
**Crude petroleum and liquid petroleum
products — Laboratory determination of
density — Hydrometer method**

*Pétrole brut et produits pétroliers liquides — Détermination en laboratoire
de la masse volumique — Méthode à l'aréomètre*



Foreword

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International Standard ISO 3675 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, subcommittee SC 3, *Static petroleum measurement*.

This third edition cancels and replaces the second edition (ISO 3675:1993), of which it constitutes a Technical revision.

Annex A forms an integral part of this International Standard. Annex B is for information only.

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Printed in Switzerland

Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method

WARNING — The use of this International Standard may involve hazardous materials, operations and equipment. This International Standard does not purport to address all of the safety problems 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.

1 Scope

This International Standard specifies a method for the laboratory determination, using a glass hydrometer, of the density at 15 °C of crude petroleum, liquid petroleum products, and mixtures of petroleum and non-petroleum products normally handled as liquids and having a Reid vapour pressure (RVP) of 100 kPa or less.

This International Standard is suitable for determining the density of mobile transparent liquids. It can also be used for viscous liquids by carrying out the determinations at temperatures above ambient using a suitable liquid bath for temperature control. It can also be used for opaque liquids by reading the hydrometer scale where the top of the meniscus meets the stem of the hydrometer and applying a correction from table 1 (see 11.2).

Since hydrometers are calibrated to read correctly at the specified temperature, scale readings made at other temperatures are only hydrometer readings and not values of density at these other temperatures.

NOTES

1 The accuracy of the density, determined by the procedures given in this International Standard, for volatile and/or waxy crude oils containing free and/or suspended water and sediments can be less than inferred from the precision data quoted in clause 13. This is due to the possible loss of light components during sample mixing. However, sample mixing is necessary to ensure that the test portion transferred to the hydrometer cylinder is as representative as possible of the bulk sample. Techniques are given in clause 7 which are designed to minimize such loss of light component.

2 Values of density at 15 °C can be converted using standard measurement tables to equivalent values of API gravity or relative density so that measurements may be made in the units of local convenience.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 91-1:1992, *Petroleum measurement tables — Part 1: Tables based on reference temperatures of 15 °C and 60 °F*.

ISO 649-1:1981, *Laboratory glassware — Density hydrometers for general purposes — Part 1: Specification*.

ISO 3170:1988, *Petroleum liquids — Manual sampling*.

ISO 3171:1988, *Petroleum liquids — Automatic pipeline sampling*.

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1

density

mass per unit volume expressed in either kilograms per cubic metre or grams per millilitre at 15 °C and 101,325 kPa

3.2

cloud point

temperature at which a cloud of wax crystals first appears in a liquid when it is cooled under specified conditions

3.3

wax appearance temperature

WAT

temperature at which waxy solids form when petroleum or petroleum products are cooled under specified conditions

3.4

pour point

lowest temperature at which a sample of petroleum or petroleum product will continue to flow when it is cooled under specified conditions

4 Principle

The sample is brought to a specified temperature and a test portion transferred to a hydrometer cylinder that has been brought to approximately the same temperature. The appropriate hydrometer, whose temperature has also been regulated, is lowered into the test portion and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale is read, the temperature of the test portion taken and the observed hydrometer reading reduced to 15 °C using standard measurement tables. If necessary, the hydrometer cylinder and its contents are placed in a constant temperature bath to avoid excessive temperature variation during the test.

5 Apparatus

5.1 Hydrometer cylinder, of clear glass, plastics material, or metal, with an inside diameter at least 25 mm greater than the outside diameter of the hydrometer (5.2) and a height such that the hydrometer floats in the test portion with at least 25 mm clearance between the bottom of the hydrometer and the bottom of the cylinder.

Plastics material used for the construction of hydrometer cylinders shall be resistant to discolouration or attack and shall not affect the properties of the material being tested. In addition, they shall not become opaque under prolonged exposure to light.

NOTE — For convenience in pouring, the hydrometer cylinder may have a lip on the rim.

5.2 Hydrometers, of glass, graduated in units of density, conforming to ISO 649-1 and the requirements given in table 1. (See also annex A.)

