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A COMMERCIAL APPLICATION OF FIRE RETARDANTS TO DRY-FORMED HARDB--ETC(U)
1977 G C MYERS, C A HOLMES
FSRP-FPL-298

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A COMMERCIAL APPLICATION OF FIRE RETARDANTS TO DRY-FORMED HARDBOARDS

USDA Forest Service
Research Paper
FPL 298
1977

U.S. Department of Agriculture
Forest Service
Forest Products Laboratory
Madison, Wis.

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ABSTRACT

Based on laboratory performance with a number of fire-retardant chemicals, disodium octaborate tetrahydrate-boric acid and dicyandiamide-phosphoric acid-formaldehyde were selected for treating fiber and making 4-foot by 8-foot dry-formed hardboards on a commercial production line. The boards were evaluated for performance under exposure to fire, strength, dimensional stability, and durability. Both treatment systems produced boards that met the acceptance flamespread criteria for Class B material in a 25-foot tunnel furnace. The disodium octaborate tetrahydrate-boric acid gave the lowest smoke development index and resulted in the strongest and most stable boards. The treatments did not offer resistance to water leaching.

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A COMMERCIAL APPLICATION OF FIRE RETARDANTS TO DRY-FORMED HARDBOARDS.

11 1977

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By

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14 FSRP-FPL-298

and

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U.S. Department of Agriculture

9 Forest Service research paper

INTRODUCTION

Flammability has been a problem with wood fiber-base products; thus their use in building has been limited. Previous investigation of 21 chemical treatments (8)^{2/} at this Laboratory has shown that the fire performance of dry-formed hardboard could be improved. Two promising fire-retardant treatment formulations, disodium octaborate

tetrahydrate-boric acid (4:1) (DOT-BA) and dicyandiamide-phosphoric acid-formaldehyde (DPF) (Appendix) were selected for commercial trials to provide large size boards for testing in a 25-foot tunnel furnace and to determine the problems, if any, that might be encountered in commercial production.

EXPERIMENTAL

Boardmaking

The hardboard mill did not have facilities for continuously treating with both resin and fire-retardant chemical; therefore this was done at the Forest Products Laboratory. The mill supplied untreated and dried aspen fiber that had been refined under pressure.

Small batches of fiber, while in a revolving drum, were sprayed with solutions of each of the two fire-retardant formulations to give a 20-percent chemical treatment based on the oven-dry weight of the fiber. The wet fiber was dried in a circulating hot air oven (220° F), and the moisture content reduced to approximately 4 percent. The dried fiber was stored in bin pallets.

Two to five days prior to boardmaking, batches of the treated fiber, while being tumbled in the revolving drum, were sprayed with a

solution of resin to give a 4-percent resin solids based on oven-dry weight of resin and fiber. The resin had low alkalinity and was a low advanced (polymerization), water-soluble phenolic (7.2 pH). The resin-treated fiber was returned to bin pallets for transporting to the hardboard mill. In addition to fiber with the fire-retardant chemical, untreated fiber was treated with phenolic resin for use as control boards.

Boards 4 feet by 8 feet were made by introducing the treated fiber into the mill's system prior to reaching the mat former. The mats were formed, pre-pressed, then hot

1/ The Laboratory is maintained at Madison, Wis., in cooperation with the University of Wisconsin.
2/ Underlined numbers in parentheses refer to Literature Cited at end of this report.

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pressed for 3-1/3 minutes at 380° F in a multi-opening hot press. After pressing, the boards were heat-treated for 2 hours at 250° F, then placed under humidification for 5 hours.

Evaluations

Fire performance was determined by the following methods and tests: The 25-foot tunnel furnace method of ASTM E 84 (4); the 8-foot tunnel furnace method of ASTM E 286 (1); and the Schlyter spread-of-flame test (9) after a 42-day accelerated weathering exposure of

ASTM D 2898, Method B (3). The 25-foot tunnel furnace test was conducted in the laboratory of the Hardwood Plywood Manufacturer's Association, Arlington, Va. The strength tests—static bending, internal bond, and tensile strength—and the accelerated aging exposure followed procedures specified in ASTM D 1037-72a (2). Linear and thickness movements with changes in moisture were determined by exposing 1/2-inch by 6-inch specimens for 30 days at 90 percent relative humidity (RH) or to "watersoak" after they had been conditioned and measured at 50 percent RH.

