



Standard Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Bingham Pycnometer¹

This standard is issued under the fixed designation D1480; 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 two procedures for the measurement of the density of materials which are fluid at the desired test temperature. Its application is restricted to liquids of vapor pressures below 80 kPa (600 mm Hg) and viscosities below 40 000 mm²/s (cSt) at the test temperature. The method is designed for use at any temperature between 20 °C and 100 °C. It can be used at higher temperatures; however, in this case the precision section does not apply.

NOTE 1—For the determination of density of materials which are fluid at normal temperatures, see Test Method [D1217](#).

1.2 This test method provides a calculation procedure for converting density to specific gravity.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 **WARNING**—Mercury has been designated by many regulatory agencies as a hazardous material that can cause central nervous system, kidney and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website—<http://www.epa.gov/mercury/faq.htm>—for additional information. Users should be aware that selling mercury and/or mercury containing products in your state or country may be prohibited by law.

1.5 *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 This test method is under the jurisdiction of ASTM Committee [D02](#) on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee [D02.04.0D](#) on Physical and Chemical Methods.

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2. Referenced Documents

2.1 *ASTM Standards*:²

[D1217](#) Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer

[D4052](#) Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

[E1](#) Specification for ASTM Liquid-in-Glass Thermometers

3. Terminology

3.1 *Definitions*:

3.1.1 *density, n*—mass per unit volume at a specified temperature. **D4052**

3.1.2 *relative density, n*—the ratio of the density of a material at a stated temperature to the density of water at a stated temperature. **D4052**

4. Summary of Test Method

4.1 The liquid sample is introduced into the pycnometer, equilibrated to the desired temperature, and weighed. The density or specific gravity is then calculated from this weight and the previously determined calibration factor, and a correction is applied for the buoyancy of air.

5. Significance and Use

5.1 Density is a fundamental physical property that can be used in conjunction with other properties to characterize both the light and heavy fractions of petroleum and to assess the quality of crude oils.

5.2 Determination of the density or relative density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperatures of 15 °C.

5.3 The determination of densities at the elevated temperatures of 40 °C and 100 °C is particularly useful in providing the data needed for the conversion of kinematic viscosities in

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

mm²/s (centistokes) to the corresponding dynamic viscosities in mPa·s (centipoises).

6. Apparatus

6.1 *Pycnometer*,³Bingham-type of 10 mL capacity (as shown in Fig. 1), constructed of heat-resistant⁴ glass.

NOTE 2—Pycnometers having capacities of 2 mL to 25 mL are available but have not been cooperatively evaluated.

6.2 *Constant-Temperature Bath*, provided with suitable pycnometer holders and means for maintaining temperatures constant to ± 0.01 °C in the desired range. Water-glycerin mixtures can be used for temperatures up to 100 °C.

6.3 *Bath Thermometer*, graduated in 0.1 °C subdivisions and standardized for the range of use to the nearest 0.01 °C (ASTM Saybolt Viscosity Thermometers 17 °C to 22 °C, conforming to the requirements in Specification E1, are recommended). For most hydrocarbons the density coefficient is about 0.0008 units/°C, and therefore an error of ± 0.013 °C would cause an error of ± 0.00001 g/mL in density. A standardized platinum resistance thermometer may also be used, and it offers the best means for observing temperature changes in the bath.

6.4 *Thermal Shields*, as shown in Fig. 2, to hold the pycnometer and syringe during the filling procedure, constructed of two aluminum shells with suitably spaced viewing ports, the upper bored to hold a 30 mL hypodermic syringe and the lower bored to hold a 25 mL Bingham pycnometer. A winding of No. 26 Chromel “A” wire, insulated from the

³ There is more than one supplier. If you cannot find a supplier, then contact Subcommittee D02.04.0D on Physical and Chemical Methods for possible suppliers.

⁴ Borosilicate glass has been found satisfactory for this purpose.

