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RESEARCH NOTE
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CORRELATION BETWEEN 8-FOOT TUNNEL FURNACES

Abstract

Flammability tests were conducted with four 8-foot tunnel furnaces on matched samples of 14 different materials, and the results compared. The average flame-spread index value for each material with any one of the furnaces was usually within plus or minus 10 percent of the average for the material by the other three furnaces. The heat-contributed and smoke-index values showed greater variability than the flame-spread index values.

In general, the correlations obtained in this series of tests were similar to those reported for the two other flame-spread methods—ASTM E84 (25-foot tunnel furnace) and ASTM E162 (radiant panel furnace).

CORRELATION BETWEEN 8-FOOT TUNNEL FURNACES [1]

By

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Introduction

In an effort to determine the surface flammability of wood and wood-based materials by a comparatively inexpensive, reproducible method, the Forest Products Laboratory developed an 8-foot tunnel furnace (4).[3] This original model was modified and the new method attracted enough attention that, by 1962, three more furnaces were in operation. More furnaces were in operation at the laboratories of the Armstrong Cork Company, Lancaster, Pa., Simpson Timber Company, Bellevue, Wash., and United States Plywood Corporation, Brewster, N. Y. These new furnaces were fabricated and operated according to the information developed by the Forest Products Laboratory and included in the ASTM Committee E-5 Report for 1960 (1). Further information on the development and application of this method for measuring surface flammability characteristics has also been more recently released (3, 5, 6).

It was considered desirable in order to check the completeness and accuracy of the method description and the reproducibility of the flame-spread test to make correlating tests by these four 8-foot tunnel furnaces on matched samples of materials. This report summarizes the procedures and results for this series of correlating tests.

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[1] Excellent cooperation was provided in establishing this program, providing test materials, and supervising the test operations at the cooperating laboratories by Messrs. O. Selber, United States Plywood Corporation, Z. Zabawsky, Armstrong Cork Company, and C. Pevey, Simpson Timber Company.

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

[3] Underscored figures in parentheses refer to Literature Cited at the end of this report,

Procedure

Materials

The cooperating laboratories each supplied three or four types of products so that the entire group of products represented a range from low to high flammability. For each type of product, matched samples, selected to be homogenous and uniform, were supplied to the four laboratories. The materials supplied are in some instances from experimental runs, and therefore the results of these tests should not be considered to represent the performance of commercial products of any one of the cooperators.

The following listing gives the materials included in the roundrobin series of tests:

1. Wood fiber acoustical tile, drilled, Class D finish,
2. Mineral acoustical tile, drilled, coated.
3. 1/2–inch–thick unfinished fiberboard.
4. 3/8–inch–thick particle board.
5. 1/4–inch–thick birch plywood with clear plastic film covering.
6. 3/8–inch–thick Douglas–fir plywood with high–density paper plastic overlay.
7. Wood–fiber acoustical tile, drilled, Class C finish.
8. Wood–fiber acoustical tile with integral fire–retardant treatment, drilled, Class A finish.
9. 1/4–inch–thick untempered hardboard.
10. 3/8–inch–thick Douglas–fir plywood, AC exterior grade.
11. 3/8–inch–thick Douglas–fir plywood, AC exterior grade, treated with 4,5 to 5.0 pounds per cubic foot retention of monoammonium phosphate.
12. 3/8–inch–thick Douglas–fir plywood, AC exterior grade with two coats of commercial fire–retardant paint.
13. 5/8–inch–thick polyurethane foam sheeting.
14. 25/32–inch–thick red oak flooring, randomly selected to be in the range of 37 to 42 pounds per cubic foot.

Sufficient material was furnished to each laboratory so that two 8–foot tunnel tests could be made on each type of matched material, with an extra specimen available for check tests in the 8–foot tunnel or by other flammability tests. An extra set of specimens was also retained at the Forest Products Laboratory to send to laboratories requiring more than one check test on a product.

The test material was conditioned to equilibrium weight conditions at 80° F. and 30-34 percent relative humidity at three of the laboratories. At the other laboratory, where conditioning to a higher moisture content is normally used, conditioning was at 72° F. and 50 percent relative humidity. This slight difference in conditioning procedure, however, was not believed to be a significant factor, as the red oak standard material was also conditioned at the same condition as the test material, and the index values are relative.

