



Standard Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester ¹

This standard is issued under the fixed designation D4944; 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 outlines procedures for determining the water (moisture) content of soil by chemical reaction using calcium carbide as a reagent to react with the available water in the soil producing a gas. A measurement is made of the gas pressure produced when a specified mass of wet or moist soil is placed in a testing device with an appropriate volume of reagent and mixed.

1.2 This test method is not intended as a replacement for Test Method [D2216](#); but as a supplement when rapid results are required, when testing is done in field locations, or where an oven is not practical for use. Test Method [D2216](#) is to be used as the test method to compare for accuracy checks and correction.

1.3 This test method is applicable for most soils. Calcium carbide, used as a reagent, reacts with water as it is mixed with the soil by shaking and agitating with the aid of steel balls in the apparatus. To produce accurate results, the reagent must react with all the water which is not chemically hydrated with soil minerals or compounds in the soil. Some highly plastic clay soils or other soils not friable enough to break up may not produce representative results because some of the water may be trapped inside soil clods or clumps which cannot come in contact with the reagent. There may be some soils containing certain compounds or chemicals that will react unpredictably with the reagent and give erroneous results. Any such problem will become evident as calibration or check tests with Test Method [D2216](#) are made. Some soils containing compounds or minerals that dehydrate with heat (such as gypsum) which are to have special temperature control with Test Method [D2216](#) may not be affected (dehydrated) in this test method.

1.4 This test method is limited to using calcium carbide moisture test equipment made for 20 g, or larger, soil specimens and to testing soil which contains particles no larger than the No. 4 Standard sieve size.

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.

Current edition approved Nov. 1, 2011. Published December 2011. Originally approved in 1989. Last previous edition approved in 2004 as [D4944 – 04](#). DOI: 10.1520/D4944-11.

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

1.5.1 Cited sieve sizes are the standard sieve sizes given in Table 1 of Specification [E11](#).

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice [D6026](#) unless 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; 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 analytical methods for engineering design.

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. For specific hazards statements, 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](#)

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

- Construction Materials Testing
- D6026 Practice for Using Significant Digits in Geotechnical Data
- E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
- E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method can be found in Terminology D653.

4. Summary of Test Method

4.1 A measured volume of calcium carbide, in excess of that needed to react with the water, is placed in the testing apparatus along with two steel balls and a representative specimen of soil having all particles smaller than the No. 4 sieve size and having a mass equal to that specified by the manufacturer of the instrument or equipment. The apparatus is shaken vigorously in a rotating motion so the calcium carbide reagent can contact all the available water in the soil. Acetylene gas is produced proportionally to the amount of available water present. The apparent water content is read from a pressure gauge on the apparatus calibrated to read in percent water content for the mass of soil specified.

4.2 A calibration curve is developed for each instrument and each soil type by plotting the pressure gauge reading and the water content determined from Test Method D2216 using representative specimens of the soil. The calibration curve is used to determine a corrected water content value for subsequent tests on the same type of soil.

5. Significance and Use

5.1 The water content of soil is used throughout geotechnical engineering practice, both in the laboratory and in the field. Results are sometimes needed within a short time period and in

locations where it is not practical to install an oven or to transport samples to an oven. This test method is used for these occasions.

5.2 The results of this test have been used for field control of compacted embankments or other earth structures such as in the determination of water content for control of soil moisture and dry density within a specified range.

5.3 This test method requires specimens consisting of soil having all particles smaller than the No. 4 sieve size.

5.4 This test method may not be as accurate as other accepted methods such as Test Method D2216. Inaccuracies may result because specimens are too small to properly represent the total soil, from clumps of soil not breaking up to expose all the available water to the reagent and from other inherent procedural, equipment or process inaccuracies. Therefore, other methods may be more appropriate when highly accurate results are required, or when the use of test results is sensitive to minor variations in the values obtained.

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/sampling/inspection. Users of this standard 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 *Calcium Carbide Pressure Tester Set Including:*

- 6.1.1 Testing chamber with attached pressure gauge.
- 6.1.2 A set of tared manual balances or portable electronic balance meeting the requirements of a GP2 of Specification D4753.

NOTE 2—Testers that use a smaller mass are available, but are considered too inaccurate for this standard. The testing chamber with pressure gauge and the balances are calibrated as a set (see Section 8). A typical apparatus is shown in Fig. 1.

