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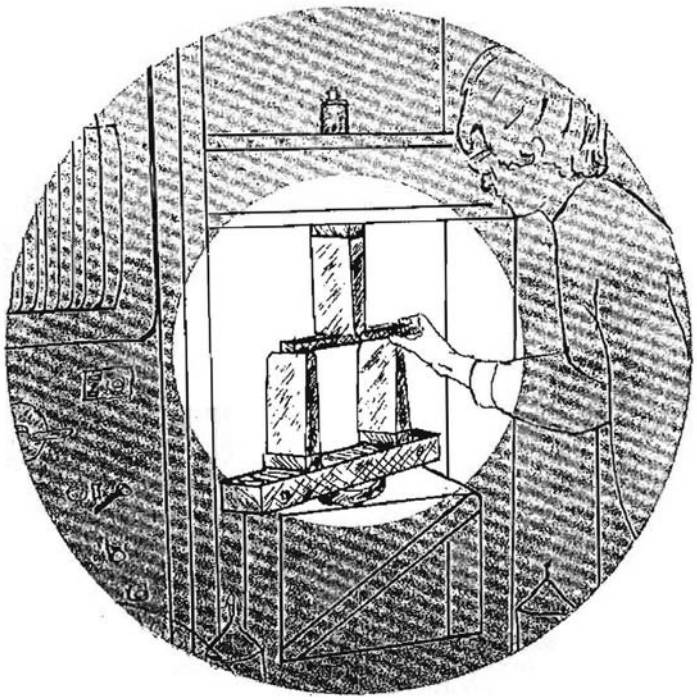

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ABSTRACT

Since fire-retardant-treated wood is gaining more acceptance year by year, it is desirable that its strength properties be known, particularly far structural applications. This paper summarizes the results of several studies conducted at the Forest Products Laboratory and elsewhere on the bending properties of air-dried and kiln-dried fire-retardant-treated wood. Collectively the studies indicate that modulus of rupture and work to maximum load in bending were reduced by varying amounts depending on species and type of fire retardant. In general, the reductions are consistent with the 10 percent reduction in design stresses recommended for fire-retardant-treated lumber.

EFFECT OF FIRE-RETARDANT TREATMENT ON BENDING STRENGTH OF WOOD

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INTRODUCTION

Some structural applications require that wood and wood products be made fire retardant. Many chemicals and formulations of chemicals have proven their effectiveness in reducing the flaming and glowing characteristics of wood (2,3).[2] These are collectively called wood fire retardants.

Several types of test methods are used to evaluate the fire performance of materials including fire-retardant-treated wood (1). Many of these provide means for rating the material on the basis of test results. Building codes and specifications (2,9) establish levels of these ratings which must be met before a material can be classified as acceptable for use according to the type of building, occupancy, and location,

Besides the fire performance ratings, specifications may also limit the amount that fire retardants can affect strength, hygroscopicity, corrosivity, etc., depending on use requirements, For example, Military Specification MIL - L - 19140C (9) requires that fire-retardant wood retain on the average at least 80 percent of the MOR (modulus of rupture) and MOE (modulus of elasticity) and 65 percent of the work to maximum load in bending of a matched sample of untreated wood and have other qualities as well. One design specification for lumber (8) calls for a 10 percent reduction in allowable design stresses if lumber is to be treated with a fire retardant.

The Forest Products Laboratory has evaluated several different fire-retardant treatments for wood, some according to MIL-L-19140C. None of these evaluations was published, however, because each study by itself was of limited value. Other laboratories have evaluated strength properties of fire-retardant wood and published their results (4,5,6,7). This report summarizes unpublished work of the Laboratory and that reported by others,

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin

[2] Underlined numbers in parentheses refer to Literature Cited at the end of this report.

FOREST PRODUCTS LABORATORY STUDIES

Eight different studies were conducted at this Laboratory to evaluate the static bending properties of fire-retardant-treated wood, All studies were conducted on Douglas-fir or southern pine, or both. Of the fire retardants used, five wore proprietary and represented materials currently used for fire-retardant treating. In addition, one chemical formulation consisted of ammonium polyphosphate and a second involved ammonium polyphosphate and ammonium sulfate in equal weighted amounts.

