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Standard Specification for Laboratory Glass Volumetric Apparatus[1]

This standard is issued under the fixed designation E694; 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 specification covers general requirements common to glass volumetric apparatus. Specific dimensions and tolerances for applicable instruments are given in other specifications as cited throughout this specification. Glass must conform to Specifications E438 and be calibrated in accordance with Practice E542.

1.1.1 *Class A*—Each instrument shall be marked with the letter *A* to signify compliance with applicable construction and accuracy requirements. Instruments may be marked with an identification marker (serial number) at the option of the manufacturer.

1.1.2 *Class B*—General purpose instruments are of the same basic design as Class A. However, volumetric tolerances for Class B instruments shall be within twice the specified range allowed for Class A unless otherwise specified.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C188 Test Method for Density of Hydraulic Cement
E237 Specification for Laboratory Glass Microvolumetric Vessels (Volumetric Flasks and Centrifuge Tubes)
E287 Specification for Laboratory Glass Graduated Burets
E288 Specification for Laboratory Glass Volumetric Flasks
E438 Specification for Glasses in Laboratory Apparatus
E542 Practice for Calibration of Laboratory Volumetric Apparatus
E671 Specification for Maximum Permissible Thermal Residual Stress in Annealed Glass Laboratory Apparatus
E675 Specification for Interchangeable Taper-Ground Stopcocks And Stoppers
E676 Specification for Interchangeable Taper-Ground Joints
E788 Specification for Pipet, Blood Diluting
E911 Specification for Glass Stopcocks with Polytetrafluoroethylene (PTFE) Plugs
E969 Specification for Glass Volumetric (Transfer) Pipets
E1045 Specification for Pipet, Sahli Hemoglobin
E1272 Specification for Laboratory Glass Graduated Cylinders
E1878 Specification for Laboratory Glass Volumetric Flasks, Special Use

3. General Requirements

3.1 *Units of Volume*—The unit of volume shall be the cubic centimetre (cm^3) or, in special cases, the cubic decimetre (dm^3) or cubic millimetre (mm^3).

NOTE 1—The term millilitre (mL) is commonly used as a special name for the cubic centimetre (cm^3) and, similarly the litre for the cubic decimetre (dm^3) and the microlitre (μL) for the cubic millimetre (mm^3), in accordance with the International System of Units (SI).

3.2 *Standard Temperature*—The standard reference temperature, that is, the temperature at which the article of volumetric glassware is intended to contain or deliver its nominal volume (nominal capacity), shall be 20°C.

NOTE 2—When it is necessary in tropical countries to work at an ambient temperature considerably above 20°C, and it is not desired to use the standard reference temperature of 20°C, it is recommended that a temperature of 27°C be adopted.

3.3 *Material and Annealing*—Volumetric glassware shall be constructed of glass of suitable chemical and thermal properties. It shall be as free as possible from visible defects and shall conform to Specification E671.

3.4 *Limit of Error*—On an article having multiple graduation lines, the limit of volumetric error may occur at any graduation line unless otherwise specified. For example, on a 100-mL graduated cylinder having a limit of error of ±1.00 mL, the volume at 10 mL could range from 9.00 to 11.00 mL.

3.5 *Stability*—Vessels provided with a flat base shall stand firmly thereon without rocking when placed on a level surface and, unless specified otherwise, the axis of the graduated portion of the vessel should be vertical. Except for special cases, vessels shall not topple when placed empty and without a stopper on a surface inclined at an angle to the horizontal of 15° for sizes 25 cm^3or greater and 10° for vessels less than 25

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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.

cm^3. Vessels provided with a base that is not circular shall meet this requirement in all directions.

3.6 *Stoppers and Stopcocks:*

3.6.1 *Stoppers*—Glass stoppers should be ground so as to be interchangeable, in which case the ground portions shall be in accordance with Specification E675. Stoppers of a suitable inert plastics material may be permitted as an alternative to glass. In such cases, the glass socket into which the stopper fits shall be in accordance with Specification E675. All stoppers shall bear a proper size identification.

3.6.2 *Stopcocks*—Stopcocks and similar devices shall be designed to permit smooth and precise control of outflow and to prevent a rate of leakage greater than that allowed in the specification for the article and shall be in accordance with Specification E675. Stopcocks shall be made from glass or from suitable inert plastics material.

