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Standard Test Methods for MOISTURE CONTENT OF WOOD¹

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This method has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

INTRODUCTION

The importance of moisture content control of lumber and other wood products for various uses cannot be overemphasized. Moisture content control in the processing and fabrication of consumer items of wood requires a rapid and reliable means of moisture determination. Four methods of wood moisture content determination are described herein: One, the electrical method, is non-destructive and practically instantaneous; the other three, namely the oven-drying method, a distillation method, and a hygrometric method, are destructive in that they require that the lot be sampled for specimens that are subsequently analyzed for moisture content.

1. Scope

1.1 These methods cover the determination of the moisture content of wood. The methods provide a means whereby producers, fabricators, processors, and users of wood and wood products can facilitate inspection for adherence to moisture quality-control specifications. The requirements, advantages, and limitations of the different methods are outlined.

1.2 The methods described are commonly used in research and by the producing industries to ascertain the amount of moisture present in specific specimens representing the lot or on samples tested with the electronic moisture meters. These different methods are not equally suitable for moisture content determinations in any given case; therefore, it is important to select the one that is best for the intended application and a specific method may be specified. If these methods are referenced without designation of the specific method to be used, it shall be assumed that all methods are equally acceptable and that the choice will be made by the party responsible for the moisture-

content determination. The following guide to the advantages and limitations of the various methods will assist in making the proper choice:

1.2.1 *Method A—Oven-Drying Method*—The moisture content is calculated from weight values obtained before and after drying a representative specimen of wood in an oven. This has been the most universally accepted method for determining moisture content in research, in wood-seasoning operations such as air drying, predrying, and kiln drying, in moisture content control techniques in processing in wood-working factories. Its limitations are that it is a destructive test in that the samples representing the lot must be cut to produce the specimens; it takes several hours to make an accurate analysis; and accuracy is limited if the wood contains an appreciable amount of volatile extractives, or if the wood has been impreg-

¹ These methods are under the jurisdiction of ASTM Committee D-7 on Wood.

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nated with either volatile or nonvolatile chemicals.

1.2.2 Method B—Electronic Moisture Meter Method—Moisture content control often requires a rapid, nondestructive and reliable means of inspection for moisture content, and this requirement is met most conveniently by electronic moisture meters. Reliable results, however, can be obtained with moisture meters only when they are correctly used. A standard procedure should be established and accepted by users of these instruments and the method presented herein is intended to provide a uniform procedure for the use of electronic moisture meters for wood so that determinations made with them may be reliable and strictly comparable.

1.2.3 Method C—Distillation Method—The distillation method is destructive as is the oven-dry method. The procedure for selecting the specimen for analysis is the same as for the oven-drying method. The method is used when the wood contains volatiles other than water, such as pitch or oil-type preservatives, or has been impregnated with other chemicals that are soluble in toluene. The method generally consists of distilling the water from the fractured specimen along with a liquid that is immiscible with water such as toluene, catching the water in a trap and measuring its volume, and calculating the moisture content. The time required for the test method is often less than 2 h. This method also may be used to determine the quantity of any volatile material such as creosote in the wood specimen.

1.2.4 Method D—Hygrometric Method—The hygrometric method is also destructive as are the oven-drying and distillation methods. However, it is a fairly rapid method for obtaining moisture content estimates on wood samples that have been treated with preservatives or other chemicals. The method is limited to wood having a moisture content less than the fiber-saturation point.

2. Definitions and Description of Terms

2.1 Moisture Content of Wood—The moisture content of wood as determined by any of the methods described herein shall be expressed as a percentage of the oven-dry weight of the wood unless otherwise stipulated. The physical and mechanical properties of wood as they vary with changes in moisture content are generally

reported as a function of moisture content expressed as a percentage of the oven-dry weight of the wood. Moisture content values may exceed 100 per cent.

2.2 unit—one of a number of similar products, parts, specimens, etc., of wood.

