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Comparison of Test Protocols for the Standard Room/ Corner Test

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As part of international efforts to evaluate alternative reaction-to-fire tests, several series of room/corner tests have been conducted. Materials tested were mostly different wood products but included gypsum board and a few foam plastics. This is a review of the overall results of related studies in which the different test protocols for the standard room/corner test were used. Differences in the test protocols involved two options for the ignition burner scenario and whether or not the ceiling was also lined with the test materials. The test materials were placed on three walls of the room in all the tests. The two burner scenarios were (1) 40 kW for 300 s followed by 160 kW for 300 s and (2) 100 kW for 600 s and 300 kW for 600 s. The 40 and 160 kW burner scenario without the ceiling lined did not provide a severe enough test for flashover to occur with fire-retardant-treated materials. Use of the 100 and 300 kW burner scenario without lining the ceiling provided the ability to differentiate between wood products with ASTM E 84 flame spread indexes of 70 to 125 and those with higher flame spread indexes. Lining the ceiling with test material creates a more severe test.

INTRODUCTION

The standard room/corner test is the full-scale reaction-to-fire test for evaluating building materials. It is not only used to evaluate building materials but is often used as the basis for evaluating the validity of bench-scale reaction-to-fire tests. The ISO standard' provides for alternatives with respect to the burner scenario and whether the ceiling is also lined with the test material. The room/corner tests were largely part of international efforts to evaluate alternative reaction-to-fire tests. Materials tested were mostly wood products but included gypsum board and a few foam plastics. The tests were conducted either at the USDA Forest Service, Forest Products Laboratory (FPL) in Madison, WI, USA, or at the National Research Council of Canada (NRCC) at Ottawa, Ontario, Canada. Tests at FPL were conducted in cooperation with the State Forest Products Research Institute of Slovakia (SDVU) (Bratislava, Solvakia). The test materials were largely provided by Forintek Canada Corp., Ottawa, ON, and American Forest & Paper Association (AF&PA) (Washington, DC). Selected tests of the American Society for Testing and Materials (ASTM) interlaboratory evaluation of a proposed ASTM test protocol are also included. In addition to the room/corner tests, most of the materials were also tested in the cone calorimeter. However, this paper is limited to the room/corner tests with emphasis on the flashover times for the different protocols. This paper reviews the overall results of these related studies and compares the different protocols.

METHODS

The tests were conducted according to ISO Standard 9705[1] and the proposed ASTM standard. The proposed ASTM protocol was published as a proposed standard in 1982[2] and used for the ASTM Institute for Standards Research (ISR) interlaboratory test pragramme.[3] The standard room/corner test involves a propane burner in the corner of a room that is 3.6 m long, 2.4 m wide and 2.4 m high. The room has a single door for ventilation in the centre of one 2.4 x 2.4 m end wall.

In this series of tests, we investigated two differences in the test protocols, the two options for the ignition burner scenario and whether or not the ceiling was also lined with the test materials. The two burner scenarios were (1) 40 kW for 300 s followed by a change to 160 kW for 300 s (ASTM option) and (2) 100 kW for 600 s followed by a change to 300 kW for 600 s (ISO option).

Burner Scenario 1 was the primary protocol for the proposed ASTM procedure. The ISO 9705 standard

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Table 1. List of materials evaluated in the room/corner test

Material ID number	Material	Thickness (mm)	Density (kg/m^3)
1	Gypsum board	13	755
2	FRT plywood N	13	—
3	FRT plywood M	13	653
4	FRT plywood F	13	600
5	FRT plywood R	13	560
6	Foil-faced FR polyurethane foam N	40	—
7	FR polyurethane foam R	23	29
8	Expanded polystyrene foam	50	29
9	White spruce lumber	19	361
10	Redwood lumber	19	420
11	Red oak lumber	19	624
12	Southern pine lumber	19	593
13	Spruce plywood	13	—
14	Douglas-fir plywood M	13	515
15	Douglas-fir plywood R	13	540
16	Southern pine plywood	13	605
17	Oak-veneered plywood	13	480
18	Particleboard M	13	790
19	Particleboard N1	13	—
20	Particleboard N2	13	—
21	Hardboard	6	1025
22	Hardboard, imitation stucco coating	10	930
23	Oriented strandboard	13	645
24	Waferboard	13	620

specifies an additional 600 s for the 160 kW burner after 300 s of 40 kW as an alternative ignition programme. Scenario 2 is the primary option in the ISO room/corner test standard. In addition to the kilowatt settings, the ASTM and ISO test protocols also each specify a different size burner. In all the NRCC tests, the 305 x 305 mm burner of the ASTM protocol was used. In the FPL tests, the ASTM burner was used for Scenario 1 tests, and the 170 x 170 mm burner of ISO 9705 was used for the Scenario 2 tests. In NRCC tests without flashover, the tests were terminated at 900 s.

