STANDARD OPERATING PROCEDURE NO. 75

SPECIFIC GRAVITY TEST

REVISION LOG					
Revision Number	Description	Date			
75.0	Original SOP by FFJ (UBC)	02/02/05			
75.1	Revisions by BEB (UBC)	2/04/05			
75v1	Lynne rmember to look at email notes that came with this one from BEB dated 8Febo5	8/15/05			
75v2	VCV, LMK final edits	8/24/05			
75v3	Procedural Corrections made by KMD	2/12/2007			
75v3	Minor corrections by LMK Finalized by LMK for posting on the Molycorp project website and to send to George Robinson for lab audit.	4/4/07			
75v4	Editorial by SKA	10/28/08			

1.0 PURPOSE AND SCOPE

These test methods cover the determination of the specific gravity of soil solids. Two different procedures are provided to test soil particles that pass the 4.75 mm (No. 4) sieve, Standard Test Methods for Specific Gravity of Soils by Water Pycnometer, Designation D-854-02 and to calculate the specific gravity of aggregates coarser than the No. 4 (4.75 mm) sieve, Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate, Designation C 127-04. An average of the calculated specific gravity is used as the specific gravity of the entire sample.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The Team Leader will have the overall responsibility for implementing this SOP. He/she will be responsible for assigning appropriate staff to implement this SOP and for ensuring that the procedures are followed accurately.

All personnel performing these procedures are required to have the appropriate health and safety training. In addition, all personnel are required to have a complete understanding of the procedures described within this SOP, and to receive specific training regarding these procedures, if necessary.

All environmental staff and assay laboratory staff are responsible for reporting deviations from this SOP to the Team Leader

3.0 DATA QUALITY OBJECTIVES

- Perform specific gravity test in order to support other geotechnical tests such as grain size analysis as well as the calculation of the volume mass properties of the sample.
- To perform geotechnical testing of the rock pile and weathered material followed by mathematical modeling of the future stability of the rock piles.

4.0 RELATED STANDARD OPERATING PROCEDURES

The procedures set forth in this SOP are intended for use with the following SOPs:

- SOP 1 Data management (including verification and validation)
- SOP 2 Sample management (chain of custody)
- SOP 4 Taking photographs
- SOP 5 Sampling outcrops, rock piles, and drill core (solid)
- SOP 6 Drilling, logging and sampling of subsurface materials (solid)
- SOP 8 Sample preparation (solids)
- SOP 9 Test pit excavation, logging and sampling

The procedures set forth in this SOP are also intended for use with the ASTM standard designations D854-02 and C127-04 (Appendices 2 and 3, respectively).

5.0 EQUIPMENT LIST

- a) For material passing the No. 4 (4.75 mm) sieve:
 - Pycnometer: a volumetric flask with a minimum capacity of 500 ml
 - Balance: with 0.01 g readability and a capacity of at least 1000 g.
 - *Drying Oven:* capable of maintaining a uniform temperature of 110 +- 5°C.
 - Thermometer: with a -1 to 60° C range.
 - Entrapped Air Removal Apparatus: Hot Plate and/or Vacuum System.
 - Sieve No. 4 (4.75 mm).
 - Hot Plate or Bunsen Burner capable of maintaining a temperature adequate to boil water.
 - *Pycnometer filling tube*: It can be 25 ml pipettes, beaker, or plastic tubes fine enough not to disturb the slurry solution.
 - *Miscellaneous Equipment*, such as a computer or calculator, spray bottle, mortar and pestle, funnel, paper towels, specimen dishes, and insulated gloves.
 - Distilled Water

- Test data sheet (Appendix 1) and pen
- b) For aggregates coarser than the No. 4 (4.75 mm) sieve:
 - *Balance* A device for determining mass that is sensitive, readable, and accurate to 0.5 g. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the platform or pan of the balance.
 - Sample Container A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5 mm. The container shall be constructed so as to prevent trapping air when the container is submerged.
 - *Water Tank* A watertight tank into which the sample container is placed while suspended below the balance.
 - Test data sheet (Appendix 1) and pen

6.0 TEST SPECIMEN

a) For material passing the No. 4 (4.75 mm) sieve:

The test specimen shall be oven-dry soil and shall be representative of the soil solids in the total sample that pass the No. 4 sieve. If the material is predominantly composed of silt and clay about 50 g is required for the test. If the material is mainly composed of sand and gravel about 100 g shall be used.

b) For aggregates coarser than the No. 4 (4.75 mm) sieve:

From the oven-dried material retained on the No. 4 (4.75 mm) sieve, the minimum mass of test sample to be used is given as follows:

Maximum size, mm (in)	Mass kg (lb)
$12.5 (^{1}/_{2})$ or less	2 (4.4)
$19.0 (^{3}/_{4})$	3 (6.6)
25.0 (1)	4 (8.8)
$37.5 (1^{1}/_{2})$	5 (11)
50 (2)	8 (18)
$63(2^{1}/_{2})$	12 (26)
75 (3)	18 (40)
$90(3^{1}/_{2})$	25 (55)
100 (4)	40 (88)

7.0 TEST PROCEDURES

7.1 For particles passing the No. 4 (4.75 mm) sieve:

- 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. Record the mass of dry soil used for the test. Note however, that it is preferable to use the dry mass calculated at the end of the test in calculations.

