Designation: D287 – 12b

Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[1]

This standard is issued under the fixed designation D287; 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 U.S. Department of Defense.

1. Scope*

1.1 This test method covers the determination by means of a glass hydrometer in conjunction with a series of calculations of the API gravity of crude petroleum and petroleum products normally handled as liquids and having a Reid vapor pressure (Test Method D323) of 101.325 kPa (14.696 psi) or less. Gravities are determined at 60°F (15.56°C), or converted to values at 60°F, by means of Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1). These tables are not applicable to nonhydrocarbons or essentially pure hydrocarbons such as the aromatics.

1.2 The initial values obtained are uncorrected hydrometer readings and not density measurements. Values are measured on a hydrometer at either the reference temperature or at another convenient temperature, and readings corrected for the meniscus effect, the thermal glass expansion effect, alternate calibration temperature effects and to the reference temperature by means of volume correction tables.

1.3 The hydrometer readings determined shall be recorded before performing any calculations. Then the calculations required in Section 9 shall be performed and documented before using the final result in a subsequent calculation procedure (measurement ticket calculation, meter factor calculation, or base prover volume determination).

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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.* For specific warning statement, see 8.3.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)

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

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

E1 Specification for ASTM Liquid-in-Glass Thermometers

E100 Specification for ASTM Hydrometers

2.2 *EI Standards:*[3]

Specifications for IP Standard Thermometers

IP Specifications for Petroleum Hydrometers

2.3 *API Standards:*[4]

MPMS Chapter 9.1 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method (ASTM Test Method D1298)

MPMS Chapter 9.3 Test Method for Density, Relative Density, and API Gravity of Crude Petroleum and Liquid Petroleum Products by Thermohydrometer Method (ASTM Test Method D6822)

MPMS Chapter 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils (Adjunct to ASTM D1250)

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and the API Committee on Petroleum Measurement, and is the direct responsibility of Subcommittee D02.02 /COMQ, the joint ASTM-API Committee 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] Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K., http://www.energyinst.org.

[4] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

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

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2.4 *ASTM Adjuncts:*

Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1)[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *API gravity, n*—a special function of relative density 60/60°F (15.56/15.56°C), represented by:

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

No statement of reference temperature is required, since 60°F is included in the definition.

3.1.2 *hydrometer reading, n*—the point on the hydrometer scale at which the surface of the liquid cuts the scale.

3.1.2.1 *Discussion*—In practice for transparent fluids this can be readily determined by aligning the surface of the liquid on both sides of the hydrometer and reading the Hydrometer scale where these surface readings cut the scale (Hydrometer Reading – Observed). For nontransparent fluids the point at which the liquid surface cuts the Hydrometer scale cannot be determined directly and requires a correction (Meniscus Correction). The value represented by the point (Meniscus Reading) at which the liquid sample rises above the main surface of the liquid subtracted from the value represented by where the main surface of the liquid cuts the Hydrometer scale is the amount of the correction or Meniscus correction. This meniscus correction is documented and then subtracted from the value represented by the Meniscus Reading to yield the Hydrometer Reading corrected for the Meniscus (Hydrometer Reading – Observed, Meniscus Corrected).

3.1.3 *specific gravity, n*—historical term, no longer used, which has been replaced by *relative density*.

4. Summary of Test Method

4.1 This test method is based on the principle that the gravity of a liquid varies directly with the depth of immersion of a body floating in it. The floating body, which is graduated by API gravity units in this test method, is called an API hydrometer.

4.2 The API gravity is read by observing the freely floating API hydrometer and noting the graduation nearest to the apparent intersection of the horizontal plane surface of the liquid with the vertical scale of the hydrometer, after temperature equilibrium has been reached. The temperature of the sample is read from a separate accurate ASTM thermometer in the sample.

4.3 The observed hydrometer reading is corrected for the meniscus effect, the thermal glass expansion effect, alternate calibration temperature effects and reduced to the reference temperature by means of the volume correction 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] Available from ASTM International Headquarters. Order Adjunct No. ADJD1250. Original adjunct produced in 1983.

5. Significance and Use

5.1 Accurate determination of the gravity of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperature of 60°F (15.56°C).

