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Standard Guide for Moisture Conditioning of Wood and Wood-Based Materials[1]

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1. Scope

1.1 This guide covers standard procedures for conditioning and equilibrating wood and wood-based materials to constant moisture content. The procedures apply to solid wood, wood-based fiber and particulate materials and panels, and wood products containing adhesives. They are intended for use in research and development activities, testing laboratories, quality control, and for all other classes of producers and users. This guide includes background material on the importance of moisture content control, important definitions and technical data, possible types of apparatus, procedures, and the importance of conditioning time. Users should recognize that the necessary degree of precision and bias varies with the intentions of the users. Some research and testing, for example, might require very close control of moisture content, whereas control in an industrial storage facility might not require such close control. This guide offers procedures that include these different requirements.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 The following safety hazards caveat pertains only to the procedure section, Section 6, of this guide.*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

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

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

2.2 *ISO Standard:*

ISO 554 Atmospheres for Conditioning and/or Testing—Specifications[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The following terms are defined in accordance with Terminology D9.

3.1.2 *equilibrium moisture content*—a moisture content at which wood neither gains nor loses moisture to the surrounding air.

[1] This guide is under the jurisdiction of ASTM Committee D07 on Wood and is 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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.2.1 *Discussion—*

Equilibrium moisture content (EMC) generally connotes a moisture content at which a nominal species of solid wood will equilibrate." Nominal" is used in the sense of a "hypothetical average" rather than an actual species. At constant EMC environmental conditions, however, various wood-base materials can reach different levels of EMC. It is more appropriate, therefore, to refer to conditioning at specified relative humidity (RH) and temperature conditions than to a particular EMC. Recommendations for conditioning are given in ISO 554. Nominal values for equilibrium moisture content (EMC) are given in Appendix X1. Caution must be used in calculating or using these values since they represent a compromise between variation with species, and adsorption and desorption. Also, wood containing high levels of extractives or chemicals may equilibrate at different moisture contents. The data in Tables X1.1 and X1.2 were generated from the regression equation in X1.1, which is explained in more detail in Ref (**1**).[4]

3.1.3 *moisture content*—the amount of water contained in the wood, usually expressed as a percentage of the mass of the oven-dry wood.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hysteresis*—the equilibrium moisture content (EMC) that wood attains at any given relative humidity and temperature depends upon the direction from which the EMC is approached. During desorption, the EMC will be higher (sometimes by several percent moisture content) than during adsorption. The analog of the magnetic hysteresis curve has been used to describe this phenomenon. Furthermore, the EMC during a portion of the initial desorption from the never-dried condition may be higher than those in any subsequent desorption cycle.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

3.2.1.1 *Discussion—*

For relative humidities between 10 and 85 % and within a broad range of temperatures, the hysteresis ratio (absorption MC/desorption MC) is approximately 0.85.

3.2.2 *time constant*—the time required for a physical quantity to (a) rise from 0 to $1 - 1/e$ (that is, 63.2 %) of its final steady value when it varies with time, *t*, as $1 - e^{-kt}$, or (b) fall to $1/e$ (that is, 36.8 %) of its initial value when it varies with time, *t*, as e^{-kt} ((**2**)).

3.2.2.1 *Discussion—*

When applying the concept of time constant to moisture conditioning, the "initial value" is the initial MC of the specimen and the" final value" is the EMC that would be attained with extended exposure. One time constant is the time period from the start of exposure to the point of MC that is 63.2 % of the change between initial and final values. This applies in adsorption or desorption. The use of the time constant in conditioning is explained in 6.4.1.1.

4. Significance and Use

4.1 Many physical and mechanical properties of wood and wood-based materials change in response to the environmental equilibrium moisture content, and any comparison of these properties must take moisture content into account. A consistent base for comparison among different test samples and different laboratories is necessary. Shrinkage and dimensional change in particular are dependent on moisture content, and tests involving their measurement must be conducted with good equilibrium moisture content control. Conditioning can also be important in industrial settings where there are optimum moisture content levels for many products and processes, and conformance to these levels can reduce losses in quality and yield.

