Designation: D2162 – 17

Standard Practice for
Basic Calibration of Master Viscometers and Viscosity Oil Standards[1]

1. Scope*

1.1 This practice covers the calibration of master viscometers and viscosity oil standards, both of which may be used to calibrate routine viscometers as described in Test Method D445 and Specifications D446 over the temperature range from 15 °C to 100 °C.

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

1.2.1 The SI-based units for calibration constants and kinematic viscosities are mm^2/s^2 and mm^2/s, respectively.

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.* For specific warning statements, see Section 7.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D446 Specifications and Operating Instructions for Glass Capillary Kinematic Viscometers
D1193 Specification for Reagent Water
D1250 Guide for Use of the Petroleum Measurement Tables
D1480 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Bingham Pycnometer
D1590 Test Method for Surface Tension of Water
E1 Specification for ASTM Liquid-in-Glass Thermometers
E563 Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature
E644 Test Methods for Testing Industrial Resistance Thermometers
E1137 Specification for Industrial Platinum Resistance Thermometers
E1750 Guide for Use of Water Triple Point Cells
E2593 Guide for Accuracy Verification of Industrial Platinum Resistance Thermometers
E2877 Guide for Digital Contact Thermometers

2.2 *ISO Standard:*[3]

ISO 3666 Viscosity of Water

3. Terminology

3.1 *Definitions:*

3.1.1 *digital contact thermometer (DCT) , n*—an electronic device consisting of a digital display and associated temperature sensing probe.

3.1.1.1 *Discussion*—This device consists of a temperature sensor connected to a measuring instrument; this instrument measures the temperature-dependent quantity of the sensor, computes the temperature from the measured quantity, and provides a digital output. This digital output goes to a digital display and/or recording device that may be internal or external to the device. These devices are sometimes referred to as "digital thermometers."

3.1.1.2 *Discussion*—PET is an acronym for portable electronic thermometers, a subset of digital contact thermometers (DCT).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *basic calibration, n*—calibration based on the primary standard, water.

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[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

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

***A Summary of Changes section appears at the end of this standard**

3.2.1.1 *Discussion*—Pure water has a kinematic viscosity of 1.0034 mm^2/s at 20 °C. See ISO 3666.

3.2.2 *master viscometer, n*—glass capillary viscometer with a liquid driving head of at least 400 mm.

3.2.2.1 *Discussion*—It is specially designed to minimize errors due to surface tension, kinetic energy, and capillary end effects.

3.2.3 *viscosity oil standard, n*—stable Newtonian liquid, the kinematic viscosity of which has been related to the kinematic viscosity of water through the step-up procedure described in this practice.

4. Summary of Practice

4.1 Two or more master viscometers, having calibration constants in the 0.001 mm^2/s^2 to 0.003 mm^2/s^2 range, are calibrated with water at 20 °C. The kinematic viscosities of two or more oil standards are measured at 40 °C in these two master viscometers. Corrections are made for buoyancy and, where necessary, for temperature and surface tension.

4.2 A third master viscometer, with a calibration constant of 0.003 mm^2/s^2 to 0.009 mm^2/s^2 , is then calibrated at 40 °C with the two standard oils and its calibration factor calculated at standard conditions for water at 20 °C. In like manner additional viscosity oil standards and additional master viscometers are calibrated at 40 °C using the average results from at least two master viscometers or two oil standards. Steps between successive calibration constants or viscosities increase by a factor of three or less until the desired viscosity range is covered.

4.3 Oils are calibrated at other temperatures using the average result from at least two master viscometers.

5. Significance and Use

5.1 Because there are surface tension or kinematic viscosity differences, or both, between the primary standard (7.4) and kinematic viscosity standards (7.5), special procedures using master viscometers are required to "step-up" from the kinematic viscosity of the primary standard to the kinematic viscosities of oil standards.

5.2 Using master viscometers calibrated according to this practice, an operator can calibrate kinematic viscometers in accordance with Specifications D446.

5.3 Using viscosity oil standards established in this practice, an operator can calibrate kinematic viscometers in accordance with Specifications D446.

6. Apparatus

6.1 *Master Viscometers: Cannon*[4] or Ubbelohde[5] Type—Acceptable viscometers are shown in Fig. 1 and Fig. 2. Two masters are required with calibration constants in the 0.001 mm^2/s^2 to 0.003 mm^2/s^2 range. Additional masters have factors increasing in three-fold steps.

