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**Petroleum products — Transparent  
and opaque liquids — Determination  
of kinematic viscosity and calculation  
of dynamic viscosity**

*Produits pétroliers — Liquides opaques et transparents —  
Détermination de la viscosité cinématique et calcul de la viscosité  
dynamique*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*. [ISO 3104:2020](https://standards.iteh.ai/catalog/standards/sist/765bac05-3691-4151-bd0e-631842811010/iso-3104-2020)

This third edition cancels and replaces the second edition (ISO 3104:1994), which has been technically revised.

The main changes compared to the previous edition are as follows:

- precision data have been updated to all actual fuels on the market;
- biodiesel (FAME) blends and paraffinic diesel have been included in the scope;
- the procedure description and allowance of automated techniques have been included.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Many petroleum products, and some non-petroleum materials, are used as lubricants, and the correct operation of equipment depends upon the appropriate viscosity of the liquid being used. In addition, the viscosity of many petroleum fuels is important for the estimation of optimum storage, handling and operational conditions. Thus, the accurate measurement of viscosity is essential to many product specifications.

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# Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity

**WARNING** — This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of users of this document to take appropriate measures to ensure the safety and health of personnel prior to the application of this document, and to determine the applicability of any other restrictions.

## 1 Scope

This document specifies Procedure A, using manual glass viscometers, and Procedure B, using glass capillary viscometers in an automated assembly, for the determination of the kinematic viscosity,  $\nu$ , of liquid petroleum products, both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer. The dynamic viscosity,  $\eta$ , is obtained by multiplying the measured kinematic viscosity by the density,  $\rho$ , of the liquid. The range of kinematic viscosities covered in this test method is from 0,2 mm<sup>2</sup>/s to 300 000 mm<sup>2</sup>/s over the temperature range -20 °C to +150 °C.

**NOTE** The result obtained from this document is dependent upon the behaviour of the sample and is intended for application to liquids for which primarily the shear stress and shear rates are proportional (Newtonian flow behaviour). If, however, the viscosity varies significantly with the rate of shear, different results can be obtained from viscometers of different capillary diameters. The procedure and precision values for residual fuel oils, which under some conditions exhibit non-Newtonian behaviour, have been included.

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## 2 Normative references

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The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 3696:1987, *Water for analytical laboratory use — Specification and test methods*

ASTM E1137, *Standard Specification for Industrial Platinum Resistance Thermometers*

ASTM E2877, *Standard Guide for Digital Contact Thermometers*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org>

**3.1  
kinematic viscosity**

$\nu$

resistance to flow of a fluid under gravity

Note 1 to entry: For gravity flow under a given hydrostatic head, the pressure head of a liquid is proportional to its density,  $\rho$ . For any particular viscometer, the time of flow of a fixed volume of fluid is directly proportional to its kinematic viscosity,  $\nu$ :

$$\nu = \eta/\rho$$

Note 2 to entry: where  $\eta$  is the dynamic viscosity coefficient.

**3.2  
dynamic viscosity**

coefficient of dynamic viscosity  
viscosity

$\eta$

ratio between the applied shear stress and rate of shear of a liquid

Note 1 to entry: It is a measure of the resistance to flow or deformation of a liquid.

Note 2 to entry: The term dynamic viscosity is also used in a different context to denote a frequency-dependent quantity in which shear stress and shear rate have a sinusoidal time dependence.

**3.3  
density**

$\rho$

mass per unit volume of a substance at a given temperature

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**4 Principle**

The time is measured for a fixed volume of liquid to flow under gravity through the glass capillary of a calibrated viscometer under a reproducible driving head and at a known and closely controlled temperature. The kinematic viscosity is the product of the measured flow time and the calibration constant of the viscometer.

**5 Reagents and materials**

**5.1 Cleaning solution**, strongly-oxidizing cleaning solution or alkaline cleaning solutions can be used.

Alkaline cleaning solutions with a pH of greater than 10 are not recommended as they have been shown to change the viscometer calibration. If these are used, then the viscometer calibration should be verified to ensure there is no change.

**5.2 Sample solvent**, completely miscible a prewash with an aromatic solvent such as toluene or heptane might be necessary to remove asphaltenic material. When cleaning capillaries inside the bath, the boiling point of the cleaning solution shall be higher than the bath temperature.

