Designation: D4643 – 08

Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating[1]

This standard is issued under the fixed designation D4643; 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 U.S. Department of Defense.

1. Scope*

1.1 This test method outlines procedures for determining the water (moisture) content of soils by incrementally drying soil in a microwave oven.

1.2 This test method can be used as a substitute for Test Method D2216 when more rapid results are desired to expedite other phases of testing and slightly less accurate results are acceptable.

1.3 When questions of accuracy between this test method and Test Method D2216 arise, Test Method D2216 shall be the referee method.

1.4 This test method is applicable for most soil types. For some soils, such as those containing significant amounts of halloysite, mica, montmorillonite, gypsum or other hydrated materials, highly organic soils, or soils in which the pore water contains dissolved solids (such as salt in the case of marine deposits), this test method may not yield reliable water content values.

1.5 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this test method.

1.6 Refer to Practice D6026 for guidance concerning the use of significant figures. This is especially important if the water content will be used to calculate other relationships such as moist mass to dry mass or vice versa, wet unit weight to dry unit weight or vice versa, and total density to dry density or vice versa. For example, if four significant digits are required in any of the above calculations, then the water content has to be recorded to the nearest 0.1 %. This occurs since 1 plus the water content (not in percent) will have four significant digits regardless of what the value of the water content is; that is, 1 plus 0.1/100 = 1.001, a value with four significant digits. While, if three significant digits are acceptable, then the water content can be recorded to the nearest 1 %.

1.7 *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.* See Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
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

3. Terminology

3.1 *Definitions:*

3.1.1 All definitions are in accordance with Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *microwave heating*—a process by which heat is induced within a material due to the interaction between dipolar molecules of the material and an alternating, high frequency electric field. Microwaves are electromagnetic waves with 1 mm to 1 m wavelengths.

3.2.2 *water (moisture) content*—the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of soil to the mass of the solid particles.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

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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 the ASTM website. DOI: 10.1520/D4643-08.

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

4. Summary of Test Method

4.1 A moist soil specimen is placed in a suitable container and its mass is determined. It is then placed in a microwave oven, subjected to an interval of drying, and removed from the oven and its new mass is determined. This procedure is repeated until the mass becomes nearly constant.

4.2 The difference between the mass of the moist specimen and the dried specimen is used as the mass of water originally contained in the specimen. The water content is determined by dividing the mass of water by the dry mass of soil, multiplied by 100. For a given soil and sample size, the time to achieve a constant dry mass can be noted and used as a minimum drying time for subsequent tests using the same size specimen of the same soil.

5. Significance and Use

5.1 The water content of a soil is used throughout geotechnical engineering practice both in the laboratory and in the field. The use of Test Method D2216 for water content determination can be time consuming and there are occasions when a more expedient method is desirable. The use of a microwave oven is one such method.

5.2 The principal objection to the use of the microwave oven for water-content determination has been the possibility of overheating the soil, thereby yielding a water content higher than would be determined by Test Method D2216. While not eliminating this possibility, the incremental drying procedure described in this test method will minimize its effects. Some microwave ovens have settings at less than full power, which can also be used to reduce overheating.

5.3 The behavior of a soil, when subjected to microwave energy, is dependent on its mineralogical compositions, and as a result no one procedure is applicable for all types of soil. Therefore, the procedure recommended in this test method is meant to serve as a guide when using the microwave oven.

5.4 This test method is best suited for minus No. 4 sized material. Larger size particles can be tested; however, care must be taken because of the increased chance of particle shattering.

5.5 The use of this method may not be appropriate when highly accurate results are required, or the test using the data is extremely sensitive to moisture variations.

5.6 Due to the localized high temperatures that the specimen is exposed to in microwave heating, the physical characteristics of the soil may be altered. Degregation of individual particles may occur, along with vaporization or chemical transition. It is therefore recommended that samples used in this test method not be used for other tests subsequent to drying.

NOTE 1—The quality of the results produced by this test method 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 test method are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Microwave Oven*—A microwave oven, preferably with a vented chamber, is suitable. The required size and power rating of the oven is dependent on its intended use. Ovens with variable power controls and input power ratings of about 700 W have been found to be adequate for this use. Variable power controls are important and reduce the potential for overheating of the test specimen.

NOTE 2—Microwave ovens equipped with built-in scales and computer controls have been developed for use in drying soils. Their use is compatible with this test method.

6.2 *Balances,* having a capacity of 2000 g or greater and meeting the requirements of Specification D4753 for a balance of 0.1 g readability.

6.3 *Specimen Containers*—Suitable containers made of a nonmetallic nonabsorbent material, resistant to thermal shock, and not subject to changes in mass or shape when subjected to repeated heating, cooling, or cleaning. Porcelain evaporating dishes and standard borosilicate glass dishes perform satisfactorily. Other containers, such as paper cups or plates, also have been used satisfactorily; however, they may require pre-drying prior to use.

6.4 *Container Handling Apparatus*—A glove or holder, suitable for removing hot containers from the oven.

6.5 *Desiccator*—A desiccator cabinet or jar of suitable size containing silica gel, anhydrous calcium phosphate, or equivalent. It is preferable to use a desiccant that changes color to indicate that it needs reconstitution.

6.6 *Heat Sink*—A material or liquid placed in the microwave to absorb energy after the moisture has been driven from the test specimen. The heat sink reduces the possibility of overheating the specimen and damage to the oven. Glass beakers filled with water and materials that have a boiling point above water, such as nonflammable oils, have been used successfully. Moistened bricks have also been used.