- Place the funnel into the pycnometer. 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.
- 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 a slurry is formed. Rinse any soil adhering to the pycnometer into the slurry. If the slurry is not formed but you have a viscous paste, use a pycnometer with a larger volume or reduce the mass of soil used.
- Entrapped air in the soil slurry can be removed using either heat (boiling), vacuum, or a combination of heat and vacuum:
 - a) 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.
 - b) If only 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.
 - c) 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.
- Fill the pycnometer with deaired water (by heat and/or vacuum) to the calibration mark.
- If heat has been used, allow the specimen to cool to approximately room temperature.
- Adjust the water to the calibration mark and dry the rim using a paper towel. Be sure the entire exterior of the flask is dry.
- Measure and record the mass of pycnometer, soil, and water to the nearest 0.01 g using the same balance used for pycnometer calibration.
- Measure and record the temperature of the slurry/soil-water mixture to the nearest 0.1°C. This is the test temperature.
- Determine the mass of a pan to the nearest 0.01 g. Transfer the soil slurry to the tare or pan. It is of paramount importance that all of the soil be transferred. Measure the wet mass of soil solids plus tare to the nearest 0.01 g using the designated balance and oven dry the sample at 110 +- 5°C to a constant weight. Calculate and record the mass of dry soil solids to the nearest 0.01 g.
- Record all measurements on data sheet and enter into computer spreadsheet.

7.2 Coarse fraction – retained on the No. 4 (4.75 mm) sieve

- Dry the test sample in the oven to a constant mass at a temperature of 110 + 5 °C, cool in air at room temperature for 1 to 3 h.
- Immerse the aggregate in water at room temperature for a period of 24 h.

- Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to the nearest 0.5 g.
- After determining the mass in air, immediately place the saturated surface-dry test sample in the sample container and determine its apparent mass in water at 23 +- 2.0 °C. The difference between the mass in air and the mass when the sample is submerged in water equals the mass of water displaced by the sample.
- Dry the test sample in the oven to constant mass at a temperature of 110 + 5 °C, cool in air at room temperature 1 to 3 h, and determine the mass.

8.0 CALCULATIONS

8.1 For material passing the No. 4 (4.75 mm) sieve:

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

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

where:

 M_{pwt} = mass of pycnometer and water at the test temperature (T_t), g

 M_p = the average calibrated mass of dry, clean pycnometer, g

 V_p = the average calibrated volume of the pycnometer, ml

 $\rho_{w,t}$ = the density of water at the test temperature (Tt), g/ml from Table 2 in Apendix 2

- Calculate the specific gravity G_t as follows:

or,

$$M_{pwt} = W_p + V_p (1 + \Delta T \varepsilon) x (\gamma_T - \gamma_a)$$

where:

 M_{pwt} = weight of pycnometer plus water at test temperature

 W_p = weight of dry, clean pycnometer

 V_p = calibrated volume of the pycnometer at T_c

 $\Delta T = T - T_c$

T = Temperature in degrees centigrade at which W_p is desired

 T_c = Calibration temperature of pycnometer (usually 20°C)

 ϵ = Thermal coefficient of cubic expansion for Pyrex glass = 0.1 x 10⁻⁴ per °C

 γ_T = unit weight of water at the test temperature (see ASTM 854-02 in Appendix 2)

 γ_a = unit weight of air (0.0012 g/cm³)

$$G_t = M_s / (M_{pwt} - (M_{pwst} - M_s))$$

where:

 G_t = specific gravity at test temperature

 M_s = the mass of dry soil solids, (g) and

 M_{pwst} = the mass of pycnometer, water and soil at the test temperature (${}^{o}C$).

8.2 For aggregate coarser than the No. 4 (4.75 mm) sieve:

- Calculate the specific gravity on the basis of oven-dry aggregate as follows:

Specific Gravity
$$OD = A / (B - C)$$

where:

A = mass of oven dry test sample in air, g

B = mass of saturated surface-dry test sample in air, g, and

C = apparent mass of saturated test sample in water, g.

