AP-42 Section 11.30
Reference 9
Report Sect.
Reference

8

SOURCE SAMPLING REPORT FOR MEASUREMENT OF PARTICULATE AND HEAVY METAL EMISSIONS

MDC INDUSTRIES
PHILADELPHIA FACILITY
SCRUBBER OUTLET

G/C, Inc., REPORT R-10-0620-001-1
NOVEMBER, 1988

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MDC INDUSTRIES
PHILADELPHIA FACILITY
SCRUBBER OUTLET

G/C, INC., REPORT R-10-0620-001-1
NOVEMBER, 1988

PREPARED BY

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December 12, 1988

MDC Industries
Collins & Willard Streets
Philadelphia, PA 19134

Attention: Mr. Joseph Carol

Re: Submittal of Source Sampling Report for
Measurement of Particulate and Heavy
Metal Emissions
MDC Industries
Scrubber Stack
Philadelphia Facility
G/C, Inc., Report R-10-0620-001-1

Gentlemen:

We are pleased to submit six copies of our Report R-10-0620-001-1, dated December 12, 1988. This report contains results of source sampling for par~~ticulate~~ and heavy metal emissions and determination of flue gas characteristics for the drying kiln scrubber at your Philadelphia facility, as conducted on November 9, 1988.

The source sampling program defined by this report incorporates standard sampling procedures. The results of the sampling program are representative of flue gas emissions at the outlet of the scrubber under referenced normal operating conditions.

Information contained in this report and the accompanying Appendices includes field data, laboratory analyses, and a computer printout of all results developed by the testing program. We have attempted to present this information in a form that is readily discernible and suitable for your continued use.

Gilbert/Commonwealth, Inc., is pleased to have been of service to MDC Industries and trusts that this report will meet your complete acceptance.

Very truly yours,

David Hofmann

David Hofmann
Testing Supervisor
Testing Services Group

DH:mas

Green Hills, Reading, PA 19603-1498, (215) 775-2600 • 525 Lancaster Avenue, Reading, PA 19603-1498, (215) 775-2600
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SECTION I - SUMMARY OF TEST RESULTS

A summary of test results from the source sampling program is presented in Table 1. As such, the results are considered representative of emission characteristics from the drying kiln scrubber during referenced operating conditions. The results show the particulate emissions are above the limit of 0.04 gr/dscf.

TABLE 1

SUMMARY OF TEST RESULTS
MDC INDUSTRIES
PHILADELPHIA FACILITY

G/C, INC. REPORT R-10-0620-001-1

LOCATION	SCRUBBER STACK		
RUN NO.	MDC-1N	MDC-1P	MDC-2N
DATE	11/9/88	11/9/88	11/9/88
TIME	0805	1116	1341
PROCESS RATE	17	17	17
Tons/hr	15-18	15-18	15-18
FLUE GAS CHARACTERISTICS			
	5685	6108	6221
	7227	7634	7959
	132	132	136
	13.5	12.2	13.5
IONS			
		0.0561	
		3.00 = 0.18 lb/ton	
CF		0.0561	
SCF		0.04	
	2.0	1.6	1.8 %
CO2	779.66 lb/hr 780 46 lb/ton	670.13 lb/hr 670 39 lb/ton	767.85 lb/hr 768 45 lb/ton

1 PM Run (M5)

2 Metals (M12) runs

~~3~~

CO2 - 3 runs ~~3~~

TABLE 2

SUMMARY OF HEAVY METAL RESULTS

SCRUBBER STACK

MDC INDUSTRIES

RUN NO.			MDC-IN					MDC-2N		
HEAVY METALS	MG	DSCF	DSCFM	GR/DSCF	LB/HR	MG	DSCF	DSCFM	GR/DSCF	LB/HR
					0.000080			0.0000081		
ANTIMONY	0.1	55.320	5685	0.000028	0.00136	0.1	59.737	6221	0.000026	0.00137
					0.00024		0.00024		~~0.00166~~	
ARSENIC	0.3	55.320	5685	0.000084	0.00407	~~0.30~~	~~59.737~~	6221	~~0.000077~~	~~0.00412~~
				0.0000082			0.0000082			.00279
BERYLLIUM	0.01	55.320	5685	0.000003	0.00014	~~0.01~~	59.737	6221	0.000003	0.00014
				0.0038					0.0049	
LEAD	4.73	55.320	5685	0.001317	0.06415	6.11	59.737	6221	0.001575	0.08398
				0.00081				0.0077		
CADMIUM	1.02	55.320	5685	0.000284	0.01383	1.35	59.737	6221	0.000348	0.01855
				0.00052				0.00037		
CHROMIUM	0.65	55.320	5685	0.000181	0.00882	0.46	59.737	6221	0.000119	0.00632
				0.000074				0.000047		
MANGANESE	0.093	55.320	5685	0.000026	0.00126	0.058	59.737	6221	0.000015	0.00080
				0.0000017					0.0000017	
MERCURY	0.002	55.320	5685	0.000001	0.00003	0.002	59.737	6221	0.000001	0.00003
				0.000080				0.000081		
THALLIUM	0.1	55.320	5685	0.000028	0.00136	0.1	59.737	6221	0.000026	0.00137
				0.0028				0.0023		
NICKEL	3.55	55.320	5685	0.000988	0.04815	2.80	59.737	6221	0.000722	0.03848
				17 TON/HR				17 TON/HR		

SECTION II - ANALYSIS

1. Introduction

The data presented in this report represents the results of source sampling exhaust emissions at the stack location of the venturi scrubber during referenced operating conditions.

Specific requirements of this source sampling program include the following:

a. Identification of final particulate and heavy metal emissions from the venturi scrubber.

b. Average flue gas temperature, moisture, and volume of flow at the sampling location.

c. Orsat analysis of flue gas conditions at the point of sampling.

d. Record of pertinent operating conditions during period of the test run.

The sampling program was completed on November 9, 1988 by the Gilbert field test crew, with the assistance of personnel assigned by MDC Industries and witnessed by the City of Philadelphia.

2. Description of the Plant Exhaust System

The process involves drying copper and boiler slag through a rotary kiln. The exhaust gas is drawn off to a venturi scrubber, then into a settling tank before exhausting through a stack. An estimated amount of 15-18 tons/hour of processed slag was used.

3. Sampling Program Procedures

To satisfy the objectives established for this project, the sampling program was set-up on a basis of using one test train positioned at the test location and completing three test runs at the location. One test run consisted of a particulate test using EPA Method 5 and the other two consisted of an EPA Method 12.

The location and number of sampling ports and traverse points are detailed in Figure 1.

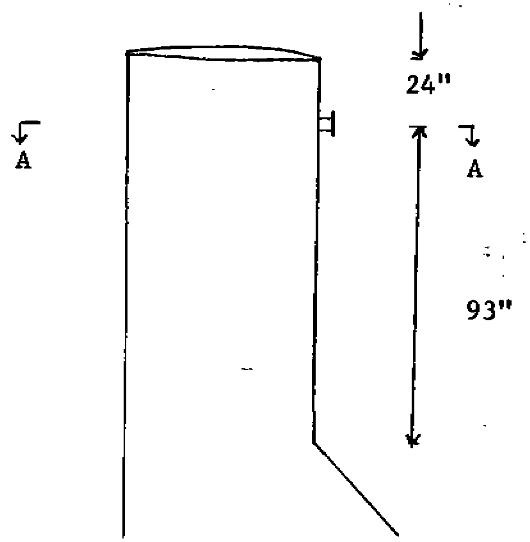
4. Operating Conditions

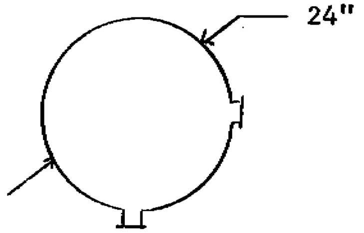
In the execution of this sampling program, an attempt was made to achieve near normal load for the plant. The amount of product generated was recorded by the operator. This record is included in the summary table (see Table 1).

5. Results

Test data developed by each test run, together with analytical results from laboratory analysis of samples generated by the field sampling program, are reproduced in the Appendices included with this report. Information on basic gas characteristics developed by each test run is contained in the printout of the computer program included as Appendix 7.

A summary of pertinent test results and essential information to evaluate test results developed for each test run is included with this report as Tables 1 and 2.





Section A-A

Point No.	Distance From Port, Inches
1	1.00
2	1.61
3	2.83
4	4.25
5	6.00
6	8.54
7	15.46
8	18.00
9	19.75
10	20.69
11	22.39
12	23.00

FIGURE 1

Summary of Test Port and Traverse Point Locations
MDC
Philadelphia Facility

SECTION III

APPENDICES

SECTION III - APPENDICES

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PROJECT PARTICIPANTS

APPENDIX I
PROJECT PARTICIPANTS

The following members of Gilbert/Commonwealth's staff participated in the planning and execution of this project and preparation of this report.

Field Sampling Crew:

Don Wary	Engineering Technician
Klaus Burger	Engineering Technician

Laboratory Participants:

Carl J. Wummer	Chemist
Vaughan O'Neill	Laboratory Technician

All field tests were completed with the assistance of technical personnel from MDC Industries and witnessed by the City of Philadelphia.

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.1 STANDARD EPA TEST METHODS

2.2 ACTUAL SAMPLING PROCEDURES/PARTICULATE

2.3 ANALYTICAL METHODS/PARTICULATE

2.4 ANALYTICAL METHODS/HEAVY METALS

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.1 STANDARD EPA TEST METHODS

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

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

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

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

2. *Procedure*

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

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

where L = length and W = width.

An alternative procedure is available for determining the acceptability of a measurement location not meeting the criteria above. This precedure, determination of gas flow angles at the sampling points and comparing the results with acceptability criteria, is described in Section 2.5.

[2.1 amended by 51 FR 20288, June 4, 1986]

2.2 Determining the Number of Traverse Points.

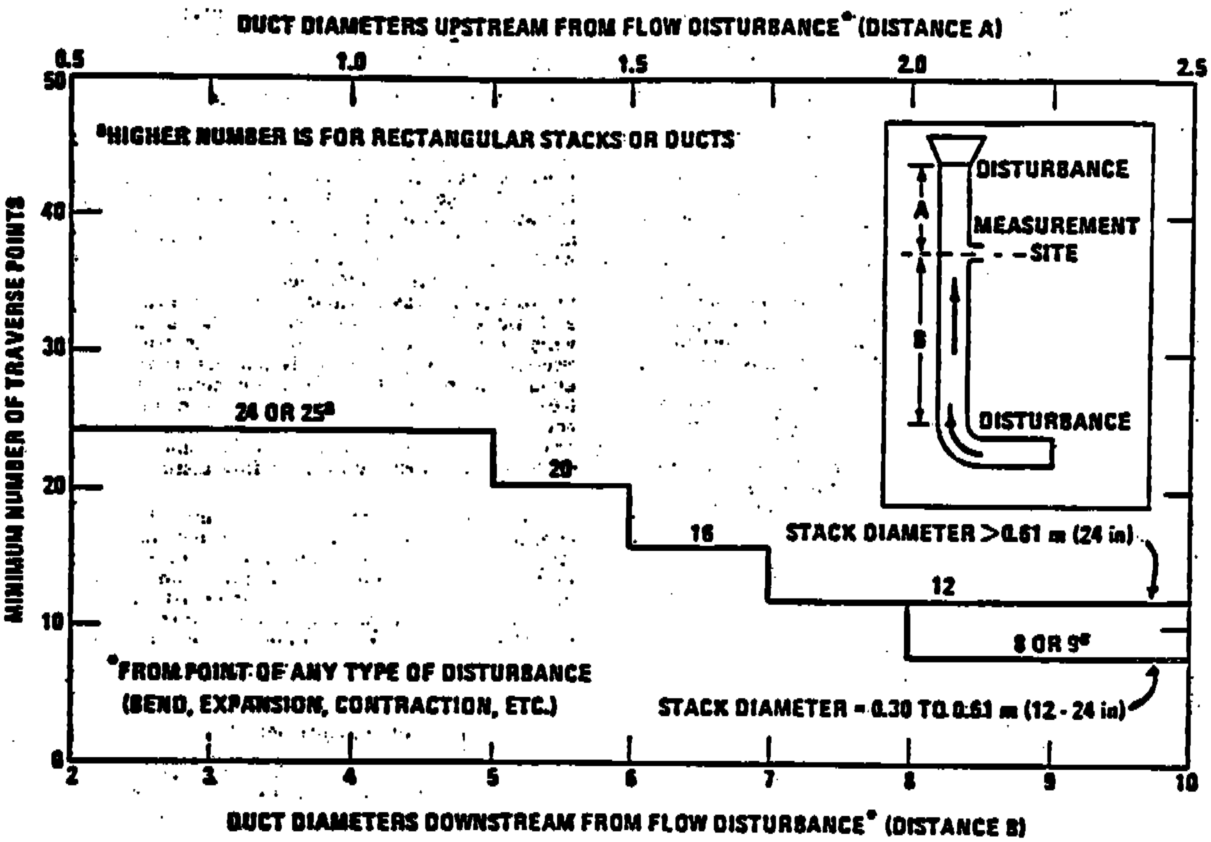

Figure 1-1. Minimum number of traverse points for particulate traverses.

[Method 1—Figure 1-1 revised by 52 FR 34639, September 14, 1987]

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

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

TABLE 1-1. CROSS-SECTION LAYOUT FOR RECTANGULAR STACKS

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

[Appendix A, Method 1]

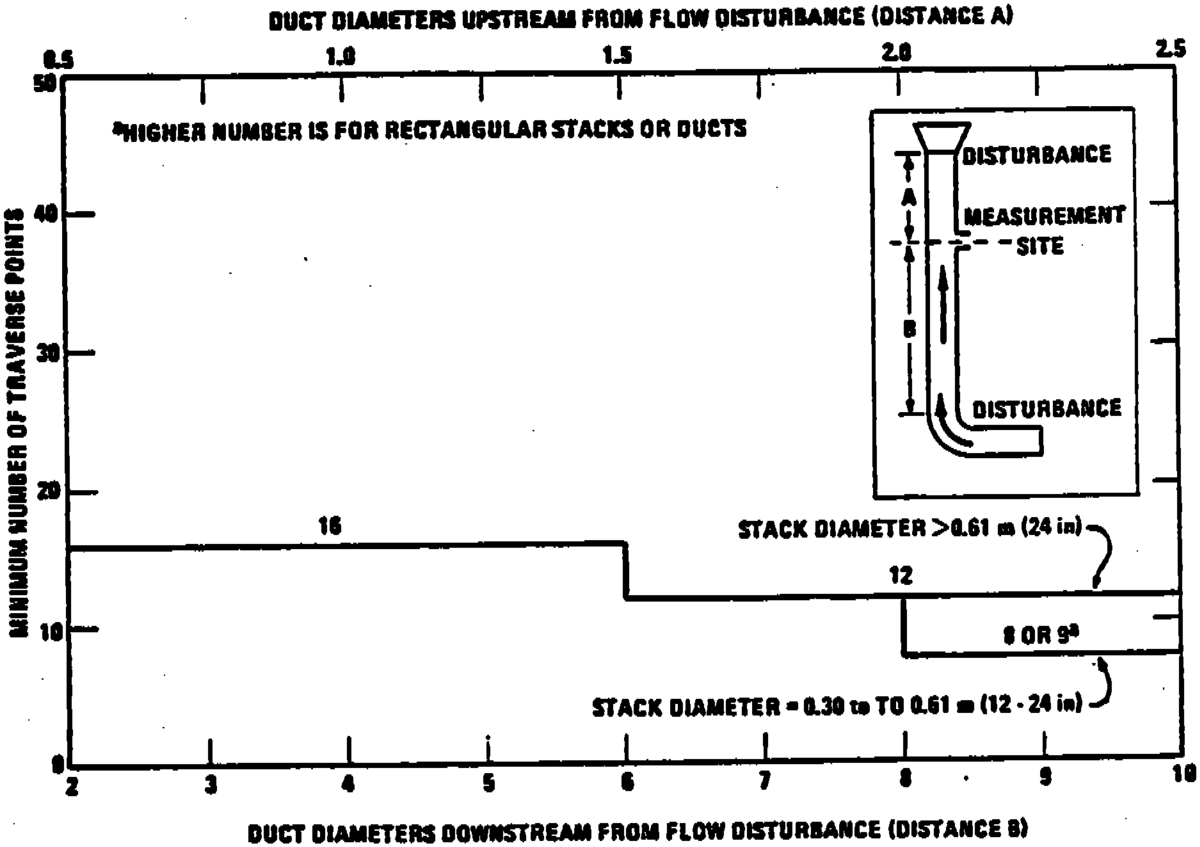

Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

[Method 1—Figure 1-2 revised by 52 FR 34639, September 14, 1987]

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

2.3 Cross-sectional Layout and Location of Traverse Points.

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

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

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

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

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

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.6
3	29.6
4	70.4
5	85.4
6	95.6

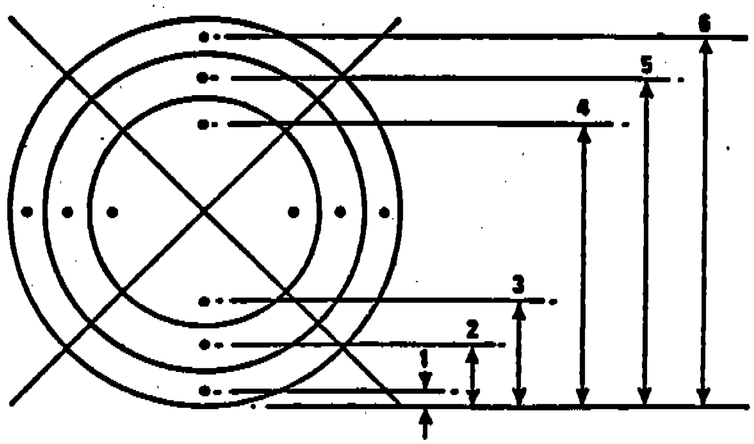

Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

[Method 1—Figure 1-3 revised by 52 FR 34639, September 14, 1987]

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 Stack 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 to the centroid of each equal area according to the example in Figure 1-4.

If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one or the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4×3 "minimum number of points" matrix were expanded to 36 points, the final matrix could be 9×4 or 12×3, and would not necessarily have to be 6×6. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

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

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

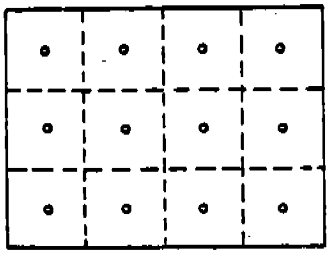

Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of α; assign α values of 0° to those points for which no rotation was required and include these in the overall average. If the average value of α is greater than 20°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

The alternative procedure described in Section 2.5 may be used to determine the rotation angles in lieu of the procedure described above.

[2.4 amended by 51 FR 20288, June 4, 1986; 52 FR 34639, September 14, 1987]

3. Bibliography

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14. Gerhart, P.M. and M.J. Dorsey. Investigation of Field Test Procedures for Large Fans. University of Akron, Akron, Ohio. (EPRI Contract CS-1651). Final Report (RP-1649-5) December 1980.

