, Cu. Ft	Pitot Manometer (Δp) in H_2O	Orifice Manometer (ΔH) in H_2O Desired	Orifice Manometer (ΔH) in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum in Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	% CO_2	% O_2
A 1	0	48.20	0.46	3.78	3.78	120	112	11.2	270	58	174		
2	4	52.55	0.44	3.60	3.60	128	112	9.8	265	60	173		
3	8	56.80	0.35	2.88	2.88	134	112	5.8	245	61	172		
4	12	60.65	0.26	2.12	2.12	139	113	5.0	250	61	172		
B 1	16/0	63.96	0.28	2.30	2.30	134	114	5.5	255	60	173		
2	4	67.38	0.12	1.02	1.02	135	114	3.8	250	57	173		
3	8	69.70	0.28	2.30	2.30	137	114	5.5	245	56	171		
4	12	73.12	0.29	2.39	2.39	139	115	5.8	250	55	172		
C 1	16/0	76.61	0.11	0.93	0.93	136	116	3.5	255	58	173		
2	4	78.85	0.08	0.69	0.69	136	116	3.0	255	56	173		
3	8	80.82	0.21	1.73	1.73	136	116	4.0	260	52	172		
4	12	83.78	0.30	2.45	2.45	138	117	5.9	250	54	171		
D 1	16/0	87.32	0.21	1.73	1.73	137	117	4.2	250	55	173		
2	4	90.34	0.18	1.50	1.50	138	117	4.1	250	59	172		
3	8	93.16	0.26	2.12	2.12	139	118	5.2	255	60	172		
4	12	96.45	0.32	2.61	2.61	142	118	5.7	245	62	172		
	16	100.08											

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METHOD 3 - ORSAT AND DRY MOLECULAR WEIGHT DETERMINATION

Plant Johnson Controls - Winston Salem, NC Sample Location Grid Caster #7

Sample Type - Continuous 500cc/min Pump Leakfree @ 10" ? ✓

Oxygen Check 20.9% ± 0.1% ✓ Fuel Type Nat. Gas

Orsat Leak Check @ 4 min.: Pipet Levels - Leakfree ? Yes

Buret 16.7 - 16.7 = <0.2 ml ? O/C

Run No. 1 Sample Date 12/10/87 Ambient Temp. °F 96°F

Sampling Time (24 - hr clock) 0830-0943 Analysis By JSM

Gas \ Run	1 Actual	1 Net	2 Actual	2 Net	3 Actual	3 Net	Avg. %	Mult.	Molecular Wt. Dry lb/lb mole
CO_2	0.3	0.3	0.3	0.3	0.3	0.3	0.30	.44	0.132
O_2	20.7	20.4	20.7	20.4	20.7	20.4	20.40	.32	6.528
CO	20.7	0.0	20.7	0.	20.7	0.0	0.00	.28	0.000
N_2	100	79.3	100	79.3	100	79.3	79.30	.28	22.204
								Total	28.864

$F_o = \frac{20.9 - \%O_2}{\%CO_2} = 1.667$

Run No. 2 Sample Date 12/10/87 Ambient Temp. °F 96

Sampling Time (24 - hr clock) 1000-1113 Analysis By JSM

Gas \ Run	1 Actual	1 Net	2 Actual	2 Net	3 Actual	3 Net	Avg. %	Mult.	Molecular Wt. Dry lb/lb mole
CO_2	0.2	0.2	0.2	0.2	0.3	0.3	0.23	.44	0.101
O_2	20.8	20.6	20.8	20.6	20.7	20.4	20.53	.32	6.570
CO	20.8	0.0	20.8	0.0	20.7	0.0	0.000	.28	0.000
N_2	100	79.2	100	79.2	100	79.3	79.23	.28	22.184
								Total	28.855

$F_o = \frac{20.9 - \%O_2}{\%CO_2} = 1.609$

Run No. 3 Sample Date 12/10/87 Ambient Temp. °F 96

Sampling Time (24 - hr clock) 1145-1256 Analysis By JSM

Gas \ Run	1 Actual	1 Net	2 Actual	2 Net	3 Actual	3 Net	Avg. %	Mult.	Molecular Wt. Dry lb/lb mole
CO_2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	.44	0.132
O_2	20.7	20.4	20.7	20.4	20.7	20.4	20.4	.32	6.528
CO	20.7	0.0	20.7	0.0	20.7	0.0	0.0	.28	0.000
N_2	100	79.3	100	79.3	100	79.3	79.3	.28	22.864
								Total	28.864

$F_o = \frac{20.9 - \%O_2}{\%CO_2} = 1.667$

Fuel type	F_o range
Coal:	
Anthracite and lignite	1.016–1.130
Bituminous	1.083–1.230
Wood	1.000–1.120
Wood bark	1.003–1.130

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METHOD 12 SAMPLE RECOVERY AND INTEGRITY SHEET

Plant Johnson Controls - Winston Salem, NC Recovered By FLH
Sample Location Grid Caster #7 Recovery Date 12-11-87

Run Number	1	2	3
Sample Date	12-10-87	12-10-87	12-10-87
Sample Box Number	1	2	3
Probe Number	1	2	3

MOISTURE DETERMINATION AND SAMPLE RECOVERY - IMPINGERS

Impingers Cont. Number	1-1	1-2	1-3
Description of Water	clear	clear	clear
Liquid Level Marked	✓	✓	✓
Final Volume (wt.), ml	203	204	203
Initial Volume (wt.), ml	200	200	200
Net Volume (wt.), ml (g)	3	4	3
Silica Gel Cont. Number	1-1	1-2	1-3
Silica Gel % Spent	20	20	20
Final Weight, g	214.6	212.3	213.0
Initial Weight, g	200.0	200.0	200.0
Net Weight, g	14.6	12.3	13.0
Total Moisture, g	17.6	16.3	16.0

SAMPLE RECOVERY - FILTER

Filter Cont. Number	1-1 M12 1	1-2 M12 2	1-3 M12 3
Particulate Description	black	black	black
Filter Cont. Sealed	✓	✓	✓
Probe Rinse Cont. Number	1-1 Probe	1-2 Probe	1-3 Probe
Liquid Level Marked	✓	✓	✓

SAMPLE WEIGHT CALCULATION

Run #	Conc., mg/l	x	Vol., l	-	Blank, mg	=	Total mg Lead
1	0.461	x	0.250	-	<0.010	=	0.105
2	1.231	x	0.250	-	<0.010	=	0.298
3	0.639	x	0.250	-	<0.010	=	0.150

BLANK CALCULATIONS

Conc., mg/l	x	Volume, l	=	Total mg	
<0.050	x	0.100	=	<0.005	Filter Blank
<0.050	x	0.100	=	<0.005	Filter Blank
<0.050	x	0.100	=	<0.005	HNO_3 Blank
				<0.010	Total Blank

LABORATORY CUSTODY

Received By: FLH Date Received: 12-10-87
Stored and Locked: ✓ Remarks: NA

METHOD 12 ATOMIC ABSORPTION DATA

Grid Caster #7

CALIBRATION DATA

Standard No. 1	= 0.500	mg/l	Absorbance	=	0.024
Standard No. 2	= 1.000	mg/l	Absorbance	=	0.047
Standard No. 3	= 2.500	mg/l	Absorbance	=	0.111
Standard No. 4	= 5.000	mg/l	Absorbance	=	0.198

SAMPLE CONCENTRATION DATA

Mean Concentration Run No. 1	= 0.461	mg/l
Mean Concentration Run No. 2	= 1.231	mg/l
Mean Concentration Run No. 3	= 0.639	mg/l
Mean Concentration Run No.	= —	mg/l
Mean Concentration Filter Blk.	= <0.050	mg/l
Mean Concentration Filter Blk.	= <0.050	mg/l
Mean Concentration 0.10N HNO_3	= <0.050	mg/l

Analyzed by LGK Date 12/22/87

Remarks NA

METHOD 12 ATOMIC ABSORPTION DATA

Grid Caster #8

CALIBRATION DATA

Standard No. 1	= 0.500	mg/l	Absorbance	=	0.024
Standard No. 2	= 1.000	mg/l	Absorbance	=	0.047
Standard No. 3	= 2.500	mg/l	Absorbance	=	0.111
Standard No. 4	= 5.000	mg/l	Absorbance	=	0.198

SAMPLE CONCENTRATION DATA

Mean Concentration Run No. 1	= 1.034	mg/l
Mean Concentration Run No. 2	= 1.591	mg/l
Mean Concentration Run No. 3	= 1.069	mg/l
Mean Concentration Run No.	= —	mg/l
Mean Concentration Filter Blk.	= <0.050	mg/l
Mean Concentration Filter Blk.	= <0.050	mg/l
Mean Concentration 0.10N HNO_3	= <0.050	mg/l

Analyzed by LGK Date 12-22-87

Remarks NA

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METHOD 12 SAMPLE RECOVERY AND INTEGRITY SHEET

Plant Johnson Controls Winston Salem, NC Recovered By FLH
Sample Location Grid Caster #8 Recovery Date 12-11-87

	1	2	3
Run Number			
Sample Date	12-10-87	12-10-87	12-10-87
Sample Box Number	4	5	6
Probe Number	4	5	6

MOISTURE DETERMINATION AND SAMPLE RECOVERY - IMPINGERS

Impingers Cont. Number	2-1	2-2	2-3
Description of Water	clear	clear	clear
Liquid Level Marked	✓	✓	✓
Final Volume (wt.), ml	203	203	202
Initial Volume (wt.), ml	200	200	200
Net Volume (wt.), ml (g)	3	3	2
Silica Gel Cont. Number	2-1	2-2	2-3
Silica Gel % Spent	20	20	20
Final Weight, g	212.9	208.8	211.3
Initial Weight, g	200.0	200.0	200.0
Net Weight, g	12.9	8.8	11.3
Total Moisture, g	15.9	11.8	13.3

SAMPLE RECOVERY - FILTER

Filter Cont. Number	2-1 M124	2-2 M125	2-3 M126
Particulate Description	black	black	black
Filter Cont. Sealed	✓	✓	✓
Probe Rinse Cont. Number	2-1 Probe	2-2 Probe	2-3 Probe
Liquid Level Marked	✓	✓	✓

SAMPLE WEIGHT CALCULATION

Run #	Conc., mg/l	x	Vol., l	-	Blank, mg	=	Total mg Lead
1	1.034	x	0.250	-	<0.010	=	0.249
2	1.591	x	0.250	-	<0.010	=	0.388
3	1.069	x	0.250	-	<0.010	=	0.257

BLANK CALCULATIONS

Conc., mg/l	x	Volume, l	=	Total mg	
<0.050	x	0.100	=	<0.005	Filter Blank
<0.050	x	0.100	=	<0.005	Filter Blank
<0.050	x	0.100	=	<0.005	HNO_3 Blank
				<0.010	Total Blank

LABORATORY CUSTODY

Received By: FLH Date Received: 12-10-87
Stored and Locked: ✓ Remarks: N/A

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METHOD 3 - ORSAT AND DRY MOLECULAR WEIGHT DETERMINATION

Plant Johnson Controls - Winston-Salem, NC Sample Location Grid Caster #8

Sample Type - Continuous ✓ Pump Leakfree @ 10" ? ✓

Oxygen Check 20.9% ± 0.1% ✓ Fuel Type NAT. GAS

Orsat Leak Check @ 4 min.: Pipet Levels - Leakfree ? Yes

Buret 16.7 - 16.7 = <0.2 ml ? OK

Run No. 1 Sample Date 12/10/87 Ambient Temp. °F 82

Sampling Time (24 - hr clock) 0835-0937 Analysis By JSM

Gas \ Run	1		2		3		Avg. %	Mult.	Molecular Wt. Dry lb/lb mole
	Actual	Net	Actual	Net	Actual	Net			
CO_2	0.2	0.2	0.1	0.1	0.2	0.2	0.17	.44	0.075
O_2	20.7	20.5	20.8	20.7	20.7	20.5	20.57	.32	6.582
CO	20.7	0.0	20.8	0.0	20.7	0.0	0.00	.28	0.000
N2	100	79.3	100	79.2	100	79.3	79.27	.28	22.196
								Total	28.853

$F_o = \frac{20.9 - \%O_2}{\%CO_2} = 1.941$

Run No. 2 Sample Date 12/10/87 Ambient Temp. °F 85

Sampling Time (24 - hr clock) 1000-1103 Analysis By JSM

Gas \ Run	1		2		3		Avg. %	Mult.	Molecular Wt. Dry lb/lb mole
	Actual	Net	Actual	Net	Actual	Net			
CO_2	0.1	0.1	0.2	0.2	0.2	0.2	0.17	.44	0.075
O_2	20.8	20.7	20.8	20.6	20.7	20.5	20.60	.32	6.592
CO	20.8	0.0	20.8	0.0	20.7	0.0	0.00	.28	0.000
N2	100	79.2	100	79.2	100	79.3	79.23	.28	22.184
								Total	28.851

$F_o = \frac{20.9 - \%O_2}{\%CO_2} = 1.765$

Run No. 3 Sample Date 12/10/87 Ambient Temp. °F 85

Sampling Time (24 - hr clock) 1145-1251 Analysis By JSM

Gas \ Run	1		2		3		Avg. %	Mult.	Molecular Wt. Dry lb/lb mole
	Actual	Net	Actual	Net	Actual	Net			
CO_2	0.1	0.1	0.2	0.2	0.2	0.2	0.17	.44	0.075
O_2	20.8	20.7	20.7	20.5	20.8	20.6	20.60	.32	6.592
CO	20.8	0.0	20.7	0.0	20.8	0.0	0.00	.28	0.000
N2	100	79.2	100	79.3	100	79.2	79.23	.28	22.184
								Total	28.851

Fuel type	F_o range
Coal:	
Anthracite and lignite	1.016-1.130
Bituminous	1.083-1.230
Wood	1.000-1.120
Wood bark	1.003-1.130

$F_o = \frac{20.9 - \%O_2}{\%CO_2} = 1.765$

METHOD 5 PARTICULATE FIELD DATA

Plant Johnson Controls Winston-Salem, NC
Run No. 2
Location Grid Caster #8
Date 12/10/87
Operator JSM - PRJ
Sample Box No. 5
Meter Box No. 1264
Filter No. M12 5
Probe No. 5
Pilot Tube Cp 0.84

Very Important — Fill In All Blanks
Leak Checks: Beg. @ 15" .005
End @ 8" .001
Pilot Tube: ⊕ < 0.1 @ 4.3 "H₂O
⊖ < 0.1 @ 4.3 "H₂O
Static Pressure: -0.007 "H₂O
Start: 1000
Finish: 1108
Observer L. Chai Agency ECDEA

Bar. Press. "Hg 28.96
Meter Box ΔH@ 1.91 Y = 1.00
Assumed Tm, °F 110
Dry Bulb, °F 160
Wet Bulb, °F 85
Db - Wb, °F 75
Assumed Moisture % 37%
Ps/Pm 1.0
C Factor 1.08

Ambient Temp., °F 84°F
Heater Box Setting, °F 250
Probe Tip Dia., in. .335
Probe Length 4' glass lined
Probe Heater Setting 850
Average Δp .1433 Δp .15
Average ΔH 1.75 ΔH Ref
Process Weight
Steam Load NA
Steam Pressure NA

3 × 16 grids/min.

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pilot Manometer (Δp) in H_2O	Orifice Manometer (ΔH) in H_2O Desired	Orifice Manometer (ΔH) in H_2O Actual	Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Pump Vacuum in Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	% CO_2	% O_2
A1	0	810.32	.19	2.3	2.3	98	98	6.0	260	56	161		
2	5	814.65	.18	2.2	2.2	108	97	6.0	265	48	161		
3	10	818.97	.15	1.85	1.85	114	98	6.0	260	55	162		
4	15	823.72	.12	1.5	1.5	121	99	3.0	230	58	159		
5	20	827.18	.14	1.7	1.7	119	99	4.0	255	53	162		
6	25	830.57	.17	2.05	2.05	120	100	5.0	255	54	160		
B1	30/0	834.47	.14	1.7	1.7	118	101	4.5	260	60	162		
2	5	838.08	.12	1.5	1.5	119	103	4.5	265	58	160		
3	10	841.67	.10	1.25	1.25	120	103	3.5	270	50	159		
4	15	844.83	.10	1.25	1.25	121	104	3.5	265	52	158		
5	20	847.83	.11	1.35	1.35	121	106	4.0	270	51	162		
6	25	851.21	.11	1.35	1.35	121	106	4.0	260	49	163		
	30	854.58											

METHOD 5 PARTICULATE FIELD DATA

Plant Johnson Controls - Winston-Salem, NC
Run No. 3
Location Grid Caster #8
Date 12/10/87
Operator JSM - PRT
Sample Box No. 6
Meter Box No. 1264
Filter No. M12 6
Probe No. 6
Pilot Tube Cp 0.84

Very Important — Fill In All Blanks
Leak Checks: Beg. @ 15" .003
End @ 11" .002
Pilot Tube: (+) x 0.1 @ 4.1 "H2O
(-) x 0.1 @ 4.1 "H2O
Static Pressure: -0.007 "H2O
Start: 1145
Finish: 1251
Observer L. Choi Agency FCDEA

Bar. Press. "Hg 28.96
Meter Box ΔH@ 1.81 Y = 1.00
Assumed Tm, °F 110
Dry Bulb, °F 160
Wet Bulb, °F 85
Db - Wb, °F 75
Assumed Moisture % 3%
Ps/Pm 1.0
C Factor 1.08

Ambient Temp., °F 85°F
Heater Box Setting, °F 250
Probe Tip Dia., in. .337
Probe Length 4' glass lined
Probe Heater Setting 852
Average Δp 1.433 Δp .115
Average ΔH 1.75 ΔH Ref
Process Weight
Steam Load NA
Steam Pressure NA

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pitot Manometer (Δp) in H_2O	Orifice Manometer (ΔH) in H_2O Desired	Orifice Manometer (ΔH) in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum in Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	% CO_2	% O_2
A 1	0	854.76	.23	2.8	2.8	95	95	8.0	250	40	163		
2	5	859.69	.21	2.6	2.6	106	95	5.0	255	48	162		
3	10	864.23	.17	2.1	2.1	112	96	5.0	245	49	162		
4	15	868.35	.14	1.73	1.73	116	96	4.0	240	55	160		
5	20	872.13	.18	2.2	2.2	117	98	4.5	250	57	161		
6	25	876.31	.19	2.35	2.35	119	99	5.5	255	54	159		
B 1	30/0	880.68	.16	1.95	1.95	120	101	4.5	260	55	161		
2	5	884.63	.14	1.73	1.73	121	101	4.0	265	48	162		
3	10	888.47	.12	1.45	1.45	121	103	3.5	270	50	162		
4	15	891.92	.11	1.35	1.35	121	103	4.0	270	49	161		
5	20	895.28	.13	1.58	1.58	121	104	3.5	265	51	160		
6	25	898.85	.12	1.5	1.5	121	105	3.5	260	59	160		
	30	902.57											

METHOD 5 PARTICULATE FIELD DATA

Plant Johnson Controls Winston-Salem, NC
Run No. 1
Location Grid Caster #8
Date 12/10/97
Operator JSM-PRJ
Sample Box No. 4
Meter Box No. 1264
Filter No. M12 4
Probe No. 4
Pitot Tube Cp 0.84

Very Important — Fill In All Blanks
Leak Checks: Beg. @ 15" .002
End @ 9" .002
Pitot Tube: ⓐ < 0.1 @ 4 "H₂O
ⓒ < 0.1 @ 4 "H₂O
Static Pressure: -0.007 "H₂O
Start: 0235
Finish: 0937
Observer L. Choi Agency FCDEA

Bar. Press. "Hg 28.96
Meter Box ΔH@ 1.81 Y = 1.00
Assumed Tm, °F 110
Dry Bulb, °F 140 160
Wet Bulb, °F 80 85
Db - Wb, °F 60 75
Assumed Moisture % ~~2%~~ 3%
Ps/Pm 1.0
C Factor 1.12

Ambient Temp., °F 82°F
Heater Box Setting, °F 250
Probe Tip Dia., in. ~~.315~~ .337
Probe Length 4' glass lined
Probe Heater Setting 850
Average Δp .1433 Δp .15
Average ΔH ~~2.75~~ 2.75 ΔH Ref
Process Weight
Steam Load NA
Steam Pressure NA

Point	Clock Time	Dry Gas Meter, Cu. Ft.	Pilot Manometer (Δp) in H_2O	Orifice Manometer (ΔH) in H_2O Desired	Orifice Manometer (ΔH) in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum in Hg Gauge	Box Temp. °F	Impinger Temp. °F	Stack Temp. °F	% CO_2	% O_2
A 1	0	763.30	.21	2.9	2.9	78	78	8.0	230	~~250~~ 62	161		
2	5	768.51	.20	2.7	2.7	91	80	5.0	240	60	160		
3	10	772.81	.15	1.8	1.8	98	82	3.0	240	65	160		
4	15	776.77	.12	1.5	1.5	102	84	3.0	260	65	158		
5	20	780.31	.17	2.05	2.05	108	86	3.5	250	60	159		
6	25	784.29	.18	2.15	2.15	110	88	4.0	255	57	157		
B 1	30	788.42	.17	2.1	2.1	109	91	4.0	270	57	159		
2	5	792.50	.14	1.72	1.72	114	94	3.5	270	50	161		
3	10	796.40	.12	1.5	1.5	115	95	3.0	265	51	162		
4	15	799.85	.11	1.35	1.35	116	98	2.5	250	55	160		
5	20	~~8~~03.25	.12	1.5	1.5	118	98	3.0	265	52	160		
6	25	806.63	.12	1.5	1.5	118	98	3.0	265	53	157		
	30	810.18											

METHOD 2 GAS VELOCITY AND CYCLONIC FLOW DETERMINATION

Plant and City Johnson Controls Run Date 12/10/87

Sampling Location Grid Caster #8 Clock Time 0750

Run Number 1 Operator SM-PEJ Amb. Temp., °F 82°F

Bar. Press., in. Hg 28.96 Static Press., in. H_2O -0.09

Stack Press., in. Hg 28.959 Static Press., in. Hg -0.007

Stack Dimension, in. - Diam. or side 1 13.75 side 2 13.75

Pitot Tube (C_p) 0.84 Pitot Tube Leak Check <0.1 @ 3.8 in. H_2O

Field data

Traverse point number	Position, in.	Velocity head (Δp_s), in. H_2O	Stack temp., °F	Cyclonic flow determination: Δp_s at 0° reference	Cyclonic flow determination: Angle (α) which yields a null Δp
A 1	1.855	0.20	145	.03	7
2	3.758	0.20		.01	3
3	5.320	0.15		.02	3
4	10.930	0.11		.01	5
5	12.993	0.12		.01	5
6	14.395	0.19		.01	5
B 1	1.855	0.14		.03	8
2	3.758	0.12		.02	7
3	5.320	0.12		.02	6
4	10.930	0.11		.01	5
5	12.993	0.13		.01	5
6	14.395	0.13	145	.01	3
		$\overline{\Delta p}$ = 0.1433			
				Average angle (α)[a]	5.3°

[a] Average of (α) must be < 10 degrees to be acceptable. ✓

Nutec

NOMAGRAPH DATA

$\Delta H_@$ 1.81 T_m 110 %M 2% P_s/P_m 1.0 C 1.12 D_b 140

$\overline{\Delta p}$ 0.14 T_s 150 DN_c 0.337 DN_a 0.337 (0.335) Ref. Δp 0.14 W_b 80 (60)

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

Plant Johnson Controls

Date 12-10-87

Sampling location Grid Caster #8

Inside of far wall to outside of nipple (I) 15"

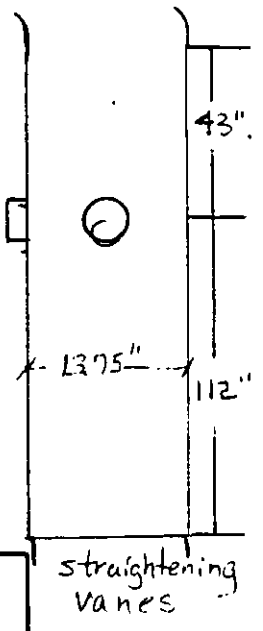
Inside of near wall to outside of nipple (nipple length) (I) 1.25"

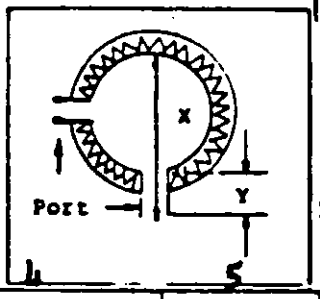
Stack I.D. (I-I) 13.75"

