Standard Test Method for Evaluating the Flexural Properties and Internal Bond Strength of Fire-Retarded Mat-Formed Wood Structural Composite Panels Exposed to Elevated Temperatures[1]

1. Scope

1.1 This test method is designed as a laboratory screening test. It is intended to establish an understanding of the respective contributions of the many wood material, fire-retardant, resin and processing variables, and their interactions, upon the mechanical properties of fire-retarded mat-formed wood structural composite (FRSC) panels as they affect flexural and internal bond (IB) performance and as they are often affected later during exposure to high temperature and humidity. Once the critical material and processing variables have been identified through these small-specimen laboratory screening tests, additional testing and evaluation shall be required to determine the effect of the treatment on the panel structural properties and the effect of exposure to high temperature on the properties of commercially produced FRSC panels. In this test method, treated structural composite panels are exposed to a temperature of 77°C (170°F) and at least 50% relative humidity.

1.2 The purpose of the preliminary laboratory-based test method is to compare the flexural properties and IB strength of FRSC panels relative to untreated structural composite panels with otherwise identical manufacturing parameters. The results of tests conducted in accordance with this test method provide a reference point for estimating strength temperature relationships for preliminary purposes. They establish a starting point for subsequent full-scale testing of commercially produced FRSC panels.

1.3 This test method does not cover testing and evaluation requirements necessary for product certification and qualification or the establishment of design value adjustment factors for FRSC panels.

NOTE 1—One potentially confounding limitation of this preliminary screening test method is that it may be conducted with laboratory panels that may not necessarily represent commercial quality panels. A final qualification program should likely be conducted using commercial quality panels and the scope of the review should include evaluation of the effects of the treatment and elevated temperature exposure on all relevant mechanical properties of the commercially produced panel.

1.4 This test method is not intended for use with structural plywood.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that 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 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

D198 Test Methods of Static Tests of Lumber in Structural Sizes

D1037 Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials

D1165 Nomenclature of Commercial Hardwoods and Softwoods

D2395 Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials

D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

D3043 Test Methods for Structural Panels in Flexure

D5516 Test Method for Evaluating the Flexural Properties of Fire-Retardant Treated Softwood Plywood Exposed to Elevated Temperatures

D6305 Practice for Calculating Bending Strength Design Adjustment Factors for Fire-Retardant-Treated Plywood Roof Sheathing

[1] This test method is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.07 on Fire Performance of Wood.

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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.

E84 Test Method for Surface Burning Characteristics of Building Materials
E176 Terminology of Fire Standards
E2768 Test Method for Extended Duration Surface Burning Characteristics of Building Materials (30 min Tunnel Test)

2.2 *Other Standards:*

AWPA U-1 Commodity Specification H: Fire Retardants[3]
NFPA 703 Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials[4]
PS 2 U.S. Performance Standard for Structural-Use Panels[5]

3. Terminology

3.1 *Definitions*—Definitions used in this test method are in accordance with Terminologies D9 and E176 and Nomenclature D1165.

3.1.1 Structural Composite Panels: wood composite panels of various sizes and thicknesses manufactured using flakes, strands, wafers or particles derived from wood or similar bio-based resources assembled together with thermoset resins and other complementary materials, such as waxes or chemical additives in a hot-press intended for load-bearing applications as building materials.

4. Summary of Test Method

4.1 The purpose of this test method is to determine the effect of fire-retarded chemical treatment on flexural properties and IB strength of FRSC panels and to evaluate the effect of exposure to elevated temperatures on these properties.

4.2 Specimens of both the FRSC panel and an untreated panel manufactured with otherwise identical parameters are preconditioned to constant moisture content under conditions sufficient to produce moisture content of 10 ± 2 % in the untreated specimens.

4.3 After preconditioning (see section 6.4), 203-mm (8-in) wide specimens of treated and untreated treated structural composite panels are exposed to 77°C (170°F) temperature and relative humidity equal to or greater than 50 % for various time periods.

4.4 After the elevated-temperature exposure, the specimens are subjected to post-exposure conditioning under the same temperature and relative humidity used for preconditioning.

