



Standard Test Method for Determination of Water Content of Soil By Direct Heating¹

This standard is issued under the fixed designation D4959; 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.

1. Scope*

1.1 This test method covers procedures for determining the water content of soils by drying with direct heat, such as using a hotplate, stove, blowtorch, and the like.

1.2 This test method can be used as a substitute for Test Methods [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 Methods [D2216](#) arise, Test Methods [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 that contain 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 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 3/4-in., respectively, in parentheses.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in [D6026](#), unless otherwise superseded by this standard.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.*

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](#)

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.

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

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions*—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 *direct heating*—a process by which the soil is dried by conductive heating from the direct application of heat in excess of 110°C to the specimen container, such as provided by a hot plate, gas stove or burner, heatlamps, or other heat sources. Direct application of heat by flame to the specimen is not appropriate.

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 subjected to drying by the application of direct heat until dry by appearance, removed from the heat source, and its new mass is determined. This procedure is repeated until the mass becomes nearly constant within specified limits.

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

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 Methods **D2216** for water content determination can be time consuming and there are occasions when a more expedient method is desirable. Drying by direct heating is one such method. Results of this test method have been demonstrated to be of satisfactory accuracy for use in field control work, such as in the determination of water content, and in the determination of in-place dry unit weight of soils.

5.2 The principal objection to the use of the direct heating for water content determination is the possibility of overheating the soil, thereby yielding a water content higher than would be determined by Test Methods **D2216**. While not eliminating this possibility, the incremental drying procedure in this test method will minimize its effects. Some heat sources have settings or controls that can also be used to reduce overheating. Loose fitting covers or enclosures can also be used to reduce overheating while assisting in uniform heat distribution.

5.3 The behavior of a soil when subjected to direct heating is dependent on its mineralogical composition, and as a result, no one procedure is applicable for all types of soils or heat sources. The general procedure of this test method applies to all soils, but test details may need to be tailored to the soil being tested.

5.4 When this test method is to be used repeatedly on the same or similar soil from a given site, a correction factor can usually be determined by making several comparisons between the results of this test method and Test Methods **D2216**. A correction factor is valid when the difference is consistent for several comparisons, and is reconfirmed on a regular specified basis.

5.5 This test method may not be appropriate when precise results are required, or when minor variations in water content will affect the results of other test methods, such as borderline situations where small variations in the measured water content could affect acceptance or rejection.

5.6 This test method is not appropriate for specimens known to contain flammable organics or contaminants, and other test methods should be utilized in these situations.

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/sampling/inspection. 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. Interferences

6.1 When testing sand and gravel size particles, additional care should be taken to avoid the possibility of particle shattering.

6.2 Due to the localized high temperatures in the soil during testing, the physical characteristics of the soil may be altered. Degradation of individual particles may occur, along with vaporization, chemical transition, or loss of organics. Therefore, specimens used in this test method should not be used for other tests subsequent to drying.

7. Apparatus

7.1 *Direct Heat Source*—Any source of heat that can be directed to the soil specimen to raise the specimen temperature to or above 110°C. Commonly used sources include electric, gas, butane or oil-fired stoves, and hotplates, blowtorches, heat lamps, hair driers, space heaters, etc. Heat sources that directly apply open flame to the specimen may cause extreme degradation of the specimen along with oxidation of and depositing of soot in the specimen and should not be used.

7.2 *Balances*—All balances shall meet the requirements of Guide **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**).

7.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and a change in mass upon repeated heating, cooling, and cleaning. One container is needed for each water content determination.

7.4 *Container Handling Apparatus*—Gloves or suitable holder for moving hot containers after drying.

7.5 *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.

7.6 *Miscellaneous (as needed)*—Mixing tools such as spatulas, spoons, etc.; eye protection, such as safety glasses or goggles; dry light-weight paper of tissue, and knives.

8. Hazards

8.1 Container holders or gloves are recommended for handling hot containers. Some soil types can retain considerable heat, and serious burns could result from improper handling.

8.2 Suitable eye protection such as safety glasses or goggles is recommended due to the possibility of particle shattering during heating, mixing, or mass determinations.

8.3 Highly organic soils, and soils containing oil or other contaminants may ignite during drying with direct heat sources. Means for smothering flames to prevent operator injury or equipment damage should be available during testing. Fumes given off from contaminated soils or wastes may be toxic, and should be vented accordingly.

