Designation: D 792 – 07

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

This standard is issued under the fixed designation D 792; 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 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.

NOTE 1—Alternatively, Test Method D 1505 may be applied to many such forms, as well as to films and sheeting.

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

1.4 *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.*

NOTE 2—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 891 Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals[3]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[2]

D 1622 Test Method for Apparent Density of Rigid Cellular Plastics[2]

D 1898 Practice for Sampling of Plastics[2]

E 1 Specification for ASTM Thermometers[4]

E 12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases[5]

E 380 Practice for Use of the International System of Units (SI) (the Modernized Metric System)[6]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[6]

3. Terminology

3.1 *General*—The units, symbols, and abbreviations used in these test methods are in accordance with Practice E 380.

3.2 *Definitions:*

3.2.1 *specific gravity (relative density)*—the ratio of the mass in air of a unit volume of the impermeable portion of the material at 23°C to the mass in air of equal density of an equal volume of gas-free distilled water at the same temperature. The form of expression shall be:

Specific gravity (relative density) 23/23°C
(or sp gr 23/23°C)

NOTE 3—This definition is essentially equivalent to the definition for apparent specific gravity and apparent density in Terminology E 12, because the small percentage difference introduced by not correcting for the buoyancy of air is insignificant for most purposes.

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

D^{23}, kg/m^3 (Notes 2-4)

NOTE 4—The SI unit of density, as defined in Practice E 380 is kg/m^3. To convert density in g/cm^3 to density in kg/m^3, multiply by 1000.

NOTE 5—Specific gravity 23/23°C can be converted to density 23°C, kg/m^3, by use of the following equation:

$$D^{23\,C},\ kg/m^3 = \text{sp gr } 23/23°C \times 997.6$$

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 can be measured conveniently to identify a material, to

[1] These test methods are under the jurisdiction of ASTM Committee D-20 on Plastics and are the direct responsibility of Subcommittee D20.70 on Analytical Methods (Section D20.70.01).

Current edition approved Feb. 10, 2007. Published March 2007. Originally published as D 792 – 44. Last previous edition D 792 – 04.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 15.05.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] Discontinued; see *1995 Annual Book of ASTM Standards*, Vol 15.05.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

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

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 specimen may be due to changes in crystallinity, loss of plasticizer, absorption of solvent, or to other causes. Portions of a sample may differ in density because of difference in crystallinity, thermal history, porosity, and composition (types or proportions of resin, plasticizer, pigment, or filler).

NOTE 6—Reference is made to Test Method D 1622.

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, in accordance with Practice D 1898.

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 cannot 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 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be 1°C and ±2 % relative humidity.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be 1°C and ±2 % 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 within 0.1 mg, accuracy within 0.05 % relative (that is, 0.05 % of the mass of the specimen in air), and equipped with a stationary support for the immersion vessel above the balance pan (“pan straddle”).

NOTE 7—Assurance that the balance meets the performance requirements should be provided by frequent checks on adjustments of zero point and sensitivity and by periodic calibration for absolute accuracy, using standard masses.

9.2 *Sample Holder*, corrosion-resistant.

9.3 *Sinker*—A sinker for use with specimens of plastics that have specific gravities less than 1.000. 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 should have an opening to facilitate attachment to the specimen and wire.

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

9.5 *Thermometer*—A thermometer with an accuracy of ±1°C is required if the test is not performed in the standard laboratory atmosphere of Practice D 618, (refer to 17.4).

10. Materials

10.1 *Water*—The water shall be substantially air-free and distilled or demineralized water.

NOTE 8—Water may be rendered substantially air-free by boiling and cooling or by shaking under vacuum in a heavy-walled vacuum flask. (**Precaution:** Use gloves and shielding.) If the water does not wet the specimen, a few drops of a wetting agent shall be added. If this solution does not wet the specimen, Method B shall be used.

11. Test Specimen

11.1 The test specimen shall be a single piece of the material under test of any size and shape that can conveniently be prepared and tested, 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 should be at least 1 mm for each 1 g of weight. A specimen weighing 1 to 5 g usually will be found convenient, but specimens up to approximately 50 g may be used (Note 9). Care should be taken in cutting specimens to avoid changes in density resulting from compressive stresses or frictional heating.

NOTE 9—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 Measure and record the water temperature.

12.2 Weigh the specimen in air to the nearest 0.1 mg for specimens of mass 1 to 10 g or to the nearest mg for specimens of mass more than 10 to 50 g.

12.3 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. Attach the specimen to the wire such that it is suspended about 25 mm above the vessel support.

