



Designation: D 854 – 00

## Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer<sup>1</sup>

This standard is issued under the fixed designation D 854; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope \*

1.1 These test methods cover the determination of the specific gravity of soil solids that pass the 4.75-mm (No. 4) sieve, by means of a water pycnometer. When the soil contains particles larger than the 4.75-mm sieve, Test Method C 127 shall be used for the soil solids retained on the 4.75-mm sieve and these test methods shall be used for the soil solids passing the 4.75-mm sieve.

1.1.1 Soil solids for these test methods do not include solids which can be altered by these methods, contaminated with a substance that prohibits the use of these methods, or are highly organic soil solids, such as fibrous matter which floats in water.

NOTE 1—The use of Test Method D 5550 may be used to determine the specific gravity of soil solids having solids which readily dissolve in water or float in water, or where it is impracticable to use water.

1.2 Two methods for performing the specific gravity are provided. The method to be used shall be specified by the requesting authority, except when testing the types of soils listed in 1.2.1

1.2.1 *Method A*—Procedure for Moist Specimens, described in 9.2. This procedure is the preferred method. For organic soils; highly plastic, fine grained soils; tropical soils; and soils containing halloysite, Method A shall be used.

1.2.2 *Method B*—Procedure for Oven-Dry Specimens, described in 9.3.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D 6026.

1.3.1 The procedures used to specify how data are collected/recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering design.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in these test methods.

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.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate<sup>2</sup>
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>3</sup>
- D 1140 Test Method for Amount of Material in Soils Finer Than the No. 200 (75- $\mu$ m) Sieve<sup>3</sup>
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass<sup>3</sup>
- D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>3</sup>
- D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction<sup>3</sup>
- D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Related Construction Materials Testing<sup>3</sup>
- D 5550 Test Method for Specific Gravity of Soil Solids by Gas Pycnometer<sup>3</sup>
- D 6026 Practice for Using Significant Digits in Geotechnical Data<sup>4</sup>
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>5</sup>
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods<sup>5</sup>
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method<sup>5</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in these test

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.08.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.09.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 14.02.

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



methods, refer to Terminology D 653.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *specific gravity of soil solids,  $G_s$ ,  $n$* —the ratio of the mass of a unit volume of a soil solids to the mass of the same volume of gas-free distilled water at 20°C.

## 4. Significance and Use

4.1 The specific gravity of a soil solids is used in calculating the phase relationships of soils, such as void ratio and degree of saturation.

4.1.1 The specific gravity of soil solids is used to calculate the density of the soil solids. This is done by multiplying its specific gravity by the density of water (at proper temperature).

4.2 The term soil solids is typically assumed to mean naturally occurring mineral particles or soil like particles that are not readily soluble in water. Therefore, the specific gravity of soil solids containing extraneous matter, such as cement, lime, and the like, water-soluble matter, such as sodium chloride, and soils containing matter with a specific gravity less than one, typically require special treatment (see Note 1) or a qualified definition of their specific gravity.

4.3 The balances, pycnometer sizes, and specimen masses are established to obtain test results with three significant digits.

NOTE 2—The quality of the result produced by these test methods is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of these test methods are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

## 5. Apparatus

5.1 *Pycnometer*—The water pycnometer shall be either a stoppered flask, stoppered iodine flask, or volumetric flask with a minimum capacity of 250 mL. The volume of the pycnometer must be 2 to 3 times greater than the volume of the soil-water mixture used during the deairing portion of the test.

5.1.1 The stoppered flask mechanically sets the volume. The stoppered iodine flask has a flared collar that allows the stopper to be placed at an angle during thermal equilibration and prevents water from spilling down the sides of the flask when the stopper is installed. The wetting the outside of the flask is undesirable because it creates changes in the thermal equilibrium. When using a stopper flask, make sure that the stopper is properly labeled to correspond to the flask.

5.2 *Balance*—Meeting the requirements of Specification D 4753, class GP1. This balance has a readability of 0.01 g and capacity of at least 2000 g.

5.3 *Drying Oven*—Thermostatically controlled oven, capable of maintaining a uniform temperature of  $110 \pm 5^\circ\text{C}$  throughout the drying chamber. These requirements usually require the use of a forced-draft oven.

