Designation: D5220 − 14

Standard Test Method for Water 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 D5220; 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 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.

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 *Units*—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.

1.5 All observed and calculated values shall conform to the guide for significant digits and rounding established in Practice D6026.

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 8.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4428/D4428M Test Methods for Crosshole Seismic Testing
D5195 Test Method for Density of Soil and Rock In-Place at Depths Below Surface by Nuclear Methods
D6026 Practice for Using Significant Digits in Geotechnical Data
D6938 Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

3. Terminology

3.1 *Definitions*—For definitions of common technical terms in this standard, refer to Terminology D653.

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

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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] 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.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *detector*—a device to observe and measure radiation.

3.2.2 *dry density*—same as density of dry soil or rock (as defined in Terminology D653); 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 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 *wet density*—same as bulk density (as defined in Terminology D653); the total mass (solids plus water) per total volume.

4. Summary of Test Method

4.1 This test method uses thermalization of neutron radiation to calculate the in-place water 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 D6938.

4.2 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.

4.3 In the absence of interference elements as discussed in Section 6, 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.

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

5.1 This test method is useful as a rapid, nondestructive technique for the calculation of the in-place water mass per unit volume of soil and rock at desired depths below the surface.

5.2 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 mass per unit volume using procedures and methods described in A1.2.3.

5.3 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.

5.4 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 D2216.

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 D3740 are generally considered capable of competent and objective testing/sampling/inspection, and the like. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Interferences

6.1 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.

6.1.1 Hydrogen, in forms other than water, as defined by Test Method D6938 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.

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.

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

6.3 The actual sample volume that the instrument measures 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. For example, the sample volume is approximately 0.048 m^3 (1.7 ft^3) for a soil with a water content of 200 kg/m^3 (12.5 lbm/ft^3).

7. Apparatus (See Fig. 1)

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

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

7.1.2 A suitable timed scaler and power source.

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.

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.

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

7.5 *Accessories:*

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

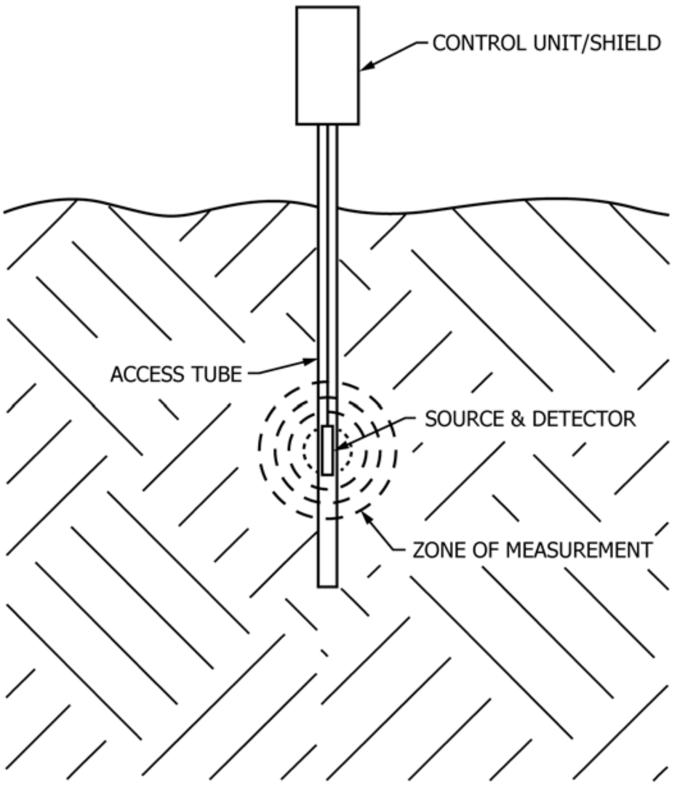

FIG. 1 Schematic Diagram; Water Content by Neutron Depth Probe Method

required the tubing shall be of a material such as aluminum, steel, or polyvinyl chloride, having an interior diameter large enough to permit 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.

