Designation: D3195/D3195M – 10 (Reapproved 2015)

Standard Practice for Rotameter Calibration[1]

This standard is issued under the fixed designation D3195/D3195M; 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.

1. Scope

1.1 This practice covers the calibration of variable-area flowmeters (rotameters) used to determine air sample volumes at or close to ambient conditions of pressure and temperature, in the analysis of atmospheres for pollutant content.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *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:*[2]

D1071 Test Methods for Volumetric Measurement of Gaseous Fuel Samples

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D3631 Test Methods for Measuring Surface Atmospheric Pressure

E1 Specification for ASTM Liquid-in-Glass Thermometers

E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

E1137/E1137M Specification for Industrial Platinum Resistance Thermometers

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology D1356.

3.1.2 *Standard conditions* are taken as 25°C [77°F] and 101.3 kPa (760 mm Hg) at existing ambient humidity. This conforms to most of the ASTM methods for atmospheric sampling and analysis that involve volumetric corrections. Absolute temperature scales are to be used when substituting values into the formulae used in this procedure.

4. Summary of Practice

4.1 Two alternative methods of performing the required volume determinations for rotameter calibration are described:

4.1.1 Using the water-sealed rotating drum meter (wet test meter). See Section 7.

4.1.2 Using the volumetric gasometer (bell prover). See Section 8.

5. Significance and Use

5.1 Choice of method depends primarily on which equipment is available. Higher accuracy is possible with the gasometer. The accuracies of the methods of atmospheric analysis, for which the calibration procedure is intended, do not warrant the very highest possible accuracy in flow measurement.

6. Apparatus

6.1 *Wet Test Meter, or Volumetric Gasometer,* with water seal and equipped with a water manometer on the inlet.

6.2 *Counter Balance Weights,* for gasometer.

6.3 *Mercury Barometer*—See Test Methods D3631.

6.4 *Psychrometer,* (if room air is used for calibration gas). See Test Method E337.

6.5 *Thermometer,* to measure ambient temperature. See Specifications E1, E1137/E1137M, and E2251.

6.6 *Stopwatch.*

6.7 *Air Supply,* either a cylinder of compressed air or a diaphragm type pump of adequate capacity and a ballast volume or restrictor to eliminate pulsations.

6.8 *Needle Valve.*

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[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.01 on Quality Control.

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[2] 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.

7. Procedure Using Wet Test Meter

7.1 Unless it was already calibrated within the previous three months, calibrate the wet test meter by Test Methods D1071. The method described in Section 19 is recommended for highest accuracy.

7.2 Set up the apparatus as shown in Fig. 1, making connections as short as possible and large enough inside diameter to avoid any appreciable pressure drops.

7.3 Before and after the complete calibration run, record room temperature, barometric pressure in accordance with Test Methods D3631, and relative humidity (when room air is used for calibrating gas) in accordance with Test Method E337. Use average values for subsequent calculations.

7.4 Start air flowing through the rotameter and wet test meter. Adjust the flow to the desired rate with the needle valve. Take a pair of timed readings on the wet test meter, under steady flow, for each of five or more uniformly spaced points on the rotameter scale, going from low values to high values. Repeat, going from high to low. Note the manometer reading and meter water temperature for each meter reading.

8. Procedure Using Gasometer

8.1 Unless it was already calibrated within the previous six months, in the same location, calibrate the gasometer by Test Methods D1071.

8.2 Set up the apparatus as shown in Fig. 2, making connections as short as possible and large enough inside diameter to avoid any appreciable pressure drops.

8.3 Before and after the complete calibration run, record the room temperature, barometric pressure, and relative humidity (when room air is used for calibrating gas). Use average values for subsequent calculations.

8.4 Start air flowing through the rotameter and into the gasometer. Adjust the flow to the desired value with the needle valve.

8.5 Adjust eight counterbalance weights on the gasometer as required to maintain no greater than 2 in. of water back-pressure when operating. (It is pertinent to leave the units in non-SI units as this calibration is in accordance with the procedure of manufacturer specifications for testing, thus no equivalent SI units given.)