6.2 *Temperature Measuring Devices*—Use either a digital contact thermometer (DCT) or a liquid-in-glass thermometer meeting the requirements in 6.2.1 or 6.2.1.1 respectively:

6.2.1 *Digital Contact Thermometer*—A device conforming to Guide E2877 Class A and meeting or exceeding the following additional requirements:

(1) The only acceptable sensors are resistance temperature devices (RTD) or high precision thermistors. However a standard platinum resistance thermometer (SPRT) is preferable.

(2) Meeting Class A requirements of Guide E2877 preferably with a minimum display resolution of 0.001 °C.

(3) A combined (display and probe) accuracy of ±7 mK (0.007 °C) at a 95 % confidence level over intended range of use.

(4) A response time of less than 25 s as defined in Specification E1137.

(5) Linearity of less than 7 mK (0.007 °C) over the range of temperatures to be measured.

(6) Both the temperature sensor and measurement bridge components of the DCT shall have a report of temperature calibration from a calibration laboratory with a demonstrated competency in temperature calibration traceable to a national calibration or metrology standards body.

(7) The calibration report shall include data for the series of test points which are appropriate for the range of intended use.

(8) If the DCT display unit (measuring instrument such as a bridge) is calibrated separate from the probe, it should be calibrated annually.

6.2.1.1 The DCT probe is to be immersed by more than its minimum immersion depth in a constant temperature bath so that the center of the probe's sensing region is at the same level as the lower half of the working capillary provided the probes minimum immersion depth is met. The end of the probe's sheath shall not extend past the bottom of the viscometer's lower reservoir.

NOTE 1—With respect to DCT probe immersion depth, a procedure is available in Test Methods E644, Section 7, for determining the minimum depth. With respect to an ice bath, Practice E563 provides guidance on the preparation of an ice bath however variance from the specific steps is permitted provided preparation is consistent as it is being used to track change in calibration.

6.2.1.2 Verify the calibration at least annually. The probe shall be recalibrated when the check value differs by more than 0.01 °C from the last probe calibration. Verification can be accomplished with the use of a water triple point cell, an ice bath or other suitable constant temperature device which has a known temperature value of suitable precision. See Practice E563, Guide E1750, and Guide E2593 for more information regarding checking calibrations.

6.2.2 *Liquid-in-Glass Thermometer*—Kinematic viscosity thermometers having a range from 18.5 °C to 21.5 °C, or 38.5 °C to 41.5 °C, and conforming to the requirements for Thermometers 44C and 120C, as prescribed in Specification E1, and calibrated to ±5 mK (0.005 °C). The thermometer shall have a report of temperature calibration from a calibration laboratory with a demonstrated competency in temperature calibration traceable to a national calibration or metrology standards body.

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[4] Cannon, M. R., "Viscosity Measurement, Master Viscometers," *Industrial and Engineering Chemistry.* Analytical Edition, Vol 16, 1944, p. 708.

[5] Ubbelohde, L., "The Suspended Lever Viscometer," *Journal Institute Petroleum Technologists* (London), Vol 22, 1936, p. 37.

