Methods for

Determination of the viscosity of liquids

Confirmed
February 2012

UDC 532.13.08

Cooperating organizations

Technical Committee C/17, Viscosity, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and professional and industrial organizations:

British Lampblown Scientific Glassware Manufacturers Association
British Resin Manufacturers Association
Chemical Industries Association Ltd.
Chemical Society
Institute of Petroleum
Ministry of Defence
National Physical Laboratory (Department of Industry)
Oil and Colour Chemists Association
Standardization of Tar Products Tests Committee

This British Standard, having been prepared under the direction of the Chemical Divisional Council, was published under the authority of the Executive Board on 31 December 1976

First published November 1923
First revision May 1929
Second revision May 1937
Third revision July 1957
Fourth revision December 1976

The following BSI references relate to the work on this standard:
Committee reference C/17
Draft for comment 75/88163 DC

ISBN 0 580 09409 7

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

Section 1. General

Section 2. Method using glass capillary viscometers

Section 3. Falling sphere method

Foreword

BS 188 was first published in 1923 and revised editions were issued in 1929, 1937 and 1957. After nearly two decades it was timely to prepare this revision to take account of developments that have led to changes in emphasis, though not of principle. Three particular changes have been made to bring the standard as a whole up-to-date. First, precedence is given to SI units over CGS units. Second, the definitions given are based on those in BS 5168. Third, the recommended test temperatures are taken from ISO 3205.

The techniques of viscosity measurement owe much to the work of the petroleum industry, and two International Standards have been prepared by ISO/TC 28, Petroleum Products. They are ISO 3104, on the method of measuring viscosity of petroleum products, and ISO 3105, on (design of) glass capillary viscometers for the same purpose. Taking them into account, the content of BS 188:1957 has been rearranged so that the method using glass capillary viscometers and associated material is presented as an entity, section 2. Other industries are also active in the field of viscosity measurement, and besides those relying upon the glass capillary method there is a continuing call for the falling sphere method, which is retained as section 3 with minor revisions such as reference to spheres of common metric sizes and to materials additional to hardened steel.

In section 2 (glass capillary viscometers), the basis of the practical scale remains unchanged, namely the value adopted in 1953 for the dynamic and kinematic viscosities of freshly distilled water at 20.00 °C, together with a step-by-step comparison procedure for calibrating viscometers through the range. In the previous 1957 revision a reduced expression $\upsilon = Ct - B/t$ was well recognized, where υ is kinematic viscosity; C, the viscometer factor; t, flow time; B, the kinetic energy factor of significance at rapid flows, i.e. short flow times, particularly in fine capillaries. The variability of B between viscometers apparently alike in other respects had been a long-standing problem, and the 1957 edition gave special attention to B. Since then the trend has been to require calibrating laboratories to state the minimum flow time for which the simpler expression $\upsilon = Ct$ is of sufficient precision. Certain refinements in design in 1957 also helped to reduce the magnitude of B. The necessary safeguards with respect to flow time having been established, the B factor has been eliminated from the calculations in the present edition. Another change relates to the specification of detailed designs of particular glass capillary viscometers. In the 1957 edition dimensional details were specified for seven designs. As, however, full information about accepted designs is now available in ISO 3105, the information given in this revision is concentrated on the salient features of use and design of representative viscometers from five well-known families.

Particular attention has been given in the details of the method to amplifying ISO 3104 in ways considered likely to be helpful to the user.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This British Standard describes the determination of the viscosity of liquids by the method using glass capillary viscometers (section 2) and by the falling sphere method (section 3).

The standard applies only to liquids exhibiting Newtonian flow under the conditions of measurement. A test for Newtonian flow is described in each section.

2 References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purposes of this British Standard the following definitions apply.

3.1
viscosity

the property of a liquid to resist shear deformation increasingly with increasing rate of deformation

shear is the orderly movement of layers of liquid relative to parallel adjacent layers. In a steady shear the rate of relative movement of layers is known as the **rate of shear**[1)] and the tangential force per unit area applied to the layers to sustain the motion is the **shear stress**

thus viscosity is the property that resists orderly laminar flow of liquid through a capillary; in this case the layers involved are concentric cylinders

3.2
dynamic viscosity, η

the shear stress divided by the rate of shear for steady flow of the liquid

3.3
kinematic viscosity, v

the dynamic viscosity divided by the density of the liquid, both measured at the same temperature

NOTE to **3.1** to **3.3** The word "viscosity" is used also as a contraction for "coefficient of viscosity", and a distinction is made between (coefficient of) dynamic viscosity and (coefficient of) kinematic viscosity.

3.4
newtonian flow

a liquid is said to exhibit Newtonian flow when the shear stress and the rate of shear are directly proportional; that is, at constant temperature and pressure the viscosity is independent of the rate of shear

4 Units

The SI unit of dynamic viscosity is the pascal second (symbol Pa s). The SI unit of kinematic viscosity is the metre squared per second (m^2/s).

Submultiples of these units are as follows:

millipascal second (mPa s), i.e. 10^{-3} Pa s; this is equal to the centipoise (cP);

millimetre squared per second (mm^2/s), i.e. 10^{-6} m^2/s; this is equal to the centistokes (cSt).

Appendix H gives information on the derivation of the SI units for dynamic and kinematic viscosity and on their relationship to the corresponding CGS units.

Section 2. Method using glass capillary viscometers

5 Field of application

This section describes the use of glass capillary viscometers for the measurement of kinematic viscosity of liquids exhibiting Newtonian flow (see note) under the measuring conditions. The method provides for the measurement of kinematic viscosity and for the calculation of dynamic viscosity from a knowledge of the kinematic viscosity and the density determined at the same temperature.

The method is described in detail for typical viscometers; sources of information about various glass capillary viscometers are indicated. The range of kinematic viscosity covered by these viscometers is 0.3 mm^2/s to 300 000 mm^2/s.

Additional information useful in viscometry is supplied in appendices.

NOTE A simple test for Newtonian flow is to determine the kinematic viscosity at the same temperature in glass capillary viscometers having calibration factors differing by at least three times. If the results agree within the specified reproducibility figure (see **10.2**), the liquid can be considered to exhibit Newtonian flow for the purposes of this method.

[1)] In capillary flow, "rate of shear" is sometimes called "velocity gradient" and may be thought of as the change in velocity associated with a displacement across the layers. It has the dimensions of velocity divided by length.

6 Principle

The time is measured for a reproducible volume of the liquid to flow through the capillary viscometer under an accurately reproducible head and at a closely controlled temperature. The kinematic viscosity is then calculated from the measured flow time and the calibration factor of the viscometer. If the density is measured at the same temperature as applied to the determination of kinematic viscosity, the product of the two results is the dynamic viscosity at that temperature.

Four precepts for precise viscometry are

a) a clean instrument,

b) a clean liquid,

c) constant temperature during the course of a measurement,

d) accurate measurements of temperature and flow time.

7 Apparatus

The principal items of apparatus are as follows.

7.1 *Viscometers* of the glass capillary type, capable of measuring viscosity within the tolerances for repeatability and reproducibility given in clause **10** and having a certificate of calibration.

NOTE Information about viscometers is given in Appendix A.

7.2 *Viscometer holders* to hold the viscometers firmly in the thermostatic bath in the alignment stated in the certificate of calibration.

7.3 *Temperature-measuring device*. A thermometric device that, when used in the manner described in its certificate of calibration, will enable the temperature of the bath adjacent to the sample to be measured to 0.01 °C in the range 15 °C to 100 °C, and to 0.03 °C outside that range. If a liquid-in-glass thermometer is used, it shall be of the “total immersion” type with a valid calibration chart (see also Appendix E).

7.4 *Thermostatic bath*. A transparent liquid or vapour bath of sufficient depth that during the measurement no portion of the sample is less than 20 mm below the surface of the bath medium or less than 20 mm above the bottom of the bath.

The temperature control shall be such that within the range of 15 °C to 100 °C the temperature of the bath during the period of measurement does not vary from the desired temperature by more than 0.01 °C over the length of the viscometer, or between viscometers. For temperatures outside the range 15 °C to 100 °C, the variation shall not exceed 0.03 °C.

If there is freedom of choice, the temperatures 100, 55, 40, 25, 20, 0, – 25 and – 40 °C are recommended (see ISO 3205) as options for determination of viscosity.

7.5 *Timing device*. Any timing device may be used provided that its readings discriminate to 0.2 s or finer and that its rate is accurate to ± 0.07 % over 15 min. A discrimination of 0.1 s can be used with advantage by a skilled operator on flow times of the order of 200 s to 300 s.

