Designation: D 4444 – 92 (Reapproved 2003)

Standard Test Methods for Use and Calibration of Hand-Held Moisture Meters[1]

This standard is issued under the fixed designation D 4444; 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 Department of Defense.

1. Scope

1.1 These test methods apply to the measurement of moisture content of solid wood, including veneer, and wood products containing additives, that is, chemicals or adhesives (subject to conditions in 6.4 and 9.4). They also provide guidelines for meter use and calibration by manufacturers and users as alternatives to ovendry measurements.

1.2 Conductance and dielectric meters are not necessarily equivalent in their readings under the same conditions. When these test methods are referenced, it is assumed that either type of meter is acceptable unless otherwise specified. Both types of meters are to be calibrated with respect to moisture content on an oven-dry mass basis as determined by Test Methods D 4442.

1.3 The method title indicates the procedures and uses for each type of meter:

		Section
Method A	Conductance Meters	5 to 7
Method B	Dielectric Meters	8 to 10

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials[2]

D 4933 Guide for Moisture Conditioning of Wood and Wood-Base Materials[2]

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 dc. Direct-current conduct-ance meters are commonly referred to as "resistance" meters. Most commercial conductance meters are high-input impedance (about 10^{12} Ω), wide-range (10^4 to 10^{12} Ω) ohmmeters. Their scales are calibrated to read directly in moisture content (oven-dry mass basis) for a particular calibration species and at a specific reference temperature. Readings of conductance meters are practically independent of the relative density (specific gravity) of the specimen material.

3.1.2 *dielectric meters*—There are two general types of dielectric meters that may be arbitrarily categorized by their predominant mode of response—power loss and admittance (or capacitance). Both have surface contact electrodes and readout scales that are usually marked in arbitrary units. Most dielectric meters operate in the r-f frequency range, generally between 1 and 10 MHz. Admittance meters respond primarily to capacitance (dielectric constant) of the material being measured. Power loss meters react primarily to resistance of the material. Readings of dielectric meters are significantly affected by the relative density (specific gravity) of the specimen material.

4. Significance and Use

4.1 Hand-held meters provide a rapid means of sampling moisture content of wood-based materials during and after processing to maintain quality assurance and compliance with standards. However, these measurements are inferential, that is, electrical parameters are measured and compared against a calibration curve to obtain an indirect measure of moisture content. The electrical measurements are influenced by actual moisture content, a number of other wood variables, environmental conditions, geometry of the measuring probe, 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 these test methods.

[1] These test methods are under the jurisdiction of ASTM Committee D07 on Wood and are the direct responsibility of Subcommittee D07.01 on Fundamental Test Methods and Properties.

These test methods replace, in part, Test Methods D 2016 (*Annual Book of ASTM Standards,* Vol 04.09).

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[2] *Annual Book of ASTM Standards,* Vol 04.10.

METHOD A—CONDUCTANCE METERS

5. Standardization and Calibration

5.1 Periodic standardization shall be performed on the meter to test the integrity of the meter and electrode. Laboratory calibration procedures are intended to provide reference data under controlled conditions that include the wood and ambient variables. Field calibration tests on species shall be performed only with a meter that has been standardized and properly compensated for temperature and pin configuration. Initially, standardization should be performed before each period of use. The time interval may be extended if experience shows that the particular meter is stable for a longer time under equivalent use conditions.

5.1.1 *Standardization*—The meter circuit shall be tested by connecting external resistors to the electrode pins, noting the corresponding *MC* (moisture content) value, and comparing with manufacturer's data. At least two, and preferably three points shall be used to standardize the meter. The manufacturer shall indicate (in the manual, on the meter or meter scale, or on the supplied resistance standard) the meter model, wood species, and number of pins for which the resistances are valid.

5.1.2 *Laboratory Calibration*—This procedure is designed for full-scale calibration of the meter. If only a limited portion of the scale requires calibration, the number of *EMC* (equilibrium moisture content) levels can be reduced to as low as two. In any case, the calibration should not be extrapolated below the lowest value. Extrapolation above 21 % *EMC* to the fiber saturation point is permissible, provided a value near 21 % is obtained. Material other than solid wood shall be prepared and tested in a manner that is consistent with the following calibration procedures. Specimen size and shape may be altered to permit testing of product-sized specimens.

5.1.2.1 *Test Sample Preparation*—A minimum of 75 green, flat-sawn specimens 20 mm thick by 75 mm (min) wide by 100 mm along the grain shall be used for a given species. Specimens must be free of visible irregularities such as knots, decay, reaction wood, and resin concentrations (Note 1). The specimens shall be divided into 5 groups of 15 each and conditioned at 25 ± 1°C and selected relative humidities to each of five *EMC* levels between 7 and 21 % (see Guide D 4933). Each group will then be moisture meter tested in accordance with 5.2.2, and moisture contents determined by a direct method (Test Methods D 4442). Alternatively, 15 specimens may be equilibrated (following a desorption path) at each of the 5 *EMC* conditions.