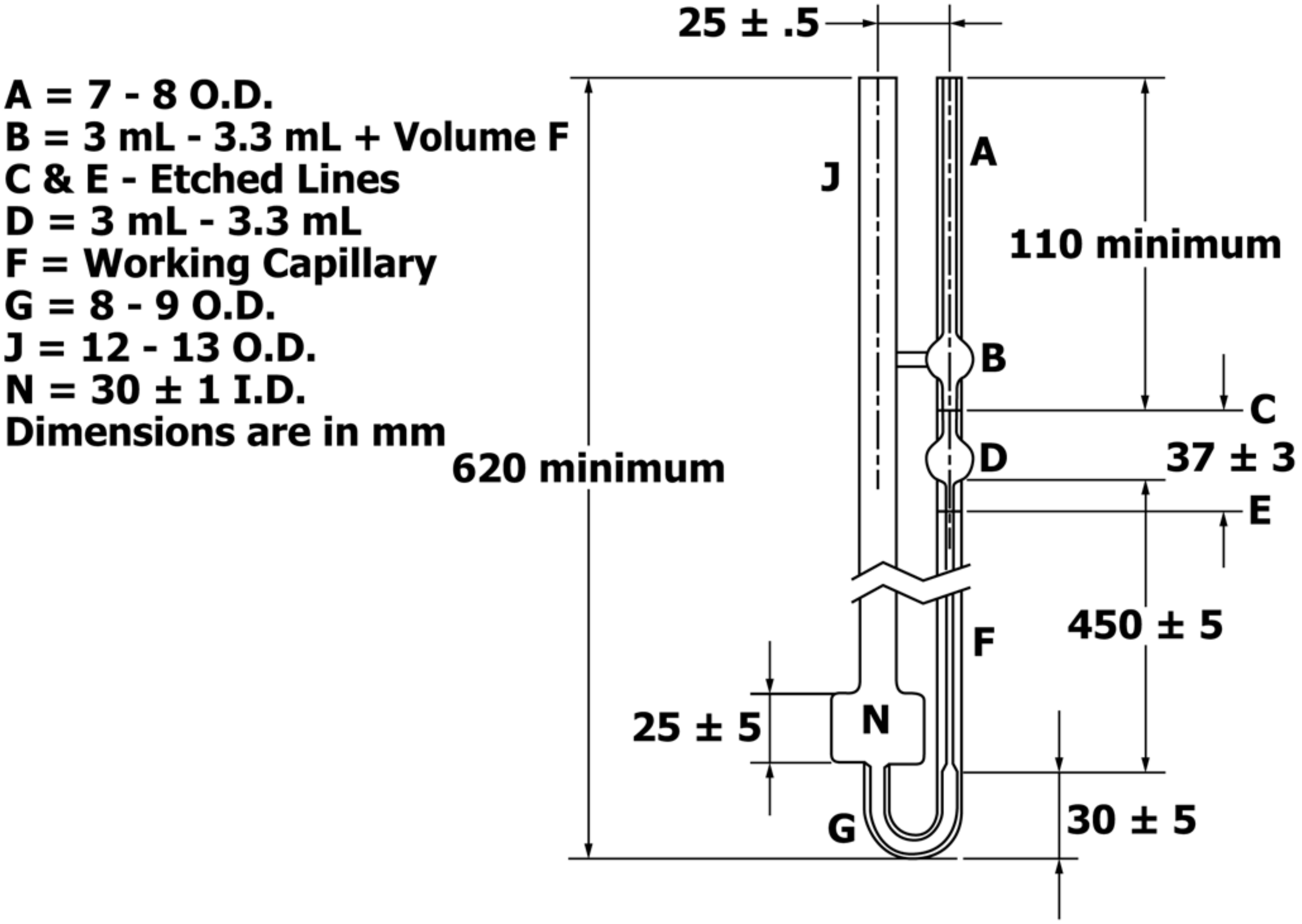

FIG. 1 Cannon Master Viscometer

6.2.2.1 *Calibration Check*—Verify the thermometer at least annually against a reference thermometer in a constant temperature bath or an ice bath. The thermometer is to be inserted to its immersion depth. If using an ice bath, the ice point reading is to be taken within 60 min after the thermometer has been at test temperature for at least 3 min. If the corrected temperature reading deviates more than the calibration tolerance from the reference thermometer or the ice point then repeat this calibration check. If the thermometer deviates from the reference value on two successive checks then a full thermometer recalibration is needed.

6.2.2.2 *Recalibration*—A complete recalibration of the liquid-in-glass thermometer, while permitted, is not necessary in order to meet the accuracy ascribed to liquid-in-glass thermometer's design until the thermometers corrected measured temperature deviates from the reference thermometer or ice point by one scale division, or until five years has elapsed since the last full calibration.

6.3 *Bath*—A thermostated bath containing water or other transparent liquid deep enough to immerse the master viscometers so that the upper fiducial mark is at least 50 mm below the surface. The efficiency of stirring and the balance between heat loss and input must be such that the temperature of the water does not vary by more than ±0.01 °C over the length of the viscometer or from one viscometer position to another. The working section of the bath should be shielded from direct radiation from heaters and lights. A standard platinum resistance thermometer, approximately 450 mm in length, may be used to ensure that the variation in temperature does not exceed ±0.01 °C. Firm supports should be provided to hold the master viscometer in a rigid and reproducible position within 0° 15 min of vertical.

6.4 *Timer*—A spring-wound, electric, or digital timer capable of measuring time intervals of 300 s to 10 000 s with an accuracy of ±0.03 %. The stop watch, fully but not tightly wound, must be used and tested in the same position. For example, if used at 45° inclination, it should have been tested previously in that position. Electric, not electronic, timers must be operated on circuits, the frequencies of which are controlled. Commercial power sources, the frequencies of which are intermittently and not continuously controlled, are not satisfactory. Both mechanical and electric timers can be sensitive to abnormally low ambient temperature and should not be used when cold.

