



## Standard Test Method for Viscosity of Transparent Liquids by Bubble Time Method<sup>1</sup>

This standard is issued under the fixed designation D1545; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

### 1. Scope

1.1 This test method covers the determination of the viscosity in bubble seconds by timing. The bubble seconds are approximately equal to stokes for most liquids.

1.2 The test method is applicable to transparent liquids that are free from crystalline or gel particles.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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. Terminology

#### 2.1 Definitions:

2.1.1 *viscosity,  $n$* —the resistance experienced by one portion of a liquid moving over another portion of the liquid. The absolute unit of viscosity in the cgs, centimeter-gram-second, system is the poise which is expressed as dyne-seconds per square centimetre. Stokes are equal to poises divided by density. The absolute SI, International System of Units (metric system), viscosity unit is the pascal-second.

### 3. Apparatus

3.1 *Constant-Temperature Bath*—Any suitable bath capable of maintaining temperature at  $25 \pm 0.1^\circ\text{C}$  with water as the bath medium.

3.2 *Standard Viscosity Tubes* of clear glass and with flat bottoms,  $10.65 \pm 0.025$  mm in inside diameter;  $114 \pm 1$  mm in outside length. Plainly legible lines shall be located as follows (**Note 1**):

$27 \pm 0.5$  mm

$100 \pm 0.5$  mm

$108 \pm 0.5$  mm

The distance between the first and second lines shall be  $73 \pm 0.5$  mm.

NOTE 1—All distances shall be measured from the outside bottom of the tube.

3.3 *Reference Standards*—A series of standard viscosity tubes (**3.2**) filled with transparent liquids having predetermined viscosities in stokes and bubble seconds and spaced in logarithmically even increments of about 26 % ( $\log 1.260 = 0.100$ ), as listed in **Table 1**. The standards shall be marked alphabetically or numerically as shown in **Table 1** without reference to stokes or bubble time (**Note 2**). Also listed in **Table 1**, for general and historical reference only, is the long established series of Gardner-Holdt letter standards, in tubes that do not have the three lines and are shorter than the standard viscosity tubes described in **3.2**.

NOTE 2—For convenience, the reference standards can be divided in three series: light series, 15 tubes marked 0.22 to 8.0; heavy series, 14 tubes marked 10 to 200; and very heavy series, 7 tubes, marked 250 to 1000.

3.4 *Timing Device*—Stopwatch or electric stop clock capable of being read to a precision of 0.1 s.

3.5 *Tube Racks*, capable of inverting one or more viscosity tubes  $180^\circ$  to within  $1^\circ$  of a vertical position while rack and tubes are immersed in the constant temperature bath.

3.6 *Viscosity Tube Corks*, No. 2 short.

### 4. Procedure

4.1 Fill a standard viscosity tube with the material to be tested to approximately level with the 108-mm line.

4.2 Transfer the tube to a constant  $25^\circ\text{C}$  temperature bath with the cork loosely inserted. Hold at this temperature for 10 min.

NOTE 3—Adequate control of the temperature bath is essential. A variation of  $0.1^\circ\text{C}$  in the temperature of the bath will cause a 1 % variation in the timed bubble travel.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.24 on Physical Properties of Liquid Paints and Paint Materials.

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**TABLE 1 Recommended Numerical Standards for Comparator Viscosity Tubes<sup>A</sup>**

