



Designation: ~~D4546 – 14~~<sup>ε1</sup> D4546 – 21

## Standard Test Methods for One-Dimensional Swell or Collapse of Soils<sup>1</sup>

This standard is issued under the fixed designation D4546; 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.

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~~<sup>ε1</sup> NOTE—Editorially updated units of measurement statement in April 2018.~~

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### 1. Scope\*

1.1 This standard covers two laboratory test methods for measuring the magnitude of one-dimensional wetting-induced swell or collapse of unsaturated soils and one method for measuring load-induced compression subsequent to wetting-induced deformation.

1.1.1 Test Method A is a procedure for measuring one-dimensional wetting-induced swell or hydrocompression (collapse) of reconstituted specimens simulating field condition of compacted fills. The magnitude of swell pressure (the minimum vertical stress required to prevent swelling), and free swell (percent swell under a pressure of 1 kPa or 20 lbf/ft<sup>2</sup>) can also be determined from the results of Test Method A.

1.1.2 Test Method B is a procedure for measuring one-dimensional wetting-induced swell or collapse deformation of intact specimens obtained from a natural deposit or from an existing compacted fill. The magnitude of swell pressure and free swell can also be determined from the results of Test Method B.

1.1.3 Test Method C is a procedure for measuring load-induced strains on a reconstituted or intact specimen after the specimen has undergone wetting-induced swell or collapse deformation.

1.2 In Test Method A, a series of reconstituted specimens duplicating compaction condition of the fine fraction of the soil in the field (excluding the oversize particles) are assembled in consolidometer units. Different loads corresponding to different fill depths are applied to different specimens and each specimen is given access to free water until the process of primary swell or collapse is completed (Fig. 1) under a constant vertical total stress (Fig. 2). The resulting swell or collapse deformations are measured. This test method can be referred to as *wetting-after-loading tests* on multiple reconstituted specimens. The data from these tests can be used to estimate one-dimensional ground surface heave or settlement that can occur due to full wetting after fill construction. In addition, the magnitude of swell pressure and the magnitude of free swell can be interpreted from the test results.

1.3 Test Method B is commonly used for measuring one-dimensional wetting-induced swell or hydrocompression of individual intact samples. This method can be referred to as *single-point wetting-after-loading test*. The vertical pressure at wetting for the specimen is chosen equal to the vertical in-situ stress (overburden stress plus structural stress, if any) corresponding to the sampling depth. The test result indicates the amount of heave or hydrocompression that can result when the soil at a given fill depth is wetted from the current moisture condition to full inundation condition. If intact specimens from various depths are tested, the swell or collapse strain data can be used to estimate heave or settlement of the ground surface. If the objective of the test is to measure swell pressure for an expansive soil, a series of intact specimens from a given depth zone can be wetted under a range of pressures (similar to Test Method A) and the results interpreted to determine the magnitude of the swell pressure.

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.05 on Strength and Compressibility of Soils.

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

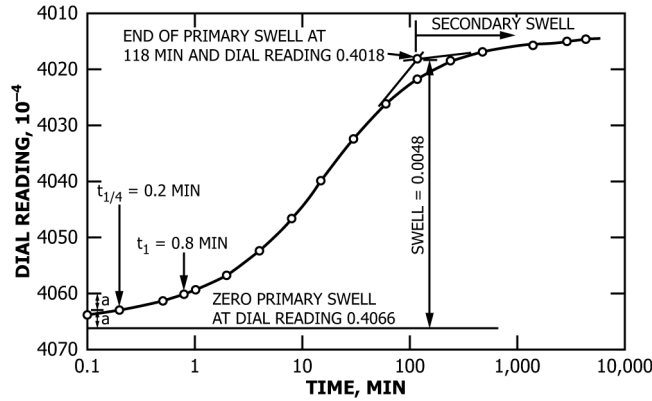


FIG. 1 Time-Swell Curve

1.4 Test Method C is for measuring load-induced strains after wetting-induced swell or collapse deformation has occurred. This method can be referred to as *loading-after-wetting test*. The test can be performed on either intact or reconstituted specimens, and can be on one specimen or a series of specimens. The results would apply to situations where new fill, additional structural loads, or both, are applied to the ground that has previously gone through wetting-induced heave or settlement. The first part of the test is the same as in Test Method A or B. After completion of the swell or collapse under a given vertical load, additional vertical load increments are applied to the specimen in the same manner as in a consolidation test (Test Methods [D2435/D2435M](#)) and the load-induced strains are measured.