NOTE 10—The specimen may be weighed 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 (10.1) at a temperature of 23 ± 2°C. The vessel must not touch wire or specimen. Remove any bubbles adhering to the specimen, wire, or sinker, paying particular attention to holes in the specimen and sinker. Usually these bubbles can be removed by rubbing them with another wire. If

the bubbles cannot be removed by this method or if bubbles are continuously formed (as from dissolved gases), the use of vacuum is recommended (Note 12). Determine the mass of the suspended specimen to the required precision (12.2) (Note 11). 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 11—It may be necessary to change the sensitivity adjustment of the balance to overcome the damping effect of the immersed specimen.

NOTE 12—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.

12.5 Weigh the wire (and sinker, if used) in water with immersion to the same depth as used in the previous step (Notes 13 and 14). Record this height as *w* (mass of the wire in liquid).

NOTE 13—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 which may be 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 14—If the wire is left attached to the balance arm during a series of determinations, the mass *a* may be determined either with the aid of a tare on the other arm of the balance or as in Note 12. 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 of Section 23. Additional specimens may be required to give the desired precision.

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:

$$D^{23C}, \text{ kg/m}^3 = \text{sp gr } 23/23°\text{C} \times 997.6$$

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, reported as sp gr 23/23°C = ___, or average density reported as D^{23C} = ___ kg/m^3,

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 Any evidence of porosity of the material or specimen,

14.1.6 The method of test (Method A of Methods D 792), and

14.1.7 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 which 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:

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 is the 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 is the 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 is the within-laboratory critical interval between two test results = 2.8 × S_r.

[D] R is the 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	0.00676
LDPE	0.9215	0.00109	0.00195	0.00308	0.00552
HDPE	0.9678	0.00126	0.00189	0.00356	0.01007
Thermoset	1.3130	0.00160	0.00217	0.00453	0.01282

[A] S_r is the 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 is the 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 is the within-laboratory critical interval between two test results = $2.8 \times S_r$.
[D] R is the between-laboratories critical interval between two test results = $2.8 \times S_R$.

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 not fewer than four divisions per °C 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 handled inside the balance case will be found convenient. ASTM Thermometer 23C (see Specification E 1) 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 should wet it and should have a specific gravity less than that of the specimen. In addition, the immersion liquid should be nonhygroscopic, have a low vapor pressure, a low viscosity, and a high flash point, and should 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 can be used to assure the desired precision.

NOTE 15—For the determination of the specific gravity of the liquid, the use of a standard plummet of known volume (Note 15) or of Method A, C, or D of Test Methods D 891, 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 and determine the mass with the other 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 may be used (compare 30.2).

NOTE 16—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 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:

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

22. Report

22.1 See Section 14.

23. Precision and Bias

23.1 Tables 1 and 2 are based on an interlaboratory study[7] conducted in 1985 in accordance with Practice E 691, involving 5 materials tested with Test Method A by 6 laboratories or 4 materials tested with Test Method B by 6 laboratories. Each test result was based on two individual determinations and each laboratory obtained four test results for each material.

[7] Supporting data are available from ASTM Headquarters. Request RR:D20-1133.

NOTE 17—**Caution:** The explanations of *r* and *R* are only intended to present a meaningful way of considering the approximate precision of these test methods. The data of Tables 1 and 2 should not be applied 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 should apply the principles outlined in Practice E 691 to generate data specific to the materials and laboratory (or between specific laboratories). The principles of 23.2-23.2.3 would then be valid for such data.

23.2 Concept of *r* and *R* in Tables 1 and 2—If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages from 4 test results for each material, then:

23.2.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the *r* value for that material. The concept *r* is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

23.2.2 *Reproducibility*—Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the *R* value for that material. The concept *R* is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

23.2.3 Any judgment in accordance with 23.2.1 or 23.2.2 would have an approximate 95 % (0.95) probability of being correct.

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

SUMMARY OF CHANGES

Committee D-20 has identified the location of selected changes to these test methods since the last issue that may impact the use of these test methods.

D 792 – 98:

(*1*) An ISO equivalency statement (Note 2) was added and subsequent notes were renumbered.

(*2*) Practice E 380 was added to the text.

(*3*) Paragraph 9.2 was revised to include the identification of a sample holder.

(*4*) "And" was added to 10.1.

(*5*) Paragraphs 12.1 and 14.1.4 were added and subsequent paragraphs were renumbered.

(*6*) "I_r" and I_R were changed to "*r*" and "*R*" in Tables 1 and 2.

(*7*) Section 23 was rewritten.