Designation: D6822 – 12b (Reapproved 2017)

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 (API *MPMS* Chapter 11.5) 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 9 shall be applied to the initial thermohydrometer reading with observations and results reported as required by Section 11 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.

1.6.1 *Exception*—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.*

1.8 *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]

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

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D5854 Practice for Mixing and Handling of Liquid Samples

[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). This test method has been approved by the sponsoring committees and accepted by the Cooperating Societies in accordance with established procedures.

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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.

of Petroleum and Petroleum Products
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 8.1 Practice for Manual Sampling of Petroleum and Petroleum Products (ASTM Practice D4057)
MPMS Chapter 8.2 Practice for Automatic Sampling of Petroleum and Petroleum Products (ASTM Practice D4177)
*MPMS*Chapter 8.3 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products (ASTM Practice D5854)
MPMS Chapter 9.1 Hydrometer Test Method for Density, Relative Density or API Gravity of Crude Petroleum and Liquid Petroleum Products (ASTM Test Method D1298)
MPMS Chapter 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils (Adjunct to ASTM D1250)
MPMS Chapter 11.5 Density/Weight/Volume Intraconversion

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

3.1.3.1 *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).

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

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

3.1.5 *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.

3.1.5.1 *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.

3.1.6 *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 Adjunct to D1250 Guide for Petroleum Measurement Tables (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

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

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

opaque liquids, or both. This procedure, when used for opaque liquids, requires the use of a meniscus correction (see 9.2). 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