6.7 *Stirring Tools*—Spatulas, putty knives, and glass rods for cutting and stirring the test specimen before and during the test. Short lengths of glass rods have been found useful for stirring and may be left in the specimen container during testing, reducing the possibility of specimen loss due to adhesion to the stirring tool.

7. Hazards

7.1 Handle hot containers with a container holder. Some soil types can retain considerable heat, and serious burns could result from improper handling.

7.2 Suitable eye protection is recommended due to the possibility of particle shattering during the heating, mixing, or mass determinations.

7.3 Safety precautions supplied by the manufacturer of the microwave should be observed. Particular attention should be paid to keeping the door sealing gasket and door interlocks clean and in good working condition.

NOTE 3—The use of a microwave oven for the drying of soils may be considered abusive by the manufacturers and constitute voiding of

warranties. Microwave drying of soils containing metallic materials may cause arcing in the oven. Highly organic soils and soils containing oils and coal may ignite and burn during microwave drying. Continued operation of the oven after the soil has reached constant weight may also cause damage or premature failure of the microwave oven.

NOTE 4—When first introduced, microwave ovens were reported to affect heart pacemakers, primarily because of the operating frequencies of the two devices. Since that time, pacemakers have been redesigned, and the microwave oven is not regarded as the health hazard it once was. However, it may be advisable to post warnings that a microwave is in use.

7.4 Highly organic soils and soils containing oil or other contaminates may ignite into flames during microwave drying. Means for smothering flames to prevent operator injury or oven damage should be available during testing. Fumes given off from contaminated soils or wastes may be toxic, and the oven should be vented accordingly.

7.5 Due to the possibility of steam explosions, or thermal stress shattering porous or brittle aggregates, a covering over the sample container may be appropriate to prevent operator injury or oven damage. A cover of heavy paper toweling has been found satisfactory for this purpose. This also prevents scattering of the test sample in the oven during the drying cycle.

7.6 Do not use metallic containers in a microwave oven because arcing and oven damage may result.

7.7 Observe manufacturer's operating instructions when installing and using the oven.

7.8 The placement of the test specimen directly on the glass liner tray provided with some ovens is strongly discouraged. The concentrated heating of the specimen may result in the glass tray shattering, possibly causing injury to the operator.

8. Samples

8.1 Keep the samples that are stored prior to testing in non-corrodible airtight containers at a temperature between approximately 3 and 30°C in an area that prevents direct exposure to sunlight.

8.2 The water content determination should be performed as soon as practical after sampling, especially if potentially corrodible containers (such as steel thin-walled tubes, paint cans, and the like) or unsealed sample bags are used.

9. Test Specimen

9.1 For water contents being determined as part of another ASTM test method, the specimen selection process, specimen mass requirement, and techniques specified in that test method shall be followed. If no minimum specimen mass is provided in that method then the values given in Table 1 below shall apply.

9.2 The manner in which the test specimen is selected and its required mass is basically dependent on the purpose (application) of the test, type of material being tested, and the type of sample (specimen from another test, bag, tube, split-barrel, and the like). In all cases, however, a representative portion of the total sample shall be selected. If a thinly layered soil or more than one soil type is encountered, select an average portion or individual portions, or both, and note which portion(s) was tested in the report of the results.

9.2.1 For bulk samples, select the test specimen from the material after it has been mixed thoroughly. The mass of moist material selected shall be in accordance with Table 1.

9.2.2 For small (jar) samples, select a representative portion in accordance with the following procedure:

9.2.2.1 For cohesionless soils, mix thoroughly the material, and then select a test specimen having a mass of moist material in accordance with Table 1.

9.2.2.2 For cohesive soils, remove about 3 mm of material from the exposed periphery of the sample and slice the remaining specimen in half (to check if the material is layered), prior to selecting the test specimen. If the soil is layered, see 9.2. The mass of moist material selected should be in accordance with Table 1, if coarse-grained particles are noted. Breaking or cutting of cohesive samples to approximately 6-mm particles will speed drying and prevent crusting or the overheating of the surface while drying the interior.

9.3 Using a test specimen smaller than the minimum mass indicated previously requires discretion, though it may be adequate for the purpose of the test. A specimen having a mass less than the previously indicated value shall be noted in the report of the results.

NOTE 5—In many cases, when working with a small sample containing a relatively large coarse-grained particle, it is appropriate not to include this particle in the test specimen. If this occurs, it should be noted in the report of the results.

9.4 When results of a water (moisture) content determination by the use of this test method are to be compared to the results of another method, such as Test Method D2216, a second sample should be obtained during the selection of the sample for this test method. Precautions should be taken to obtain a sample of the same water (moisture) content. The comparison sample should be processed as quickly as possible to avoid moisture losses.

TABLE 1 Test Specimen Masses

Sieve Retaining Not More Than About 10 % of Sample	Recommended Mass of Moist Specimen, g
2.0 mm (No. 10)	100 to 200
4.75 mm (No. 4)	300 to 500
19 mm (¾ in.)	500 to 1000

10. Conditioning

10.1 Prepare and process the specimens as quickly as possible to minimize unrecorded moisture loss that will result in erroneous water content determinations.

10.2 Cut or break up the soil into small size aggregations to aid in obtaining more uniform drying of the specimen.

10.3 If the specimens are not to be tested immediately, store them in sealed containers to prevent loss of moisture.

11. Procedure

11.1 Determine the mass of a clean, dry container or dish, and record.

11.2 Place the soil specimen in the container, and immediately determine and record the mass.