The second difference in the test protocols was whether or not the ceiling was lined with the test materials. In Europe, room/corner tests have generally been conducted with the ISO primary method, which is the ISO burner and the test material on the ceiling. In the United States, the ASTM protocol called for the ASTM burner and no test material on the ceiling. The test materials were placed on three walls of the room in all the tests. No test material is placed on the fourth wall, which has the door opening. In tests with no test materials on the ceiling, the ceiling was lined with gypsum board.

In the Slovakia-US projects[4] the room/corner test protocol was a combination of the European and US methods; i.e. the ISO burner but no test material on the ceiling. The Forintek-NRCC project[5,6] was largely a comparison of the ISO and ASTM test protocol but includes some tests of all four variations. Many of the wood products tested in the Slovakia project had previously been tested by FPL using the ASTM protocol' or by laboratories in the ASTM ISR interlaboratory test programme.

In the standard test, the exhaust from the room is collected via a hood and the heat release rate is determined using the oxygen consumption methodology. Visual observations are made of flame spread and the times that flames are observed emerging beyond the doorway. A heat flux meter is located at the geometric centre of the floor.

The times for flashover can be determined by a number of different criteria. In this paper, two criteria are used: the visual observation of flames emerging out the door and a heat flux of 20 kW/m^2 to the floor.

MATERIALS

Altogether, 24 materials were used in the different test series. These materials included gypsum board, four fire-retardant-treated (FRT) plywood products, a foil-faced fire retarded (FR) polyurethane foam insulation, a second FR polyurethane foam insulation, a blue-coloured expanded polystyrene foam insulation (EPS), four particleboards, two Douglas-fir plywoods, and ten additional untreated wood products (Table 1). The designations F, M, N, N1, N2 and R were used to differentiate between similar material based on the source of the materials. The F stands for Forintek, M for the material bank of wood products for fire research belonging to AF&PA, N for NRCC, and R for round robin materials (ASTM ISR interlaboratory evaluation). The material ID numbers listed in the tables are used to identify the materials in the figures.

RESULTS

Tables 2-7 show all the test series. Table 2 is the initial FPL test series using the 40 and 160 kW burner protocol

Table 2. FPL-AF&PA room/corner tests using 40 and 160 kW burner and test materials on walls only[7]

Material	Material ID no.	Times for flashover (s): Flame out door	Times for flashover (s): 20 kW/m^2 to floor
Gypsum board	1	NFO[a]	NFO[a]
FRT plywood M	3	NFO[a]	NFO[a]
Redwood lumber	10	378	378
Douglas-fir plywood M	14	380	378
Southern pine plywood	16	344	348
Particleboard M	18	336	342
Oriented strandboard	23	266	270

[a] NFO, no flashover; Test terminated at 600 s.

Table 3. ASTM ISR room/corner tests using 40 and 160 kW burner and test materials on walls only[3]

Material	Material ID no.	Number of tests	Mean time for flashover, 20 kW/m^2 to floor(s)	ASTM E 84 flame spread index[8]
FRT plywood R	5	5	NFO[a]	17.0
FR polyurethane Foam R	7	6	358	23.9
Douglas-fir Plywood R	15	10	391	91.2

[a] NFO, no flashover; Test terminated at 600 s.

with the test material on the walls.[7] Table 3 lists the average results for three of the materials tested as part of the ASTM ISR interlaboratory test programme. These three materials were later tested using the 100 and 300 kW protocol. The average ASTM E 84 flame spread index[8] (FSI) for the three materials is also included in Table 3. Table 4 lists the results for the initial NRCC series, which involved all four variations of the burner-ceiling lining protocols.' Results for a second series at NRCC are listed in Table 5.[6] These tests were limited to the primary ASTM and the primary ISO test protocols. Table 6 shows the FPL-SDVU results using the 100 and 300 kW burner scenario and the ceilings not lined. Initial results were previously reported.[4] The ASTM E 84 flames spread index values listed in Tables 6 and 7 are estimated values from the published literature and Table 3. Table 7 shows additional tests from an FPL-Forintek cooperative effort.

