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

Pétroles bruts et produits pétroliers liquides — Détermination en laboratoire de la masse volumique ou de la densité relative — Méthode à l'aréomètre

Reference number
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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

This second edition cancels and replaces the first edition (ISO 3675:1976), which has been technically revised.

Annex A of this International Standard is for information only.

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

1 Scope

1.1 This International Standard specifies a method for the laboratory determination, using a glass hydrometer, of the density or relative density of crude petroleum, petroleum products and homogeneous mixtures of petroleum and non-petroleum products normally handled as liquids, and having a Reid vapour pressure of 180 kPa (1,8 bar) or less, determined according to ISO 3007.

Hydrometer readings are obtained at convenient temperatures, readings of density being reduced to 15 °C or 20 °C, and readings of relative density to 60/60 °F, by means of international standard measurement tables. By means of these same tables, values determined in each of the three systems of measurement are convertible to equivalent values in the other, so that measurements may be made in the units of local convenience.

1.2 Accurate determination of the density or relative density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperatures of 15 °C/20 °C or 60 °F and also volume to mass and vice versa.

1.3 The hydrometer method is most suitable for determining the density or relative density of mobile transparent liquids. It can also be used for viscous oils by allowing sufficient time for the hydrometer to reach equilibrium, or for opaque oils by employing a suitable meniscus correction.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. 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 degrees F.*

ISO 91-2:1991, *Petroleum measurement tables — Part 2: Tables based on a reference temperature of 20 °C.*

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

ISO 650:1977, *Relative density 60/60 degrees F hydrometers for general purposes.*

ISO 3007:1986, *Petroleum products — Determination of vapour pressure — Reid method.*

3 Definitions

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

3.1 density: Mass of the liquid divided by its volume at 15 °C or 20 °C, reported in units of mass and volume, together with the standard reference temperature; for example, kilograms per cubic metre at 15 °C (see note 1).

For practical purposes, the apparent mass in air corrected for air buoyancy may be taken to represent the mass.

3.2 relative density: Ratio of the mass of a volume of a substance at a temperature t_1 to the mass of an equal volume of another substance at a temperature t_2.

The temperatures t_1 and t_2 may be equal. For the purposes of this International Standard, the other substance is water, i.e. the relative density is the ratio of the density of the substance at temperature t_1 to the density of water at temperature t_2.

When reporting the relative density, the temperatures t_1 and t_2 shall be explicitly stated. ISO 91 refers only to tables for the reduction of relative density to 60/60 °F. If results are required using another reference temperature, the determination should be carried out at that temperature.

NOTES

1 Since all hydrometers are calibrated to read correctly at a specified reference temperature, scale readings made at another temperature are only hydrometer readings and not values of density or relative density at that other temperature.

2 When used in connection with bulk oil measurements, errors due to volume correction are minimized by reading the hydrometer at a temperature close to that of bulk oil temperature.

4 Principle

The petroleum sample and a hydrometer cylinder are brought within a prescribed temperature range and a test portion is transferred to the cylinder at approximately the same temperature. The appropriate hydrometer is lowered into the test portion and allowed to settle. After thermal equilibrium has been reached, the hydrometer scale is read, and the temperature of the test portion is noted. If necessary, the cylinder and its contents are placed in a constant-temperature bath to avoid excessive temperature variation during the test.

5 Apparatus

5.1 Hydrometers, of glass and of the general form and dimensions specified in ISO 649-1 and ISO 649-2, indicating density or relative density at the appropriate reference temperature as required, conforming to the requirements listed in table 1.

NOTE 3 Smaller hydrometers are widely used for product quality control; their essential requirements are given in annex A (see also note 4).

5.2 Thermometers, having ranges, graduation intervals and maximum permitted scale error as shown in table 2.

Thermometers ASTM 12C, IP 64C and 64F are suitable, but any thermometer conforming to the requirements of table 2 may be used.

Table 1 — Essential requirements for hydrometers

Units	Range	Scale		Maximum scale error	Meniscus correction
		Each unit	Interval		
Density g/ml at 15 °C or 20 °C	0,600 - 1,100 0,600 - 1,100	0,05 0,05	0,000 5 0,001 0	± 0,000 3 ± 0,000 6	+ 0,000 7 + 0,001 4
Density kg/m^3 at 15 °C or 20 °C	600 - 1 100 600 - 1 100	50 50	0,5 1,0	± 0,3 ± 0,6	+ 0,7 + 1,4
Relative density 60/60 °F	0,600 - 1,100 0,600 - 1,100 0,650 - 1,100	0,05 0,05 0,05	0,000 5 0,001 0,000 5	± 0,000 3 ± 0,000 6 ± 0,000 5	+ 0,000 7 + 0,001 4 —