2.3 lot—a specific quantity of similar wood units or collection of similar units from a common source; in wood moisture-inspection work, the quantity offered for inspection and acceptance at any one time. It may be a collection of mill items such as boards, dimension, dimension stock, or veneer, or semifinished parts or subassemblies such as furniture items, flooring, trusses, beams, or panels, that are inspected for moisture content during production, or a consignment of finished products to be sent out for service.

2.4 sample—a portion of material or a group of units taken from a larger quantity of material or collection of units, which serves to provide information that can be used as a basis for action on the larger quantity or on the production process.

2.5 specimen—a section, block, core, or other type of test piece cut from a sample or, in the case of nondestructive determinations, the area of a sample piece subjected to a moisture content analysis.

3. Sampling

3.1 The objective of sampling for moisture content specimens or for nondestructive electronic moisture meter tests is to obtain values that represent the lot. Three objectives are sought, namely: (1) an unbiased estimate of the population, or lot, mean; (2) an unbiased estimate of the variance; and (3) the estimates to be as accurate as possible for the time and money spent.

METHOD A—OVEN-DRYING METHOD

4. Apparatus

4.1 Oven—An oven that can be maintained at a temperature of 103 ± 2 C (217.4 ± 3.6 F) throughout the drying chamber for the time required to dry the specimen to constant weight. Ovens may require forced-air circulation to maintain uniform temperature. An accurate thermometer or pyrometer shall be used to check the temperature. For convenience, ovens will normally be thermostatically

controlled. Ovens shall be vented to allow the evaporated moisture to escape.

4.2 *Weighing Device*—A scale or balance that will weigh a specimen within accuracy of ± 0.2 percent. The accuracy and sensitivity of the weighing apparatus shall be checked at least every year against standard weights. Knife edges shall be kept clean to assure accuracy. A torsion balance, Harvard trip balance, triple-beam balance, and automatic direct-reading balance are examples of suitable equipment.

5. Test Specimens

5.1 Specimens vary widely, depending on the type of material being analyzed and the anticipated use of the results. Specimens shall be selected that represent the lot. Unless otherwise specified, specimens shall be full cross sections no less than 25 mm (1 in.) along the grain, but longer as needed to provide a minimum volume of 33 cm³ (2 in.³). The section shall be cut with a sharp saw. All loosely attached slivers shall be removed from the section before it is weighed. Specimens from large items such as logs, poles, posts, piling, and timbers shall be (1) full cross sections, (2) representative sectors of such sections, (3) increment core borings, or (4) auger chips. When the latter two types of specimens are used on round items to represent the average moisture content of the sample, they shall be divided into zones and a weighted average moisture content determined arithmetically from the relative proportion of the cross section each zone represents. Because of the small volume of borings and auger chips, a more sensitive balance is required than would be required for specimens cut from lumber and other sawed items.

6. Procedure

6.1 *Initial Weighing*—Weigh each specimen immediately after cutting from the sample representing the lot or else protect it from a moisture change until weighed. Weigh each specimen to an accuracy of ± 0.2 percent, for example, if the specimen weighs 250 g, obtain the weight to the nearest 0.5 g. Record the weight either on the specimen or on a data sheet that is numbered to correspond with the number on the specimen. If a delay between cutting the specimen and weighing cannot be avoided, place the specimen in a vapor-tight container or

wrapper immediately upon cutting and allow it to remain in the container or wrapper until it can be weighed. Suitable wrappers can be made of aluminum foil or polyethylene film. The delay between cutting and weighing of the protected specimen shall be as short as possible, but in no case to exceed 2 h. Obtaining weights in grams rather than in grains or ounces simplifies calculations.

6.2 *Drying*—After they have been weighed, place the specimens in an oven when convenient and heat at 103 ± 2 C (217.4 ± 3.6 F) until they reach constant weight. Place the specimens in the oven in a manner that will allow free access of heated air to each. To test for constant weight, weigh the heaviest specimens at intervals of 2 h or more until they show no further weight loss within the accuracy of weighing required. Avoid drying for periods longer than necessary to achieve constant weight since prolonged distillation or oxidation of the wood will produce a weight loss reflecting a higher-than-actual moisture content. Newly cut specimens should not be placed in the oven with partially dried ones since the drier specimens will be retarded in drying.