RESULTS

The fire performance of fire-retardant-treated boards after exposure in a 25-foot (ASTM E 84) tunnel furnace and in an 8-foot (ASTM E 286) tunnel furnace is given in table 1. Both treatment systems gave average flamespread values that meet acceptance flamespread criteria for Class B material—75 or under. In both furnace tests, the DPF material gave lower flamespread values than did the DOT-BA treated, but much less smoke developed with the DOT-BA treatment. Smoke development for this treatment was only 17 in the 25-foot furnace and 27 in the 8-foot furnace compared to 399 for the untreated board

in the 25-foot furnace and 208 in the 8-foot furnace.

Smoke development for treated wood products is usually high in the 8-foot furnace. This is due to the exposure of the specimen to a radiant panel and to the low or nonflaming combustion associated with treated materials that tend to produce more smoke. Consequently, the DOT-BA system affords an acceptably low fire hazard as evidenced by the exceptionally low smoke development and Class B flamespread rating. The higher smoke development, however, of ~~614~~ ²⁰⁸ by the DPF treatment should not restrict acceptance of

Table 1.—Fire performance of 4- by 8-foot fire-retardant-treated hardboards

Fire-retardant treatment	Tunnel furnace ^{1/}					
	ASTM E 84 25-foot ^{2/}			ASTM E 286 8-foot		
	Flamespread classification	Fuel contributed	Smoke developed	Flame-spread index	Fuel contributed	Smoke developed
Untreated (control)	180	121	399	106 (8.6)	165 (1.7)	208 (28.1)
Disodium octaborate tetrahydrate-boric acid (4:1)	58 (3.7)	32 (4.4)	17 (108.1)	68 (12.5)	30 (2.3)	27 (47.1)
Dicyandiamide-phosphoric acid-formaldehyde	47 (7.6)	29 (0)	208 (6.5)	43 (6.6)	8 (74.9)	614 (0.8)

^{1/}Values are averages of two tests except for one test on untreated board in 25-foot furnace. Values in parentheses are coefficients of variations (pct).

^{2/}Tests by the Hardwood Plywood Manufacturers Association, Arlington, Va.

Table 2.—Strength properties of the fire-retardant-treated 4-foot by 8-foot hardboards^{1/}

Strength properties	Treatment		
	Untreated control ^{2/}	Disodium octaborate tetrahydrate-boric acid (4:1) ^{3/}	Dicyandiamide-phosphoric acid-formaldehyde ^{4/}
After conditioning 30 days at 73° F and 50 pct RH ^{5/} :			
Static bending—			
1) As tested			
Density (lb/ft ³)	65.4 (3.2)	65.8 (4.2)	59.9 (4.2)
MOR (lb/in. ²)	7,320 (16.0)	8,210 (13.3)	3,380 (22.2)
MOR (1,000 lb/in. ²)	714 (8.9)	981 (10.1)	519 (14.8)
2) Adjusted to 60 lb/ft ³ density			
MOR (lb/in. ²)	6,720 (16.0)	7,490 (13.3)	3,390 (22.2)
MOE (1,000 lb/in. ²)	655 (8.9)	895 (10.1)	520 (14.8)
Internal bond			
Maximum stress (lb/in. ²)	411 (13.6)	279 (25.0)	131 (14.0)
Tensile strength			
Maximum stress (lb/in. ²)	5,210 (7.3)	5,140 (11.2)	2,270 (14.4)
After accelerated aging ^{6/} :			
Static bending—			
Density (lb/ft ³)	55.9 (2.3)	45.7 (8.4)	43.5 (5.9)
MOR (lb/in. ²)	3,330 (13.4)	1,800 (31.2)	1,120 (21.4)
MOR (1,000 lb/in. ²)	280 (8.4)	153 (25.7)	112 (15.6)
Internal bond			
Maximum stress (lb/in. ²)	132 (36.3)	28 (81.1)	13 (48.3)
Tensile strength			
Maximum stress (lb/in. ²)	2,900 (11.6)	1,350 (34.2)	850 (22.5)

^{1/}Values in parentheses are coefficients of variations (pct).

