Wall and Corner Fire Tests on Selected Wood Products

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ABSTRACT: As part of a fire growth program to develop and validate a compartment fire model, several bench-scale and full-scale tests were conducted. This paper reports the full-scale wall and corner test results of step 2 of this study. A room fire test following the ASTM proposed standard specifications was used for these full-scale tests. In step 1, we investigated the combination of factots for evaluating wood products in wall and corner fire tests. They were the position of the ignition sources power output from the source, and combination of lining materials. We concluded from the sensitivity study (step 1) that for wall and corner fire tests, a burner output program consisting of 40 kW exposure for 5 min followed by 160 kW exposure for 5 min was the most informative. In this paper, step 2 of the research program, results from wall and corner tests using six wood materials having different flame spread indices (according to ASTM E 84) are given. The two-step burner setting was confirmed to be better than a constant setting for evaluating wood materials. The relative performance of these materials was in line with thier ASTM E 84 flame spread propeties. Smoke release rates obtained by white-light and laser systems showed excellent agreement. Only rate of heat and smoke release, selected tempera-

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tures, and heat fluxes are reported. the complete reduced data set will be published later.

KEY WORDS: room fire tests, fire growth, modeling, compartment fire, wall and corner fire.

INTRODUCTION

IN A JOINT effort to develop a validated wall fire model and eventual]y a model for compartment fire growth, the USDA Forest Service, Forest Products Laboratory (FPL), and the National Forest Products Association (NFPA) initiated a research program in which selected wood products were evaluated both in bench-scale and full-scale tests. The bench-scale tests provide input data for the model, and the full-scale test data are used to verify model predictions.

For bench-scale tests, we used two heat release rate calorimeters: the Ohio State University (OSU) apparatus [1] and the National Institute of Standards and Technology (NIST) cone calorimeter [2]. The Lateral Ignition and Flame Spread Test (LIFT) apparatus [4] at NIST was used to determine ignition and flame spread properties. Approximate flame spread indices based on the ASTM E 84 standard test [3] are known for many wood products used in this program. The E 84 flame spread indices are not used for model input, but they are important for reference in light of current building code requirements in North America.

In step 1 of this research program, a sensitivity study [6] was conducted using the ASTM proposed room fire test [5] as the test method. Three factors were varied: location of the burner, burner output program, and lining materials. The burner was located at either the centerline of the rear wall or a rear corner. Four burner output programs represented the range of exposure proposed by ASTM and other researchers. Douglas-fir plywood was used in combination with either gypsum board or a ceramic fiber blanket for the ceiling and the walls that were not covered with plywood. A ceramic fiber blanket has several advantages over gypsum board such as well-known thermal properties and survivability from test to test. Therefore, it was considered a candidate for these tests. We found that the burner program consisting of 40 kW exposure for 5 min followed by 160 kW exposure for an additional 5 min was the optimum combination to test wood products. We also found that the ceramic fiber blanket used to line the ceiling and remaining walls was much more insulating than the gypsum board and resulted in faster flashover. Therefore, at least for the corner tests, which were more severe than the wall tests, gypsum board was the preferred material. Thermal exposure from the source was not as severe in the wall tests; thus, ceramic fiber lining was selected primarily for convenience.

As part of this NFPA and FPL fire research program, a materials bank has been gathered to provide materials to the program participants and to establish a database of wood products. A subset of the materials bank was selected to be tested in this study. Five materials having a range of flame spread indices plus the Douglas-fir plywood data from the sensitivity study [6] were used in step 2 of the research program and are the subject of this paper.

EXPERIMENTAL P'ROGRAM

Room Test Facility

The FPL room test facility was constructed to conform with the specifications of the ASTM proposed standard. Figure 1 shows the geometry of the room and location of the burner for the two test positions–wall and corner. The gas burner is a square, sand burner. Propane (C. P. grade, of at least 99% purity) was metered by an electronic mass-flow controller. The basic instrumentation included heat flux meters, two of which were placed at the geometric center of the floor to monitor radiative heat flux from the heated ceiling and the upper hot gas layer. Two thermocouples, 0.1 m below the geometric center of the ceiling and 0.1 m below the top of the door sill, measured the temperature change during the course of the fire test. In addition, many thermocouples were placed at selected locations to monitor temperature-height profiles in the room and in the doorway. Several differential pressure probes were placed at selected heights on the front wall to monitor pressure drops across the doorway. At least one pressure drop measurement combined with temperature profiles in the doorway and within the room provided information for calculations of mass flow in and out of the doorway. Mass flow rates are needed for model validation.