7.5.2 *Drilling Tool(s)*—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.

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.

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.

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

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 standardization with the gauge far enough away from other apparatus containing radioactive sources to prevent interference due to radiation from the other apparatus. In addition, perform the standardization far enough away from large masses or other items which can affect the reference count rates due to reflections from these masses or items.

NOTE 2—Separation of nuclear gauges by a distance of 9 m (30 ft) from one another has typically proven sufficient in preventing radiation from one gauge from being detected by another gauge and potentially causing an incorrect standardization count. This separation can be reduced by the proper use of shielding. With regards to reflections from large masses or other items potentially causing incorrect standardization counts, a separation of 1 m (3 ft) between the gauge and the mass or item in question has typically proven sufficient to prevent such reflections from influencing the standardization counts.

9.3.3 Turn on the gauge and allow for stabilization according to the manufacturer's recommendations.

9.3.4 Using the reference standard, take at least four repetitive readings at the normal measurement period and obtain the mean. If available on the gauge, one measurement at four or more times the normal measurement period is acceptable. This constitutes one standardization check. Use the procedure recommended by the gauge manufacturer to establish the compliance of the standard measurement to the accepted range. Without specific recommendations from the gauge manufacturer, use the procedure in 9.3.5.

9.3.5 If the value of the current standardization count is outside the limits set by Eq 1, repeat the standardization check. If the second standardization check satisfies Eq 1, the gauge is considered in satisfactory operating condition.

$$0.98N_c e^{\frac{-ln(2)t}{T_{1/2}}} \leq N_0 \leq 1.02N_c e^{\frac{-ln(2)t}{T_{1/2}}} \quad (1)$$

where:

$T_{1/2}$ = the half-life of the isotope that is used for the density or moisture determination in the gauge. For example, ^{241}Am:Be, the isotope most commonly used for density determination in these gauges, $T_{1/2}$ is 157 788 days,

N_c = the standardization count acquired at the time of the last calibration or verification,

N_0 = the current standardization count,

t = the time that has elapsed between the current standardization test and the date of the last calibration or verification. The units selected for t and $T_{1/2}$ should be consistent, that is, if $T_{1/2}$ is expressed in days, then t should also be expressed in days,
ln( ) = the natural logarithm function, and
e = the positive real number for which the natural logarithm value is equal to one. *e* itself is equal to 2.71828182845904.

9.3.6 *Example*—A nuclear gauge containing a ^{241}Am:Be source for density determination (half-life = 157 788 days) is calibrated on March 1 of a specific year. At the time of calibration, the density standard count was 720 counts per minute (prescaled). According to Eq 1, what is the allowed range of standard counts for November 1 of the same year? For this example, a total of 245 days have elapsed between the date of calibration or verification (March 1) and the date of the gauge standardization (November 1).

Therefore:

t = 245 days
$T_{1/2}$ = 157 788 days
N_c = 720 counts

According to Eq 1, therefore, the lower limit for the density standard count taken on November 1, denoted by N_0, is

$$0.98(N_c)e^{\frac{-(ln(2))t}{T_{1/2}}} = 0.98(720)e^{\frac{-(ln(2))\cdot 245}{157\ 788}} = 706e^{-0.00108} = 705\ counts$$

Likewise, the upper limit for the density standard count taken on November 1, denoted by N_0, is

$$1.02(N_c)e^{\frac{-(ln(2))t}{T_{1/2}}} = 1.02(720)e^{\frac{-(ln(2))\cdot 245}{157\ 788}} = 734e^{-0.00108} = 733\ counts$$

Therefore, the density standard count acquired on November 1 should lie somewhere between 705 and 733 counts, or $705 \leq N_0 \leq 733$.

9.3.7 If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

10. Procedure

10.1 *Installation of Access Tubing (Casing):*

10.1.1 Drill the access tube hole and install access tubing in a manner dependent upon the material to be tested, the depth to be tested, and the available drilling equipment.