Table 2 — Requirements for thermometers

Range	Graduation interval	Maximum scale error
− 20 °C to + 102 °C − 5 °F to + 215 °F	0,2 0,5	± 0,1 ± 0,25

NOTE 4 A hydrometer or a thermometer that is provided with a calibration certificate issued by a recognized standardizing body is classed as "certified" and the appropriate corrections listed in the certificate shall be applied to the observed readings. Instruments that satisfy the requirements of this test method, but are not provided with a recognized calibration certificate, are classed as "uncertified".

5.3 Hydrometer cylinder, of clear glass or plastics material, or of metal for testing opaque samples (see note 6). Plastics materials used for the construction of hydrometer cylinders shall be resistant to discoloration or attack by oil samples, shall not become opaque under prolonged exposure to sunlight and oil samples, and shall not affect the properties of the sample. For convenience in pouring, the cylinder may have a lip on the rim. The inside diameter of the cylinder shall be at least 25 mm greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that the hydrometer floats in the sample with at least 25 mm clearance between the bottom of the hydrometer and the bottom of the cylinder.

5.4 Constant-temperature bath, for use when the nature of the sample requires a test temperature much above or below room temperature or when the requirements of 7.8 cannot otherwise be met.

6 Temperature of test

6.1 The determination of density or relative density by the hydrometer method is most accurate at or near the appropriate standard reference temperature. This or any other temperature between −18 °C and +90 °C shall be used, insofar as it is consistent with the type of sample and necessary limiting conditions shown in table 3.

6.2 When the hydrometer value is to be used to select multipliers for correcting volumes to standard reference temperatures, the hydrometer reading should be made preferably at a temperature within ± 3 °C (± 5 °F) of the temperature at which the bulk volume of the oil was measured (see note 5). However, in cases when appreciable amounts of light fractions may be lost during determination at the bulk oil temperature, the limits given in table 3 shall be applied.

NOTE 5 The tables for correcting volume, density or relative density to standard temperatures are based on an average expansion for a number of typical crude oils and products (see 8.2.1). The same coefficients are used in computing all the sets of tables referred to in ISO 91-1 and another set of coefficients for the tables in ISO 91-2. Therefore corrections made over the same temperature interval minimize errors arising from possible differences between the coefficients of the material under test and the standard coefficients. This effect becomes more important as temperatures diverge significantly from the selected reference temperature.

7 Procedure

7.1 Adjust the temperature of the sample according to the indications given in clause 6. Bring the hydrometer cylinder (5.3) and the appropriate thermometer (5.2) and hydrometer (5.1) (see note 11) to approximately the same temperature as the sample to be tested.

Table 3 — Limiting conditions and test temperatures

Sample type	Initial boiling point	Other limits	Test temperature
Highly volatile	—	Reid vapour pressure below 180 kPa (1,8 bar)	Cool in original closed container to 2 °C or lower.[1]
Moderately volatile	⩽ 120 °C	—	Cool in original closed container to 18 °C or lower.
Moderately volatile and viscous	⩽ 120 °C	Viscosity too high at 18 °C [2]	Heat to minimum temperature to obtain sufficient fluidity.
Non-volatile	> 120 °C	—	Use any convenient temperature between − 18 °C and 90 °C.
Mixtures with non-petroleum products	—	—	Test at 15 °C ± 0,2 °C, 20 °C ± 0,2 °C.

1) Cooling some crude oils to 2 °C or lower could cause wax precipitation, which will effect the measured density or relative density. In such cases the test temperature should be as low as possible to minimize light end loss, but not below the temperature of wax precipitation.

2) The maximum acceptable viscosity depends on the length of time allowed for the hydrometer to settle. The viscosity should not exceed 15 000 mm^2/s but at this level the hydrometer would take several minutes to settle.

7.2 Transfer the test portion (see note 6) to the clean temperature-stabilized hydrometer cylinder without splashing, to avoid the formation of air bubbles and to reduce to a minimum the evaporation of the lower boiling constituents of the more volatile samples. Transfer highly volatile samples to the cylinder by water displacement or by siphoning (see notes 7 and 8). Remove any air bubbles formed, after they have collected on the surface of the test portion, by touching them with a piece of clean filter paper before inserting the hydrometer.

NOTES

6 When testing completely opaque samples, metal hydrometer cylinders may be used. When metal cylinders are used, accurate reading of the hydrometer can only be ensured if the level of the sample is within 5 mm of the top of the cylinder.

