



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 Mechanical Properties of 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
- 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
- U.S. Product Standard PS 20 American Softwood Lumber Standard⁵

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 849, Woodstock, MD 21163.

⁵ Available from The American Lumber Standard Committee, P.O. Box 210, Germantown, MD 20875-0210.

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.

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

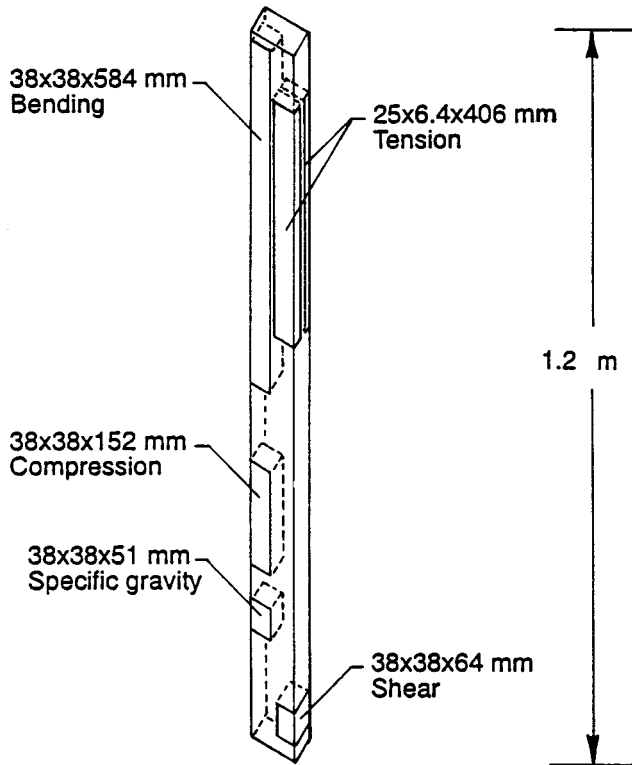


FIG. 1 Hypothetical Cutting Patterns to Obtain One Bending, Two Tension Parallel, One Compression Parallel, One Block Shear, and One Specific Gravity Block from Each 1.2-m (4-ft) Lumber Specimen

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 extended to 30 min, when the flame spread progresses no more than 3.2 m (10.5 ft) beyond the center line of the burners during the extended test and shows no evidence of significant progressive combustion.

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. For 21 of the first 24 h of drying, the dry bulb temperature shall not be more than 2°C (4°F) below the maximum redry temperatures specified during that step of the manufacturer's procedures. For the remainder of the required kiln drying period, the dry bulb temperature shall not be more than 3°C (5°F) below the manufacturer's maximum for that step. Sticker all test pieces to obtain proper air flow across both surfaces and to provide even drying.

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 2—A Spruce/Fir mixture can be obtained by obtaining Canadian Spruce-Pine-Fir and removing the Lodgepole and Jack pine which can be visually segregated from the remaining spruces and firs.

NOTE 3—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.

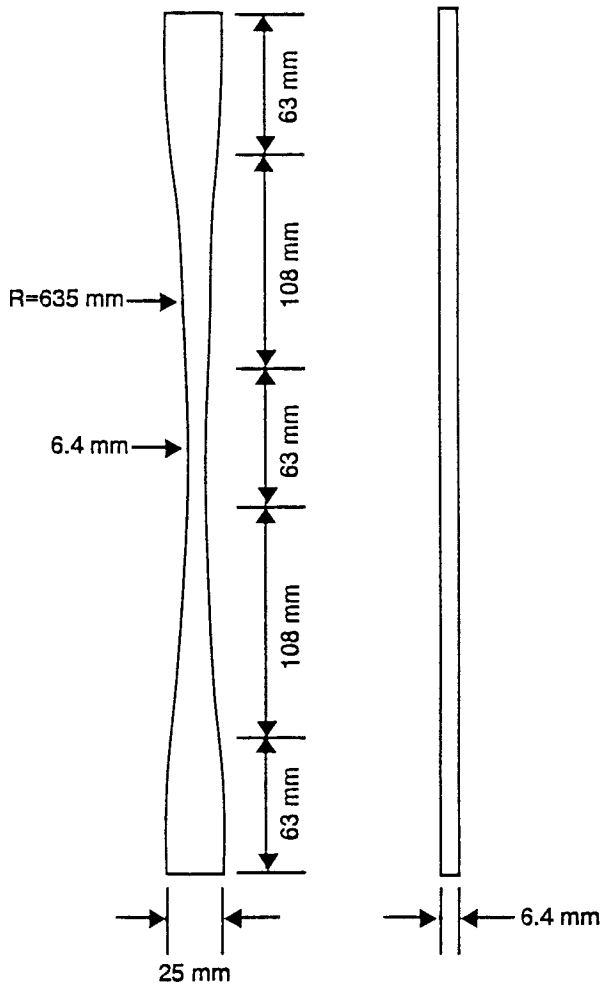


FIG. 2 Dimensions of the Modified Tension Parallel to Grain Specimen Using Test Methods D 3500

