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Standard Test Method for Measured Speed of Oil Diffusion Pumps[1]

This standard is issued under the fixed designation E295; 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 test method covers the determination of the measured speed (volumetric flow rate) of oil diffusion pumps.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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]

E297 Test Method for Calibrating Ionization Vacuum Gage Tubes (Withdrawn 1983)[3]

3. Terminology

3.1 *measured speed*—the mass flow rate of gas admitted from a flowmeter divided by the resulting increase in equilibrium static pressure near the inlet of the pump, using the equipment in Fig. 1.

4. Summary of Test Method

4.1 The pump under test is fitted with a test dome of specified design (Fig. 1). Gas is admitted to the test dome in a specified manner at a measured rate, and the resulting change in equilibrium pressure is measured in a specified way.

5. Apparatus

5.1 *Test Dome*—The test dome (Fig. 1) may be constructed by any material and by any method acceptable in high-vacuum practice, and will normally be connected to the pump by the method provided for in the design of the pump. The inside diameter of the test dome shall be equal to that of the pump inlet, and its mean height shall be 1.5 times this diameter (Note 1). The gas shall be admitted through a tube projecting into the dome and bent upward so that its exit is located on the axis, facing away from the pump inlet port, and at a distance from the pump inlet equal to the dome diameter. The opening to the vacuum gage shall be through a tube radially projecting into the test dome. The tubulation center line shall be above the inlet flange, 1 in. (25 mm) or ¼ D above the top of the flange, whichever is larger (see Fig. 1).

NOTE 1—A 10° slope of the dome roof is required only if the dome is to be used for back-streaming measurements.

5.2 *Gage Attachment*—The gage connecting line shall be less than 6 in. (152 mm) long and at least ¾ in. (19 mm) in inside diameter; shall contain one right-angle bend upward to the gage; and shall project ⅛ in. (3.2 mm) into the test dome. If a McLeod gage is used, it shall be attached in a similar manner, except that the connecting line, including a mercury vapor trap, need not meet the dimensional restrictions above. The use of grease, wax, and rubber in assembling the gage lines should be minimized.

5.3 *Flow-Measuring Devices:*

5.3.1 For flows greater than about 5×10^{-4} torr L/s (that is, about 25 min/atmospheric cm^3), and up to approximately 5 torr L/s (that is, about 15 s/100 atmospheric cm^3), some type of constant-pressure displacement tube with low-vapor pressure fluid shall be used. These tubes should be provided in a series of overlapping ranges so that very small through-puts may be measured in a reasonably short time and that very large through-puts may be measured in a time interval long enough to allow precise measurement.

5.3.2 Flow rates less than about 5×10^{-4} torr L/s may be determined by a conductance method in which the test gas contained in a reservoir at known pressure is admitted to the test dome through a known conductance.

5.3.3 For flows greater than 5 torr L/s, special types of constant-pressure fluid-displacement devices or a series of variable-area flowmeters (rotameters) of sufficient overlap to ensure precise measurement should be used.

5.3.4 The timing in all flow measurements shall be made with a ¹⁄₁₀-s stop watch or by some equally precise method.

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[1] This test method is under the jurisdiction of the ASTM Committee E21 on Space Simulation and Applications of Space Technology and is the direct responsibility of Subcommittee E21.04 on Space Simulation Test Methods.

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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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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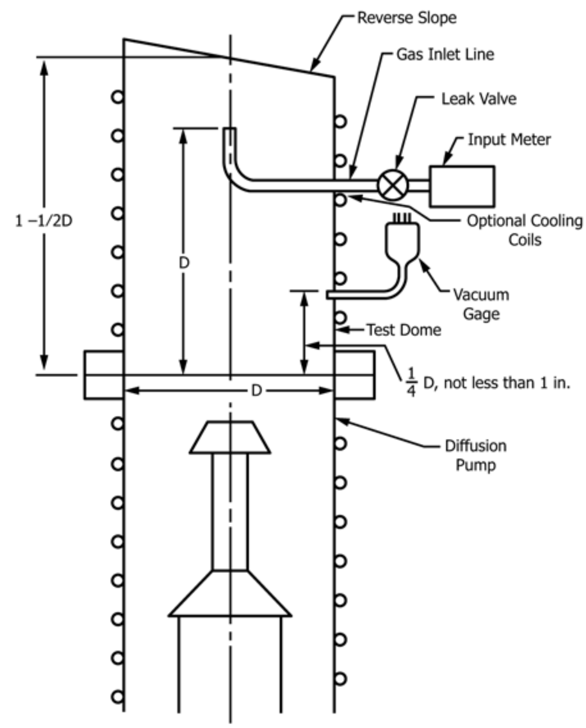