8.3 Average Specific Gravity

- Calculate an average specific gravity combining the two fractions as follows:

$$Gavg = \frac{l}{\frac{R}{100 \times Gl} + \frac{p}{100 \times G2}}$$

where:

R =the percentage of soil retained on the 4.75 mm sieve

P =the percentage of soil passing the 4.75 mm sieve

G1 = the specific gravity of soil retained on the 4.75 mm sieve and,

G2 = the specific gravity of soil passing the 4.75 mm sieve.

9.0 REPORTING

Test data sheets will be stored electronically and are available upon request (Appendix 1). Data are recorded in the data base.

Record as a minimum the following information:

- Identification of the soil (material) being tested, such as boring number, sample number, depth, and test number.
- Visual classification of the soil being tested
- Percent of soil particles passing the No. 4 (4.75 mm) sieve.
- If any soil or material was excluded from the test specimen, describe the excluded material.
- All mass measurements (to the nearest 0.01 g for fines and 0.5 g for coarse aggregates).
- Test temperature (to the nearest 0.1°C).
- Specific gravity to the nearest 0.01.
- Average specific gravity to the nearest 0.01, if applicable.

10.0 QUALITY ASSURANCE/QUALITY CONTROL

All equipment used in this test shall be calibrated, including the volume and dry weight of the pycnometer (Refer to ASTM 854-02 for details on pycnometer calibration). The same scale shall be used to weigh the pycnometer when it is dry and when it is filled with soil and water. The pycnometer shall be filled to the exact calibration mark existing on the volumetric flask.

Where feasible, samples should be archived for future studies.

11.0 REFERENCES

- ASTM D854-02; Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer.
- ASTM C127-04. Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.

APPENDIX 1. FORMS (Test Data Sheets)

Specific Gravity Test

Sample:	Place:		
Depth:		Date:	

Passing the No 4 (4.75 mm)

Hygroscopic moisture		Specific gravity # 4.75 mm	Soil (g) =
Tare N°		Pycnometer N°	
Tare (g)		Temperature (°C)	
Tare + WS (g)		Pyc. + water (g) (1)	
Tare + DS (g)		Pyc.+water+soil(g)	
Moisture (%)		G (g/cm ³) (2)	
	w (%):		G_s :

(1)
$$M_{pwt} = W_p + V_p (1 + \Delta T \varepsilon) x (\gamma_T - \gamma_a)$$

(2) $Gs = M_s / (M_{pwt} - (M_{pwst} - M_s))$

Fraction retained on the No 4 (4.75 mm)

A = Mass of oven drdy test sample in air =	
B = Mass of saturated-surface-dry of test sample in air (g) =	
C = Aparent mass of saturated test sample in water (g) =	
Specific Gravity of coarse agregate (g/cm3) (3) =	

(3) Specific Gravity OD = A / (B - C)

Average Specifc Gravity (g/cm3) (4) =

(4)
$$Gavg = \frac{l}{\frac{R}{100 \text{ x G1}} + \frac{p}{100 \text{ x G2}}}$$

Where:

R =the percentage of soil retained on the 4.75 mm sieve

P =the percentage of soil passing the 4.75 mm sieve

G1 =the specific gravity of soil retained on the 4.75 mm sieve and,

G2 = the specific gravity of soil passing the 4.75 mm sieve.

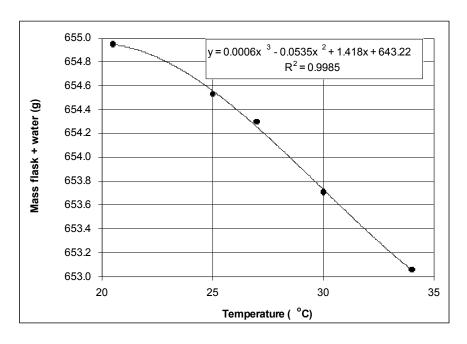
SPECIFIC GRAVITY TEST

Project		Molycorp Questa Min	е	
Sample ID				
Date start			Technicians:	
Maximum Particle size		No4 sieve (4.75mm)		Flask - C

Test or Sample No.	1		
Sample Mass (g) M s			
Temperature of soil+water when weighed (°C)			
Mass flask+water+soil at (°C) above M ρws t			
Mass flask+water at (°C) from calibration M ws,t	643.22		
Correction factor (ASTM Procedure) K			
Specific gravity of soil at 20°C G	0.00		

PYCNOMETER CALIBRATION - FLASK C

Pycnometer:	1	2	3	4	5
Mass flask+water (g)	654.95	654.53	654.3	653.71	653.06
Temperature (°C)	20.5	25	27	30	34



Checked By: Date:

APPENDIX 2. ASTM D854-02



Designation: D 854 - 02

Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer¹

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 (e) 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.
- $N_{\text{OTE}}\,$ 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.
- $1.3~{
 m All}$ 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 This standard is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.
- Current edition approved July 10, 2002. Published September 2002. Originally published as D 854 45. Last previous edition D 854 00°¹.