DISCUSSION

Four protocols

The differences in the test protocols affect the room/corner test's sensitivity to differences in the fire performance of the materials being tested (Figs 1-4). The products listed in Table 1 are grouped in the order of gypsum board, FRT plywoods, foam plastics, sawn lumber, plywood products and untreated composite wood products. This order is approximately in the order of increasing ASTM E 84 FSI. In the following discussion, we review the results for each of the four protocols. The data in this discussion and the figures are the times for the 20 kW/m^2 to the floor criterion. When there were no such data (Table 5), the times for flames out the door were used. In most cases, the times for these two criteria are nearly identical. As will be discussed later, the exceptions are the FR products.

With the 40 and 160 kW burner programme and the unlined ceiling protocol, flashover occurred shortly after the increase to 160 kW for almost all untreated wood products (Fig. 1). Only one untreated wood product (oriented strandboard) resulted in flashover during the

Table 4. NRCC room/corner tests using different test protocols[5]

Material	Material-ID no.	Times for flashover (s): 40/160 kW, ceiling unlined	40/160 kW, ceiling lined	100/300 kW, ceiling unlined	100/300 kW, ceiling lined
		20 kW/m^2 to floor			
FRT plywood N	2	NFO[a]	740	NFO[a]	640
FR polyurethane foam N	6	NFO[a]	320	690	50
Particleboard N2	20	335	275	230	140
		Flames out door			
FRT plywood N	2	NFO[a]	NFO[a]	NFO[a]	640
FR polyurethane foam N	6	NFO[a]	330	NFO[a]	63
Particleboard N2	20	335	240	230	140

[a] NFO, no flashover; Test terminated at 900 s.

Table 5. NRCC-Forintek room/corner test using different test protocols[6]

Material	Material ID no.	Time for flashover. flames out door (s) 40/160 kW ceiling unlined	100/300 kW, ceiling lined
FRT plywood F	4	NFO[a]	NFO[b]
Expanded polystyrene	8	174	36
Spruce plywood	13	372	186
Oak-veneered plywood F	17	330	78
Particleboard N1	19	306	156
Hardboard, imitation stucco coating	22	324	174

[a] NFO, no flashover; Test terminated at 900 s.
[b]Test terminated at 840 s. Floor heat flux exceeded 20 kW/m^2 during a 'steady' combustion period between 600 s and termination of test that never resulted in steady flaming out of the doorway. Heat release rate exceeded 1000 kW at about 735 s.

initial 300 s of the 40 kW burner. Using the ASTM protocol, Gardner and Thomson' found that even sawn blackbutt, which has an FSI equal to 48, had a flashover time of only 432 s. Data suggest that flashover times with this protocol cannot clearly distinguish materials that are Class II (26 to 75) in the ASTM E 84 test. There was no flashover with gypsum board, the FRT plywood products, and one of the FR polyurethane foam insulation. These materials have flame spread indexes of 25 or less.

The data for the 40 and 160 kW burner programme and the test materials on the ceiling and walls are very limited (Table 4; Fig. 2). By adding the test material to the ceiling, the particleboard N2 had flashover before the change to the 160 kW burner setting. In addition, FRT plywood N and FR polyurethane foam insulation N resulted in flashover with the test material on the ceiling (Fig. 2). When tested without the ceiling lined, these two materials did not flashover with the 40 and 160 kW burner programme.

With the 100 and 300 kW burner programme and unlined ceiling, flashovers occurred during the entire 600 s of the 100 kW burner (Fig. 3). Flashover with the waferboard occurred in 141 s. Six of the thirteen untreated wood products resulted in flashover in a narrow range of 174 and 240 s. The remaining six untreated wood products had times that ranged from 318 to 594 s. All the flashover times for untreated wood products occurred before the step increase of the burner to 300 kW at 600 s. With the FRT plywood and FR polyurethane foam plastics, flashover only occurred with the change to the 300 kW burner. In the test with FRT plywood N and in the test with gypsum board, no flashover occurred before termination of the test.