10.1.2 The access hole must be clear enough to allow installing the tubing yet must provide a snug fit. Voids along the sides of the tubing may cause erroneous readings.

10.1.2.1 If voids are suspected to be caused by the drilling process they can be grouted using procedures in Test Method D4428/D4428M.

10.1.2.2 The only method to determine the presence of voids is to perform field calibrations provided in A1.2.3.

10.1.3 Record and note the position of the ground water table, perched water tables, and changes in strata as drilling progresses.

10.1.3.1 If ground water is encountered or saturated conditions are expected to develop, seal the tube at the bottom to prevent water seepage into the tube using procedures given in Test Method D4428/D4428M or the manufacturer's recommended procedures. This will prevent erroneous readings and possible damage to the probe.

10.1.4 The tubing should project above the ground and be capped to prevent foreign material from entering. The access tube should not project above the ground so high that it might be damaged by equipment passing over it.

10.1.4.1 Install all tubes at the same height above the ground as this enables marking the cable to indicate the measured depth to be used for all tubes.

10.2 Lower a dummy probe down the access tube to verify proper clearance before lowering the probe containing the radioactive source.

10.3 Standardize the apparatus.

10.4 Proceed with the test as follows:

10.4.1 Seat the apparatus firmly over the access tube, then lower the probe into the tube to the desired depth. Secure the probe by cable clamps (usually provided by the apparatus manufacturer).

10.4.2 Take a measurement count at the selected timing period.

11. Interpretation

11.1 Determine the ratio of the reading obtained compared to the standard count. Then using the calibration data combined with appropriate calibration adjustments, or apparatus direct readout features, calculate the water mass per unit volume of the material under test.

NOTE 3—Some instruments have built-in provisions to compute and display the ratio and corrected water mass per unit volume. The functional relationship between the gauge count response and the water mass per unit volume of the soil or rock being measured is typically linear over short ranges of moisture, quadratic or exponential for larger moisture ranges, or third order polynomial for large ranges of moistures. The functional relationship is highly dependent on the soil type.

11.2 If water content as a percentage of dry density is required, the in-place density may be determined by using either the same apparatus or a different apparatus that determines density at depths below the surface by the nuclear method (see Test Method D5195) or by a method such as density determination of soil in-place by the drive-cylinder method (see Test Method D2937).

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

12.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s) as given below is covered in Section 1.5.

12.2 Record at a minimum the following general information (data):

12.2.1 Make, model, and serial number of the apparatus,
12.2.2 Date of calibration,
12.2.3 Name of operator/test technician,
12.2.4 Method of calibration, such as field, factory, etc.,
12.2.5 Calibration adjustments,
12.2.6 Date of test,
12.2.7 Standard count(s) for the day of the test,
12.2.8 Any adjustment data for the day of the test,
12.2.9 Test site identification including tube location(s), tube number(s),

12.2.10 Tube type and tube installation methods (method of drilling, installing and any initial gravimetric and count data),

12.2.11 Geologic log of the borehole, and

12.2.12 Depth, measurement count data, and calculated water mass per unit volume of each measurement.

13. Precision and Bias

13.1 *Precision*—It is not possible to specify the precision of the procedure in this test method for measuring water mass per unit volume of soil and rock in-place at depths below the surface because the precision of this test method is operator dependent and a function of the care exercised in installing the access tubing and performing the steps of the procedures properly. Interferences as described in Section 6, such as voids, large rocks, and varying water mass per unit volume quantities at different depths of the access tube would also prevent developing a meaningful precision statement.