Seven of the studies involved small clear bending specimens that were tested according to ASTM D143 or equivalent to account for size of specimen material. An eighth study involved structural-size glued-laminated beams, All small clear bending specimens were conditioned at about 75° F. and 64 percent relative humidity before test.

For convenience, the studies will be referred to by arbitrarily assigned numbers. Individual fire retardants are not identified.

Study 1

This study, conducted about late 1944, was limited to Douglas-fir. Twenty 4 by 8's, each 24 feet long, were cut into 12-foot lengths to make 20 matched pairs of beams.

One beam of each pair was pressure treated with a fire-retardant chemical solution for 45 hours: the solution temperature wad 180° F. Ten of these treated beams were then dried in a kiln at a maximum temperature of 150° F. along with the 10 untreated matched control beams; control beams were dried for 5 days and treated beams for 9 days,

The remaining 10 treated beams, along with their matched controls, were maintained in the wet condition, All 40 beams were then tested in bending at another laboratory.

After test, a 4-foot length was cut from an undamaged portion of each 4 by 8 at least 18 inches in from an end. An oversize 2-inch-square clear stick was cut from a corner of each 4-foot section and sent to this Laboratory, This became the sample material for study 1.

Each stick was finished to a 2- by 2- by 30-inch bending specimen before test. No more than about 1/16 inch was removed from the two faces that formed the corner of the 4 by 8's. The specimens were oriented in the bending test so that one of those faces was stressed in tension. The time lag between treatment of beams and testing of small clear specimens was 7 months, by far the longest time lag for any of the FPL studies.

Study 2

Another study, conducted in 1951, was also limited to Douglas-fir, Twelve clear, straight-grained pieces of air-dry Douglas-fir measuring 3-3/4 by 4-3/4 inches by 8 feet were crosscut into 4-foot lengths. One 4-foot length from each piece was pressure treated commercially with the fire retardant. Treated pieces were apparently air-dried rather than kiln-dried.

A 2-foot length of each piece was cut into four 1- by 1- by 16-inch bending specimens. Thus, a total of 48 untreated and 48 treated specimens were tested.

Study 3

This study, conducted in 1961, included two different fire retardants and the two species: Douglas-fir and southern pine, Sample material consisted of 20 clear, straight-grain, 8-foot-long 2 by 4's of each species. The Douglas-fir was green and the southern pine kiln dried.

Each 2 by 4 was cut into three 32-inch lengths. The central portion was left untreated as a control, One end portion was treated with one of the fire retardants and the other with the other fire retardant. Treatment, including kiln drying, was d on e commercially or followed commercial schedules. The green Douglas-fir control material was dried at this Laboratory to about 15 percent moisture content using a mild schedule that did not exceed 145° F.

After preconditioning, two 1- by 16-inch specimens were prepared from each 32-inch length of 2 by 4. Each small clear specimen from treated material contained one face that was directly exposed to the treating solution; that face was oriented to be in tension in the bending test.

Study 4

This study was conducted in 1963 according to MIL-L-19140. Sample material was limited to five 30-inch lengths of clear southern pine 2 by 10's pressure treated and kiln dried commercially and their end-matched untreated controls of the same size. Two specimens containing the full thickness were cut Prom each piece, yielding two end-matched pairs of specimens per 2 by 10. The specimens, 1-1/2 inches wide by 23-3/4 inches long, were preconditioned at 80° F. and 80 percent relative humidity for 2 days prior to final conditioning at 75° F. and 64 percent relative humidity. They were tested on a 21-3/4-inch span. Treated faces were oriented to be in either tension or compression and control specimens were oriented to match the loading of the treated specimens.

Study 5

This study was conducted in 1966 according to MIL-L-19140, Sample material was limited to 10 clear 24-inch-long pieces of 1- by 2-inch southern pine treated and kiln dried commercially and their end-matched controls.