4.5 After post-exposure conditioning (see section 7.2), flexure and internal bond tests are conducted on exposed specimens. Flexural properties considered include maximum moment, bending stiffness, and work to maximum load.

5. Significance and Use

5.1 The properties evaluated by this test method are intended to provide comparative information on the effects of fire-retardant chemical formulations and environmental conditions on the flexural properties and IB strength of FRSC panels.

5.2 This practice uses a controlled elevated-temperature environment to produce temperature-induced losses in the mechanical properties of FRSC panels and untreated panels.

5.3 Prediction of performance in natural environments has not been directly correlated with the results of this test method.

5.4 The reproducibility of results in elevated-temperature exposure is highly dependent on the type of specimens tested and the evaluation criteria selected, as well as the control of the operating variables. In any testing program, sufficient replicates shall be included to establish the variability of the results. Variability is often observed when similar specimens are tested in different chambers even though the testing conditions are nominally similar and within the ranges specified in this test method.

6. Test Specimens

6.1 *Material Selection:*

6.1.1 Source panels for this test shall be selected from laboratory panels manufactured on a hot press large enough to provide flexural specimens having a span-to-depth ratio not less than 48:1 after allowances for both sufficient edge trimming to remove panel edges and ensuring the D3043 required overhang beyond the flexural test supports. The nominal panel thickness shall be between 9 mm (11⁄32 in.) and 19 mm (3⁄4 in.).

NOTE 2—The initial experiments that provide the scientific basis for this method used specimens cut from larger mat-formed structural composites and evaluated at approximately a 70:1 span-to-depth ratio. (**1**, **2**, **3**).[6]

NOTE 3—If larger panels and hot presses are used, more test specimens can be expected. If smaller panels and presses are used fewer specimens can be obtained. In all cases experience suggests that at least 25-mm should be trimmed from all four panel edges prior to cutting any test specimens.

6.1.2 Both treated and matched untreated panels shall be manufactured from a single batch of matched wood materials. Other than the fire-retardant treatment, both sets of panels shall be manufactured using the same manufacturing parameters including, but not limited to, thickness, density, resin content, wax content, and press schedule.

NOTE 4—For the resulting data to have maximum utility, it is recommended that both materials and process conditions be selected to closely parallel those used in manufacturing commercial panels.

6.1.3 Each panel shall be free of manufacturing defects, such as abnormally large surface voids, internal blows, or visible damage. Orientation, size, and shape, of surface flakes, strands or fibers shall be uniform and representative of normal commercial production. Ensure that enough materials are produced or obtained because it is required that all materials in this study be obtained from a single batch of structural composite panels.

NOTE 5—Depending on the initial size of panels used, users should ensure that a number of additional untreated and FRSC source panels are available because potential culling of small 200-mm (8-in) wide specimens may require additional FRSC panels.

6.2 *Treatment:*

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

[4] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[5] Available for National Institute for Standards and Technology (NIST), 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899 http://www.nist.gov.

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

6.2.1 The fire-retardant treatment shall be impregnated into the panel and shall provide a flame-spread index of 25 or less when tested in accordance with Test Method E2768 or when tested in accordance with ASTM E84 for an extended period of 30 min, and also show no evidence of significant progression of combustion. Additionally the flame front shall not progress more than 3.2 m (10.5 ft) beyond the centerline of the burners at any time during the test.

6.2.1.1 Materials listed as fire-retardant-treated wood are deemed to comply with the provisions of 6.2.1. When alternative performance criteria for the treatment are being evaluated, the test report on specimens of that treatment shall state clearly the alternative criteria and that the fire-retardant treatment retention was limited to that required for those alternative criteria.

6.2.2 Treatment of FRSC panels is done during panel manufacture. The fire-retardant retention level of every treated panel and each specimen cut from those panels shall not be less than the value midway between the median of the retention range and the maximum retention desired for the treated structural composite panels.

6.2.3 Weigh all materials used to produce the structural composite panels before pressing and weigh the manufactured panels immediately after pressing. Complete a treating report for each batch of panels to document the materials used, press cycle, times, pressures, and fire-retardant retentions.

6.3 *Specimen Preparation:*

6.3.1 Source panels and all experimental test specimens shall be inspected and the culling of specimens done as necessary in accordance with the criteria in 6.1.3.