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

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

1. *Principle and Applicability*

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

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

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

2. *Apparatus*

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

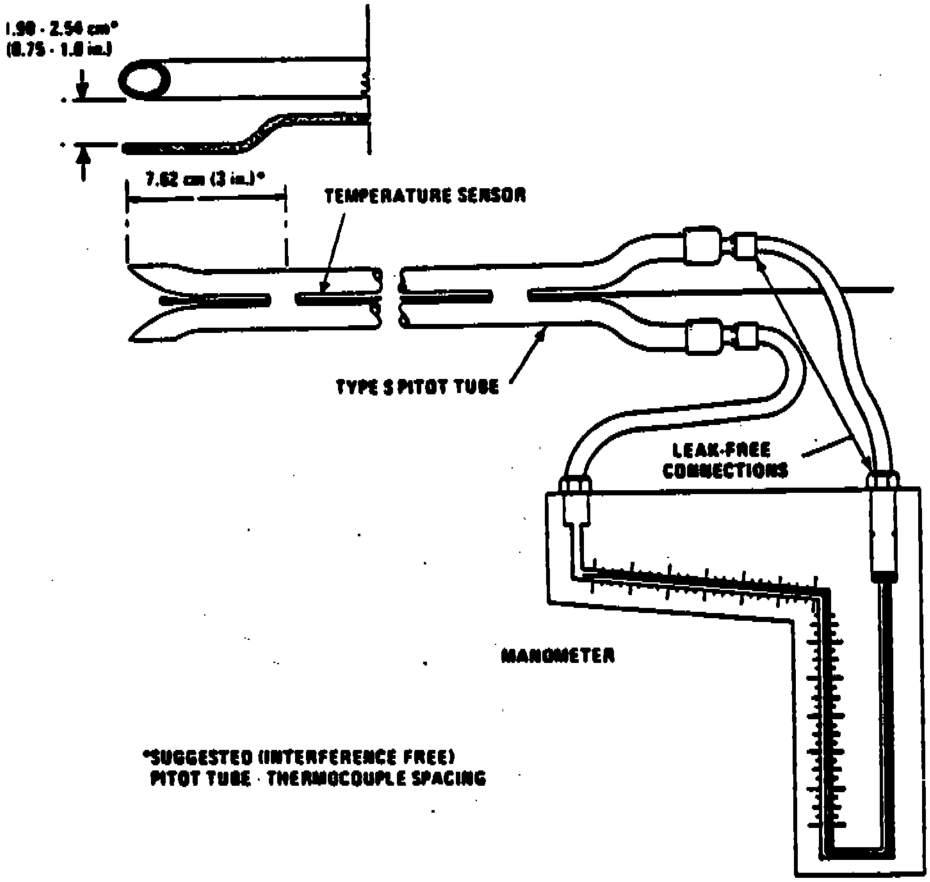


Figure 2-1. Type S pitot tube manometer assembly.

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

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

[Appendix A, Method 2]

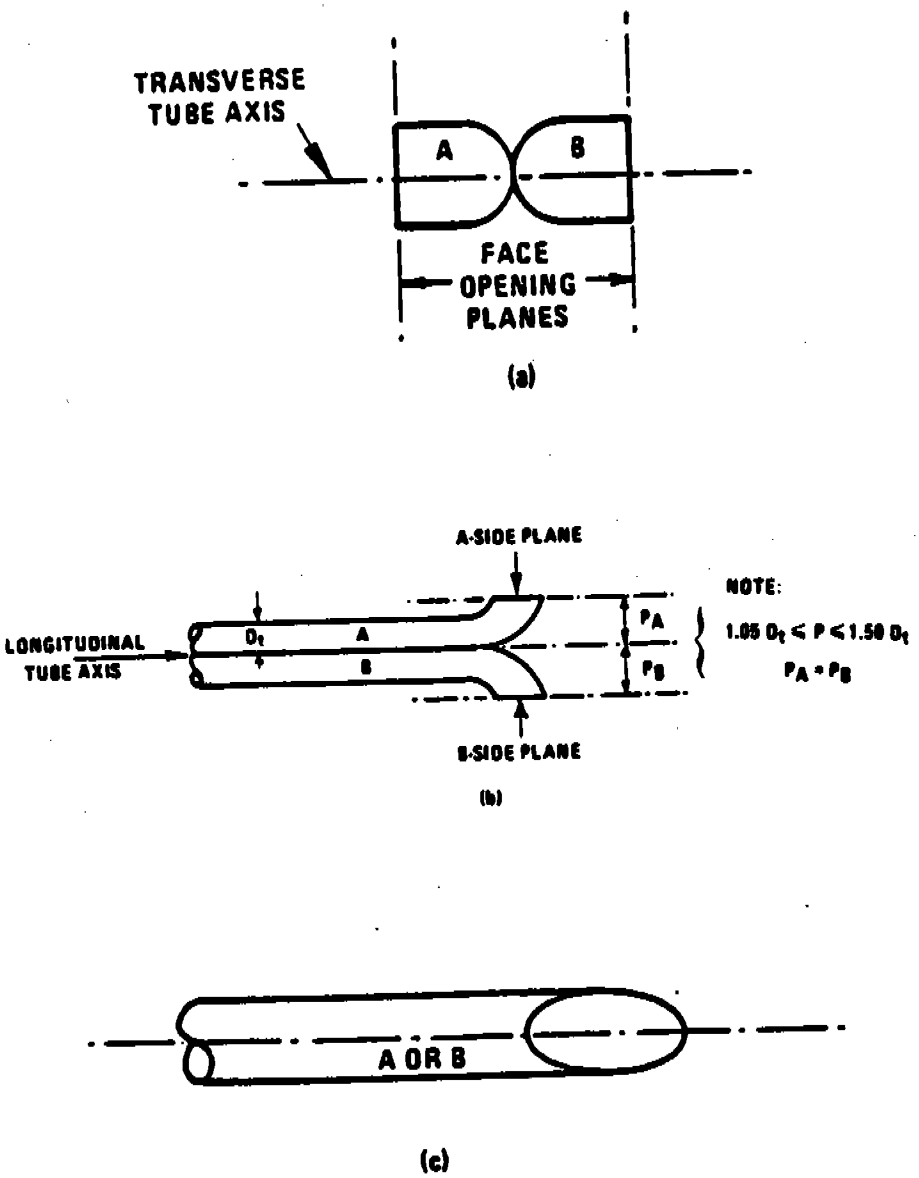


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline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

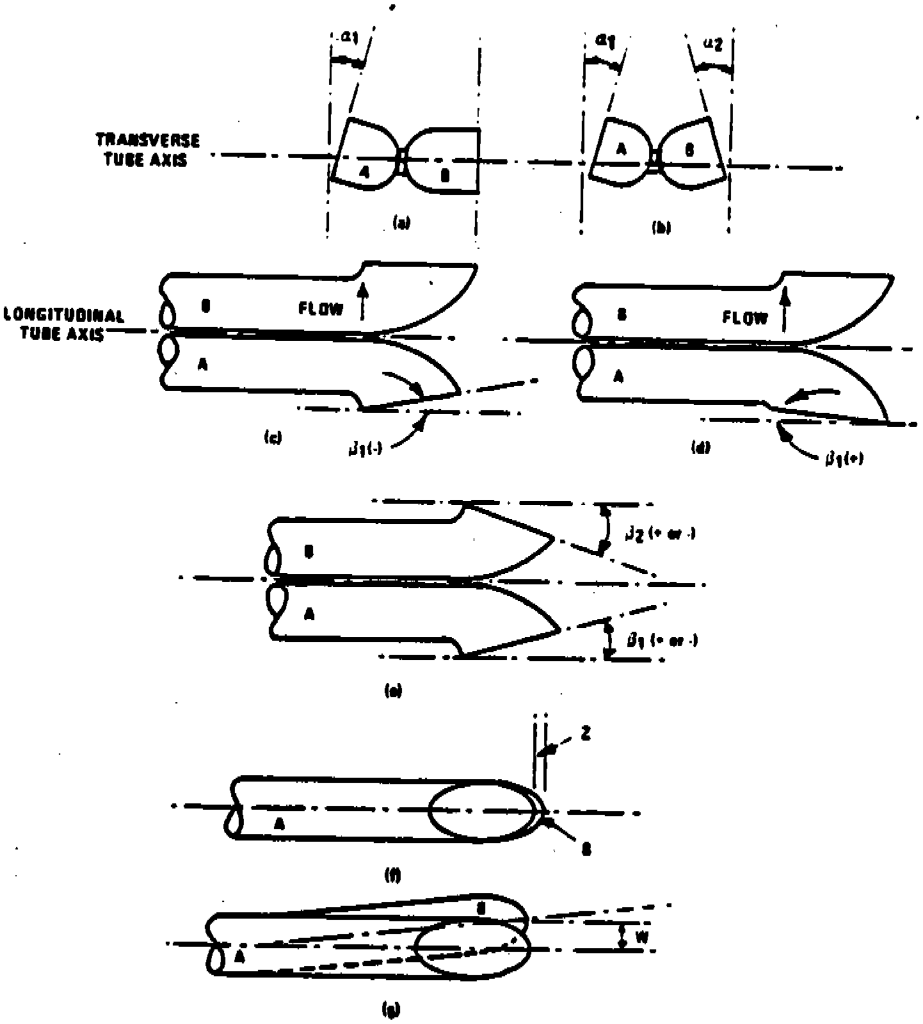


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as $\alpha 1$ and $\alpha 2$ 10°, $\beta 1$ and $\beta 2$ 5°, z 0.32 cm (1/8 in.) and w 0.08 cm (1/32 in.) (citation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

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.7 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not plugged up during the traverse period; this can be done by taking a velocity head (Δp) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another Δp reading. If the Δp readings made before and after the air purge are the same (±5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be taken, as above, for the last two back purges at which suitably high Δp readings are observed.

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

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

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

where:

Δp_i = Individual velocity head reading at a traverse point, mm H_2O (in. H_2O).
n = Total number of traverse points.
K = 0.13 mm H_2O when metric units are used and 0.005 in H_2O when English units are used.

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

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

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

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

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

[The second 2.5 was added by 51 FR 20288, June 4, 1986]

2.5 Alternative Measurement Site Selection Procedure. This alternative applies to sources where measurement locations are less than 2 equivalent stack or duct diameters downstream or less than ½ duct diameter upstream from a flow disturbance. The alternative should be limited to ducts larger than 24 in. in diameter where blockage and wall effects are minimal. A directional flow-sensing probe is used to measure pitch and yaw angles of the gas flow at 40 or more traverse points; the resultant angle is calculated and compared with acceptable criteria for mean and standard deviation.

Note.—Both the pitch and yaw angles are measured from a line passing through the traverse point and parallel to the stack axis. The pitch angle is the angle of the gas flow component in the plane that INCLUDES the traverse line and is parallel to the stack axis. The yaw angle is the angle of the gas flow component in the plane PERPENDICULAR to the traverse line at the traverse point and is measured from the line passing through the traverse point and parallel to the stack axis.

2.5.1 Apparatus.

2.5.1.1 Directional Probe. Any directional probe, such as United Sensor Type DA Three-Dimensional Directional Probe, capable of measuring both the pitch and yaw angles of gas flows is acceptable. (Note: Mention of trade name or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.) Assign an identification number to the directional probe, and permanently mark or engrave the number on the body of the probe. The pressure holes of directional probes are susceptible to plugging when used in particulate-laden gas streams. Therefore, a system for cleaning the pressure holes by "back-purging" with pressurized air is required.

2.5.1.2 Differential Pressure Gauges. Inclined manometers, U-tube manometers, or other differential pressure gauges (e.g., magnehelic gauges) that meet the specifications described in Method 2, § 2.2.

Note.—If the differential pressure gauge produces both negative and positive readings, then both negative and positive pressure readings shall be calibrated at a minimum of three points as specified in Method 2, § 2.2.

2.5.2 Traverse Points. Use a minimum of 40 traverse points for circular ducts and 42 points for rectangular ducts for the gas flow angle determinations. Follow § 2.3 and Table 1-1 or 1-2 for the location and layout of the traverse points. If the measurement location is determined to be acceptable according to the criteria in this alternative procedure, use the same traverse point number and locations for sampling and velocity measurements.

2.5.3 Measurement Procedure.

2.5.3.1 Prepare the directional probe and differential pressure gauges as recommended by the manufacturer. Capillary tubing or surge tanks may be used to dampen pressure fluctuations. It is recommended, but not required, that a pretest leak check be conducted. To perform a leak check, pressurize or use suction on the impact opening until a reading of at least 7.6-cm (3 in.) H_2O registers on the differential pressure gauge, then plug the impact opening. The pressure of a leak-free system will remain stable for at least 15 seconds.

2.5.3.2 Level and zero the manometers. Since the manometer level and zero may drift because of vibrations and temperature changes, periodically check the level and zero during the traverse.

2.5.3.3 Position the probe at the appropriate locations in the gas stream, and rotate until zero deflection is indicated for the yaw angle pressure gauge. Determine and record the yaw angle. Record the pressure gauge readings for the pitch angle, and determine the pitch angle from the calibration curve. Repeat this procedure for each traverse point. Complete a "back-purge" of the pressure lines and the impact openings prior to measurements of each traverse point.

A post-test check as described in § 2.5.3.1 is required. If the criteria for a leak-free system are not met, repair the equipment, and repeat the flow angle measurements.

2.5.4 Calculate the resultant angle at each traverse point, the average resultant angle, and the standard deviation using the following equations. Complete the calculations retaining at least one extra significant figure beyond that of the acquired data. Round the values after the final calculations.

2.5.4.1 Calculate the resultant angle at each traverse point:

$$R_i = \text{arc cosine}\ [(\text{cosine}\ Y_i)(\text{cosine}\ P_i)] \qquad \text{Eq. 1-2}$$

Where:

R_i = Resultant angle at traverse point i, degree.

Y_i = Yaw angle at traverse point i, degree.

P_i = Pitch angle at traverse point i, degree.

2.5.4.2 Calculate the average resultant for the measurements:

$$\bar{R} = \frac{\Sigma R_i}{n} \qquad \text{Eq. 1-3}$$

where:

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

n = Total number of traverse points.

[2.5.4.2 corrected by 51 FR 29104, August 14, 1986]

2.5.4.3 Calculate the standard deviations:

$$S_d \sqrt{\frac{\sum_{i=1}^{n} (R_i - \bar{R})^2}{(n-1)}} \qquad \text{Eq. 1-4}$$

[2.5.4.3, Eq. 1-4 corrected by 51 FR 29104, August 14, 1986]

Where:

S_d = Standard deviation, degree.

2.5.5 The measurement location is acceptable if $\bar{R} \leq 20°$ and $S_d \leq 10°$.

2.5.6 Calibration. Use a flow system as described in Sections 4.1.2.1 and 4.1.2.2 of Method 2. In addition, the flow system shall have the capacity to generate two test-section velocities: one between 365 and 730 m/min (1200 and 2400 ft/min) and one between 730 and 1100 m/min (2400 and 3600 ft/min).

2.5.6.1 Cut two entry ports in the test section. The axes through the entry ports shall be perpendicular to each other and intersect in the centroid of the test section. The ports should be elongated slots parallel to the axis of the test section and of sufficient length to allow measurement of pitch angles while maintaining the pitot head position at the test-section centroid. To facilitate alignment of the directional probe during calibration, the test section should be constructed of plexiglass of some other transparent material. All calibration measurements should be made at the same point in the test section, preferably at the centroid of the test-section.

2.5.6.2 To ensure that the gas flow is parallel to the central axis of the test section, follow the procedure in Section 2.4 for cyclonic flow determination to measure the gas flow angles at the centroid of the test section from two test ports located at 90° apart. The gas flow angle measured in each port must be ±2° of 0°. Straightening vanes should be installed, if necessary, to meet this criterion.

2.5.6.3 Pitch Angle Calibration. Perform a calibration traverse according to the manufacturer's recommended protocol in 5° increments for angles from −60° to +60° at one velocity in each of the two ranges specified above. Average the pressure ratio values obtained for each angle in the two flow ranges, and plot a calibration curve with the average values of the pressure ratio (or other suitable measurement factor as recommended by the manufacturer) versus the pitch angle. Draw a smooth line through the data points. Plot also the data values for each traverse point. Determine the differences between the measured data values and the angle from the calibration curve at the same pressure ratio. The difference at each comparison must be within 2° for angles between 0° and 40° and within 3° for angles between 40° and 60°.

2.5.6.4 Yaw Angle Calibration. Mark the three-dimensional probe to allow the determination of the yaw position of the probe. This is usually a line extending the length of the probe and aligned with the impact opening. To determine the accuracy of measurements of the yaw angle, only the zero or null position need be calibrated as follows. Place the directional probe in the test section, and rotate the probe until the zero position is found. With a protractor or other angle measuring device, measure the angle indicated by the yaw angle indicator on the three-demensional probe. This should be within 2° of 0°. Repeat this measurement for any other points along the length of the pitot where yaw angle measurements could be read in order to account for variations in the pitot markings used to indicate pitot head positions.

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

2.7 Calibration Pitot Tube. When calibration of the Type S pitot tube is necessary (see Section 4), a standard pitot tube is used as a reference. The standard pitot tube shall, preferably, have a known coefficient, obtained either (1) directly from the National Bureau of Standards, Route 270, Quince Orchard Road, Gaithersburg, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot tube designed according to the criteria given in 2.7.1 through 2.7.5 below and illustrated in Figure 2-4 (see also Citations 7, 8, and 17 in Section 6) may be used. Pitot tubes designed according to these specifications will have baseline coefficients of about 0.99±0.01.

2.7.1 Hemispherical (shown in Figure 2-4), ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon *D*, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, following the 90 degree bend.

2.7.4 Static pressure holes of equal size (approximately 0.1 *D*), equally spaced in a piezometer ring configuration.

2.7.5 Ninety degree bend, with curved or mitered junction.

2.8 Differential Pressure Gauge for Type S Pitot Tube Calibration. An inclined manometer or equivalent is used. If the single-velocity calibration technique is employed (see Section 4.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O). For multivelocity calibrations, the gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in H_2O) for Δp values between 1.3 and 25 mm H_2O (0.05 and 1.0 in. H_2O), and to the nearest 1.3 mm H_2O (0.05 in. H_2O) for Δp values above 25 mm H_2O (1.0 in. H_2O). A special, more sensitive gauge will be required to read Δp values below 1.3 mm H_2O [0.05 in. H_2O] (see Citation 18 in Section 6).

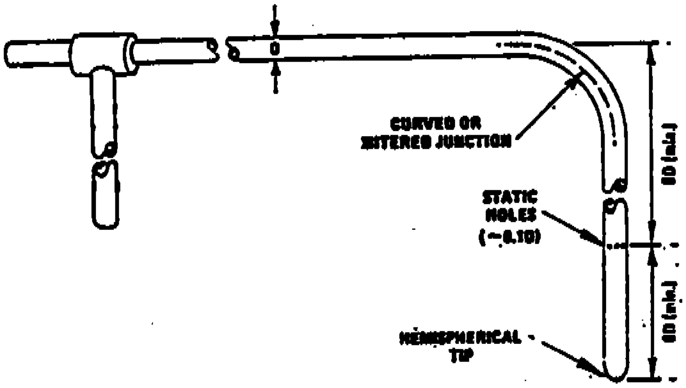


Figure 2-4. Standard pitot tube design specifications.

3. Procedure

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

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

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

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

3.5 Determine the atmospheric pressure.

PLANT ____________________
DATE ____________________ RUN NO. ____________________
STACK DIAMETER OR DIMENSIONS, m(in.) ____________________
BAROMETRIC PRESSURE, mm Hg (in. Hg) ____________________
CROSS SECTIONAL AREA, $m^2(ft^2)$ ____________________
OPERATORS ____________________
PITOT TUBE I.D. NO. ____________________
AVG. COEFFICIENT, C_p = ____________________
LAST DATE CALIBRATED ____________________

SCHEMATIC OF STACK CROSS SECTION

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

Figure 2-5. Velocity traverse data.