6.1.3 Carrying case.

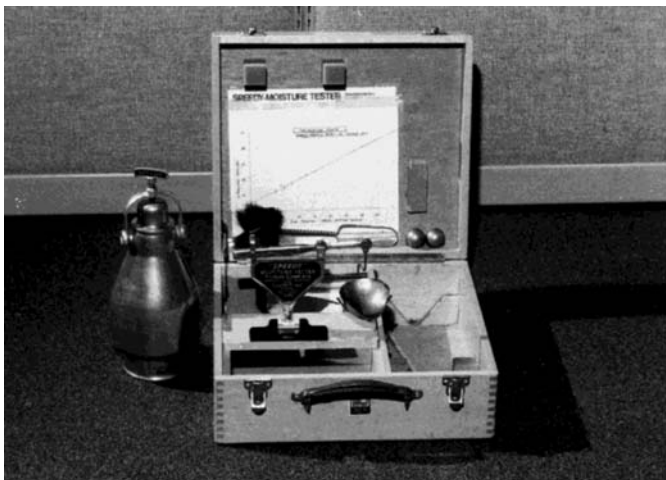


FIG. 1 Typical Calcium Carbide Gas Pressure Test Apparatus for Water Content of Soil Set with Manual Tared Balance

FIG. 1a (left) Apparatus Set with Manual Tared Balance
FIG. 1b (right) Apparatus Set with Portable Electronic Balance

6.1.4 Typical apparatus configurations are shown in **Fig. 1**.

6.2 *Small Scoop*, for measuring reagent.

6.3 *Two Steel Balls*, (manufacturer supplied).

6.4 *Brush and Cloth*, for cleaning and other incidental items.

6.5 *Sieve*, No. 4 (4.75 mm), conforming to the requirements of Specification **E11**.

6.6 *Calcium Carbide Reagent*, finely pulverized, of a grade that will readily combine with the available sample moisture and is capable of producing acetylene gas in the amount of at least 0.14 cubic meters/kg (2.25 cu ft/lb). It is best to purchase calcium carbide in small containers with air tight replaceable lids, to store it in a dry place, to keep the lid on the container at all times except when measuring out a portion for use in a test, and to use a complete container before opening a new one. Calcium carbide quality will deteriorate with time after it becomes exposed to the atmosphere or any source of moisture. Periodic purchase of a new supply is recommended.

6.7 *Miscellaneous Clothing or Safety Equipment*, such as goggles to protect the operator (see **7.2**).

6.8 *Equipment*, as listed in Test Method **D2216**, for performing comparison tests to make calibration curves.

NOTE 3—Calibration kits are available from manufacturers for testing gasket leakage and for calibrating the gauge. Periodic checks for gasket leakage are recommended. The gasket should be changed when leakage is suspected. Gauge calibration problems can usually be detected as the instrument calibration curves are made (see Section 8). When the gauge needs adjusting, any good quality calibrating gauge can be used.

7. Safety Hazards

7.1 When combined with water, the calcium carbide reagent produces a highly flammable or explosive acetylene gas. Testing should not be carried out in confined spaces or in the vicinity of an open flame, embers or other source of heat that can cause combustion. Care should be exercised when releasing the gas from the apparatus to direct it away from the body. Lighted cigarettes, hot objects or open flames are extremely dangerous in the area of testing.

7.2 As an added precaution, the operator should use a dust mask, clothing with long sleeves, gloves and goggles to keep the reagent from irritating the eyes, respiratory system, or hands and arms.

7.3 Attempts to test excessively wet soils or improper use of the equipment, such as adding water to the testing chamber, could cause pressures to exceed the safe level for the apparatus. This may cause damage to the equipment and an unsafe condition for the operator.

7.4 Care should be taken not to dispose or place a significant amount of the calcium carbide reagent where it may contact water because it will produce an explosive gas.

7.5 Calcium carbide is classified as a hazardous material and the user should conform to appropriate regulations regarding the use, storage, handling and transportation of calcium carbide.

8. Calibration

8.1 The manufacturer-supplied equipment set, including the testing chamber with attached gauge and the balance scales, are calibrated as a unit and paired together for the testing procedure.

8.2 Calibration curves must be developed for each equipment set using the general soil types to be tested and the expected water content range of the soil. As new materials are introduced, further calibration is needed to extend the curve data for the specific instrument. If tests are made over a long period of time on the same soil, a new calibration curve should be made periodically, not exceeding 12 months. Before a new batch of reagent is used for testing, two checkpoints shall be compared to the existing curve. If variation is exceeded by more than 1.0 % of moisture, a new calibration curve shall be established.