5.2 This procedure is most suitable for determining the API gravity of low viscosity transparent liquids. This test method 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 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 as close to reference temperature as feasible.

5.4 Gravity is a factor governing the quality of crude oils. However, the gravity of a petroleum product is an uncertain indication of its quality. Correlated with other properties, gravity can be used to give approximate hydrocarbon composition and heat of combustion.

5.5 Gravity 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 degrees API as listed in Table 1 and conforming to Specification E100.

6.1.1 The user should ascertain that the instruments used for this method conform to the requirements set out above with 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 a range from −5 to +215°F and conforming to the requirements for Thermometer 12F as prescribed in Specification E1 or Thermometer 64F of the Specification for IP Standard Thermometers.

6.2.1 Alternate measuring devices or systems may be used, provided that the total uncertainty of the calibrated system is no

TABLE 1 Available Hydrometers Scaled, Degrees API

Designation	Type	API Range, deg		Scale	
		Series Total	Each Unit	Division	Error
1H to 10H	long plain	−1 to 101	12	0.1	0.1
21H to 40H	short plain	0 to 101	6	0.1	0.2
51H to 60H	thermo	−1 to 101	12	0.1	0.1
71H to 74H	thermo	−1 to 41	12	0.1	0.1
[A]	thermo	15 to 51	8		

[A] Eight-degree range thermohydrometers are available.

greater than when using liquid-in-glass thermometers. The stated repeatability and reproducibility values are not applicable if alternate fluids are used in the liquid-in-glass thermometers.

NOTE 1—The ASTM Gravity Thermometer 12F has 0.5°F subdivisions and allowable ±0.25°F scale error.

6.3 *Hydrometer Cylinder,* clear glass, plastic, or metal (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 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.

7. Temperature of Test

7.1 The gravity determined by the hydrometer method is most accurate at or near the standard temperature of 60°F (15.56°C). Use this or any other temperature between 0 and 195°F (–18 and + 90°C) for the test, so far as it is consistent with the type of sample and necessary limiting conditions shown in Table 2.

8. Procedure

8.1 For referee testing, use the long plain form of hydrometer (1H to 10H). For field testing, use the thermohydrometer method in Test Method D6822 (API *MPMS* Chapter 9.3).

8.2 Adjust the temperature of the sample in accordance with Table 2. For field testing, test temperatures other than those listed in Table 2 may be used. The hydrometer cylinder shall be approximately the same temperature as the sample to be tested.

8.3 Transfer the sample into the clean hydrometer cylinder without splashing, so as 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. (**Warning—** Extremely flammable. Vapors may cause flash fire.) For the more volatile samples, transfer to the hydrometer cylinder by siphoning. (Do not start the siphon by mouth.) Use a rubber aspirator bulb. Remove any air bubbles formed, after they have collected on the surface of the sample, by touching them with a piece of clean filter paper or other suitable means before inserting the hydrometer. For field testing, make the gravity measurement directly in the sampling thief. Place the cylinder containing the sample in a vertical position in a location free from air currents. Take precautions to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. During this period, the temperature of the surrounding medium should not change more than 5°F (2°C).

8.4 Lower the hydrometer gently into the sample and, when it has settled, depress it about two scale divisions into the liquid and then release it; keep the rest of the stem dry, as unnecessary liquid on the stem changes the effective weight of the instrument, and so affects the reading obtained. With samples of low viscosity, a slight spin imparted to the instrument on releasing assists in bringing it to rest, floating freely away from the walls of the hydrometer cylinder. Allow sufficient time for the hydrometer to become completely stationary and for all air bubbles to come to the surface. This is particularly necessary in the case of the more viscous samples.

8.5 When the hydrometer has come to rest, floating freely, and the temperature of the sample is constant to 0.2°F (0.1°C), read the hydrometer to the nearest scale division. The correct reading is that point on the hydrometer scale at which the 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.

8.6 To make a reading with nontransparent liquids, observe the point on the hydrometer scale to which the sample rises above its main surface, placing the eye slightly above the plane surface of the liquid. This reading requires a correction. Determine this correction for the particular hydrometer in use by observing the height above the main surface of the liquid to which the sample rises on the hydrometer scale when the hydrometer in question is immersed in a transparent liquid having a surface tension similar to that of a sample under test.