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

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

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

4. *Calibration*

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

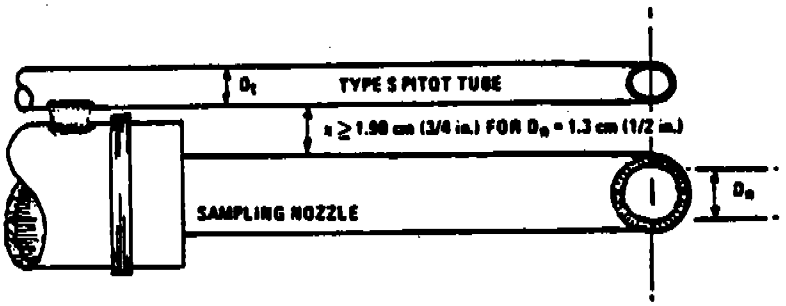
After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8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

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

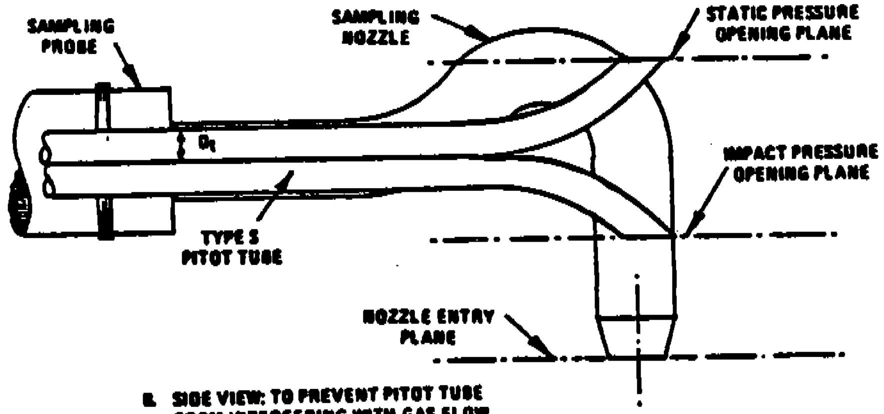
4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of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

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

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



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 2-6 amended by 52 FR 34639, September 14, 1987]

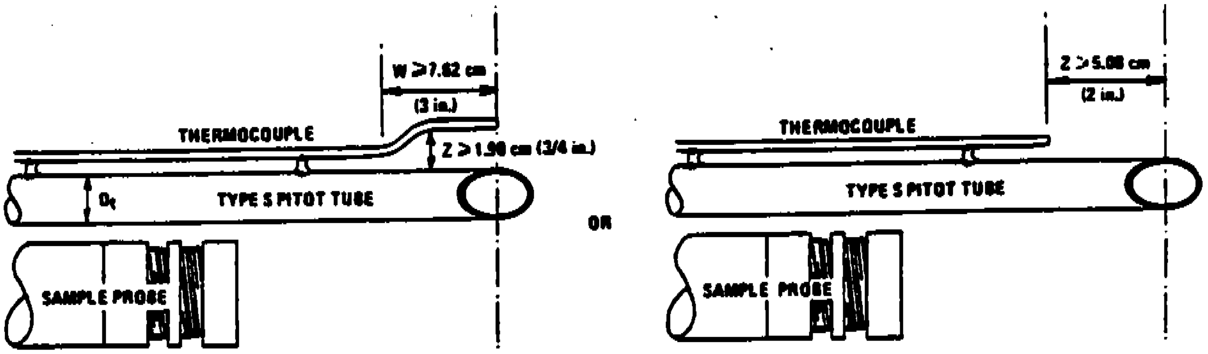


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

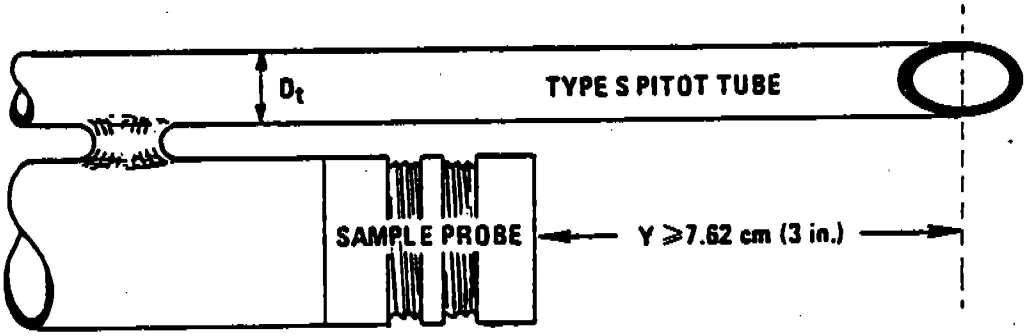


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

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

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

$$D = \frac{2LW}{(L+W)}$$ Equation 2-1

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

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

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

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min (1,000 ft/min) and to within ±5 to 6 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min). If a more precise correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 and 14 in Section 6 for details).

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

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

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

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

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

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

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

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

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

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

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

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

PITOT TUBE IDENTIFICATION NUMBER: ______________ **DATE:** __________

CALIBRATED BY: ______________________________

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

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

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

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

Figure 2-9. Pitot tube calibration data.

[Appendix A, Method 2]

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

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 H₂O (in. H₂O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H₂O (in H₂O)

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

[4.1.4.2 amended by 52 FR 34639, September 14, 1987]

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

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

Equation 2-3

[4.1.4.3 amended by 52 FR 34639, September 14, 1987]

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

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

Equation 2-4

[4.1.4.4 amended by 52 FR 34639, September 14, 1987]

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 $\overline{C}_p$ (A) and $\overline{C}_p$ (B) is 0.01 or less.

[4.1.4.5 amended by 52 FR 34639, September 14, 1987]

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., $\overline{C}_p$ (side A) and $\overline{C}_p$ (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).

[4.1.5.1.1 amended by 52 FR 34639, September 14, 1987]

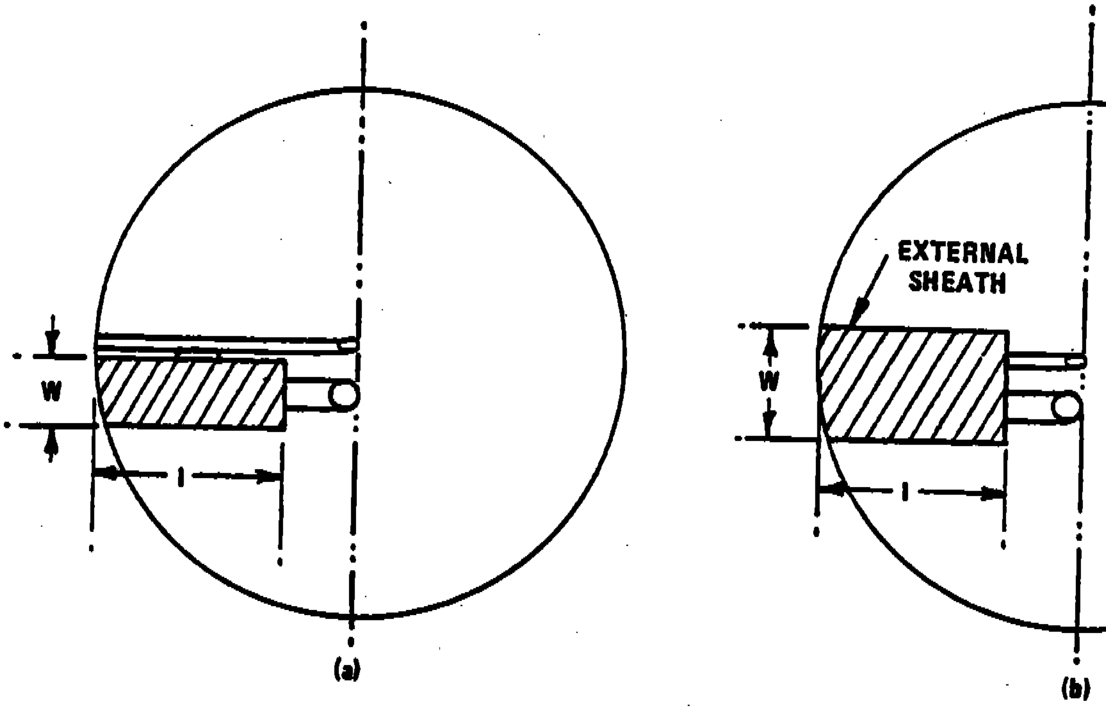
4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination 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).

[4.1.5.3 amended by 52 FR 34639, September 14, 1987]



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

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

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

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

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $C_{p(s)}$. Consult Citation 9 in Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Section 6).

4.1.6.2 Recalibration.

4.1.6.2.1 Isolated Pitot Tubes. After each field use, the pitot tube shall be carefully reexamined in top, side, and end views. If the pitot face openings are still aligned within the specifications illustrated in Figure 2-2 or 2-3, it can be assumed that the baseline coefficient of the pitot tube has not changed. If, however, the tube has been 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).

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

Eq. 2-5

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

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

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

$= P_{bar} + P_g$

Equation 2-6

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

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

t_s = Stack temperature, °C (°F).

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

$= 273 + t_s$ for metric

Equation 2-7

$= 460 + t_s$ for English

Equation 2-8

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

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

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

3,600 = Conversion factor, sec/hr.

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

5.2 Average stack gas velocity.

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

Equation 2-9

5.3 Average stack gas dry volumetric flow rate.

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

Equation 2-10

To convert Q_{sd} from dscm/hr (dscf/hr) to dscm/min (dscf/min), divide Q_{sd} by 60.

[5.3 amended by 52 FR 34639, September 14, 1987]

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

1. *Applicability and Principle.*

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

1.2 Principle. A gas volume meter is used to measure gas volume directly. Temperature and pressure measurements are made to correct the volume to standard conditions.

2. *Apparatus.*

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

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

[2.1 amended by 52 FR 34639, September 14, 1987]

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

2.3 Stopwatch. Capable of measurement to within 1 second.

3. *Procedure.*

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

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

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

3.3 Volume Measurement.

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

Plant ____________________

Date ____________________ Run Number ____________________

Sample Location ____________________

Barometric Pressure mm Hg Start ______ Finish ______

Operators ____________________

Meter Number ____________________ Meter Calibration Coefficient ______

Last Date Calibrated ____________

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

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

[Appendix A, Method 2A]

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

4. *Calibration.*

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

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

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

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

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

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

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

Eq. 2A-1

Where:

Y_m=Test volume meter calibration coefficient, dimensionless.

V_r=Reference meter volume reading, m³.

V_m=Test meter volume reading, m³.

t_r=Reference meter average temperature, °C.

t_m=Test meter average temperature, °C.

P_b=Barometric pressure, mm Hg.

P_g=Test meter average static pressure, mm Hg.

f=Final reading for run.

i=Initial reading for run.

Compare the three Y_m values at each of the flow rates tested and determine the maximum and minimum values. The difference between the maximum and minimum values at each flow rate should be no greater than 0.030. Extra runs may be required to complete this requirement. If this specification cannot be met in six successive runs, the test meter it not suitable for use. In addition, the meter coefficients should be between 0.95 and 1.05. If these specifications are met at all the flow rates, average all the Y_m values from runs meeting the specifications to obtain an average meter calibration coefficient, Y_m.

The procedure above shall be performed at least once for each volume meter. Thereafter, an abbreviated calibration check shall be completed following each field test. The calibration of the volume meter shall be checked by performing three calibration runs at a single, intermediate flow rate (based on the previous field test) with the meter pressure set at the average value encountered in the field test. Calculate the average value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the full range of flow as described above.

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

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

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

5. *Calculations.*

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

5.1 Nomenclature

P_b=Barometric pressure, mm Hg.

P_g=Average static pressure in volume meter, mm Hg.

Q_s=Gas flow rate, m³/min, standard conditions.

T_m=Average absolute meter temperature, °K.

V_m=Meter volume reading, m³.

Y_m=Average meter calibration coefficient, dimensionless.

f=Final reading for test period.

i=Initial reading for test period.

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

Θ=Elapsed test period time, min.

5.2 Volume.

$$V_{ms} = 0.3853\ Y_m\ (V_{mf}-V_{mi}) \frac{(P_b+P_g)}{T_m}$$

Eq. 2A-2

5.3 Gas Flow Rate.

$$Q_s = \frac{V_{ms}}{\Theta}$$

Eq. 2A-3

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METHOD 2B—DETERMINATION OF EXHAUST GAS VOLUME FLOW RATE FROM GASOLINE VAPOR INCINERATORS

1. *Applicability and principle*

1.1 Applicability. This method applies to the measurement of exhaust volume flow rate from incinerators that process gasoline vapors consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons). It is assumed that the amount of auxiliary fuel is negligible.

1.2 Principle. The incinerator exhaust flow rate is determined by carbon balance. Organic carbon concentration and volume flow rate are measured at the incinerator inlet. Organic carbon, carbon dioxide (CO_2), and carbon monoxide (CO) concentrations are measured at the outlet. Then the ratio of total carbon at the incinerator inlet and outlet is multiplied by the inlet volume to determine the exhaust volume and volume flow rate.

2. *Apparatus.*

2.1 Volume Meter. Equipment described in Method 2A.

2.2 Organic Analyzers (2). Equipment described in Method 25A or 25B.

2.3 CO Analyzer. Equipment described in Method 10.

2.4 CO_2 Analyzer. A nondispersive infrared (NDIR) CO_2 analyzer and supporting equipment with comparable specifications as CO analyzer described in Method 10.

3. *Procedure.*

3.1 Inlet Installation. Install a volume meter in the vapor line to incinerator inlet according to the procedure in Method 2A. At the volume meter inlet, install a sample probe as described in Method 25A. Connect to the probe a leak-tight, heated (if necessary to prevent condensation) sample line (stainless steel or equivalent) and an organic analyzer system as described in Method 25A or 25B.

3.2 Exhaust Installation. Three sample analyzers are required for the incinerator exhaust: CO_2, CO, and organic analyzers. A sample manifold with a single sample probe may be used. Install a sample probe as described Method 25A. Connect a leak-tight heated sample line to the sample probe. Heat the sample line sufficiently to prevent any condensation.

3.3 Recording Requirements. The output of each analyzer must be permanently recorded on an analog strip chart, digital recorder, or other recording device. The chart speed or number of readings per time unit must be similar for all analyzers so that data can be correlated. The minimum data recording requirement for each analyzer is one measurement value per minute.

3.4 Preparation. Prepare and calibrate all equipment and analyzers according to the procedures in the respective methods. For the CO_2 analyzer, follow the procedures described in Method 10 for CO analysis substituting CO_2 calibration gas where the method calls for CO calibration gas. The span value for the CO_2 analyzer shall be 15 percent by volume. All calibration gases must be introduced at the connection between the probe and the sample line. If a manifold system is used for the exhaust analyzers, all the analyzers and sample pumps must be operating when the calibrations are done. Note: For the purposes of this test, methane should not be used as an organic calibration gas.

3.5 Sampling. At the beginning of the test period, record the initial parameters for the inlet volume meter according to the procedures in Method 2A and mark all of the recorder strip charts to indicate the start of the test. Continue recording inlet organic and exhaust CO_2, CO, and organic concentrations throughout the test. During periods of process interruption and halting of gas flow, stop the timer and mark the recorder strip charts so that data from this interruption are not included in the calculations. At the end of the test period, record the final parameters for the inlet volume meter and mark the end on all of the recorder strip charts.

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

4. *Calculations.*

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

4.1 Nomenclature.

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

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

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

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

K = Calibration gas factor
= 2 for ethane calibration gas.
= 3 for propane calibration gas.
= 4 for butane calibration gas.
= Appropriate response factor for other calibration gas.

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

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

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

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

Θ = Sample run time, min.

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

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

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

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

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

Eq. 2B-1

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

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

Eq. 2B-2

[4.4 Eq. 2 B-2 amended by 52 FR 34639, September 14, 1987]

5. *Bibliography.*

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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. U.S. Environmental Protection Agency

2. *Apparatus*

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

2.1 Grab Sampling (Figure 3-1).

2.1.1 Probe. The probe should be made of stainless steel or borosilicate glass tubing and should be equipped with an in-stack or out-stack filter to remove particulate matter (a plug of glass wool is satisfactory for this purpose). Any other 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.

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

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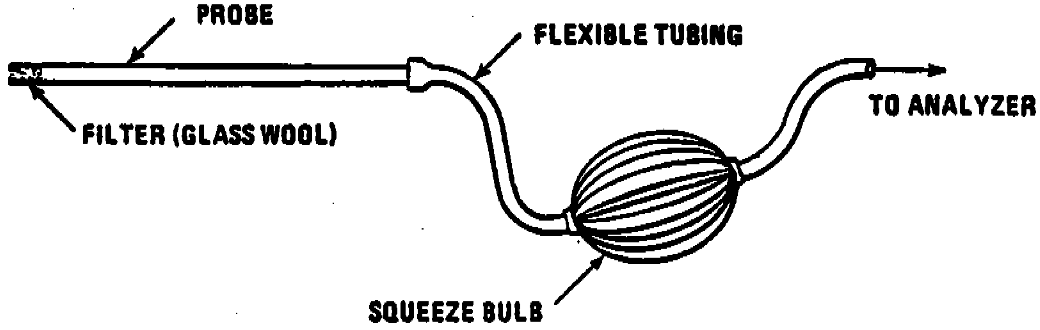

Figure 3-1. Grab-sampling train.

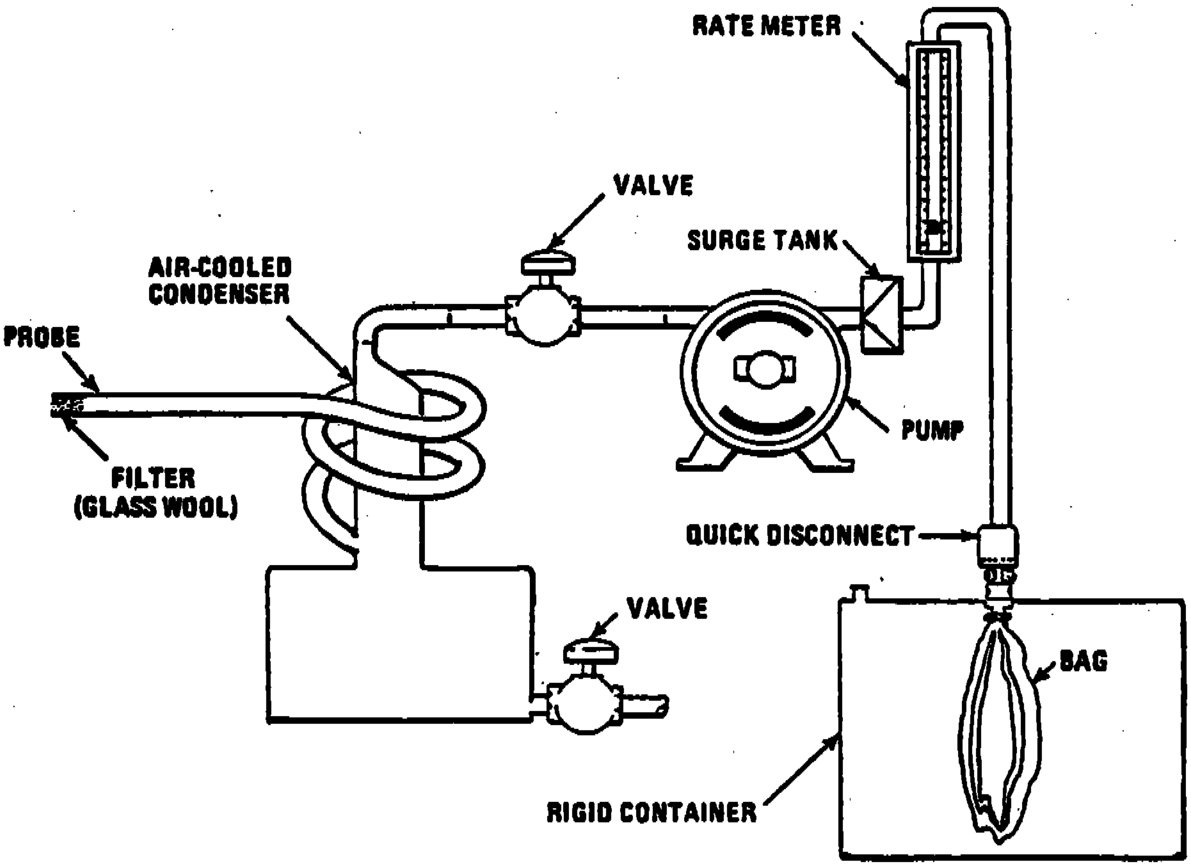

Figure 3.2. Integrated gas-sampling train.

[Appendix A, Method 3]

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

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

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

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

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

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

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 30 cm (12 in.) is used for the flexible bag leak-check.