5. Apparatus

5.1 *Hygrometers, Psychrometers*—The accuracy of hygrometers and psychrometers should be within the range of required RH control, which depends on the desired level of EMC control.

5.2 *Thermometers*—Thermometers to measure air temperature should be capable of measuring temperature within one-half of the temperature control requirement (see Section 8). Thermometers used in psychrometers for determining relative humidity (see 5.1) must have an accuracy which is consistent with the required sensitivity. This sensitivity can be determined from analyzing the tables which convert measured temperatures to relative humidities.

5.3 *Weighing Device*—A balance is required to weigh specimens with an accuracy that will allow measurement of the EMC within the desired limits (see Test Methods D4442).

5.4 *Conditioning Chamber*—The chamber in which specimens are conditioned should be monitored for constant temperature and humidity conditions. If aqueous solutions (saturated salts, glycerin, or sulfuric acid) are to be used, follow the procedure described in Practice E104. Commonly used saturated salt solutions are given in Table X2.1.

NOTE 1—If such solutions are used, precautions must be taken to assure that the specimens do not overly depress (or raise) the RH conditions. This can be tested by adding an equivalent dummy volume of specimens and observing how RH is affected. An RH sensor or simple mechanical hygrometer can show relative effects on RH.

6. Procedure

6.1 *Specimens*—Weigh an appropriate number of specimens periodically to determine when equilibrium is reached. No strict number of specimens can be established because the intent of the test will determine how critical sampling should be. A guideline would be to include enough samples for a statistical analysis. The specimens should be uniformly distributed throughout the conditioning chamber. Consideration should also be given to selecting samples that are representative of the material of interest.

NOTE 2—Typical conditioning time required for 20-mm thick and 100-mm wide end-coated solid wood specimens, initially at equilibrium at 50 % RH and 20°C, and exposed to 90 % RH at 20°C, is 60 days. As a rule of thumb, required conditioning time is proportional to the square of ratio of thickness. A similar specimen of 40 mm thickness, therefore, would equilibrate in about 240 days; a 10-mm one in about 15 days.

6.2 *Specimen Moisture Content*—A decision must be made concerning whether adsorption or desorption (or both) values are to be obtained. This may require preconditioning before the desired exposure. By using the relationship in the discussion under *hysteresis*, an appropriate precondition MC can be selected (below or above the EMC condition for adsorption or desorption MC, respectively).

6.3 *Specimen Preparation:*

6.3.1 If small specimens are used to represent larger or full-size specimens, coat the appropriate edges or ends of the specimens, or both, to obtain moisture content distributions that are typical of larger specimens. Coating is necessary also when using small specimens to determine the conditioning time requirement for larger specimens.

6.3.2 *Stacking*—Stack with spacers so that adjacent surfaces are separated.

6.4 *Equilibrium Determination*—The rate of moisture content changes during conditioning is approximately exponential, that is, rapid changes early in conditioning are followed by a gradual decrease in rate of change. As equilibrium is approached, the mass change becomes very slow. One of the greater potentials for error in conditioning tests is interpretation of slow mass changes as equilibrium. There are several approaches to endpoint determination, all of which require some judgment.

NOTE 3—If one knew the exact final EMC that samples would attain, it would be easy to determine the endpoint. Because of variability in the EMC-relative humidity relationship and the lack of initial dry mass data that often occurs, this approach is seldom exact. Knowledge of approximate final EMC, however, can still be a useful guideline. A specified percentage change in mass over some specified time period could also be used in endpoint determination. Such changes, however, are only relative, and there is no real basis for establishing exact percentages. Individual experiences with repetitive conditioning tests may, however, lead to more useful guidelines.