^{2/}Each entry is average of 12 specimens.

^{3/}Each entry is average of 24 specimens.

^{4/}Each entry is average of 18 specimens.

^{5/}RH, relative humidity.

^{6/}Strength properties calculated from thickness at time of testing.

this treatment wherever Class B materials are permitted under building codes.

Neither of the treatments exhibited good leach resistance as shown by the Schlyter spread-of-flame results. Thus these treatments would be suitable only for interior applications.

Strength and dimensional stability.—Strength properties of specimens cut from the fire-retardant-treated 4-foot by 8-foot boards are presented in table 2. Compared to the control board with no fire-retardant chemical, the DOT-BA treated board had a 35-percent increase in bending modulus with no change in tensile and bending strengths. However internal bond strength was reduced by more than 30 percent. With the DPF treatment, losses of 27 percent to 68 percent in all of these properties were observed. These types of losses were not observed in the laboratory-made boards (Appendix). This may be due to the lapse in time between treating

the fiber and pressing the boards, or possibly to the difference in wood species.

The linear movement from 50 percent to 90 percent RH and from 50 percent RH to watersoaked for the boards with DPF treated fiber was greater than that for the control board (table 3). The DOT-BA treated board had about the same linear movement as the control. Thickness swell under both exposure conditions increased more for the fire-retardant-treated boards than for the untreated board.

After the accelerated aging exposure, the control boards, as well as the fire-retardant-treated boards, exhibited losses in all strength properties. Largest reductions were noted in the fire-retardant-treated boards. A higher percentage of original properties was retained by the boards treated with DPF. The DOT-BA formulation was a water-soluble salt, whereas the DPF formulation was a "curing type" organic phosphate (5,6), and was ex-

Table 3.—Dimensional movement and water absorption properties of the fire-retardant-treated 4-foot by 8-foot hardboards^{1/}

Dimensional movement and water absorption ^{2/}	Treatment		
	Untreated control	Disodium octaborate tetrahydrate-boric acid (4:1)	Dicyandiamide-phosphoric acid-formaldehyde
From 50 pct RH to 90 pct RH (pct change)			
Length	0.16 (2.2)	0.15 (6.3)	0.25 (3.4)
Thickness	6.65 (7.4)	7.44 (7.8)	9.50 (5.7)
Weight	6.15 (2.2)	10.73 (1.1)	11.88 (4.9)
From 50 pct RH to watersoak (pct change)			
Length	0.26 (3.6)	0.26 (15.9)	0.34 (3.9)
Thickness	20.30 (1.8)	21.25 (8.9)	21.14 (3.6)
Weight	42.36 (3.6)	38.33 (19.4)	49.11 (5.5)

^{1/}Values in parentheses are coefficients of variations (pct).

^{2/}RH, relative humidity.

pected to have better aging characteristics.

Production Problem

No particular board production problems were noted with either of the treatments. The DPF treated fiber had a tendency to stick to the cauls, but the sticky material was easily remov-

ed with the normal caul cleaning procedure.

When removed from the humidification chamber, the boards treated with DOT-BA had crystals on their surfaces; however, they were readily removed by light brushing. No difficulty was reported in finishing any of the boards when they were passed through the regular commercial flat-sheet finishing line.

CONCLUSIONS

Both treatments easily met the acceptance flamespread criteria for Class B with flamespread values under 75. The boards treated with disodium octaborate tetrahydrate-boric acid (4:1) had low smoke development

and high strength and linear stability. Because of the boards' low leach resistance, the treatments are not necessarily suited for exposure to high moisture.