The 12-inch lengths containing the end-matched ends served as the specimens for this study, yielding 10 matched pairs. The specimens, left full size, were tested on an 11-inch span.

Study 6

Study 6 was conducted in 1967 according to MIL-L-19140. It was limited to southern pine and two formulations that were potentially useful as fire retardants: one consisting of ammonium polyphosphate alone and the other of ammonium polyphosphate with ammonium sulfate in equal weighted quantities.

Sample material consisted of two sets of five clear 10-foot-long 1 by 6 southern pine boards. Each board, crosscut in half, furnished an untreated control piece, The two seta of five remaining ends were treated with one or the other formulation to a retention of 6 pounds of dry salt per cubic foot of wood and kiln dried at this Laboratory. Maximum temperature in the kiln was 140° F.

Control and treated boards were preconditioned at 80° F. and 80 percent relative humidity for 2 weeks prior to final conditioning. Two 12-inch-long specimens were then cut side by side from each piece near the matched end, yielding 10 end-matched pairs of specimens per formulation. The specimens were cut to 1 inch wide by the thickness of the board, and tested over a 10-1/2-inch span with centerpoint loading. Each was oriented so that the two original board surfaces were stressed in either tension or compression.

Study 7

This study, conducted in 1969, was limited to southern pine treated and kiln dried commercially and untreated controls. The sample material consisted of 10 treated 4-foot lengths of 1 by 6 boards and their 10 end-matched untreated controls of the same size,

Conditioning was extended for 3-1/2 months to allow the treated material to come up to equilibrium. Then a specimen 12 inches long, 1 inch wide, and the board thickness was cut from near the matched end of each piece, yielding 10 end-matched pairs of specimens. The specimens, teated over a 10-1/2-inch span, were so oriented that the board surfaces were stressed in either tension or compression.

Study 8

Study 8 was conducted in 1961 on southern pine glued-laminated beams made commercially either of boards treated commercially with a fire-retardant or of untreated boards.

Nine matched pairs of glue-laminated beams, 5-1/4 by 9-1/4 inches by 14 feet long, were furnished by the cooperator, Each beam was constructed of 14 laminations of 1 by 6 boards resawn from kiln dried southern pine 2 by 6 laminating stock of grade C and Better for outer laminations and No. 1 and Better for inner laminations. Of the pair of boards resawn from each 2 by 6, one was treated with the fire retardant and kiln dried to about 6 percent moisture content, and the other was left untreated. The laminated beams were made either of all untreated boards or of treated boards. A pair of beams, one treated and one untreated, were matched by

locating pairs of boards from each of the 2 by 6's--lamination for lamination--in the paired beams.

The laminated beams were conditioned at 73° F, and 50 percent relative humidity for at least 12 days after they were received at this Laboratory.

The bending tests of the laminated beams were conducted according to ASTM D 198. Span was 13 feet and loading was applied symmetrically to the narrow face at two points spaced 3 feet apart.

Results of FPL Studies

Average results of the bending tests for the eight studies are presented in table 1. Statistics on the paired-t test are given in table 2 for seven of the studies, (The paired-t test does not strictly apply to the sampling plan of study 2.)

Table 1 shows that the fire-retardant-treated wood always averaged somewhat less than the controls in all three properties of the static bending test for each study. In table 2, the significance level is the number of times out of 100 of probably being wrong in concluding that there is a difference between treated and control specimens. Many of the differences between control and treated samples are statistically significant at least at the 1 percent level. This trend is less apparent for MOE than it is for MOR and work to maximum load.

STUDIES CONDUCTED AT OTHER LABORATORIES

King and Matteson (7)

Their study was conducted on 50, 4- by 8-foot panels of three-ply, A-C exterior Douglas-fir plywood. The A face veneers were sapwood. Each panel, sanded to 1/4-inch thickness, was cut into 4- by 4-foot sheets; one sheet was for controls and the other for fire-retardant treatment,

The sheets to be treated were sent to commercial treating. plants where they were treated with one of two types of fire retardant and kiln-dried according to standard commercial practice. The fire retardants were referred to as A or B; 25 sheets were treated with each fire retardant, Then all sheets were stored at 75° F. and 50 percent relative humidity for several weeks prior to being cut into test specimens.