NOTE 1—Ideally, samples shall be chosen to be entirely sapwood or heartwood, or two separate groups of each, but not mixed in the same specimens. In the event that sapwood/heartwood mixing is unavoidable, testing and test results shall be modified to report the effect of mixing on the results.

5.1.2.2 *Moisture Meter Testing*—The equalized specimens are numbered, weighed, and moisture meter tested at their centers using an electrode in accordance with 6.5. The pins are to be aligned so that the current flow is parallel to the grain. Meter scale readings are to be taken and recorded immediately after the electrode pins are inserted.

5.1.2.3 *Species Correction Factor Determination*—The moisture meter scale reading must be regressed against the corresponding moisture content for each specimen in the sample by linear regression analysis. The equation for the regression line ($Y = a + bX$) shall be used to establish the correction factor ($Y - X$) for meter scale readings *(Y)* of 7 to 21 inclusive.

5.1.2.4 The following wood sample information shall be recorded: moisture content, size (dimensions in each plane), species, sapwood/heartwood percentage, relative density, growth rate (rings/25 mm), 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, applied voltage, and electrode type and configuration.

5.2 *Field Calibration*—Under processing conditions, laboratory calibration procedure is impractical, particularly because of moisture gradients. The procedure in 5.1.2 should be applied to develop a meaningful relationship between meter reading and actual *MC*. All field calibrations must be referenced to oven-dry tests to determine precision and bias. Standardization procedures (5.1.1) must be followed to assure valid field calibration at the specific field conditions during testing. Special care must be taken to minimize errors caused by the influence of wood temperature on readings. Specimen size for field testing may be full size or sections thereof.

6. Conductance Meter Use

6.1 *Readings*:

6.1.1 *Range*—The range of moisture contents that can be detected by these meters is from a minimum of 6 or 7 % *MC* to a maximum of 25 to 27 % *MC* (nominal value of the fiber saturation point). Meter scales extend above this limit only to permit temperature corrections of moisture contents up to the fiber saturation point, and do not imply reliability of readings above the fiber saturation point.

NOTE 2—One use of the temperature correction is for "hot metering" of kiln-dried lumber during which readings are taken to determine if the load has reached the desired endpoint *MC*. However, such readings are subject to considerable error because of "edge-readings," assumptions of wood temperature, unknown moisture gradients, and temperature effects on the meter circuitry. A further use of this correction is for moisture measurement of dry lumber that is exposed to below-freezing temperatures. As with hot lumber, considerable errors are possible due to assumptions of wood temperature, unknown moisture gradients, and temperature effects on meter circuitry.

6.1.2 *Moisture Content Readings*—Conductance moisture meters can be used to determine "point" moisture content directly or average moisture content indirectly. Take all readings with the pins aligned so that the current flow is parallel to the grain. Average moisture content can be obtained through the thickness by integrating moisture content versus thickness. Under the following conditions it can also be inferred from a single point measure.

6.1.2.1 *Single Point Average MC Reading*—Wood of rectangular cross section tends to develop a parabolic gradient during drying (assuming that the maximum moisture content is below FSP (fiber saturation point). From the geometry of a parabola, the point of average *MC* lies between one fourth and one fifth of the total thickness. Therefore, if the pins are driven to this point, an approximation can be obtained for average *MC* of the cross section. Using the same principle, a circular cross section has its average *MC* at one sixth to one seventh of the diameter.

NOTE 3—The above generalizations do not pertain if lumber has been dried in conditions that induce steep moisture gradients (such as in drying above 100°C) or if the lumber is known or thought to contain wet pockets or streaks. This can be examined by driving pins to mid-thickness.

6.1.3 *Moisture Gradients*—Unless the moisture distribution and measuring techniques are well understood, readings can be easily misinterpreted. Four special problems should be considered:

6.1.3.1 Noninsulated electrodes (see 6.5.1).

6.1.3.2 Nonparabolic gradients (see Note 3).

6.1.3.3 *Surface Moisture on Electrode*—Surface films of moisture, particularly from condensation on the electrode (insulated pin holder) may cause larger errors. Keep electrodes clean, and store and use under noncondensing conditions.

6.1.3.4 *High Surface MC on Sample*—High surface *MC* of the material from condensation, wetting, and high relative humidity can cause excessively high readings if noninsulated pins are used.

