

METHOD 2H—DETERMINATION OF STACK GAS VELOCITY TAKING INTO ACCOUNT VELOCITY DECAY NEAR THE STACK WALL

1.0 Scope and Application

1.1 This method is applicable in conjunction with Methods 2, 2F, and 2G (40 CFR Part 60, Appendix A) to account for velocity decay near the wall in circular stacks and ducts.

1.2 This method is not applicable for testing stacks and ducts less than 3.3 ft (1.0 m) in diameter.

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 A wall effects adjustment factor is determined. It is used to adjust the average stack gas velocity obtained under Method 2, 2F, or 2G of this appendix to take into account velocity decay near the stack or duct wall.

2.2 The method contains two possible procedures: a calculational approach which derives an adjustment factor from velocity measurements and a default procedure which assigns a generic adjustment factor based on the construction of the stack or duct.

2.2.1 The calculational procedure derives a wall effects adjustment factor from velocity measurements taken using Method 2, 2F, or 2G at 16 (or more) traverse points specified under Method 1 of this appendix and a total of eight (or more) wall effects traverse points specified under this method. The calculational procedure based on velocity measurements is not applicable for horizontal circular ducts where build-up of particulate matter or other material in the bottom of the duct is present.

2.2.2 A default wall effects adjustment factor of 0.9900 for brick and mortar stacks and 0.9950 for all other types of stacks and ducts may be used without taking wall effects measurements in a stack or duct.

2.3 When the calculational procedure is conducted as part of a relative accuracy test audit (RATA) or other multiple-run test procedure, the wall effects adjustment factor derived from a single traverse (i.e., single RATA run) may be applied to all runs of the same RATA without repeating the wall effects measurements. Alternatively, wall effects adjustment factors may be derived for several traverses and an average wall effects adjustment factor applied to all runs of the same RATA.

3.0 Definitions.

3.1 *Complete wall effects traverse* means a traverse in which measurements are taken at  $d_{em}$  (see section 3.3) and at 1-in. intervals in each of the four Method 1 equal-area sectors closest to the wall, beginning not farther than 4 in. (10.2 cm) from the wall and

extending either (1) across the entire width of the Method 1 equal-area sector or (2) for stacks or ducts where this width exceeds 12 in. (30.5 cm) (i.e., stacks or ducts greater than or equal to 15.6 ft [4.8 m] in diameter), to a distance of not less than 12 in. (30.5 cm) from the wall. Note: Because this method specifies that measurements must be taken at whole number multiples of 1 in. from a stack or duct wall, for clarity numerical quantities in this method are expressed in English units followed by metric units in parentheses. To enhance readability, hyphenated terms such as "1-in. intervals" or "1-in. incremented," are expressed in English units only.

3.2  $d_{last}$  Depending on context,  $d_{last}$  means either (1) the distance from the wall of the last 1-in. incremented wall effects traverse point or (2) the traverse point located at that distance (see Figure 2H-2).

3.3  $d_{rem}$  Depending on context,  $d_{rem}$  means either (1) the distance from the wall of the centroid of the area between  $d_{last}$  and the interior edge of the Method 1 equal-area sector closest to the wall or (2) the traverse point located at that distance (see Figure 2H-2).

3.4 "May," "Must," "Shall," "Should," and the imperative form of verbs.

3.4.1 "May" is used to indicate that a provision of this method is optional.

3.4.2 "Must," "Shall," and the imperative form of verbs (such as "record" or "enter") are used to indicate that a provision of this method is mandatory.

3.4.3 "Should" is used to indicate that a provision of this method is not mandatory but is highly recommended as good practice.

3.5 *Method 1* refers to 40 CFR part 60, appendix A, "Method 1—Sample and velocity traverses for stationary sources."

3.6 *Method 1 exterior equal-area sector and Method 1 equal-area sector closest to the wall* mean any one of the four equal-area sectors that are closest to the wall for a circular stack or duct laid out in accordance with section 2.3.1 of Method 1 (see Figure 2H-1).

3.7 *Method 1 interior equal-area sector* means any of the equal-area sectors other than the Method 1 exterior equal-area sectors (as defined in section 3.6) for a circular stack or duct laid out in accordance with section 2.3.1 of Method 1 (see Figure 2H-1).

3.8 *Method 1 traverse point and Method 1 equal-area traverse point* mean a traverse point located at the centroid of an equal-area sector of a circular stack laid out in accordance with section 2.3.1 of Method 1.

3.9 *Method 2* refers to 40 CFR part 60, appendix A, "Method 2—Determination of stack gas velocity and volumetric flow rate (Type S pitot tube)."

3.10 *Method 2F* refers to 40 CFR part 60, appendix A, "Method 2F—Determination of stack gas velocity and volumetric flow rate with three-dimensional probes."

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3.11 *Method 2G* refers to 40 CFR part 60, appendix A, "Method 2G—Determination of stack gas velocity and volumetric flow rate with two-dimensional probes."

3.12 *1-in. incremented wall effects traverse point* means any of the wall effects traverse points that are located at 1-in. intervals, i.e., traverse points  $d_1$  through  $d_{last}$  (see Figure 2H-2).

3.13 *Partial wall effects traverse* means a traverse in which measurements are taken at fewer than the number of traverse points required for a "complete wall effects traverse" (as defined in section 3.1), but are taken at a minimum of two traverse points in each Method 1 equal-area sector closest to the wall, as specified in section 8.2.2.

3.14 *Relative accuracy test audit (RATA)* is a field test procedure performed in a stack or duct in which a series of concurrent measurements of the same stack gas stream is taken by a reference method and an installed monitoring system. A RATA usually consists of series of 9 to 12 sets of such concurrent measurements, each of which is referred to as a RATA run. In a volumetric flow RATA, each reference method run consists of a complete traverse of the stack or duct.

3.15 *Wall effects-unadjusted average velocity* means the average stack gas velocity, not accounting for velocity decay near the wall, as determined in accordance with Method 2, 2F, or 2G for a Method 1 traverse consisting of 16 or more points.

3.16 *Wall effects-adjusted average velocity* means the average stack gas velocity, taking into account velocity decay near the wall, as calculated from measurements at 16 or more Method 1 traverse points and at the additional wall effects traverse points specified in this method.

3.17 *Wall effects traverse point* means a traverse point located in accordance with sections 8.2.2 or 8.2.3 of this method.

### 4.0 Interferences. [Reserved]

### 5.0 Safety

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

### 6.0 Equipment and Supplies

6.1 The provisions pertaining to equipment and supplies in the method that is used to take the traverse point measurements

(i.e., Method 2, 2F, or 2G) are applicable under this method.

### 7.0 Reagents and Standards. [Reserved]

### 8.0 Sample Collection and Analysis

8.1 Default Wall Effects Adjustment Factors. A default wall effects adjustment factor of 0.9900 for brick and mortar stacks and 0.9950 for all other types of stacks and ducts may be used without conducting the following procedures.

8.2 Traverse Point Locations. Determine the location of the Method 1 traverse points in accordance with section 8.2.1 and the location of the traverse points for either a partial wall effects traverse in accordance with section 8.2.2 or a complete wall effects traverse in accordance with section 8.2.3.

8.2.1 Method 1 equal-area traverse point locations. Determine the location of the Method 1 equal-area traverse points for a traverse consisting of 16 or more points using Table 1-2 (Location of Traverse Points in Circular Stacks) of Method 1.

8.2.2 Partial wall effects traverse. For a partial wall effects traverse, measurements must be taken at a minimum of the following two wall effects traverse point locations in all four Method 1 equal-area sectors closest to the wall: (1) 1 in. (2.5 cm) from the wall (except as provided in section 8.2.2.1) and (2)  $d_{rem}$ , as determined using Equation 2H-1 or 2H-2 (see section 8.2.2.2).

8.2.2.1 If the probe cannot be positioned at 1 in. (2.5 cm) from the wall (e.g., because of insufficient room to withdraw the probe shaft) or if velocity pressure cannot be detected at 1 in. (2.5 cm) from the wall (for any reason other than build-up of particulate matter in the bottom of a duct), take measurements at the 1-in. incremented wall effects traverse point closest to the wall where the probe can be positioned and velocity pressure can be detected.

8.2.2.2 Calculate the distance of  $d_{rem}$  from the wall to within  $\pm 1/4$  in. (6.4 mm) using Equation 2H-1 or Equation 2H-2 (for a 16-point traverse).

$$d_{last} \leq d_b \quad \text{Eq. 2H-3}$$

Where:

$r$ =the stack or duct radius determined from direct measurement of the stack or duct diameter in accordance with section 8.6 of Method 2F or Method 2G, in. (cm);

$p$ =the number of Method 1 equal-area traverse points on a diameter,  $p \geq 8$  (e.g., for a 16-point traverse,  $p=8$ );  $d_{last}$  and  $d_{rem}$  are defined in sections 3.2 and 3.3 respectively, in. (cm).