Table 1 — Requirements for hydrometers

Unit	Density range	Each unit	Scale interval	Maximum scale error	Meniscus correction
kg/m ³ at 15 °C	600 to 1100	20	0,2	± 0,2	+ 0,3
	600 to 1100	50	0,5	± 0,3	+ 0,7
	600 to 1100	50	1,0	± 0,6	+ 1,4
g/ml at 15 °C	0,600 to 1,100	0,02	0,000 2	± 0,000 2	+ 0,000 3
	0,600 to 1,100	0,05	0,000 5	± 0,000 3	+ 0,000 7
	0,600 to 1,100	0,05	0,001 0	± 0,000 6	+ 0,001 4

5.3 Constant temperature bath, if required, of dimensions such that it can accommodate the hydrometer cylinder with the test portion fully immersed below the surface of the bath liquid and a temperature control system capable of maintaining the bath at the test temperature $\pm 0,25$ °C, throughout the duration of the test.

5.4 Thermometer, having a range, graduation intervals and maximum permitted scale error as shown in table 2.

Table 2 — Requirements for thermometers

Range °C	Graduation interval	Maximum scale error
– 1 to 38	0,1	± 0,1
– 20 to 102	0,2	± 0,15

NOTES

1 Thermometers IP 39C and IP 64C/ASTM 12C are suitable.

2 Resistance thermometers may be used, provided that the total uncertainty of the calibrated system is not greater than the uncertainty when using liquid-in-glass thermometers.

5.5 Glass or plastics stirring rod, optional, approximately 450 mm in length.

6 Sampling

Samples shall be taken in accordance with ISO 3170, ISO 3171, or an equivalent National Standard.

NOTE — When sampling volatile liquids using an automatic sampling technique, unless a sample receiver of variable volume is used to collect the sample and transport it to the laboratory, loss of light components may occur which will affect the accuracy of the density measurement.

7 Sample preparation

7.1 Sample mixing

The portion of the sample tested shall be as representative as possible of the bulk sample, and sample mixing may be necessary. However, precautions shall be taken to maintain the integrity of the sample during this operation.

The mixing of volatile crude oils and petroleum products containing sediments and/or water, or the heating of waxy volatile crude oils or petroleum products may result in the loss of light components. Guidance as to how to treat the different materials and to minimize such light component loss is given in 7.1.1 to 7.1.4.

7.1.1 Volatile crude oils and petroleum products having a RVP greater than 50 kPa

Mix the sample wherever possible in the original container, and in a closed system in order to minimize the loss of light components.

NOTE — Mixing volatile samples in open containers will lead to loss of light components and will affect the value of the density obtained.

7.1.2 Waxy crude oils

If the crude oil has a pour point above 10 °C, or a cloud point or WAT (3.3) above 15 °C, warm the sample to 9 °C above its pour point, or 3 °C above its cloud point or WAT, prior to mixing. Mix the sample wherever possible in the original container, and in a closed system in order to minimize the loss of light components.

7.1.3 Waxy distillates

Warm the sample to 3 °C above its cloud point or WAT prior to mixing.

7.1.4 Residual fuel oils

Heat the sample to the test temperature prior to mixing (see 7.2.1 and note 2 in 7.2.1).

7.2 Test temperature

7.2.1 Bring the sample to the test temperature which shall be such that the sample is sufficiently fluid, but not so high as to cause loss of light components, nor so low as to result in the presence of wax in the test sample.

NOTES

1 The density determined by the hydrometer method is most accurate at or near the reference temperature of 15 °C.

2 The hydrometer reading is obtained at a temperature appropriate to the physio-chemical characteristics of the material being tested. This temperature is preferably close to the reference temperature of 15 °C or, when the density is used in conjunction with bulk oil measurements, close to ± 3 °C, or at the bulk oil temperature, to minimize errors due to volume correction.

7.2.2 For crude oil, bring the sample to 15 °C, or 9 °C above its pour point, or 3 °C above its cloud point or wax appearance temperature, whichever is the higher.

