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

This standard is issued under the fixed designation D 4442; 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.

ε[1] NOTE—Section 9, Keywords, was added editorially in March 1997.

1. Scope

1.1 These test methods cover the determination of the moisture content (*MC*) of solid wood, veneer, and other wood-base 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:

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

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.

1.3 The secondary methods (B through D) are intended for special purposes or under circumstances where the primary procedure is not desired or justified. In these procedures, moisture content values cannot be reported with an accuracy greater than integer percentage values. However, a greater level of accuracy may be reported if the appropriate primary procedures are used.

1.4 Distillation (secondary) method is intended for use with materials that have been chemically treated or impregnated such that the oven-drying procedures introduce greater error than desired in the results.

1.5 *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 9 Terminology Relating to Wood[2]

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

3. Terminology

3.1 *Definition:*

3.1.1 *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 D 9).

3.1.1.1 *Discussion*—The moisture content of wood or other wood-based materials can be expressed on either as a percentage of oven-dry mass of the sample (oven-dry basis) or as a percentage of initial 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-based materials can be misleading since untreated wood frequently contains varying amounts of volatile compounds (extractives which 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-base 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 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

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These test methods replace, in part, Test Methods D 2016, for Moisture Content of Wood, discontinued 1989.

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

determining moisture content of wood and wood-base materials. Methods B through D are secondary methods to permit relatively simple procedures of measuring moisture content, but with less precision than Method A. However, greater precision may be obtained with supporting data by using the appropriate procedures in Method A.

5. Method A—Oven-Drying (Primary)

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.

NOTE 1—The ratio of sample mass to chamber volume and the air velocity within the oven are not critical as long as 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.

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

Reporting Precision Level, *MC*, %	Minimum Balance Readability, 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.

5.2 *Test Material*—Any conveniently sized wood or wood-based material can be used, consistent with the use of closed weighing jars (5.4.6) 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 *Specimen Selection and Preparation*—Douglas-fir shall be ground to sawdust and that 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.

5.3.1.2 *Equilibration*—The moisture content of the specimen 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 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 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. Calculate variability by the equation in 5.5.2.

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 D 4933.

5.4.2 Store specimens in individual vapor-tight containers if any delay could occur between sampling and weighing.

5.4.3 Weigh the specimens using a balance consistent with the desired precision (see 5.1.2).

5.4.4 Place specimens in the oven within the volume tested for oven precision.

5.4.5 *Endpoint*—Assume that the endpoint has been reached when the mass loss in a 3-h interval is equal to or less than twice the selected balance sensitivity. For example, with a 10-g (oven-dry) specimen, the balance sensitivity for 0.01 % *MC* precision is 0.1 mg (see 5.1.2), therefore, dry to 0.2 mg or less mass loss in a 3-h period.

5.4.6 *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.

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

$$= (4.40/52.30) \times 100 = 8.4\ \% \quad (2)$$

NOTE 3—If wood has been treated with a nonvolatile chemical and if the mass of the retained chemical 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:

$$S_w = (S_{ow}^{\ 2} - S_o^{\ 2})^{½} \quad (4)$$

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

5.6 *Report*—Report the following information: nominal oven-dry mass, type of material, oven variance, specimen variance, balance sensitivity, oven model and type, and any deviation from the prescribed method. The number of decimal

places reported shall not exceed the precision level (5.1.2).

5.7 *Precision and Bias*:

5.7.1 *Precision of Measurement*—By definition, the accuracy 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. With this approach the actual accuracy may 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.

6. Method B—Oven-Drying (Secondary)

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 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, 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 moisture content values are desired. See 6.7.

6.4 *Procedure*:

6.4.1 Specimens to be equilibrated shall be processed as in Guide D 4933.

6.4.2 Store specimens in individual vaportight containers 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 *Endpoint*—Assume that the endpoint has been reached when no appreciable change is noted in final mass readings made at approximately 4-h intervals.

NOTE 5—As a guide, an air-dry solid 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.

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

6.5 *Calculation of Moisture Content*:

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.

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

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

Round to 8 % (see 1.3 and 6.7.1)

NOTE 6—If wood has been treated with a nonvolatile chemical and if the mass of the retained chemical 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*—Report the following information: Mean, standard deviation, number of specimens, and any deviation from the method. Moisture content values shall be integer only (see 6.7.1).

6.7 *Precision and Bias*:

6.7.1 The precision is assumed to be no greater than ± 1 % moisture content for any measurement unless the appropriate procedures in Section 5 are used.

6.7.2 No bias calculations may be made from this procedure.

7. Method C—Distillation

7.1 *Apparatus*:

7.1.1 *Extraction Flask*—A 500-mL flask and thimble holder, as shown in Fig. 1. The flask and holder may be combined 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.)