8.7 Observe the temperature of the sample to the nearest 0.25°F (0.1°C) immediately before and after the observation of the gravity, the liquid in the cylinder being thoroughly but cautiously stirred with the thermometer (Note 2), and the whole of the mercury thread being immersed. Should these temperature readings differ by more than 1°F (0.5°C), repeat the temperature and gravity observations when the temperature of the sample has become more stable. Record the mean of the thermometer reading before and after the final hydrometer reading, to the nearest 1°F, as the temperature of the test.

NOTE 2—When thermohydrometers are used, stir the sample by

TABLE 2 Limiting Conditions and Testing Temperatures

Sample Type	Gravity Limits	Initial Boiling Point Limits	Other Limits	Test Temperature
Highly volatile	lighter than 70° API			Cool to 35°F (2°C) or lower in original closed container.
Moderately volatile	heavier than 70° API	below 250°F (120°C)		Cool to 65°F (18°C) or lower in original closed container.
Moderately volatile and viscous	heavier than 70° API	below 250°F (120°C)	Viscosity too high at 65°F (18°C)	Heat to minimum temperature for sufficient fluidity.
Nonvolatile	heavier than 70° API	above 250°F (120°C)		Any temperature between 0 and 195°F (–18 and 90°C) as convenient.
Mixtures of nonpetroleum products or essentially pure hydrocarbons				60 ± 0.25°F (15.56 ± 0.1°C)

carefully raising and lowering the hydrometer. It is satisfactory in this case to read the thermometer scale after the hydrometer reading has been observed. Read the thermometer to the nearest 1°F (0.5°C).

9. Calculation

9.1 Apply any relevant thermometer corrections to the temperature reading observed in 8.3 and 8.7 and record the average of those two temperatures to the nearest 1°F.

9.2 Record the observed hydrometer scale readings to the nearest 0.1° API for transparent liquids.

9.3 When gravities have been observed on opaque liquids using the procedure given in 8.6, subtract the meniscus correction from the hydrometer reading observed.

NOTE 3—The meniscus correction for a particular hydrometer in use is determined by observing the maximum height above the principal surface of the liquid to which liquid rises on the hydrometer scale when the hydrometer in question is immersed in a transparent liquid having a surface tension similar to that of the sample under test.

9.4 Apply any meniscus hydrometer correction to the observed hydrometer reading and record the meniscus corrected hydrometer scale reading to the nearest 0.1° API.

9.5 Application of the glass thermal expansion correction depends upon what edition of Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) will be used to calculate the base density.

9.5.1 The 1980 version of the Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) has the hydrometer glass thermal expansion correction included. Input into the VCF software requires the Hydrometer Reading – Observed or Hydrometer Reading – Observed, Meniscus Corrected in API units from 9.2 or 9.4, observed temperature of the sample, and the built-in hydrometer glass thermal correction switch set to on (0) or off (1). It will return API @ 60°F.

9.5.2 The 2004 version of the Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) does not include the hydrometer glass thermal expansion correction, so that correction must be made before entering the software. Depending on the specific end use of the calculation results, the final value may be left rounded or unrounded. See 9.6.

9.6 The following steps are required to implement 9.5.2:

Step 1. Convert the meniscus corrected hydrometer scale reading to density in kg/m^3 using Eq 2.

Hydrometer Scale Reading Units	Conversion to Density
For API gravity:	

$$density\ (kg\ /\ m^3) = (141.5*999.016)/(131.5+API) \quad (2)$$

Leave the result unrounded.

Step 2. Calculate the hydrometer thermal glass expansion correction factor (HYC) using the appropriate equation below (t is observed temperature).

Correction for a Base Temperature (T_b) of 60°F:

$$HYC = 1.0 - [0.00001278\ (t - 60)] - [0.0000000062\ (t - 60)^2] \quad (3)$$

Leave the result unrounded.