**5.3 Drying solvent**, suitable and volatile at the used temperature. Filter before use. If moisture remains, use a drying solvent miscible with water (5.4).

NOTE When cleaning capillaries inside the bath and if the bath temperature is higher than 50 °C, acetone is not suitable.

**5.4 Water**, deionized or distilled, conforming to Grade 3 of ISO 3696:1987. Filter before use.



**5.5 Certified viscosity reference standards (CRM)**, with data provided by an accredited calibration laboratory — traceable to the international agreed value of distilled water (1,003 4 mm<sup>2</sup>/s at 20 °C as specified in ISO/TR 3666) and calibrated in accordance with a standard practice for the basic calibration of master viscometers and viscosity oils, such as in ASTM D2162<sup>[8]</sup>. ISO 17034 specifies the requirements for CRM producers.

## 6 Apparatus design and requirements

**6.1 Drying tubes**, consisting of a desiccant drying system, consisting of either externally mounted drying tubes or an integrated desiccant drying system designed to remove ambient moisture from the capillary tube. Ensure that they are packed loosely and that the desiccant is not saturated with water.

**6.2 Sample filter**, micron screen or fretted (sintered) glass filter, no more than 75 µm.

**6.3 Reagent filter**, micron screen or fretted (sintered) glass filter, no more than 11 µm.

**6.4 Ultrasonic bath**, unheated — with an operating frequency between 25 kHz to 60 kHz and a typical power output of ≤100 W, of suitable dimensions to hold container(s) placed inside of bath, for use in effectively dissipating and removing air or gas bubbles that can be entrained in viscous sample types prior to analysis. It is permissible to use ultra-sonic baths with operating frequencies and power outputs outside this range; however, it is the responsibility of the laboratory to conduct a data comparison study to confirm that results determined with and without the use of such ultrasonic baths does not materially impact results.

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**6.5 Manual apparatus**

**6.5.1 Glass capillary viscometer**, calibrated in accordance with ISO 3105.

The viscometer shall have a certificate of calibration provided by a laboratory that meets ISO/IEC 17025. The calibration constant should be checked before first use of the capillary and only changed if necessary.

The calibration constant,  $C$ , is dependent upon the gravitational acceleration at the place of calibration. The variation in the value of  $g$  across the earth's surface is about 0,5 % due to latitude plus approximately 0,003 % per 100 m altitude. Apply a gravity correction to the viscometer calibration constant as in [Formula \(1\)](#), if the acceleration of gravity of the testing laboratory differs by more than 0,1 % of the calibration laboratory.

$$C_2 = \left( \frac{g_2}{g_1} \right) C \quad (1)$$

where the subscripts 1 and 2 indicate, respectively, the calibration laboratory and the testing laboratory.

NOTE Calculation of acceleration of gravity values can be found at [www.NPL.co.uk](http://www.NPL.co.uk).

**IMPORTANT — Viscometers used for silicone fluids, fluorocarbons and other liquids, which are difficult to remove using a cleaning agent, shall be reserved for the exclusive use of those fluids, except during their calibration. Subject such viscometers to calibration checks at frequent intervals. The solvent washings from these viscometers shall not be used for the cleaning of other viscometers. If the viscometer is cleaned using the material in 5.1 then the user shall verify the calibration before further use.**

**6.5.2 Viscometer holder or mounting device within the temperature-controlled bath**, enabling the glass viscometer to be suspended so that the upper meniscus is directly above the lower meniscus vertically within  $1^\circ$  in all directions.

Those viscometers whose upper meniscus is offset from directly above the lower meniscus shall be suspended vertically within  $0,3^\circ$  in all directions (see ISO 3105).

The proper alignment of vertical parts may be confirmed by using a plumb line, but for rectangular baths with opaque ends, this might not be possible.

**6.5.3 Temperature-controlled bath**, containing a transparent liquid of sufficient depth such that at no time during the measurement is any portion of the sample in the viscometer less than 20 mm below the surface of the bath liquid or less than 20 mm above the bottom of the bath.

