Standard Test Methods for
Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials[1]

This standard is issued under the fixed designation D2395; 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.

ε[1] NOTE—Corrections were made editorially in October 2015.

1. Scope

1.1 These test methods cover the determination of the density and specific gravity (relative density) of wood and wood-based materials to generally desired degrees of accuracy and for specimens of different sizes, shapes, and moisture content conditions. The method title is indicative of the procedures used or the specific area of use.

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1.2 *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:*[2]

D9 Terminology Relating to Wood and Wood-Based Products

D2555 Practice for Establishing Clear Wood Strength Values

D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials

D5456 Specification for Evaluation of Structural Composite Lumber Products

D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters

E1547 Terminology Relating to Industrial and Specialty Chemicals

2.2 *Other Standards:*

CAN/CSA O86 Engineering Design in Wood[3]

ANSI/AWC National Design Specification for Wood Construction[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this standard, refer to Terminology D9.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *density,* ρ [kg/m^3, g/cm^3 or lb/ft^3], *n*—the mass of a unit volume of a specimen at specified moisture content.

NOTE 1—The moisture content is specified for both mass and volume. For further discussion, see Appendix X3.

3.2.1.1 *density at moisture content M*—density based on the mass of a specimen including moisture and its volume at the same moisture content.

NOTE 2—The mass and volume at 12 % moisture content are frequently used.

3.2.1.2 *density, basic or conventional,* ρ_b—density based on the oven-dry mass of a specimen and its green volume.

3.2.1.3 *density, oven-dry or in the absolute dry condition,* ρ_0—density based on the oven-dry mass of a specimen and its oven-dry volume.

3.2.2 *green volume, n*—the volume of wood specimen before any shrinkage occurs due to drying to moisture content below the fiber saturation point (about 30 %).

NOTE 3—Green volume may also be obtained by water soaking of partially dry wood specimens until they reach fully swollen condition above the fiber saturation point (e.g., see 12.2.3.1). See Appendix X3. The fiber saturation point of wood averages approximately 30% moisture

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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.

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[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.

[3] Available from CSA Group, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, http://www.csa.ca.

[4] Available from American Wood Council (AWC) 222 Catoctin Circle, SE, Suite 201 Leesburg, VA 20175, www.awc.org.

content, but in individual species and individual pieces of wood it can vary by several percentage points from that value.

3.2.3 *moisture content, M [%]*—the amount of water contained in a specimen, expressed as a percentage of its oven-dry mass.

3.2.4 *specific gravity (relative density), S, n*—the ratio of the oven-dry mass of a specimen to the mass of a volume of water equal to the volume of the specimen at a specified moisture content.

Note 4—The volume may be that in the oven-dry, partially dry, or green (fully swollen) condition. Further in this standard, the terms specific gravity and relative density are used interchangeably. For further discussion, see Appendix X3.

3.2.4.1 *specific gravity at moisture content M, n*—specific gravity based on the oven-dry mass of a specimen and its volume at a specified moisture content between the oven-dry condition and the fiber saturation point.

Note 5—The volume at 12 % moisture content is frequently used.

3.2.4.2 *specific gravity, basic (or green), S_b, n*—specific gravity based on the oven-dry mass of a specimen and its green volume.

3.2.4.3 *specific gravity, oven-dry or on oven-dry basis, S_0, n*—specific gravity based on the oven-dry mass of a specimen and its oven-dry volume.

4. Summary of Test Methods

4.1 The precision of test results obtained on a representative specimen depends upon the precision of the measurements made. Method A is used for precise measurements when the specimens are carefully prepared and regular in shape. Method B is used for precise measurements if the specimens are irregularly shaped and if due care is taken to prevent sorption of water. Test Method C is an approximate method that is permitted for use as part of a production procedure or in other situations where less precision is acceptable. Test Methods D and E are especially adapted to density or specific gravity measurements of living trees or of in-place elements, and the precision of the result is dependent upon the care used in obtaining the specimen. Test Method F is a specific procedure for wood chips.

5. Significance and Use

5.1 Density and specific gravity are cornerstone terms that help define many useful properties of wood and wood-based products. These terms designate concepts that have distinct definitions though they relate to the same characteristic (mass in a unit volume). Generally, in the US and Canada, density of wood is measured in terms of *specific gravity*, or *relative density*. In the wood-based composites industry and internationally the term density is often preferred.

5.2 The *basic density* and *basic specific gravity* of wood are used in the forestry industry for calculating the oven-dry weight of wood fiber contained in a known wood volume of various wood species. Thus, it serves as an indicator of the amount of wood pulp that could be produced, the workability of the material or its shipping weight. This information is

referenced in various resources, including Wood Handbook.[5] Note that specific gravity varies within a tree, between trees, and between species. Since the specific gravity of wood cell wall substance is practically constant for all species (approximately 1.53), it is apparent that individual specific gravity value is indicative of the amount of wood cell wall substance present. It affords a rapid and valuable method for selection of wood for specific uses. In US and Canadian building codes, the *oven-dry specific gravity* is correlated to various strength characteristics of wood products (e.g., compression perpendicular to grain, shear strength and fastener holding capacity).

5.3 It is often desirable to know the density or specific gravity of a living tree, a structural member already in place, a log cross section, a segment of a research element, or the earlywood or latewood layer. Therefore, it is possible that specimens will be large or small, regular or irregular in shape, and at a variety of moisture contents. These test methods give procedures that include all of these variables and provides for calculation of density and specific gravity values to degrees of precision generally needed.

5.4 In the wood-based composites industry, the product density or specific gravity also provides an important indicator of potential product attributes. For wood-based materials, the same test methods are used; however, the measurements typically combine the mass from the wood substance with any resin, wax, or other solid additives present in the material. These properties are not to be confused with *equivalent specific gravity* of structural composite lumber used to characterize its fastener-holding capacity determined in accordance with D5456.