NOTE — For crude oil, an indication of the wax appearance temperature can be found using IP 389 (see [4] in annex B) with the modification of using 50 μl $\pm$ 0,5 μl of sample. The precision for determining WAT of crude oils using IP 389 has not been determined.

8 Verification of apparatus

8.1 Hydrometers shall be regularly verified by comparison with a reference hydrometer traceable to a National Standard or a traceable density certified reference material (CRM), and where necessary recalibrated at least every five years.

8.2 Thermometers shall be regularly verified by comparison with a reference thermometer traceable to a National Standard.

9 Preparation of apparatus

9.1 Check that the hydrometer scale is correctly located within the hydrometer stem by reference to the datum mark. If the scale has moved, reject the hydrometer.

9.2 Bring the hydrometer cylinder and hydrometer to approximately the sample temperature (see 7.2.1 and note 2 in 7.2.1).

10 Procedure

10.1 Transfer a portion of the sample at test temperature (see 7.2.1 and note 2 in 7.2.1) to the clean hydrometer cylinder (5.1) at a stabilized temperature, without splashing, avoiding the entrainment of air bubbles, and reducing to a minimum the evaporation of the lower boiling constituents of volatile materials.

10.2 Remove any bubbles that have collected on the surface of the sample, by touching them with a piece of clean filter paper.

10.3 Place the cylinder containing the sample in a vertical position in a location free from air currents and where the temperature of the surrounding medium will not change by more than 2 °C during the time taken to carry out the test. When testing at temperatures differing by more than ± 2 °C from ambient, a constant-temperature bath (5.3) shall be used to avoid excessive temperature changes (see 10.13).

10.4 Stir the test portion with the appropriate thermometer (see table 2), or, if using a resistance thermometer, with a stirring rod (5.5), using a combination of vertical and rotational motions, to ensure uniform temperature and density throughout the cylinder. Record the temperature to the nearest 0,1°C. Remove the thermometer, and if appropriate the stirring rod, from the hydrometer cylinder.

10.5 Lower the appropriate hydrometer (5.2) into the liquid and release it when in a position of equilibrium, taking care to avoid wetting the stem above the level at which it floats freely. Observe the meniscus shape when the hydrometer is pressed below the point of equilibrium by 1 mm or 2 mm and allowed to return to equilibrium. If the meniscus shape changes, clean the hydrometer stem. Repeat this procedure until the meniscus shape remains constant.

10.6 For opaque viscous liquids, allow the hydrometer to settle slowly into the liquid.

10.7 For transparent low viscosity liquids, depress the hydrometer approximately two scale divisions into the liquid and release it. The remainder of the stem of the hydrometer, which is above the level of the liquid, shall be kept dry, since unnecessary liquid on the stem affects the reading obtained.

10.8 Impart a slight spin to the hydrometer on releasing it, to assist in bringing it to rest floating freely away from the walls of the cylinder. Allow sufficient time for the hydrometer to come to rest and for any bubbles that form to come to the surface (see 10.2). Remove any bubbles from the hydrometer before taking a reading.

10.9 When using a cylinder made from plastics, dissipate any static charge by wiping the outside of the cylinder with a damp cloth.