FIG. 1 Test Dome Dimensions

5.4 *Leak Control Valve*—The leak control valve should provide good control of flow and flow changes as reflected in equilibrium pressures through the pressure range of interest.

6. Test Gas

6.1 Air shall normally be used in the measurement of pump speeds; and measured speed for air will be considered a basic performance characteristic of a pump.

6.2 The apparatus and method herein described may be used for measuring pumping speeds for gases other than air as may be required.

7. Calibration and Precision of Flow-Measuring Devices

7.1 *Constant-Pressure Displacement Tubes*—To cover conveniently the input range suggested in 5.3, displacement tubes of at least three overlapping ranges should be provided. The displacement tubes should be precision burets of glass tubing selected for uniformity of bore and having accurately measured inside diameters (accuracy 0.25 %, commercially available). The instruments should be designed, calibrated, and used in such a way as to measure the actual quantity of gas transferred to the test dome in some conveniently measurable time. Ambient temperature during the measurement shall be 23 ± 3°C. Meters of the constant-pressure displacement type may take various forms. Two of these are shown in Fig. X1. and discussed in Appendix X2.

7.2 *Conductance Method*—This method of measuring input rate requires a conductance of accurately known dimensions and a reservoir of test gas in which the pressure can be varied and accurately measured (see Fig. X2. and Fig. X3. and Appendix X3). It requires, in addition, that the dimensions of the conductance be so chosen as to permit the desired maximum through-put (5×10^{-4} torr L/s or more) at a reservoir pressure that does not exceed the condition for free molecular flow through any part (that is, the mean free path of gas in the reservoir must be equal to or greater than ten times the largest linear dimension of the reservoir). Gas introduced into the reservoir must be directed away from the conductance entrance.

8. Calibration and Precision of Vacuum Gages

8.1 To cover the full range of pressures at which pump speeds should be measured requires that at least two types of vacuum gages be used:

8.1.1 *McLeod Gage*—For measuring pressures greater than 10^{-3} torr, a McLeod gage shall be used. The McLeod gage may also be used at lower pressures (down to about 10^{-5} torr) provided the gage has an error less than ±5 % at these lower pressures. Only gages having individually determined gage constants and individually calculated scales can be depended upon for this precision. Also, approved procedures must be followed, particularly in the lower range of measurable pressures.

8.1.2 *Ionization Gage*—For measuring pressures less than 10^{-5} torr, an untrapped ionization gage of the Bayard-Alpert type shall be used.

8.2 Calibration of vacuum gages used in this test method shall be based on Test Method E297.

9. Procedure

9.1 The following operating conditions should be noted for subsequent incorporation in the report of speed measurements: type and speed of fore-pump system, type and quantity of diffusion pump fluid, power input to diffusion pump, and (optionally) cooling water flow rate, inlet temperature, and discharge temperature.

9.2 Speed measurements should not be made until the pressure p_o in the test dome has become 1 decade lower than the lowest test point, p.

9.3 After the pressure p_o has become constant, introduce gas to the test dome at some constant measured mass flow rate, Q, for not less than 15 min and note the resulting equilibrium pressure, p. If p varies, use the arithmetic average value over the time interval during which Q is measured. The pumping speed at this pressure is then derived from the following equation:

$$S = Q/(p - p_o) \quad (1)$$

9.4 Adjust the rate of gas input to a series of values and determine the pumping speed at each resulting equilibrium pressure. Speed measurements should be made at pressures distributed over the whole operating pressure range of the pump.

10. Results

10.1 The measured speed of a pump shall be displayed by a graph on which the speed is plotted on the ordinate as a linear function and the pressure plotted on the abscissa as a log function.