- 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 $\operatorname{Aggregate}^2$
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids³
- D 1140 Test Method for Amount of Material in Soils Finer Than the No. 200 (75- μ m) Sieve³
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass³
- D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)³
- 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 Construction³
- D 4753 Guide for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Related Construction Materials Testing³
- D 5550 Test Method for Specific Gravity of Soil Solids by Gas Pycnometer³
- D 6026 Practice for Using Significant Digits in Geotechnical Data^4
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes⁵
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁵
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method⁵

3. Terminology

3.1 Definitions—For definitions of terms used in these test

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

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² Annual Book of ASTM Standards, Vol 04.02.

Annual Book of ASTM Standards, Vol 04.08.
 Annual Book of ASTM Standards, Vol 04.09.

⁵ Annual Book of ASTM Standards, Vol 14.02.



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—A balance meeting the requirements of Guide D 4753 for a balance of 0.01 g readability. When using the 250-mL pycnometers, the balance capacity shall be at least 500 g and when using the 500-mL pycnometers, the balance capacity shall be at least 1000 g.
- 5.3~Drying~Oven—Thermostatically controlled oven, capable of maintaining a uniform temperature of $110~\pm~5^{\circ}\mathrm{C}$ 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°C and an immersion depth ranging between 25 to 80 mm. Full immersion thermometers shall not

be used. Either a general-purpose precision mercury thermometer or a digital thermometer with a -1 to 57° 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 1/4 to 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.⁶
- 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.

⁶ 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, 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:

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

where:

 M_{pwc} = 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

 ρ_{vec} = 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 To disperse the soil put about 100 mL of water into the mixing container of a blender or equivalent device. Add the soil and blend. 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

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TABLE 2 Density of Water and Temperature Coefficient (K) for Various Temperatures^A

Temperature (°C)	Density (g/mL) ^B	Temperature Coefficient (<i>K</i>)	Temperature (°C)	Density (g/mL) ^B	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL) ^B	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL) ^B	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	1.00069	.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	0.99770	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	0.99668	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	0.99684	0.99863	.8	0.99657	0.99836
.9	0.99732	0.99912	.9	0.99707	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	0.99565	0.99744
.1	0.99649	0.99828	.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

AReference: CRC Handbook of Chemistry and Physics, David R. Lide, Editor-in-Chief, 74th Edition, 1993–1994.

 $B_{mL} = cm^3$

pycnometer using a wash/spray squirt bottle.

- 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 $110 \pm 5^{\circ}$ 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

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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, 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 $8.\overline{5}$. 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 ± 5°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

10. Calculation

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

$$M_{\text{pw,t}} = M_{\text{p}} + (V_{p} \cdot \rho_{w,t}) \tag{2}$$

where:

= mass of the pycnometer and water at the test $M_{\mathsf{pw}t}$ temperature (T_i) , g,

= the average calibrated mass of the dry pycnometer, g,

= the average calibrated volume of the pycnometer, mL. and

= 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:

$$G_{t} = \frac{\rho_{s}}{\rho_{w,t}} = \frac{M_{s}}{(M_{\rho_{w,t}} - (M_{pws,t} - M_{s}))}$$
(3)

where:

= the density of the soil solids Mg/m³ or g/cm³,

 ρ_s = the density of water at the test temperature (T_r) , $\rho_{w.t}$ from Table 2, g/mL or g/cm³.

= the mass of the oven dry soil solids (g), and = 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:

$$G_{20^{\circ}\text{C}} = K \cdot G_t \tag{4}$$

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 ± 1.7°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:

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

where:

R

= the percent of soil retained on the 4.75-mm

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

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 $G_{2@20^{\circ}\mathrm{C}}$ = 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 , $G_{20°C}$) 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 $G_{avg@20°C}$) 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. 7 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)	(2) Number of	(3)	(4)	(5) Acceptable		
	Triplicate Test	Average	Standard	Range of Two		
Soil Type	Labs	Value ^A	Deviation ^B	Results [©]		
Single-Operator Results (Within- Laboratory Repeatability):						
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		
Mult	ilaboratory Results	(Between- La	boratory Reprod	ucibility):		
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		

^AThe 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.

^EStandard deviation is calculated in accordance with Practice E 691 and is referred to as the 1s limit.

 C 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)^A

_					
	(1)	(2)	(3)	(4)	(5)
		Number of Test	Average	Standard	Acceptable Range of Two
	Soil Type	Laboratories	Value	Deviation	Results
	Multilah	oratory Results (Si	ngle-Test Pei	rformed by Each	Laboratory):
	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

ASee 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.

 $^{^{7}\,\}mathrm{Supporting}$ 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 (00e1) that may impact the use of this standard.

(1) The balance capacity was reduced from 2000 g to either 500 g or 1000 g depending on pycnometer size.

