

Summary

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New Document:

[Method 1 - Sample And Velocity Traverses For Stationary Sources](#)

36 pages (562 KB)

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Old Document:

[m-01](#)

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1.0 Scope and Application.

Method 1 - Sample And Velocity Traverses For Stationary Sources

NOTE: This method does not include all of the specifications (*e.g.*, equipment and supplies) and procedures (*e.g.*, sampling) essential to its performance. Some material is incorporated by reference from other methods in this part. Therefore, to obtain reliable results, persons using this method should have a thorough knowledge of at least the following additional test method: **Method 2**.

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1.1 Measured Parameters.

The purpose of the method is to provide guidance for the selection of sampling ports and traverse points at which sampling for air pollutants will be performed pursuant to regulations set forth in this part. Two procedures are presented: a simplified procedure, and an alternative procedure (see Section 11.5). The magnitude of cyclonic flow of effluent gas in a stack or duct is the only parameter quantitatively measured in the simplified procedure.

1.2 Applicability.

This method is applicable to gas streams flowing in ducts, stacks, and flues. This method cannot be used when: (1) the flow is cyclonic or swirling; or (2) a stack is smaller than 0.30 meter (12 in.) in diameter, or 0.071 m² (113 in.²) in cross-sectional area. The simplified procedure cannot be used when the measurement site is less than two stack or duct diameters downstream or less than a half diameter upstream from a flow disturbance.

1.3 Data Quality Objectives.

Adherence to the requirements of this method will enhance the quality of the data obtained from air pollutant sampling methods.

NOTE: The requirements of this method must be considered before construction of a new facility from which emissions are to 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.

2.0 Summary of Method.

2.1 This method is designed 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. Traverse points are then located within each of these equal areas.

3.0 Definitions. [Reserved]

4.0 Interferences. [Reserved]

5.0 Safety.

5.1 Disclaimer.

This method may involve hazardous materials, operations, and equipment. This test method may not address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to performing this test method.

6.0 Equipment and Supplies.

6.1 Apparatus.

The apparatus described below is required only when utilizing the alternative site selection procedure described in Section 11.5 of this method.

6.1.1 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. Before using the Probe, 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 procedure for cleaning the pressure holes by "back-purging" with pressurized air is required.

6.1.2 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, Section 6.2.**

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,**

Section 6.2.

7.0 Reagents and Standards. [Reserved]

8.0 Sample Collection, Preservation, Storage, and Transport. [Reserved]

9.0 Quality Control. [Reserved]

10.0 Calibration and Standardization. [Reserved]

11.0 Procedure.

11.1 Selection of Measurement Site.

11.1.1 Sampling and/or velocity measurements are 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.

11.1.2 An alternative procedure is available for determining the acceptability of a measurement location not meeting the criteria above. This procedure described in Section 11.5 allows for the determination of gas flow angles at the sampling points and comparison of the measured results with acceptability criteria.

11.2 Determining the Number of Traverse Points.

11.2.1 Particulate Traverses.

11.2.1.1 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 and 24 in.); and (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12 and 24 in.).

11.2.1.2 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 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.

11.2.2 Velocity (Non-Particulate) Traverses.

When velocity or volumetric **flow rate** is to be determined (but not particulate matter), the same procedure as that used for particulate traverses (Section 11.2.1) is followed, except that Figure 1-2 may be used instead of Figure 1-1.

11.3 Cross-Sectional Layout and Location of Traverse Points.

11.3.1 Circular Stacks.

11.3.1.1 Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (see examples in References 2 and 3 in Section 16.0) that gives the same values as those in Table 1-2 may be used in lieu of Table 1-2.

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

11.3.1.3 In addition, for elliptical stacks having unequal perpendicular diameters, separate traverse points shall be calculated and located along each diameter. To determine the cross-sectional area of the elliptical stack, use the following equation:

$$\text{Square Area} = D_1 \times D_2 \times 0.7854$$

Where: D_1 = Stack diameter 1

D_2 = Stack diameter 2

11.3.1.4 In addition, for stacks having diameters greater than 0.61 m (24 in.), no traverse points shall be 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.

11.3.2 Stacks With Diameters Greater Than 0.61 m (24 in.).

11.3.2.1 When any of the traverse points as located in Section 11.3.1 fall within 2.5 cm (1.0 in.) of the stack walls, relocate them away from the stack walls to: (1) a distance of 2.5 cm (1.0 in.); or (2) a distance equal to the probe nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

11.3.2.2 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 and/or velocity measurement procedure, and in recording of the data.

11.3.3 Stacks With Diameters Equal To or Less Than 0.61 m (24 in.).

Follow the procedure in Section 11.3.1.1, 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 probe nozzle inside diameter, whichever is larger.

11.3.4 Rectangular Stacks.

11.3.4.1 Determine the number of traverse points as explained in Sections 11.1 and 11.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

11.3.4.2 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 x 3 "minimum number of points" matrix were expanded to 36 points, the final matrix could be 9 x 4 or 12 x 3, and would not necessarily have to be 6 x 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.

11.3.4.3 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.

11.4 Verification of Absence of Cyclonic flow.

11.4.1 In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi

scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

11.4.2 Level and zero the manometer. Connect a **Type S pitot tube** to the manometer and leak-check system. 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 $\pm 90^\circ$ yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle ($^\circ$) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of $^\circ$; assign $^\circ$ values of 0 to those points for which no rotation was required, and include these in the overall average. If the average value of $^\circ$ 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.

11.5 The Alternative Site Selection

The alternative site selection procedure may be used to determine the rotation angles in lieu of the procedure outlined in Section 11.4.

11.5.1 Alternative Measurement Site Selection Procedure.

This alternative applies to sources where measurement locations are less than 2 equivalent or duct diameters downstream or less than one-half 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 **flowsensing 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.

11.5.2 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 the procedure outlined in Section 11.3 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.

11.5.3 Measurement Procedure.

11.5.3.1 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.) **H₂O** 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.

11.5.3.2 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.

11.5.3.3 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.

11.5.3.4 A post-test check as described in Section 11.5.3.1 is required. If the criteria for a leak-free system are not met, repair the equipment, and repeat the flow angle measurements.

11.5.4 calibration.

Use a flow system as described in Sections 10.1.2.1 and **10.1.2.2 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 (1,200 and 2,400 ft/min) and one between 730 and 1,100 m/min (2,400 and 3,600 ft/min).