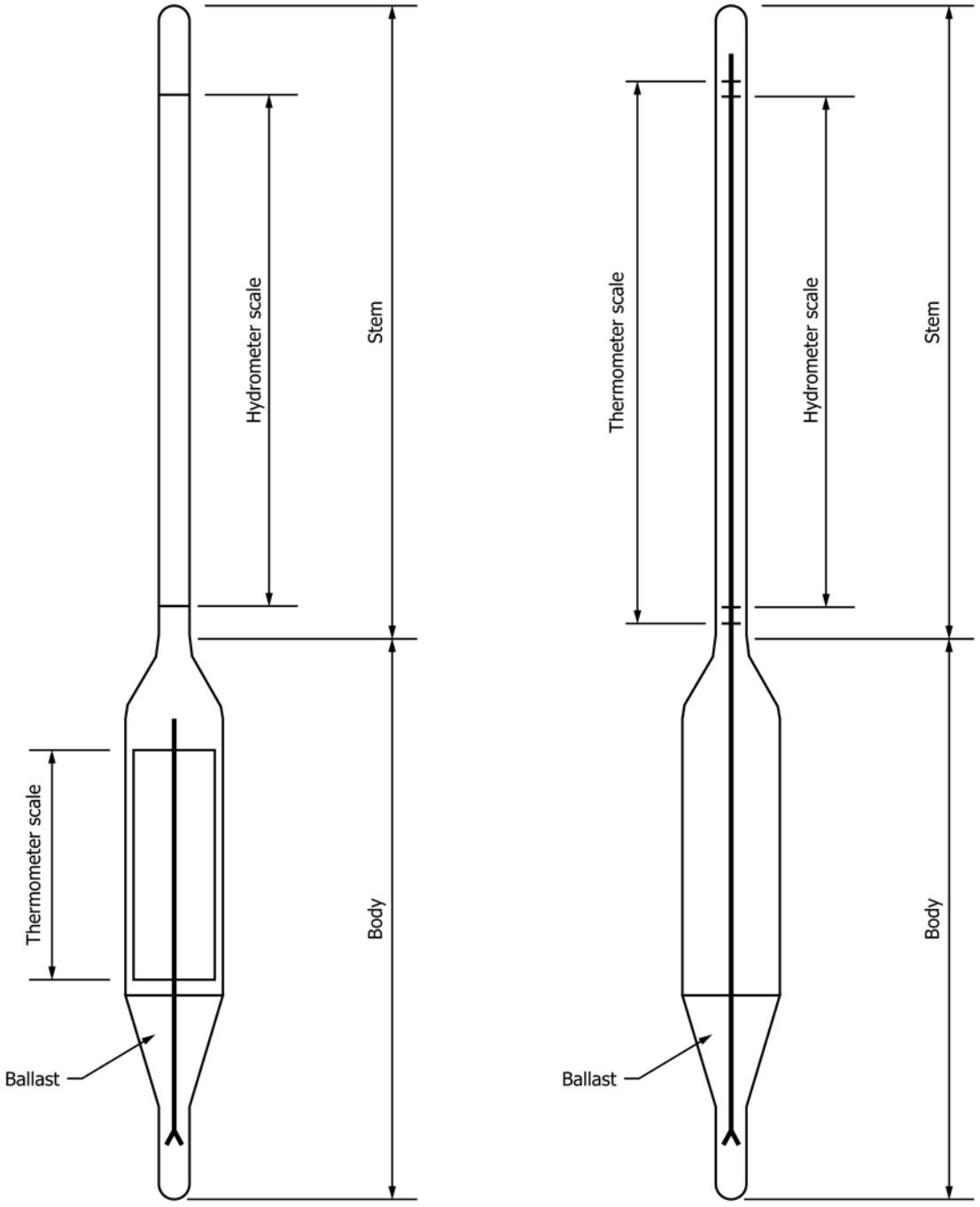

FIG. 1 Typical Thermohydrometer Designs

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
345H	775 to 825
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

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.

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. Sampling, Test Specimens, and Test Units

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

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 sections (7.3.1 – 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 3).

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 *Effect of Test Temperature:*

TABLE 2 API Gravity Thermohydrometers

NOTE 1—For petroleum products and other liquids of similar surface tensions (33 dynes/cm or less).

Thermometer Scale in Body		Thermometer Scale in Stem	
ASTM Hydrometer No.	Nominal API Gravity Range, degrees	ASTM Hydrometer No.	Nominal API Gravity Range, degrees
41H-66	15 to 23	71H-62	–1 to +11
42H-66	22 to 30	72H-62	9 to 21
43H-66	29 to 37	73H-62	19 to 31
44H-66	36 to 44	74H-62	29 to 41
45H-66	43 to 51		
51H-62	–1 to +11		
52H-62	9 to 21		
53H-62	19 to 31		
54H-62	29 to 41		
55H-62	39 to 51		
56H-62	49 to 61		
57H-62	59 to 71		
58H-62	69 to 81		
59H-62	79 to 91		
60H-62	89 to 101		
255H-04	37 to 49		
258H-04	64 to 76		

Hydrometer		
	Thermometer Scale in Body	Thermometer Scale in Stem
Total length, mm	374 to 387	374 to 387
Body diameter, mm	18 to 25	23 to 27
Stem diameter, mm, min	4.0	6.0
Total Length, mm (thermometer scale) for 255H and 258H	110 to 140	

Hydrometer Scale	
Standard temperature, °F	60
Subdivisions, °API	0.1
Intermediate lines at, °API	0.5
Main (numbered) lines at, °API	1.0
Scale error at any point not to exceed, °API	0.1
Length of nominal scale, mm	125 to 145

Thermometer Scale		
	Thermometer Scale in Body	Thermometer Scale in Stem
Range, °F[A]		
Designation L	0 to 150	
Designation M	30 to 180	30 to 220
Designation H	60 to 220	
Designation H (for Aviation Fuels only)	0 to 100	
Immersion	Total	Total
Subdivisions, °F	2	2
Intermediate lines at, °F	10	10
Main (numbered) lines at, °F	20	20
Scale error at any point not to exceed, °F	1	1
Scale length, mm	80 to 110	105 to 145

[A] Indication of the thermometer range is made by the use of the listed designation used as a suffix to the ASTM hydrometer number. For example, 54HL is an instrument with an API gravity range of 29 to 41°API and a thermometer range of 0 °F to 150 °F. An instrument with the same gravity range but a thermometer range of 60 °F to 220 °F would be designated 54HH. The number 57HM would identify an instrument with an API gravity range of 59 to 71°API and a thermometer range of 30 °F to 180 °F.

9.1.1 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.

9.1.2 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 2—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.

NOTE 3—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

TABLE 3 Limiting Conditions and Test Temperatures

Sample Type	Initial Boiling Point	Other Limits	Test Temperature
Volatile	120 °C (250 °F) or lower		Cool in original closed container to 18 °C (65 °F) or lower
Volatile and viscous	120 °C (250 °F) or lower	Viscosity too high at 18 °C (65 °F)	Heat to minimum temperature to obtain sufficient fluidity
Non-volatile	Above 120 °C (250 °F)		Use any temperature between –18 °C and 90 °C (0 °F and 195 °F) as convenient
Mixture with non-petroleum products	. . .		Test at 15 °C ± 0.2 °C or 60 °F ± 0.5 °F

of the bulk temperature (see 5.3).