5.4 *Thermometer*—Thermometer capable of measuring the temperature range within which the test is being performed, readable to the nearest  $0.1^\circ\text{C}$  and an immersion depth ranging between 25 to 80 mm. Full immersion thermometers shall not be used. Either a general-purpose precision mercury thermom-

eter or a digital thermometer with a  $-1$  to  $57^\circ\text{C}$  range will meet this requirement.

5.5 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulfate.

NOTE 3—It is preferable to use a desiccant that changes color to indicate when it needs reconstitution.

5.6 *Entrapped Air Removal Apparatus*—To remove entrapped air (deairing process), use one of the following:

5.6.1 *Hot Plate or Bunsen Burner*, capable of maintaining a temperature adequate to boil water.

5.6.2 *Vacuum System*, a vacuum pump or water aspirator, capable of producing a partial vacuum of 100 mm of mercury (Hg) or less absolute pressure.

NOTE 4—A partial vacuum of 100 mm Hg absolute pressure is approximately equivalent to a 660 mm (26 in.) Hg reading on vacuum gauge at sea level.

5.7 *Insulated Container*—A Styrofoam cooler and cover or equivalent container that can hold between three and six pycnometers plus a beaker, a water bottle, and a thermometer. This is required to maintain a controlled temperature environment where changes will be uniform and gradual.

5.8 *Funnel*—A non-corrosive smooth surface funnel with a stem that extends past the calibration mark on the volumetric flask or stoppered seal on the stoppered flasks. The diameter of the stem of the funnel must be large enough that soil solids will easily pass through.

5.9 *Pycnometer Filling Tube with Lateral Vents (optional)*—A device to assist in adding deaired water to the pycnometer without disturbing the soil-water mixture. The device may be fabricated as follows. Plug a  $\frac{1}{4}$  to  $\frac{3}{8}$  in. diameter plastic tube at one end and cut two small vents (notches) just above the plug. The vents should be perpendicular to the axis of the tube and diametrically opposed. Connect a valve to the other end of the tube and run a line to the valve from a supply of deaired water.

5.10 *Sieve*—No. 4 (4.75 mm) conforming to the requirements of Specification E 11.

5.11 *Blender (optional)*—A blender with mixing blades built into the base of the mixing container.<sup>6</sup>

5.12 *Miscellaneous Equipment*, such as a computer or calculator (optional), specimen dishes, and insulated gloves.

## 6. Reagents

6.1 *Purity of Water*—Distilled water is used in this test method. This water may be purchased and is readily available at most grocery stores; hereafter, distilled water will be referred to as water.

## 7. Test Specimen

7.1 The test specimen may be moist or oven-dry soil and shall be representative of the soil solids that passes the U. S. Standard No. 4 sieve in the total sample. Table 1 gives guidelines on recommended dry soil mass versus soil type and pycnometer size.

<sup>6</sup> Manufacturers of such blenders include, but are not limited to, Waring or Osterizer.

**TABLE 1 Recommended Mass for Test Specimen**

Soil Type	Specimen Dry Mass (g) When Using 250 mL Pycnometer	Specimen Dry Mass (g) When Using 500 mL Pycnometer
SP, SP-SM	60 ± 10	100 ± 10
SP-SC, SM, SC	45 ± 10	75 ± 10
Silt or Clay	35 ± 5	50 ± 10

7.1.1 Two important factors concerning the amount of soil solids being tested are as follows. First, the mass of the soil solids divided by its specific gravity will yield four-significant digits. Secondly, the mixture of soil solids and water is a slurry not a highly viscous fluid (thick paint) during the deairing process.

## 8. Calibration of Pycnometer

8.1 Determine the mass of the clean and dry pycnometer to the nearest 0.01 g (typically five significant digits). Repeat this determination five times. One balance should be used for all of the mass measurements. Determine and record the average and standard deviation. The standard deviation shall be less than or equal to 0.02 g. If it is greater, attempt additional measurements or use a more stable or precise balance.

8.2 Fill the pycnometer with deaired water to above or below the calibration mark depending on the type of pycnometer and laboratory preference to add or remove water.

8.2.1 It is recommended that water be removed to bring the water level to the calibration mark. The removal method reduces the chances of altering the thermal equilibrium by reducing the number of times the insulated container is opened.

