Designation: D6822 – 12

API Designation: Manual of Petroleum Measurement Standards (MPMS), Chapter 9.3

Standard Test Method for Density, Relative Density, and API Gravity of Crude Petroleum and Liquid Petroleum Products by Thermohydrometer Method[1]

This standard is issued under the fixed designation D6822; 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.

1. Scope*

1.1 This test method covers the determination, using a glass thermohydrometer 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 pressures 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 thermohydrometer readings obtained are uncorrected hydrometer readings and not density measurements. Readings are measured on a thermohydrometer 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 calculations and Adjunct to D1250, Guide for Use of the Petroleum Measurement Tables (API *MPMS* Chapter 11.1).

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 Use of the Petroleum Measurement Tables (API *MPMS* Chapter 11.1), or both, or tables as applicable.

1.4 The initial thermohydrometer reading shall be recorded before performing any calculations. The calculations required in Section 7 shall be applied to the initial thermohydrometer reading with observations and results reported as required by Section 8 prior to use in a subsequent calculation procedure (measurement ticket calculation, meter factor calculation, or base prover volume determination).

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

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

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

D6300 Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products and Lubricants

E100 Specification for ASTM Hydrometers

2.2 *API Standards:*[3]

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

MPMS Chapter 11.1–2004, including Addendum 1–2007 Temperature and Pressure Volume Correction

[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 Subcommittee D02.02.09 on Density Determination (API MPMS Chapter 9.0).

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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 American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, www.api.org.

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

Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils

2.3 *ASTM Adjuncts:*

Adjunct to D1250, Guide for Use of the Petroleum Measurement Tables (API *MPMS* Chapter 11.1)[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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

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

3.1.2 *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 (kg/m^3).

3.1.2.1 *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.

3.1.3 *observed values*, *n*—hydrometer readings observed at a temperature other than the defined reference temperature.

3.1.3.1 *Discussion*—These values are only hydrometer readings and not density, relative density, or API gravity at the temperature.

3.1.4 *relative density*, *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.

3.1.4.1 *Discussion*—Common reference temperatures include 15/15°C, 60/60°F, 20/20°C, and 20/4°C. The historic term specific gravity may still be found.

3.1.5 *thermohydrometer*, *n*—a glass hydrometer with a self-contained thermometer.

4. Summary of Test Method

4.1 The density or API gravity, after temperature equilibrium has been reached, is read by observing the freely floating thermohydrometer 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 observed thermohydrometer reading is reduced to the reference temperature value by means of the Petroleum Measurement Tables (the appropriate adjunct to Guide D1250/API *MPMS* Chapter 11.1) and observed temperature from the enclosed thermometer.

5. Significance and Use

5.1 Density and API gravity are used in custody transfer quantity calculations and to satisfy transportation, storage, and regulatory requirements. Accurate determination of density or API gravity of crude petroleum and liquid petroleum products is necessary for the conversion of measured volumes to volumes at the standard temperatures of 15°C or 60°F.

5.2 Density and API gravity are also factors that indicate the quality of crude petroleum. Crude petroleum prices are frequently posted against values in kg/m^3 or in degrees API. However, this property of petroleum is an uncertain indication of its quality unless correlated with other properties.

5.3 *Field of Application*—Because the thermohydrometer incorporates both the hydrometer and thermometer in one device, it is more applicable in field operations for determining density or API gravity of crude petroleum and other liquid petroleum products. The procedure is convenient for gathering main trunk pipelines and other field applications where limited laboratory facilities are available. The thermohydrometer method may have limitations in some petroleum density determinations. When this is the case, other methods such as Test Method D1298 (API *MPMS* Chapter 9.1) may be used.

5.4 This procedure is suitable for determining the density, relative density, or API gravity of low viscosity, transparent or opaque liquids, or both. This procedure, when used for opaque liquids, requires the use of a meniscus correction (see 7.2). 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. This procedure can also be used for viscous liquids by allowing sufficient time for the thermohydrometer to reach temperature equilibrium.

6. Apparatus

6.1 *Glass Thermohydrometers*, as specified in Specification E100 (shown in Fig. 1), and graduated in:

6.1.1 Kilograms/cubic metre (kg/m^3) and degrees Celsius for density hydrometers, as shown in Table 1.

6.1.2 Degrees API (°API) and degrees Fahrenheit for hydrometers measuring in API Gravity, as shown in Table 2.

6.1.3 The user should ascertain that the instruments used for this procedure 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 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.

6.2 *Hydrometer Cylinders*, clear glass, plastic, or metal. For convenience of pouring, the cylinder may have a pouring lip. The inside diameter shall be at least 25 mm (1 in.) greater than the outside diameter of the thermohydrometer used. The height of the cylinder shall be such that the bottom of the thermohydrometer clears the bottom of the cylinder by at least 25 mm (1 in.) when suspended in the sample test portion.