For a 16-point Method 1 traverse, Equation 2H-1 becomes:

$$d_{rem} = r - \sqrt{\frac{7}{8}r^2 - rd_{last}} + \frac{1}{2}d_{last}^2 \quad \text{Eq. 2H-2}$$

8.2.2.3 Measurements may be taken at any number of additional wall effects traverse points, with the following provisions.

(a)  $d_{last}$  must not be closer to the center of the stack or duct than the distance of the interior edge (boundary),  $d_b$ , of the Method 1 equal-area sector closest to the wall (see Figure 2H-2 or 2H-3). That is,

Where:

$$d_b = r \left( 1 - \sqrt{1 - \frac{2}{p}} \right) \quad \text{Eq. 2H-4}$$

Table 2H-1 shows  $d_b$  as a function of the stack or duct radius,  $r$ , for traverses ranging from 16 to 48 points (i.e., for values of  $p$  ranging from 8 to 24).

(b) Each point must be located at a distance that is a whole number (e.g., 1, 2, 3) multiple of 1 in. (2.5 cm).

(c) Points do not have to be located at consecutive 1-in. intervals. That is, one or more 1-in. incremented points may be skipped. For example, it would be acceptable for points to be located at 1 in. (2.5 cm), 3 in. (7.6 cm), 5 in. (12.7 cm),  $d_{last}$ , and  $d_{rem}$ ; or at 1 in. (2.5 cm), 2 in. (5.1 cm), 4 in. (10.2 cm), 7 in. (17.8 cm),  $d_{last}$ , and  $d_{rem}$ . Follow the instructions in section 8.7.1.2 of this method for recording results for wall effects traverse points that are skipped. It should be noted that the full extent of velocity decay may not be accounted for if measurements are not taken at all 1-in. incremented points close to the wall.

8.2.3 Complete wall effects traverse. For a complete wall effects traverse, measurements must be taken at the following points in all four Method 1 equal-area sectors closest to the wall.

(a) The 1-in. incremented wall effects traverse point closest to the wall where the probe can be positioned and velocity can be detected, but no farther than 4 in. (10.2 cm) from the wall.

(b) Every subsequent 1-in. incremented wall effects traverse point out to the interior edge of the Method 1 equal-area sector or to 12 in. (30.5 cm) from the wall, whichever comes first. Note: In stacks or ducts with diameters greater than 15.6 ft (4.8 m) the interior edge of the Method 1 equal-area sector is farther from the wall than 12 in. (30.5 cm).

(c)  $d_{rem}$ , as determined using Equation 2H-1 or 2H-2 (as applicable). Note: For a complete traverse of a stack or duct with a diameter less than 16.5 ft (5.0 m), the distance between  $d_{rem}$  and  $d_{last}$  is less than or equal to ½ in. (12.7 mm). As discussed in section 8.2.4.2, when the distance between  $d_{rem}$  and

$d_{last}$  is less than or equal to ½ in. (12.7 mm), the velocity measured at  $d_{last}$  may be used for  $d_{rem}$ . Thus, it is not necessary to calculate the distance of  $d_{rem}$  or to take measurements at  $d_{rem}$  when conducting a complete traverse of a stack or duct with a diameter less than 16.5 ft (5.0 m).

8.2.4 Special considerations. The following special considerations apply when the distance between traverse points is less than or equal to ½ in. (12.7 mm).

8.2.4.1 A wall effects traverse point and the Method 1 traverse point. If the distance between a wall effects traverse point and the Method 1 traverse point is less than or equal to ½ in. (12.7 mm), taking measurements at both points is allowed but not required or recommended; if measurements are taken at only one point, take the measurements at the point that is farther from the wall and use the velocity obtained at that point as the value for both points (see sections 8.2.3 and 9.2 for related requirements).

8.2.4.2  $d_{rem}$  and  $d_{last}$ . If the distance between  $d_{rem}$  and  $d_{last}$  is less than or equal to ½ in. (12.7 mm), taking measurements at  $d_{rem}$  is allowed but not required or recommended; if measurements are not taken at  $d_{rem}$ , the measured velocity value at  $d_{last}$  must be used as the value for both  $d_{last}$  and  $d_{rem}$ .

8.3 Traverse Point Sampling Order and Probe Selection. Determine the sampling order of the Method 1 and wall effects traverse points and select the appropriate probe for the measurements, taking into account the following considerations.

8.3.1 Traverse points on any radius may be sampled in either direction (i.e., from the wall toward the center of the stack or duct, or vice versa).

8.3.2 To reduce the likelihood of velocity variations during the time of the traverse and the attendant potential impact on the wall effects-adjusted and unadjusted average velocities, the following provisions of this method shall be met.

8.3.2.1 Each complete set of Method 1 and wall effects traverse points accessed from the same port shall be sampled without interruption. Unless traverses are performed simultaneously in all ports using separate probes at each port, this provision disallows first sampling all Method 1 points at all ports and then sampling all the wall effects points.

8.3.2.2 The entire integrated Method 1 and wall effects traverse across all test ports shall be as short as practicable, consistent with the measurement system response time

(see section 8.4.1.1) and sampling (see section 8.4.1.2) provisions of this method.

8.3.3 It is recommended but not required that in each Method 1 equal-area sector closest to the wall, the Method 1 equal-area traverse point should be sampled in sequence between the adjacent wall effects traverse points. For example, for the traverse point configuration shown in Figure 2H-2, it is recommended that the Method 1 equal-area traverse point be sampled between  $d_{last}$  and  $d_{em}$ . In this example, if the traverse is conducted from the wall toward the center of the stack or duct, it is recommended that measurements be taken at points in the following order:  $d_1$ ,  $d_2$ ,  $d_{last}$ , the Method 1 traverse point,  $d_{em}$ , and then at the traverse points in the three Method 1 interior equal-area sectors.

8.3.4 The same type of probe must be used to take measurements at all Method 1 and wall effects traverse points. However, different copies of the same type of probe may be used at different ports (e.g., Type S probe 1 at port A, Type S probe 2 at port B) or at different traverse points accessed from a particular port (e.g., Type S probe 1 for Method 1 interior traverse points accessed from port A, Type S probe 2 for wall effects traverse points and the Method 1 exterior traverse point accessed from port A). The identification number of the probe used to obtain measurements at each traverse point must be recorded.

8.4 Measurements at Method 1 and Wall Effects Traverse Points. Conduct measurements at Method 1 and wall effects traverse points in accordance with Method 2, 2F, or 2G and in accordance with the provisions of the following subsections (some of which are included in Methods 2F and 2G but not in Method 2), which are particularly important for wall effects testing.

8.4.1 Probe residence time at wall effects traverse points. Due to the steep temperature and pressure gradients that can occur close to the wall, it is very important for the probe residence time (i.e., the total time spent at a traverse point) to be long enough to ensure collection of representative temperature and pressure measurements. The provisions of Methods 2F and 2G in the following subsections shall be observed.

8.4.1.1 System response time. Determine the response time of each probe measurement system by inserting and positioning the "cold" probe (at ambient temperature and pressure) at any Method 1 traverse point. Read and record the probe differential pressure, temperature, and elapsed time at 15-second intervals until stable readings for both pressure and temperature are achieved. The response time is the longer of these two elapsed times. Record the response time.

8.4.1.2 Sampling. At the start of testing in each port (i.e., after a probe has been inserted into the stack gas stream), allow at

least the response time to elapse before beginning to take measurements at the first traverse point accessed from that port. Provided that the probe is not removed from the stack gas stream, measurements may be taken at subsequent traverse points accessed from the same test port without waiting again for the response time to elapse.

8.4.2 Temperature measurement for wall effects traverse points. Either (1) take temperature measurements at each wall effects traverse point in accordance with the applicable provisions of Method 2, 2F, or 2G; or (2) use the temperature measurement at the Method 1 traverse point closest to the wall as the temperature measurement for all the wall effects traverse points in the corresponding equal-area sector.

8.4.3 Non-detectable velocity pressure at wall effects traverse points. If the probe cannot be positioned at a wall effects traverse point or if no velocity pressure can be detected at a wall effects point, measurements shall be taken at the first subsequent wall effects traverse point farther from the wall where velocity can be detected. Follow the instructions in section 8.7.1.2 of this method for recording results for wall effects traverse points where velocity pressure cannot be detected. It should be noted that the full extent of velocity decay may not be accounted for if measurements are not taken at the 1-in. incremented wall effects traverse points closest to the wall.

8.5 Data Recording. For each wall effects and Method 1 traverse point where measurements are taken, record all pressure, temperature, and attendant measurements prescribed in section 3 of Method 2 or section 8.0 of Method 2F or 2G, as applicable.

8.6 Point Velocity Calculation. For each wall effects and Method 1 traverse point, calculate the point velocity value ( $v_i$ ) in accordance with sections 12.1 and 12.2 of Method 2F for tests using Method 2F and in accordance with sections 12.1 and 12.2 of Method 2G for tests using Method 2 and Method 2G. (Note that the term ( $v_i$ ) in this method corresponds to the term ( $v_{a(i)}$ ) in Methods 2F and 2G.) When the equations in the indicated sections of Method 2G are used in deriving point velocity values for Method 2 tests, set the value of the yaw angles appearing in the equations to  $0^\circ$ .

