



# Standard Test Method for Viscosity of Paints and Related Materials by ISO Flow Cups<sup>1</sup>

This standard is issued under the fixed designation D5125; 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.

## 1. Scope

1.1 This test method covers the determination of the flow time (viscosity) of Newtonian and near-Newtonian paints, and related coatings and products using ISO capillary flow cups.

NOTE 1—If the liquid is non-Newtonian, that is shear-thinning or thixotropic, Test Methods D2196 should be used.

1.2 The cup-orifice combination (ISO cup with orifice diameter of 3 mm, 4 mm, 5 mm, or 6 mm)<sup>2</sup> is selected to provide an efflux time with the range of 20 to 100 s and viscosities up to 700 cSt (700 mm<sup>2</sup>/s). The most commonly used cup is the one with the 4-mm orifice.

1.3 This test method is limited to testing materials for which the breakpoint of the flow from the orifice of the flow cup can be determined with certainty. This point is difficult to determine and reproduce for materials with flow times in excess of 100 s due to slowing-down effects.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address 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.*

NOTE 2—The International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) include in their regulations a similar test (ISO 2431) to determine the viscosity of hazardous viscous liquids. The viscosity is then used to place these liquids in a hazard packaging group depending on their viscosity/flashpoint relationship. The U. S. Department of Transportation permits the use of these regulations for transshipment of hazardous material within the U.S. when bound for foreign destinations.

<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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<sup>2</sup> An ISO-type cup with an orifice diameter of 8 mm is available, but it is not listed in ISO 2431 and precision and accuracy are not known.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

D2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer

D3924 Specification for Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials

D3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings

E1 Specification for ASTM Liquid-in-Glass Thermometers

### 2.2 ISO Documents:

ISO 2431 Paints and Varnishes: Determination of Flow Time by Use of a Flow Cup<sup>4</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *dynamic viscosity, n*—the ratio of the applied shear stress to shear rate.

3.1.1.1 *Discussion*—The SI unit for dynamic viscosity is the pascal second (Pas). The traditional unit is the centipoise (cP); 1 cP = 1 mPas.

3.1.2 *flow time, n*—the elapsed time from the moment when the material under test starts to flow from the orifice of the filled cup to the moment when the flow stream of material first breaks close to the orifice.

3.1.3 *kinematic viscosity, n*—the ratio of the dynamic viscosity to the density of the liquid.

3.1.3.1 *Discussion*—The SI unit for kinematic viscosity is the square metre per second (m<sup>2</sup>/s). The traditional unit is the centistokes (cSt); 1 cSt = 1 mm<sup>2</sup>/s.

3.1.4 *near-Newtonian liquid, n*—a liquid in which the variation of viscosity with shear rate is small and the effect on viscosity of mechanical disturbances such as stirring is negligible.

3.1.5 *Newtonian liquid, n*—a liquid in which the viscosity is independent of the shear stress or shear rate. Compare non-Newtonian liquid.

<sup>3</sup> 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.

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.6 *non-Newtonian liquid, n*—a liquid in which the ratio of shear stress to shear rate is not constant.

#### 4. Summary of Test Method

4.1 The ISO flow cup is filled level full with the material under test that has been conditioned at the specified measuring temperature (see 10.2.2) and the time for the material to flow through one of the standard orifices is determined.

#### 5. Significance and Use

5.1 This test method is useful for the determination of package and application viscosities of paints and other coatings. It is limited to Newtonian or near-Newtonian liquids.

5.2 This test method may be used similarly to ISO 2431 in conjunction with flashpoint to determine the hazard grouping of viscous liquids in international regulations.

#### 6. Apparatus

6.1 *ISO Capillary Flow Cups*—ISO cups look like Ford cups, but instead of the non-capillary hole in the bottom of the Ford cup, the ISO cup has a 20-mm capillary and is more like a true capillary viscometer.

6.1.1 *Dimensions*—The dimensions of the ISO flow cup and the tolerances allowed in manufacture shall be as given in Fig. 1. The most critical tolerance is the internal diameter of the jet of the cup, because the flow time is inversely proportional to the fourth power of this dimension. The jet of the cup shall be made of stainless steel or sintered carbide unless otherwise specified, and the body of the cup shall be made of a material that is corrosion resistant and is not affected by the products to be tested.