Nearest upstream disturbance 3.13 dd

Nearest downstream disturbance 8.15 dd

Calculated by PRJ





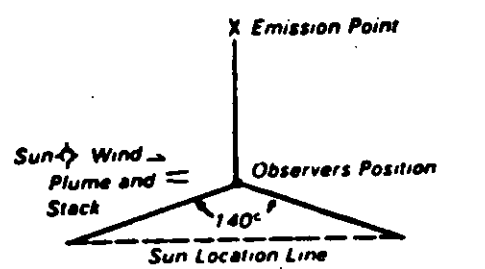
SCHEMATIC OF SAMPLING LOCATION

1 TRAVERSE POINT NUMBER	2 FRACTION OF STACK I.D.	3 STACK I.D.	4 PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	NIPPLE LENGTH	5 TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	0.044	13.75	0.605	1.25	1.855
2	0.146	13.75	2.008	1.25	3.758
3	0.296	13.75	4.070	1.25	5.320
4	0.704	13.75	9.680	1.25	10.930
5	0.854	13.75	11.743	1.25	12.993
6	0.956	13.75	13.145	1.25	14.395

Visible Emission Observation Form

SOURCE NAME: Johnson Controls
ADDRESS:
CITY: Winston Salem | STATE: N C | ZIP:
PHONE: Gridcaster 7 | SOURCE ID NUMBER:
PROCESS EQUIPMENT: | OPERATING MODE:
CONTROL EQUIPMENT: | OPERATING MODE:
DESCRIBE EMISSION POINT: START 13.75" dia. duct STOP ✓
HEIGHT ABOVE GROUND LEVEL: START 100' STOP ✓ | HEIGHT RELATIVE TO OBSERVER: START 40' STOP ✓
DISTANCE FROM OBSERVER: START 100' STOP | DIRECTION FROM OBSERVER: START SE* STOP
DESCRIBE EMISSIONS: START No VE's STOP ✓
EMISSION COLOR: START — STOP — | PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
WATER DROPLETS PRESENT: NO ☒ YES ☐ | IF WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START 1 diameter STOP ✓
DESCRIBE BACKGROUND: START BUILDING - ROOF STOP ✓
BACKGROUND COLOR: START LIGHT GREY STOP ✓ | SKY CONDITIONS: START OVER CAST RAIN STOP ✓
WIND SPEED: START 1-3 STOP | WIND DIRECTION: START N STOP E
AMBIENT TEMP: START 15°C STOP ✓ | WET BULB TEMP: | RH, percent:

Source Layout Sketch — Draw North Arrow



OBSERVATION DATE	START TIME	STOP TIME
12-10-87	0830	0930

SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1	0	0	0	0	31	0	0	0	0
2	0	0	0	0	32	0	0	0	0
3	0	0	0	0	33	0	0	0	0
4	0	0	0	0	34	0	0	0	0
5	0	0	0	0	35	0	0	0	0
6	0	0	0	0	36	0	0	0	0
7	0	0	0	0	37	0	0	0	0
8	0	0	0	0	38	0	0	0	0
9	0	0	0	0	39	0	0	0	0
10	0	0	0	0	40	0	0	0	0
11	0	0	0	0	41	0	0	0	0
12	0	0	0	0	42	0	0	0	0
13	0	0	0	0	43	0	0	0	0
14	0	0	0	0	44	0	0	0	0
15	0	0	0	0	45	0	0	0	0
16	0	0	0	0	46	0	0	0	0
17	0	0	0	0	47	0	0	0	0
18	0	0	0	0	48	0	0	0	0
19	0	0	0	0	49	0	0	0	0
20	0	0	0	0	50	0	0	0	0
21	0	0	0	0	51	0	0	0	0
22	0	0	0	0	52	0	0	0	0
23	0	0	0	0	53	0	0	0	0
24	0	0	0	0	54	0	0	0	0
25	0	0	0	0	55	0	0	0	0
26	0	0	0	0	56	0	0	0	0
27	0	0	0	0	57	0	0	0	0
28	0	0	0	0	58	0	0	0	0
29	0	0	0	0	59	0	0	0	0
30	0	0	0	0	60	0	0	0	0

AVERAGE OPACITY FOR HIGHEST PERIOD: 0 | NUMBER OF READINGS ABOVE 0 % WERE 0
RANGE OF OPACITY READINGS: 0 MINIMUM 0 MAXIMUM
OBSERVER'S NAME (PRINT): Jeff Francis
OBSERVER'S SIGNATURE: Jeff Francis | DATE: 12-10-87
ORGANIZATION: Environmental Testing Inc.
CERTIFIED BY: SCDHEC | DATE: 9-30-87
VERIFIED BY: | DATE:

COMMENTS: * Due to location of stack smoke must be read from adjusted angle. Observer-L. Choi

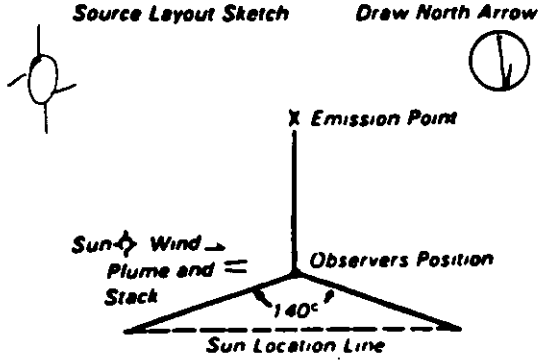
I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE:
TITLE: | DATE:

Visible Emission Observation Form

SOURCE NAME: Johnson Controls	OBSERVATION DATE: 12-10-87
ADDRESS:	START TIME: 1000
	STOP TIME: 1100
CITY: Winston-Salem	STATE: NC ZIP:
PHONE:	SOURCE ID NUMBER:
PROCESS EQUIPMENT: Gridcaster 7	OPERATING MODE:
CONTROL EQUIPMENT:	OPERATING MODE:
DESCRIBE EMISSION POINT: START 13.75" dia duct STOP	
HEIGHT ABOVE GROUND LEVEL: START 100' STOP	HEIGHT RELATIVE TO OBSERVER: START 40' STOP ✓
DISTANCE FROM OBSERVER: START 180' STOP	DIRECTION FROM OBSERVER: START SSW STOP ✓
DESCRIBE EMISSIONS: START No V.E.s STOP ✓	
EMISSION COLOR: START — STOP —	PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
WATER DROPLETS PRESENT: NO ☒ YES ☐	IF WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START 1 diameter STOP ✓	
DESCRIBE BACKGROUND: START BUILDING ROOF STOP ✓	
BACKGROUND COLOR: START LIGHT green STOP ✓	SKY CONDITIONS: START OVER CAST STOP ✓ RAIN
WIND SPEED: START 1-3 STOP	WIND DIRECTION: START E STOP ✓
AMBIENT TEMP: START 15C STOP ✓	WET BULB TEMP: — RH.percent: —

SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1	0	0	0	0	31	0	0	0	0
2	0	0	0	0	32	0	0	0	0
3	0	0	0	0	33	0	0	0	0
4	0	0	0	0	34	0	0	0	0
5	0	0	0	0	35	0	0	0	0
6	0	0	0	0	36	0	0	0	0
7	0	0	0	0	37	0	0	0	0
8	0	0	0	0	38	0	0	0	0
9	0	0	0	0	39	0	0	0	0
10	0	0	0	0	40	0	0	0	0
11	0	0	0	0	41	0	0	0	0
12	0	0	0	0	42	0	0	0	0
13	0	0	0	0	43	0	0	0	0
14	0	0	0	0	44	0	0	0	0
15	0	0	0	0	45	0	0	0	0
16	0	0	0	0	46	0	0	0	0
17	0	0	0	0	47	0	0	0	0
18	0	0	0	0	48	0	0	0	0
19	0	0	0	0	49	0	0	0	0
20	0	0	0	0	50	0	0	0	0
21	0	0	0	0	51	0	0	0	0
22	0	0	0	0	52	0	0	0	0
23	0	0	0	0	53	0	0	0	0
24	0	0	0	0	54	0	0	0	0
25	0	0	0	0	55	0	0	0	0
26	0	0	0	0	56	0	0	0	0
27	0	0	0	0	57	0	0	0	0
28	0	0	0	0	58	0	0	0	0
29	0	0	0	0	59	0	0	0	0
30	0	0	0	0	60	0	0	0	0

Source Layout Sketch — Drew North Arrow



AVERAGE OPACITY FOR HIGHEST PERIOD: 0	NUMBER OF READINGS ABOVE 0% WERE 0
RANGE OF OPACITY READINGS: 0 MINIMUM	0 MAXIMUM
OBSERVER'S NAME (PRINT): Jeff Francis	
OBSERVER'S SIGNATURE: Jeff Francis	DATE: 12-10-87
ORGANIZATION: Environmental Testing Inc	
CERTIFIED BY: SCDHEC	DATE: 9-30-87
VERIFIED BY:	DATE:

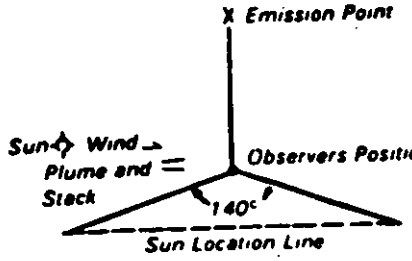
COMMENTS: Due to location of stack smoke must be read from adjusted angle. Observer-L. Chi.

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE
TITLE — DATE

Visible Emission Observation Form

SOURCE NAME: Johnson Controls
ADDRESS:
CITY: Winston-Salem | STATE: NC | ZIP:
PHONE: | SOURCE ID NUMBER:
PROCESS EQUIPMENT: Gridcaster 7 | OPERATING MODE:
CONTROL EQUIPMENT: | OPERATING MODE:
DESCRIBE EMISSION POINT: START 3.75" dia duct STOP ✓
HEIGHT ABOVE GROUND LEVEL: START 100' STOP ✓ | HEIGHT RELATIVE TO OBSERVER: START 40' STOP —
DISTANCE FROM OBSERVER: START 180' STOP ✓ | DIRECTION FROM OBSERVER: START SSW STOP ✓
DESCRIBE EMISSIONS: START No VE's STOP ✓
EMISSION COLOR: START — STOP — | PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
WATER DROPLETS PRESENT: NO ☒ YES ☐ | IF WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START 1 diameter STOP ✓
DESCRIBE BACKGROUND: START BUILDING ROOF STOP —
BACKGROUND COLOR: START LIGHT GREEN STOP — | SKY CONDITIONS: START OVER CAST STOP ✓ RAIN
WIND SPEED: START 1-3 STOP — | WIND DIRECTION: START E STOP ✓
AMBIENT TEMP: START 15°C STOP ~ | WET BULB TEMP: | RH, percent:

Source Layout Sketch — Draw North Arrow



COMMENTS: Due to stack location smoke must be read from adjusted angle.

Observer - L. Choi

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE | DATE
TITLE

OBSERVATION DATE: 12-10-87 | START TIME: 1145 | STOP TIME: 1245

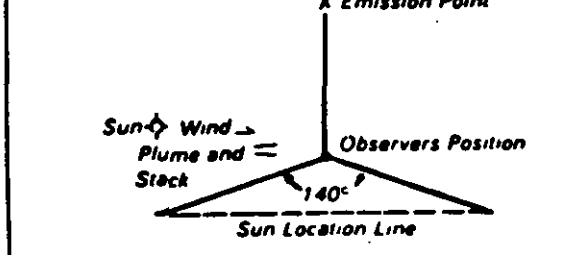
SEC / MIN	0	15	30	45	MIN	0	15	30	45
1	0	0	0	0	31	0	0	0	0
2	0	0	0	0	32	0	0	0	0
3	0	0	0	0	33	0	0	0	0
4	0	0	0	0	34	0	0	0	0
5	0	0	0	0	35	0	0	0	0
6	0	0	0	0	36	0	0	0	0
7	0	0	0	0	37	0	0	0	0
8	0	0	0	0	38	0	0	0	0
9	0	0	0	0	39	0	0	0	0
10	0	0	0	0	40	0	0	0	0
11	0	0	0	0	41	0	0	0	0
12	0	0	0	0	42	0	0	0	0
13	0	0	0	0	43	0	0	0	0
14	0	0	0	0	44	0	0	0	0
15	0	0	0	0	45	0	0	0	0
16	0	0	0	0	46	0	0	0	0
17	0	0	0	0	47	0	0	0	0
18	0	0	0	0	48	0	0	0	0
19	0	0	0	0	49	0	0	0	0
20	0	0	0	0	50	0	0	0	0
21	0	0	0	0	51	0	0	0	0
22	0	0	0	0	52	0	0	0	0
23	0	0	0	0	53	0	0	0	0
24	0	0	0	0	54	0	0	0	0
25	0	0	0	0	55	0	0	0	0
26	0	0	0	0	56	0	0	0	0
27	0	0	0	0	57	0	0	0	0
28	0	0	0	0	58	0	0	0	0
29	0	0	0	0	59	0	0	0	0
30	0	0	0	0	60	0	0	0	0

AVERAGE OPACITY FOR HIGHEST PERIOD: 0 | NUMBER OF READINGS ABOVE 0 % WERE 0
RANGE OF OPACITY READINGS: MINIMUM 0 MAXIMUM 0
OBSERVER'S NAME (PRINT): Jeff Francis
OBSERVER'S SIGNATURE: Jeff Francis | DATE: 12-10-87
ORGANIZATION: Environmental Testing Inc.
CERTIFIED BY: SCDHEC | DATE: 9-30-87
VERIFIED BY: | DATE:

Visible Emission Observation Form

SOURCE NAME: Johnson Controls
ADDRESS:
CITY: Winston-Salem | STATE: NC | ZIP:
PHONE: | SOURCE ID NUMBER:
PROCESS EQUIPMENT: Gridcaster 8 | OPERATING MODE:
CONTROL EQUIPMENT: | OPERATING MODE:
DESCRIBE EMISSION POINT: START 13.75" dia duct STOP ✓
HEIGHT ABOVE GROUND LEVEL: START 100' STOP ✓ | HEIGHT RELATIVE TO OBSERVER: START 40' STOP ✓
DISTANCE FROM OBSERVER: START 100' STOP ✓ | DIRECTION FROM OBSERVER: START SE+ STOP ✓
DESCRIBE EMISSIONS: START No V.E.'s STOP
EMISSION COLOR: START ____ STOP ____ | PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
WATER DROPLETS PRESENT: NO ☒ YES ☐ | IF WATER DROPLET PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START 1 diameter STOP ✓
DESCRIBE BACKGROUND: START BUILDING ROOF STOP ✓
BACKGROUND COLOR: START LIGHT GREEN STOP ✓ | SKY CONDITIONS: START OVER CAST STOP ✓
WIND SPEED: START 1-3 STOP | WIND DIRECTION: START N STOP E
AMBIENT TEMP: START 15°c STOP ✓ | WET BULB TEMP: ____ | RH,percent: ____

Source Layout Sketch — Draw North Arrow



OBSERVATION DATE	START TIME	STOP TIME
12-10-87	0830	0930

SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1	0	0	0	0	31	0	0	0	0
2	0	0	0	0	32	0	0	0	0
3	0	0	0	0	33	0	0	0	0
4	0	0	0	0	34	0	0	0	0
5	0	0	0	0	35	0	0	0	0
6	0	0	0	0	36	0	0	0	0
7	0	0	0	0	37	0	0	0	0
8	0	0	0	0	38	0	0	0	0
9	0	0	0	0	39	0	0	0	0
10	0	0	0	0	40	0	0	0	0
11	0	0	0	0	41	0	0	0	0
12	0	0	0	0	42	0	0	0	0
13	0	0	0	0	43	0	0	0	0
14	0	0	0	0	44	0	0	0	0
15	0	0	0	0	45	0	0	0	0
16	0	0	0	0	46	0	0	0	0
17	0	0	0	0	47	0	0	0	0
18	0	0	0	0	48	0	0	0	0
19	0	0	0	0	49	0	0	0	0
20	0	0	0	0	50	0	0	0	0
21	0	0	0	0	51	0	0	0	0
22	0	0	0	0	52	0	0	0	0
23	0	0	0	0	53	0	0	0	0
24	0	0	0	0	54	0	0	0	0
25	0	0	0	0	55	0	0	0	0
26	0	0	0	0	56	0	0	0	0
27	0	0	0	0	57	0	0	0	0
28	0	0	0	0	58	0	0	0	0
29	0	0	0	0	59	0	0	0	0
30	0	0	0	0	60	0	0	0	0

AVERAGE OPACITY FOR HIGHEST PERIOD: 0
NUMBER OF READINGS ABOVE 0% WERE: 0
RANGE OF OPACITY READINGS: 0 MINIMUM 0 MAXIMUM
OBSERVER'S NAME (PRINT): Jeff Francis
OBSERVER'S SIGNATURE: Jeff Francis | DATE: 12-10-87
ORGANIZATION: Environmental Testing Inc.
CERTIFIED BY: SCDHEC | DATE: 9-30-87
VERIFIED BY: | DATE:

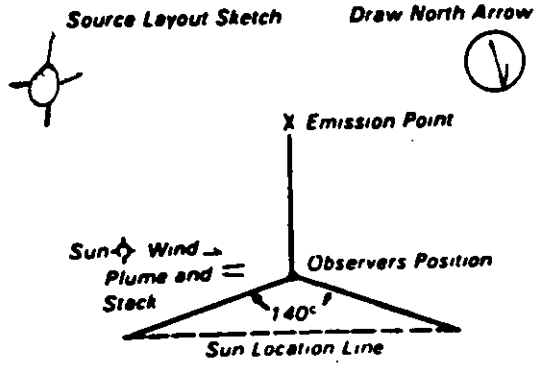
COMMENTS: * Due to location of stack smoke must be read from adjusted angle.
Observer L.Chei

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS
SIGNATURE | TITLE | DATE

Visible Emission Observation Form

SOURCE NAME	Johnson Controls
ADDRESS	
CITY	Winston-Salem
STATE	N C
ZIP	
PHONE	
SOURCE ID NUMBER	
PROCESS EQUIPMENT	Gridcaster 8
OPERATING MODE	
CONTROL EQUIPMENT	
OPERATING MODE	
DESCRIBE EMISSION POINT	START 13.75" dia duct STOP ✓
HEIGHT ABOVE GROUND LEVEL	START 100' STOP
HEIGHT RELATIVE TO OBSERVER	START 40' STOP ✓
DISTANCE FROM OBSERVER	START 180' STOP ✓
DIRECTION FROM OBSERVER	START SSW STOP ✓
DESCRIBE EMISSIONS	START No V.E.'s STOP ✓
EMISSION COLOR	START — STOP —
PLUME TYPE	CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
WATER DROPLETS PRESENT	NO ☒ YES ☐
IF WATER DROPLET PLUME	ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED	START 1 diameter STOP —
DESCRIBE BACKGROUND	START BUILDING ROOF STOP ✓
BACKGROUND COLOR	START LIGHT GREEN STOP ✓
SKY CONDITIONS	START OVER-CAST STOP —
WIND SPEED	START 1-3 STOP —
WIND DIRECTION	START E STOP —
AMBIENT TEMP	START 15°C STOP —
WET BULB TEMP	
RH,percent	—

Source Layout Sketch — Draw North Arrow



OBSERVATION DATE	START TIME	STOP TIME
12-10-87	1000	1100

SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1	0	0	0	0	31	0	0	0	0
2	0	0	0	0	32	0	0	0	0
3	0	0	0	0	33	0	0	0	0
4	0	0	0	0	34	0	0	0	0
5	0	0	0	0	35	0	0	0	0
6	0	0	0	0	36	0	0	0	0
7	0	0	0	0	37	0	0	0	0
8	0	0	0	0	38	0	0	0	0
9	0	0	0	0	39	0	0	0	0
10	0	0	0	0	40	0	0	0	0
11	0	0	0	0	41	0	0	0	0
12	0	0	0	0	42	0	0	0	0
13	0	0	0	0	43	0	0	0	0
14	0	0	0	0	44	0	0	0	0
15	0	0	0	0	45	0	0	0	0
16	0	0	0	0	46	0	0	0	0
17	0	0	0	0	47	0	0	0	0
18	0	0	0	0	48	0	0	0	0
19	0	0	0	0	49	0	0	0	0
20	0	0	0	0	50	0	0	0	0
21	0	0	0	0	51	0	0	0	0
22	0	0	0	0	52	0	0	0	0
23	0	0	0	0	53	0	0	0	0
24	0	0	0	0	54	0	0	0	0
25	0	0	0	0	55	0	0	0	0
26	0	0	0	0	56	0	0	0	0
27	0	0	0	0	57	0	0	0	0
28	0	0	0	0	58	0	0	0	0
29	0	0	0	0	59	0	0	0	0
30	0	0	0	0	60	0	0	0	0

AVERAGE OPACITY FOR HIGHEST PERIOD	0
NUMBER OF READINGS ABOVE	0 % WERE 0
RANGE OF OPACITY READINGS	0 MINIMUM 0 MAXIMUM
OBSERVER'S NAME (PRINT)	Jeff Francis
OBSERVER'S SIGNATURE	Jeff Francis
DATE	12-10-87
ORGANIZATION	Environmental Testing Inc.
CERTIFIED BY	SCDHEC
DATE	9-30-87
VERIFIED BY	
DATE	

COMMENTS Due to location of stack smoke must be read from adjusted angle.

Observer - C. Choi

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SIGNATURE

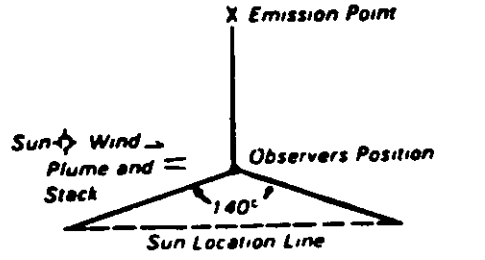
TITLE

DATE

Visible Emission Observation Form

SOURCE NAME: Johnson Controls		OBSERVATION DATE:	START TIME: 1145 / STOP TIME: 1245
ADDRESS:			
CITY: Winston-Salem	STATE: NC	ZIP:	
PHONE:	SOURCE ID NUMBER:		
PROCESS EQUIPMENT: Gridcaster 8	OPERATING MODE:		
CONTROL EQUIPMENT:	OPERATING MODE:		
DESCRIBE EMISSION POINT: START 13.75" dia. duct	STOP ✓		
HEIGHT ABOVE GROUND LEVEL: START 100'	STOP ✓	HEIGHT RELATIVE TO OBSERVER: START 40'	STOP ✓
DISTANCE FROM OBSERVER: START 180'	STOP ✓	DIRECTION FROM OBSERVER: START SSW	STOP ✓
DESCRIBE EMISSIONS: START No Vis.	STOP ✓		
EMISSION COLOR: START ✓	STOP ✓	PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐	INTERMITTENT ☐
WATER DROPLETS PRESENT: NO ☒ YES ☐		IF WATER DROPLET PLUME: ATTACHED ☐	DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: START 1 diameter	STOP ✓		
DESCRIBE BACKGROUND: START BUILDING ROOF	STOP ✓		
BACKGROUND COLOR: START LIGHT GREEN	STOP ✓	SKY CONDITIONS: START OVER-CAST	STOP ✓
WIND SPEED: START 1-3	STOP ✓	WIND DIRECTION: START E	STOP ✓
AMBIENT TEMP: START 15°C	STOP ✓	WET BULB TEMP: ✓	RH, percent: ✓

Source Layout Sketch — Draw North Arrow



SEC / MIN	0	15	30	45	SEC / MIN	0	15	30	45
1	0	0	0	0	31	0	0	0	0
2	0	0	0	0	32	0	0	0	0
3	0	0	0	0	33	0	0	0	0
4	0	0	0	0	34	0	0	0	0
5	0	0	0	0	35	0	0	0	0
6	0	0	0	0	36	0	0	0	0
7	0	0	0	0	37	0	0	0	0
8	0	0	0	0	38	0	0	0	0
9	0	0	0	0	39	0	0	0	0
10	0	0	0	0	40	0	0	0	0
11	0	0	0	0	41	0	0	0	0
12	0	0	0	0	42	0	0	0	0
13	0	0	0	0	43	0	0	0	0
14	0	0	0	0	44	0	0	0	0
15	0	0	0	0	45	0	0	0	0
16	0	0	0	0	46	0	0	0	0
17	0	0	0	0	47	0	0	0	0
18	0	0	0	0	48	0	0	0	0
19	0	0	0	0	49	0	0	0	0
20	0	0	0	0	50	0	0	0	0
21	0	0	0	0	51	0	0	0	0
22	0	0	0	0	52	0	0	0	0
23	0	0	0	0	53	0	0	0	0
24	0	0	0	0	54	0	0	0	0
25	0	0	0	0	55	0	0	0	0
26	0	0	0	0	56	0	0	0	0
27	0	0	0	0	57	0	0	0	0
28	0	0	0	0	58	0	0	0	0
29	0	0	0	0	59	0	0	0	0
30	0	0	0	0	60	0	0	0	0

AVERAGE OPACITY FOR HIGHEST PERIOD: 0	NUMBER OF READINGS ABOVE: 0 % WERE 0
RANGE OF OPACITY READINGS: 0 MINIMUM	0 MAXIMUM
OBSERVER'S NAME (PRINT): Jeff Francis	
OBSERVER'S SIGNATURE: Jeff Francis	DATE: 12-10-87
ORGANIZATION: Environmental Testing Inc.	
CERTIFIED BY: SCDHEC	DATE: 9-30-87
VERIFIED BY:	DATE:

COMMENTS: Due to location of stack smoke must be read from adjusted angle. Observer L. Choi

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS

SIGNATURE | TITLE | DATE

Johnson Controls, Inc.
Battery Division
Old Greensboro Road
Post Office Box 1002
Winston-Salem, NC 27102
Tel. 919/761 1550

APPENDIX C

JOHNSON CONTROLS

December 18, 1987

Paul Jenkins
Environmental Testing
1700 University Commercial Place
Charlotte, NC 28213

Dear Mr. Jenkins:

Our production for Grid Casting on December 10, 1987 was:

Bank #8: 40,600 grids

Bank #7: 24,900 grids

2x# Panels

Sincerely,

Mark Pegram/dcl

Mark Pegram
Engineering Manager

MP:dcl

JOHNSON CONTROLS

KEY: 2100

JOHNSON CONTROLS, INC.

