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Designation 559/12

Standard Test Method for Density, Relative Density, or API Gravity of Liquid Petroleum by Portable Digital Density Meter¹

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^{ε1} NOTE—The formatting of SI units was corrected editorially in November 2018.

1. Scope

1.1 This test method covers the determination of the density, relative density, or API gravity of liquid petroleum products using portable digital density meters at test temperatures between 0 °C and 40 °C (32 °F to 104 °F). Its application is restricted to samples with a dry vapor pressure equivalent up to 80 kPa (11.6 psi) and a viscosity below 100 mm²/s (cSt) at the test temperature.

1.2 This test method is suitable for determining the density to the nearest 1 kg/m³. To determine the density to the nearest 0.1 kg/m³, use Test Method [D4052](#).

1.3 This test method is easily calibrated and primarily suitable for field applications. It is important for the user to know and understand the electrical classification of the area in which the analyzer is to be used and to select an analyzer appropriate for that classification.

1.4 Test Methods [D287](#), [D1298](#), and [D6822](#) are used in field applications. This test method provides an alternative field method that is easily calibrated and does not pose the hazard of hydrometer glass breakage present in current field methods.

1.5 Portable digital density meters measure the density and temperature of the filled-in sample at the sample temperature. The measured density and temperature are automatically converted into:

Density at 15 °C / density at 60 °F

Relative density 15 °C/15 °C / relative density 60 °F/60 °F

API gravity 15 °C / API gravity 60 °F

¹ This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.04.0D on Physical and Chemical Methods.

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by the instrument using the calculation routines for Generalized Products as defined in Guide [D1250](#).

1.6 If the density meter does not have in-built software to calculate the density at the reference temperature, this is calculated from the observed density at test temperature using the Petroleum Measurement Tables.

1.7 The accepted units of measure for density are kilograms per cubic metre (SI unit) or grams per cubic centimetre. Values in SI units are to be regarded as the standard. Values in parentheses are for information only. Both SI and customary units have been rounded; they may not be exactly equivalent.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*²

[D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products \(Hydrometer Method\)](#)

[D1193 Specification for Reagent Water](#)

[D1250 Guide for Use of the Petroleum Measurement Tables](#)

[D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method](#)

[D4052 Test Method for Density, Relative Density, and API](#)

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Gravity of Liquids by Digital Density Meter

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D6822 Test Method for Density, Relative Density, and API Gravity of Crude Petroleum and Liquid Petroleum Products by Thermohydrometer Method

2.2 *Energy Institute Standards*:³

IP 475 Petroleum Liquids – Manual Sampling

2.3 *ASTM Adjuncts*:

Adjunct to D1250-04 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils⁴

3. Terminology

3.1 Definitions:

3.1.1 *adjustment, n*—operation of bringing the portable digital density meter to a state of performance suitable for its use, by setting or adjusting the instrument constants.

3.1.2 *API gravity, n*—special function of relative density (specific gravity) SG_{60° F/60 °F}, represented by:

$$^{\circ}\text{API} = 141.5 / (\text{SG}_{60^{\circ}\text{F}/60^{\circ}\text{F}}) - 131.5$$

3.1.2.1 *Discussion*—Relative density SG_{15 °C/15 °C} is also applied.

3.1.3 *calibration, n*—operation that establishes the relationship between the reference density of standards and the corresponding reading of the instrument.

3.1.3.1 *validation, n*—operation of checking the calibration of the portable digital density meter at a single point close to the required operating point.

3.1.4 *density, n*—mass per unit volume at a given temperature.

3.1.4.1 *Discussion*—Standard units of density are kg/m³ (SI unit) or mg/cm³. Less preferred units, for example, kg/L or g/mL, are still in use.

3.1.5 *relative density (specific gravity), n*—ratio of the mass of a given volume of a liquid at a temperature t_1 to the mass of an equal volume of pure water at a temperature t_2 . Both temperatures shall be explicitly stated.

3.1.5.1 *Discussion*—The unit SG has no dimension. Common reference temperatures include 15 °C/15 °C, 60 °F/60 °F, 20 °C/20 °C, and 20 °C/4 °C.