3.7 *Graduation Lines:*

3.7.1 Graduation lines shall be clean, permanent lines of uniform vertical thickness. This thickness shall be 0.2–0.6 mm for articles not having a scale. On articles having a scale, the specified thickness of the lines shall be 0.2–0.4 mm. All graduation lines shall lie in planes at right angles to the longitudinal axis of the graduated portion of the article. On articles provided with a flat base, the graduation lines shall therefore lie in planes parallel to the base.

3.7.2 In general, graduation lines should be confined to cylindrical portions of an article's cross section and should preferably be situated not less than 10 mm from any change in diameter. In special circumstances, preferably for Class B articles only, graduation lines may be provided on a parallel side portion of noncircular cross section or on a conical or tapered portion of the article.

3.7.3 On articles not having a scale, all graduation lines should extend completely around the circumference of the article, except that a gap, not exceeding 10 % of the circumference, may be permitted. In the case of an article that is restricted as to the normal direction of viewing in use, the gap should be at the right or left of the normal direction of view.

3.8 *Spacing of Graduation Lines*—There should be no evident irregularity spacing of graduation lines (except in special cases where the scale is on a conical or tapered portion of the article and a change of subdivision takes place). The minimum distance, L, between the centers of adjacent graduation lines shall be not less, in relation to diameter, than that calculated as follows:

$$L = (0.8 + 0.02D) \quad (1)$$

where D is the maximum permitted internal diameter of the tube in millimetres (see also Annex A1).

3.9 *Length of Graduation Lines* (see Fig. 1)—On articles of circular cross section having a scale, the length of the graduation lines shall be varied so as to be clearly distinguishable and shall be in accordance with the following provisions:

3.9.1 *Graduation Pattern I:*

3.9.1.1 The length of the short lines should be approximately, but not less than, 50 % of the circumference of the article.

3.9.1.2 The length of the medium lines should be approximately 65 % of the circumference of the article and should extend symmetrically at each end beyond the end of the short lines.

3.9.1.3 The long lines should extend completely around the circumference of the article, but a gap, not exceeding 10 % of the circumference, may be permitted (see 3.6).

3.9.2 *Graduation Pattern II:*

3.9.2.1 The length of the short lines should be not less than 10 % and not more than 20 % of the circumference of the article.

3.9.2.2 The length of the medium lines should be approximately 1.5 times the length of the short lines and should extend symmetrically at each end beyond the end of the short lines.

3.9.2.3 The long lines should extend completely around the circumference of the article, but a gap, not exceeding 10 % of the circumference, may be permitted (see 3.6).

3.9.3 *Graduation Pattern III:*

3.9.3.1 The length of the short lines should not be less than 10 % and not more than 20 % of the circumference of the article.

3.9.3.2 The length of the medium lines should be approximately 1.5 times the length of the short lines and should extend symmetrically at each end beyond the ends of the short lines.

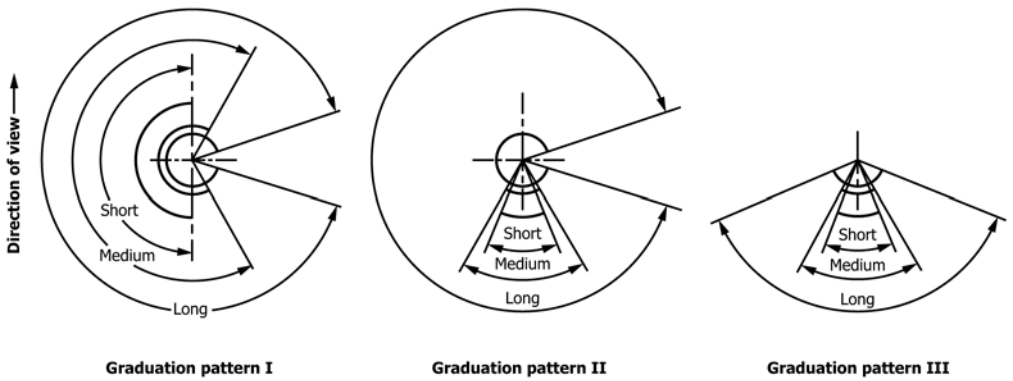

FIG. 1 Position of Graduation Lines

3.9.3.3 The length of the long lines should be not less than twice the length of the short lines and should extend symmetrically at each end beyond the ends of the short and medium lines.