13.2 *Bias*—No information can be presented on the bias of the procedure in this test method for measuring water mass per unit volume of soil and rock in-place at depths below the surface because no methods are presently available that provide sufficiently accurate values of water mass per unit volume of soil and rock in-place against which this test method can be compared

14. Keywords

14.1 depth probe; in-place water content; in situ water content; neutron probe; nuclear methods; water mass per unit volume

ANNEXES

(Mandatory Information)

A1. APPARATUS CALIBRATION

A1.1 At least once each year, establish or verify calibration curves, tables, or equations by determining the count rate of at least three samples of different known water mass per unit volume. These data may be presented in the form of a graph, table, equation coefficients, or stored in the apparatus, to allow converting the count rate data to water mass per unit volume. The method and test procedures used in establishing these count ratios must be the same as those used for obtaining the count ratios for in-place material. The water mass per unit volume of materials used to establish the calibration must vary through a range to include the water mass per unit volume of materials to be tested and be of a similar density.

A1.2 Calibration standards may be established using one of the following methods. The standards must be verified to be of sufficient size to not change the count rate if enlarged in any dimension. Access tubing used in the standards must be the same type and size as that to be used for in-place measurements.

A1.2.1 Prepare homogeneous standards of hydrogenous materials having a water mass per unit volume determined by comparison (using a nuclear instrument gauge) to a saturated silica sand standard with a known water mass per unit volume. As an alternate, determine the equivalent water mass per unit volume by calculation if the hydrogen, carbon, and oxygen content is known or can be calculated from the specific gravity and chemical composition. A zero water content standard can be prepared by using a non-hydrogenous material, such as magnesium, as the standard.

A1.2.2 Prepare containers of soil and rock compacted to uniform densities with a range of water mass per unit volumes. Determine the percent water content of the materials by oven drying (see Test Method D2216) and a wet density calculated from the mass of the material and the inside dimensions of the container. Whenever possible, use soil and rock obtained from the test site for this calibration.

A1.2.3 Where neither of the previous calibration standards are available or a higher accuracy of calibration is required, the apparatus may be calibrated in the field by using the following methods:

A1.2.3.1 Use a minimum of three selected test sites containing a homogeneous material with as wide a range of water mass per unit volumes as possible. As the access hole is drilled, take gravimetric samples from the soil or rock samples taken by any suitable drilling and sampling method appropriate for the material (see Method D1586 and Practices D1452, D1587, D2113, and D3550) and determine the percent water content by oven drying (see Test Method D2216). Note the sampling intervals for the gravimetric samples. (See Note A1.1.)

NOTE A1.1—For agricultural purposes it is highly practical to obtain the gravimetric samples (see Practice D1452) above the water table in shallow installations. The gravimetric sample will represent a mixture of materials over the interval samples. For a higher level of calibration accuracy it is recommended to obtain samples directly in the measurement interval by other referenced methods.

A1.2.3.2 As soon as possible after the access tubing has been installed, take sufficient measurements at the desired depths in accordance with Section 9 and calculate the count ratio and measured volumetric water content.

A1.2.3.3 The test measurement counts are to be taken at approximate depths that will correspond to the depth location of the gravimetric samples.

A1.2.4 Report any anomalous values, such as voids, grout plugs, changes in strata, or perched water layers, and their probable causes obtained from this calibration.

A1.3 For the highest level of calibration, obtain gravimetric samples from each access hole over the measurement intervals to be tested using the methods given in A1.2.3. At a minimum, obtain gravimetric samples at 2 m intervals and at changes in strata.

A1.3.1 As soon as possible after the access tubing has been installed, take sufficient measurements at the desired depths in accordance with Section 8 and calculate the count ratio and measured water mass per unit volume. The test measurement counts are to be taken at approximate depths that will correspond to the depth location of the gravimetric samples. The initial count profile and adjusted water mass per unit volume data should be reported with later readings to review changes in water mass per unit volume with subsequent readings.

A2. CALIBRATION ADJUSTMENTS

A2.1 Check the calibration response prior to performing tests on materials that are distinctly different from the material types used in establishing the calibration. Also check the calibration response on newly acquired or repaired apparatus.

A2.2 Take sufficient measurements and compare them to samples obtained by other accepted methods such as a volumetric sampling (see Test Method D2937) to establish a correlation between the apparatus calibration and the other method.