6.1.2 *Construction*—The dimensions not specified, such as wall thickness, shall be such that no distortion of the cup can occur in use. The external shape shown in Fig. 1 is recommended, but may be modified for convenience of use, or manufacture, provided that the protruding jet of the cup is protected from accidental damage as far as possible by an external protective sleeve. Such a protective sleeve shall not be immediately adjacent to the jet, so as to prevent a capillary action when the material under test flows out.

6.1.3 *Finish*—The interior surfaces of the cups, including the orifice, shall be smooth and free of turning marks, crevices, ledges and burrs that may cause random flow, or trap sample or cleaning material. The standard of finish required is equivalent to a maximum roughness of not more than 0.5  $\mu\text{m}$  (see Note 3).

NOTE 3—Roughness defined as the arithmetical mean deviation  $R_a$  from the mean line of the profile.

6.2 *Thermometer*, accurate to 0.2°C (0.4°F) and graduated at 0.1°C (0.2°F) intervals. Saybolt viscosity thermometer conforming to requirements for thermometer 17C and 17F (10 to 27°C) (60 to 80°F) as prescribed in Specification E1 is required. In addition, temperature measuring devices such as non-mercury liquid-in-glass thermometers, thermocouples, or platinum resistance thermometers that provide equivalent or better accuracy and precision, that cover the temperature range for thermometer 17C and 17F, may be used.

6.3 *Stand*, suitable for holding the flow cup and provided with leveling screws.

6.4 *Spirit Level*, preferably of the circular type.

6.5 *Flat Glass Plate or Straight-Edge Scraper*.

6.6 *Stopwatch*, or other suitable timing-device with scale divisions of 0.5 s or finer and accurate to within 0.2 % when tested over a 60-min period.

6.7 *Temperature-Controlled Room or Enclosure*, capable of maintaining the cup and sample at a recommended, constant temperature.

#### 7. Reagents and Materials

7.1 Certified kinematic viscosity standards.<sup>5</sup>

#### 8. Sampling

8.1 Sample material in accordance with Practice D3925.

8.2 Before testing, it is advisable to strain the sample through an appropriate sieve into a clean dry container. This is mandatory for referee purposes. Mix the material thoroughly while at the same time avoiding, as far as possible, loss of solvent by evaporation.

NOTE 4—150 mL of strained material is sufficient for one test.

#### 9. Calibration

9.1 Dimensionally similar cups will give, with Newtonian liquids, such as a standard oil, similar flow times, provided that the temperature of testing is precisely the same. The use of such liquids to calibrate cups provides a useful means of initially checking that dimensionally similar cups are within the accepted tolerances of performance and also for checking from time to time whether any wear or damage has taken place sufficient to bring a cup outside the accepted tolerances.

9.2 For calibration of any particular cup, use a standard oil<sup>5</sup> of known kinematic viscosity and draw a graph of kinematic viscosity versus temperature from the data given by the supplier for the oil.

9.3 Using the relevant procedure described in Section 1010, determine the flow time of the oil at a known temperature within the range 20 to 30°C (68 to 80°F), measured to the nearest 0.1°C.

9.3.1 Record this flow time, which should be in the range 30 to 100 s and preferably near the midpoint of this range, to an accuracy of 0.2 s.