When the 100 and 300 kW burner programme was used with the test material on the ceiling as well as the walls, there were large reductions in the flashover times (Fig. 4). This was particularly the case with the FR polyurethane foam plastic N, which had a flashover time of 50 s with the ceiling lined but 690 s without the ceiling lined. With the ceiling lined, the FRT plywood products tested with this protocol resulted in flashover shortly after the increase to the 300 kW burner setting (600 to 640 s) compared with times close to or exceeding 900 s (840 to 882 s, and no flashover at 900 s) when the ceiling was not lined. A similar comparison by Tsantaridis[10] included Swedish data for the 100 and 300 kW Burner programme for tests with and without the ceiling lined. The results for particleboard, medium-density fibre board, textile wallcovering on rockwool, and paper wallcovering on gypsum board all showed reductions in the flashover times when the ceiling was also lined with the test material. In the case of the paper wallcovering on gypsum board, there was no flashover without the ceiling lined but flashover occurred as soon as the burner was

Table 6. FPL-SDVU room/corner test using 100 and 300 kW burner and test materials and walls only

Material	Material ID no.	Time for flashover (s) Flames out door	20 kW/m^2 to floor	Estimated ASTM E 84 flame spread index
Gypsum board	1	NFO[a]	NFO[a]	10
FRT plywood M	3	870[b]	882[b]	—
FRT plywood F	4	870	873	—
FRT plywood R	5	894	849	17
FR polyurethane foam R	7	618	621	24
White spruce lumber	9	594	594	65
Redwood lumber	10	519	498	70
Southern pine lumber	12	243	240	160
Douglas-fir plywood M	14	520	531	—
Douglas-fir plywood R	15	465	474	91
Southern pine plywood	16	324	321	120
Oak-veneered plywood F	17	174	174	—-
Particleboard M	18	241	237	150
Hardboard	21	227	222	185
Oriented strandboard	23	189	186	175
Waferboard	24	150	141	—

“NFO, no flashover; Test terminated at 1200 s.
[b]Actual test involved only 300 s of 100 kW burner exposure prior to the increase to 300 kW. Thus, 300 s was added to actual flashover times to obtain these values.

Table 7. FPL-Forintek room/corner tests

Material	Material ID no.	Test protocol	Time for flashover (s)	
			Flames out door	20 kW/m² to floor
FRT plywood M	3	100/300-kW burner, ceiling lined	636	633
Red oak flooring	11	100/300-kW burner, ceiling unlined	324	318
Red oak flooring	11	40/160-kW burner, ceiling unlined	366	369

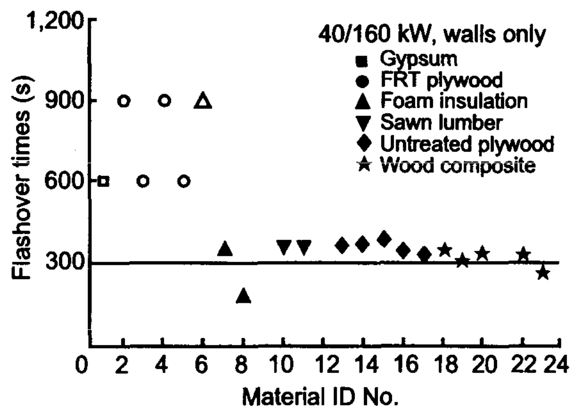

Figure 1. Flashover times for the different materials tested with the 40 and 160 kW burner programme and test material on the walls only. The material ID numbers are listed in Table 1 and are approximately in order of their ASTM E 84 FSI. If an open symbol is used, the test was terminated at that point without flashover.

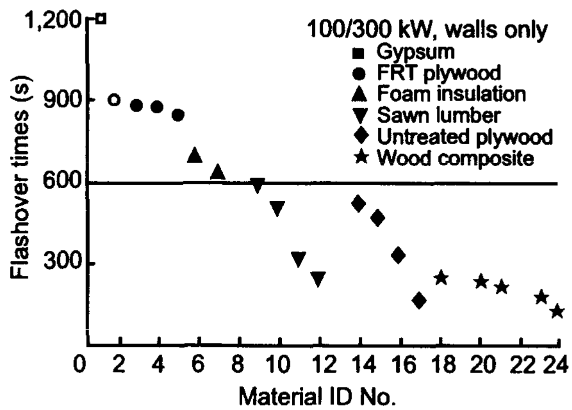

Figure 3. Flashover times for the different materials tested with the 100 and 300 kW burner programme and with test material on walls only. Material ID numbers are listed in Table 1 and are approximately in order of their ASTM E 84 FSI. If an open symbol is used, the test was terminated at that point without flashover. All but three of the tests were with the 170 mm burner.