[2.2.7 amended by 52 FR 34639, September 14, 1987]

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 that 15.0 percent) concentrations, the measuring burette of the Orsat must have at least 0.1 percent subdivisions.

3. *Dry Molecular Weight Determination*

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

3.1 Single-Point, Grab Sampling and Analytical Procedure.

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

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

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

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

3.2 Single-Point, Integrated Sampling and Analytical Procedure.

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

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

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

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

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

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

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

3.3.2 Follow the procedures outlined in sections 3.2.2 throught 3.2.5, except for the following: traverse all sampling points and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3.

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

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

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

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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		

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

[Figure 3-3 footnote amended by 52 FR 34639, September 14, 1987]

4.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer. For emission rate correction factor determination, immediately analyze the sample, as outlined in Sections 4.1.4 and 4.1.5, for percent CO_2 or percent O_2. If excess air is desired, proceed as follows: (1) immediately analyze the sample, as in Sections 4.1.4 and 4.1.5, for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air as outlined in Section 6.2.

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

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

NOTE: Since this single-point, grab sampling and analytical procedure in normally conducted in conjunction with a single-point, grab sampling and analytical procedure for a pollutant, only one analysis is ordinarily conducted. Therefore, great care must be taken to obtain a valid sample and analysis. Although in most cases only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 4.4 be used to validate the analytical data.

[4.1.5 Note amended by 48 FR 49459, October 25, 1983]

4.2 Single-Point, Integrated Sampling and Analytical Procedure.

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

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

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

4.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. For emission rate correction factor determination, analyze the sample within 4 hours after it is taken for percent CO_2 or percent O_2 (as outlined in Sections 4.2.5 through 4.2.7). The Orsat analyzer must be leak-check (see Section 5) before the analysis. If excess air is desired, proceed as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 4.2.5 through 4.2.7) for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; (3) calculate percent excess air, as outlined in Section 6.2.

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

4.2.6 Repeat the analysis until the following criteria are met:

4.2.6.1 For percent CO_2, repeat the analytical procedure until the results of any three analyses differ by no more that (a) 0.3 percent by volume when CO_2 is greater than 4.0 percent or (b) 0.2 percent by volume when CO_2 is less than or equal to 4.0 percent. Average the three acceptable values of percent CO_2 and report the results to the nearest 0.1 percent.

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

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

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

NOTE: Although in most instances only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 4.4.1 to be used to validate the analytical data.

[4.2.7 Note amended by 48 FR 49459, October 25, 1983; 52 FR 34639, September 14, 1987]

4.3 Multi-Point, Integrated Sampling and Analytical Procedure.

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

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

[Section 4.4 added by 48 FR 49459, October 25, 1983]

4.4 Quality Control Procedures.

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

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

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

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

Where:

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

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

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

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

Where:

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

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

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

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

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

5. *Leak-Check Procedure for Orsat Analyzers*

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

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

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

5.1.3 Record the meniscus position.

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

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

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

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

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

6. *Calculations*

6.1 Nomenclature.

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

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

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

Equation 3-1

[6.2 Eq. 3-1 amended by 52 FR 34639, September 14, 1987]

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

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

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

Equation 3-2

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

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METHOD 3A—DETERMINATION OF OXYGEN AND CARBON DIOXIDE CONCENTRATIONS IN EMISSIONS FROM STATIONARY SOURCES (INSTRUMENTAL ANALYZER PROCEDURE)

[Method 3A added by 51 FR 21165, June 11, 1986]

1. *Applicability and Principle*

1.1 Applicability. This method is applicable to the determination of oxygen (O_2) and carbon dioxide (CO_2) concentrations in emissions from stationary sources only when specified within the regulations.

1.2 Principle. A sample is continuously extracted from the effluent stream: a portion of the sample stream is conveyed to an instrumental analyzer(s) for determination of O_2 and CO_2 concentration(s). Performance specifications and test procedures are provided to ensure reliable data.

2. *Range and Sensitivity*

Same as Method 6C, Sections 2.1 and 2.2, except that the span of the monitoring system shall be selected such that the average O_2 or CO_2 concentration is not less than 20 percent of the span.

3. *Definitions*

3.1 Measurement System. The total equipment required for the determination of the O_2 or CO_2 concentration. The measurement system consists of the same major subsystems as defined in Method 6C, Sections 3.1.1, 3.1.2, and 3.1.3.

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

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

4. *Measurement System Performance Specifications*

Same as Method 6C, Sections 4.1 through 4.4.

5. *Apparatus and Reagents*

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

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

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

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

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

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

6. *Measurement System Performance Test Procedures*

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

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

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

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

7. *Emission Test Procedure*

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

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

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

8. *Quality Control Procedures*

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

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

8.2 If only O_2 is measured using Method 3A, measurements of the sample stream CO_2 concentration should be obtained at the sample by-pass vent discharge using an Orsat or Fyrite analyzer, or equivalent. Duplicate samples should be obtained concurrent with at least one run. Average the duplicate Orsat or Fyrite analysis results for each run. Use the average CO_2 values for comparison with the O_2 measurements in accordance with the procedures described in Section 4.4 of Method 3.

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

9. *Emission Calculation*

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

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

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

Eq. 3A-1

Where:

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

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

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

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

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

C=Average gas concentration indicated by the gas analyzer, dry basis, percent.

10. *Bibliography*

Same as bibliography of Method 6C.

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.

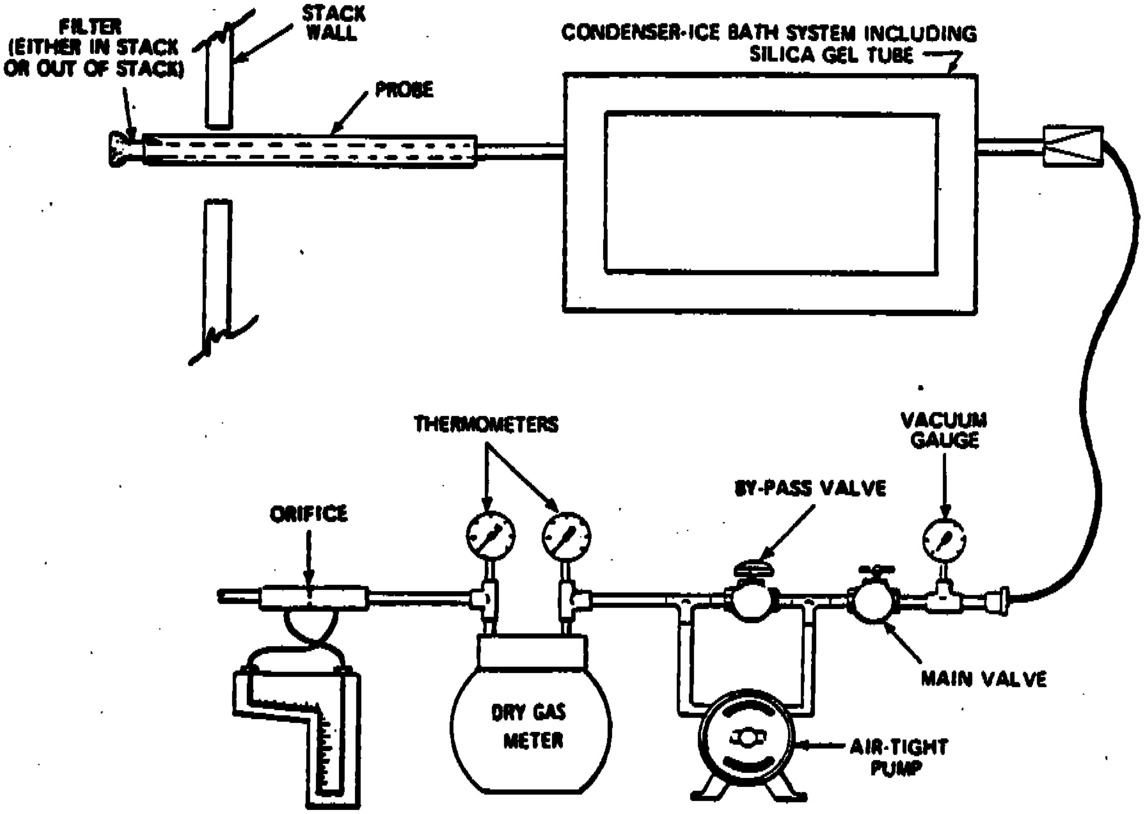

Figure 4-1. Moisture sampling train-reference method.

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 particular matter.

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

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

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

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

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

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

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

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

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

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

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

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.60 scm (21 scf) will be collected, at a rate no greater than 0.021 m^3/min (0.75 cfm). When both moisture content and pollutant emission rate are to be determined, the moisture determination shall be simultaneous with, and for the same total length of time as, the pollutant emission rate run, unless otherwise specified in an applicable subpart of the standards.

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or (if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

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

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

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

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

[2.2.7 added by 48 FR 55671, December 14, 1983]

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.

[Appendix A, Method 4]

	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) (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_m = Dry gas volume measured by dry gas meter, dcm (dcf).
ΔV_m = Incremental dry gas volume measured by dry gas meter at each traverse point, dcm (dcf).
$V_{m(std)}$ = Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{wc(std)}$ = Volume of water vapor condensed corrected to standard conditions, scm (scf).
$V_{wsg(std)}$ = Volume of water vapor collected in silica gel corrected to standard conditions, scm (scf).
V_f = Final volume of condenser water, ml.
V_i = Initial volume, if any, of condenser water, ml.
W_f = Final weight of silica gel or silica gel plus impinger, g.
W_i = Initial weight of silica gel or silica gel plus impinger, g.
Y = Dry gas meter calibration factor.
ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

2.3.2 Volume of water vapor condensed.

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

Equation 4-1

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

2.3.3 Volume of water vapor collected in silica gel.

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

Equation 4-2

where:
K_2 = 0.001335 m³/g for metric units
= 0.04715 ft³/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 lead rate (Section 2.2.6) exceeds the allowable rate, correct the value of V_m in Equation 4-3, as described in Section 6.3 of Method 5.

2.3.5 Moisture Content.

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

Equation 4-4

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

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

3. *Approximation Method*

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

3.1 Apparatus.

3.1.1 Probe. Stainless steel 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 lpm (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.

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

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

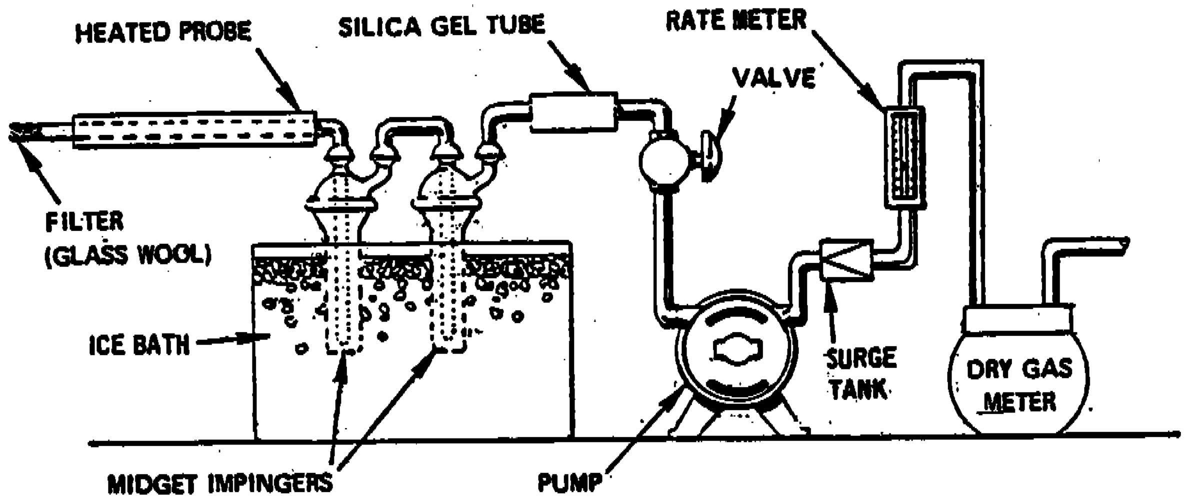

Figure 4-4. Moisture-sampling train - approximation method.

LOCATION ____________________ **COMMENTS**

TEST ____________________

DATE ____________________

OPERATOR ____________________

BAROMETRIC PRESSURE ____________________

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

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

[Appendix A, Method 4]

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

B_{ws} = 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).

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

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

Y = Dry gas meter calibration factor.

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.

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

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

Equation 4-7

4. *Calibration*

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

5. *Bibliography*

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 Administrator, U.S. Environmental Protection Agency, for a particular application. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

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

2. *Apparatus*

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

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

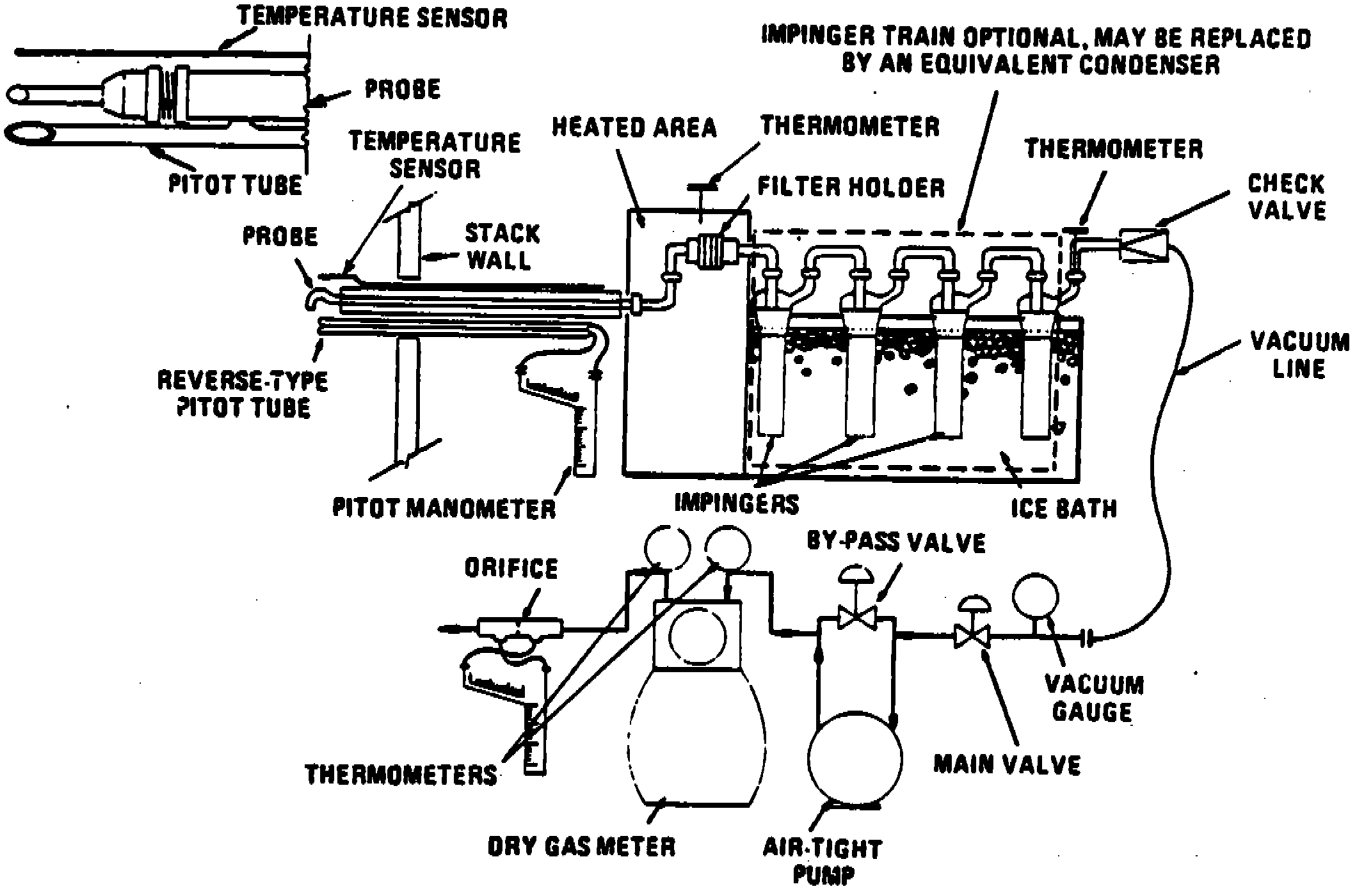

Figure 5-1. Particulate-sampling train

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

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

[2.1.1 amended by 52 FR 34639, September 14, 1987]

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

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

sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

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

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

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

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

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

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

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

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

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

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

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

2.2 Sample Recovery. The following items are needed.

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

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

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

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

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

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

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

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

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

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 Beakers. 250 ml.

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

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

3. *Reagents*

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

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

[3.1.1 amended by 48 FR 3735, January 27, 1983]

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

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

3.1.4 Crushed Ice.

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

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

3.3 Analysis. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

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

4. *Procedure*

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

4.1.1 Pretest Preparation. It is suggested that sampling equipment be maintained according to the procedures described in APTD-0576.

[4.1.1 amended by 50 FR 1165, January 9, 1985]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Place crushed ice around the impingers.

4.1.4 Leak-Check Procedures.

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

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

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

If an asbestos string is used, do not connect the probe to the train during the leak-check. Instead, leak-check the train by first plugging the inlet to the filter holder (cycone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in. Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in. Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable.

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

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

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes unecessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction will need to be applied to the total volume of dry gas metered; if, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

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

4.1.4.3 Post-test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leakcheck shall be done in accordance with the procedures outlined in Section 4.1.4.1, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction need be applied to the total volume of dry gas metered. If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

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

For each run, record the data required on a data sheet such as the one shown in Figure 5-2. Be sure to record the initial dry gas meter reading. Record the dry gas meter readings at the beginning and end of each sampling time increment, when changes in flow rates are made, before and after each leak-check, and when sampling is halted. Take other readings required by Figure 5-2 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

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

[4.1.5 amended by 48 FR 39011, August 26, 1983]

PLANT ____________

LOCATION ____________

OPERATOR ____________

DATE ____________

RUN NO. ____________

SAMPLE BOX NO. ____________

METER BOX NO. ____________

METER ΔHφ ____________

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

[Appendix A, Method 5]

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 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 occured during transport. Label the container to clearly identify its contents.

[4.2 Container No. 2 amended by 52 FR 34639, September 14, 1987]

Container No. 3. Note the color of the indicting silica gel to determine if it has been completely spent and make a notation of its condition. Transfer the silica gel from the fourth impinger to its original container and seal. A funnel may make it easier to pour the silica gel without spilling. A rubber policeman may be used as an aid in removing the silica gel from the impinger. It is not necessary to remove the small amount of dust particles that may adhere to the impinger wall and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, follow the procedure for container No. 3 in Section 4.3.

Impinger Water. Treat the impingers as follows; Make a notation of any color or film in the liquid catch. Measure the liquid which is in the first three impingers to within ± 1 ml by using a graduated cylinder or by weighing it to within ±0.5 g by using a balance (if one is available). Record the volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas.

Discard the liquid after measuring and recording the volume or weight, unless analysis of the impinger catch is required (see Note, Section 2.1.7).

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

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

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

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

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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).

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

Figure 5-3. Analytical data.

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

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

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

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

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

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

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

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

Eq. 5-9

Where:

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

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

P_{bar}=Barometric pressure, in. Hg.

Θ=Total sampling time, min.

Y=Dry gas meter calibration factor, dimensionless.

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

0.0319=(0.0567 in. Hg/°R) x (0.75 cfm)²

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

$$Y_c = \frac{10}{V_m}\left[\frac{0.0319\ T_m}{P_{bar}}\right]^{1/2} \quad \text{Eq. 5-10}$$

Where:

Y_c=Dry gas meter calibration check value, dimensionless.

10=10 minutes of run time.

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

$0.97Y < Y_c < 1.03Y$

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

4.4.2. Calibration Critical Orifice. A calibrated critical orifice, calibrated against a wet test meter or spirometer and designed to be inserted at the inlet of the sampling meter box, may be used as a quality control check by following the procedure of Section 7.2.