NOTE 2—Time signals as broadcast by the National Institute of Standards and Technology are a convenient and primary standard reference for calibrating timing devices. The following can be used:

WWV	Fort Collins, CO	(2.5, 5, 10, 15, 20) MHz
WWVH	Kauai, HI	(2.5, 5, 10, 15) MHz
CHU	Ottawa, Canada	(3.33, 7.335, 14.67) MHz

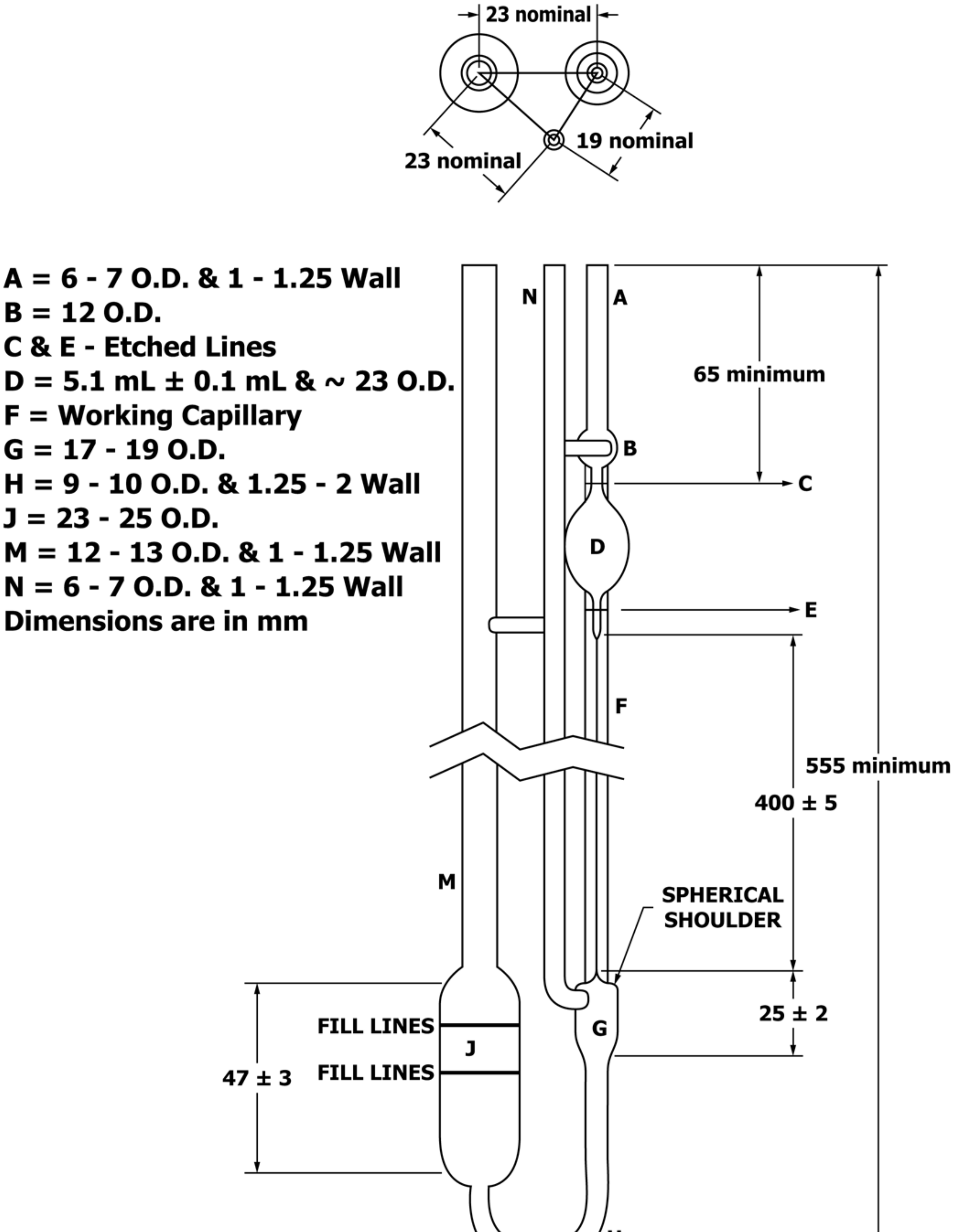

FIG. 2 Ubbelohde Master Viscometer

Radio broadcast of voice and audio on a telephone line at phone number: 303-499-7111. Additional time services are available from the National Institute of Standards and Technology.

