Designation: ~~D4442 – 16~~ D4442 – 20

Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials[1]

This standard is issued under the fixed designation D4442; 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 These test methods cover the determination of the moisture content (*MC*) of wood, veneer, and other wood-based materials, including those that contain adhesives and chemical additives. The test ~~methods below describe primary (A) and secondary (B through D) procedures to measure moisture content:~~ procedures appear in the following order:

Method A—Primary Oven-Drying Method
Method B—Secondary Oven-Drying Method
~~Method C—Distillation (Secondary) Method~~
~~Method D—Other Secondary Methods.~~

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Method A—Primary Oven-Drying Method	5
Method B—Secondary Oven-Drying Method	6

1.2 The primary oven-drying method (Method A) is intended as the sole primary method. It is structured for ~~research~~ purposes where the highest accuracy or degree of precision is ~~needed.~~ needed (for example, research or calibration).

1.3 The secondary ~~methods (B through D) are~~oven-drying method (Method B) is intended for ~~special purposes or under circumstances~~ the purposes where the primary procedure (Method A) is not desired or justified. ~~In these procedures, moisture content values cannot be reported with an accuracy greater than integer percentage values (that is, lower than in Method A).~~Test results in this method are generally less precise than in Method A.

1.4 ~~Distillation (secondary) method is intended for use with~~ For materials that have been chemically treated or impregnated with creosote, petroleum, and their solutions such that the oven-drying procedures introduce greater ~~error~~bias than desired in the ~~results.~~results, other methods, such as AWPA A6, are recommended.

1.5 *Units*—The values stated in SI units are to be regarded as standard. ~~No other units of measurement are included in this~~ The values given in parentheses after SI units are provided for information only and are not considered standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D9 Terminology Relating to Wood and Wood-Based Products

D4933 Guide for Moisture Conditioning of Wood and Wood-Based Materials

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[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.

Current edition approved ~~Nov. 15, 2016~~March 1, 2020. Published ~~November 2016~~April 2020. Originally approved in 1984. Last previous edition approved in ~~2015~~2016 as ~~D4442 – 15.~~D4442 – 16. DOI: ~~10.1520/D4442-16.~~10.1520/D4442-20.

These test methods replace, in part, Test Methods D2016, for Moisture Content of Wood, discontinued 1989.

[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.

2.2 *Other Standard:*
AWPA Standard A6 Standard Method for the Determination of Retention of Oil-Type Preservatives from Small Samples[3]

3. Terminology

3.1 *Definitions:*
3.1.1 For definitions of terms used in this ~~test method,~~ standard, refer to Terminology D9.
3.1.2 *moisture content*—~~the~~ amount of water contained in the wood, usually expressed as a percentage of the mass of the oven-dry wood (in accordance with Terminology D9).

3.1.2.1 *Discussion*—

The moisture content of wood or other wood-based materials can be expressed either as a percentage of oven-dry mass of the sample (oven-dry basis) or as a percentage of the original mass (wet basis). The methods described in this standard refer to the oven-dry basis. Because oven-dry mass is used, moisture content values may exceed 100 %. The term moisture content when used with wood or other wood-based materials can be misleading since they frequently contain varying amounts of volatile compounds (extractives that are evaporated when determining moisture content). Definition of the moisture content of wood is further complicated when determined by a thermal method because of thermal degradation, which causes the final moisture-free mass to decrease from small but continuous losses.

4. Significance and Use

4.1 Moisture content is one of the most important variables affecting the properties of wood and wood-based materials. The procedures in these test methods are structured to permit the full range of use from fundamental research to industrial processing. Method A is the reference (primary) standard for determining moisture content of wood and wood-based materials, which is designed for obtaining the most precise values of moisture content consistent with the needs of the user. It ~~also~~ provides means of assessing variability contributed by the oven or specimen hygroscopicity, or both. In addition, criteria are described for defining the endpoint in oven-drying. Method ~~A is the reference (primary) standard for determining moisture content of wood and wood-based materials. Methods B through D are secondary methods to permit~~ B provides relatively simple procedures of measuring moisture content, but generally with ~~less~~ a lower precision than Method A. Representativeness of the specimens to the full-size product, including knots, sapwood, and heartwood, needs to be considered. These methods are not recommended for use with treated wood products impregnated with creosote, petroleum, and their solutions where the volatile non-wood chemicals contained in the specimen introduce greater bias than desired in the results.