6. Test Specimens

6.1 The test specimens shall be fully representative of the material from which they are taken. The specimen size shall be such that accurate measurements of mass and volume are easy to attain. Where other standards specify the location and size of test specimens, these requirements shall be carefully followed. The specimens shall be carefully cut from the larger element to ensure clean-cut surfaces. All loose fibers shall be carefully removed before the specimen is weighed and measured. The specimen shall be free from knots, and if pitch or other infiltrates are present, this shall be noted in the report or they shall be extracted before taking measurements and weighing.

6.2 *Measurements*—The dimensions of test specimens shall be measured to a precision of ±0.3 % or less, and the mass shall be determined to a precision of ±0.2 % or less. Where drying of specimens is required, this shall be done in a forced convection oven that can be maintained at 103 ± 2°C throughout the drying chamber for the time required to dry the specimen to reach practical equilibrium (see Note 6). The oven shall be vented to allow the evaporated moisture to escape.

Note 6—For most specimens of wood, wood structural panels and structural composite lumber 1 in. (25 mm) in length parallel to grain, drying for 24 h in an oven having good air circulation and exchange will be sufficient to reach practical equilibrium (no more than 0.2% mass

change over 8 h period of drying). For other wood-based materials, the drying time should be established by test. For further discussion, see Appendix X3.

7. Test Method A—Volume by Measurement

7.1 *Applicability:*

7.1.1 This procedure is adaptable to any size of specimen at any moisture content. The specimen shall be regular in shape with right-angle corners for determination of volume by lineal measurement. If the surfaces of the specimen are smooth and sufficient measurements are taken, the volume can be obtained with high precision. Special care shall be taken in measurement of very small or thin specimens. Volume of irregular or rough-surfaced specimens shall be obtained by Test Method B.

7.2 *Procedures:*

7.2.1 *Volume*—Measure the length, width, and thickness of the specimen in accordance with 6.2 in a sufficient number of places to ensure a precise indication of volume.

7.2.2 *Initial mass, (m_M)*—Determine the initial mass of the specimen at the time of test in accordance with 6.2.

7.2.3 *Oven-dry mass (m_0)*—Oven-dry mass of the specimen shall be determined by drying to practical equilibrium in accordance with 6.2 or by calculation (13.1.2) in special situations (7.2.4.4).

7.2.4 *Moisture Content*—Determine the moisture content (*M*) of the specimen to permit description of the basis on which the density or specific gravity is computed. Test Methods D4442 and D7438 indicate procedures that shall be used.

7.2.4.1 *Small Specimens*—The entire specimen shall be used for determination of moisture content in accordance with D4442.

7.2.4.2 *Intermediate Specimens*—When the specimen is of a size that is unsuitable for moisture content determinations (the time to oven-dry to constant mass would be excessive), a segment shall be cut from the specimen in accordance with 6.1 for moisture content measurement using methods D4442. Select this segment so that its moisture content is representative of that of the larger specimen. Where possible in wood elements and structural composite lumber, the moisture content specimen shall be of full cross-sectional dimensions approximately 1 in. (25 mm) in length (parallel to grain). In sheet materials the specimen shall be equal in thickness to the thickness of the material and 3 by 6 in. (76 by 122 mm) in size.

7.2.4.3 *Structural Elements*—In full-size members, the moisture content shall be determined on a segment cut from the member in accordance with 6.1. It shall be of full cross-sectional dimensions and approximately 1 in. (25 mm) in length parallel to grain, and shall be selected from a representative area of the member (see Note 7).

NOTE 7—The specimens should be cut in the area of interest. Where possible, avoid the effects of end drying.

7.2.4.4 *Special Situations*—Where the specimen or element cannot be cut to secure a moisture content segment, an approximate moisture content shall be obtained through the use of a moisture meter in accordance with Test Methods D7438 (see Note 8). The use of moisture meters shall not be permitted for materials other than wood.

NOTE 8—Since the moisture content value obtained with moisture meter is approximate, it should be recognized that the specific gravity values obtained are approximate.

8. Test Method B—Volume by Water Immersion

8.1 *Applicability:*

8.1.1 This procedure is particularly adaptable to specimens of irregular shape or having a rough surface (see Note 9).

NOTE 9—Limitations on specimen size are based primarily on size of immersion tanks available. In small size specimens, less than 1 cm³ in volume, air bubbles adhering to the specimen surface can result in considerable error in volume measurement and thus in the computed density or specific gravity value. Freshly cut green wood will not absorb appreciable quantities of water during the brief immersion period. If any drying has taken place, the surface of the specimen needs to be sealed before immersion in water or else the volumetric displacement of the specimen will be in error in an amount equal to the volume of water absorbed by the wood.

8.2 *Procedures:*

8.2.1 *Initial mass (m_M)*—Determine the initial mass of the specimen at time of test in accordance with 6.2.

8.2.2 *Volume*—Determine the volume of the specimen by measuring the volume or the mass of the water displaced by the specimen using one of the following modes. The mass of water in grams is numerically equal to its volume in cubic centimeters. Unless the volume is determined on a specimen of green wood, the surfaces of the specimen shall be adequately sealed (see 8.2.2.5).

8.2.2.1 *Mode I*—Place the specimen in a tank of known volume and add sufficient water to fill the tank with the specimen being fully submerged. Then remove the specimen and determine the volume of water remaining. The tank volume less the volume of water remaining is equal to the volume of the specimen. The relationship between specimen volume and tank volume shall be such that the precision of specimen volume measurement is adequate to the purpose of the test.

8.2.2.2 *Mode II*—Place a container holding enough water to completely submerge the specimen on a balance as shown in Fig. 1. Then tare the balance to the combined mass of the container and water. Using a sharp, pointed, slender rod, place the specimen in the container so that it is completely submerged in the water without touching the sides of the container. After reaching the equilibrium, the reading on the balance is equal to the mass of water displaced by the specimen.

