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.

Designation: D4643 – 17

Standard Test Method for Determination of Water Content of Soil and Rock 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 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 significant amounts of dissolved solids (such as salt in the case of marine deposits), this test method may not yield reliable water content values due to the potential for heating above 110°C or lack of means to account for the presence of precipitated solids that were previously dissolved.

1.5 The values stated in SI units are to be regarded as the standard. Performance of the test method utilizing another system of units shall not be considered non-conformance. The sieve designations are identified using the "standard" system in accordance with Specification E11, such as 2.0-mm and 19-mm, followed by the "alternative" system of No. 10 and ¾-in., respectively, in parentheses.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless otherwise superseded by this standard.

1.6.1 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 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 this standard to consider significant digits used in analysis methods for engineering design.

1.6.2 Significant digits are 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 %, for water contents below 100 %. 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 (below 100 %); 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

D4220 Practices for Preserving and Transporting Soil Samples

[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**

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D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D5079 Practices for Preserving and Transporting Rock Core Samples (Withdrawn 2017)[3]
D6026 Practice for Using Significant Digits in Geotechnical Data
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to 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.

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 4.75-mm (No. 4) sieve 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*—All balances must meet the requirements of Specification D4753 and this section. A Class GP2 balance of 0.1 g readability is generally required. However, the balance used may be controlled by the number of significant digits needed (see 1.6).

6.3 *Specimen Containers*—Suitable, microwave safe 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 (optional)*—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

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

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, breaking up, 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 Soil samples shall be preserved and transported in accordance with Practice D4220 Section 8, Groups B, C, or D. Rock samples shall be preserved and transported in accordance with Practice D5079 Section 7.5.2, Special Care Rock. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct contact with sunlight. Disturbed samples in jars or other containers shall be stored in such a way to minimize moisture condensation on the insides of the containers.

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 For those samples consisting entirely of rock or gravel-sized aggregate, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles.

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.

9.4 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.

9.5 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, etc.).

9.6 For disturbed samples such as trimmings, bag samples, etc; obtain the test specimen by one of the following methods (listed in order of preference):

9.6.1 If the material is such that it can be manipulated and handled without significant moisture loss and segregation, the material should be mixed thoroughly. Select a representative portion using a scoop of a size that no more than a few

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

scoopfuls are required to obtain the proper size of specimen defined in 9.1. Combine all the portions for the test specimen.

9.6.2 If the material is such that it cannot be thoroughly mixed or mixed and sampled by a scoop, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.

9.6.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as practical, using random locations that will best represent the moisture condition. Combine all the portions for the test specimen.

9.7 Intact samples such as block, tube, split barrel, etc, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample:

9.7.1 Using a knife, wire saw, or other sharp cutting device, trim the outside portion of the sample a sufficient distance to see if the material is layered, and to remove material that appears drier or wetter than the main portion of the sample. If the existence of layering is questionable, slice the sample in half. If the material is layered, see 9.7.3.

9.7.2 If the material is not layered, obtain the specimen meeting the mass requirements in 9.1 by: (*1*) taking all or one-half of the interval being tested; (*2*) trimming a representative slice from the interval being tested; or (*3*) trimming the exposed surface of one-half or from the interval being tested.

NOTE 5—Migration of moisture in some cohesionless soils may require that the entire sample be tested.

9.7.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on the test data forms or test data sheets.

9.8 When results of a water 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 content. The comparison sample should be processed as quickly as possible to avoid moisture losses.

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 specimen 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 and record the mass of a clean, dry specimen container.

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

11.3 Place the specimen container with the specimen in a microwave oven with the heat sink and turn the oven on for 3 minutes. If experience with a particular soil type and specimen size indicates shorter or longer initial drying times can be used without overheating, the initial and subsequent drying times may be adjusted.

NOTE 6—The 3-minute initial setting is for a minimum sample mass of 100 g, as indicated in Table 1. Smaller samples are not recommended when using the microwave oven because drying may be too rapid for proper control. When very large samples are needed to represent soil containing large gravel particles, the sample may need to be split into segments and dried separately to obtain the dry mass of the total sample.

NOTE 7—Most ovens have a variable power setting. For the majority of soils tested, a setting of "high" should be satisfactory; however, for some soils such a setting may be too severe. The proper setting can be determined only through the use of and experience with a particular oven for various soil types and sample sizes. The energy output of microwave ovens may decrease with age and usage; therefore, power settings and drying times should be established for each oven.

11.4 After the set time has elapsed, remove the specimen container with specimen from the oven, either weigh the specimen container with specimen immediately, or cool (preferably in a desiccator) to allow handling and to prevent damage to the balance. Determine and record the mass.

11.5 With a small spatula or knife or short length of glass rod carefully mix the soil, taking special precaution not to lose any soil.

11.6 Return the specimen container with specimen to the oven and reheat in the oven for 1 minute.

11.7 Repeat 11.4 – 11.6, until the change between two consecutive mass determinations would have an insignificant effect on the calculated water content. A change of 0.1 % or less of the initial wet mass of the soil should be acceptable for most specimens.

11.8 Use the final mass determination in calculating the water content. Obtain this value immediately after the heating cycle, or, if the mass determination is to be delayed, after cooling in desiccator.