6.2.1 For field testing, a sample thief of suitable dimensions may be more convenient than a hydrometer cylinder. The liquid level shall be level with the top of the thief.

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

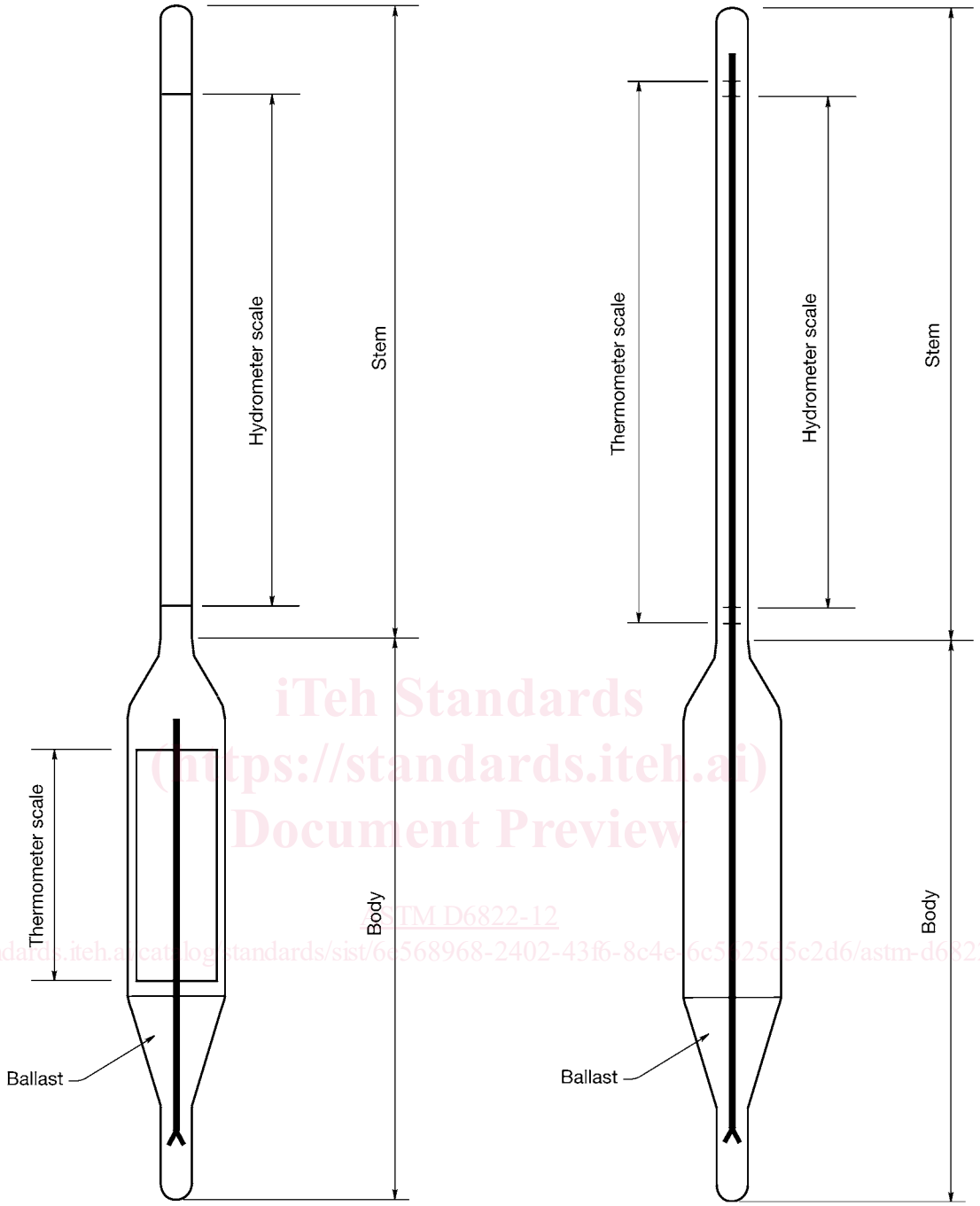

FIG. 1 Typical Thermohydrometer Designs

6.3 *Temperature Bath*, to control temperature close to the bulk hydrocarbon temperature or to control temperature close to the reference temperature of 15°C or 60°F.

7. Procedure

7.1 *Effect of Test Temperature*:

7.1.1 The density or API gravity determined by the thermohydrometer method is most accurate at or near the reference temperature of 15°C or 60°F. Other temperatures within the range of the enclosed thermometer may be used, if consistent with the type of sample and the necessary limiting conditions shown in Table 3.

7.1.2 Bring the sample to the test temperature which shall be such that the sample is sufficiently fluid but not as high as to cause the loss of light components, or so low as to result in the appearance of wax in the test portion.

NOTE 1—The volume and density, the relative density, and the API corrections in the volume correction procedures are based on the average expansions of a number of typical materials. Since the same coefficients were used in compiling each set of tables, corrections made over the same temperature interval minimize errors arising from possible differences between the coefficient of the material under test and the standard coefficients. This effect becomes more important as temperatures diverge from the reference temperature.