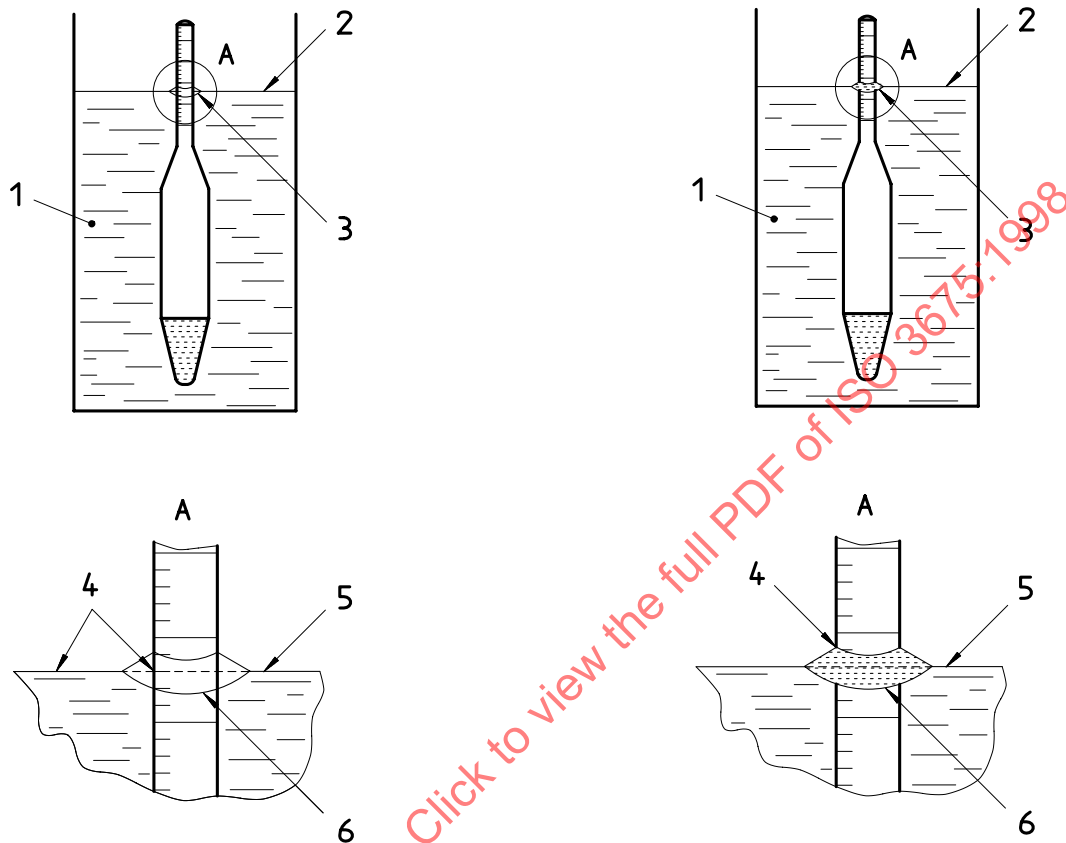
NOTE — Static charges often build up when using such cylinders and may prevent the hydrometer from floating freely.

10.10 When the hydrometer has come to rest, floating freely away from the walls of the cylinder, read the hydrometer scale to the nearest one fifth of a scale division, in accordance with 10.11 or 10.12.

10.11 For transparent liquids, record the hydrometer reading at the point on the hydrometer scale at which the principal surface of the liquid cuts the scale by placing the eye slightly below the level of the liquid and slowly raising it until the surface, first seen as a distorted ellipse, appears to become a straight line cutting the hydrometer scale, (see figure 1).

10.12 For opaque liquids, record the hydrometer reading at the point on the hydrometer scale to which the sample rises by observing with the eye slightly above the plane of the surface of the liquid, (see figure 2).

NOTE — When testing completely opaque samples using metal hydrometer cylinders, accurate reading of the hydrometer can only be assured if the level of the sample is within 5 mm of the top of the cylinder.



Key

- 1 Liquid
- 2 Horizontal plane surface of liquid
- 3 Bottom of meniscus
- 4 Read scale at this point
- 5 Horizontal plane surface of liquid
- 6 Meniscus

Figure 1 — Hydrometer scale reading for transparent liquids

Figure 2 — Hydrometer scale reading for opaque liquids

10.13 Immediately after recording the hydrometer scale reading, carefully lift the hydrometer out of the liquid and stir the sample vertically with the thermometer. Record the temperature of the test portion to the nearest 0,1 °C. If this temperature differs from the reading taken at the start of the test by more than 0,5 °C, repeat the hydrometer observations, and then the thermometer observations, until the temperature becomes stable within $\pm 0,5$ °C. If a stable temperature cannot be obtained, place the hydrometer cylinder and its contents in a constant temperature bath and repeat the procedure from 10.3.

10.14 If the test temperature is greater than 38 °C, allow all hydrometers, of the lead shot in wax type, to drain and cool in a vertical position.

11 Calculation

11.1 Apply any thermometer correction to the temperature reading observed in 10.13 and record the temperature to the nearest 0,1 °C.

