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Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[1]

This standard is issued under the fixed designation D1298; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the laboratory determination using a glass hydrometer in conjunction with a series of calculations, of the density, relative density, or API gravity of crude petroleum, petroleum products, or mixtures of petroleum and nonpetroleum products normally handled as liquids, and having a Reid vapor pressure of 101.325 kPa (14.696 psi) or less. Values are determined at existing temperatures and corrected to 15°C or 60°F by means of a series of calculations and international standard tables.

1.2 The initial hydrometer readings obtained are uncorrected hydrometer readings and not density measurements. Readings are measured on a hydrometer at either the reference temperature or at another convenient temperature, and readings are corrected for the meniscus effect, the thermal glass expansion effect, alternate calibration temperature effects and to the reference temperature by means of the Petroleum Measurement Tables; values obtained at other than the reference temperature being hydrometer readings and not density measurements.

1.3 Readings determined as density, relative density, or API gravity can be converted to equivalent values in the other units or alternate reference temperatures by means of Interconversion Procedures, or Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1), or both, or tables, as applicable.

1.4 The initial hydrometer readings determined in the laboratory shall be recorded before performing any calculations. The calculations required in Section 10 shall be applied to the initial hydrometer reading with observations and results reported as required by Section 11 prior to use in a subsequent calculation procedure (ticket calculation, meter factor calculation, or base prover volume determination).

1.5 Annex A1 contains a procedure for verifying or certifying the equipment for this test method.

1.6 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only.

1.7 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1250 Guide for Use of the Petroleum Measurement Tables

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products (API *MPMS* Chapter 8.1)

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products (API *MPMS* Chapter 8.2)

D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products (API *MPMS* Chapter 8.3)

E1 Specification for ASTM Liquid-in-Glass Thermometers

E100 Specification for ASTM Hydrometers

2.2 *API Standards:*[3]

MPMS Chapter 8.1 Manual Sampling of Petroleum and Petroleum Products (ASTM Practice D4057)

MPMS Chapter 8.2 Automatic Sampling of Petroleum and Petroleum Products (ASTM Practice D4177)

MPMS Chapter 8.3 Mixing and Handling of Liquid Samples

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and the API Committee on Petroleum Measurement, and is the direct responsibility of D02.02 /COMQ on Hydrocarbon Measurement for Custody Transfer (Joint ASTM-API).

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[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.

[3] Published as Manual of Petroleum Measurement Standards. Available from the American Petroleum Institute (API), 1220 L St., NW, Washington, DC 20005.

***A Summary of Changes section appears at the end of this standard.**

of Petroleum and Petroleum Products (ASTM Practice D5854)

MPMS Chapter 11.1-2004 including Addendum 1-2007 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils‖

2.3 *Energy Institute Standards:*[4]

IP 389 Determination of wax appearance temperature (WAT) of middle distillate fuels by differential thermal analysis (DTA) or differential scanning calorimetry (DSC)

IP Standard Methods Book, Appendix A, Specifications – IP Standard Thermometers

2.4 *ISO Standards:*[5]

ISO 649-1 Laboratory glassware – Density hydrometers for general purpose – Part 1: Specification

2.5 *ASTM Adjuncts:*

Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1)[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *API gravity*, *n*—a special function of relative density (specific gravity) 60/60°F, represented by:

$$^{\circ}\text{API} = [141.5/(\text{relative density } 60/60^{\circ}\text{F}) - 131.5 \quad (1)$$

3.1.1.1 *Discussion*—No statement of reference temperature is required, as 60°F is included in the definition.

3.1.2 *cloud point*, *n*—temperature at which a cloud of wax crystals first appears in a liquid when it is cooled under specific conditions.

3.1.3 *density*, *n*—the mass of liquid per unit volume at 15°C and 101.325 kPa with the standard unit of measurement being kilograms per cubic metre.

3.1.3.1 *Discussion*—Other reference temperatures, such as 20°C, may be used for some products or in some locations. Less preferred units of measurement (for example, kg/L or g/mL) are still in use.

3.1.4 *observed values*, *n*—values observed at temperatures other than the specified reference temperature. These values are only hydrometer readings and not density, relative density (specific gravity), or API gravity at that other temperature.