8 Procedure

The description that follows deals with selecting equipment, preparing the sample, filling the viscometer, timing the flow and repeating observations. However, the different designs of viscometer result in some differences in the procedure for filling, mounting and starting the flow. Accordingly a general description is given followed by examples of handling particular designs. For instruction about designs not described in detail, reference should be made to the calibration certificate and/or the supplier.

8.1 Selection of equipment

8.1.1 Check that there are current calibration reports for the thermometer and time-measuring device to be used.

NOTE For information see Appendix E and Appendix F.

8.1.2 If specified, condition the sample in the manner required. It is usual to filter the sample through a 75 µm aperture sieve, but a sample of low viscosity that is to be evaluated in a viscometer having a fine bore capillary may require filtering through a fritted glass filter.

At all stages protect the sample from contamination.

8.1.3 Estimate the order of viscosity of the sample and select a calibrated, dry, clean[2] viscometer of appropriate range for measuring the estimated viscosity.

If the sample is a silicone liquid or a fluorocarbon, which may affect the capillary by leaving a film that is difficult to remove, only viscometers reserved for such liquids should be used.

If the sample is transparent and forms a cleanly outlined meniscus, a direct flow viscometer should be used. Suspended level, direct flow Cannon-Fenske and direct flow U-tube viscometers are typical examples.

If the sample is opaque, a reverse flow viscometer should be used. Reverse flow U-tube and reverse flow Cannon-Fenske viscometers are examples.

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[2] See Appendix G.

If resources permit, more than one viscometer and thermometer should be used.

8.2 Setting up the apparatus

8.2.1 Maintain the bath at the test temperature as given by the readings of the thermometer when used with the precautions and the corrections supplied in the certificate of calibration.

With a total immersion thermometer, immerse the entire liquid column of the thermometer in the medium so that the top of the mercury column is visible just above or just below (generally within 2 mm) the surface of the medium. The thermometer should be mounted vertically.

If the temperature of the test is below the dewpoint, loosely packed drying tubes may be fitted to the open ends of the viscometer to prevent water condensation; however, it is essential that they do not set up a pressure differential and affect the rate of flow.

8.2.2 Charge the viscometer with the sample in accordance with the recommended method (examples are given in **8.4.1** to **8.4.5**). Avoid trapping air bubbles in the viscometer.

If the sample is very viscous, filling at ambient temperature is slow. Provided that the nature of the sample is not adversely affected, charging may be facilitated by warming it gently and evenly to reduce its viscosity.

8.2.3 Mount the viscometer in a holder in the bath, the aim being to repeat the criterion used when the viscometer was calibrated; i.e. the appropriate tube as stated in the certificate of calibration is to be set vertical, usually by sighting its parallelism with a plumb line.

8.2.4 Allow time for the charged viscometer to reach the same temperature as the bath. Usually 30 min suffice; it may take longer with a viscous sample from which air bubbles are slow to disperse. Unnecessary delay should be avoided, as the most consistent results are obtained shortly after reaching temperature equilibrium with a freshly charged viscometer.

Finally, adjust the volume of the charge if necessary.

8.3 Flow time measurement

8.3.1 *First measurement*. Adjust the level of the sample by suction or pressure to a position 5 mm above the upper timing mark of a direct flow viscometer, or 5 mm below the lower timing mark of a reverse flow viscometer. Suction may be controlled through a clean rubber tube connected to an open end of a viscometer. When using a *direct flow* viscometer, release the control, allow the sample to flow freely and measure to within 0.2 s the time for the bottom of the meniscus to pass from the first to the second timing mark. When using a *reverse flow* viscometer, release the control, allow the sample to flow freely and measure to within 0.2 s the time for the advancing ring of contact of the sample with the glass to pass from the first to the second timing mark.

If this flow time is less than the minimum stated on the certificate of calibration of the viscometer, select a viscometer of smaller factor and recommence the test.

Record the corrected thermometer readings at the beginning of, during and at the end of a timed flow.

8.3.2 *Repeat measurements*. When using a *direct flow* viscometer, repeat the measurement of flow time at once without emptying or recharging the instrument until two successive flow times agree within 0.2 % of their mean. When using a *reverse flow* viscometer, it is common practice and advantageous to have three timing marks spanning two timing bulbs so that the end of a first timing is the beginning of a second timing. Only in this way may a second flow time be obtained without emptying the viscometer, recharging and duplicating the flow measurement. Agreement of the values obtained from the successive timings within 0.35 % of their mean is required.

8.3.3 *Duplicate determinations*. It is advisable to flow the sample in two or more viscometers simultaneously but, if more than one are not available, then refilling and redetermination are desirable. Poor repeatability may be attributed to an unsuccessfully filtered sample, a contaminated viscometer or sample, unstable temperature conditions or heterogeneity of sample.

8.4 Detailed procedure for typical glass capillary viscometers

8.4.1 *U-tube viscometers for direct flow* (type BS/U) (see Figure 1). Charge the dry, clean viscometer through tube L with a slight excess of the sample, using a long pipette to minimize any wetting of the tube above the mark G.

Mount the viscometer in the bath, taking particular care that the capillary tube is set vertical.

When temperature equilibrium with the bath has been attained, adjust the volume of the sample so that the bottom of the meniscus settles at the mark G.

Apply suction or pressure to bring the liquid level to a point about 5 mm above the timing mark E. Release the suction or pressure and record the flow time taken for the bottom of the meniscus to pass from the top edge of mark E to the top edge of mark F. Record the corrected thermometer readings at the beginning of, during and at the end of the timed flow.

Repeat the measurement of flow time immediately, without emptying or recharging, until two successive flow times agree within 0.2 %.

8.4.2 *Suspended-level viscometers* (type BS/IP/SL) (see Figure 2). Charge the dry, clean viscometer with the sample through tube L, the amount charged being such that ventilating tube M will not be blocked during use. The initial filling may be done away from the bath.

Mount the viscometer in the bath with the capillary tube vertical.

When temperature equilibrium has been attained, close tube M and apply suction to capillary tube N until the liquid reaches a level about 5 mm above mark E. Hold the liquid at this level by closing tube N. Open tube M so that the sample drops away from the lower end of the capillary tube. (With very viscous samples, a little pressure can be applied to tube M to expedite this.)

When the sample is clear of the capillary end and the lower end of tube M, open tube N. The flow time is the time taken for the bottom of the meniscus to pass from the top edge of mark E to the top edge of mark F. Record the corrected thermometer readings at the beginning of, during and at the end of the timed flow.

If the end of tube M becomes blocked by the sample at any time while the flow is being measured, that measurement is unsatisfactory. The opening and closing of the tubes may conveniently be done by applying finger pressure, or by clips on clean flexible tubing attached to the end of the tubes, making sure that no fluff or other contaminant enters the tube.

Repeat the measurement of flow time immediately, without emptying or recharging, until two successive flow times agree within 0.2 %.