6.4.1 The timer shall be calibrated at least every 12 months.

NOTE 3—A laboratory's measurement uncertainty is dependent on the performance of the apparatus used. The uncertainty can be improved (decreased) by using equipment that exceeds (smaller tolerance) the minimum requirements shown in Section 6 as will rigorous maintenance of the equipment.

7. Reagents

7.1 *Acetone,* reagent grade. (**Warning**—Extremely flammable.)

7.2 *Chromic Acid Cleaning Solution*— Carefully pour 1 L of concentrated sulfuric acid (H_2SO_4, relative density 1.84) into 35 mL of a saturated solution of technical grade sodium dichromate ($Na_2Cr_2O_7$) in water. Strongly oxidizing acid cleaning solutions containing no chromium[6] may be substituted to avoid disposal problems of chromium-containing solutions. (**Warning**—Causes severe burns.)

7.3 *Petroleum Spirit,* or other solvent completely miscible with petroleum oils. (**Warning**—Combustible. Vapor harmful.)

7.4 *Primary Standard Water,* deionized or distilled, then distilled fresh the same day of use. Store in a glass-stoppered chromic acid-cleaned bottle of borosilicate glass. See Specification D1193.

7.5 *Viscosity Oil Standards*—Stable petroleum oils selected to cover the desired kinematic viscosity range. They should be transparent and have vapor pressures below 10 mmHg at 40 °C. Store away from heat and light in suitable containers, preferably glass.

8. Calibration of Master Viscometers with Water at 20 °C

8.1 Maintain the water bath at 20 °C ± 0.01 °C applying the necessary thermometer corrections. Two check thermometers are recommended to detect any change in calibration.

8.2 Clean a master viscometer having a calibration constant of 0.001 mm^2/s^2 to 0.003 mm^2/s^2 with chromic acid cleaning solution to remove organic deposits, rinse thoroughly with distilled water and acetone and dry with a stream of filtered air.

8.3 Clean a 50 mL Erlenmeyer flask with cleaning solution and rinse thoroughly with distilled water. Add freshly distilled primary standard water and bring to a boil to remove dissolved gases. Cover the flask to prevent entrance of dust and allow to cool. If a Cannon master viscometer is being calibrated, cool the water to 20 °C ± 3 °C.

8.4 Charge the Cannon master as follows:

8.4.1 Connect a rubber tube to large arm *J*. Invert the viscometer and dip the end of small arm *A* into the beaker of water. Apply suction to arm *J* and draw liquid through bulbs *B* and *D* to etched line *E*. Turn the viscometer back to its normal vertical position, wipe tube *A* clean, insert the viscometer into a holder and place it in the constant temperature bath.

8.4.2 Support the master viscometer firmly and align it in a vertical position with the aid of a plumb bob with a length of about 560 mm. One can be made by use of a cork to fit the large tube *J*, a piece of thread, and an 18 mm length of 3 mm diameter solder lead. Remove the cork (or slot it) during the test so that no back pressure is developed.

8.5 Charge the Ubbelohde master as follows:

8.5.1 Tilt the instrument about 30° from the vertical with bulb *A* below the capillary and then introduce enough water into large arm 1 to bring the level up to the lower filling line. The level should not be above the upper filling line when the viscometer is returned to the vertical position and the liquid has been drained from tube 1. Charge the viscometer in such a manner that the *U*-tube at the bottom fills completely without trapping air.

8.5.2 Place the viscometer into a holder and place it in the constant temperature bath. Align the large tube 1 in a vertical position with a plumb bob as described for the Cannon master.

8.6 Allow the charged viscometer to stand in the bath long enough for the sample to reach bath temperature. Fifteen minutes are usually sufficient.

8.7 With gentle vacuum or pressure, force the liquid about 5 mm above the upper timing mark. Avoid splashing liquid in the upper bulb or forming any bubbles in the liquid. When using a Ubbelohde viscometer, hold a finger over the upper end of tube 3 during this operation; then remove it and immediately place it over tube 2 until the liquid drops away from the lower end of the capillary.

8.8 Measure the efflux of water from upper to lower timing mark (which should be 300 s or more) to the nearest 0.1 s. Repeat this measurement two additional times and average if the lowest and highest times agree within 0.1 %. If the measurements do not agree within this tolerance, repeat the procedure paying particular attention to cleaning the viscometer, filtering the sample, avoiding contamination during filling and afterwards, checking the temperature control and the timing device.

8.9 Clean the viscometer and dry with filtered air. Reload the viscometer and measure the efflux time in triplicate. Average if the lowest and highest times agree within 0.1 %.