11.5.4.1 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 or 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.

11.5.4.2 To ensure that the gas flow is parallel to the central axis of the test section, follow the procedure outlined in Section 11.4 for cyclonic flow determination to measure the gas flow angles at the centroid of the test section from two test ports located **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.

11.5.4.3 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**.

11.5.4.4 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-dimensional **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.

12.0 Data Analysis and Calculations.

12.1 Nomenclature.

L = length

n = total number of traverse points.

P_i = pitch angle at traverse point **i**, degree.

R_{avg} = average resultant angle, degree.

R_i = resultant angle at traverse point **i**, degree.

S_d = standard deviation, degree.

W = width.

Y_i = yaw angle at traverse point i, degree.

12.2 For a rectangular cross section

An equivalent diameter (D_e) shall be calculated using the following equation, to determine the upstream and downstream distances:

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

Eq. 1-1

12.3 If use of the alternative site selection procedure (Section 11.5 of this method) is required

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

12.3.1 Calculate the resultant angle at each traverse point:

$$R_i = \arccos [(\cos Y_i)(\cos P_i)]$$

Eq. 1-2

12.3.2 Calculate the average resultant for the measurements:

$$R_{avg} = \sum R_i/n$$

Eq. 1-3

12.3.3 Calculate the standard deviations:

$$S_d = \sqrt{\frac{\sum_{i=1}^n (R_i - R_{avg})^2}{(n-1)}}$$

Eq. 1-4

12.3.4 Acceptability Criteria.

The measurement location is acceptable if $R_{\text{avg}} \leq 20$ and $S_d \leq 10$.

13.0 Method Performance. [Reserved]

14.0 Pollution Prevention. [Reserved]

15.0 Waste Management. [Reserved]

16.0 References.

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14. Gerhart, P.M. and M.J. Dorsey. Investigation of Field Test Procedures for Large Fans. University of Akron. Akron, OH. (EPRI Contract **CS-1651**). Final Report (**RP-1649- 5**). December 1980.
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17.0 Tables, Diagrams, flowcharts, and Validation Data.

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

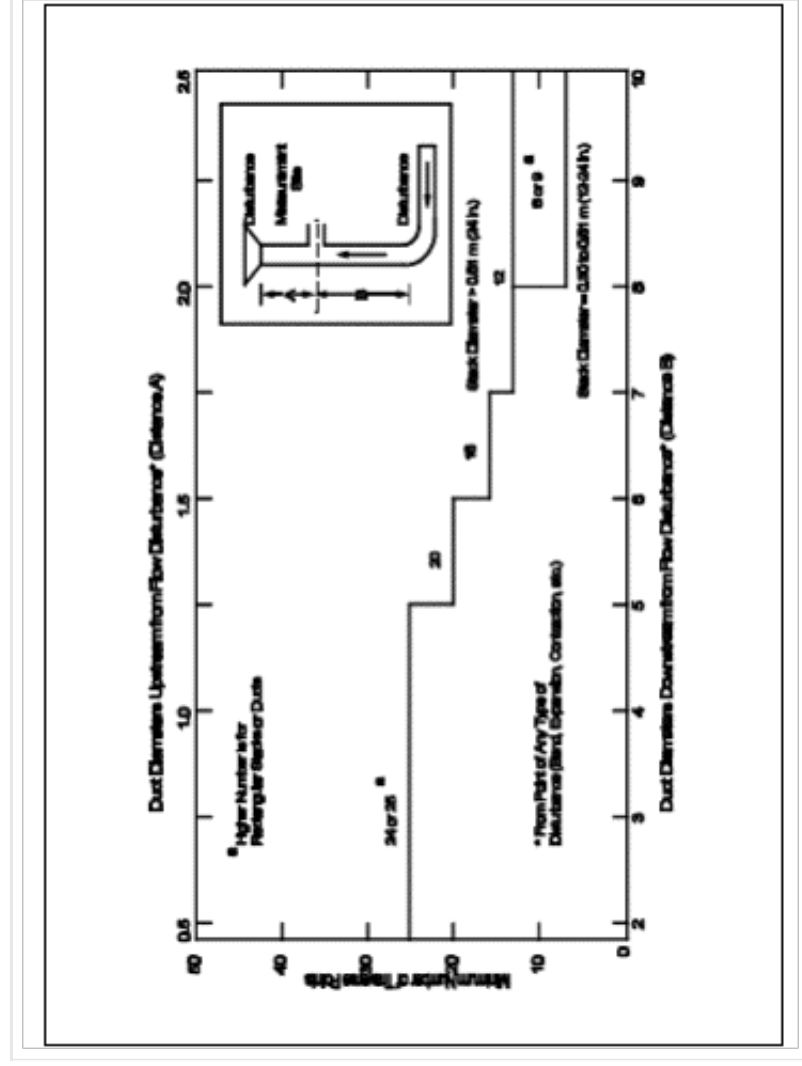


TABLE 1-1. CROSS-SECTION LAYOUT FOR

RECTANGULAR STACKS

Number of traverse points Matrix layout ▶

9 3 x 3 ▶
12 4 x 3 ▶
16 4 x 4 ▶
20 5 x 4 ▶
25 5 x 5 ▶
30 6 x 5 ▶
36 6 x 6 ▶
42 7 x 6 ▶
49 7 x 7 ▶