One flexure specimen 2 inches wide by 14 inches long and several shear and impact specimens were cut from each 4 by 4 sheet. The flexure specimens were tested according to ASTM D 805-52. A pair of specimens (control and treated from the same panel) were tested with the same face in tension, Test results were formed into ratios for each pair: treated to controls, Averages of the ratios based on flexural test results are given below and indicate the relation of treated specimens to controls,

	Fire retardant A	Fire retardant B
	Pct.	Pct.
MOE	94	89
Stiffness	98	102
MOR	94	76
Maximum load	101	62
Work to maxlmum load	102	69

It was concluded that treatment A did not appreciably affect flexural properties of Douglas-fir plywood but that treatment B caused substantial reductions in MOE, MOR, load-carrying capacity, and shock resistance but not stiffness.

Jessome (5)

Jessome's study involved Douglas-fir and red pine and the three fire-retardant formations referred to as ZAB (zinc chloride-ammonium sulfate-boric acid type) and APS I and APS II (both containing ammonium phosphate-ammonium sulfate but in different proportions). Douglas-fir specimens included both solid wood and 3/8-inch plywood but red pine was limited to solid wood, Plywood specimens were 2 inches wide by 20 inches long. Solid wood specimens were 2 by 2 by 30 inches. Besides controls, specimens were treated with either water or one of the fire retardants. Treatment and kiln drying was done in the laboratory. Twenty replicate specimens randomly assigned were provided for each variable.

The static bending tests were conducted according to ASTM D 143 and D 805. The results of those tests indicated that: (1) MOE values of Douglas-fir and red pine solid wood were not significantly affected by the fire-retardant treat-

Table 1.--Average static bending properties of control (C) and fire-retardant treated (T) beams tested at Forest Products Laboratory

Study No.[1]	Modulus of elasticity		Modulus of rupture		Work to maximum load	
	C	T	C	T	C	T
	Million p.s.i.		1,000 p.s.i.		In.-lb./cu. in.	
			DOUGLAS-FIR			
[2]1-A	1.86	1.77	11.5	10.2	9.4	4.3
[3]1-A	1.77	1.63	10.6	9.5	7.3	4.4
2-C	1.96	1.73	13.3	9.4	12.4	7.8
3-B		2.03		10.4		8.4
3	2.13		12.4		12.4	
3-C		2.02		10.3		8.4
			SOUTHERN PINE			
3-B		1.62		10.0		8.4
3	1.76		11.5		11.0	
3-C		1.61		10.3		7.9
4	1.62	1.41	11.2	9.3	10.4	7.0
5-A	2.00	1.83	16.1	14.3	15.0	11.1
[4]6	1.86	1.63	15.2	12.3	15.6	12.3
[5]6	1.52	1.48	13.3	11.1	16.4	9.1
7	1.60	1.54	15.1	14.2	18.1	9.6
8-B	1.96	1.93	10.4	9.1	--	--

[1]Common letters indicate same fire retardant name.

[2]Air-dried.

[3]Kiln-dried.

[4]Ammonium polyphosphate.

[5]Ammonium polyphosphate-ammonium sulfate.

ments, (2) MOE of the plywood was reducedabout 16 percent, (3) MOR was reduced from 12 to 20 percent for Douglas-fir solid wood, from 13 to 28 percent for red pine solid wood, and 24 percent for Douglas-fir plywood depending on the type of fire retardant. The ZAB type generally affected strength the least. Work values for fire-retardant specimens were substantially below those for control specimens.

Graham (4)

Graham's study was designed to evaluate the long-term effects of different fire retardants on strength of Douglas-fir, His plan called for testing of flexure specimens after 1-, 3-, 6-, and 10-year storage periods at either moderate or hot, dry conditions.