8.2.2 The water must be deaired to ensure that there are no air bubbles in the water. The water may be deaired using either boiling, vacuum, combination of vacuum and heat, or a deairing device. This deaired water should not be used until it has equilibrated to room temperature. Also, this water shall be added to the pycnometer following the guidance given in 9.6.

8.3 Up to six pycnometers can be calibrated concurrently in each insulated container. Put the pycnometer(s) into a covered insulated container along with the thermometer (in a beaker of water), stopper(s) (if a stoppered pycnometer is being used), and deaired water in a bottle along with either an eyedropper or pipette. Let the pycnometer(s) come to thermal equilibrium (for at least 3 h). The equilibrium temperature should be within 4°C of room temperature and between 15 and 30°C.

8.4 Move the insulated container near the balance or vice versa. Open the container and remove one pycnometer. Only the rim of the pycnometer shall be touched as to prevent the heat from handling changing the thermal equilibrium. Either work in the container or place the pycnometer on an insulated block (Styrofoam) while making water level adjustments.

8.4.1 If using a volumetric flask as a pycnometer, adjust the water to the calibration mark, with the bottom of the meniscus level with the mark. If water has to be added, use the thermally equilibrated water from the insulated container. If water has to be removed, use a small suction tube or paper towel. Check for and remove any water beads on the pycnometer stem or on the exterior of the flask. Measure and record the mass of pycnometer and water to the nearest 0.01 g.

8.4.2 If a stoppered flask is used, place the stopper in the

bottle, then remove the excess water using an eyedropper. Dry the rim using a paper towel. Be sure the entire exterior of the flask is dry. Measure and record the mass of pycnometer and water to the nearest 0.01 g.

8.5 Measure and record the temperature of the water to the nearest 0.1°C using the thermometer that has been thermally equilibrated in the insulated container. Insert the thermometer to the appropriate depth of immersion (see 5.4). Return the pycnometer to the insulated container. Repeat the measurements for all pycnometers in the container.

8.6 Readjust the water level in each pycnometer to prepare for the next calibration and allow the pycnometers to thermally equilibrate (for at least 3 h). Repeat the procedure to obtain five independent measurements on each pycnometer. The temperatures do not need to bracket any particular temperature range.

8.7 Using each of these five data points, compute the calibrated volume of each pycnometer,  $V_p$ , using the following equation:

$$V_p = \frac{(M_{pw,c} - M_p)}{\rho_{w,c}} \quad (1)$$

where:

$M_{pw,c}$  = the mass of the pycnometer and water at the calibration temperature, g,

$M_p$  = the average mass of the dry pycnometer at calibration, g, and

$\rho_{w,c}$  = the mass density of water at the calibration temperature g/mL, (Table 2).

8.8 Calculate the average and the standard deviation of the five volume determinations. The standard deviation shall be less than or equal to 0.05 mL (rounded to two decimal places). If the standard deviation is greater than 0.05 mL, the calibration procedure has too much variability and will not yield accurate specific gravity determinations. Evaluate areas of possible refinement (adjusting the volume to the calibration mark, achieving temperature equilibrium, measuring temperature, deairing method or changing to the stoppered flasks) and revise the procedure until the standard deviation is less than or equal to 0.05 mL.

## 9. Procedure

9.1 *Pycnometer Mass*—Using the same balance used to calibrate the pycnometer, verify that the mass of the pycnometer is within 0.06 g of the average calibrated mass. If it is not, re-calibrate the dry mass of the pycnometer.

9.2 *Method A—Procedure for Moist Specimens*:

9.2.1 Determine the water content of a portion of the sample in accordance with Test Method D 2216. Using this water content, calculate the range of wet masses for the specific gravity specimen in accordance with 7.1. From the sample, obtain a specimen within this range. Do not sample to obtain an exact predetermined mass.

9.2.2 Disperse the soil using a blender or equivalent device to disperse the soil. Add the soil to about 100 mL of water. The minimum volume of slurry that can be prepared by this equipment will typically require using a 500-mL pycnometer.

9.2.3 Using the funnel, pour the slurry into the pycnometer. Rinse any soil particles remaining on the funnel into the pycnometer using a wash/spray squirt bottle.