Figure 2 illustrates the feature of the exhaust, hood and duct system, which is crucial in the measurement of heat and smoke release rate. Flow rate in the duct was calculated on the basis of differential pressure across a bidirectional probe and gas temperature at the location of the probe. An exhaust gas sample was drawn from the sampling probe and anal,yzed for O_2, CO, CO_2, and H_2O vapor. Flow rate and

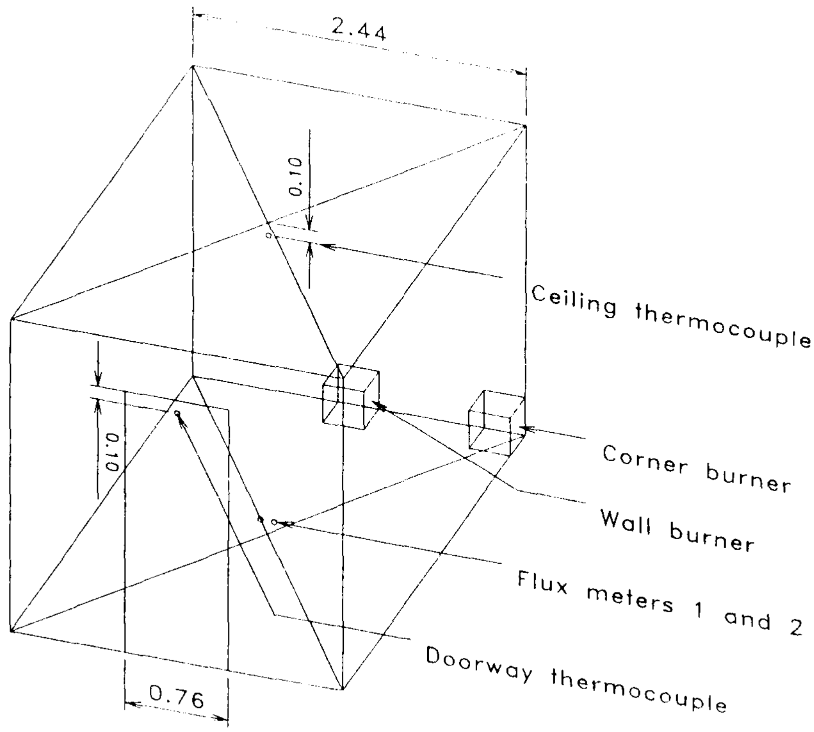

Figure 1. *Three-demensional view of burn room (dimensions are in meters).*

species concentrations were needed for oxygen consumption calorimetry of heat release [7]. For smoke release rate measurement, a white-light smoke system measured transmittance of light across the duct. In several tests in this series, a He–Ne laser smoke system (632 nm) was added and placed between the gas sampling probe and the white-light smoke system. Thus, smoke opacity was measured simultaneously by both systems.

The exhaust rate can be adjusted by a blower having a capacity of 1 to 3 m^3/s. For all tests, the exhaust rate was set at the lowest setting and increased after flashover to remove all exhaust gases. Data were recorded on a personal computer at a sampling rate of 6 s. Three min of baseline data were collected before ignition of the burner.

Materials

The six wood materials in this study were Douglas-fir (DF) plywood, redwood, southern pine (SP) plywood, particleboard, oriented strandboard (OSB), and fire-retardant-treated (FRT) SP plywood. The DF plywood was also used in the sensitivity study [6]. The other five materials are a subset of the materials bank. The DF plywood was 5-ply CD grade, 32/16, PSI-83, all Douglas-fir veneer. Redwood was tongue and groove lumber. The SP plywood was 4-ply CD grade, 32/16, PSI-83, all southern pine veneer. Particleboard was southern pine, urea bonded for interior use. The OSB consisted mostly of aspen flakes and was bonded by phenolic resins. The FRT plywood was from the same stock as the SP plywood and was treated with a proprietary treatment. Prior to testing, the materials were conditioned at 23° C and 50% relative humidity. Material thickness, density, and measured equilibrium moisture content after conditioning are given in Table 1.