3.1.5 *pour point*, *n*—lowest temperature at which a test portion of crude petroleum or petroleum product will continue to flow when it is cooled under specified conditions.

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

3.1.6.1 *Discussion*—Common reference temperatures include 60/60°F, 20/20°C, 20/4°C. The historic deprecated term *specific gravity* may still be found.

3.1.7 *wax appearance temperature (WAT)*, *n*—temperature at which waxy solids form when a crude petroleum or petroleum product is cooled under specified conditions.

4. Summary of Test Method

4.1 The sample is brought to a specified temperature and a test portion is transferred to a hydrometer cylinder that has been brought to approximately the same temperature. The appropriate hydrometer and thermometer, also at a similar temperature, are lowered into the test portion and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale is read, and the temperature of the test portion is taken. The observed hydrometer reading is corrected for the meniscus effect, the thermal glass expansion effect, alternate calibration temperature effects and then reduced to the reference temperature by means of the volume correction factors or tables as applicable by use of the appropriate Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) and observed temperature from the thermometer.

4.2 If necessary, the hydrometer cylinder and its contents are placed in a constant temperature bath to avoid excessive temperature variation during the test.

5. Significance and Use

5.1 Accurate determination of the density, relative density (specific gravity), or API gravity of petroleum and its products is necessary for the conversion of measured volumes to volumes or masses, or both, at the standard reference temperatures of 15°C or 60°F during custody transfer.

5.2 This procedure is most suitable for determining the density, relative density (specific gravity), or API gravity of low viscosity transparent liquids. This procedure can also be used for viscous liquids by allowing sufficient time for the hydrometer to reach temperature equilibrium, and for opaque liquids by employing a suitable meniscus correction. Additionally for both transparent and opaque fluids the readings shall be corrected for the thermal glass expansion effect and alternate calibration temperature effects before correcting to the reference temperature.

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

5.4 Density, relative density, or API gravity is a factor governing the quality and pricing of crude petroleum. However, this property of petroleum is an uncertain indication of its quality unless correlated with other properties.

5.5 Density is an important quality indicator for automotive, aviation and marine fuels, where it affects storage, handling and combustion.

6. Apparatus

6.1 *Hydrometers*, of glass, graduated in units of density, relative density, or API gravity as required, conforming to Specification E100 or ISO 649-1, and the requirements given in Table 1.

6.1.1 The user should ascertain that the instruments used for this procedure conform to the requirements set out above with

[4] Available from Energy Institute, 61 New Cavendish St., London, W1M 8AR, UK.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[6] Available from ASTM International Headquarters. Order Adjunct No. ADJD1250. Original adjunct produced in 1983.

TABLE 1 Recommended Hydrometers

Units	Range		Scale[A]		Meniscus
	Total	Each Unit	Interval[A]	Error[A]	Correction
Density, kg/m^3 at 15°C	600 - 1100	20	0.2	± 0.2	+0.3
	600 - 1100	50	0.5	± 0.3	+0.7
	600 - 1100	50	1.0	± 0.6	+1.4
Relative density (specific gravity) 60/60°F	0.600 - 1.100	0.020	0.0002	± 0.0002	+0.0003
	0.600 - 1.100	0.050	0.0005	± 0.0003	+0.0007
	0.600 - 1.100	0.050	0.001	± 0.0006	+0.0014
Relative density (specific gravity), 60/60°F	0.650 - 1.100	0.050	0.0005	±0.0005	
API	–1 - +101	12	0.1	± 0.1	

[A]Interval and Error relate to Scale.

respect to materials, dimensions, and scale errors. In cases where the instrument is provided with a calibration certificate issued by a recognized standardizing body, the instrument is classed as certified and the appropriate corrections for the meniscus effect, the thermal glass expansion effect, and alternative calibration temperature effects shall be applied to the observed readings prior to corrections. Instruments that satisfy the requirements of this test method, but are not provided with a recognized calibration certificate, are classed as uncertified.

6.2 *Thermometers*, having range, graduation intervals and maximum permitted scale error shown in Table 2 and conforming to Specification E1 or IP Appendix A.