EMPLOYEE'S EARNINGS COMPUTATION WORKSHEET

DEPARTMENT 11

WORK CENTER 3

FACILITY CODE H

FACILITY NAME W/S

PROD-TRANS-DATE: 12-10-87 PROD-SHIFT-NBR ~~1~~ 2 3 MACHINE-LINE-NBR 1 2 3 4 5 6 ~~7~~ 8 9 10

OPERATOR NAME	JOB CL.	CLOCK NUMBER	TOTAL WORK HRS. *	MEASURED HOURS	DAYWORK HOURS *	TRANSFER	BOOST	EARNED HOURS	TOTAL PAY HOURS	COVERAGE 68 %
W. Hustead	6	41002	8.0	5.4	2.6			7.85		MEASURED 145%
		TOTAL								131%

PRODUCTIVE

OPER. NO.	DESCRIPTION	MACH NO.	PART NUMBER	PANELS PRODUCED	STANDARD HOURS/C	UNIT	EARNED HOURS	START QTY. (-)	PANELS TO STORAGE(+)	FINISH QTY. (+)
200	CAST AT 15 PANELS/MIN.	1	030-10079	6750	.0572	PANELS		6550		12800
204	CAST AT 16 PANELS/MIN.		030-		.0554	PANELS				
			030-							
			030-							
200	CAST AT 15 PANELS/MIN.	2	030-10182	Down	.0572	PANELS		1100		1100
204	CAST AT 16 PANELS/MIN.		030-		.0554	PANELS				
			030-							
			030-							
200	CAST AT 15 PANELS/MIN.	3	030-11632	6200	.0572	PANELS		13,450	15750	3900
204	CAST AT 16 PANELS/MIN.		030-		.0554	PANELS				
			030-							
			030-							
			030-							
			030-							
			030-							
			030-							
			030-							
			030-							
			030-							
	TOTAL PANELS PRODUCED			12,450			712			

15,750
13,450
2300
3800
6100

12800
6550
6250

REPORTED LEAD USAGE (PIGS)

BEGINNING INVENTORY (+)	PIGS MOVED TO MACHINE (+)	ENDING INVENTORY (-)	PART NUMBER	LOT NUMBER	PIGS USED
73		35	080- CA	442	38
-35			080-	467	
38			080-	7519	
			080-10226 REMELT		
				GRAND TOTAL	38

POUNDS OF DROSS GENERATED DURING THIS SHIFT

080-10257 _____ LBS.

GRID SCRAP (IN LBS.)

080- _____ LBS.

OPERATOR SIGNATURE

Wm Hustead

SUPERVISOR APPROVAL

PBG

FORM 211-153 REV. 6/87

JOHNSON TRLS

JOHNSON CONTROLS, INC.

EMPLOYEE'S EARNINGS COMPUTATION WORKSHEET

DEPARTMENT 11

WORK CENTER 3

FACILITY CODE H

FACILITY NAME W/S

21

J-TRANS-DATE 12-10-87 PROD-SHIFT-NBR (1) 2 3 MACHINE-LINE-NBR 1 2 3 4 5 6 7 (8) 9 10

OPERATOR NAME	JOB CL.	CLOCK NUMBER	TOTAL WORK HRS.	MEASURED HOURS	DAYWORK HOURS	TRANSFER	BOOST	EARNED HOURS	TOTAL PAY HOURS	COVERAGE 98 %
Hampton	6	143	8	7.8	.2			1749		MEASURED 160
										159
		TOTAL								

PRODUCTIVE

OPER. NO.	DESCRIPTION	MACH NO.	PART NUMBER	PANELS PRODUCED	STANDARD HOURS/C	UNIT	EARNED HOURS	START QTY. (-)	PANELS TO STORAGE(+)	FINISH QTY. (+)
208	CAST AT 15 PANELS/MIN.	1	030-10488	6750	.0572	PANELS		7000		13750
204	CAST AT 16 PANELS/MIN.		030-		.0554	PANELS				
			030-							
			030-							
208	CAST AT 15 PANELS/MIN.	2	030-10482	6800	.0572	PANELS		13350	15562	4400
204	CAST AT 16 PANELS/MIN.		030-		.0554	PANELS				
			030-				13,552			
			030-							
208	CAST AT 15 PANELS/MIN.	3	030-10480	6750	.0572	PANELS		600		7350
204	CAST AT 16 PANELS/MIN.		030-		.0554	PANELS				
			030-							
			030-							
			030-							
			030-							
			030-							
			030-							
			030-							
	TOTAL PANELS PRODUCED			20300			1161			

REPORTED LEAD USAGE (PIGS)

BEGINNING INVENTORY (+)	PIGS MOVED TO MACHINE (+)	ENDING INVENTORY (-)	PART NUMBER	LOT NUMBER	PIGS USED
99	0	25	080-CA		74
			080-		
			080-		
			080-10226 REMELT		
			GRAND TOTAL		74

POUNDS OF DROSS GENERATED DURING THIS SHIFT

080-10257 _____ LBS.

GRID SCRAP (IN LBS.)

080- _____ LBS.

OPERATOR SIGNATURE

M. Hampton

SUPERVISOR APPROVAL

FORM 211-153 REV. 6/87

APPENDIX D

TEST PARTICIPANTS

James S. McCormack, P.E.	President Environmental Testing, Inc.
Paul R. Jenkins, Jr.	Vice-President Environmental Testing, Inc.
F. Larson Harsey	Biologist Environmental Testing, Inc.
Jeff A. Francis	Biologist Environmental Testing, Inc.

federal register

THURSDAY, AUGUST 18, 1977
PART II

ENVIRONMENTAL PROTECTION AGENCY

■

STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Revision to Reference Method 1-8

have peroxide impurities that will cause erroneously high sulfuric acid mist measurements, a test for peroxides in isopropanol has been included in the method.

4. The gravimetric technique for moisture content (rather than volumetric) has been specified because a mixture of isopropyl alcohol and water will have a volume less than the sum of the volumes of its content.

5. A closer correspondence has been made between similar parts of Methods 8 and 5.

MISCELLANEOUS

Several commenters questioned the meaning of the term "subject to the approval of the Administrator" in relation to using alternate test methods and procedures. As defined in § 60.2 of subpart A, the "Administrator" includes any authorized representative of the Administrator of the Environmental Protection Agency. Authorized representatives are EPA officials in EPA Regional Offices or State, local, and regional governmental officials who have been delegated the responsibility of enforcing regulations under 40 CFR 60. These officials in consultation with other staff members familiar with technical aspects of source testing will render decisions regarding acceptable alternate test procedures.

In accordance with section 117 of the Act, publication of these methods was preceded by consultation with appropriate advisory committees, independent experts, and Federal departments and agencies.

(Secs. 111, 114 and 301(a) of the Clean Air Act, sec. 4(a) of Pub. L. No. 91-604, 84 Stat. 1683; sec. 4(a) of Pub. L. No. 91-604, 84 Stat. 1687; sec. 2 of Pub. L. No. 90-148, 81 Stat. 504 [42 U.S.C. 1857c-6, 1857c-0, 1857g(a)].)

NOTE.—The Environmental Protection Agency has determined that this document does not contain a major proposal requiring preparation of an Economic Impact Analysis under Executive Orders 11821 and 11949 and OMB Circular A-107.

Dated: August 10, 1977.

DOUGLAS M. COSTLE,
Administrator.

Part 60 of Chapter I of Title 40 of the Code of Federal Regulations is amended by revising Methods 1 through 8 of Appendix A—Reference Methods as follows:

APPENDIX A—REFERENCE METHODS

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

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

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

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

Minor changes in the reference methods should not necessarily affect the validity of the results and it is recognized that alternative and equivalent methods exist. Section 114 provides authority for the Administrator to specify or approve (1) equivalent methods, (2) alternative methods, and (3) minor changes in the methodology of the reference methods. It should be *clearly understood* that unless otherwise identified all such methods and changes must have prior approval of the Administrator. An owner employing such methods or deviations from the reference methods without obtaining prior approval does so at the risk of subsequent disapproval and retesting with approved methods.

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

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

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

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

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

2. *Procedure*

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

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

Dated: September 22, 1983.
William D. Ruckelshaus,
Administrator.

PART 60—[AMENDED]

Appendix A of 40 CFR Part 60 is amended by revising Method 1 as follows:

1. By revising Figure 1–1 and Figure 1–2 as shown:

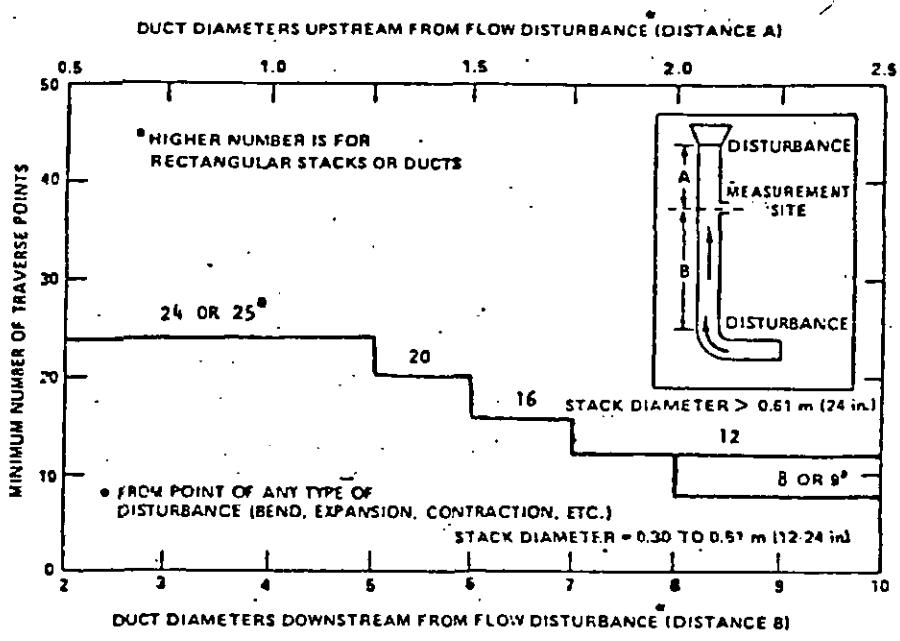


Figure 1-1. Minimum number of traverse points for particulate traverses.

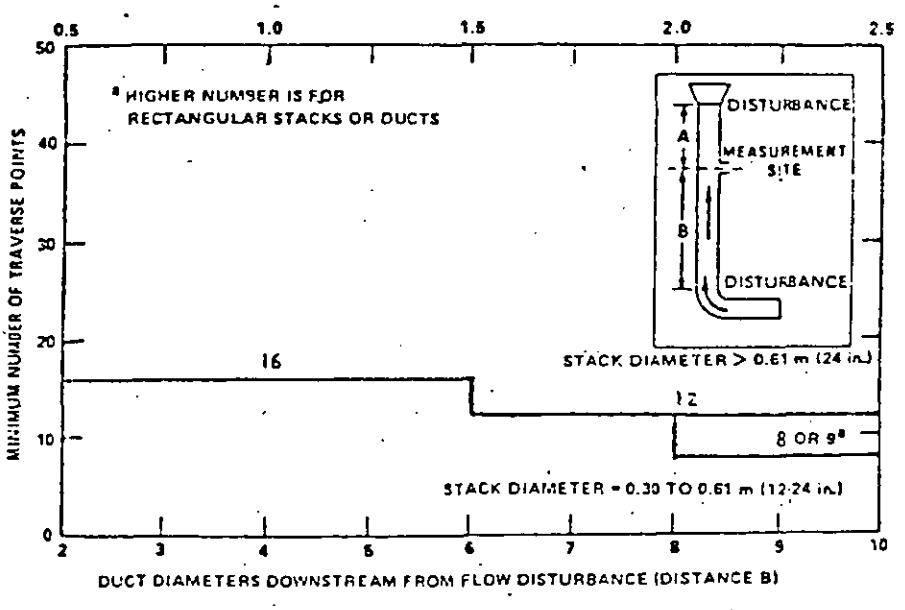


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

2. By adding Citations 7 through 12 to Section 3 (Bibliography) as follows:

Appendix A—Reference Methods

* * * * *

Method 1. Sample and Velocity Traverses for Stationary Sources

* * * * *

3. * * *

7. Hanson, H.A., R.J. Davini, J.K. Morgan, and A.A. Iversen. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA–600/2–76–170. June 1976. 350 p.

8. Brooks, E.F., and R.L. Williams. Flow and Gas Sampling Manual. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA–600/2–76–203. July 1976. 93 p.

9. Entropy Environmentalists, Inc. Traverse Point Study. EPA Contract No. 68–02–3172. June 1977. 18 p.

10. Brown, J. and K. Yu. Test Report: Particulate Sampling Strategy in Circular Ducts. Emission Measurement Branch. Emission Standards and Engineering Division. U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711. July 31, 1980. 12 p.

11. Hawksley, P.G.W., S. Badzioch, and J.H. Blackett. Measurement of Solids in Flue Gases. Leatherhead, England. The British Coal Utilisation Research Association, 1961. p. 129–133.

12. Knapp, K.T. The Number of Sampling Points Needed for Representative Source Sampling. In: Proceedings of the Fourth National Conference on Energy and the Environment, Theodore, L., et al. (ed.). Dayton, Dayton Section of the American Institute of Chemical Engineers. October 3–7, 1976. p. 563–568.

(Secs. 111, 114, and 301(a) of the Clean Air Act, as amended (42 U.S.C. 7411, 7414, and 7601(a)))

[FR Doc. 83-26377 Filed 9-29-83, 8:45 am]
BILLING CODE 6560-50-M

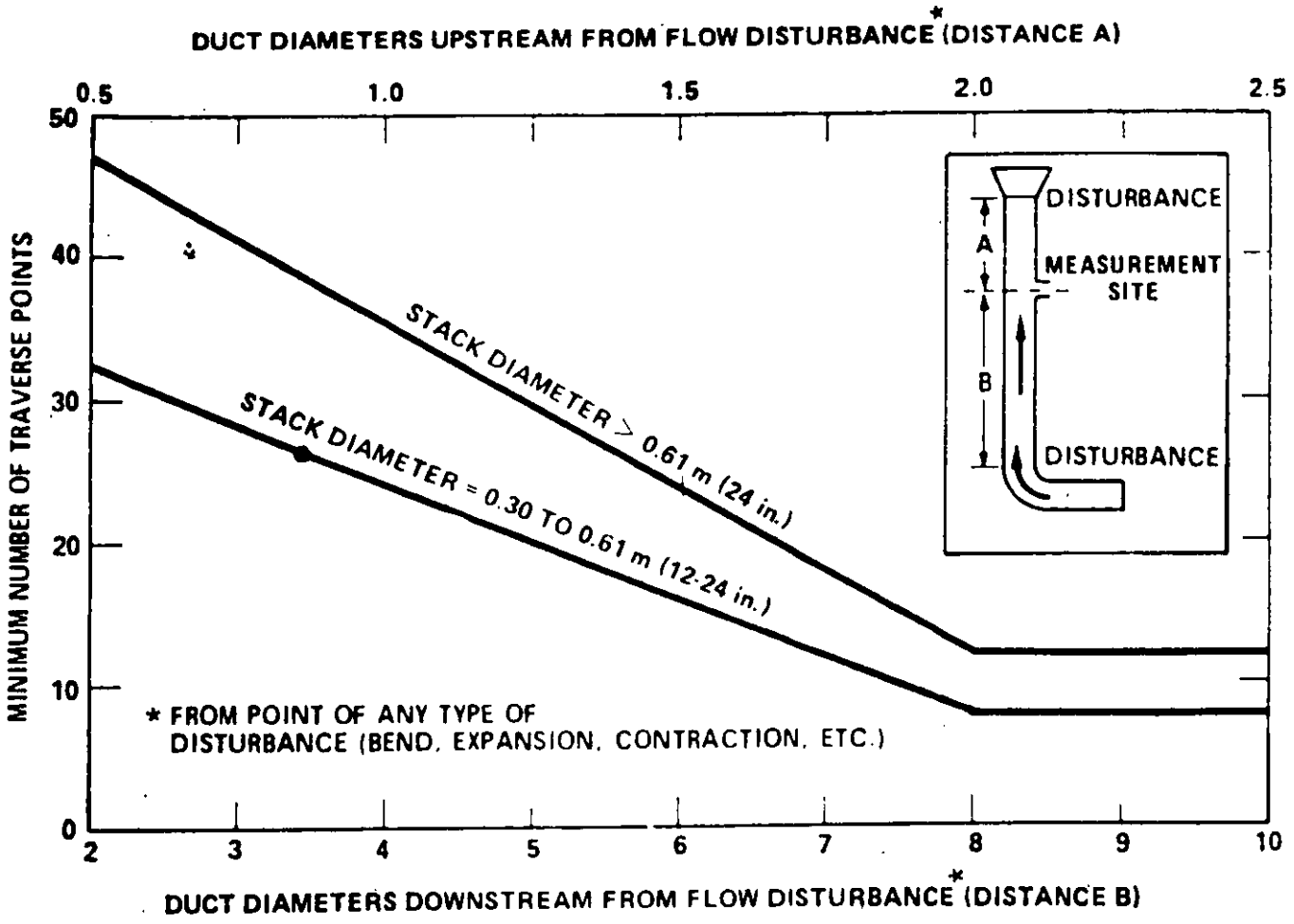


Figure 1-1. Minimum number of traverse points for particulate traverses.

where L = length and W = width.

2.2 Determining the Number of Traverse Points.

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

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

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

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

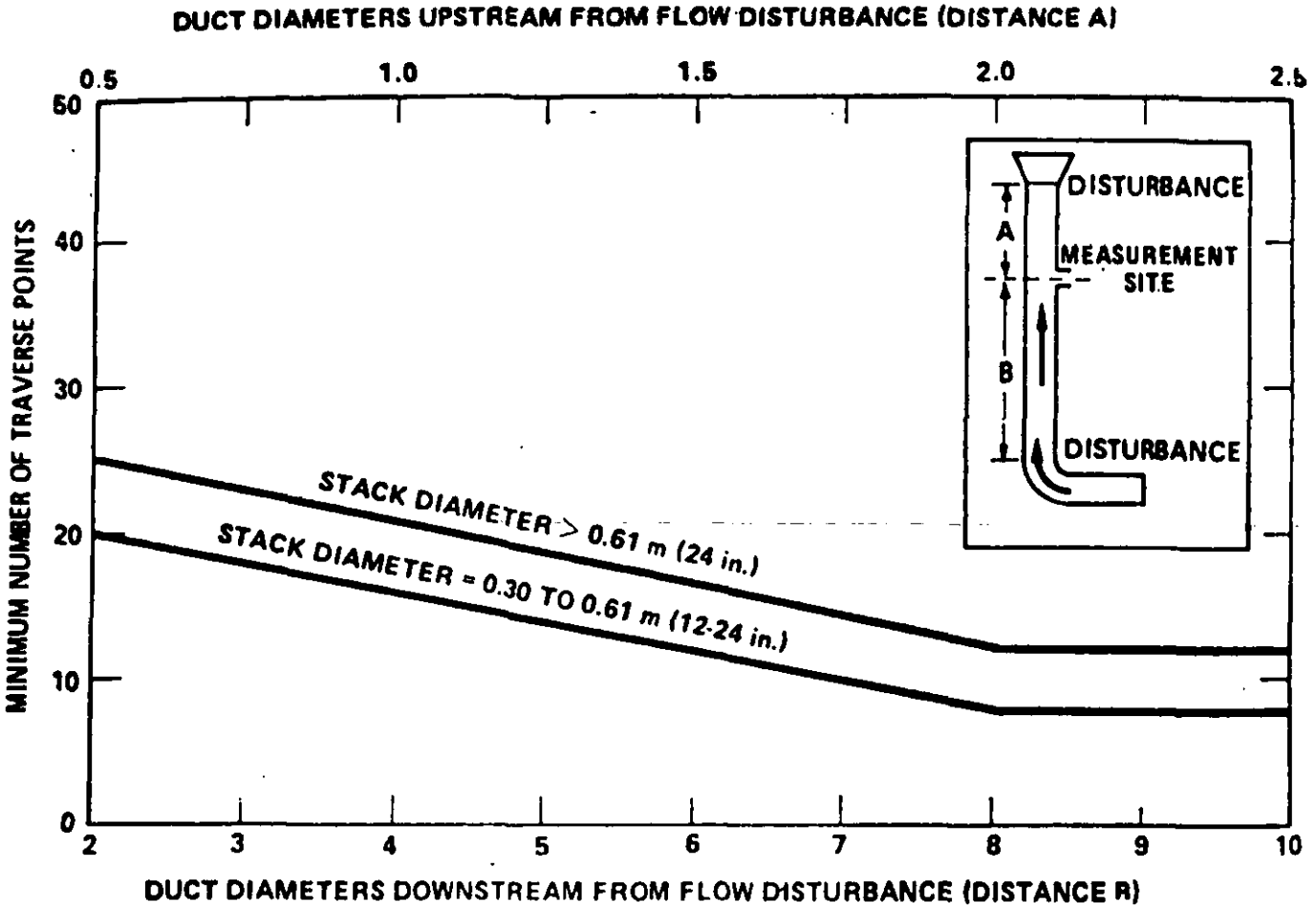


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

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

2.3 Cross-Sectional Layout and Location of Traverse Points.

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

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

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

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

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

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.7
3	29.6
4	70.5
5	85.3
6	95.6

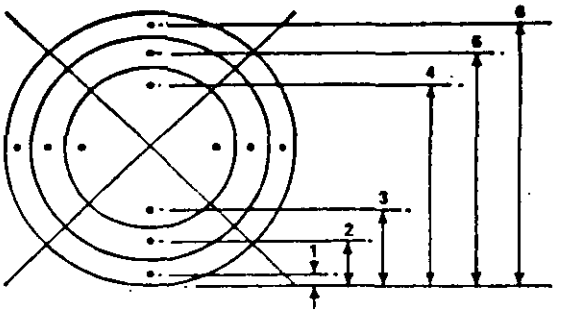


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

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

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

Traverse point number on a diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22 0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8				96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10					97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94 0	89 5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

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

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

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

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

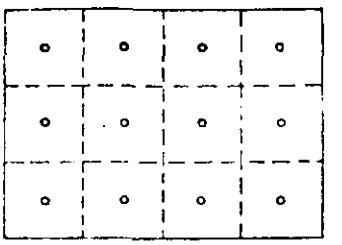


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

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

3. *Bibliography*

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

6. Entropy Environmentalists, Inc. Determination of the Optimum Number of Sampling Points: An Analysis of Method 1 Criteria. Environmental Protection Agency, *Research Triangle Park, N.C. EPA Contract No. 68-02-3172, Task 7.*

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 pitot tube 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 velocity data may not 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.

2.6 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.

