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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Logging In Situ Moisture Content and Density of Soil and Rock by the Nuclear Method in Horizontal, Slanted, and Vertical Access Tubes[1]

This standard is issued under the fixed designation D 6031; 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 collection and comparison of logs of thermalized-neutron counts and back-scattered gamma counts along horizontal or vertical air-filled access tubes.

1.2 The in situ water content in mass per unit volume and the density in mass per unit volume of soil and rock at positions or in intervals along the length of an access tube are calculated by comparing the thermal neutron count rate and gamma count rates respectively to previously established calibration data.

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

1.4 *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, see Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]
D 1586 Test Method for Penetration Test and Split/Barrel Sampling of Soils[2]
D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]
D 2113 Practice for Diamond Core Drilling for Site Investigation[2]
D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[2]
D 2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)[2]
D 2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method[2]
D 3017 Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)[2]
D 4428/D 4428M Test Methods of Crosshole Seismic Testing[2]
D 4564 Test Method for Density of Soil in Place by the Sleeve Method[2]
D 5195 Test Method for Density of Soil and Rock In-Place at Depths Below the Surface by Nuclear Methods[3]
D 5220 Test Method for Water Content of Soil and Rock In-Place by the Neutron Depth Probe Method[3]

3. Significance and Use

3.1 This test method is useful as a repeatable, nondestructive technique to monitor in-place density and moisture of soil and rock along lengthy sections of horizontal, slanted, and vertical access holes or tubes. With proper calibration in accordance with Annex A1, this test method can be used to quantify changes in density and moisture content of soil and rock.

3.2 This test method is used in vadose zone monitoring, for performance assessment of engineered barriers at waste facilities, and for research related to monitoring the movement of liquids (water solutions and hydrocarbons) through soil and rock. The nondestructive nature of the test allows repetitive measurements at a site and statistical analysis of results.

3.3 The fundamental assumptions inherent in this test method are that the dry bulk density of the test material is constant and that the response to fast neutrons and gammaray energy associated with soil and liquid chemistry is constant.

4. Interferences

4.1 The sample heterogeneity and chemical composition of the material under test will affect the measurement of both moisture and density. The apparatus should be calibrated to the material under test at a similar density of dry soil or rock and in the similar type and orientation of access tube, or adjustments must be made in accordance with Annex A2.

4.2 Hydrogen, in forms other than water, as defined by Test Method D 2216, will cause measurements in excess of the true moisture content. 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 moisture content. Some elements with atomic numbers greater than 20

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

such as iron or other heavy metals may cause measurements higher than the true density value.

4.3 The measurement of moisture and density using this test method exhibits spatial bias in that it is more sensitive to the material closest to the access tube. The density and moisture measurements are necessarily an average of the total sample involved.

4.4 The sample volume for a moisture measurement is approximately 0.11 m^3 (3.8 ft^3) at a moisture content of 200 kg/m^3 (12.5 lbf/ft^3). The actual sample volume for moisture is indeterminate and varies with the apparatus and the moisture content of the material. In general the greater the moisture content of the material, the smaller the measurement volume.

4.5 A density measurement has a sample volume of approximately 0.028 m^3 (0.8 ft^3). The actual sample volume for density is indeterminate and varies with the apparatus and the density of the material. In general, the greater the density of the material, the smaller the measurement volume.

4.6 Air gaps between the probe and the access tube or voids around the access tube will cause the indicated moisture content and density to be less than the calibrated values.

4.7 Condensed moisture inside the access tube may cause the indicated moisture content to be greater than the true moisture content of material outside the access tube.

5. Apparatus

5.1 While exact details of construction of the apparatus may vary, the system shall consist of:

5.1.1 *Fast Neutron Source*—A sealed mixture of a radioactive material such as americium or radium and a target material such as beryllium, or other fast neutron sources such as californium that do not require a target.

5.1.2 *Slow Neutron Detector*—Any type of slow neutron detector, such as boron trifluoride or helium-3 proportional counters.

5.1.3 *High-Energy Gamma-Radiation Source*—A sealed source of radioactive material, such as cesium-137, cobalt-60, or radium-226.

5.1.4 *Gamma Detector*—Any type of gamma detector, such as a Geiger-Mueller tube.

5.1.5 *Suitable Readout Device*:

5.1.6 *Cylindrical Probe*—The apparatus shall be equipped with a cylindrical probe, containing the neutron and gamma sources and the detectors, connected by a cable or cables of sufficient design and length, that are capable of raising and lowering the probe in vertical applications and pulling it in horizontal applications, to the desired measurement location.