Test materials were selected based on their relative flame spread classification in the ASTM E 84 test. According to that test, materials are divided into three classes based on their flame spread index (FSI). Class I has FSI of 0-25, class 1126--75, and class III 76-200. The FRT plywood had an FSI of 25, class I. Redwood had an FSI of 70, class II. The DF plywood and SP plywood had an FSI of about 115 to 130 and were in the low range of class III. The particleboard had an FSI of about 150, class III. The OSB material used had an FSI of 175, also class III.

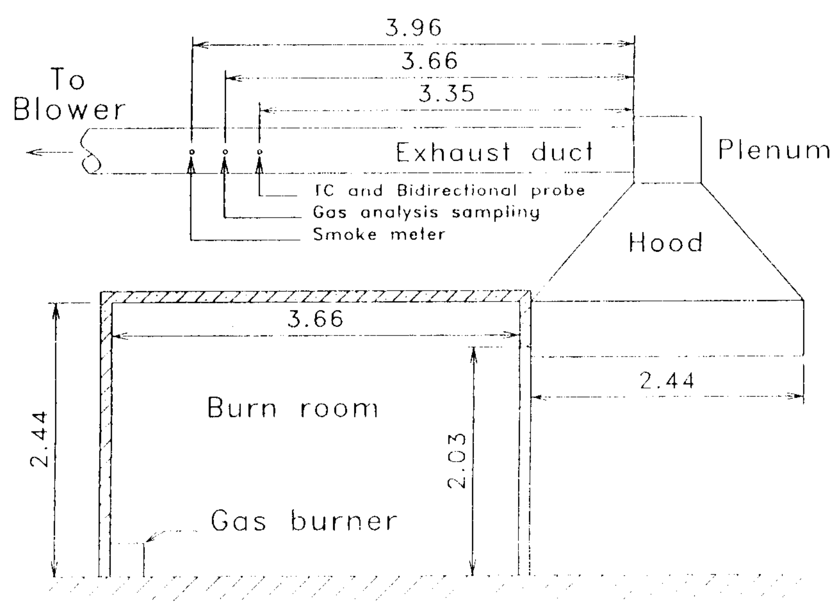

Figure 2. *Cross section of room and* exhaust system *(dimensions are in meters)*

Table 1. Material properties.

Material	Thickness (mm)	Oven-Dry Density (kg/m^3)	Equilibrium Moisture Content (%)
Douglas-fir plywood	12	526	9.1
Redwood	19	389	7.9
Southern pine plywood	12	580	8.8
Particleboard	13	788	7.1
Oriented strandboard	12	644	7.3
Fire-retardant-treated plywood	12	653	9.2

Test Series

A series of calibration tests with ceramic fiber blankets or gypsum board and with the burner in both the wall and corner positions was completed in the sensitivity study. The burner was the only source of heat in these tests. A summary of these tests is given in a published paper [6] and will not be repeated here.

In the study reported here tests on wood materials were subdivided into two series, wall and corner. Most tests were conducted in the winter in Wisconsin; therefore, the ambient test conditions were fairly dry. The materials were installed in the room test facility within 48 hours prior to testing. Changes in moisture content of the materials could not be controlled once the materials were installed. Instead, the material moisture content was measured at test time using small samples that were exposed to the same conditions as the test materials. The wall and corner test series and the moisture content of the materials on the day of the test are summarized in Table 2. All materials were mounted on type X gypsum board hacking.

In the wall tests, only the rear wall was lined with wood. The ceiling and remaining walls were lined with ceramic fiber. The burner was against the rear wall at the centerline. A wall test with DF plywood from the sensitivity study (test 16R) and five materials from the materials bank (tests 27–31) comprised this series. In the sensitivity study, the ceramic fiber blanket was found to increase the severity of the test. However, in the wall tests, the burner did not cause as severe an exposure as in the corner tests. Therefore, the ceramic fiber blanket for the wall tests was used mainly for convenience.

