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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 Method¹

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.

^{ε1} NOTE—Editorially corrected adjunct information in March 2023.

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

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~~safety, health, and environmental 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 the Use of the Joint API and ASTM Adjunct for Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils: API MPMS Chapter 11.1

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

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

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, Liquid Fuels, and Lubricants

E100 Specification for ASTM Hydrometers

2.2 API Standards:³

MPMS Chapter 1 Terms and Definitions Database

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** Standard Guide for the Use of the Joint API and ASTM Adjunct for Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricant Oils: API MPMS Chapter 11.1, Addenda 1 and 2⁴

3. Terminology

3.1 Definitions:

3.1.1 For terms and definitions used in this test method, refer to Terminology **D4175** and API MPMS Ch 1 Terms and Definitions Database.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 **API gravity** ($^{\circ}\text{API}$), n —a special function of relative density 60/60 °F, represented by:

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

3.2.1.1 Discussion—

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

3.2.2 **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).

3.2.2.1 Discussion—

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. [ADJD1250-A1A2-E-PDF](http://www.astm.org/ASTM/D6822-23/ADJD1250-A1A2-E-PDF). Original adjunct produced in 1983.

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.

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

3.2.3.1 *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).

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

3.2.4.1 *Discussion*—

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

3.2.5 *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.

3.2.5.1 *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.

3.2.6 *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/m³ 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 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 ($^\circ\text{API}$) 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

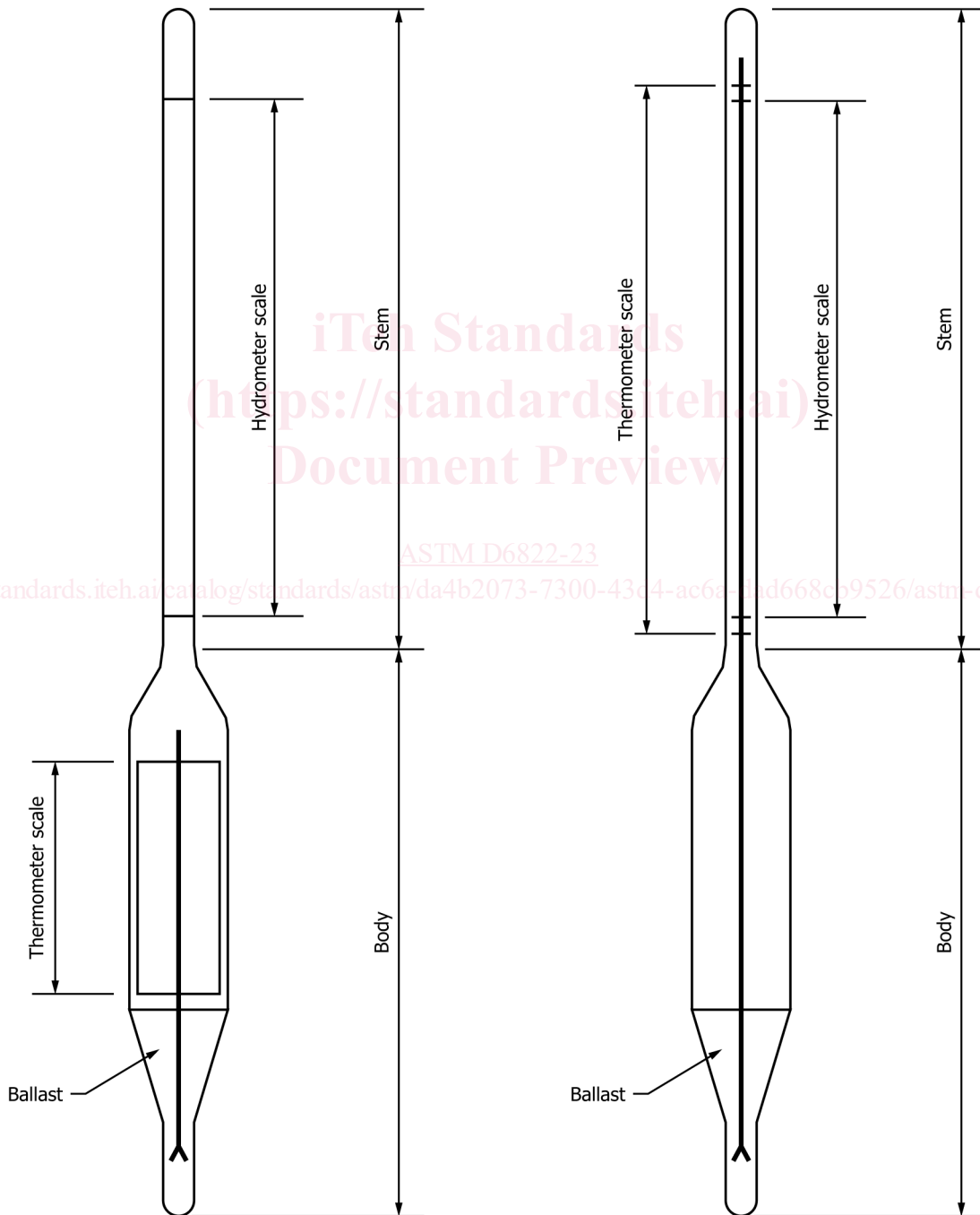


FIG. 1 Typical Thermohydrometer Designs

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

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.

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.

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.

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.