8.7 Tabulating Calculated Point Velocity Values for Wall Effects Traverse Points. Enter the following values in a hardcopy or electronic form similar to Form 2H-1 (for 16-point Method 1 traverses) or Form 2H-2 (for Method 1 traverses consisting of more than 16 points). A separate form must be completed for each of the four Method 1 equal-area sectors that are closest to the wall.

- (a) Port ID (e.g., A, B, C, or D)
- (b) Probe type
- (c) Probe ID

(d) Stack or duct diameter in ft (m) (determined in accordance with section 8.6 of Method 2F or Method 2G)

(e) Stack or duct radius in in. (cm)

(f) Distance from the wall of wall effects traverse points at 1-in. intervals, in ascending order starting with 1 in. (2.5 cm) (column A of Form 2H-1 or 2H-2)

(g) Point velocity values ( $v_d$ ) for 1-in. incremented traverse points (see section 8.7.1), including  $d_{last}$  (see section 8.7.2)

(h) Point velocity value ( $v_{drem}$ ) at  $d_{rem}$  (see section 8.7.3).

8.7.1 Point velocity values at wall effects traverse points other than  $d_{last}$ . For every 1-in. incremented wall effects traverse point other than  $d_{last}$ , enter in column B of Form 2H-1 or 2H-2 either the velocity measured at the point (see section 8.7.1.1) or the velocity measured at the first subsequent traverse point farther from the wall (see section 8.7.1.2). A velocity value must be entered in column B of Form 2H-1 or 2H-2 for every 1-in. incremented traverse point from  $d_1$  (representing the wall effects traverse point 1 in. [2.5 cm] from the wall) to  $d_{last}$ .

8.7.1.1 For wall effects traverse points where the probe can be positioned and velocity pressure can be detected, enter the value obtained in accordance with section 8.6.

8.7.1.2 For wall effects traverse points that were skipped [see section 8.2.2.3(c)] and for points where the probe cannot be positioned or where no velocity pressure can be detected, enter the value obtained at the first subsequent traverse point farther from the wall where velocity pressure was detected and measured and follow the entered value with a "flag," such as the notation "NM," to indicate that "no measurements" were actually taken at this point.

8.7.2 Point velocity value at  $d_{last}$ . For  $d_{last}$ , enter in column B of Form 2H-1 or 2H-2 the measured value obtained in accordance with section 8.6.

8.7.3 Point velocity value ( $v_{drem}$ ) at  $d_{rem}$ . Enter the point velocity value obtained at  $d_{rem}$  in column G of row 4a in Form 2H-1 or 2H-2. If the distance between  $d_{rem}$  and  $d_{last}$  is less than or equal to  $\frac{1}{2}$  in. (12.7 mm), the measured velocity value at  $d_{last}$  may be used as the value at  $d_{rem}$  (see section 8.2.4.2).

#### 9.0 Quality Control.

9.1 Particulate Matter Build-up in Horizontal Ducts. Wall effects testing of horizontal circular ducts should be conducted only if build-up of particulate matter or other material in the bottom of the duct is not present.

9.2 Verifying Traverse Point Distances. In taking measurements at wall effects traverse points, it is very important for the probe impact pressure port to be positioned as close as practicable to the traverse point locations in the gas stream. For this reason, before beginning wall effects testing, it is important to calculate and record the tra-

verse point positions that will be marked on each probe for each port, taking into account the distance that each port nipple (or probe mounting flange for automated probes) extends out of the stack and any extension of the port nipple (or mounting flange) into the gas stream. To ensure that traverse point positions are properly identified, the following procedures should be performed on each probe used.

9.2.1 Manual probes. Mark the probe insertion distance of the wall effects and Method 1 traverse points on the probe sheath so that when a mark is aligned with the outside face of the stack port, the probe impact port is located at the calculated distance of the traverse point from the stack inside wall. The use of different colored marks is recommended for designating the wall effects and Method 1 traverse points. Before the first use of each probe, check to ensure that the distance of each mark from the center of the probe impact pressure port agrees with the previously calculated traverse point positions to within  $\pm\frac{1}{4}$  in. (6.4 mm).

9.2.2 Automated probe systems. For automated probe systems that mechanically position the probe head at prescribed traverse point positions, activate the system with the probe assemblies removed from the test ports and sequentially extend the probes to the programmed location of each wall effects traverse point and the Method 1 traverse points. Measure the distance between the center of the probe impact pressure port and the inside of the probe assembly mounting flange for each traverse point. The measured distances must agree with the previously calculated traverse point positions to within  $\pm\frac{1}{4}$  in. (6.4 mm).

9.3 Probe Installation. Properly sealing the port area is particularly important in taking measurements at wall effects traverse points. For testing involving manual probes, the area between the probe sheath and the port should be sealed with a tightly fitting flexible seal made of an appropriate material such as heavy cloth so that leakage is minimized. For automated probe systems, the probe assembly mounting flange area should be checked to verify that there is no leakage.

9.4 Velocity Stability. This method should be performed only when the average gas velocity in the stack or duct is relatively constant over the duration of the test. If the average gas velocity changes significantly during the course of a wall effects test, the test results should be discarded.

#### 10.0 Calibration

10.1 The calibration coefficient(s) or curves obtained under Method 2, 2F, or 2G and used to perform the Method 1 traverse are applicable under this method.

11.0 Analytical Procedure

11.1 Sample collection and analysis are concurrent for this method (see section 8).

12.0 Data Analysis and Calculations

12.1 The following calculations shall be performed to obtain a wall effects adjustment factor (*WAF*) from (1) the wall effects-unadjusted average velocity (*T<sub>avg</sub>*), (2) the replacement velocity (*v̂<sub>e</sub>*) for each of the four Method 1 sectors closest to the wall, and (3) the average stack gas velocity that accounts for velocity decay near the wall (*v̂<sub>avg</sub>*).

12.2 Nomenclature. The following terms are listed in the order in which they appear in Equations 2H-5 through 2H-21.

*v<sub>avg</sub>*=the average stack gas velocity, unadjusted for wall effects, actual ft/sec (m/sec);

*v<sub>i</sub>*=stack gas point velocity value at Method 1 interior equal-area sectors, actual ft/sec (m/sec);

*v<sub>e</sub>*=stack gas point velocity value, unadjusted for wall effects, at Method 1 exterior equal-area sectors, actual ft/sec (m/sec);

*i*=index of Method 1 interior equal-area traverse points;

*j*=index of Method 1 exterior equal-area traverse points;

*n*=total number of traverse points in the Method 1 traverse;

*v<sub>dec,i</sub>*=the wall effects decay velocity for a sub-sector located between the traverse points at distances *d-1* (in metric units, *d-2.5*) and *d* from the wall, actual ft/sec (m/sec);

*v<sub>d</sub>*=the measured stack gas velocity at distance *d* from the wall, actual ft/sec (m/sec); Note: *v<sub>0</sub>*=0;

*d*=the distance of a 1-in. incremented wall effects traverse point from the wall, for traverse points *d<sub>1</sub>* through *d<sub>last</sub>*, in. (cm);

*A<sub>d</sub>*=the cross-sectional area of a sub-sector located between the traverse points at distances *d-1* (in metric units, *d-2.5*) and *d* from the wall, in.<sup>2</sup> (cm<sup>2</sup>) (e.g., sub-sector *A<sub>2</sub>* shown in Figures 2H-3 and 2H-4);

*r*=the stack or duct radius, in. (cm);

*Q<sub>d</sub>*=the stack gas volumetric flow rate for a sub-sector located between the traverse points at distances *d-1* (in metric units, *d-2.5*) and *d* from the wall, actual ft-in.<sup>2</sup>/sec (m-cm<sup>2</sup>/sec);

*Q<sub>d<sub>1</sub>→d<sub>last</sub></sub>*=the total stack gas volumetric flow rate for all sub-sectors located between the wall and *d<sub>last</sub>*, actual ft-in.<sup>2</sup>/sec (m-cm<sup>2</sup>/sec);

*d<sub>last</sub>*=the distance from the wall of the last 1-in. incremented wall effects traverse point, in. (cm);

*A<sub>drem</sub>*=the cross-sectional area of the sub-sector located between *d<sub>last</sub>* and the interior edge of the Method 1 equal-area sector closest to the wall, in.<sup>2</sup> (cm<sup>2</sup>) (see Figure 2H-4);

*p*=the number of Method 1 traverse points per diameter, *p*≥8 (e.g., for a 16-point traverse, *p*=8);

*d<sub>rem</sub>*=the distance from the wall of the centroid of the area between *d<sub>last</sub>* and the interior edge of the Method 1 equal-area sector closest to the wall, in. (cm);

*Q<sub>drem</sub>*=the total stack gas volumetric flow rate for the sub-sector located between *d<sub>last</sub>* and the interior edge of the Method 1 equal-area sector closest to the wall, actual ft-in.<sup>2</sup>/sec (m-cm<sup>2</sup>/sec);