6.1.4 *Drift*—Direct current conductance meters may show appreciable drift toward lower *MC* when readings are taken at the upper portion of the *MC* range. If such drift occurs, take the reading as soon as possible after the pins are driven in and voltage applied.

6.2 *Temperature Corrections*:

6.2.1 *Temperature Effect on Meter*—Meter circuits can be temperature-sensitive, therefore, frequent zero or span adjustments, or both, may be necessary during use. The manufacturer shall indicate the optimum range of temperature for operation of the meter without loss of accuracy due to temperature. It is recommended that whenever possible, the meter be equilibrated with the measurement environment before readings are taken. In no case shall temperature or humidity alter the operating characteristics of a meter (that has been equilibrated and adjusted) to the degree that the accuracy is impaired.

6.2.2 *Temperature Correction*—Make temperature corrections. These are obtainable from manufacturer's data, published data, or using built-in adjustments in the meter. Temperature corrections require special care to obtain the wood (not air) temperature, and may be unreliable to correct some species. A reference temperature of 25°C shall be standard for zero correction. Clearly indicate the reference temperature at some point on the meter. Always make temperature correction before species correction.

6.3 *Species Corrections*:

6.3.1 *Species Correction*—Only use manufacturer's data for the particular meter for either the dial calibration species or corrections for other species or species groups (Note 4) if the data have been developed in accordance with acceptable calibration procedures (5.2) (Note 5). Where correction data are not available, calibrate the meter in accordance with procedure 5.2.

NOTE 4—Species groups (such as Hem-Fir and Spruce-Pine-Fir) may contain species which cannot be visually separated at the point of moisture measurement, or where such separation is impractical.

NOTE 5—For some species, or species groups, property variations related to site or genetics may introduce discrepancies in the correction. In this case, a special calibration should be made, with emphasis on documenting the wood properties.

6.3.2 *Heartwood/Sapwood*——Some species have substantial differences in meter readings for heartwood and sapwood portions having the same actual moisture contents. In field measurements where these zones cannot be visually separated or where separate heartwood/sapwood measurements are impractical, make some judgment for the correct calibration.

6.4 *Corrections For Additives*:

6.4.1 *Chemicals*—Wood products which have been treated with preservatives, fire retardants, or dimensional stabilization agents may give abnormal readings (usually high). Of these chemicals, creosote and pentachlorophenol solutions appear to have insignificant effects.[3] However, salt solutions may cause abnormally high readings, that should be considered qualitative or semiquantitative at best. Conductance meters having insulated pins can be used to measure *MC* of materials that have been surface-treated with chemicals provided that confirmation is made of the accuracy through direct *MC* determination (Test Methods D 4442).

NOTE 6—CCA-C treatment[4] has been reported to be less conductive than salt treatments, reducing the error of readings of treated southern pine to about 2 % MC in the range of 12 to 24 % MC.

6.4.2 *Adhesives*—Adhesives may cause abnormally high readings in reconstituted wood products. Before any particular meter is used in moisture sensing of any particular product containing adhesives, its calibration must be demonstrated on that product. Recalibration must be carried out following any change in processing conditions. The calibrations must be consistent with these test methods.

6.5 *Electrodes*:

6.5.1 Preferred electrodes for the conductance meter for solid wood measurements are of a two-pin type, insulated except for the tips. If noninsulated pins are used, the wood must be tested for surface moisture content (6.1.3.4). If any other electrode is used, such as four-pin for wood or eight-pin for veneer, the readings must be adjusted as specified by the manufacturer (Note 7) or incorporated into the scale corrections. In no case shall different pin configurations be used interchangeably on the same meter without the appropriate corrections.

NOTE 7—Acceptable corrections for solid wood are:[5] reading (two-pin) = 0.29 + 0.91 (reading four-pin), or reading (four-pin) = 1.1 (two-pin) − 0.32. These pin corrections must be made *after* the temperature correction and *before* the species correction.

6.5.2 *Noninsulated Pins*—Noninsulated pins will bias the reading toward the highest moisture content in contact with the

[3] James, W. L., "Effects of Wood Preservatives on Electric Moisture Meter Readings," *U.S. Forest Service Research Note,* FPL-0.06, 1965.

[4] Richards, M. J., "Effect of CCA-C Wood Preservative on Moisture Content Readings by the Electronic-Type Moisture Meter," *Forest Products Journal*, 40(2):29–33, 1990.

[5] Cech, M. Y., and Pfaff, F. "Moisture Content Correction Tables for Resistance-Type Moisture Meters," *Canadian Forestry Service, Eastern Forest Products Laboratory, Forestry Technical Report 7,* 1975.