6.3.2 A minimum of 100 untreated and 100 FRSC test specimens shall be prepared.

6.3.3 Each test specimen shall be at least 200-mm (8-in) wide and long enough to meet the span-to-depth requirements (6.1.1). Each test specimen shall be labeled to identify the original panel and location of the specimen within that panel. Care should be taken to avoid assigning more than one specimen from each panel to any experimental group. Care shall also be taken to ensure assignment of equal numbers of specimens cut from center and cut from nearer an original edge for each group of 20 experimental specimens.

NOTE 6—The initial experiments that provide the scientific basis for this method used specimens cut from larger FRSC panels and evaluated specimens from 102-mm (4-in) to 305-mm (12-in) wide and found that specimens of at least 200-mm (8-in) wide provide stable coefficient of variation for both flexural stiffness and strength (Fig. 1). The above width limitation of 200-mm (8-in) specimen width reflects those findings (**2**, **3**, **4**).

6.3.4 Randomly select 20 of the 100 untreated and treated specimens to serve as the sets of unexposed controls. The remaining 80 treated and 80 untreated specimens shall be randomly assigned to 4 sets of 20 specimens for both the treated and untreated material. Three of these four sets are then subjected to elevated temperature exposure followed by strength testing. This leaves 1 treated and 1 untreated set of specimens not assigned to any set for testing (see Note 7).

NOTE 7—The resulting extra set of 20 treated and 20 untreated specimens can be saved as replacement sets if the number of specimens in a set drops below the minimum of 18 (7.3.5). Alternatively, the extra 20 treated and untreated specimens can be used to increase the number of specimens in each set.

6.4 *Preconditioning*—Condition all sets of treated and untreated specimens at an ambient temperature and relative humidity to achieve an equilibrium moisture content in the

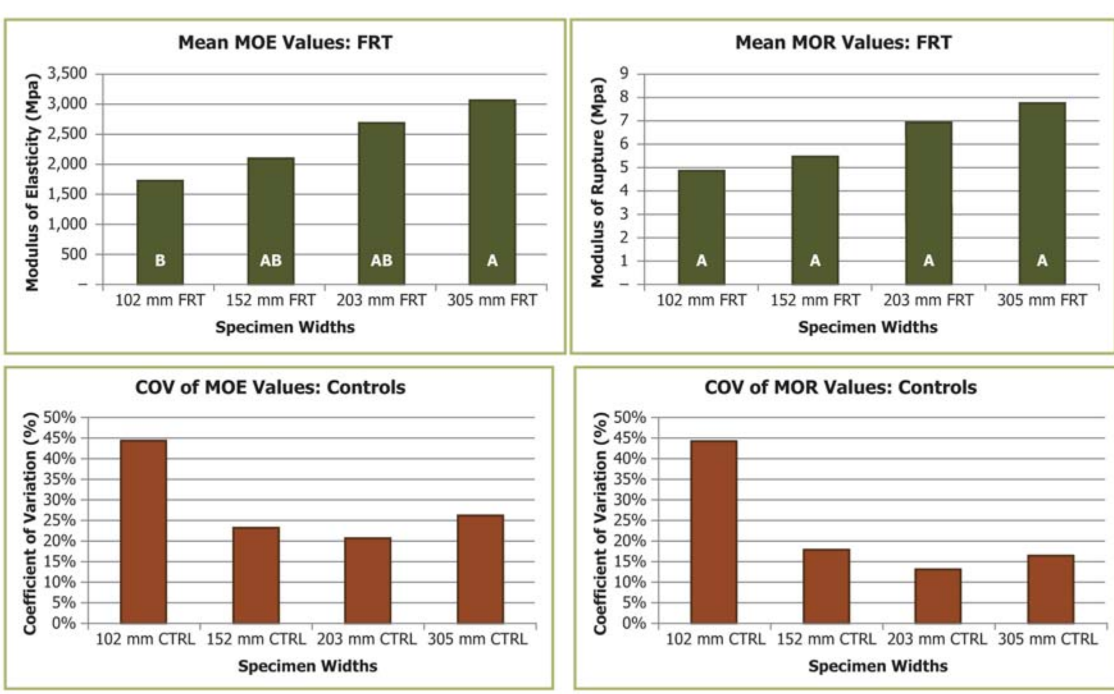

FIG. 1 An Example of Relationship Between Strandboard Specimen Width and the Corresponding Mean Test Values and Coefficient of Variations for Both Flexural Stiffness and Strength for FRSC Over Time of Exposure at 77°C (170°F) (from 2, 3)