*v<sub>drem</sub>*=the measured stack gas velocity at distance *d<sub>rem</sub>* from the wall, actual ft/sec (m/sec);

*Q<sub>f</sub>*=the total stack gas volumetric flow rate for the Method 1 equal-area sector closest to the wall, actual ft-in.<sup>2</sup>/sec (m-cm<sup>2</sup>/sec);

*v̂<sub>e</sub>*=the replacement stack gas velocity for the Method 1 equal-area sector closest to the wall, i.e., the stack gas point velocity value, adjusted for wall effects, for the *j*<sup>th</sup> Method 1 equal-area sector closest to the wall, actual ft/sec (m/sec);

*v̂<sub>avg</sub>*=the average stack gas velocity that accounts for velocity decay near the wall, actual ft/sec (m/sec);

*WAF*=the wall effects adjustment factor derived from *v<sub>avg</sub>* and *v̂<sub>avg</sub>* for a single traverse, dimensionless;

*v̂<sub>final</sub>*=the final wall effects-adjusted average stack gas velocity that replaces the unadjusted average stack gas velocity obtained using Method 2, 2F, or 2G for a field test consisting of a single traverse, actual ft/sec (m/sec);

*ŴAF*=the wall effects adjustment factor that is applied to the average velocity, unadjusted for wall effects, in order to obtain the final wall effects-adjusted stack gas velocity, *v̂<sub>final</sub>* or, *v̂<sub>final(k)</sub>*, dimensionless;

*v̂<sub>final(k)</sub>*=the final wall effects-adjusted average stack gas velocity that replaces the unadjusted average stack gas velocity obtained using Method 2, 2F, or 2G on run *k* of a RATA or other multiple-run field test procedure, actual ft/sec (m/sec);

*v<sub>avg(k)</sub>*=the average stack gas velocity, obtained on run *k* of a RATA or other multiple-run procedure, unadjusted for velocity decay near the wall, actual ft/sec (m/sec);

*k*=index of runs in a RATA or other multiple-run procedure.

12.3 Calculate the average stack gas velocity that does not account for velocity decay near the wall (*v<sub>avg</sub>*) using Equation 2H-5.

$$v_{avg} = \frac{\left( \sum_{i=1}^{n-4} v_i + \sum_{j=1}^4 v_{e_j} \right)}{n} \quad \text{Eq. 2H-5}$$

(Note that  $v_{avg}$  in Equation 2H-5 is the same as  $v_{(a)avg}$  in Equations 2F-9 and 2G-8 in Methods 2F and 2G, respectively.)

For a 16-point traverse, Equation 2H-5 may be written as follows:

$$v_{avg} = \frac{\left( \sum_{i=1}^{12} vi_i + \sum_{j=1}^4 ve_j \right)}{16} \quad \text{Eq. 2H-6}$$

12.4 Calculate the replacement velocity,  $ve_j$ , for each of the four Method 1 equal-area sectors closest to the wall using the procedures described in sections 12.4.1 through 12.4.8. Forms 2H-1 and 2H-2 provide sample tables that may be used in either hardcopy or spreadsheet format to perform the calculations described in sections 12.4.1 through 12.4.8. Forms 2H-3 and 2H-4 provide examples

of Form 2H-1 filled in for partial and complete wall effects traverses.

12.4.1 Calculate the average velocity (designated the "decay velocity,"  $vdec_d$ ) for each sub-sector located between the wall and  $d_{last}$  (see Figure 2H-3) using Equation 2H-7.

$$vdec_d = \frac{v_{d-1} + v_d}{2} \quad \text{Eq. 2H-7}$$

For each line in column A of Form 2H-1 or 2H-2 that contains a value of  $d$ , enter the corresponding calculated value of  $vdec_d$  in column C.

12.4.2 Calculate the cross-sectional area between the wall and the first 1-in. incremented wall effects traverse point and between successive 1-in. incremented wall effects traverse points, from the wall to  $d_{last}$  (see Figure 2H-3), using Equation 2H-8.

$$A_d = \frac{1}{4} \pi(r-d+1)^2 - \frac{1}{4} \pi(r-d)^2 \quad \text{Eq. 2H-8}$$

For each line in column A of Form 2H-1 or 2H-2 that contains a value of  $d$ , enter the value of the expression  $\frac{1}{4} \pi(r-d+1)^2$  in column D, the value of the expression  $\frac{1}{4} \pi(r-d)^2$  in column E, and the value of  $A_d$  in column F. Note that Equation 2H-8 is designed for use only with English units (in.). If metric units (cm) are used, the first term,  $\frac{1}{4} \pi(r-d+1)^2$ , must be changed to  $\frac{1}{4} \pi(r-d+2.5)^2$ . This change must also be made in column D of Form 2H-1 or 2H-2.

12.4.3 Calculate the volumetric flow through each cross-sectional area derived in

section 12.4.2 by multiplying the values of  $vdec_d$ , derived according to section 12.4.1, by the cross-sectional areas derived in section 12.4.2 using Equation 2H-9.

$$Q_d = vdec_d \times A_d \quad \text{Eq. 2H-9}$$

For each line in column A of Form 2H-1 or 2H-2 that contains a value of  $d$ , enter the corresponding calculated value of  $Q_d$  in column G.

12.4.4 Calculate the total volumetric flow through all sub-sectors located between the wall and  $d_{last}$ , using Equation 2H-10.

$$Q_{d_1 \rightarrow d_{last}} = \sum_{d=1}^{d_{last}} Q_d \quad \text{Eq. 2H-10}$$

Enter the calculated value of  $Q_{d_1 \rightarrow d_{last}}$  in line 3 of column G of Form 2H-1 or 2H-2.

12.4.5 Calculate the cross-sectional area of the sub-sector located between  $d_{last}$  and the

interior edge of the Method 1 equal-area sector (e.g., sub-sector  $A_{drem}$  shown in Figures 2H-3 and 2H-4) using Equation 2H-11.

$$A_{drem} = \frac{1}{4} \pi(r-d_{last})^2 - \frac{p-2}{4p} \pi(r)^2 \quad \text{Eq. 2H-11}$$

For a 16-point traverse (eight points per diameter), Equation 2H-11 may be written as follows:

$$A_{drem} = \frac{1}{4} \pi (r - d_{last})^2 - \frac{3}{16} \pi (r)^2 \quad \text{Eq. 2H-12}$$

Enter the calculated value of  $A_{drem}$  in line 4b of column G of Form 2H-1 or 2H-2.

12.4.6 Calculate the volumetric flow for the sub-sector located between  $d_{last}$  and the interior edge of the Method 1 equal-area sector, using Equation 2H-13.

$$Q_{drem} = v_{drem} \times A_{drem} \quad \text{Eq. 2H-13}$$

In Equation 2H-13,  $v_{drem}$  is either (1) the measured velocity value at  $d_{rem}$  or (2) the measured velocity at  $d_{last}$ , if the distance between  $d_{rem}$  and  $d_{last}$  is less than or equal to 1/2 in. (12.7 mm) and no velocity measurement is taken at  $d_{rem}$  (see section 8.2.4.2). Enter the calculated value of  $Q_{drem}$  in line 4c of column G of Form 2H-1 or 2H-2.

12.4.7 Calculate the total volumetric flow for the Method 1 equal-area sector closest to the wall, using Equation 2H-14.

$$Q_T = Q_{d1 \rightarrow d_{last}} + Q_{drem} \quad \text{Eq. 2H-14}$$

Enter the calculated value of  $Q_T$  in line 5a of column G of Form 2H-1 or 2H-2.

12.4.8 Calculate the wall effects-adjusted replacement velocity value for the Method 1 equal-area sector closest to the wall, using Equation 2H-15.

$$\hat{v}e_j = \frac{Q_T}{\frac{1}{2p} \pi (r)^2} \quad \text{Eq. 2H-15}$$

For a 16-point traverse (eight points per diameter), Equation 2H-15 may be written as follows:

$$\hat{v}e_j = \frac{Q_T}{\frac{1}{16} \pi (r)^2} \quad \text{Eq. 2H-16}$$

Enter the calculated value of  $\hat{v}e_j$  in line 5B of column G of Form 2H-1 or 2H-2.

12.5 Calculate the wall effects-adjusted average velocity,  $\hat{v}_{avg}$ , by replacing the four values of  $v_{e_j}$  shown in Equation 2H-5 with the four wall effects-adjusted replacement velocity values,  $\hat{v}e_j$ , calculated according to section 12.4.8, using Equation 2H-17.

$$\hat{v}_{avg} = \frac{\left( \sum_{i=1}^{n-4} v_{i_1} + \sum_{j=1}^4 \hat{v}e_j \right)}{n} \quad \text{Eq. 2H-17}$$

For a 16-point traverse, Equation 2H-17 may be written as follows:

$$\hat{v}_{avg} = \frac{\left( \sum_{i=1}^{12} v_{i_1} + \sum_{j=1}^4 \hat{v}e_j \right)}{16} \quad \text{Eq. 2H-18}$$

12.6 Calculate the wall effects adjustment factor, WAF, using Equation 2H-19.

$$\text{WAF} = \frac{\hat{v}_{avg}}{v_{avg}} \quad \text{Eq. 2H-19}$$

12.6.1 Partial wall effects traverse. If a partial wall effects traverse (see section 8.2.2) is conducted, the value obtained from Equation 2H-19 is acceptable and may be reported as the wall effects adjustment factor provided that the value is greater than or equal to 0.9800. If the value is less than 0.9800, it shall not be used and a wall effects adjustment factor of 0.9800 may be used instead.