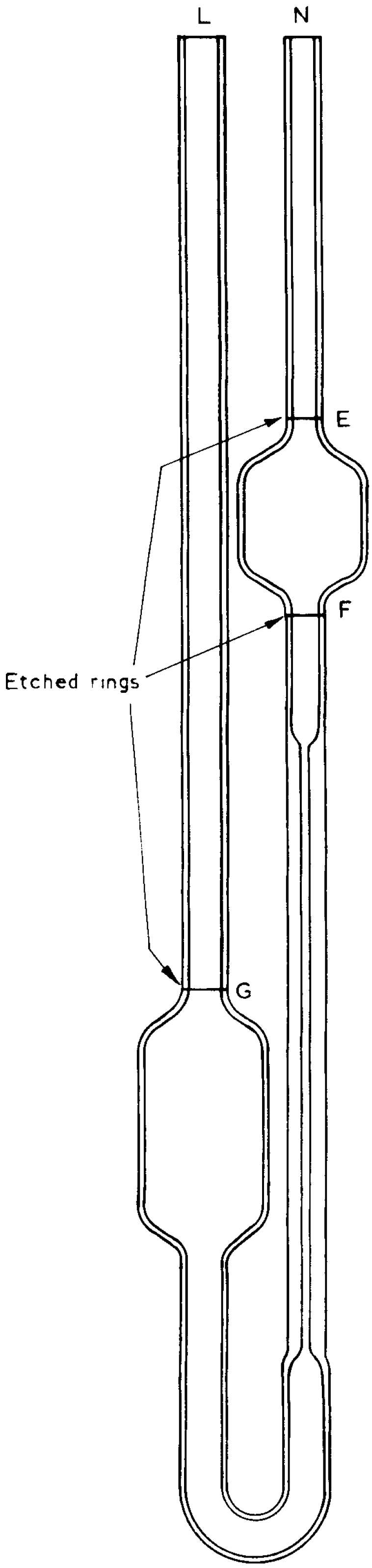

Figure 1 — BS/U viscometer

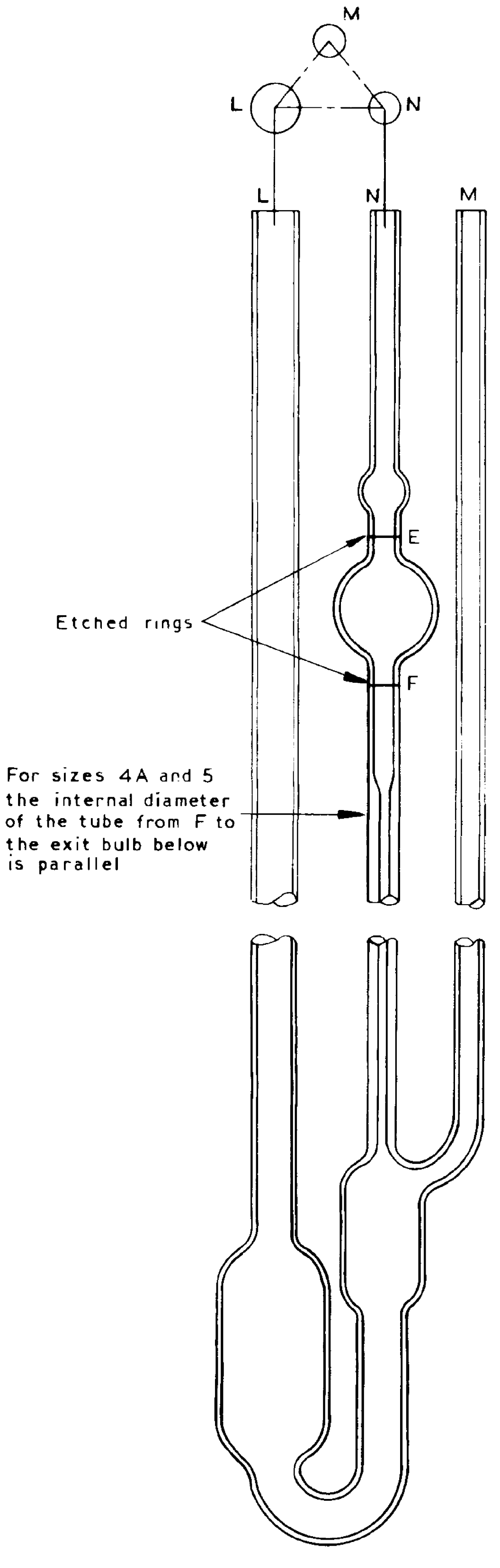

Figure 2 — Suspended-level viscometer, BS/IP/SL

8.4.3 *Cannon-Fenske viscometers* (type BS/IP/CF) (see Figure 3). Invert the dry, clean viscometer so that the end of tube N is immersed in the sample. Apply suction to tube L so that the sample is drawn up a few millimetres beyond the etched ring F. Remove tube N from the sample and allow the liquid to flow back until it reaches the line F; use a clean finger to block and gently release tube N to set the liquid level at F, thus ensuring that the viscometer contains the correct volume of sample at the filling temperature. Return the viscometer to its normal upright position and wipe the exterior clean of sample, making sure that no dirt or fluff enters the tubes. Place the viscometer in its holder in the bath.

Carry out the filling procedure within the temperature range advised in the calibration certificate. Record the filling temperature, which may enter into the calculation of the results (see clause **9**).

Mount the viscometer in the bath with the upper portion of the outside of tube L (not the capillary tube) vertical.

When temperature equilibrium has been attained, apply pressure or suction to bring the liquid level to a point about 5 mm above mark E. Release the pressure or suction. The flow time is the time taken for the bottom of the meniscus to pass from the top of mark E to the top of mark F. Record the corrected thermometer readings at the beginning of, during and at the end of the timed flow.

Repeat the measurement of flow times immediately, without emptying or recharging, until two successive flow times agree within 0.2 %.

8.4.4 *Reverse flow U-tube viscometers* (type BS/IP/RF) (see Figure 4). Mount the dry, clean viscometer in the bath so that the straight portion of the capillary tube R is set vertical, and allow the viscometer to reach the bath temperature.

Use a rubber bung fitted with a glass tube and stopcock, or a similar device, so that a controllable, very slight excess pressure can be applied to tube L. Pour sufficient sample into the filling tube N to a point just below the upper filling mark H, avoiding wetting the glass above H. Allow the sample to flow through the capillary tube R, taking care that the liquid column remains unbroken, until it has reached a position about 5 mm below the lower filling mark G; arrest its flow at this point by closing the tube L.

Add more of the sample to the filling tube N to bring the upper liquid surface to just below mark H. Allow the sample to reach the bath temperature and any air bubbles to rise to the surface (at least 30 min is required).