8.2.2.3 *Mode III*—Place a container holding enough water to completely submerge the specimen on a balance as shown in Fig. 2. The container shall be sufficiently large so that immersion of the specimen causes no significant change in water level. Suspend a wire basket of sufficient mass to keep the specimen submerged and immerse it in the water. Tare the balance to the mass of the basket when freely immersed. Weigh the specimen in air. Place the specimen in the basket and hold it completely submerged without touching the container. After reaching the equilibrium, the mass reading on the balance, if the specimen is lighter than water, plus the mass of the specimen in air equals the volume of water displaced. If the specimen is heavier than water, subtract the mass reading on the balance from the mass of the specimen in air to determine the volume of water displaced.
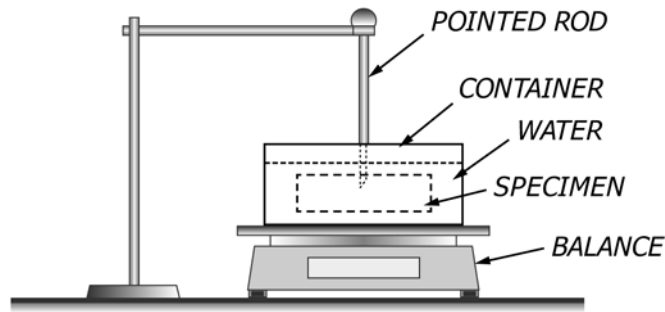
FIG. 1 Diagrammatic Sketch of Apparatus Used to Measure Volume of Specimens by Test Method B (Mode II)
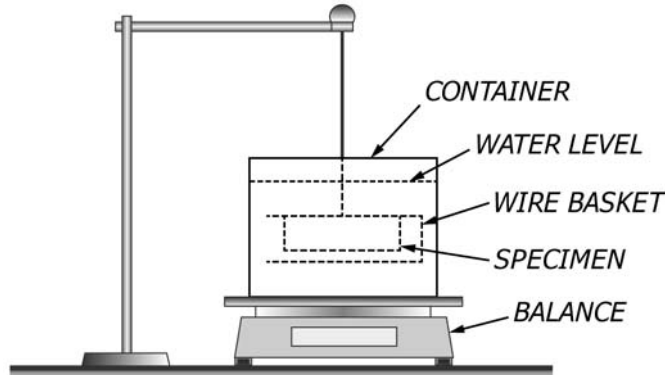

FIG. 2 Diagrammatic Sketch of Apparatus Used to Measure Volume of Specimens by Test Method B (Mode III)

8.2.2.4 *Mode IV*—Immerse the specimen, of an elongated shape, in a graduated tube having a cross section only slightly larger than that of the specimen as shown in Fig. 3. Read the water level in the tube, preferably to an even graduation mark, before immersing the specimen. Immerse the specimen, hold it submerged with a slender pointed rod if necessary, and determine the water level again. The difference in water level is equal to the volume of the specimen.

8.2.2.5 *Surface Treatment of Specimen*—Partially dry or oven-dry specimens shall be dipped in hot paraffin wax before making volume determinations (see Note 10). After the wax dip, weigh the specimen again and use this mass in conjunction with the immersed mass for determining volume in Mode II and Mode III (8.2.2.2 and 8.2.2.3).

NOTE 10—Specimens of green wood may be briefly immersed in water without appreciable absorption that will affect volume determinations.

8.2.3 *Oven-dry mass (m_0)*—Oven-dry mass of the test specimen shall be determined by drying to practical equilibrium in accordance with 6.2.

8.2.4 *Moisture Content*—Determine the moisture content (*M*) of the specimen in accordance with Test Methods D4442 to permit description of the basis on which the density or specific gravity is calculated.

9. Test Method C—Flotation Tube

9.1 *Applicability:*

9.1.1 This procedure provides a rapid means for obtaining an approximate density or specific gravity for an elongated specimen of uniform cross section and known moisture content (see Note 11).
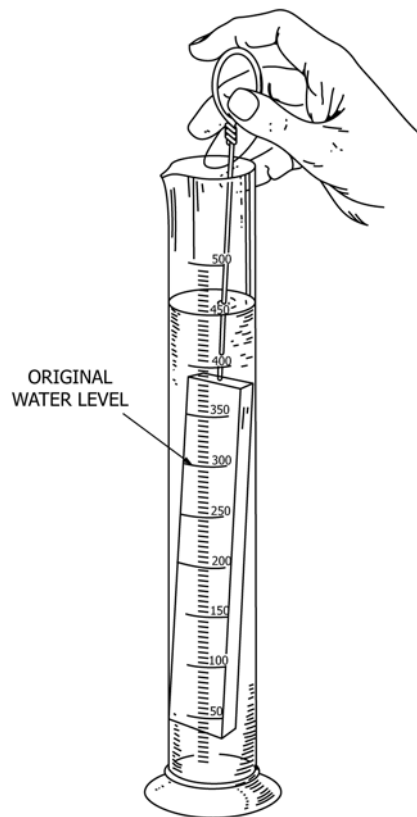

FIG. 3 Measuring Volume of Elongated Specimens Using a Graduated Tube by Test Method B (Mode IV)

NOTE 11—Estimates of density or specific gravity to the nearest 0.02 g/cm^3 (0.02) can be readily made.

9.2 *Procedures:*

9.2.1 *Specimen Preparation*—The specimen shall be slender and of uniform cross section, preferably approximately 1 in. (25 mm) on a side and 10 in. (25 cm) long.

9.2.2 *Measurement*—Place the specimen in a slender cylinder filled with water and allow it to float in as nearly a vertical position as possible (Fig. 4). The cylinder diameter shall be slightly larger than the specimen cross section, and the specimen shall not touch the cylinder wall until immersed as far as it will go. With the specimen floating in an upright position, quickly note the water level on the specimen to avoid excessive absorption of water by the specimen.

9.2.3 *Moisture Content*—Determine the moisture content (*M*) of the specimen in accordance with Test Methods D4442 or D7438 to permit description of the basis on which the density or specific gravity is computed (see Note 12).

NOTE 12—Precautions should be used to minimize the influence of the water immersion on the measurement of the moisture content.