8.6 Take a pair of timed readings on the gasometer scale, under steady flow, for each of five or more uniformly spaced points on the rotameter scale going from low values to high values. Repeat, going from high to low.

9. Calculations

9.1 Convert all temperature and pressure readings to absolute units, as follows:

$$°F + 460 = °R \quad (1)$$

$$°C + 273 = K$$

$$\text{in. of water} \times 0.249 = \text{kPa}$$

$$\text{in. of water} \times 0.0737 = \text{in. Hg}$$

$$\text{in. of water} \times 1.87 = \text{mm Hg}$$

9.2 Calculate the indicated flow readings for all recorded rotameter points by dividing the indicated delta volumes by the time.

9.3 Using the following equation, convert these indicated flow readings to actual flows that would be indicated by the rotameter if it were calibrated for air at the standard conditions stated in 3.1.2:

$$Q_1 = Q(P_m - D)T_a/P_mT_m\sqrt{T_a/T_s} \quad (2)$$

where (see Appendix X1):

Q_1 = flow rate rotameter should indicate,
Q = flow rate indicated by wet test meter or gasometer,
T_s = standard temperature, absolute units (298 K or 537°R),
T_m = meter temperature, absolute units (water temperature for wet test meter; room temperature for gasometer),
T_a = room temperature, absolute units
P_m = gas pressure during calibration (inlet pressure for wet test meter; barometric pressure for gasometer) (kPa, in. water, mm Hg), and
D = vapor pressure of water in the calibrating gas (kPa, in. water, mm Hg).