6.4.1 *Periodic Weighings*—Weigh the specimens periodically to establish a record of mass change so that judgments on equilibrium can be made. A general guideline is: frequent weighings early in conditioning (perhaps once or twice a day), followed by a gradual increase in time between weighings, and ending with periods possibly up to several weeks. A geometric progression in time is recommended. The trend is clearer in a plot of specimen mass versus logarithm of time. A significant change in linearity connotes an approach to equilibrium.

6.4.1.1 The plotted data can be analyzed for the time to equilibrium; equilibrium is usually assumed to occur in 4 or 5 time constants. Although actual equilibrium mass is usually greater than calculated, it will not cause appreciable error in the time constant. In any case, the time constant can be recalculated to adjust the prediction. The relationship between time constant and the proximity to the final value is:

Time Constant	Percentage of Change
1	63.2
2	86
3	95
4	98
5	99

NOTE 4—The following examples demonstrate the calculation of time constant for specimens either increasing or decreasing toward equilibrium:

(a) Initial MC: 6 %; EMC: 18 % (assumed to be the final value). The MC value at one time constant is the initial value (6 %) plus 0.632 of the difference between initial and final values: $MC_{tc} = MC_i + 0.632\ (MC_f - MC_i) = 6 + 0.632\ (18 - 6) = 13.6$ %. The MC at two time constants is 16.4 %, etc.

(b) Initial MC: 18 %; EMC: 6 % (reverse of conditions in *(a)*): $MC_{tc} = MC_i + 0.632\ (MC_f - MC_i) = 18 + 0.632\ (6 - 18) = 10.4$ %. The MC at two time constants is 7.6 %, etc. Either mass or moisture content can be used in the above relationships.

6.4.2 *Endpoint Fluctuations*—In practice, relative humidity control is not exact, and regular or irregular fluctuations occur over time. Since the fluctuations are usually small relative to the total change that a conditioning specimen will experience, a steady increase or decrease in mass will occur during most of the conditioning period. As the specimen approaches very close to equilibrium, the fluctuations in relative humidity begin to affect the periodic weighings. The direction of mass change may begin to change randomly, which is a reliable sign that equilibrium has been reached within the practical limitations of the conditioning test. Unless some other method can establish a more exact endpoint, the reversal of direction of mass change can be used for endpoint determination. A minimum of three reversals is recommended.

7. Calculation

7.1 Calculate moisture content as described in Test Methods D4442.

8. Report

8.1 Report the method of relative humidity control, the level of EMC control specified, temperature, initial and final moisture contents, a summary of the results of the periodic weighings, a statement of how endpoint was determined, and whether the value of MC is for adsorption or desorption.

9. Precision and Bias

9.1 The precision of measurements will depend on the desired precision of resulting moisture content which depends largely on the requirements of the user. Industrial quality control, for example, usually will not require as precise control of EMC as a scientific test.

NOTE 5—The major controllable variable that influences EMC is relative humidity. Thus, a user specifying that EMC should be controlled within certain limits is also, in effect, specifying the RH should be controlled within certain limits. Furthermore, the effect of RH control on EMC control is not constant with levels of RH. At high RH levels, much closer control of RH is required for a given level of EMC control than at lower levels. Similarly, temperature has an effect on EMC, and temperature variations, even at constant RH, cause EMC to vary. The temperature effect, however, is much smaller than the effect of RH. Figs. X1.1 and X1.2 (**3**) give the degree of RH control necessary to control EMC of solid wood and composites within four different levels (±0.25, ±0.50, ±1.0, and± 2.0 % MC). For example, to control EMC of solid wood within ±1 % moisture content at 30 % RH and 27°C, it is necessary to control within ±6 % RH (Fig. X1.1). Fig. X1.3 gives the degree of temperature control necessary to maintain EMC of solid wood and wood-base materials within ±0.25 % MC at a number of relative humidities. For example, at 75 % RH and 49°C, temperature must be maintained within ±3.3°C to maintain EMC control within ±0.25 % MC. It should be emphasized that the control levels of Figs. X1.1-X1.3 require that the other variable, temperature or relative humidity, be held constant. ISO 554, X1.1, provides guidelines for ordinary and close tolerances for both temperature and relative humidity.