A2.2.1 Adjust the existing calibration to correct for the difference or establish a new calibration in accordance with Annex A1.

NOTE A2.1—Some apparatus utilizing a microprocessor may have provision to input a correction factor that is established by determining the correlation between the apparatus measurement and oven drying (see Test Method D2216).

A3. PRECISION OR APPARATUS

A3.1 Instrument precision is defined as the change in measured water mass per unit volume that occurs corresponding to a one standard deviation change in the count due to the random decay of the radioactive source. The water mass per unit volume of the material and time period of the count must be stated. The precision of the apparatus at a water mass per unit volume of 200 kg/m^3 (12.5 lbm/ft^3) shall be better than 5 kg/m^3 (0.3 lbm/ft^3) at the manufacturer's stated period of time for the measurement (see Note A3.1). Other timing periods may be available that may be used where higher or lower precisions are desired for statistical purposes. The precision shall be determined by the procedure defined in A3.2 or A3.3.

NOTE A3.1—While 30 s is the usual timing period and may be used for comparison of various apparatus, the intent of this test method is to require a measurement period that produces the stated precision for all acceptance testing.

A3.2 The precision of the apparatus is determined from the slope of the calibration response and the statistical deviation of the count (detected neutrons) for the period of measurement:

$$P = \sigma\sqrt{S} \qquad \text{(A3.1)}$$

where:

P = apparatus precision in water mass per unit volume (kg/m^3 or lbm/ft^3),
σ = standard deviation in counts per measurement period, and
S = slope in change in counts per measurement period divided by the change in water mass per unit volume (kg/m^3 or lbm/ft^3).

A3.2.1 The counts per measurement period shall be the total number of thermal neutrons detected during the timed period. The displayed value must be corrected for any prescaling that is built into the apparatus. The prescale value (F) is a divisor that reduces the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.

A3.2.2 The standard deviation in counts per measurement period shall be obtained by:

$$\sigma = \sqrt{C/F} \qquad \text{(A3.2)}$$

where:

σ = standard deviation in counts per measurement period,
C = counts per measurement period (before prescale correction) at a water mass per unit volume of 200 kg/m^3 (12.5 lbm/ft^3); and
F = value of prescale (see A3.2.1).

A3.2.3 The counts per measurement period (before prescale correction) may be obtained from the calibration curve, tables, or equation by multiplying the count ratio by the apparatus standard count.

A3.2.4 The slope of calibration response in counts per measurement period (before prescale correction) at a water mass per unit volume of 200 kg/m^3 (12.5 lbm/ft^3) shall be determined from the calibration curve, tables, or equation.

A3.3 Compute the precision by determining the standard deviation of at least 20 repetitive measurements (apparatus not moved after the first measurement) on material having a water mass per unit volume of 160 to 240 kg/m^3 (10 to 15 lbm/ft^3). In order to perform this procedure, the resolution of the count display, calibration response, or other method of displaying water content must be equal to or better than ±1 kg/m^3 (±0.1 lbm/ft^3).

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D5220 – 08) that may impact the use of this standard. (Approved June 15, 2014.)

(1) Added "Units" before 1.4.
(2) Deleted old 3.2.7 (*water content*) as this term is already defined in Terminology D653.
(3) Report section now makes an indirect reference to D6026, has the proper title and instructions.
(4) Fixed circular term references in 3.2.1 and 3.2.4.
(5) Updated 3.1 to standard language.
(6) Used standard language in precision and bias statements in Section 13.
(7) Changed incorrect reference to D2216 to D6938 in 6.1.1.
(8) Added a title to 7.5.2.
(9) Deleted old Note 3 that pertained to destructive testing by alternating drilling and tube installation.
(10) Former Note 4 (which is now Note 3 due to the deletion of the previous Note 3) expands on the functional relationships typically noted between the count response of the type of gauges described in this standard and the water mass per unit volume of the soil being measured.
(11) Subsection 6.3 was clarified.