(2) 8.3 and 9.8. The thermometer no longer is required to be in

the beaker during thermal equilibrium.

(3) 9.2 The dispersion technique is better defined.

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APPENDIX 3. ASTM C127-04



Designation: C 127 - 04

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate¹

This standard is issued under the fixed designation C 127; 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 This test method covers the determination of the average density of a quantity of coarse aggregate particles (not including the volume of voids between the particles), the relative density (specific gravity), and the absorption of the coarse aggregate. Depending on the procedure used, the density (kg/m3(lb/ft3)) is expressed as oven-dry (OD), saturatedsurface-dry (SSD), or as apparent density. Likewise, relative density (specific gravity), a dimensionless quantity, is expressed as OD, SSD, or as apparent relative density (apparent specific gravity). The OD density and OD relative density are determined after drying the aggregate. The SSD density, SSD relative density, and absorption are determined after soaking the aggregate in water for a prescribed duration.

1.2 This test method is used to determine the density of the essentially solid portion of a large number of aggregate particles and provides an average value representing the sample. Distinction is made between the density of aggregate particles as determined by this test method, and the bulk density of aggregates as determined by Test Method C 29/ C 29M, which includes the volume of voids between the particles of aggregates.

1.3 This test method is not intended to be used with lightweight aggregates.

1.4 The values stated in SI units are to be regarded as the standard for conducting the tests. The test results for density shall be reported in either SI units or inch-pound units, as appropriate for the use to be made of the results.

1.5 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.6 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: 2
- C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
- C 125 Terminology Relating to Concrete and Concrete Aggregates
- C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
- C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
- C 566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying
- C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- C 702 Practice for Reducing Samples of Aggregate to Testing Size
- D 75 Practice for Sampling Aggregates
- D 448 Classification for Sizes of Aggregate for Road and Bridge Construction
- E 11 Specification for Wire Cloth and Sieves for Testing Purposes
- 2.2 AASHTO Standard:
- AASHTO No. T 85 Specific Gravity and Absorption of Coarse Aggregate³

3. Terminology

- 3.1 Definitions:
- 3.1.1 absorption, n—the increase in mass of aggregate due to water penetration into the pores of the particles during a prescribed period of time, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

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

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 $^{^{\}rm 1}\,{\rm This}$ test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee

Converted and control Meight Aggregates.

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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

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- 3.1.2 oven-dry (OD), adj—related to aggregate particles, the condition in which the aggregates have been dried by heating in an oven at 110 ± 5 °C for sufficient time to reach a constant mass.
- 3.1.3 saturated-surface-dry (SSD), adj—related to aggregate particles, the condition in which the permeable pores of aggregate particle are filled with water to the extent achieved by submerging in water for the prescribed period of time, but without free water on the surface of the particles.
- 3.1.4 *density*, *n*—the mass per unit volume of a material, expressed as kilograms per cubic metre (pounds per cubic foot).
- 3.1.4.1 *density (OD), n*—the mass of oven dry aggregate per unit volume of aggregate particles, including the volume of permeable and impermeable pores within the particles, but not including the voids between the particles.
- 3.1.4.2 density (SSD), n—the mass of saturated-surface-dry aggregate per unit volume of the aggregate particles, including the volume of impermeable pores and water-filled voids within the particles, but not including the pores between the particles.
- 3.1.4.3 apparent density, n—the mass per unit volume of the impermeable portion of the aggregate particles.
- 3.1.5 relative density (specific gravity), n—the ratio of the density of a material to the density of distilled water at a stated temperature; the values are dimensionless.
- 3.1.5.1 relative density (specific gravity) (OD), n—the ratio of the density (OD) of the aggregate to the density of distilled water at a stated temperature.
- 3.1.5.2 relative density (specific gravity) (SSD), n—the ratio of the density (SSD) of the aggregate to the density of distilled water at a stated temperature.
- 3.1.5.3 apparent relative density (apparent specific gravity), n—the ratio of the apparent density of aggregate to the density of distilled water at a stated temperature.
- 3.1.6 For definitions of other terms related to aggregates, see Terminology C 125.

4. Summary of Test Method

 $4.1\,\mathrm{A}$ sample of aggregate is immersed in water for 24 ± 4 h to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and the mass determined. Subsequently, the volume of the sample is determined by the displacement of water method. Finally, the sample is oven-dried and the mass determined. Using the mass values thus obtained and formulas in this test method, it is possible to calculate density, relative density (specific gravity), and absorption.

5. Significance and Use

5.1 Relative density (specific gravity) is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Relative density (specific gravity) is also used in the computation of voids in aggregate in Test Method C 29/C 29M. Relative density (specific gravity) (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied.