1.5 It shall be the responsibility of the agency requesting this test to specify the magnitude of each load for Test Method A and Test Method B. For Test Method C, the agency requesting the test should specify the magnitude of the stress under which the specimen is wetted, and the magnitudes of the additional stress increments subsequent to wetting.

1.6 These test methods do not address the measurement of soil suction and suction-controlled swell-collapse tests. The addition of suction-controlled wetting does not constitute nonconformance to these test methods.

1.7 These test methods have a number of limitations and their results can be affected by one or a combination of factors including the effect of significant amounts of oversize particles (in Test Method A), sampling disturbance (in Test Method B) and differences between the degree of wetting in the laboratory test specimens and in the field. For details of these and other limitations, see Section 6.

1.8 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard. Test results recorded in units other than SI shall not be regarded as nonconformance with this standard. Figures depicting the test results can be either in SI units or in inch-pound units.

1.8.1 The converted inch-pound units use the gravitational system of units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The slug unit is not given, unless dynamic ( $F = ma$ ) calculations are involved.

1.8.2 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in  $\text{lbm/ft}^3$  shall not be regarded as nonconformance with this standard.

1.8.3 The terms density and unit weight are often used interchangeably. Density is mass per unit volume whereas unit weight is force per unit volume. In this standard density is given only in SI units. After the density has been determined, the unit weight is calculated in SI or inch-pound units, or both.

1.9 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice [D6026](#).

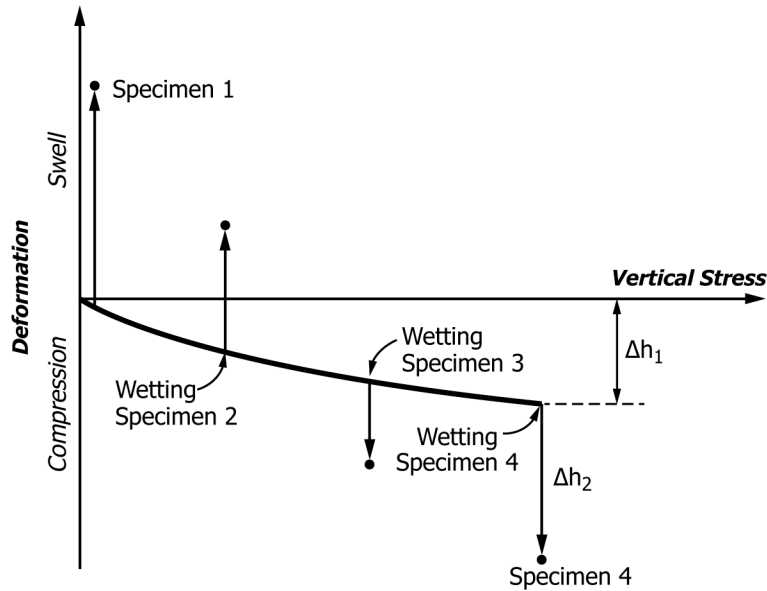


FIG. 2 Deformation Versus Vertical Stress, Test Method A

1.9.1 The procedures used to specify how data are collected/recorded, or 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 consideration 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 this standard to consider significant digits used in analysis methods for engineering design.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

[C127 Test Method for Relative Density \(Specific Gravity\) and Absorption of Coarse Aggregate](#)

[D422 Test Method for Particle-Size Analysis of Soils \(Withdrawn 2016\)<sup>3</sup>](#)

[D653 Terminology Relating to Soil, Rock, and Contained Fluids](#)

[D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer](#)

[D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes](#)

[D2216 Test Methods for Laboratory Determination of Water \(Moisture\) Content of Soil and Rock by Mass](#)

[D2435/D2435M Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading](#)

[D2487 Practice for Classification of Soils for Engineering Purposes \(Unified Soil Classification System\)](#)

[D2488 Practice for Description and Identification of Soils \(Visual-Manual Procedures\)](#)

[D3550/D3550M Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils](#)

[D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction](#)

[D4220/D4220M Practices for Preserving and Transporting Soil Samples](#)

[D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils](#)

[D4718/D4718M Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles](#)

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

[D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing](#)

[D6026 Practice for Using Significant Digits in Geotechnical Data](#)

[D6027/D6027M Practice for Calibrating Linear Displacement Transducers for Geotechnical Purposes](#)

[D6913/D6913M Test Methods for Particle-Size Distribution \(Gradation\) of Soils Using Sieve Analysis](#)

### 3. Terminology

3.1 *Definitions*—For definitions of common technical terms in this standard, refer to Terminology [D653](#).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *collapse or hydrocompression (L)*—wetting-induced decrease in height of a soil element or test specimen.