5. Method ~~A—Oven-Drying (Primary)~~ A—Primary Oven-Drying Method

5.1 *Apparatus:*
5.1.1 *Oven*—A forced-convection oven that can be maintained at a temperature of 103 ± 2°C throughout the drying chamber for the time required to dry the specimen to the endpoint shall be used. Ovens shall be vented to allow the evaporated moisture to ~~escape.~~escape (see Note 1). For calibration purposes, the oven shall be furnished with two shelves positioned at one third and two thirds of the cavity height.

NOTE 1—The ratio of sample mass to chamber volume and the air velocity within the oven are not critical ~~as long as~~ if temperature and relative humidity within the oven are ~~constant. Room relative humidity should be less than 70 % relative humidity, at which condition the oven is at 1.7 % relative humidity. For best precision, drying should be carried out in a constant relative humidity room with the relative humidity as low as possible.~~constant and uniform. To maintain uniform conditions throughout the oven the number of specimens in the oven should be limited and they should be well spaced to allow good air movement around all specimens. When high moisture content specimens are being dried, more frequent air exchanges are needed.

NOTE 2—For higher precision and smaller bias, the oven should be in a controlled climate room that maintains the relative humidity as low as possible. In a room with 70 % relative humidity, the same air in an oven heated to 103°C will have a relative humidity of 1.7 %. At a temperature of 103°C and 1.7 % relative humidity, the equilibrium moisture content of solid wood is approximately 0.13 %, according to Guide D4933 Eq. X1.1.

5.1.2 *Balance*—Based on a 10 g (oven-dry) specimen, ~~minimum readability~~the sensitivity of the balance shall be determined by the desired ~~reporting level~~ precision of ~~precision:~~weighing:

~~Reporting Precision Level, MC, %~~ Precision of Weighing, %	~~Minimum Balance Readability, mg~~ Balance Sensitivity, mg
0.01	1
0.05	5
0.1	10
0.5	50
1.0	100

For other oven-dry mass levels, the sensitivity requirement shall be scaled appropriately.

[3] Available from American Wood Protection Association (AWPA), P.O. Box 361784, Birmingham, AL 35236-1784, http://www.awpa.com.

5.1.3 *Weighing Bottles*—Weighing bottles made of a vapor-tight material that can withstand the drying temperature in the oven (5.1.1) shall be used. Each weighing bottle shall be furnished with a stopper to prevent moisture uptake or loss during handling and weighing of the specimens. The stopper shall be assigned and kept with each bottle in case each stopper has a slightly different weight.

5.1.4 *Desiccator*—A container filled with moisture absorbing material (desiccant) shall be used for maintaining moisture-free conditions of weighing bottles and for samples cooling.

5.2 *Test Material*—Any conveniently sized wood or wood-based material can be used, consistent with the use of closed weighing ~~jars~~bottles (~~5.4.7~~5.1.3) and the balance readability (5.1.2).

~~NOTE 2—If specimens contain any degree of volatilizable material other than water, it may be necessary to either use Method C or run Method A and C concurrently.~~

5.3 *Calibration and Standardization*—Determination of specimen variability requires a separate measurement of the contribution of variability within the oven.

5.3.1 *Determination of Oven Variability*—This section permits a separate evaluation of the oven variability from that of specimens distributed in the oven.

5.3.1.1 *Calibration Specimen Selection and Preparation*—~~Douglas-fir~~ A sample of Douglas-fir wood shall be ground to sawdust and ~~that~~the fraction contained in a 40/60 mesh screen used. The sample origin or drying history is not critical. The sawdust shall be tumbled in a closed container until thoroughly mixed. All replicates shall be prepared at the same time from the same batch of material. All material shall be transferred and stored in ~~air-tight weighing jars.~~vapor-tight weighing bottles with stoppers (see 5.1.3).

5.3.1.2 *Equilibration*—The moisture content of the ~~specimen~~specimens is not important if the preparation techniques described under 5.3.1.1 are used. Equilibration is not required, although it is preferable that the material be as uniform as possible in moisture content.