8.3 Calibration curves are produced by selecting several samples representing the range of soil materials to be tested and having a relatively wide range of water content. Each sample is carefully divided into two specimens by quartering procedures or use of a sample splitter. Taking care to not lose any moisture, one specimen is tested in accordance with the procedure of this test method (see **10.1 – 10.6**) without using a calibration curve, and the other specimen is tested in accordance with Test Method **D2216**.

8.4 The results of the oven dry water content determined by Test Method **D2216** from all the selected samples are plotted versus the gauge reading from the calcium carbide tester for the corresponding test specimen pair. A best fit curve is plotted through the points to form a calibration curve for each soil type. Comparisons should be relatively consistent. A wide scatter in data indicates that either this test method or Test Method **D2216** is not applicable to the soil or conditions. **Fig. 2** shows a typical calibration curve.

8.5 A comparison of this test method with Test Method **D2216** for a given soil can be made by using the calibration curve. Points that plot off the curve indicate deviations. Standard and maximum deviations can be determined if desired.

9. Sampling

9.1 For water content testing being done in conjunction with another method (such as Test Method **D2216**), the requirements for sample and test specimen selection and handling in the other standard shall govern.

9.2 Equipment limitations require the use of specimens smaller than is recommended to properly represent the total soil. Extra care must be exercised to select specimens that are representative of the soil.

9.3 Specimens are to contain only soil particles smaller than the No. 4 Standard sieve size.

10. Procedure

10.1 Remove the cap from the testing chamber of the apparatus and place the recommended amount of calcium carbide reagent along with the two steel balls into the testing

CALIBRATION CURVE

CALCIUM CARBIDE TESTER NO. 721915

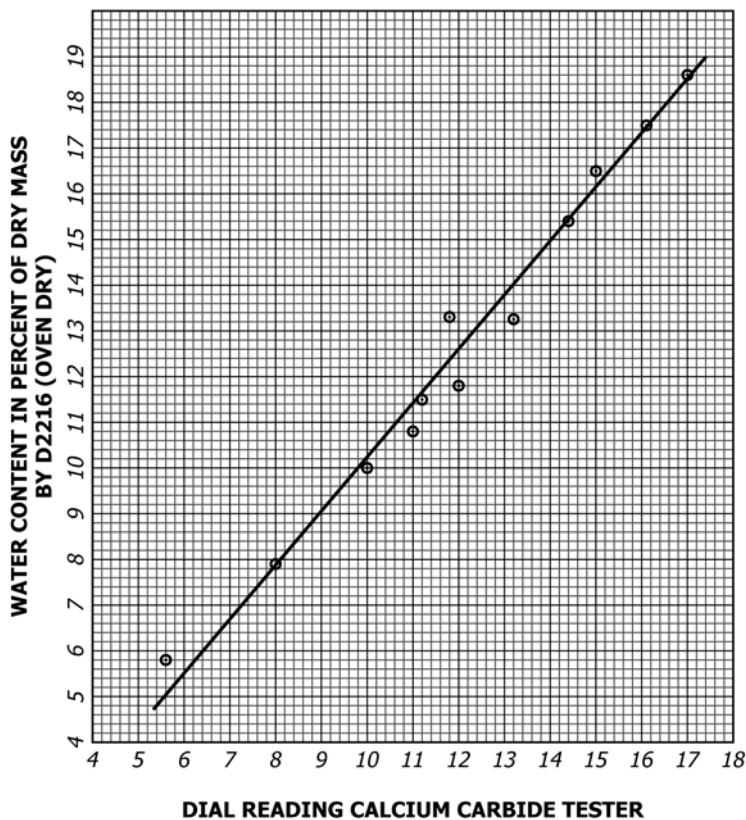


FIG. 2 Typical Calibration Curve

chamber. Most equipment built to test 20-g samples requires approximately 22 g of reagent (measured using the supplied scoop, which is filled two times).

10.2 Use either the manual or portable electronic balance to obtain a specimen of soil that has a mass recommended for the equipment and contains particles smaller than the No. 4 sieve size. Determine the mass to the nearest 0.1 g. One-half specimen size should be used when the water content is expected to exceed the limits of the gauge on the gas pressure chamber or when it actually reaches or exceeds the gauge limit in any test (see 10.6).

10.3 Place the soil specimen in the testing chamber cap; then, with the apparatus in the horizontal position, insert the cap in the testing chamber and tighten the clamp to seal the cap to the unit. Take care that no calcium carbide comes in contact with the soil until a complete seal is achieved.

NOTE 4—The soil specimen may be placed in the chamber with the calcium carbide in the cap if desired.