In the corner tests, the rear and the right walls were lined with wood material. The burner was flush with these two walls. Six materials, the DF plywood tested previously (test 5) and the five materials in the

Table 2. Test series.

Series and Lining*	Test	Material	Moisture Content (%)
Wall, ceramic fiber	16R	Douglas-fir plywood	6.6
	27	Redwood	5.0
	28	Southern pine plywood	5.9
	29	Particleboard	6.7
	30	Oriented strandboard	5.1
	31	Fire-retardant-treated plywood	9.2
Corner, gypsum board	5	Douglas-fir plywood	9.1
	32	Redwood	7.6
	33	Southern pine plywood	7.8
	34	Particleboard	6.7
	35	Oriented strandboard	5.1
	36	Fire-retardant-treated plywood	9.3

*Lining of ceiling and remaining walls

materials bank (tests 32–36), were used. In this corner series, the ceiling and the remaining walls were lined with type X gypsum board, 16 mm thick. Gypsum board was used because ceramic fiber would increase the severity of the test and make it difficult to evaluate the materials.

RESULTS

Data Reduction and Calculations

Data reported in this paper include the following:

1. Heat release rate (HRR) from the test using the oxygen consumption method. The equations used in the data reduction are those developed by Parker [7].
2. Flashover times using three common criteria: Flames observed outside the door (flameover), radiant heating flux to the floor exceeding 20 kW/m^2, and the temperature near the top of the doorway (0.1 m from sill) exceeding 600 °C.
3. Smoke release rate in units of specific extinction area, as defined by Babrauskas [8]. This measurements requires knowledge of the mass loss rate. Mass loss rate of the test material was not available, Therefore, it was estimated based on HRR divided by the effective heat of combustion of the materials as obtained in the bench-scale tests.

Heat Release Rate

Calibration runs were conducted to check the burner output and the HRR calculation programs. The burner output with the 40 and 160 kW exposure is shown in Figure 3. Good agreement between the calculated HRR and the control was obtained. The noise in the HRR curve is due mostly to the pressure transducer used to monitor pressure drop across the bidirectional probe in the duct. The mass loss of the propane tank was checked over several calibration tests. and the total mass loss agreed with the total amount of propane measured by the mass flow controller within 5% uncertainty.

The HRR from the tests was calculated using the oxygen consumption method. The heat release from the mall materials was obtained by subtracting the HRR from the burner obtained as a three-point smoothed average of the solid curve showm in Figure 3. The HRR curves of the wall and corner tests are shown in Figures 4 and 5. respectively. The HRR curves are shown up to flashover because after the exhaust blower was increased, a sharp peak results as an artifact of a sudden increase in flow rate in the duct. Also, the fire was extinguished soon after flashover.

In the wall tests (Figure 4), HRR was low during the first ,5 min at 40 kW exposure. Upon increasing the burner to 160 kW, HRR acceler-