8.10 If the two average times fall within 0.1 %, average the two to obtain an average of the two fills.

8.11 Calculate the viscometer constant as follows:

$$c = 1.0034/t \quad (1)$$

where:

c = calibration constant of the viscometer with water at 20 °C, mm^2/s^2, and
t = efflux time, s.

8.12 Repeat the operations described in 8.1 through 8.8 with a second master viscometer having a constant not greater than 0.003 mm^2/s^2 .

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[6] The sole source of supply of non-chromium containing cleaning solution known to the committee at this time is Godax Laboratories Inc., 480 Canal Street, New York, NY 10013. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

NOTE 4—Normally master viscometers are calibrated and used in the same location. If subsequently the viscometer is used at a laboratory other than the calibrating one, the c constant should be corrected for the difference in the acceleration of gravity, g at the two locations as follows:

$$c_2 = (g_2/g_1) \times c_1 \quad (2)$$

where:

c_2 and g_2 = calibration constant and gravity at the new locations, and
c_1 and g_1 = calibration constant and gravity at the original location.

Certificates for viscometers should state the value of g at the location of the calibrating laboratory. Failure to correct a viscometer constant for change of gravity can result in errors as high as 0.2 %, which is twice the error permitted between checks in this test method.

9. Calibration of Viscosity Oil Standards at 40 °C

9.1 Choose an oil with a kinematic viscosity of about 3 mm^2/s at 40 °C. Filter a portion into a clean beaker through a 200 mesh (75 µm) sieve, or other suitable filter, to remove dirt or sediment. If necessary, adjust the temperature of the oil to within 3 °C of 20 °C.

9.2 Adjust the temperature of the bath to 40 °C ± 0.01 °C applying the necessary thermometer corrections.

NOTE 5—The procedure is given for 40 °C because kinematic viscosities of petroleum oils are traditionally measured at this temperature and so viscosity oil standards at 40 °C are in common use. Master viscometers may, however, be calibrated at any convenient bath temperature and used, with any necessary corrections, at other temperatures.

9.3 Charge one of the master viscometers, already calibrated with water, with the oil. Allow the charged viscometer to stand in the bath long enough to reach bath temperature.

9.4 Measure the efflux time to the nearest 0.1 s three times and average if the lowest and highest times agree within 0.1 %.

9.5 Clean the viscometer with petroleum spirit followed by acetone and dry with filtered air. Reload the viscometer with oil and measure the efflux time in triplicate. Average if the lowest and highest times agree within 0.1 %.

9.6 If the average times fall within 0.1 %, average the two.

9.7 Using the second calibrated master viscometer, repeat the procedure described in 9.1 through 9.6 on the same oil.

10. Corrections and Calculation of Kinematic Viscosity at 40 °C

10.1 *Buoyancy Correction:*

NOTE 6—Applicable to both Cannon and Ubbelohde viscometers.

10.1.1 In kinematic viscometers the driving head of liquid is slightly reduced by the counterpoised head of air in the empty arm of the viscometer. This buoyancy effect is measured by the density of air divided by the density of the liquid. In going from water at 20 °C to oil at another temperature, the net effect is the difference between the two as follows:

$$c_b = (d_{a20}/d_{w20}) - (d_{aT}/d_{oT}) \quad (3)$$

where:

c_b = buoyancy correction expressed as a fraction of the driving head.
d_{a20} = density of moist air at 20 °C (0.00120 g/mL),
d_{w20} = density of water at 20 °C (0.998 g/mL),
d_{aT} = density of moist air at the test temperature, g/mL (see Table 1), and
d_{oT} = density of oil at the test temperature, g/mL.

TABLE 1 Density of Moist Air[A]

Temperature °C	Density, g/mL
–54	0.00162
–40	0.00150
0	0.00128
20	0.00120
25	0.00118
40	0.00113
60	0.00105
100	0.00094

[A] These densities assume an atmospheric pressure of 760 mm and, at 20 °C and above, a dew point of 150 °C (the mean of an anticipated 5 °C to 25 °C).

10.1.2 Determine the density of the oil standard at 40 °C in accordance with Test Method D1480.[7] Alternatively, determine the relative density of the oil at some convenient temperature and obtain the relative density at 40 °C in accordance with Guide D1250. Relative density is close enough to density for the purposes of this correction.

10.1.3 Calculate the buoyancy correction by the equation given in 10.1.1, inserting the determined oil density at 40 °C and the density of air at 40 °C from Table 1. For most petroleum oils the approximate buoyancy correction is – 0.0002 when correcting from water at 20 °C to oil at 40 °C.

