



Designation: D4444 – 13 (Reapproved 2018)

Standard Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters¹

This standard is issued under the fixed designation D4444; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method applies to the measurement of moisture content (MC) of solid wood products, including those containing additives (that is, chemicals or adhesives) for laboratory standardization and calibration of hand-held moisture meters

1.2 This test method makes no distinction between meter measurement technologies for standardization and calibration requirements. Provision is made for test specimen size to accommodate specific meters. [Appendix X1](#) provides an explanatory discussion and history corresponding to the mandatory sections. Fundamental measurement technologies are described in [Appendix X2](#) when available.

1.2.1 Meters employing differing technologies may not provide equivalent readings under the same conditions. When this test method has been applied, it is assumed that the referenced meter is acceptable unless otherwise specified. Meters shall be calibrated with respect to MC by direct measurement as determined by Test Methods [D4442](#).

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This test method is under the jurisdiction of ASTM Committee [D07](#) on Wood and is the direct responsibility of Subcommittee [D07.01](#) on Fundamental Test Methods and Properties.

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2. Referenced Documents

2.1 ASTM Standards:²

[D1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens](#)

[D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products](#)

[D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials](#)

[D4933 Guide for Moisture Conditioning of Wood and Wood-Based Materials](#)

[D5536 Practice for Sampling Forest Trees for Determination of Clear Wood Properties](#)

[D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters](#)

2.2 Other ASTM Sources:

[ASTM Standards on Precision and Bias for Various Applications, 1992](#)

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *conductance meters*—Conductance meters are those that measure predominantly ionic conductance between points of applied voltage, usually direct current. Direct-current conductance meters are commonly referred to as “resistance” meters. Most commercial conductance meters are high-input impedance (about $10^{12} \Omega$), wide-range (10^4 to $10^{12} \Omega$) ohm-meters.

3.1.2 *capacitive-admittance meters*—Capacitive-admittance meters transmit electromagnetic wave energy into the wood to detect the influence of moisture in the wood on these waves as

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.

an estimate of MC. Wave energy is most often in the radio-frequency range; hand-held meters commonly are placed directly on the wood surface.

4. Significance and Use

4.1 Hand-held meters provide a rapid means of sampling MC of wood-based materials during and after processing to maintain quality assurance and compliance with standards. These measurements are influenced by actual MC, a number of other wood variables, environmental conditions, geometry of the measuring probe circuitry, and design of the meter. The maximum accuracy can only be obtained by an awareness of the effect of each parameter on the meter output and correction of readings as specified by this test method.

4.1.1 This test method employs controlled conditions and straight-grain, clear wood specimens to provide measurements that are reproducible in a laboratory. The controlled conditions prevent moisture and temperature gradients in the test specimen.

4.1.2 In laboratory calibration, the reference direct moisture measurements (for example, Test Methods [D4442](#)) shall be made only in the area of direct measurement of the meter. This minimizes error associated with sampling of differing areas of measurement between this test method and that of the reference (Test Methods [D4442](#)).

4.2 Most uses of hand-held moisture meters employ correlative (predictive) relationships between the meter reading and wood areas or volumes that exceed that of the direct meter measurement (for example, larger specimens, pieces of lumber, or lots). These correlative relationships are beyond the scope of this test method. (See Practice [D7438](#).)

5. Standardization

5.1 *General*—Standardization provides a measured relationship to a standard reference material that can be used to ensure that a meter is operating properly. Standardization shall be performed to establish the integrity of the meter and electrode. Standardization shall be done before calibration and use. If alternate electrodes can be used with a meter, standardization shall be done for all electrode types and alternate assemblies.

5.2 Standardization shall be based, where feasible, on the direct measurement region of the meter as supplied by the meter manufacturer. If not supplied by the manufacturer, the area of direct measurement shall be determined by test.

5.2.1 If the manufacturer recommends an area, a method, or a standard specimen for standardization that does not reflect the entire direct measurement area of the meter, this shall be noted as the manufacturer recommendation.