12.6.2 Complete wall effects traverse. If a complete wall effects traverse (see section 8.2.3) is conducted, the value obtained from Equation 2H-19 is acceptable and may be reported as the wall effects adjustment factor provided that the value is greater than or equal to 0.9700. If the value is less than 0.9700, it shall not be used and a wall effects adjustment factor of 0.9700 may be used instead. If the wall effects adjustment factor for a particular stack or duct is less than 0.9700, the tester may (1) repeat the wall effects test, taking measurements at more Method 1 traverse points and (2) recalculate the wall effects adjustment factor from these measurements, in an attempt to obtain a wall effects adjustment factor that meets the 0.9700 specification and completely characterizes the wall effects.

12.7 Applying a Wall Effects Adjustment Factor. A default wall effects adjustment factor, as specified in section 8.1, or a calculated wall effects adjustment factor meeting the requirements of section 12.6.1 or 12.6.2

may be used to adjust the average stack gas velocity obtained using Methods 2, 2F, or 2G to take into account velocity decay near the wall of circular stacks or ducts. Default wall effects adjustment factors specified in section 8.1 and calculated wall effects adjustment factors that meet the requirements of section 12.6.1 and 12.6.2 are summarized in Table 2H-2.

12.7.1 Single-run tests. Calculate the final wall effects-adjusted average stack gas velocity for field tests consisting of a single traverse using Equation 2H-20.

$$\hat{v}_{\text{final}} = \overline{\text{WAF}} \times v_{\text{avg}} \quad \text{Eq. 2H-20}$$

The wall effects adjustment factor, WAF, shown in Equation 2H-20, may be (1) a default wall effects adjustment factor, as specified in section 8.1, or (2) a calculated adjustment factor that meets the specifications in sections 12.6.1 or 12.6.2. If a calculated adjustment factor is used in Equation 2H-20, the factor must have been obtained during the same traverse in which  $v_{\text{avg}}$  was obtained.

12.7.2 RATA or other multiple run test procedure. Calculate the final wall effects-adjusted average stack gas velocity for any run  $k$  of a RATA or other multiple-run procedure using Equation 2H-21.

$$\hat{v}_{\text{final}(k)} = \overline{\text{WAF}} \times v_{\text{avg}(k)} \quad \text{Eq. 2H-21}$$

The wall effects adjustment factor,  $\overline{\text{WAF}}$ , shown in Equation 2H-21 may be (1) a default wall effects adjustment factor, as specified in section 8.1; (2) a calculated adjustment factor (meeting the specifications in sections 12.6.1 or 12.6.2) obtained from any single run of the RATA that includes run  $k$ ; or (3) the arithmetic average of more than one WAF (each meeting the specifications in sections 12.6.1 or 12.6.2) obtained through wall effects testing conducted during several runs of the RATA that includes run  $k$ . If wall effects adjustment factors (meeting the specifications in sections 12.6.1 or 12.6.2) are determined for more than one RATA run, the arithmetic average of all of the resulting calculated wall effects adjustment factors must be used as the value of  $\overline{\text{WAF}}$  and applied to all runs of that RATA. If a calculated, not a default, wall effects adjustment factor is used in Equation 2H-21, the average velocity unadjusted for wall effects,  $v_{\text{avg}(k)}$  must be obtained from runs in which the number of Method 1 traverse points sampled does not exceed the number of Method 1 traverse points in the runs used to derive the wall effects adjustment factor,  $\overline{\text{WAF}}$ , shown in Equation 2H-21.

12.8 Calculating Volumetric Flow Using Final Wall Effects-Adjusted Average Velocity Value. To obtain a stack gas flow rate that accounts for velocity decay near the wall of circular stacks or ducts, replace  $v_s$  in Equation 2-10 in Method 2, or  $v_{\text{a(avg)}}$  in Equa-

tions 2F-10 and 2F-11 in Method 2F, or  $v_{\text{a(avg)}}$  in Equations 2G-9 and 2G-10 in Method 2G with one of the following.

12.8.1 For single-run test procedures, use the final wall effects-adjusted average stack gas velocity,  $\hat{v}_{\text{final}}$ , calculated according to Equation 2H-20.

12.8.2 For RATA and other multiple run test procedures, use the final wall effects-adjusted average stack gas velocity,  $\hat{v}_{\text{final}(k)}$ , calculated according to Equation 2H-21.

13.0 Method Performance. [Reserved]

414.0 Pollution Prevention. [Reserved]

15.0 Waste Management. [Reserved]

#### 16.0 Reporting

16.1 Field Test Reports. Field test reports shall be submitted to the Agency according to the applicable regulatory requirements. When Method 2H is performed in conjunction with Method 2, 2F, or 2G to derive a wall effects adjustment factor, a single consolidated Method 2H/2F (or 2H/2G) field test report should be prepared. At a minimum, the consolidated field test report should contain (1) all of the general information, and data for Method 1 points, specified in section 16.0 of Method 2F (when Method 2H is used in conjunction with Method 2F) or section 16.0 of Method 2G (when Method 2H is used in conjunction with Method 2 or 2G) and (2) the additional general information, and data for Method 1 points and wall effects points, specified in this section (some of which are included in section 16.0 of Methods 2F and 2G and are repeated in this section to ensure complete reporting for wall effects testing).

16.1.1 Description of the source and site. The field test report should include the descriptive information specified in section 16.1.1 of Method 2F (when using Method 2F) or 2G (when using either Method 2 or 2G). It should also include a description of the stack or duct's construction material along with the diagram showing the dimensions of the stack or duct at the test port elevation prescribed in Methods 2F and 2G. The diagram should indicate the location of all wall effects traverse points where measurements were taken as well as the Method 1 traverse points. The diagram should provide a unique identification number for each wall effects and Method 1 traverse point, its distance from the wall, and its location relative to the probe entry ports.

16.1.2 Field test forms. The field test report should include a copy of Form 2H-1, 2H-2, or an equivalent for each Method 1 exterior equal-area sector.

16.1.3 Field test data. The field test report should include the following data for the Method 1 and wall effects traverse.

16.1.3.1 Data for each traverse point. The field test report should include the values

specified in section 16.1.3.2 of Method 2F (when using Method 2F) or 2G (when using either Method 2 or 2G) for each Method 1 and wall effects traverse point. The provisions of section 8.4.2 of Method 2H apply to the temperature measurements reported for wall effects traverse points. For each wall effects and Method 1 traverse point, the following values should also be included in the field test report.

(a) Traverse point identification number for each Method 1 and wall effects traverse point.

(b) Probe type.

(c) Probe identification number.

(d) Probe velocity calibration coefficient (i.e.,  $C_p$  when Method 2 or 2G is used;  $F_2$  when Method 2F is used).

For each Method 1 traverse point in an exterior equal-area sector, the following additional value should be included.

(e) Calculated replacement velocity,  $\hat{v}_e$ , accounting for wall effects.

16.1.3.2 Data for each run. The values specified in section 16.1.3.3 of Method 2F (when using Method 2F) or 2G (when using either Method 2 or 2G) should be included in the field test report once for each run. The provisions of section 12.8 of Method 2H apply for calculating the reported gas volumetric flow rate. In addition, the following Method 2H run values should also be included in the field test report.

(a) Average velocity for run, accounting for wall effects,  $\hat{v}_{avg}$ .

(b) Wall effects adjustment factor derived from a test run, WAF.

16.1.3.3 Data for a complete set of runs. The values specified in section 16.1.3.4 of Method 2F (when using Method 2F) or 2G (when using either Method 2 or 2G) should be included in the field test report once for each complete set of runs. In addition, the field test report should include the wall effects adjustment factor,  $WAF$ , that is applied in accordance with section 12.7.1 or 12.7.2 to obtain the final wall effects-adjusted average stack gas velocity  $\hat{v}_{final}$  or  $\hat{v}_{final(k)}$ .

16.1.4 Quality assurance and control. Quality assurance and control procedures, specifically tailored to wall effects testing, should be described.

16.2 Reporting a Default Wall Effects Adjustment Factor. When a default wall effects adjustment factor is used in accordance with section 8.1 of this method, its value and a description of the stack or duct's construction material should be reported in lieu of submitting a test report.

#### 17.0 References.

(1) 40 CFR Part 60, Appendix A, Method 1—Sample and velocity traverses for stationary sources.

(2) 40 CFR Part 60, Appendix A, Method 2—Determination of stack gas velocity and volumetric flow rate (Type S pitot tube).