10.2 *Temperature Correction:*

NOTE 7—Necessary only with Cannon-type viscometer and only when test temperature differs from the calibration temperature, 20 °C.

10.2.1 The effects of thermal expansion of glass capillary-tube viscometers of the kinematic type are virtually self-compensating and usually may be neglected. However, in viscometers in which the working volume is fixed at 20 °C ± 3 °C but which are used at another temperature, the driving head changes with expansion or contraction of the liquid. The correction is given as follows:

$$c_T = V(d_T - d_{20})/\pi R^2 h d_T \quad (4)$$

where:

c_T = temperature correction expressed as a fraction of the driving head,
V = total volume of fill at 20 °C, mL,
d_{20} = density of the liquid when filled at 20 °C, g/mL,
d_T = density of the liquid at the test temperature, g/mL,
R = inside radius of the reservoir, cm, and
h = driving head, cm, at 20 °C.

NOTE 8—The volume of fill, the inside radius of the reservoir, and the driving head may be measured approximately since errors in these measurements have only slight effects on the final corrected viscosity. For Cannon masters conforming to the dimensions shown in Fig. 1 the equation reduces to:

$$c_T = 0.023 \times [(d_T - d_{20})/d_T]. \quad (5)$$

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[7] Swindells, J. F., Hardy, R. C., and Cottington, R. L., "Precise Measurements with Bingham Viscometers and Cannon Master Viscometers" *Journal of Research*, National Institute of Standards and Technology, Vol 52, No. 3, March 1954, pp. 105 (RP 2479).

TABLE 2 Surface Tension Correction

Surface Tension Divided by Density	Correction
30	+ 0.0016
35	+ 0.0014
40	+ 0.0012

10.2.2 Determine the density of the oil at 20 °C in accordance with Test Method D1480. Alternatively, determine the relative density of the oil at some convenient temperature and obtain the relative density at 20 °C and 40 °C in accordance with Guide D1250. Relative density may be substituted for density in this equation.

10.2.3 Calculate the temperature correction by the equation given in 10.2.1, inserting the density of the oil at 20 °C and the density of the oil at 40 °C as determined in 10.1 or as calculated in accordance with Guide D1250. For most petroleum oils the approximate temperature correction is −0.0003 when correcting from 20 °C to 40 °C.

10.3 *Surface Tension Correction:*

NOTE 9—Necessary only with the Cannon-type viscometer, when it is calibrated with one liquid and used with another liquid having a different surface tension and density.

10.3.1 If the upper liquid meniscus in a viscometer flows in a narrower tube than the bottom meniscus, the driving head is slightly reduced by the capillary rise in the smaller diameter tube or bulb. The surface tension and capillary rise of water are greater than that of oil. Consequently, the driving head is reduced more with water in the viscometer and the driving head is less with water in the viscometer than it is with oil. A correction is required for the difference in capillary rise of water and oil.

10.3.2 Equations have been derived relating capillary rise to surface tension in tubes of small diameter. These equations are not exact when applied to larger tubes. The corrections given in Table 2 are based upon actual measurements of capillary rise with both water and oil in a bulb simulating the Cannon master efflux bulb.[7] They are empirical corrections to be applied only to Cannon master viscometers having the dimensions shown in Fig. 1. The efflux bulb must be spherical and have a volume of 3.0 cm^3, the lower reservoir must have a diameter of 30 mm, and the head must be 470 mm ± 40 mm.

10.3.3 Determine the surface tension of the oil standard at 40 °C in accordance with Test Methods D1590.

10.3.4 Divide surface tension by density at 40 °C as determined in 10.1.2. Select the surface tension correction from Table 2. The correction is expressed as a fraction of the driving head.

NOTE 10—In Cannon master viscometers, the approximate surface tension correction for most petroleum oils is + 0.0014 when correcting from water at 20 °C to oil at 40 °C. In Ubbelohde master viscometers the surface tension correction will be nearly zero if the diameter of the meniscus in the vent bulb below the capillary is 75 % that of the meniscus in the efflux bulb at the maximum diameter. If the diameter of the lower meniscus varies from 70 % to 80 % of the maximum upper meniscus diameter, the surface tension correction, c_s, will vary from − 0.0002 to + 0.0002 (−0.02 % to + 0.02 %); when the viscometer is made as shown in Fig. 2, the surface tension correction should be within these limits. If the diameter of the lower meniscus varies from 60 % to 90 % of the maximum upper meniscus diameter, the surface tension correction, c_s, will vary from − 0.0005 to + 0.0005 (−0.05 % to + 0.05 %).