5.1.7 *Reference Standard*—A device containing dense, hydrogenous material for checking equipment operation and to establish conditions for a reproducible reference count rate. It also may serve as a radiation shield.

5.2 Accessories shall include:

5.2.1 *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 it must be of a material, such as aluminum, steel, or plastic, having an interior diameter large enough to permit probe access without binding, and an exterior diameter as small as possible to provide close proximity of the material under test. The same type of tubing must be used in the field as is used in calibration.

5.2.2 *Hand Auger or Power Drilling/Trenching Equipment*—Equipment that can be used to establish the access hole or position the access tube when required (see 5.2.1). Any equipment that provides a suitable clean open hole for installation of access tubing and insertion of the probe that ensures the measurements are performed on undisturbed soil and rock while maintaining a constant diameter per width shall be acceptable. The type of equipment and methods of advancing the access hole should be reported.

5.2.3 *Winching Equipment or Other Motive Devices*—Equipment that can be used to move the probe through the access tubing. The type of such equipment is dependent upon the orientation of the access tubing and the distance over which the probe must be moved.

6. Hazards

NOTE 1—**Warning:** This 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 all 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.

NOTE 2—**Caution:** When using winching or other motive equipment, the user should take additional care to learn its proper use in conjunction with measurement apparatus. Known safety hazards such as cutting and pinching exist when using such equipment.

NOTE 3—This test method does not cover all safety precautions. It is the responsibility of the users to familiarize themselves with all safety precautions.

7. Calibration, Standardization, and Reference Check

7.1 Calibrate the instrument in accordance with Annex A1.

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

7.3 *Standardization and Reference Check*:

7.3.1 Nuclear apparatus are subject to the long-term decay of the radioactive source and aging of detectors and electronic systems that may change the relationship between count rate and either the material density or the moisture content of the material, or both. To correct for these changes, the apparatus may be calibrated periodically. To minimize error, moisture and density measurements commonly are reported as count ratios, the ratio of the measured count rate to a count rate made in a reference standard. The reference count rate should be similar or higher than the count rates over the useful measurement range of the apparatus.

7.3.2 Standardization of equipment on the reference standard is required at the start of each day's use and a permanent record of these data shall be retained. The standardization shall be performed with the equipment located at least 10 m (33 ft) away from other radioactive sources and large masses or other items that may affect the reference count rate.

7.3.3 If 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.

7.3.4 Using the reference standard, take at least four repetitive readings at the manufacturer's recommended measurement period of 20 or more at some shorter period and obtain the mean. If available on the instrument, one measurement at a period of four or more times the normal test measurement period is acceptable. This constitutes one standardization check.

7.3.5 If the value obtained in 7.3.4 is within the following limits, 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 obtained is outside these limits, another standardization check should be made. If the second standardization check is within the limits, the equipment may be used. If it also fails the test, however, the equipment shall be adjusted or repaired as recommended by the manufacturer.

$$No + 2F\sqrt{\frac{No}{F}} > Ns > No - 2F\sqrt{\frac{No}{F}}$$

where:

Ns = value of current standardization check (7.3.4) on the reference standard,
No = average of the past values of *Ns* taken for prior usage, and
F = value of prescale, a multiplier that alters the count value for the purpose of display (see A3.1.1.1).

7.3.6 If the apparatus standardization has not been checked within the previous three months, perform at lest four new standardization checks and use the mean as the value for *No*.

7.3.7 The value of *Ns* will be used to determine the count ratios for the current day's use of the equipment. If, for any reason, either the measured density or moisture content become suspect during the day's use, perform another standardization to ensure that the equipment is stable.

8. Procedure

8.1 *Installation of Access Tubing (Casing)*:

8.1.1 Drill the access hole or excavate a trench at the desired location and install the access tube in a manner to maximize contact with test material and minimize voids. The access tubes should fit snugly into the access hole or trench. Unstable conditions in fill material around the access tube may result in redistribution of solids over time, piping, or other phenomena that will degrade precision. Voids caused during drilling, tube installation, or backfilling, or a combination thereof, may cause erroneously low results. Excessive compaction of clay-rich backfill material will limit the effectiveness of moisture monitoring for leak detection. Backfill should approximate the composition, water content, and bulk density of test material as nearly as possible.

8.1.2 Grouting of annular spaces, if required, should be of minimum functional thickness, and grout mixtures should not contain excessive water. Grouts thicker than 5 cm (2 in.) create high background counts that will obscure moisture content changes in fine-textured soils and severely limit meaningful density measurements in all soil types. Grouting should not be used unless it is required to seal off flow pathways along the access tube, such as in some vertical borings and where trenches cross engineered barriers. Grouting can be accomplished using procedures described in Test Methods D 4428/D 4428M.

