INTERNATIONAL

~~Designation:D 5220–02~~ Designation: D 5220 – 08

Standard Test Method for Water ~~Content~~Mass per Unit Volume of Soil and Rock In-Place by the Neutron Depth Probe Method[1]

This standard is issued under the fixed designation D 5220; 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 the calculation of the water ~~content~~ mass per unit volume of soil and rock by thermalization or slowing of fast neutrons where the neutron source and the thermal neutron detector are placed at the desired depth in the bored hole lined by an access tube (see Note ~~1~~3).

~~1.2The water content, in mass per unit volume of the material under test, is calculated by comparing the thermal neutron count rate with previously established calibration data (see~~

1.1.1 For limitations see Section 6 on Interferences.

1.2 The water mass per unit volume, expressed as mass per unit volume of the material under test, is calculated by comparing the thermal neutron count rate with previously established calibration data (see Annex A1).

1.3 A precision statement has not been developed for this standard at this time. Therefore, this standard should not be used for acceptance or rejection of a material for purchasing purposes unless correlated to other accepted ASTM methods.

1.4 The values expressed in SI units are regarded as the standard. The inch-pound units given in parentheses may be approximate and are provided for information only.

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1.5 All observed and calculated values shall conform to the guide for significant digits and rounding established in Practice D 6026.

1.5.1 The procedures used to specify how data are collected, recorded, and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally 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 *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.* Specific hazards are given in Section ~~7~~8.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1452 Practice for Soil Investigation and Sampling by Auger Borings

D 1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils

D 1587~~Practice for Thin Walled Tube Sampling of Soils~~[2] Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D 2113~~Practice for Diamond Core Drilling for Site Investigation~~[2] Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 2216~~Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures~~[2] Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D 2937~~Test Method for Density of Soil in Place by the Drive-Cylinder Method~~[2]

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[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] Annual Book of ASTM Standards, Vol 04.08.~~

[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.**

D3017Test Method for Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)[2] Test Method for Density of Soil in Place by the Drive-Cylinder Method
D 3550Practice for Ring-Lined Barrel Sampling of Soils[2] Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D 3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4428/D4228M Test Method for Crosshole Seismic Testing[2] 4428/D 4428M Test Methods for Crosshole Seismic Testing
D 5195Test Method for Density of Soil and Rock in Place at Depths Below the Surface by Nuclear Methods Test Method for Density of Soil and Rock In-Place at Depths Below Surface by Nuclear Methods
D 6026 Practice for Using Significant Digits in Geotechnical Data
D 6938 Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

3. Terminology

3.1 See Terminology D 653 for general definitions.
3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *detector*—a device to detect and measure radiation.
3.2.2 *dry density*—same as density of dry soil or rock (as defined in Terminology D 653); the mass of solid particles per the total volume of soil or rock.
3.2.3 *neutron probe*—a cylindrical device containing a fast neutron source and a thermal neutron detector.
3.2.4 *neutron (radiation) source*—a sealed source of radioactive material that emits neutron radiation as it decays.
3.2.5 *thermalization*—the process of "slowing down" fast neutrons by collisions with light-weight atoms, such as hydrogen.
3.2.6 *volumetric water content*—the volume of water as a percent of the total volume of soil or rock material.
3.2.7 *water content*—the ratio of the mass of water contained in the pore spaces of soil or soil-aggregate, to the solid mass of particles in that material, expressed as a percentage (this is sometimes referred to in some scientific fields as gravimetric water content to differentiate it from volumetric water content).
3.2.8 *wet density*—same as bulk density (as defined in Terminology D 653); the total mass (solids plus water) per total volume.

4. Summary of Test Method

3.1This4.1 This test method uses thermalization of neutron radiation to calculate the in-place water content mass per unit volume of soil and rock at various depths by placing a probe containing a neutron source and a thermal neutron detector at desired depths in a bored hole lined by an access tube as opposed to surface measurements in accordance with Test Method D3017D 6938.
34.2 Neutrons emitted by the source are thermalized (slowed) by collisions with materials of low atomic numbers. Hydrogenous materials, such as water and other compounds containing hydrogen, are most effective in thermalizing neutrons. In this apparatus the neutrons thermalized by the material under test are detected by the thermal neutron detector.
3.3In4.3 In the absence of interference elements as discussed in Section 56, the number of thermalized neutrons is a function of the hydrogen content of the material under test and the water content is proportional to the hydrogen content.
3.4By the use of a calibration process the water content is calculated by correlating the count rate to known water contents.
4.
4.4 By the use of a calibration process the water mass per unit volume is calculated by correlating the count rate to known water mass per unit volume values.