NOTE 1—As a guide, an air-dry specimen about 50 by 100 mm (2 by 4 in.) in cross section and 25 mm (1 in.) along the grain will usually attain constant weight within 24 h at the specified temperature when dried in an electric oven having good forced-air circulation.

6.3 *Final Weighing*—Weigh each specimen immediately after it is removed from the oven upon attaining constant weight or store in a desiccator while awaiting weighing. The accuracy shall be the same as required for initial weighing.

7. Calculation

7.1 Calculate the moisture content as follows:

$$\text{Moisture content, percent} = [(A - B)/B] \times 100$$

or, for more convenient slide rule or computer calculation:

$$\text{Moisture content, percent} = ((A/B) - 1) \times 100$$

where:

A = original weight, and

B = oven-dry weight.

Example—A 25-mm (1-in.) specimen of lumber weighed 56.7 g. After oven-drying, the weight was 52.3 g.

$$\begin{aligned} \text{Moisture content, percent} \\ &= [(56.7 - 52.3)/52.3] \times 100 \\ &= (4.4/52.3) \times 100 = 8.4 \text{ percent} \end{aligned}$$

NOTE 2—If wood has been treated with a water-borne nonvolatile chemical and if the weight of the retained chemical is known, the moisture content may be determined as follows:

$$\text{Moisture content, percent} = [(A - B)/D] \times 100$$

where $D = B -$ weight of retained chemical in sample.

METHOD B—ELECTRONIC MOISTURE METER METHOD

8. Scope

8.1 The range of moisture content in wood that can be measured reliably with electric moisture meters is limited to 0 to 30 percent when using dielectric-type meters, and 6 to 30 percent when using a resistance-type meter. The precision of the meters decreases near the limits of their useful range. This method is applicable only to those species of wood for which calibrations have been established. Species corrections are supplied by moisture meter manufacturers or may be developed from basic resistance-moisture content data (1), (2).²

8.2 The temperature of the lumber affects the readings of electric moisture meters (1); (3); (4). When available temperature corrections (Fig. 1) are used, reliable moisture content determinations may be obtained with a resistance-type meter over a wood temperature range from about -40 to $+90$ C (-40 to 200 F). Temperature corrections for the power-loss and capacitive admittance meters are most accurately made graphically (3), (Figs 2 and 3) but can be put into tabular form for some applications.

8.3 This method is applicable particularly to the manual inspection of wood and wood products using portable equipment, and is not generally applicable to such procedures as automatic inspection of moving material with permanently installed equipment.

9. Apparatus

9.1 *Resistance Meters*—Resistance measurements shall be made with commercial resistance-type moisture meters or electronic ohmmeters capable of measuring resistance from $10 \text{ k}\Omega$ to $1 \text{ t}\Omega$ (10^4 to 10^{12} ohms) to an accuracy of ± 10 percent. No instrument shall be used that applies to the test specimen a d-c potential exceeding 45 V. No attempt shall be

made to measure moisture content with an ohmmeter unless reliable data are available for calibration of the ohmmeter as a moisture meter.

9.2 *Electrodes* for resistance measurements shall be of the needle type. The needles shall be mounted on a fixture of high-quality moisture-resistant insulation, permitting driving the needles into the wood to the proper depth. Surface contact electrodes shall not be used with resistance-type meters. Because of the possibility that unknown moisture gradients exist in the wood, it is desirable to use electrode needles of the type that are covered, except for the tip, with an insulating coating. If for any reason insulated needles cannot be used, the wood shall be tested for surface moisture as described in 11.1.4. If the available electrode needles are too short to penetrate to the required depth, as specified in 11.1.5, substitute electrode needles such as uncoated nails or coated nails from whose tips the coating has been removed may be used. The diameter of the nails is not critical, but nails with a diameter near that of the regular electrode needles are preferred. Measurements on wood 6 mm ($\frac{1}{4}$ in.) or less in thickness shall be made with an electrode consisting of approximately 6 to 12 short, fine needles.