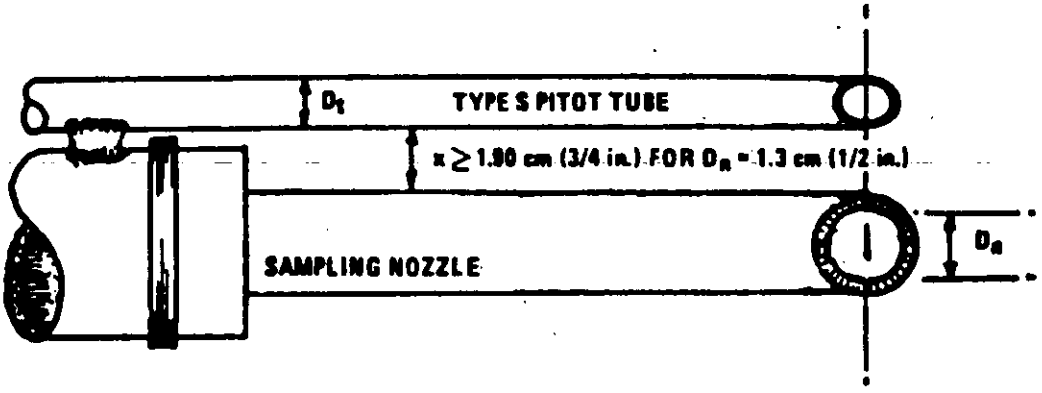
After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8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

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

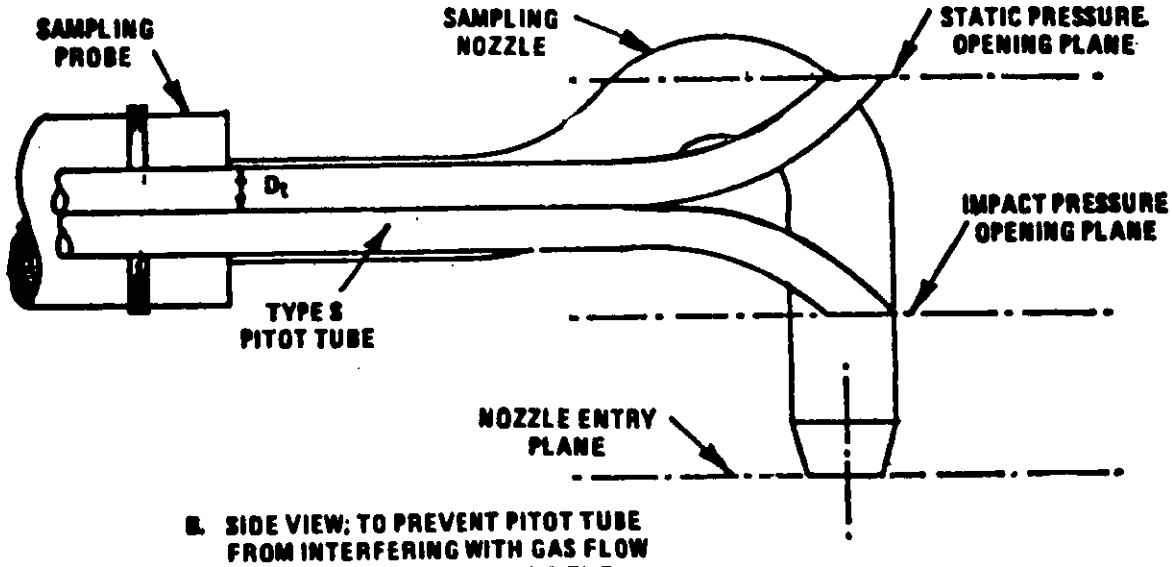
4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Citation 9 in Section 5); therefore an assigned (or otherwise known) baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. Figures 2-6 through 2-8 illustrate interference-free component arrangements for Type S pitot tubes having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

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

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



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



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

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

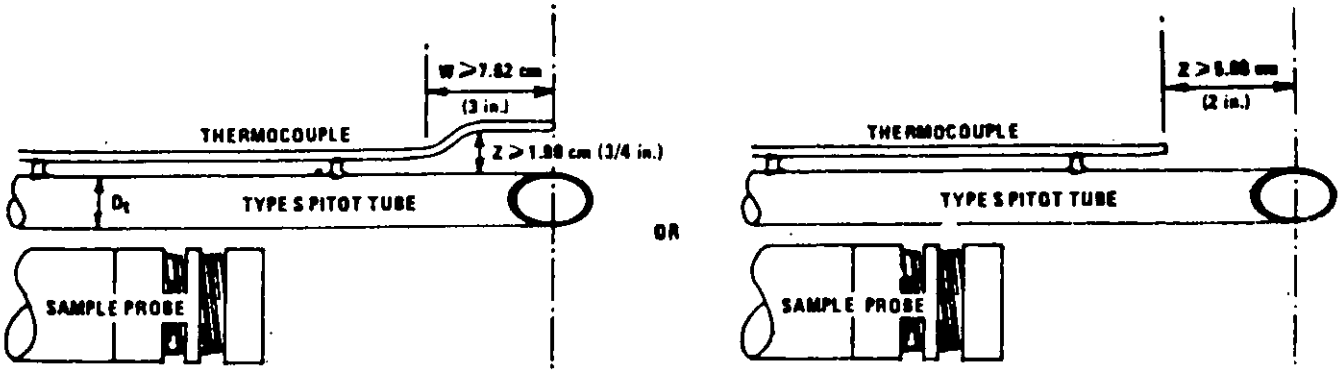


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

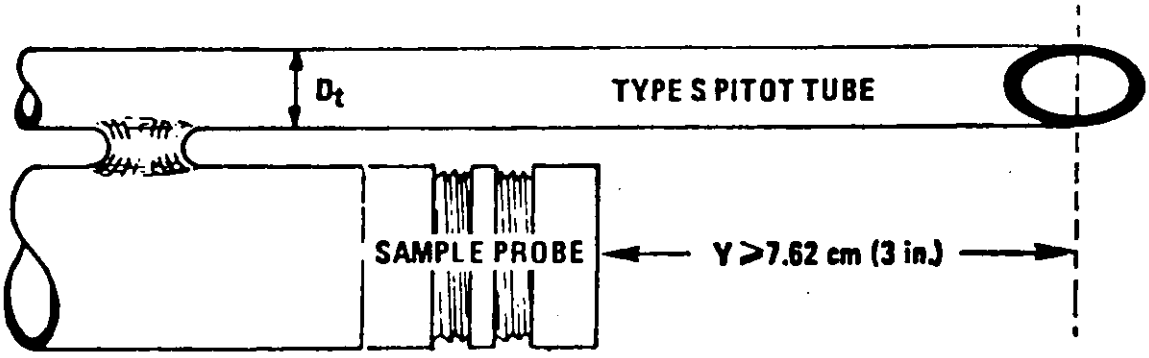


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

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

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

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

Equation 2-1

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

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

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

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min (1,000 ft/min) and to within ±6 to 8 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min). If a more precise correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 and 24 in Section 6 for details).

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

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

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

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

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

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

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

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

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

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

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

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

PITOT TUBE IDENTIFICATION NUMBER: _____ DATE: _____

CALIBRATED BY: _____

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

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

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

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

Figure 2-9. Pitot tube calibration data.

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

Equation 2-2

where:

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

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

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

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

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

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

Equation 2-3

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

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

Equation 2-4

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

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

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

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

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

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

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

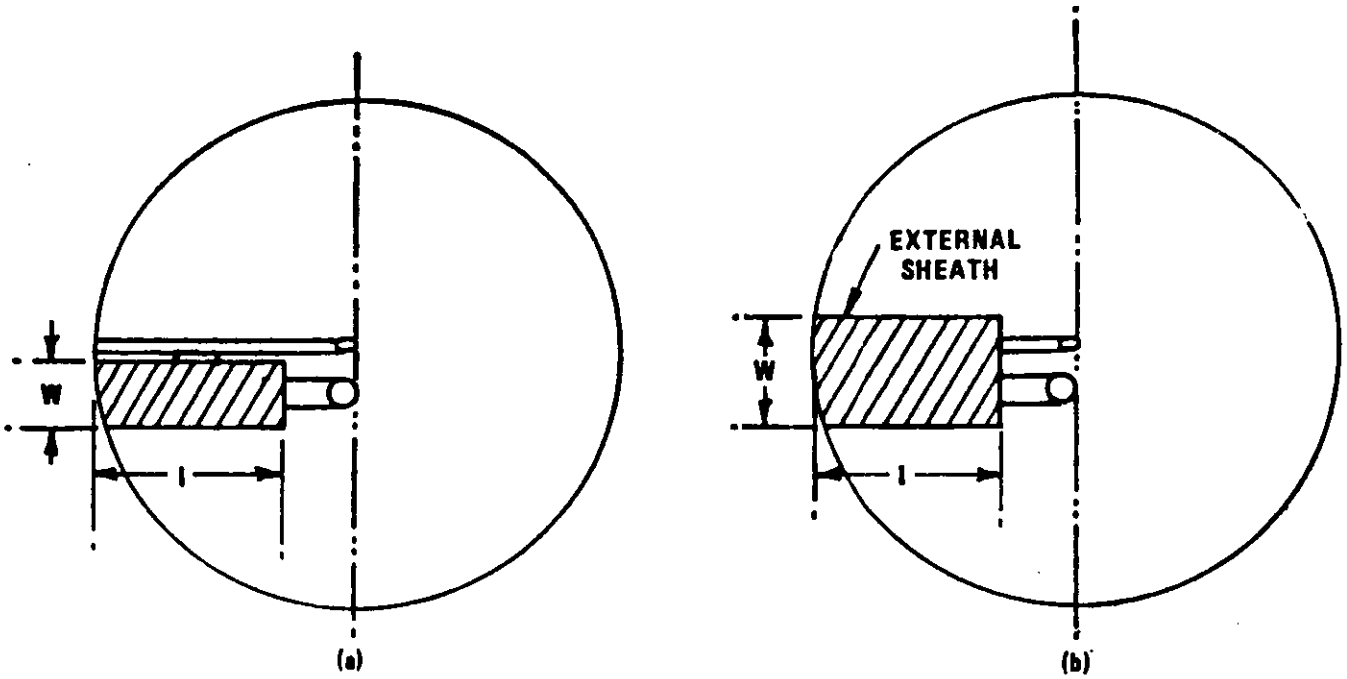


Figure 2-10. Projected-area models for typical pitot tube assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

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

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $\overline{C}_{p(s)}$. Consult Citation 9 in Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 10 in Section 6).

4.1.6.2 Recalibration.

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

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

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

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

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

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

5. *Calculations*

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

5.1 Nomenclature.

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

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

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant,

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

for the metric system and

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

for the English system.

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

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

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

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

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

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

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

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

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

t_s = Stack temperature, °C (°F).

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

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

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

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

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

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

3,600 = Conversion factor, sec/hr.

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

5.2 Average stack gas velocity.

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

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[1] analyzer may be used for the analysis; for excess air or emission rate correction factor determination, an Orsat analyzer must be used.

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

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

2. *Apparatus*

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

2.1 Grab Sampling (Figure 3-1).

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

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

2.2 Integrated Sampling (Figure 3-2).

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

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

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

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

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

2.2.5 Rate Meter. The rotameter, or equivalent rate meter, used should be capable of measuring flow rate to within ±2 percent of the selected flow rate. A flow rate range of 500 to 1000 cm^3/min is suggested.

2.2.6 Flexible Bag. Any leak-free plastic (e.g., Tedlar, Mylar, Teflon) or plastic-coated aluminum (e.g., aluminized Mylar) bag, or equivalent, having a capacity consistent with the selected flow rate and time length of the test run, may be used. A capacity in the range of 56 to 90 liters is suggested.

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

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 28 cm (12 in.) is used for the flexible bag leak-check.

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

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

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

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

3. Dry Molecular Weight Determination

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

3.1 Single-Point, Grab Sampling and Analytical Procedure.

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

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

3.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer and immediately analyze it for percent CO_2 and percent O_2. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

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

3.2 Single-Point, Integrated Sampling and Analytical Procedure.

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

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

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

3.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. Within 8 hours after the sample is taken, analyze it for percent CO_2 and percent O_2 using either an Orsat analyzer or a Fyrite-type combustion gas analyzer. If an Orsat analyzer is used, it is recommended that the Orsat leak-check described in Section 5 be performed before this determination; however, the check is optional. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

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

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

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

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

4.1 Single-Point, Grab Sampling and Analytical Procedure.

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

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

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

[a] $\%\ DEV = \left(\frac{Q - Q\ avg}{Q\ avg}\right) 100$ (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 Citation 5 in the Bibliography be used to validate the analytical data.

4.2 Single-Point, Integrated Sampling and Analytical Procedure.

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

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

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

4.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. For emission rate correction factor determination, analyze the sample within 4 hours after it is taken for percent CO_2 or percent O_2 (as outlined in Sections 4.2.5 through 4.2.7). The Orsat analyzer must be leak-checked (see Section 5) before the analysis. If excess air is desired, proceed as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 4.2.5 through 4.2.7) for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (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 0.5 percent. Average the three acceptable values of percent CO and report the results to the nearest 0.1 percent.

4.2.7 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis. Note: Although in most instances only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Citation 5 in the Bibliography be used to validate the analytical data.

4.3 Multi-Point, Integrated Sampling and Analytical Procedure.

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

4.3.2 Follow the procedures outlined in Sections 4.2.2 through 4.2.7, except for the following: Traverse all sampling points and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-6.

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 into the graduated portion of the burette and then close the manifold stopcock.

5.1.3 Record the meniscus position.

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

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

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

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

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

6. *Calculations*

6.1 Nomenclature.

M_d = Dry molecular weight, g/g-mole (lb/lb-mole).
%EA = Percent excess air.
$\%CO_2$ = Percent CO_2 by volume (dry basis).
$\%O_2$ = Percent O_2 by volume (dry basis).
%CO = Percent CO by volume (dry basis).
$\%N_2$ = Percent N_2 by volume (dry basis).
0.264 = Ratio of O_2 to N_2 in air, v/v.
0.280 = Molecular weight of N_2 or CO, divided by 100.
0.320 = Molecular weight of O_2 divided by 100.
0.440 = Molecular weight of CO_2 divided by 100.

6.2 Percent Excess Air. Calculate the percent excess air (if applicable), by substituting the appropriate values of percent O_2, CO, and N_2 (obtained from Section 4.1.3 or 4.2.4) into Equation 3-1.

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

Equation 3-1

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

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

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

Equation 3-2

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

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METHOD 4—DETERMINATION OF MOISTURE CONTENT IN STACK GASES

1. *Principle and Applicability*

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

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

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

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

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

2. *Reference Method*

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

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

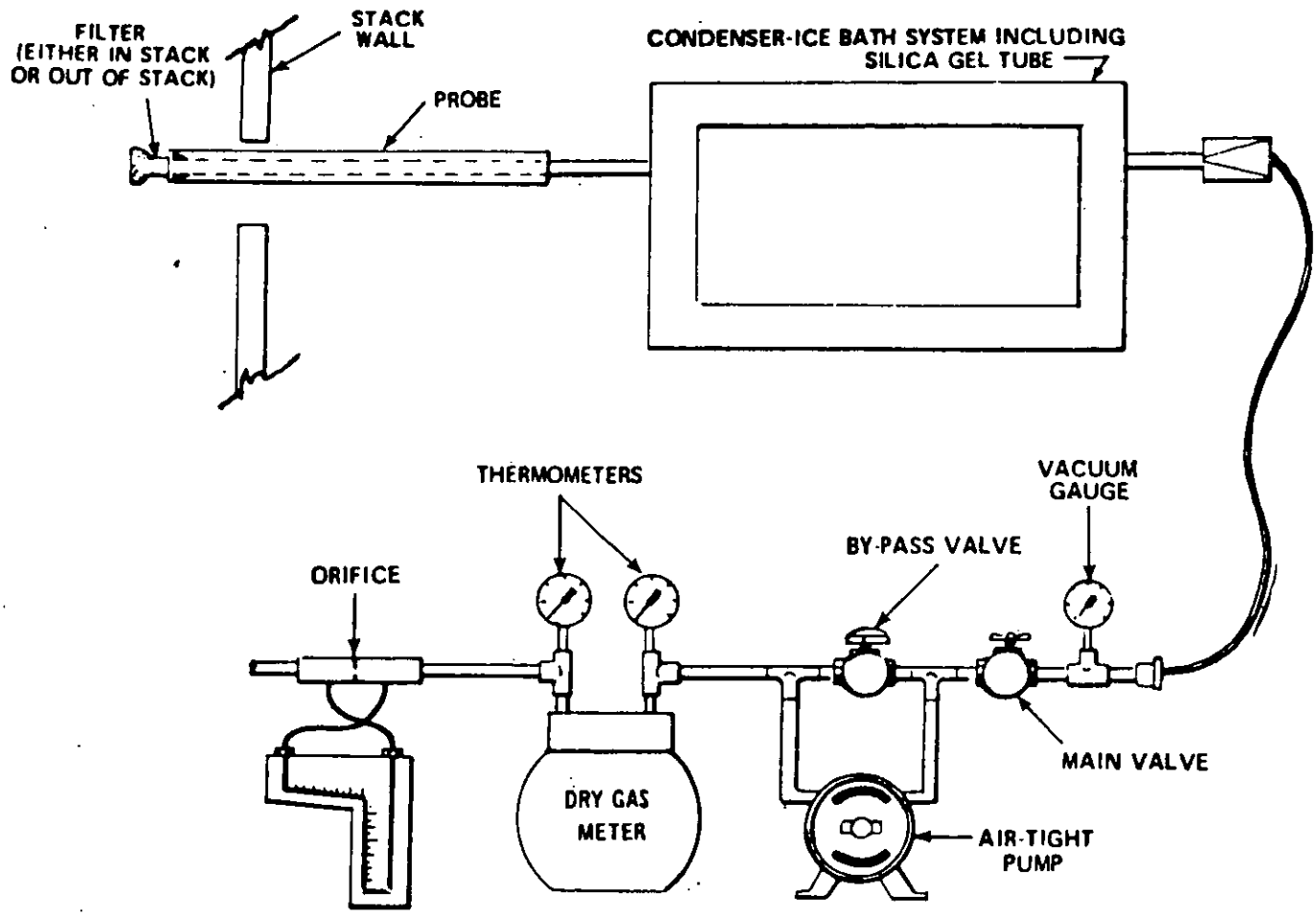

Figure 4-1. Moisture sampling train-reference method.

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or

(if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

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

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

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

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

PLANT _____

LOCATION _____

OPERATOR _____

DATE _____

RUN NO. _____

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

PROBE LENGTH m(ft) _____

SCHEMATIC OF STACK CROSS SECTION

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

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

$V_{w(std)}$ = 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.

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

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.

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

Equation 4-2

where:

K_2 = 0.001338 m^3/g for metric units
= 0.04715 ft^3/g for English units

2.3.4 Sample gas volume.

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

Equation 4-3

where:

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

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

2.3.5 Moisture Content.

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

Equation 4-4

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

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

3 *Approximation Method*

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

3.1 Apparatus.

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

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

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

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

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

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

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

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

3.1.9 Graduated Cylinder. 25 ml.

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

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

3.2 Procedure.

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

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft³) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

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

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

3.3.1 Nomenclature.

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

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

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

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

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

R = Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/(lb-mole) (°R) for English units.

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

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

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

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

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

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

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

3.3.2 Volume of water vapor collected.

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

Equation 4-5

where:

K_1 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units.

3.3.3 Gas volume.

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

Equation 4-6

where:

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

3.3.4 Approximate moisture content.

$$B_{wo} = \frac{V_{wc}}{V_{wc} + V_{m(std)}} + B_{ws} = \frac{V_{wc}}{V_{wc} + V_{m(std)}} + (0.025)$$

Equation 4-7

4. *Calibration*

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

5. *Bibliography*

1. Air Pollution Engineering Manual (Second Edition). Danielson, J. A. (ed.). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, N.C. Publication No. AP-40. 1973.

2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District, Los Angeles, Calif. November, 1963.

3. Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co., Los Angeles, Calif. Bulletin WP-50. 1968.

Method 5—Determination of Particulate Emissions From Stationary Sources

1. *Principle and Applicability*

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120±14° C (248±25° F) or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator, U.S. Environmental Protection Agency, for a particular application. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources.

2. *Apparatus*

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 5-1. Complete construction details are given in APTD-0581 (Citation 2 in Section 7); commercial models of this train are also available. For changes from APTD-0581 and for allowable modifications of the train shown in Figure 5-1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Section 7). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

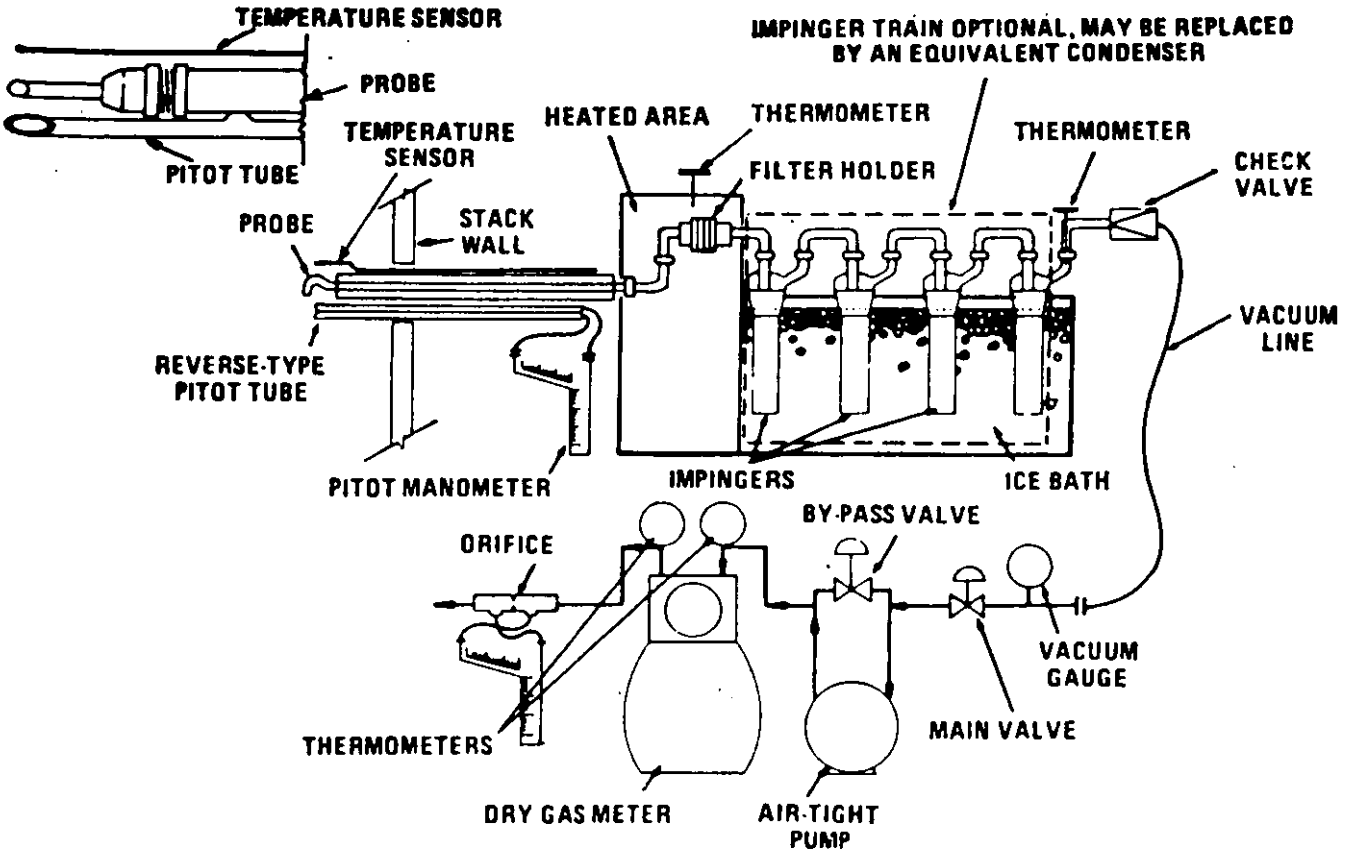

Figure 5-1. Particulate-sampling train.

2.1.1 Probe Nozzle. Stainless steel (316) or glass with sharp, tapered leading edge. The angle of taper shall be ≤30° and the taper shall be on the outside to preserve a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing; other materials of construction may be used, subject to the approval of the Administrator.

A range of nozzle sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1.27 cm (⅛ to ½ in.)—or larger if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (1/16 in.). Each nozzle shall be calibrated according to the procedures outlined in Section 5.

2.1.2 Probe Liner. Borosilicate or quartz glass tubing with a heating system capable of maintaining a gas temperature at the exit end during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. (The tester may opt to operate the equipment at a temperature lower than that specified.) Since the actual temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APTD-0581 and utilizing the calibration curves of APTD-0576 (or calibrated according to the procedure outlined in APTD-0576) will be considered acceptable.

Either borosilicate or quartz glass probe liners may be used for stack temperatures up to about 480° C (900° F); quartz liners shall be used for temperatures between 480 and 900° C (900 and 1,650° F). Both types of liners may be used at higher temperatures than specified for short periods of time, subject to the approval of the Administrator. The softening temperature for borosilicate is 820° C (1,508° F), and for quartz it is 1,500° C (2,732° F).

Whenever practical, every effort should be made to use borosilicate or quartz glass probe liners. Alternatively, metal liners (e.g., 316 stainless steel, Incoloy 825,[1] or other corrosion resistant metals) made of seamless tubing may be used, subject to the approval of the Administrator.

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

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

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

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

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

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

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

NOTE.—If a determination of the particulate matter collected in the impingers is desired in addition to moisture content, the impinger system described above shall be used, without modification. Individual States or control agencies requiring this information shall be contacted as to the sample recovery and analysis of the impinger contents.

2.1.8 Metering System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 5-1. Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that described in APTD-0581 or APTD-0576 may be used provided that the specifications of this method are met.

2.1.9 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg). In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is

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

the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.10 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3. The temperature sensor shall, preferably, be permanently attached to the pitot tube or sampling probe in a fixed configuration, such that the tip of the sensor extends beyond the leading edge of the probe sheath and does not touch any metal. Alternatively, the sensor may be attached just prior to use in the field. Note, however, that if the temperature sensor is attached in the field, the sensor must be placed in an interference-free arrangement with respect to the Type S pitot tube openings (see Method 2, Figure 2-7). As a second alternative, if a difference of not more than 1 percent in the average velocity measurement is to be introduced, the temperature gauge need not be attached to the probe or pitot tube. (This alternative is subject to the approval of the Administrator.)