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

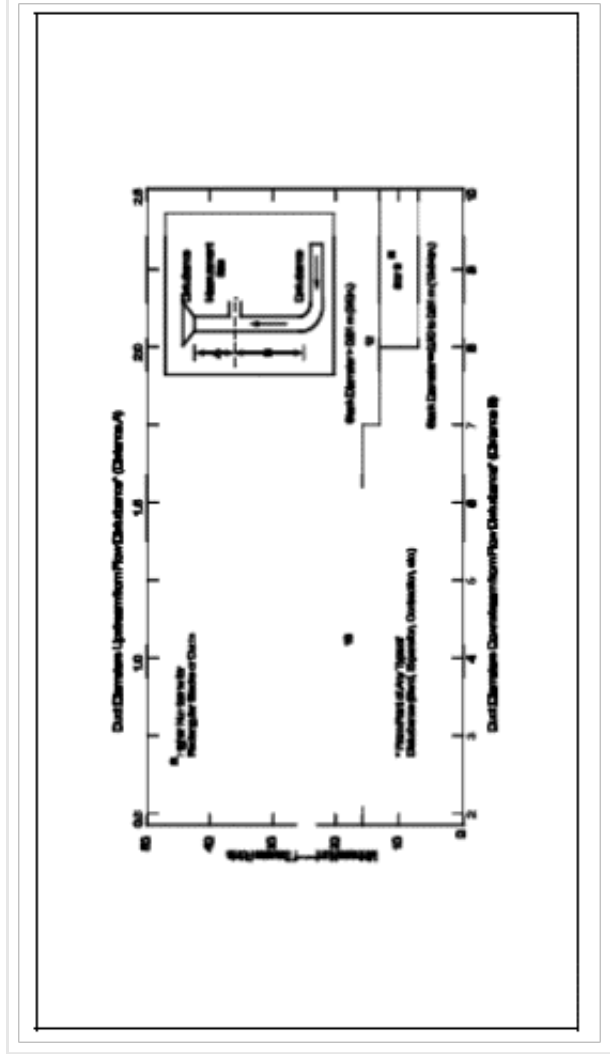


TABLE 1-2

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

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

Traverse Point	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	8.7	4.4	3.2	2.8	2.3	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.8	10.2	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2	3.2
3	35.0	22.5	16.4	14.5	11.9	10.0	8.5	7.5	6.7	6.0	5.5	5.3
4	45.0	30.4	22.3	22.6	17.7	14.6	12.3	10.9	9.7	8.7	7.9	7.4
5	55.0	38.7	28.4	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5	9.9
6	65.0	46.8	35.8	43.9	32.5	26.9	22.0	18.9	16.5	14.6	13.2	12.2
7	75.0	54.8	43.4	53.6	39.6	32.5	26.9	22.0	18.9	16.5	14.6	13.2
8	85.0	62.7	51.1	63.6	46.4	37.5	30.6	25.0	21.8	18.6	16.4	14.6
9	95.0	70.4	58.8	73.1	53.6	39.6	32.5	26.9	23.6	20.2	17.0	14.6
10	105.0	78.1	66.4	82.6	61.3	44.5	35.8	29.7	25.0	21.8	18.6	16.4
11	115.0	85.8	74.1	92.1	69.6	51.1	41.3	33.2	27.5	23.6	20.2	17.0
12	125.0	93.5	81.8	101.6	77.9	58.8	48.2	38.7	31.2	26.9	23.6	20.2
13	135.0	101.2	89.5	111.1	86.4	66.4	55.1	44.5	35.8	30.6	26.9	23.6
14	145.0	108.9	97.2	120.6	94.8	74.1	62.7	51.1	41.3	35.8	31.2	26.9
15	155.0	116.6	104.9	130.1	103.1	82.6	70.4	58.8	48.2	41.3	35.8	31.2
16	165.0	124.3	112.6	139.6	111.4	91.2	78.1	66.4	55.1	44.5	41.3	35.8
17	175.0	132.0	120.3	149.1	119.7	100.0	85.8	73.1	62.7	51.1	44.5	41.3
18	185.0	139.7	128.0	158.6	128.0	108.9	93.5	80.6	69.6	58.8	51.1	44.5
19	195.0	147.4	135.7	168.1	136.3	117.8	101.2	88.7	77.9	66.4	58.8	51.1
20	205.0	155.1	143.4	177.6	144.6	126.9	110.0	96.8	86.4	74.1	66.4	58.8
21	215.0	162.8	151.1	187.1	152.9	136.0	118.9	104.9	94.8	82.6	74.1	66.4
22	225.0	170.5	158.8	196.6	161.2	145.1	127.8	113.8	103.7	91.2	82.6	74.1
23	235.0	178.2	166.5	206.1	169.5	154.2	136.9	122.7	112.6	99.6	91.2	82.6
24	245.0	185.9	174.2	215.6	177.8	163.3	146.0	131.6	121.5	108.5	99.6	91.2

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

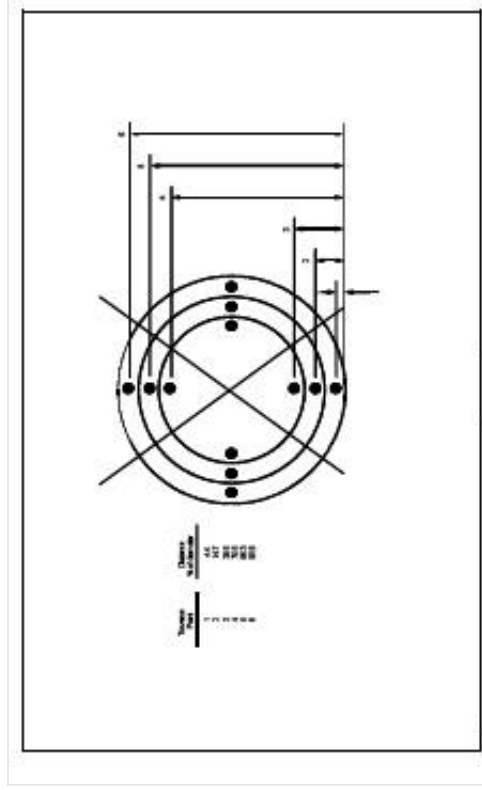
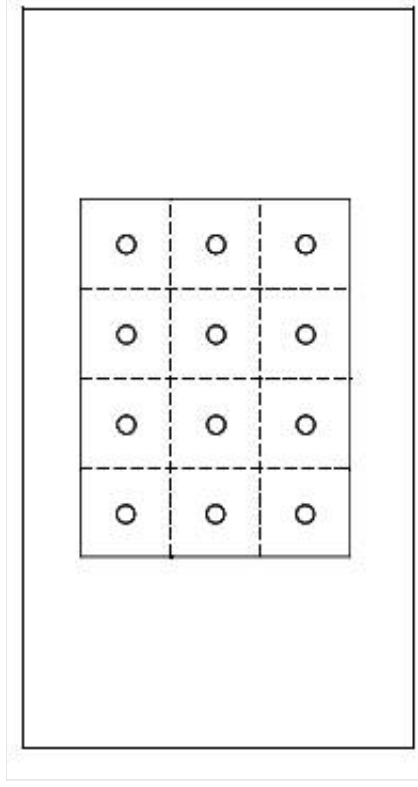


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with traverse points at centroid of each area.