Test Equipment

Insofar as is known, equipment at each of the four laboratories was the same fabricated according to detailed drawings supplied by the Forest Products Laboratory, with the exceptions:

Smoke index measurements were made with a Fireye light source and sensor at Laboratories 1, 2, and 3; with readings indicated on a Fireye dial indicator at Laboratories 1 and 3, and on a Fireye circular chart at Laboratory 2. Laboratory 4 used a GE light andphotocell with readings indicated on GE 3–milliampere meter.

Bottled propane gas was used at Laboratory 3, and to obtain proper burning, it was found necessary to use a larger injector–mixer and to substitute a straight–type 2–1/2–inch pipe burner in place of the perforated T–head 1–1/4–inch pipe burner normally used in the 8–foot tunnel furnace.

Operating Procedure

All laboratories used the same operating procedures as detailed in the proposed method of test (1), except for minor variations in the gas consumption rate required so as to have the flame travel time on standard red oak samples (37–42 pounds per cubic foot) standardized between 18 and 20 minutes. This gas consumption rate was then kept constant throughout the tests, correcting when possible for variations in gas heating value, temperature, and pressure. Flame–spread, heat–contributed, and smoke index values were computed relative to the initial standard red oak test specimens having aflame travel time over the specimen length of:

Laboratory	Time (min.)
1	18.4
2	18.6
3	20.0
4	18.5

All materials, including the acoustical tile units, were tested as self-supporting panels with no backing panel. The tile unit specimens were prepared with the edge joint in the center, and these edges were bonded together with resorcinol-resin adhesive so that the specimen was self supporting across the width of the furnace.

For several of the laboratories, these tests were performed soon after installation of the equipment, and therefore, the operator had little opportunity to gain experience. Also, in some instances, several operators performed the tests with a furnace before the entire series of correlating tests were completed,

Results

The results of roundrobin tests for the four furnaces on 14 types of materials are given in tables 1, 2, and 3.

The correlation of the flame-spread index values between the four furnaces was very good, While no statistical analysis was attempted, it can be seen that seldom does the average value for a material by one of the furnaces differ by more than ±10 percent from the average for that material by the other three furnaces. Furnace 1 showed appreciable differences only for the polyurethane foam values, which were lower than the other furnaces. Furnace 2 was high on Class C wood fiber tile, and furnace 3 was low on fire-retardant-treated plywood, Furnace 4 showed more frequent differences, with appreciable lower values being obtained on Class D wood fiber tile, particle board, fire-retardant-treated wood fiber tile, and fire-retardant painted plywood, Figure 1 shows average results of each of the three 8-foot tunnel furnaces in comparison to average results by the original Forest Products Laboratory 8-foot tunnel furnace.

The correlations between the four furnaces for the heat-contributed and smoke-intensity index values were not as good as for the flame-spread index values. For the heat-contributed index values, the reproducibility of results with each of the furnaces appeared to be very good, but the values between furnaces showed some inconsistencies. However, these values are sufficiently consistent as to be accurate for broad general comparisons of the amount of heat contributed by the burning of materials relative to red oak.

For the smoke–intensity values, the situation was similar to the heat–contributed values, with the reproducibility with each of the furnaces being good. There were, however, more variations in values between furnaces than for the heat–contributed data. Because of numerous inconsistencies, correlation between furnaces was not as good as for the flame–spread index values. Here again, the data appear to be sufficiently consistent only for broad general comparisons of the amount of smoke contributed in the burningof materials relative to that produced by red oak. Because, under the conditions of this test, only a moderately small amount of smoke is contributed by the red oak standard, many of the materials showed a considerably higher smoke–intensity index than for red oak.

Sufficient matched sample material was available for four radiant–panel furnace tests on each material. These tests were performed at the laboratories of the Armstrong Cork Company under the supervision of Mr. Z. Zabawsky. The average results from these tests on each material in comparison with the average results by the four 8–foot tunnel furnaces are given in table 4.

Discussion

The correlation of the flame–spread index values for the 8–foot tunnel was very good, considering that 14 materials and 4 furnaces were involved in this series of roundrobin tests. Most flame–spread index values were within the range of ± 10 percent of the average index value for the material, independent of which of the four furnaces was used.

Values for the heat–contributed and smoke–intensity indexes were usually consistent for a material with one furnace, but inconsistencies were observed between furnaces. Therefore, these heat and smoke indexes have more limited application in the general comparisons relative to the red oak standard.

A review of previous correlation data for the ASTM E84 (2, 7, 8) and E162 methods (data by National Bureau of Standards on correlation of radiant panel results) indicates that the variations in the three index values with the 8–foot tunnel furnace and method are sufficiently accurate for use in preparing a tentative standard which will result in reproducible data on the relative flammability of building materials.

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Table 1.--Flame-spread index results[1] between 8-foot tunnel furnaces

Sample No.	Material	Furnace 1	Furnace 2	Furnace 3	Furnace 4	Average
1	Class D wood fiber tile	152	170 (170)	170	[2] 79 (143)	
		153	169	165	[2] 79 (138)	
		152	170	168	140	158
2	Mineral tile	0	12 (0)	0	0	
		0	12 (5)	0	0	
		0	7	0	0	2
3	Unfinished fiberboard	195 (193)	190	190 (180)	176	
		199	209	206	200	
		196	200	192	188	194
4	Particle board	105 (99)	113 (117)	96	86	
		106	115	103	83	
		103	115	100	84	100
5	Plastic-coated plywood	106	123	120	125 (125)	
		111	115	124	127 (118)	
		108	119	122	124	118
6	Paper-overlaid plywood	124	118	107	112 (112)	
		116	125	105	111	
		120	122	106	112	115
7	Class C wood fiber tile	146	165 (176)	124	148	
		144	165 (174)	155	115	
		145	170	140	132	147
8	FR treated wood fiber tile	55 (41)	43	48	38	
		52 (48)	46	59	38	
		49	44	54	38	46
9	Untempered hardboard	96 (96)	94	104	86	
		99 (97)	94	107	86	
		97	94	106	86	96
10	Douglas-fir plywood	131	120	114 (117)	115	
		120	122	120	116	
		126	121	117	116	120
11	FR treated plywood	28	25	0 (3)	13 (14)	
		21	18	0	10	
		24	22	1	12	14
12	FR painted plywood	47 (44)	46	48	28	
		45 (52)	46	52	31	
		47	46	50	30	43
13	Polyurethane foam	224	372	408	350	
		259	388	400	350	
		242	380	404	350	344
14	Red oak lumber	105	94	91	116	
		108	95	91	83	
		106	94	91	100	98

[1]Values in parentheses are duplicate runs made on matched material in subsequent check tests. The results of all tests are included in the averages unless otherwise indicated.

[2]Results excluded from the averages because of improper operation of test.

Table 2.--Heat-contributed index results[1] between 8-foot tunnel furnaces

Sample No.	Material	Furnace 1	Furnace 2	Furnace 3	Furnace 4	Average
1	Class D wood fiber tile	107	122 (139)	90	75 (83)	
		111	135	89	80 (79)	
		109	132	90	79	102
2	Mineral tile	12	22 (26)	19	8	
		10	27 (25)	17	8	
		11	25	18	8	16
3	Unfinished fiberboard	163 (158)	131	139 (139)	185	
		163	133	145	196	
		161	132	141	190	156
4	Particle board	151 (150)	131 (165)	93	106	
		144	133	105	109	
		148	143	99	108	124
5	Plastic-coated plywood	127	127	124	[2]187 (119)	
		130	129	132	[2]241 (129)	
		128	128	128	124	127
6	Paper-overlaid plywood	147	152	93	[2]105 (156)	
		145	144	92	[2] 81	
		146	148	92	156	135
7	Class C wood fiber tile	90	110 (113)	80	100	
		95	114 (124)	88	60	
		92	115	84	80	93
8	FR treated wood fiber tile	23 (22)	27	93	6	
		25 (22)	21	92	0	
		23	24	92	3	33
9	Untempered hardboard	166 (180)	163	140	132	
		179 (178)	169	124	124	
		176	166	132	128	150
10	Douglas-fir plywood	158	94	92 (97)	136	
		153	109	100	132	
		156	102	96	134	122
11	FR treated plywood	14	0	19 (20)	5 (0)	
		12	2	24	8	
		13	1	21	4	10
12	FR painted plywood	16 (18)	27	22	21	
		18 (22)	27	27	4	
		18	27	24	12	20
13	Polyurethane foam	38	46	(3)	(3)	
		43	51	(3)	(3)	
		40	48	(3)	(3)	44
14	Red oak lumber	137	87	92	[4]100	
		122	89	111	[4]100	
		130	88	102	100	105

[1]Values in parentheses are duplicate runs made on matched material in subsequent check tests. The results of all tests are included in the averages unless otherwise indicated.

[2]Results excluded from the averages because of improper operation of test.

[3]Test discontinued when flames reached end of specimen, so complete data are not available with which to complete index.

[4]Missing data arbitrarily assigned value of 100.

Table 3.--Smoke-intensity index results[1] between 8-foot tunnel furnaces

Sample No.	Material	Furnace 1	Furnace 2	Furnace 3	Furnace 4	Average
1	Class D wood fiber tile	117	108 (116)	172	[2]206 (170)	
		152	52	103	[2]231 (123)	
		135	92	138	146	127
2	Mineral tile	71	6 (0)	81	61	
		81	6 (0)	38	50	
		76	3	60	56	49
3	Unfinished fiberboard	230 (265)	153	124 (184)	204	
		171	129	134	321	
		222	141	147	262	193
4	Particle board	121 (93)	130 (202)	143	152	
		131	137	152	162	
		115	156	148	157	144
5	Plastic-coated plywood	161	111	163	208 (228)	
		128	132	158	136 (244)	
		144	122	160	204	158
6	Paper-overlaid plywood	139	167	104	147	
		146	68	140	189	
		142	118	122	168	138
7	Class C wood fiber tile	98	36 (73)	132	120	
		75	5 (34)	104	141	
		86	37	118	130	93
8	FR treated wood fiber tile	342 (132)	154	95	102	
		355 (106)	146	108	89	
		234	150	102	96	145
9	Untempered hardboard	319 (238)	309	243	184	
		372 (262)	235	247	233	
		298	272	245	208	256
10	Douglas-fir plywood	160	140	102 (90)	178	
		140	238	94	230	
		150	189	95	204	160
11	FR treated plywood	329	279	300 [2](118)	[2]98	
		344	351	280	[2]76 (161)	
		336	315	290	161	275
12	FR painted plywood	1,228 (1,053)	724	562	482	
		1,248	652	555	503	
		1,173	688	558	492	728
13	Polyurethane foam	778	346	(3)	(3)	
		816	453	(3)	(3)	
		797	400	(3)	(3)	598
14	Red oak lumber	148	130	111	[4]100	
		126	107	91	[4]100	
		137	118	101	100	114

[1]Values in parentheses are duplicate runs made on matched material in subsequent check tests. The results of all tests are included in the averages unless otherwise indicated.

[2]Results excluded from the averages because of improper operation of test.

[3]Test discontinued when flames reached end of specimen, so complete data are not available with which to complete index.

[4]Missing data arbitrarily assigned value of 100.

Table 4.--Results of correlating tests by 8-foot tunnel furnaces and radiant panel on matched sample material

Sample No.	Material	8-foot tunnel[1]			Radiant panel[2]			
		Flame-spread index	Heat-contributed index	Smoke intensity index	Flame-spread index	Heat evaluation factor	Smoke deposit: Weight	Smoke deposit: Optical density
							Mg.	
1	Class D wood fiber tile	158	102	127	72	8.2	0.9	1.2
2	Mineral tile	2	16	49	1	1.0	.5	.1
3	Unfinished fiberboard	194	156	193	330	15.1	1.2	3.8
4	Particle board	100	124	144	105	18.1	1.5	>3.9
5	Plastic-coated plywood	118	127	158	156	18.5	2.3	>3.9
6	Paper-overlaid plywood	115	135	138	142	12.2	.6	2.4
7	Class C wood fiber tile	147	93	93	74	7.9	.9	1.0
8	FR treated wood fiber tile	46	33	145	3	3.1	1.2	.4
9	Untempered hardboard	96	150	256	187	31.3	1.9	>3.9
10	Douglas-fir plywood	120	122	160	209	14.2	.1	2.0
11	FR treated plywood	14	10	275	2	1.8	4.2	2.1
12	FR painted plywood	43	20	728	3	3.0	1.5	1.3
13	Polyurethane foam	344	44	598	944	9.5	.....	>3.9

[1] Results are the averages for four 8-foot tunnel furnaces, with two to four tests made with each furnace.

[2] Results are the average for four tests made with Armstrong Cork Company radiant panel furnace.

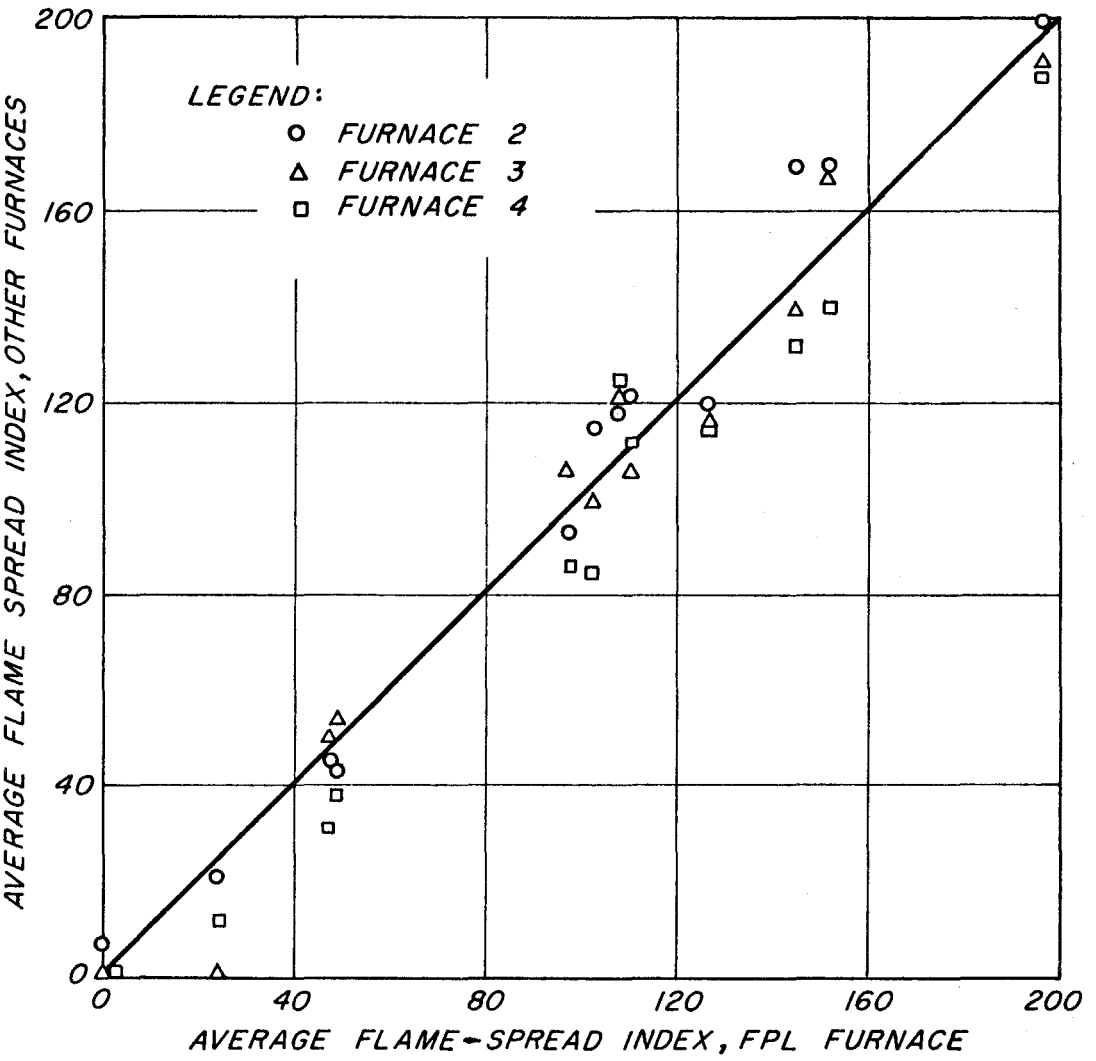

Figure 1.--Correlation of average flame-spread index values by other 8-foot tunnel furnaces to the average values by the original FPL tunnel furnace for a range of materials.

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