Designation: D3464 – 96 (Reapproved 2014)

Standard Test Method for Average Velocity in a Duct Using a Thermal Anemometer[1]

This standard is issued under the fixed designation D3464; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method describes the measurement of the average velocity with a thermal anemometer for the purpose of determining gas flow in a stack, duct, or flue (**1-5**).[2] It is limited to those applications where the gas is essentially air at ambient conditions and the temperature, moisture, and contaminant loading are insignificant as sources of error compared to the basic accuracy of the typical field situation.

1.2 The range of the test method is from 1 to 30 m/s (3 to 100 ft/s).

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D3796 Practice for Calibration of Type S Pitot Tubes

2.2 *Other Standards:*

ASME PTC 19.5-72 *Application of Fluid Meters*, Sixth Ed. 1971 (Interim Supplement 19.5 on Instruments & Apparatus)[4]

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology D1356.

4. Summary of Test Method

4.1 This test method describes the operational and calibration procedures necessary for the measurement of point velocity and calculation of the average velocity of air or gas flows in flues, ducts, or stacks utilizing a thermal anemometer.

5. Significance and Use

5.1 The method presented is a "short method" that may be used where contamination levels are less than 5000 ppm by weight or volume, temperatures are between 0°C (32°F) and 65°C (150°F), and the humidity is not considered. The gas is considered as standard air and the velocity is read directly from the instrument.

5.2 This test method is useful for determining air velocities in HVAC ducts, fume hoods, vent stacks of nuclear power stations, and in performing model studies of pollution control devices.

6. Apparatus

6.1 *Thermal Anemometer*—A commercially available electrically operated hot sensor anemometer with direct readout. A thermal anemometer senses the cooling effect of a moving gas stream passing over an electrically heated sensor. This cooling effect or heat transfer rate is correlated to the velocity of the gas stream. The instrument is calibrated to display a direct readout in terms of velocity.

6.2 *Sensors and Probes*—There are a number of different types of sensors available for thermal anemometry including the hot-wire sensor, the hot-film sensor, and the quartz-coated sensor. Probes are available in many different shapes depending upon application.

6.3 *Temperature Compensation*—If the temperature of the gas stream changes during velocity measurements, the anemometer reading will change accordingly unless a constant-temperature or "temperature-compensated" anemometer is utilized. This type of instrument shall be specified for most applications of this measurement standard.

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[1] This test method is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres and Source Emissions.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

6.3.1 *Temperature-Compensated Anemometer*—A temperature-compensated anemometer has a temperature-sensing probe within the instrument sensor that automatically corrects errors caused by changes in temperature in the gas stream. For temperature-compensated anemometers, a change in temperature (ΔT) of 28°C (50°F) typically produces an error of 2 %.

6.3.2 *Temperature-Uncompensated Anemometer*—For a "constant-current" or uncompensated anemometer a change in temperature (ΔT) of 28°C (50°F) typically produces a 25 % error. For laboratory work where this type of anemometer might be preferred, the output data shall be corrected for temperature changes in the gas stream.

6.4 *Calibration Apparatus:*

6.4.1 *Flows above 3 m/s (10 ft/s)*—See Section 6, Practice D3796.

6.4.2 *Flows below 3 m/s (10 ft/s)*—See PTC 19.5-72.

7. Calibration

7.1 For velocities in excess of 3 m/s (10 ft/s) calibrate the thermal anemometer with a standard pitot tube, in accordance with Practice D3796. It is preferable to make these calibrations under laboratory conditions; however, where expediency dictates, field calibration at the sampling site is permissible.

7.2 For velocities below 3 m/s (10 ft/s) calibrate in the laboratory using a calibrated orifice or nozzle in accordance with PTC 19.5-72.

7.3 Calibrate the thermal anemometer for a minimum of three velocities covering the range of velocities which are anticipated for a particular test. Calibrate an increased number of points, typically five to seven, for the complete range of the instrument if the anticipated test velocity range is not known. (**Warning—** If this test method is used for gases other than air, calibrate using the test gas.)

8. Single-Point Velocity Measurement

8.1 *Velocity*—The hot-wire anemometer is effective for measuring velocities over a range from 1 m/s (3 ft/s) to 30 m/s (100 ft/s). Record measurements at specific points within the flue in accordance with a plan determined by the flue size. Place marks on the instrument probe or probe extension to aid in locating the sampling points at which the velocity is to be measured.

9. Average Velocity Measurements

9.1 *Average Velocity*—Average flue gas velocity is equal to the algebraic average of the single point velocity measurements made in accordance with 9.2 – 9.2.4.

9.2 To determine the average velocity in a flue it is necessary to record several velocities. This is true even if the flow does not vary with time. Velocities in any flue cannot be assumed to be uniform across any large cross-sectional area. However, in any single subarea, one may assume a constant rate of change of velocity over the area with average velocity at the centroid of this area. Determine the number of points and their locations, at which velocities are to be recorded in accordance with commonly accepted practices when gas flow patterns are essentially uniform, that is, 80 to 90 % of the measurements are greater than 10 % of the maximum flow. In all cases, divide the effective inside area of the flue into a number of equal areas, and record the gas velocity at the centroid of each of these areas.

9.2.1 In rectangular flues, divide the cross-sectional area into equal rectangular subareas as shown in Fig. 1. The number of areas to be used depends on the flow pattern and flue size. Use Table 1 to find the minimum number of areas when sampling at least eight equivalent diameters downstream and two equivalent diameters upstream from the nearest flow disturbance, such as a bend, expansion or contraction. The equivalent diameter can be determined as follows:

$$D_e = 2LW/(L+W) \tag{1}$$

where:

D_e = equivalent diameter, m (ft),
L = duct length, m (ft), and
W = duct width, m (ft).

