



Standard Test Method for Evaluating the Effects of Fire-Retardant Treatments and Elevated Temperatures on Strength Properties of Fire-Retardant Treated Lumber¹

This standard is issued under the fixed designation D 5664; 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.

1. Scope

1.1 This test method covers procedures for obtaining data to assess the initial adjustments to allowable design stresses for lumber treated with candidate commercial fire-retardant (FR) formulations and further procedures for obtaining data to assess the effect of extended exposure to elevated temperature of $66 \pm 2^\circ\text{C}$ ($150 \pm 4^\circ\text{F}$).

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:

- D 9 Terminology Relating to Wood²
- D 143 Methods of Testing Small Clear Specimens of Wood²
- D 1165 Nomenclature of Domestic Hardwoods and Softwoods²
- D 3500 Test Methods for Structural Panels in Tension²
- D 4761 Test Method for Mechanical Properties of Lumber and Wood-Base Structural Material²
- D 5516 Test Method for Evaluating the Flexural Properties of Fire-Retardant Treated Softwood Plywood Exposed to Elevated Temperatures²
- E 84 Test Method for Surface Burning Characteristics of Building Materials³
- E 176 Terminology of Fire Standards³

2.2 Other Standards:

- AWPA C20 Lumber—Fire Retardant Treatment by Pressure Processes⁴

- NFPA 703 Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials⁵
- U.S. Product Standard PS 20 American Softwood Lumber Standard⁶

3. Terminology

3.1 *Definitions*—Definitions used in this test method are in accordance with Terminologies D 9 and E 176 and Nomenclature D 1165.

4. Summary of Test Method

4.1 The general objectives of this test method are to develop data to adjust allowable design stresses of FR-treated lumber for the initial effects for the tested FR-formulation(s) and to develop data on in-service thermal stability after extended exposure to environmental conditions up to $66 \pm 2^\circ\text{C}$ ($150 \pm 4^\circ\text{F}$) and $\geq 50\%$ relative humidity.

4.2 *Procedure 1*—This procedure uses small clear specimens cut from end-matched nominal 2 by 4 (38 by 89-mm) dimension lumber (see Fig. 1) to compare the initial effects of fire-retardant treatments to untreated controls for bending, tension parallel, compression parallel, and horizontal shear properties.

4.3 *Procedure 2*—This procedure uses small clear specimens cut from end matched nominal 2 by 4 (38 by 89-mm) dimension lumber. This second set of specimens is used to assess the differential trends between end-matched fire-retardant treated and untreated specimens on bending and tension parallel properties over the course of a prolonged exposure to elevated temperature.

4.4 *Procedure 3*—The optional third procedure uses full-sized nominal 2 by 4 (38 by 89-mm) dimension lumber to modify the small clear specimen results from 4.2 and 4.3 for size effects.

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 *Annual Book of ASTM Standards*, Vol 04.10.

³ *Annual Book of ASTM Standards*, Vol 04.07.

⁴ Available from American Wood-Preservers Assoc., P.O. Box 5690, Granbury, TX 76049-0690.

⁵ Available from National Fire Protection Association, P.O. Box 9191, Quincy, MA 02269-9101.

⁶ Available from The American Lumber Standard Committee, P.O. Box 210, Germantown, MD 20875-0210.