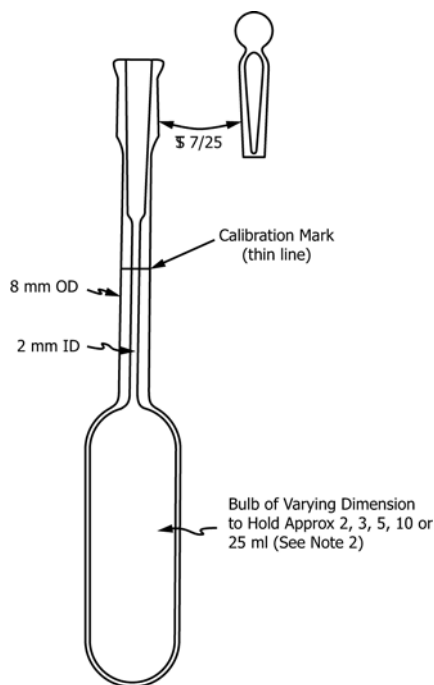
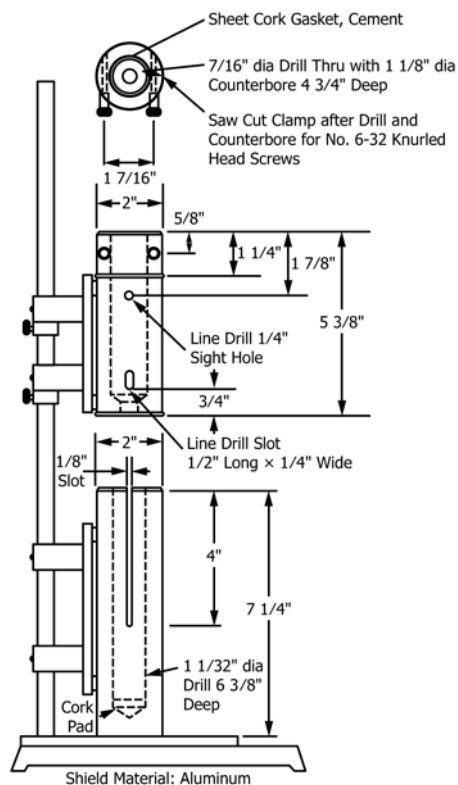


FIG. 1 Bingham-Type Pycnometer



Metric Equivalents

in.	mm	in.	mm	in.	mm	in.	mm
1/8	3.2	5/8	15.9	1 1/4	31.8	4	102
1/4	6.4	3/4	19.1	1 7/16	36.5	4 3/4	121
7/16	11.1	1 1/32	26.2	1 7/8	47.6	5 5/8	136
1/2	12.7	1 1/8	28.6	2	50.8	6 3/8	162
						7 1/4	184

NOTE 1—Cover shields with mica or insulating cement. Wind with No. 26 gauge Chromel “A” wire: Upper block 1.52 m (60 in.) (25.4 Ω), lower block 2.16 m (85 in.) (35.0 Ω) wound vertically. Cover with insulating tape or insulating cement and connect heaters in series. Insulate shields from stand with 1/4 in. Transite.

FIG. 2 Details of Thermal Shields for 30 mL Syringe and 25 mL Pycnometer

shields with mica, covered with insulating tape, and having resistances connected in series of 25 Ω on the upper shield and 35 Ω on the lower produces controlled heat to the shields by means of a variable transformer. A stand is necessary to support the shields in such a manner that the center of the wells may be aligned, and the upper shield raised 180 mm to 200 mm and swung through 45°.

6.5 *Hypodermic Syringes*, 2 mL to 30 mL capacity, of chemically resistant glass, equipped with a 170 mm, 16 gauge (0.065 in.) filling needle made from stainless-steel tubing, as shown in Fig. 3.

6.6 *Draw-off Needle*, made of stainless-steel tubing, as shown in Fig. 3.

6.7 *Solvent Cleaning Assembly*, as shown in Fig. 4.

6.8 *Chromic Acid Cleaning Apparatus*, similar to that shown in Fig. 5.

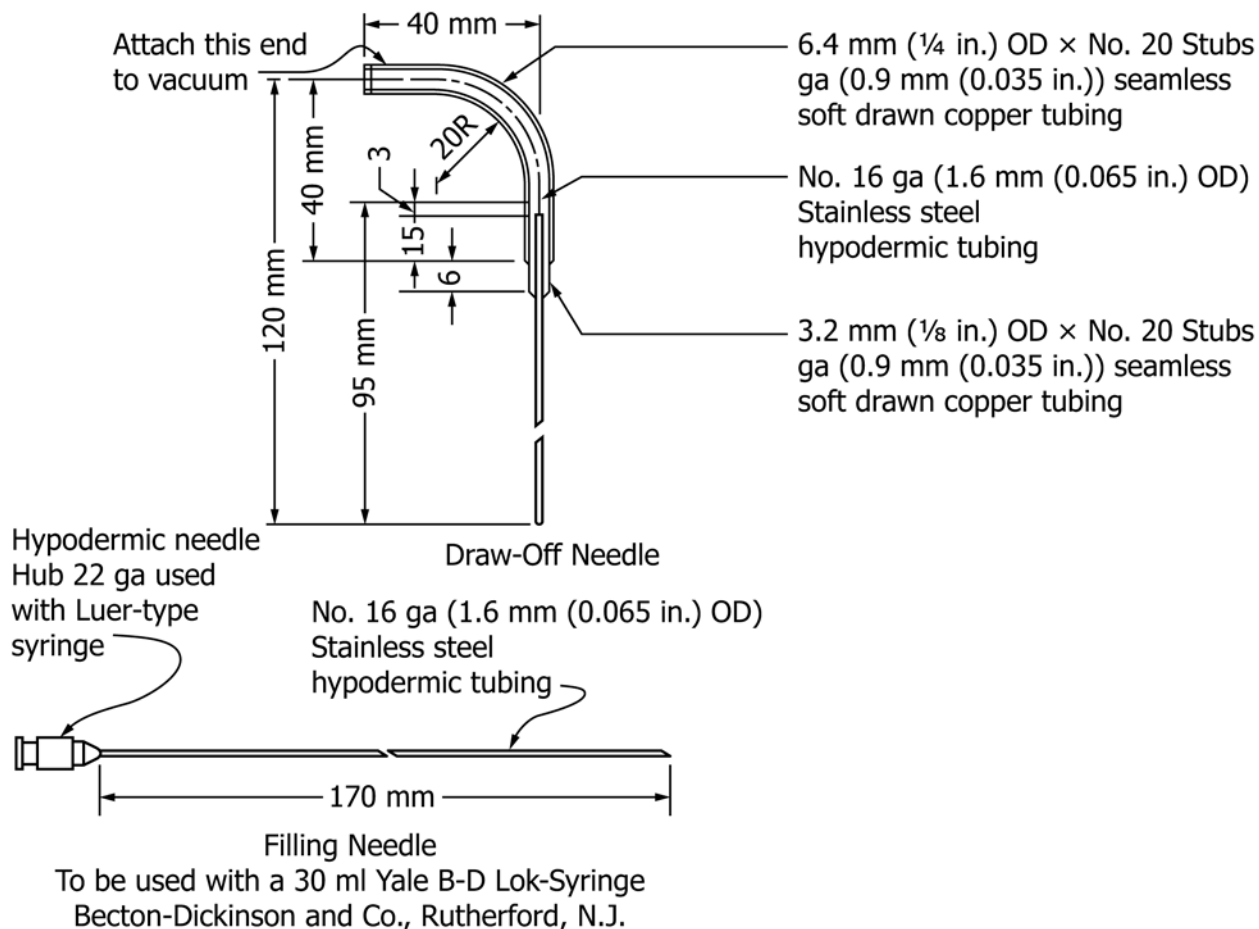


FIG. 3 Accessories for Bingham-Type Pycnometer

6.9 *Balance*, capable of reproducing weighings within 0.1 mg when carrying a load of 30 g. The balance shall be located in a room shielded from drafts and fumes and in which the temperature changes between related weighings (empty and filled pycnometer) do not cause a significant change in the ratio of the balance arms. The same balance shall be used for all related weighings.

6.10 *Weights*, whose relative values are known to the nearest 0.05 mg or better. Use the same set of weights for the calibration of the pycnometer and the determination of densities.

7. Reagents and Materials

7.1 *Acetone*—(Warning—Extremely flammable. Use adequate ventilation.)

7.2 *Isopentane*—(Warning—Extremely flammable. Avoid build up of vapors and remove all sources of ignition, especially non-explosion proof electrical apparatus.)

7.3 *Chromic Acid (Potassium Dichromate/Conc. Sulfuric Acid)*—(Warning—Causes severe burns. A recognized carcinogen. Do not get in eyes, on skin, or on clothing.)

8. Preparation of Apparatus

8.1 Clean the pycnometer thoroughly with hot chromic acid cleaning solution by means of the assembly shown in Fig. 5 (Warning—See 7.3.) Chromic acid solution is the most effective cleansing agent. However, surfactant cleansing fluids have also been used successfully. Mount the apparatus firmly and connect the trap to the vacuum. Warm the necessary amount of cleaning acid in the beaker, place the pycnometer on the ground joint, and evacuate by opening the stopcock to vacuum. Fill the pycnometer with acid by turning the stopcock, and either repeat several times, or remove the filled pycnometer and allow it to stand for several hours at 50 °C to 60 °C. Remove the acid from the pycnometer by evacuation, empty the acid from the trap, and flush the pycnometer with distilled water. Clean in this manner whenever the pycnometer is to be calibrated or whenever liquid fails to drain cleanly from the walls of the pycnometer or its capillary. Ordinarily, the pycnometer may be cleaned between determinations by washing with a suitable solvent, rinsing with pure, dry acetone, followed by isopentane, and vacuum drying. (Warning—See 7.1 and 7.2.)

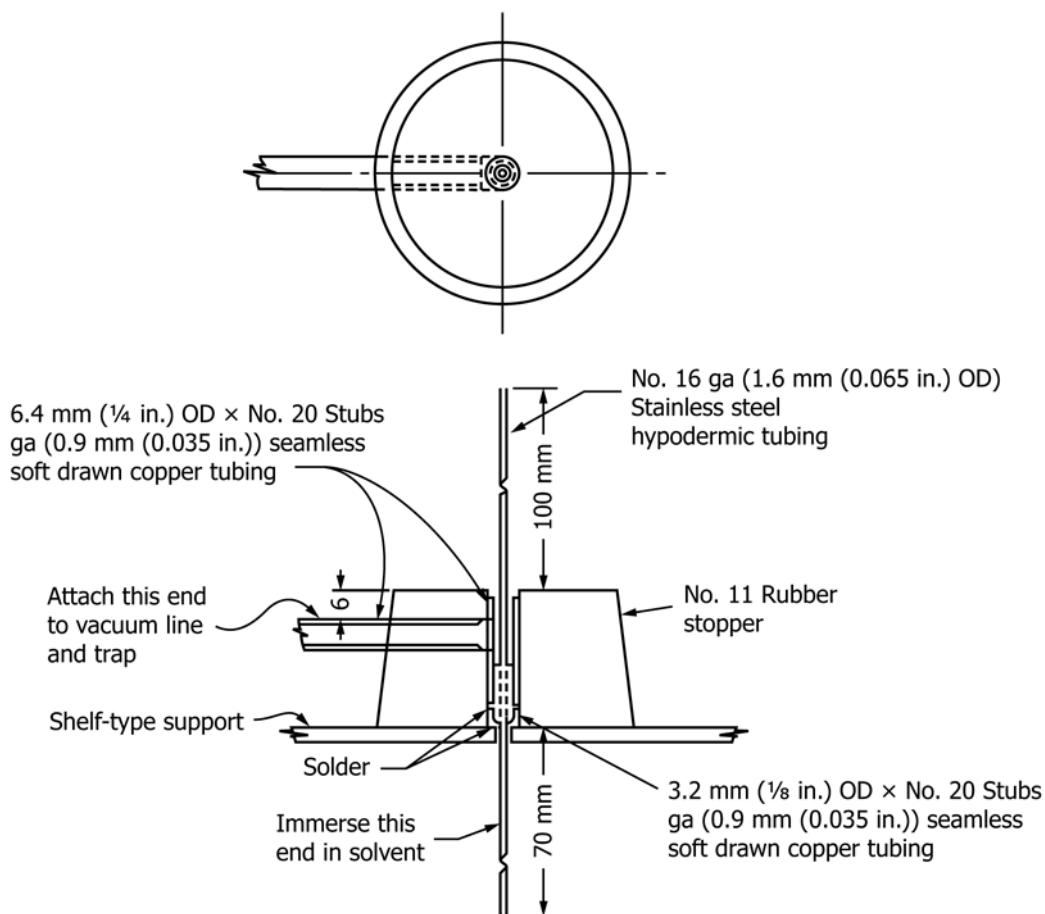


FIG. 4 Cleaner Assembly for Bingham-Type Pycnometer

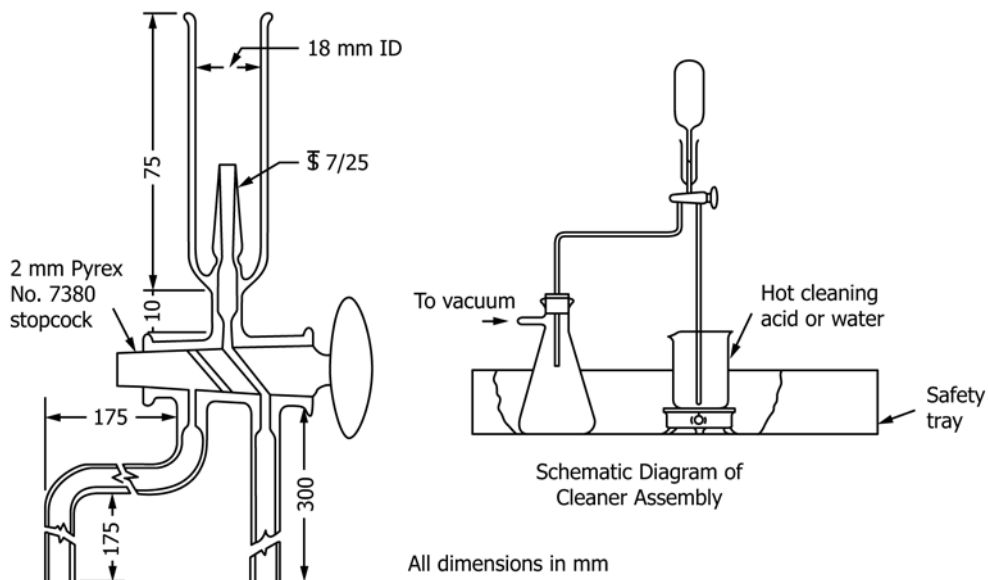


FIG. 5 All-Glass Pycnometer Cleaner Assembly for Use with Hot Chromic Acid Cleaning Solution

8.2 Transfer the pycnometer to the cleaner assembly shown in Fig. 4, with vacuum line and trap attached to the side tube as indicated. Place the pycnometer on the cleaner with the upper hypodermic needle extending upward into the

pycnometer, and press the edge of the ground joint on the rubber stopper until the vacuum holds it in place. Draw out all the liquid or sample. Immerse the lower end of the hypodermic tube in a suitable solvent and draw 20 mL to 25 mL through the

pycnometer. Leaving the pycnometer in place, draw air through it until it is dry. Clean the hypodermic syringe with the same apparatus.

9. Calibration of Pycnometers

9.1 Weigh the clean, dry pycnometer to 0.1 mg and record the weight.

NOTE 3—It is convenient to use the lightest of a set of pycnometers as a tare. For best results the treatment and environment of both pycnometer and tare should be identical for some time prior to weighing.

9.2 With a syringe of suitable size, transfer freshly boiled and cooled distilled water to the pycnometer through the filling needle (Note 6). Avoid trapping air bubbles in the bulb or capillary of the pycnometer, removing bubbles, as they form, with the syringe, when possible. Also remove any water above the calibration mark and dry the overflow chamber and capillary with a cotton-fiber pipe cleaner or cotton swab which has been moistened slightly with acetone. Do not touch the plunger of the syringe or hypodermic needle with fingers as minute quantities of oil transferred this way would cause faulty drainage in the capillary neck of the pycnometer.

9.3 Close the pycnometer with the glass stopper and immerse it to a point above the calibration mark in the constant-temperature bath adjusted to a constancy of ± 0.01 °C at the desired temperature (Note 4). Periodically, or before the liquid expands into the overflow chamber, remove the stopper, raise the pycnometer sufficiently to expose the calibration mark to view, and readjust the liquid level to the mark by withdrawing liquid through the steel draw-off needle until expansion has stopped, indicating that the liquid has reached the temperature of the thermostat. To minimize errors caused by faulty drainage, do not allow the liquid to expand more than 10 mm above the calibration mark at any time. Allow the contents to equilibrate an additional 10 min and draw the level down exactly to the calibration line, avoiding parallax and using a

magnifier, if necessary, to obtain good visibility. Remove any liquid adhering to the walls above the calibration mark, with the draw-off needle or pipe cleaner, depending upon the volatility of the sample. Portions in the overflow bulb can be removed with a cotton swab moistened with acetone.

NOTE 4—For temperatures above 80 °C calculate the volume from the coefficient of expansion of the glass observed from calibrations made at 60 °C, 70 °C, and 80 °C.

9.4 Replace the glass stopper, remove the pycnometer from the bath, wash the outside surface with acetone, and dry thoroughly with a chemically clean, lint-free, slightly damp cloth. Place the pycnometer in or near the balance case for 20 min and weigh to the nearest 0.1 mg.

NOTE 5—In atmospheres of low humidity (60 % or lower), drying the pycnometer by rubbing with a dry cotton cloth will induce static charges equivalent to a loss of about 1 mg in the weight of the pycnometer. This charge may not be completely dissipated in less than 30 min. The use of about 0.1 mg of radium bromide- or polonium-coated foil in the balance case, or maintaining the relative humidity at 60 % or higher, aids in reducing weighing difficulties due to static charges.

9.5 Calculate the pycnometer calibration factor, F_p , from the equation:

$$F_p = (\text{density of water at } t^\circ\text{C}) / \quad (1)$$

(weight of water in pycnometer at $t^\circ\text{C}$)

See Table 2 for the density of water between 0 °C and 100 °C.

9.6 Duplicate determinations should not show a variation greater than ± 0.2 mg in the net weight of the water in the pycnometer.

10. Procedure for Viscous Liquids

10.1 Weigh the pycnometer as directed in Section 8.

TABLE 1 Vacuum Corrections to be Applied to Densities Observed in Air of Various Densities

NOTE 1—Interpolate linearly for intermediate sample densities.

NOTE 2—For air densities outside this table the vacuum correction shall be calculated from the equation $C = d_a [1 - (F_p W_p)]$, d_a being the density of the air in the balance case in grams per millilitre. See Section 10 of Test Method D1217 for calculating the air density.

Observed Density	Air Density g/mL			
	0.00116	0.00118	0.00120	0.00122
	Corrections to be Added			
0.60	0.00046	0.00047	0.00048	0.00049
0.65	0.00040	0.00041	0.00042	0.00042
0.70	0.00034	0.00035	0.00036	0.00036
0.75	0.00029	0.00029	0.00030	0.00030
0.80	0.00023	0.00024	0.00024	0.00024
0.85	0.00017	0.00018	0.00018	0.00018
0.90	0.00011	0.00012	0.00012	0.00012
0.95	0.00005	0.00006	0.00006	0.00006
1.00	0	0	0	0
	Corrections to be Subtracted			
1.05	0.00005	0.00006	0.00006	0.00006
1.10	0.00011	0.00012	0.00012	0.00012
1.15	0.00017	0.00018	0.00018	0.00018
1.20	0.00023	0.00024	0.00024	0.00024

TABLE 2 Density of Water^A

NOTE 1—Several metrological entities have issued water density tables and alternative water density data is referenced in publications external to ASTM and this test method. Using water density data from an alternative recognized source does not pose a compliance issue with this test method as the variation in the data typically is limited to the sixth decimal place.

Temperature, °C	Density, g/mL	Temperature, °C	Density, g/mL	Temperature, °C	Density, g/mL
0.01	0.999844	21	0.997996	40	0.992216
3	0.999967	22	0.997773	45	0.990213
4	0.999975	23	0.997541	50	0.988035
5	0.999967	24	0.997299	55	0.985693
10	0.999703	25	0.997048	60	0.983196
15	0.999103	26	0.996786	65	0.980551
15.56	0.999016	27	0.996516	70	0.977765
16	0.998946	28	0.996236	75	0.974843
17	0.998778	29	0.995947	80	0.971790
18	0.998599	30	0.995650	85	0.968611
19	0.998408	35	0.994033	90	0.965310
20	0.998207	37.78	0.993046	99.9	0.958421

^A Densities conforming to the International Temperature Scale 1990 (ITS 90) were extracted from Lemmon, E. W., McLinden, M. O., and Friend, D. G., "Thermophysical Properties of Fluid Systems," *NIST Chemistry WebBook*, NIST Standard Reference Database No. 68, Eds. P. J. Linstrom and W. G. Mallard, National Institute of Standards and Technology, Gaithersburg, Md., <http://webbook.nist.gov>. (retrieved July 24, 2013).

10.2 Warm, in an oven or convenient warming chamber, the pycnometer, syringe with needle, and sample to a convenient working temperature consistent with the fluidity and volatility of sample. Draw the requisite amount of sample into the syringe and immediately fill the warmed pycnometer taking care to avoid occluding air bubbles in the pycnometer bulb or capillary. Continue the addition of sample, withdrawing the filling needle gradually so that the tip remains immersed in the sample, until the sample has been added to a depth of 10 mm or 20 mm in the expansion chamber above the capillary, depending upon the amount of contraction expected.

10.3 Immerse the pycnometer bulb in the constant-temperature bath. As the sample contracts continue sample addition before the level recedes into the capillary or until a sufficient amount has been added to maintain the meniscus slightly above the calibration mark at the reference temperature. Allow to equilibrate to reference temperature.

NOTE 6—Equilibration time depends upon the viscosity and temperature of the sample at the time of filling. Usually this is three to four times that required for a fluid sample. A safe criterion is to allow 15 min more equilibration time after the meniscus remains stationary.

10.4 Remove excess sample with the 16 gauge needle attached to a vacuum line, warming the needle if necessary. Swab the capillary above the calibration mark and the overflow chamber several times with a pipe cleaner or small cotton swab slightly moistened with a suitable solvent. Follow with a dry swab. Final adjustment to the mark may be done by picking out sample with a small probe, splinter, or wire.

10.5 Remove the pycnometer from the bath, wash the outer surface with a suitable solvent followed by acetone and dry thoroughly with a clean, lint-free, slightly damp cloth. Observe the same cleaning procedure as used in calibrating the pycnometer in the bath. Allow the pycnometer to come to room temperature and weigh to the nearest 0.1 mg.

11. Procedure for Melted Solids at High Temperature

11.1 Place the sample in a heat-resistant container and bring to a temperature 8 °C to 12 °C above its melting point in an explosion-proof oven.

11.2 Insert the pycnometer, previously weighed to the nearest 0.1 mg, in the lower chamber of the thermal shield and lightly clamp the syringe in the upper chamber so that the filling needle is inside the pycnometer. Apply power to the shields until the temperature is 2 °C to 3 °C above the melting point of the sample, then reduce the voltage until the shield temperature increases less than 0.5 °C/min.

NOTE 7—In the absence of a thermal shield, an oven can be fitted with a rack to support the pycnometer and hypodermic, and the whole operation of charging the syringe and filling the pycnometer performed in the oven. Weights applied to the syringe plunger reduce the filling time. An internal light and glass door for the oven are aids in this procedure.

11.3 After thermal equilibrium of sample, pycnometer, and syringe has been established, raise the upper shield, swing to one side, and quickly charge the syringe.

11.4 Quickly wipe the needle, swing the syringe over, and lower into the pycnometer. Fill the pycnometer in the usual manner, as given in 10.2. Remove the syringe and needle and

place the pycnometer in the bath for temperature equilibration. Remove excess sample with a thin strip of filter paper or heated draw-off needle, taking care not to remove sample below the calibration mark.

11.5 Close the pycnometer with the glass stopper and immerse it to a point above the calibration mark in the constant-temperature bath, adjusted to the desired temperature within ± 0.01 °C. Periodically, or before the liquid expands into the overflow chamber, remove the stopper, raise the pycnometer sufficiently to expose the calibration mark to view, and readjust the liquid level to the mark by withdrawing liquid with thin strips of filter paper. Continue in this manner until expansion has stopped, indicating that the liquid has reached the temperature of the bath. To minimize errors caused by faulty drainage, do not allow the liquid to expand more than 10 mm above the calibration mark at any time. Allow the contents to equilibrate an additional 10 min and draw the level down exactly to the top of the calibration line, avoiding parallax and using a magnifier, if necessary, to obtain good visibility. Remove any liquid adhering to the walls above the calibration mark with filter paper or a pipe cleaner, barely moistened with a suitable solvent if necessary.

11.6 Replace the glass stopper, and proceed as directed in 10.5.

12. Calculation

12.1 Calculate the density of the sample, corrected to vacuum, by the following equation:

$$\text{Density in vacuum } (d_t), \text{ g/mL} = (F_t)(W_t) + C \quad (2)$$

where:

F_t = calibration factor of the pycnometer at t °C,
 W_t = weight of sample, g, in pycnometer at t °C, and
 C = vacuum correction, obtained from Table 1.

12.2 Calculate the relative density (specific gravity) of the sample by dividing the density, as obtained in 12.1, by the density of water at the reference temperature obtained from Table 2.

13. Precision and Bias

13.1 The precision of the test method as obtained by statistical examination of interlaboratory test results is as follows:

13.1.1 *Repeatability*—The difference between successive test 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 the following value only in 1 case in 20:

Pycnometer Volume, mL	Repeatability, g/mL
10	0.0005

13.1.2 *Reproducibility*—The difference between two single and independent results, obtained by different operators, working in different laboratories on identical test material, would in the long run, in the normal and correct operation of the test method, exceed the following value only in 1 case in 20:

Pycnometer Volume, mL
10Reproducibility, g/mL
0.00014**14. Keywords**

14.1 density; gravity; pycnometer; relative density; specific gravity

NOTE 8—If pycnometers of other than 10 mL in volume are used, or if the temperature of test exceeds 100 °C, this precision statement may not apply.

13.1.3 *Bias*—The difference of results from the established value when compared to pure reference materials is not expected to be more than ± 0.00014 g/mL. Specific bias has not been established by cooperative testing.

SUMMARY OF CHANGES

Subcommittee D02.04 has identified the location of selected changes to this standard since the last issue (D1480 – 12) that may impact the use of this standard. (Approved Dec. 1, 2015.)

(1) Revised water density reference values in **Table 1**.

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