**TABLE 2 Density of Water and Temperature Coefficient (K) for Various Temperatures<sup>A</sup>**

Temperature (°C)	Density (g/mL) <sup>B</sup>	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL) <sup>B</sup>	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL) <sup>B</sup>	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL) <sup>B</sup>	Temperature Coefficient (K)
15.0	0.99910	1.00090	16.0	0.99895	1.00074	17.0	0.99878	1.00057	18.0	0.99860	1.00039
.1	0.99909	1.00088	.1	0.99893	1.00072	.1	0.99876	1.00055	.1	0.99858	1.00037
.2	0.99907	1.00087	.2	0.99891	1.00071	.2	0.99874	1.00054	.2	0.99856	1.00035
.3	0.99906	1.00085	.3	0.99890	1.00089	.3	0.99872	1.00052	.3	0.99854	1.00034
.4	0.99904	1.00084	.4	0.99888	1.00067	.4	0.99871	1.00050	.4	0.99852	1.00032
.5	0.99902	1.00082	.5	0.99886	1.00066	.5	0.99869	1.00048	.5	0.99850	1.00030
.6	0.99901	1.00080	.6	0.99885	1.00064	.6	0.99867	1.00047	.6	0.99848	1.00028
.7	0.99899	1.00079	.7	0.99883	1.00062	.7	0.99865	1.00045	.7	0.99847	1.00026
.8	0.99898	1.00077	.8	0.99881	1.00061	.8	0.99863	1.00043	.8	0.99845	1.00024
.9	0.99896	1.00076	.9	0.99879	1.00059	.9	0.99862	1.00041	.9	0.99843	1.00022
19.0	0.99841	1.00020	20.0	0.99821	1.00000	21.0	0.99799	0.99979	22.0	0.99777	0.99957
.1	0.99839	1.00018	.1	0.99819	0.99998	.1	0.99797	0.99977	.1	0.99775	0.99954
.2	0.99837	1.00016	.2	0.99816	0.99996	.2	0.99795	0.99974	.2	0.99773	0.99952
.3	0.99835	1.00014	.3	0.99814	0.99994	.3	0.99793	0.99972	.3	0.99771	0.99950
.4	0.99833	1.00012	.4	0.99812	0.99992	.4	0.99791	0.99970	.4	0.99768	0.99947
.5	0.99831	1.00010	.5	0.99810	0.99990	.5	0.99789	0.99968	.5	0.99766	0.99945
.6	0.99829	1.00008	.6	0.99808	0.99987	.6	0.99786	0.99966	.6	0.99764	0.99943
.7	0.99827	1.00006	.7	0.99806	0.99985	.7	0.99784	0.99963	.7	0.99761	0.99940
.8	0.99825	1.00004	.8	0.99804	0.99983	.8	0.99782	0.99961	.8	0.99759	0.99938
.9	0.99823	1.00002	.9	0.99802	0.99981	.9	0.99780	0.99959	.9	0.99756	0.99936
23.0	0.99754	0.99933	24.0	0.99730	0.99909	25.0	0.99705	0.99884	26.0	0.99679	0.99858
.1	0.99752	0.99931	.1	0.99727	0.99907	.1	0.99702	0.99881	.1	0.99676	0.99855
.2	0.99749	0.99929	.2	0.99725	0.99904	.2	0.99700	0.99879	.2	0.99673	0.99852
.3	0.99747	0.99926	.3	0.99723	0.99902	.3	0.99697	0.99876	.3	0.99671	0.99850
.4	0.99745	0.99924	.4	0.99720	0.99899	.4	0.99694	0.99874	.4	0.99666	0.99847
.5	0.99742	0.99921	.5	0.99717	0.99897	.5	0.99692	0.99871	.5	0.99665	0.99844
.6	0.99740	0.99919	.6	0.99715	0.99894	.6	0.99689	0.99868	.6	0.99663	0.99842
.7	0.99737	0.99917	.7	0.99712	0.99892	.7	0.99687	0.99866	.7	0.99660	0.99839
.8	0.99735	0.99914	.8	0.99710	0.99889	.8	0.99694	0.99873	.8	0.99657	0.99836
.9	0.99732	0.99912	.9	0.98707	0.99887	.9	0.99681	0.99860	.9	0.99654	0.99833
27.0	0.99652	0.99831	28.0	0.99624	0.99803	29.0	0.99595	0.99774	30.0	0.99585	0.99744
.1	0.99649	0.99628	.1	0.99621	0.99800	.1	0.99592	0.99771	.1	0.99562	0.99741
.2	0.99646	0.99825	.2	0.99618	0.99797	.2	0.99589	0.99768	.2	0.99559	0.99738
.3	0.99643	0.99822	.3	0.99615	0.99794	.3	0.99586	0.99765	.3	0.99556	0.99735
.4	0.99641	0.99820	.4	0.99612	0.99791	.4	0.99583	0.99762	.4	0.99553	0.99732
.5	0.99638	0.99817	.5	0.99609	0.99788	.5	0.99580	0.99759	.5	0.99550	0.99729
.6	0.99635	0.99814	.6	0.99607	0.99785	.6	0.99577	0.99756	.6	0.99547	0.99726
.7	0.99632	0.99811	.7	0.99604	0.99783	.7	0.99574	0.99753	.7	0.99544	0.99723
.8	0.99629	0.99808	.8	0.99601	0.99780	.8	0.99571	0.99750	.8	0.99541	0.99720
.9	0.99627	0.99806	.9	0.99598	0.99777	.9	0.99568	0.99747	.9	0.99538	0.99716