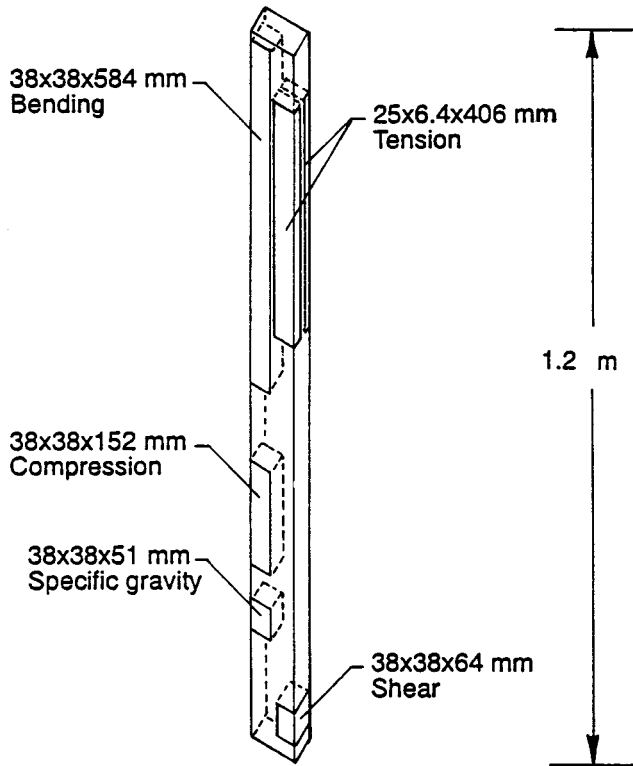


FIG. 1 Hypothetical Cutting Patterns to Obtain One Bending, Two Tension Parallel, One Compression Parallel, One Block Shear, and One Specific Gravity Block from Each 1.2-m (4-ft) Lumber Specimen

5. Significance and Use

5.1 The mechanical properties evaluated by this test method provide the following:

5.1.1 Data for use in developing modification factors for the allowable design properties of fire-retardant treated lumber when used at or near room temperatures (see 6.3).

5.1.2 Data for use in developing modification factors for allowable design properties of fire-retardant treated lumber when exposed to elevated temperatures and humidity (see 6.4).

5.1.3 Data (optional) for use in modifying these factors for size effects when fire-retardant treated lumber is used at or near room temperature and when exposed to elevated temperatures and humidity (see 6.5).

5.2 Data from the first two procedures in this test method of evaluation are indicative only for that species.

NOTE 1—The results of the three listed species (Southern pine, Douglas fir, and either white spruce or a Spruce/Fir mixture) may be used together to make inference on untested wood species because the three tested species represent the full spectrum of expected treatability.

5.3 Data from the optional third part of this three-part method of evaluation are indicative for all species because it is primarily used to assess size effects.

6. Procedures

6.1 Treatment:

6.1.1 Pressure treat those pieces designated for treatment with the fire-retardant formulation being evaluated. The gage retention level of each charge shall not be less than the

midpoint of the retention range as specified for the species by the agency certifying the flame spread index of the treated lumber. The retention range specified by the certifying agency shall provide a flame-spread index of 25 or less when tested in accordance with Test Method E 84 for 10 min, show no evidence of significant progression combustion when the test is continued for an additional 20-min period and not allow progression of the flame front beyond a distance of 3.2 m (10.5 ft) beyond the centerline of the burners anytime during the 30-min extended test.

6.1.1.1 The provisions of 6.1.1 are not intended to prevent use of this test standard when the fire-retardant treatments being certified are for applications other than those requiring conformance to AWPA Standard C-20, NFPA Standard 703, or similar building code requirements for “fire-retardant-treated wood” that require the Test Method E 84 test extended to 30 min. When alternative performance criteria for the treatment are being certified, the test report on specimens of that treatment shall state clearly the alternative performance criteria and that the treatment retention was limited to that required for the alternative performance criteria.

6.1.2 Weigh all treated pieces before and immediately after treatment to determine the chemical retention based on the solution retained and the concentration of chemicals in the solution. Complete a treating report for each charge of material to document the treating cycle, times, pressures, gage retention, and piece retentions.

6.2 Post-treatment Drying:

6.2.1 After pressure treatment, kiln dry the treated pieces to a maximum moisture content of 19 % following the standard redrying procedures established for the treatment and species by the manufacturer. Redry the treated pieces at the manufacturer’s maximum specified dry bulb temperature with a minus 2°C (4°F) tolerance for 21 h of the first 24-h period. For the remainder of the drying period, the tolerance shall be minus 3°C (5°F). There is no upper limit on the redrying temperature. Sticker all test pieces to obtain proper air flow across both surfaces and to provide even drying.