7.1.4 *Extraction Cup*—Either a Wiley siphon cup of suitable size or a basket made of approximately 45 mesh, stainless steel gauze and having the approximate dimensions of 42 mm in outside diameter and 127 mm in length. The siphon cup is recommended for borings from heavily treated piling. When a siphon cup is used, the loss of wood particles should be prevented either by placing a conical screen at the bottom of the siphon cup or by putting the chips or borings in a wire gauze basket which is then placed inside the siphon cup.

7.1.5 *Hot Plate*:

7.1.6 *Weighing Bottle*—The weighing bottle shall have a ground glass stopper and be of sufficient size to contain the wire extraction cup or Wiley siphon described in 7.1.4.

7.1.7 *Rod*—A rod approximately 3 mm in diameter made of some material to which water does not adhere such as TFE-fluorocarbon resin.

7.1.8 *Oven*—The oven shall be maintained at a temperature of 103 ± 2°C.

7.1.9 *Desiccator*:

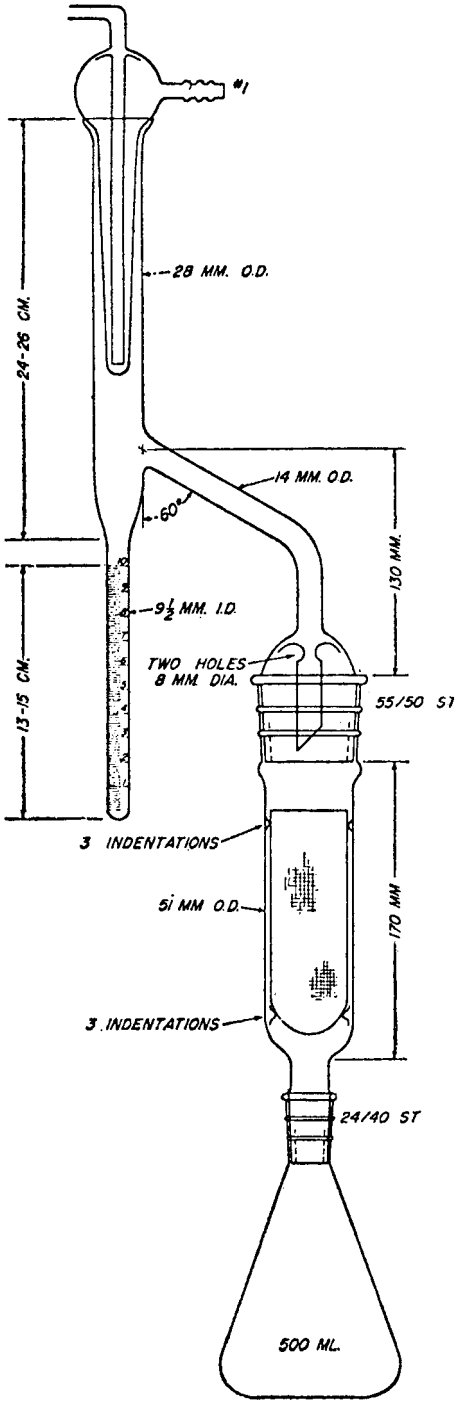

FIG. 1 Extraction Apparatus, Method C

7.1.10 *Balance*—The balance shall have a sensitivity of 0.01 g.

7.1.11 *Increment Borer*:

7.2 *Reagents and Materials*:

7.2.1 *Desiccant*—Calcium chloride, silica gel, etc.

7.2.2 *Toluene*—The toluene shall be of the grade known as industrial pure, boiling within 2°C.

7.3 *Preparation of Apparatus*:

7.3.1 Place about 200 mL of toluene and 1 to 2 mL of distilled water in the extraction flask. Assemble the apparatus on the hot plate, apply heat, and reflux for about 30 min. Allow the contents of the water trap to cool to room temperature, then using the rod, transfer any water adhering to the walls of the condenser or to the walls of the water trap to the water layer in the trap. Read and record the volume of water in the trap to the nearest 0.01 mL.

NOTE 7—If the flask, water trap, and inner walls of the condenser are carefully dried, this procedure may be eliminated, and dry toluene used for the extraction.

7.3.2 Before using the increment borer to take a sample for moisture or preservative determination, calibrate the borers. Take 20 borings from material of like species. Measure each boring at its midpoint to the nearest 0.025 mm, once in the transverse grain direction and once in the longitudinal grain direction. Average these two measurements and square the result. Calculate the sum of the 20 squares and divide the total by 20. Calculate the square root of the quotient to the nearest 0.025 mm. Use this result as the calibrated diameter of the borer.

7.4 *Procedure*:

7.4.1 Weigh the wire extraction basket or the Wiley siphon and the weighing bottle separately to the nearest 0.01 g. Place the basket or siphon in the weighing bottle.

7.4.2 When using the increment borer, take a minimum of 20 borings from the lot of wood to be sampled. As each boring is taken, carefully cut and measure the desired portion for assay. Place each boring section in the extraction basket or Wiley siphon as it is cut. Stopper the weighing bottle at all times except when actually placing or removing borings from it. When a specimen other than an increment boring is used, it should be composed of fragments that are no more than 6 mm along the grain, and of cross-sectional dimensions convenient to fit the extraction container. Mix the fragments quickly in a suitable container and then transfer a portion of about 25 g into the extraction basket.