10.2 Each speed curve shall be accompanied by a listing of the operating conditions specified in 9.1. Also, the pressure p_o before the time the measurements were made shall be indicated.

11. Precision

11.1 All equipment and procedures used in making speed measurements shall be selected so that the probable error in the reproducibility of test results will be no more than ±5 % unless otherwise noted.

APPENDIXES

(Nonmandatory Information)

X1. INTERPRETATION OF FLOW

X1.1 The lowest rate for intentionally admitted gas into the test dome has been arbitrarily set to raise the pressure p to a value at least ten times the pressure p_o to ensure that the measured rate of flow of gas, Q, represents essentially all the gas flowing through the pump under test conditions.

X1.2 The total quantity of gas passing through the pump, Q_T, may be explained more readily by the following expression:

$$Q_T = Q_O + Q_L + Q \quad (X1.1)$$

where:

Q_O = gas originating within this test dome as the result of outgassing,

Q_L = gas leaking into the test dome unintentionally as the result of the permeation through the materials of construction, leaks, and so forth, and

Q = gas admitted intentionally through the controlled leak.

X1.3 When speed measurements are made too near the pressure p_o of a pump, the resulting speed measurements may be in error. Arbitrarily raising the pressure p to 10 p_o avoids this problem.

X1.4 The use of the term $p - p_o$ also eliminates the misleading concept that the speed of a diffusion pump drops to zero at some low pressure p_o when no gas is intentionally admitted into the pump test dome.

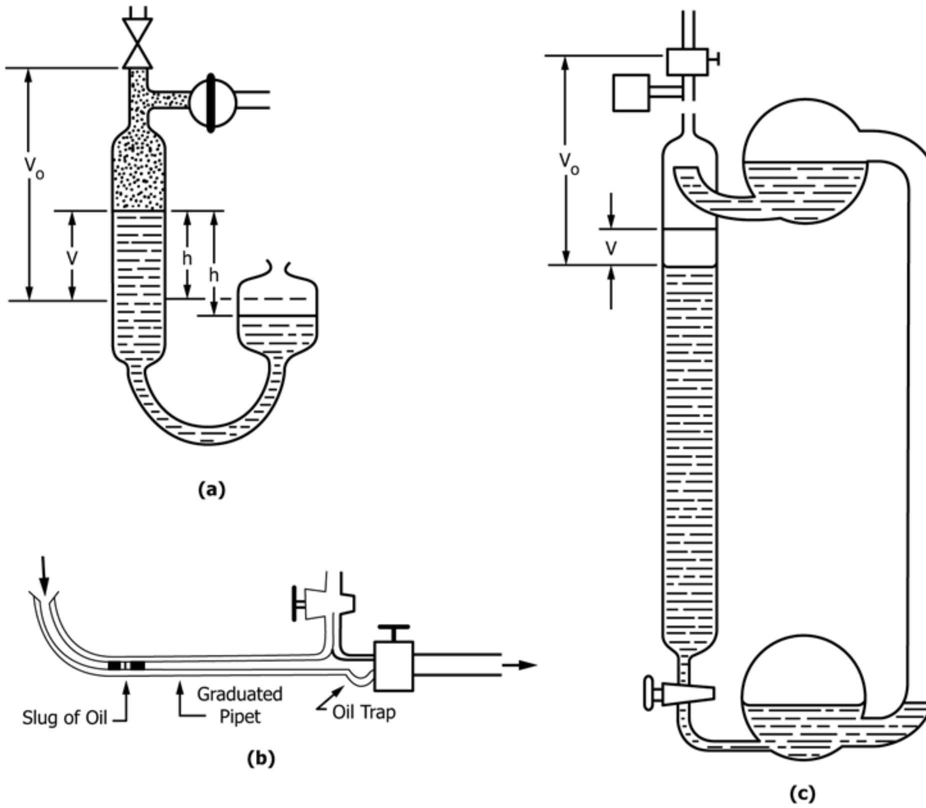

FIG. X1.1 Constant-Pressure Flow-Measuring Devices

X2. GAS FLOW MEASUREMENT BY CONSTANT-PRESSURE METHOD

X2.1 Constant-pressure displacement meters of many types have been used for measuring flow rates. Some simple types are shown in Fig. X1.1. Referring to Fig. X1.1(*a*), a leak rate is determined by observing the time *t*required for the displaced fluid to rise (or fall) through some arbitrary distance *h* in the displacement tube. The leak rate,*Q*, can be determined in*PV* units per second as follows:

$$Q = [BV_o - (B - P_h)(V_o - v)]/t = [B_v + P_h(V_o - v)]/t \quad \text{(X2.1)}$$

where:

B	=	pressure of the gas filling the displacement meter at time zero,
V_o	=	corresponding volume,
P_h	=	pressure due to fluid head h,
$B - P_h$	=	pressure of the gas remaining at time t, and
$V_o - v$	=	corresponding volume.

X2.1.1 Displacement devices may be designed so that the quantity $P_h(V_o - \mathrm{v})$ is negligibly small as compared with the quantity Bv. In such cases, Eq X2.1 reduces to

$$Q = B\,v/t \quad \text{(X2.2)}$$

X2.1.2 If it is not convenient to make $P_h(V_o - \mathrm{v})$ negligibly small, Eq X2.1 may be used to construct a displacement scale that reads quantity change directly.

X2.2 For very small flow rates, a simple small bore tube or pipet, using a "slug" of fluid such as shown in Fig. X1.1(*b*), is ideal.

X2.3 For very large flow rates (5 to 50 torr L/s), a vertical displacement device with the fluid reservoir on top as shown in Fig. X1.1(*c*) can be used conveniently and with a precision of about ±1 % either as a primary measuring instrument or as a standard for calibrating variable-area-type meters (rotameters).

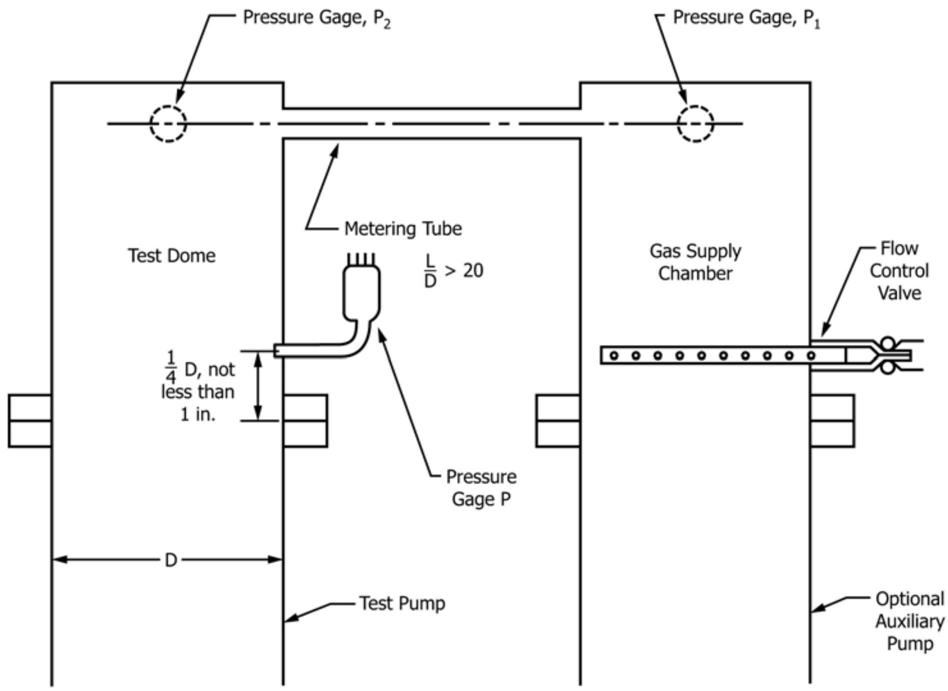

FIG. X2.1 Speed Testing by Conductance-Tube Method

X3. GAS FLOW MEASUREMENT BY CONDUCTANCE-TUBE METHOD

X3.1 Two arrangements for controlling and determining the flow into the test dome by the conductance-tube method are illustrated. Figure X2.1 shows schematically an arrangement whereby the conductance tube connects two large chambers in which the pressure measurements are made. A gas supply chamber, pumped by an auxiliary (diffusion) pump, is connected to the test dome by a tube whose conductance, *C*, can be derived from its dimensions. The equilibrium pressure in the test chamber can be varied by varying the leak rate into the chamber, or by adjusting the net speed of the auxiliary pumping system connected to the gas supply chamber. Bayard-Alpert ionization gages shall be used for pressure-drop measurements. The flow rate, *Q*, into the test dome due to the pressure increase in the gas supply chamber is calculated as follows:

$$Q = C[(P_1 - P_{01}) - (P_2 - P_{02})] \quad \text{(X3.1)}$$

where:

P_{01} = ultimate pressure in the gas supply chamber,
P_{02} = ultimate pressure in the test dome,
P_1 = equilibrium pressure in the gas supply chamber when a leak is admitted, and
P_2 = corresponding pressure in the test dome.

X3.1.1 In practice, the tube conductance should be so chosen that the ratio $(P_1 - P_{01})/(P_2 - P_{02})$ is not less than 100. In this case, Eq X3.1 may be simplified to

$$Q = C(P_1 - P_{01}) \quad \text{(X3.2)}$$

and gage P_2 may be omitted.

X3.1.2 The speed of the test pump, *S*, in litres per second, is defined as

$$S = Q/(P - P_o) \quad \text{(X3.3)}$$

where:

P = equilibrium pressure at the test pump inlet and
P_o = ultimate pressure at the test pump inlet.

X3.1.3 From this it follows that

$$S = C[(P_1 - P_{01})/(P - P_o)] \quad \text{(X3.4)}$$

Since the conductance of a tube is constant and determinable only for free molecular conditions, it is essential that the conductance-tube method not be used at supply-gas pressures too high to permit this type of flow.

X3.2 Fig. X3. shows schematically an arrangement whereby the pressure drop in a straight tube is determined downstream from the source of gas flow. This arrangement lends itself to both theoretical conductance computation and comparative measurement (in some pressure ranges) with constant-pressure displacement devices such as are described in Appendix X2.

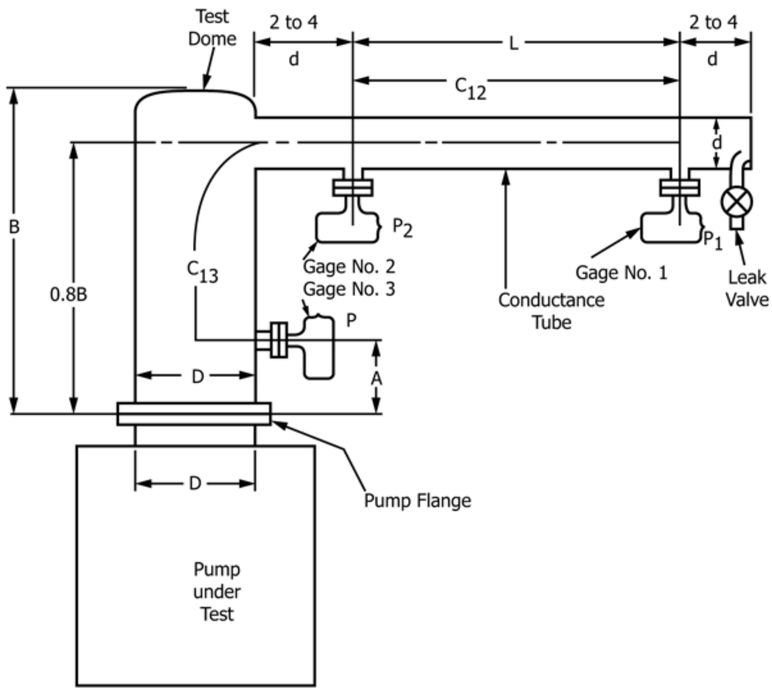

FIG. X3.1 Schematic Diagram of Conductance-Tube Method for Measuring Pumping Speed

X3.3 If, as is generally the case, the speed of pumps changes only slowly with pressure, absolute gage calibrations are not essential. However, in using the expression for *S* above, it is only necessary that the relative sensitivities of the various gages be known accurately. To obtain the relative sensitivities, it is then merely necessary to run the entire system at the same pressure.

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