[4.4.2 Amended by 52 FR 9658, March 26, 1987]

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.

[5.1 amended by 52 FR 34639, September 14, 1987]

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

5.3 Metering System.

[5.3 revised by 50 FR 1165, January 1985]

5.3.1 Calibration Prior to Use. Before its initial use in the field, the metering system shall be calibrated as follows: Connect the metering system inlet to the outlet of a wet test meter that is accurate to within 1 percent. Refer to Figure 5.5. The wet test meter should have a capacity of 30 liters/rev (1 ft³/rev). A spirometer of 400 liters (14 ft³) or more capacity, or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should be periodically calibrated with a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained. Run the metering system pump for about 15 minutes with the orifice manometer indicating a median reading as expected in field use to allow the pump to warm up and to permit the interior surface of the wet test meter to be thoroughly wetted. Then, at each of a minimum of three orifice manometer settings, pass an exact quantity of gas through the wet test meter and note the gas volume indicated by the dry gas meter. Also note the barometric pressure, and the temperatures of the wet test meter, the inlet of the dry gas meter, and the outlet of the dry gas meter. Select the highest and lowest orifice settings to bracket the expected field operating range of the orifice. Use a minimum volume of 0.15 m³ (5 cf) at all orifice settings. Record all the data on a form similar to Figure 5.6, and calculate Y, the dry gas meter calibration factor, and $\Delta H@$, the orifice calibration factor, at each orifice setting as shown on Figure 5.6. Allowable tolerances for individual Y and $\Delta H@$, values are given in Figure 5.6. Use the average of the Y values in the calculations in Section 6.

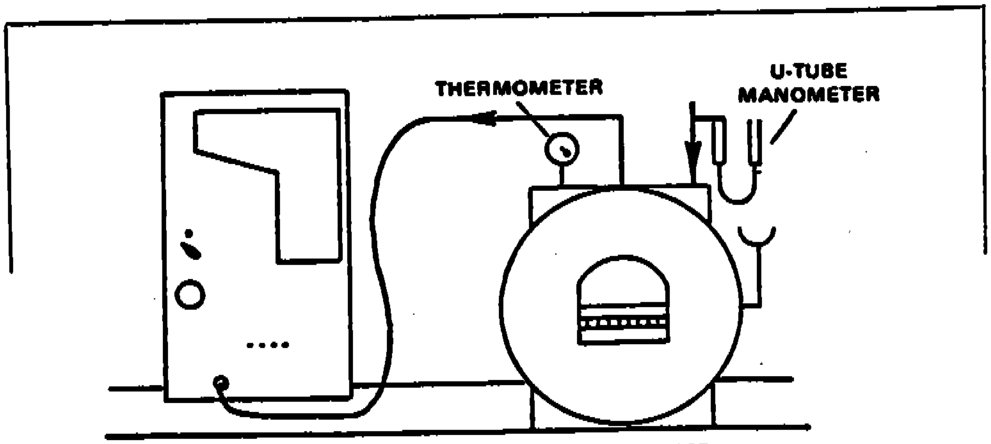

Figure 5.5 Equipment arrangement for metering system calibration.

Date____________________

Metering System
Identification:________________

Barometric pressure, P_b = ______ in. Hg

Orifice manometer setting ΔH in. H_2O	Spirometer (wet meter) gas volume V_w ft^3	Dry gas meter volume V_m ft^3	Temperatures				Time θ min
			Spirometer (wet meter) t_w °F	Dry Gas Meter			
				Inlet t_i °F	Outlet t_o °F	Average t_m °F	

Calculations

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

Y = Ratio of reading of wet test meter to dry test meter; tolerance for individual values ±0.02 from average.

ΔH@ = Orifice pressure differential that equates to 0.75 cfm of air @ 68°F and 29.92 inches of mercury, in. H_2O; tolerance for individual values ±0.20 from average.

Figure 5.6. Example data sheet for calibration of metering system (English units).

[Figure 5.6 revised by 52 FR 34639, September 14, 1987]

Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057m³/min (0.02 cfm); at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divided the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m³/min (0.02 cfm).

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

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

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

5.4 Probe Heater Calibration. The probe heating system shall be calibrated before its initial use in the field.

[5.4 revised by 50 FR 1165, January 9, 1985]

Use a heat source to generate air heated to selected temperatures that approximate those expected to occur in the sources to be sampled. Pass this air through the probe at a typical simple flow rate while measuring the probe inlet and outlet temperatures at various probe heater settings. For each air temperature generated, construct a graph of probe heating system setting versus probe outlet temperature. The procedure outlined in APTD-0576 can also be used. Probes constructed according to APTD-0581 need not be calibrated if the calibration curves in APTD-0576 are used. Also, probes with outlet temperature monitoring capabilities do not require calibration.

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

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

5.7 Barometer. Calibrate against a mercury barometer.

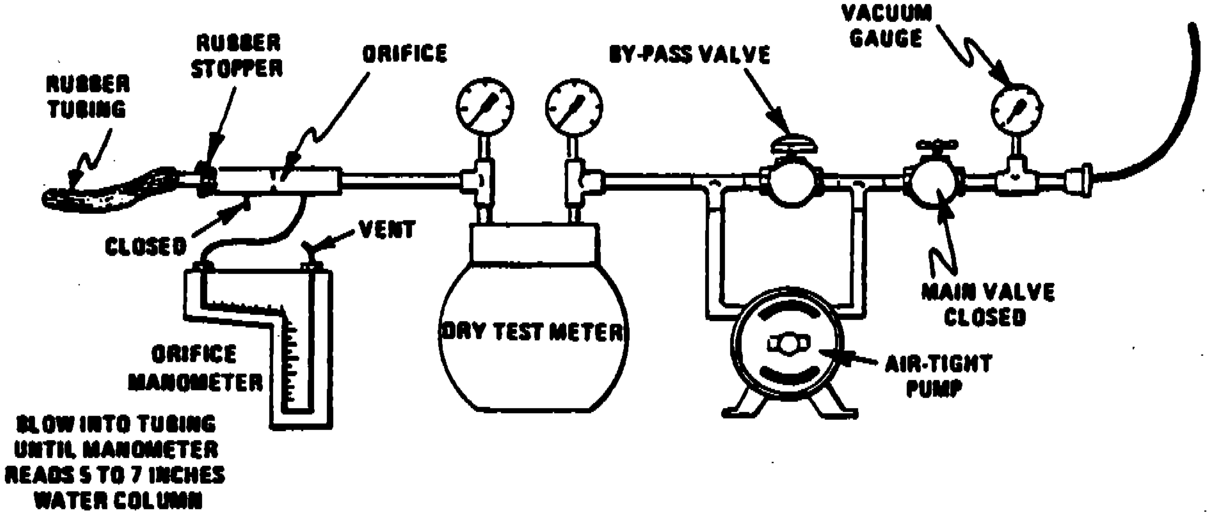

Figure 5-4. Leak check of meter box.

[Appendix A, Method 5]

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6. *Calculations*

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

6.1 Nomenclature

A_n = Cross-sectional area of nozzle, m² (ft²).
B_{ws} = Water vapor in the gas stream, proportion by volume.
C_a = Acetone blank residue concentration, mg/mg.
c_s = Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).
I = Percent of isokinetic sampling.
L_a = Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.0057 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_n = Total amount of particulate matter collected, mg.
M_w = Molecular weight of water, 18.0 g/g-mole (18.0lb/lb-mole).
m_a = Mass of residue of acteone after evaporation, mg.
P_{bar} = Barometric pressure at the sampling site, mm Hg (in. Hg).
P_s = Absolute stack gas pressure, mm Hg (in. Hg).
P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
R = Ideal gas constant, 0.06236 mm Hg-m³/°K-g-mole (21.85 in. Hg-ft³/°R-lb-mole).
T_m = Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).
T_s = Absolute average stack gas temperature (see Figure 5-2), °K (°R).
T_{std} = Standard absolute temperature, 293° K (528° R).
V_a = Volume of acetone blank, ml.
V_{aw} = Volume of acetone used in wash, ml.
V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.
V_m = Volume of gas sample as measured by dry gas meter, dcm (dscf).
$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).
$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).
v_s = Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).
W_a = Weight of residue in acetone wash, mg.
Y = Dry gas meter calibration factor.
ΔH = Average pressure differential across the orifice meter (see Figure 5-2), mm 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_i = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.
θ_p = Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.
13.6 = Specific gravity of mercury.
60 = Sec/min.
100 = Conversion to percent.

[6.1 amended by 52 FR 34639, September 14, 1987]

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.

Equation 5-2

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

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

6.5 Moisture Content.

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

Equation 5-3

NOTE.—In saturated or water droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one from the impinger analysis (Equation 5-3), and a second from the assumption of saturated conditions. The lower of the two values of B_w shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the Note of Section 1.2 of Method 4. For the purposes of this method, the average stack gas temperature from Figure 5-2 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is ± 1° C (2° F).

6.6 Acetone Blank Concentration.

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

6.7 Acetone Wash Blank.

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

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 4.1.5 to assist in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

$$c_s = (0.001\ g/mg)\ (m_n / V_{m(std)})$$

Equation 5-6

[Appendix A, Method 5]

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.2 ACTUAL SAMPLING PROCEDURES/PARTICULATE

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.2 ACTUAL SAMPLING PROCEDURES/PARTICULATE

Particulate matter in the exhaust gas stream at the stack sampling location was sampled according to procedures and type of equipment as basically described in EPA Method 5 (see Appendix 2.1 for a complete description).

In place of the fragile glass material, the in-stack probe liner was constructed of high corrosion resistant Inconel stainless steel, which was enclosed in an outer protective sheath and heat traced to minimize condensation within the probe.

The basic test train consisted of a stainless steel nozzle followed by a heated probe liner, glass fiber filter, and glass impingers with all glass connectors.

The required sampling time for the compliance test, in terms of time per traverse point and overall sampling time per individual test run, was selected on the basis of maintaining a minimum sampling time of 2.5 minutes at each of the traverse points.

The test program was completed with one test train located at the stack. All sampling activities were halted in the event of any test equipment malfunction or at the report of any operational problem. There was no planned interruption or extensive delay during the completion of the test runs.

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.3 ANALYTICAL METHODS/PARTICULATE

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.3 ANALYTICAL METHODS/PARTICULATE

The reported particulate emissions included the total particulate catch from the water then acetone wash of the nozzle and probe, plus accumulations on the glass fiber filter. The impinger water was filtered through a .22 micron filter. These results along with the probe wash and glass fiber filter are considered particulate emissions in the Commonwealth of Pennsylvania.

The soluble water from the impingers was dried down and weighed. This particulate weight is only reported and is not counted toward the total particulate weight.

In the clean-up of the front half of the sampling equipment, the nozzle from the front of the probe was removed, brushed out, and washed with water then acetone. The probe liner was also brushed out and washed with water then acetone. The glass fiber filter was removed from the fritted disc of the filter holder and replaced in its petri dish. All adhering filter particles were removed from the silicone rubber gasket and placed in the same petri dish prior to sealing for transport back to the Gilbert assigned laboratory for final analysis. The filter holder was then washed with water then acetone and combined with the probe and nozzle wash.

The clean-up procedure for the back half of the sampling train initially involved removal of the silica gel from the last impinger and replacement in its original container for final weighing to determine moisture pickup. Water collected in the impingers was measured and placed in a sample bottle. The impingers and glass connectors were rinsed with water then acetone. This rinse was also placed in sample bottles to be analyzed.

Laboratory analysis of samples collected during the test run proceeded according to EPA Method 5 (Appendix 2.1).

All critical items of sampling and analytical equipment were certified and/or calibrated for accuracy and results considered within acceptable limits for source sampling operations (see Appendix 6).

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.4 ANALYTICAL METHODS/HEAVY METALS

APPENDIX 2

TESTING AND ANALYTICAL PROCEDURES

2.3 ANALYTICAL METHODS/HEAVY METALS

The reported heavy metal emissions included the total catch from the nitric acid wash of the nozzle and probe, plus accumulations on the glass fiber filter. The impingers, which contained nitric acid, were washed with nitric acid, as well as the back half of the filter holder and all connecting glassware.

In the clean-up of the front half of the sampling equipment, the nozzle from the front of the probe was removed, brushed out, and washed with nitric acid. The probe liner was then brushed out and washed with nitric acid. All of the wash solutions for the probe and filter holder were combined into a single sample for analysis. The glass fiber filter was removed from the fritted disc of the filter holder and replaced in its Petri dish. All adhering filter particles were removed from the silicone rubber gasket and placed in the same Petri dish prior to sealing for transport back to the Gilbert-assigned laboratory for final analysis.

The clean-up procedure for the back half of the sampling train initially involved removal of the silica gel from the last impinger and replacement in its original container for final weighing to determine moisture pickup. The content of the impingers was measured for volume and then put into sample bottles. The impingers, back half of the filter holder, and connecting glassware were then rinsed with nitric acid and placed into the sample bottle.

The collected heavy metal samples analysis proceeded according to EPA Method 12 (Appendix 2.1).

All critical items of sampling and analytical equipment were certified and/or calibrated for accuracy and results considered within acceptable limits for source sampling operations (see Appendix 6).

APPENDIX 3

OPERATING DATA

(SEE TABLE 1)

B.N
9:40 TO 10:40 15 TONS

8:30	9"	MANOMETER
8:45	9"	
9:00	9"	
9:15	9"	
9:30	9"	
9:45	9"	
10:00	9"	
10:15	9"	
10:30	9"	
10:45	10"	
11:00	10"	
11:15	9"	
11:30	10½"	
11:45	10½"	
12:00	10½"	
12:15	10½"	
12:30	10½"	
12:45	10½"	
1:00	10"	STARTED USING MAGNEHELIC
1:15	9"	
1:30	13"	
1:45	15½"	
2:00	9½"	
2:15	10½"	
2:30	11½"	
2:45	12"	
3:00	12"	
3:15	12½"	

APPENDIX 4

ANALYTICAL RESULTS FOR PARTICULATES

(CLEAN-UP SHEETS)

SSM
SPOTTS, STEVENS and McCOY, INC
ENGINEERS • PLANNERS • SCIENTISTS

CERTIFICATE OF ANALYSIS

CLIENT: GILBERT/COMMONWEALTH, INC.
P. O. BOX 1498
READING, PA. 19603

DATE REPORTED: 11/21/88
REPORT NO: 8821434
DATE SAMPLED: 11/9/88
DATE RECEIVED: 11/11/88
PURCHASE NO.: 51922
ORDER NO.: 13361-001

SAMPLE TYPE: STACK
SAMPLED BY: CLIENT
SAMPLE IDENTIFICATION: MDC
W.O. #10-0620-001

LAB. NO.	RUN	PARTICULATE SOURCE	PARTICULATE WT. (mg)
8821434-1	MDC-1P	Impinger Water	13.8
8821434-1	MDC-1P	Impinger Water (>0.22 um Filter)	5.0
8821434-1	MDC-1P	Impinger Acetone	5.7
8821434-1	MDC-1P	Probe Acetone	4.5
8821434-1	MDC-1P	Probe Water	25.3
8821434-1	MDC-1P	Filter	184.0

Respectfully submitted,

Carl J. Wummer

CARL J. WUMMER - GROUP LEADER
LABORATORY SERVICES

cc: Steve Brockel

Form No. L11a Rev. 1/87

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Allentown PA 18052-3439
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☐ BALTIMORE OFFICE
698 Fairmount Avenue
Suite 105
Baltimore MD 21204-2819
(301) 494-0500

SSM
SPOTTS, STEVENS and McCOY, INC
ENGINEERS • PLANNERS • SCIENTISTS

CERTIFICATE OF ANALYSIS

CLIENT: GILBERT/COMMONWEALTH, INC.
P. O. BOX 1498
READING, PA. 19603

DATE REPORTED: 11/21/88

REPORT NO: 8821436

DATE SAMPLED: 11/9/88

SAMPLE TYPE: STACK

DATE RECEIVED: 11/11/88

SAMPLED BY: CLIENT

PURCHASE NO.: 51922

SAMPLE IDENTIFICATION: MDC
W.O. #10-0620-001

ORDER NO.: 13361-001

			8821436-1 MDC-1N	8821436-2 MDC-2N
Antimony	mg	Sb	< 0.1	< 0.1
Beryllium	mg	Be	< 0.01	< 0.01
Cadmium	mg	Cd	1.02	1.35
Chromium	mg	Cr	0.65	0.46
Lead	mg	Pb	4.73	6.11
Manganese	mg	Mn	.093	.058
Nickel	mg	Ni	3.55	2.80
Thallium	mg	Tl	< 0.1	< 0.1
Arsenic	mg	As	0.30	0.64
Mercury	mg	Hg	.002	.002

Respectfully submitted,

Carl J. Wummer

CARL J. WUMMER - GROUP LEADER
LABORATORY SERVICES

cc: Steve Brockel

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698 Fairmount Avenue
Suite 105
Baltimore MD 21204-2819
(301) 494-0500

GILBERT ASSOCIATES, INC.
AIR POLLUTION CONTROL DEPT.
PARTICULATE CLEAN UP AND REPORT SHEET

Run Date: 11/9/88
Run No.: MSC-1P
Sample Box No.:
Operator: DSW

Client: MOC
W. O. No.: 100620001
Plant:
Sampling Location: Stack

FRONT HALF

Laboratory Results

Nozzle-Acetone Wash — Lab No. 1434-1 — Residue 4.5 mg

Probe, Thimble Holder, Cyclone (bypass), Flask, Front Half Filter Holder-Acetone Wash H_2O — Lab No. 1434-1 — Residue 25.3 mg

Thimble No.	Lab No.	Weight Results
		mg
		mg
		mg
		mg

Thimble particulate weight mg

Filter No.	Lab No.	Weight Results
5-753	1434-1	mg
		mg
		mg
		mg

Filter particulate weight 184.0 mg

FRONT HALF Sub Total 213.8 mg

BACK HALF

Impinger Content and Water Wash of Impingers Connectors and Back Half of Filter Holder — Lab No. 1434-1

Ether-Chloroform Extract mg
Collected on 0.22u Filter 5.0 mg
Aqueous Residue 13.8 mg

Impinger, Connectors and Back Half of Filter Holder - Acetone Wash — Lab No. 1434-1 Residue 5.7 mg

BACK HALF Sub Total 24.5 mg
TOTAL WEIGHT 238.3 mg

MOISTURE

Impingers:
216
234

Final Volume 450
Initial Volume 300
Net Volume 150

Silica Gel

Weight after test:	260			
Weight before test:	232			
Net Weight	28			
Container No.:	1. 11	2.	3.	4.