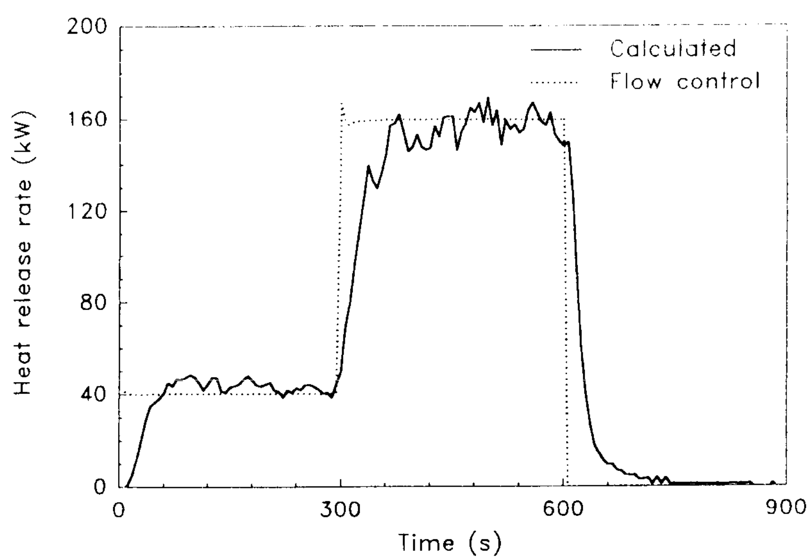

Figure 3. *Calibration test 21, corner test with ceramic fiber lining*

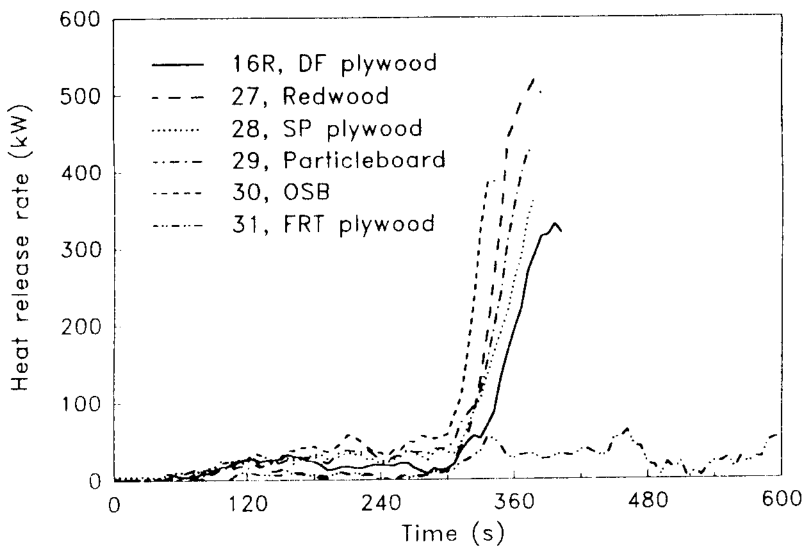

Figure 4. *Heat release rate of wall tests, no burner contribution*

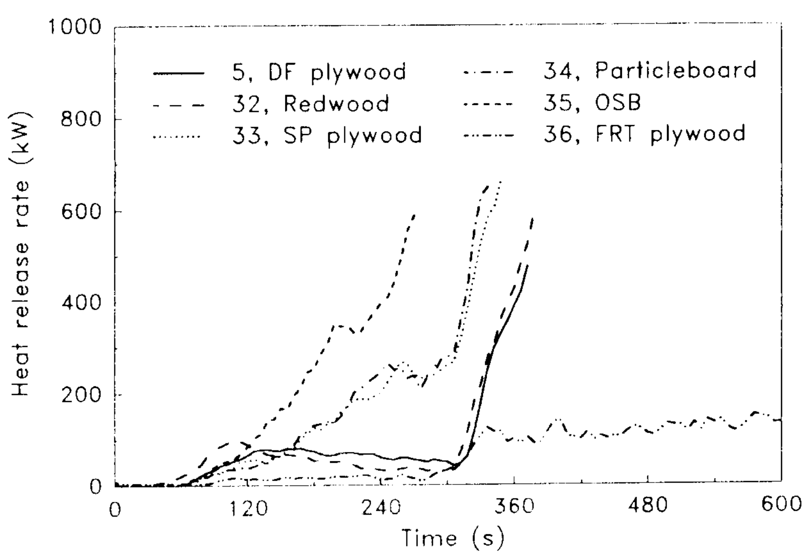

Figure 5. *Heat release rate of corner tests, no burner contribution.*

ated in all tests, except for the test on FRT plywood, which did not lead to flashover after 5 min exposure to 160 kW. In the corner tests (Figure 5), the separation between materials was more pronounced. Similar to the wall tests, all corner tests led to flashover except for the test on FRT plywood. The DF plywood and redwood had a similar fire growth pattern. The HRR was low during the first 5 min of 40 kW exposure and accelerated after the increase to 160 kW. The SP plywood and particleboard had a steadily increasing HRR during the first 5 min and caused flashover shortly after the burner increase. The OSB had the steepest HRR curve during the first 5 min, resulting in flashover before the burner increase. The FRT plywood did not release sufficient heat for flashover.