Method 2 - Determination Of Stack Gas Velocity And Volumetric Flow Rate (Type S Pitot Tube)

NOTE: This method does not include all of the specifications (*e.g.*, equipment and supplies) and procedures (*e.g.*, sampling) essential to its performance. Some material is incorporated by reference from other methods in this part. Therefore, to obtain reliable results, persons using this method should have a thorough knowledge of at least the following additional test method: **Method 1.**

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1.1 This method is applicable for the determination of the average velocity and the volumetric flow rate of a gas stream.

1.2 This method is not applicable at measurement sites that fail to meet the criteria of **Method 1, Section 11.1.** Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams;

Section 11.4 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, must be employed to produce 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.

1.3 Data Quality Objectives. Adherence to the requirements of this method will enhance the quality of the data obtained from air pollutant sampling methods.

2.0 Summary of Method.

2.1 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.

3.0 Definitions. [Reserved]

4.0 Interferences. [Reserved]

5.0 Safety.

5.1 Disclaimer.

This method may involve hazardous materials, operations, and equipment. This test method may not address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to performing this test method.

6.0 Equipment and Supplies.

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.

6.1 Type S Pitot Tube.

6.1.1 pitot tube made of metal tubing (e.g., stainless steel)

As shown in Figure 2-1. It is recommended that the external tubing diameter (dimension D_t , Figure 2-2b) be between 0.48 and 0.95 cm (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).

6.1.2 The Type S Pitot Tube shall have a known coefficient

Determined as outlined in Section 10.0. An identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube. A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 6.7 and 10.2. Note, however, that the static and impact pressure holes of standard pitot tube s 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 accomplished by comparing the velocity head (Δp) measurement recorded at a selected traverse point (readable Δp value) with a second Δp measurement recorded after "back purging" with pressurized air to clean the impact and static holes of the standard pitot tube . If the

before and after Δp measurements are within 5 percent, then the traverse data are acceptable. Otherwise, the data should be rejected and the traverse measurements redone. Note that the selected traverse point should be one that demonstrates a readable Δp value. If "back purging" at regular intervals is part of a routine procedure, then comparative Δp measurements shall be conducted as above for the last two traverse points that exhibit suitable Δp measurements.

6.2 Differential Pressure Gauge.

An inclined manometer or equivalent device. 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 1.27 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 1.27 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 1.27 mm (0.05 in.) H_2O ; or (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.27 mm (0.05 in.) H_2O . Reference 18 (see Section 17.0) describes commercially available instrumentation for the measurement of low-range gas velocities.

6.2.1 As an alternative to criteria (1) through (3) above, Equation 2-1 (Section 12.2) may be used to determine the necessity of using a more sensitive differential pressure gauge. 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.

6.3 Temperature Sensor.

A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in glass thermometer, or other gauge capable of measuring temperatures to within 1.5 percent of the minimum absolute stack

temperature. The Temperature Sensor 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 Figure 2-4). Alternative positions may be used if the pitot tube-temperature gauge system is calibrated according to the procedure of Section 10.0. 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.

6.4 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. 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.

6.5 barometer.

A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.54 mm (0.1 in.) Hg.

NOTE: The barometric pressure reading may be obtained from a nearby National Weather Service station. In this 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 made at a rate of minus 2.5 mm (0.1 in.) Hg per 30 m (100 ft) elevation increase or plus 2.5 mm (0.1 in.) Hg per 30 m (100 ft.) for elevation decrease.

6.6 Gas Density Determination equipment.

Method 3 equipment, if needed (see Section 8.6), to determine the stack gas dry molecular weight, and **Method 4** (reference method) or **Method 5** equipment for moisture content determination. Other methods may be used subject to approval of the Administrator. ▶

6.7 Calibration Pitot Tube.

When calibration of the Type S Pitot Tube is necessary (see Section 10.1), a **standard pitot tube** shall be used for a reference. The **standard pitot tube** shall, preferably, have a known coefficient, obtained either (1) directly from the National Institute of Standards and Technology (NIST), Gaithersburg MD 20899, (301) 975-2002, or (2) by calibration against another **standard pitot tube** with an NIST-traceable coefficient. Alternatively, a **standard pitot tube** designed according to the criteria given in Sections 6.7.1 through 6.7.5 below and illustrated in Figure 2-5 (see also References 7, 8, and 17 in Section 17.0) may be used. pitot tubes designed according to these specifications will have baseline coefficients of 0.99 ± 0.01 .

6.7.1 Standard Pitot Design.

6.7.1.1 Hemispherical (shown in Figure 2-5), ellipsoidal, or conical tip.

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

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

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

6.7.1.5 90 bend, with curved or mitered junction.

6.8 Differential Pressure Gauge for Type S Pitot Tube calibration.

An inclined manometer or equivalent. If the single-velocity calibration technique is employed (see Section 10.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.127 mm (0.005 in.) H₂O. For multivelocity calibrations, the gauge shall be readable to the nearest 0.127 mm (0.005 in.) H₂O for Δp values between 1.27 and 25.4 mm (0.05 and 1.00 in.) H₂O, and to the nearest 1.27 mm (0.05 in.) H₂O for Δp values above 25.4 mm (1.00 in.) H₂O. A special, more sensitive gauge will be required to read Δp values below 1.27 mm (0.05 in.) H₂O (see Reference 18 in Section 16.0).

7.0 Reagents and Standards. [Reserved]

8.0 Sample Collection and Analysis.

8.1 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 (3.0 in.) H₂O velocity head 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 (3.0 in.) H₂O. Other leak-check procedures, subject to the approval of the Administrator, may be used.

8.2 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 (at least once per hour). Record all necessary data on a form similar to that shown in Figure 2-6.

8.3 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 6.2). 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 8.1 above, to validate the traverse run.

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

8.5 Determine the atmospheric pressure.

8.6 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.

8.7 Obtain the moisture content from Method 4 (reference method, or equivalent) or from Method 5.

8.8 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. Do not assume that stack diameters are equal. Measure each diameter distance to verify its dimensions.

9.0 Quality Control.

Section	Quality Control Measure	Effect
10.1-10.4	Sampling equipment calibration	Ensure accurate measurement of stack gas flow rate, sample volume

10.0 Calibration and Standardization.

10.1 Type S Pitot Tube.

Before its initial use, carefully examine the Type S Pitot Tube top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figures 2-2 and 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 10.1.2 through 10.1.5, 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 10.1.1). If D_T , P_A , and P_B are outside the specified limits, the pitot tube must be calibrated as outlined in Sections 10.1.2 through 10.1.5.