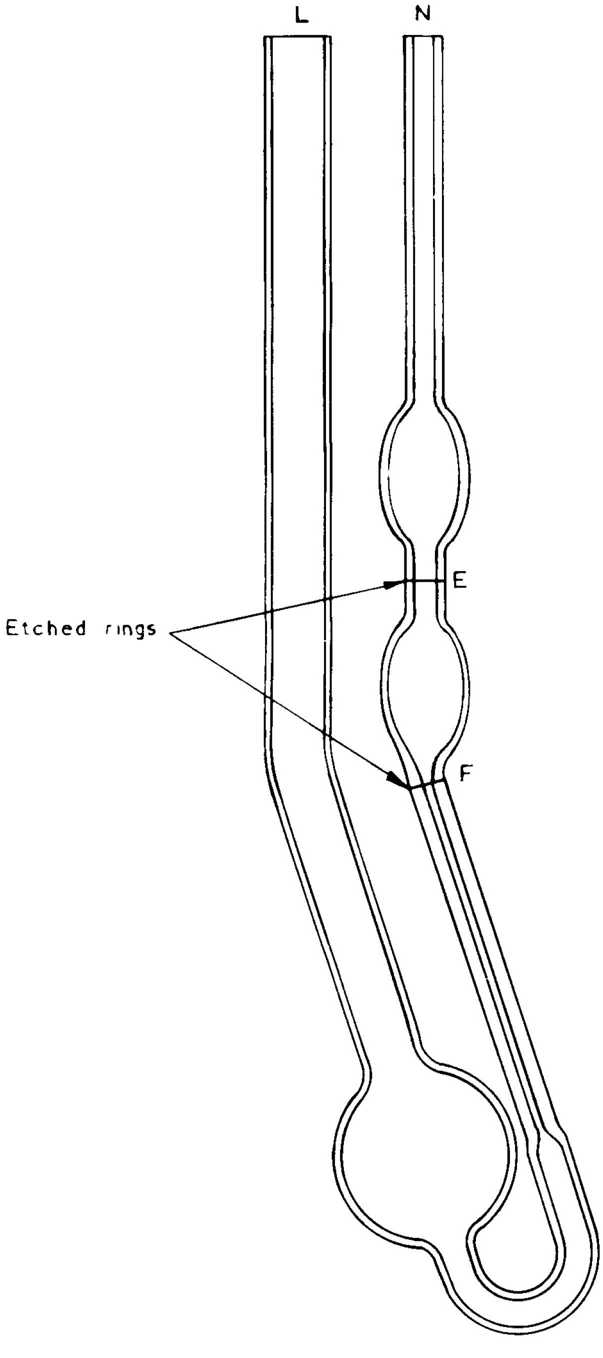

Figure 3 — Cannon-Fenske viscometer, BS/IP/CF

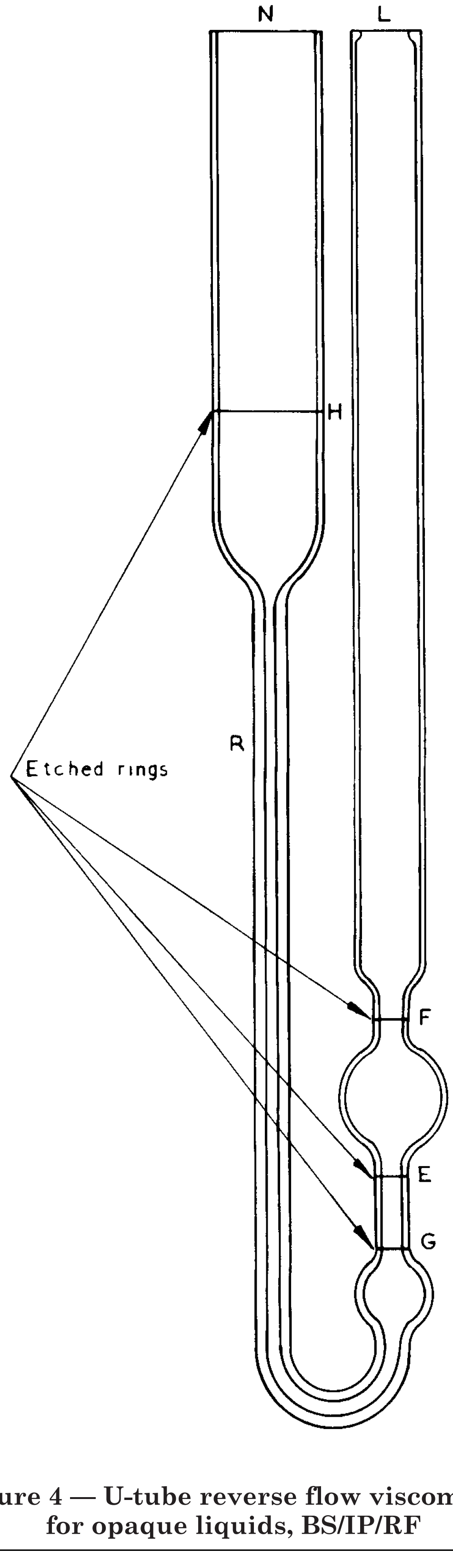

Figure 4 — U-tube reverse flow viscometer for opaque liquids, BS/IP/RF

Gently manipulate the stopcock or the bung closing tube L until the lower level of the sample is arrested at mark G, the uppermost ring of contact of the sample with the glass being coincident with the bottom of mark G. Add sample to tube N until the uppermost ring of contact of the sample with the filling tube N coincides with the bottom of filling mark H. Allow a little time for this additional amount of sample to reach the bath temperature.

Remove the rubber bung from tube L or open the stopcock to the atmosphere and allow the liquid to flow under its own head. Measure the time in seconds for the uppermost ring of contact of the sample with the glass to rise from the bottom of the lower timing mark E to the bottom of the upper timing mark F. Record the corrected thermometer readings at the beginning of, during and at the end of the timed flow.

As some of the sample may remain on the walls of the viscometer between the timing marks, repeat determinations of flow time may be made only after emptying, cleaning and drying the viscometer, refilling it, and then repeating the flow time measurement. Agreement of 0.35 % between the results of successive determinations is required.

8.4.5 *Reverse flow Cannon-Fenske viscometers* (type ISO/CF/RF) (see Figure 5). Use a rubber bung fitted with a glass tube and stopcock, or a similar device, for control purposes on tube L. Charge the dry, clean viscometer by inverting the instrument, immersing tube N in the liquid sample, applying suction to tube L, and thus drawing liquid into tube N through bulb D until the uppermost ring of contact of the sample with the glass coincides with the bottom of mark G. This volume of sample is critical. Wipe excess sample from tube N and return the viscometer to its normal upright position. Control the flow of the liquid down the capillary tube by operating the control on tube L and closing it when the sample enters bulb A. The temperature of the sample for filling shall be within the limits stated in the calibration certificate and shall be recorded.

Mount the viscometer in the bath with the outside of tube L vertical.

When temperature equilibrium has been attained, open the clip and allow the sample to be driven by its own head up tube L. Measure the flow time for the uppermost ring of contact of the sample with the glass to coincide successively with the bottom of marks E and F and of F and I. For such consecutive timings a watch called a “split second” timer is advantageous. Record the corrected thermometer readings at the beginning of, during and at the end of the timed flows.

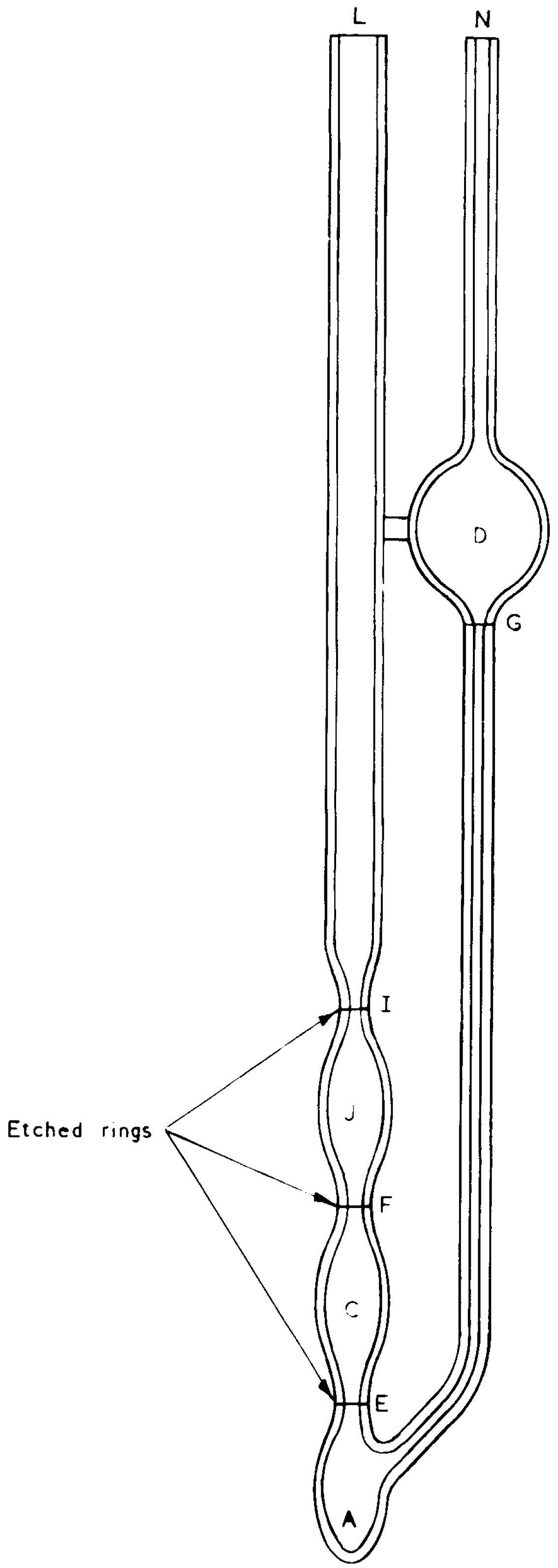

Figure 5 — Reverse flow Cannon-Fenske viscometer, ISO/CF/RF

Repeat determinations of flow time may be made only after emptying, cleaning and recharging the viscometer and then repeating the procedure. Agreement within 0.35 % of their mean is required between the results of successive determinations.

8.5 Determination of density. For calculation of dynamic viscosity from the determined value of kinematic viscosity, it is required to know the density of the sample liquid at the same temperature. This can be determined by using the method described in BS 4522. It is recommended that the bath and thermometers used for determination of kinematic viscosity should also be used for the determination of density.

9 Calculation and expression of results

9.1 Kinematic viscosity, υ. Use the formula[3].

$$\upsilon = Ct$$

where

t is the mean flow time (in s) (see **8.3**)

C is the factor[a] for the viscometer given in its calibration certificate

[a] For gravity flow, the value of C depends on the acceleration due to gravity (see Appendix C). With Cannon-Fenske viscometers, differences in the various temperatures of filling for calibration, of filling with test sample, during flow in calibration and during flow of the test sample also affect C (see Appendix C). The calibration certificate for the viscometer should refer to corrections to C.

Express the result in mm^2/s, a convenient SI unit (see clause **4**). State the temperature of the determination along with the result.

9.2 Dynamic viscosity, η. Calculate from the formula

$$\eta = \upsilon\rho$$

where

υ is the kinematic viscosity from **9.1** (in mm^2/s)

ρ is the density measured at the same temperature (in g/cm^3)

υ and ρ expressed in the units here stated will give η in mPa s, i.e. in cP. State the temperature of the determination of kinematic viscosity and density along with the result.

10 Repeatability and reproducibility

The following tolerances apply to clean transparent liquids tested between 15 °C and 100 °C and for viscosities up to 20 000 mm^2/s.

10.1 Repeatability. Duplicate results by the same operator using the same viscometer shall be considered suspect if their difference is greater than 0.35 % of their mean.