- Conversely, the relative density (specific gravity) (OD) is used for computations when the aggregate is dry or assumed to be dry.
- 5.2 Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.
- 5.3 Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time. Aggregates mined from below the water table commonly have a moisture content greater than the absorption determined by this test method, if used without opportunity to dry prior to use. Conversely, some aggregates which have not been continuously maintained in a moist condition until used are likely to contain an amount of absorbed moisture less than the 24-h soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture is determined by deducting the absorption from the total moisture content determined by Test Method C 566.
- 5.4 The general procedures described in this test method are suitable for determining the absorption of aggregates that have had conditioning other than the 24-h soak, such as boiling water or vacuum saturation. The values obtained for absorption by other test methods will be different than the values obtained by the prescribed soaking, as will the relative density (specific gravity) (SSD).
- 5.5 The pores in lightweight aggregates are not necessarily filled with water after immersion for 24 h. In fact, the absorption potential for many such aggregates is not satisfied after several days' immersion in water. Therefore, this test method is not intended for use with lightweight aggregate.

6. Apparatus

- 6.1 Balance—A device for determining mass that is sensitive, readable, and accurate to 0.05 % of the sample mass at any point within the range used for this test, or 0.5 g, whichever is greater. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the platform or pan of the balance.
- 6.2 Sample Container—A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm (1½-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.
- 6.3 Water Tank—A watertight tank into which the sample container is placed while suspended below the balance.
- 6.4 Sieves—A 4.75-mm (No. 4) sieve or other sizes as needed (see 7.2-7.4), conforming to Specification E 11.
- 6.5 Oven—An oven of sufficient size, capable of maintaining a uniform temperature of 110 \pm 5 °C (230 \pm 9 °F).

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7. Sampling

7.1 Sample the aggregate in accordance with Practice D 75.

7.2 Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in Practice C 702. Reject all material passing a 4.75-mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm sieve (such as for Size No. 8 and 9 aggregates in Classification D 448), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm sieve. Alternatively, separate the material finer than the 4.75-mm sieve and test the finer material according to Test Method C 128.

Note 1—If aggregates smaller than 4.75 mm (No. 4) are used in the sample, check to ensure that the size of the openings in the sample container is smaller than the minimum size aggregate.

7.3 The minimum mass of test sample to be used is given as follows. Testing the coarse aggregate in several size fractions is permitted. If the sample contains more than 15 % retained on the 37.5-mm (1½-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size,	Minimum Mass of Test
mm (in.)	Sample, kg (lb)
12.5 (1/2) or less	2 (4.4)
19.0 (¾)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 (11/2)	5 (11)
50 (2)	8 (18)
63 (21/2)	12 (26)
75 (3)	18 (40)
90 (31/2)	25 (55)
100 (4)	40 (88)
125 (5)	75 (165)

7.4 If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with Test Method C 136, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75-mm (No. 4) sieve (or 2.36-mm (No. 8) sieve when that sieve is used in accordance with 7.2).

Note 2—When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and the values obtained combined for the computations described in Section 9.

8. Procedure

8.1 Dry the test sample in the oven to constant mass at a temperature of 110 \pm 5 °C, cool in air at room temperature for 1 to 3 h for test samples of 37.5-mm (1½-in.) nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50 °C). Subsequently immerse the aggregate in water at room temperature for a period of 24 \pm 4 h.

8.2 Where the absorption and relative density (specific gravity) values are to be used in proportioning concrete

mixtures in which the aggregates will be in their naturally moist condition, the requirement in 8.1 for initial drying is optional, and, if the surfaces of the particles in the sample have been kept continuously wet until tested, the requirement in 8.1 for $24 \pm 4 \, h$ soaking is also optional.

Note 3—Values for absorption and relative density (specific gravity) (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with 8.1. This is especially true of particles larger than 75 mm since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

8.3 Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. A moving stream of air is permitted to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores during the surface-drying operation. Determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to the nearest 0.5 g or 0.05 % of the sample mass, whichever is greater.

8.4 After determining the mass in air, immediately place the saturated-surface-dry test sample in the sample container and determine its apparent mass in water at 23 \pm 2.0 °C. Take care to remove all entrapped air before determining its mass by shaking the container while immersed.

 $N_{\text{OTE}}\,$ 4—The difference between the mass in air and the mass when the sample is submerged in water equals the mass of water displaced by the sample.

Note 5—The container should be immersed to a depth sufficient to cover it and the test sample while determining the apparent mass in water. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

8.5 Dry the test sample in the oven to constant mass at a temperature of 110 ± 5 °C, cool in air at room temperature 1 to 3 h, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50 °C), and determine the mass.