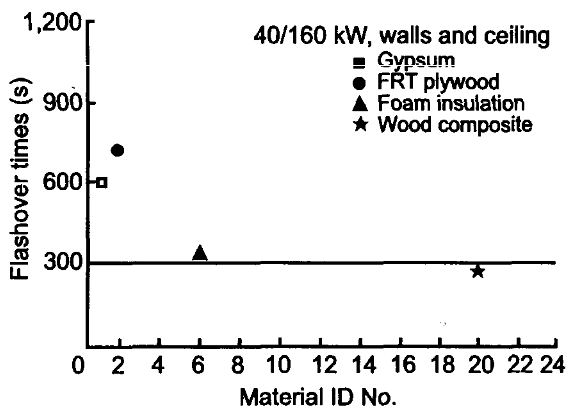

Figure 2. Flashover times for the different materials tested with the 40 and 160 kW burner programme and with the test material on both the walls and the ceiling. Material ID numbers are listed in Table 1 and are approximately in order of their ASTM E 84 FSI. If an open symbol is used, the test was terminated at that point without flashover.

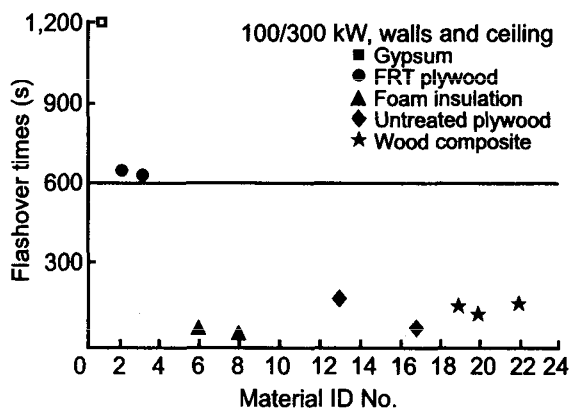

Figure 4. Flashover times for the different materials tested with the 100 and 300 kW burner programme and with the test material on the walls and the ceiling. Material ID numbers are listed in Table 1 and are approximately in order of their ASTM E 84 FSI. If an open symbol is used, the test was terminated at that point without flashover. All but two of the tests were with the 305 mm burner.

increased to 300 kW when the ceiling was lined with the paper wallcovering.

European results for FRT wood products on the walls and ceiling showed either no flashover or flashover shortly after the change to the 300 kW burner[11,12] level. In a report on 28 different materials," only one material resulted in flashover between 200 s and the change to the 300 kW burner level at 600 s. A melamine-faced particleboard had a flashover time of 465 s. Our results for 100 and 300 kW with ceiling lined are in agreement with other results of 131 to 157 s for untreated wood products.[11,12] In tests of particleboard with the 100 and

Table 8. Tests using different burner scenarios with plywood on walls only[16]

Burner programme	Time for flashover (s)	
	Flames out door	20 kW/m^2 to floor
15 min of 40 kW	604	606
5 min of 40 kW then 5 min of 160 kW	335	330
30 s of 40 kW, 30 s of 80 kW, 30 s of 120 kW, then 8 min of 160 kW	123	120
5 min of 40 kW, 5 min of 100 kW, then 5 min of 160 kW	370	366

300 kW burner programme,[12] flashover occurred at 150 s with walls and ceiling lined, 248 s with walls only, and 835 s with only the ceiling lined.

Burner size and programme

Different size burners were used in the different 100 and 300 kW tests. In the 100 and 300 kW walls only tests, all but three of the tests (Table 4) were conducted with the 170 by 170 mm burner of the ISO standard. All but one of the nongypsum tests using the 100 and 300 kW walls and ceiling protocol (Table 7) were conducted with the 305 × 305 mm burner of the ASTM protocol. All the 40 and 160 kW tests were conducted with the ASTM burner. Characteristics of 170, 300 and 500 mm burners in an open corner are discussed by Kokkala.[13] Contours of constant heat flux are different for the three burners. The constant heat flux contours are higher above the burner for the 170 mm burner than the 300 mm burner. For a 100 kW output, the maximum heat flux behind the flame of the 170 mm burner is 45 kW/m^2 compared with about 80 kW/m^2 for the 300 mm burner.[13]