The study included three AWPA fire retardants

Table 2.—Differences between bending properties of control and fire-retardant beams tests at Forest Products Laboratory[1]

Study[2]	Modulus of elasticity				Modulus of rupture				Work to maximum load			
	$\bar{d}$	$S_{\bar{d}}$	t	Significance level	$\bar{d}$	$S_{\bar{d}}$	t	Significance level	$\bar{d}$	$S_{\bar{d}}$	t	Significance level
	Million p.s.i.	Million p.s.i.		Pct.	1,000 p.s.i.	1,000 p.s.i.		Pct.	In.-lb. per cu. in.	In.-lb. per cu. in.		Pct.
DOUGLAS-FIR												
[3]1-A	0.09	0.057	1.57	16	1.35	0.407	3.32	< 1	5.1	0.57	8.94	< 1
[4]1-A	.14	.102	1.40	20	1.10	.524	2.10	8	2.9	.81	3.57	< 1
3-B	.10	.023	4.31	< 1	1.98	.157	12.65	< 1	4.0	.54	7.40	< 1
3-C	.11	.021	4.96	< 1	2.10	.165	12.70	< 1	4.0	.62	6.53	< 1
SOUTHERN PINE												
3-B	.14	.032	4.52	< 1	1.55	.202	7.67	< 1	2.6	.53	4.93	< 1
3-C	.15	.027	5.63	< 1	1.19	.164	7.29	< 1	3.1	.47	6.72	< 1
4	.21	.069	2.98	2	1.90	.352	5.42	< 1	3.3	1.11	3.00	2
5-A	.17	.018	9.34	< 1	1.76	.277	6.34	< 1	3.9	.94	4.12	< 1
[5]6	.22	.082	2.73	3	2.87	.523	5.48	< 1	3.3	1.87	1.75	12
[6]6	.04	.059	.63	> 50	2.21	.320	6.90	< 1	7.3	1.65	4.40	< 1
7	.05	.060	.89	40	.90	.635	1.42	19	8.5	2.22	3.83	< 1
8-B	.02	.023	1.08	32	1.29	.530	2.43	3	—	—	—	—

[1]Symbols are defined as:

$\bar{d}$ = average within-pair difference (control minus treated).

$S_{\bar{d}}$ = standard error of the average difference

$t = \bar{d} \div S_{\bar{d}}$

[2]Common letters indicate same fire retardant name.

[3]Air-dried.

[4]Kiln-dried.

[5]Ammonium polyphosphate.

[6]Ammonium polyphosphate-ammonium sulfate.

(CZC FR (type B), Minalith (type C), and Pyresote (type D)), a boric acid:sodium tetraborate formulation, ammonium sulfate, and proprietary formulations listed as F and G.

Vertical grain, kiln dry, Douglas-fir dimension lumber was cut into 1- by 1- by 16-inch bending specimens with limits on growth rate, specific gravity, and moisture content. Some specimens were left untreated as controls. A group of specimens treated with water also provided control. Other groups of specimens were treated with one of the fire retardants at one of two solution concentrations. Solution temperatures ranged from 120° to 160° F. depending on formulation and concentration. After treatment all specimens were stored at 70°F. and 65 percent relative humidity until near equilibrium. Only the group treated with formulation F was kiln dried before storage, After preconditioning, half of the specimens were retained in that storage condition and another half were subjected to cyclic conditions consisting of 3 months at 140° to 150° F. followed by 9 months at 90° F. and 30 percent relative humidity. The cycle was ended after 3 years, at which time the heated specimens were retained at 90° F. and 30 percent relative humidity until tested in flexure.

Eight specimens were randomly selected from each group treated and conditioned alike for test after 1, 3, 6, and 10 years. Only the results for 1- and 3-year storage have been reported so far (4). In general, the results indicated that only the shock resistance of Douglas-fir was significantly affected by the fire-retardant treatment and conditions imposed afterwards. In fact, some of the treatments result in an improvement of strength and stiffness of Douglas-fir, particularly at the hot-dry storage condition and particularly for the boric acid: borax formulation.