Temperature control of the bath liquid shall be such that, for each series of flow-time measurements, within the range of  $15\text{ }^\circ\text{C}$  to  $100\text{ }^\circ\text{C}$  the temperature of the bath medium does not vary by more than  $\pm 0,02\text{ }^\circ\text{C}$  from the selected temperature over the length of the viscometer, and/or between the position of each viscometer, and/or at the location of the thermometer i.e. the temperature needs to be constant at the capillary and at the position of the thermometer within a maximum difference of  $0,04\text{ }^\circ\text{C}$ . For temperatures outside this range, the deviation from the desired temperature shall not exceed  $\pm 0,05\text{ }^\circ\text{C}$ .

Adjust and maintain the viscometer bath at the required test temperature within the limits given in [6.5.3](#), taking account of the conditions given in [Annex B](#) and of the corrections supplied on the certificates of calibration for the thermometers. Maintain the bath temperature at the test temperature using the readings of the temperature measuring device with the corrections supplied by the certificate of calibration.

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Thermometers shall be held in an upright position under the same conditions of immersion as when calibrated. In order to obtain the most reliable temperature measurement, it is recommended that two thermometers with valid calibration certificates be used. They should be viewed with a lens assembly giving approximately  $5\times$  magnification and be arranged to eliminate parallax errors.

**6.5.4 Temperature-measuring device**, for the range  $0\text{ }^\circ\text{C}$  to  $100\text{ }^\circ\text{C}$ , being either:

- a) a calibrated liquid-in-glass thermometer, (see [Annex B](#)) with a calibration and measurement capability (CMC) of  $\pm 0,02\text{ }^\circ\text{C}$  after correction or better, or
- b) a digital contact thermometer (DTC) as described in [6.5.4.2](#) with equal or better CMC.

**6.5.4.1** The calibration data should be traceable to a calibration or metrology standards body and meet the uncertainty of measurement required. The calibration certificate shall include data covering the series of temperature test points which are appropriate for its intended use. When two thermometers are used in the same bath in this range, they shall agree within  $0,04\text{ }^\circ\text{C}$ . See [Annex B](#) for the list of complying thermometers.

If calibrated liquid-in-glass thermometers are used, the use of two thermometers is recommended.

Outside the range  $0\text{ }^\circ\text{C}$  to  $100\text{ }^\circ\text{C}$ , a calibrated liquid in-glass thermometer (see [Annex B](#)) or a DTC as described in [6.5.4.2](#) with a CMC of  $\pm 0,05\text{ }^\circ\text{C}$  or better shall be used, and when two thermometers are used in the same bath they shall agree within  $\pm 0,1\text{ }^\circ\text{C}$ .

When using liquid-in-glass thermometers, use a magnifying device to read the thermometer to the nearest  $1/5$  division (e.g.  $0,01\text{ }^\circ\text{C}$  or  $0,02\text{ }^\circ\text{C}$ ) to ensure that the required test temperature and temperature control capabilities are met. It is recommended that thermometer readings (and any corrections supplied on the certificates of calibrations for the thermometers) be recorded on a periodic basis to demonstrate compliance with the test method requirements.

**6.5.4.2** A DCT meeting the requirements in [Table 1](#).

NOTE The resulting uncertainty of calibration can be dependent upon the immersion depth.

**6.5.4.3** The DCT probe is to be immersed no less than the immersion depth stated on the calibration certificate.

NOTE With respect to DCT probe immersion depth, a procedure is available in ASTM E644-11:2011, Section 7<sup>[10]</sup>, for determining the minimum depth. With respect to an ice bath, ASTM E563<sup>[9]</sup> 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.

**Table 1 — DCT requirements**

Criteria	Minimum requirements
DCT	ASTM E2877 Class A
Display resolution	0,01 °C, recommended 0,001 °C
Display accuracy	±20 mK (±0,02 °C) for combined probe and sensor
Sensor type	RTD, such as a PRT or thermistor
Drift	less than 10 mK (0,01 °C) per year
Response time	less than or equal to 6 s, as defined in specification ASTM E1137/E1137M
Linearity	10 mK over range of intended use
Calibration report	The DCT shall have a report of temperature calibration which should be traceable to a national calibration or metrology standards body issued by a calibration laboratory with demonstrated competency in temperature calibration <sup>a</sup> .
Calibration data	The calibration report shall include at least 3 calibration temperatures including 0 °C and 2 other points including the test temperature of use and state the immersion depth under which this was calibrated and the resulting uncertainty.
<sup>a</sup> An ISO/IEC 17025 accredited laboratory with temperature calibration in its accreditation scope and which meets the stated measurement uncertainty would meet this requirement.	