8.4 Due to the possibility of steam explosions, or thermal stress shattering of porous or brittle aggregates, a vented covering over the sample container may be appropriate to prevent operator injury or equipment damage. This also prevents scattering of the test specimen during the drying cycle while aiding in uniform heating of the specimen.

9. Samples

9.1 Perform the water content determination as soon as practical after sampling to prevent water loss and damage to potentially corrodible containers.

9.2 Prior to testing, store samples in non-corrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct exposure to sunlight.

10. Test Specimens

10.1 Select a representative portion of the total sample. If a layered soil or more than one soil type is encountered, select an average portion or individual portions of each, and note which portion(s) were tested in the report of the results.

10.1.1 For cohesionless soils, mix the material thoroughly, and select a test specimen having a mass of moist material in accordance with [Table 1](#).

10.1.2 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 a test specimen having a moist mass in accordance with [Table 1](#). If the soil is layered, see [10.1](#). Breaking or cutting of cohesive samples to approximately 6

mm particles speeds drying and prevents crusting or overheating the surface while drying the interior.

10.2 Using a test specimen smaller than the minimum mass indicated in [Table 1](#) requires discretion, though it may be adequate for the purpose of the test. Note a specimen having a mass less than the previously indicated value in the report of results.

NOTE 2—When working with a small sample containing a relatively large coarse-grained particle, it may be appropriate not to include this particle in the test specimen, depending on the use of test results. If this is done, such exclusion should be noted in the report of the results.

10.3 When the result of a water content determination by the use of this test method is to be compared to the results of another method, such as Test Methods [D2216](#), obtain a second specimen during selection of the specimen for this comparison. Take precautions to obtain a specimen that represents the same water content as closely as possible. Protect the comparison specimens from water loss by transporting and storing the specimens in sealed containers. A correction factor can be determined for use on subsequent water content determinations on the same soil types from the same site when the difference is relatively constant using several comparisons. Check the correction factor on a regular, specified basis. Recognize that different technicians, heat sources, and such may result in different correction factors.

11. Conditioning

11.1 Prepare, process, and test all specimens as quickly as possible to minimize unrecorded moisture loss.

11.2 Cut or break up the soil into small size aggregations to aid in obtaining more uniform drying of the specimen, taking care to avoid any loss of soil.

11.3 If the specimens are not being tested immediately, place the specimens in containers that can be closed and stored in an area not exposed to direct sunlight, to prevent loss of moisture prior to initial mass determinations.

12. Procedure

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

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

12.3 Apply heat to the soil specimen and container, taking care to avoid localized overheating. Continue heating while stirring the specimen to obtain even heat distribution. Continue application of heat until the specimen first appears dry. A comparatively uniform color should result. Avoid localized burnt or darkened appearance of any part of the soil by intermittent mixing and stirring.

12.3.1 Experience with a particular soil type indicates when shorter or longer initial drying periods can be used without overheating.

NOTE 3—A piece of dry, light-weight paper or tissue, such as cigarette paper, placed on the surface of the apparently dry soil will curl or ripple if the soil still contains significant water.

TABLE 1 Test Specimen Masses

Sieve Size Retaining More Than 10 % of Sample, mm	Minimum Mass of Moist Specimen, g ^A
2.0 (No. 10)	200 to 300
4.75 (No. 4)	300 to 500
19.0 (No. ¾)	500 to 1000

^ALarger specimens may be used and are encouraged. Generally, inherent test inaccuracies are minimized by using specimens with as large a mass as practical.

12.4 After an initial heating period has been completed (soil appears dry), remove the container and soil from the heat source and weigh either immediately or after cooling (preferably in a desiccator) to allow handling and prevent damage to the balance. Determine and record the mass of the soil and container.

12.5 Return the container and soil to the heat source for an additional application of heat.

12.6 With a small spatula or knife, carefully stir and mix the soil, taking care not to lose any soil.

12.7 Repeat 12.3 through 12.6 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 dry mass of the soil for the last two determinations should be acceptable for most specimens.

12.8 Use the final dry mass determination in calculating the water content.

12.9 When routine testing of similar soils is contemplated, the drying times and number of cycles may be established and correlated for each heat source and used for subsequent determinations. When pre-determined drying times and cycles are utilized, periodic verification in accordance with the procedure in 12.7 should be performed to ensure that the results of the final dry mass determination are equivalent.