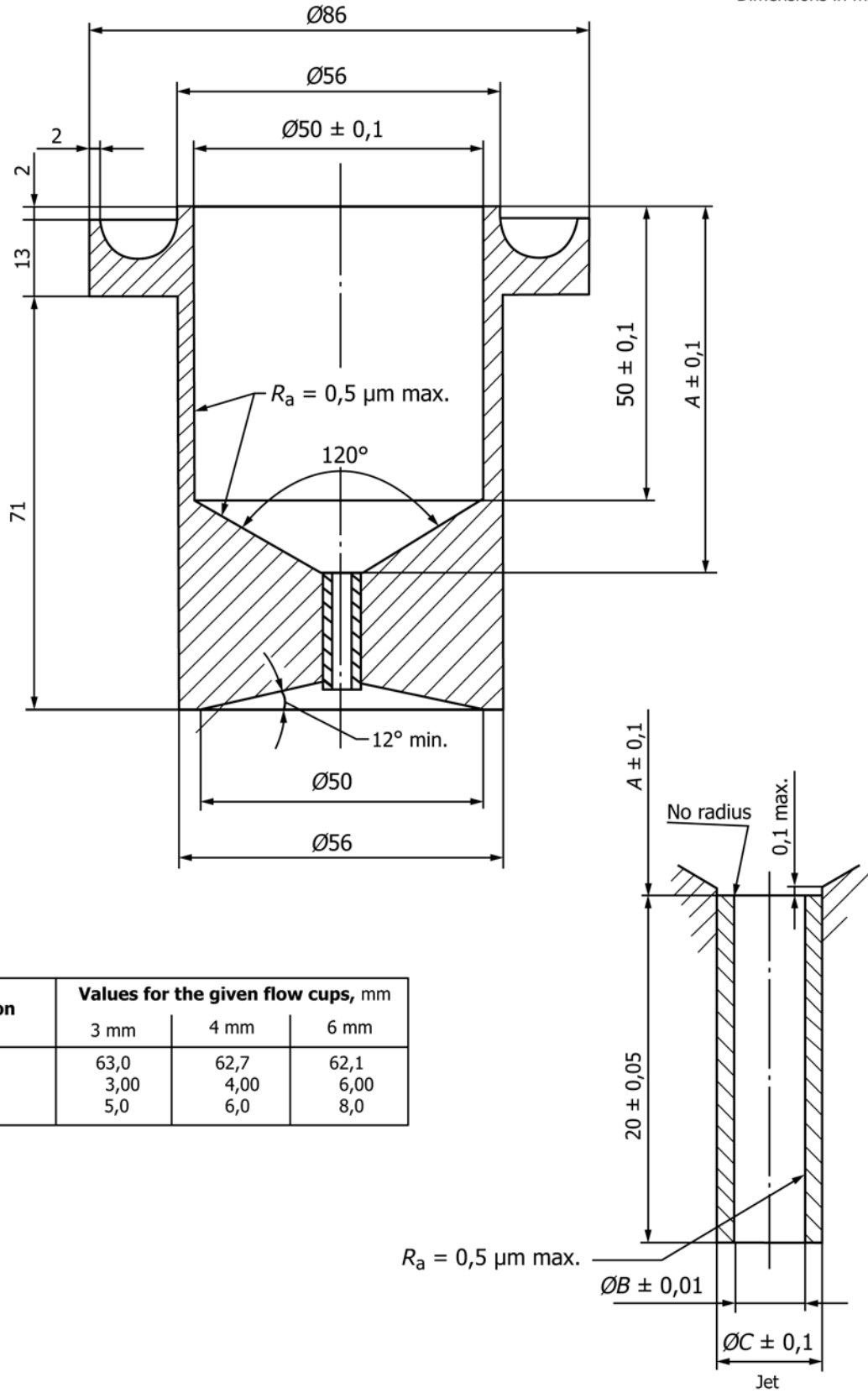
9.4 From the prepared graph, read the kinematic viscosity at the test temperature.

9.4.1 Using the appropriate calibration graph of Fig. 2, Fig. 3, Fig. 4 or Fig. 5, read the flow time corresponding to this kinematic viscosity.

9.5 If the two values of flow time obtained do not differ by more than 3 %, the cup may be deemed satisfactory for use.

9.6 For reference purposes, a correction factor corresponding to the flow time deviation from that obtained using the oil may be applied.

<sup>5</sup> Standards, available from the Cannon Instrument Company, P.O. Box 16, State College, PA 16801 have been found suitable for this purpose.



| Dimension | Values for the given flow cups, mm |      |      |
|-----------|------------------------------------|------|------|
|           | 3 mm                               | 4 mm | 6 mm |
| A         | 63,0                               | 62,7 | 62,1 |
| B         | 3,00                               | 4,00 | 6,00 |
| C         | 5,0                                | 6,0  | 8,0  |