Flashover Information

Flashover has been defined in many ways. However, it is generally recognized as the point of fire buildup that is sufficient to ignite all materials within a compartment through radiative heat transfer. Several criteria determine the point of flashover: 1) flameover; that is, excess pyrolyzate burning outside the compartment doorway, 2) radiative heat flux to the center of the floor from the heated ceiling or the upper layer >20 kW/m^2, and 3) temperature > 600°C near the top of the doorway. These events may or may not occur at the same time, depending on the burning characteristics within the room. For all tests, the times to flashover using these three criteria and the HRR that includes the burner contribution at flashover using the flux criterion are shown in Table 3.

The FRT plywood material did not cause flashover in either the wall or the corner tests. The remaining five materials caused flashover after the burner was increased to 160 kW in the wall tests. In the corner tests, flashover occurred shortly before the increase of the burner for OSB. For the remaining materials, flashover occurred after the increase of the burner to 160 kW. The HRR at flashover, including the burner output, was about 500 kW in the wall tests and 700 kW in the corner tests.

In the wall tests, flameover did not occur even though the flux and temperature flashover criteria were reached. The temperature criterion was met significantly later than the flux criterion. Evidently, because of the high degree of insulation of the ceramic fiber, radiative feedback from the extended ceiling and the upper layer caused the flux criterion to be exceeded first. However, no excess pyrolyzate was available for flaming outside the door. In the corner tests, the flame and flux criteria agreed well with each other. The temperature criterion agreed sufficiently well with the flame and flux criteria for the two plywoods and was significantly delayed for particleboard and OSB. In test 32 with redwood, the doorway thermocouple malfunctioned at 360 s before flashover occurred. In test 35 with OSB, the maximum temperature of 590 °C was reached significantly later than the *flame* and flux criteria. The flux criterion is the most reliable indicator of flashover conditions; therefore, we will use this criterion when referring to flashover from here on.

Smoke Release Rate

Smoke extinction in the duct was continuously monitored in all tests with a white-light smoke system. In most corner tests, an additional laser smoke extinction system was added. Smoke release rate is calculated as the product of the extinction coefficient k and the volumetric flow rate V in the duct. Extinction coefficient according to de Bouguer's law is defined as

$$k = \frac{1}{L} \ln\left(\frac{I}{I_0} \right) \qquad (1)$$

where L is the path length *(m)* across the duct, and I_o, and I are intensities of the incident light and transmitted light, respectively (W/m^2).

Table 3. Flashover information

Series	Test	Material	t_{flame}* (s)	t_{flux}** (s)	t_{door}† (s)	HRR (kW) (Including Burner)
Wall	16R	Douglas-fir plywood	None	384	450	447
	27	Redwood	None	348	378	500
	28	Southern pine plywood	None	366	390	497
	29	Particleboard	None	360	372	547
	30	Oriented strandboard	None	336	342	534
	31	Fire-retardant-treated plywood	None	None	None	N/A
Corner	5	Douglas-fir plywood	380	378	372	707
	32	Redwood	378	378	Malfunction	719
	33	Southern pine plywood	344	348	336	725
	34	Particleboard	336	342	390	705
	35	Oriented strandboard	266	270	312	676
	36	Fire-retardant-treated plywood	None	None	None	N/A

* t_{flame} is time to flame out the door
** t_{flux} is time to 20 kW/m^2 at the door
† t_{door} is time to read 600°C in upper layer; 592°C for test 34