Step 3. Multiply the hydrometer reading in kg/m^3 from Step 1 by HYC from Step 2 to obtain the glass expansion corrected hydrometer reading.

$$kg/m^3{}_{HYC} = kg/m^3 * HYC \quad (4)$$

Step 4a. Convert the hydrometer reading in density (kg/m$^3{}_{HYC}$) from Step 3 to a R.D. (relative density) hydrometer reading.

NOTE 4—The current C source code, compiled dll and Excel Add-in has an omission and cannot use a kg/m^3 call with degree F.

$$R.D. = kg/m^3{}_{HYC}/999.016 \quad (5)$$

Step 4b. Input R.D. and degree F into section 11.1.6.2 of the Adjunct to D1250-04 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1-2004) which returns R.D. @ 60°F.

NOTE 5—Pressure will have to be atmospheric gauge, or 0 psig as the Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) values are only valid at atmospheric pressure.

Step 4c. Convert the calculated R.D. value @ 60°F to a calculated API Gravity @ 60°F using Eq 6.

$$API\ Gravity = (141.5/R.D.) - 131.5 \quad (6)$$

9.7 Future versions of the Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) code will be corrected so that it can accept any combination of input units and return any combination of output units. When available, the Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) code can be accessed directly from Step 3 and return API Gravity @ 60 °F, R.D. @ 60 °F, and kg/m^3 at any selected base temperature.

Example 1

Sample:	Crude Oil	
Observed Temperature:	77°F	
Observed Hydrometer Reading:	33.2 API Gravity	
Observed Pressure:	0 psig	
Base Temperature:	60°F	
Step 1:	858.292434730...	(Eq 2)
Step 2:	0.999780948...	(Eq 3)
Step 3:	858.104424227...	(Eq 4)
Step 4a:	0.858949631...	(Eq 5)
Step 4b:	0.865678279...	
Step 4c.1:	31.955643312... unrounded	(Eq 6)
Step 4c.2:	32.0 °API rounded	(Eq 6)

10. Report

10.1 Report the corrected hydrometer reading as degrees API (°API) or as API Gravity.

10.2 Report the final value as API gravity, at the reference temperature, to the nearest 0.1° API.

10.3 The reporting values have no precision or bias determination. It is up to the user to determine whether this test method provides results of sufficient accuracy for the intended purpose.

10.4 If the hydrometer readings are being used as an input to a calculation process intended to return a volume correction factor for use in ticket or meter proving calculations, stop the calculation process identified above at Step 3 (if the density value is desired at flowing conditions) or Step 4 (if the density value is desired at base density conditions) and input the results into the calculation process.

10.5 Certified hydrometers from a recognized standardizing body, such as NIST, report the output density as 'Density in Vacuo'.

11. Precision and Bias

11.1 The precision of this test method as obtained by statistical examination of interlaboratory test results is as follows:

11.1.1 *Repeatability*—The difference between successive test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material, would in the long run, in the normal and correct operation of the test method, exceed 0.2° API only in one case in twenty.

11.1.2 *Reproducibility*—The difference between two single and independent results, obtained by different operators, working in different laboratories on identical test material, would in the long run, in the normal and correct operation of the test method, exceed 0.5° API only in one case in twenty.

NOTE 6—The precision for this test method was not obtained in accordance with RR:D02-1007.

NOTE 7—This precision statement applies only to measurements made at temperatures differing from 60°F (15.56°C) by less than 18°F (10°C).

11.2 *Bias*—Bias for this test method has not been determined.

12. Keywords

12.1 API gravity; crude petroleum; hydrometer; thermohydrometer; thermometer

SUMMARY OF CHANGES

Subcommittee D02.02 has identified the location of selected changes to this standard since the last issue (D287–12a) that may impact the use of this standard. (Approved June 1, 2012)

(1) Revised Section 1.

(2) Revised Section 3.

Subcommittee D02.02 has identified the location of selected changes to this standard since the last issue (D287–12) that may impact the use of this standard. (Approved May 15, 2012)

(1) Revised Section 9.

Subcommittee D02.02 has identified the location of selected changes to this standard since the last issue (D287–92(2006)) that may impact the use of this standard. (Approved April 1, 2012)

(1) Expanded Section 8.
(2) Added 9.6.
(3) Revised Sections 10 and 11.

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