If a site less than eight diameters downstream and two diameters upstream from a flow disturbance, such as a bend, expansion or contraction is used increase the number of sampling points in accordance with 9.2.4.

9.2.2 In circular flues divide the area concentrically as shown in Fig. 2. The minimum number areas to be used and the distance to the test point are shown in Table 2 or calculate as follows:

$$r_n = D_s \sqrt{(2n-1)/4N} \tag{2}$$

where:

D_s = internal diameter of flue, cm (in.),
r_n = radial distance from center of flue to nth sampling point, cm (in.),
n = nth sampling point from center of flue, and
N = number of sampling points across a diameter.

Conduct traverses across two diameter axes right angles to each other. Again, if a site less than eight diameters downstream and two diameters upstream from a flow disturbance is used, increase the number of sampling points as indicated in 9.2.4.

9.2.3 When readings must be taken in an irregular-shaped flue, divide the flue into equal areas of any shape, and measure the parameters at the centroid of each area.

9.2.4 Increase the number of sampling points when sampling less than eight diameters downstream and two diameters upstream from any flow disturbance. When only four to six diameters of straight duct are available, double the number of

FIG. 1 Traverse Positions for Rectangular Flue

TABLE 1 Minimum Number of Measurements for Rectangular Ducts

Cross Sectional Area of Sampling Sites m^2 (ft^2)	Number of Measurements
Less than 0.2 (2)	4
0.2 to 2.3 (2 to 25)	12
Greater than 2.3 (25)	20

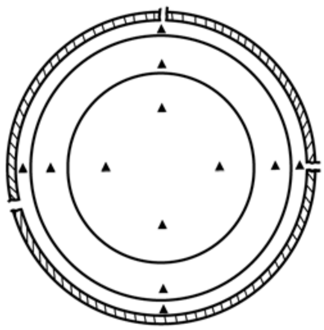

FIG. 2 Traverse Positions for Round Flue

TABLE 2 Location of Traverse Points in Circular Stacks
(Percent of Stack Diameter From Inside Wall to Traverse Point)

Traverse Point Number on a Diameter	Number of Traverse Points on a Diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8				96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.6	19.4
9					91.8	82.3	73.1	62.5	38.6	30.6	26.2	23.0
10					97.4	88.2	79.9	71.7	61.8	38.9	31.5	27.2
11						93.3	85.3	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

points. Sampling sites less than four diameters downstream from any flow disturbance are special cases, and each case shall be determined on its own merits in the field. Where sampling sites are less than two diameters downstream from any flow disturbances, reasonable accuracy with this type measurement cannot be expected and another method for determining stack gas velocity should be used.

9.3 *Changing Flow Conditions*—If the flow rate changes moderately during the test period, continuously monitor this change by measuring the velocity at a single point and relating this velocity to the total flow obtained during a fairly stable period. Determine the point of approximate average velocity during stable flow conditions and locate a fixed probe at this point for reference during the period of changing flow. The average velocity in a flue is then equal to the average velocity during a stable run multiplied by the ratio of the velocity at the reference point to the velocity at the reference point during the stable run.

$$u_{avg} = (u_s)_{avg}(u_r/u_s) \quad (3)$$

where:

u_{avg} = average flue gas velocity, m/s (ft/s),
u_r = flue gas velocity at reference point, m/s (ft/s),
(u_s) = velocity at reference point during stable run, m/s (ft/s), and
$(u_s)_{avg}$ = average flue gas velocity during stable run, m/s (ft/s).

10. Set-up Procedures

10.1 *Number of Traverse Points*—Select traverse points as indicated in 9.2 – 9.2.4.

10.2 *Preparation of Probe or Probe Holder*—A simple method for marking off the probe or probe holder for use in taking a velocity traverse is as follows:

10.2.1 Slide the probe all the way through the sampling port until the tip touches the far wall of the flue and is aligned in accordance with the manufacturer's instructions. Using a china marker or other suitable means, mark the probe at a point immediately adjacent to the sampling port fitting.

10.2.2 Slide the probe out of the port until the tip is even with the inner wall of the stack. Again mark it at a point immediately adjacent to the sampling port fitting.

10.2.3 The distance between the two lines is the internal diameter of the stack (D_s). Mark the centerline halfway between these two points.

10.2.4 Mark the traverse points on the probe after referring to Table 2, or use Eq 1. (It is advisable to mark the traverse points in one manner and the centerline and end points in a different manner.)

10.2.5 Determine the velocity only at the traverse points and not at the centerline or at the walls. This method allows for wall thickness, breach fittings, etc., so that only the internal dimensions are considered.

10.3 *Assembling Equipment*—If the length of the probe is insufficient to make a valid traverse of the duct, it will be necessary to attach the probe to a pipe or pole to extend its effective length. This effective length is the limiting factor on the size of the ducts that can be measured.

NOTE 1—As this method becomes acceptable, it is anticipated that probes of adequate length will be available for most cases where this "short" method applies.

10.4 *Insertion*—Align the probe so that it is parallel to the duct walls and faces the gas stream. Seal the breach around the probe to prevent air from leaking into or out of the duct. The probe can now be moved to each point on the traverse plan.

10.5 *Measurement*—Record the velocity where applicable at each traverse point.

11. Precision and Bias

11.1 Velocities of 0.025 to 5 m/s (0.08 to 17 ft/s) give accuracies better than ±20 % and above 10 m/s (33 ft/s), the accuracy becomes ±10 % or better (**6**).

12. Keywords

12.1 air velocity; anemometer; atmospheres; gas velocity; hot wire anemometer; measurements; pitot tube; thermal anemometer

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