10. Test Method D—Forstner Bit

10.1 *Applicability:*

10.1.1 This procedure is particularly adaptable for determining the density or specific gravity of logs, timbers, or any in-place elements from which it would be difficult to saw a more conventional sample. The volume of the hole formed by the lead screw of a Forstner bit is negligible; therefore, the volume of the specimen can be calculated from the diameter of the bit and the depth of the hole. Care shall be taken to collect all of the shavings.
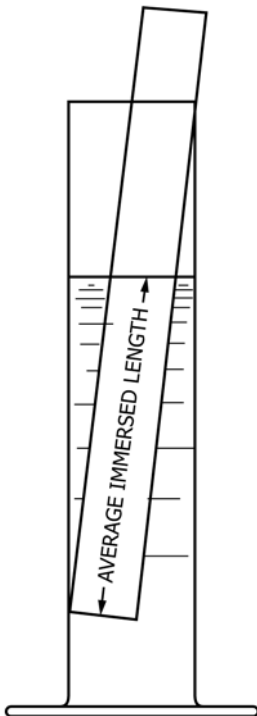
10.2 *Procedures:*

10.2.1 *Volume*—Obtain the volume of specimen material by boring a hole into the element in question with a Forstner-type bit. The diameter of hole and depth of boring shall be such that an adequate sample is obtained without damage to the element. Accurately measure the diameter of the bit and depth of the hole. Use these dimensions to calculate the specimen volume.

10.2.2 *Initial mass (m_M)*—Carefully collect all of the chips obtained by boring and immediately weigh them to determine the initial mass.

10.2.3 *Oven-dry mass (m_0)*—Oven-dry mass of the chips shall be determined by drying to practical equilibrium in accordance with 6.2 (see Note 13).

NOTE 13—Drying chips in a forced convection oven should be done with care: as the chips dry, small particles may be blown away from dishes and lost for the oven-dry mass measurements.

10.2.4 *Moisture Content*—Determine the moisture content (*M*) in accordance with Test Methods D4442 to permit description of the basis on which the density or specific gravity is computed.

11. Test Method E—Increment Cores

11.1 *Applicability:*

11.1.1 This procedure is particularly adaptable for obtaining specimens to determine the density or specific gravity of standing trees but is also suitable for use on logs, poles, piles, or other structural elements. Since only a pencil-sized hole is made in the member in question, it has no material effect on the properties of the member and can be easily sealed.

11.2 *Procedures:*

11.2.1 *Volume*—Obtain the specimen material by extracting a core from the member by means of a standard increment borer. Obtain the volume from the diameter of the cutting edge of the increment borer and measure the length of the core immediately after it is removed from the member. Handle the core carefully to prevent damage or loss of any portion.

11.2.2 *Initial mass (m_M)*—When the moisture content of the element is desired, weigh the increment core immediately after the length is measured in order to obtain the initial mass. If the immediate weighing is impractical, the core shall be protectively wrapped to prevent loss of moisture.

11.2.3 *Oven-dry mass (m_0)*—Oven-dry mass of the specimen shall be determined by drying to practical equilibrium in accordance with 6.2.

11.2.4 *Moisture Content*—When necessary, determine the moisture content (*M*) in accordance with Test Methods D4442 to permit description of the basis on which the density or specific gravity is computed (see Note 14).

NOTE 14—For example, when determining the basic density or specific gravity of a standing tree, the determination of the moisture content may not always be necessary.

FIG. 4 Cylinder and Specimen Used in Flotation Tube Test Method (Method C)

12. Test Method F—Chips[6]

12.1 *Applicability:*

12.1.1 This procedure is specifically designed to determine the basic density or basic specific gravity of wood chips, although the values at any other moisture content can also be obtained.

12.2 *Procedures:*

12.2.1 *Specimen*—Select a representative sample of chips weighing 0.66 to 0.77 lb (approximately 300 to 350 g) for test. Remove sawdust and undersized chips by shaking on a three-mesh sieve.

12.2.2 *Initial mass* (m_M)—Obtain the initial mass of the chips in accordance with 6.2.

12.2.3 *Volume:*

12.2.3.1 Submerge the chips in water at room temperature for at least 1 h to ensure that they are at their green volume and will not absorb water during volume measurement. Then remove the chips from the water, allow them to drain in a wire-mesh basket, and place them in the centrifuge basket. Centrifuge the chips from 800 to 1200 rpm for 1 to 4 min.

12.2.3.2 Place a container holding enough water to freely submerge the chip holder on a balance. Submerge the empty chip holder, except for its wire handle, in the water container. The chip holder must not touch the sides or bottom of the container. Tare the balance. Transfer the chips to the chip holder and slowly lower them into the container of water, being careful to remove any entrapped air. After reaching the equilibrium, the balance reading represents the volume of water equal to the volume of chips (V).

12.2.4 *Oven-dry mass* (m_0)—Oven-dry mass of the chips shall be determined by drying to practical equilibrium in accordance with 6.2.

13. Calculation

13.1 *Moisture Content (M) or Oven-Dry Mass* (m_0):

13.1.1 If Test Methods D4442 are used, the moisture content is calculated as follows:

$$M = \frac{m_M - m_0}{m_0} \times 100 \qquad (1)$$

where:

M = moisture content of specimen at the time of test, percent,
m_M = initial mass, and
m_0 = oven-dry mass.

13.1.2 If Test Methods D7438 are used, the moisture content is determined from moisture meter readings corrected for temperature and species. In this case, the oven-dry mass is estimated as follows:

$$m_0 = \frac{m_M}{1 + 0.01M} \qquad (2)$$

where:

m_0 = oven-dry mass,
m_M = initial mass, and
M = moisture content determined by moisture meter, percent (Test Methods D7438).

13.2 *Density* (ρ) (see Appendix X3)*:*

13.2.1 For Methods A, B, D, E, and F, density is calculated using the following formulae:

13.2.1.1 *Density at moisture content M:*

$$\rho_M = \frac{m_M}{V_M} \qquad (3)$$

13.2.1.2 *Oven-dry density:*

$$\rho_0 = \frac{m_0}{V_0} \qquad (4)$$

13.2.1.3 *Basic density:*

$$\rho_b = \frac{m_0}{V_{max}} \qquad (5)$$

where:

m_0 = oven-dry mass of specimen as determined in 13.1,
V_M = volume of specimen at moisture content M,
V_0 = oven-dry volume of specimen, and
V_{max} = green volume of specimen.

