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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, of the density, relative density (specific gravity), or API gravity of crude petroleum and liquid petroleum products with 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 international standard tables.

1.2 The values stated in either SI units or inch pound-units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *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]

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

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 Temperature and Pressure Volume Correction 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.

[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/COMQ, the joint ASTM-API Committee on Static Petroleum Measurement.

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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.

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

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 /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 test method is suitable for determining the density, relative density, or API gravity of low viscosity transparent or opaque liquids, or both. This test method, when used for opaque liquids, requires the use of a meniscus correction (see 7.2).

6. Apparatus

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

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

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.

6.2 *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. 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.

TABLE 2 API Gravity Thermohydrometers

NOTE—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		

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

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	
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 to 150°F. An instrument with the same gravity range but a thermometer range of 60 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 to 180°F.

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 and 195°F) as convenient
Mixture with non-petroleum products	. . .		Test at 15 ± 0.2°C or 60 ± 0.5°F

7.1.2 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

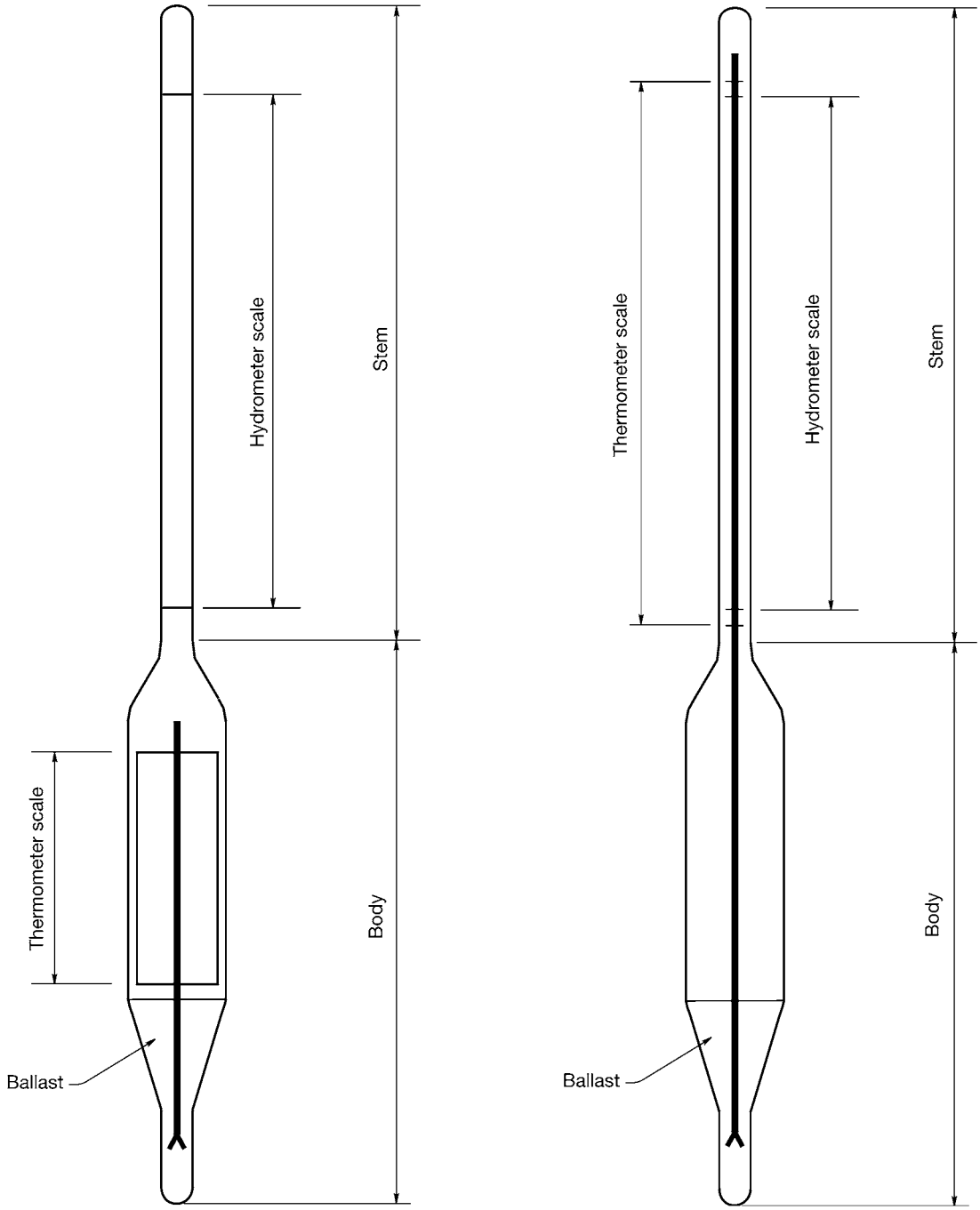

FIG. 1 Typical Thermohydrometer Designs

reading. Historically, the following equations have been used within volume correction factor tables.

$$\rho_{corrected} = \rho_{test} \times HYC \quad (2)$$

where:

HYC = hydrometer thermal correction factor,
$\rho_{corrected}$ = test density, corrected for the effects of temperature on the thermohydrometer, and
ρ_{test} = test density, as observed by reading the thermohydrometer.

$$HYC = 1 - 0.00001278(t - 60) - 0.0000000062(t - 60)^2 \quad (3)$$

where:

t = observed temperature (°F) or

$$HYC = 1 - 0.000023(t - 15) - 0.00000002(t - 15)^2 \quad (4)$$

where:

t = observed temperature (°C).