10.2 Reproducibility. The results submitted by each of two laboratories shall be considered suspect if their difference is greater than 0.7 % of their mean.

NOTE Product specifications should state increased tolerances over those given in clause **10** for repeatability and reproducibility when measurements of kinematic viscosity are made outside the range of 15 °C to 100 °C, according to the variation in temperature of the bath and the uncertainty of calibration of the thermometer.

Liquids that are opaque and/or do not give a well-formed meniscus may not give the desired repetition of flow times. Repeatability and reproducibility will be correspondingly less certain.

Section 3. Falling sphere method

11 Field of application

This section describes the determination of viscosity of a transparent liquid of high viscosity by means of a sphere falling freely through the sample. The description applies only to liquids exhibiting Newtonian flow under the conditions of measurement.

NOTE Departure from Newtonian flow is indicated by different viscosity values when spheres of different diameters are used and by variation in the rate of fall of the sphere during its transit down the tube. The differences may be accepted if repeatability and reproducibility in accordance with clause **15** can be obtained; the liquid is then deemed to exhibit Newtonian flow under the conditions of measurement.

12 Apparatus

The principal items of apparatus are as follows.

12.1 *Fall tube and thermostatic bath*. The fall tube shall be as specified in Appendix D and shown in Figure 6. It shall be supported vertically in a bath that shall be constructed of clear glass or shall have clear glass windows of such length as to allow observation of all graduations on the fall tube. The bath shall be filled to at least 30 mm above the topmost graduation of the fall tube. The bath shall be provided with a cover bored to carry a tube to hold the spheres to be used for the test and for location of the fall tube s) in a vertical position to within 1°. The temperature in the bath shall not vary by more than ± 0.01 °C from the desired temperature in the range 15 °C to 100 °C.

12.2 *Spheres*. Hardened tool steel ball bearings are suitable, being usually available with uniformity within a batch guaranteed to within ± 0.0025 mm of nominal size and to within 0.0025 mm for sphericity. Selected ball bearings of finer precision of size and sphericity can also be obtained.

Spheres in small batches are available in corrosion-resistant steel, in tungsten carbide and in synthetic sapphire.

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[3] See Appendix B.

NOTE Upon request in the order, manufacturers will usually guarantee specific limits for closeness to size and sphericity in a minimum batch package.

12.3 *Temperature-measuring device*. The requirement as stated in **7.3** applies, subject to **13.2.1**.

12.4 *Timing device*. The requirements in **7.5** apply. The type of stopwatch known as a “split second timer” facilitates the timing options given by the various intervals on the fall tube in Figure 6.

13 Procedure

13.1 Preliminary estimation. Make an estimation of the density of the sample and the approximate order of its viscosity.

13.2 Selection of equipment

13.2.1 Check that there are current calibration reports for the thermometer and time-measuring device (see Appendix E and Appendix F). While an accuracy of 0.01 °C on temperature measurement is specified for referee purposes, an accuracy of 0.02 °C may suffice for many routine tests.

13.2.2 Select spheres of suitable diameter and material. The relationship of the diameter of the sphere, its density, and the density and viscosity of the sample is stated in equations (1) and (2) in clause **14**. Typical information for tool steel balls is given in Table 1 as a guide to selection of diameter.

Table 1 — Rates of fall for steel balls of different diameters in liquids of density 0.8 g/cm^3 and various viscosities[a]

Diameter of steel ball	Rates of fall of steel ball			
	10 mm/s	3 mm/s	1 mm/s	0.3 mm/s
	Corresponding kinematic viscosities			
mm	mm^2/s	mm^2/s	mm^2/s	mm^2/s
1	460	1 500	4 600	15 000
2	1 800	6 100	18 000	61 000
3	4 100	13 700	41 000	137 000
4	7 300	24 300	73 000	243 000

[a] The tabulated viscosities are rounded.

A choice of material is available between synthetic sapphire (density about 4 g/cm^3), tool steel (density about 7.5 g/cm^3), noncorroding steel (density about 8 g/cm^3) and tungsten carbide (density about 15 g/cm^3). Spheres having diameters in 0.5 mm steps may be obtained.

Spheres should be chosen so that the rate of fall does not exceed 10 mm/s and that the sphere diameter does not exceed one-tenth of the tube diameter.

13.3 Sphere diameter. The diameters of the spheres chosen for use shall be measured. Distinction between nominal sizes can be made with a hand micrometer, but precise measurements of diameter require a bench micrometer. Ball bearing manufacturers are equipped for making measurements of diameter and sphericity, and their guarantees may be used.

13.4 Sphere mass and sphere density. For each nominal size, determine the mean mass of the spheres to be used by weighing a known number of spheres after cleaning and drying. Calculate the mean density from the mean mass and the diameter. For this purpose the nominal size of the sphere is sufficiently accurate.

13.5 Preparation of sample. If specified, condition the sample in the manner required. If practicable, filter the sample through a 75 µm aperture sieve.

At all stages protect the sample from contamination.

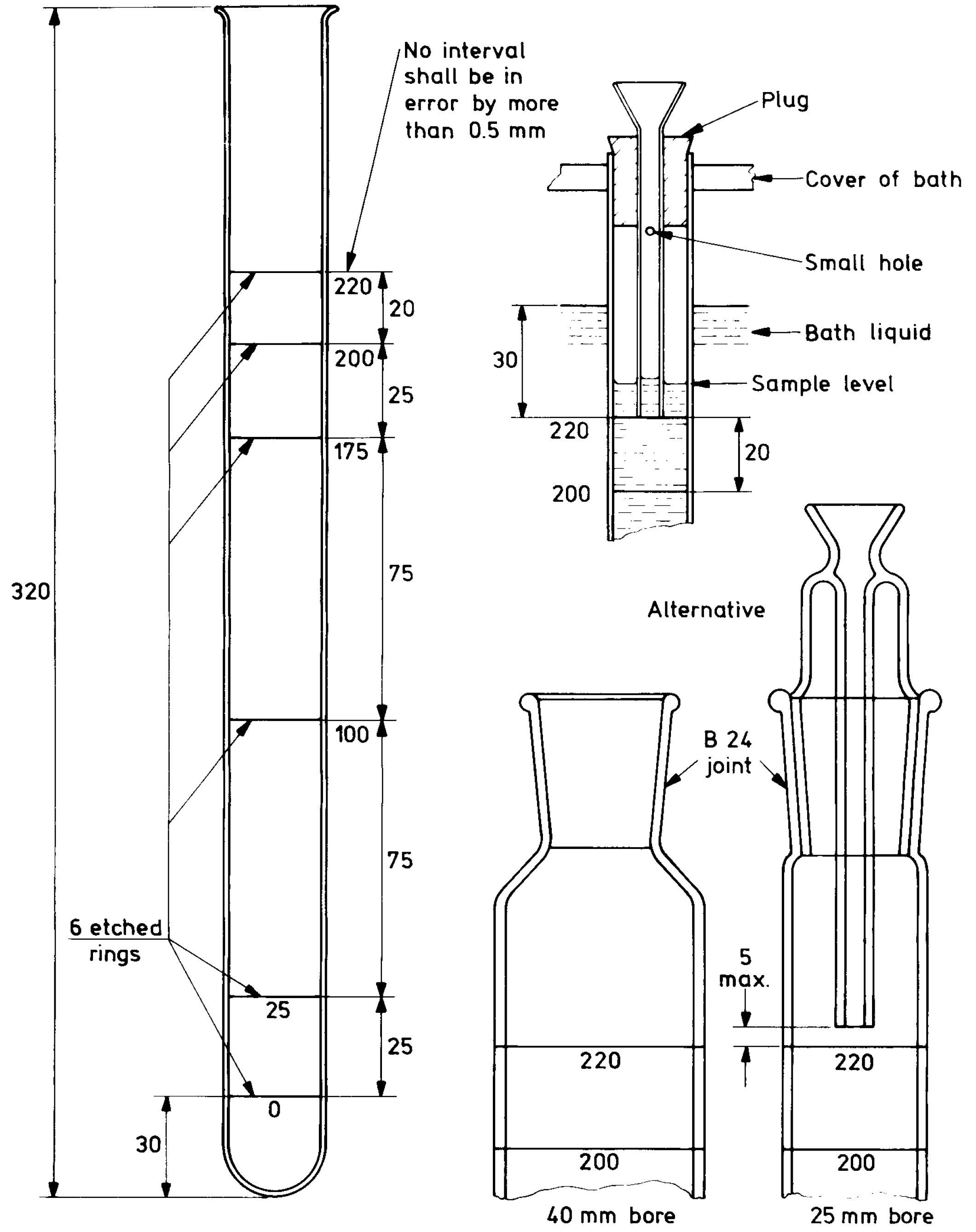
13.6 Setting up the apparatus

13.6.1 Fill the tube to at least 3 mm above the topmost mark with the filtered sample, which has been brought approximately to the temperature of observation. It is essential that the sample used be free of air bubbles, and care should be taken to avoid their formation during filling. Check that the tube is vertical.