NOTE 2—Research has shown that high kiln drying temperatures can adversely affect the structural properties of wood products. The American Wood-Preservers’ Association (AWPA) and National Fire Protection Association (NFPA) standards for fire retardant treated wood products limit kiln dry bulb temperatures. AWPA Standard C20 requires that the dry bulb temperature of the kiln not exceed 70°C (160°F) during any kiln drying of plywood treated with fire retardants. In the case of exterior fire-retardants that require curing at higher temperatures, curing after the moisture content is 19 % or less is permitted. However, such elevated curing temperatures must not exceed 99°C (210°F) and the total curing time must not exceed 48 h. In NFPA Standard 703, the dry bulb temperature must not exceed 70°C (160°F) until the average moisture content of the wood has dropped to 25 % or less.

NOTE 3—To establish the worst-case strength properties of treated lumber, the laboratory must redry the test material within a small negative tolerance of the maximum temperature used by the manufacturer. Therefore, there is no upper limit for the temperature used in the tests. If a manufacturer desires to establish conservative property values or provide a basis for evaluating production material that exceeds the limit, the test material can be redried at that temperature. A manufacturer then is allowed to determine the necessary production schedule for their treatment and equipment or conditions. Thus, a stepped schedule (for example, 10 h at 54°C (130°F), 10 h at 60°C (140°F); 10 h at 71°C (160°F), etc.) is allowed

by the standard, provided the maximum temperature tolerance requirement is met. These provisions provide for air-drying production material provided the redry conditions in the tests are within the tolerance of the maximum temperature specified by the manufacturer.

6.2.2 Monitor the moisture content of the test pieces during the drying cycle by individually weighing representative pieces. Keep a well-documented kiln charge report and kiln recorder chart showing dry and wet bulb temperatures during the redrying period.

6.3 Procedure 1—The first procedure presents a methodology using small clear wood specimens to assess the initial effect of fire-retardant treatment on median mechanical properties. The results may be used to adjust the allowable design stresses of lumber based on estimates of median reductions in bending, tension parallel, compression parallel, and horizontal shear properties using small clear specimens cut from larger end-matched dimension lumber specimens.

6.3.1 For each species/species grouping (Southern pine, Douglas fir, and either white spruce or a Spruce/Fir mixture), twenty five (25) 2.44-m (8-ft) long, high-grade nominal 2 by 4s (38 by 89 mm) shall be obtained and cut into 1.22-m (4-ft) halves. Each specimen shall be marked to identify it with its matched-sister(s) specimen(s). For each specimen, one 1.22-m (4-ft) half shall be randomly allotted to remain untreated and the other half assigned to be treated with the candidate fire-retardant treatment and each half shall be appropriately marked.

NOTE 4—A Spruce/Fir mixture can be obtained by obtaining Canadian Spruce-Pine-Fir and removing the Lodgepole pine and Jack pine, which can be visually segregated from the remaining spruces and firs of this specific species group. The Lodgepole pine and Jack pine have numerous longitudinal resin canals that are generally quite evenly distributed in the outer portion of every growth ring. In the four spruces (Black, Engelmann, Red, and White), the longitudinal resin canals are generally sparse. In the two firs (Alpine and Balsam), the longitudinal resin canals are normally absent.

NOTE 5—High Grade is a relative term, but some latitude is required because it is a common industry practice to group grades for some species/species groupings into “and better” categories. If available, Select Structural often is desirable because it provides an adequate yield of small clear specimens. It should also be noted that initial use of ≥ 30 specimens will usually ensure 25 acceptable specimens when using lower grades which have lower yields.