(3) 40 CFR Part 60, Appendix A, Method 2F—Determination of stack gas velocity and volumetric flow rate with three-dimensional probes.

(4) 40 CFR Part 60, Appendix A, Method 2G—Determination of stack gas velocity and volumetric flow rate with two-dimensional probes.

(5) 40 CFR Part 60, Appendix A, Method 3—Gas analysis for carbon dioxide, oxygen, excess air, and dry molecular weight.

(6) 40 CFR Part 60, Appendix A, Method 3A—Determination of oxygen and carbon dioxide concentrations in emissions from stationary sources (instrumental analyzer procedure).

(7) 40 CFR Part 60, Appendix A, Method 4—Determination of moisture content in stack gases.

(8) Emission Measurement Center (EMC) Approved Alternative Method (ALT-011) "Alternative Method 2 Thermocouple Calibration Procedure."

(9) The Cadmus Group, Inc., 1998, "EPA Flow Reference Method Testing and Analysis: Data Report, Texas Utilities, DeCordova Steam Electric Station, Volume I: Test Description and Appendix A (Data Distribution Package)," EPA/430-R-98-015a.

(10) The Cadmus Group, Inc., 1998, "EPA Flow Reference Method Testing and Analysis: Data Report, Texas Utilities, Lake Hubbard Steam Electric Station, Volume I: Test Description and Appendix A (Data Distribution Package)," EPA/430-R-98-017a.

(11) The Cadmus Group, Inc., 1998, "EPA Flow Reference Method Testing and Analysis: Data Report, Pennsylvania Electric Co., G.P.U. Genco Homer City Station: Unit 1, Volume I: Test Description and Appendix A (Data Distribution Package)," EPA/430-R-98-018a.

(12) The Cadmus Group, Inc., May 1999, "EPA Flow Reference Method Testing and Analysis: Findings Report," EPA/430-R-99-009.

(13) The Cadmus Group, Inc., 1997, "EPA Flow Reference Method Testing and Analysis: Wind Tunnel Experimental Results," EPA/430-R-97-013.

(14) National Institute of Standards and Technology, 1998, "Report of Special Test of Air Speed Instrumentation, Four Prandtl Probes, Four S-Type Probes, Four French Probes, Four Modified Kiel Probes," Prepared for the U.S. Environmental Protection Agency under IAG No. DW13938432-01-0.

(15) National Institute of Standards and Technology, 1998, "Report of Special Test of Air Speed Instrumentation, Five Autoprobes," Prepared for the U.S. Environmental Protection Agency under IAG No. DW13938432-01-0.

(16) National Institute of Standards and Technology, 1998, "Report of Special Test of Air Speed Instrumentation, Eight Spherical

Probes,” Prepared for the U.S. Environmental Protection Agency under IAG No. DW13938432-01-0.

(17) National Institute of Standards and Technology, 1998, “Report of Special Test of Air Speed Instrumentation, Four DAT Probes,” Prepared for the U.S. Environmental Protection Agency under IAG No. DW13938432-01-0.

(18) Massachusetts Institute of Technology (MIT), 1998, “Calibration of Eight Wind Speed Probes Over a Reynolds Number Range of 46,000 to 725,000 per Foot, Text and Summary Plots,” Plus Appendices, WBWT-TR-1317,

Prepared for The Cadmus Group, Inc., under EPA Contract 68-W6-0050, Work Assignment 0007AA-3.

(19) Fossil Energy Research Corporation, Final Report, “Velocity Probe Tests in Non-axial Flow Fields,” November 1998, Prepared for the U.S. Environmental Protection Agency.

(20) Fossil Energy Research Corporation, “Additional Swirl Tunnel Tests: E-DAT and T-DAT Probes,” February 24, 1999, Technical Memorandum Prepared for U.S. Environmental Protection Agency, P.O. No. 7W-1193-NALX.

**Table 2H-1. Distance from the Wall for the Interior Boundary,  $d_b$ , of a Method 1 Exterior Equal-Area Sector as a Function of the Stack or Duct Radius,  $r$ , and Number of Method 1 Traverse Points**

Number of Method 1 Traverse Points	$d_b$
16	$0.134 \times r$
20	$0.106 \times r$
24	$0.087 \times r$
28	$0.074 \times r$
32	$0.065 \times r$
36	$0.057 \times r$
40	$0.051 \times r$
44	$0.047 \times r$
48	$0.043 \times r$

**Table 2H-2 Default and Minimum Acceptable Calculated Wall Effects Adjustment Factors**

		Brick and Mortar Stacks	All Other Stacks and Ducts
Default WAF		0.9900	0.9950
Minimum Acceptable WAF	Partial Traverse	0.9800	
	Complete Traverse	0.9700	

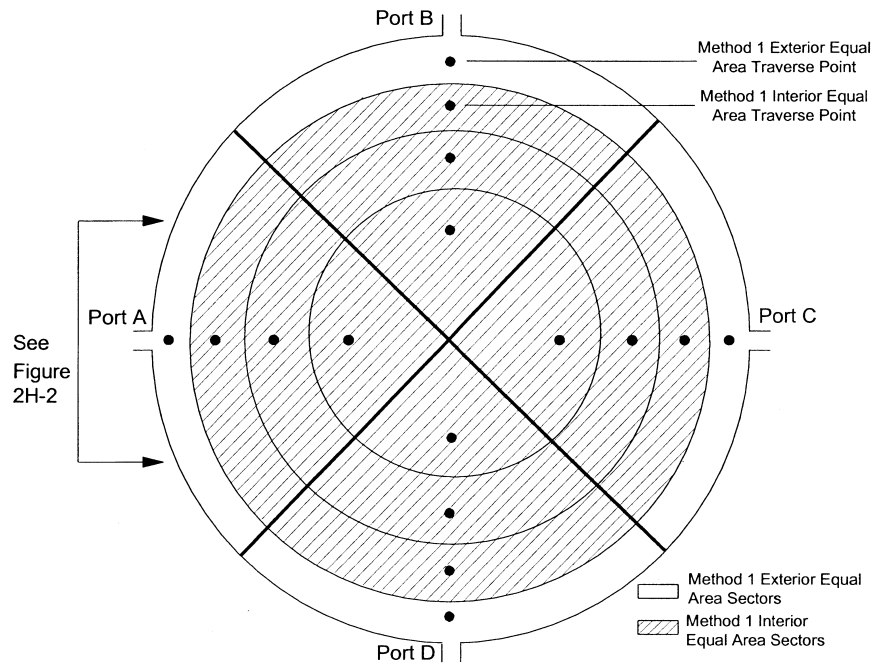


Figure 2H-1. Method 1 exterior and interior equal-area sectors with traverse points indicated.

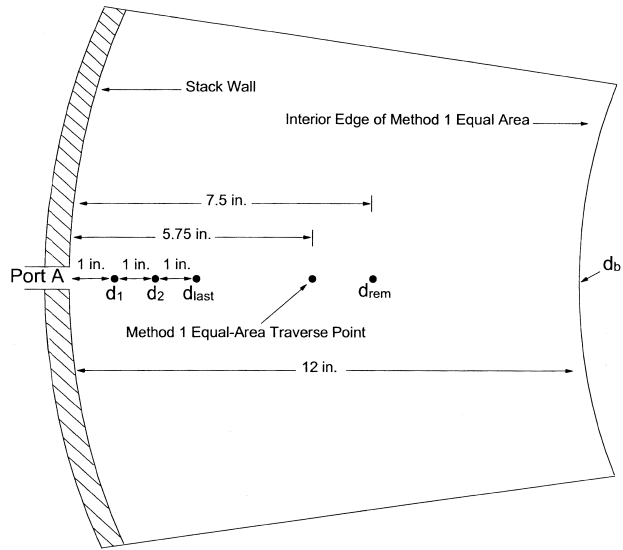


Figure 2H-2. Figure showing part of a Method 1 equal-area sector closest to the stack wall with three illustrative wall effects points at 1 in. intervals, the Method 1 equal-area traverse point, and  $d_{rem}$  for a 15 ft diameter stack.<sup>1</sup>

<sup>1</sup> Metric equivalents of English units used in Figure 2H-2 are as follows: 1 in. = 2.5 cm; 5.75 in. = 14.6 cm; 7.5 in. = 19.0 cm; 12 in. = 30.5 cm; and 15 ft = 4.6 m.