NOTE If the sample is very viscous, filling at ambient temperature is slow. Provided that the nature of the sample is not adversely affected, charging may be facilitated by warming it gently and evenly to reduce its viscosity.

13.6.2 Leave the tube in the stirred bath for a sufficient time for any air bubbles present to disperse and for temperature equilibrium to be attained. Usually ½ h to 1 h is required when the filling temperature is near the test temperature. Longer times are necessary when the test and filling temperatures are markedly different, and for viscous liquids.

13.6.3 Clean the spheres, moisten the surface with a little sample and, with tweezers, introduce them individually into the delivery tube.



All dimensions are in millimetres.

Figure 6 — Falling sphere viscometer. Diagram of fall tube and ball-releasing device, with alternative designs (see also Appendix D)

13.7 Determination of the time of fall. By means of the timing device, determine the time required for the sphere to fall through a suitable distance. The passage of the sphere may be observed by means of a telescope or other device for avoiding parallax error. The operation of the timing device shall coincide with the moments at which the lowest part of the sphere passes through the planes of the tops of the timing marks. Normally the sphere is timed from the 175 mm mark to the 25 mm mark, but the time from the 200 mm mark to the 0 mark may also be measured; if the fall is very slow, the definitive timing may be from the 175 mm mark to the 100 mm mark, using the time from the 200 mm mark to the 175 mm mark to provide an estimate of the rate. Using spheres of the same material and diameter, obtain two successive times agreeing within 0.5 %. Poor repeatability may be attributed to a contaminated sample, unstable temperature conditions or heterogeneity of sample.

Record the corrected thermometer readings at the beginning of, during and at the end of the timed falls.

13.8 Determination of density. Proceed as described in **8.5**.

14 Calculation and expression of results

14.1 Kinematic viscosity, ν. Calculate the kinematic viscosity in mm^2/s by using either equation (1) or (2) below, as convenient, (See **14.2** to obtain the Faxén̄ factor, F, required in these equations, and note that reduced forms of the equations applicable to specific conditions are given in **14.3**.)

$$\nu = \frac{mg(\delta - \rho)}{0.003\pi v d \rho \delta} \times F \qquad \text{...(1)}$$

$$\nu = \frac{d^2 g(\delta - \rho)}{18 v \rho} \times F \qquad \text{...(2)}$$

where

m is the mass of the sphere (in g)

d is the diameter of the sphere (in mm)

δ is the density of the sphere (in g/cm^3)

ρ is the density of the liquid (in g/cm^3)

v is the velocity of fall (in mm/s)

g is the local acceleration due to gravity (in mm/s^2)

F is known as the Faxén factor and is a correction for the effect of the wall of the fall tube on the motion of the sphere

14.2 Faxén factor, F. Calculate the Faxén factor from the diameter d of the sphere and the diameter D of the fall tube as follows:

$$F = 1 - 2.104d/D + 2.09d^3/D^3 - 0.9d^5/D^5$$

For practical purposes F is required only to the third place of decimals and the term $0.9d^5/D^5$ may then be ignored.

Typical values of F are given in Table 2.

Table 2 — Typical Faxén correction factors

Diameter d of sphere	Faxén correction factor F for fall tube internal diameter of	
	D = 25 mm	D = 40 mm
mm		
1	0.916	0.947
2	0.833	0.895
3	0.751	0.843
4	0.672	0.792

14.3 Reductions of equations. Under specific conditions equations (1) and (2) can be reduced, as indicated in the following example.

If a sphere takes t seconds to fall 150 mm, i.e. $v = 150/t$, in London where g = 9812 mm/s^2, then equations (1) and (2) become

$$\nu = 6941\,\frac{mt}{d}\left(\frac{1}{\rho} - \frac{1}{\delta}\right) \times F \qquad \text{...(3)}$$

$$\nu = 3.634\,d^2 t\left(\frac{\delta}{\rho} - 1\right) \times F \qquad \text{...(4)}$$

If nominal diameters are assumed for the spheres, these equations become

$$\nu = K_m\, mt\left(\frac{1}{\rho} - \frac{1}{\delta}\right) \qquad \text{...(5)}$$

$$\nu = K_d t\left(\frac{\delta}{\rho} - 1\right) \qquad \text{...(6)}$$

Values for K_m and K_d for a 150 mm fall and for various sphere diameters are given in Table 3.

Table 3 — Values for K_m and K_d

Diameter d of sphere	For 150 mm fall in t seconds			
	D = 25 mm		D = 40 mm	
	K_m	K_d	K_m	K_d
mm				
1	6 358	3.329	6 573	3.441
2	2 891	12.11	3 106	13.01
3	1 737	24.56	1 950	27.57
4	1 166	39.07	1 374	46.05

NOTE If the above values are used in equations (5) and (6), and if m is expressed in grams, ρ and δ in g/cm^3 and t in seconds, the units of ν will be mm^2/s, i.e. cSt.

14.4 Dynamic viscosity, η. Calculate the dynamic viscosity of the sample as described in **9.2**.

15 Repeatability and reproducibility

The method is suited to measurement of high viscosity liquids, and equations (1) and (2) in **14.1** show the various terms that contribute to the final result.

Under optimum conditions, repeatability of 0.5 % and reproducibility of 1.0 % can be obtained. However, the properties of the sample, the effect of small temperature variations and restricted choice in the sphere diameters or fall tube available may justify an agreed relaxation of these tolerances.

Appendix A Glass capillary viscometers

A.1 Accepted designs. Glass capillary viscometers that have been found by experience to achieve the repeatability and reproducibility specified in clause **10** are listed below by name and/or code.

Direct flow viscometers

U-type in which the charge is adjusted in the temperature bath:

- BS/U tube
- BS/U/M miniature
- Zeitfuchs
- SIL

U-type in which an initial precise charge is not adjusted in the temperature bath:

- Cannon-Fenske
- Pinkevitch
- Cannon-Manning semi-micro

Suspended level type:

- BS/IP/SL
- BS/IP/SL (S)
- BS/IP/MSL
- Ubbelohde
- Cannon-Ubbelohde semi-micro
- Fitz Simons

Reverse flow viscometers

U-tube type in which the charge is adjusted in the temperature bath:

- BS/IP/RF
- Lanz-Zeitfuchs

U-tube type in which an initial precise charge is not adjusted in the temperature bath:

- Cannon-Fenske ISO/CF/RF
- Zeitfuchs cross-arm

NOTE 1 The above viscometers are listed in ISO 3105.

NOTE 2 "Miniature" and "semi-micro" indicate suitability for use with a relatively small volume of sample.

NOTE 3 Other designs of viscometer may be added to the lists when the desired quality of performance is confirmed.

A.2 Designation, range and overall length of glass capillary viscometers. The viscometers listed in **A.1** are specified in detail in ISO 3105. Five typical viscometers, the use of which is described in **8.4**, are tabulated as follows for designation, nominal factor *C* and approximate viscosity range. The nominal overall length is stated since it relates to accommodation in the thermostatic bath (**7.4**).

U-tube viscometer BS/U (nominal overall length 300 mm)

Destination	Nominal factor C	Viscosity range[b]		
	mm^2/s^2	mm^2/s		
0[a]	0.001	0.3[c]	to	1
A	0.003	0.9[c]	to	3
B	0.01	2	to	10
C	0.03	6	to	30
D	0.1	20	to	100
E	0.3	60	to	300
F	1	200	to	1 000
G	3	600	to	3 000
H	10	2 000	to	10 000

[a] Additional to ISO 3105.

[b] The upper value corresponds with a flow time of 1 000 s, which is convenient but not mandatory. The lower value corresponds with a minimum flow time of 200 s or with a figure subject to footnote (c).

[c] These values are approximate; precise information should be found on the calibration document for the particular viscometer.

Suspended-level BS/IP/SL (nominal overall length 330 mm)

Designation	Nominal factor *C*	Viscosity range[a]
	mm²/s²	mm²/s
1	0.01	3.5[b] to 10
1A	0.03	6 to 30
2	0.1	20 to 100
2A	0.3	60 to 300
3	1	200 to 1 000
3A	3	600 to 3 000
4	10	2 000 to 10 000
4A	30	6 000 to 30 000
5	100	20 000 to 100 000

[a] The upper value corresponds with a flow time of 1 000 s, which is convenient but not mandatory. The lower value corresponds with a minimum flow time of 200 s or with a figure subject to footnote ([b]).