<sup>A</sup>Reference: CRC Handbook of Chemistry and Physics, David R. Lide, Editor-in-Chief, 74<sup>th</sup> Edition, 1993–1994.

<sup>B</sup>mL = cm<sup>3</sup>.

9.2.4 Proceed as described in 9.4.

### 9.3 Method B—Procedure for Oven-Dried Specimens:

9.3.1 Dry the specimen to a constant mass in an oven maintained at 110 ± 5°C. Break up any clods of soil using a mortar and pestle. If the soil will not easily disperse after drying or has changed composition, use Test Method A. Refer to 1.2.1 for soils that require use of Test Method A.

9.3.2 Place the funnel into the pycnometer. The stem of the funnel must extend past the calibration mark or stopper seal. Spoon the soil solids directly into the funnel. Rinse any soil particles remaining on the funnel into the pycnometer using a wash/spray squirt bottle.

9.4 *Preparing the Soil Slurry*—Add water until the water level is between 1/3 and 1/2 of the depth of the main body of the pycnometer. Agitate the water until slurry is formed. Rinse any soil adhering to the pycnometer into the slurry.

9.4.1 If slurry is not formed, but a viscous paste, use a pycnometer having a larger volume. See 7.1.1.

NOTE 5—For some soils containing a significant fraction of organic matter, kerosene is a better wetting agent than water and may be used in place of distilled water for oven-dried specimens. If kerosene is used, the entrapped air should only be removed by use of an aspirator. Kerosene is a flammable liquid that must be used with extreme caution.

9.5 *Deairing the Soil Slurry*—Entrapped air in the soil slurry can be removed using either heat (boiling), vacuum or combining heat and vacuum.

9.5.1 When using the heat-only method (boiling), use a duration of at least 2 h after the soil-water mixture comes to a full boil. Use only enough heat to keep the slurry boiling. Agitate the slurry as necessary to prevent any soil from sticking to or drying onto the glass above the slurry surface.

9.5.2 If only a vacuum is used, the pycnometer must be continually agitated under vacuum for at least 2 h. Continually agitated means the silt/clay soil solids will remain in suspension, and the slurry is in constant motion. The vacuum must remain relatively constant and be sufficient to cause bubbling at the beginning of the deairing process.

9.5.3 If a combination of heat and vacuum are used, the pycnometers can be placed in a warm water bath (not more than 40°C) while applying the vacuum. The water level in the bath should be slightly below the water level in the pycnometer, if the pycnometer glass becomes hot, the soil will typically stick to or dry onto the glass. The duration of vacuum and heat must be at least 1 h after the initiation of boiling. During the process, the slurry should be agitated as necessary

to maintain boiling and prevent soil from drying onto the pycnometer.

**9.6 Filling the Pycnometer with Water**—Fill the pycnometer with deaired water (see 8.2.2) by introducing the water through a piece of small-diameter flexible tubing with its outlet end kept just below the surface of the slurry in the pycnometer or by using the pycnometer filling tube. If the pycnometer filling tube is used, fill the tube with water, and close the valve. Place the tube such that the drainage holes are just at the surface of the slurry. Open the valve slightly to allow the water to flow over the top of the slurry. As the clear water layer develops, raise the tube and increase the flow rate. If the added water becomes cloudy, do not add water above the calibration mark or into the stopper seal area. Add the remaining water the next day.