Johnson (6)

Johnson limited his study to coast-type Douglas-fir. His sample consisted of unseasoned, 12-foot-long 2 by 6's graded into four different strength ratio classes: 53-57, 63-67, 73-77, and 83-87 percent. Grading was done on the basis of worst edge in tension under third-point loading in bending, The strength ratio for each graded piece was controlled by a knot in the middle third length. Each class contained 155 pieces.

Each specimen was tested on edge for its MOE while still unseasoned, Within each class, the pieces were ranked according to MOE in groups of five--the five lowest, the five next lowest, and so on up to the five highest. Within groups, assignment was at random to one of five sets. One set was left untreated. Two sets were given a fire-retardant treatment at one commercial plant (treatment 1) and the remaining two sets at another (treatment 2). The fire retardants were not named. One set of each treatment was kiln dried and the other air dried along with the untreated specimens. Specimens were not incised, All specimens were subsequently allowed to air dry in the laboratory for more than 6 months, Untreated specimens had attained a moisture content of about 8 percent after that time.

Static bending tests with the worst edge in tension were made using two-point loading centrally spaced 4 feet apart over a support span of 11 feet, 4 inches. This was the same setup as used to determine MOE on edge.

Results for MOE indicated that the fire-retardant-treated lumber was generally not significantly different from the untreated lumber. The only minor difference that proved to be statistically significant (at the 5 percent level) was for treatment 2 in the lowest strength ratio class: here MOE was reduced by 5 percent for kiln-dried treated lumber and reduced by 3 percent for air-dried treated lumber compared to the untreated average. On a stiffness basis, however, none of the treated groups averaged less than comparable untreated groups; the lumber in the treated groups did not shrink quite as much as the untreated lumber.

Results of the bending test indicated that MOR of the fire-retardant-treated lumber was generally less than that for untreated lumber, particularly if the lumber was kiln dried after treatment. Both treatments resulted in about the same loss in strength when the lumber was kiln dried. In order of increasing strength ratio classes, the relative losses in MOR compared to the untreated values were: 17, 10, 20, and 10 percent, respectively. The first and third values corresponded to losses that were significant at least at the 5 percent level. Air drying in contrast to kiln drying did not cause any significant losses in strength of treated lumber, although the MOR for treatment 1 averaged about 95 percent of the MOR for untreated lumber.

SUMMARY AND CONCLUSIONS

Several independent studies have been made of the bending strength of fire-retardant-treated wood, These studies were generally limited to small clear specimens of solid wood, but two involved small plywood specimens, one involved 2 by 6 lumber, and one involved 5-1/47 by 9-1/4-inch glued-laminated beams,

All but one of the studies conducted at the Forest Products Laboratory and some conducted at other labs involved kiln drying after treatment, A few were limited to air drying after treatment.

The results of all the studios except Graham's (4) are summarized in table 3. The data under MOE, MOR, and work to maximum load are ratios of the average property values for treated specimens relative to the average property values for their controls, in percent. Perusal of table 3 reveals that MOR for fire-retardant-treated wood is consistently lower than that for untreated wood if fire-retardant treatment is followed by kiln drying, The same is true for MOE except for four cases and work to maximum load except for one case. If fire-retardant-treated wood is air dried rather than kiln dried, then the effect maybe loss or even negligible, according to the results of the studies by Graham (4) and Johnson (6).

The dispersion of values for the different combinations of species, fire retardant, and type of sample shown in table 3 suggest that more than one strength-reducing factor may be appropriate to account for losses in strength after wood is treated and kiln dried. For the present, however, only a single factor per property is warranted because of the variety of studies and large dispersion of average values. Overall, the losses from fire-retardant treating and kiln drying for small clear wood specimens averaged about 13 percent for MOR and 5 percent for MOE. For structural sizes, losses were about 14 percent for MOR and 1 percent for MOE. If the swelling resulting from treatment is taken into account, the losses in load-carrying capacity and stiffness of bending members are consistent with the 10 percent reduction in design stresses recommended for fire-retardant lumber (8). The overall loss in work to maximum load, a measure of shock resistance, averaged about 34 percent in small clear specimens treated with fire-retardant and kiln-dried.