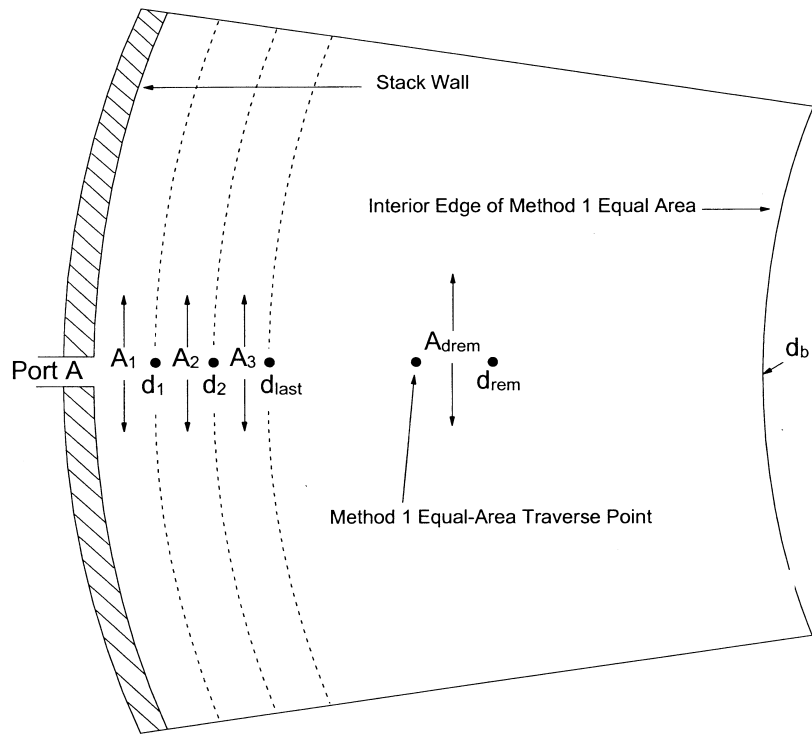
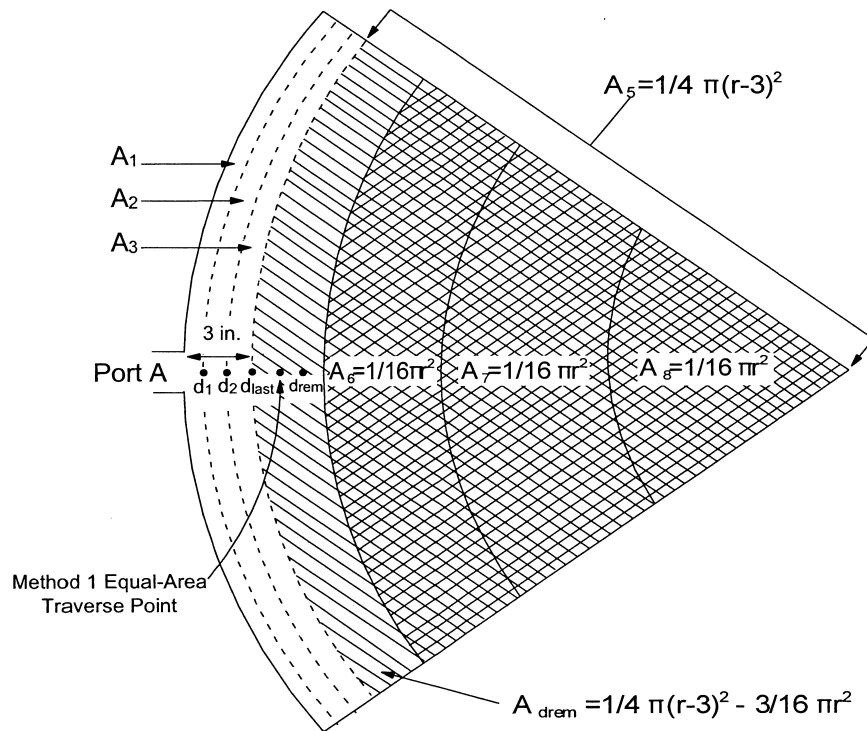


Figure 2H-3. Figure showing part of a Method 1 equal-area sector closest to the stack wall with three illustrative sub-sectors between the stack wall and  $d_{last}$  and the sub-sector represented by  $d_{rem}$ .  $A_1$  is the area between the stack wall and  $d_1$ ,  $A_2$  is the area between  $d_1$  and  $d_2$ ,  $A_3$  is the area between  $d_2$  and  $d_{last}$ , and  $A_{drem}$  is the area between  $d_{last}$  and the interior edge of the Method 1 equal-area sector.



**Figure 2H-4.** Figure illustrating the calculations in Equation 2H-12 used to calculate the cross sectional area of the sub-sector between  $d_{last}$  and the interior edge of the Method 1 sector closest to the stack wall ( $A_{drem}$ ) for a 16-point Method 1 traverse. The Method 1 equal-area traverse point and four wall effects traverse points ( $d_1$ ,  $d_2$ ,  $d_{last}$ , and  $d_{rem}$ ) within the Method 1 sector closest to the stack wall are also shown.<sup>1</sup>

<sup>1</sup> All dimensions are given in in. Metric equivalents (in cm) are as follows: 3 in. = 7.6 cm;  $A_5 = \frac{1}{4} \pi (r-7.6)^2$ ; and  $A_{drem} = \frac{1}{4} \pi (r-7.6)^2 - \frac{3}{16} \pi r^2$ .

**Form 2H-1. Calculation of Wall Effects Replacement Velocity Values (16-Point Method 1 Traverse)**

1<sup>st</sup> Probe Type/ID/Pts. Sampled: \_\_\_\_\_ Tester(s): \_\_\_\_\_

2<sup>nd</sup> Probe Type/ID/Pts. Sampled: \_\_\_\_\_ Affiliation: \_\_\_\_\_

Entry Port ID (e.g., A, B, C, or D): \_\_\_\_\_

1. Diameter of the stack or duct (ft)		Radius, <i>r</i> , of the stack or duct (in.) (= diameter × 6)				
2. Location (column A), measured and decay velocities (columns B and C), and volumetric flow (column G) associated with each successive wall effects traverse point.						
(A)	(B)	(C)	(D) Intermediate Calculations		(F)	(G)
Distance ( <i>d</i> ) from Wall	Measured Velocity ( <i>v<sub>d</sub></i> ) at Distance <i>d</i>	Decay Velocity ( <i>v<sub>dec,d</sub></i> )			Area of Sub-sector ( <i>A<sub>d</sub></i> )	Volumetric Flow in Sub-sector ( <i>Q<sub>d</sub></i> )
		$\frac{v_{d-1} + v_d}{2}$ Note: <i>v<sub>0</sub></i> = 0	$\frac{1}{4}\pi[r-d+1]^2$	$\frac{1}{4}\pi[r-d]^2$	(Col. D - Col. E)	(Col. C × Col. F)
(in.)	(ft/sec)	(ft/sec)	(in. <sup>2</sup> )	(in. <sup>2</sup> )	(in. <sup>2</sup> )	(ft-in. <sup>2</sup> /sec)
<i>d</i> = 1						
<i>d</i> = 2						
...						
<i>d<sub>last</sub></i>						
Note: <i>d<sub>last</sub></i> ≤ 0.1340 <i>r</i> , where <i>r</i> is the radius of the stack or duct. See section 8.2.2.3 of the method.						
3. Total volumetric flow for all sub-sectors located between stack wall and <i>d<sub>last</sub></i> (total Col. G).						
4. Volumetric flow for remainder of the Method 1 equal-area sector.						
a. Velocity measurement at distance <i>d<sub>rem</sub></i> from stack wall ( <i>v<sub>drem</sub></i> ). (If <i>d<sub>rem</sub></i> - <i>d<sub>last</sub></i> < ½ in., then no measurement at <i>d<sub>rem</sub></i> is necessary. Enter the velocity at <i>d<sub>last</sub></i> on this line.)						
b. Total area in remainder of Method 1 equal-area segment ( <i>A<sub>drem</sub></i> ). Subtract $\frac{3}{16}\pi(r)^2$ from last entry in item 2, column E, and enter the result on this line.						
c. Multiply values on lines 4a and 4b. ( <i>Q<sub>drem</sub></i> )						
5. Wall effects-adjusted velocity in the Method 1 equal-area sector.						
a. Add the values on lines 3 and 4c. ( <i>Q<sub>r</sub></i> )						
b. Divide line 5a by $\frac{1}{16}\pi(r)^2$ . The resulting value is one of four "replacement" point velocity values adjusted for wall effects, $\hat{v}_{e_j}$ , as derived in Equation 2H-16.						
6. Substitute the value shown in 5b for the unadjusted velocity value in the Method 1 sector. (See Eq. 2H-18.)						

Notes: 1. Column B: If no measurement is taken at distance *d*, enter the velocity value obtained at the first subsequent traverse point where a measurement was taken, followed by the letters "NM". See section 8.7.1.2.  
 2. For clarity, only English units are shown in this form. Following are metric equivalents of the English units used in the form. In row 2, column A: 1 in. = 2.5 cm; 2 in. = 5.1 cm. In row 2, column D: If metric units (cm) are used, the term  $\frac{1}{4}\pi(r-d+1)^2$  must be changed to  $\frac{1}{4}\pi(r-d+2.5)^2$ . In row 4a: ½ in. = 12.7 mm. Throughout the form, the metric equivalents of in., in.<sup>2</sup>, ft./sec., and ft-in<sup>2</sup>/sec are cm, cm<sup>2</sup>, m./sec., and m-cm<sup>2</sup>/sec, respectively.