**9.6.1** If using the stoppered iodine flask, fill the flask, such that the base of the stopper will be submerged in water. Then rest the stopper at an angle on the flared neck to prevent air entrapment under the stopper. If using a volumetric or stoppered flask, fill the flask to above or below the calibration mark depending on preference.

**9.7** If heat has been used, allow the specimen to cool to approximately room temperature.

**9.8 Thermal Equilibrium**—Put the pycnometer(s) into the insulated container. The thermometer (in a beaker of water), and some deaired water in a bottle along with either an eyedropper or pipette should also be placed in the insulated container. Keep these items in the closed container overnight to achieve thermal equilibrium.

**9.9 Pycnometer Mass Determination**—If the insulated container is not positioned near a balance, move the insulated container near the balance or vice versa. Open the container and remove the pycnometer. Only touch the rim of the pycnometer because the heat from hands can change the thermal equilibrium. Place the pycnometer on an insulated block (Styrofoam or equivalent).

**9.9.1** If using a volumetric flask, adjust the water to the calibration mark following the procedure in 8.4.1.

**9.9.2** If a stoppered flask is used, place the stopper in the bottle while removing the excess water using an eyedropper. Dry the rim using a paper towel. Be sure the entire exterior of the flask is dry.

**9.10** Measure and record the mass of pycnometer, soil, and water to the nearest 0.01 g using the same balance used for pycnometer calibration.

**9.11 Pycnometer Temperature Determination**—Measure and record the temperature of the slurry/soil-water mixture to the nearest 0.1°C using the thermometer and method used during calibration in 8.5. This is the test temperature,  $T_t$ .

**9.12 Mass of Dry Soil**—Determine the mass of a tare or pan to the nearest 0.01 g. Transfer the soil slurry to the tare or pan. It is imperative that all of the soil be transferred. Water can be added. Dry the specimen to a constant mass in an oven maintained at  $110 \pm 5^\circ\text{C}$  and cool it in a desiccator. If the tare can be sealed so that the soil can not absorb moisture during cooling, a desiccator is not required. Measure the dry mass of soil solids plus tare to the nearest 0.01 g using the designated

balance. Calculate and record the mass of dry soil solids to the nearest 0.01 g.

**NOTE 6**—This method has been proven to provide more consistent, repeatable results than determining the dry mass prior to testing. This is most probably due to the loss of soil solids during the de-airing phase of testing.

## 10. Calculation

**10.1** Calculate the mass of the pycnometer and water at the test temperature as follows:

$$M_{pw,t} = M_p + (V_p \cdot \rho_{w,t}) \quad (2)$$

where:

- $M_{pw,t}$  = mass of the pycnometer and water at the test temperature ( $T_t$ ), g,
- $M_p$  = the average calibrated mass of the dry pycnometer, g,
- $V_p$  = the average calibrated volume of the pycnometer, mL, and
- $\rho_{w,t}$  = the density of water at the test temperature ( $T_t$ ), g/mL from Table 2.

**10.2** Calculate the specific gravity at soil solids the test temperature,  $G_t$  as follows:

$$G_t = \frac{\rho_s}{\rho_{w,t}} = \frac{M_s}{(M_{pw,t} - (M_{pws,t} - M_s))} \quad (3)$$

where:

- $\rho_s$  = the density of the soil solids Mg/m<sup>3</sup> or g/cm<sup>3</sup>,
- $\rho_{w,t}$  = the density of water at the test temperature ( $T_t$ ), from Table 2, g/mL or g/cm<sup>3</sup>.
- $M_s$  = the mass of the oven dry soil solids (g), and
- $M_{pws,t}$  = the mass of pycnometer, water, and soil solids at the test temperature, ( $T_t$ ), g.

**10.3** Calculate the specific gravity of soil solids at 20°C as follows:

$$G_{20^\circ\text{C}} = K \cdot G_t \quad (4)$$

where:

$K$  = the temperature coefficient given in Table 2.