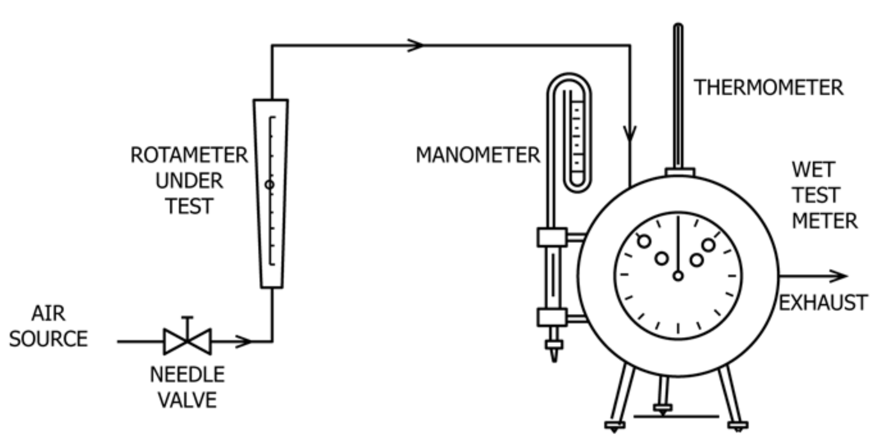

FIG. 1 Calibration Assembly Using Wet Test Meter

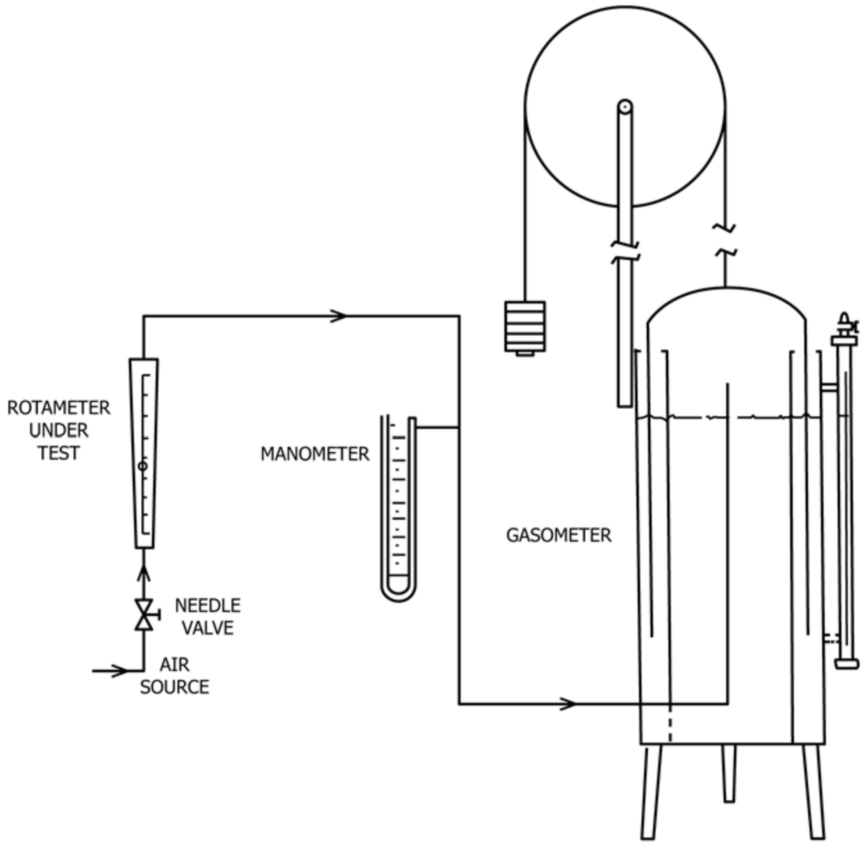

FIG. 2 Calibration Assembly Using Gasometer

9.4 Prepare the calibration curve by best fit to all points. It should be labeled "... at 25°C [77°F] and 101.3 kPa (760 mm Hg)."

10. Keywords

10.1 calibration; flowmeter; rotameter

APPENDIX

(Nonmandatory Information)

X1. DERIVATION OF FLOWMETER EQUATION

X1.1 The equation is based on the premise that the calibrated rotameter should read air flow correctly at standard conditions, as defined. Therefore, in order to prepare the calibration curve it is first necessary to convert the wet test meter or gasometer readings to the values that would be indicated by the rotameter if it had been calibrated under standard conditions. This can be done logically in several steps. First, the indicated values are corrected for the water vapor added by the wet test meter or gasometer, assuming saturation, by operating with the factor:

$$P_m - D/P_m \quad \text{(X1.1)}$$

where:

P_m = gas pressure during calibration (inlet pressure for wet test meter; barometric pressure for gasometer), and

D = vapor pressure of water at 100 % R.H. and temperature T_m, minus the vapor pressure of water in the calibrating gas.

X1.2 Next, the volume measured in the wet test meter or gasometer is corrected to what it was in the rotameter. This factor is:

$$T_a/T_m \quad \text{(X1.2)}$$

where:

T_a = room temperature, absolute units and

T_m = meter temperature, absolute units (water temperature for wet test meter; room temperature for gasometer).

X1.3 This is what the rotameter should read but if it were calibrated with air at standard temperature and used to measure air at this different temperature, the viscosity effect would cause a slightly different reading. Since viscosity is proportional to the square root of absolute temperature (independent of pressure up to 10 atmospheres), the indicated flow would differ from actual flow by the factor:

$$\sqrt{T_a/T_s} \tag{X1.3}$$

where:

T_s = standard temperature, absolute units (298 K or 537°R).

X1.4 Putting these elements all together gives us the equation indicated in the body of the method.

X1.5 Subsequent use of the rotameter normally involves taking the indicated flow off the curve and correcting it to standard conditions. The factor for this correction is:

$$T_s P_r / T_a P_s \sqrt{T_s/T_a} \tag{X1.4}$$

where:

P_r = rotameter pressure, kPa (mm Hg) and
P_s = standard pressure 101.3 kPa (760 mm Hg).

NOTE X1.1—In many cases, P_r is, or can be assumed to be, the same as barometric pressure. However, when any question exists, and for highest accuracy, a water manometer should be used, just downstream of the rotameter.