10.1.1 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 (*e.g.*, thermocouple, sampling Probe, 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 (Reference 9 in Section 17.0); 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 2-4, 2-7, and 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 2-4, 2-7, and 2-8 shall be calibrated according to the procedure outlined in Sections 10.1.2 through 10.1.5, and prior to calibration, the values of the intercomponent spacings (pitot-probe nozzle, pitot-thermocouple, pitot-Probe sheath) shall be measured and recorded.

NOTE: Do not use a Type S Pitot Tube assembly that is constructed such that the impact pressure opening plane of the pitot tube is below the entry plane of the probe nozzle (see Figure 2-6B).

10.1.2 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 performed in a flow system having the following essential design features:

10.1.2.1 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 30.48 cm (12 in.); for rectangular cross sections, the width (shorter side) shall be at least 25.4 cm (10 in.).

10.1.2.2 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 according to Equation 2-2 (see Section 12.3), to determine the number of duct diameters. 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 has been demonstrated to be or found stable and parallel to the duct axis.

10.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 910 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 910 m/min (3,000 ft/min) will generally be valid to ± 3 percent for the measurement of velocities above 300 m/min (1,000 ft/min) and to ± 6 percent for the measurement of velocities between 180 and 300 m/min (600 and 1,000 ft/min). If a more precise correlation between the pitot tube coefficient (C_p), and velocity is desired, the flow system should have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,500 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see References 9 and 14 in Section 17.0 for details).

10.1.2.4 Two entry ports, one for each of 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.

10.1.3 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 10.1.5. 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:

10.1.3.1 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.

10.1.3.2 Level and zero the manometer. Switch on the fan, and allow the flow to stabilize. Seal the Type S Pitot Tube entry port.

10.1.3.3 Ensure that the manometer is level and zeroed. Position the **standard pitot tube** at the calibration point (determined as outlined in Section 10.1.5.1), and align the tube so that its tip is pointed directly into the flow. Particular care should be taken in aligning the tube to avoid yaw and pitch angles. Make sure that the entry port surrounding the tube is properly sealed.

10.1.3.4 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.

10.1.3.5 Connect the Type S Pitot Tube to the manometer and leak-check. Open the Type S tube 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.

10.1.3.6 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.

10.1.3.7 Repeat Steps 10.1.3.3 through 10.1.3.6 until three pairs of Δp readings have been obtained for the A side of the Type S Pitot Tube.

10.1.3.8 Repeat Steps 10.1.3.3 through 10.1.3.7 for the B-side of the Type S Pitot Tube.

10.1.3.9 Perform calculations as described in Section 12.4. Use the Type S Pitot Tube only if the values of F_A and F_B are less than or equal to 0.01 and if the absolute value of the difference between $C_{p(A)}$ and $C_{p(B)}$ is 0.01 or less.

10.1.4 Special Considerations.

10.1.4.1 Selection of calibration Point.

10.1.4.1.1 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 Section 10.1.3. The Type S pitot coefficients measured or calculated, [i.e. $C_{p(A)}$ and $C_{p(B)}$] will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (probe nozzle, thermocouple, sample Probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-4, 2-7, and 2-8).

10.1.4.1.2 For Type S Pitot Tube-thermocouple combinations (without Probe assembly), select a calibration point at or near the center of the duct, and follow the procedures outlined in Section 10.1.3.

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 2-4, 2-7, and 2-8).

10.1.4.1.3 For Type S Pitot Tube combinations with complete Probe assemblies, 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 interference and blockage and yield incorrect coefficient values (Reference 9 in Section 17.0). 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).

10.1.4.2 For those Probe assemblies in which pitot tube-probe nozzle interference is a factor (*i.e.*, those in which the pitot-probe nozzle separation distance fails to meet the specifications illustrated in Figure 2-7A), the value of $C_{p(s)}$ depends upon the amount of free space between the tube and probe nozzle and, therefore, is a function of probe nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used probe nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger probe nozzle sizes (>0.635 cm or $1/4$ in.) are not ordinarily used for isokinetic sampling at velocities around 910 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 Reference 19 in Section 17.0).

10.1.4.3 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 (F) value of 0.01 or less (see Section 10.1.4.4).

10.1.5 Field Use and Recalibration.

10.1.5.1 Field Use.

10.1.5.1.1 When a Type S Pitot Tube (isolated or in an 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.

10.1.5.1.2 When a Probe assembly is used to sample a small duct, 30.5 to 91.4 cm (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 Reference 9 (see Section 17.0) for details. Conventional pitot-sampling Probe assemblies are not recommended for use in ducts having inside diameters smaller than 30.5 cm (12 in.) (see Reference 16 in Section 17.0).

10.1.5.2 Recalibration.

10.1.5.2.1 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 and 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 and 2-3, the damage shall either be repaired to restore proper alignment of the face openings, or the tube shall be discarded.

10.1.5.2.2 Type S Pitot Tube. After each field use, check the face opening alignment of the pitot tube, as in Section 10.1.5.2.1. 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 Figure 2-2 and Figure 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.

10.2 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 6.7 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).

10.3 Temperature Sensors.

10.3.1 After each field use, calibrate dial thermometers, liquid-filled bulb thermometers, thermocouple potentiometer systems, and other sensors at a temperature within 10 percent of the average absolute stack temperature. For temperatures up to 405C (761F), use an ASTM mercury in-glass reference thermometer, or equivalent, as a reference. Alternatively, either a reference thermocouple and potentiometer (calibrated against NIST standards) or thermometric fixed points (*e.g.*, ice bath and boiling water, corrected for barometric pressure) may be used. For temperatures above 405C (761F), use a reference thermocouple-potentiometer system calibrated against NIST standards or an alternative reference, subject to the approval of the Administrator. ▶

10.3.2 The temperature data recorded in the field shall be considered valid. If, during calibration, the absolute temperature measured with the sensor being calibrated and the reference sensor 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.

10.4 barometer.

Calibrate the barometer used against a mercury barometer.

11.0 Analytical Procedure.

Sample collection and analysis are concurrent for this method (see Section 8.0).

12.0 Data Analysis and Calculations.

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

12.1 Nomenclature.

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

B_{ws} = Water vapor in the gas stream [from **Method 4** (reference method) or **Method 5**], proportion by volume.

C_p = pitot tube coefficient, dimensionless.

C_{p(s)} = Type S Pitot Tube coefficient, dimensionless.