8.1.3 Record and note the position of the ground water table, perched water tables, and changes in soil texture as drilling or trenching progresses.

8.1.4 If ground water is encountered or saturated conditions are expected to develop, seal the tube at seams and open ends to prevent water seepage into the tube. This will prevent erroneous measurements and possible damage to the probe.

8.1.5 The access tube should project above the ground and be capped to prevent foreign material from entering. The access tube should not project out of the test material far enough to be damaged by equipment traffic.

8.2 Pass a dummy probe through the access tube to verify proper clearance before deploying the radioactive sources.

8.3 Standardize the apparatus (see 7.3).

8.4 Proceed with the test run in a continuous logging mode or in a noncontinuous logging mode as follows:

8.4.1 Set up the winching equipment or other motive devices (see 5.2.3) to begin a logging run by stationing the probe at one end of the access tube to be logged.

8.4.2 Select a timing period for collecting measurement counts based on desired precision (see Annex A3), anticipated measurement response, or site-specific logistical criteria.

8.4.3 For testing in continuous logging mode, advance the probe continuously through the access tube while recording data that relate gamma counts and thermal neutron counts to position intervals or time (for constant logging speed), or both.

8.4.4 For testing in noncontinuous logging mode, advance the probe through the access tube to the desired position and stop, record counts while probe is stationary, advance the probe to the next desired position, and repeat. Record data relating gamma counts and thermal neutron counts to discrete positions along the access tube.

9. Calculation

9.1 Calculations related to reporting density as calibrated units are provided in Test Method D 5195. For moisture content, these same calculations are provided in Test Method D 3017.

9.2 Data can be used in a comparative mode, as in graphs or charts. For example, measurements from repeated logging events can be compared directly at each position (or interval) and analyzed to detect statistically significant changes from background.

9.2.1 For data reported as uncalibrated counts, the accepted estimator of the standard deviation of a population of nuclear count measurements is equal to the square root of the mean.[4] Standard deviation estimated from more than one background measurement at any given position (or over any specific interval) can be used to define tolerance levels. The tolerance level defines a threshold neutron count above which there is a defined probability that the count is higher than background.

10. Report

10.1 Report the following information:

[4] Kramer, J. H., Everett, L. G., and Cullen, S. J., 1992. "Vadose Zone Monitoring with Neutron Moisture Probe," *Ground Water Monitoring Review*, Vol 12, No. 2, 1992, pp. 177–187.

10.1.1 Make, model, and serial number of the apparatus.

10.1.2 Date of test.

10.1.3 Standard count for day of the test.

10.1.4 Test site identification including tube location(s) and tube number(s).

10.1.5 Distance (depth), measurement count data, and count ratios or calculated density and moisture content.

10.1.6 Optional graphical display of the magnitude of count measurements along the access tube transect.

10.1.7 Report results in both SI and inch-pound units.

11. Precision and Bias

11.1 *Precision*—The precision of the procedure in Test Method D 6031 must be determined using site-specific samples. Annex A3 is the precision of the instrument and should not be confused with the precision of the test method.

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for Test Method D 6031 for measuring the moisture or density, or both, of soil, bias cannot be determined.

ANNEXES

(Mandatory Information)

A1. CALIBRATION

A1.1 *Calibration Curves*—Calibration curves, tables, or equations shall be established or verified once each year or as recommended by the manufacturer, by determining the nuclear count rate of at least two samples of different known moisture content and at least three samples of different known density. This 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 material moisture content or density. The method and test procedures used in establishing these count rate data must be the same as those used for obtaining the count rate data for in-place material.

A1.2 *Density*—Calibration standards may be established using one of the following methods, or as recommended by the manufacturer. The standards must 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 containers of soil and rock of a range of different densities. Place the material in lifts of thickness that depends upon the compaction method being used. Each lift is to receive equal compactive effort. Calculate the density of each container of material based on the measured volume and mass (weight) of the material.

A1.2.2 Prepare containers of cured concrete using different aggregate to sand ratio mixes to obtain a range of densities. Place the concrete in the containers in a way that will ensure a uniform mixture and uniform densities.

A1.2.3 Prepare containers of non-soil materials. Calculate the soil and rock equivalent density of each container of material based on the measured volume and mass (weight) of the material.

A1.2.4 Take sufficient measurements in each prepared container to establish a correlation between the apparatus measurements and the densities of the material in the containers.

A1.3 *Field Calibration for Density*—The apparatus may be calibrated in the field by using the following method when a verification of laboratory calibration accuracy to field materials is required, or in instances where neither of the previous calibration standards are available, or a more accurate calibration is required.

