Designation: C693 – 93 (Reapproved 2013)

Standard Test Method for Density of Glass by Buoyancy[1]

This standard is issued under the fixed designation C693; 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 of the density of glasses at or near 25°C, by buoyancy.

1.2 *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:*

E12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases (Withdrawn 1996)[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *density of solids*—the mass of a unit volume of a material at a specified temperature. The units shall be stated as grams per cubic centimetre (see Terminology E12).

4. Significance and Use

4.1 Density as a fundamental property of glass has basic significance. It is useful in the physical description of the glass and as essential data for research, development, engineering, and production.

5. Apparatus

5.1 *Analytical Balance,* with sensitivity and accuracy of 0.1 mg.

5.2 *Beaker,* of convenient capacity (250 to 750 cm^3) to fit inside the balance chamber and allow immersion of the basket or wire loop specimen holder in distilled water.

5.3 *Thermometers,* calibrated (20 to 30°C), sensitive to 0.1°C for determining air and water temperatures.

5.4 *Nickel-Chromium-Iron or Platinum-Alloy Wire,* less than 0.2-mm diameter for suspending the specimen either in a basket or a loop made of the same wire. The suspension wire shall be cleaned by degreasing or heating in a vacuum.[3] An acceptable alternative method of cleaning the platinum-alloy wire is to heat in an oxidizing gas flame until there is no longer any color emitted from the gases passing around the wire.

5.5 *Weights,* with accuracy of 0.1 mg.

5.6 *Barometer,* with sensitivity of 1-mm Hg (optional, see Note 3).

6. Reagent

6.1 *Distilled Water,* fresh, boiled, and used within 24 h, allowed to stabilize at balance air temperature for at least 2 h in the beaker.

7. Test Specimen

7.1 Specimens weighing about 20 g, with a minimum of seeds or other inclusions (Note 1), shall be taken or cut from the sample object, preferably in cylindrical or rectangular bar form with smooth, slightly rounded surfaces having no cracks or sharp edges.

NOTE 1—For a specimen of 20 g with a density of approximately 2.5 g/cm^3, a gaseous void of diameter 2 mm will cause an error in measured density of 0.05 %.

7.2 The specimens shall be cleaned, handling them with tweezers throughout subsequent operations, by immersion preferably in an ultrasonic bath of hot nitric acid, chromic-sulfuric acid, or organic degreasing solvent, followed by a rinsing in alcohol and distilled water. For samples only soiled by ordinary handling or exposure, adequate cleaning may be obtained using a warm 2 % volume MICRO-brand[4] detergent, followed by a deionized or distilled water rinse.

8. Procedure

8.1 Hold the specimens and covered beaker of boiled distilled water near the laboratory balance until the water has cooled to ambient temperature before weighing.

[1] This test method is under the jurisdiction of ASTM Committee C14 on Glass and Glass Products and is the direct responsibility of Subcommittee C14.04 on Physical and Mechanical Properties.

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

[3] Bowman, H. A., and Schoonover, R. M., "Procedure for High Precision Density Determinations by Hydrostatic Weighing." *Journal of Research*, National Bureau of Standards, Vol 71C, No. 3, July–August 1967, pp. 179–198.

[4] Manufactured by International Products Corporation, PO Box 70, Burlington, NJ 08016.

TABLE 1 Density of Dry Air, g/cm³

Temperature, °C	Pressure, mm Hg					
	720	730	740	750	760	770
20	0.001 141	0.001 157	0.001 173	0.001 189	0.001 205	0.001 221
21	137	153	169	185	201	216
22	134	149	165	181	197	212
23	130	145	161	177	193	208
24	126	142	157	173	189	204
25	122	138	153	169	185	200
26	118	134	149	165	181	196
27	115	130	146	161	177	192
28	111	126	142	157	173	188
29	107	123	138	153	169	184
30	104	119	134	150	165	180

8.2 Read the laboratory air temperature to the nearest 1°C. Read the barometric pressure to the nearest 1-mm Hg. A fixed laboratory average barometric pressure estimate is an acceptable alternative to the barometric pressure measurement (see Note 3). Determine the density, ρ_A, of the air from Table 1.