5.3.1.3 *Number and Location of Calibration Specimens*—Each test shall consist of a set of eight replicated specimens. These shall be located at third-point positions with respect to height, width, and depth of the oven cavity. With this scheme four ~~samples~~specimens will be positioned on each of two shelves at one third and two thirds of the cavity height.

5.3.2 *Determination of Combined Specimen and Oven Variability*—Procedures are the same as 5.3.1.1 – 5.3.1.3 except that ~~specimens of any origin and size or shape can be used.~~the specimens in a set shall be of similar size and shape in accordance with 5.2 without grinding (see Note 3). Calculate variability by the equation in 5.5.2.

NOTE 3—The specimen variability depends on various factors including the wood species, the size and the moisture condition of the specimens, because varying amounts of volatile compounds are evaporated during oven-drying (see Discussion of 3.1.2).

5.3.3 *Procedure*—Use the primary oven-drying procedure (5.4).

5.4 *Procedure:*

5.4.1 Specimens to be equilibrated shall be processed as in Guide D4933.

5.4.2 Store specimens in individual vapor-tight containers (for example, plastic bags) if any delay could occur between sampling and weighing.

5.4.3 Weigh ~~the specimens~~ each specimen in a closed weighing bottle (see 5.1.3) using a balance consistent with the desired precision (see 5.1.2~~).~~) at room temperature.

NOTE 4—Be aware that static electricity affects the mass readings.

5.4.4 Preheat the oven to a temperature of 103 ± ~~2°C~~2°C.

5.4.5 Place specimens in the open weighing bottles in the oven within the volume tested for oven ~~precision.~~variability (see 5.3.2).

5.4.6 After drying, close the weighing bottles containing the dried specimens before taking out of the hot oven and store them in a desiccator with fresh desiccant until they have reached room temperature. Weigh the specimens in accordance with 5.4.3 (see Note 4).

5.4.7 *Endpoint*—Assume that the endpoint has been reached when the mass loss in a ~~3-h~~3-h interval is equal to or less than twice the selected balance sensitivity. ~~For example, given a specimen weight of 10 g and for a balance sensitivity of 1 mg chosen in 5.1.2 to allow reporting to a 0.01 % MC precision, the endpoint is assumed to have been reached when the change in weight is 2 mg or less in a 3-h period.~~

NOTE 5—For example, given a specimen weight of 10-g and for a balance sensitivity of 1 mg chosen in 5.1.2 to allow reporting to a 0.01 % *MC* precision, the endpoint is assumed to have been reached when the change in weight is 2 mg or less in a 3-h period.

~~5.4.7 *Handling and Weighing Procedures*—Dried samples shall be stored in a desiccator with fresh desiccant until they have reached room temperature. All weighings shall be carried out using closed weighing jars.~~

5.5 *Calculations:*

5.5.1 Calculate moisture content as follows:

$$MC, \% = (A - B)/B \times 100 \quad (1)$$

where:

A = original mass, g, and
B = oven-dry mass, g.

Example—A specimen of wood weighs 56.70 g. After oven-drying, the mass is 52.30 g.

~~$$MC, \% = (56.70 - 52.30)/52.30 \times 100 \quad (2)$$~~

~~$$= (4.40/52.30) \times 100 = 8.4\ \%$$~~

$$MC = (56.70 - 52.30)/52.30 \times 100 = 8.4\ \% \quad (2)$$

~~NOTE 3—If wood has been treated with a nonvolatile chemical, or if a wood-based material contains a large amount of non-wood chemicals that cannot be neglected, and if the mass of the retained chemical(s) is known, the moisture content may be determined as follows:~~

~~$$MC, \% = (A - B)/D \times 100 \quad (3)$$~~

~~where:~~

~~D = B minus mass of retained chemical in sample.~~

NOTE 6—If wood has been treated with a nonvolatile chemical, or if a wood-based material contains a large amount of non-wood chemicals that cannot be neglected, and if the mass of the retained chemical(s) is known, the moisture content may be determined as follows:

$$MC, \% = (A - B)/D \times 100 \quad (3)$$

where:

D = B minus mass of retained chemical in sample.