9.3 *Dielectric-Type Meters* (Power-Loss and Capacitive-Admittance Type)—Dielectric-type moisture meters shall be equipped with an electrode suitable for the surface and thickness of the material. No attempt shall be made to use the dielectric meters for moisture measurements unless a reliable calibration, applicable to the species of wood and the type of electrode, is available for the meter being used.

10. Test Specimens

10.1 Specimens for moisture tests may be either whole pieces from the lot being inspected or smaller sections cut from such pieces. If whole pieces are used, readings shall be taken near the middle of the widest surface at least 500 mm (20 in.) from the end of the piece. If sections are cut, these shall be cut so that no less than 500 mm (20 in.) of the piece are discarded from either end, and the sections shall be large enough to contact the electrode

² Boldface numbers in parentheses refer to the list of references appended to this method.

completely with an amount to spare on all sides at least as large as the thickness of the specimen. The moisture content of small sections shall be measured soon after they are cut to prevent error from rapid end-grain drying. Readings shall be taken in areas free of defects such as splits, knots, and decay. When a dielectric meter is used, the surface of the specimen shall conform to the surface for which the available electrode was calibrated.

10.2 The readings of electric moisture meters show some variability, even on specimens that are at the same moisture content, because properties of wood other than moisture content affect these readings. Dielectric meters are affected more than are resistance meters, so the readings of dielectric meters will generally show more variability than corresponding readings of resistance meters. Because of this variability, and because of natural variability in the moisture content of any quantity of lumber, reliable indications of the average moisture content of a given quantity of lumber can be obtained only if a sufficient sample is taken. For routine inspection of any lot of lumber, no fewer than 10 percent of the lot or 20 specimens whichever is greater, shall be tested when using a resistance meter. No fewer than 20 percent of the lot, or 20 specimens, whichever is greater, shall be tested when using a dielectric meter. Specimens shall be selected at random throughout the lot; the only deviation from random selection shall be that defective specimens and specimens that clearly do not represent the lot (different species, thickness, history, etc.) shall be discarded.

11. Procedure

11.1 *Using Resistance-Type Meter:*

11.1.1 Commercial instruments for measuring moisture content or high resistance usually are accompanied by detailed manuals of instructions. The importance of following these instructions carefully should be stressed. The procedures given here are general and do not supersede instructions provided by the instrument manufacturer. It is particularly important to apply the corrections for species and temperature when they are supplied by the manufacturer.

11.1.2 Test suitable specimens for moisture content according to the instructions for the particular meter being used. Use insulated

needles if they can be obtained. Drive the needles into the wood oriented so the current flows parallel to the grain.

11.1.3 If the reading drifts toward lower moisture content, take the reading immediately after the needle electrodes are driven into the specimen.

11.1.4 When the meter is being used with uninsulated needles, note the moisture indication with the needle points just pricking the surface and as the needles are driven into the wood. If the meter reading with the needles just pricking the surface is as high as that with the needles penetrating one fourth of the specimen thickness, the specimen may have a wet surface and the accuracy of the reading is doubtful. If the meter reading increases progressively as the needles are driven deeper, the specimen does not have a wet surface and uninsulated needles will give correct indications.

11.1.5 Wood of rectangular cross-section that has been drying under reasonably constant equilibrium conditions generally has a moisture distribution across its thickness such that at a depth below the surface of one fourth to one fifth of the thickness the moisture content is equal to the average for the cross section. Correspondingly, for wood of circular cross section, the average moisture content occurs at a depth below the surface of about one sixth to one seventh of the diameter. Therefore to measure the average moisture content with a resistance-type meter, drive the electrode needles to a depth of about one fourth to one fifth of the thickness of specimens of rectangular cross section, and to about one sixth to one seventh of the diameter of cylindrical specimens. If the regular electrode needles are too short to reach the specified depth, use nails or other substitute electrodes. Drive the substitute electrodes to the proper depth and about the same distance apart as the needles on the standard electrode. The reading may then be obtained by touching the regular electrode needles to the exposed ends of the substitute electrode needles.