13.2.2 For Method C, density of the specimen at moisture content M is calculated using Eq 6, which yields the value numerically equal to the density in g/cm^3:

$$\rho_M = \frac{L_i}{L} \qquad (6)$$

where:

L_i = immersed length of specimen, and
L = total length of specimen.

13.2.3 *Conversion of Values*—It is often desirable to convert the density of wood obtained at one moisture content to that at some other moisture content condition. Relations between the density and moisture content are presented in Appendix X1.

13.3 *Specific Gravity (S)* (see Appendix X3)*:*

13.3.1 For Test Methods A, B, D, E, and F, specific gravity is calculated using the following formulae (see notation in 13.2):

13.3.1.1 *Specific gravity at moisture content M:*

$$S_M = \frac{Km_0}{V_M} \qquad (7)$$

13.3.1.2 *Oven-dry specific gravity:*

$$S_0 = \frac{Km_0}{V_0} \qquad (8)$$

13.3.1.3 *Basic specific gravity:*

$$S_b = \frac{Km_0}{V_{max}} \qquad (9)$$

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[6] Additional information on this test method may be obtained from TAPPI 258 om-06, Basic Density and Moisture Content of Pulpwood. Available from Technical Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Norcross, GA 30092, http://www.tappi.org.

where:

K = constant determined by the units used to measure mass and volume:
- = 27.680 in.^{3}/lb when mass is in lb and volume is in in.^{3},
- = 453.59 cm^3/lb when mass is in lb and volume is in cm^3,
- = 453 590 mm^3/lb when mass is in lb and volume is in mm^3,
- = 0.061024 in.^{3}/g when mass is in g and volume is in in.^{3},
- = 1.000 cm^3/g when mass is in g and volume is in cm^3,
- = 1000 mm^3/g when mass is in g and volume is in mm^3.

13.3.2 For Test Method C, specific gravity of the specimen at moisture content M is calculated using the following formula (see notation in 13.1, 13.2.2 and Note 15):

$$S_M = \frac{L_i}{L(1 + 0.01\,M)} \qquad (10)$$

NOTE 15—The term $(1 + 0.01M)$ accounts for the mass of moisture in the specimen. For oven-dry specimens it equals unity.

13.3.3 *Conversion of Values*—It is often desirable to convert the specific gravity of wood obtained at one moisture content to that at some other moisture content condition. Relations between the specific gravity and moisture content are presented in Appendix X2.

13.4 *Relations between specific gravity and density*—Relations between the values of specific gravity and density are expressed as follows (see Note 16).

13.4.1 *Values at moisture content M:*

$$S_M = \frac{\rho_M}{\rho_w(1 + 0.01\,M)} \qquad (11)$$

13.4.2 *Oven-dry values:*

$$S_0 = \frac{\rho_0}{\rho_w} \qquad (12)$$

13.4.3 *Basic values:*

$$S_b = \frac{\rho_b}{\rho_w} \qquad (13)$$

where:

ρ_w = density of water (see Appendix X3), and
M = moisture content of specimen, percent.

NOTE 16—If the values of density are expressed in g/cm^3, oven-dry specific gravity and oven-dry density are numerically equal, as well as the values of basic specific gravity and basic density. However, the values of specific gravity and density at moisture content M are not equal. For example, for a specimen with density $\rho_{12} = 0.45$ g/cm^3, the corresponding specific gravity is $S_{12} = 0.45/[1.00×(1 + 0.01×12)] = 0.40$. Similarly, for a specimen with specific gravity $S_{12} = 0.45$, the corresponding density is $\rho_{12} = 0.45× [1.00×(1 + 0.01×12)] = 0.50$ g/cm^3.

14. Report

14.1 *Report*—The report shall identify the material as completely as possible, the method of selecting test specimens, the test procedure used, and the conditions under which the volume and mass were determined.

14.2 The basis for calculating the density or specific gravity shall be clearly referenced as shown in Section 13.

15. Precision and Bias

15.1 The precision and bias of these test methods have not been established.

16. Keywords

16.1 chips; Forstner bit; increment cores; moisture content; volume by immersion; volume by measurement

APPENDIXES

(Nonmandatory Information)

X1. DENSITY/MOISTURE CONTENT RELATIONSHIPS

X1.1 It is often desirable to convert the density of wood obtained at one moisture content to that at some other moisture content condition. This may be approximated by the use of the following formulae based upon assumed moisture/dimensional change relationships for wood at moisture content below the fiber saturation point.[7] They do not apply to structural composite lumber, panel products, or other wood-based composites.

X1.1.1 Density (ρ_M) at any moisture content (M) below the fiber-saturation point determined from the basic density (ρ_b) and the oven-dry density (ρ_0):

$$\rho_M = \left[\rho_0 - (\rho_0 - \rho_b)\frac{M}{30} \right](1 + 0.01\,M) \qquad (X1.1)$$

X1.1.2 Density (ρ_M) at any moisture content (M) below the fiber-saturation point determined from the basic density (ρ_b):

$$\rho_M = \frac{\rho_b(1 + 0.01\,M)}{1 - 0.009(30 - M)\dfrac{\rho_b}{\rho_w}} \qquad (X1.2)$$

X1.1.3 Density (ρ_M) at any moisture content (M) below the fiber-saturation point determined from the oven-dry density (ρ_0):

$$\rho_M = \frac{\rho_0(1 + 0.01\,M)}{1 + 0.009M\dfrac{\rho_0}{\rho_w}} \qquad (X1.3)$$

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[7] Beyond the fiber saturation point the density increases in linear proportion equivalent to the moisture uptake: $\rho_M = \rho_b(1 + 0.01M)$.