5. Significance and Use

4.1This5.1 This test method is useful as a rapid, nondestructive technique for the calculation of the in-place water content mass per unit volume of soil and rock at desired depths below the surface.
4.2This5.2 This test method is useful for informational and research purposes. It should only be used for quality control and acceptance testing when correlated to actual water contentsmass per unit volume using procedures and methods described in A1.2.3.
4.3The5.3 The non-destructive nature of this test method allows repetitive measurements to be made at a single test location for statistical analysis and to monitor changes over time.
4.4The5.4 The fundamental assumptions inherent in this test method are that the material under test is homogeneous and hydrogen present is in the form of water as defined by Test Method D 2216.
5.

NOTE 1—The quality of the result produced by this standard 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 D 3740 are generally considered capable of competent and objective testing/sampling/inspection, and the like. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Interferences

5.1The6.1 The sample heterogeneity, density, and chemical composition of the material under test will affect the measurements.

The apparatus must be calibrated to the material under test or adjustments made in accordance with Annex A2.

5̲6.1.1 Hydrogen, in forms other than water, as defined by Test Method D 2216 and carbon, present in organic soils, will cause measurements in excess of the true water value. Some elements such as boron, chlorine, and minute quantities of cadmium, if present in the material under test, will cause measurements lower than the true water value.

~~5.2This~~6.2 This test method exhibits spatial bias in that it is more sensitive to water contained in the material closest to the access tube. The measurement is not necessarily an average water content of the total sample involved.

5̲6.2.1 Voids around the access tube can affect the measurement (see ~~11.1.2~~10.1.2).

~~5.3The~~6.3 The sample volume is approximately 0.048 m ^{3} (1.7 ft^3) with a water content of 200 kg/m^3 ~~(12.5 lbf/ft~~(12.5 lbm/ft^3~~)~~). The actual sample volume is indeterminate and varies with the apparatus and the water content of the material. In general, the greater the water content of the material, the smaller the volume involved in the measurement.

~~6.~~

7. Apparatus (See Fig. 1)

~~6.1The~~7.1 The apparatus shall consist of a nuclear instrument capable of measuring water ~~content~~ mass per unit volume at various depths below the surface containing the following:

~~6.1.1A~~7.1.1 A sealed mixture of a radioactive material such as americium or radium with a target element such as beryllium, and a suitable thermal neutron detector, and

~~6.1.2A~~7.1.2 A suitable timed scaler and power source.

~~6.2The~~7.2 The apparatus shall be equipped with a cylindrical probe containing the neutron source and detector, connected by a cable of sufficient design and length, that is capable of being lowered down the cased hole to desired test depths.

~~6.3The~~7.3 The apparatus shall be equipped with a reference standard, a fixed shape of hydrogenous material used for checking apparatus operation and to establish conditions for a reproducible reference count rate. It may also serve as a radiation shield.

~~6.4~~7.4 *Apparatus Precision*—See Annex A3 for the precision of the apparatus.

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7.5 *Accessories:*

~~6.5.1~~

7.5.1 *Access Tubing*—The access tubing (casing) is required for all access holes in nonlithified materials (soils and poorly consolidated rock) that cannot maintain constant borehole diameter with repeated measurements. If access tubing is required the tubing shall be of a material such as aluminum, steel, or polyvinyl chloride, having an interior diameter large enough to permit