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 6.7.1 to 6.7.5 of this method.

D_e = Equivalent diameter.

K = 0.127 mm H₂O (metric units) = 0.005 in. H₂O (English units).

K_p = Velocity equation constant.

L = Length.

M_d = Molecular weight of stack gas, dry basis (see Section 8.6), g/g-mole (lb/lb-mole).

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

n = Total number of traverse points.

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

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

P_s = Absolute stack pressure ($P_{bar} + P_g$), mm Hg (in. Hg),

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 = Sensitivity factor for differential pressure gauges .

T_s = Stack temperature, C (F).

$T_{s(abs)}$ = Absolute stack temperature, K (R).

= 273 + T_s for metric units,

= 460 + T_s for English units.

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

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

W = Width.

Δp = Velocity head of stack gas, mm H₂O (in. H₂O).

Δp_i = Individual velocity head reading at traverse point "i", mm (in.) H₂O.

Δp_{std} = Velocity head measured by the **standard pitot tube** , cm (in.) H₂O.

Δp_s = Velocity head measured by the Type S Pitot Tube, cm (in.) H₂O.

3600 = Conversion Factor, sec/hr.

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

12.2 Calculate T as follows:

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

Eq. 2-1

12.3 Calculate D_e as follows:

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

Eq. 2-2

12.4 calibration of Type S Pitot Tube.

12.4.1 For each of the six pairs of Δp readings (i.e., three from side A and three from side B) obtained in Section 10.1.3, calculate the value of the Type S Pitot Tube coefficient according to Equation 2-3:

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

Eq. 2-3

12.4.2 Calculate $C_{p(A)}$, the mean A-side coefficient, and $C_{p(B)}$, the mean B-side coefficient. Calculate the difference between these two average values.

12.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $C_{p(A)}$, and the deviation of each of the three B-side values of $C_{p(s)}$ from $C_{p(B)}$, using Equation 2-4:

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

Eq. 2-4

12.4.4 Calculate F, the average deviation from the mean, for both the A and B sides of the pitot tube. Use Equation 2-5:

$$F_{A \text{ or } B} = \frac{\sum_{i=1}^3 |C_{p(s)} - \bar{C}_{p(A \text{ or } B)}|}{3}$$

Eq. 2-5

12.5 Molecular Weight of Stack Gas.

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

Eq. 2-6

12.6 Average Stack Gas Velocity.

$$v_s = K_p C_p \sqrt{\Delta P_{avg}} \sqrt{\frac{T_s^{(abs)}}{P_s M_s}}$$

Eq. 2-7

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

Metric

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

English

12.7 Average Stack Gas Dry Volumetric flow rate.

$$Q = 3600(1 - B_{ws}) v_s A \left[\frac{T_{std} P_s}{T_s^{(abs)} P_{std}} \right]$$

Eq. 2-8

13.0 Method Performance. [Reserved]

14.0 Pollution Prevention. [Reserved]

15.0 Waste Management. [Reserved]

16.0 References.

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 16. Vollaro, R.F. Recommended Procedure for Sample Traverses in Ducts Smaller than 12 Inches in Diameter. U.S. Environmental Protection Agency, Emission Measurement Branch, Research Triangle Park, NC. November 1976.
 17. Ower, E. and R.C. Pankhurst. The Measurement of Air flow, 4th Ed. London, Pergamon Press. 1966.
 18. Vollaro, R.F. A Survey of Commercially Available Instrumentation for the Measurement of Low-Range Gas Velocities. U.S. Environmental Protection Agency, Emission Measurement Branch, Research Triangle Park, NC. November 1976. (Unpublished Paper).
 19. Gnyp, A.W., *et al.* An Experimental Investigation of the Effect of pitot Tube-Sampling Probe Configurations on the Magnitude of the S Type pitot Tube Coefficient for Commercially Available Source Sampling Probes. Prepared by the University of Windsor for the Ministry of the Environment, Toronto, Canada. February 1975.

17.0 Tables, Diagrams, flowcharts, and Validation Data.

Figure 2-1. Type S Pitot Tube manometer Assembly.

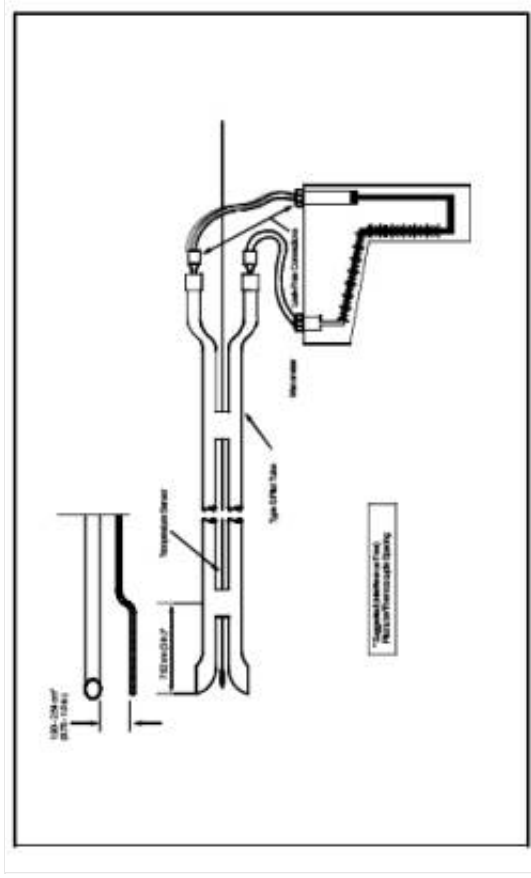


Figure 2-2. Properly Constructed Type S Pitot Tube.