X1.1.4 In general, density (ρ_2) at moisture content M_2 can be determined from the density (ρ_1) at moisture content M_1 (both below the fiber saturation point) as follows:

$$\rho_2 = \frac{\rho_1\left[1 + 0.01\left(M_2 - M_1\right)\right]}{1 + 0.009\left(M_2 - M_1\right)\dfrac{\rho_1}{\rho_w}} \qquad (X1.4)$$

X1.1.5 For softwood lumber, a simplified formula can be used to estimate the density (ρ_2) at moisture content M_2 from the density (ρ_1) at moisture content M_1 (both below the fiber saturation point) assuming that the density increases/decreases 0.5% for each 1.0% increase/decrease in moisture content up to the fiber saturation point:[8]

$$\rho_2 = \rho_1\left[1 + 0.005\left(M_2 - M_1\right)\right] \qquad (X1.5)$$

where:

M, M_1, M_2 = moisture content, percent,
ρ_1 and ρ_2 = density values at moisture content values of M_1 and M_2, respectively,
ρ_0 = oven-dry density,
ρ_b = basic density, and
ρ_w = density of water (see Appendix X3).

X1.2 The relationship between density and moisture content presented in Eq X1.3 and X1.4 can be illustrated by the use of the chart in Fig. X1.1. The values of oven-dry density ρ_0 are read on the left-hand side scale. The values of density ρ_M at moisture content M are plotted on the diagonal lines. To illustrate the use of the chart, assume the oven-dry density ρ_0 = 0.55 g/cm³ and it is desired to find the density for a 19% moisture condition (ρ_{19}). Enter the chart at the left-hand scale at the value of ρ_0 = 0.55 g/cm³ and move parallel to the diagonals up to an intersection with the moisture content vertical line at M = 19%, then move horizontally to the left-hand scale to read ρ_{19} = 0.60 g/cm³. If the density at 15% moisture content ρ_{15} = 0.45 g/cm³ and the density at 8% moisture content (ρ_0) is desired, enter the chart on the left-hand side at the value of 0.55 g/cm³ and move horizontally to the right till an intersection with the moisture content vertical line at M = 15%, then move to the left parallel to the diagonal lines down to the intersection with the moisture content vertical line at M = 8% and then horizontally to the left-hand scale to read ρ_8 = 0.43.

[8] Dinwoodie, J.M. 2002. *Timber: Its nature and behavior*, Second edition. Taylor & Francis. New York, NY. ISBN 0-419-2555008
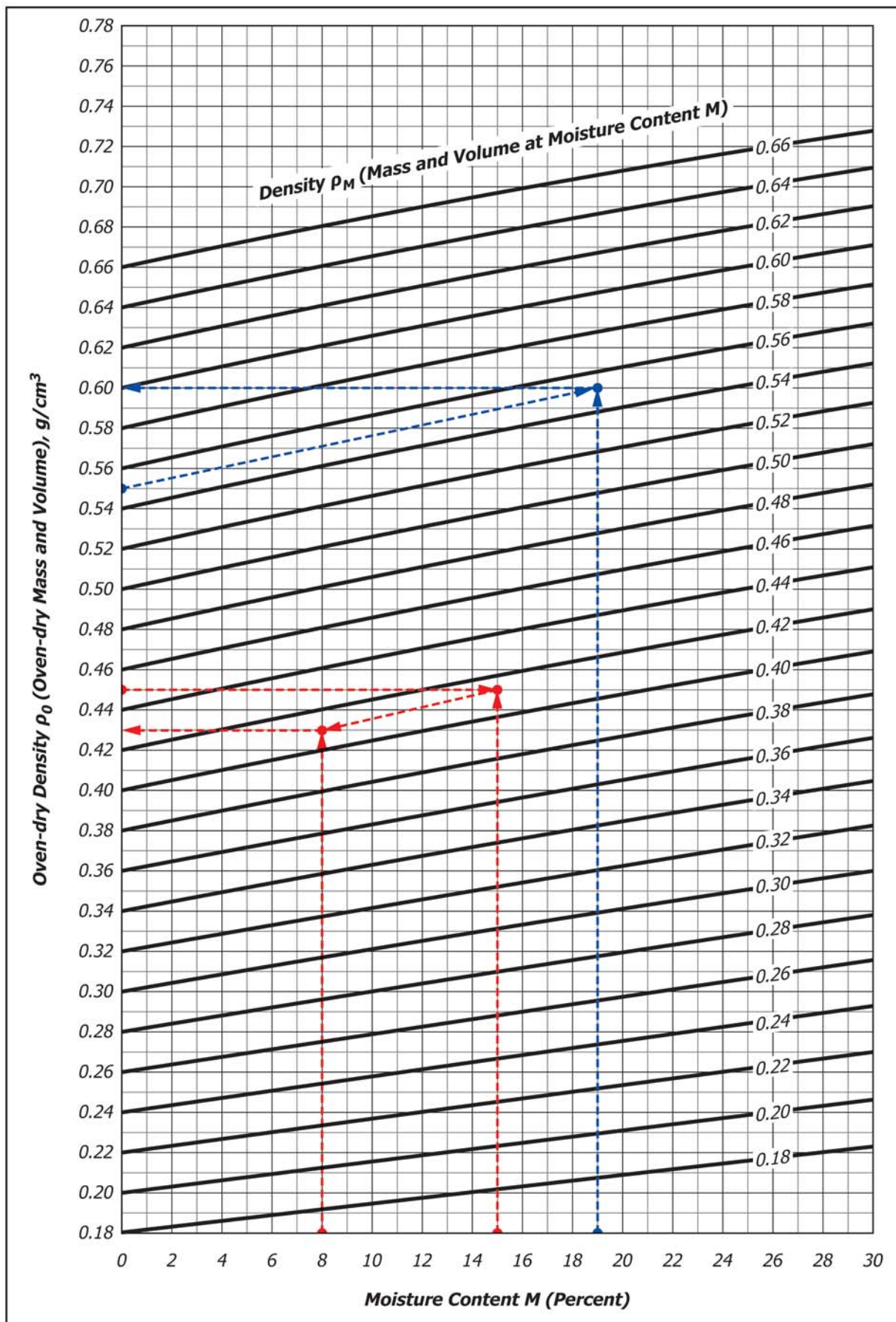
FIG. X1.1 Relation of Density and Moisture Content

X2. SPECIFIC GRAVITY/MOISTURE CONTENT RELATIONSHIPS

X2.1 It is often desirable to convert the specific gravity of wood at one moisture content to that at some other moisture content condition. This may be approximated by the use of the following formulae based upon assumed moisture/dimensional change relationships for wood at moisture content below the fiber saturation point.[9] They do not apply to structural composite lumber, panel products, or other wood-based composites.