2.2 Sample Recovery. The following items are needed:

2.2.1 Probe-Liner and Probe-Nozzle Brushes. Nylon bristle brushes with stainless steel wire handles. The probe brush shall have extensions (at least as long as the probe) of stainless steel, Nylon, Teflon, or similarly inert material. The brushes shall be properly sized and shaped to brush out the probe liner and nozzle.

2.2.2 Wash Bottles—Two. Glass wash bottles are recommended; polyethylene wash bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as to be leak-free and resistant to chemical attack by acetone. (Narrow mouth glass bottles have been found to be less prone to leakage.) Alternatively, polyethylene bottles may be used.

2.2.4 Petri Dishes. For filter samples, glass or polyethylene, unless otherwise specified by the Administrator.

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

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

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

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

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

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 Beakers. 250 ml.

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

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

3. *Reagents*

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

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

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

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

3.1.4 Crushed Ice.

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

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

3.3 Analysis. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

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

4. *Procedure*

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

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

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

Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper diameter on the back side near the edge using numbering machine ink. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccate the filters at 20±5.6° C (68±10° F) and ambient pressure for at least 24 hours and weigh at intervals of at least 6 hours to a constant weight, i.e., <0.5 mg change from previous weighing; record results to the nearest 0.1 mg. During each weighing the filter must not be exposed to the laboratory atmosphere for a period greater than 2 minutes and a relative humidity above 50 percent. Alternatively (unless otherwise specified by the Administrator), the filters may be oven dried at 105° C (220° F) for 2 to 3 hours, desiccated for 2 hours, and weighed. Procedures other than those described, which account for relative humidity effects, may be used, subject to the approval of the Administrator.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number of sampling points according to Method 1 or as specified by the Administrator. Determine the stack pressure, temperature, and the range of velocity heads using Method 2; it is recommended that a leak-check of the pitot lines (see Method 2, Section 3.1) be performed. Determine the moisture content using Approximation Method 4 or its alternatives for the purpose of making isokinetic sampling rate settings. Determine the stack gas dry molecular weight, as described in Method 2, Section 3.6, if integrated Method 3 sampling is used for molecular weight determination. The integrated bag sample shall be taken simultaneously with, and for the same total length of time as, the particulate sample run.

Select a nozzle size based on the range of velocity heads, such that it is not necessary to change the nozzle size in order to maintain isokinetic sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads encountered (see Section 2.2 of Method 2).

Select a suitable probe liner and probe length such that all traverse points can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce the length of probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 min (or some greater time interval as specified by the Administrator), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximate average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors.

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

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

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

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

When glass liners are used, install the selected nozzle using a Viton A O-ring when stack temperatures are less than 260° C (500° F) and an asbestos string gasket when temperatures are higher. See APTD-0576 for details. Other connecting systems using either 316 stainless steel or Teflon ferrules may be used. When metal liners are used, install the nozzle as above or by a leak-free direct mechanical connection. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

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

Place crushed ice around the impingers.

4.1.4 Leak-Check Procedures.

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

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

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

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

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

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

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

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

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

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

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

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

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

PLANT _____

LOCATION _____

OPERATOR _____

DATE _____

RUN NO. _____

SAMPLE BOX NO. _____

METER BOX NO. _____

METER $\Delta H_@$ _____

C FACTOR _____

PITOT TUBE COEFFICIENT, C_p _____

SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

ASSUMED MOISTURE, % _____

PROBE LENGTH, m (ft) _____

NOZZLE IDENTIFICATION NO. _____

AVERAGE CALIBRATED NOZZLE DIAMETER, cm (in.) _____

PROBE HEATER SETTING _____

LEAK RATE, m^3/min. (cfm) _____

PROBE LINER MATERIAL _____

STATIC PRESSURE, mm Hg (in. Hg) _____

FILTER NO. _____

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

Figure 5-2. Particulate field data.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Container No. 4. 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 impinger 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 2.1.5).

If a different type of condenser is used, measure the amount of moisture condensed either volumetrically or gravimetrically.

Whenever possible, containers should be shipped in such a way that they remain upright at all times.

4.3 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Handle each sample container as follows:

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, with no less than 6 hours of desiccation time between weighings.

Plant _____

Date _____

Run No. _____

Filter No. _____

Amount liquid lost during transport _____

Acetone blank volume, ml _____

Acetone wash volume, ml _____

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

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

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

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

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

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

Figure 5-3. Analytical data.

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

Container No. 3. 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. 4. Weigh the spent silica gel (or silica gel plus impingers) to the nearest 0.5 g using a balance. This step may be conducted in the field.

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

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

5. Calibration

Maintain a laboratory log of all calibrations.

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

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

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

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

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

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

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

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

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

5.7 Barometer. Calibrate against a mercury barometer.

6. Calculations

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

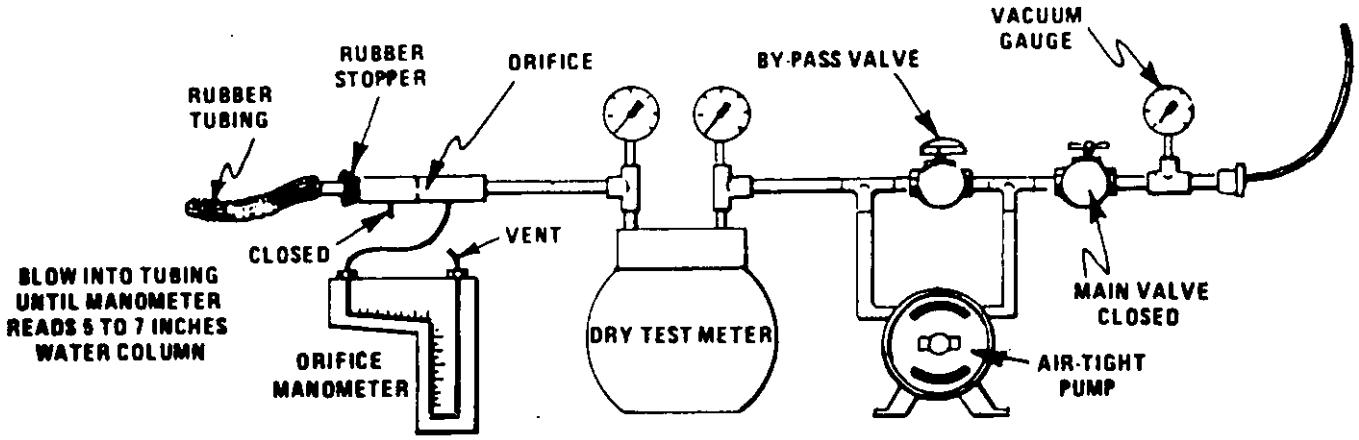

Figure 5-4. Leak check of meter box.

6.1 Nomenclature.

A_n = Cross-sectional area of nozzle, m² (ft²).
B_{ws} = Water vapor in the gas stream, proportion by volume.
C_a = Acetone blank residue 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_m = Absolute stack gas pressure, mm Hg (in. Hg).
P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
R = Ideal gas constant, 0.06236 mm Hg-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).
T_m = Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).
T_s = Absolute average stack gas temperature (see Figure 5-2), °K (°R).
T_{std} = Standard absolute temperature, 293° K (528° R).
V_a = Volume of acetone blank, ml.
V_{aw} = Volume of acetone used in wash, ml.
V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.
V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).
$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
V_s = Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).
W_a = Weight of residue in acetone wash, mg.
Y = Dry gas meter calibration factor.
ΔH = Average pressure differential across the orifice meter (see Figure 5-2), mm H_2O (in. H_2O).
ρ_a = Density of acetone, mg/ml (see label on bottle).
ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).
θ = Total sampling time, min.
θ_1 = Sampling time interval, from the beginning of a run until the first component change, min.
θ_2 = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.
θ_p = Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.
13.6 = Specific gravity of mercury.
60 = Sec/min.
100 = Conversion to percent.

6.2 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 5-2).

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

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

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

Equation 5-1

where:
K_1 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

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

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

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

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

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

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

6.4 Volume of water vapor.

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

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

6.5 Moisture Content.

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

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.

$$C_a = \frac{m_a}{V_a \rho_a} \quad \text{Equation 5-4}$$

6.7 Acetone Wash Blank.

$$W_a = C_a V_{aw} \rho_a \quad \text{Equation 5-5}$$

6.8 Total Particulate Weight. Determine the total particulate catch from the sum of the weights obtained from containers 1 and 2 less the acetone blank (see Figure 5-3). NOTE.—Refer to Section 4.1.3 to assist in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

$$c_s = (0.001\ g/mg)\ (m_n/V_{m(std)}) \quad \text{Equation 5-6}$$

6.10 Conversion Factors:

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

6.11 Isokinetic Variation.

6.11.1 Calculation From Raw Data.

$$I = \frac{100\ T_s[K_3 V_{lc} + (V_m/T_m)(P_{bar} + \Delta H/13.6)]}{60\theta v_s P_s A_n} \quad \text{Equation 5-7}$$

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

6.11.2 Calculation From Intermediate Values.

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

$$= K_4 \frac{T_s V_{m(std)}}{P_s v_s A_n \theta (1 - B_{ws})} \quad \text{Equation 5-8}$$

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. *Bibliography*

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METHOD 6—DETERMINATION OF SULFUR DIOXIDE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted from the sampling point in the stack. The sulfuric acid mist (including sulfur trioxide) and the sulfur dioxide are separated. The sulfur dioxide fraction is measured by the barium-thorin titration method.

1.2 Applicability. This method is applicable for the determination of sulfur dioxide emissions from stationary sources. The minimum detectable limit of the method has been determined to be 3.4 milligrams (mg) of SO_2/m³ (2.12×10⁻⁷ lb/ft³). Although no upper limit has been established, tests have shown that concentrations as high as 80,000 mg/m³ of SO_2 can be collected efficiently in two midget impingers, each containing 15 milliliters of 3 percent hydrogen peroxide, at a rate of 1.0 lpm for 20 minutes. Based on theoretical calculations, the upper concentration limit in a 20-liter sample is about 93,300 mg/m³.

Possible interferents are free ammonia, water-soluble cations, and fluorides. The cations and fluorides are removed by glass wool filters and an isopropanol bubbler, and hence do not affect the SO_2 analysis. When samples are being taken from a gas stream with high concentrations of very fine metallic fumes (such as in inlets to control devices), a high-efficiency glass fiber filter must be used in place of the glass wool plug (i.e., the one in the probe) to remove the cation interferents.

Free ammonia interferes by reacting with SO_2 to form particulate sulfite and by reacting with the indicator. If free ammonia is present (this can be determined by knowledge of the process and noticing white particulate matter in the probe and isopropanol bubbler), alternative methods, subject to the approval of the Administrator, U.S. Environmental Protection Agency, are required.

2. *Apparatus*

those required by standards of performance for new sources.

Finally, States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the NAAQS under Section 110. Accordingly, new sources may in some cases be subject to limitations more stringent than EPA's standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

This regulation will be reviewed 4 years from the date of promulgation as required by the Clean Air Act. This review will include an assessment of such factors as the need for integration with other programs, the existence of alternative methods, enforceability, improvements in emission control technology, and reporting requirements. The reporting requirements in the regulation will be reviewed as required under EPA's sunset policy for reporting requirements in regulations.

Under Executive Order 12291, EPA must judge whether a regulation is "Major" and therefore subject to the requirement of a Regulatory Impact Analysis. This regulation is not Major because: (1) The national annualized compliance costs, including capital charges resulting from the standards total less than $100 million; (2) the standards do not cause a major increase in prices or production costs; and (3) the standards do not cause significant adverse effects on domestic competition, employment, investment, productivity, innovation or competition in foreign markets. This regulation was submitted to the Office of Management and Budget (OMB) for review as required by Executive Order 12291.

Section 317 of the Clean Air Act requires the Administrator to prepare an economic impact assessment for any new source standard of performance promulgated under Section 111(b) of the Act. An economic impact assessment was prepared for the promulgated regulations and for other regulatory alternatives. All aspects of the assessment were considered in the formulation of the promulgated standards to insure that the standards would represent the best system of emission reduction considering costs. The economic impact assessment is included in the background information document.

List of Subjects in 40 CFR Part 60

Air pollution control, Aluminum, Ammonium sulfate plants, Cement industry, Coal, Copper, Electric power-plants, Glass and glass products, Grains, Intergovernmental relations, Iron, Lead, Metals, Motor vehicles, Nitric acid plants, Paper and paper products industry, Petroleum, Phosphate, Sewage disposal, Steel, Sulfuric acid plants, Waste treatment and disposal, Zinc.

Dated: April 9, 1982.

Note.—The regulation does not involve a "collection of information" as defined under the Paperwork Reduction Act of 1980. Therefore, the provisions of the Paperwork Reduction Act applicable to collections of information do not apply to this regulation.

Anne M. Gorsuch,
Administrator.

PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

40 CFR Part 60 is amended by adding a new Subpart KK and by adding a new reference method to Appendix A as follows:

1. A new subpart is added as follows:

Subpart KK—Standards of Performance for Lead-Acid Battery Manufacturing Plants

Sec.

Authority: Sec. 111, 301(a) of the Clean Air Act as amended (42 U.S.C. 7411, 7601(a)), and additional authority as noted below.

Subpart KK—Standards of Performance for Lead-Acid Battery Manufacturing Plants

§ 60.370 Applicability and designation of affected facility.

(a) The provisions of this subpart are applicable to the affected facilities listed in paragraph (b) of this section at any lead-acid battery manufacturing plant that produces or has the design capacity to produce in one day (24 hours) batteries containing an amount of lead equal to or greater than 5.9 Mg (6.5 tons).

(b) The provisions of this subpart are applicable to the following affected facilities used in the manufacture of lead-acid storage batteries:

(1) Grid casting facility.
(2) Paste mixing facility.
(3) Three-process operation facility.
(4) Lead oxide manufacturing facility.
(5) Lead reclamation facility.
(6) Other lead-emitting operations.

(c) Any facility under paragraph (b) of this section the construction or modification of which is commenced after January 14, 1980, is subject to the requirements of this subpart.

§ 60.371 Definitions.

As used in this subpart, all terms not defined herein shall have the meaning given them in the Act and in Subpart A of this part.

(a) "Grid casting facility" means the facility which includes all lead melting pots and machines used for casting the grid used in battery manufacturing.

(b) "Lead-acid battery manufacturing plant" means any plant that produces a storage battery using lead and lead compounds for the plates and sulfuric acid for the electrolyte.

(c) "Lead oxide manufacturing facility" means a facility that produces lead oxide from lead, including product recovery.

(d) "Lead reclamation facility" means the facility that remelts lead scrap and casts it into lead ingots for use in the battery manufacturing process, and which is not a furnace affected under Subpart L of this part.

(e) "Other lead-emitting operation" means any lead-acid battery manufacturing plant operation from which lead emissions are collected and ducted to the atmosphere and which is not part of a grid casting, lead oxide manufacturing, lead reclamation, paste mixing, or three-process operation facility, or a furnace affected under Subpart L of this part.

(f) "Paste mixing facility" means the facility including lead oxide storage, conveying, weighing, metering, and charging operations; paste blending, handling, and cooling operations; and plate pasting, takeoff, cooling, and drying operations.

(g) "Three-process operation facility" means the facility including those processes involved with plate stacking, burning or strap casting, and assembly of elements into the battery case.

§ 60.372 Standards for lead.

(a) On and after the date on which the performance test required to be conducted by § 60.8 is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere:

(1) From any grid casting facility any gases that contain lead in excess of 0.40 milligram of lead per dry standard cubic meter of exhaust (0.000176 gr/dscf).

(2) From any paste mixing facility any gases that contain in excess of 1.00 milligram of lead per dry standard cubic meter of exhaust (0.00044 gr/dscf).

(3) From any three-process operation facility any gases that contain in excess of 1.00 milligram of lead per dry

standard cubic meter of exhaust (0.00044 gr/dscf).

(4) From any lead oxide manufacturing facility any gases that contain in excess of 5.0 milligrams of lead per kilogram of lead feed (0.010 lb/ton).

(5) From any lead reclamation facility any gases that contain in excess of 4.50 milligrams of lead per dry standard cubic meter of exhaust (0.00198 gr/dscf).

(6) From any other lead-emitting operation any gases that contain in excess of 1.00 milligram per dry standard cubic meter of exhaust (0.00044 gr/dscf).

(7) From any affected facility other than a lead reclamation facility any gases with greater than 0 percent opacity (measured according to Method 9 and rounded to the nearest whole percentage).

(8) From any lead reclamation facility any gases with greater than 5 percent opacity (measured according to Method 9 and rounded to the nearest whole percentage).

(b) When two or more facilities at the same plant (except the lead oxide manufacturing facility) are ducted to a common control device, an equivalent standard for the total exhaust from the commonly controlled facilities shall be determined as follows:

$$S_e = \sum_{a=1}^{N} S_a(Q_{sd_a}/Q_{sd_t})$$

Where:

S_e = is the equivalent standard for the total exhaust stream.

S_a = is the actual standard for each exhaust stream ducted to the control device.

N = is the total number of exhaust streams ducted to the control device.

Q_{sd_a} = is the dry standard volumetric flow rate of the effluent gas stream from each facility ducted to the control device.

Q_{sd_t} = is the total dry standard volumetric flow rate of all effluent gas streams ducted to the control device.

§ 60.373 Monitoring of emissions and operations.

The owner or operator of any lead-acid battery manufacturing facility subject to the provisions of this subpart and controlled by a scrubbing system(s) shall install, calibrate, maintain, and operate a monitoring device(s) that measures and records the pressure drop across the scrubbing system(s) at least once every 15 minutes. The monitoring device shall have an accuracy of ±5 percent over its operating range.

(Sec. 114 of the Clean Air Act as amended (42 U.S.C. 7414))

§ 60.374 Test methods and procedures.

(a) Reference methods in Appendix A of this part, except as provided under § 60.8(b), shall be used to determine compliance according to § 60.8 as follows:

(1) Method 12 for the measurement of lead concentrations.

(2) Method 1 for sample and velocity traverses.

(3) Method 2 for velocity and volumetric flow rate, and

(4) Method 4 for stack gas moisture.

(b) For Method 12, the sampling time for each run shall be at least 60 minutes and the sampling rate shall be at least 0.85 dscm/h (0.53 dscf/min), except that shorter sampling times, when necessitated by process variables or other factors, may be approved by the Administrator.

(c) When different operations in a three-process operation facility are ducted to separate control devices, the lead emission concentration from the facility shall be determined using the equation:

$$C_{ms_t} = \sum_{a=1}^{N} (C_{ms_a} Q_{sd_a}/Q_{sd_t})$$

Where:

C_{ms_t} = is the facility emission concentration for the entire facility.

N = is the number of control devices to which separate operations in the facility are ducted.

C_{ms_a} = is the emission concentration from each control device.

Q_{sd_a} = is the dry standards volumetric flow rate of the effluent gas stream from each control device.

Q_{sd_t} = is the total dry standard volumetric flow rate from all of the control devices.

(d) For lead oxide manufacturing facilities, the average lead feed rate to a facility, expressed in kilograms per hour, shall be determined for each test run as follows:

(1) Calculate the total amount of lead charged to the facility during the run by multiplying the number of lead pigs (ingots) charged during the run by the average mass of a pig in kilograms or by another suitable method.

(2) Divide the total amount of lead charged to the facility during the run by the duration of the run in hours.

(e) Lead emissions from lead oxide manufacturing facilities, expressed in milligrams per kilogram of lead charged, shall be determined using the following equation:

$$E_m = C_m Q_{sd}/F$$

Where:

E_m = is the lead emission rate from the facility in milligrams per kilogram of lead charged.

C_m = is the concentration of lead in the exhaust stream in milligrams per dry standard cubic meter as determined according to paragraph (a)(1) of this section.

Q_{sd} = is the dry standard volumetric flow rate in dry standard cubic meters per hour as determined according to paragraph (a)(3) of this section.

F = is the lead feed rate to the facility in kilograms per hour as determined according to paragraph (d) of this section.

(Sec. 114 of the Clean Air Act as amended (42 U.S.C. 7414))

2. Appendix A to Part 60 is amended by adding new Reference Method 12 as follows:

Appendix A—Reference Methods

* * * * *

Method 12. Determination of Inorganic Lead Emissions From Stationary Sources

1. *Applicability and Principle.*

1.1 Applicability. This method applies to the determination of inorganic lead (Pb) emissions from specified stationary sources only.

1.2 *Principle.* Particulate and gaseous Pb emissions are withdrawn isokinetically from the source and collected on a filter and in dilute nitric acid. The collected samples are digested in acid solution and analyzed by atomic absorption spectrometry using an air acetylene flame.

2. *Range, Sensitivity, Precision, and Interferences.*

2.1 Range. For a minimum analytical accuracy of ±10 percent, the lower limit of the range is 100 μg. The upper limit can be considerably extended by dilution.

2.2 Analytical Sensitivity. Typical sensitivities for a 1-percent change in absorption (0.0044 absorbance units) are 0.2 and 0.5 μg Pb/ml for the 217.0 and 283.3 nm lines, respectively.

2.3 Precision. The within-laboratory precision, as measured by the coefficient of variation ranges from 0.2 to 9.5 percent relative to a run-mean concentration. These values were based on tests conducted at a gray iron foundry, a lead storage battery manufacturing plant, a secondary lead smelter, and a lead recovery furnace of an alkyl lead manufacturing plant. The concentrations encountered during these tests ranged from 0.61 to 123.3 mg Pb/m³.

2.4 Interferences. Sample matrix effects may interfere with the analysis for Pb by flame atomic absorption. If this interference is suspected, the analyst may confirm the presence of these matrix effects and frequently eliminate the interference by using the Method of Standard Additions.

High concentrations of copper may interfere with the analysis of Pb at 217.0 nm. This interference can be avoided by analyzing the samples at 283.3 nm.

3. *Apparatus.*

3.1 Sampling Train. A schematic of the sampling train is shown in Figure 12-1; it is similar to the Method 5 train. The sampling train consists of the following components:

3.1.1 Probe Nozzle, Probe Liner, Pitot Tube, Differential Pressure Gauge, Filter Holder, Filter Heating System, Metering System, Barometer, and Gas Density Determination Equipment. Same as Method 5, Sections 2.1.1 to 2.1.8 and 2.1.8 to 2.1.10, respectively.

3.1.2 Impingers. Four impingers connected in series with leak-free ground glass fittings or any similar leak-free noncontaminating fittings. For the first, third, and fourth impingers, use the Greenburg-Smith design, modified by replacing the tip with a 1.3 cm (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. For the second impinger, use the Greenburg-Smith design with the standard tip. Place a thermometer, capable of measuring temperature to within 1°C (2°F) at the outlet of the fourth impinger for monitoring purposes.

BILLING CODE 6560-50-M

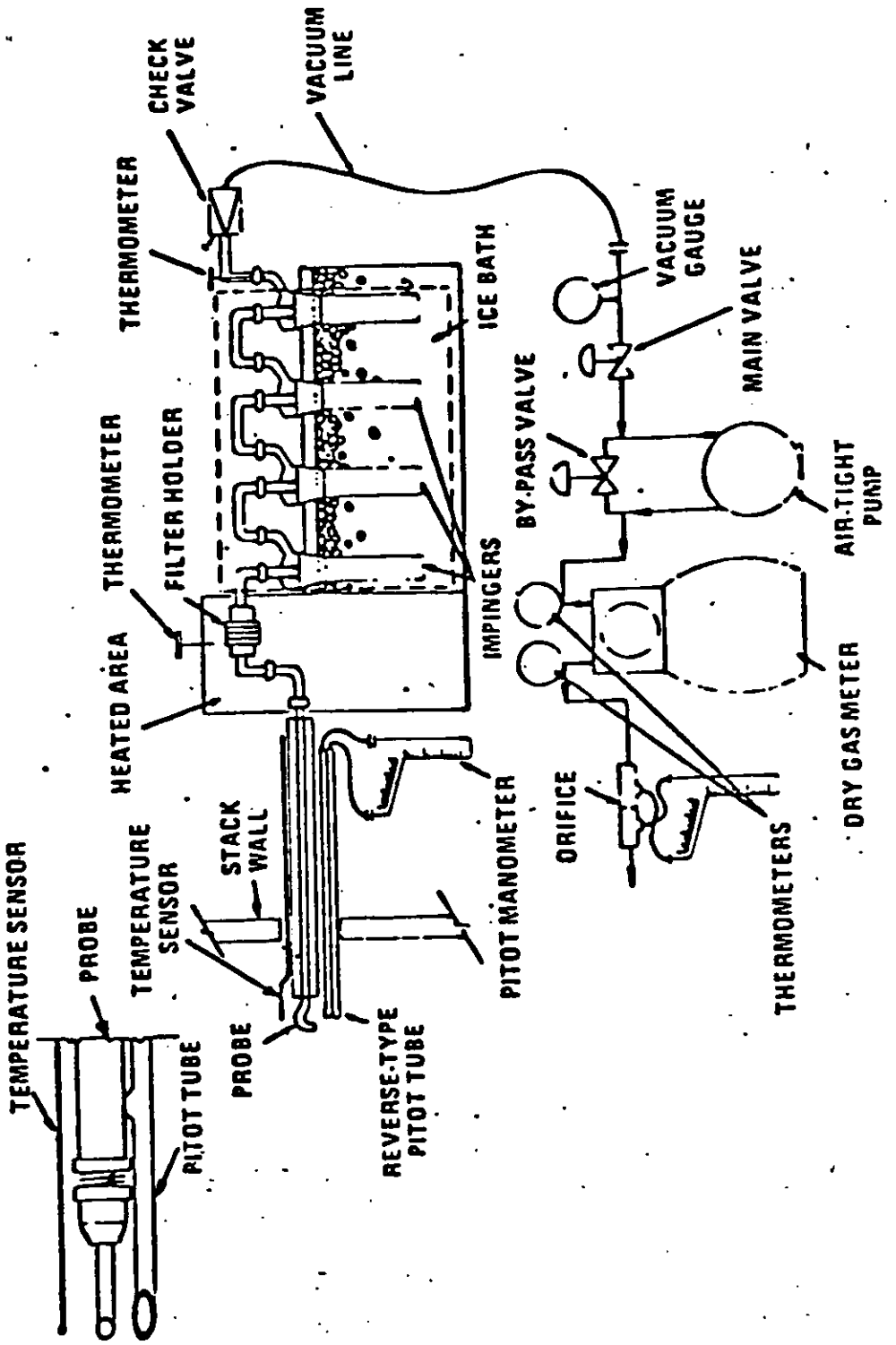

Figure 12-1. Inorganic lead sampling train.