5.5.2 Calculate variance of the specimens as follows:

$$S_w^2 = S_{ow}^2 - S_o^2 \quad (4)$$

where:

S_w^2 = specimen material variance,
~~S_o^2 = oven variance (from 5.3.1), and~~
S_o^2 = oven variance (from 5.3.1), and
S_{ow}^2 = combined specimen and oven variance (5.3.2).

5.6 *Report:*

5.6.1 Report the following information:

5.6.1.1 Test method used and any deviation from the standard procedures,

5.6.1.2 Balance model and sensitivity,

5.6.1.3 Oven model, type, and variance,

5.6.1.4 Type of material,

5.6.1.5 Description of specimens and their nominal oven-dry mass,

5.6.1.6 ~~Oven variance,~~Number of specimens,

~~5.6.1.4 Specimen variance,~~

~~5.6.1.5 Balance sensitivity,~~

5.6.1.7 ~~Oven model and type,~~ Moisture content values including mean value, and

5.6.1.8 ~~Any deviation from the prescribed method.~~Specimen material variance or standard deviation.

5.6.2 The number of decimal places in moisture content values reported shall not exceed the precision level ~~(~~(see ~~5.1.2~~5.7.2).

5.7 *Precision and Bias:*

5.7.1 ~~*Precision*~~*Uncertainty of Measurement*—By definition, the ~~accuracy~~uncertainty of measurement has been set equal to the determined precision of ~~test measurement, that is, there is no assumed bias of~~ measurement due to the inability to ~~accurately assess moisture content.~~ determine the bias of measurement. With this approach, it is possible that the ~~actual accuracy will be poorer than the stated accuracy. At this time, no data are available from which to report typical variances in ovens or from specimen material.~~reported value of moisture content deviates from the true value with greater uncertainty than the determined precision.

5.7.2 *Precision*—The precision of measurement depends on many factors including variance in the oven and in the specimen material, room ambient conditions (see 5.1.1 and Note 1), sensitivity of the balance (see 5.1.2), the size of the specimen, etc.

5.7.3 *Bias*—The bias of this test method is unknown because the values are determined solely in terms of this test method itself. However, the values of moisture content determined in accordance with this test method generally contain some degree of bias by definition, due to varying amounts of volatile compounds or of non-wood chemicals contained in the material (see Discussion of 3.1.2 and Appendix X1).

6. Method ~~B—Oven-Drying (Secondary)~~ B—Secondary Oven-Drying Method

6.1 *Apparatus:*

6.1.1 *Oven*—An oven that can maintain 103 ± 2°C near the drying endpoint shall be used.

6.1.2 *Balance*—The sensitivity shall be ~~a minimum of~~ sufficient to measure within 0.1 % of the nominal oven-dry mass of the specimen (see 5.1.2).

6.2 *Test Material*—Any conveniently sized wood or wood-based material can be ~~used,~~used; however, the balance readability shall be consistent with the desired precision (see 5.1.2 and 5.3).

~~NOTE 4—If specimens contain any degree of volatilizable material other than water, it may be necessary to either use Method C, or run Methods B and C concurrently.~~

6.3 *Calibration and Standardization*—No specific tests are required unless greater precision than integer percent moisture content values are ~~desired. See~~desired (see ~~6.7~~6.7.1; and Note 3).

6.4 *Procedure:*

6.4.1 Specimens to be equilibrated shall be processed as in Guide D4933.

6.4.2 Store specimens in individual ~~vaportight containers~~ vapor-tight containers (for example, plastic bags) or wrapping if any delay could occur between sampling and weighing.

6.4.3 Weigh the specimens using a balance consistent with the desired precision (see 6.1.2).

6.4.4 Preheat the oven to a temperature of 103 ± 2°C and place specimens in the oven.

6.4.5 *Endpoint*—Assume that the endpoint has been reached when ~~no appreciable change is noted in final mass readings made at approximately 4 h intervals.~~the mass loss in a 3-h interval is equal to or less than twice the selected balance sensitivity.

NOTE 7—As a guide, an air-dry wood specimen about 50 by 100 mm in cross section and 25 mm along the grain will usually attain "constant mass" within 24 h when dried in a forced convection oven using this procedure.