[b] These values are approximate; precise information should be found on the calibration document for the particular viscometer.

Cannon-Fenske BS/IP/CF (nominal overall length 250 mm)

Designation	Nominal factor *C*	Viscosity range[a]
	mm²/s²	mm²/s
25	0.002	0.5[b] to 2
50	0.004	0.8 to 4
75	0.008	1.6 to 8
100	0.015	3 to 15
150	0.035	7 to 35
200	0.1	20 to 100
300	0.25	50 to 250
350	0.5	100 to 500
400	1.2	240 to 1 200
450	2.5	500 to 2 500
500	8	1 600 to 8 000
600	20	4 000 to 20 000

[a] The upper value corresponds with a flow time of 1 000 s, which is convenient but not mandatory. The lower value corresponds with a minimum flow time of 200 s or with a figure subject to footnote ([b]).

[b] These values are approximate; precise information should be found on the calibration document for the particular viscometer.

U-tube reverse flow BS/IP/RF(nominal overall length 275 mm)

Designation	Nominal factor C	Viscosity range[a]
	mm^2/s^2	mm^2/s
1	0.003	0.6 to 3
2	0.01	2 to 10
3	0.03	6 to 30
4	0.1	20 to 100
5	0.3	60 to 300
6	1	200 to 1 000
7	3	600 to 3 000
8	10	2 000 to 10 000
9	30	6 000 to 30 000
10	100	20 000 to 100 000
11	300	60 000 to 300 000

[a] The upper value corresponds with a flow time of 1 000 s, which is convenient but not mandatory. The lower value corresponds with a minimum flow time of 200 s or with a figure subject to footnote ([b]).

[b] These values are approximate; precise information should be found on the calibration document for the particular viscometer.

Cannon-Fenske ISO/CF/RF (nominal overall length 295 mm)

Designation	Nominal factor C	Viscosity range[a]
	mm^2/s^2	mm^2/s
25	0.002	0.4 to 2
50	0.004	0.8 to 4
75	0.008	1.6 to 8
100	0.015	3 to 15
150	0.035	7 to 35
200	0.1	20 to 100
300	0.25	50 to 250
350	0.5	100 to 500
400	1.2	240 to 1 200
450	2.5	500 to 2 500
500	8	1 600 to 8 000
600	20	4 000 to 20 000

[a] The upper value corresponds with a flow time of 1 000 s, which is convenient but not mandatory. The lower value corresponds with a minimum flow time of 200 s or with a figure subject to footnote ([b]).

[b] These values are approximate; precise information should be found on the calibration document for the particular viscometer.

A.3 Calibration of viscometers

A.3.1 *Calibration*. The calibration of a viscometer should be undertaken by a laboratory suitably equipped for the purpose and with reference viscometers whose C factors are directly traceable to a national laboratory such as the National Physical Laboratory.

In outline, the kinematic viscosity of a liquid is measured in two or more reference viscometers. Simultaneously the flow time of a charge of the same liquid in the viscometer under calibration is observed; to this end the reference viscometers and the viscometer under calibration are mounted in the same thermostatic bath. Uniformity of temperature in the bath is essential, but an exact absolute temperature determination is not of major importance.

Successive determinations are carried out on at least three liquids of viscosities υ_L, υ_S, υ_M selected to give corresponding flow times in the viscometer under calibration of t_L of 1 200 s to 1 500 s, t_S of 200 s to 300 s, and t_M of 600 s to 800 s.

Referring to equation (2) in Appendix B,

$$\upsilon = Ct - B/t$$

the long flow time t_L diminishes the B/t_L term to insignificance relative to Ct_L, so that C may be calculated from υ_L/t_L.

B can be calculated by substituting υ_S, t_S and C in equation (2). B is not expressed in the calibration document, but a minimum flow time t_{min} is established so that when the viscometer under calibration is used the expression $\upsilon = Ct$ may be applied without increasing the uncertainty by more than 0.1 %. Since, then,

$$\frac{B/t}{Ct} \times 100 < 0.1$$

t_{min} has to be not less than $10\sqrt{(10B/C)}$.

The intermediate flow time t_M and viscosity υ_M are used to confirm the value of the C factor.

The calibration document should be supplied either with an adequate description of the method of charging the viscometer, setting it up and using it, or with references to sources for this information.

A.3.2 *Reference viscometers*. Most countries have agreed to adopt the value of 1.002 mPa s for the dynamic viscosity, and 1.0038 mm^2/s for the kinematic viscosity, of freshly distilled water at 20.00 °C. This basis is used for determining the *C* factor of a primary master viscometer of fine bore. This instrument is then used to measure the viscosity of a liquid sample having a viscosity greater than that of distilled water. This sample is used to calibrate a reference viscometer having a slightly larger diameter capillary than the initial primary master. The process of "stepping up" is continued throughout the range of viscometers.

A.3.3 *Reference materials*. Reference materials for viscosity are used in many countries. These are usually oils and are highly refined, stable liquids of accurately measured viscosity at a precise temperature. Such samples may be used to calibrate a viscometer provided that suitable recently calibrated thermometers are used at the same time.

Appendix B Poiseuille's law and correction for kinetic energy

Poiseuille's law applied to gravity flow in a capillary tube viscometer, including a correction for kinetic energy of efflux, gives the following equation:

$$\nu = \frac{\pi d^4 hgt}{128LV} - \frac{aV}{8\pi Lt} \qquad \text{...(1)}$$

where

υ is the (coefficient of) kinematic viscosity

d is the diameter of capillary tube

h is the mean head of liquid

g is the acceleration due to gravity

L is the corrected length of capillary tube, i.e. the actual length plus the Couette correction which may be taken as three times the diameter of the capillary tube

V is the volume of liquid that flows in the time t

a is a constant to which various workers have attributed small positive values up to 1.5

When the linear unit used for d, L, h, V and g is millimetres, and t is in seconds, υ is obtained in terms of the sub-multiple SI unit mm^2/s, as is required in **9.1**.

For a particular instrument, equation (1) may be reduced to the form

$$v = Ct - B/t \qquad \text{...(2)}$$

where

$$C = \frac{\pi d^4 hg}{128LV} \text{ and } B = \frac{aV}{8\pi L}$$

and the appropriate units for C and B are mm^2/s^2 and mm^2 respectively.

If the flow rates are sufficiently slow, i.e. if t is sufficiently large, the effect of the correcting term B/t can be made negligible in comparison with Ct, and the simplified equation

$$v = Ct \qquad \text{...(3)}$$

is applicable.

In the method of section 2 of this standard, the simplified equation, (3), is used throughout. However, the factor C for each viscometer to be used is established by the procedure given in **A.3.1**, not by calculation from the theoretical formula under equation (2). While establishing the value of factor C, the calibrating laboratory is responsible for stating the minimum flow time for which the equation $v = Ct$ may be used without increasing the uncertainty by more than 0.1 %.

Appendix C Corrections to the viscometer factor *C*

C.1 Gravity correction. The rate of flow of a liquid through a glass capillary viscometer is dependent on the value of gravity at the place of use. If a viscometer is used where the gravity differs in value from where the viscometer was calibrated, a correction should be made as follows:

$$C_2 = \frac{g_2}{g_2} \times C_1$$

where

C_1 is the factor reported under gravity g_1

C_2 is the factor applicable under gravity g_2

For viscometers calibrated in the United Kingdom ($g_1 = 9.812\ \text{m/s}^2$), the following values of the factor g_2/g_1 generally apply.

Latitude of use	g_2/g_1
90° to 68°	1.002
68° to 56°	1.001
56° to 46°	1.000
46° to 35°	0.999
35° to 22°	0.998
22° to 0°	0.997

These values do not take local gravitational anomalies into account and also assume that tests are made at or near mean sea level.

C.2 Temperature correction. Changes in factor C with temperature for U-tube and suspended-level viscometers are considered to be negligible.

For Cannon-Fenske direct flow and Pinkevitch viscometers, the following equation can be used for calculation of C at test temperatures other than the calibration temperature.

$$C_2 = C_1 \left[1 + \frac{4V(\rho_2 - \rho_1)}{\pi D^2 h \rho_2}\right]$$ [4]

---

[4] These formulae apply provided that the viscometer is charged for calibration and subsequently for determination of viscosity with liquid at the same temperature within, say, 10 °C. It is recommended practice to charge the viscometer at 27 ± 5 °C and to calibrate it at 40 °C.