TOTAL WEIGHT-Silica Gel 28 gm
TOTAL VOLUME- Impingers 150 ml
TOTAL MOISTURE 178 gm

Comments:

LAB: DATE RECEIVED 10/10/88
DATE REPORTED 10/21/88

VO
ANALYTICAL CHEMIST

HPS/APC 12/74

GILBERT ASSOCIATES, INC.
AIR POLLUTION CONTROL DEPT.
PARTICULATE CLEAN UP AND REPORT SHEET

Run Date: 11/9/82
Run No.: MDC-1N
Sample Box No.: ____
Operator: DCW

Client: MDC
W. O. No.: 100620001
Plant: ____
Sampling Location: Stack

FRONT HALF

Laboratory Results

Nozzle-Acetone Wash — Lab No. ____ Residue ____ mg

Probe, Thimble Holder, Cyclone (bypass), Flask, Front Half Filter Holder-Acetone Wash — Lab No. ____ Residue ____ mg

Thimble No.	Lab No.	Weight Results
		mg
		mg
		mg
		mg

Thimble particulate weight ____ mg

Filter No.	Lab No.	Weight Results
S-754		mg
		mg
		mg
		mg

Filter particulate weight ____ mg

FRONT HALF Sub Total ____ mg

BACK HALF

Impinger Content and Water Wash of Impingers Connectors and Back Half of Filter Holder — Lab No. ____ Ether-Chloroform Extract ____ mg

Collected on 0.22μ Filter ____ mg

Aqueous Residue ____ mg

Impinger, Connectors and Back Half of Filter Holder - Acetone Wash — Lab No. ____ Residue ____ mg

BACK HALF Sub Total ____ mg

TOTAL WEIGHT ____ mg

MOISTURE

Impingers:
200
164

Final Volume 364
Initial Volume 200 .1 Nitric
Net Volume 164

Silica Gel

Weight after test:	252			
Weight before test:	232			
Net Weight	20			

Container No.: 1. 4 2. ____ 3. ____ 4. ____

TOTAL WEIGHT-Silica Gel 20 gm
TOTAL VOLUME- Impingers 164 ml
TOTAL MOISTURE 184 gm

Comments: ____

LAB: DATE RECEIVED ____
DATE REPORTED ____

____ ANALYTICAL CHEMIST

HFS/APC 12/74

GILBERT ASSOCIATES, INC.
AIR POLLUTION CONTROL DEPT.
PARTICULATE CLEAN UP AND REPORT SHEET

Run Date: 11/9/88
Run No.: MDC-2N
Sample Box No.: ____
Operator: ____

Client: MDC
W. O. No.: 100620001
Plant: ____
Sampling Location: Stack

FRONT HALF

Nozzle-Acetone Wash

Probe, Thimble Holder, Cyclone (bypass), Flask, Front Half Filter Holder-Acetone Wash

Laboratory Results

Lab No. ____ Residue ____ mg
Lab No. ____ Residue ____ mg

Thimble No.	Lab No.	Weight Results
		mg
		mg
		mg
		mg

Thimble particulate weight ____ mg

Filter No.	Lab No.	Weight Results
5-256		mg
		mg
		mg
		mg

Filter particulate weight ____ mg

FRONT HALF Sub Total ____ mg

BACK HALF

Impinger Content and Water Wash of Impingers Connectors and Back Half of Filter Holder

Lab No. ____ Ether-Chloroform Extract ____ mg
Collected on 0.22u Filter ____ mg
Aqueous Residue ____ mg

Impinger, Connectors and Back Half of Filter Holder - Acetone Wash

Lab No. ____ Residue ____ mg

BACK HALF Sub Total ____ mg
TOTAL WEIGHT ____ mg

MOISTURE

Impingers:
138
132

Final Volume 370
Initial Volume 200 .1 Nitric
Net Volume 170

Silica Gel

Weight after test:	260			
Weight before test:	232			
Net Weight	28			

Container No.: 1. θ 2. ____ 3. ____ 4. ____

TOTAL WEIGHT-Silica Gel 28 gm
TOTAL VOLUME- Impingers 170 ml
TOTAL MOISTURE 198 gm

Comments: ____

LAB: DATE RECEIVED ____
DATE REPORTED ____

____
ANALYTICAL CHEMIST

HFS/APC 12/74

APPENDIX 5

RAW FIELD DATA

Sheet 1 of 2

PARTICULATE FIELD DATA

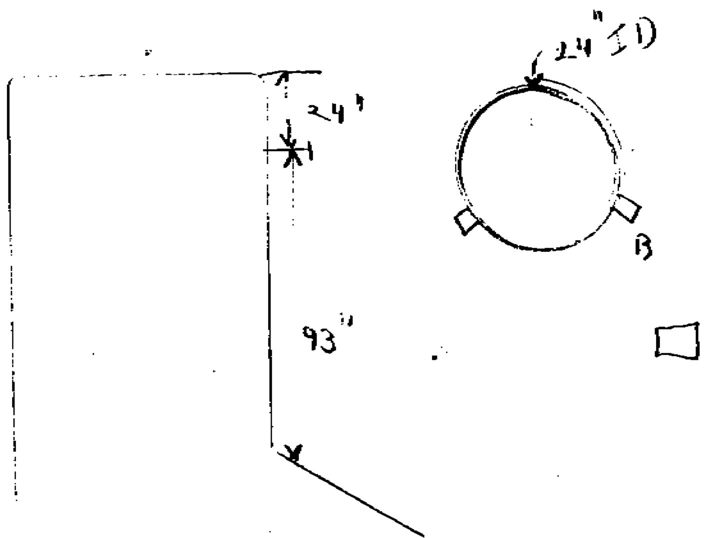
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point

Client MDC
W. O. No. 100620001
Plant Castor Ave.
Run No. MDC-IN
Location stack
Date 11/9/88
Operator DCW
Sample Box No.
Meter Box No. 2838
MeterΔH 1.86
C Factor

Pitot Calibration 0.84
Thimble No. —
Filter No. S-254
Ambient Temp. °F 49
Bar. Press. "Hg 30.42
Assumed Moisture % 10
Heater Box Setting, °F 250
Probe Tip Dia., In. 0.250
Probe Length 3'
Probe Heater Setting 65 KV 250°
Avg.ΔP
Avg. ΔH

SKETCH



POINT	DISTANCE IN INCHES	CLOCK TIME ACTUAL	CLOCK TIME RUN	DRY GAS METER, CF	PITOT IN. H2O ΔP	ORIFICE Δ H IN. H_2O DESIRED	ORIFICE Δ H 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	O_2	STACK TEMP. °F
B 1		0805.	0.0	703.205	0.26		0.88	50.	48.	-	240	40		125.
2			3.5	705.1	0.30		1.03	54.	48.	-	245			128.
3			7.0	706.9	0.26		0.83	57.	49.	-	255			130.
4			10.5	708.9	0.32		1.11	62.	50.	-	265	42		132.
5			14.0	710.9	0.31		1.08	66.	50.	-	260		19.5	132.
6			17.5	712.7	0.30		1.03	68.	51.	-	265		19.2	132.
7			21.0	715.1	0.37		1.28	70.	52.	1	260	44		133.
8			24.5	717.1	0.44		1.52	74.	54.	2	255		19.1	133.
9			28.0	719.3	0.52		1.78	76.	55.	2	255			132.
10			31.5	721.9	0.50		1.73	78.	57.	2	250	45	19.0	132.
11			35.0	724.3	0.50		1.73	77.	57.	2	245			131.
12			38.5	726.7	0.46		1.60	79.	58.	2	250		18.7	131.
STOP		0847.	42.0	729.228										

-.25

imp 205 Gel
164 20

CO_2 2.0
2.6

.254

Client MDC

W.O. No. 100620001

Plant Castor Ave.

Run No. MDC-IN

PARTICULATE FIELD DATA
(continued)

Sheet 2 of 2

Location stack

Date 11/9/88

POINT	DISTANCE IN INCHES	CLOCK TIME		DRY GAS METER, CF	PITOT IN. H_2O ΔP	ORIFICE ΔH IN. H_2O		DRY GAS TEMP. °F		PUMP VACUUM IN. Hg GAUGE	BOX TEMP °F	IMPINGER TEMP °F	O_2	STACK TEMP. °F
		ACTUAL	RUN			DESIRED	ACTUAL	INLET	OUTLET					
A- 1		0854.	0.0	729.228	0.28		0.96	65.	56.	–	245	47		129.
2			3.5	731.3	0.27		0.88	68.	58.	–	250			129.
3			7.0	733.1	0.29		1.01	71.	59.	–	260		19.0	129.
4			10.5	735.2	0.26		0.88	72.	59.	–	265	48		129.
5			14.0	737.2	0.25		0.88	72.	59.	1	260		18.6	136.
6			17.5	739.0	0.20		0.73	72.	59.	1	255			136.
7			21.0	740.6	0.45		1.50	73.	59.	1	250	50	18.7	136.
8			24.5	743.0	0.61		1.92	78.	60.	3	255			134.
9			28.0	745.6	0.68		2.30	79.	60.	3	265		18.5	133.
10			31.5	748.5	0.74		2.52	80.	60.	4	270	50		133.
11			35.0	751.6	0.77		2.60	82.	61.	4	270		18.5	133.
12			38.5	754.5	0.75		2.57	84.	62.	4	265			133.
STOP		0936.	42.0	757.500										
END														

COMMENTS:

733.205

leak at 5" .004

-.37

2.0
2.0

1.8

Sheet 1 of 2

PARTICULATE FIELD DATA

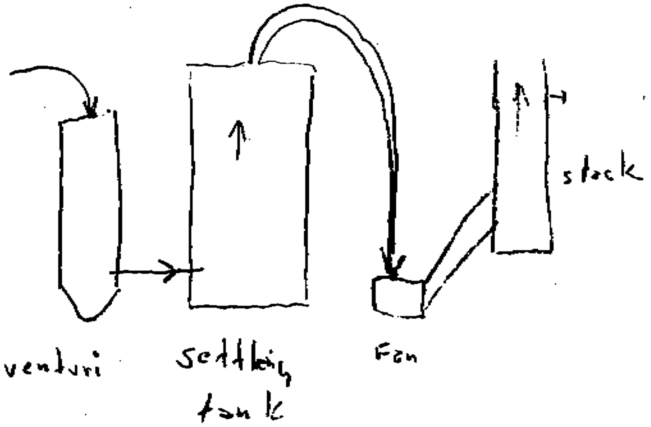
Pots

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point

Client MDC
W. O. No. 10062001
Plant Castor Ave.
Run No. MDC-1P
Location Stack
Date 11/9/88
Operator DCW
Sample Box No.
Meter Box No. 2838
Meter∆H
C Factor

SKETCH



Pitot Calibration 0.84
Thimble No. –
Filter No. 5-753
Ambient Temp. °F 52
Bar. Press. "Hg 30.49
Assumed Moisture % 10
Heater Box Setting, °F
Probe Tip Dia., In. 0.254
Probe Length
Probe Heater Setting
Avg.∆P
Avg. ∆H

POINT	DISTANCE IN INCHES	CLOCK TIME ACTUAL	CLOCK TIME RUN	DRY GAS METER, CF	PITOT IN. H2O ∆P	ORIFICE ∆ H IN. H_2O DESIRED	ORIFICE ∆ H 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	O_2	STACK TEMP. °F
B-1		1116.	0.0	259.806	0.36		1.23	60.	56.	–	270	42		121.
2			3.5	261.8	0.42		1.45	65.	56.	–	265			124.
3			7.0	264.1	0.40		1.38	72.	57.	–	260			129.
4			10.5	266.4	0.41		1.40	74.	58.	–	265	44		131.
5			14.0	268.8	0.38		1.30	77.	60.	–	260		18.5	132.
6			17.5	271.0	0.35		1.20	79.	60.	–	255			132.
7			21.0	273.2	0.37		1.28	80.	61.	–	250	44		132.
8			24.5	275.4	0.61		2.08	81.	62.	2	250		18.4	131.
9			28.0	278.6	0.67		2.28	82.	63.	3	245			131.
10			31.5	280.8	0.60		2.03	82.	64.	3	255	46		130.
11			35.0	283.7	0.57		1.97	83.	64.	3	250		18.5	130.
12			38.5	286.7	0.53		1.81	84.	65.	3	250			130.
Stop			42.0	289.043										

14.

Client MDC

W.O. No. 1802-20001

Plant Cordor Ave.

Run No. MDC-1P

PARTICULATE FIELD DATA
(continued)

Sheet 2 of 2

Location stack

Date 11/9/88

POINT	DISTANCE IN INCHES	CLOCK TIME ACTUAL	CLOCK TIME RUN	DRY GAS METER, CF	PITOT IN. H_2O ΔP	ORIFICE ΔH IN. H_2O DESIRED	ORIFICE 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	O_2	STACK TEMP. °F
A-1		1203.	0.0	789.043	0.24		0.82	73.	64.	1	245	46		130.
2			3.5	791.0	0.23		0.78	75.	64.	1	250			132.
3			7.0	792.7	0.22		0.74	78.	65.	1	245		18.4	132.
4			10.5	794.3	0.25		0.85	79.	65.	1	240	48		132.
5			14.0	796.4	0.20		0.70	80.	65.	1	245		18.1	135.
6			17.5	797.7	0.18		0.62	81.	66.	1	250			135.
7			21.0	799.4	0.50		1.72	84.	67.	3	255	48		134.
8			24.5	802.1	0.68		2.32	88.	68.	4	260			135.
9			28.0	805.0	0.82		2.80	90.	69.	6	260		18.3	137.
10			31.5	808.1	0.87		3.00	92.	70.	6	265	52		139.
11			35.0	811.2	0.81		2.80	93.	70.	6	270			136.
12			38.5	814.9	0.75		2.58	94.	70.	6	265		18.1	136.
Stop			42.0	817.560										
[illegible]														

COMMENTS:

-.39

leak at 6" dead

CO_2
1.8
1.6

15-18 ton/hr.

Sheet 1 of 2

PARTICULATE FIELD DATA

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point

SKETCH

Client MDC
W. O. No. 10062000)
Plant Cosvor Nya.
Run No. MDC-2N
Location stack
Date 11/9/88
Operator DCW
Sample Box No.
Meter Box No. 2838
MeterΔH
C Factor

Pitot Calibration 0.84
Thimble No. –
Filter No.
Ambient Temp. °F 56
Bar. Press. "Hg 30.46
Assumed Moisture % 10
Heater Box Setting, °F 250
Probe Tip Dia., In. .254
Probe Length
Probe Heater Setting
Avg.ΔP Avg. ΔH

POINT	DISTANCE IN INCHES	CLOCK TIME		DRY GAS METER, CF	PITOT IN. H2O ΔP	ORIFICE Δ H IN. H_2O		DRY GAS TEMP. °F		PUMP VACUUM IN. Hg GAUGE	BOX TEMP. °F	IMPINGER TEMP. °F	O_2	STACK TEMP. °F
		ACTUAL	RUN			DESIRED	ACTUAL	INLET	OUTLET					
B-1		1341.	0.0	818.811	0.36		1.23	62.	61.	-	240	50		137.
2			3.5	820.9	0.38		1.30	70.	62.	-	245			139.
3			7.0	823.1	0.37		1.26	76.	62.	–	250			138.
4			10.5	825.2	0.38		1.30	78.	62.	–	255	48	18.6	139.
5			14.0	827.5	0.35		1.20	80.	63.	–	250			138.
6			17.5	829.6	0.35		1.20	81.	64.	–	255		18.4	138.
7			21.0	832.1	0.56		1.92	83.	64.	2	260	50		141.
8			24.5	835.0	0.79		2.70	85.	65.	3	265		18.1	141.
9			28.0	838.1	0.80		2.72	92.	66.	3	270		18.0	139.
10			31.5	841.0	0.78		2.64	92.	68.	3	270	50		138.
11			35.0	844.3	0.74		2.50	93.	70.	3	265		18.1	136.
12			38.5	847.0	0.68		2.33	92.	70.	3	260			138.
Stop			42.0	849.942										

-.46

Imp 170
[illegible]

2.2
2.7

Client MOC

PARTICULATE FIELD DATA
(continued)

Sheet 2 **of** 2

W.O. No. 10062001

Plant Castor Ave

Location stack

Run No. MOC-2N

Date 11/9/88

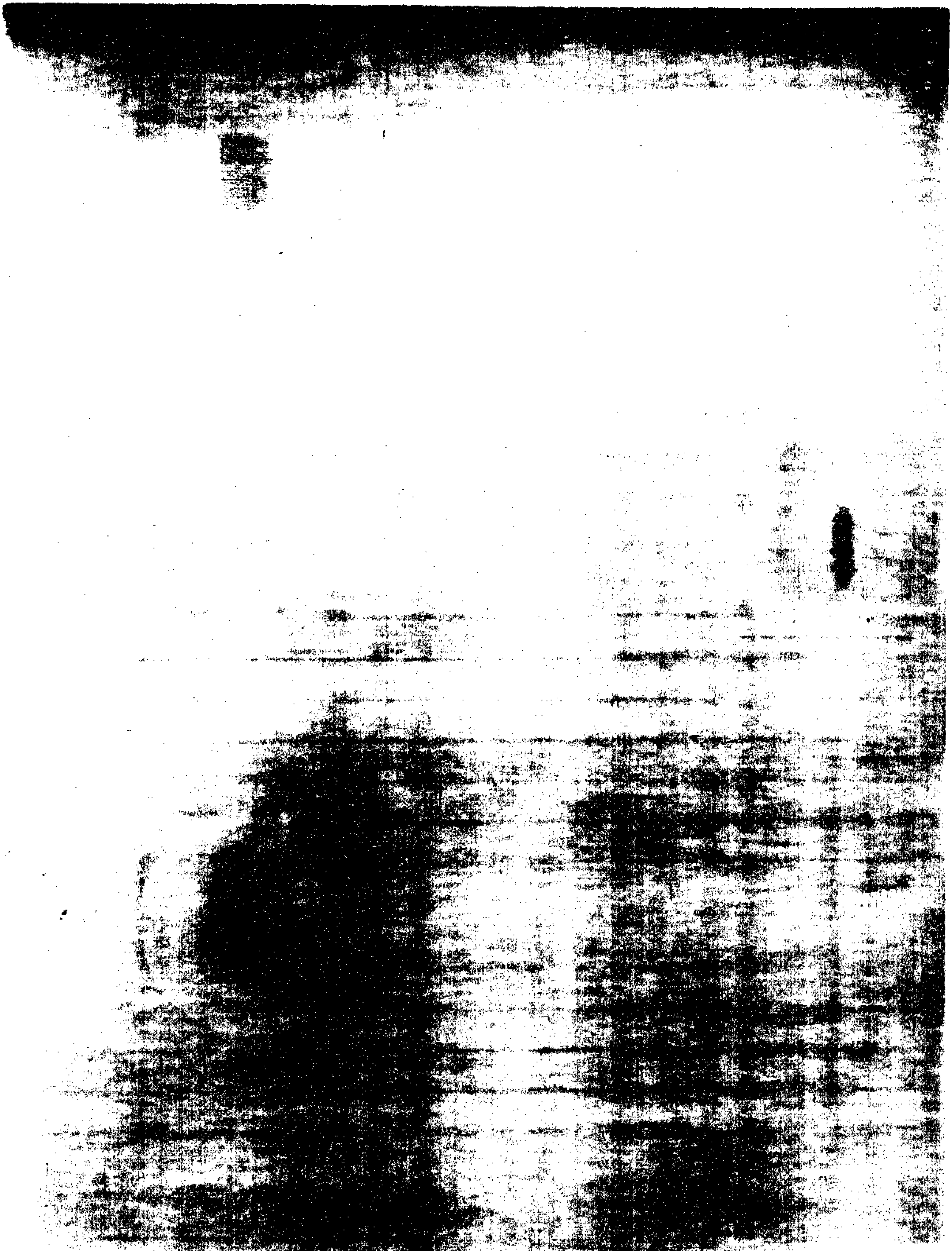
POINT	DISTANCE IN INCHES	CLOCK TIME ACTUAL	CLOCK TIME RUN	DRY GAS METER, CF	PITOT IN. H_2O ΔP	ORIFICE ΔH IN. H_2O DESIRED	ORIFICE ΔH IN. H_2O ACTUAL	DRY GAS TEMP. °F INLET	DRY GAS TEMP. °F OUTLET	PUMP VACUUM IN. Hg GAUGE	BOX TEMP °F	IMPINGER TEMP °F	O_2	STACK TEMP. °F
D-1		1429.	0.0	849.942	0.22		0.74	80.	70.	~	265	54		130.
2			3.5	851.7	0.23		0.78	80.	70.	1	260			131.
3			7.0	853.5	0.24		0.82	80.	70.	1	255		17.1	132.
4			10.5	855.3	0.26		0.89	81.	69.	1	250	56	18.7	133.
5			14.0	857.2	0.20		0.69	81.	69.	1	245		18.1	135.
6			17.5	858.8	0.16		0.55	81.	69.	1	250		17.9	137.
7			21.0	860.6	0.52		1.79	84.	69.	3	255	58	18.0	137.
8			24.5	863.6	0.68		2.32	90.	70.	4	260			130.
9			28.0	866.0	0.82		2.82	92.	70.	5	260		18.2	130.
10			31.5	869.1	0.88		3.00	93.	70.	5	265	58		139.
11			35.0	872.2	0.89		3.02	94.	71.	5	260			140.
12			38.5	875.4	0.75		2.58	96.	72.	5	255			139.
STP			42.0	878.685										
END														