10.4 Raise the apparatus to the vertical (upright) position so that the contents of the cap fall into the testing chamber. Strike the side of the apparatus with an open hand to assure that all the material falls out of the cap.

10.5 Shake the apparatus vigorously with a rotating motion so that the steel balls roll around the inside circumference and

impact a grinding effect on the soil and reagent. This motion also prevents the steel balls from striking the orifice that leads to the pressure gauge. Shake the apparatus for at least 1 min for sands, increasing the time for silts, and up to 3 min for clays. Some highly plastic clay soils may take more than 3 min. Periodically check the progress of the needle on the pressure gauge dial. Allow time for the needle to stabilize as the heat from the chemical reaction is dissipated.

10.6 When the pressure gauge dial needle stops moving, read the dial while holding the apparatus in the horizontal position. If the dial goes to the limit of the gauge, 10.1 – 10.6 should be repeated using a new specimen having a mass half as large as the recommended specimen. When a half size specimen is used, the final dial reading is multiplied by two for use with the calibration curve.

10.7 Record the final pressure gauge dial reading and use the appropriate calibration curve to determine the corrected water content in percent of dry mass of soil and record.

10.8 With the cap of the testing chamber pointed away from the operator, slowly release the gas pressure (see Section 7). Empty the chamber and examine the specimen for lumps. If the material is not completely pulverized, the test should be repeated using a new specimen.

10.9 Clean the testing chamber and cap with a brush or cloth and allow the apparatus to cool before performing another test. Repeated tests can cause the apparatus to heat up which will affect the results of the test. The apparatus should be at about the same temperature as it was during calibration (determined by touch). This may require warming the instrument up to calibration temperature before use when the temperature is cold.

10.10 Discard the specimen where it will not contact water and produce an explosive gas. It is recommended that the specimen soil not be used for further testing as it is contaminated with the reagent.

11. Report:Data Sheet(s)/Form(s)

11.1 The Data Sheet is to include the following information:

11.1.1 Test number assigned and identification of the sample by location (segment of the project, station, elevation, zone or feature) and by classification or description of the material.

11.1.2 Apparatus identification by number.

11.1.3 Specimen mass and final pressure gauge dial reading from the apparatus, and

11.1.4 Water content of the sample (from the calibration curve) to the nearest 1 %.

12. Precision and Bias

12.1 The precision of this test method is based on an intralaboratory study of Test Method D4944 conducted in 2007 by the Florida Department of Transportation. Eight technicians convened at a single location to participate in this study, analyzing one material at three different water contents. Each “test result” reported represents an individual determination and all participants reported three to five replicate test results for each water content. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report RR:D18-1020.³

³ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D18-1020.

12.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the “*r*” value for that material; “*r*” is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Table 1 below.

12.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the “*R*” value for that material; “*R*” is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

12.1.2.1 Reproducibility limits are listed in Table 1 below.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

12.1.4 Any judgment in accordance with statements 12.1.1 and 12.1.2 would have an approximate 95 % probability of being correct.

12.2 *Bias*—At the time of the study, the calculated water content was also determined by oven drying in accordance with Test Method D2216, and a relative bias for each water content is reported in Table 1.

12.3 The precision statement was determined through statistical examination of 78 test results, conducted by eight individuals, for three water contents. The test material was a medium to fine sand with about 5 % of non-plastic fines. The test material was prepared at three target water contents:

- Target water content A: 8 %
- Target water content B: 12.5 %
- Target water content C: 16.5 %

13. Keywords

13.1 acceptance test; calcium carbide; gas pressure; moisture content; pressure-measuring instrument; quick test; soil moisture; soil water content; water content

TABLE 1 Water Moisture Content of Soil (%)

Target Water Content	Average ^A	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit	Calculated Water Content ^B	Chart Moisture Bias as Compared to the Calculated Water Content (%)
	\bar{x}	s_r	s_R	r	R		
A	8.7	0.22	0.24	0.61	0.68	8.1	106.9
B	13.2	0.23	0.39	0.63	1.10	12.8	103.4
C	17.5	0.60	0.94	1.67	2.62	16.5	105.8

^AThe average of the laboratories’ calculated averages.

^BThe average response from eight laboratories.

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D4944-04, that may impact the use of this test method. (Approved November 1, 2011)

- | | |
|---|--|
| (1) Revised Scope to include requirements for significant digits. | (3) Revised Section 7 to warn user that calcium carbide is classified as a hazardous material. |
| (2) Revised Section 6 to permit the use of portable electronic balances | (4) Heavily revised Section 12 Precision and Bias, including new Table 1. |

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