7.4.3 Weigh the bottle, container, and contents to the nearest 0.01 g. Transfer the container and contents to the extraction section of the apparatus. Weigh the empty, stoppered weighing bottle to the nearest 0.01 g without removing any condensate from it. The difference between this mass and the original tared mass of the weighing bottle represents the first portion of water in the sample.

7.4.4 Apply heat to the extraction apparatus and reflux the toluene at a rate of at least 1drop/s from the tip of the condenser. With freshly creosoted wood, continue the refluxing for at least 2 h. Extract at least 5 h for wood freshly treated with creosote-coal tar solutions. After the appropriate reflux period, allow the contents of the trap to cool to room temperature. By means of the rod, transfer any water adhering to the walls of the condenser to the walls of the water trap to the water layer in the trap, then read and record the volume of water on the trap to the nearest 0.01 mL. The difference between this reading and the first reading (7.3.1) represents the second and final portion of water in the sample.

7.4.5 While the extraction is in process, clean the weighing bottle by rinsing with acetone, dry in the oven, cool in the desiccator, then reweigh and place back in the desiccator.

7.4.6 Remove the extraction container and contents from the extraction flask and place under a hood for 15 min; then

place in the oven preheated to 125°C. Dry for 2 ± 0.5 h.

7.4.7 When the container and borings have dried for the prescribed period, transfer to the weighing bottle. Cool the uncovered weighing bottle and contents to room temperature in a desiccator; then weigh with cover to the nearest 0.01 g. Calculate and record the weight of dry extracted wood.

7.5 *Calculations*:

7.5.1 Calculate the moisture content as follows:

$$\text{MC, percentage of extracted wood} = (A + B)/C \times 100 \quad (8)$$

where:
A = first portion of water, g (7.4.3),
B = water measured in trap, mL (7.4.4), and
C = final mass of bottle plus container plus contents minus final tared mass of bottle minus tared mass of container, g. This is the mass of the dry extracted wood.

7.5.2 Should the mass of the preservative in the sample, volume of the sample, and retention be desired, the following equations shall be used:

$$\text{mass of preservative in sample, g} = A - B - C - D \quad (9)$$

where:
A = original mass of bottle plus container plus contents minus original tared mass of bottle minus tared mass of container, g,
B = final mass of bottle plus container plus contents minus final tared mass of bottle minus tared mass of container, g,
C = water measured in trap, mL, and
D = first portion of water (7.4.3), g.

$$\text{volume of sample, cm}^3 = \Pi\, Lr^2 \quad (10)$$

where:
L = total length of borings, cm, and
r = calibrated diameter of borings, cm.

$$\text{content of preservative, g/cm}^3 = m/V \quad (11)$$

where:
m = mass of preservative, g, and
V = volume of sample, cm.^{3}

7.6 *Report*—Report the following information: type of material, treatment chemical if known, specimen variance, and any deviations from specified apparatus, agents, or procedure.

7.7 *Precision and Bias*:

7.7.1 The precision is assumed to be ±1 % *MC* or less unless the appropriate procedures in Section 5 are used.

7.7.2 No bias calculations may be made from this procedure.

8. Method D—Other Secondary

8.1 A variety of other methods have been used to measure moisture content of wood-based materials. These include Karl Fischer titration, infrared (heating and absorption), microwave (heating and absorption), nuclear magnetic resonance (NMR), vacuum-oven drying, etc. There are no recommended procedures for these methods. As such, results obtained using them should be no better than the precision of Method B. Greater precision may be reported only if the procedures in Method A are used to confirm the stated level of precision. The general practices and intent of the oven-dry and other methods should be employed.

9. Keywords

9.1 moisture content; wood; wood-base materials

APPENDIX

(Nonmandatory Information)

X1. RATIONALE (COMMENTARY)

X1.1 Historically, laboratory values for moisture content of wood and wood-base materials have been obtained using ovens operated slightly above the boiling point of water. This low temperature permits a minimum of thermal degradation of the "oven-dry" residue and minimal loss of volatiles other than water. However, the procedure introduces variation in final oven-dry mass because (*1*) Non-aqueous materials are volatilized, and (*2*) The oven-drying endpoint is approached asymptotically as the "water of constitution" (protonated hydroxyls) is removed. The assumed equivalence of water and volatiles has been accepted as a necessary error that allows the use of rather simple equipment in obtaining moisture content. If the specimen contains "excessive" volatiles, some judgment is required to determine if an alternative method should be used. Endpoint error can be minimized by using a rate of mass change criterion, which may also simultaneously reduce the volatilization variability. Although there may be existing methods that provide more precise or unbiased results, the oven-dry method has been universally accepted as the reference technique. Before a replacement or alternative method can be proposed, its relationship to the oven-dry method must be quantified in terms of precision and bias. These test methods contain suitable procedures to assess such alternative methods.