5.2.2 The meter circuit and electrode shall be tested with external reference material to verify the precision and bias in the meter response range of anticipated use. The meter shall be evaluated over the range of environmental conditions recommended by the manufacturer. The sensitivity of this standardization procedure to temperature of the meter shall be part of the evaluation.

5.2.2.1 The sensitivity of the standardization reference material to the range of environmental conditions in [5.2.2](#) shall be evaluated.

5.2.3 *Report*—The report shall indicate (in the meter manual, on the meter or meter scale, or on the supplied reference standard) the meter model, and the electrodes for which the standardization is valid. The sensitivity of the meter, the electrode assembly and the reference material, as evaluated in [5.2.2.1](#), shall be reported.

5.2.3.1 The manufacturer's recommendation on frequency of standardization shall be included in the report.

6. Calibration

6.1 *General*—Calibration of a meter and the electrode shall establish reference data to adjust meter response for species, ambient conditions, and specimen variables, such as size and density. Meter and electrode assemblies shall be standardized in accordance with Section 5 prior to calibration.

6.2 Calibration:

6.2.1 *Area of Measurement*—Calibration shall be based, where feasible, on the direct measurement region of the meter as supplied by the meter manufacturer. If not supplied by the manufacturer, the area of direct measurement shall be determined by test. Every effort shall be made to quantify the capability of the meter assembly to estimate moisture content by reducing extraneous sources of error.

6.2.2 *Sampling and Analysis*—This calibration procedure is designed for full-scale calibration of the meter and electrode assembly. If only a limited portion of the scale requires calibration, the number of equilibrium moisture content (EMC) levels can be reduced to as low as two. Calibration should not be extrapolated below the lowest value. Extrapolation above 21 % EMC to the fiber saturation point is permissible, provided that caution be taken in regression extension beyond the moisture data high end point. Calculation of confidence limit envelopes are recommended with use of regression in this fashion. Stratified sampling and analysis of variance, or both, can be applied to quantify sensitivity to wood characteristics. If the test material is other than solid wood, it shall be prepared and tested in a manner consistent with the solid wood calibration procedures.

6.2.2.1 *Wood Characteristics*—Wood characteristics that need to be treated as measurement variables because they may influence meter readings shall be represented in the calibration sampling. Examples of these variables are density and mineral content. These characteristics shall be included, identified, and measured as part of random sampling from a target population or they shall be sampled separately as part of a strategy of stratified sampling.

6.2.3 *Sample Preparation*—The sample size shall be based on the sampling principles of Practice [D2915](#), Section 3.4, based upon subsequent subdivision of the sample into sub-sets for conditioning and testing. Specimen size shall be selected to encompass the direct measurement region of the meter/electrode assembly with minimal excess material. Specimens must be free of visible irregularities such as knots, decay, reaction wood, and resin concentrations. The specimens shall be conditioned at $25 \pm 1^\circ\text{C}$ and selected relative humidities to each of five EMC levels between 7 and 21 % (see Guide [D4933](#)). Alternatively, specimens may be equilibrated (following a desorption path) at each of the fiber saturation point

6.2.3.1 *Species*—Species shall be identified. If the sample represents a species group, the individual species of each specimen shall be identified if anatomically possible.

6.2.3.2 *Sapwood/Heartwood*—Specimens shall be chosen to be entirely sapwood or heartwood, or two separate groups of each, but not mixed in the same specimens. It shall be reported if sapwood/heartwood mixing is unavoidable.

6.2.3.3 *Wood Characteristics*—Specimen selection for wood characteristics shall be considered in setting sample size.

6.2.4 *Testing*—There are two steps in the testing phase of calibration. The first is meter measurements on the wood samples following the procedures of this test method and the applicable criteria provided by the manufacturer. The second step is conducting a direct moisture content determination following Test Methods [D4442](#).

6.2.4.1 *Meter Measurement*—The equilibrated specimens are numbered, weighed, and a meter measurement taken with the electrode aligned on the specimen in accordance with the manufacturers recommendation. The speed of response of the meter will determine the timing of the meter reading; manufacturer's recommendations shall be followed unless this variable is examined as part of the calibration process.