A1.3.1 During placement of access tubing, obtain undisturbed samples of the material around the tubing from points along it that are representative of the material to be tested. Take undisturbed samples from the soil or rock by any suitable drilling and sampling method appropriate for the material (see Practices D 1452, D 1587, and D 2113, double-tube or triple-tube core samplers, piston samplers, or double-tube hollow stem samplers), and determine the average sample density by trimming excess material and measuring the mass and volume of the samples. Samples should be taken over the length of the access tube in which the probe will be used. At a minimum, obtain undisturbed samples at 2-m (6.6-ft) intervals and at all locations where the material around the access tube changes composition or texture.

A1.3.2 As soon as possible after the access tubing has been installed, take measurements in accordance with Section 8 using the appropriate type of winching equipment detailed in Section 5. The winching speed for continuous logging mode shall be determined by the user, but generally it will fall within the range from 0.6 to 3.0 m (2.0 to 10.0 ft)/min. Based upon laboratory calibrations, calculate the gage density measurement for each reading taken. Take the test measurement counts so that they will include or be adjacent to the location of the undisturbed samples. Compare the sample densities to the gage measurement(s) closest to it (with respect to length along the tubing), and make any needed adjustments to the laboratory calibrations (see Annex A2). Follow the manufacturer's recommendations for any such adjustments. The sample density and measurement count ratios may be presented in the form of a graph, table, equation coefficients, or stored in the gage to allow converting future instrument count ratios to material densities.

A1.3.3 Report all sample data including changes in strata and all anomalous data obtained, such as voids. The initial count profile and adjusted density data should be reported with later readings to review changes in density with subsequent readings.

A1.4 *Moisture Content*—Calibration standards may be established using one of the following methods or as recommended by the manufacturer. The standards must be verified to be large enough to not change the observed count rate (or ratio as defined in 7.3.1) if made larger 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.

A1.4.1 Prepare homogenous standards of hydrogenous materials having moisture contents determined by comparison (using a nuclear instrument) to saturated silica sand standards with known moisture contents. As an alternative, determine the equivalent moisture content by calculation if the hydrogen, carbon, and oxygen content is known or can be calculated from the specific gravity and chemical composition. A zero moisture content standard can be prepared by using an non-hydrogenous material, such as a magnesium alloy, as the standard.

A1.4.2 Prepare containers of soil and rock compacted to uniform densities with a range of moisture contents. Determine the moisture content of the materials by oven drying (see Test Method D 2216). If desired, calculate volumetric moisture content θ_v using Test Methods D 2937 or D 4564 and Eq A1.1. Whenever possible, use soil and rock obtained from the test site for this calibration.

$$\theta_v = \theta_g \times \frac{\rho_d}{\rho_w} \tag{A1.1}$$

where:

θ_v = volumetric moisture content, cm^3/cm^3,
θ_g = gravimetric moisture content, g water/g soil,
ρ_d = in-place dry density of soil, g/cm^3, and
ρ_w = density of water, 1 g/cm^3.

A1.4.3 Take sufficient measurements in each prepared container to establish a correlation between the apparatus measurements and the moisture contents of the material in the containers.

A1.5 *Field Calibration for Moisture Content*—The instrument may be calibrated in the field using the following method when a verification of laboratory calibration accuracy to field materials is required, or in instances where neither of the previous calibration standards are available or a more accurate calibration is required.

A1.5.1 During placement of access tubing obtain undisturbed samples of the material from around the tubing. Take volumetric or gravimetric samples from the soil or rock by any suitable drilling and sampling method appropriate for the material (see Test Method D 1586 and Practices D 1452, D 1587, D 2113, and D 3550) and determine the percent moisture content by oven drying (see Test Method D 2216). Note the sampling intervals for the samples. Samples should be taken over the length of the access tube that the probe will be taking measurements. At a minimum obtain samples at 2-m (6.6-ft) intervals and at all locations where the material around the access tube changes composition.

A1.5.2 As soon as possible after the access tubing has been installed, take measurements in accordance with Section 8 using the appropriate type of winching equipment detailed in Section 5. The winching speed for continuous logging mode shall be determined by the user. Generally, it will fall within the range from 0.6 to 3.0 m (2.0 to 10.0 ft)/min. In addition to these initial measurements, measurements also should be taken when periodic samples are taken. Take the test measurement counts so that they will include or be adjacent to the location of the gravimetric or volumetric samples. Compare the sample moisture contents to the gage measurement(s) closest to it (with respect to length along the tubing), and make any needed adjustments to the laboratory calibrations (see Annex A2). Follow the manufacturer's recommendations for any such adjustments. The sample moisture content and measurement count ratios may be presented in the form of a graph, table, equation coefficients, or stored in the gage to allow converting future instrument count ratios to material moisture contents.