10. Keywords

10.1 equilibrium moisture content; moisture conditioning; moisture content; wood; wood-based materials

APPENDIXES

(Nonmandatory Information)

Included in the appendix are equations and tables to determine nominal EMC values (see the*Discussion* in 3.1.2).

X1. NOMINAL EMC VALUES

X1.1 Method of calculating nominal EMC for solid wood ((**1**).)

$$M = \frac{1800}{W}\left[\frac{Kh}{1-Kh}+\frac{K_1 Kh+2K_1 K_2 K^2 h^2}{1+K_1 Kh+K_1 K_2 K^2 h^2}\right]$$

TABLE X1.1 EMC Data for Solid Wood ~~(Ref (4))~~

Temperature (°C)	Relative Humidity (%) 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	98
0	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3	26.9
10	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3	26.9
~~20~~	~~1.3~~	~~2.5~~	~~3.5~~	~~4.5~~	~~5.4~~	~~6.2~~	~~6.9~~	~~7.7~~	~~8.5~~	~~9.2~~	~~10.1~~	~~11.0~~	~~12.0~~	~~13.1~~	~~14.4~~	~~16.0~~	~~17.9~~	~~20.5~~	~~23.9~~	~~26.6~~
20	1.3	2.5	3.6	4.5	5.4	6.2	7.0	7.7	8.5	9.3	10.1	11.0	12.0	13.1	14.5	16.0	18.0	20.5	23.9	26.6
~~30~~	~~1.2~~	~~2.3~~	~~3.4~~	~~4.3~~	~~5.2~~	~~6.0~~	~~6.7~~	~~7.5~~	~~8.2~~	~~9.0~~	~~9.8~~	~~10.6~~	~~11.6~~	~~12.7~~	~~14.0~~	~~15.5~~	~~17.4~~	~~20.0~~	~~23.4~~	~~26.1~~
30	1.2	2.4	3.4	4.3	5.2	6.0	6.7	7.5	8.2	9.0	9.8	10.6	11.6	12.7	14.0	15.5	17.5	20.0	23.4	26.1
~~40~~	~~1.1~~	~~2.2~~	~~3.2~~	~~4.1~~	~~4.9~~	~~5.7~~	~~6.4~~	~~7.1~~	~~7.8~~	~~8.6~~	~~9.4~~	~~10.1~~	~~11.1~~	~~12.1~~	~~13.4~~	~~14.9~~	~~16.8~~	~~19.3~~	~~22.7~~	~~25.4~~
40	1.1	2.2	3.2	4.1	5.0	5.7	6.4	7.2	7.9	8.6	9.4	10.2	11.1	12.2	13.4	15.0	16.9	19.3	22.7	25.5
~~50~~	~~1.1~~	~~2.1~~	~~3.0~~	~~3.9~~	~~4.7~~	~~5.4~~	~~6.1~~	~~6.8~~	~~7.5~~	~~8.2~~	~~8.9~~	~~9.7~~	~~10.6~~	~~11.6~~	~~12.8~~	~~14.3~~	~~16.1~~	~~18.5~~	~~21.9~~	~~24.6~~
50	1.0	2.1	3.0	3.9	4.7	5.4	6.1	6.8	7.5	8.2	8.9	9.7	10.6	11.6	12.8	14.3	16.1	18.6	21.9	24.6