9.1.3 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.

9.1.4 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.

9.1.5 If the hydrometer has been calibrated at a temperature other than the reference temperature, use the equation below to correct the hydrometer scale reading:

$$\rho r = \frac{\rho t}{1 - [23 \times 10^{-6}\ (t - r) - 2 \times 10^{-8}\ (t - r)^2]} \qquad (2)$$

where:

ρ_r = hydrometer reading at the reference temperature, r °C, and

ρ_t = hydrometer reading on the hydrometer scale whose reference temperature is t °C.

9.1.6 When the thermohydrometer value is used to select factors for correcting volumes to standard temperatures, the thermohydrometer reading preferably should be made at a temperature within ±3 °C (±5 °F) of the temperature at which the bulk volume of the oil was measured (see Note 2). However, 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.

9.2 *Density Measurement:*

9.2.1 Adjust the temperature of the sample in accordance with Table 3. For field testing, test temperatures other than those listed in Table 3 may be used, however, accuracy may be sacrificed. The hydrometer cylinder shall be at approximately the same temperature as the sample to be tested.

9.2.2 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 a flash fire).For the more volatile samples, transfer to the hydrometer cylinder by siphoning (**Warning—**Siphoning by mouth could result in ingestion of sample). Use a rubber aspirator bulb to siphon the more volatile samples. Remove any air bubbles formed, after they have collected on the surface of the sample, by touching them with a piece of clean absorbent paper before inserting the thermohydrometer. For field testing, the thermohydrometer may be inserted directly into a 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.

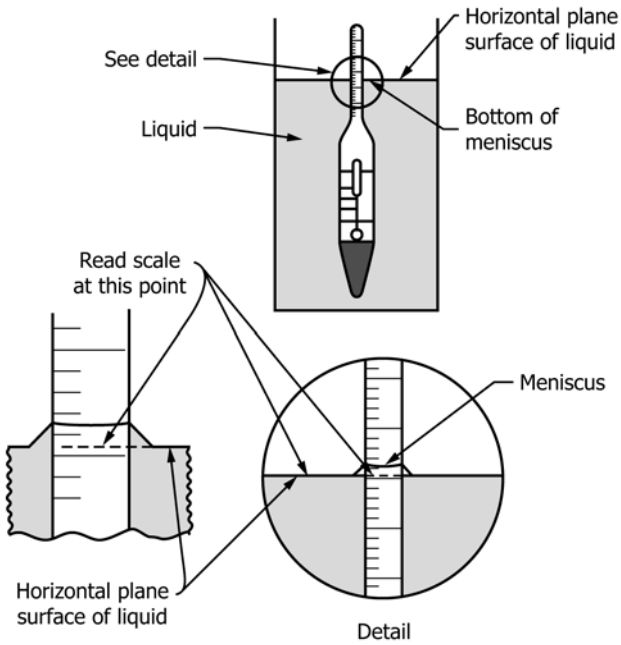

FIG. 2 Hydrometer Reading for Transparent Fluids

9.2.2.1 During this period, the temperature of the surrounding medium should not change more than 3 °C (5 °F).

9.2.3 Lower and raise the thermohydrometer no more than two scale divisions in the sample cylinder to minimize vapor loss and in such a manner that the stem will not be wetted higher than the approximate floating position.

9.2.3.1 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.

9.2.3.2 Gently lower the thermohydrometer into the center of the hydrometer cylinder. When the thermohydrometer has settled, ensure it is not resting on the bottom of the cylinder by depressing it no more than two scale divisions into the liquid. Give the thermohydrometer a slight spin, allowing it to float freely away from the walls of the hydrometer cylinder.

9.2.3.3 Allow enough time for the thermohydrometer to come to rest, all air bubbles to come to the surface, and the

thermohydrometer temperature to stabilize, usually 3 min to 5 min. This is particularly necessary in the case of more viscous samples. Use a temperature bath if control of the sample temperature is required.

9.2.4 Read the thermohydrometer to the nearest scale division (see 9.2.8 for details). The correct reading is that point on the thermohydrometer scale at which the surface of the liquid cuts the scale. To make a reading for transparent liquids in a transparent hydrometer cylinder, 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 thermohydrometer scale. See Fig. 2 for details on reading the meniscus.

9.2.5 To make a reading with opaque liquids, observe the point on the thermohydrometer scale to which the sample rises above its main surface, placing the eye slightly above the plane surface of the liquid. This reading requires meniscus correction (see Note 4). Determine this correction for the particular thermohydrometer in use by observing the height above the main surface of the liquid to which the sample rises on the thermohydrometer scale when the thermohydrometer in question is immersed in a transparent liquid having a surface tension similar to that of a sample under test. Refer to Fig. 3 for details of reading the meniscus.

NOTE 4—When determination of the actual meniscus correction is not practical, industry practice has been to add 0.5 kg⁄m^3 to the density reading or to subtract 0.1°API from the API reading.

9.2.6 Read and record the thermohydrometer scale reading with meniscus correction to the nearest 0.5 kg⁄m^3 or 0.1°API and the thermometer reading to the nearest 0.5 °C (1.0 °F).

9.2.7 Determine the thermohydrometer meniscus correction or utilize the value from the standard industry practice if determining the thermohydrometer reading in an opaque liquid. Apply the meniscus correction to the thermohydrometer scale reading and record the thermohydrometer scale reading with meniscus correction to the nearest 0.5 kg⁄m^3 or 0.1°API.

9.2.8 It may be difficult to ensure that the temperature of the thermohydrometer and liquid has stabilized. To provide this assurance, two successive determinations of density or gravity may be made with the same liquid and each determination corrected to 15 °C (60 °F). The two successive corrected values should be within 0.5 kg⁄m^3 or 0.1°API to be acceptable. If this repeatability cannot be obtained, the temperature may not have stabilized or loss of light hydrocarbons may be occurring.

9.2.9 Gradually withdraw and wipe the thermohydrometer to expose the thermometer scale until a reading can be made. Always make sure the thermometer bulb remains in the liquid when reading the temperature. Read the temperature to the nearest 0.5 °C (1.0 °F).

10. Calculation

10.1 Apply any relevant thermometer corrections to the temperature reading observed in 9.2.5 and 9.2.7 and record the average of those two temperatures to the nearest 0.1 °C.

10.2 Record the observed hydrometer scale readings to the nearest 0.1 kg⁄m^3 in density, 0.0001 g⁄mL, kg⁄L or relative density, or 0.1° API for transparent liquids.

10.2.1 For opaque samples, apply the relevant meniscus correction given in Table 1 or determine it as indicated in 12.2 to the observed hydrometer reading (12.2) as hydrometers are calibrated to be read at the principal surface of the liquid.

10.3 Apply any hydrometer correction identified in a calibration certificate to the observed reading and record the corrected hydrometer scale reading to the nearest 0.1 kg⁄m^3 in density, 0.0001 g/mL, kg/L or relative density, or 0.1° API.

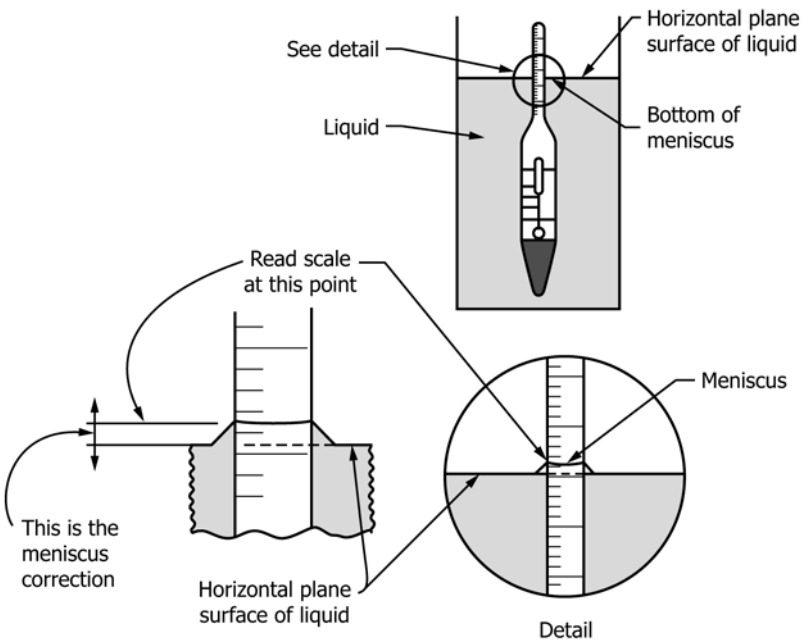

FIG. 3 Hydrometer Reading for Opaque Fluids

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

(a) 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, R.D., or kg/m^3 units from 12.2, 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 or R.D. @ 60 °F or kg/m^3 @ 15 °C.

(b) 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.

The following steps are required to implement 10.1b:

Step 1. Convert the corrected hydrometer scale reading to density in kg/m^3 if necessary, using either Eq 3 or Eq 4.

Scale Units Conversion
API gravity

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

Scale Units Conversion
Relative density

$$Density\,(kg/m^3) = R.D.*999.016 \quad (4)$$

Leave the result unrounded.

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

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

$$HYC = 1.0 - [0.00001278\,(t-60)] - [0.0000000062\,(t-60)^2] \quad (5)$$

Correction for a Base Temperature (T_b) of 15 °C:

$$HYC = 1.0 - [0.000023\,(t-15)] - [0.00000002\,(t-15)^2] \quad (6)$$

Correction for a Base Temperature (T_b) of 20 °C:

$$HYC = 1.0 - [0.000023\,(t-20)] - [0.00000002\,(t-20)^2] \quad (7)$$

Leave the result un-rounded.

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

$$kg/m^3{}_{HYC} = kg/m^3*HYC \quad (8)$$

If the temperature was in degrees Celsius, skip to Step 5.

Step 4a. Convert the densities calculated in Step 3 that started as API Gravity or Relative Density (RD) to RD (Relative Density).

NOTE 5—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.

$$R.D. = kg/m^3{}_{HYC}/999.016 \quad (9)$$

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 6—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 @ 60 °F using Eq 10, if the original input was in API units.

$$\text{API Gravity} = (141.5/\text{R.D.}) - 131.5 \quad (10)$$

Step 5. Input the density calculated in Step 3 in kg/m^3 HYC, degree C, base temperature (15 °C or 20 °C) into Section 11.1.7.2 of the Adjunct to D1250–04 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1–2004), which will return a calculated density in kg/m^3 units at the selected base temperature.

NOTE 7—Pressure will have to be atmospheric gauge, 0 psig, 101.325 kPa or 0 bar as the Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) values are only valid at atmospheric pressure.

c. 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 @ 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	
Base Temperature:	60 °F	
Step 1:	858.2924347298...	Eq 3, Eq 4
Step 2:	0.999780948...	Eq 5, Eq 6, Eq 7
Step 3:	858.104424227	Eq 8
Step 4a:	0.858949631...	Eq 9
Step 4b:	0.865678279...	
Step 4c1:	31.955643312...	Eq 10 unrounded
Step 4c2:	32.0°API	Eq 10 rounded

Example 2:

Sample:	Crude Oil	
Observed Temperature:	25.0 °C	
Observed Hydrometer Reading:	858.29 kg/m^3	
Observed Pressure:	0 bar	
Base Temperature:	15 °C	
Step 1:	858.290000000...	no conversion necessary
Step 2:	0.999768000...	Eq 5, Eq 6, Eq 7
Step 3:	858.090876720...	Eq 8
Step 5.1:	865.207470082...	unrounded
Step 5.2	865.21 kg/m^3	rounded

Example 3:

Sample:	Crude Oil	
Observed Temperature:	77.0 °F	
Observed Hydrometer Reading (R.D.):	0.859138	
Observed Pressure	0 psig	
Base Temp:	60 °F	
Step 1:	858.292608208...	Eq 3, Eq 4
Step 2:	0.999780948...	Eq 5, Eq 6, Eq 7
Step 3:	858.104597667...	Eq 8
Step 4a:	0.858949804...	Eq 9
Step 4b	0.865678451...	unrounded
Step 4c	0.8657...	rounded

10.5 If the hydrometer has been calibrated at a temperature other than the reference temperature, use the equation below to correct the hydrometer scale reading:

$$\rho r = \frac{\rho t}{1 - [23 \times 10^{-6}\,(t-r) - 2 \times 10^{-8}\,(t-r)^2]} \quad (11)$$

where:

ρ_r = hydrometer reading at the reference temperature, r °C, and

ρ_t = hydrometer reading on the hydrometer scale whose reference temperature is t °C.