BILLING CODE 6560-50-C

3.2 Sample Recovery. The following items are needed:

3.2.1 Probe-Liner and Probe-Nozzle Brushes, Petri Dishes, Plastic Storage Containers, and Funnel and Rubber Policeman. Same as Method 5, Sections 2.2.1, 2.2.4, 2.2.6, and 2.2.7, respectively.

3.2.2 Wash Bottles. Glass (2).

3.2.3 Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for 0.1 nitric acid (HNO_3) impinger and probe solutions and washes, 1000-ml. Use screw-cap liners that are either rubber-backed Teflon* or leak-free and resistant to chemical attack by 0.1 N HNO_3. (Narrow mouth glass bottles have been found to be less prone to leakage.)

3.2.4 Graduated Cylinder and/or Balance. To measure condensed water to within 2 ml or 1 g. Use a graduated cylinder that has a minimum capacity of 500 ml, and subdivisions no greater than 5 ml. (Most laboratory balances are capable of weighing to the nearest 0.5 g or less.)

3.2.5 Funnel. Glass, to aid in sample recovery.

3.3 Analysis. The following equipment is needed:

3.3.1 Atomic Absorption Spectrophotometer. With lead hollow cathode lamp and burner for air/acetylene flame.

3.3.2 Hot Plate.

3.3.3 Erlenmeyer Flasks. 125-ml, 24/40 S.

3.3.4 Membrane Filters. Millipore SCWP 4700 or equivalent.

3.3.5 Filtration Apparatus. Millipore vacuum filtration unit, or equivalent, for use with the above membrane filter.

3.3.6 Volumetric Flasks. 100-ml, 250-ml, and 1000-ml.

4. *Reagents.*

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

4.1.1 Filter. Gelman Spectro Grade, Reeve Angel 934 AH, MSA 1106 BH, all with lot assay for Pb, or other high-purity 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. Conduct the filter efficiency test using ASTM Standard Method D 2986–71 or use test data from the supplier's quality control program.

4.1.2 Silica Gel, Crushed Ice, and Stopcock Grease. Same as Method 5, Section 3.1.2, 3.1.4, and 3.1.5, respectively.

4.1.3 Water. Deionized distilled, to conform to ASTM Specification D 1193–74, Type 3. If high concentrations of organic matter are not expected to be present, the analyst may delete the potassium permanganate test for oxidizable organic matter.

4.1.4 Nitric Acid, 0.1 N. Dilute 6.5 ml of concentrated HNO_3 to 1 liter with deionized distilled water. (It may be desirable to run blanks before field use to eliminate a high blank on test samples.)

4.2 Pretest Preparation. 6 N HNO_3 is needed. Dilute 390 ml of concentrated HNO_3 to 1 liter with deionized distilled water.

*Mention of trade names or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.

4.3 Sample Recovery. 0.1 N HNO_3 (same as 4.1.4 above) is needed for sample recovery.

4.4 Analysis. The following reagents are needed for analysis (use ACS reagent grade chemicals or equivalent, unless otherwise specified):

4.4.1 Water. Same as 4.1.3 above.

4.4.2 Nitric Acid, Concentrated.

4.4.3 Nitric Acid, 50 percent (V/V). Dilute 500 ml of concentrated HNO_3 to 1 liter with deionized distilled water.

4.4.4 Stock Lead Standard Solution, 1000 μg Pb/ml. Dissolve 0.1598 g of lead nitrate [$Pb(NO_3)_2$] in about 60 ml of deionized distilled water, add 2 ml concentrated HNO_3, and dilute to 100 ml with deionized distilled water.

4.4.5 Working Lead Standards. Pipet 0.0, 1.0, 2.0, 3.0, 4.0, and 5.0 ml of the stock lead standard solution (4.4.4) into 250-ml volumetric flasks. Add 5 ml of concentrated HNO_3 to each flask and dilute to volume with deionized distilled water. These working standards contain 0.0, 4.0, 8.0, 12.0, 16.0, and 20.0 μg Pb/ml, respectively. Prepare, as needed, additional standards at other concentrations in a similar manner.

4.4.6 Air. Suitable quality for atomic absorption analysis.

4.4.7 Acetylene. Suitable quality for atomic absorption analysis.

4.4.8 Hydrogen Peroxide, 3 percent (V/V). Dilute 10 ml of 30 percent H_2O_2 to 100 ml with deionized distilled water.

5. *Procedure.*

5.1 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.

5.1.1 Pretest Preparation. Follow the same general procedure given in Method 5, Section 4.1.1, except the filter need not be weighed.

5.1.2 Preliminary Determinations. Follow the same general procedure given in Method 5, Section 4.1.2.

5.1.3 Preparation of Collection Train. Follow the same general procedure given in Method 5, Section 4.1.3, except place 100 ml of 0.1 HNO_3 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. Set up the train as shown in Figure 12–1.

5.1.4 Leak-Check Procedures. Follow the general leak-check procedures given in Method 5, Sections 4.1.4.1 (Pretest Leak-Check), 4.1.4.2 (Leak-Checks During the Sample Run), and 4.1.4.3 (Post-Test Leak-Check).

5.1.5 Sampling Train Operation. Follow the same general procedure given in Method 5, Section 4.1.5. For each run, record the data required on a data sheet such as the one shown in EPA Method 5, Figure 5–2.

5.1.6 Calculation of Percent Isokinetic. Same as Method 5, Section 4.1.6.

5.2 *Sample Recovery.* Begin proper cleanup procedure as soon as the probe is removed from the stack at the end of the sampling period.

Allow the probe to cool. When it can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it. 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 liquid from the impingers into the filter.

Before moving the sampling train to the cleanup site, remove the probe from the sapling 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 glassware inlet where the probe was fastened and cap the inlet. Remove the umbilical cord from the last impinger and cap the impinger. The tester may use ground-glass stoppers, plastic caps, or serum caps to close these openings.

Transfer the probe and filter-impinger assembly to a cleanup area, which is clean and protected from the wind so that the chances of contaminating or losing the sample are minimized.

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

5.2.1 *Container No. 1* (Filter). Carefully remove the filter from the filter holder and place it in its identified petri dish container. If it is necessary to fold the filter, do so such that the sample-exposed side is inside the fold. Carefully transfer to the petri dish any visible sample matter and/or filter fibers that adhere to the filter holder gasket by using a dry Nylon bristle brush and/or a sharp-edged blade. Seal the container.

5.2.2 *Container No. 2* (Probe). Taking care that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover sample matter or any condensate from the probe nozzle, probe fitting, probe liner, and front half of the filter holder by washing these components with 0.1 N HNO_3 and placing the wash into a glass sample storage container. Measure and record (to the nearest 2-ml) the total amount of 0.1 N HNO_3 used for each rinse. Perform the 0.1 N HNO_3 rinses as follows:

Carefully remove the probe nozzle and rinse the inside surfaces with 0.1 N HNO_3 from a wash bottle while brushing with a stainless steel, Nylon-bristle brush. Brush until the 0.1 N HNO_3 rinse shows no visible particles, then make a final rinse of the inside surface.

Brush and rinse with 0.1 N HNO_3 the inside parts of the Swagelok fitting in a similar way until no visible particles remain.

Rinse the probe liner with 0.1 N HNO_3. While rotating the probe so that all inside surfaces will be rinsed with 0.1 N HNO_3, tilt the probe and squirt 0.1 N HNO_3 into its upper end. Let the 0.1 N HNO_3 drain from the lower end into the sample container. The tester may use a glass funnel to aid in transferring liquid washes to the container. Follow the rinse with a probe brush. Hold the probe in an inclined position, squirt 0.1 N HNO_3 into the upper end of the probe as the probe brush is being pushed with a twisting action through the probe; hold the sample container underneath the lower end of the probe and catch any 0.1 N HNO_3 and sample matter that is brushed from the probe. Run the brush through the probe three times or more until no visible sample matter is carried out with the 0.1 N HNO_3 and none remains on 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 sample matter can be entrapped. Rinse the brush with 0.1 N HNO_3 and quantitatively collect these washings in the sample container. After the brushing make a final rinse of the probe as described above.

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

After insuring that all joints are wiped clean of silicone grease, brush and rinse with 0.1 N HNO_3 the inside of the front half of the filter holder. Brush and rinse each suface three times or more, if needed, to remove visible sample matter. Make a final rinse of the brush and filter holder. After all 0.1 N HNO_3 washings and sample matter are collected in the sample container, tighten the lid on the sample container so that the fluid will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether leakage occurs during transport. Label the container to clearly identify its contents.

5.2.3 *Container No. 3* (Silica Gel). Check 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 the original container and seal. The tester may use a funnel to pour the silica gel and a rubber policeman to remove the silica gel from the impinger. It is not necessary to remove the small amount of particles that may adhere to the walls and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, the tester may follow procedure for Container No. 3 under Section 5.4 (Analysis).

5.2.4 *Container No. 4* (Impingers). Due to the large quantity of liquid involved, the tester may place the impinger solutions in several containers. Clean each of the first three impingers and connecting glassware in the following manner:

1. Wipe the impinger ball joints free of silicone grease and cap the joints.

2. Rotate and agitate each impinger, so that the impinger contents might serve as a rinse solution.

3. Transfer the contents of the impingers to a 500-ml graduated cylinder. Remove the outlet ball joint cap and drain the contents through this opening. Do not separate the impinger parts (inner and outer tubes) while transferring their contents to the cylinder. Measure the liquid volume to within ±2 ml. Alternatively, determine the weight of the liquid to within ±0.5 g. Record in the log the volume or weight of the liquid present, along with a notation of any color or film observed in the impinger catch. The liquid volume or weight is needed, along with the silica gel data, to calculate the stack gas moisture content (see Method 5, Figure 5-3).

4. Transfer the contents to Container No. 4.

5. Note: In steps 5 and 6 below, measure and record the total amount of 0.1 N HNO_3 used for rinsing. Pour approximately 30 ml of 0.1 N HNO_3 into each of the first three impingers and agitate the impingers. Drain the 0.1 N HNO_3 through the outlet arm of each impinger into Container No. 4. Repeat this operation a second time; inspect the impingers for any abnormal conditions.

6. Wipe the ball joints of the glassware connecting the impingers free of silicone grease and rinse each piece of glassware twice with 0.1 N HNO_3; transfer this rinse into Container No. 4. (*Do not rinse or brush the glass-fritted filter support.*) Mark the height of the fluid level to determine whether leakage occurs during transport. Label the container to clearly identify its contents.

5.2.5 Blanks. Save 200 ml of the 0.1 N HNO_3 used for sampling and cleanup as a blank. Take the solution directly from the bottle being used and place into a glass sample container labeled "0.1 N HNO_3 blank."

5.3 Sample Preparation.

5.3.1 *Container No. 1* (Filter). Cut the filter into strips and transfer the strips and all loose particulate matter into a 125-ml Erlenmeyer flask. Rinse the petri dish with 10 ml of 50 percent HNO_3 to insure a quantitative transfer and add to the flask. (Note: If the total volume required in Section 5.3.3 is expected to exceed 80 ml, use a 250-ml Erlenmeyer flask in place of the 125-ml flask.)

5.3.2 *Containers No. 2 and No. 4* (Probe and Impingers). (Check the liquid level in Containers No. 2 and/or No. 4 and confirm as to whether or not leakage occurred during transport; note observation on the analysis sheet. If a noticeable amount of leakage had occurred, either void the sample or take steps, subject to the approval of the Administrator, to adjust the final results.) Combine the contents of Containers No. 2 and No. 4 and take to dryness on a hot plate.

5.3.3 Sample Extraction for lead. Based on the approximate stack gas particulate concentration and the total volume of stack gas sampled, estimate the total weight of particulate sample collected. Then transfer the residue from Containers No. 2 and No. 4 to the 125-ml Erlenmeyer flask that contains the filter using rubber policeman and 10 ml of 50 percent HNO_3 for every 100 mg of sample collected in the train or a minimum of 30 ml of 50 percent HNO_3, whichever is larger.

Place the Erlenmeyer flask on a hot plate and heat with periodic stirring for 30 min at a temperature just below boiling. If the sample volume falls below 15 ml, add more 50 percent HNO_3. Add 10 ml of 3 percent H_2O_2 and continue heating for 10 min. Add 50 ml of hot (80° C) deionized distilled water and heat for 20 min. Remove the flask from the hot plate and allow to cool. Filter the sample through a Millipore membrane filter or equivalent and transfer the filtrate to a 250-ml volumetric flask. Dilute to volume with deionized distilled water.

5.3.4 Filter Blank. Determine a filter blank using two filters from each lot of filters used in the sampling train. Cut each filter into strips and place each filter in a separate 125-ml Erlenmeyer flask. Add 15 ml of 50 percent HNO_3 and treat as described in Section 5.3.3 using 10 ml of 3 percent H_2O_2 and 50 ml of hot, deionized distilled water. Filter and dilute to a toal volume of 100 ml using deionized distilled water.

5.3.5 0.1 N HNO_3 Blank. Take the entire 200 ml of 0.1 N HNO_3 to dryness on a steam bath, add 15 ml of 50 percent HNO_3, and treat as described in Section 5.3.3 using 10 ml of 3 percent H_2O_2 and 50 ml of hot, deionized distilled water. Dilute to a total volume of 100 ml using deionized distilled water.

5.4 Analysis.

5.4.1 Lead Determination. Calibrate the spectrophotometer as described in Section 8.2 and determine the absorbance for each source sample, the filter blank, and 0.1 N HNO_3 blank. Analyze each sample three times in this manner. Make appropriate dilutions, as required, to bring all sample Pb concentrations into the linear absorbance range of the spectrophotometer.

If the Pb concentration of a sample is at the low end of the calibration curve and high accuracy is required, the sample can be taken to dryness on a hot plate and the residue dissolved in the appropriate volume of water to bring it into the optimum range of the calibration curve.

5.4.2 Mandatory Check for Matrix Effects on the Lead Results. The analysis for Pb by atomic absorption is sensitive to the chemical composition and to the physical properties (viscosity, pH) of the sample (matrix effects). Since the Pb procedure described here will be applied to many different sources, many sample matrices will be encountered. Thus, check (mandatory) at least one sample from each source using the Method of Additions to ascertain that the chemical composition and physical properties of the sample did not cause erroneous analytical results.

Three acceptable "Method of Additions" procedures are described in the General Procedure Section of the Perkin Elmer Corporation Manual (see Citation 9.1). If the results of the Method of Additions procedure on the source sample do not agree within 5 percent of the value obtained by the conventional atomic absorption analysis, then the tester must reanalyze all samples from the source using the Method of Additions procedure.

5.4.3 *Container No. 3* (Silica Gel). The tester may conduct this step in the field. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g; record this weight.

6. *Calibration.*

Maintain a laboratory log of all calibrations.

6.1 Sampling Train Calibration. Calibrate the sampling train components according to the indicated sections of Method 5: Probe Nozzle (Section 5.1); Pitot Tube (Section 5.2); Metering System (Section 5.3); Probe Heater (Section 5.4); Temperature Gauges (Section 5.5); Leak-Check of the Metering System (Section 5.6); and Barometer (Section 5.7).

6.2 Spectrophotometer. Measure the absorbance of the standard solutions using the instrument settings recommended by the spectrophotometer manufacturer. Repeat until good agreement (±3 percent) is obtained between two consecutive readings. Plot the absorbance (y-axis) versus concentration in μg Pb/ml (x-axis). Draw or compute a straight line through the linear portion of the curve. Do not force the calibration curve through zero, but if the curve does not pass through the origin or at least lie closer to the origin than ±0.003

absorbance units, check for incorrectly prepared standards and for curvature in the calibration curve.

To determine stability of the calibration curve, run a blank and a standard after every five samples and recalibrate, as necessary.

7. Calculations.

7.1 Dry Gas Volume. Using the data from this test, calculate $V_{m(std)}$, the total volume of dry gas metered corrected to standard conditions (20°C and 760 mm Hg), by using Equation 5-1 of Method 5. If necessary, adjust $V_{m(std)}$ for leakages as outlined in Section 6.3 of Method 5. See the field data sheet for the average dry gas meter temperature and average orifice pressure drop.

7.2 Volume of Water Vapor and Moisture Content. Using data obtained in this test and Equations 5-2 and 5-3 of Method 5, calculate the volume of water vapor $V_{w(std)}$ and the moisture content B_{ws} of the stack gas.

7.3 Total Lead in Source Sample. For each source sample correct the average absorbance for the contribution of the filter blank and the 0.1 N HNO_3 blank. Use the calibration curve and this corrected absorbance to determine the μg Pb concentration in the sample aspirated into the spectrophotometer. Calculate the total Pb content C'_{Pb} (in μg) in the original source sample; correct for all the dilutions that were made to bring the Pb concentration of the sample into the linear range of the spectrophotometer.

7.4 Lead Concentration. Calculate the stack gas Pb concentration C_{Pb} in mg/dscm as follows:

$$C_{Pb} = K \frac{C'_{Pb}}{V_{m(std)}}$$

Where:

K = 0.001 mg/μg for metric units.

= 2.205 lb/μg for English units.

7.5 Isokinetic Variation and Acceptable Results. Same as Method 5, Sections 6.11 and 6.12, respectively. To calculate v_s, the average stack gas velocity, use Equation 2-9 of Method 2 and the data from this field test.

8. Alternative Test Methods for Inorganic Lead.

8.1 Simultaneous Determination of Particulate and Lead Emissions. The tester may use Method 5 to simultaneously determine Pb provided that (1) he uses acetone to remove particulate from the probe and inside of the filter holder as specified by Method 5, (2) he uses 0.1 N HNO_3 in the impingers, (3) he uses a glass fiber filter with a low Pb background, and (4) he treats and analyzes the entire train contents, including the impingers, for Pb as described in Section 5 of this method.

8.2 Filter Location. The tester may use a filter between the third and fourth impinger provided that he includes the filter in the analysis for Pb.

8.3 In-stack Filter. The tester may use an in-stack filter provided that (1) he uses a glass-lined probe and at least two impingers, each containing 100 ml of 0.1 N HNO_3, after the in-stack filter and (2) he recovers and analyzes the probe and impinger contents for Pb. Recover sample from the nozzle with acetone if a particulate analysis is to be made.

9. Bibliography

9.1 Perkin Elmer Corporation. Analytical Methods for Atomic Absorption Spectrophotometry. Norwalk, Connecticut. September 1976.

9.2 American Society for Testing and Materials. Annual Book of ASTM Standards. Part 31: Water, Atmospheric Analysis. Philadelphia, Pa. 1974. p. 40-42.

9.3 Klein, R. and C. Hach. Standard Additions—Uses and Limitations in Spectrophotometric Analysis. *Amer. Lab.* 9:21-27. 1977.

9.4 Mitchell, W.J. and M.R. Midgett. Determining Inorganic and Alkyl Lead Emissions from Stationary Sources. U.S. Environmental Protection Agency, Emission Monitoring and Support Laboratory, Research Triangle Park, N.C. (Presented at National APCA Meeting, Houston, June 26, 1978).

9.5 Same as Method 5, Citations 2 to 5 and 7 of Section 7.

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(Secs. 111, 114, and 301(a) of the Clean Air Act as amended (42 U.S.C. 7411, 7414, and 7601(a)))

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METHOD 9--VISUAL DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES

METHOD 9—VISUAL DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES

Many stationary sources discharge visible emissions into the atmosphere; these emissions are usually in the shape of a plume. This method involves the determination of plume opacity by qualified observers. The method includes procedures for the training and certification of observers, and procedures to be used in the field for determination of plume opacity. The appearance of a plume as viewed by an observer depends upon a number of variables, some of which may be controllable and some of which may not be controllable in the field. Variables which can be controlled to an extent to which they no longer exert a significant influence upon plume appearance include: Angle of the observer with respect to the plume; angle of the observer with respect to the sun; point of observation of attached and detached steam plume; and angle of the observer with respect to a plume emitted from a rectangular stack with a large length to width ratio. The method includes specific criteria applicable to these variables.

Other variables which may not be controllable in the field are luminescence and color contrast between the plume and the background against which the plume is viewed. These variables exert an influence upon the appearance of a plume as viewed by an observer, and can affect the ability of the observer to accurately assign opacity values to the observed plume. Studies of the theory of plume opacity and field studies have demonstrated that a plume is most visible and presents the greatest apparent opacity when viewed against a contrasting background. It follows from this, and is confirmed by field trials, that the opacity of a plume, viewed under conditions where a contrasting background is present can be assigned with the greatest degree of accuracy. However, the potential for a positive error is also the greatest when a plume is viewed under such contrasting conditions. Under conditions presenting a less contrasting background, the apparent opacity of a plume is less and approaches zero as the color and luminescence contrast decrease toward zero. As a result, significant negative bias and negative errors can be made when a plume is viewed under less contrasting conditions. A negative bias decreases rather than increases the possibility that a plant operator will be cited for a violation of opacity standards due to observer error.

Studies have been undertaken to determine the magnitude of positive errors which can be made by qualified observers while

reading plumes under contrasting conditions and using the procedures set forth in this method. The results of these studies (field trials) which involve a total of 769 sets of 25 readings each are as follows:

(1) For black plumes (133 sets at a smoke generator), 100 percent of the sets were read with a positive error [1] of less than 7.5 percent opacity; 99 percent were read with a positive error of less than 5 percent opacity.

(2) For white plumes (170 sets at a smoke generator, 168 sets at a coal-fired power plant, 298 sets at a sulfuric acid plant), 99 percent of the sets were read with a positive error of less than 7.5 percent opacity; 95 percent were read with a positive error of less than 5 percent opacity.

The positive observational error associated with an average of twenty-five readings is therefore established. The accuracy of the method must be taken into account when determining possible violations of applicable opacity standards.

1. *Principle and Applicability*

1.1 Principle. The opacity of emissions from stationary sources is determined visually by a qualified observer.

1.2 Applicability. This method is applicable for the determination of the opacity of emissions from stationary sources pursuant to § 60.11(b) and for qualifying observers for visually determining opacity of emissions.

2. *Procedures*

The observer qualified in accordance with paragraph 3 of this method shall use the following procedures for visually determining the opacity of emissions:

2.1 Position. The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140° sector to his back. Consistent with maintaining the above requirement, the observer shall, as much as possible, make his observations from a position such that his line of vision is approximately perpendicular to the plume direction, and when observing opacity of emissions from rectangular outlets (e.g., roof monitors, open baghouses, noncircular stacks), approximately perpendicular to the longer axis of the outlet. The observer's line of sight should not include more than one plume at a time when multiple stacks are involved, and in any case the observer should make his observations with his line of sight perpendicular to the longer axis of such a set of multiple stacks (e.g., stub stacks on baghouses).

2.2 Field Records. The observer shall record the name of the plant, emission location, type facility, observer's name and affiliation, and the date on a field data sheet (Figure 9-1). The time, estimated distance to the emission location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds), and plume background are recorded on a field data sheet at the time opacity readings are initiated and completed.

2.3 Observations. Opacity observations shall be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present. The observer shall not look continuously at the plume, but instead shall observe the plume momentarily at 15-second intervals.

2.3.1 Attached Steam Plumes. When condensed water vapor is present within the plume as it emerges from the emission outlet, opacity observations shall be made beyond the point in the plume at which condensed water vapor is no longer visible. The observer shall record the approximate distance from the emission outlet to the point in the plume at which the observations are made.