7 Highly volatile samples containing alcohols or other water-soluble material should always be transferred by siphoning.

8 Crude oils should not be transferred by water displacement as this may alter the sample's water content.

7.3 Place the cylinder containing the test portion in a vertical position in a location free from air currents. Ensure that the temperature of the test portion does not change appreciably during the time necessary to complete the test; during this period, the temperature of the surrounding medium should not vary by more than 2 °C. When testing at temperatures much above or below room temperature, a constant-temperature bath (5.4) may be necessary to avoid excessive temperature changes.

7.4 Lower the hydrometer gently into the test portion. Take care to avoid wetting the stem above the level to which it will be immersed in the liquid. Continuously stir the test portion with the thermometer, taking care that the mercury thread is kept fully immersed and that the stem of the hydrometer is not wetted above the immersion level. As soon as a steady reading is obtained, record the temperature of the test portion to the nearest half division and then remove the thermometer.

7.5 Depress the hydrometer about two scale divisions into the liquid, and then 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. With samples of low viscosity, impart a slight spin to the hydrometer on releasing 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 all air bubbles to come to the surface. This waiting period is particularly necessary in the case of more viscous samples.

7.6 When the hydrometer has come to rest, floating freely away from the walls of the cylinder (see note 9), estimate the hydrometer scale reading to the nearest one-fifth or one-tenth (depending on the hydrometer type) interval of density or relative density. The correct hydrometer reading is that point on the hydrometer scale at which the principal surface of the liquid cuts the scale. Determine this point 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).

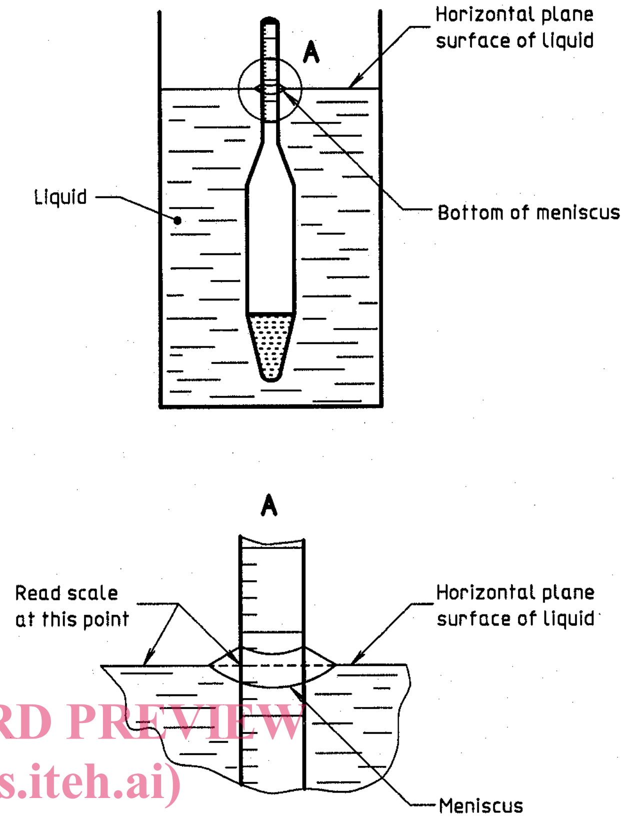

Figure 1 — Hydrometer scale reading for transparent liquids

NOTE 9 When using a cylinder of plastics material, dissipate any static charge by wiping the outside of the cylinder with a moist cloth before taking the reading. Static charges often build up when using such cylinders and may prevent the hydrometer from floating freely.

7.7 With an opaque liquid, take a reading by observing, with the eye slightly above the plane of the surface of the liquid, the point of the hydrometer scale to which the sample rises. This reading, at the top of the meniscus, requires correction since hydrometers, unless otherwise stated, are calibrated to be read at the principal surface of the liquid. The correction for the particular hydrometer in use may be 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 (see figure 2).

NOTE 10 Alternatively, corrections as given in table 1 may be applied.