**10.4** For soil solids containing particles greater than the 4.75-mm (No. 4) sieve for which Test Method C 127 was used to determine the specific gravity of these particles, calculate an average specific gravity. Test Method C 127 requires the test be performed at  $23 \pm 1.7^\circ\text{C}$  and does not require the specific gravity data to be corrected to 20°C. Use 10.3 to correct this measurement to 20°C. Use the following equation to calculate the average specific gravity:

$$G_{\text{avg}@20^\circ\text{C}} = \frac{1}{\frac{R}{100 \cdot G_{1@20^\circ\text{C}}} + \frac{P}{100 \cdot G_{2@20^\circ\text{C}}}} \quad (5)$$

where:

- $R$  = the percent of soil retained on the 4.75-mm sieve,
- $P$  = the percent of soil passing the 4.75-mm sieve,
- $G_{1@20^\circ\text{C}}$  = the apparent specific gravity of soils retained on the 4.75-mm sieve as determined by Test Method C 127, corrected to 20°C

$G_{2@20^{\circ}\text{C}}$  = the specific gravity of soil solids passing the 4.75-mm sieve as determined by these test methods (Equation 4).

### 11. Report: Test Data Sheets(s)/Form(s)

11.1 The method used to specify how data are recorded on the test data sheets or forms, as given below, is the industry standard, and are representative of the significant digits that should be retained. These requirements do not consider in situ material variation, use of the data, special purpose studies, or any considerations for the user's objectives. It is common practice to increase or reduce significant digits of reported data commensurate with these considerations. It is beyond the scope of the standard to consider significant digits used in analysis methods for engineering design.

11.2 Record as a minimum the following information (data):

11.2.1 Identification of the soil (material) being tested, such as boring number, sample number, depth, and test number.

11.2.2 Visual classification of the soil being tested (group name and symbol in accordance with Practice D 2487).

11.2.3 Percent of soil particles passing the No. 4 (4.75-mm) sieve.

11.2.4 If any soil or material was excluded from the test specimen, describe the excluded material.

11.2.5 Method used (Method A or Method B).

11.2.6 All mass measurements (to the nearest 0.01 g).

11.2.7 Test temperature (to the nearest 0.1°C).

11.2.8 Specific gravity at 20°C ( $G$ ,  $G_s$ ,  $G_{20^{\circ}\text{C}}$ ) to the nearest 0.01. If desired, values to the nearest 0.001 may be recorded.

11.2.9 Average specific gravity at 20°C ( $G_{ave}$  or  $G_{avg@20^{\circ}\text{C}}$ ) to the nearest 0.01, if applicable.

### 12. Precision and Bias

12.1 *Precision*—Criteria for judging the acceptability of test results obtained by these test methods on a range of soil types using Method A (except the soil was air dried) is given in Tables 3 and 4. These estimates of precision are based on the results of the interlaboratory program conducted by the ASTM Reference Soils and Testing Program.<sup>7</sup> In this program, some laboratories performed three replicate tests per soil type (triplicate test laboratory), while other laboratories performed a single test per soil type (single test laboratory). A description of the soils tested is given in 12.1.4. The precision estimates may vary with soil type and method used (Method A or B). Judgement is required when applying these estimates to another soil or method.

12.1.1 The data in Table 3 are based on three replicate tests performed by each triplicate test laboratory on each soil type. The single operator and multilaboratory standard deviation shown in Table 3, Column 4 were obtained in accordance with Practice E 691, which recommends each testing laboratory perform a minimum of three replicate tests. Results of two properly conducted tests performed by the same operator on the same material, using the same equipment, and in the shortest practical period of time should not differ by more than

**TABLE 3 Summary of Test Results from Triplicate Test Laboratories (Specific Gravity)**

(1) Soil Type	(2) Number of Triplicate Test Labs	(3) Average Value <sup>A</sup>	(4) Standard Deviation <sup>B</sup>	(5) Acceptable Range of Two Results <sup>C</sup>
<i>Single-Operator Results (Within- Laboratory Repeatability):</i>				
CH	14	2.717	0.009	0.03
CL	13	2.670	0.006	0.02
ML	14	2.725	0.006	0.02
SP	14	2.658	0.006	0.02
<i>Multilaboratory Results (Between- Laboratory Reproducibility):</i>				
CH	14	2.717	0.028	0.08
CL	13	2.670	0.022	0.06
ML	14	2.725	0.022	0.06
SP	14	2.658	0.008	0.02

<sup>A</sup>The number of significant digits and decimal places presented are representative of the input data. In accordance with Practice D 6026, the standard deviation and acceptable range of results cannot have more decimal places than the input data.

