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Designation: D6822 – 12b

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. 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, 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 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

[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.

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

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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 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

[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.

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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

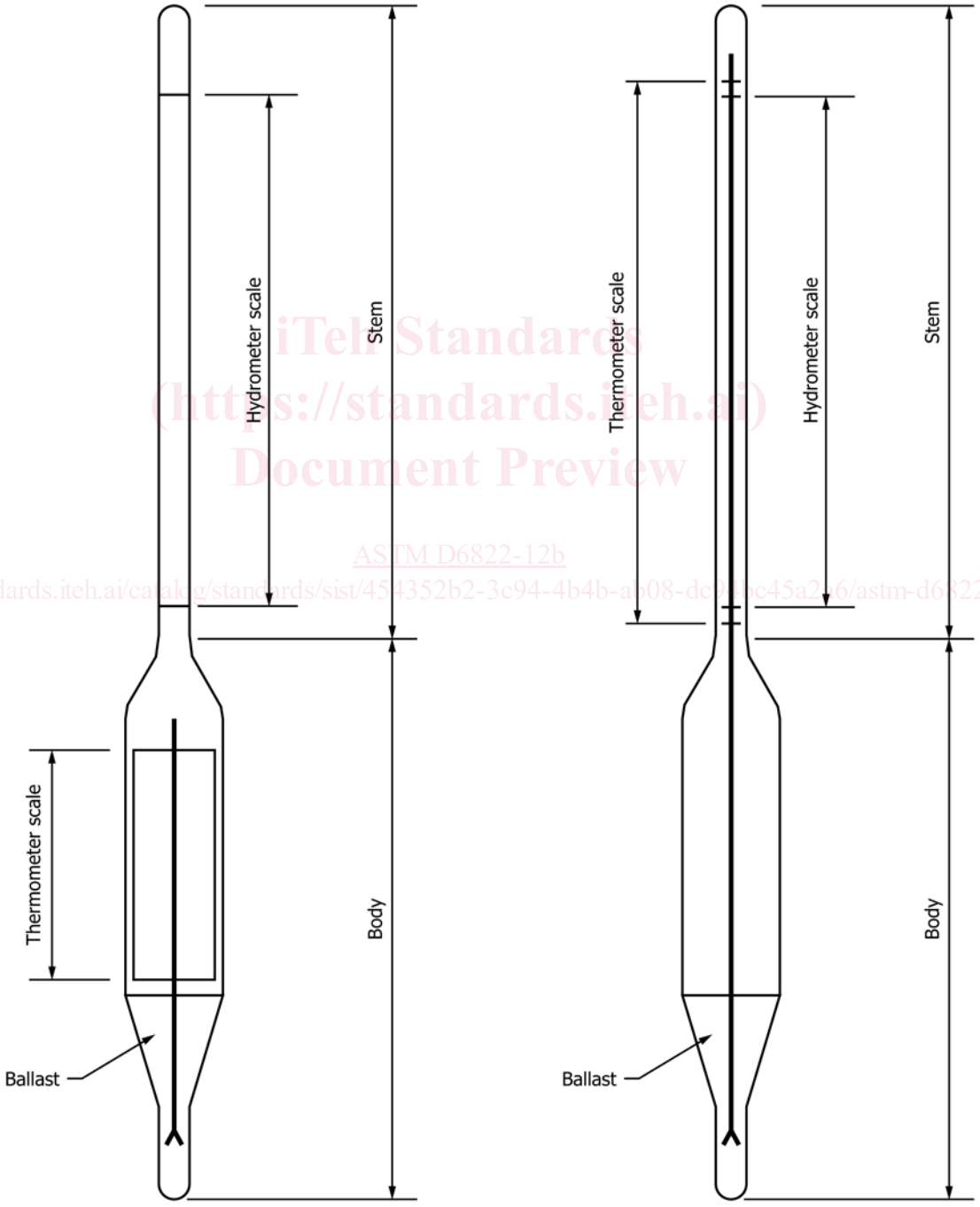

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FIG. 1 Typical Thermohydrometer Designs

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

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:*

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.

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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 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

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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 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:

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

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.

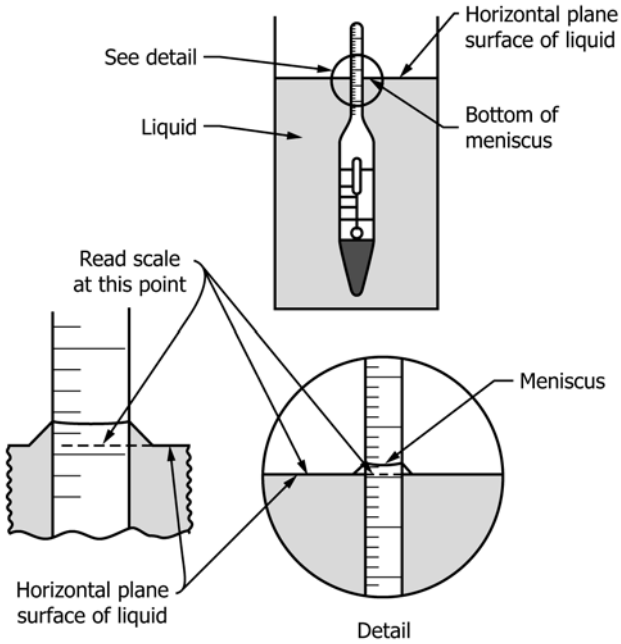

FIG. 2 Hydrometer Reading for Transparent Fluids

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 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

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