4. Summary of Test Method

4.1 The test sample is brought to a temperature close to that of the density meter. If present, the density meter's software program for calculating the density at the reference temperature is selected, and the oscillating U-tube of the density meter is filled with the test portion in accordance with the manufacturer's instructions. After stabilizing, the density meter's in-built software calculates the density at the reference temperature.

If the density meter does not have in-built software to calculate the density at the reference temperature, this is calculated from the observed density at test temperature using the Petroleum Measurement Tables.⁴ The apparatus' system is regularly checked using reagent grade water.

5. Significance and Use

5.1 The density, relative density, or API gravity of petroleum products are important quality indicators and are used in quantity calculations or to satisfy application, transportation, storage, and regulatory requirements.

5.2 This test method should not be used to determine density for custody transfer quantity calculations, particularly where mass or weight is the unit of quantity measurement. Test Method **D4052** is appropriate for these applications.

6. Apparatus

6.1 *Portable Digital Density Meter*—Capable, once calibrated, of determining density with an accuracy of $\pm 1 \text{ kg/m}^3$, fitted with a temperature sensing device capable of measuring temperatures to $\pm 0.5^{\circ}\text{C}$, a pump mechanism for filling and emptying the U-tube and a digital display of the results. Some density meters have in-built software for calculating the density at 15 °C from the observed density at test temperature. Some density meters have a mechanism for adjusting the meter during calibration; for others, this adjustment is carried out using the in-built software.

NOTE 1—The meter may also have a memory for storing results, or a facility for connecting the meter to either a printer or a computer, or both.

6.1.1 If the meter has in-built software it shall have been type tested to ensure that its firmware duplicates the Petroleum Measurement Tables over the working temperatures and density ranges of the test method.

6.1.2 If the meter is to be used in an environment where a risk assessment has identified that a flammable atmosphere is likely to be present, the use of a portable digital density meter with proper safety rating for the zone the instrument is being operated in and the gas group that is being handled is mandatory.

6.1.3 The instrument shall be capable of converting the measured density and temperature into:

Density at 15 °C / density at 60 °F

Relative density 15 °C/15 °C / relative density 60 °F/60 °F

API gravity 15 °C / API gravity 60 °F

according to Guide **D1298**. The instrument shall be capable of meeting the precision requirements described in this test method.

6.2 *Source of Low-Pressure Air*—For drying the U-tube.

NOTE 2—An aquarium air pump fitted with a tube filled with a desiccant has been found to be suitable.

6.3 *Density Meter Stand*—(Optional).

6.4 *Syringe*—Glass or plastic (see **Note 3**), approximately 10 mL capacity with a Luer fitting (optional).

NOTE 3—Many plastic syringes designed for medical use are supplied with a coating of lubricant in the barrel. Some of these coatings can dissolve in the test portion samples altering the sample density. It is

³ Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K., <http://www.energyinst.org>.

⁴ Available from ASTM International Headquarters. Order Adjunct No. ADJD1250CD or ADJD1250CS. Original adjunct produced in 2004.

therefore recommended that only syringes specified as non-lubricated should be used.

7. Reagents and Materials

7.1 *Water*—Conforming to Specification **D1193**, Type III.

7.2 *Cleaning Solvent*—General purpose reagent grade, for cleaning the U-tube.

NOTE 4—Heptane or 40-60 Petroleum Spirit have been found to be suitable.

7.3 *Propan-2-ol*—General purpose reagent for cleaning the U-tube.

7.4 *Certified Reference Material (CRM)*—With a density approximating to the material under test, whose expansivity is in accordance with the Petroleum Measurement Tables (see **Note 5**).

NOTE 5—While single compound hydrocarbons such as dodecane are suitable, it has been found that their expansivity is not described well by either the Petroleum Measurement Table 54 or ADJD1250CD⁴, and a correction has to be applied. See **Table A1.2** on predicted densities at various temperatures for dodecane.