<sup>B</sup>Standard deviation is calculated in accordance with Practice E 691 and is referred to as the 1s limit.

<sup>C</sup>Acceptable range of two results is referred to as the d2s limit. It is calculated as  $1.960\sqrt{2} \cdot 1s$ , as defined by Practice E 177. The difference between two properly conducted tests should not exceed this limit. The number of significant digits/decimal places presented is equal to that prescribed by these test methods or Practice D 6026. In addition, the value presented can have the same number of decimal places as the standard deviation, even if that result has more significant digits than the standard deviation.

**TABLE 4 Summary of Single Test Result from Each Laboratory (Specific Gravity)<sup>A</sup>**

(1) Soil Type	(2) Number of Test Laboratories	(3) Average Value	(4) Standard Deviation	(5) Acceptable Range of Two Results
<i>Multilaboratory Results (Single-Test Performed by Each Laboratory):</i>				
CH	18	2.715	0.027	0.08
CL	18	2.673	0.018	0.05
ML	18	2.726	0.022	0.06
SP	18	2.660	0.007	0.02

<sup>A</sup>See footnotes in Table 3.

the single-operator d2s limits shown in Table 3, Column 5. For definition of d2s see Footnote C in Table 3. Results of two properly conducted tests performed by different operators and on different days should not differ by more than the multilaboratory d2s limits shown in Table 3, Column 5.

12.1.2 In the ASTM Reference Soils and Testing Program, many of the laboratories performed only a single test. This is common practice in the design and construction industry. The data in Table 4 are based upon the first test result from the triplicate test laboratories and the single test results from the other laboratories. Results of two properly conducted tests performed by two different laboratories with different operators using different equipment and on different days should not vary by more than the d2s limits shown in Table 4, Column 5. The results in Tables 3 and 4 are dissimilar because the data sets are different.

12.1.3 Table 3 presents a rigorous interpretation of triplicate test data in accordance with Practice E 691 from prequalified laboratories. Table 4 is derived from test data that represents common practice.

12.1.4 *Soil Type*—Based on the multilaboratory test results, the soil used in the program is described below in accordance with Practice D 2487. In addition, the local name of the soil is given.

<sup>7</sup> Supporting data is available from ASTM Headquarters. Request RR: D18-1009.

CH—Fat clay, CH, 99 % fines, LL=60, PI=39, grayish brown, soil had been air dried and pulverized. Local name—Vicksburg Buckshot Clay  
CL—Lean clay, CL, 89 % fines, LL=33, PI=13, gray, soil had been air dried and pulverized. Local name—Annapolis Clay  
ML—Silt, ML, 99 % fines, LL=27, PI=4, light brown, soil had been air dried and pulverized. Local name—Vicksburg Silt

SP—Poorly graded sand; SP, 20 % coarse sand, 48 % medium sand, 30 % fine sand, 2 % fines, yellowish brown. Local name—Frederick sand

12.2 *Bias*—There is no acceptable reference value for this test method, therefore, bias cannot be determined.

## SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (98) that may impact the use of this standard.

- (1) The title changed to reflect multiple methods are used, soil solids are tested, and water pycnometer is used.
- (2) In Scope section, reworded 1.1.1 and added note (Note 1) that references D 5550. The remaining notes were renumbered.
- (3) Additional referenced documents were added.
- (4) In Significance and Use section, inserted 4.1.1 covering the use of specific gravity to calculate the density of soil solids and reworded 4.2 to include “soil like particles” may be tested.
- (5) In Apparatus section, added such apparatus as *insulated container* (for thermal equilibration), *funnel*, *pycnometer filling tube (optional)*, *No. 4 sieve*, *blender (optional)*, and *computer or calculator (optional)*. In addition, the acceptable size of pycnometer was changed along with the thermometer requirements to increase the test precision.
- (6) Requirement that water is distilled.

- (7) The specimen mass requirements were changed to be a function of soil type and pycnometer size. Added subsection 7.1.1 explaining these requirements.
- (8) The calibration technique for the pycnometer was completely changed to increase the precision of the test results.
- (9) The testing methods were changed to increase the precision of the test results.
- (10) The calculations were changed because of the changes in the testing methods.
- (11) The table for the density and temperature coefficient of water was expanded to be readable to the same accuracy as the temperature measurement.
- (12) The precision data was changed because test results with the above changes produced more precise data.

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