3.9.4 In special cases where scales are required on noncircular cross section or conical or tapered portions of an article, the requirements of 3.8.1, 3.8.2, or 3.8.3 should be modified appropriately.

3.10 *Sequence of Graduation Lines* (see Fig. 2):

3.10.1 On articles in which the volume equivalent of the smallest scale division is millilitre (or a decimal multiple or submultiple thereof):

3.10.1.1 Every tenth graduation line is a long line;

3.10.1.2 There is a medium line midway between two consecutive long lines; and

3.10.1.3 There are four short lines between consecutive medium and long lines.

3.10.2 On articles in which the volume equivalent of the smallest scale division is 2 mL (or a decimal multiple or submultiple thereof):

3.10.2.1 Every fifth graduation line is a long line; and

3.10.2.2 There are four short lines between two consecutive long lines.

3.10.3 On articles in which the volume equivalent of the smallest scale division is 5 mL (or a decimal multiple or submultiple thereof):

3.10.3.1 Every tenth graduation line is a long line;

3.10.3.2 There are four medium lines equally spaced between two consecutive long lines; and

3.10.3.3 There is one short line between two consecutive medium lines or between consecutive medium and long lines.

3.11 *Position of Graduation Lines* (see Fig. 1):

3.11.1 On articles graduated according to Pattern I with vertical scales in accordance with 3.9.1, the ends of the short graduation lines shall lie on an imaginary vertical line down the center of the front of the article, the lines themselves extending preferably to the left when the article is viewed from the front in the position of normal use.

3.11.2 On articles graduated according to Pattern II or III, with vertical scales in accordance with 3.9.2 or 3.9.3, the midpoints of the short and medium graduation lines shall lie on an imaginary vertical line down the center of the front of the article, when the article is viewed from the front in the position of normal use.

3.12 Two scales are not permitted on the same piece of apparatus. For example, apparatus should not be graduated in both fluid ounces and millilitres (cubic centimetres). In the case of two units, one of which is an exact multiple of the other, such, for example, as drams and fluid ounces, there is no objective to having the 8-dr line, 16-dr line, etc., marked respectively, 1 fluid oz, 2 fluid oz, etc., provided that the two series of numbers are placed on opposite sides of the apparatus and the value of each subdivision is suitably indicated.

3.13 *Figuring of Graduation Lines:*

3.13.1 On articles with one graduation line, the number representing nominal capacity may be included with the other inscriptions and need not be adjacent to the graduation line.

3.13.2 On articles having two or three graduation lines, the numbers representing nominal capacity need not be adjacent to the lines to which they relate, if some other more suitable method of identification is used.

3.13.3 On articles having one principal graduation line and a small number of subsidiary lines, the number representing the principal capacity may be included with the other inscriptions as in 3.13.1 provided that the subsidiary graduation lines are suitably identified.

3.13.4 *On Articles Having a Scale:*

3.13.4.1 The scale shall be figured so as to enable the value corresponding to each graduation line to be identified readily;

3.13.4.2 The scale should have normally only one set of figures;

3.13.4.3 At least every tenth line shall be figured;

3.13.4.4 Figures shall be confined to long graduation lines and should be placed immediately above the line and slightly to the right of the adjacent shorter graduation lines; and