| Bubble Seconds <sup>B</sup> | Tube <sup>C</sup> Number | Stokes  | Gardner-Holdt Letter | Bubble Seconds <sup>B</sup> and Tube <sup>C</sup> Number | Stokes  | Gardner-Holdt Letter |
|-----------------------------|--------------------------|---------|----------------------|----------------------------------------------------------|---------|----------------------|
|                             |                          | – 0.10– |                      | 10–                                                      | – 10–   |                      |
|                             |                          | – 0.13– |                      | 13–                                                      | – 13–   | –W                   |
|                             |                          | – 0.16– | –A3                  | 16–                                                      | – 16–   | –X                   |
|                             |                          | – 0.20– |                      | 20–                                                      | – 20–   | –Y                   |
| 0.75–                       | – 0.22–                  |         | –A2                  |                                                          |         | –Z                   |
|                             |                          | – 0.25– |                      | 25–                                                      | – 25–   | –Z1                  |
|                             |                          | – 0.32– | –A1                  | 32–                                                      | – 32–   | –Z2                  |
| 0.81–                       | – 0.34–                  |         |                      |                                                          |         | –Z3                  |
|                             |                          | – 0.40– |                      | 40–                                                      | – 40–   |                      |
| 0.90–                       | – 0.50–                  | – 0.50– | –A                   | 50–                                                      | – 50–   |                      |
|                             |                          | – 0.63– | –B                   | 63–                                                      | – 63–   | –Z4                  |
| 1.00–                       | – 0.68–                  |         | –C                   |                                                          |         |                      |
|                             |                          | – 0.80– |                      | 80–                                                      | – 80–   |                      |
| 1.15–                       | – 0.92–                  |         |                      |                                                          |         | –Z5                  |
|                             |                          | – 1.00– | –D                   | 100–                                                     | – 100–  |                      |
| 1.30–                       | – 1.15–                  | – 1.25– | –E                   | 125–                                                     | – 125–  |                      |
|                             |                          | – 1.60– | –F                   |                                                          |         | –Z6                  |
| 1.55–                       | – †1.45–                 |         | –G                   | 160–                                                     | – 160–  |                      |
|                             |                          | – 2.00– | –H                   | 200–                                                     | – 200–  |                      |
| 1.85–                       | – 1.80–                  |         | –I                   |                                                          |         |                      |
| 2.20–                       | – 2.15–                  | – 2.50– | –J                   | 250–                                                     | – 250–  |                      |
| 2.65 <sup>D</sup> –         | – 2.65 <sup>D</sup> –    |         | –K                   |                                                          |         |                      |
|                             |                          | – 3.20– | –L                   | 320–                                                     | – 320–  |                      |
| 3.20–                       | – 3.20–                  |         | –M                   |                                                          |         |                      |
|                             |                          | – 4.00– | –N                   |                                                          |         | –Z7                  |
| 4.00–                       | – 4.00–                  |         | –O                   |                                                          |         |                      |
|                             |                          | – 4.00– | –P                   | 400–                                                     | – 400–  |                      |
|                             |                          | – 5.00– | –Q                   |                                                          |         |                      |
| 5.00–                       | – 5.00–                  |         | –R                   | 500–                                                     | – 500–  |                      |
|                             |                          | – 6.30– | –S                   |                                                          |         | –Z8                  |
| 6.30–                       | – 6.30–                  | – 6.30– | –T                   |                                                          |         |                      |
| 8.00–                       | – 8.00–                  | – 8.00– | –U                   | 630–                                                     | – 630–  |                      |
|                             |                          |         | –V                   | 800–                                                     | – 800–  | –Z9                  |
| 10.0–                       | – 10.0–                  | – 10.0– |                      | 1000–                                                    | – 1000– | –Z10                 |

<sup>A</sup> Arranged to show relationship between stokes, bubble seconds, and Gardner-Holdt letters. Stokes are shown in logarithmic progression.

<sup>B</sup> The bubble time, in seconds, of the numerical tubes under 4 s was determined by a technique employing a movie camera.

<sup>C</sup> For reference purposes only. Numbered tubes are no longer commercially available.

<sup>D</sup> Above 2.65 the bubble seconds as measured by the kinematic method are approximately equivalent for most products. Below 2.65 this relationship does not hold.

† Editorially corrected.

4.3 At the end of 10 min adjust the level of the liquid so that the bottom meniscus will be level with the 100-mm line. Insert

the cork so that the bottom of the cork is on the level with the 108-mm line. This will ensure a bubble of suitable and uniform size.

4.4 Insert the tube in the rack and immerse in the 25°C water bath. Allow the tube(s) to stand with cork down in the bath a minimum of 20 min before determining the viscosity.

NOTE 4—For viscosities of liquids that have a timed bubble travel of 4 s or less, more precise results can be obtained by comparison against reference standards having a predetermined viscosity or timed bubble travel.

4.5 To read, invert the tube quickly and determine the time required for the bubble to rise in seconds. When determining the time in seconds start the timing device when the top of the bubble becomes tangent to the 27-mm line on the tube. Stop the timing when the top of the bubble becomes tangent with the 100-mm line. This gives a 73-mm timed bubble travel. All timings shall be made with the tube in an exact vertical position.

NOTE 5—Positioning of the tube in a vertical position is mandatory. A tube one radius off the vertical will give an error of approximately 10 % in the time of bubble travel.

## 5. Report

5.1 Report the following information:

5.1.1 The viscosity obtained by the timing method expressed as “bubble seconds” or “approximate stokes.”

NOTE 6—The time in seconds or “bubble seconds” is an approximate measurement of stokes when the bubble time method is applied to most raw materials and finished products encountered by the paint, varnish, and lacquer industries. This relationship does not hold for silicones or water dispersions of gums or similar materials. Viscosity results by this test method are influenced by non-Newtonian behavior and by surface tension. Other variations on bubble-tube viscometers are described in ASTM STP 500, Section 3.2.9.<sup>2</sup>

## 6. Precision and Bias

6.1 *Precision*—On the basis of an interlaboratory study<sup>3</sup> of this test method in which ten laboratories tested liquids ranging in viscosity from 4.5 to 440 St, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

6.1.1 Two results obtained by the same operator should be considered suspect if they differ by more than 4.9 % relative.

6.1.2 Two results, each the mean of duplicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 9.0 % relative.

6.2 *Bias*—No information can be presented on the bias of this test method because no materials having an accepted reference value is available.

## 7. Keywords

7.1 Gardner-Holdt; GH viscosity; viscosity

<sup>2</sup> *Paint Testing Manual*, ASTM STP 500, ASTM, 1972.

<sup>3</sup> See Holt, K. E., *Proceedings*, ASTM, Vol 57, 1957, pp. 297–300, and *Official Digest*, Federation of Societies for Paint Technology, Vol 30, May 1958, pp. 540–543.

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