6.3.2 After treating and redrying are completed, each treated and untreated nominal 2 by 4 (38 by 89-mm) piece shall be cut into small clear specimens as shown in Fig. 1. Care shall be taken to avoid cutting specimens containing strength-reducing characteristics such as knots, cross-grain, or slope-of-grain in excess of 1 in 12. When cutting small test specimens, an original wide surface shall remain unmachined and each specimen shall later be tested so that this surface is exposed to the greater stress during that particular mechanical test. Each end-matched treated and untreated specimen shall be tested with the same relative surfaces in tension and compression. Tension parallel specimens shall be machined as shown in Fig. 2. Horizontal shear specimens shall be machined as shown in Fig. 3.

6.3.3 After cutting, all specimens (treated and untreated) shall be equilibrated to constant weight at $22 \pm 5^\circ\text{C}$ ($72 \pm 9^\circ\text{F}$) and $65 \pm 1\%$ relative humidity.

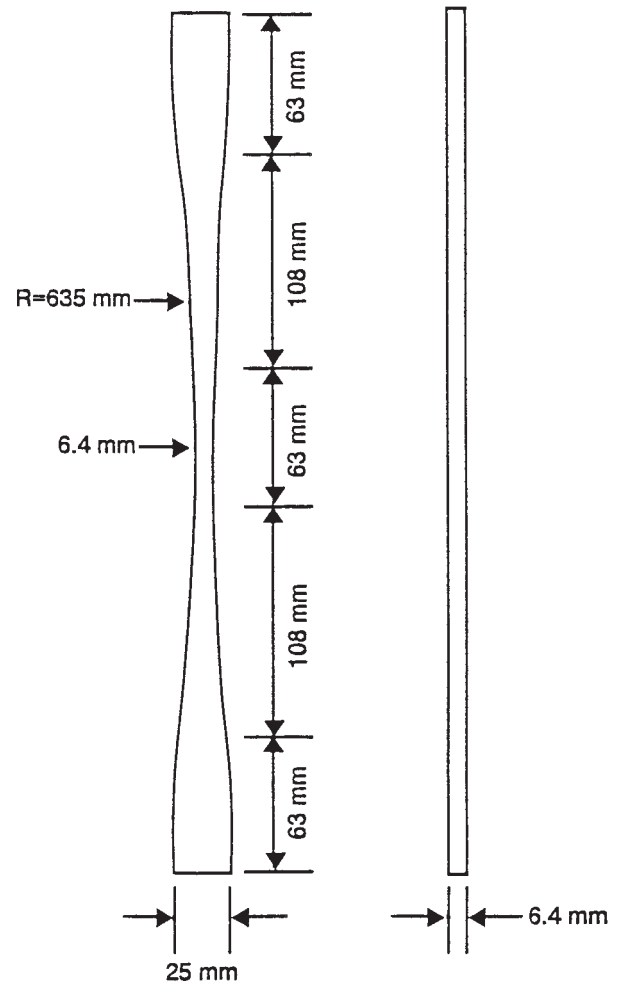


FIG. 2 Dimensions of the Modified Tension Parallel to Grain Specimen Using Test Methods D 3500

6.3.4 Appropriate treated and untreated specimens shall be alternately tested in bending, compression parallel, and horizontal shear using Methods D 143 and tension parallel using Test Methods D 3500, but with the exceptions listed in Table 1.

6.4 Procedure 2—For each species (Southern pine, Douglas fir and white spruce, four sets of 25 end-matched treated and untreated small clear bending and tension parallel specimens shall be cut from at least 25 nominal 2 by 4 (38 by 89 mm) 2.44-m (8-ft) long pieces. These specimens shall be used to assess the differential effects of exposure to elevated temperature between untreated and FR-treated clear wood specimens.

6.4.1 One set of 25 FR-treated and untreated specimens of each species shall be used as an unexposed control (that is, 0 days of exposure).

6.4.2 Three FR-treated and untreated groups of 25 specimens of each species shall be exposed in a controlled environment of $66 \pm 2^\circ\text{C}$ ($150 \pm 4^\circ\text{F}$) and $>50\%$ relative humidity.