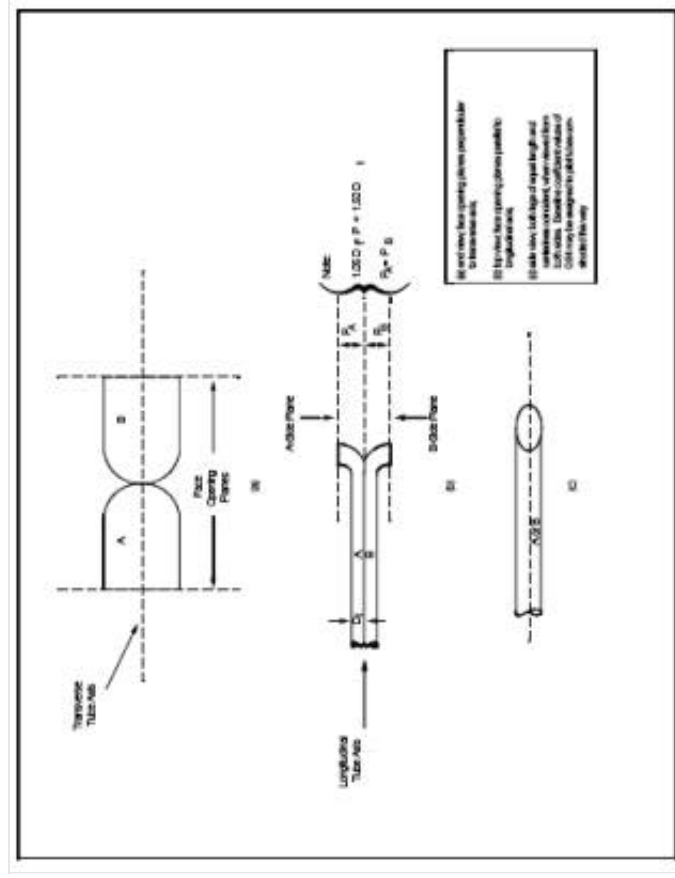


Figure 2-3. Types of face-opening misalignments that can result from field use or improper construction of Type S Pitot Tubes.

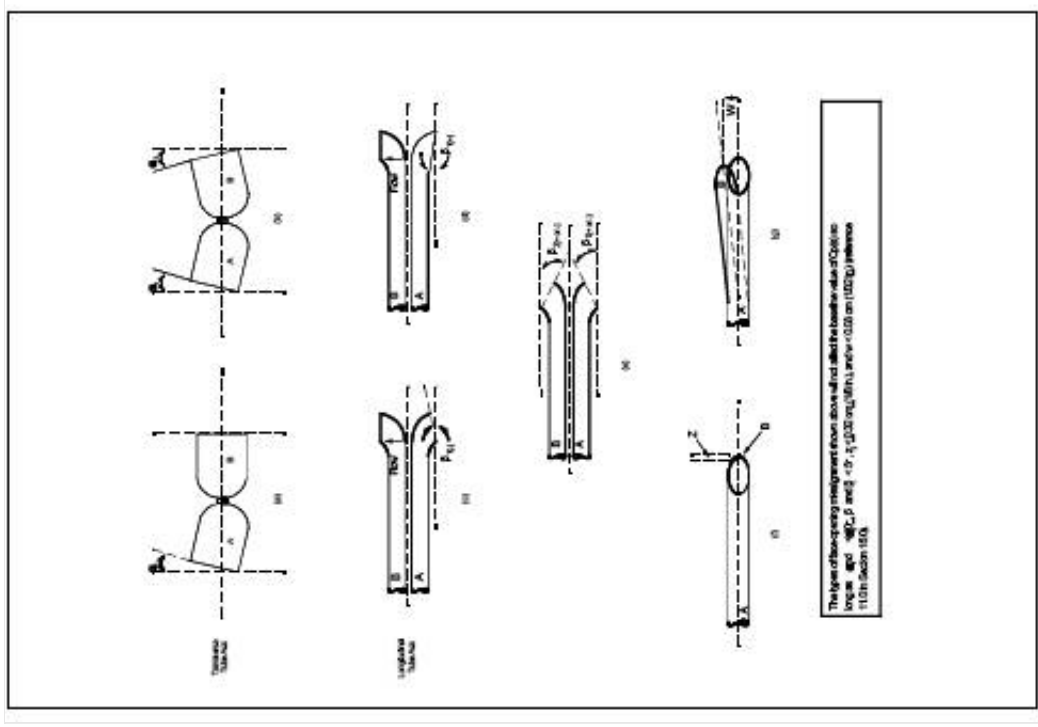


Figure 2-4. Proper temperature sensor placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in).

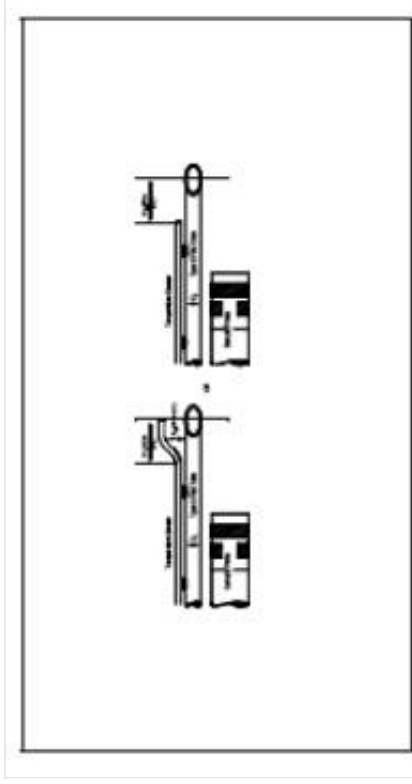


Figure 2-5. standard pitot tube design specifications.

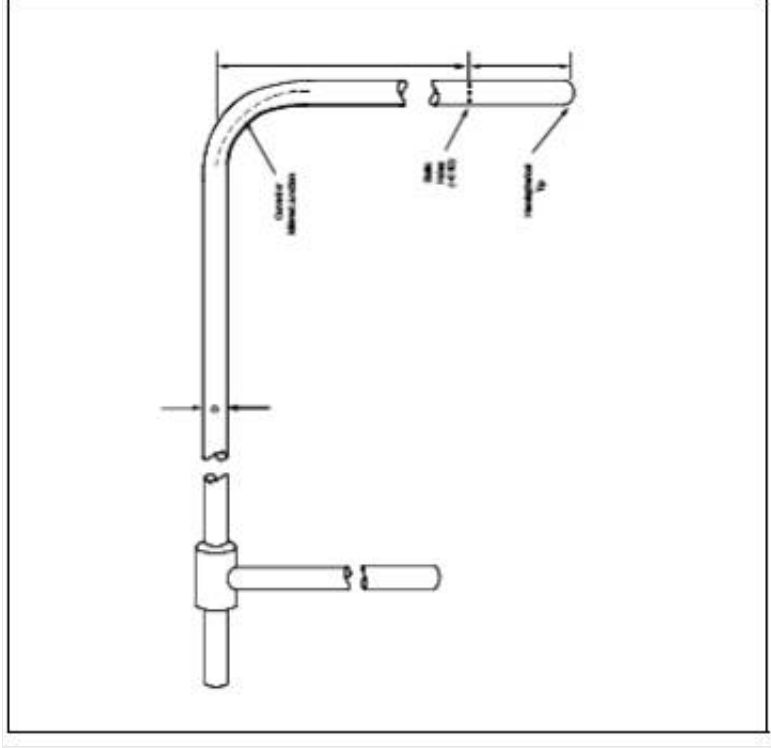


Figure 2-6. Velocity traverse data.