9. Calculations

9.1 Relative Density (Specific Gravity):

9.1.1 Relative Density (Specific Gravity) (OD)—Calculate the relative density (specific gravity) on the basis of oven-dry aggregate as follows:

Relative density (specific gravity) (OD) =
$$A/(B-C)$$
 (1)

where:

A = mass of oven-dry test sample in air, g,

B = mass of saturated-surface-dry test sample in air, g, and
 C = apparent mass of saturated test sample in water, g.

9.1.2 Relative Density (Specific Gravity) (SSD)—Calculate the relative density (specific gravity) on the basis of saturated-surface-dry aggregate as follows:

Relative density (specific gravity) (SSD) =
$$B/(B-C)$$
 (2)

9.1.3 Apparent Relative Density (Apparent Specific Gravity)—Calculate the apparent relative density (apparent specific gravity) as follows:

Apparent relative density (apparent specific gravity) = A/(A-C)

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9.2 Density:

9.2.1 Density (OD)—Calculate the density on the basis of oven-dry aggregate as follows:

Density (OD),
$$kg/m^3$$
, = 997.5 $A/(B-C)$ (4

Density (OD),
$$lb/ft^3$$
, = 62.27 $A/(B-C)$ (5

Note 6-The constant values used in the calculations in 9.2.1-9.2.3 (997.5 kg/m3 and 62.27 lb/ft3) are the density of water at 23 °C.

9.2.2 Density (SSD)—Calculate the density on the basis of saturated-surface-dry aggregate as follows:

Density (SSD),
$$kg/m^3$$
, = 997.5 B/(B - C) (6

Density (SSD),
$$lb/ft^3$$
, = 62.27 B/(B - C) (7)

9.2.3 Apparent Density—Calculate the apparent density as follows:

Apparent density,
$$kg/m^3 = 997.5 A/(A-C)$$
 (8)

Apparent density,
$$1b/ft^3 = 62.27 A/(A-C)$$
 (9)

9.3 Average Density and Relative Density (Specific Gravity) Values—When the sample is tested in separate size fractions, compute the average values for density or relative density (specific gravity) of the size fraction computed in accordance with 9.1 or 9.2 using the following equation:

$$G = \frac{1}{\frac{P_1}{100 G_1} + \frac{P_2}{100 G_2} + \dots \frac{P_n}{100 G_n}} \text{ (see Appendix X1)}$$
 (10)

where:

G

= average density or relative density (specific gravity). All forms of expression of density or relative density (specific gravity) can be averaged in this manner,

 G_p G_2 ... G_n = appropriate average density or relative density (specific gravity) values for each size fraction depending on the type of density or relative density (specific gravity) being averaged, and

 $P_{p}, P_{2}, \dots P_{n}$ = mass percentages of each size fraction present in the original sample (not including finer material—see 7.4).

9.4 Absorption—Calculate the percentage of absorption, as follows:

Absorption,
$$\% = [(B - A)/A] \times 100$$
 (11)

Note 7-Some authorities recommend using the density of water at 4 °C (1000 kg/m³ or 1.000 Mg/m³ or 62.43 lb/ft ³) as being sufficiently

9.5 Average Absorption Value—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in 9.4, weighted in proportion to the mass percentages of each size fraction present in the original sample (not including finer material—see 7.4) as follows:

$$A = (P_1 A_1/100) + (P_2 A_2/100) + \dots (P_n A_n/100)$$
 (12)

where:

= average absorption, %,

= absorption percentages for each size frac-

tion, and

 P_p P_2 ... P_n = mass percentages of each size fraction present in the original sample.

10. Report

10.1 Report density results to the nearest 10 kg/m³, or 0.5 lb/ft³, relative density (specific gravity) results to the nearest 0.01, and indicate the basis for density or relative density (specific gravity), as either (OD), (SSD), or apparent.

10.2 Report the absorption result to the nearest 0.1 %

10.3 If the density, relative density (specific gravity) and absorption values were determined without first drying the aggregate, as permitted in 8.2, note that fact in the report.

11. Precision and Bias

11.1 The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and AASHTO Method T 85. The significant difference between the methods is that Test Method C 127 requires a saturation period of 24 \pm 4 h, while Method T 85 requires a saturation period of 15 h minimum. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories. The precision estimates for density were calculated from values determined for relative density (specific gravity), using the density of water at 23 °C for the conversion.

11.2 Bias—Since there is no accepted reference material for determining the bias for the procedure in this test method, no statement on bias is being made.