3.2.2 *collapse or hydrocompression strain*—%-wetting-induced change in height divided by the height immediately prior to wetting.

3.2.3 *compression (L)*—decrease in height of a soil element or test specimen due to wetting (synonymous with hydrocompression or collapse) or due to increase in total stress.

3.2.4 *free swell, %*—percent swell following absorption of water at the seating pressure of 1 kPa (20 lbf/ft<sup>2</sup>).

3.2.5 *intact specimen*—a test specimen obtained from a natural deposit or from an existing compacted fill or embankment using undisturbed sampling equipment.

3.2.6 *percent heave or settlement, %*—change in vertical height divided by the height of a column of soil immediately before wetting.

3.2.7 *primary swell or collapse (L)*—amount of swell or collapse characterized as being completed at the intersection of the two tangents to the curve shown in [Fig. 1](#).

3.2.8 *reconstituted specimen*—a test specimen compacted into a mold.

3.2.9 *secondary swell or collapse (L)*—long-term swell or collapse characterized as the linear portion of the plot shown in [Fig. 1](#) following completion of primary swell or collapse.

3.2.10 *settlement (L)*—decrease in vertical height of a column of soil.

3.2.11 *swell (L)*—increase in thickness of a soil element or a soil specimen following absorption of water.

3.2.12 *swell pressure ( $FL^{-2}$ )*—the minimum stress required to prevent swelling.

### 4. Summary of Test Methods

4.1 In these test methods a soil specimen is restrained laterally in a rigid mold and loaded vertically (axially) in increments up to a load that depends on the purpose of the test. Subsequent to reaching equilibrium under the applied load, the specimen is inundated with test water and the one-dimensional wetting-induced swell or collapse strain is measured. Test Method A is specified for specimens that are reconstituted using the fill material excluding the oversize fraction. Test Method B is for intact samples of a natural soil or an existing fill. In both cases, the measured strains are wetting-induced, not load-induced. Test Method C is used for measuring load-induced compression subsequent to wetting-induced swell or ~~collapse~~collapse.

### 5. Significance and Use

5.1 The wetting-induced swell/collapse strains measured from Test Methods A and B can be used to develop estimates of heave

or settlement of a confined soil profile (1 and 1-24).<sup>4</sup> They can also be used to estimate the magnitudes of the swell pressure (Fig. 3) and the free swell strain-strain (percent swell under a pressure of 1 kPa (20 lbf/ft<sup>2</sup>)). The load-induced strains after wetting from Test Method C can be used to estimate stress-induced settlement following wetting-induced heave or settlement. Selection of test method, loading, and inundation sequences should, as closely as possible, simulate field conditions because relatively small variations in density and water content, or sequence of loading and wetting can significantly alter the test results (1, 35 and 46).

NOTE 1—The quality of the result produced by this standard 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 D3740 are generally considered capable of competent and objective testing. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depends on several factors; Practice D3740 provides a means of evaluating some of these factors.

6. Limitations

6.1 When using data from these test methods, the following limitations should be considered:

6.1.1 Laboratory one-dimensional tests simulate vertical deformation with full lateral restraint; they do not simulate lateral collapse or lateral swell.

6.1.2 Inundation of specimens in the laboratory represent an extreme case of wetting and the results represent upper bound values for swell/collapse strains, and the degrees of saturation typically rise to 90–95 % (not 100 %, (1)). The wetting situation in the field rarely produces inundation; wetting is often caused by water percolation. In-situ water contents and degrees of saturation typically end up being somewhat lower than those caused by inundation in the laboratory. Consequently, the magnitudes of swell/collapse strains in the field might be somewhat smaller than those measured in the laboratory. Partial wetting tests can be performed for estimating a partial wetting reduction factor can be estimated for use in conjunction with heave/settlement calculations using data from soil suction measurements in the field (13), 2, and or data from partial wetting tests (51).