## 6.6 Automated apparatus

### 6.6.1 General

Automated viscometers, which use the technical principles of this document, are acceptable provided they meet the accuracy and precision of all the equipment listed in 6.5. In addition, if they are used to measure kinematic viscosity in samples subject to conditioning using the steps in Annex C, a heated sample tray shall be used if the sample is not analysed immediately after conditioning. This sample tray (6.6.2) shall be heated to a temperature which will not allow the sample to fall below the testing temperature.

Flow times of less than 200 s are acceptable; however, the kinetic energy correction shall be calculated and should not exceed 3 % of the measured viscosity. Where a value of greater than 3 % is achieved the analysis should be repeated using a smaller diameter viscometer tube.

### 6.6.2 Sample trays

Some automated equipment contain sample loading trays for analysis of multiple samples. When a sample has been subjected to conditioning using the steps in Annex C, the sample shall not be allowed to cool below the testing temperature on the loading tray as this will result in an increase in measured viscosity as compared to the manual procedure. As the temperature of the conditioned sample can drop very quickly, for analysis of these samples, the sample loading trays shall be heated above the test temperature to ensure the temperature of the sample does not fall below the test temperature at the time of analysis, and the nature of the sample is not changed. For analysis of these samples at 50 °C a sample tray heated at 54 °C has been shown to be sufficient to maintain the sample temperature above 50 °C for at least 40 min. For analysis of these samples at other temperatures the lab should establish the correct sample tray temperature and time before analysis.

### 6.6.3 Temperature measuring device

If embedded, a temperature measuring device shall fully meet the requirements of 6.5.4 and be removable for an external calibration. The embedded device will provide an independent reference temperature read-out, allowing the temperature control of the automated apparatus to be adjusted at the required set-point of test.

**6.7 Timing device**, capable of taking readings with a discrimination of 0,1 s or better, and having an uncertainty within  $\pm 0,07$  % of the reading when tested over intervals of 200 s and 1 000 s.

Regularly check timers for accuracy and maintain records of such checks.

Time signals as broadcast by the National Institute of Standards and Technology (NIST) are a convenient and primary standard reference for calibrating timing devices.

NOTE Many broadcast networks put out a standard frequency signal, as do many telephone networks. Such signals are suitable for checking the timing devices used to an accuracy of 0,1 s.

Timing devices employed in automated viscometers may be an integral part of the apparatus and typically are digital (using a precision crystal oscillator) with precision discriminations of 0,01 s or better. As such, the timing devices may not be able to be individually verified once installed. Documentation of the accuracy of the timing device over the intended measuring range of the viscometer tube should therefore be provided by the manufacturer. Independent verification of timing devices should be provided in cases where the above-mentioned limits are not satisfied.

Electrical timing devices may be used if the current frequency is controlled to an uncertainty of 0,05 % or better. Alternating currents, as provided by some public power systems, are controlled intermittently rather than continuously. When used to actuate electrical timing devices, such control can cause large errors in viscosity flow measurements.

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## 7 Verification

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### 7.1 Viscometer

Verify the calibration of the viscometer using a certified viscosity reference standard (5.5) following Procedure A (manual, Clause 11) or Procedure B (automated, Clause 12). Acceptable tolerance bands for this verification check shall be as detailed in Annex D. If the measured kinematic viscosity does not fall within this acceptable range, recheck each step in the procedure, including thermometer and viscometer calibrations and cleaning to locate the source of error. Table 1 in ISO 3105:1994 gives details of standards available.

Alternatively verify working viscometers against a reference viscometer having a certificate of calibration provided by an accredited calibration laboratory accredited to ISO 3105.

Verification is required at least prior to first use of the viscometer and whenever a physical change is made to the apparatus e.g. re-calibrating the temperature set-point, after cleaning or investigating the failure of QA/QC protocol in place.

### 7.2 Liquid-in-glass thermometer

Verify the calibration of the liquid in a glass thermometer on a periodic basis in line with B.2 at least at the frequencies described and maintain records of such checks. A complete new recalibration of the thermometer, while permitted, is not necessary in order to meet the accuracy ascribed to the design of the thermometer until the ice point change from the last full calibration amounts to one scale division such as 0,05 °C. Some thermometers have an ice point scale for this activity.