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

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 $66 + 2^{\circ}\text{C}$ ($150 + 4^{\circ}\text{F}$) 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 $22 + 5^{\circ}\text{C}$ ($72 + 9^{\circ}\text{F}$) and $65 + 1\%$ relative

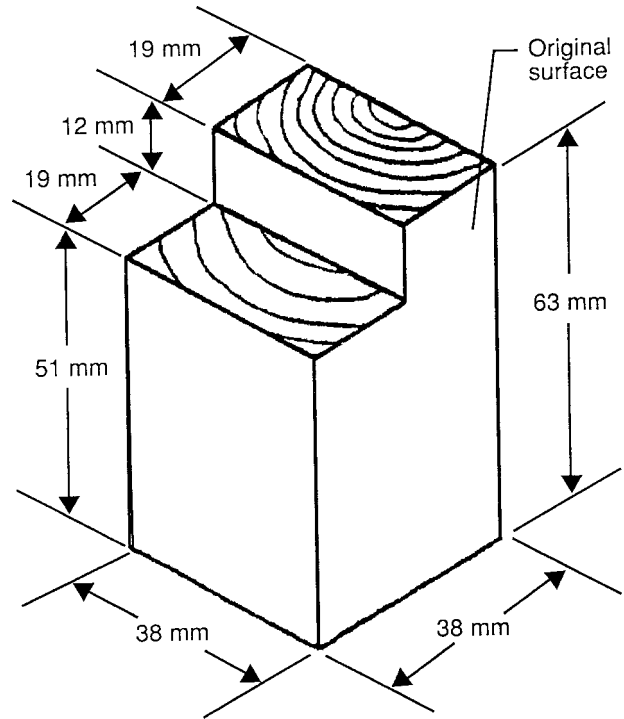


FIG. 3 Dimensions of the Modified Block Shear Specimen

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.

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.

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).⁶

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 $22 + 5^{\circ}\text{C}$ ($72 + 9^{\circ}\text{F}$) and $65 + 1\%$ 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 $66 + 2^{\circ}\text{C}$ ($150 + 4^{\circ}\text{C}$) 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 $22 + 5^{\circ}\text{C}$ ($72 + 9^{\circ}\text{F}$) and $65 + 1\%$ 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 the following information:

7.1.1 Any deviation from any procedure in Section 6.

7.1.1.1 Considering that consensus analytical procedures for these results are not yet available, test results shall be reported in a comprehensive manner which allows the architect/engineer the ability to interpret the implications of the data.

7.1.2 Initial effects on bending, tension parallel, compression parallel, and horizontal shear properties from small clear specimens shall be described as follows:

7.1.2.1 A cumulative frequency distribution for the 25 specimens tested for Modulus of Elasticity (MOE), Modulus of Rupture (MOR), Ultimate Tensile Stress (UTS), Maximum Crushing Strength (MCS), and horizontal shear.

7.1.2.2 A tabulated comparison of the relative difference in each reported property reported in 7.1.2.1 at the median.

7.1.3 *Trends/ Elevated Temperature Effects on MOE, MOR, and WML in Bending and UTS in Tension:*

7.1.3.1 The median, standard deviation, and range shall be reported for each property/duration combination. Results from 7.1.2 shall be used as the zero days exposure at 66°C (150°F) and $\geq 50\%$ relative humidity.

7.1.3.2 A plot of both FR-treated and untreated median values over duration of exposure for each property shall also be reported. Side bars shall indicate a 67 % confidence bound for each reported value (that is, +1 standard deviation).

7.1.3.3 A linear regression shall be fit using all test values to assess the trend (that is, slope) of the FR-treated and untreated data. This trend shall be reported.

7.1.4 Initial effects on bending properties of nominal 2 by 4 lumber shall be described as follows:

7.1.4.1 A cumulative frequency distribution for MOE, MOR, and WML in bending.

7.1.4.2 An overall comparison of the relative difference in each reported property in 7.1.2.1 over the entire distribution.

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

⁶ The boldface numbers in parentheses refer to the list of references at the end of this test method.

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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