untreated specimens of 10 ± 2 %. Specimens are considered to be at equilibrium moisture content when a constant weight has been achieved. A constant weight is assumed when two consecutive weighings at a 24-h interval differ by no more than ±0.2 %.

6.5 *Measurements*—Measure the length, width, thickness and mass of each specimen after pre-conditioning.

7. Procedure

7.1 *Specimen Exposure:*

7.1.1 After preconditioning, test the unexposed controls (see 6.4) as described in 7.3 for initial, unexposed bending strength and IB properties.

7.1.2 Expose three sets of treated and untreated specimen sets in a chamber controlled to 77 ± 1°C (170 ± 2°F) and a minimum of 50 % relative humidity. The control of the relative humidity in the chamber shall be ±4 % and average ±1 % around the set point.

7.1.3 The first set of 20 untreated and 20 treated specimens shall be subjected to flexural test after at least 20 days exposure in the 77°C (170°F) chamber. Remove two additional sets of 20 treated and 20 untreated specimens at well-spaced, appropriate intervals to establish the slope of the line when the strength properties are plotted versus time. Experience has shown that removals at 2 to 3-week intervals over a total exposure period of at least 60 days are normally sufficient.

7.2 *Post-Exposure Conditioning*—After exposure to elevated temperatures, condition all sets of treated and untreated specimens at the same temperature and relative humidity conditions used for preconditioning. Permit the treated specimens to equilibrate to whatever equilibrium moisture content these conditions produce.

7.2.1 *Measurements*—Measure the length, width, thickness and mass of each specimen after post-exposure conditioning and use these measurements in the analysis according to Section 8.

7.3 *Strength Testing—Flexural Properties:*

7.3.1 Test untreated and treated specimens for flexural stiffness and strength using the general procedures specified in Test Methods D3043, Test Method A except to use a 200-mm (8-in) wide specimen (**1, 2, 3**). If the original panel had aligned strands, then test specimens shall be tested in the strong-axis direction.

7.3.2 Deviations from Method A of Test Method D3043, are required as follows:

7.3.2.1 Test span shall ensure maintaining a minimum span-to-depth ratio of 48:1.

7.3.2.2 Rotational end plates or lateral rotation of end supports are optional. However, the end supports shall be rounded if rotational end plates are not provided.

7.3.2.3 Loading rate of 5 mm/min (0.2 in./min).

7.3.2.4 A yoke is not required for measurement of deflection.

7.3.3 Load and deflection data shall be collected up to the maximum load and continued until the specimen can no longer withstand 50 % of the maximum load.

7.3.4 If a defect, as defined in 6.1.3, is observed at the location of failure in a specimen, then it shall be measured and reported.

7.3.5 Defects are reasons for elimination of specimens from subsequent calculations. However, not more than 2 out of 20 specimens in any group may be censored. Strength and stiffness data shall be reported both with and without results from censored specimens containing these defects.

7.4 *Strength Testing—IB Strength:*

7.4.1 A 50- by 50-mm (2- by 2-in.) specimen shall be cut from an undamaged area of each flexural specimen tested in 7.3. (see Note 8).

NOTE 8—It is recommended that IB specimens be cut away from the edges near the flexural test support locations.

7.4.2 Each 50- by 50-mm (2- by 2-in.) specimen shall be measured for thickness and tested in tension perpendicular to surface (Internal Bond) per method described in D1037, Section 11.

8. Analysis

8.1 The following properties shall be determined for each specimen (see Note 9):

8.1.1 Dimensions,
8.1.2 Specific gravity (oven-dry mass/volume at test),
8.1.3 Moisture content at test,
8.1.4 Maximum load,
8.1.5 Maximum moment,
8.1.6 Modulus of rupture,
8.1.7 Flexural stiffness (EI),
8.1.8 Modulus of elasticity,
8.1.9 Work to maximum load, and
8.1.10 Internal Bond strength.

