Designation: D792 – 20

Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[1]

This standard is issued under the fixed designation D792; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods describe the determination of the specific gravity (relative density) and density of solid plastics in forms such as sheets, rods, tubes, or molded items.

1.2 Two test methods are described:

1.2.1 *Test Method A*—For testing solid plastics in water, and

1.2.2 *Test Method B*—For testing solid plastics in liquids other than water.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 **Warning—***Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Use caution when handling mercury and mercury-containing products. See the applicable product Safety Data Sheet (SDS) for additional information. The potential exists that selling mercury or mercury-containing products, or both, is prohibited by local or national law. Users must determine legality of sales in their location.*

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This standard is not equivalent to ISO 1183–1 Method A. This test method provides more guidelines on sample weight and dimension. ISO 1183-1 allows testing at an additional temperature of 27 ± 2°C.

1.6 *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]

D618 Practice for Conditioning Plastics for Testing

D891 Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals

D4968 Practice for Annual Review of Test Methods and Specifications for Plastics

D6436 Guide for Reporting Properties for Plastics and Thermoplastic Elastomers

E12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases (Withdrawn 1996)[3]

E456 Terminology Relating to Quality and Statistics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

E2935 Practice for Conducting Equivalence Testing in Laboratory Applications

IEEE/ASTM SI-10 Practice for Use of the International System of Units (SI) (the Modernized Metric System)

3. Terminology

3.1 *General*—The units, symbols, and abbreviations used in these test methods are in accordance with IEEE/ASTM SI-10.

3.1.1 For terms relating to precision and bias and associated issues, the terms used in this test method are in accordance with the definitions in Terminology E456.

3.2 *Definitions:*

3.2.1 *specific gravity (relative density)*—the ratio of the mass of a given volume of the impermeable portion of the material at 23°C to the mass of an equal volume of gas-free

[1] These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and are the direct responsibility of Subcommittee D20.70 on Analytical Methods (Section D20.70.01).

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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] The last approved version of this historical standard is referenced on www.astm.org.

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

distilled or de-mineralized water at the same temperature; the form of expression shall be:

$$\text{Specific gravity (relative density) } 23/23°C \text{ (or sp gr } 23/23°C)$$

NOTE 2—This definition is essentially equivalent to the definition for apparent specific gravity and apparent density in Terminology E12, because the small percentage difference introduced by not correcting for the buoyancy of air is insignificant for most purposes.

3.2.2 *density*—cubic metre of impermeable portion of the material at 23°C. The form of expression shall be:

$$D^{23}, \text{kg/m}^3$$

NOTE 3—The SI unit of density, as defined in IEEE/ASTM SI-10, is kg/m^3. To convert density in g/cm^3 to density in kg/m^3, multiply by 1000.

NOTE 4—To convert specific gravity 23/23°C to density 23°C, kg/m^3, use the following equation:

$$D^{23\,C}, \text{kg/m}^3 = \text{sp gr } 23/23°C \times 997.5$$

Where 997.5 kg/m^3 is the density of water at 23°C.

4. Summary of Test Method

4.1 Determine the mass of a specimen of the solid plastic in air. It is then immersed in a liquid, its apparent mass upon immersion is determined, and its specific gravity (relative density) calculated.

5. Significance and Use

5.1 The specific gravity or density of a solid is a property that is conveniently measured to identify a material, to follow physical changes in a sample, to indicate degree of uniformity among different sampling units or specimens, or to indicate the average density of a large item.

5.2 Changes in density of a single material are due to localized differences in crystallinity, loss of plasticizer, absorption of solvent, or to other causes. It is possible that portions of a sample differ in density because of their differences in crystallinity, thermal history, porosity, and composition (types or proportions of resin, plasticizer, pigment, or filler).

5.3 Density is useful for calculating strength-weight and cost-weight ratios.

6. Sampling

6.1 The sampling units used for the determination of specific gravity (relative density) shall be representative of the quantity of product for which the data are required.

6.1.1 If it is known or suspected that the sample consists of two or more layers or sections having different specific gravities, either complete finished parts or complete cross sections of the parts or shapes shall be used as the specimens, or separate specimens shall be taken and tested from each layer. The specific gravity (relative density) of the total part shall not be obtained by adding the specific gravity of the layers, unless relative percentages of the layers are taken into account.

7. Conditioning

7.1 *Conditioning*—Condition the test specimens at 23 ± 2°C and 50 ± 10 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, unless otherwise specified by the contract or relevant material specifications. In cases of disagreement, the tolerances shall be ±1°C and ±5 % relative humidity.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 10 % relative humidity, unless otherwise specified in this specification or by the contract or relevant material specification. In cases of disagreement, the tolerances shall be ±1°C and ±5 % relative humidity.

TEST METHOD A FOR TESTING SOLID PLASTICS IN WATER (SPECIMENS 1 TO 50 g)

8. Scope

8.1 This test method involves weighing a one-piece specimen of 1 to 50 g in water, using a sinker with plastics that are lighter than water. This test method is suitable for plastics that are wet by, but otherwise not affected by water.

9. Apparatus

9.1 *Analytical Balance*—A balance with a precision of 0.1 mg or better is required for materials having densities less than 1.00 g/cm^3 and sample weights less than 10 grams. For all other materials and sample weights, a balance with precision of 1 mg or better is acceptable. The balance shall be equipped with a stationary support for the immersion vessel above the balance pan (“pan straddle”).

9.1.1 The balance shall provide the precision that all materials tested have three significant figures on density. In case that materials with different densities are tested on one single balance, use the balance that provides at least three significant figures for all materials concerned.

NOTE 5—To ensure that the balance meets the performance requirements, check on zero point and sensitivity frequently and perform periodic calibration.

9.2 *Sample Holder,* corrosion-resistant (for example, wire, gemholder, etc.).

9.3 *Sinker*—A sinker for use with specimens of plastics that have specific gravities less than 1.00. The sinker shall: (*1*) be corrosion-resistant; (*2*) have a specific gravity of not less than 7.0; (*3*) have smooth surfaces and a regular shape; and (*4*) be slightly heavier than necessary to sink the specimen. The sinker shall have an opening to facilitate attachment to the specimen and sample holder.

9.4 *Immersion Vessel*—A beaker or other wide-mouthed vessel for holding the water and immersed specimen.

9.5 *Thermometer*—A thermometer readable to 0.1°C or better.

10. Materials

10.1 *Water*—The water shall be substantially air-free and distilled or de-mineralized water. If this solution does not wet the specimen, Method B shall be used.

NOTE 6—Air in water can be removed by boiling and cooling the water, or by shaking the water under vacuum in a heavy-walled vacuum flask. (**Warning—**Use gloves and shielding.) If the water does not wet the

specimen, add a few drops of a wetting agent into the water.

11. Test Specimen

11.1 The test specimen shall be a single piece of material with a size and shape suitable for the testing apparatus, provided that its volume shall be not less than 1 cm^3 and its surface and edges shall be made smooth. The thickness of the specimen shall be at least 1 mm for each 1 g of weight. A specimen weighing 1 to 5 g was found to be convenient, but specimens up to approximately 50 g are also acceptable (see Note 7). Care shall be taken in cutting specimens to avoid changes in density resulting from compressive stresses or frictional heating.

NOTE 7—Specifications for certain plastics require a particular method of specimen preparation and should be consulted if applicable.

11.2 The specimen shall be free from oil, grease, and other foreign matter.

12. Procedure

12.1 For density calculation, measure and record the water temperature. This is not needed for specific gravity calculation.

12.2 Weigh the specimen in air. Weigh to the nearest 0.1 mg for specimens of mass 1 to 10 g and density less than 1.00 g/cm^3. Weigh to the nearest 1 mg for other specimens.

12.3 If necessary, attach to the balance a piece of fine wire sufficiently long to reach from the hook above the pan to the support for the immersion vessel. In this case attach the specimen to the wire such that it is suspended about 25 mm above the vessel support.

12.3.1 If a wire is used, weigh the specimen in air after hanging from the wire. In this case, record the mass of the specimen, a = (mass of specimen + wire, in air) – (mass of wire in air).

12.4 Mount the immersion vessel on the support, and completely immerse the suspended specimen (and sinkers, if used) in water (see 10.1) at a temperature of 23 ± 2°C. The vessel must not touch sample holder or specimen. Remove any bubbles adhering to the specimen, sample holder, or sinker, by rubbing them with a wire. Pay particular attention to holes in the specimen and sinker. If the bubbles are not removed by this method or if bubbles are continuously formed (as from dissolved gases), the use of vacuum is recommended (see Note 8). Determine the mass of the suspended specimen to the required precision (see 12.2) (see Note 9). Record this apparent mass as b (the mass of the specimen, sinker, if used, and the partially immersed wire in liquid). Unless otherwise specified, weigh rapidly in order to minimize absorption of water by the specimen.

NOTE 8—Some specimens may contain absorbed or dissolved gases, or irregularities which tend to trap air bubbles; any of these may affect the density values obtained. In such cases, the immersed specimen may be subjected to vacuum in a separate vessel until evolution of bubbles has substantially ceased before weighing (see Test Method B). It must also be demonstrated that the use of this technique leads to results of the required degree of precision.

NOTE 9—It may be necessary to change the sensitivity adjustment of the balance to overcome the damping effect of the immersed specimen.

12.5 Weigh the sample holder (and sinker, if used) in water with immersion to the same depth as used in the previous step (Notes 10 and 11). Record this weight as w (mass of the sample holder in liquid).

NOTE 10—If a wire is used, it is convenient to mark the level of immersion by means of a shallow notch filed in the wire. The finer the wire, the greater the tolerance is permitted in adjusting the level of immersion between weighings. With wire Awg No. 36 or finer, disregard its degrees of immersion and, if no sinker is used, use the mass of the wire in air as w.

NOTE 11—If the wire is used and is left attached to the balance arm during a series of determinations, determine the mass a with the aid of a tare on the other arm of the balance or as in 12.3.1. In such cases, care must be taken that the change of mass of the wire (for example, from visible water) between readings does not exceed the desired precision.

12.6 Repeat the procedure for the required number of specimens. Two specimens per sample are recommended. Determine acceptability of number of replicate test specimens by comparing results with precision data given in Tables 1 and 2. Use additional specimens if desired.

13. Calculation

13.1 Calculate the specific gravity of the plastic as follows:

$$\text{sp gr } 23/23°\text{C} = a/(a + w - b)$$

where:

a = apparent mass of specimen, without wire or sinker, in air,

b = apparent mass of specimen (and of sinker, if used) completely immersed and of the wire partially immersed in liquid, and

w = apparent mass of totally immersed sinker (if used) and of partially immersed wire.

13.2 Calculate the density of the plastic as follows:

TABLE 1 Test Method A Specific Gravity Tested in Water

Material	Mean	S_r[A]	S_R[B]	r[C]	R[D]
Polypropylene	0.9007	0.00196	0.00297	0.00555	0.00841
Cellulose Acetate Butyrate	1.1973	0.00232	0.00304	0.00657	0.00860
Polyphenylene Sulfide	1.1708	0.00540	0.00738	0.01528	0.02089
Thermoset	1.3136	0.00271	0.00313	0.00767	0.02171
Polyvinyl Chloride	1.3396	0.00243	0.00615	0.00688	0.01947

[A] S_r = within laboratory standard deviation for the individual material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories:

$$S_r = [[(s_1)^2 + (s_2)^2 \ldots + (s_n)^2]/n]^{1/2}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation: $S_R = [S_r^2 + S_L^2]^{1/2}$ where S_L is the standard deviation of laboratory means.

[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.

[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

TABLE 2 Test Method B Specific Gravity Tested in Liquids Other Than Water

Material	Mean	S_r[A]	S_R[B]	r[C]	R[D]
Polypropylene	0.9023	0.00139	0.00239	0.00393	0.00669
LDPE	0.9215	0.00109	0.00195	0.00308	0.00546
HDPE	0.9678	0.00126	0.00189	0.00356	0.00529
Thermoset	1.3130	0.00160	0.00217	0.00453	0.00608

[A] S_r = within laboratory standard deviation for the individual material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories:

$$S_r = [[(s_1)^2 + (s_2)^2 \ldots + (s_n)^2]/n]^{1/2}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation: $S_R = [S_r^2 + S_L^2]^{1/2}$ where S_L is the standard deviation of laboratory means.
[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.
[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

$$D^{23C}, \text{kg/m}^3 = \text{sp gr } 23/23°\text{C} \times 997.5$$

13.3 If the temperature of the water is different than 23°C, use the density of water listed in Table 3 directly, or use the following equations to calculate the density of water at testing temperature:

$$M = \Delta D/\Delta t \quad (1)$$

$$D(\text{conversion to } 23°\text{C}),\ \text{kg/m}^3 \quad (2)$$

$$= \text{sp gr } t_a/t_w \times [997.5 + (t_w - 23) \times M]$$

and

$$\text{sp gr } 23/23 = D\ (\text{conversion to } 23°\text{C})/997.5 \quad (3)$$

where:

M = slope,
ΔD = difference between the lowest and highest temperature tolerance for the standard density of water (D @ 21°C – D @ 25°C),
Δt = difference between the highest and lowest temperature tolerance recommended, (21°C–25°C),
t_a = temperature of air, and
t_w = temperature of water.

14. Report

14.1 Report the following information:

14.1.1 Complete identification of the material or product tested, including method of specimen preparation and conditioning,

14.1.2 Average specific gravity (relative density) for all specimens from a sampling unit corrected to 23.0°C (Table 3) are reported as sp gr 23/23°C = ___, or average density reported as D^{23C} = ___ kg/m^3,

NOTE 12—Reporting density in g/cm^3 is also acceptable provided that it is agreed upon by the users.

14.1.3 A measure of the degree of variation of specific gravity or density within the sampling unit such as the standard deviation and number of determinations on a homogeneous material or the averages plus these measures of dispersion on different layers or areas of a nonhomogeneous product,

14.1.4 Report the temperature of the water.

14.1.5 Report the density and specific gravity with three significant figures.

14.1.6 Any evidence of porosity of the material or specimen,

14.1.7 The method of test (that is, Method A of Test Method D792), and

14.1.8 Date of test.

15. Precision and Bias

15.1 See Section 23.

TEST METHOD B FOR TESTING SOLID PLASTICS IN LIQUIDS OTHER THAN WATER (SPECIMENS 1 TO 50 g)

16. Scope

16.1 Test Method B uses a liquid other than water for testing one-piece specimens, 1 to 50 g, of plastics that are affected by water or are lighter than water.

17. Apparatus

17.1 The apparatus shall include the balance, wire, and immersion vessel of Section 8, and, optionally, the following:

17.2 *Pycnometer with Thermometer*—A 25-mL specific gravity bottle with thermometer, or

17.3 *Pycnometer*—A pycnometer of the Weld type, preferably with a capacity of about 25 mL and an external cap over the stopper.

17.4 *Thermometer*—A thermometer having ten divisions per degree Celsius over a temperature range of not less than 5°C or 10°F above and below the standard temperature, and having an ice point for calibration. A thermometer short enough to be

TABLE 3 Standard Density of Water[A]

°C	ρ=/kg m^{-3}									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
21	997.9948	9731	9513	9294	9073	8852	8630	8406	8182	7957
22	997.7730	7503	7275	7045	6815	6584	6351	6118	5883	5648
23	997.5412	5174	4936	4697	4456	4215	3973	3730	3485	3240
24	997.2994	2747	2499	2250	2000	1749	1497	1244	0990	0735
25	997.0480	0223	9965[B]	9707[B]	9447[B]	9186[B]	8925[B]	8663[B]	8399[B]	8135[B]

[A] Obtained from *CRC Handbook of Chemistry and Physics*, 78th edition, 1997-1998.
[B] The leading figure decreases by 1.

handled inside the balance case will be found convenient. ASTM Thermometer S63C (see Specification E2251) and Anschütz-type thermometers have been found satisfactory for this purpose.

17.5 *Constant-Temperature Bath*—An appropriate constant-temperature bath adjusted to maintain a temperature of 23 ± 0.1°C.

18. Materials

18.1 *Immersion Liquid*—The liquid used shall not dissolve, swell, or otherwise affect the specimen, but shall wet it and shall have a specific gravity less than that of the specimen. In addition, the immersion liquid shall be non-hygroscopic, has a low vapor pressure, a low viscosity, and a high flash point, and shall leave little or no waxy or tarry residue on evaporation. A narrow cut distilled from kerosine meets these requirements for many plastics. The specific gravity 23/23°C of the immersion liquid shall be determined shortly before and after each use in this method to a precision of at least 0.1 % relative, unless it has been established experimentally in the particular application that a lesser frequency of determination also provides the desired precision.

NOTE 13—For the determination of the specific gravity of the liquid, the use of a standard plummet of known volume or of Method A, C, or D of Test Methods D891, using the modifications required to give specific gravity 23/23°C instead of specific gravity 60/60°F, is recommended. One suggested procedure is the following:

If a constant-temperature water bath is not available, determine the mass of the clean, dry pycnometer with thermometer to the nearest 0.1 mg on an analytical balance. Fill the pycnometer with water (10.1) cooler than 23°C. Insert the thermometer-stopper, causing excess water to be expelled through the side arm. Permit the filled bottle to warm in air until the thermometer reads 23.0°C. Remove the drop of water at the tip of the side arm with a bit of filter paper, taking care not to draw any liquid from within the capillary, place the cap over the side arm, wipe the outside carefully, and determine the mass of the filled bottle again to the nearest 0.2 mg. Empty the pycnometer, dry, and fill with immersion liquid. Determine the mass with the liquid in the same manner as was done with the water. Calculate the specific gravity 23/23°C of the liquid, *d,* as follows:

$$d = (b - e)/(w - e)$$

where:

e = apparent mass of empty pycnometer,
w = apparent mass of pycnometer filled with water at 23.0°C, and
b = apparent mass of pycnometer filled with liquid at 23.0°C.

If a constant-temperature water bath is available, a pycnometer without a thermometer is optional to used (compare 30.2).

NOTE 14—One standard object which has been found satisfactory for this purpose is the Reimann Thermometer Plummet. These are normally supplied calibrated for measurements at temperatures other than 23/23°C, so that recalibration is not necessary for the purposes of these methods.

19. Test Specimen

19.1 See Section 11.

20. Procedure

20.1 The procedure shall be similar to Section 12, except for the choice of immersion liquid, and the temperature during the immersed weighing (12.3) shall be 23 ± 0.5°C.

21. Calculation

21.1 The calculations shall be similar to Section 13, except that *d,* the specific gravity 23/23°C of the liquid, shall be placed in the numerator: (see 13.1)

$$Sp\,gr\,23/23°C = (a \times d)/(a + w - b)$$

22. Report

22.1 See Section 14.

23. Precision and Bias

23.1 Tables 1 and 2 are based on an interlaboratory study[4] conducted in 1985 in accordance with Practice E691, involving 5 materials tested with Test Method A by six laboratories or four materials tested with Test Method B by six laboratories. Each test result was based on two individual determinations and each laboratory obtained four test results for each material. (**Warning—**Do not apply the data of Table 1 and Table 2 to acceptance or rejection of materials, as these data apply only to the materials tested in the round robin and are unlikely to be rigorously representative of other lots, formulations, conditions, materials, or laboratories. Users of this test method need to apply the principles outlined in Practice E691 to generate data specific to the materials and laboratory (or between specific laboratories).)

23.2 For information on equivalence, see Practice E2935.

23.3 There are no recognized standards by which to estimate bias of this test method.

24. Keywords

24.1 density; relative density; specific gravity

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1133.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D792 - 13) that may impact the use of this standard. (July 1, 2020)

(1) 1.5—Added Mercury warning.
(2) 2.1—Removed standard E1; Added E456, E2251, E2935.
(3) 3.1.1—Added Precision and Bias terminology.
(4) Note 5—Made Note 5 into 9.1.1.
(5) 10.1.1—Added wetting information.
(6) Note 7—Removed wetting information.
(7) 12.1—Added temperature is for Density calculation.
(8) Note 9—Made Note 9 into 12.3.1.
(9) 17.4—Updated thermometer information for Liquid-in-Glass Thermometers.
(10) Note 15—Removed permissive language.
(11) 23.1—Updated precision and bias terminology.
(12) 23.2—Removed old precision and bias terminology.
(13) 23.3—Added equivalence information.