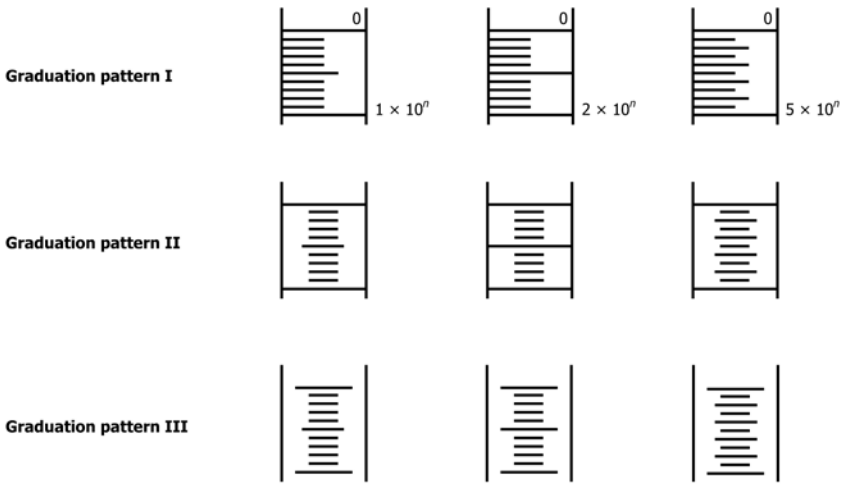

FIG. 2 Length and Sequence of Graduation Lines

NOTE 3—Where long lines complying with 3.9.2 are used (that is, those lines not extending completely around the article), an alternative scheme of figuring may be permitted, in which the figure is placed slightly to the right of the end of the long line in such a way that an extension of the line would bisect it.

3.13.4.5 Where it is necessary in special cases to use a number relating to a medium or short graduation line, the number should be placed slightly to the right of the end of the line in such a way that an extension of the line would bisect it.

3.14 *Inscriptions:*

3.14.1 Every instrument shall bear in permanent legible characters the capacity, the temperature at which it is to be used, the method of use (that is, whether to contain or to deliver), and on instruments that deliver through an outflow nozzle, the time required to empty the total nominal capacity with unrestricted outflow. The inscriptions may be engraved or printed provided such marking is neat and clear. Grit-blasted serial numbers will be permitted with the same provision. Every instrument shall bear the name or trademark of the maker. Every Class A instrument may bear the symbol *A*. Serial numbers may be marked on each instrument at the option of the manufacturer and detachable parts, such as stoppers, stopcocks, etc., belonging thereto, if not interchangeably ground, shall bear the same number. Interchangeable ground-glass parts shall be marked on both members with the proper standard taper symbol and the size designation, in accordance with Specification E676. Fig. 3 illustrates several arrangements of designating marks that are considered suitable. Marks may be placed elsewhere on apparatus if they are easily readable and do not interfere with the proper use of the apparatus.

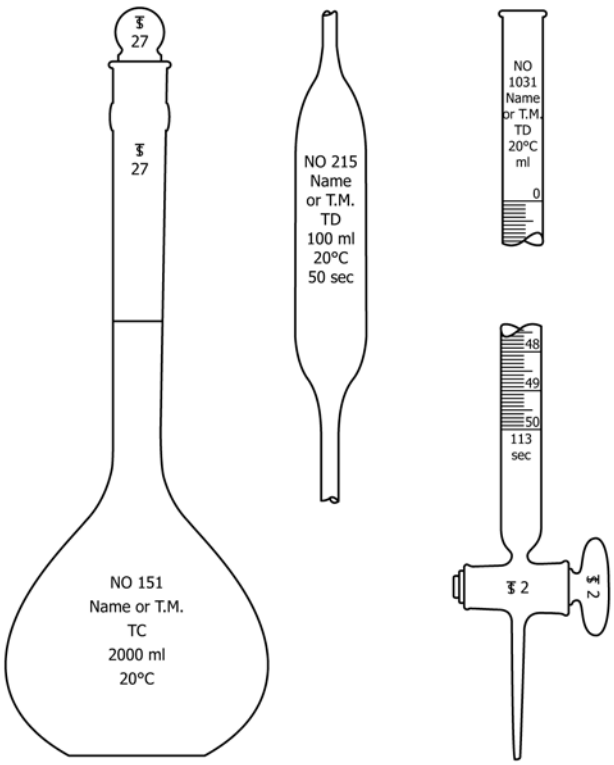

FIG. 3 Examples of Inscriptions Suitable for Volumetric Apparatus

3.14.2 In the case of a special-purpose article of volumetric glassware that is to be graduated for direct reading of capacity when used with a specific liquid other than water, the specification should also indicate the corresponding capacity when used to disperse pure water so that the latter can be used for verification.

4. Special Requirements

4.1 *Volumetric Flasks*—The limiting dimensions for volumetric flasks are given in Specification E288. For flasks smaller than 5-mL capacity, the limits shall be as shown in Specification E237.