NOTE 9—Guidance is available in D198, D2395, D1037 and/or D3043 of various property determinations.

8.2 For specific gravity, moisture content, modulus of rupture, modulus of elasticity and work to maximum load, the following statistics shall be determined for each sample. If defects are noted per 7.3.4, the statistics shall be calculated both with defective specimens included and with defective specimens excluded.

8.2.1 Mean,
8.2.2 Median,
8.2.3 Standard deviation, and
8.2.4 Coefficient of variation.

8.3 The ratios of treated to untreated means shall be calculated for modulus of elasticity, modulus of rupture, maximum load, maximum moment, work to maximum load and internal bond strength.

8.4 Adjustment of strength or stiffness properties based on moisture content differences between treated specimens and untreated specimens shall not be permitted.

9. Report

9.1 Report the following information:

9.1.1 The average relative humidity and temperature for each conditioning environment.

9.1.2 Details of FR treatment results and conditioning and exposure conditions (i.e., temperatures, relative humidities, duration of exposure).

9.1.3 The statistics determined in 8.2 for each sample. If the data includes specimens with defects, the report shall include statistics calculated both with and without the defective specimens included.

9.1.4 A description and measurements of any defects noted for a specimen after testing.

9.1.5 The ratio of the averages of the treated to untreated values at each exposure level for flexural stiffness, modulus of rupture, maximum moment and internal bond strength.

9.1.6 The equilibrium moisture content (oven dry basis).

9.1.7 Any deviations from the procedure.

9.2 *Other Items That Can Be Reported:*

9.2.1 Graphical reports to indicate trends, but a full tabular report must also be given.

9.2.2 Any curve-fitting techniques and correlation coefficients.

10. Precision and Bias

10.1 The precision of this test method has not yet been determined. Initial test data obtained during the development of this test method are contained in Barnes et al. (**1**). When further data are available, a precision statement will be included.

10.2 Since there is no accepted reference material suitable for determining the bias of the procedure in this test method, bias has not been determined.

11. Keywords

11.1 bending strength; fire retardant; fire-retardant treatment; flexural properties; roof sheathing; structural composite panels; temperature

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 Fire retardants have been used to treat structural plywood panels and lumber for many decades in the United States. The application of fire-retardant treatments to mat-formed structural composites is relatively new. Many fire-retardant treatments can reduce the flame spread of the treated wood products to such an extent that in some applications, codes and regulations will allow the use of some fire-retarded wood materials in applications often reserved for noncombustible materials. This method evaluates mat-formed wood structural composites but its general technique is based on previous work on FR-treated plywood that lead to the development of ASTM Standard D5516 (**5**).

X1.2 While many methods/mechanisms exist to impart fire retardancy, many fire retardants in wood work by lowering the temperature at which wood pyrolyses. By lowering this pyrolysis temperature, fire retardants can cause an increase in the amount of char formed and a reduction in the amount of flammable volatiles released (**6, 7, 8**). This serves to reduce the flame spread. However, this same mechanism of fire retardancy can often at times be responsible for the strength loss previously observed in FRT plywood roof sheathing.

X1.3 Specimens need to be large enough to have significant measurable mechanical properties, but small enough to be practically used. Work by Hill 2011 (**2**) and Winandy et al 2016 (**3**) has shown that 200 by 900-mm (strands parallel to long axis) bending specimens were sufficient to obtain stable property values (Fig. 1).

X1.4 Flexural properties, specifically modulus of elasticity, stiffness, modulus of rupture, maximum bending moment, and work to maximum load, are evaluated because flexural performance was considered critical for structural composite panels. Internal bond testing was considered critical to evaluate the effect of the chemical treatment and elevated temperature exposure on bond quality.

X1.5 In some uses such as roof sheathing, structural composite panels are exposed to both cyclic temperature and humidity conditions on a daily basis, as well as seasonal temperature and humidity cycles. Because recreating laboratory conditions that mimic actual field conditions would be both extraordinarily time-consuming and cost-prohibitive, the laboratory exposure technique chosen was a steady-state, elevated temperature and humidity exposure. This exposure is faster and more extreme than cyclic exposure.