11.9 When routine testing of similar soils is contemplated, the drying times and number of cycles may be standardized for each oven. When standardized drying times and cycles are utilized, periodic verification to assure that the results of the final dry mass determination are equivalent to the procedure in 11.7 should be performed.

NOTE 8—Incremental heating, together with stirring, will minimize overheating and localized drying of the soil, thereby yielding results more consistent with results obtained by Test Method D2216. The recommended time increments have been suitable for most specimens having particles smaller than a No. 4 sieve and with a mass of approximately 200 g; however, they may not be appropriate for all soils and ovens, and adjustment may be necessary.

NOTE 9—Water content specimens should be discarded after testing and not used in any other tests due to particle breakdown, chemical changes or losses, melting, or losses of organic constituents.

11.10 A copy of a sample data sheet is shown in Appendix X1. Any data sheet can be used, provided the form contains all the required data.

12. Calculations

12.1 Calculate the water content of the specimen as follows:

$$w = [(\text{mass of water})/(\text{mass of ovendried specimen})] \times 100 \quad (1)$$

$$w = [(M_1 - M_2)/(M_2 - M_c)] \times 100 = (M_w / M_s) \times 100$$

where:

w = water content, %,
M_1 = mass of container and moist specimen, g,
M_2 = mass of container and ovendried specimen, g,
M_c = mass of container, g,
M_w = mass of water, g, and
M_s = mass of ovendried soil, g.

13. Report: Test Data Sheets(s)/Form(s)

13.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.6.

13.2 Record as a minimum, the following general information:

13.2.1 Name of individual performing test,

13.2.2 Date of test,

13.2.3 Identification of the sample (material) being tested, by boring number, sample number, test number, and the like.

13.3 Record as a minimum, the following test specimen data:

13.3.1 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum mass of the specimen, readability of the scale, and intended use of the results, as discussed in 1.6.

13.3.2 Indicate if test specimen has a mass less than the minimum indicated in Table 1.

13.3.3 Indicate if test specimen contains more than one soil type (layered, and the like).

13.3.4 Indication of any material (size, amount, and layer or layer sequences) excluded from the test specimen.

13.3.5 Time and setting of initial drying period and subsequent incremental drying periods.

13.3.6 Initial mass of test specimen prior to drying and the mass after the final incremental drying periods.

13.3.7 Indicate whether or not a desiccator was used.

13.3.8 Identification of comparison test(s) if performed, and the method of test utilized.

13.3.9 Identification of the microwave oven and the drying settings and cycles used, when standardized drying is utilized.

NOTE 10—Water content determinations conducted in accordance with Test Method D2216 or other methods may be recorded on the same report. This is not a mandatory requirement, but may be convenient when the results of the two methods are to be compared.

14. Precision and Bias

14.1 *Precision*—Test data on precision is not presented due to the nature of the soil or rock materials tested by this method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation.

14.1.1 Subcommittee D18.08 is seeking pertinent data from users of this test method on precision and bias comparisons.

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

15. Keywords

15.1 microwave; microwave moisture; microwave oven; moisture content; rapid moisture test; water content

APPENDIX

(Nonmandatory Information)

X1. WATER CONTENT OF SOIL AND ROCK SAMPLE DATA SHEET

X1.1 Refer to Fig. X1.1.

Project Name: _____ Project Number: _____

Laboratory Number					
Boring Number					
Container / Lid Number					
Container Mass, g M_c					
Container+Moist Specimen Mass, g M_1					
Duration in Oven					
Initial Container + Oven Dry Specimen, g					
Duration in Oven					
Secondary Container + Oven Dry Specimen, g					
Duration in Oven					
Third Container + Oven Dry Specimen, g					
Duration in Oven					
Final Container + Oven Dry Specimen, g M_2					
Duration in Oven					
Mass of Water, g $M_w = M_1 - M_2$					
Mass of Solids, g $M_s = M_2 - M_c$					
Water Content, g $w = (M_w / M_s) \times 100$					
Unified Soil Classification Group Symbol (Visual)					
Microwave Power Setting Used					

Remarks: _____

_____

Tested By: _____ Date: _____ Reviewed By: _____

Dry Mass By: _____ Date: _____ Reviewed By: _____

Calculated By: _____ Date: _____ Reviewed By: _____

FIG. X1.1 Water Content of Soil and Rock Sample Data Sheet

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SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (D4643 – 08) that may impact the use of this standard. (February 1, 2017)

(1) The title was changed to reflect current D18 terminology for "water content" and to reflect the applicability to rock.
(2) Clarification regarding the potential limitation of this test method due to lack of temperature control was added to 1.4.
(3) The term "water (moisture) content" was removed from the Definitions section as this term is no longer used in the standard. It has been replaced with "water content" which appears in Terminology D653.
(4) The requirements for the balance have been made less restrictive and consistent with those in D2216.
(5) The use of a desiccator was made optional.
(6) Revisions were made to sampling and minimum sample size requirements for clarity, and to be more consistent with Test Method D2216.
(7) The name of the individual performing the test, the date of the test, and whether or not a desiccator was used were made mandatory in the Report section.
(8) The indication of drying times reflected on the sample data sheet was revised for clarity.
(9) Minor editorial changes were made throughout for improved clarity.

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