For Cannon-Fenske reverse flow viscometers,

$$C_2 = C_1 \left[1 - \frac{4V(\rho_2 - \rho_1)}{\pi D^2 h \rho_2}\right]$$ [5]

In the two preceding equations,

V	is the volume of charge
D	is the average diameter of the meniscus in the lower reservoir for the Cannon-Fenske direct flow and Pinkevitch viscometers, or the average diameter of the meniscus in the upper reservoir of a Cannon-Fenske reverse flow viscometer
h	is the average driving head
C_1	is the factor determined at a temperature where the density of the liquid used is ρ_1
C_2	is the factor to be used for the sample at a temperature where the density of the sample is ρ_2

The order of correction to C if the viscometer is calibrated with an oil at 40 °C, and used with an oil at 100 °C, is about 0.7 %.

Appendix D Fall tubes

Fall tubes shall be constructed of clear glass as free as possible from visible defects, to the design and dimensions shown in Figure 6.

The tubes shall be 320 ± 3 mm in overall length. The lower end shall be rounded and the open end finished square to the axis.

The tubes shall be etched with fine marks at the distances shown in Figure 6 measured from a line 30 mm distant from the closed end. These marks shall be carried right round the tube at right angles to the axis, and no interval shall be in error by more than 0.5 mm. The numbers shall be etched below the line in each case.

To ensure axial delivery of the sphere, the fall tube shall be fitted either with a bored plug of inert, nonabsorbent material carrying a glass delivery tube or with a glass insert of the form shown in Figure 6, adjusted so that the exit end of the tube is within 5 mm of the 220 mark on the fall tube. A diametral clearance of 1 mm between the internal diameter of the delivery tube and the largest sphere is suitable.

Appendix E Mercury-in-glass thermometers

To achieve the accuracies of temperature measurement necessary in accurate viscosity determinations, it is essential to use the thermometers to maximum advantage. The following notes are a brief guide; fuller information may be obtained from reference books on thermometry.

Only calibrated thermometers may be used; calibration and recalibration from time to time should be undertaken by an authorized laboratory suitably equipped for the purpose and with standards traceable to the National Physical Laboratory.

The user should use the thermometer in the manner described in the calibration report and apply the various corrections supplied. The user should bear in mind that a sensitive thermometer is a finely made instrument and should safeguard it against thermal or mechanical shock and against vibration.

The dimensions of the bulb and capillary bore may change slightly, particularly in the months immediately following manufacture, and thus lead to alterations to the corrections to the readings. Control may be kept in the following ways.

a) It is advantageous to use two thermometers simultaneously in a determination of viscosity. A difference between the corrected readings of the two instruments indicates a need for recalibration.

b) It should be a standing practice to recalibrate a thermometer at intervals.

c) When circumstances prevent a ready redetermination of the corrections to readings on the main scale, a check may be made at the ice point using ice made from distilled or deionized water. If the correction is found to differ from the previous determination, the main scale needs rechecking.

---

[5] These formulae apply provided that the viscometer is charged for calibration and subsequently for determination of viscosity with liquid at the same temperature within, say, 10 °C. It is recommended practice to charge the viscometer at 27 ± 5 °C and to calibrate it at 40 °C.

d) If formal recalibration is not readily possible, the user may make temporary checks as in a) by using the viscosity bath to compare a thermometer in question with a reference thermometer.

A record should be maintained of the history of the corrections to the readings of a thermometer. In its early life a thermometer should preferably be calibrated at three-monthly intervals. When the record shows that the corrections have stabilized, the intervals between recalibration may be increased.

If resources permit, it is advantageous to purchase a precision thermometer a year or two in advance of its being needed for full service, and to carry out calibrations from time to time to ascertain the stability of its corrections to readings.

Appendix F Timer calibration

The National Physical Laboratory is prepared to test stop-watches and electronic timing devices. Timing devices may also be checked by comparison with time signals based on standard frequencies.

Appendix G Cleaning of apparatus

It is essential for the full success of the method that all apparatus coming into contact with the liquid under test be scrupulously clean. Any impurities such as dust, traces of solvent or filaments in the viscometer will cause false results to be obtained.

Before test, clean the viscometer and all the apparatus used (glass vessels, pipettes, sintered glass filters, rubber tubing, etc.). Aqua regia[6]. may be needed to remove inorganic residues from the glassware and a suitable solvent may be required to remove oil and grease. Following this, dry the glass apparatus and then clean it with freshly prepared chromic acid solution[6], keeping it in contact with the solution overnight at a minimum temperature of 20 °C. For more active cleaning, warm the chromic acid gently on a water bath if this is possible. Exercise great care in the handling of aqua regia and chromic acid, and wash off any splashes on the skin immediately with plenty of cold water.

Remove the chromic acid, and rinse at least five times with distilled or deionized water. Dry in an electric oven, or rinse at least five times with filtered dry acetone[7] and dry the apparatus with a slow stream of filtered dry air or, preferably, with a vacuum line.

Between successive determinations of the viscosity of samples of a similar nature, the viscometer may be cleaned as follows. Drain, thoroughly rinse with a suitable volatile filtered solvent and dry with a slow stream of filtered dry air, with a vacuum line, or in an electric oven.

It is recommended that viscometers used for silicone fluids and fluorocarbons should be reserved for the exclusive use of these fluids and these viscometers should be subjected to calibration checks at frequent intervals. Take great care that silicone fluids and fluorocarbons do not contaminate other apparatus either directly or indirectly (e.g. through the use of contaminated solvent).

Appendix H Note on derivation of units

The SI unit for shear stress is the pascal (Pa), which can be otherwise stated as the newton per square metre (N/m^2).

The SI unit for rate of shear is the inverse second (s^{-1}).

The SI unit for dynamic viscosity is

$$\left(\frac{\text{the unit for shear stress}}{\text{the unit for rate of shear}}\right) \text{ i.e. } \frac{\mathrm{Pa}}{\mathrm{s}^{-1}}$$

and is the pascal second (Pa s).

The SI unit for density is the kilogram per cubic metre (kg/m^3).

The SI unit for kinematic viscosity is

$$\left(\frac{\text{the unit for dynamic viscosity}}{\text{the unit for density}}\right) \text{ i.e. } \frac{\mathrm{Pa\ s}}{(\mathrm{kg/m^3})}$$

---

[6] Precautions should be taken to avoid contact with the skin and inhalation of the vapour.

[7] Complying with the requirements of BS 509.

which can be resolved into the simpler expression metre squared per second ($\mathrm{m^2/s}$), because

$$1\ \mathrm{Pa} = 1\ \mathrm{N/m^2} \text{ and } 1\ \mathrm{N} = 1\ \mathrm{kg\ m/s^2}$$

Similarly, the CGS unit for dynamic viscosity is the ($\mathrm{dyn/cm^2}$) s, and this has the special name poise (P).

$$1\ \mathrm{P} = 1\ (\mathrm{dyn/cm^2})\ \mathrm{s} = \frac{10^{-5}\ \mathrm{N\ s}}{(\mathrm{m}/100)^2}$$

$$= 10^{-1}\ (\mathrm{N/m^2})\ \mathrm{s} = 10^{-1}\ \mathrm{Pa\ s}$$

The commonly used CGS unit is the centipoise (cP).

$$1\ \mathrm{cP} = 10^{-2}\ \mathrm{P} = 10^{-3}\ \mathrm{Pa\ s} = 1\ \mathrm{mPa\ s}$$

Thus in SI terms the centipoise is the millipascal second.

Again, the CGS unit for kinematic viscosity is the $\mathrm{cm^2/s}$, and this has the special name stokes (St).

$$1\ \mathrm{St} = 1\ \mathrm{cm^2/s} = 10^{-4}\ \mathrm{m^2/s}$$

The commonly used CGS unit is the centistokes (cSt).

$$1\ \mathrm{cSt} = 10^{-2}\ \mathrm{St} = 10^{-6}\ \mathrm{m^2/s} = 1\ \mathrm{mm^2/s}$$

Thus in SI terms the centistokes is the millimetre squared per second.

Publications referred to

BS 509, *Acetone.*

BS 4522, *Method for the determination of density of liquids at 20 °C.*

BS 5168, *Glossary of rheological terms.*

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity.*

ISO 3105, *Glass capillary kinematic viscometers — Specification and operating instructions.*

ISO 3205, *Preferred test temperatures.*

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