10.4 *Kinematic Viscosity Calculation:*

10.4.1 For a Cannon master viscometer, calculate the kinematic viscosity of the oil standard as follows:

$$v = \left(1+c_b+c_T+c_s\right) \times Ct \tag{6}$$

where:

v = kinematic viscosity of the oil at 40 °C, mm^2/s,
c_b = buoyancy correction (see 10.1),
c_T = temperature correction (see 10.2),
c_s = surface tension correction (see 10.3),
C = calibration constant of master viscometer with water at 20 °C, mm^2/s^2 , and
t = average efflux time, s.

10.4.2 For a Ubbelohde master viscometer, calculate the kinematic viscosity of the oil standard as follows:

$$v = \left(1+c_b\right) \times Ct \tag{7}$$

where:

v, c_b, C, and t are as given in 10.4.1.

NOTE 11—The value of $(1 + c_b + c_T + c_s)$ will average about 1.0009 for the Cannon master and 0.9998 for the Ubbelohde master viscometer. The total correction is therefore of the same order or below the repeatability limit of this practice.

10.5 Repeat the calculation for the data obtained in 9.7 with the second master viscometer. Average the kinematic viscosities if they agree within 0.1 %.

11. Calibration of Additional Master Viscometers and Viscosity Oil Standards at 40 °C

11.1 Choose an oil with a kinematic viscosity of 6 mm^2/s to 10 mm^2/s at 40 °C. Determine the average kinematic viscosity in the two calibrated master viscometers as directed in Sections 9 and 10.

11.2 Select a new, third master viscometer with a calibration constant in the 0.003 mm^2/s^2 to 0.009 mm^2/s^2 range. Determine its calibration constant using the 3 mm^2/s and 10 mm^2/s kinematic viscosity oil standards following the procedure given in 9.1 through 9.6.

11.3 Calculate the calibration constant as follows:

11.3.1 For Cannon master viscometers:

$$C = v/\left[\left(1+c_b+c_T+c_s\right) \times t\right] \tag{8}$$

where:

C = calibration factor for water at 20 °C, mm^2/s^2
v = kinematic viscosity of the oil standard mm^2/s,
c_b = buoyancy correction (10.1),
c_T = temperature correction (10.2),
c_s = surface tension correction (10.3), and
t = average efflux time, s.

11.3.2 For Ubbelohde master viscometers:

$$C = v/\left[\left(1+c_b\right) \times t\right] \tag{9}$$

where:

C, v, c_b, and t are as given in 11.3.1.

NOTE 12—For consistency, all viscometer calibration factors are corrected back to water at 20 °C. Corrections for other oils and temperatures are made from this standard condition. Calibration factors with oil at 40 °C are used in routine calibration work.

11.4 Average the calibration factors found with the two oil standards if they agree within 0.1 %.

11.5 Continue to calibrate viscometers and viscosity oil standards in like manner using two or more viscosity oil standards to determine the factor of each viscometer and two viscometers to determine the kinematic viscosity of each oil standard.

11.6 Periodically clean all master viscometers with chromic acid cleaning solution to remove organic deposits.

12. Calibration of Viscosity Oil Standards at Other Temperatures

12.1 Select a master viscometer having an efflux time between 300 s and 3000 s with the oil at the temperature of test.

12.2 If it is suspected that the oil sample might contain solid particles, filter the sample through a 200 mesh (75 µm) filter into a clean beaker. When calibrating with Cannon master viscometers adjust the temperature to 20 °C ± 3 °C. Charge the viscometer as described in 8.4 or 8.5.

12.3 Adjust the temperature of the bath to the new test temperatures within ±0.01 °C of the test temperature. For temperatures below 15 °C, the bath temperature should be constant within ±0.02 °C. When working near or below the dew point, use drying tubes to prevent condensation of moisture in the viscometer.

12.4 Determine efflux time of the oil at the new test temperature as directed in 9.3 through 9.6. Select another master viscometer having an efflux time between 300 s and 3000 s and repeat the determination of efflux time.

12.5 Calculate the kinematic viscosity as directed in Section 10, substituting air density, oil density, and surface tension at the new test temperature for the densities and surface tension at 40 °C.

13. Keywords

13.1 kinematic viscosity; master viscometers; viscosity oil standards

SUMMARY OF CHANGES

Subcommittee D02.07 has identified the location of selected changes to this standard since the last issue (D2162 – 14) that may impact the use of this standard. (Approved May 1, 2017.)

(1) Revised 3.1.1.