COMMENTS: look at 6" .003

-.38

1.8
1.6
1.6

362



APPENDIX 6

CALIBRATION DATA

Gilbert/Commonwealth Inc.
Testing Services Group
METER BOX CALIBRATION

DATE: 11/10/88 METER BOX NUMBER: 2838

BAROMETRIC PRESS. (Pb) = 29.73 in. Hg CALIBRATED BY: WARY

	GAS VOLUME		TEMPERATURES						
				Dry Gas Meter					
Orifice Manometer Setting (delta H) In. H20	Wet Test Meter (Vw) cu. ft.	Dry Gas Meter (Vd) cu. ft.	Wet Test Meter (Tw) deg. F	Inlet (Tdi) deg. F	Outlet (Tdo) deg. F	Average (Td) deg. F	Time min.	Yi	delta H@i
0.5	5.000	5.077	70	81	75	78.0	12.37	1.00	1.71
1.0	5.000	5.130	71	89	78	83.5	9.00	1.00	1.81
1.5	10.500	10.926	71	99	84	91.5	15.53	0.99	1.81
2.0	10.000	10.581	71	105	90	97.5	13.13	0.99	1.86
3.0	10.500	11.273	71	111	93	102.0	11.60	0.98	1.94
4.0	10.000	10.853	71	115	96	105.5	9.62	0.97	1.93
							AVERAGE Yi	0.99	

FORMULAS

$$Yi = \frac{(Vw)(Pb)(Td+460)}{(Vd)(Pb+(H/13.6))(Tw+460)}$$

$$\text{delta H@i} = \frac{0.921}{(Km)(Km)}$$

$$Km = Qm \sqrt{\frac{(Pb)(29)}{(Tdo+460)(\text{delta H})}}$$

$$Qm = \frac{(Vd)(Tdo+460)}{(Time)(Td+460)}$$

Gilbert/Commonwealth Inc.
Testing Services Group

METER BOX CALIBRATION

DATE: 10/25/88

METER BOX NUMBER: 2838

BAROMETRIC PRESS. (Pb) = 29.74 in. Hg

CALIBRATED BY: Burger

	GAS VOLUME		TEMPERATURES						
				Dry Gas Meter					
Orifice Manometer Setting (delta H) In. H2O	Wet Test Meter (Vw) cu. ft.	Dry Gas Meter (Vd) cu. ft.	Wet Test Meter (Tw) deg. F	Inlet (Tdi) deg. F	Outlet (Tdo) deg. F	Average (Td) deg. F	Time min.	Yi	delta H@i
0.5	5.250	5.268	70	77	71	74.0	12.90	1.00	1.72
1.0	5.000	5.116	70	87	74	80.5	8.93	0.99	1.78
1.5	10.000	10.417	70	99	82	90.5	15.00	0.99	1.86
2.0	11.250	11.869	70	105	89	97.0	14.75	0.99	1.86
3.0	10.000	10.728	70	112	94	103.0	11.00	0.98	1.93
4.0	10.750	11.667	70	115	97	106.0	10.40	0.97	1.95
							AVERAGE Yi	0.99	

FORMULAS

$$Yi = \frac{(Vw)(Pb)(Td+460)}{(Vd)(Pb+(H/13.6))(Tw+460)}$$

$$\text{delta H@i} = \frac{0.921}{(Km)(Km)}$$

$$Km = Qm \sqrt{\frac{(Pb)(29)}{(Tdo+460)(\text{delta H})}}$$

$$Qm = \frac{(Vd)(Tdo+460)}{(Time)(Td+460)}$$

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT MDC

PROJECT

FILING CODE 100620001

W.O.

PAGE OF

ENGINEER

DATE 11/10/88

REVIEWED BY

DATE

SYSTEM

CALCULATION FOR Pot Meter-Thermocouple Calibration

Pot Meter # 5

Thermocouple Type K

Ice Bath Temperature °F 33
Certified Mercury Bulb °F 33

Ambient Temperature °F 70
Certified Mercury Bulb °F 70

Boiling H_2O °F
Certified Mercury Bulb °F

Hot Synthetic Oil °F 378
Certified Mercury Bulb °F 376

Remarks:

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT

PROJECT

FILING CODE

W.O.

PAGE OF

ENGINEER

DATE 9/23/88

SYSTEM

CALCULATION FOR Pot Meter-Thermocouple Calibration

REVIEWED BY

DATE

Pot Meter # 5

Thermocouple Type K

Ice Bath Temperature °F 34

Certified Mercury Bulb °F 34

Ambient Temperature °F 72

Certified Mercury Bulb °F 72

Boiling H_2O °F

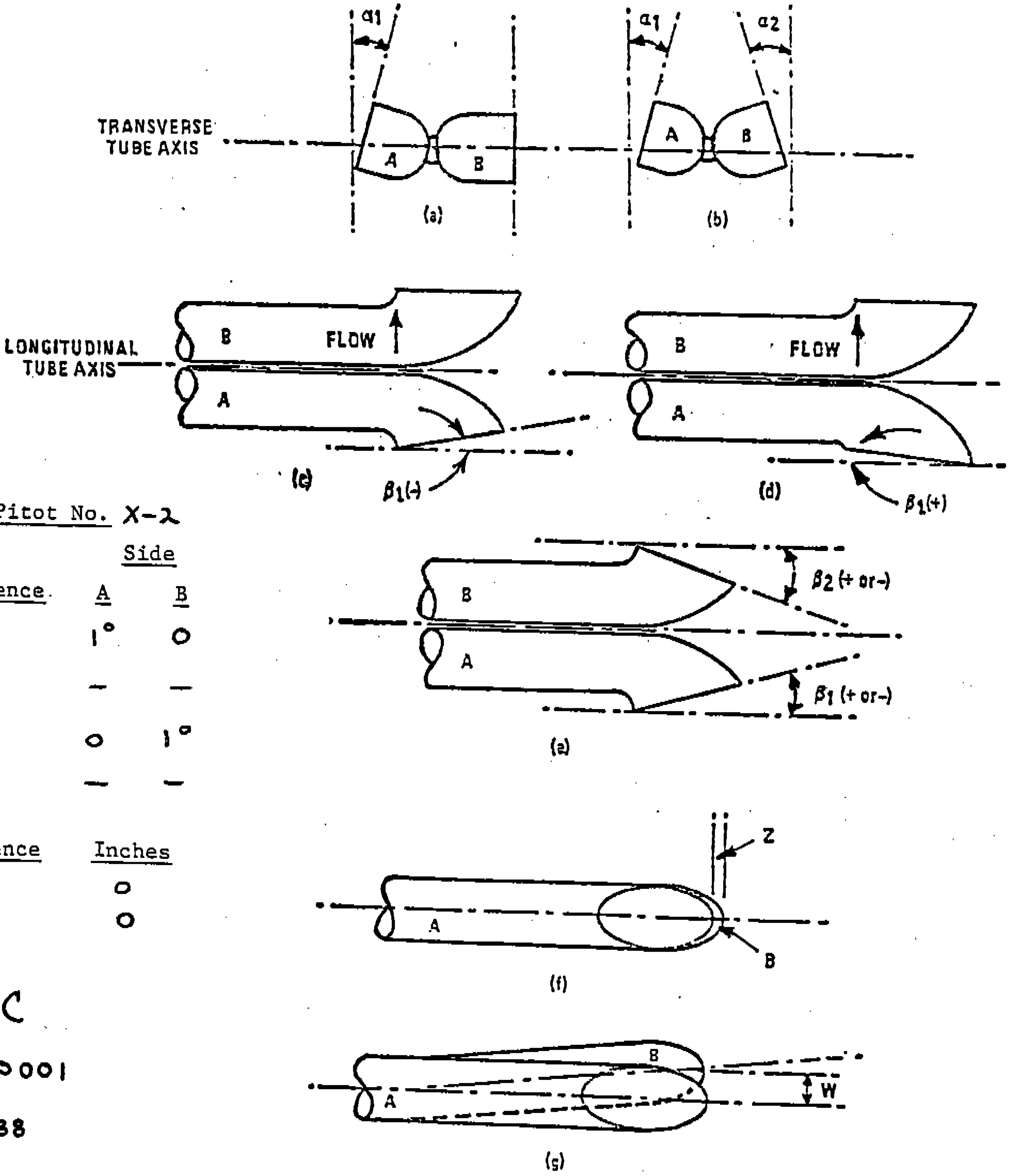
Certified Mercury Bulb °F

Hot Synthetic Oil °F 380

Certified Mercury Bulb °F 379

Remarks:

FILING CODE



Pitot No. X-2

Reference	Side A	Side B
A_1	1°	0
A_2	—	—
B_1	0	1°
B_2	—	—

Reference	Inches
Z	0
W	0

MDC

100620001

11/10/88

Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\overline{C}p(s)$ so long as α_1 and $\alpha_2 < 10^\circ$, β_1 and $\beta_2 < 5^\circ$, $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).

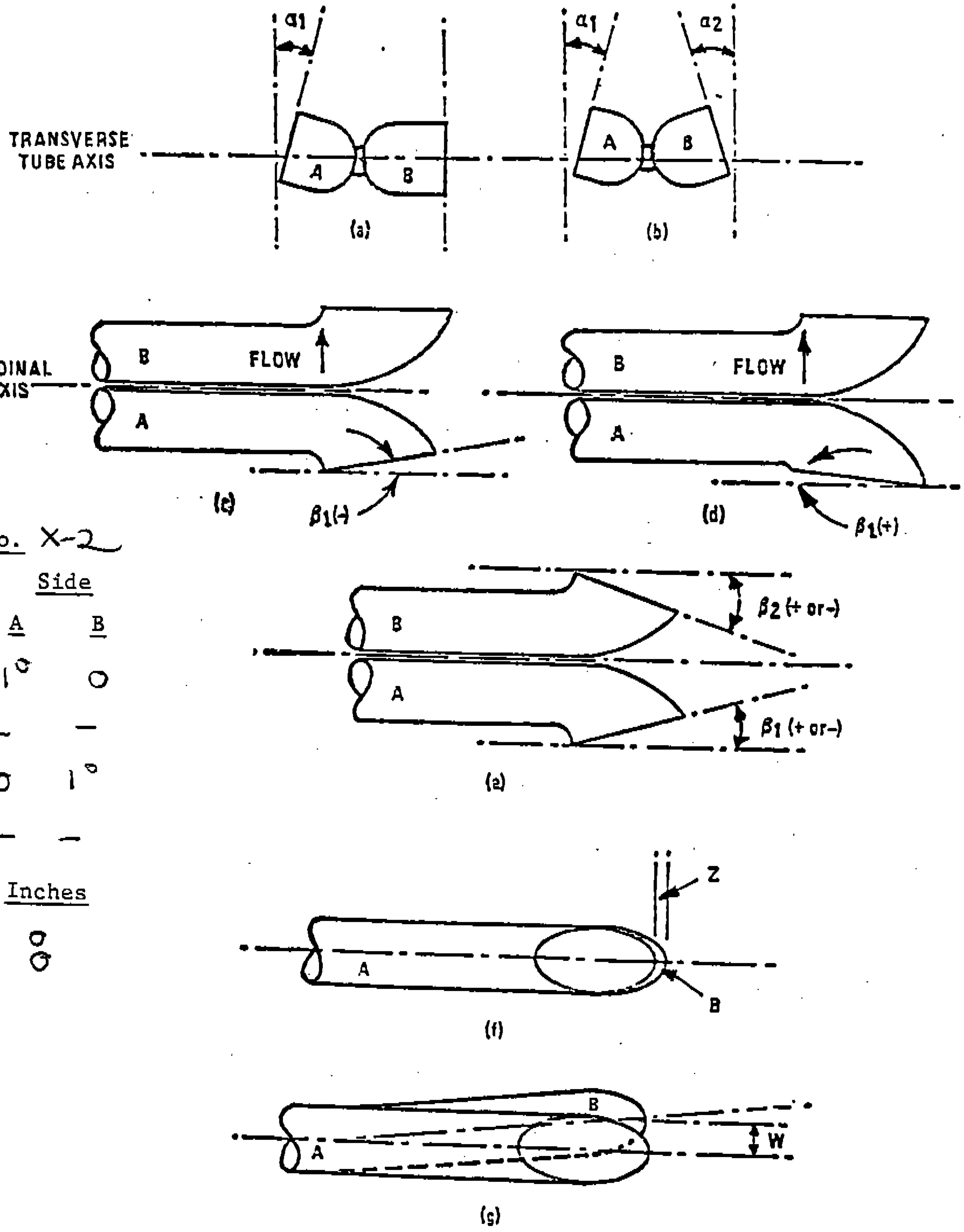


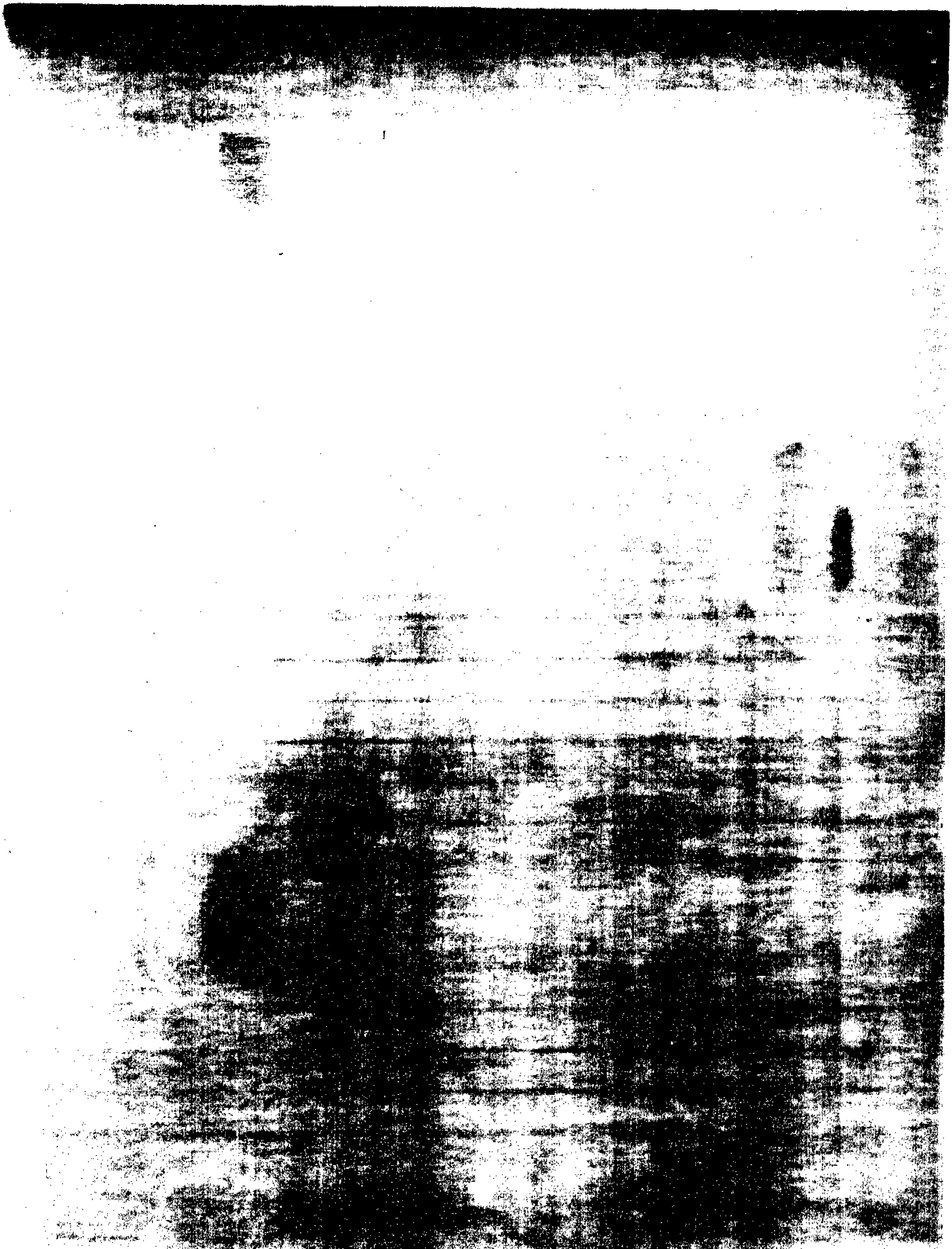
Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\bar{C}p(s)$ so long as α_1 and $\alpha_2 < 10^\circ$, β_1 and $\beta_2 < 5^\circ$, $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).

Pitot No. X-2

Reference	Side A	Side B
A_1	1°	0
A_2	—	—
B_1	0	1°
B_2	—	—

Reference	Inches
Z	0
W	0

8/22/88



APPENDIX 7

COMPUTER PRINTOUT

(Flue Gas Characteristics, Isokinetic Calculations, and Test Results for Particulates)

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                         ISOKINETIC SAMPLING ANALYSIS


                                PROGRAM - I005


CLIENT NAME   - M D C INDUSTRIES            PLANT LOCATION  - PHILADELPHIA PA


PROCESS       - DRYING KILN                 CONTROL EQUIPMT - VENTURI SCRUBBER


SAMPLING POINT- STACK                       POLLUTANTS      - METALS PARTICULATE

                                                                 GILBERT ASSOCIATES, INC.
                                                                 READING, PENNA.
                                                                 100620001      11/11/88
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          GILBERT ASSOC., INC. - INDUSTRIAL DIVISION - ISOKINETIC SAMPLING ANALYSIS        11/11/88        PAGE  1

RESULTS OF FLOW AND ISOKINETIC CALCULATIONS -

RUN NUMBER -                                          MDC-1N      MDC-1P      MDC-2N
DATE OF RUN -                                        11-9-88     11-9-88     11-9-88
TIME AT BEGINNING OF RUN                              805.0      1116.0      1341.0
TIME AT END OF RUN                                    936.0      1245.0      1511.0
DN     SAMPLING NOZZLE DIAMETER      IN.               0.254       0.254       0.254
Y      DRY GAS METER FACTOR            -               0.990       0.990       0.990
PB     BAROMETRIC PRESSURE           IN. HG. ABS.  30.42       30.49       30.46
TT     NET TIME OF TEST              MIN.          84.0        84.0        84.0
VM     SAMPLED GAS VOLUME            CU. FT.       54.295      59.754      59.874
TM     AVG. GAS METER TEMPERATURE    DEGR. F.      64.         72.         76.
PM     AVG. ORIFICE PRESSURE DROP    IN. H2O        1.43        1.63        1.76
VMSTD  VOLUME OF DRY GAS SAMPLED     DSCF          55.320      60.076      59.737

VW     H2O FROM IMPINGER, SILICA GEL ML            184.0       178.0       198.0
VWGAS  H2O COLLECTED AT STD.COND.    STD. CU. FT.   8.666       8.384       9.326
M      STACK GAS MOISTURE BY VOLUME  PERCENT       13.5        12.2        13.5
       CO2 IN DRY STACK GASES        PERCENT        2.0         1.6         1.8
       O2 IN DRY STACK GASES         PERCENT       18.9        18.3        18.3
       CO IN DRY STACK GASES         PERCENT        0.0         0.0         0.0
       N2 IN DRY STACK GASES         PERCENT       79.1        80.1        79.9
MD     MOL FRACTION OF DRY GAS         -            0.86        0.88        0.86
MWD    MOL WGT. OF STACK GAS, DRY      -           29.08       28.99       29.02
EA     EXCESS AIR                    PERCENT      953.4       642.9       655.1
MW     MOL WGT. OF STACK GAS, WET      -           27.58       27.64       27.53

AS     STACK AREA                    SQ. IN.      452.4       452.4       452.4
PST    STATIC PRESSURE OF STACK GAS  IN. HG.       -0.02       -0.02       -0.03
PS     STACK GAS PRESSURE            IN. HG. ABS.  30.40       30.47       30.43
TS     AVG. STACK TEMPERATURE        DEGR. F.     132.        132.        136.
CP     PITOT TUBE COEFFICIENT          -            0.840       0.840       0.840
VS     STACK GAS VELOC., STACK COND. AFPM         2300.       2430.       2533.
QS     STACK GAS VOL., DRY STD. COND. DSCFM       5685.       6108.       6221.
QA     STACK GAS VOLUMN, STACK COND. ACFM         7227.       7634.       7959.