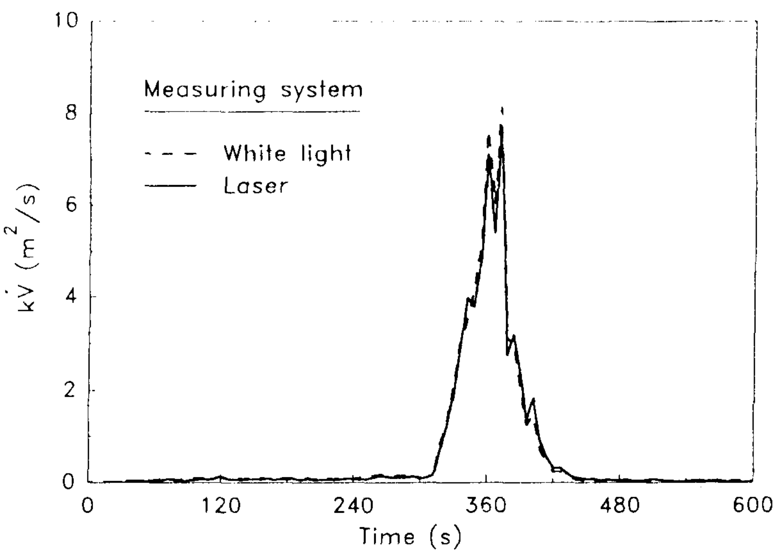

Figure 6. *Smoke release rate from corner test 33, Southern pine plywood*

A typical smoke release rate curve with both smoke measuring systems is shown in Figure 6. Agreement between the white-light and laser systems is excellent. For analysis, the white-light system data were used because they were available for all tests.

For modeling purposes, smoke data were reduced to smoke specific extinction area σ (in m^2/kg), defined [2,8] as

$$\sigma = \frac{k\dot{V}}{\dot{m}} \tag{2}$$

where in is the mass loss rate of the burning material (kg/s), and V is the volumetric flow rate of gases at the smoke measuring point (m^3/s).

Mass loss rate of the materials was not directly measured. It was estimated from HRR divided by the effective heat of combustion obtained in the bench-scale tests. The effective heat of combustion was obtained in an OSU chamber modified at FPL for the oxygen consumption method. Because of the noise in HRR data, specific extinction area calculated was also very noisy. Therefore, the data were reduced further to an average extinction area as follows:

$$\bar{\sigma} = \Delta h_c \frac{\Sigma(k\dot{V}\Delta t)}{THR} \tag{3}$$

where the numerator is the integral of $k\,V$ up to flashover, THR is the cumulative heat release (no burner contribution) up to flashover, Δh, is the effective heat of combustion obtained from the bench-scale OSU tests. The smoke contribution from the propane burner was assumed to be negligible.

The specific extinction areas at flashover and the average extinction areas for all tests are given in Table 4. For the FRT plywood test, which did not flashover, the specific extinction area at 10 min is given. Note that specific extinction area is a measured of “smokiness” based on the mass loss rate. For wood materials, it is about 50 to 100, which is very low compared to that of some nonwood materials. The FRT plywood produced significantly less smoke than did the other wood materials.

DISCUSSION

Repeatability of a room fire test is deemed very good. A replicate of a DF plywood test done at FPL at a later date gave almost identical results to the test reported here. A similar test run at Weyerhaeuser Fire Technology Laboratory using DF plywood (not from the same stock) gave identical results.

Moisture content of wood materials at the time of testing can be significantly different from the equilibrium moisture content. Moisture contents of the wood materials were measured with an ovendrying technique using small samples. The moisture content values in Table 2 are lower than those obtained at equilbrium in the conditioning chamber (Table 1). Becuase small samples were used (25 to 50 mm wide), we

Table 4. Smoke release rate

	Specific Extinction Area σ (m^2/kg)			
	Wall Tests		Corner Tests	
Material	Average	At Flashover	Average	At Flashover
Douglas-fir plywood	43.6	34.3	System malfunction	
Redwood	95.9	79.7	61.7	86.6
Southern pine plywood	39.5	53.8	34.3	98.6
Particleboard	36.7	39.4	38.8	80.4
Oriented strandboard	23.1	8.4	35.3	69.0
Fire-retardant-treated plywood*	0.7	0.1	18.2	5.9

*Flashover did not occur. Specific extinction area at 10 min is given.

expected that their moisture content would change faster than that of the full-sized panels mounted against the wall. The true moisture content values of the panels were expected to lie between those values listed in Tables 1 and 2. The relatively long time required to install the materials and to instrument the room presents problems in running full-scale tests. Although the moisture content effect was not characterized in our test series, it is expected that the lower moisture content adversely affected the performance of the materials. The effect of moisture content remains a subject of study which is not dealt with in this study. Most wood materials did not cause flashover during the 40 kW "preheat" period; therefore, a preheat period may be advantageous in partially "equalizing" the moisture content between tests.