8. Sampling

8.1 Use only representative samples obtained as described in the Practices **D4057**, **D4177**, or IP 475 unless otherwise specified for test specimens and test units. The sampling procedure for the calibration or adjustment of the apparatus, or both, and for testing is as follows:

8.1.1 Make sure that the portable digital density meter is in thermal equilibrium with the ambient temperature. If the instrument has been transferred from a much warmer or much colder place immediately before use, wait for several minutes before measuring. Do not transfer the instrument frequently between places with very different ambient temperatures, as humidity condensations may cause measuring errors.

8.1.2 Make sure to have the samples at or above ambient temperature. Do not fill samples which are much colder (5 °C/9 °F) than the ambient temperature. This may generate humidity condensation on the oscillating U-tube sensor, causing incorrect measurements and potentially harming the instrument.

8.1.3 Follow the manufacturer's instructions for filling samples into the instrument. If the sampling system of the portable density meter is not completely free of liquid, drain it first as much as possible. Then fill a first portion of the sample and drain it immediately. Then fill the sample portion to be measured.

8.1.4 Fill the samples gently. Ensure that gas bubbles are not present in the oscillating U-tube sensor once filling is completed. If gas bubbles are present in the oscillating U-tube sensor, drain this sample and gently refill with a new sample.

8.2 After the measurement is finished, drain the sample as much as possible. If samples of similar composition are to be measured immediately after, rinse the U-tube by filling and emptying U-tube with the sample at least three times, see **Note 7**. If the instrument is not being used for extended periods of time after a measurement or if strongly colored or viscous samples or samples which may cause deposits in the oscillating U-tube sensor have been measured, remove sample residues by

rinsing with proper solvent. The rinsing solvent has to be selected according to its ability to dissolve residues of the measured sample. If the solvent used to remove sample residues is not volatile by itself, the use of a volatile second solvent to remove residues of the first solvent is recommended. Follow the manufacturer's instructions for further cleaning requirements.

9. Calibration and Adjustment of the Instrument

9.1 At least once every 12 months, verify the correct functioning of the meter using a Certified Reference Material (CRM) (see **7.4** and **Note 5**).

NOTE 6—It is recommended that this apparatus verification is carried out either by the manufacturer or a qualified third party laboratory specializing in the measurement of density.

9.2 Check that the U-tube is clean and dry and if necessary clean and dry in accordance with the recommended cleaning procedure given in **Appendix X1**.

9.3 Clean the outside of the filling tube with cleaning solvent and wipe dry.

9.4 Bring the CRM and the density meter to thermal equilibrium.

9.5 Meters with In-Built Software:

9.5.1 Select the density at reference temperature program in accordance with the manufacturer's instructions.

9.5.2 Fill the U-tube with the CRM and check that there are no air bubbles present. If there are bubbles, empty and refill. Allow the meter to stabilize. Record the density of the CRM. If the CRM is a single compound hydrocarbon, apply a correction to the result, see **Note 5** and **Table A1.2**. The result obtained shall be equal to or less than R/1.414 from the certified value of the CRM, where R is the reproducibility of this test method.

9.5.3 If the value obtained does not meet these criteria, clean the U-tube and reverify using the CRM. If the value obtained still fails to meet this criteria, either carry out a recalibration following the manufacturer's instructions or return the meter to the manufacturer for servicing and adjustment.

9.6 Meters without In-Built Software:

9.6.1 Fill the U-tube with the CRM and check that there are no air bubbles present. If there are bubbles, empty and refill. Allow the meter to stabilize. Record the density of the CRM and the test temperature. Using either the Petroleum Measurement Table 54 or ADJD1250CD,⁴ calculate the density of the CRM at reference temperature. If the CRM is a single compound hydrocarbon apply corrections to the result. For dodecane, see **Table A1.2**. The result obtained shall be equal to or less than R/1.414 from the certified value of the CRM, where R is the reproducibility of this test method.

9.6.2 If the value obtained does not meet these criteria, clean the U-tube and reverify using the CRM. If the value obtained still fails to meet this criteria return the meter to the manufacturer for servicing and adjustment.

10. Procedure

10.1 Meters with In-Built Software: