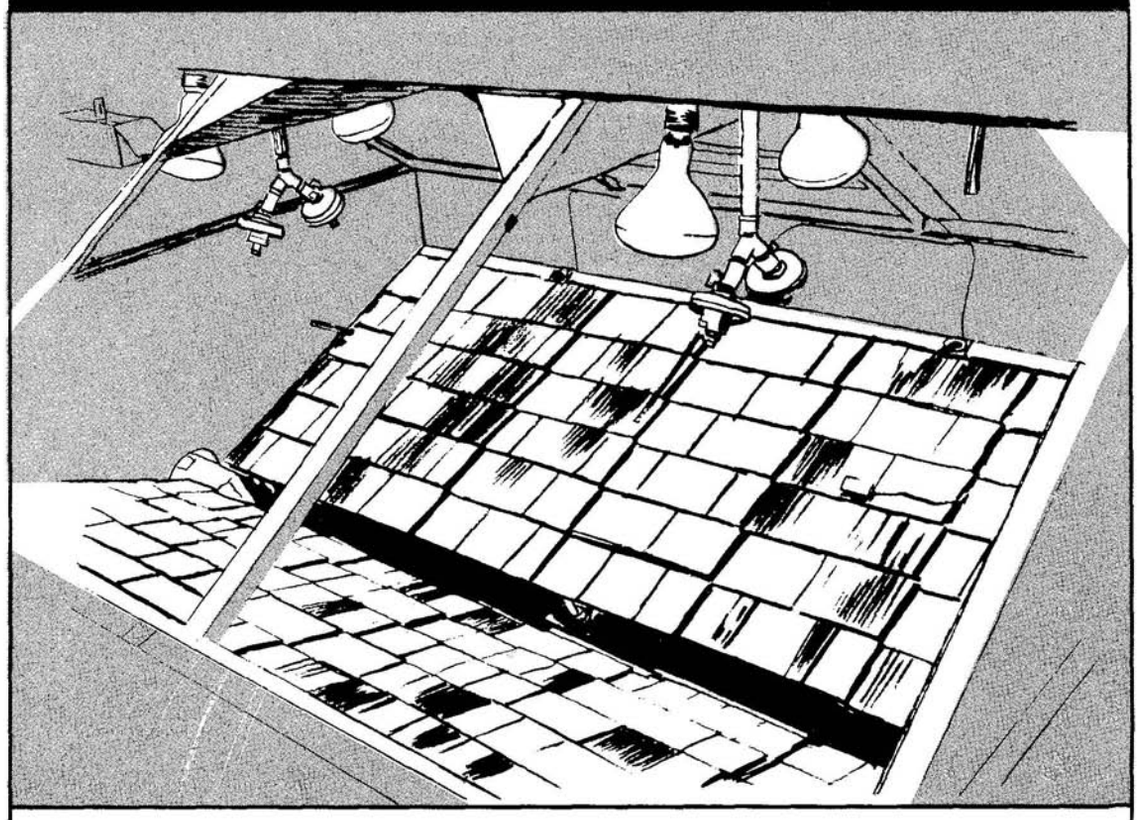
CORRELATION OF ASTM EXPOSURE TESTS FOR EVALUATING DURABILITY OF FIRE-RETARDANT TREATMENT OF WOOD



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SUMMARY

A cooperative study was carried out to determine the equivalency of two alternate methods of exposure testing described in ASTM Standard D 2898–70T, "Tentative Methods of Test for Durability of Fire–Retardant Treatment of Wood." Matched specimens of 5/8–inch Douglas–fir plywood, pressure treated with leach–resistant and nonleach-resistant fire-retardant chemical systems, were exposed by methods A and B of the standard and fire tested in the 25–foot and 8–foot tunnel furnaces. Method A is the 12–week "rain test" exposure in use at Underwriters' Laboratories, Inc., and method B is the 1,000–hour accelerated weathering chamber apparatus in use at the Forest Products Laboratory.

The two methods differ in the cycling time of water–spray and drying. However, the percent water pick up by treated specimens during the water–spray periods of the exposure cycle was approximately the same for both methods, 20 to 24 percent of initial weight. During the drying periods, specimens under method A were brought back to initial weight or below, while specimens under method B retained about an additional 6 to 8 percent water.

The flame–spread results on the treated specimens by both fire test furnaces did not show any significant difference in the leaching effect between the two exposure methods. Thus overall exposure by either method can provide conditions that differentiate between leach–resistant and nonleach–resistant treatments.