7.1.2.1 All parties affected by the measurement should agree upon the need for and the method of correction.

7.1.3 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 1). 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.

NOTE 1—Volume and density correction tables are based on average expansion for a number of typical materials. Since the same coefficients were used in computing both sets of tables, corrections made over the same temperature interval minimize errors arising from possible differences between the coefficients of the material under test and the standard coefficients. This effect becomes more important as temperatures diverge significantly from 15°C or 60°F.

7.2 *Density Measurement*:

7.2.1 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.

7.2.2 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.

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

7.2.3 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.

7.2.3.1 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.

7.2.3.2 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 about 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.

7.2.3.3 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 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.

7.2.4 Read the thermohydrometer to the nearest scale division (see 7.2.7 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.

7.2.5 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 2). 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 2—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.

7.2.6 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).

7.2.7 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.

7.2.8 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

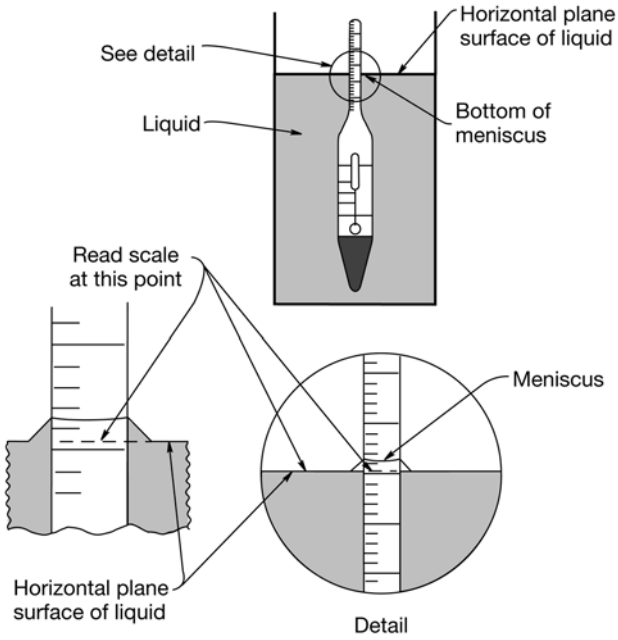

FIG. 2 Hydrometer Reading for Transparent Fluids

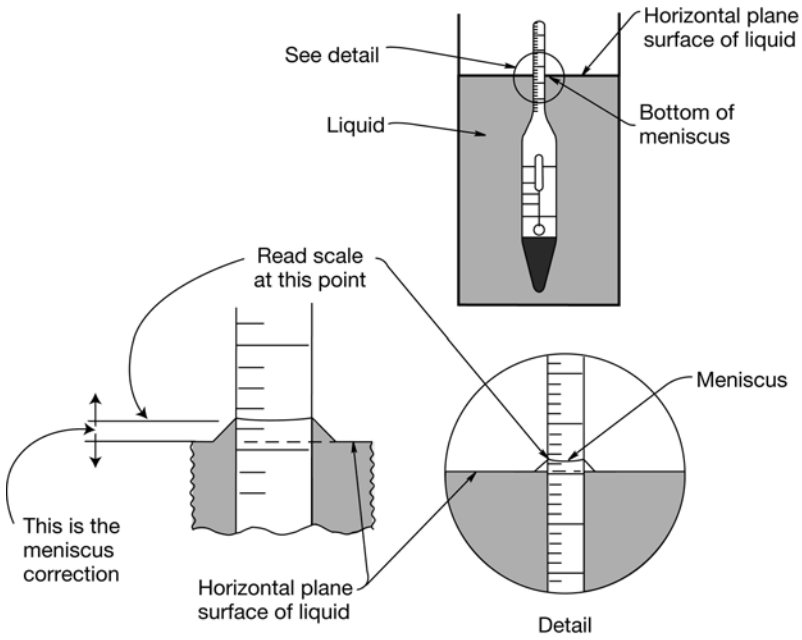

FIG. 3 Hydrometer Reading for Opaque Fluids

when reading the temperature. Read the temperature to the nearest 0.5°C (1.0°F).

8. Reports

8.1 *Reporting of Observed Readings*:

8.1.1 Apply any relevant corrections to the observed thermohydrometer reading.

8.1.1.1 For opaque samples, make the appropriate correction to the observed thermohydrometer scale reading given in 7.2.5.

8.1.2 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.

8.2 *Correction to Standard Temperatures*:

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

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

8.2.1.2 When an API scale thermohydrometer was employed, use Tables 5A, 5B, or 5D from the appropriate adjuncts to Guide (API *MPMS* Chapter 11.1) to obtain the gravity in °API.

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

8.3 *Unit Conversions*:

8.3.1 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.

8.3.1.1 For conversion from density at 15°C to other units, use Table 5 in the appropriate adjunct to Guide (API *MPMS* Chapter 11.1).

8.3.1.2 For conversion from API gravity to other units, use Table 3 in the appropriate adjunct to Guide (API *MPMS* Chapter 11.1).

8.4 *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.

9. Precision and Bias

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

9.1.1 *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.

9.1.2 *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 3—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 ± 10°C or 60 ± 15°F.

9.2 *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 re-verification may be required.

10. Keywords

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