While the characteristics of the 305 and 170 mm burners were different, there were no apparent differences in the flashover times for the two burners in our 100 and 300 kW tests of similar products. In tests of particleboard on walls only, we obtained similar flashover times with the 305 × 305 mm burner and with the 170 × 170 mm burner (230 s for particleboard N2 vs. 237 s for particleboard M). In the tests of the FRT plywoods (walls only), there was no flashover at the 900 s termination of the test with the 305 mm burner (FRT plywood N) but the flashover times for the 170 mm burner were 849 to 882 s (FRT plywoods M, F and R). Also, the times were 633 s for the ISO burner (FRT plywood M) and 640 s for the ASTM burner (FRT plywood N) in tests with the FRT plywoods on the walls and ceiling. Although the FR polyurethane foam insulations were different, the time for the 305 mm burner (FR polyurethane N) was 690 s compared with 621 s for the 170 mm burner (FR polyurethane R). Ahonen and others[14] conducted nine tests, with three burner size (500, 300 and 170 mm) and three burner outputs (40, 160 and 300 kW), of particleboard on walls and ceiling.[12,13] The size of the burner had little effect at 160 and 300 kW. At 40 kW, flashover times for the 500 mm burner were significantly greater than for the other two burner sizes. Characteristics of the ASTM burner were also measured by Tran and Janssens.[15]

In our series of tests, only two burner scenarios were used. In a few of our tests, flashover occurred without a change in the burner output. In our tests with particleboard N2 on walls and ceiling, flashover times were 275 s with the 40 kW burner and 140 s with the 100 kW burner. In the tests of oriented strandboard on walls only, flashover occurred at 270 s with the 40 kW burner and 186 s with the 100 kW burner. In earlier tests at FPL, the effect of different burner programmes was invesigated with Douglas-fir plywood on the walls only (Table 8).[16] This is the same plywood identified as Material 14 in Table 1. The ceiling was lined with ceramic fibre insulation. In the tests mentioned above, Ahonen and others[14] found that increasing the burner output from 40 and 160 kW reduced the flashover times for the particleboard on walls and ceiling from about 220 s to about 100 s but a further increase to 300 kW only decreased the flashover times to about 70 s.[13] All the above results are shown in Fig. 5. The results for plywood (Table 8) are shown in Fig. 5 as the duration of exposure needed for flashover for the different burner settings after an initial 300 s exposure to 40 kW. The curvilinear nature of the data in Fig. 5 indicates that there are upper limits for burner settings that will result in further significant reductions in the flashover times. The data suggest an upper limit for untreated wood products between 100 and 160 kW.

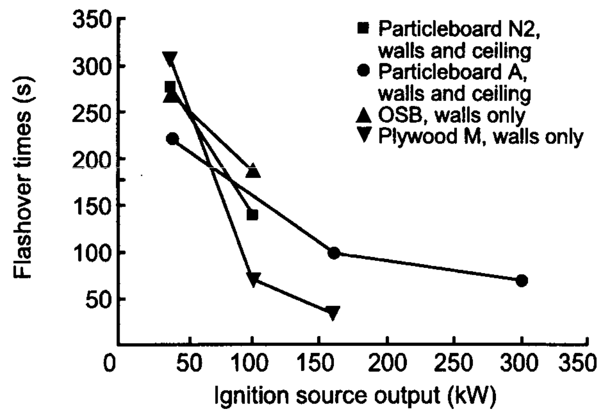

Figure 5 . Effect of changes in the burner output on the flashover times. There was a 300 s preheating using a 40 kW burner in the plywood tests. Other tests were performed with a single constant burner only. Materials are particleboard of Ahonen and others[14] (particleboard A), particleboard N2, oriented strandboard, and Douglas-fir plywood M.

Comparison and selection of protocols

The selection of which protocol to use depends on the intended purpose. The 40 and 160 kW burner with ceiling

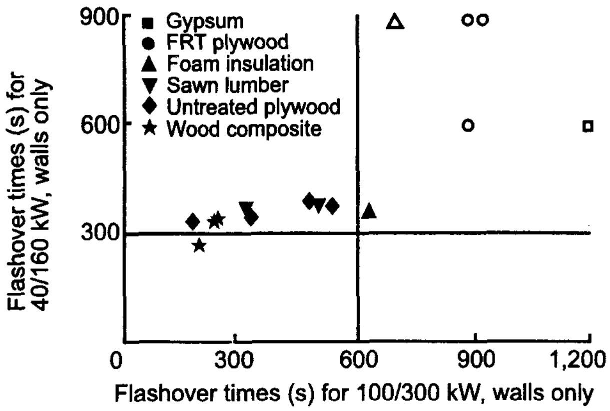

Figure 6. Comparison of flashover times for the 40 and 160 kW walls only protocol with those for the 100 and 300 kW walls only protocol. If an open symbol is used, one or both of the tests was terminated at that point without flashover.