FIG. 1 Flow Cup ISO

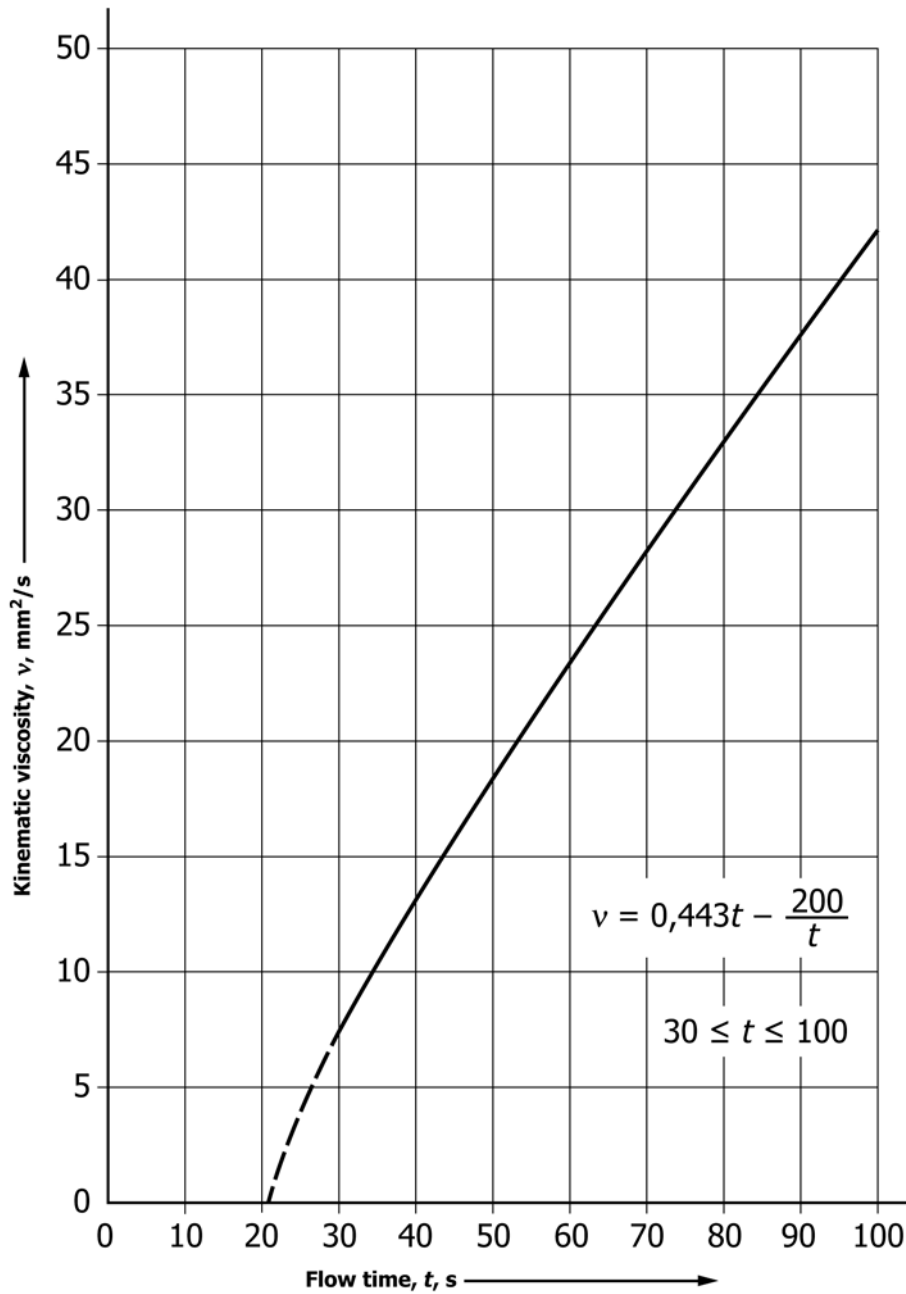


FIG. 2 Calibration Curve for 3-mm Cup

## 10. Procedure

### 10.1 Preliminary check:

NOTE 5—This check is carried out to show that the material is suitable for the test (that is, is Newtonian or near-Newtonian).

10.1.1 Choose a flow cup that will give a flow time of between 30 and 100 s for the material.

10.1.2 Determine the flow time by the procedure specified in 10.2, making sure that the material is well agitated before pouring into the cup. Remove the finger within 5 s of filling the flow cup.

10.1.3 Repeat the determination but this time allow the material to remain in the flow cup for 60 s before removing the finger.

10.1.4 If the second result differs from the first by more than 10 %, the material shall be deemed to be non-Newtonian and therefore unsuitable for consistency control by flow-time measurement.