X2.1.1 Specific gravity (S_M) at any moisture content M below the fiber-saturation point determined from the basic specific gravity (S_b) and the oven-dry specific gravity (S_0):

$$S_M = S_0 - (S_0 - S_b)\frac{M}{30} \qquad (X2.1)$$

X2.1.2 Specific gravity (S_M) at any moisture content M below the fiber-saturation point determined from the basic specific gravity (S_b):

$$S_M = \frac{S_b}{1 - 0.009(30 - M)S_b} \qquad (X2.2)$$

X2.1.3 Specific gravity (S_M) at any moisture content M below the fiber-saturation point determined from the oven-dry specific gravity (S_0):

$$S_M = \frac{S_0}{1 + 0.009MS_0} \qquad (X2.3)$$

X2.1.4 In general, the specific gravity (S_2) at moisture content M_2 can be determined from the specific gravity (S_1) at moisture content M_1 (both below the fiber saturation point) as follows:

$$S_2 = \frac{S_1}{1 + 0.009(M_2 - M_1)S_1} \qquad (X2.4)$$

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[9] MacLean, J.D. 1944. Effect of moisture content on the shrinkage, swelling, specific gravity, air or void space, weight and similar properties of wood. USDA FPL Rep. No. R1448. Madison, WI.

where:

M, M_1, M_2 = moisture content, percent,
S_1 and S_2 = specific gravity values at moisture content values of M_1 and M_2, respectively,
S_O = oven-dry specific gravity, and
S_b = basic specific gravity.

X2.2 The relationship between specific gravity and moisture content presented in Eq X2.2-X2.4 can be illustrated by the use of the chart in Fig. X2.1. The values of specific gravity based on oven-dry volume or volume at the current moisture content below the fiber saturation point are read on the left-hand scale. The basic specific gravity values (based on green volume) are plotted on the diagonal lines. All values are based on oven-dry mass. To illustrate the use of the chart, assume the basic specific gravity $S_b = 0.55$ and it is desired to find the specific gravity for a 12 % moisture content condition (S_{12}). Enter the chart at the moisture content $M = 12$ % and move vertically to the point where this line intersects the basic specific gravity line $S_b = 0.55$ (between diagonals 0.54 and 0.56) and move horizontally to the left-hand scale to read the specific gravity value $S_{12} = 0.60$. If the oven-dry specific gravity $S_0 = 0.54$ and the specific gravity at 15 % moisture content (S_{15}) is desired, enter the chart at $S_M = 0.54$ on the left-hand scale and move parallel to the diagonals to an intersection with the moisture content vertical line $M = 15$ %, then move horizontally to the left-hand scale to read $S_{15} = 0.50$. If the specific gravity at 8 % moisture content $S_8 = 0.45$ and the value at 19 % moisture content is desired, enter the chart with the moisture content $M = 8$ % on the lower scale and $S_M = 0.45$ on the left-hand scale; from this intersection move parallel to the diagonal lines to an intersection with the vertical moisture content line $M = 19$ % and then horizontally to the left-hand scale to read $S_{19} = 0.43$.
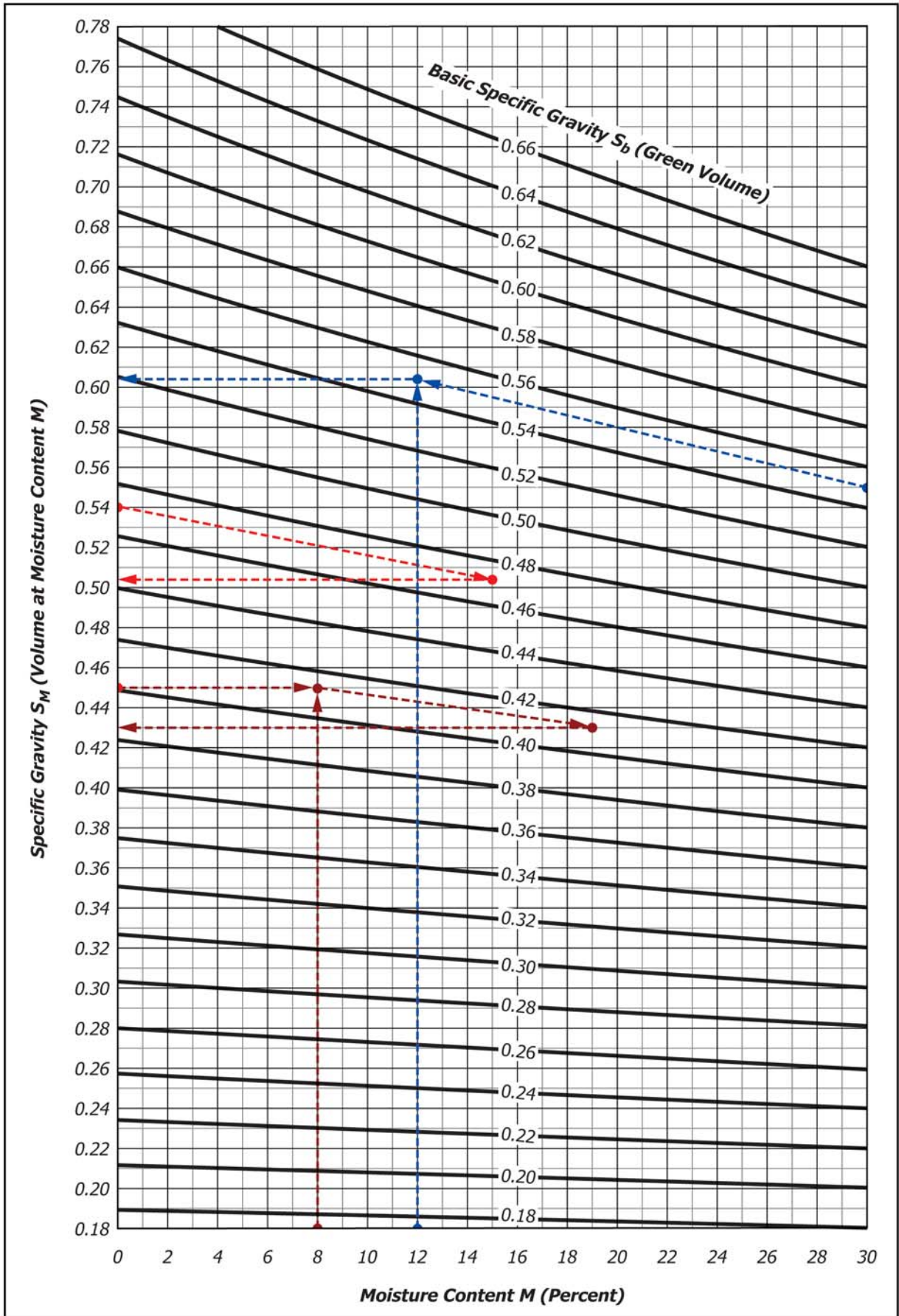
FIG. X2.1 Relation of Specific Gravity and Moisture Content