TABLE 1 Precision

	Standard Deviation (1s) ^A	Acceptable Range of Two Results (d2s) ^A
Single-Operator Precision:		
Density (OD), kg/m ³	9	25
Density (SSD), kg/m ³	7	20
Apparent density, kg/m ³	7	20
Relative density (specific gravity) (OD)	0.009	0.025
Relative density (specific gravity) (SSD)	0.007	0.020
Apparent relative density (apparent specific gravity)	0.007	0.020
Multilaboratory Precision:		
Density (OD), kg/m ³	13	38
Density (SSD), kg/m ³	11	32
Apparent density, kg/m ³	11	32
Relative density (specific gravity) (OD)	0.013	0.038
Relative density (specific gravity) (SSD)	0.011	0.032
Apparent relative density (apparent specific gravity)	0.011	0.032

A These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory proficiency sample data from laboratories using 15 h minimum saturation times and other laboratories using 24 \pm 4 h saturation times. Testing was performed on normal-weight aggregates, and started with aggregates in the oven-dry condition

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12. Keywords

12.1 absorption; aggregate; apparent density; apparent relative density; coarse aggregate; density; relative density; specific gravity

APPENDIXES

(Nonmandatory Information)

X1. DEVELOPMENT OF EQUATIONS

X1.1 The derivation of the equation is from the following simplified cases using two solids. Solid 1 has a mass M_1 in grams and a volume V_1 in millilitres; its relative density (specific gravity) (G_1) is therefore M_1/V_1 . Solid 2 has a mass M_2 and volume V_2 , and $G_2 = M_2/V_2$. If the two solids are considered together, the relative density (specific gravity) of the combination is the total mass in grams divided by the total volume in millilitres:

$$G = (M_1 + M_2) / (V_1 + V_2)$$
 (X1.1)

Manipulation of this equation yields the following:

$$G = \frac{1}{\frac{V_1 + V_2}{M_1 + M_2}} = \frac{1}{\frac{V_1}{M_1 + M_2} + \frac{V_2}{M_1 + M_2}}$$
(X1.2)

$$G = \frac{1}{\frac{M_1}{M_1 + M_2} \left(\frac{V_1}{M_1}\right) + \frac{M_2}{M_1 + M_2} \left(\frac{V_2}{M_2}\right)}$$
(X1.3)

However, the mass fractions of the two solids are:

$$M_1/(M_1 + M_2) = P_1/100 \text{ and } M_2/(M_1 + M_2) = P_2/100 \quad (X1.4)$$

and,

$$1/G_1 = V_1/M_1$$
 and $1/G_2 = V_2/M_2$ (X1.5)

Therefore,

$$G = \frac{1}{\frac{P_1}{100} \frac{1}{G_1} + \frac{P_2}{100} \frac{1}{G_2}}$$
 (X1.6)

An example of the computation is given in Table X1.1.

TABLE X1.1 Example of Calculation of Weighted Values of Relative Density (Specific Gravity) and Absorption for a Coarse Aggregate Tested in Separate Sizes

Size Fraction, mm (in.)	% in Original Sample	Sample Mass Used in Test, g	Relative Density (Specific Gravity) (SSD)	Absorption, %
4.75 to 12.5 (No. 4 to ½)	44	2213.0	2.72	0.4
12.5 to 37.5 (½ to 1½)	35	5462.5	2.56	2.5
37.5 to 63 (1½ to 2½)	21	12593.0	2.54	3.0

Average Relative Density (Specific Gravity) (SSD)

$$G_{\rm SSD} = \frac{1}{\frac{0.44}{2.72} + \frac{0.35}{2.56} + \frac{0.21}{2.54}} = 2.62$$

Average Absorption

$$A = (0.44)(0.4) + (0.35)(2.5) + (0.21)(3.0) = 1.7 \%$$

X2. INTERRELATIONSHIPS BETWEEN RELATIVE DENSITIES (SPECIFIC GRAVITIES) AND ABSORPTION AS DEFINED IN TEST METHODS C 127 AND C 128

X2.1 Where:

 relative density (specific gravity) (OD),
 relative density (specific gravity) (SSD),
 apparent relative density (apparent specific gravity), and

= absorption in %.

X2.2 Calculate the values of each as follows:

$$S_s = (1 + A/100)S_d \tag{X2.1}$$

$$S_a = \frac{1}{\frac{1}{S} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}}$$
 (X2.2)

$$S_{a} = \frac{1}{\frac{1}{S_{d}} - \frac{A}{100}} = \frac{S_{d}}{1 - \frac{AS_{d}}{100}}$$

$$S_{a} = \frac{1}{\frac{1 + A/100}{S_{c}} - \frac{A}{100}} = \frac{S_{c}}{1 - \left[\frac{A}{100}(S_{c} - 1)\right]}$$
(X2.2)

$$A = \left(\frac{S_s}{S_d} - 1\right) 100 \tag{X2.4}$$

$$A = \left(\frac{S_a - S_s}{S_a (S_s - 1)}\right) 100 \tag{X2.5}$$

∰ C 127 – 04

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 127 – 01, that may impact the use of this test method. (Approved August 1, 2004)

(1) Added new section 6.5.

(2) Modified sections 8.1 and 8.5.

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