**Form 2H-2. Calculation of Wall Effects Replacement Velocity Values (Any Method 1 Traverse ≥ 16 Points)**

1<sup>st</sup> Probe Type/ID/Pts. Sampled: \_\_\_\_\_ Tester(s): \_\_\_\_\_

2<sup>nd</sup> Probe Type/ID/Pts. Sampled: \_\_\_\_\_ Affiliation: \_\_\_\_\_

Entry Port ID (e.g., A, B, C, or D): \_\_\_\_\_

1. Diameter of the stack or duct (ft)		Radius, <i>r</i> , of the stack or duct (in.) (= diameter × 6)				
2. Location (Column A), measured and decay velocities (Columns B and C), and volumetric flow (Column G) associated with each successive wall effects traverse point.						
(A)	(B)	(C)	(D)	(E)	(F)	(G)
Distance ( <i>d</i> ) from Wall	Measured Velocity ( <i>v<sub>d</sub></i> ) at Distance <i>d</i>	Decay Velocity ( <i>v<sub>dec,d</sub></i> )	Intermediate Calculations		Area of Sub-sector ( <i>A<sub>d</sub></i> )	Volumetric Flow in Sub-sector ( <i>Q<sub>d</sub></i> )
		$\frac{v_{d-1} + v_d}{2}$ Note: <i>v<sub>0</sub></i> = 0	$\frac{2}{p} \pi [r-d+1]^2$	$\frac{2}{p} \pi [r-d]^2$	(Col. D - Col. E)	(Col. C × Col. F)
(in.)	(ft/sec)	(ft/sec)	(in. <sup>2</sup> )	(in. <sup>2</sup> )	(in. <sup>2</sup> )	(ft-in. <sup>3</sup> /sec)
<i>d</i> = 1						
<i>d</i> = 2						
...						
<i>d<sub>last</sub></i>						
Note: <i>d<sub>last</sub></i> ≤ <i>d<sub>0</sub></i> , as defined in section 8.2.2.3 of the method.						
3. Total volumetric flow for all sub-sectors located between stack wall and <i>d<sub>last</sub></i> (total Col. G).						
4. Volumetric flow for remainder of the Method 1 equal-area sector.						
a. Velocity measurement at distance <i>d<sub>rem</sub></i> from stack wall ( <i>v<sub>drem</sub></i> ). (If <i>d<sub>rem</sub></i> - <i>d<sub>last</sub></i> < ½ in., then no measurement at <i>d<sub>rem</sub></i> is necessary. Enter the velocity at <i>d<sub>last</sub></i> on this line.)						
b. Total area in remainder of Method 1 equal-area segment ( <i>A<sub>drem</sub></i> ). Subtract $\left(\frac{p-2}{4p}\right) \pi (r)^2$ from last entry in item 2, column E, and enter the result on this line.						
c. Multiply values on lines 4a and 4b. ( <i>Q<sub>drem</sub></i> )						
5. Wall effects-adjusted velocity in the Method 1 near-wall equal-area segment.						
a. Add the values on lines 3 and 4. ( <i>Q<sub>r</sub></i> )						
b. Divide line 5a by $\left(\frac{1}{2p}\right) \pi (r)^2$ . The resulting value is one of four "replacement" point velocity values adjusted for wall effects, $\hat{v}_e$ , as derived in Equation 2H-15.						
6. Substitute the value shown in 5b for the unadjusted velocity value in the Method 1 sector. (See Eq. 2H-17.)						

Notes: 1. Column B: If no measurement is taken at distance *d*, enter the velocity value obtained at the first subsequent traverse point where a measurement was taken, followed by the letters "NM". See section 8.7.1.2.  
 2. For clarity, only English units are shown in this form. Following are metric equivalents of the English units used in the form. In row 2, column A: 1 in. = 2.5 cm; 2 in. = 5.1 cm. In row 2, column D: If metric units (cm) are used, the term  $\frac{1}{4} \pi (r-d+1)^2$  must be changed to  $\frac{1}{4} \pi (r-d+2.5)^2$ . In row 4a: ½ in. = 12.7 mm. Throughout the form, the metric equivalents of in., in.<sup>2</sup>, ft., ft./sec., and ft-in.<sup>3</sup>/sec are cm, cm<sup>2</sup>, m, m/sec, and m-cm<sup>3</sup>/sec, respectively.



**Form 2H-4 Calculation of Replacement Velocity Values for a Method 1 Equal-Area Sector Closest to the Stack Wall for a 16-Point Method 1 Traverse, Using a Complete Traverse**

1<sup>st</sup> Probe Type/ID/Pts. Sampled: Type S Straight-up/S-13/All Tester(s): Test Team III  
 2<sup>nd</sup> Probe Type/ID/Pts. Sampled: \_\_\_\_\_ Affiliation: Contractor III  
 Entry Port ID (e.g., A, B, C, or D): A

1. Diameter of the stack or duct (ft)		24	Radius, <i>r</i> , of the stack or duct (in.) (= diameter × 6)			144	
2. Location (column A), measured and decay velocities (columns B and C), and volumetric flow (column G) associated with each successive wall effects traverse point.							
(A)	(B)	(C)	(D)		(E)	(F)	(G)
Distance ( <i>d</i> ) from Wall	Measured Velocity ( <i>v<sub>d</sub></i> ) at Distance <i>d</i>	Decay Velocity ( <i>v<sub>dec,d</sub></i> )	Intermediate Calculations		Area of Sub-sector ( <i>A<sub>d</sub></i> )	Volumetric Flow in Sub-sector ( <i>Q<sub>d</sub></i> )	
		$\frac{v_{d-1} + v_d}{2}$ Note: <i>v<sub>0</sub></i> = 0	$\frac{1}{4}\pi[r-d+1]^2$	$\frac{1}{4}\pi[r-d]^2$	(Col. D - Col. E)	(Col. C × Vol. F)	
(in.)	(ft/sec)	(ft/sec)	(in. <sup>2</sup> )	(in. <sup>2</sup> )	(in. <sup>2</sup> )	(ft-in. <sup>2</sup> /sec)	
<i>d</i> = 1	51.71 NM	25.85	16,286.00	16,060.59	225.41	5,827.47	
<i>d</i> = 2	51.71 NM	51.71	16,060.59	15,836.76	223.84	11,573.72	
<i>d</i> = 3	51.71	51.71	15,836.76	15,614.49	222.27	11,492.51	
<i>d</i> = 4	62.26	56.98	15,614.49	15,393.79	220.70	12,576.24	
<i>d</i> = 5	67.16	64.71	15,393.79	15,174.67	219.13	14,179.40	
<i>d</i> = 6	69.44	68.30	15,174.67	14,957.11	217.56	14,858.32	
<i>d</i> = 7	72.63	71.03	14,957.11	14,741.13	215.98	15,341.75	
<i>d</i> = 8	71.37	72.00	14,741.13	14,526.71	214.41	15,437.01	
<i>d</i> = 9	74.37	72.87	14,526.71	14,313.87	212.84	15,510.03	
<i>d</i> = 10	75.80	75.08	14,313.87	14,102.60	211.27	15,863.30	
<i>d</i> = 11	77.15	76.47	14,102.60	13,892.90	209.70	16,035.93	
<i>d<sub>last</sub></i> = 12	78.58	77.86	13,892.90	13,684.77	208.13	16,205.92	
3. Total volumetric flow for all sub-sectors located between stack wall and <i>d<sub>last</sub></i> (total Col. G).						164,901.59	
4. Volumetric flow for remainder of the Method 1 equal-area sector.							
a. Velocity measurement at distance <i>d<sub>rem</sub></i> from stack wall ( <i>v<sub>drem</sub></i> ). (If <i>d<sub>rem</sub></i> - <i>d<sub>last</sub></i> < ½ in., then no measurement at <i>d<sub>rem</sub></i> is necessary. Enter the velocity at <i>d<sub>last</sub></i> on this line.)						78.51	
b. Total area in remainder of Method 1 equal-area segment ( <i>A<sub>drem</sub></i> ). Subtract $\frac{3}{16}\pi(r)^2$ from last entry in item 2, column E, and enter the result on this line.						1,470.26	
c. Multiply values on lines 4a and 4b. ( <i>Q<sub>drem</sub></i> )						115,430.44	
5. Wall effects-adjusted velocity in the Method 1 equal-area sector.							
a. Add the values on lines 3 and 4c. ( <i>Q<sub>T</sub></i> )						280,332.03	
b. Divide line 5a by $\frac{1}{16}\pi(r)^2$ . The resulting value is one of four "replacement" point velocity values adjusted for wall effects, <i>v<sub>e</sub></i> , as derived in Equation 2H-16.						68.85	
6. Substitute the value shown in 5b for the unadjusted velocity value in the Method 1 sector. (See Eq. 2H-18.)							

METHOD 3—GAS ANALYSIS FOR THE DETERMINATION OF DRY MOLECULAR WEIGHT

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 in-

corporated by reference from other methods in this part. Therefore, to obtain reliable results, persons using this method should also have a thorough knowledge of Method 1.

1.0 Scope and Application

1.1 Analytes.