### 10.2 Determination of Flow Time:

10.2.1 Choose a flow cup that will give a flow time between 20 and 100 s, but preferably between 30 and 100 s for the test material.

10.2.2 Adjust the temperature of the strained sample and the flow cup, to  $23 \pm 0.5^\circ\text{C}$  ( $73.5 \pm 1.0^\circ\text{F}$ ) (in accordance with Specification D3924) to  $25 \pm 0.5^\circ\text{C}$  ( $77 \pm 1.0^\circ\text{F}$ ) or to an other alternatively agreed upon temperature.

NOTE 6—The temperature  $23^\circ\text{C}$  ( $73.5^\circ\text{F}$ ) is the standard environment

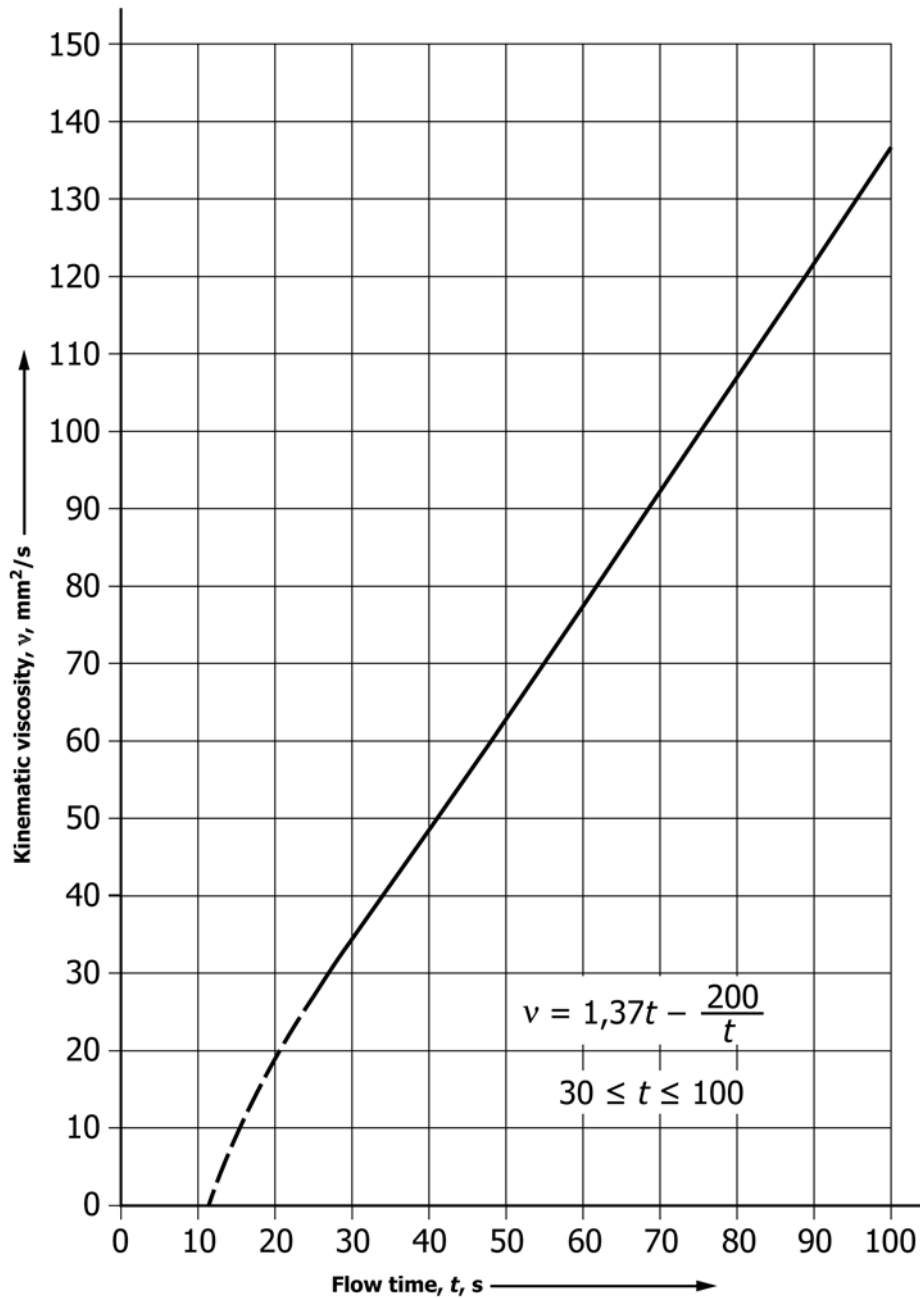


FIG. 3 Calibration Curve for 4-mm Cup

for conditioning and testing paint as specified in Specification D3924. It also is the test temperature specified in international shipping regulations. However, 25°C (77°F) has been the standard temperature for measuring the viscosity of paint and other materials for many years and is the choice of many operators.

10.2.3 If the temperature-controlled enclosure is used, as recommended, it is advisable to condition the cup and the sample before straining, by placing them in the enclosure before use. The sample shall be considered ready for test immediately after any air bubbles entrained during the preparation and sieving procedures have dispersed. Carry out a final check that the temperature of the sample is within 0.5°C (1°F) of the agree test temperature immediately prior to filling the cup.

10.2.4 Place the flow cup on the stand, in a position free of drafts and, by using the level and adjusting the leveling screws of the stand, ensure that the upper rim of the flow cup is in a horizontal plane.

10.2.5 With the orifice closed by a finger, fill the cup with the freshly strained, bubble-free sample, pouring slowly to avoid the formation of air bubbles. If any bubbles are formed, allow them to rise to the surface and remove them. If the cup has been properly leveled, the sample will overflow evenly over the rim into the gallery. Remove any meniscus formed either by drawing the straight-edge scraper over the entire rim of the cup or by sliding over the rim, a flat glass plate with rounded edges so that no air bubbles form between the glass