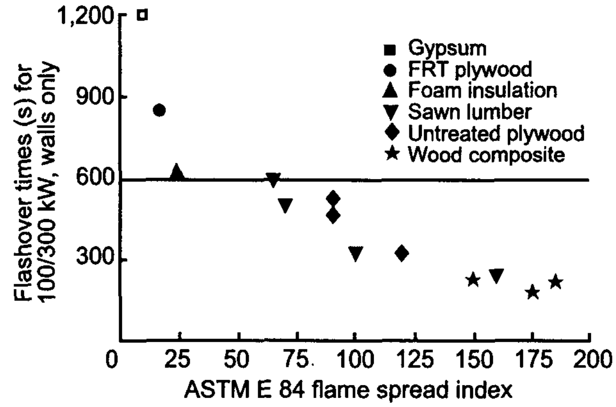

Figure 7. Comparison of the times for flashover using the 100 and 300 kW burner programme with walls only lined, with estimates for the ASTM E 84 flame spread index.

unlined resulted in small differences between the different untreated wood products but did produce a clear distinction for FR treated products in that there was no flashover for those products (Fig. 1). Because of the low 40 kW burner and its short 300 s duration, few materials will probably results in flashover during this initial exposure. Also, the 300 s of 160 kW does not distinghish between the different FR materials. Gardner and Thomson[9] found a linear relationship between the natural logarithm of the flashover times for this protocol and the ASTM E 84 FSI.

By adding the test material to the ceiling, both the FRT plywood and the FR polyurethane foam plastic resulted in flashover before the end of the test. It is also likely that more materials with low ignition characteristics will flashover during the initial 40 kW exposure with the test material also on the ceiling.

In contrast with the 40 and 160 kW scenario (Fig. 1), the use of the 100 and 300 kW scenario and the ceiling unlined (Fig. 3) provides an improved ability to differentiate the untreated wood products. This is illustrated in Fig. 6, which is a comparison of the times of the 40 and 160 kW programme and the 100 and 300 kW burner programme (both walls only).

The protocol with the 100 and 300 kW burner programme with the ceiling unlined produced results that were consistent with expected performance in the ASTM E 84 flame spread test currently used to regulate surface flammability in the United States and Canada (Fig. 7). The flame spread values used in Fig. 7 are mostly estimates based on the published literature for the generic wood products. Although the data were limited and almost totally for wood products, the groupings of results were consistent with the US classification system of I, II and III, which corresponds to ASTM E 84 FSIs of 25 or less, 26 to 75, and 76 to 200. In particular, the data suggest that flashover times with this protocol can more clearly distinguish materials that are Class II (26 to 75) in the ASTM E 84 test.

The limited comparative data suggest that there is a reduction in the ability to differentiate between the untreated wood products when the test material is also on the ceiling with the 100 and 300 kW burner programme (Figs 4 and 8). But, a more definite distinction between the broader groups of materials may be gained. Our results and results in the literature for the 100 and 300 kW walls and ceiling protocol indicate that flashover occurs with few exceptions in the first 300 s of the 600 s duration of the 100 kW burner setting or after the increase to 300 kW at 600 s (Fig. 4). Thus, the subsequent 300 s of 100 kW exposure provides a clear dividing line between classes of materials. In the one FPL test with FRT plywood in which the initial exposure was mistakenly set at 300 s (Table 6), the flashover times were identical to that for the 600 s exposure to 100 kW of the other two FRT plywoods except for the additional 300 s. With the test material on the ceiling and the 100 and 300 kW burner programme, one probably gains a more severe test of materials with very low flammability. This is seen in the Swedish results of flashover with paper wallcovering on gypsum board[10] and the large reduction in flashover times for the foil-faced FR polyurethane foam insulation N when the test material is also applied to the ceiling (Table 4).