I      ISOKINETIC RATIO              PERCENT      103.1       104.2       101.8

NO PARTICULATE DATA GIVEN
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           GILBERT ASSOC., INC. - INDUSTRIAL DIVISION - ISOKINETIC SAMPLING ANALYSIS        11/11/88        PAGE  2
                                      LISTING OF FIELD DATA AND RESULTS AT EACH POINT

POINT    POINT    CLOCK   TIME   DRY GAS  ORIFICE  GAS TEMPERATURES  VELOCITY   STACK     STACK   (VEL. HD.)X   SQR ROOT OF  STACK
 NO.   DISTANCE   TIME   INCRMT   METER   DELTA H   IN        OUT      HEAD     PRESS      TEMP  (STACK TEMP.)   PREVIOUS     GAS
                                                                                                                  RESULT      VEL
         (IN)            (MINS)   (CF)   (IN. H2O)   (DEGREES F)   (IN. H2O) (IN. H2O) (DEGR. F) (IN. H2O-DEG R)             (AFPM)


RUN NO. -     MDC-IN
 B-1       0.0    805.0   0.0   703.205   0.88     50.0     48.0    0.260     -0.31    125.0        152.10        12.33     1835.6
 B-2       0.0    808.5   3.5   705.100   1.03     54.0     48.0    0.300     -0.31    128.0        176.40        13.28     1976.8
 B-3       0.0    812.0   7.0   706.900   0.88     57.0     49.0    0.260     -0.31    130.0        153.40        12.39     1843.4
 B-4       0.0    815.5  10.5   708.900   1.11     62.0     50.0    0.320     -0.31    132.0        189.44        13.76     2048.6
 B-5       0.0    819.0  14.0   710.900   1.08     66.0     50.0    0.310     -0.31    132.0        183.52        13.55     2016.3
 B-6       0.0    822.5  17.5   712.700   1.03     68.0     51.0    0.300     -0.31    132.0        177.60        13.33     1983.5
 B-7       0.0    826.0  21.0   715.100   1.28     70.0     52.0    0.370     -0.31    133.0        219.41        14.81     2204.7
 B-8       0.0    829.5  24.5   717.100   1.52     74.0     54.0    0.440     -0.31    133.0        260.92        16.15     2404.2
 B-9       0.0    833.0  28.0   719.300   1.78     76.0     55.0    0.520     -0.31    132.0        307.84        17.55     2611.4
 B-10      0.0    836.5  31.5   721.900   1.73     78.0     57.0    0.500     -0.31    132.0        296.00        17.20     2560.7
 B-11      0.0    840.0  35.0   724.300   1.73     77.0     57.0    0.500     -0.31    131.0        295.50        17.19     2558.6
 B-12      0.0    843.5  38.5   726.700   1.60     79.0     58.0    0.460     -0.31    131.0        271.86        16.49     2454.1
 STOP             847.0  42.0   729.228
 A-1       0.0    854.0   0.0   729.228   0.96     65.0     56.0    0.280     -0.31    129.0        164.92        12.84     1911.4
 A-2       0.0    857.5   3.5   731.300   0.88     68.0     58.0    0.270     -0.31    129.0        159.03        12.61     1877.0
 A-3       0.0    901.0   7.0   733.100   1.01     71.0     59.0    0.290     -0.31    129.0        170.81        13.07     1945.2
 A-4       0.0    904.5  10.5   735.200   0.88     72.0     59.0    0.260     -0.31    129.0        153.14        12.37     1841.9
 A-5       0.0    908.0  14.0   737.200   0.88     72.0     59.0    0.250     -0.31    136.0        149.00        12.21     1816.8
 A-6       0.0    911.5  17.5   739.000   0.73     72.0     59.0    0.200     -0.31    136.0        119.20        10.92     1625.0
 A-7       0.0    915.0  21.0   740.600   1.50     73.0     59.0    0.450     -0.31    136.0        268.20        16.38     2437.5
 A-8       0.0    918.5  24.5   743.000   1.92     78.0     60.0    0.610     -0.31    134.0        362.34        19.04     2833.2
 A-9       0.0    922.0  28.0   745.600   2.30     79.0     60.0    0.680     -0.31    133.0        403.24        20.08     2988.8
 A-10      0.0    925.5  31.5   748.500   2.52     80.0     60.0    0.740     -0.31    133.0        438.82        20.95     3117.9
 A-11      0.0    929.0  35.0   751.600   2.60     82.0     61.0    0.770     -0.31    133.0        456.61        21.37     3180.4
 A-12      0.0    932.5  38.5   754.500   2.57     84.0     62.0    0.750     -0.31    133.0        444.75        21.09     3138.9
 STOP             936.0  42.0   757.500

                           TT      VM       PM          TM                       PST       TS
OVERALL RESULTS           84.0   54.295    1.43        63.5          0.420     -0.31    131.7        248.92        15.46     2300.5
                         (NET)   (NET)    (AVG)       (AVG)          (AVG)     (AVG)    (AVG)        (AVG)         (AVG)     (AVG)
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          GILBERT ASSOC., INC. - INDUSTRIAL DIVISION - ISOKINETIC SAMPLING ANALYSIS        11/11/88        PAGE  3
                                 LISTING OF FIELD DATA AND RESULTS AT EACH POINT

POINT    POINT    CLOCK    TIME    DRY GAS   ORIFICE   GAS TEMPERATURES  VELOCITY   STACK      STACK    (VEL. HD.)X     SQR ROOT OF   STACK
 NO.    DISTANCE  TIME    INCRMT    METER    DELTA H    IN         OUT     HEAD     PRESS       TEMP   (STACK TEMP.)     PREVIOUS      GAS
                                                                                                                       RESULT        VEL
          (IN)            (MINS)    (CF)    (IN. H2O)    (DEGREES F)    (IN. H2O) (IN. H2O) (DEGR. F) (IN. H2O-DEG R)               (AFPM)


RUN NO. -     MDC-1P
 B-1      0.0   1116.0    0.0    757.806     1.23      60.0      56.0    0.360      -0.32     121.0        209.16          14.46       2147.5
 B-2      0.0   1119.5    3.5    761.800     1.45      65.0      56.0    0.420      -0.32     124.0        245.28          15.66       2325.6
 B-3      0.0   1123.0    7.0    764.100     1.38      72.0      57.0    0.400      -0.32     129.0        235.60          15.35       2279.2
 B-4      0.0   1126.5   10.5    766.400     1.40      74.0      58.0    0.410      -0.32     131.0        242.31          15.57       2311.4
 B-5      0.0   1130.0   14.0    768.800     1.30      77.0      60.0    0.380      -0.32     132.0        224.96          15.00       2227.2
 B-6      0.0   1133.5   17.5    771.000     1.20      79.0      60.0    0.350      -0.32     132.0        207.20          14.39       2137.4
 B-7      0.0   1137.0   21.0    773.200     1.28      80.0      61.0    0.370      -0.32     132.0        219.04          14.80       2197.7
 B-8      0.0   1140.5   24.5    775.400     2.08      81.0      62.0    0.610      -0.32     131.0        360.51          18.99       2819.4
 B-9      0.0   1144.0   28.0    778.600     2.28      83.0      63.0    0.670      -0.32     131.0        395.97          19.90       2954.8
 B-10     0.0   1147.5   31.5    780.800     2.03      82.0      64.0    0.600      -0.32     130.0        354.00          18.81       2793.8
 B-11     0.0   1151.0   35.0    783.700     1.97      83.0      64.0    0.570      -0.32     130.0        336.30          18.34       2723.1
 B-12     0.0   1154.5   38.5    786.700     1.81      84.0      65.0    0.530      -0.32     130.0        312.70          17.68       2625.8
 STOP           1158.0   42.0    789.043
 A-1      0.0   1203.0    0.0    789.043     0.82      73.0      64.0    0.240      -0.32     130.0        141.60          11.90       1767.0
 A-2      0.0   1206.5    3.5    791.000     0.78      75.0      64.0    0.230      -0.32     132.0        136.16          11.67       1732.7
 A-3      0.0   1210.0    7.0    792.700     0.74      78.0      65.0    0.220      -0.32     132.0        130.24          11.41       1694.6
 A-4      0.0   1213.5   10.5    794.300     0.85      79.0      65.0    0.250      -0.32     132.0        148.00          12.17       1806.5
 A-5      0.0   1217.0   14.0    796.400     0.70      80.0      65.0    0.200      -0.32     135.0        119.00          10.91       1619.8
 A-6      0.0   1220.5   17.5    797.700     0.62      81.0      66.0    0.180      -0.32     135.0        107.10          10.35       1536.7
 A-7      0.0   1224.0   21.0    799.400     1.72      84.0      67.0    0.500      -0.32     134.0        297.00          17.23       2559.0
 A-8      0.0   1227.5   24.5    802.100     2.32      88.0      68.0    0.680      -0.32     135.0        404.60          20.11       2986.8
 A-9      0.0   1231.0   28.0    805.000     2.80      90.0      69.0    0.820      -0.32     137.0        489.54          22.13       3285.4
 A-10     0.0   1234.5   31.5    808.100     3.00      92.0      70.0    0.870      -0.32     139.0        521.13          22.83       3389.8
 A-11     0.0   1238.0   35.0    811.200     2.80      93.0      70.0    0.810      -0.32     136.0        482.76          21.97       3262.6
 A-12     0.0   1241.5   38.5    814.900     2.58      94.0      70.0    0.750      -0.32     136.0        447.00          21.14       3139.4
 STOP           1245.0   42.0    817.560

                           TT       VM        PM             TM                     PST        TS
OVERALL RESULTS           84.0    59.754     1.63           72.0        0.476      -0.32     131.9        281.96          16.37       2430.1
                         (NET)    (NET)     (AVG)          (AVG)        (AVG)      (AVG)     (AVG)        (AVG)           (AVG)       (AVG)
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     GILBERT ASSOC., INC. - INDUSTRIAL DIVISION - ISOKINETIC SAMPLING ANALYSIS       11/11/88       PAGE  4
                                     LISTING OF FIELD DATA AND RESULTS AT EACH POINT

POINT    POINT     CLOCK   TIME   DRY GAS   ORIFICE  GAS TEMPERATURES  VELOCITY   STACK     STACK   (VEL. HD.)X    SQR ROOT OF  STACK
 NO.   DISTANCE    TIME   INCRMT   METER    DELTA H    IN        OUT     HEAD     PRESS      TEMP  (STACK TEMP.)   PREVIOUS     GAS
                                                                                                                  RESULT      VEL
         (IN)            (MINS)    (CF)   (IN. H2O)   (DEGREES F)   (IN. H2O) (IN. H2O) (DEGR. F) (IN. H2O-DEG R)             (AFPM)


RUN NO. -    MDC-2N
 B-1      0.0   1341.0   0.0   818.811    1.23     62.0     61.0    0.360     -0.42    137.0     214.92       14.66     2182.6
 B-2      0.0   1344.5   3.5   820.900    1.30     70.0     62.0    0.380     -0.42    138.0     227.24       15.07     2244.3
 B-3      0.0   1348.0   7.0   823.100    1.26     76.0     62.0    0.370     -0.42    138.0     221.26       14.87     2214.5
 B-4      0.0   1351.5  10.5   825.200    1.30     78.0     62.0    0.380     -0.42    139.0     227.62       15.09     2246.2
 B-5      0.0   1355.0  14.0   827.500    1.20     80.0     63.0    0.350     -0.42    138.0     209.30       14.47     2153.9
 B-6      0.0   1358.5  17.5   829.600    1.20     81.0     64.0    0.350     -0.42    138.0     209.30       14.47     2153.9
 B-7      0.0   1402.0  21.0   832.100    1.92     83.0     64.0    0.560     -0.42    141.0     336.56       18.35     2731.3
 B-8      0.0   1405.5  24.5   835.000    2.70     88.0     65.0    0.790     -0.42    141.0     474.79       21.79     3244.0
 B-9      0.0   1409.0  28.0   838.100    2.72     92.0     66.0    0.800     -0.42    139.0     479.20       21.89     3259.1
 B-10     0.0   1412.5  31.5   841.000    2.64     92.0     68.0    0.780     -0.42    138.0     466.44       21.60     3215.4
 B-11     0.0   1416.0  35.0   844.300    2.50     93.0     70.0    0.740     -0.42    136.0     441.04       21.00     3126.6
 B-12     0.0   1419.5  38.5   847.000    2.33     92.0     70.0    0.680     -0.42    138.0     406.64       20.17     3002.2
 STOP           1423.0  42.0   849.942
 A-1      0.0   1429.0   0.0   849.942    0.74     80.0     70.0    0.220     -0.42    130.0     129.80       11.39     1696.2
 A-2      0.0   1432.5   3.5   851.700    0.78     80.0     70.0    0.230     -0.42    131.0     135.93       11.66     1735.8
 A-3      0.0   1436.0   7.0   853.500    0.82     80.0     70.0    0.240     -0.42    132.0     142.08       11.92     1774.6
 A-4      0.0   1439.5  10.5   855.300    0.89     81.0     69.0    0.260     -0.42    133.0     154.18       12.42     1848.6
 A-5      0.0   1443.0  14.0   857.200    0.69     81.0     69.0    0.200     -0.42    135.0     119.00       10.91     1624.1
 A-6      0.0   1446.5  17.5   858.800    0.55     81.0     69.0    0.160     -0.42    137.0      95.52        9.77     1455.1
 A-7      0.0   1450.0  21.0   860.600    1.79     84.0     69.0    0.520     -0.42    137.0     310.44       17.62     2623.1
 A-8      0.0   1453.5  24.5   863.600    2.32     90.0     70.0    0.680     -0.42    130.0     401.20       20.03     2982.0
 A-9      0.0   1457.0  28.0   866.000    2.82     92.0     70.0    0.820     -0.42    130.0     483.80       22.00     3274.7
 A-10     0.0   1500.5  31.5   869.100    3.00     93.0     70.0    0.880     -0.42    139.0     527.12       22.96     3418.1
 A-11     0.0   1504.0  35.0   872.200    3.02     94.0     71.0    0.890     -0.42    140.0     534.00       23.11     3440.4
 A-12     0.0   1507.5  38.5   875.400    2.58     96.0     72.0    0.750     -0.42    139.0     449.25       21.20     3155.6
 STOP           1511.0  42.0   878.685

                          TT      VM        PM           TM                      PST       TS
OVERALL RESULTS          84.0    59.874    1.76         75.7          0.516     -0.42     136.4      308.19       17.02     2533.4
                         (NET)   (NET)     (AVG)        (AVG)         (AVG)     (AVG)     (AVG)       (AVG)        (AVG)     (AVG)
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APPENDIX 8

SAMPLE CALCULATIONS

SAMPLE CALCULATIONS

Particulate Isokinetic Sampling

I. Calculations for stack volume and Isokinetic Ratio

Time	Dry Gas Meter Ft^3	Pitot ΔP, In.H_2O	Orifice ΔH, In.H_2O	Dry Gas Temp °F		Stack Static Pressure In. H_2O	Stack Temp °F
				In	Out		
T	VM	ΔP	PM	TMI	TMO	PST	TS

1. DN = Nozzle Diameter, inches

2. PB = Barometric Pressure, inches Hg

3. TT = Net Sampling Time, minutes

4. VM = VM final - VM initial = Sample Gas Volume, ft^3

5. TM = Average Dry Gas Temperature at Meter, °F

$$TM = \frac{\text{Avg. TMI} + \text{Avg. TMO}}{2}$$

6. PM = Average Orifice Pressure Drop, inches H_2O

$$PM = \text{Avg. } \Delta H$$

7. Volume of dry gas sampled at standard conditions[a], DSCF

$$VMSTD = \frac{17.65 \times VM \times Y \left(BP + \frac{PM}{13.6}\right)}{(TM + 460)}$$

8. VW = Total Water Collected = gm H_2O Silica gel + ml Imp. H_2O = ml

9. Volume of water vapor at standard conditions[b], SCF

$$VW\ gas = 0.0471 \times VW = SCF$$

10. Percent moisture in stack gas

$$\%\ M = \frac{100 \times VW\ gas}{VM\ STD + VW\ gas}$$

11. Mole fraction of dry gas

$$MD = \frac{100 - \%M}{100}$$

12. Molecular weight of dry stack gas

$$MWD = (\%CO_2 \times \frac{44}{100}) + (\%O_2 \times \frac{32}{100}) + \left[(\%CO + \%N_2) \times \frac{28}{100} \right]$$

12A. $$\%EA = \%\text{ Excess Air} = \frac{[(\%\ O_2) - 0.5\ (\%CO)]}{0.264\ (\%N_2) - [(\%O_2) + 0.5\%\ (CO)]} \times 100$$

13. Molecular weight of wet stack gas

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

14. AS = Stack Area, square inches

15. PS = Stack Pressure, inches Hg

$$PS = PB \pm \text{Avg. } PST$$

NOTE: $$PST\text{ in. Hg.} = \frac{PST\text{ in. } H_2O}{13.6}$$

16. TS = Average Stack Temperature, °F

TS = Average TS

17. $$SDE = \text{Average } \sqrt{\text{Velocity Head } (\Delta P) \times (\text{Stack Temperature} + 460)}$$

(Calculated each line)

$$SDE = \text{Avg } \sqrt{\Delta P \times (TS + 460)}$$

18. Stack gas velocity at stack conditions, fpm

$$VS = 5130 \times Cp \times \text{Avg}(SDE) \times \left[\frac{1}{PS \times MW}\right]^{1/2} = FPM$$

Cp = pitot tube coefficient

19. Stack gas volumetric flow rate at standard conditions[c], DSCFM

$$Q_s = \frac{0.123 \times VS \times AS \times MD \times PS}{(TS + 460)} = DSCFM$$

20. Stack gas volumetric flow rate at stack conditions, ACFM

$$Q_a = \frac{.05667 \times QS\ (TS + 460)}{PS \times MD} = ACFM$$

21. Percent isokinetic

$$\%I = \frac{1{,}032 \times (TS + 460) \times VMSTD}{VS \times TT \times PS \times MD \times (DN)^2}$$

NOTES: [a] Dry standard cubic feet at 69°F, 29.92 in. Hg.

[b] Standard conditions at 68°F, 29.92 in. Hg.

[c] Dry standard cubic feet per minute at 68°F, 29.92 in. Hg.

II. Calculations for grain loading and emission rates

22. Particulate, gr/DSCF

$$gr/DSCF = 0.0154 \times \frac{mg}{VMSTD}$$

23. Particulate at stack conditions, gr/ACF

$$gr/ACF = \frac{17.65\ gr/DSCF \times PS \times MD}{(TS + 460)}$$

24. Particulate, lb/hr conc. method

$$lb/hr = 0.00857 \times gr/DSCF \times QS$$

25. Particulate lb/hr area method $= 0.132 \times \dfrac{\text{gms particulate} \times AS}{\left(\dfrac{DN^2}{2}\right) \times TT}$

26. Particulate, combustion

$$\frac{lb/hr}{10^6\ BTU/hr}$$

27. Particulate, process lb/ton

$$lb/ton = \frac{lb/hr}{tons/hr}$$

28. Particulate, lb/MMBTU, F-Factor Method =

Using O_2 =

$$\frac{0.0154 \times mg \times \text{F-Factor} \times 20.9}{7000 \times VMSTD \times (20.9 - \%O_2)}$$

Using CO_2:

$$\frac{0.0154 \times mg \times \text{F-Factor} \times 100}{7000 \times VMSTD \times \%\ CO_2}$$

29. F-Factor, dscf/mmBtu

O_2 Format:

$$\text{F-Factor} = \frac{10^6(3.64(\%H)+1.53(\%C)+0.57(\%S)+0.14(\%N)-0.46(\%O_2))}{GCV}$$

CO_2 Format:

$$\frac{10^6(0.321)(\%C)}{GCV}$$