11.2 For opaque liquids, apply the relevant meniscus correction, as given in table 1, to the observed hydrometer reading (see 10.12), since hydrometers are calibrated to be read at the principal surface of the liquid.

NOTE — The correction for the particular hydrometer in use is determined by observing the maximum height above the principal surface of the liquid to which oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test. For hydrometers specified in this method, see table 1.

11.3 Apply any hydrometer correction to the observed hydrometer reading and record to the nearest 0,1 kg/m³ (0,0001 g/ml).

11.4 Convert the corrected hydrometer reading to a density using Petroleum Measurement Tables 53A, 53B or 53D, described in ISO 91-1:1992, according to the nature of the material being tested:

- a) crude oils: 53A;
- b) petroleum products: 53B;
- c) lubricating oils: 53D.

The standard procedure for the conversion is to use the computer implementation procedures contained in Petroleum Measurement Tables, Volume X, described in ISO 91-1:1992. The correction for glass hydrometer readings shall be incorporated into the sub-routine. If the printed tables are used, the errors listed in errata sheets given in ISO 91-1:1992 shall be applied. The printed tables are entered directly with the observed hydrometer reading after applying, if necessary, corrections for meniscus effect and calibration temperature (see annex A).

NOTES

- 1 To convert densities in kilograms per cubic metre to densities in grams per millilitre, divide by 10³.
- 2 To convert a hydrometer reading from one unit to another, use either table 3 or table 51 of ISO 91-1:1992.

If the hydrometer has been calibrated at a temperature other than 15 °C, correct the reading in accordance with annex A.

12 Expression of results

Report the final result to the nearest 0,1 kg/m³ (0,000 1 g/ml) at 15 °C.

13 Precision

13.1 Repeatability

The difference between successive test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material, in the normal and correct operation of the test method, would exceed the values given in table 3 in only one case in 20.

Table 3 — Repeatability

Product	Temperature range °C	Units	Repeatability
Transparent low viscosity	– 2 to 24,5	kg/m ³ g/ml	0,5 0,000 5
Opaque	– 2 to 24,5	kg/m ³ g/ml	0,6 0,000 6

13.2 Reproducibility

The difference between two test results, independently obtained by different operators working in different laboratories on nominally identical test material, in the normal and correct operation of the test method, would exceed the values given in table 4 in only one case in 20.

Table 4 — Reproducibility

Product	Temperature range °C	Units	Reproducibility
Transparent low viscosity	– 2 to 24,5	kg/m ³ g/ml	1,2 0,001 2
Opaque	– 2 to 24,5	kg/m ³ g/ml	1,5 0,001 5

NOTES

1 For viscous crude oils and products, or when the temperature of the test lies outside the limits given in 13.1 and 13.2, no precision data are available.

2 The precision data given in 13.1 and 13.2 were obtained using specified hydrometers with a maximum permissible scale error of 0,6 kg/m³ (0,000 6 g/ml). No data are available for the use of specified hydrometers with a maximum permissible scale uncertainty of 0,2 kg/m³ (0,000 2 g/ml) and 0,3 kg/m³ (0,000 3 g/ml), but an equal or better precision would be expected.

14 Test report

The test report shall contain at least the following information:

- the type and identification of the material tested;
- a reference to this International Standard;
- the result of the test (see clause 12);
- any deviation, by agreement or otherwise, from the procedure specified;
- the date of the test.

Annex A

(normative)

Corrections to hydrometer readings for soda-lime glass hydrometers calibrated at temperatures other than 15 °C

If a hydrometer is used which has been calibrated at a temperature other than 15 °C, correct the reading to that of a hydrometer calibrated at 15 °C using the following equation:

$$\rho_{15} = \frac{\rho_t}{1 - 23 \times 10^{-6} (t - 15) - 2 \times 10^{-8} (t - 15)^2}$$

where

ρ_{15} is the density at 15 °C;

t is the reference temperature, in degrees Celsius, of the hydrometer used;

ρ_t is the reading of the hydrometer whose reference temperature is t in degrees Celsius (i.e. other than 15 °C).

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