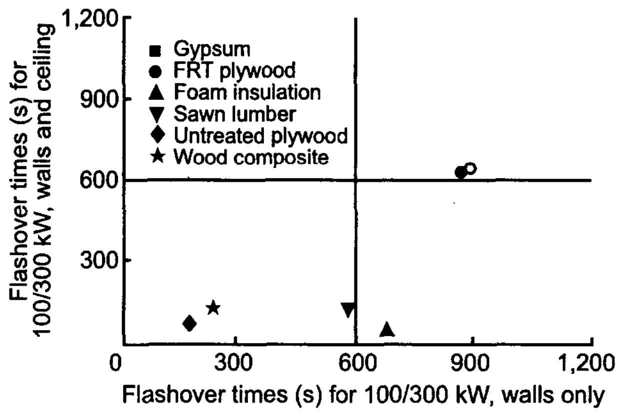

Figure 8. Comparison of flashover times for 100 and 300 kW walls and ceiling protocol with those for the 100 and 300 kW walls only protocol. If an open symbol is used, one or both of the tests was terminated at that point without flashover. Spruce lumber data for 100 and 300 kW walls and ceiling obtained from literature.[12]

Flashover criteria

A number of different criteria have been used to determine the times for flashover. In this paper, we reported data for flames out the door and heat flux of 20 kW/m^2 to the floor. In all the figures, the times for heat flux of 20 kW/m^2 to the floor are used except when data for the criteria were not reported. In Europe, the criterion of a 1000 kW heat release rate (including burner) is commonly used. Other criteria include ignition of paper bundles on the floor, average ceiling temperature of 600°C, and doorway temperature of 600°C. Criteria such as those based on heat release rate, heat flux to floor, and temperature provide greater precision in recording the flashover times compared with the subjective visual observation of flames out the door.

In tests of untreated wood products, we found agreement between the flames out the door and 20 KW/m^2 to the floor. However, there were inconsistencies in the results depending on the flashover criteria with the FRT wood products and the treated polyurethane plastics. In the 100 and 300 kW walls only tests of the foil-faced FR polyurethane foam N, the criteria of ceiling temperature of 600°C, floor heat flux of 20 kW/m^2, and paper ignition were satisified but there was no apparent flame extension out the doorway nor a 1000 kW heat release rate. Similar results were obtained with the 100 and 300 kW walls only tests of FRT plywood N in which the 600°C ceiling temperature, 1000 kW heat release rate, and paper ignition were satisified but flames out the door or 20 kW/m^2 to the floor did not occur.

Other examples of inconsistent times include the following results for FRT plywoods. In the 100 and 300 kW ceiling-lined test of FRT plywood F, the heat release rate increased quickly to about 800 kW after the burner increased to 300 kW but remained steady at this level until the test was terminated at 840 s. The heat flux to floor exceeded 20 kW/m^2 but steady flames out the door were not apparent. In the 100 and 300 kW ceiling unlined test of FRT plywood M, the 20 kW/m^2 criterion was first exceeded at 640 s while flames out the door, 1000 kW heat release rate, and the second occurrence of the 20 kW/m^2 to floor occurred later at about 880 s. In the 100 and 300 kW ceiling unlined test of FRT plywood F, the 20 kW/m^2 to floor and the 1000 kW heat release rate were initially exceeded shortly after the change to the 300 kW burner but then decreased until increasing later when flames extended out the door at 870 s.

CONCLUSIONS

As part of international efforts to evaluate alternative reaction-to-fire tests, several series of room/corner tests were conducted. Materials tested were mostly different' wood products but included gypsum board and a few types of foam plastic insulation. Results depended on the burner scenario and whether the ceiling was lined with the test material. The 40 and 160 kW burner without the ceiling lined did not provide a severe enough test to cause flashover with FRT materials. Use of the 100 and 300 kW burner programme without lining the ceiling provided a wider range of flashover times for untreated and FR-treated materials. Results were consistent with the expected performance of the wood products in the ASTM E 84 flames spread test currently used to regulate flammability in the United States and Canada. In particular, the data suggest the flashover times with this protocol can more clearly distinguish materials that are Class II (26 to 75) in the ASTM E 84 test. Lining the ceiling with the test materials provided a more severe test, particularly for FR-treated materials.

The limited data did not show any difference in this flashover time between the 170 × 170 mm ISO burner and the 305 × 305 mm ASTM burner. Burner settings of 100 and 160 kW are consistent with probable upper limits for burner settings that will result in further significant reductions in the flashover times for untreated wood products. Flashover criteria based on the heat flux to floor or heat release rate can occur without the visual observation of flames out the doorway.

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