~~60~~	~~0.9~~	~~1.9~~	~~2.8~~	~~3.6~~	~~4.3~~	~~5.0~~	~~5.7~~	~~6.3~~	~~7.0~~	~~7.7~~	~~8.4~~	~~9.1~~	~~10.0~~	~~11.0~~	~~12.1~~	~~13.6~~	~~15.3~~	~~17.7~~	~~21.0~~	~~23.7~~
60	0.9	1.9	2.8	3.6	4.3	5.0	5.7	6.3	7.0	7.7	8.4	9.1	10.0	11.0	12.2	13.6	15.4	17.7	21.0	23.7
~~70~~	~~0.8~~	~~1.6~~	~~2.4~~	~~3.2~~	~~3.9~~	~~4.6~~	~~5.2~~	~~5.8~~	~~6.4~~	~~7.1~~	~~7.8~~	~~8.5~~	~~9.4~~	~~10.3~~	~~11.5~~	~~12.8~~	~~14.5~~	~~16.8~~	~~20.0~~	~~22.6~~
70	0.8	1.7	2.5	3.2	4.0	4.6	5.3	5.9	6.5	7.2	7.8	8.6	9.4	10.3	11.5	12.8	14.5	16.8	20.0	22.6
~~80~~	~~0.7~~	~~1.4~~	~~2.2~~	~~2.9~~	~~3.6~~	~~4.2~~	~~4.8~~	~~5.4~~	~~6.0~~	~~6.6~~	~~7.2~~	~~7.9~~	~~8.8~~	~~9.7~~	~~10.7~~	~~12.0~~	~~13.7~~	~~15.9~~	~~19.0~~	~~21.6~~
80	0.7	1.4	2.2	2.9	3.6	4.2	4.8	5.4	6.0	6.6	7.3	8.0	8.8	9.7	10.7	12.0	13.7	15.9	19.0	21.6
~~90~~	~~0.5~~	~~1.2~~	~~1.8~~	~~2.5~~	~~3.1~~	~~3.7~~	~~4.3~~	~~4.8~~	~~5.4~~	~~6.0~~	~~6.6~~	~~7.3~~	~~8.0~~	~~8.9~~	~~9.9~~	~~11.2~~	~~12.8~~	~~14.9~~	~~17.8~~	~~20.4~~
90	0.6	1.2	1.9	2.5	3.1	3.7	4.3	4.8	5.4	6.0	6.6	7.3	8.1	8.9	10.0	11.2	12.8	14.9	17.9	20.4
~~100~~	~~0.5~~	~~1.0~~	~~1.6~~	~~2.1~~	~~2.7~~	~~3.2~~	~~3.8~~	~~4.3~~	~~4.9~~	~~5.4~~	~~6.0~~	~~6.7~~	~~7.4~~	~~8.3~~	~~9.2~~	~~10.4~~	~~12.0~~	~~14.0~~	~~16.9~~	~~19.3~~
100	0.5	1.0	1.5	2.1	2.6	3.2	3.7	4.2	4.8	5.4	6.0	6.6	7.3	8.2	9.2	10.4	11.9	13.9	16.8	19.2
~~110~~	~~0.3~~	~~0.8~~	~~1.2~~	~~1.6~~	~~2.1~~	~~2.6~~	~~3.1~~	~~3.6~~	~~4.2~~	~~4.7~~	~~5.3~~	~~6.0~~	~~6.7~~	*	*	*	*	*	*	*
110	0.3	0.8	1.2	1.6	2.1	2.6	3.0	3.5	4.1	4.6	5.2	5.8	6.5	*	*	*	*	*	*	*
~~120~~	~~0.2~~	~~0.4~~	~~0.7~~	~~1.0~~	~~1.3~~	~~1.7~~	~~2.1~~	~~2.5~~	~~2.9~~	*	*	*	*	*	*	*	*	*	*	*
120	0.2	0.5	0.8	1.1	1.4	1.8	2.2	2.6	3.1	*	*	*	*	*	*	*	*	*	*	*
130	0.1	0.2	0.3	0.4	0.6	0.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*

* Conditions not possible at atmospheric pressure.