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APPENDIX

In an earlier investigation (8), essentially a laboratory screening study, 21 chemicals were examined for their potential to impart fire resistance to dry-formed hardboards. Although all of the chemicals were investigated at a 10-percent level of treatment, the results with three of the most promising chemicals showed that as much as a 20-percent level would be required to provide a reasonably high degree of satisfactory performance in exposure to fire. Several of the chemicals were hygroscopic, acid salts that could, with changes in moisture,

adversely affect board stability and durability.

The objective of the work was to establish performance under exposure to fire of boards treated with seven of the most promising chemicals (from the original 21) at the 20-percent treatment level and to determine what effect, if any, a treatment might have on other desirable board properties. From these results two treatments were chosen for commercial application and the results were presented in the main portion of this report.

BOARDMAKING

Ponderosa pine fiber, commercially produced and refined under pressure, was treated with 20 percent (based on oven-dry weight) of each of the following seven fire-retardant chemicals: Disodium octaborate tetrahydrate-boric acid (4:1); monoammonium phosphate-ammonium sulfate (1:1); borax-boric acid (1:1); ammonium polyphosphate (12-44-0); melamine-dicyandiamide-phosphoric acid; and dicyandiamide-phosphoric acid-formaldehyde (table A-1). After redrying,

the fiber was then treated with 4 percent of a low-alkalinity, low-advanced (polymerization), water-soluble phenolic resin (7.2 pH). Four 22.5-inch by 24-inch by 1/8-inch thick high-density hardboards were made with each of the treated fibers; control boards were also made with fiber treated with resin only (no fire-retardant chemical). Detailed information on the chemical compositions and boardmaking procedures have been published (8).

RESULTS

Fire Performance

Fire performance by the 8-foot tunnel method (1) is shown in table A-1. Three of the treatments had flamespread indices of 21, 17, and 7. The best value of 7 was obtained with the liquid ammonium polyphosphate (12-44-0). However, this was offset by the unusually high smoke density index of 1,057. Low flamespread indices, 17 and 21, were obtained with the monoammonium phosphate-ammonium sulfate treatment and the dicyandiamide-phosphoric acid-formaldehyde treatments, respectively. Again, smoke development was high for these treatments, 825 and 919. Specimens treated with borax and boric acid developed the lowest smoke density index, 93, of the various treatments.

The next lowest in smoke index was the disodium octaborate tetrahydrate-boric acid treatment, 261, but a relatively high flamespread of 69 resulted.

Flamespread results from the 2-foot furnace (10) did not correlate with those from the 8-foot furnace. Experience at this Laboratory has shown that the 2-foot furnace will detect the flame-suppressing effect of fire-retardant treatments in wood, but does not consistently discriminate between treatment levels.

Strength Properties

Several of the treated boards had strength properties equal to or better than the control boards (table A-1). The best mechanical properties were noted with the di-

Table A-1.—Strength, dimensional movement, and fire performance properties of laboratory hardboards treated with 20 percent fire-retardant chemicals.^{1/}