6.4.3 One treated and one untreated group of 25 shall be withdrawn after 36 ± 3 , 72 ± 3 , and 108 ± 3 days.

6.4.4 Each group of specimens shall be equilibrated to constant weight at $22 \pm 5^\circ\text{C}$ ($72 \pm 9^\circ\text{F}$) and $65 \pm 1\%$ relative humidity then tested in bending in accordance with Methods D 143 and tension parallel in accordance with Test Methods D 3500, but with the exceptions listed in Table 1.

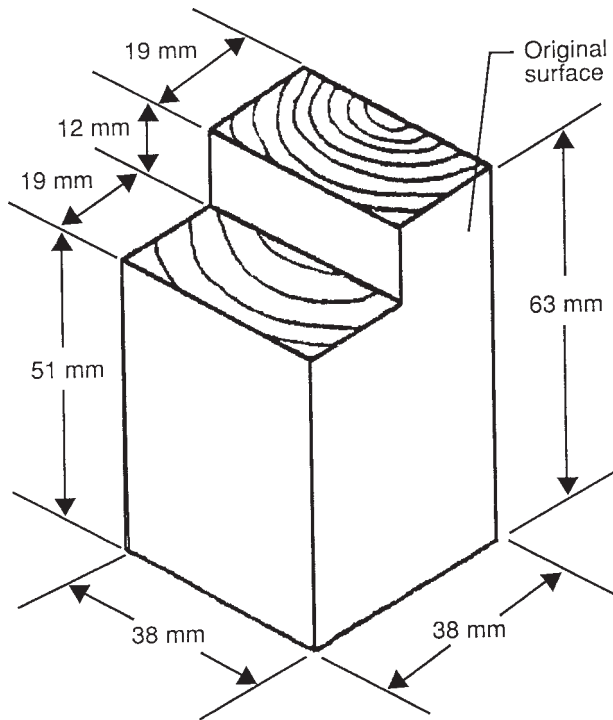


FIG. 3 Dimensions of the Modified Block Shear Specimen

TABLE 1 Deviations of Specified Test Conditions in Methods D 143 or Test Methods D 3500

	Gross Specimen Size ^A	Span	Bearing Block Radius	Test Speed, ^B mm/min	ASTM Standard
	mm	mm	mm		
Bending	38 × 38 × 584	532	58	1.9	D 143
Compression parallel	38 × 38 × 152	...	...	0.46	D 143
Shear	38 × 38 × 63	...	...	0.6	D 143
Tension parallel	25 × 6.4 × 406	...	...	0.9	D 3500

^AFor exact dimensions of the shear specimen, see Fig. 2, and for tension parallel specimen, see Fig. 3.

^BThe test speed attempts to maintain the same rate-of-strain specified in Method D 143 within the critical section.

6.5 Procedure 3—The optional third procedure expands the results of the small clear results obtained in 6.3 and 6.4 to include additional information on size effects. It assesses both the initial effects of fire-retardant treatments on the allowable design stresses of lumber and the potential for additional strength loss after extended exposure to elevated temperatures. To address the former, bending properties shall be assessed using matched FR-treated and untreated groups of 50 specimens. To address the latter, the differential trend in bending properties shall be assessed after 108 days of exposure at elevated temperature using matched lots of 50 specimens obtained from specimens originally matched for density and stiffness to the specimens in the initial effects procedure.

6.5.1 Use 200 pieces ≥ 3.66 m (≥ 12 ft) long, nominal 2 by 4 (38 by 89-mm) dimension lumber grade-marked by an approved grading agency (see U.S. Product Standard PS 20).

6.5.1.1 Lumber 3.66 m (12 ft) or longer is suggested because shorter lengths tend to have a disproportionate number

of boards which were end-trimmed to upgrade the board into a higher grade. This might tend to bias the results, but the extent is unknown.