FLANT _____
 DATE _____ RUN NO. _____
 STACK DIA. OR DIMENSIONS, m (in.) _____
 BAROMETRIC PRESS., mm Hg (in. Hg) _____
 CROSS SECTIONAL AREA, m² (ft²) _____
 OPERATORS _____
 PIOT TUBE I.D. NO. _____
 AVG. COEFFICIENT, Cp = _____
 LAST DATE CALIBRATED _____
 SCHEMATIC OF STACK _____

CROSS SECTION

Traverse Pt. No.	Vel. Hd., Δp mm (in.) H ₂ O	Stack Temperature		P _s mm Hg (in. Hg)	$(\Delta p)^{1/2}$
		T _s , °C (°F)	T _s , °K (°R)		
		Average			

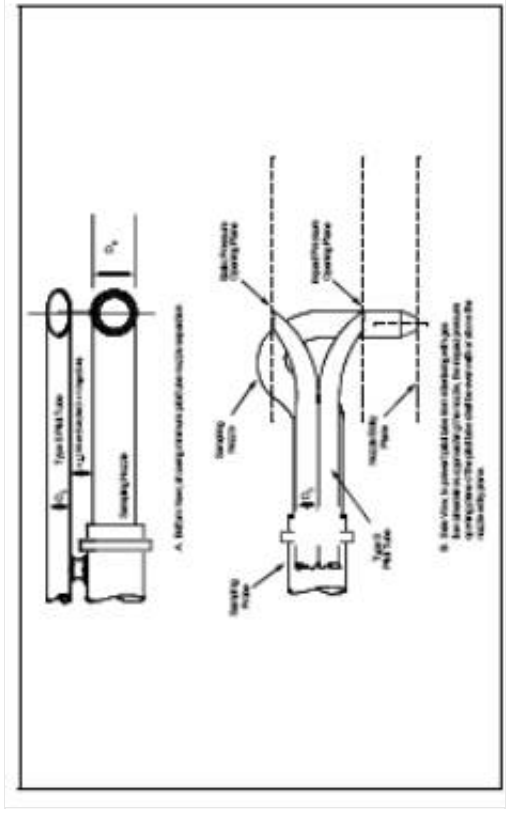


Figure 2-8. Minimum pitot-sample Probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in).

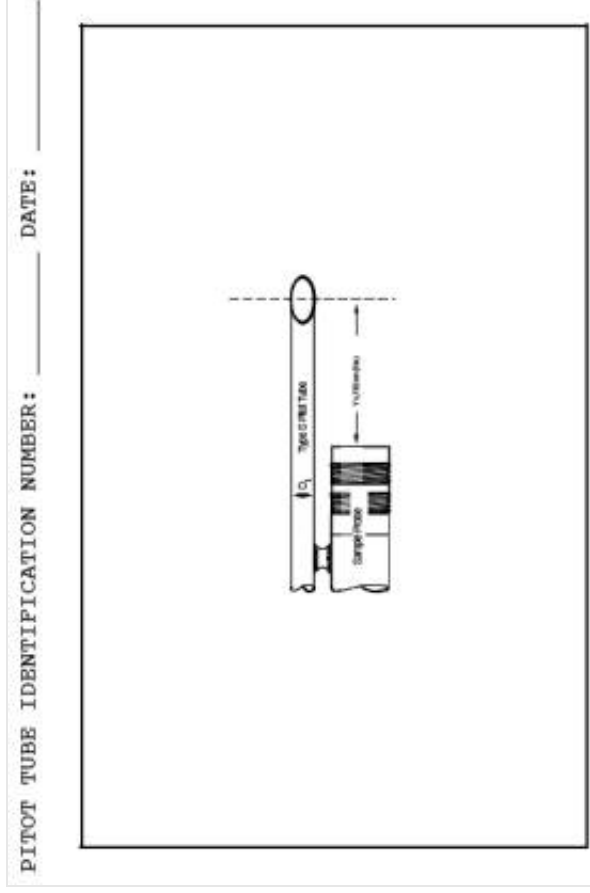


Figure 2-9. pitot tube calibration data.

CALIBRATED BY: _____

"A" SIDE CALIBRATION			
RUN NO.	ΔP_{std} CM H ₂ O (in H ₂ O)	$\Delta P_{(s)}$ CM H ₂ O (in H ₂ O)	Deviation $C_{p(s)} - C_p(A)$
1			
2			
3			
$C_{p,avg}$ (SIDE A)			

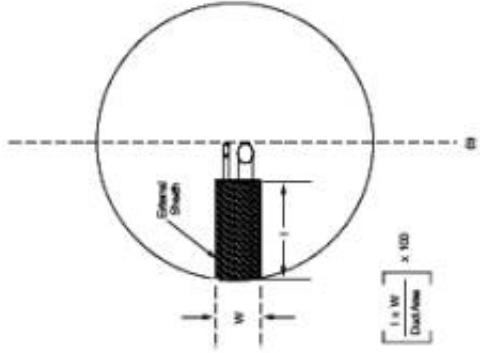
"B" SIDE CALIBRATION			
RUN NO.	ΔP_{std} CM H ₂ O (in H ₂ O)	$\Delta P_{(s)}$ CM H ₂ O (in H ₂ O)	Deviation $C_{p(s)} - C_p(B)$
1			
2			
3			
$C_{p,avg}$ (SIDE B)			

$$* A_{or B} = \frac{\sum_{i=1}^3 |C_{p(s)} - \bar{C}_{p(AorB)}|}{3} \quad \text{Eq. 2-5}$$

$[C_{p,avg} \text{ (side A)} - C_{p,avg} \text{ (side B)}]$ *

* Must be less than or equal to 0.01

Figure 2-10. Projected-area models for typical Type S Pitot Tube.



$$\text{Estimated Duct Leakage (ft}^3/\text{hr)} = \left[\frac{1 + W}{\text{Duct Area}} \right] \times 100$$