A1.5.3 Report all sample data including changes in strata and all anomalous data obtained, such as voids. The initial count profile and adjusted moisture content data should be reported with later readings to review changes in moisture content 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 apparatus calibration. The calibration response also shall be checked on newly acquired or repaired apparatuses.

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 gravimetric measurements.

A2.2 Take sufficient measurements and compare them to other accepted methods, such as volumetric sampling (see Test Methods D 2937 or D 4564), 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.

A3. PRECISION OF APPARATUS

A3.1 *Density*—The precision of the apparatus on a sample of approximately 2000 kg/m^3 (125 lbf/ft^3) shall be better than 8 kg/m^3 (0.5 lbf/ft^3) at the manufacturer's stated period of time for the measurement. Other timing periods may be available that may be used where higher or lower precision is desired for statistical purposes. The precision shall be determined by the procedure defined in A3.1.1 and A3.1.2.

A3.1.1 The precision of the apparatus is determined from the slope of the calibration response and the statistical deviation of the count (detected gamma radiation) for the period of measurement as follows:

$$P = \sigma/S \quad \text{(A3.1)}$$

where:
P = apparatus precision in density, kg/m^3 or lbf/ft^3,
σ = standard deviation in counts/measurement period, and
S = slope of change in counts/measurement period at a density of 2000 kg/m^3(125 lbf/ft^3) divided by the change in density, kg/m^3 or lbf/ft^3.

A3.1.1.1 The count per measurement period shall be the total number of photons detected during the time period. The displayed value must be corrected for any prescaling which is built into the apparatus. The prescale value (F) is a factor that changes the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.

A3.1.1.2 The standard deviation in counts/measurement period shall be obtained as follows:

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

where:
σ = standard deviation in counts per measurement period,
C = reported counts/measurement period (before prescale correction) at a density of 2000 kg/m^3 (125 lbf/ft^3), and
F = value of prescale (see A3.1.1.1).

A3.1.1.3 The counts/measurement period (before prescale correction) may be obtained from the calibration curve, tables, or equation by multiplying the count ratio by the instrument standard count.

A3.1.1.4 The slope of calibration response in counts/measurement period (before prescale correction) at a density of 2000 kg/m^3 (125 lbf/ft^3) shall be determined from the calibration curve, tables, or equation.

A3.1.2 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 density of 1600 to 2400 kg/m^3 (100 to 150 lbf/ft^3). In order to perform this procedure, the resolution of the count display, calibration response, or other method of displaying density must be equal to or better than 1.6 kg/m^3 ($\pm$0.1 lbf/ft^3).

A3.2 *Moisture Content*—The precision of the apparatus at a moisture content of 200 kg/m^3 (12.5 lbf/ft^3) shall be better than 3 kg/m^3 (0.2 lbf/ft^3) at the manufacturer's stated period of time for the measurement. 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 A3.2.1 or A3.2.2.

A3.2.1 The precision of the apparatus is determined from the slope of the calibration response and the statistical deviation of the count (detected thermal neutrons) for the period of measurement:

$$P = \sigma/S \quad \text{(A3.3)}$$

where:
P = apparatus precision in moisture content, kg/m^3 or lbf/ft^3,
σ = standard deviation, counts per measurement period, and
S = slope in change in counts/measurement period divided by the change in moisture content, kg/m^3 or lbf/ft^3.

A3.2.1.1 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 factor that changes the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.

A3.2.1.2 The standard deviation in counts/measurement period shall be obtained by:

$$\sigma = \sqrt{(C/F)} \quad \text{(A3.4)}$$

where:
σ = standard deviation in counts per measurement period,
C = reported counts per measurement period (before prescale correction) at a water content of 200 kg/m^3 (12.5 lbf/ft^3), and
F = value of prescale (see A3.2.1.1).

A3.2.1.3 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.

A3.2.1.4 The slope of calibration response in counts per measurement period (before prescale correction) at a moisture content of 200 kg/m^3 (12.5 lbf/ft) shall be determined from the calibration curve, tables, or equation.

A3.2.2 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 moisture content of 160 to 240 kg/m^3 (10 to 15 lbf/ft^3). In order to perform this procedure, the resolution of the count display, calibration response, or other method of displaying moisture content must be equal to or better than $\pm$1.6 kg/m^3 ($\pm$0.1 lbf/ft^3).