6.2.4.2 *Direct Moisture Test*—The MC of each specimen shall be determined by the appropriate direct method (Test Methods [D4442](#)) after the meter measurement. Procedures shall be followed to prevent moisture gain or loss from the specimens between the meter measurement and the direct test.

6.2.5 *Correction Factor Determination*—The corrections applied to moisture meters and the precision and bias of the meters may differ significantly between the technology employed and manufacturing variables. Wood characteristics, species, temperature and chemical additives are specimen variables that may require correction factors. The following procedures shall be followed to determine correction factors for meters.

6.2.5.1 *Correction for Wood Sample Characteristics*—The moisture meter scale readings determined from [6.2.4.1](#) procedures shall be related to the corresponding MC from [6.2.4.2](#) for each specimen in the sample by regression or analysis of variance analysis.

(1) Species calibrations that are intended to represent an entire species (for example, to correspond to globally-determined design values assigned to structural products) shall be obtained only by conducting species-wide sampling.

(2) The species sampling suggested in this test method is not required to be species-wide. Species representation claims based on less-than species-wide sampling shall be correspondingly limited.

6.2.5.2 *Correction for Wood Sample Temperature*—This correction shall be applied after the meter has been standardized in accordance with Section [5](#) and calibrated in accordance with [6.2.5.1](#). The options for this correction are to use a standard temperature correction or to conduct a laboratory calibration.

(1) *Determination of Temperature Correction*—The correction shall be based on samples prepared as specified in [6.2.2](#) except that specimens of known MC (Guide [D4933](#)) at $25 \pm 1^\circ\text{C}$ ($77 \pm 1.8^\circ\text{F}$) shall be placed, with electrodes and

temperature probes attached, in a sealed container. The change in indicated MC (meter indication) shall be recorded while changing temperature through the desired range. A final meter reading must be made at $25 \pm 1^\circ\text{C}$ ($77 \pm 1.8^\circ\text{F}$) to confirm that the MC has not varied from the temperature cycling.

(2) *Standard Temperature Correction*—If a laboratory determination is not made for conductance meters, the following relationship shall be used to correct MC below the fiber saturation point over the temperature range of 0 to 40°C .

$$MC_2 = MC_1 + (0.06MC_1^{0.5})(T_2 - 25) \quad (1)$$

where:

MC_1 = the MC at 25°C .

This information is presented in [Appendix X2](#).

6.2.5.3 *Correction for Chemical Additives*—Meter assemblies applied to wood materials that have been treated with additives and have adhesives interspersed with the fiber, or both, shall be calibrated with those materials following the precepts of this and previous sections on sampling and preparation. Some discretion is appropriate on temperature and moisture levels, depending on the end use of the products.

6.2.6 *Report*—The following wood sample information shall be recorded: MC, size (dimensions in each plane), species and method of species identification, sapwood/heartwood percentage, density or specific gravity, growth rate (rings/25 mm) and ring orientation, and earlywood/latewood percentage. For other materials, the appropriate wood sample information shall be recorded together with adequate data to identify the product and its constituents. The following meter information shall be recorded: manufacturer and model, reference temperature, and electrode type and configuration. The following standardization and calibration information shall be reported: method of analyses and presentation, influence of wood characteristics (variables), influence of temperature and method of correction, and details of electrode placement.

6.2.6.1 If a meter is not accompanied by the calibration data of [6.2.5](#) or by a discussion of sensitivity of the meter to operating characteristics, it shall be acknowledged that the influence of these operating variables is not known. Measurement of precision and bias for such a meter may have limited merit.

7. Presentation of Corrections and Precision and Bias Statements for Moisture Meters

7.1 Meters meeting the requirements of this test method shall have standardization procedures and corrections presented in formats that permit response to the MC, and wood and environmental variables to which the meter may be subjected.

7.1.1 The precision and bias of a meter may differ between the technology and manufacturing variables. If a meter is not accompanied by the calibration data or by a discussion of sensitivity of the meter to operating characteristics, it shall be acknowledged that the influence of these operating variables is not known. Measurement of precision and bias for such a meter may have limited merit.

7.2 Generic statements of precision and bias for hand-held meters are not available at this time.