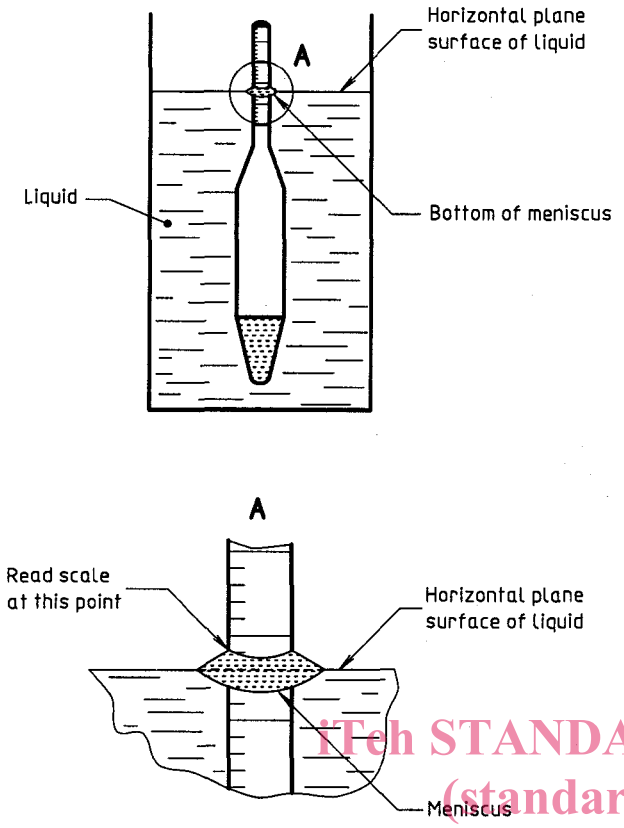

Figure 2 — Hydrometer scale reading for opaque fluids

7.8 Immediately after observing the hydrometer scale value, again cautiously stir the liquid with the thermometer, keeping the mercury thread fully immersed. Record the temperature of the liquid to the nearest half division. Should this temperature differ from the previous reading by more than 0,5 °C (1 °F), repeat the hydrometer and thermometer readings until the temperature becomes stable within 0,5 °C (1 °F).

NOTE 11 After use at temperatures higher than 38 °C, allow all hydrometers of the lead-shot-in-wax type to drain and cool in a vertical position.

8 Calculations

8.1 General procedure

Apply any relevant corrections to the thermometer reading and to the hydrometer reading. For opaque samples, make the appropriate correction to the observed hydrometer reading as specified in 7.7. Record to the nearest one-fifth or one-tenth interval (depending on the hydrometer type) the final corrected hydrometer scale reading (see note 12).

After application of any relevant corrections, record to the nearest 0,25 °C the mean of the temperature values observed immediately before and after the final hydrometer reading.

NOTE 12 Hydrometer scale readings at temperatures other than the calibration temperature should not be considered as more than scale readings since the hydrometer dimensions change with temperature (see 3.2 and 8.2).

8.2 Hydrometer reading corrections

8.2.1 For the correction of hydrometer readings, separate tables given in ISO 91-1:1992 are referred to for crude oils and products and are designated "A" and "B" respectively, e.g. tables 53A and 53B, and the correct table for the material being tested shall be used (see notes 13 and 14).

NOTES

13 The units used in ISO 91-1 and ISO 91-2 are kilograms per cubic metre, while the hydrometer readings obtained in 8.1 may be in grams per millilitre. To convert densities in grams per millilitre to densities in kilograms per cubic metre multiply by 10^3. To convert densities in kilograms per cubic metre back to densities in grams per millilitre divide by 10^3.

14 Densities in kilograms per litre are numerically equal to densities in grams per millilitre.

8.2.2 To convert the corrected hydrometer reading (see 8.1) to density or relative density at the temperature at which the hydrometer was calibrated, use the following petroleum measurement tables referred to in ISO 91-1:1992 or ISO 91-2:1991.

a) When a hydrometer calibrated in density at 15 °C has been employed, use table 53A or 53B to obtain density at 15 °C.

b) When a hydrometer calibrated in density at 20 °C has been employed, use table A referred to in ISO 91-2:1991 to obtain density at 20 °C.

c) When a hydrometer calibrated in relative density 60/60 °F has been employed, use table 23A or 23B to obtain relative density 60/60 °F.

NOTE 15 The tables in ISO 91-1 and ISO 91-2 apply only to hydrometers constructed of soda lime glass. In tables relating to the conversion of hydrometer readings, the coefficient of thermal cubic expansion for glass of 23×10^{-6} °C^{-1} has been used. This value is marginally below the conventional value quoted in ISO 1768:1975, *Glass hydrometers — Conventional value for the thermal cubic expansion coefficient (for use in the preparation of measurement tables for liquids)*, i.e. 25×10^{-6} °C^{-1}. This difference in coefficient is not significant for most temperature differences found in practice. It may be corrected for by subtracting 0,000 002 $R'(\theta - 15)$ from the hydrometer reading, before entering tables 53A and 53B with readings made using hydrometers complying with ISO 649, where