TABLE 1 Density Thermohydrometers

ASTM Hydrometer No.	Density, Range, kg/m^3
300H	600 to 650
301H	650 to 700
302H	700 to 750
303H	750 to 800
304H	800 to 850
305H	850 to 900
306H	900 to 950
307H	950 to 1000
308H	1000 to 1050
309H	1050 to 1100
Hydrometer	
Total length, mm	374 to 387
Body diameter, mm	18 to 25
Stem diameter, mm, min	4.0
Hydrometer Scale	
Standard temperature, °C	15
Subdivisions, kg/m^3	0.5
Short intermediate lines at, kg/m^3	1
Long intermediate lines at, kg/m^3	5
Main (numbered) lines at, kg/m^3	10
Scale error at any point not to exceed, kg/m^3	0.5
Length of nominal scale, mm	125 to 145
Scale extension beyond nominal range limits, kg/m^3	2.5
Thermometer Scale	
Range, °C	
Designation L	–20 to +65
Designation M	0 to +85
Designation H	+20 to +105
Immersion	total
Subdivisions, °C	1.0
Intermediate lines at, °C	5
Main (numbered) lines at, °C	10
Scale error at any point not to exceed, °C	1.0
Scale length, mm	80 to 100

NOTE 2—The hydrometer reading is obtained at a temperature appropriate to the physic-chemical characteristics of the material under test. This temperature is preferably close to the reference temperature, or when the value is used in conjunction with bulk oil measurements, within 3°C of the bulk temperature (see 5.3).

7.1.3 For crude petroleum, bring the sample close to the reference temperature or, if wax is present, to 9°C above its pour point or 3°C above its cloud point, whichever is higher.

7.1.4 If the test temperature is significantly different from the reference temperature of 15°C or 60°F, the expansion or contraction of the glass may affect the calibration of the thermohydrometer. A hydrometer correction factor (*HYC*) may be applied to the measured density value to provide a corrected reading.

7.1.5 Convert the thermohydrometer scale reading to base density, if necessary, as follows:

Step 1. Convert the thermohydrometer scale reading to density in kg/m^3 if necessary, using either Eq 2 or Eq 3. For API gravity:

$$density = (141.5 * 999.016) / (131.5 + API) \quad (2)$$

For Relative Density:

$$density = (141.5 / R.D.) - 131.5 \quad (3)$$

Leave the result left un-rounded.

Step 2. Calculate the thermohydrometer temperature expansion correction factor using the appropriate equation below (t is observed temperature):

For a Base Temperature (T_b) of 60°F:

$$HYC = 1.0 - 0.00001278\,(t - 60) - 0.0000000062\,(t - 60)^2 \quad (4)$$

For a Base Temperature (T_b) of 15°C:

$$HYC = 1.0 - 0.000023\,(t - 15) - 0.00000002\,(t - 15)^2 \quad (5)$$

For a Base Temperature (T_b) of 20°C:

$$HYC = 1.0 - 0.000023\,(t - 20) - 0.00000002\,(t - 20)^2 \quad (6)$$

Leave the result left un-rounded.

Step 3. Multiply the density in kg/m^3 by HYC and round the result to 4 places past the decimal to obtain the glass expansion corrected density.

Step 4. Using the appropriate section of Adjunct to D1250, Guide for Use of the Petroleum Measurement Tables (API *MPMS* Chapter 11.1) (section 11.1.6.2 or 11.1.7.2), perform a Type 2 (or 2M) calculation with the observed temperature to correct the glass expansion corrected density to base density. Round the output to 4 places past the decimal.

Step 5. Convert the base density in kg/m^3 to API gravity or Relative Density, if desired, using either Eq 7 or Eq 8. For API gravity:

$$API = (141.5 / (density / 999.016)) - 131.5 \quad (7)$$

For Relative Density:

$$RD = density / 999.016 \quad (8)$$

Example 1:

Sample:	Crude Oil
Observed Temp:	77°F
Observed API gravity:	33.2
Base Temp:	60°F
Step 1:	858.2924347298...
Step 2:	0.9997809482...
Step 3:	858.1044
Step 4:	864.8264
Step 5:	32.0 °API
	0.86567 R.D.

Example 2:

Sample:	Crude Oil
Observed Temp:	25°C
Observed density:	858.29
Base Temp:	15°C
Step 1:	858.29
Step 2:	0.9997680...
Step 3:	858.0909
Step 4:	865.2075 kg/m^3
Step 5:	31.9 °API
	0.86606 R.D.

Example 3:

Sample:	Crude Oil
Observed Temp:	77°C
Observed R.D.:	0.85914
Base Temp:	60°F
Step 1:	858.294606...
Step 2:	0.9997809482...
Step 3:	858.1066
Step 4:	864.8286
Step 5:	32.0 °API
	0.86568 R.D.