4.1.1 *Stoppers or Closures*—Stoppers may be either glass or plastic as desired by the user and shall conform to Specification E675. As an alternative, the flasks may have reinforced rims or screw threads for acceptance of cap style closures.

4.1.2 *Intermediate Bulb-Style Flasks*—The limiting dimensions for bulb style flasks are given in Specification E288.

4.1.3 *Dual-Purpose Flask*—A flask may be graduated both to contain and to deliver, provided the intention of the different marks is clearly indicated and provided the distance between the two marks is not less than 1 mm.

4.1.4 *Special-Purpose Volumetric Flasks*—Certain types of special-purpose volumetric flasks, such as the Engler or Saybolt viscosity flasks and the Kohlrausch and Stift sugar flasks, while not in conformity with all the special requirements for volumetric flasks listed in 4.1 because of their specific applications, will be considered Class A if they are in satisfactory conformity with the general specifications in Section 3 and the errors in capacity do not exceed the tolerances for volumetric flasks given in Specification E288. The limiting dimensions for Kohlrausch Flasks are given in Specification E1878, Style 2.

4.2 *Graduated Cylinders:* The limiting dimensions for graduated cylinders are given in Specification E1272.

4.2.1 *Method of Use*—Cylinders that are to be used dry to receive and measure liquids should be calibrated to contain. Cylinders that are to be used to pour water into other measures,

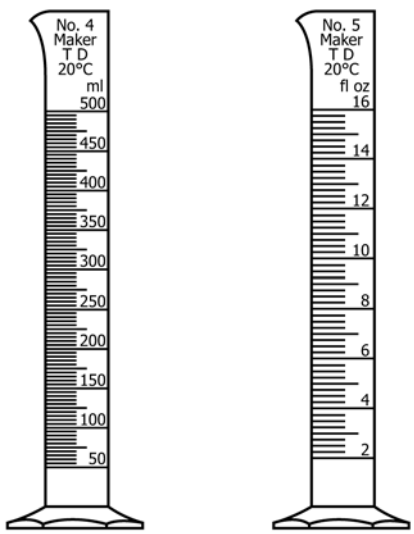

FIG. 4 Examples of Graduated Cylinders

and those which are to be used wet to contain water from other measures, should be calibrated to deliver. For example, a cylinder that is to be used in testing milk bottles, either by pouring water from the cylinder into the bottles or from the bottles into the cylinder without drying the cylinder between bottles, should be calibrated to deliver. After having been wet the cylinder will, on successive fillings and emptyings, deliver the same quantity that is poured into it. In ordering cylinders, the purchaser should consider the use to which they are to be put and should specify accordingly whether they should be calibrated to contain or to deliver.

4.2.2 *Basis of Graduation*—Cylinders calibrated in inch-pound units should be graduated in accordance with the following relations:

60 minims = 1 fluid dr
8 fluid dr = 1 fluid oz
32 fluid oz = 1 liquid qt
4 liquid qt = 1 U.S. gal
1 U.S. gal = 231 in.

For conversion to SI units, the relation is 1 fluid oz = 29.5735 mL.

4.3 *Transfer Pipets*—Pipets for delivering a single volume are designated "transfer" or "volumetric" pipets. The limiting dimensions for transfer or volumetric pipets are given in Specification E969.

4.4 *Burets*—The limiting dimensions for burets are given in Specification E287.

4.4.1 *Buret Stopcocks*—All Class A burets shall have permanently attached stopcocks. Stopcock plugs shall be provided with a retaining device. Stopcock plugs shall be made of either glass or TFE-fluorocarbon. All glass stopcocks shall conform to Size 2 of Specification E675. The TFE-fluorocarbon plugs shall conform to Size 2 of Specification E911. In addition, stopcocks which form a seal by having TFE-fluorocarbon plug ends butt against construction in the glass shell and may be used, but shall not exceed 4 mm.

4.5 *Dilution (Hemacytometer) Pipet*— The limiting dimensions for dilution pipets are given in Specification E788.

4.6 *Specific Gravity Flasks*—The specifications for these flasks are given in Test Method C188.