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Table 3.--Summary of ratios of average property values for fire-retardant treated specimens to average property values for their controls

Species	Data source[1]	Fire-retardant[2]	Size of specimen	Comments	Modulus of elasticity: Air-dried	Modulus of elasticity: Kiln dried	Modulus of rupture: Air-dried	Modulus of rupture: Kiln dried	Work to maximum load: Air-dried	Work to maximum load: Kiln dried
					Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Douglas-fir	FPL-1-A		2 x 2 x 30	Solid wood	95	92	89	90	46	60
Do.	FPL-2-C		1 x 1 x 16	do.	88	--	71	--	63	--
Do.	King	A	1/4 x 2 x 14	Plywood	--	94	--	94	--	102
		B	1/4 x 2 x 14	do.	--	89	--	76	--	69
Do.	FPL-3-B		1 x 1 x 16	Solid wood	--	95	--	84	--	68
Do.	FPL-3-C		1 x 1 x 16	do.	--	95	--	83	--	68
Do.	Jessome[3]	ZAB	2 x 2 x 30	do.	--	102	--	98	--	88
Do.	do.	APS I	2 x 2 x 30	do.	--	99	--	97	--	76
Do.	do.	APS II	2 x 2 x 30	do.	--	99	--	87	--	71
Do.	do.	ZAB	3/8 x 2 x 20	Plywood	--	90	--	87	--	92
Do.	do.	APS I	3/8 x 2 x 20	do.	--	91	--	85	--	94
Do.	do.	APS II	3/8 x 2 x 20	do.	--	91	--	84	--	98
Do.	Johnson	1	2 x 6 x 144	Strength ratio 53-57	99	99	97	83	--	--
Do.	do.	1	2 x 6 x 144	do... 63-67	101	100	93	90	--	--
Do.	do.	1	2 x 6 x 144	do... 73-77	101	99	93	80	--	--
Do.	do.	1	2 x 6 x 144	do... 83-87	100	99	96	91	--	--
Do.	do.	2	2 x 6 x 144	do... 53-57	97	95	103	83	--	--
Do.	do.	2	2 x 6 x 144	do... 63-67	99	99	103	89	--	--
Do.	do.	2	2 x 6 x 144	do... 73-77	99	100	95	80	--	--
Do.	do.	2	2 x 6 x 144	do... 83-87	97	98	102	88	--	--
Red pine	Jessome[3]	ZAB	2 x 2 x 30	Solid wood	--	102	--	90	--	58
Do.	do.	APS I	2 x 2 x 30	do.	--	95	--	71	--	38
Do.	do.	APS II	2 x 2 x 30	do.	--	95	--	77	--	45
Southern pine	FPL-3-B		1 x 1 x 16	do.	--	92	--	87	--	76
Do.	FPL-3-C		1 x 1 x 16	do.	--	92	--	90	--	72
Do.	FPL-4		1-1/2 x 1-5/8 x 24	do.	--	87	--	83	--	68
Do.	FPL-5-A		1 x 2 x 12	do.	--	91	--	89	--	75
Do.	FPL-6[4]		3/4 x 1 x 12	do.	--	88	--	81	--	79
Do.	FPL-6[5]		3/4 x 1 x 12	do.	--	97	--	84	--	55
Do.	FPL-7		3/4 x 1 x 12	do.	--	96	--	94	--	53
Do.	FPL-8-B		5-1/4 x 9-1/4 x 168	Glued-laminated	--	99	--	88	--	--

[1] Common letters indicate same fire-retardant name.

[2] Designations used in reference.

[3] Based on water-treated controls.

[4] Ammonium polyphosphate.

[5] Ammonium polyphosphate-ammonium sulfate.

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