Board treatment	Change in board ^{4/} —										Fire performance			
	Static bending ^{2/3/}		Internal ^{3/} bond maximum stress (lb/in. ²)	Length from 50 pct RH to		Thickness from 50 pct RH to		8-foot tunnel furnace ^{5/}		2-foot tunnel furnace ^{6/}				
	MOR (lb/in. ²)	MOE (1,000 lb/in. ²)		90 pct RH soaked (pct)	Water-soaked (pct)	90 pct RH soaked (pct)	Water soaked (pct)	Flame-spread index	Fuel contributed	Smoke density index	Flamespread index			
Untreated (control)	5,340 (7.4)	654 (5.1)	203 (25.5)	0.29 (0)	0.42 (1.7)	7.02 (0.5)	13.29 (7.4)	100	77	124	122 (2.9)			
Disodium octaborate tetrahydrate-boric acid (4:1)	6,610 (4.1)	796 (6.8)	285 (16.7)	0.28 (2.6)	0.31 (4.6)	27.27 (4.8)	30.82 (6.3)	69	22	261	44 (8.1)			
Monoammonium phosphate-ammonium sulfate (1:1)	3,910 (12.8)	612 (12.1)	78 (15.8)	0.37 (0)	0.39 (1.8)	8.45 (0)	10.79 (1.0)	17	1	825	35 (20.2)			
Borax-boric acid (1:1)	5,335 (18.9)	812 (22.4)	282 (21.3)	0.37 (0)	0.45 (7.9)	27.14 (5.2)	29.46 (2.6)	59	24	93	40 (0)			
12-4-0 (Liquid ammonium polyphosphate)	4,090 (6.3)	634 (6.4)	97 (18.4)	0.42 (1.7)	0.38 (1.9)	13.40 (2.5)	15.97 (4.3)	7	1	1,057	—			
MDP (Melamine-dicyandiamide-phosphoric acid)	5,407 (9.2)	667 (10.5)	171 (22.0)	0.35 (0)	0.44 (3.2)	8.74 (4.8)	10.83 (0.9)	52	18	468	88 (4.0)			
Dicyandiamide-phosphoric acid	5,654 (5.3)	755 (7.4)	98 (40.0)	0.33 (0)	0.35 (0)	11.41 (0)	17.01 (0)	59	17	938	53 (0)			
Dicyandiamide-phosphoric acid-formaldehyde	5,100 (8.2)	725 (5.3)	102 (10.1)	0.29 (0)	0.30 (2.4)	11.83 (3.8)	15.23 (7.8)	21	4	919	46 (0)			

^{1/}Values in parentheses are coefficients of variations (pct).

^{2/}Adjusted to 60 lb/ft³ density.

^{3/}Values are averages of seven tests.

^{4/}RH, relative humidity.

^{5/}Values are for one test.

^{6/}Values are averages of two tests.

sodium octaborate tetrahydrate-boric acid. This board had a high internal bond strength indicating the fire retardant did not interfere with the bonding action of the phenolic resin. The improvement in modulus of rupture and modulus of elasticity, but not internal bond, with some of the other treatments is apparently due to the physical reinforcement of the outermost fiber layers of the boards. The strength increases, although slight in some boards, are noteworthy. Inasmuch as board density and thickness remained the same, the amount of fiber per cube was less with treated boards because fire-retardant chemical was substituted for wood fiber.

Dimensional Movement

The boards with the disodium octaborate tetrahydrate-boric acid and with the dicyandiamide-phosphoric acid-formaldehyde had about the same linear movement with changes in moisture as the control board. However, with the other five treatments linear movement was greater than for the control. All fire-retardant treatments resulted in greater thickness swelling; the DOT-BA swelling was

almost triple that of the other six treatments. Linear and thickness movements with changes in moisture were determined by exposing 1/2-inch by 6-inch specimens for 30 days at 90 percent RH or to watersoak after they had been conditioned and measured at 50 percent RH.

Board Acidity

Board acidity was determined by milling to a powder a sample from the cured board. One gram of the dry powder was placed in 5 grams of boiled distilled water and pH measured (7). Wide differences in pH values for the different treatments were noted. It is generally agreed that fiber products with pH values near neutral will have better durability than those excessively acidic. Based on this, the disodium octaborate tetrahydrate-boric acid and the borax-boric acid treatments would be expected to have superior aging characteristics. The treatments that contained ammonium phosphate resulted in highly acidic boards, thus would be less desirable in long-term applications.

SUMMARY

From the seven fire-retardant treatments evaluated at the 20-percent level, two, disodium octaborate tetrahydrate-boric acid and dicyandiamide-phosphoric acid-formaldehyde, were selected for use in making the larger boards. Their selection represents a compromise of all properties — fire, strength, dimensional stability, and cured board pH.

U.S. Forest Products Laboratory.

A commercial application of fire retardants to dry-formed hardboards, by Gary C. Myers and Carlton A. Holmes, Madison, Wis., For. Prod. Lab. 1977. 9 p. (USDA For. Serv. Res. Pap. FPL 298).

Two fire-retardant treatments are tested to determine their performance in commercial production.

KEYWORDS: Dry-formed hardboards, fire retardants, disodium octaborate tetrahydrate, boric acid, dicyandiamide, phosphoric acid, formaldehyde, performance, flamespread.

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