4.7 *Sugar-Testing Flasks (Bates)*—The limiting dimensions for sugar testing flasks are give in Specification E1878, Style 1.

4.8 *Babcock Milk Test Apparatus*—Most of the states now require that all Babcock glassware used in the state be approved by officials of that state. Specifications for Babcock glassware may be found in official procedures of the Association of Official Agricultural Chemists and certain dairy associations.

4.9 *Sahli Hemoglobin Pipets*—The limiting dimensions for Sahli pipets are given in Specification E1045.

4.10 *Other Special Apparatus*—Other types of special-pur pose instruments may be calibrated and marked Class A if they conform with the general specifications (Section 3) and the errors in capacity do not exceed the applicable tolerances under specific similar items.

5. Keywords

5.1 apparatus; glass; laboratory; volumetric

ANNEX

(Mandatory Information)

A1. LIMIT OF VOLUMETRIC ERROR IN RELATION TO DIAMETER AT THE MENISCUS

A1.1 The limit of volumetric error specified for any article shall not be less than that calculated for the maximum permitted diameter.

A1.2 This requirement is designed to ensure that the intended precision of the article can be readily attained under normal conditions of use, that is, a volume equal to the limit of volumetric error should occupy a readily visible length of tube of the maximum diameter allowed.

A1.3 The following symbols are used in deriving the equation:
V = limit of volumetric error, μL,
D = internal diameter of the tube at the meniscus, mm,
L = linear equivalent of V, that is, the length of tube of diameter D occupied by a volume equal to V, mm.

A1.4 The linear measurement, L, can be considered to be made up of two components;

A1.4.1 A basic minimum of 0.4 mm which is the lowest limit, even on tubes of very small diameter, which has proved to be satisfactory in normal use and practicable for economic routine manufacture;

A1.4.2 An additional allowance for potential parallax error in reading, which is related to the diameter, and for which the symbol p is used.

A1.5 The value for this parallax component can be derived as follows:

A1.5.1 If θ is the angle between the operator's sight line to the meniscus and the horizontal plane tangential to the meniscus, then:

$$\tan\theta = p/(D/2) = \frac{H}{d+D/2} \quad \text{(A1.1)}$$

$$p = HD/(2d+D)$$

where:

p = error in reading, mm,
d = distance of the operator's eye from the scale, mm,
H = distance of the operator's eye above or below the horizontal plane tangential to the meniscus, mm, and
D = diameter of tube, neck, or column which carries the scale, mm.

A1.6 *Example:*

A1.6.1 If $H = 5$ mm, and $d = 200$ mm; then $p = 5D/(400 + D)$ over the extreme range of diameters.

A1.6.2 If $D = 1$ mm; then $p = 0.0125$ mm or $0.0125\ D$. If $D = 100$ mm; then $p = 1.0$ mm $= 0.0100\ D$. So without significant error, a constant figure of $0.01\ D$ can be substituted.

NOTE A1.1—It should be noted that this equation tends to exaggerate the potential parallax error on a meniscus greater than about 25-mm diameter. In such a case the flat center portion of the meniscus helps to minimize parallax error, but the effect does not significantly affect this equation.

A1.6.3 The total linear equivalent of the limit of volumetric error is therefore given by:

$$L \geq (0.4 + 0.01\ D) \quad \text{(A1.2)}$$

$$V \geq \frac{\pi}{4} D^2(0.4 + 0.01\ D)$$

Again without significant error $\frac{\pi}{4}$ can be rounded to 0.8 and the result can be divided by 1000 to convert to cm^3, thus:

$$V \geq \frac{0.8\ D^2}{1000}(0.4 + 0.01\ D) \quad \text{(A1.3)}$$

where D is in millimetres.

A1.7 For the series 10-12-15-20-25-30-40-50-60-80, or a suitable decimal multiple thereof, limits of volumetric error and appropriate maximum diameters at the meniscus calculated by this equation are shown in Table A1.1.