6.5.1.2 It is recommended that Southern Pine Select Structural be used. This grade is suggested because studies assessing the effects of waterborne preservatives on the strength and stiffness of 38-mm (nominal 2-in.) lumber have shown that higher grades will conservatively estimate the effects for lower grades (1).⁷

6.5.1.3 To decrease the volume of lumber in exposure and conditioning chambers it is permissible to cut 1.53-m (5-ft) lengths of 2 by 4 (38 by 89-mm) from the ≥ 3.66 m (≥ 12 ft) long ALSC-graded material. However, the ALSC grade-limiting characteristic (that is, knot, slope-of-grain, etc.) shall be retained and should be centered in the resulting 1.53-m (5-ft) long section.

6.5.2 The 200 pieces shall be sorted into four groups of 50 specimens having matched density and stiffness profiles. Such a sorting procedure yields correlated experimental results (2, 3). Before sorting, the four groups shall be equilibrated to constant weight at $22 \pm 5^\circ\text{C}$ ($72 \pm 9^\circ\text{F}$) and $65 \pm 1\%$ relative humidity. Two groups (one untreated and one treated with the candidate FR) shall be randomly chosen from the four density-E matched groups and designated for evaluating the initial effects of a given FR treatment on bending properties (see 6.5.5). The two remaining groups of specimens (one untreated/one FR-treated) shall be designated for evaluating the reduction in strength from prolonged exposure to elevated temperature (see 6.5.4).

6.5.3 One group of 50 specimens designated for initial effects and one group of 50 specimens designated for the effects of elevated temperature shall be treated with the candidate FR formulation under study. All processing parameters should be monitored and reported to ensure that pressure, vacuum, temperature, and duration, and post-treatment kiln-drying temperatures and durations are the maximum permissible in later commercial treatment.

6.5.4 The two groups of 50 specimens (one treated and one untreated) shall be exposed in a conditioning chamber to $66 \pm 2^\circ\text{C}$ ($150 \pm 4^\circ\text{C}$) and $\geq 50\%$ relative humidity for 108 ± 3 days of exposure. After exposure, the two groups shall be removed and equilibrated to constant weight at $22 \pm 5^\circ\text{C}$ ($72 \pm 9^\circ\text{F}$) and $65 \pm 1\%$ relative humidity.

6.5.5 Two groups designated for assessing initial FRT effects (one treated and one untreated group of 50) and two groups designated for assessing high-temperature exposure effects (one treated and one untreated group of 50) shall be tested on-edge in bending using Test Method D 4761. Where possible, the grade-dictating defect shall be centered in the maximum moment area and orientated toward the tension face.

7. Report

7.1 Report test results in a comprehensive manner that will allow the reviewer the ability to interpret the implications of the data.

⁷ The boldface numbers in parentheses refer to the list of references at the end of this test method.

7.2 For each of the procedures used, report the following information:

7.2.1 All deviations from procedures found in Section 6 and rationale for the deviations,

7.2.2 The average relative humidity and temperature for each conditioning environment,

7.2.3 Thickness, specific gravity (oven-dry mass/volume at test), and test moisture content of each specimen,

7.2.4 Treating cycle, times, pressures, gage retention, and piece retentions for each treating charge of material, and

7.2.5 Record of dry and wet bulb temperatures during the redrying period for each kiln charge of material.

7.3 *Procedure 1—Initial Effects on Properties of Small Clear Specimens:*

7.3.1 For each property—Modulus of Elasticity (MOE), Modulus of Rupture (MOR), Work to Maximum Load in Bending (WML), Ultimate Tensile Strength (UTS), Maximum Crushing Strength (MCS), and horizontal shear—tabulate the property value for each specimen and the treatment/untreated ratio for each end-matched pair of specimens.

7.3.2 For each untreated/treated group and species; report the mean, standard deviation, and median for all properties and treatment/untreated ratios for end-matched pairs of specimens.

7.4 *Procedure 2—Elevated Temperature Effects on Properties of Small Clear Specimens:*

7.4.1 For each duration period of 36, 72 and 108 days, report the actual duration of exposure to elevated temperature, the average relative humidity, average temperature and any deviation from the conditioning specified in 6.4.2.