2.3.2 Detached Steam Plume. When water vapor in the plume condenses and becomes visible at a distinct distance from the emission outlet, the opacity of emissions should be evaluated at the emission outlet prior to the condensation of water vapor and the formation of the steam plume.

2.4 Recording Observations. Opacity observations shall be recorded to the nearest 5 percent at 15-second intervals on an observational record sheet. (See Figure 9-2 for an example.) A minimum of 24 observations shall be recorded. Each momentary observation recorded shall be deemed to represent the average opacity of emissions for a 15-second period.

2.5 Data Reduction. Opacity shall be determined as an average of 24 consecutive observations recorded at 15-second intervals. Divide the observations recorded on the record sheet into sets of 24 consecutive observations. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and in no case shall two sets overlap. For each set of 24 observations, calculate the average by summing the opacity of the 24 observations and dividing this sum by 24. If an applicable standard specifies an averaging time requiring more than 24 observations, calculate the average for all observations made during the specified time period. Record the average opacity on a record sheet. (See Figure 9-1 for an example.)

3. *Qualifications and Testing*

3.1 Certification Requirements. To receive certification as a qualified observer, a candidate must be tested and demonstrate the ability to assign opacity readings in 5 per-

[1] For a set, positive error = average opacity determined by observers' 25 observations—average opacity determined from transmissometer's 25 recordings.

cent increments to 35 different black plumes and 25 different white plumes, with an error not to exceed 15 percent opacity on any one reading and an average error not to exceed 7.5 percent opacity in each category. Candidates shall be tested according to the procedures described in paragraph 3.2. Smoke generators used pursuant to paragraph 3.2 shall be equipped with a smoke meter which meets the requirements of paragraph 3.3.

The certification shall be valid for a period of 6 months, at which time the qualification procedure must be repeated by any observer in order to retain certification.

3.2 Certification Procedure. The certification test consists of showing the candidate a complete run of 50 plumes—25 black plumes and 25 white plumes—generated by a smoke generator. Plumes within each set of 25 black and 25 white runs shall be presented in random order. The candidate assigns an opacity value to each plume and records his observation on a suitable form. At the completion of each run of 50 readings, the score of the candidate is determined. If a candidate fails to qualify, the complete run of 50 readings must be repeated in any retest. The smoke test may be administered as part of a smoke school or training program, and may be preceded by training or familiarization runs of the smoke generator during which candidates are shown black and white plumes of known opacity.

3.3 Smoke Generator Specifications. Any smoke generator used for the purposes of paragraph 3.2 shall be equipped with a smoke meter installed to measure opacity across the diameter of the smoke generator stack. The smoke meter output shall display instack opacity based upon a pathlength equal to the stack exit diameter, on a full 0 to 100 percent chart recorder scale. The smoke meter optical design and performance shall meet the specifications shown in Table 9-1. The smoke meter shall be calibrated as prescribed in paragraph 3.3.1 prior to the conduct of each smoke reading test. At the completion of each test, the zero and span drift shall be checked and if the drift exceeds ±1 percent opacity, the condition shall be corrected prior to conducting any subsequent test runs. The smoke meter shall be demonstrated, at the time of installation, to meet the specifications listed in Table 9-1. This demonstration shall be repeated following any subsequent repair or replacement of the photocell or associated electronic circuitry including the chart recorder or output meter, or every 6 months, whichever occurs first.

TABLE 9-1—SMOKE METER DESIGN AND PERFORMANCE SPECIFICATIONS

Parameter	Specification
a. Light source	Incandescent lamp operated at nominal rated voltage.
b. Spectral response of photocell	Photopic (daylight spectral response of the human eye—reference 4.3).
c. Angle of view	15° maximum total angle.
d. Angle of projection	15° maximum total angle.
e. Calibration error	±3% opacity, maximum.
f. Zero and span drift	±1% opacity, 30 minutes.
g. Response time	5 seconds.

3.3.1 Calibration. The smoke meter is calibrated after allowing a minimum of 30 minutes warmup by alternately producing simulated opacity of 0 percent and 100 percent. When stable response at 0 percent or 100 percent is noted, the smoke meter is adjusted to produce an output of 0 percent or 100 percent, as appropriate. This calibration shall be repeated until stable 0 percent and 100 percent readings are produced without adjustment. Simulated 0 percent and 100 percent opacity values may be produced by alternately switching the power to the light source on and off while the smoke generator is not producing smoke.

3.3.2 Smoke Meter Evaluation. The smoke meter design and performance are to be evaluated as follows:

3.3.2.1 Light Source. Verify from manufacturer's data and from voltage measurements made at the lamp, as installed, that the lamp is operated within ±5 percent of the nominal rated voltage.

3.3.2.2 Spectral Response of Photocell. Verify from manufacturer's data that the photocell has a photopic response; i.e., the spectral sensitivity of the cell shall closely approximate the standard spectral-luminosity curve for photopic vision which is referenced in (b) of Table 9-1.

FIGURE 9-1
RECORD OF VISUAL DETERMINATION OF OPACITY

PAGE ___ of ___

COMPANY _____
LOCATION _____
TEST NUMBER _____
DATE _____
TYPE FACILITY _____
CONTROL DEVICE _____

HOURS OF OBSERVATION _____
OBSERVER _____
OBSERVER CERTIFICATION DATE _____
OBSERVER AFFILIATION _____
POINT OF EMISSIONS _____
HEIGHT OF DISCHARGE POINT _____

	Initial			Final
CLOCK TIME				
OBSERVER LOCATION Distance to Discharge				
Direction from Discharge				
Height of Observation Point				
BACKGROUND DESCRIPTION				
WEATHER CONDITIONS Wind Direction				
Wind Speed				
Ambient Temperature				
SKY CONDITIONS (clear, overcast, % clouds, etc.)				
PLUME DESCRIPTION Color				
Distance Visible				
OTHER INFORMATION				

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start--End	Opacity Sum	Opacity Average

Readings ranged from ____ to ____ % opacity

The source was/was not in compliance with ____ at the time evaluation was made.

FIGURE 9-2—OBSERVATION RECORD

Page —— of ——

Company ——
Location ——
Test Number ——
Date ——

Observer ——
Type facility ——
Point of emissions ——

Hr.	Min.	Seconds				Steam plume (check if applicable)		Comments
		0	15	30	45	Attached	Detached	
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
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	27							
	28							
	29							

FIGURE 9-2—OBSERVATION RECORD—(CONTINUED)

Page —— of ——

Company _____ Observer _____
Location _____ Type facility _____
Test Number _____ Point of emissions _____
Date _____

Hr.	Min.	Seconds				Steam plume (check if applicable)		Comments
		0	15	30	45	Attached	Detached	
	30							
	31							
	32							
	33							
	34							
	35							
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3.3.2.3 Angle of View. Check construction geometry to ensure that the total angle of view of the smoke plume, as seen by the photocell, does not exceed 15°. The total angle of view may be calculated from: $\theta = 2 \tan^{-1} d/2L$, where θ = total angle of view; d = the sum of the photocell diameter + the diameter of the limiting aperture; and L = the distance from the photocell to the limiting aperture. The limiting aperture is the point in the path between the photocell and the smoke plume where the angle of

view is most restricted. In smoke generator smoke meters this is normally an orifice plate.

3.3.2.4 Angle of Projection. Check construction geometry to ensure that the total angle of projection of the lamp on the smoke plume does not exceed 15°. The total angle of projection may be calculated from: $\theta = 2 \tan^{-1} d/2L$, where θ = total angle of projection; d = the sum of the length of the lamp filament + the diameter of the limiting aperture; and L = the distance from the lamp to the limiting aperture.

3.3.2.5 Calibration Error. Using neutral-density filters of known opacity, check the error between the actual response and the theoretical linear response of the smoke meter. This check is accomplished by first calibrating the smoke meter according to 3.3.1 and then inserting a series of three neutral-density filters of nominal opacity of 20, 50, and 75 percent in the smoke meter pathlength. Filters calibrated within ±2 percent shall be used. Care should be taken when inserting the filters to prevent stray light from affecting the meter. Make a total of five nonconsecutive readings for each filter. The maximum error on any one reading shall be 3 percent opacity.

3.3.2.6 Zero and Span Drift. Determine the zero and span drift by calibrating and operating the smoke generator in a normal manner over a 1-hour period. The drift is measured by checking the zero and span at the end of this period.

3.3.2.7 Response Time. Determine the response time by producing the series of five simulated 0 percent and 100 percent opacity values and observing the time required to reach stable response. Opacity values of 0 percent and 100 percent may be simulated by alternately switching the power to the light source off and on while the smoke generator is not operating.

4. *References.*

4.1 Air Pollution Control District Rules and Regulations, Los Angeles County Air Pollution Control District, Regulation IV, Prohibitions, Rule 50.

4.2 Weisburd, Melvin I., Field Operations and Enforcement Manual for Air, U.S. Environmental Protection Agency, Research Triangle Park, N.C., APTD-1100, August 1972, pp. 4.1-4.36.

4.3 Condon, E.U., and Odishaw, H., Handbook of Physics, McGraw-Hill Co., N.Y., N.Y., 1958, Table 3.1, p. 6-52.

CALIBRATION INFORMATION

NOZZLES

Each new set of nozzles purchased by ETI are first machined and calibrated before being put into field use. Thereafter, whenever it becomes apparent that a nozzel has been damaged, it is again machined and recalibrated. A set of three is matched to within 0.002 inches (Difference between high and low readings).

PITOT TUBES

All pitot tubes used by ETI whether separate or attached to a sampling probe were made by ETI personnel. Prior to being put into field use, they are calibrated. In general, if a type "S" pitot tube is constructed properly, and not positioned too closely to the probe nozzle or any other obstruction, it will have a Cp of 0.83 - 0.87. As long as the pitot tube is not damaged its calibration should not change. All ETI pitot tubes are made to have a Cp of 0.84. If a pitot tube does not initially have a Cp of 0.84, it is altered until a reading of 0.84 is obtained.

DRY GAS METER AND ORIFICE METER

Meter box calibrations are checked periodically according to their usage. If a large difference is noted between calibrations, the meter box is sent back to the manufacturer to be rechecked.

THERMOMETERS, FYRITES, ORSAT, ORSAT BAGS

Each new thermometer, pyrometer and thermocouple purchased by ETI is checked and calibrated before being put into field use. Periodically and according to each piece of equipments use it is again checked and recalibrated.

Fyrites and orsats are checked after each source test. If they do not function properly, each is refilled with fresh solutions and rechecked. Orsat gas sampling bags are leak tested and evacuated after each source test.

Calibration data and test dates are posted on each individual piece of equipment.

LABORATORY EQUIPMENT

ETI has a written quality assurance document that covers calibration and maintenance of laboratory equipment. This includes calibration of the analytical balance daily against Class S weights, and service contracts to maintain traceability to N.B.S. Calibration of thermometers, barometers, stopwatches, and wet test meters are traceable to N.B.S. A copy of our quality assurance document may be obtained by written request.

PRETEST -POSTTEST CALIBRATION CHECKS
(Method 5, Figure 5.1)

Plant Johnson Controls Winston Salem, NC Calibrated by MD PLH

Meter box number 1264/1401 Date 12-09-87

Dry Gas Meter

Pretest calibration factor, Y 1.00 (1264) / 1.00 (1348) (within ±2%)
Posttest check, Y* 1.01 / 1.01 (within ±5% of pretest)
Recalibration required? — yes ✓ no
If yes, recalibration factor, Y — (within ±2%)
Lower calibration factor, Y — for calculations (pretest or posttest)

Dry Gas Meter Thermometers

Was a pretest temperature correction used? — yes ✓ no
If yes, temperature correction — (within ±3°C (5.4°F) over range)
Posttest comparison with mercury-in-glass thermometer?* (within ±6°C (10.8°F) at ambient temperature)
Recalibration required? ✓ yes ✓ no
Recalibration temperature correction? — (within ±3°C (5.4°F) over range)*
If yes, no correction necessary for calculations if meter thermometer temperature is higher; if calibration temperature is higher, add correction to average meter temperature for calculations

Stack Temperature Sensor

Was a pretest temperature correction used? — yes ✓ no
If yes, temperature correction — °C (°F) (within ±1.5% of readings in K (°R) over range)
Average stack temperature of compliance test, T_s 692.1 (#7) / 620.4 (#8) K (°R)
Temperature of reference thermometer or solution for recalibration 612/612 K (°R)* (within ±10% of T_s)
Temperature of stack thermometer for recalibration 611/611 K (°R)
Difference between reference and stack thermometer temperatures, ΔT_s 1°/1° K (°R)
Do values agree within ±1.5%?* ✓ yes — no
If yes, no correction necessary for calculations
If no, calculations must be done twice--once with the recorded values and once with the average stack temperature corrected to correspond to the reference temperature differential (ΔT_s); both final result values must be reported since there is no way to determine which is correct

(continued)

(continued)

Barometer

Was the pretest field barometer reading correct? ✓ yes ___ no
Posttest comparison?* 0.021 ~~mm~~ (in.) Hg (~~±2.5 mm~~ (0.1 in.) Hg)
Was calibration required? — yes ✓ no
If yes, no correction necessary for calculations when the field barometer has a lower reading; if the mercury-in-glass reading is lower, subtract the difference from the field data readings for the calculation Pretest Hg 29.000 − 29.00 = 0.00 Posttest Hg in glass 28.859 − Field 28.88 = .021

Nozzle*

Was the nozzle calibrated to the nearest ~~0.025 mm~~ (0.001 in.)?
✓ yes ___ no

Impinger Thermometer

Was a pretest temperature correction used? ___ yes ✓ no
If yes, temperature correction — (within ±3°C (5.4°F) over range)

*Most significant items/parameters to be checked.

POSITEST DRY GAS METER CALIBRATION DATA FORM (English Units)

Test Number 1 Date 12-11-87 Meter Box number 1264 Plant Johnson Controls - Gridcaster #8

Barometric pressure, P_b = 28.859 in.Hg. Dry Gas Meter No. 1 Pretest Y 1.00

Orifice manometer setting, (ΔH) in. H_2O	Gas Volume: Wet test meter (V_w), ft.³	Gas Volume: Dry gas meter (V_d), ft.³	Temperature: Wet test meter, (t_w) °F	Temperature: Dry Gas Meter: Inlet (t_{d_i}) °F	Temperature: Dry Gas Meter: Outlet (t_{d_o}) °F	Temperature: Dry Gas Meter: Average (t_d) °F	Time (θ), min.	Vacuum setting, in. Hg.	Y_i	$Y_i = \frac{V_w P_b (t_d + 460)}{V_d (P_b + \frac{\Delta H}{13.6}) (t_w + 460)}$
1.84	10	10.57	66.5	118.5	94	106.25	13.64	8	1.01	$\frac{10(28.859)(106.25+460)}{10.57(28.859+\frac{1.84}{13.6})(66.5+460)}$
1.84	10	10.64	66.5	120	96	108	13.66	8	1.01	$\frac{10(28.859)(108+460)}{10.64(28.859+\frac{1.84}{13.6})(66.5+460)}$
1.84	10	10.66	66.5	121	97.5	109.25	13.69	8	1.01	$\frac{10(28.859)(109.25+460)}{10.66(28.859+\frac{1.84}{13.6})(66.5+460)}$
									Y = 1.01	

V_w = Gas volume passing through the wet test meter, ft.³

V_d = Gas volume passing through the dry gas meter, ft.³

t_w = Temperature of the gas in the wet test meter, ° F

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F

H = Pressure differential across orifice, in. H_2O

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ± 0.05Y

P_b = Barometric pressure, in. Hg

θ = Time of calibration run, min.

POSTTEST DRY GAS METER CALIBP TION DATA FORM (English Units)

Test Number 1 Date 12-16-87 Meter Box number 1401 Plant JohnsonControl-Gridca. r:7

Barometric pressure, P_b = 29.120 in.Hg. Dry Gas Meter No. 1 Pretest Y = 1.00

Orifice manometer setting, (ΔH) in. H_2O	Gas Volume: Wet test meter (V_w), ft.³	Gas Volume: Dry gas meter (V_d), ft.³	Temperature: Wet test meter, (t_w) °F	Temperature: Dry Gas Meter: Inlet (t_{d_i}) °F	Temperature: Dry Gas Meter: Outlet (t_{d_o}) °F	Temperature: Dry Gas Meter: Average (t_d) °F	Time (θ), min.	Vacuum setting, in. Hg.	Y_i	Y_i = $\frac{V_w P_b (t_d + 460)}{V_d (P_b + \frac{\Delta H}{13.6})(t_w + 460)}$
2.12	10	10.84	65	131	101.5	116.25	1309	11.2	1.01	$\frac{10(29.120)(116.25+460)}{10.84(29.120+\frac{2.12}{13.6})(65+460)}$
2.12	10	10.85	65	132	102.5	117.25	1310	11.2	1.01	$\frac{10(29.120)(117.25+460)}{10.85(29.120+\frac{2.12}{13.6})(65+460)}$
2.12	10	10.87	65	132	103	117.50	1314	11.2	1.01	$\frac{10(29.120)(117.5+460)}{10.87(29.120+\frac{2.12}{13.6})(65+460)}$
									Y = 1.01	

V_w = Gas volume passing through the wet test meter, ft.³

V_d = Gas volume passing through the dry gas meter, ft.³

t_w = Temperature of the gas in the wet test meter, ° F

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F

H = Pressure differential across orifice, in. H_2O

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ± 0.05Y

P_b = Barometric pressure, in. Hg

θ = Time of calibration run, min.

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PRETEST THERMOMETER CALIBRATION

Client Johnson Controls Winston Salem, NC Date 12-09-87

Location Grid Caster #7 & #8 Ref Thermometer #5

Thermometer	Reading, °F	Ref. Temp. (Ambient) ° F
Meter box 1264	70/70	70
Meter box 1401	70/69	70
Impinger 1	70	70
Impinger 2	70	70
Impinger 3	70	70
WB #1 / #2	70/71	70
DB #1 / #2	69/70	70
Box 1	70	70
Box 2	71	70
Box 3	71	70
WB Omega #1	70	70
DB Omega #1	70	70
WB Omega 873	70	70
DB Omega 873	69	70
Probe 4' #1	70	70
Probe 4' #2	70	70
Box 4	70	70
Box 5	71	70
Box 6	69	70
Impinger 4	68	70
Impinger 5	69	70

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POST-TEST THERMOMETER CALIBRATION

Client Johnson Controls Date 12-11-87

Location Winston Salem N.C. Ref Thermometer #22
Grid Caster #7 & #8

Thermometer	Reading, °F	Ref. Temp. (Ambient) ° F
Meter box 1264		
Meter box 1401	69/69	70
Impinger 1	70	71
Impinger 2	70	71
Impinger 3	71	71
WB #1 / #2	72 / 71	71
DB #1 / #2	70 / 71	71
Box 1	70	71
Box 2	70	71
Box 3	70	71
WB Omega #1	67	68
DB Omega #1	71	70
WB Omega 873	72	71
DB Omega 873	71	71
Probe 4' #1	71 / 151	71 / 152
Probe 4' #2	72 / 151	71 / 152
Box 4	70	71
Box 5	70	71
Box 6	70	71
Impinger 4	70	71
Impinger 5	71	71

STAKSAMPLR CALIBRATION SHEET

ENVIRONMENTAL TESTING, INC.	Valves OK
Date 02-25-87	Remarks: calibrated by PRJ
Pump Visual Inspection OK✓	Positive leak check @ 5.0" H_2O OK
Pump Oil clean, level OK✓	
Clean Quick Connects cleaned & oiled	
Manometers levels OK	
Dry Test Meter OK see calibration data	
Thermometers OK see calibration data	
Lights OK	
Electrical Check--Amphenol OK	
Variac OK	
Vacuum Gauge OK	
Leak Check at 27" Hg.--Leakage <0.001	

Calibration--Orifice and Meter

Date 02-25-87 Box No. 5-1264 P_b 29.484

Man. Orifice	CF_w	CF_d	T_w	IT_d	OT_d	T_d avg.	Time t
0.5	5	6.32	69.50	110.5	95.5	103.00	12.55
1.0	5	5.35	69.50	115.0	98.0	106.50	9.08
1.5	10	10.72	69.50	118.0	99.5	109.75	15.18
2.0	10	10.73	69.50	126.5	101.5	111.00	13.27
3.0	10	10.75	69.50	123.5	103.0	113.25	10.95
4.0	10	10.74	69.50	126.0	104.0	115.00	9.50

Calculate Y & $\Delta H_@$ as follows:

$$Y = \frac{CF_w P_b (T_{d\ avg.} + 460)}{CF_d (P_b + \frac{\Delta H}{13.6})(T_w + 460)} = \boxed{1.00}$$

$$\Delta H_@ = \frac{0.0317\ \Delta H}{P_b (T_d + 460)} \left[\frac{(T_d + 460)\ t}{CF_w} \right]^2$$

$$= \boxed{1.81}$$

Tolerances

$Y = 0.90 - 1.00 - 1.10$ $Y \pm 0.02Y$

$\Delta H_@ = 1.6 - 1.81 - 2.1$ $\Delta H_@ \pm 0.15$ in.

CALIBRATION CALCULATIONS METER AND PUMP BOX

Date 02-25-87 Box No. 51264

$\frac{0.0317 \text{ (Man. orifice)}}{P_b\ (\ T_d + 460\ )}$	$\left[\frac{(\ T_w + 460\ )\ t}{CF_w}\right]^2$	Man.	$\Delta H_@$	$\frac{CF_w\ P_b\ (T_d \text{ avg.} + 460)}{CF_d \left(P_b + \frac{\text{Man. orifice}}{13.6}\right)(T_w + 460)}$	Man.	Y
$\frac{0.01585}{29.484\ (103.00 + 460)}$	$\left[\frac{(69.50 + 460)\ 12.55}{5}\right]^2$	.5	1.687	$\frac{5 \text{ X } 29.484\ (103.00 + 460)}{5.32\ (29.484 + 0.0368)\ (69.50 + 460)}$	.5	0.998
$\frac{0.0317}{29.484\ (106.50 + 460)}$	$\left[\frac{(69.50 + 460)\ 9.08}{5}\right]^2$	1.0	1.755	$\frac{5 \text{ X } 29.484\ (106.50 + 460)}{5.35\ (29.484 + 0.0737)\ (69.50 + 460)}$	1.0	0.997
$\frac{0.04755}{29.484\ (108.75 + 460)}$	$\left[\frac{(69.50 + 460)\ 15.18}{10}\right]^2$	1.5	1.832	$\frac{10 \text{ X } 29.484\ (108.75 + 460)}{10.72\ (29.484 + 0.1103)\ (69.50 + 460)}$	1.5	0.998
$\frac{0.06340}{29.484\ (111.00 + 460)}$	$\left[\frac{(69.50 + 460)\ 13.27}{10}\right]^2$	2.0	1.859	$\frac{10 \text{ X } 29.484\ (111.00 + 460)}{10.73\ (29.484 + 0.1471)\ (69.50 + 460)}$	2.0	1.000
$\frac{0.09510}{29.484\ (113.25 + 460)}$	$\left[\frac{(69.50 + 460)\ 10.85}{10}\right]^2$	3.0	1.857	$\frac{10 \text{ X } 29.484\ (113.25 + 460)}{10.75\ (29.484 + 0.2206)\ (69.50 + 460)}$	3.0	1.000
$\frac{0.12680}{29.484\ (115.00 + 460)}$	$\left[\frac{(69.50 + 460)\ 9.50}{10}\right]^2$	4.0	1.893	$\frac{10 \text{ X } 29.484\ (115.00 + 460)}{10.74\ (29.484 + 0.2943)\ (69.50 + 460)}$	4.0	1.001

STAKSAMPLR CALIBRATION SHEET

ENVIRONMENTAL TESTING, INC.	Valves OK
Date 06-19-87	Remarks: Calibrated by PRJ
Pump Visual Inspection OK ✓	Positive leak check @ 6.0" H_2O OK
Pump Oil Clean, level OK ✓	
Clean Quick Connects cleaned & oiled	
Manometers level = OK	
Dry Test Meter OK See calibration data	
Thermometers OK See calibration data	
Lights OK	
Electrical Check--Amphenol OK	
Variac OK	
Vacuum Gauge OK	
Leak Check at 27" Hg.--Leakage <0.001	

Calibration--Orifice and Meter

Date 06-19-87 Box No. 1401 P_b 29.269

Man. Orifice	CF_w	CF_d	T_w	IT_d	OT_d	T_d avg.	Time t
0.5	5	5.29	70.90	111.0	95.0	103.00	12.93
1.0	5	5.32	70.90	117.5	97.5	107.50	9.24
1.5	10	10.73	70.90	122.0	99.5	110.75	15.27
2.0	10	10.78	70.90	124.5	101.5	113.00	13.37
3.0	10	10.91	70.90	127.5	103.5	115.50	11.06
4.0	10	10.80	70.90	129.0	104.0	116.50	9.60

Calculate Y & $\Delta H_@$ as follows:

$$Y = \frac{CF_w P_b (T_d \text{ avg.} + 460)}{CF_d (P_b + \frac{\Delta H}{13.6})(T_w + 460)} = \boxed{1.00}$$

$$\Delta H_@ = \frac{0.0317\,\Delta H}{P_b (T_d + 460)} \left[\frac{(T_w + 460)\,t}{CF_w} \right]^2 = \boxed{1.89}$$

Tolerances

$Y = 0.90 - \underline{1.00} - 1.10$ $Y \pm 0.02Y$

$\Delta H_@ = 1.6 - \underline{1.84} - 2.1$ $\Delta H_@ \pm 0.15$ in.