11. Reports

11.1 *Reporting of Observed Readings:*

11.1.1 Apply any relevant corrections to the observed thermohydrometer reading.

11.1.1.1 For opaque samples, make the appropriate correction to the observed thermohydrometer scale reading given in 9.2.5.

11.1.2 Record this corrected hydrometer scale reading to the nearest 0.5 kg/m^3 density or 0.1°API and record the thermometer reading to the nearest 0.5 °C or 1.0 °F.

11.1.3 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.

11.2 *Correction to Standard Temperatures:*

11.2.1 To correct density or API gravity to standard temperatures at 15 °C or 60 °F respectively, use the following Petroleum Measurement Tables.

11.2.1.1 When a density scale thermohydrometer was employed, use Tables 53A, 53B, or 53D from the appropriate Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) to obtain density at 15 °C.

11.2.1.2 When an API scale thermohydrometer was employed, use Tables 5A, 5B, or 5D from the appropriate Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) to obtain the gravity in °API.

11.2.1.3 When a relative density scale thermohydrometer was employed, use Tables 23A and 23B from the appropriate Adjunct to D1250 Guide for Petroleum Measurement Tables (API *MPMS* Chapter 11.1) to obtain the relative density at 60/60 °F.

11.3 *Unit Conversions:*

11.3.1 When a value is obtained with a thermohydrometer scaled in one set of units and a result is required in another set of units, convert by use of the appropriate Petroleum Measurement Tables.

11.3.1.1 For conversion from density at 15 °C to other units, use API *MPMS* Chapter 11.5.

11.3.1.2 For conversion from API gravity to other units, use API *MPMS* Chapter 11.5.

11.4 *Reporting of Final Value*—Report the final value as density at 15 °C to the nearest 0.5 kg/m^3, relative density 60/60 °F to the nearest 0.0005, or as °API to the nearest 0.1°API, whichever is applicable.

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

12. Precision and Bias

12.1 *Precision*—The precision of this test method as determined by statistical examination of interlaboratory results is as follows:

12.1.1 *Repeatability*—The difference between two 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 0.6 kg/m^3 or 0.2°API only in one case in twenty.

12.1.2 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories and on identical test material would, in the long run, in the normal and correct operation of the test method, exceed 1.5 kg/m^3 or 0.5°API only in one case in twenty.

NOTE 8—The precision of this test method was not obtained in accordance with Practice D6300. The precision statement applies only to measurements made at temperatures of 15 °C ± 10 °C or 60 °F ± 15 °F.

12.1.3 The Repeatability and Reproducibility values provided above are not based on any interlaboratory round robin results. They should be considered historical numbers, the source of which cannot be verified by either ASTM or API and have been in this document prior to the current slate of blended crude oils, RFG gasolines and reformulated distallates. These values do not apply to the current calculation procedures and it is up to the user to determine whether this method provides results of sufficient accuracy for the intended purpose.

12.2 *Bias*—Bias for this test method has not been determined. However, to determine that the bias is within acceptable limits, ensure the hydrometer and the thermometer have been verified using standards traceable to International Standards before the thermohydrometer or hydrometer and thermometer are placed into service. Periodic reverification may be required.

13. Keywords

13.1 API gravity; density; hydrometer; hydrometer cylinder; relative density; thermohydrometer; thermometer

ANNEX

(Mandatory Information)

A1. APPARATUS

A1.1 Apparatus Verification and Certification

A1.1.1 *Hydrometers,* shall either be certified or verified. Verification shall be either by comparison with a certified hydrometer (see 6.1.1) or by the use of a certified reference material (CRM) specific to the reference temperature used.

A1.1.1.1 The hydrometer scale shall be correctly located within the hydrometer stem by reference to the datum mark. If the scale has moved, reject the hydrometer.

A1.1.1.2 Hydrometers shall be certified or verified at intervals of no more than 24 months.

A1.1.2 *Thermometers,* shall be verified at intervals of no more than six months for conformance with specifications. Either comparison with a referenced temperature measurement system traceable to an international standard, or a determination of ice point, is suitable.