6.2.1 Alternate measuring devices or systems may be used, provided that the total uncertainty of the calibrated system is no greater than that specified in 6.2. The stated repeatability and reproducibility values are not applicable if alternate fluids are used in the liquid-in-glass thermometers.

6.3 *Hydrometer Cylinder*, clear glass, or plastic (see 6.3.1). The inside diameter of the cylinder shall be at least 25 mm greater than the outside diameter of the hydrometer and the height shall be such that the appropriate hydrometer floats in the sample test portion with at least 25 mm clearance between the bottom of the hydrometer and the bottom of the cylinder.

6.3.1 Hydrometer cylinders constructed of plastic materials shall be resistant to discoloration or attack by oil samples and shall not affect the material being tested. They shall not become opaque under prolonged exposure to sunlight.

6.4 *Constant-Temperature Bath*, if required, of dimensions such that it can accommodate the hydrometer cylinder with the test portion fully immersed below the test portion liquid surface, and a temperature control system capable of maintaining the bath temperature within 0.25°C of the test temperature throughout the duration of the test.

6.5 *Stirring Rod*, optional, of glass or plastic, approximately 400 mm in length.

7. Sampling

7.1 Unless otherwise specified, samples of non-volatile petroleum and petroleum products shall be taken by the procedures described in Practice D4057 (API *MPMS* Chapter 8.1) and D4177 (API *MPMS* Chapter 8.2).

TABLE 2 Recommended Thermometers

Scale	Range	Graduation Interval	Scale Error
°C	–1 - +38	0.1	± 0.1
°C	–20 - +102	0.2	± 0.15
°F	–5 - +215	0.5	± 0.25

7.2 Samples of volatile crude petroleum or petroleum products are preferably taken by Practice D4177 (API *MPMS* Chapter 8.2), using a variable volume (floating piston) sample receiver to minimize any loss of light components which may affect the accuracy of the density measurement. In the absence of this facility, extreme care shall be taken to minimize these losses, including the transfer of the sample to a chilled container immediately after sampling.

7.3 *Sample Mixing*—May be necessary to obtain a test portion representative of the bulk sample to be tested, but precautions shall be taken to maintain the integrity of the sample during this operation. Mixing of volatile crude petroleum or petroleum products containing water or sediments, or both, or the heating of waxy volatile crude petroleum or petroleum products may result in the loss of light components. The following subsections (7.3.1 to 7.3.4) will give some guidance on sample integrity maintenance.

7.3.1 *Volatile Crude Petroleum and Petroleum Products Having an RVP Greater than 50 kPa*—Mix the sample in its original closed container in order to minimize the loss of light components.

NOTE 1—Mixing volatile samples in open containers will lead to loss of light components and consequently affect the value of the density obtained.

7.3.2 *Waxy Crude Petroleum*—If the petroleum has an expected pour point above 10°C, or a cloud point or WAT above 15°C, warm the sample to a temperature that is sufficient for ensuring the material is fluid enough to provide adequate mixing without excessively heating the material that would otherwise compromise the integrity of the sample. Samples heated to 9°C above its pour point, or 3°C above its cloud point or WAT have been found to be suitable temperatures to warm samples prior to mixing. Whenever possible, mix the sample in its original closed container in order to minimize the loss of light components.

7.3.3 *Waxy Distillate*—Warm the sample to a temperature that is sufficient for ensuring the material is fluid enough to provide adequate mixing without excessively heating the material that would otherwise compromise the integrity of the sample. Samples heated to 3°C above its cloud point or WAT have been found to be suitable temperatures to warm samples prior to mixing.

7.3.4 *Residual Fuel Oils*—Heat the sample to the test temperature prior to mixing (see 9.1.1 and Note 4).

7.4 Additional information on the mixing and handling of liquid samples will be found in Practice D5854 (API *MPMS* Chapter 8.3).

8. Apparatus Verification or Certification

8.1 Hydrometers and thermometers shall be verified in accordance with the procedures in Annex A1.

9. Procedure

9.1 *Temperature of Test*:

9.1.1 Bring the sample to the test temperature which shall be such that the sample is sufficiently fluid but not so high as to