8.3 Weigh the glass specimen in air to the nearest 0.1 mg and record as W_A.

8.4 Place the beaker of water with immersed thermometer on a platform supporting it over the balance pan so that the pan or balance arm is free to swing.

8.5 Place the specimen in the basket or loop holder and hang this holder from the balance arm by means of a suitable hook and the suspension wire. Immerse the basket and specimen by raising the beaker of distilled water until the surface of the water is at a predetermined reference position on the suspension wire.

NOTE 2—Before use, the beaker of water should be covered to minimize dust. Just before the weighing of the basket and specimen, the water surface near the suspension wire may be cleaned by a vacuum nozzle or pipet technique. The suspended assembly should be agitated slightly with a vertical motion to wet the suspension wire above the meniscus at the reference position and to ensure that no air bubbles are adhering to the glass or holder.

NOTE 3—A laboratory average barometric pressure estimate may be determined from the elevation of the laboratory estimated to the nearest 170 m (500 ft). The national average barometric pressure corrected to sea level (0 elevation) is 760-mm Hg. For each 341-m (1000-ft) increase in elevation, barometric pressure decreases by approximately 25-Hg. For glass densities in the range of 2 to 6 g/cm^3 , a barometric pressure estimate based on this relationship will result in density measurement bias of less than 0.004 % under normal atmospheric pressure variations.

8.6 Weigh the glass and holder in the distilled water to the nearest 0.1 mg and record as W_T.

8.7 Remove the glass from the holder. At the reference position, weigh the empty holder in the distilled water, to the nearest 0.1 mg and record as W_O.

8.8 Read the distilled water temperature to the nearest 0.1°C and determine the water density from Table 2. Record this as ρ_W.

9. Calculation

9.1 Calculate the weight of the specimen in water, W_W, as follows:

$$W_W = W_T - W_O \quad (1)$$

9.2 Calculate the glass density, ρ, at the average air-water laboratory temperature, T_L, as follows:

$$\rho = \frac{(W_A\rho_W - W_W\rho_A)}{(W_A - W_W)} \quad (2)$$

9.3 Calculate the glass density, ρ_S, at a standard reference temperature, T_S, as follows:

$$\rho_S = \frac{\rho}{1+3\alpha(T_S - T_L)} \quad (3)$$

where α is the approximate instantaneous coefficient of linear thermal expansion at T_S.

NOTE 4—For low expansion glasses or small temperature intervals or both, this correction is not required.

10. Report

10.1 Report the following information:

10.1.1 Identification of test sample, production, manufacturer, glass type, and so forth as required,

10.1.2 Density of glass, ρ or ρ_S, in grams per cubic centimetre,

10.1.3 Temperature, T_S or T_L, for which glass density is reported,

10.1.4 Thermal history of specimen. If unknown, it should be so stated, and

10.1.5 Estimate of the volume of voids and inclusions.

11. Precision and Bias

11.1 *Precision:*

11.1.1 With proper precautions taken to minimize dissolved air in the water and adhering air bubbles during immersion of the specimen and holder, this procedure will yield glass density to a standard deviation within ±0.1 %.

11.1.2 With precautions taken to minimize air-water temperature differences and to correct for temperature, etc., effects on air and water density, this procedure will yield glass density to a standard deviation close to ±0.03 %.

11.2 *Bias*—Three glass density standard reference materials are available from the Standard Reference Materials Program, National Institute of Standards and Technology. Bias can be experimentally assessed by measurement of density by this procedure for these glasses.

TABLE 2 Density of Air-Free Water, g/cm^3

Temperature, °C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
20	0.998 20	818	816	814	812	810	808	806	804	801
21	799	797	795	793	791	788	786	784	782	779
22	777	775	773	770	768	766	763	761	759	756
23	754	752	749	747	744	742	740	737	735	732
24	730	727	725	722	720	717	715	712	710	707
25	705	702	700	697	694	692	689	687	684	681
26	679	676	673	671	668	665	662	660	657	654
27	652	649	646	643	640	638	635	632	629	626
28	624	621	618	615	612	609	606	603	600	598
29	595	592	589	586	583	580	577	574	571	568
30	565	562	559	556	553	550	547	543	540	537