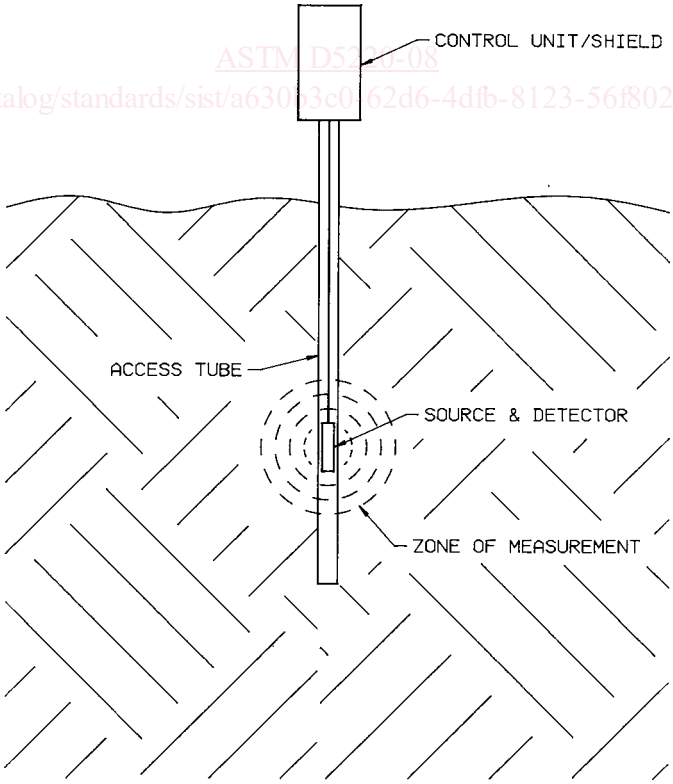

FIG. 1 Schematic Diagram; Water Content by Neutron Depth Probe Method

probe access without binding. The tubing shall be as thin-walled as possible to provide close proximity of the probe to the material under test. The same type of tubing shall be used in the field as is used in calibration.

6.7.5.2 Hand auger or power drilling equipment that can be used to establish the access hole. Any drilling equipment that provides a suitable clean open hole for installation of access tubing and insertion of the probe shall be acceptable. The equipment used shall be capable of maintaining constant borehole diameter to ensure that the measurements are performed on undisturbed soil and rock. The type of equipment and methods of advancing the access hole should be reported.

6.5.3 7.5.3 *Dummy Probe*—A cylindrical probe the same size as the probe containing the neutron source and a chain or cable of sufficient design and length to permit lowering the dummy probe down the cased hole to desired test depths.

7.Hazards

7.1This equipment utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment must become completely familiar with possible safety hazards and with all applicable regulations concerning the handling and use of radioactive materials. Effective user instructions together with routine safety procedures are a recommended part of the operation of this apparatus.

8.Calibration, Standardization, and Reference Check

8.1Calibrate the instrument in accordance with

8. Hazards

8.1 These instruments utilize radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of these instruments must become familiar with applicable safety procedures and government regulations.

8.2 Effective user instructions, together with routine safety procedures and knowledge of and compliance with Regulatory Requirements, are a mandatory part of the operation and storage of these instruments.

9. Calibration, Standardization, and Reference Check

9.1 Calibrate the instrument in accordance with Annex A1.

89.2 Adjust the calibration in accordance with Annex A2 if adjustments are necessary.

8.3*Standardization and Reference Check:*

8.3.1Nuclear apparatus are subject to the long-term decay of the radioactive source and aging of detectors and electronic system, that may change the relationship between count rate and water content. To offset these changes, the apparatus may be calibrated as the ratio of the measurement count rate to a count rate made on a reference standard. The reference count rate should be in the same or a higher order of magnitude than the range of measurement count rates over the useful water content range of the apparatus.

8.3.2Standardization of equipment should be performed at the start of each day's work and a permanent record of these data retained. Perform the standardization with the apparatus located at least 10 m (30 ft) away from other apparatus containing neutron emitting radioactive sources and clear of large masses of water or other items which may affect the reference count rate.

8.3.2.1If recommended by the apparatus manufacturer to provide more stable and consistent results: turn on the apparatus prior to use to allow it to stabilize; and leave the power on during the day's testing.

8.3.2.2Using the reference standard, take at least four repetitive readings at the manufacturer's recommended measurement period and determine the mean. If available on the apparatus, one measurement at a period of four or more times the recommended period is acceptable. These measurements constitute one standardization check.

8.3.2.3If the value obtained above is within the limits stated below, the equipment is considered to be in satisfactory condition and the value may be used to determine the count ratios for the day of use. If the value is outside these limits, allow additional time for the apparatus to stabilize, make sure the area is clear of sources of interference and then conduct another standardization check. If the second standardization check is within the limits, the apparatus may be used, but if it also fails the test, the apparatus shall be adjusted or repaired as recommended by the manufacturer. The limits are as follows:

$$N_s <= N_o + \frac{2.0\sqrt{N_o}}{\sqrt{F}}$$

and

$$N_s >= N_o - \frac{2.0\sqrt{N_o}}{\sqrt{F}}$$

9.3 *Standardization and Reference Check*:

9.3.1 Nuclear density gauges are subject to long-term aging of the radioactive sources, which may change the relationship between count rates and the material density. To correct for this aging effect, gauges are calibrated as a ratio of the measurement count rate to a count rate made on a reference standard.

9.3.2 Standardization of the gauge shall be performed at the start of each day's use, and a record of these data should be retained for the amount of time required to ensure compliance with either Section 9.3.4 or 9.3.5, whichever is applicable. Perform the