X3. COMMENTARY

X3.1 In early editions of these test methods, there were no definitions of density and specific gravity (relative density) and each method included its own calculation section, which made the calculation procedures prone to inconsistencies in interpretation between different users. To improve the structure of these test methods and to minimize ambiguities in calculations, the terminology related to specific gravity was introduced and calculation procedures for all methods were unified in one calculation section in the 2007a edition. In 2014, definitions of density, relative density and corresponding calculation procedures were added and the title of the standard was revised accordingly.

X3.2 *Density and Specific Gravity (Relative Density)* (3.2.1 and 3.2.4)—As both the mass and volume of wood substance vary with the moisture content, density and specific gravity as applied to wood and wood-based materials are indefinite quantities unless the conditions under which they are determined are clearly specified. In calculations of density at moisture content *M*, water contained in wood is included in the mass of the specimen, whereas specific gravity is always based on the oven-dry mass. Depending on the purpose of the measurement, the volume may be determined in the green, air-dry, or oven-dry condition. Density and specific gravity determined using oven-dry mass and green volume are referred to as *basic density* and *basic specific gravity*, respectively. When expressed in g/cm^3, basic density is numerically equal to basic specific gravity. These values are often used in silvicultural studies to characterize density of species. For example, basic specific gravity data for commercial species of woods grown in the United States and Canada are given in Practice D2555. Adjustments of moisture meters for wood species are commonly based on specific gravity determined on the oven-dry mass and the volume at the 12 % moisture content. Specific gravity data in Wood Handbook[5] Tables 5-3, 5-4, and 5-5 are reported on both the 12 % volume and green volume bases. Design specifications for wood, such as contained in the ANSI/AWC National Design Specification for Wood Construction and CAN/CSA O86, are based on oven-dry mass and oven-dry volume. In CAN/CSA O86 and some other literature, the term *relative density* is preferred to *specific gravity*.

X3.3 *Green Volume* (3.2.2)—In practice, green volume and swollen volume (obtained after water immersion) can differ. Sometimes the measured green volume may be less than it should be because of the handling process. Therefore, it might be desirable to lightly re-wet the specimens to compensate for any end-grain drying. Some potential differences between the two volumes may occur in some species having sufficient growth stresses (eucalypts, for example) so that swollen volume is less than the original green volume; also, certain cell wall materials (including low molecular weight wood substance) can be extracted, again reducing the volume.

X3.4 *Moisture Content* (3.2.3)—In general, the moisture content can be expressed on two different bases: as a percentage of the oven-dry mass, or as a percentage of the total mass including water. To avoid misunderstandings, it must be clear which basis is being used. In the forest industry and the wood products industry, the moisture content is always expressed as a percentage of the oven-dry mass.

X3.5 *Calculation of Density* (13.2)—In SI units, density is most frequently expressed in kg/m^3 or in g/cm^3. In the latter case, the values of oven-dry density and basic density are numerically equal to the values of oven-dry specific gravity and basic specific gravity, respectively. In Inch-Pound units, *density* is numerically different from specific gravity. To convert the values of density from SI into Inch-Pound units, the following relations are used: (1 kg/m^3 = 0.06243 lb/ft^3 and 1 g/cm^3 = 62.43 lb/ft^3).

X3.6 *Calculation of Specific Gravity* (13.3)—In general, specific gravity of a substance ($S_{x/y}$) is the ratio of mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature (in accordance with Test Method E1547) that can be expressed as follows:

$$S_{x/y} = \frac{m_x}{V_x \rho_y} \qquad \text{(X3.1)}$$

where:

m_x = mass of a unit volume of a material at temperature *x*,
V_x = unit volume of a material at temperature *x*, and
ρ_y = density of water at temperature *y*.

The reference density of gas-free distilled water at 4°C equals 1.000 g/cm^3. In these test methods, the measurements of mass and volume are allowed to be performed at a room temperature and pure water to be used in the experiments. Given the variability of the specific gravity of wood and wood-based materials, the influence of temperature variations between laboratories can be neglected for most practical applications and considered as a part of the measurement uncertainty in these test methods. However, if the purpose of the experiment requires higher precision, the reference temperature at the time of test should be considered and distilled water should be used.

X3.6.1 *Constant K* (13.3.1)—Equations in 13.3 are adjusted using a constant *K* to facilitate the calculations of specific gravity when different systems of units are used in the measurements: Inch-Pound, SI or a mixture of both. Specific gravity does not have units, and the calculation results have the same value regardless of the units used in the measurements.

X3.7 *Report* (Section 14)—Many other standards make references to these test methods for determining specific gravity. Since these test methods allow for determining specific gravity at various moisture contents, it is important that the basis and method for calculating the values of specific gravity are always stated in the report.