6.1.3 Because laboratory tests are usually performed in small molds, gravels and other granular inert particles (oversize) are excluded from the specimen. The specimen is reconstituted using water content and dry density of the fine fraction. Because of

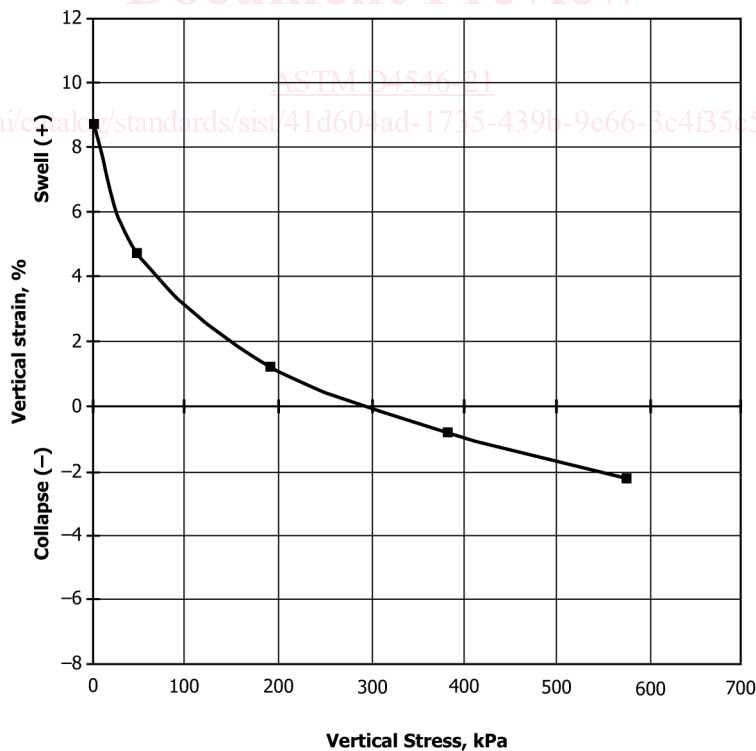


FIG. 3 Stress Versus Wetting-Induced Swell/Collapse Strain, Test Method A

<sup>4</sup> The boldface numbers in parentheses refer to a list of references at the end of this standard.

limitations on the accuracy of the oversize correction equations 1 and 2 (Practice ~~D4718~~D4718/D4718M), tests in large molds would be necessary for soils that have more than 40 % oversize particles larger than 4.75 mm (No. 4) sieve.

6.1.4 Disturbance and variability in composition of intact specimens can affect the test results. The effect of disturbance can be particularly significant for soils of low plasticity that have some cementation in their natural state (54).

6.1.5 Rates of swell or collapse as measured by laboratory time rate curves are not always reliable indicators of field rates of heave/settlement due to soil nonuniformity, fissures or localized permeable layers within the soil mass, variability in percentage of oversize particles, and non-uniform wetting (different sources of water, concurrent vertical downward percolation and lateral percolation from canyon sides, localized wetting anomalies due to leaking buried utility lines, cyclic wetting episodes).

6.1.6 Secondary long-term swell/collapse may be significant for some soils and estimates of slow time-dependent secondary heave/settlement can be added if necessary. This can be done based on the slope of plot of strain versus Log time line in Fig. 1.

6.1.7 Any differences between the chemical content of the field water and the water used in the laboratory tests might influence the amount of heave/settlement in the field.

6.1.8 For reliable test results, the stress path and the wetting sequence should as closely as possible simulate field conditions. Because the shape of the wetting-induced strain versus vertical stress curves (Figs. 3-5) depend on the stress path and the wetting sequence (1, 35, and 46), loading-after-wetting tests on a single specimen (Test Method C) should not be expected to give results applicable to wetting-after-loading cases (Test Methods A and B)B).

## 7. Apparatus

7.1 *Consolidometer*—A suitable device for applying axial loads to the specimen. The device shall be capable of maintaining the specified loads for long periods of time with a precision of  $\pm 0.5$  % of the applied load.

7.1.1 *Specimen Ring*—The consolidation ring holding the specimen shall be fabricated to a tolerance of at least 0.1 %. The ring shall be stiff enough to prevent significant lateral deformation of the specimen throughout the test. The rigidity of the ring shall be such that, under hydrostatic stress conditions in the specimen, the change in diameter of the ring will not exceed 0.04 % of the diameter under the greatest load applied. The ring shall be made of a material that is noncorrosive in relation to the soil or pore fluid. The inner surface shall be highly polished or shall be coated with a low-friction material.

7.1.2 *Minimum Specimen Diameter*—The minimum specimen diameter or inside diameter of the specimen ring shall be 50 mm (2.00 in.).

7.1.3 *Minimum Specimen Height*—The minimum initial specimen height shall be 20 mm (0.8 in.), but shall be not less than six times the maximum particle diameter in the soil.

7.1.4 *Minimum Specimen Diameter-to-Height Ratio*—The minimum specimen diameter-to-height ratio shall be 2.5.