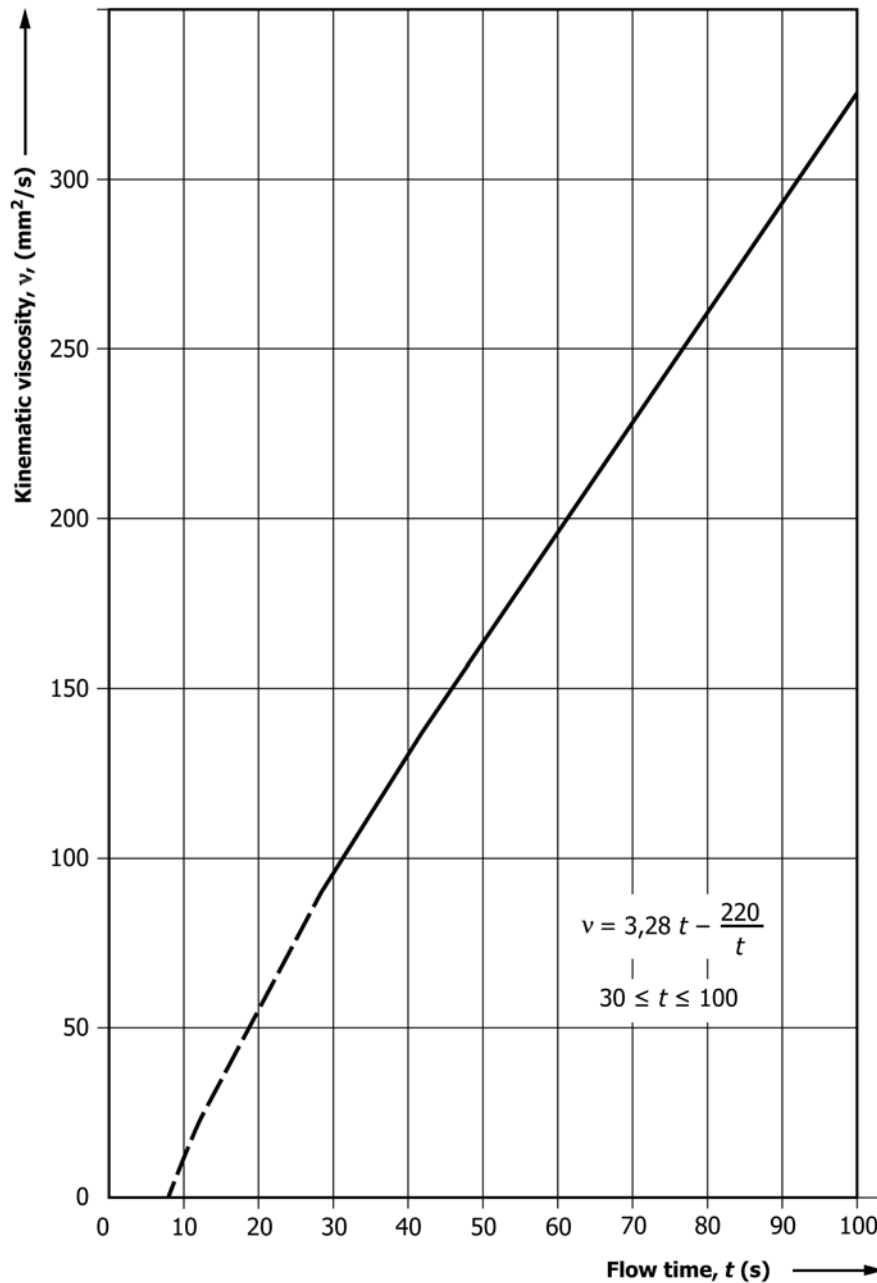


FIG. 4 Calibration Curve for 5-mm Cup

and the surface of the specimen. Then draw this plate horizontally across the rim of the cup so that, when the plate is removed, the level of the specimen coincides with the top rim of the cup.

10.2.6 Place a suitable receiver under the flow cup so that the distance between the orifice of the flow cup and the surface of the received specimen is never less than 100 mm. Remove the finger from the orifice and simultaneously start the timing device, stopping it as soon as the first break occurs in the stream of specimen close to the orifice. Record the flow time to the nearest 0.5 s.

10.2.6.1 If the test is not carried out in the temperature-controlled enclosure, place the thermometer in the stream of the specimen so as not to interfere with observation of the

break in the flow. This is conveniently done by holding the thermometer in a suitable clamping device with the bulb so placed that it is at an angle to the direction of flow and completely immersed in the emergent stream and not less than 100 mm from the orifice. It is convenient to use the same thermometer as is used to adjust the temperature of the sample initially. Any difference in temperature from the initially adjusted temperature shall not be greater than 0.5°C (1.0°F).

10.2.7 Make a second determination on another portion of the originally prepared sample and check carefully that the temperature of testing is within the prescribed limits. Record the flow time to the nearest 0.5 s. Calculate the mean of the two determinations. If the two determinations differ by more than 5 %, make a third determination. If the third determination and