13. Calculation

13.1 Refer to 1.6 regarding significant figures.

13.2 Calculate the water content of the soil as follows:

$$w = [(M_1 - M_2)/(M_2 - M_c)] \times 100 = M_w/M_s \times 100 \quad (1)$$

where:

- w = water content, %,
- M_1 = mass of container and moist specimen, g,
- M_2 = mass of container and dried specimen, g,
- M_c = mass of container, g,
- M_w = mass of water, g, and
- M_s = mass of solid particles, g.

14. Report: Test Data Sheet(s)/Form(s)

14.1 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.

14.2 Record as a minimum, the following:

- 14.2.1 Name of individual performing test,
- 14.2.2 Date of test,

14.2.3 Identification of the sample (material) being tested, by location (boring number, sample number, test number, etc.),

14.2.4 Water content of the specimen to the nearest 1 % or 0.1 % with significant figures in accordance with 1.6

14.2.5 Indication of the test specimen mass, including a note if less than the minimum indicated in Table 1,

14.2.6 Indication of test specimens containing more than one soil type (layered, and the like),

14.2.7 Indication of any material (size and amount) excluded from the test specimen,

14.2.8 Initial mass of test specimen prior to drying, and the mass after the incremental drying periods,

14.2.9 Identification of the type of direct heat source, drying settings, drying times, and number of cycles used, when standardized drying is utilized, and

14.2.10 Identification of comparison test(s) if performed, the method of test utilized and any correction factors applied (see Note 4).

NOTE 4—Water content determinations conducted in accordance with Test Methods D2216 or other methods may be recorded on the same report/data sheet. This is not a mandatory requirement, but may be convenient when the results of the two methods are to be compared.

15. Precision and Bias

15.1 *Precision*—Test data on precision is not presented due to the nature of the soil materials being tested by this test method. It is not feasible and too costly at this time to have ten or more agencies participate in a round-robin testing program. Also, it is not feasible or too costly to produce multiple specimens that have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as operator or laboratory testing variation.

15.2 The precision of this test method is operator-dependent, and is a function of the care exercised in performing the steps of the procedure, giving particular attention to careful control and systematic repetition of the procedures used.

15.2.1 Subcommittee D18.08 is seeking any data from users of this test method that might be used to make a limited statement on precision.

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

16. Keywords

16.1 acceptance tests; compaction control; density; direct heating; laboratory moisture tests; moisture content; moisture control; quality control; rapid method; soil moisture; test procedure; water content

APPENDIX

X1. Sample Data Sheet

X1.1 See Fig. X1.1.

X1. WATER CONTENT OF SOIL SAMPLE DATA SHEET

Project Name: _____		Project Number: _____		
Laboratory Number				
Boring Number				
Container/Lid Number				
Container Mass, g (M_c)				
Container + Moist Specimen Mass, g (M_1)				
Date/Time in Heating				
Initial Container & Dry Specimen Mass, g				
Date Time out of Heating				
Second Container & Dry Specimen Mass, g				
Date/Time out of Heating				
Third Container & Dry Specimen Mass, g				
Date/Time out of Heating				
Final Container and Dry Specimen Mass, g (M_2)				
Date/Time out of Heating				
Mass of Water, g ($M_w = M_1 - M_2$)				
Mass of Solids, g ($M_s = M_c$)				
Water Content, % ($w = M_w / M_s \times 100$)				
Unified Soil Classification Group Symbol (Visual)				
Heat Setting Used				
Remarks/Notes: _____				
Tested By: _____ Date: _____ Reviewed By: _____				
Dry Mass By: _____ Date: _____ Reviewed By: _____				
Calculated By: _____ Date: _____ Reviewed By: _____				

FIG. X1.1 Sample Data Sheet

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2007) that may impact the use of this standard. (January 1, 2016)

- (1) The title was changed to reflect current D18 terminology.
- (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 consistent with those in D2216.
- (5) A desiccator was added as optional equipment and its use is encouraged.
- (6) Clarifications were made to the minimum sample size requirements.
- (7) The name of the individual performing the test and the date of the test were made mandatory in the Reporting section.
- (8) Minor editorial changes were made throughout for improved clarity.
- (9) The summary of changes section was revised.

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