7.2 *Porous Disks*—The porous disks shall be of silicon carbide, aluminum oxide, or other material of similar stiffness that is not

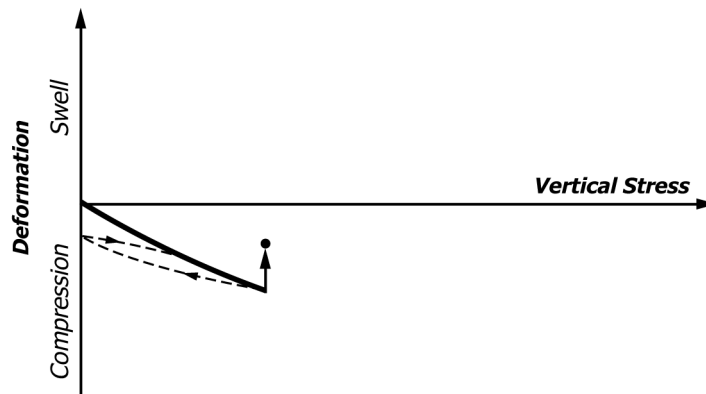


FIG. 4 Deformation Versus Vertical Stress, Single-Point Test Method B

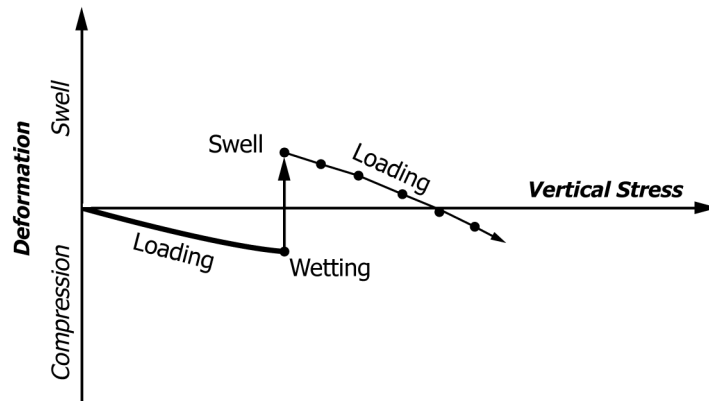


FIG. 5 Deformation Versus Vertical Stress, Loading-after-Wetting Test Method C

corroded by the specimen or pore fluid. The disks shall be fine enough that the soil will not penetrate into their pores, but have sufficient hydraulic conductivity so as not to impede the flow of water from the specimen. Porous disks shall be smooth ground and fine enough to minimize intrusion of soil into the disk if filter paper is not used, and shall reduce false displacements caused by seating of the specimen against the surface of porous disk. Errors due to such false displacements may be significant, especially if displacements and applied vertical pressures are small.

NOTE 2—A suitable pore size is 10  $\mu\text{m}$  if filter paper is not used.

7.2.1 Porous disks shall be air-dried. New porous disks should be boiled in water for about 10 minutes before air-drying to ambient temperatures. Immediately after each use, clean the porous disks with a non-abrasive brush and wash or boil to remove any soil particles.

7.2.2 Porous disks shall fit close to the consolidometer ring to avoid extrusion or punching of the soil specimen under high vertical pressures. Suitable porous disk dimensions are described in Test Methods [D2435/D2435M](#).

7.2.3 If filter paper is used with porous disks, the paper should be included when the system is being calibrated in both dry and wet conditions (see Section 9).

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NOTE 3—Filter paper is not recommended because of its high compressibility after wetting.

7.3 *Plastic Wrap, Aluminum Foil, or Moist Filter Paper*, a loose fitting cover to enclose the specimen, ring, and porous stones prior to inundating the specimen, used to minimize evaporation from the specimen.

7.4 *Micrometer or Other Suitable Device*—To measure the inside diameter of the mold and the height of the specimen to the nearest 0.025 mm (0.001 in.).

7.5 *Deformation Indicator*—To measure the axial deformation of the specimen with a resolution of 0.0025 mm (0.0001 in.) or better. Practice [D6027/D6027M](#) provides details on the evaluation of displacement transducers

7.6 *Balances*—The balance(s) shall be suitable for determining the mass of the specimen plus the containment ring and for making the water content measurements. The balance(s) shall be selected as discussed in Guide [D4753](#). The mass of specimens shall be determined to at least four significant digits.

7.7 *Drying Oven*, in accordance with Test Methods [D2216](#).

7.8 *Water Content Containers*, in accordance with Test Methods [D2216](#).

7.9 *Environment*—Unless otherwise specified by the requesting agency, the standard test temperature shall be in the range of  $22 \pm 5^\circ\text{C}$ . In addition, the temperature of the consolidometer, test specimen, and submersion reservoir shall not vary more than  $\pm 2^\circ\text{C}$