6.4.6 *Handling and Weighing Procedures*—Dried samples shall be weighed as soon as possible to minimize moisture uptake.

6.5 ~~*Calculation of Moisture Content:*~~ *Calculations:*

6.5.1 Calculate moisture content as follows:

$$MC, \% = (A - B)/B \times 100 \quad (5)$$

where:

A = original mass, g, and
B = oven-dry mass, g.

Example—A specimen of wood weighed 56.7 g. After oven-drying, the mass was 52.3 g.

~~$MC, \% = (56.7 - 52.3)/52.3 \times 100$~~ ~~(6)~~

~~$= (4.4/52.3) \times 100 = 8.4$~~

$$MC = (56.7 - 52.3)/52.3 \times 100 = 8.4\ \% \quad (6)$$

Round to 8 % (see 1.3 and ~~6.7.1~~6.7)

NOTE 8—If wood has been treated with a nonvolatile chemical, or if a wood-based material contains a large amount of non-wood chemicals that cannot be neglected, and if the mass of the retained chemical(s) is known, the moisture content may be determined as follows:

$$MC, \% = (A - B)/D \times 100 \quad (7)$$

where:

D = B minus the mass of retained chemical in sample.

6.6 *Report:*

6.6.1 Report the following information:

6.6.1.1 Test method used and any deviation from the standard procedure,

6.6.1.2 Drying temperature if different from 103 ± 2°C,

6.6.1.3 Type of material,

6.6.1.4 Description of specimens and their nominal oven-dry mass,

~~6.6.1.3 Mean,~~

~~6.6.1.4 Standard deviation,~~

6.6.1.5 Number of specimens, and

6.6.1.6 ~~Any deviation from the method.~~Moisture content values including mean and standard deviation.

6.6.2 Moisture content ~~values~~ shall be ~~integer only (see~~ reported as integer percentage values except as permitted in ~~6.7.1~~6.7.2~~)~~.

6.7 *Precision and Bias:*

6.7.1 *Uncertainty of Measurement*—See 5.7.1.

6.7.2 *Precision*—~~The precision~~ Unless a better precision has been validated by study, the precision of measurement is assumed to be no ~~greater than ±1 % moisture content for any measurement unless the appropriate procedures in Section~~ better than as follows:~~5 are used.~~

6.7.2.1 ±0.1 % *MC* provided the specimens have a volume of at least 1.2×10^{-4} m^3 (7.5 $in.^3$) and are weighed within 1 min of leaving the oven.

6.7.2.2 ±0.2 % *MC* provided the specimens have a volume of at least 1.2×10^{-4} m^3 (7.5 $in.^3$) and are weighed within 5 min of leaving the oven.

6.7.2.3 ±1 % *MC* in other cases.

6.7.3 *Bias*—The bias of this test method is unknown because the values are determined solely in terms of this test method itself. However, the values of moisture content determined in accordance with this test method generally contain some degree of bias by definition, due to varying amounts of volatile compounds or of non-wood chemicals contained in the material (see Discussion of 3.1.2 and Appendix X1).

~~7. Method C—Distillation~~

~~7.1 *Apparatus:*~~

~~7.1.1 *Extraction Flask*—A 500 mL flask and thimble holder, as shown in Fig. 1. It is acceptable to combine the flask and holder in one unit.~~

~~7.1.2 *Condenser*—A water-cooler condenser of the cold-finger type, as shown in Fig. 1, or of the straight-tube, Liebig type.~~

~~7.1.3 *Water Trap*—A glass tube preferably having an inside diameter of 9 to 10 mm and sealed at one end. If a trap with stopcock is used, the stopcock shall be securely fastened in place. The graduated portion of the tube shall have a capacity of 10 mL. The smallest graduation should be not greater than 0.1 mL with the major divisions marked 1 to 10. The water trap should be chemically clean so that the shape of the meniscus at the end of the test is the same as at the beginning. (The trap may be coated with a silicone resin to give a uniform meniscus. To coat the trap, first clean it with sulfuric acid-chromic acid mixture. Rinse the clean trap with a silicone resin and, after draining for a few minutes, bake for 1 h at approximately 200°C.)~~