CORRELATION OF ASTM EXPOSURE TESTS FOR EVALUATING DURABILITY OF FIRE-RETARDANT TREATMENT OF WOOD

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INTRODUCTION

The wood treating industry has been making an increased effort in recent years to develop leach-resistant fire-retardant treatments for wood products used in some exterior applications. A standard method of leaching exposure was needed, however, for the evaluation of the candidate treatment systems. The controlled leaching exposure of fire-retardant-treated specimens would normally be followed by testing of fire performance by standard test methods.

This need for a standard exposure method was recognized by ASTM Subcommittee D07.12 on Fire Performance of Wood and Wood-Base Products. A task group was formed to develop a proposed test method for determining the weather resistance of leach-resistant, fire-retardant treatments. The work of the task group dealt primarily with methods in use at the Forest Products Laboratory and Underwriters' Laboratories, Inc. The effectiveness of the two methods of exposure was studied initially by the task group from data submitted by each of the two laboratories summarizing moisture pick up and loss by fire-retardant-treated and untreated wood in the two exposure methods. Based on the similarity of these moisture absorption data, the methods of exposure in use at Underwriters' Laboratories and Forest Products Laboratory were included as methods A and B in the tentative ASTM Standard D 2898-70T, "Tentative Methods of Test for Durability of Fire-Retardant Treatment of Wood" (4).[2]

Further research has now been completed to establish the equivalency of the two methods in their exposure effects on treated wood when subsequently evaluated by laboratory fire tests.

[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.

SPECIMEN MATERIAL AND PROCEDURE

Eighteen matched panels of Douglas-fir plywood, 5 feet wide by 8 feet long by 5/8 inch thick, in an exterior C-C plugged and touch-sanded grade and having a solid face, core, and center were supplied by the American Plywood Association for this research. Prior to pressure treatment, each panel was ripped into three 20-inch-wide sections and each section permanently marked with a panel number and with an A, B, or C to denote position in the panel, with B designating the center section. All sections of panels 1 through 11 were treated with a leach-resistant fire retardant to a dry chemical retention of 4.6 pounds per cubic foot of wood. All sections of panels 12 through 18 weretreated with a nonleach-resistant-type fire retardant to a retention of 3.6 pounds per cubic foot. Treatments were made by Forest Products Division, Koppers Company, Inc., using the full-cell pressure process.

After the appropriate fire-retardant treatment, the panel sections were kiln dried and, where necessary, cut to the required test dimensions. The treatment type, size, exposure method, and fire test used with the specimens prepared from 16 panels are given in table 1. Panels Nos. 11 and 18 were extra and were not used.

As indicated in table 1, three fire tests were made with each of two fire test methods following exposures by the two methods (A and B) for specimens from the leach-resistant treated panels. The fire tests were conducted in the 25-foot tunnel at Underwriters' Laboratories (fig. 1) by ASTM E 84-68 (2), and in the 8-foot tunnel at Forest Products Laboratory (fig. 2) by ASTM E 286-69 (3). Likewise, two fire tests were made with each fire test method following exposures by methods A and B for specimens from the nonleach-resistant treated panels.

In addition, to obtain control data, two tests were conducted with each fire test method on unexposed specimens having both types of treatments. To determine the effects of the greater number of horizontal joints resulting from the

Table 1.--Distribution of fire-retardant-treated specimens for durrability exposure and fire testing

Number of fire tests	Testing specimens[1]		Fire-retardant treatment	Exposure method
	Number of pieces	Size of each piece		
		TESTED IN 25-FOOT FURNACE		
2	2	20 in. x 8 ft.	Leach-resistant	None
2	6	20 in. x 32 in.	do	None
3	2	20 in. x 8 ft.	do	A
3	6	20 in. x 32 in.	do	B
2	2	20 in. x 8 ft.	Nonleach-resistant	None
2	2	20 in. x 8 ft.	do	A
2	6	20 in. x 32 in.	do	B
		TESTED IN 8-FOOT FURNACE		
2	1	14 in. x 8 ft.	Leach-resistant	None
2	3	14 in. x 32 in.	do	None
3	1	14 in. x 8 ft.	do	A
3	3	14 in. x 32 in.	do	B
2	1	14 in. x 8 ft.	Nonleach-resistant	None
2	1	14 in. x 8 ft.	do	A
2	3	14 in. x 32 in.	do	B

[1] Length of test specimen for 25-foot furnace is 16 feet, and for 8-foot furnace is 8 feet.

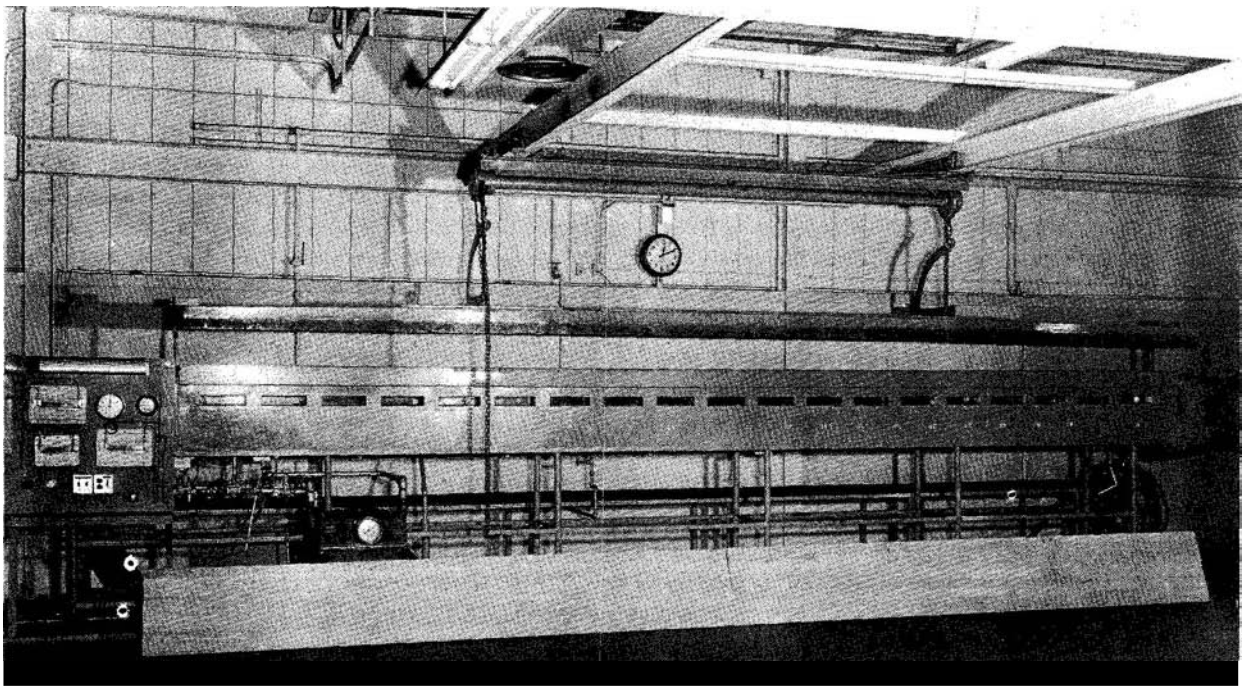

Figure 1.--Twenty-five-foot tunnel furnace, ASTM E 84-68, at Underwriters' Laboratories, Inc. On floor in front of furnace is typical 25-foot-long specimen. M 136 807

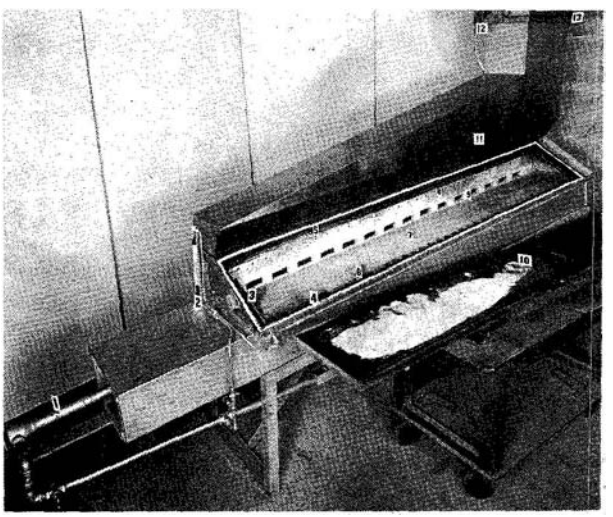

Figure 2.--Eight-foot tunnel furnace, ASTM E 286-69. 1, air-gas mixing unit to main burner; 2, gas flowmeter to igniting burner; 3, igniting burner; 4, sand seal for cover; 5, angle-iron specimen holder; 6, holes in partition plate for Meker burner tops; 7, partition plate; 8, observation ports; 9, natural draft inlets; 10, specimen cover; 11, hood for collecting combustion gases; 12, photoelectric device for smoke-density measurement; 13, thermocouple for stack temperature measurement. M 119 375

smaller sections used in exposure method B of ASTM D 2898-70T, two additional fire tests were made in the unexposed condition in each furnace using specimens made up of 32-inch lengths. In the tests made in the 25-foot furnace, only16 feet of treated specimen material was used.

Method A exposure was conducted at Underwriters' Laboratories, and method B exposure was conducted at the Forest Products Laboratory. Prior to the durability exposure, test specimens were brought to constant weight at the temperature and relative humidity conditions specified for the Particular fire test. After the durability exposure and prior to fire testing, all specimens were reconditioned to constant weight according to ASTM E 84-68 or ASTM E 286-69. Under the temperature and relative humidity conditions specified in the two standard test methods, untreated wood will come to an equilibrium moisture content, based on its ovendry weight, of 6 to 8 percent.

DESCRIPTION OF EXPOSURE METHODS

Method A Exposure

Method A of the ASTM Standard is the same as the U.L. rain-test method used in conducting their fire-resistance rating classification tests on treated wood shingle roof coverings under ASTM E 108-58 (1, 7). The apparatus (fig. 3) consists of an assembly to support the test specimens at a slope of 4 in 12. Water is applied uniformly over the specimen surfaces by spray nozzles at an average of 0.7 inch of water per hour, or 0.0073 gallon per minute per square foot of specimen surface. Specimens are subjected to twelve 1-week cycles of exposure. Each cycle consists of a continuous 96-hour water spray followed by continuous 72-hour drying at 135° to 140° F. in a room or cell with forced air circulation of at least 25 feet per minute. After the final drying period, the specimens are conditioned to a moisture content specified by the applicable fire test standard.

Method B Exposure

Method B was used at the Forest Products Laboratory in conducting an evaluation study of the various fire-retardant treatments for use with wood shingles (5). It is an adaptation of a method used under resolution No. 648, July 1, 1964, of the Board of Building and Safety Commissioners of the city of Los Angeles. The resolutionprescribed the exposure conditions for a weathering test of fire-retardant-treated shingles and shakes. The prescribed conditions were used as the basis--with some modifications--for design and construction of the FPL weathering apparatus (figs. 4 and 5).

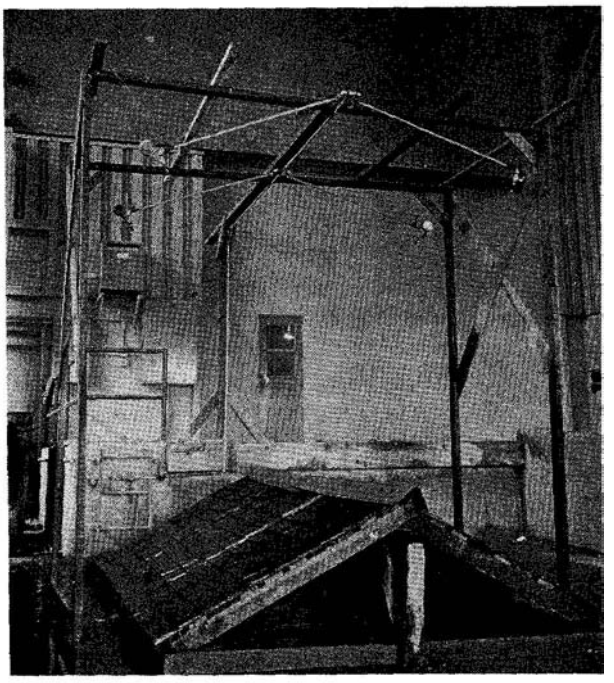

Figure 3.--Rain-test apparatus for durability exposure of fire-retardant-treated wood by method A, ASTM D 2898-70T.

The 24-hour cycle of the apparatus involves 4 hours water spray, 4 hours sunlamp radiation at 150° F., 4 hours water spray, 4 hours sunlamp radiation at 150° F., and 8 hours rest. At the conclusion of 1,000 hours of exposure, or forty-two 24-hour cycles, the specimens are conditioned as specified for the appropriate fire test.

The weathering apparatus consists of a stainless steel chamber with a V-shaped lower section containing two panel racks, which face each other, for holding the specimen panels. These racks are held at a slope of 5 in 12, but can be changed to hold the specimens at different slopes ranging from 4 in 12 to 8 in 12 maximum. Over each rack are two ultraviolet sunlamps, GE type H275 RUV 275 watt, or equivalent, directed normal to the specimen surfaces. One lamp is to be used for each 8 square feet of specimen surface. The required temperature is maintained during exposure in the chamber by circulated air heated by three 1,800 watt controlled heater elements in the blower-fan duct mounted externally on the chamber. Also over each rack are two water-spray nozzles. A pump circulates water from a separate reservoir throughthe drain at the bottom of the chamber. Solenoid-operated valves control the supply of fresh tap water into the reservoir at the start of each water-spray period and the drain of the leach water into the sewer line, During the first three water-spray periods, all water is to be drained rather than circulated. The spray rate is 0.3 ±0.02 gallons per minute per square foot of specimen surface. A program timer controls the time periods of water spray, sunlamp radiation, and rest periods.

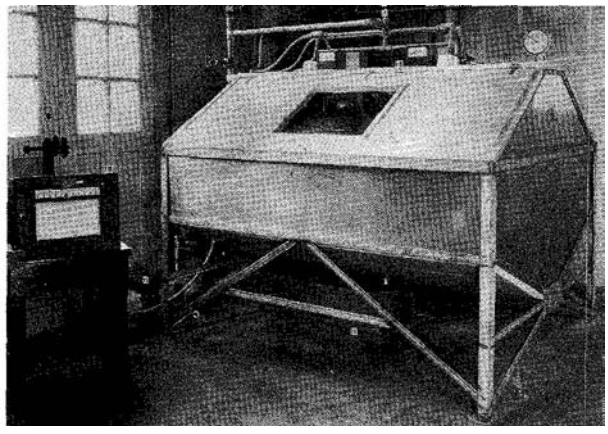

Figure 4.--Accelerated weathering apparatus for durability exposure of fire-retardant-treated wood by method B, ASTM D 2898-70T. 10, potentiometer-recorder; 11, water circulation pump and motor; 12, water reservoir; 13, meter, radiation monitor; 14, water pressure gage; 15, air temperature indicator. M 133 931

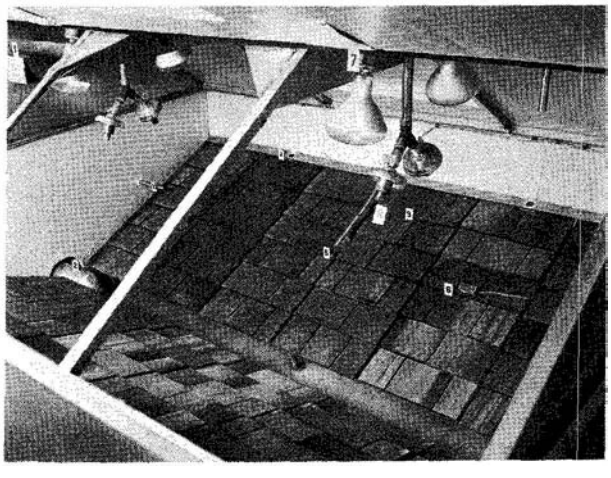

Figure 5.--Interior view of accelerated weathering apparatus. 1, hot air duct; 2, exhaust air duct; 3, controlling thermostat; 4, selenium photocell for monitoring ultraviolet light; 5, air-temperature sensor; 6, thermocouple with radiation shield; 7, type H275 RUV sunlamp; 8, water-spray nozzle; 9, specimen panel.

M 133 928

RESULTS AND DISCUSSION

The percent water pick up above initial starting weight by selected specimens during the water-spray periods under exposure methods A and B is shown in table 2.

Percent water loss from the specimens during the drying periods is illustrated in table 3.

Fire-test results obtained in the 25-foot furnace at Underwriters' Laboratories and the 8-foot furnace at Forest Products Laboratory are given in table 4.

Water Pick Up by Specimens During Exposure (Wet Cycle)

Reference to table 2 shows that the percent water pick up by the specimens by the end of the exposure period is essentially the same by either method of exposure for the specimens with the leach-resistant treatment, 22.7 percent for method A and 23.0 percent for method B. The water pick up is also about the same for the specimens with the nonleach-resistant treatment, 22.5 and 20.4 percent.

During the individual water-spray periods, the water pick up by specimens with the leach-resistant treatment varied from 21.0 to 23.9 percent for method A and from 21.4 to 23.0 percent for method B. For the nonleach-resistant treatment, the water pick up varied from 19.9 to 23.5 percent for method A and from 18.8 to 20.7 percent for method B.

Water Loss by Specimens During Exposure (Dry Cycle)

The negative values in table 3 point out that the 3-day drying periods of method A bring the water-sprayed specimens back to and slightly below their initial weight.

Such minus values indicate that all the water picked up during the water-spray period plus some of the original moisture content of the specimen was lost (dried) during the drying period, For example, a value of -3 percent means that the specimen lost all pick-up water and some of its original moisture content, which was consequently reduced from about 6 percent to about 3 percent. Plus

Table 2.--Percent water pick up above initial starting weight[1] at end of each indicated water-spray period by fire-retardant-treated Douglas-fir plywood during exposure under ASTM D 2898-70T

Method	Exposure	Fire-retardant treatment: Leach-resistant	Fire-retardant treatment: Nonleach-resistant
	Days	Pct.	Pct.
A[2]	4	23.5	23.1
	11	23.9	23.4
	18	21.9	22.3
	25	21.0	19.9
	32	22.5	23.5
	39	22.3	22.3
	46	21.7	21.4
	53	23.1	21.1
	60	21.7	21.1
	67	21.9	20.2
	74	23.9	22.3
	81	22.7	22.5
B[3]	6.5	21.4	18.8
	13.5	21.4	19.6
	20.5	22.0	20.0
	27.5	22.2	20.7
	34.5	22.6	20.7
	41.5	23.0	20.4

[1]—This weight includes an initial moisture content of 6 to 8 percent. The percent water pick up is calculated as follows: Weight of the specimen after the water-spray period minus the initial starting weight of the specimen, divided by the initial starting weight, and the result multiplied by 100.

[2]Average of three specimens with leach-resistant treatment and two specimens with nonleach-resistant treatment. Calculated from weights obtained at end of each 4-day water-spray exposure.

[3]Average of six specimens with leach-resistant treatment and six with nonleach-resistant treatment. Calculated from weights obtained at end of second water-spray period in a 24-hour cycle taken once a week.

values indicate that some pick-up water was still retained at the end of the drying period.

In method B, the drying period is less severe, 4 hours forced drying plus 8 hours rest at ambient conditions. At the end of the drying period of each day the water pick up remains at 6 to 8 percent above the initial weight.

The differences in the water pickupandloss by the Douglas-fir plywood specimens in the two methods of exposure are not reflected in the fire-test results.

Effect of Specimen Length on Fire-Test Results

There was no important difference in the average fire-test results obtained on specimens fabricated with 32-inch- and with 8-foot-long pieces (table 4). In the 25-foot furnace, the difference between the average flame-spread index results for unexposed specimens was 3-1/2. In the 8-foot furnace, the difference was 2.

Table 3.--Percent water lost from or retained above initial starting weight[1] at end of each indicated drying period by fire-retardant-treated Douglas-fir plywood during exposure under ASTM D 2898-70

Method	Exposure	Fire-retardant treatment: Leach-resistant	Fire-retardant treatment: Nonleach-resistant
	Days	Pct.	Pct.
A[2]	7	-2.8	-4.4
	14	-2.2	-4.1
	21	-2.6	-5.3
	28	-2.6	-5.0
	35	-2.8	-5.3
	42	-2.8	-5.3
	49	-3.2	-4.7
	56	-2.8	-5.3
	63	-3.0	-5.6
	70	-4.2	-7.3
	77	-3.0	-5.6
	84	-1.8	-3.8
B[3]	7	7.6	6.7
	14	7.8	6.7
	21	7.6	6.8
	28	7.2	6.5
	35	7.6	6.3
	42	7.2	5.9

[1] This weight includes an initial moisture content of 6 to 8 percent. The percent water is calculated as follows: Weight of specimen after drying minus the initial starting weight of the specimen (before water spray) divided by the initial starting weight of the specimen, and the result multiplied by 100.

[2] Average of three specimens with leach-resistant treatment and two specimens with nonleach-resistant treatment. Calculated from weights obtained at end of 3-day drying period at 135° to 140° F.