X1.6 Humidity that varied between 50 and 79 % relative humidity was considered as two realistic extremes. Eventually, 50 % relative humidity was selected to ensure initiation of the degradative mechanisms, while minimizing corrosion risks to the test equipment and possible problems of accurate moisture control.

X1.7 Using the test methods detailed in this method, thermally induced strength losses were evidenced in laboratory simulations within a reasonably short period. The environmental conditions used in the laboratory, activated chemical reactions that are considered to be similar to those occurring in the field. Results from this protocol can be used to compare relative performance for new or existing FR treatments before they are used in service conditions with periodic or sustained exposure to elevated temperatures.

X1.8 This Method does not provide means for evaluation of FRSC panels for purposes of product certification or qualification. Commercial FRSC panels must meet the performance requirements of the applicable product standard, such as DOC-PS2, including testing and evaluation of several additional properties not considered in this Method. In addition, standard requirements have not been established for the performance of these products after elevated temperature exposure.

X1.9 This Method does not provide sufficient information for the establishment of design value adjustment factors for the effects of elevated temperature exposure. While the results of this Method provide useful insight into the effect of fire-retardant chemicals and high temperature exposure on flexure and internal bond properties of structural composite panels, other critical properties, which may be affected differently than the tested properties, have not been evaluated. A complete evaluation would require separate evaluation of each critical property. In addition, the relationships established for the laboratory produced panels used in this method are not valid for commercially produced panels which may have different manufacturing parameters and could behave differently.

X1.10 While the direct comparisons between untreated and treated panels with otherwise identical manufacturing parameters may be beneficial for preliminary research purposes, it is recognized that the production of commercial FRSC panels will likely require much different manufacturing parameters than those used for untreated panels to meet the same minimum performance standards. Therefore these comparative relationships cannot be used to establish design value adjustment factors intended to be applied to design values for untreated panels.

REFERENCES

(1) Barnes, H.M., Winandy, J.E., and Hill, J.M. 2015. Development of a testing protocol for effects on strength of laboratory-manufactured, fire-retardant-treated strandboard. *Wood and Fiber Science*47(1):50-55.

(2) Hill, J.M. 2011. An evaluation of laboratory manufactured fire-retardant treated flakeboard. M.S. Thesis. (Prof. H.M.Barnes, Major Advisor) Department of Forest Products. Mississippi State University, Mississippi State, MS. (http://sun.library.msstate.edu/ETD-db/theses/available/etd-10312011-151622/unrestricted/JMHThesis.pdf).

(3) Winandy, J.E., Barnes, H.M., and Hill, J.M. 2016. Effect of specimen width when evaluating laboratory-made, fire-retardant-treated strandboard. *Wood and Fiber Science* 48(1):2-12.

(4) Curling, S.F., J. E. Winandy, C. Carll, J. A. Micales, A. Tenwolde. 2003. How variability in OSB mechanical properties affects biological durability testing. *Holzforschung*57 (2003): 8-12.

(5) Winandy, J. E., LeVan, S. L., Ross, R. J., Hoffman, S. P., and McIntyre, C. R., Thermal Degradation of Fire-Retardant Treated Structural composite panels: Development and Evaluation of a Test Protocol, Research Paper FPL-501, USDA Forest Service, Forest Products Laboratory, 1991.

(6) LeVan, S. L., Ross, R. J., and Winandy, J. E., Effect of Fire-Retardant Chemicals on the Bending Properties of Wood at Elevated Temperatures, Research Paper FPL-RP-498. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1990.

(7) Winandy, J. E., Ross, R. J., and LeVan, S. L., Fire-Retardant-Treated Wood: Research at the Forest Products Laboratory, *Proceedings of the 1991 International Timber Engineering Conference*, 1991 September 2–5, London: TRADA, 4.69–4.74, Vol 4, 1991.

(8) LeVan, S. L., and Collet, M., Choosing and Applying Fire Retardant-Treated Structural composite panels and Lumber for Roof Designs, Gen. Tech. Rep., GTR-62. Madison, WI, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1989.