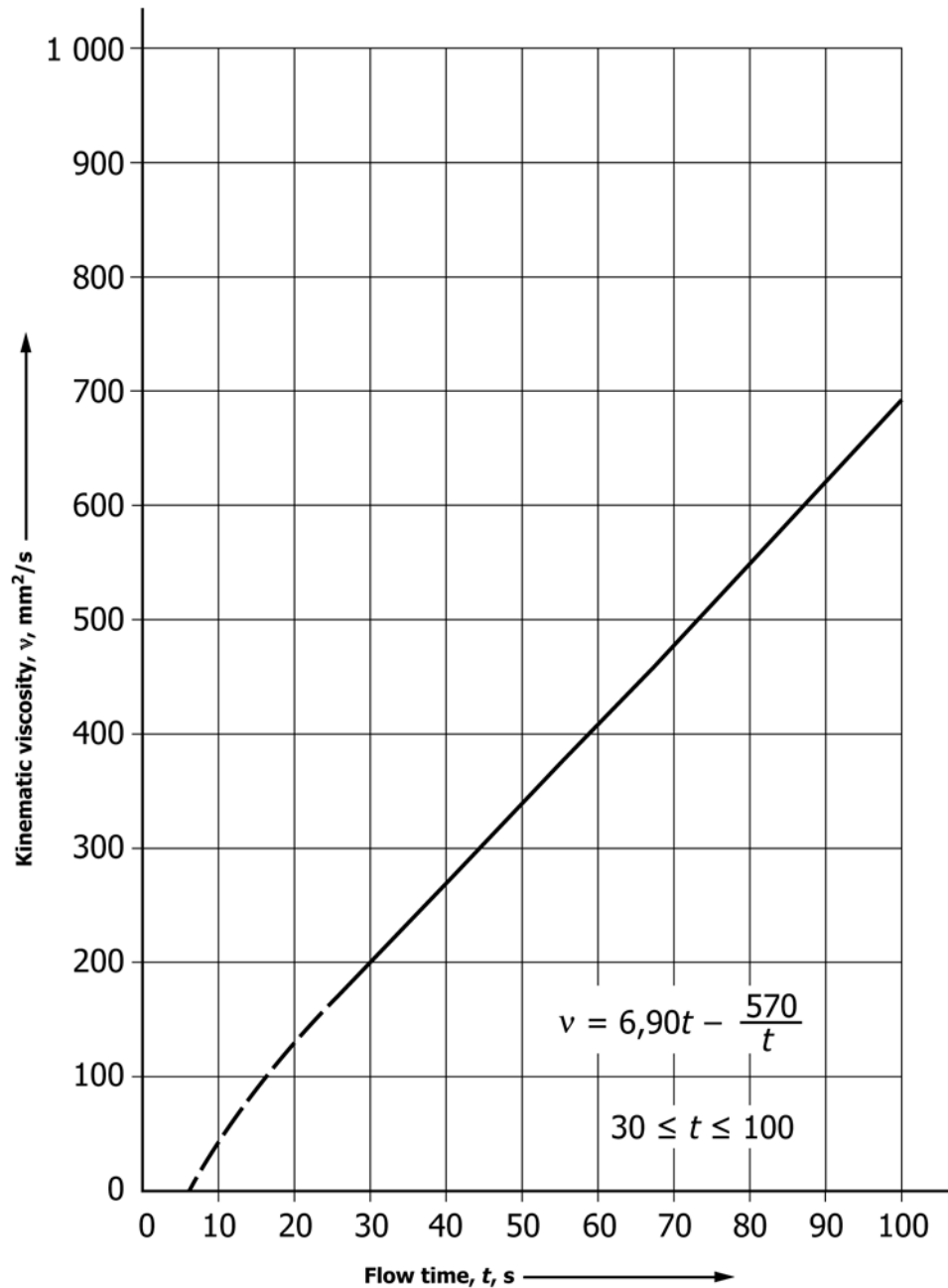


FIG. 5 Calibration Curve for 6-mm Cup

either of the previous determinations do not differ by more than 5 %, discard the other determination. Calculate the result as the mean of the two accepted determinations. If the third determination does not provide this measure of agreement, the method of test is unlikely to be suitable because of anomalous flow behavior, and consideration shall be given to other methods of test.

### 11. Care and Checking of Flow Cups

11.1 Clean the cup immediately after use and before the sample starts to dry, using a suitable solvent. Never use metal cleaning tools or wire. If the orifice becomes contaminated

with dried deposits, soften with a suitable solvent and clean carefully, for example with a soft cloth pulled through the orifice.

11.2 Check the cups periodically for wear or damage by the calibration procedure specified in Section 9.

### 12. Report

12.1 The test report shall include at least the following information:

- 12.1.1 Type and identification of the product tested,
- 12.1.2 Designation (No. 3, 4, 5, or 6) of the cup used,

12.1.3 Temperature of testing and where determined; in the cup, in the controlled environment, or in efflux stream,

12.1.4 Flow time, and

12.1.5 Any deviation, by agreement or otherwise, from the test procedure described.

### 13. Precision and Bias

13.1 *Precision*—The precision of this test method has not been determined by an ASTM Task Group and the following values should only be used as in guide until interlaboratory testing can be carried out.

13.1.1 *Repeatability (r)*—The difference between two results (each the mean of two accepted determination) obtained by the same operator with the same apparatus under constant

operating conditions on identical test material shall, at the 95 % confidence level, not exceed 5 % (as reported in ISO 2431).

13.1.2 *Reproducibility (R)*—The difference between two results (each the mean of two accepted determinations) obtained by different operators in different laboratories or identical test material shall, at the 95 % confidence level, not exceed 10 % (as reported in ISO 2431).

13.2 *Bias*—The bias of this test method will be determined using standard oils. However, this will only give the bias in terms of hydrocarbon oils and will have no meaning for other materials.

### 14. Keywords

14.1 efflux cups; flow cups; ISO cups; viscosity

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