11.2 *Using Dielectric-Type Meters:*

11.2.1 The dielectric-type moisture meter causes an alternating electric field to penetrate into the specimen, the depth of this penetration depending principally on the design of the surface-contact electrode. The reading of the

dielectric meters tends to reflect the integrated or average effect of the material penetrated by the field, to a certain extent independent of the moisture distribution. The material nearest the electrode, however, does have a predominant effect on the meter reading because the field is strongest there and consequently inaccuracies can result when a steep moisture gradient exists. For example, temporary high surface moisture content, such as from rain, dew, or very high relative humidity, will result in erroneously high readings of average moisture content. Therefore, no attempt shall be made to use a dielectric moisture meters on material that has recently been exposed to such weather conditions.

11.2.2 It is desirable to take readings with dielectric meters on material more than 50 mm (2 in.) thick on both sides of the specimen and average the results. Large differences in the readings from opposite sides may be due to one surface being temporarily wet, in which case disregard the readings. Take dielectric readings on specimens 25 mm (1 in.) or less in thickness only with the specimen supported on a base of low-density, nonhygroscopic material, such as rigid polystyrene foam, about 30 mm thick. Alternatively, the specimen may be supported as its ends so that it is at least 25 mm (1 in.) away from other solid material and the reading made at the center of the specimen. Take readings on material 3 mm ($\frac{1}{8}$ in.) thick or less only with a special veneer electrode with the specimen supported on a low-density base, as above. Alternatively, the thin material may be stacked into a pile 13 to 25 mm ($\frac{1}{2}$ to 1 in.) in thickness and the reading obtained with a standard lumber electrode, provided that sufficient pressure is exerted to hold the layers in intimate contact, and the thinner stacks are supported on the low-density base as above. The reading in this latter case will be an approximate average of the various layers penetrated by the field, but again those layers nearest the electrode have a predominant effect. Thus, if the individual layers vary greatly in moisture content, the integrated reading of the stack may be considerably different from the true average of all the layers if the layers near the electrode happen to be at extreme levels of moisture content.

11.3 *Effect of Chemicals and Glue Lines*

—Salts or other electrolytes, when present in

wood in abnormal amounts, cause large errors in the readings of electronic moisture meters of all types (5). Do not attempt to determine the moisture content with electric meters of lumber that has been treated with salt preservatives or fire retardants, or that has been in prolonged contact with sea water, unless readings no greater than 8 percent moisture content are obtained, in which case the effect of the retained salts is negligible. Any effect of retained salts is to increase the readings, so electronic meters can still be used to establish upper limits of moisture content on salt-treated wood. Preservatives such as pentachlorophenol and creosote affect the readings of electronic meters only slightly, and usually no corrections are necessary. Moisture measurements with electronic meters on plywood may be subject to large error, depending upon the type of glue used in the plywood (6). In some cases it may be possible to establish a correction factor applicable over a narrow range of moisture to one type of plywood made from one species of wood and using one type of glue. More frequently, however, the readings will be so erratic because of the variable electrical properties of the glue that they will be useless. Generally, do not attempt to determine the moisture content of plywood with electronic meters unless it can be shown conclusively by independent tests that the moisture meter readings are accurate.

11.4 *Temperature Corrections*—If the temperature of the specimen is different from that of the material used for calibrating the meter, apply a temperature correction. This temperature correction may be obtained graphically (Figs. 1, 2, 3). As indicated, the amount of correction varies with the temperature and moisture content.

11.5 *Species Corrections*—If the species of wood being tested is other than that for which the moisture meter is directly calibrated, use a species correction supplied by the instrument manufacturer. Occasionally it may be necessary to obtain moisture meter readings on species for which a correction is not available. In such instances, report the type of meter and the species for which it was calibrated in addition to the observed meter readings.

NOTE 3—The errors in moisture content that are obtained without species correction may be as much as ± 4 percent for a resistance-type meter but are