7.4.2 For each property—MOE, MOR, WML, UTS, and any other property evaluated, tabulate the property value of each specimen and treatment/untreated ratio for each end-matched pair of specimens for each duration period.

7.4.3 For each combination of untreated/treated group, species, and duration of exposure, report the mean, standard deviation, and median for all the properties and the treatment/untreated ratios (end-matched sets of specimens).

7.4.4 For each property, plot the following versus the actual duration of exposure: (1) Mean Treated, and Mean Untreated values for each duration of exposure (0.36, 72, and 108 days), (2) Median Treated and Median Untreated values for each duration of exposure, (3) Mean treatment/untreated ratios for each duration of exposure, and (4) median treatment/untreated ratios for each duration of exposure.

7.4.5 For each plot of 7.4.4, determine the linear regression parameters (slope and intercept) using the initial effects treatment values for zero (0) day exposure. Evidence of nonlinear behavior in the data shall be noted.

7.5 *Optional Procedure 3—Effects on Full Sized Specimens:*

7.5.1 Report the density and stiffness data used to create the matched groups of 50 specimens.

7.5.2 Tabulate the treatment, duration of exposure, MOE and MOR for each specimen.

7.5.3 For each duration period, report the actual duration of exposure to elevated temperature, the average relative humidity, average temperature and any deviation from the conditioning specified in 6.5.4.

7.5.4 *Initial Effects:*

7.5.4.1 For the untreated group and the FR-treated group for initial effects, report the mean, standard deviation and median for MOR and MOE.

7.5.5 *Effects of Elevated Conditioning:*

7.5.5.1 For the untreated group and the FR-treated group exposed to the 108 days of elevated temperature, report the mean, standard deviation and median for MOE and MOR.

7.5.5.2 For MOR and MOE, plot the following versus the duration of exposure: (1) Mean Treated and Mean Untreated values for 0 and 108 days of exposure; (2) Median Treated and Median Untreated values for 0 and 108 days of exposure, (3) Ratio of the mean treated by mean untreated for 0 and 108 days of exposure; and (4) Ratio of the median treated by median untreated for 0 and 108 days of exposure.

7.5.5.3 For each plot of 7.5.5.2, report the linear slope and intercept.

8. Precision and Bias

8.1 The precision of this test method has not yet been determined. When further data are available, a precision statement will be included.

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

9. Keywords

9.1 fire retardant; fire-retardant treated; lumber; mechanical properties; strength effects; temperature; thermal effects; treatment

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 A commentary on the development of test methods for evaluating the long-term effects of elevated temperatures on strength properties is in Test Method D 5516.

X1.2 In this standard, three wood species groups, which represent a range of treatability and mechanical properties, are evaluated. The two important concepts are 1) that the three species groups have distinctly different mechanical properties and 2) that each grouping represents a unique but uniform set

of treatability characteristics. White spruce is not grade-marked as a single-species grade. Thus, from a user's perspective, it is nearly impossible to obtain. Subcommittee D07.07 performed an evaluation of available treatability data. It showed no major differences in treatability characteristics between the spruces and firs of Canadian Spruce-Pine-Fir (SPF) when the pine was removed. This was the basis used to allow inclusion of SPF with the pine removed.

REFERENCES

- (1) Winandy, J. E., "Impact of Preservative and Fire-Retardant Treatments on Allowable Design Stresses for Wood," *Wood Design Focus*, Vol 2, No. 1, 1991, pp. 14–16.
- (2) Levan, S. L., Ross, R. J., Winandy, J. E., "Effect of Fire Retardant Chemicals on the Bending Properties of Wood at Elevated Temperatures," *USDA Forest Service Research Paper FPL-498*, Madison, WI, 1990.
- (3) Winandy, J. E., Levan, S. L., Ross, R. J., Hoffman, S. P., McIntyre, C. R., "Effect of Fire Retardant Chemicals on the Bending Properties of Plywood at Elevated Temperatures," *USDA Forest Service Research Paper FPL-501*, Madison, WI, 1991.

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