A1.8 The relationship between V, L, and D can be clearly demonstrated by means of a nomograph prepared on a logarithmic scale as shown in Fig. A1.1. The curved line across the nomograph results from plotting the equation $L = (0.4 + 0.01$ D) and thus oblique lines representing limits of volumetric error terminate on this curve at points which represent maximum appropriate diameters as given in the table. The thicker portions on two of these oblique lines provide examples of the method of application of the nomograph as follows:

A1.8.1 In Line A, the specification for an article gives D as 17 to 20 mm; and V as ±0.2 mL. In this example, which could apply to a volumetric flask, the upper limit of D approaches very close to the limit curve.

A1.8.2 In Line B, the application for an article gives D as 3 to 4 mm; and V as 0.02 mL. In this example, which could apply to a pipet, either a large diameter or a smaller limit of error would appear to be possible. The inference is that in this case the limit of error is controlled by the standard deviation (Note A1.2) rather than by the dimensional requirements of the maximum internal diameter.

NOTE A1.2—The limit of volumetric error specified for any article designed for delivery shall also be not less than four times the standard deviation (RMS) determined experimentally by an experienced operative from a series of at least twenty replicate determinations of delivered capacity on the same article, carried out strictly in accordance with the method specified for that article.

TABLE A1.1 Maximum Internal Diameter of Tube at the Graduation Line Appropriate to Selected Limits of Volumetric Error

Limit of Volumetric Error, ±µL	Maximum Internal Diameter of Tube at the Graduation Line, mm	Limit of Volumetric Error, ±µL	Maximum Internal Diameter of Tube at the Graduation Line, mm
0.1	0.56	100	15.2
0.2	0.78	120	17
0.3	0.96	150	18
0.4	1.1	200	20
0.5	1.2	250	23
0.6	1.3	300	25
0.8	1.5	400	27
		500	29.2
1	1.7	600	32
2	2.4	800	36
3	2.9		
4	3.4	1000	40
5	3.8	1200	44
6	4.2	1500	47
8	4.7	2000	52
		2500	57
10	5.3	3000	61
12	6.0	4000	68
15	6.4	5000	74
20	8.25	6000	80
25	8.25	8000	83
30	8.7	10 000	96
40	10		
50	11.2		
60	12		
80	13.5		

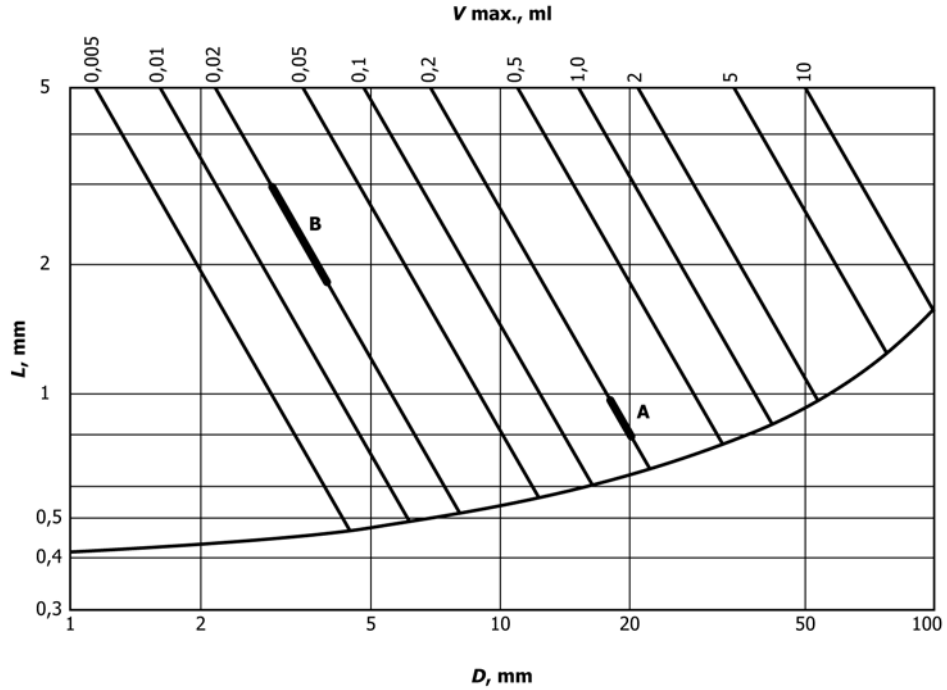

FIG. A1.1 Relationship of *V* ,*D*, and *L*