CALIBRATION CALCULATIONS METER AND PUP BOX

Date 06-19-87 Box No. 401

$$\frac{0.0317 \text{ (Man. orifice)}}{P_b\ (T_d + 460)} \left[\frac{(T_w + 460)\ t}{CF_w}\right]^2 = \Delta H_@$$

$$\frac{CF_w\ P_b\ (T_d \text{ avg.} + 460)}{CF_d \left(P_b + \frac{\text{Man. orifice}}{13.6}\right) (T_w + 460)} = Y$$

Man.	$\Delta H_@$	Y
.5	1.813	1.001
1.0	1.846	1.001
1.5	1.871	0.998
2.0	1.905	0.996
3.0	1.947	0.995
4.0	1.952	0.995

.5: $\frac{0.01585}{29.269\ (103.00 + 460)} \left[\frac{(70.90 + 460)\ 12.93}{5}\right]^2$; $\frac{5 \times 29.269\ (103.00 + 460)}{5.29\ (29.269 + 0.0368)\ (70.90 + 460)}$

1.0: $\frac{0.0317}{29.269\ (107.50 + 460)} \left[\frac{(70.90 + 460)\ 9.26}{5}\right]^2$; $\frac{5 \times 29.269\ (107.50 + 460)}{5.32\ (29.269 + 0.0737)\ (70.90 + 460)}$

1.5: $\frac{0.04755}{29.269\ (110.75 + 460)} \left[\frac{(70.90 + 460)\ 15.27}{10}\right]^2$; $\frac{10 \times 29.269\ (110.75 + 460)}{10.73\ (29.269 + 0.1103)\ (70.90 + 460)}$

2.0: $\frac{0.06340}{29.269\ (113.00 + 460)} \left[\frac{(70.90 + 460)\ 13.37}{10}\right]^2$; $\frac{10 \times 29.269\ (113.00 + 460)}{10.78\ (29.269 + 0.1471)\ (70.90 + 460)}$

3.0: $\frac{0.09510}{29.269\ (115.50 + 460)} \left[\frac{(70.90 + 460)\ 11.06}{10}\right]^2$; $\frac{10 \times 29.269\ (115.50 + 460)}{10.81\ (29.269 + 0.2206)\ (70.90 + 460)}$

4.0: $\frac{0.12680}{29.269\ (116.50 + 460)} \left[\frac{(70.90 + 460)\ 9.60}{10}\right]^2$; $\frac{10 \times 29.269\ (116.50 + 460)}{10.80\ (29.269 + 0.2941)\ (70.90 + 460)}$

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TYPE S PITOT TUBE INSPECTION DATA FORM

Date: 09-14-87

Calibrator: RCJ

Specifications:
1.) Pitot tube assembly must be level.
2.) If pitot tube is damaged explain under comments section.

Probe Length 4 ft.

$z = A \sin\gamma$ <0.125
$w = A \sin\theta$ <0.03125

Probe	α_1 (<10°)	α_2 (<10°)	β_1 (<5°)	β_2 (<5°)	γ°	θ°	A, in.	z, in.	w, in.	P_A, in.	P_B, in.	D_t, in.
1	3.0	2.5	1.5	1.5	0.5	0.0	0.926	0.008	0.000	0.463	0.463	0.378
2	0.5	2.0	2.0	2.5	0.5	0.0	0.896	0.008	0.000	0.448	0.448	0.371
3	4.0	2.5	2.5	2.0	0.5	0.5	0.875	0.008	0.008	0.437	0.438	0.375
4	0.5	4.5	3.5	1.0	0.0	0.0	0.852	0.000	0.000	0.426	0.426	0.376
5	0.5	1.0	1.5	1.0	1.0	1.0	0.866	0.015	0.015	0.433	0.433	0.372
6	2.0	0.5	0.5	0.5	1.0	0.5	0.952	0.017	0.008	0.476	0.476	0.378
36"-1	0.5	1.0	1.0	1.5	1.5	1.0	0.782	0.020	0.014	0.391	0.391	0.377
36"-2	1.5	1.0	1.0	1.0	0.5	1.0	1.151	0.010	0.020	0.576	0.575	0.376
Ander.	0.5	1.0	0.5	0.5	0.0	0.0	1.095	0.000	0.000	0.547	0.548	0.391

Probe Length 5 ft.

$z = A \sin\gamma$ <0.125
$w = A \sin\theta$ <0.03125

Probe	α_1 (<10°)	α_2 (<10°)	β_1 (<5°)	β_2 (<5°)	γ°	θ°	A, in.	z, in.	w, in.	P_A, in.	P_B, in.	D_t, in.
1	1.0	1.0	0.5	1.0	1.0	0.5	1.001	0.017	0.009	0.500	0.501	0.374
2	0.5	1.0	0.5	0.0	1.5	0.0	1.040	0.027	0.000	0.520	0.520	0.375
3	0.5	0.5	0.5	0.5	0.5	0.5	1.040	0.009	0.009	0.520	0.520	0.375
4	1.0	0.5	0.5	0.0	1.0	0.5	1.036	0.018	0.009	0.518	0.518	0.380
Pitot 54"	3.0	2.0	0.5	1.0	1.0	0.5	1.060	0.018	0.009	0.530	0.530	0.375

Probe Length 6 ft.

$z = A \sin\gamma$ <0.125
$w = A \sin\theta$ <0.03125

Probe	α_1 (<10°)	α_2 (<10°)	β_1 (<5°)	β_2 (<5°)	γ°	θ°	A, in.	z, in.	w, in.	P_A, in.	P_B, in.	D_t, in.
Pitot 66"	2.5	2.5	1.0	2.0	1.5	1.5	0.975	0.026	0.026	0.487	0.488	0.392
1	1.5	1.5	0.5	1.0	1.0	1.0	0.992	0.017	0.017	0.496	0.496	0.375
2	1.0	1.0	0.5	1.0	0.5	0.5	1.010	0.009	0.009	0.505	0.505	0.376
3	1.0	1.0	0.5	1.0	1.0	0.5	1.008	0.018	0.009	0.504	0.504	0.376
4	1.0	0.5	1.0	0.0	2.0	1.0	1.000	0.035	0.017	0.500	0.500	0.375

Comments: Only minor filing & cleaning done

Pitot tubes requiring calibration: None

NOZZLE CALIBRATION

Calibrator: ICJ

Set # 1 Brown Box

Nozzle Diameter		D_1, in	D_2, in	D_3, in	D_4, in	D_5, in	D, in	D avg.
3/16"	1	0.187	0.186	0.187	0.187	0.187	0.001	0.187
	2	0.189	0.190	0.189	0.189	0.189	0.001	0.189
	3	0.186	0.185	0.186	0.186	0.185	0.001	0.186
7/32"	1	0.206	0.207	0.207	0.206	0.207	0.001	0.207
1/4"	1	0.252	0.252	0.251	0.252	0.252	0.001	0.252
	2	0.253	0.253	0.253	0.251	0.253	0.002	0.253
	3	0.249	0.249	0.249	0.249	0.248	0.001	0.249
5/16"	1	0.304	0.303	0.303	0.302	0.303	0.002	0.303
	2	0.302	0.302	0.301	0.303	0.302	0.002	0.302
	3	0.300	0.300	0.300	0.300	0.300	0.000	0.300
3/8"	1	0.374	0.375	0.374	0.376	0.375	0.002	0.375
	2	0.376	0.375	0.377	0.376	0.377	0.002	0.376
	3	0.375	0.375	0.374	0.375	0.374	0.001	0.375
13/32"	0	0.405	0.404	0.405	0.405	0.405	0.001	0.405
1/2"	1	0.504	0.505	0.504	0.504	0.504	0.001	0.504
	2	0.502	0.501	0.503	0.503	0.502	0.002	0.502
	3	0.502	0.501	0.503	0.502	0.502	0.002	0.502
3/4"	0	0.780	0.781	0.780	0.779	0.780	0.002	0.780
1"	0	1.000	1.000	1.001	0.999	1.000	0.002	1.000

Set # 2 Blue Box

Nozzle Diameter		D_1, in	D_2, in	D_3, in	D_4, in	D_5, in	D, in	D avg.
3/16"	1	0.185	0.184	0.184	0.184	0.184	0.001	0.184
	2	0.185	0.185	0.186	0.185	0.185	0.001	0.185
	3	0.186	0.186	0.185	0.186	0.186	0.001	0.186
7/32"	2	0.207	0.206	0.207	0.207	0.207	0.001	0.207
1/4"	1	0.250	0.249	0.249	0.251	0.250	0.002	0.250
	2	0.252	0.252	0.251	0.252	0.252	0.001	0.252
	3	0.250	0.250	0.248	0.250	0.250	0.002	0.250
5/16"	1	0.302	0.302	0.303	0.302	0.302	0.001	0.302
	2	0.303	0.302	0.302	0.302	0.301	0.002	0.302
	3	0.302	0.301	0.302	0.303	0.302	0.002	0.302
3/8"	1	0.378	0.378	0.378	0.377	0.378	0.001	0.378
	2	0.376	0.377	0.376	0.377	0.376	0.001	0.376
	3	0.377	0.375	0.376	0.377	0.377	0.002	0.376
1/2"	1	0.496	0.498	0.497	0.497	0.497	0.002	0.497
	2	0.498	0.499	0.498	0.500	0.498	0.002	0.499
	3	0.497	0.498	0.499	0.498	0.497	0.002	0.498

Where:

$D_{1,2,3,4,5}$ = nozzle diameter measured on a different diameter, in.
Tolerance = measure within 0.001 in.

D = maximum difference in any two measurements, in.
Tolerance = 0.004 in.

D_{avg} = average of D_1, D_2, D_3, D_4, and D_5.

the OMEGA Group

DATE: 12-10-85

CERTIFICATE OF CALIBRATION

CUSTOMER: ENVIRONMENTAL TESTING INC
1700 UNIV COMMERICAL PL
CHARLOTTE NC 28213

Customer Purchase Order: 2861PO
OMEGA Work Order No: SO 511268760
MODEL: HH-2
SERIAL NO: 14403

OMEGA ENGINEERING certifies that the above instrumentation has been calibrated and tested to meet or exceed the published specifications. This calibration and testing was performed using instrumentation and standards that are traceable to the U.S. National Bureau of Standards.

Reference: NATIONAL BUREAU OF STANDARDS TEST NO(s): 36320

Tony D'Inverno
Supervisor, Instrumentation

CAL-3

OMEGA ENGINEERING, INC.
OMEGA PRESS
OMEGA INTERNATIONAL CORP.
BIOMEGA
One Omega Drive, Box 4047, Stamford, CT 06907-0047 (203) 359-1660 Telex 996404 Cable OMEGA FAX (203) 359-7700

Whatman Inc.

Whatman Inc. • 9 Bridewell Place, Clifton, New Jersey 07014 • Telephone: (201) 777-4825
Telex: 133426 • Cable: REEVEPAP

February 1, 1979

Mr. Paul R. Jenkins, Jr.
Vice-President
Environmental Testing Inc.
1700 University Commercial Place
Charlotte, North Carolina 28213

Dear Mr. Jenkins:

Further to our telephone conversation on January 15, 1979 Reeve Angel Grade 900AF is tested with a Q128 DOP Penetrometer manufactured by the Air Technology Association to measure DOP. This is a more sophisticated unit than that listed in the Federal Register, Part II, Thursday, August 18, 1977, Environmental Protection Agency, Standards of Performance for New Stationary Sources.

Grade 900AF will meet the EPA DOP requirements of 0.05 ≤ percent penetration on a 0.3 micron dioctyl phthalate smoke particles as listed on page 41778 of the Federal Register, Vol. 42, No. 160, Thursday, August 18, 1977 under 3. Reagent, 3.1.1 Filters.

I hope this will satisfy your inquiry. If we can be of any further service, please contact us at your convenience.

Very truly yours,

John Zacharias
Vice President
Business Manager, Paper Division, N. A.

JZ/mpm

TEMPERATURE SENSOR CALIBRATION DATA FORM
TOLERANCE: +/- 5.4 F

DATE: 07/16/87
AMBIENT TEMPERATURE, F : 72
CALIBRATOR: FLH/JPM

BAROMETRIC PRESSURE: 29.24
REFERENCE THERMOMETER # 22

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE, F	THERMOCOUPLE POTENTIOMETER TEMPERATURE, F	TEMPERATURE DIFFERENCE, %
SAMPLE BOX					
01	A.	water bath	72	73	-.19
	B.	oil bath	130	130	0.00
	C.	oil bath	194	192	0.31
	D.	oil bath	222	222	0.00
	E.	oil bath	282	282	0.00
02	A.	water bath	72	73	-.19
	B.	oil bath	130	130	0.00
	C.	oil bath	194	192	0.31
	D.	oil bath	222	222	0.00
	E.	oil bath	282	282	0.00
03	A.	water bath	72	74	-.38
	B.	oil bath	130	131	-.17
	C.	oil bath	194	195	-.15
	D.	oil bath	222	224	-.29
	E.	oil bath	282	282	0.00
04	A.	water bath	72	72	0.00
	B.	oil bath	130	130	0.00
	C.	oil bath	190	190	0.00
	D.	oil bath	226	226	0.00
	E.	oil bath	286	286	0.00
05	A.	water bath	72	72	0.00
	B.	oil bath	130	130	0.00
	C.	oil bath	190	190	0.00
	D.	oil bath	226	226	0.00
	E.	oil bath	286	288	-.27
06	A.	water bath	72	72	0.00
	B.	oil bath	130	130	0.00
	C.	oil bath	196	194	0.38
	D.	oil bath	238	238	0.00
	E.	oil bath	286	286	0.00
07	A.	water bath	72	71	0.19
	B.	oil bath	130	130	0.00
	C.	oil bath	196	194	0.38
	D.	oil bath	238	238	0.00
	E.	oil bath	288	287	0.13
08	A.	water bath	72	70	0.38
	B.	oil bath	130	130	0.00
	C.	oil bath	190	190	0.00
	D.	oil bath	230	230	0.00
	E.	oil bath	288	287	0.13

$$\text{TEMPERATURE DIFFERENCE} = \frac{(\text{REF TEMP, F} + 460) - (\text{TEST TEMP, F} + 460)}{\text{REF TEMP, F} + 460} \times 100 <= 1.5\%$$

WET-BULB DRY-BULB, BIMETALLIC

TEMPERATURE SENSOR CALIBRATION DATA FORM

TOLERANCE: +/- 5.4 F

DATE: 07/16/87
AMBIENT TEMPERATURE, F : 72
CALIBRATOR: FLH/JPM

BAROMETRIC PRESSURE: 29.24
REFERENCE THERMOMETER # 22

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE,F	THERMOCOUPLE POTENTIOMETER TEMPERATURE,F	TEMPERATURE DIFFERENCE, %
Bimetallic					
Db1	A.	water bath	73	74	-.19
	B.	oil bath	130	134	-.68
	C.	oil bath	192	196	-.61
	D.	oil bath	218	221	-.44
	E.	oil bath	286	287	-.13
Mb1	A.	water bath	73	74	-.19
	B.	oil bath	130	132	-.34
	C.	oil bath	226	228	-.29
	D.	oil bath	194	194	0.00
	E.	oil bath	286	286	0.00
Db2	A.	water bath	73	73	0.00
	B.	oil bath	130	132	-.34
	C.	oil bath	193	193	0.00
	D.	oil bath	226	229	-.44
	E.	oil bath	286	286	0.00
Mb2	A.	water bath	73	72	0.19
	B.	oil bath	130	133	-.51
	C.	oil bath	193	190	0.46
	D.	oil bath	210	210	0.00
	E.	oil bath	280	287	0.13
NOx Flask					
	A.	ice bath	34	34	0.00
	B.	ice bath	50	50	0.00
	C.	water bath	73	73	0.00
	D.	water bath	89	89	0.00
	E.	oil bath	115	114	0.17
Hot Box	A.	water bath	73	73	0.00
	B.	oil bath	130	135	-.85
	C.	oil bath	194	191	0.46
	D.	oil bath	210	210	0.00
	E.	oil bath	270	267	0.41

$$\text{TEMPERATURE DIFFERENCE} = \frac{(\text{REF TEMP, F} + 460) - (\text{TEST TEMP, F} + 460)}{\text{REF TEMP, F} + 460} \times 100 \leq 1.5\%$$

TEMPERATURE SENSOR CALIBRATION DATA FORM
TOLERANCE: +/- 5.4 F

DATE: 07/16/87
AMBIENT TEMPERATURE, F : 72
CALIBRATOR: FLH/JPM

BAROMETRIC PRESSURE: 29.24
REFERENCE THERMOMETER # 22

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE,F	THERMOCOUPLE POTENTIOMETER TEMPERATURE,F	TEMPERATURE DIFFERENCE, %
METER BOX					
1264A	A.	ice bath	36	36	0.00
	B.	water bath	72	73	-.19
	C.	oil bath	128	126	0.34
	D.	oil bath	148	148	0.00
1264B	A.	ice bath	36	36	0.00
	B.	water bath	72	73	-.19
	C.	oil bath	128	126	0.34
	D.	oil bath	148	148	0.00
1348A	A.	ice bath	35	34	0.28
	B.	water bath	72	72	0.00
	C.	oil bath	126	126	0.00
	D.	oil bath	148	148	0.00
1348B	A.	ice bath	35	35	0.00
	B.	water bath	72	73	-.19
	C.	oil bath	126	126	0.00
	D.	oil bath	148	148	0.00
1481A	A.	ice bath	35	35	0.00
	B.	water bath	72	73	-.19
	C.	oil bath	128	126	0.34
	D.	oil bath	148	148	0.00
1481B	A.	ice bath	35	36	-.28
	B.	water bath	72	73	-.19
	C.	oil bath	128	128	0.00
	D.	oil bath	148	139	0.17
1965A	A.	ice bath	34	34	0.00
	B.	water bath	72	72	0.00
	C.	oil bath	126	125	0.17
	D.	oil bath	148	148	0.00
1965B	A.	ice bath	34	33	0.28
	B.	water bath	72	72	0.00
	C.	oil bath	126	126	0.00
	D.	oil bath	148	148	0.00

$$\text{TEMPERATURE DIFFERENCE} = \frac{(\text{REF TEMP, F} + 460) - (\text{TEST TEMP, F} + 460)}{\text{REF TEMP, F} + 460} \times 100 <= 1.5\%$$

WET-BULB DRY-BULB; OMEGA TEMP

TEMPERATURE SENSOR CALIBRATION DATA FORM

TOLERANCE: +/- 5.4 F

DATE: 07/16/87
AMBIENT TEMPERATURE, F : 72
CALIBRATOR: FLH/JPM

BAROMETRIC PRESSURE: 29.24
REFERENCE THERMOMETER # 22/#23

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE, F	THERMOCOUPLE POTENTIOMETER TEMPERATURE, F	TEMPERATURE DIFFERENCE, %
Omega Temp HH-2 #1					
Db1	A.	water bath	72	72	0.00
	B.	oil bath	160	160	0.00
	C.	oil bath	185	185	0.00
	D.	oil bath	225	224	0.15
	E.	oil bath	280	280	0.00
Wb1	A.	water bath	72	72	0.00
	B.	oil bath	160	160	0.00
	C.	oil bath	186	186	0.00
	D.	oil bath	226	225	0.15
	E.	oil bath	280	280	0.00
Omega Temp HH-2 #2					
Db2	A.	water bath	72	72	0.00
	B.	oil bath	160	159	0.16
	C.	oil bath	188	187	0.15
	D.	oil bath	221	220	0.15
	E.	oil bath	283	282	0.13
Wb2	A.	water bath	72	73	-.19
	B.	oil bath	160	159	0.16
	C.	oil bath	190	190	0.00
	D.	oil bath	220	219	0.15
	E.	oil bath	283	282	0.13

$$\text{TEMPERATURE DIFFERENCE} = \frac{(\text{REF TEMP, F} + 460) - (\text{TEST TEMP, F} + 460)}{\text{REF TEMP, F} + 460} \times 100 = 1.5\%$$

TEMPERATURE SENSOR CALIBRATION DATA FORM
TOLERANCE: +/- 2.0 F

DATE: 07/16/87
AMBIENT TEMPERATURE, F : 72
CALIBRATOR: FLM/JPM

BAROMETRIC PRESSURE: 29.34
REFERENCE THERMOMETER # 22

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE, F	THERMOCOUPLE POTENTIOMETER TEMPERATURE, F	TEMPERATURE DIFFERENCE, %
#1	A.	ice bath	34	34	0.00
	B.	water bath	73	73	0.00
	C.	oil bath	112	111	0.17
#2	A.	ice bath	34	33	0.20
	B.	water bath	74	73	0.19
	C.	oil bath	112	110	0.35
#3	A.	ice bath	34	33	0.20
	B.	water bath	73	72	0.19
	C.	oil bath	110	108	0.35
#4	A.	ice bath	34	34	0.00
	B.	water bath	74	73	0.19
	C.	oil bath	112	113	-.17
#5	A.	ice bath	34	35	-.20
	B.	water bath	73	73	0.00
	C.	oil bath	110	109	0.18

STACK
TEMPERATURE SENSOR CALIBRATION DATA FORM
TOLERANCE: +/- 5.4 F

DATE: 07/24/87
AMBIENT TEMPERATURE, F : 74
CALIBRATOR: FLH

BAROMETRIC PRESSURE: 29.28
REFERENCE THERMOMETER # 22/#5

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE, F	THERMOCOUPLE POTENTIOMETER TEMPERATURE, F	TEMPERATURE DIFFERENCE, %
4'-1	A.	oil bath	92	92	0.00
	B.	oil bath	242	242	0.00
	C.	oil bath	368	367	0.12
4'-2	A.	oil bath	92	92	0.00
	B.	oil bath	242	241	0.14
	C.	oil bath	368	368	0.00
5'-1	A.	oil bath	92	91	0.18
	B.	oil bath	242	244	-.28
	C.	oil bath	376	380	-.24
5'-2	A.	oil bath	92	91	0.18
	B.	oil bath	242	244	-.28
	C.	oil bath	378	382	-.24
6'-1	A.	oil bath	90	89	0.18
	B.	oil bath	242	243	-.14
	C.	oil bath	378	377	0.12
6'-2	A.	oil bath	90	91	-.18
	B.	oil bath	242	244	-.28
	C.	oil bath	378	377	0.12
8'-1	A.	oil bath	98	96	0.36
	B.	oil bath	242	243	-.14
	C.	oil bath	378	379	-.12
8'-2	A.	oil bath	98	99	-.18
	B.	oil bath	242	244	-.28
	C.	oil bath	378	376	0.00
8'-3	A.	oil bath	98	96	0.36
	B.	oil bath	242	244	-.28
	C.	oil bath	378	379	-.12
8'-9"	A.	oil bath	98	96	0.36
	B.	oil bath	242	243	-.14
	C.	oil bath	380	381	-.12
9'-7"	A.	oil bath	184	182	0.35
	B.	oil bath	242	244	-.28
	C.	oil bath	380	381	-.12

$$\text{TEMPERATURE DIFFERENCE} = \frac{(\text{REF TEMP, F} + 460) - (\text{TEST TEMP, F} + 460)}{\text{REF TEMP, F} + 460} \times 100 <= 1.5\%$$

TEMPERATURE SENSOR CALIBRATION DATA FORM
TOLERANCE: +/- 5.4 F

DATE: 07/16/87
AMBIENT TEMPERATURE, F : 72
CALIBRATOR: FLH/JPM

BAROMETRIC PRESSURE: 29.24
REFERENCE THERMOMETER # 22/# 23

REFERENCE POINT #		SOURCE	REFERENCE THERMOMETER TEMPERATURE,F	THERMOCOUPLE POTENTIOMETER TEMPERATURE,F	TEMPERATURE DIFFERENCE, %
Omega Temp 873-F					
Db1	A.	water bath	72	73	-.19
	B.	oil bath	163	162	0.16
	C.	oil bath	186	185	0.15
	D.	oil bath	230	229	0.14
	E.	oil bath	280	279	0.14
Wb1	A.	water bath	72	73	-.19
	B.	oil bath	163	162	0.16
	C.	oil bath	188	187	0.15
	D.	oil bath	232	231	0.14
	E.	oil bath	280	279	0.14
873-F High Temp					
	A.	oil bath	280	279	0.14
	B.	M. Furnace	415	416	-.11
	C.	M. Furnace	595	596	-.09
	D.	M. Furnace	835	837	-.15
	E.	M. Furnace	1875	1877	-.13

$$\text{TEMPERATURE DIFFERENCE} = \frac{(\text{REF TEMP, F} + 460) - (\text{TEST TEMP, F} + 460)}{\text{REF TEMP, F} + 460} \times 100 = \text{\_\_\_\_\%}$$