[3] Average of six specimens with leach-resistant treatment and six with nonleach-resistant treatment. Calculated from weights obtained at end of rest period in a 24-hour cycle taken once a week.

Effect of Exposure Method on Fire-Test Results

There was no important difference in the fire-test results on specimens exposed by either method A or B when tested in either furnace. This would indicate that the two methods of exposure are equivalent from a fire-performance standpoint.

The average flame-spread results inthe 25-foot furnace for specimens with the leach-resistant treatment were 24 for method A and 27 for method B exposures. For the nonleach-resistant treatment, the average results after the method A exposure were 59 and after the method B exposure, 62.

Specimens with the leach-resistant treatment had a flame-spread index average in the 8-foot furnace of 41 after method A exposure and 35 after method B exposure. Also, in the 8-foot fur-

Table 4.--Results of 25-foot tunnel furnace (ASTM E 84) tests and 8-foot tunnel furnace (ASTM E 286) test on fire-retardant-treated Douglas-fir plywood

Specimen number		Specimen length	Exposure method[1]	Flame spread	
25-foot	8-foot			25-foot	8-foot
		Inches			
Leach-Resistant Fire-Retardant Treatment					
1-B, 2-B	8-B	96	none	23	34
3-B, 4-B	9-B	96	none	30	41
5-B, 6-B	7-C	32	none	28	45
7-A, 7-B	10-B	32	none	18	34
1-A, 2-A	8-A	96	A	25	51
3-A, 4-A	9-A	96	A	23	38
5-A, 6-A	10-A	96	A	25	34
1-C, 2-C	8-C	32	B	25	34
3-C, 4-C	9-C	32	B	28	38
5-C, 6-C	10-C	32	B	27	34
Nonleach-Resistant Fire-Retardant Treatment					
12-B,13-B	16-B	96	none	28	48
14-B,15-B	17-B	96	none	25	39
12-A,13-A	16-A	96	A	59	99
14-A,15-A	17-A	96	A	59	97
12-C,13-C	16-C	32	B	54	99
14-C,15-C	17-C	32	B	69	110

[1]Per ASTM D 2898-70T.

nace, the specimens with the nonleach-resistant treatment and exposed by method A had an average flame-spread index of 98 and those exposed by method B had an average index of 104.

Effect of Fire-Retardant Treatment Type on Fire-Test Results

As expected, both methods of exposure clearly indicated the difference in leaching between leach-resistant and nonleach-resistant systems. The leach-resistant treatment performed substantially as well in the fire testing after exposure as it did without exposure. The flame-spread values for the specimens with the nonleach-resistant treatment were more than doubled in each furnace after exposure by either method. Neither method of exposure, however, results in a complete leaching of the fire-retardant chemicals. For example, in a Forest Products Laboratory plywood flammability study, the average flame spread of two tests made in the 8-foot furnace on untreated 5/8-inch Douglas-fir exterior plywood was 128 (6). In this study, the specimens with the nonleach-resistant treatment had average flame-spread indexes of

98 after exposure by method A and 104 after exposure by method B. Some fire-retardant effectiveness still remained in these nonleach-resistant treated and exposed plywood specimens.

Fire Test Methods

In this study, for the nonleach-resistant treatment, the 8- and 25-foot furnace flame-spread index results on specimens exposed by either method were about twice those obtained on the unexposed specimens. The 8-foot furnace index results were higher than those obtained on similar specimens in the 25-foot furnace. This is consistent with past experience with the two furnaces in testing treated wood. The 8-foot furnace is somewhat more severe in its effect on treated wood than the 25-foot furnace.

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CONCLUSIONS

The two exposure methods, A and B, were equivalent in their leaching effect as demonstrated by the flame-spread results in the 25-foot and 8-foot tunnel furnaces. Both methods of exposure were able to differentiate between the leach-resistant and nonleach-resistant treatments.

Water pick up by the plywood specimens of both treatment systems was approximately the same, from 20 to 24 percent of initial starting weight, during the water-spray periods of both exposure methods A and B.

Spray-water retention by the specimens during the drying periods was somewhat greater for method B than for method A. The 3-day drying period of method A completely removed the spray-water picked up during the preceding 4-day water-spray period of the weekly cycle. The water-sprayed specimens in method B retained about 6 to 8 percent water pickup at the end of the shorter drying period.

ACKNOWLEDGMENT

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