The wall test series in this study required approximately 500 kW to reach flashover conditions with flux and temperature criteria. Only one wall was lined with the wood material. Therefore, fuel was insufficient to produce excess pyrolyzate for flaming outside the doorway. The low HRR required to attain flux and temperature criteria is explained by the high insulating effect of the ceramic fiber lining on the ceiling and remaining walls. Also, as a result of the effect of the ceramic fiber, the HRR curves of the untreated materials were very similar (Figure 4).

The separation of the materials was much better with the corner tests with gypsum board lining on the ceiling and remaining walls (Figure 5) than with the wall tests. Evidently, four different patterns developed among the six materials tested. The OSB material had the most rapid and continuously rising HRR. A short period of recession occurred, and then the HRR continued to rise to flashover, which occurred within the first 5 min of the test. The SP plywood and particleboard had a slower rate of growth in the first 5 min. Significant recession of HRR occurred between 4 and 5 min. The HRR accelerated upon the increase of the burner to 160 kW. For redwood and DF plywood, HRR did not increase during the first 5 min and required 160 kW to initiate rapid fire growth. The FRT plywood had a fairly low HRR and did not cause flashover. For the corner tests with gypsum board on the ceiling and the remaining walls, a HRR (including the burner) of approximately 700 kW was sufficient to attain flashover conditions (Table 3). However, because the HRR increased very rapidly before flashover, its magnitude at flashover is uncertain and little value should be attached to it.

The clear distinction between materials in the corner tests confirms our previous conclusion [6] that our scenario find test conditions in the corner configuration are optimal for testing wood products. A more severe scenario such as in the wall tests with ceramic fiber or in the recommended ISO test protocol** [11] would not allow for as clear a distinction to be made between the materials tested and is therefore considered undesirable.

The overall objective of this study was to generate large-scale test data to validate algorithms or models using data from bench-scale tests. Studies have shown that simple correlations can be established. However, the problem with this approach is that it is only applicable to a particular test configuration and useful only within a familiar range of products. Yet, simple correlations have their merit in linking performance of materials in a bench-scale test to behavior in one or more specific full-scale fire scenarios.

One such attempt was carried out by Gardner and Thomson [9] who correlated the FSI (ASTM E 84) and the time to flashover. Their room test protocol was similar to the corner tests carried out in this study. A fairly linear relationship between the natural log of time to flashovcr and FSI was obtained. The authors found that sawn radiata pine with a fire retardant coating and an FSI of 6 (class I) did not flashover during the 40 kW (5 min) followed by 160 kW (5 min) exposure. Lauan plywood with an FSI of 170 (high class III) caused flashover at 270 s during the 40 kW exposure. For the other materials with an FSI of 48 to 104 (class II and low class III), flashover occurred after the burner increase to 160 kW.

The results in the corner test series described in this paper were similar to those of Gardner and Thompson. The FRT plywood did not flash over. Flashover for the 0SB material having a high class III FSI occurred at the end of the 40 kW exposure. Redwood and DF plywood having an FSI of 70 and 100, respectively, caused flashover at approximately the same time (3178 s). The SP plywood and particleboard had a similar fire growth pattern during the first 5 min with flashover at approximately the same time (342 to 348 s).

With respect to the FSI, the corner tests can distinguish class I mate rials (no flash over) and high class III materials (flashover during the first 5 min at 40 kW). However, the performance of class II and low class III materials in the corner test was mixed, indicating that factors other than wind-aided flame spread, as found in the ASTM E 84 test, affected the overall fire growth. Figure 7 is a composite of Gardner and Thomson's data and the corner test results described in this paper.

Other empiriacal correlations involving a number of factors have been

**The main scenario in ISO DP 9705 prescribes lining of three walls and the ceiling with the test material and using a burner program of 100 kW for 10 min folloewd by 300 kW for another 10 min.

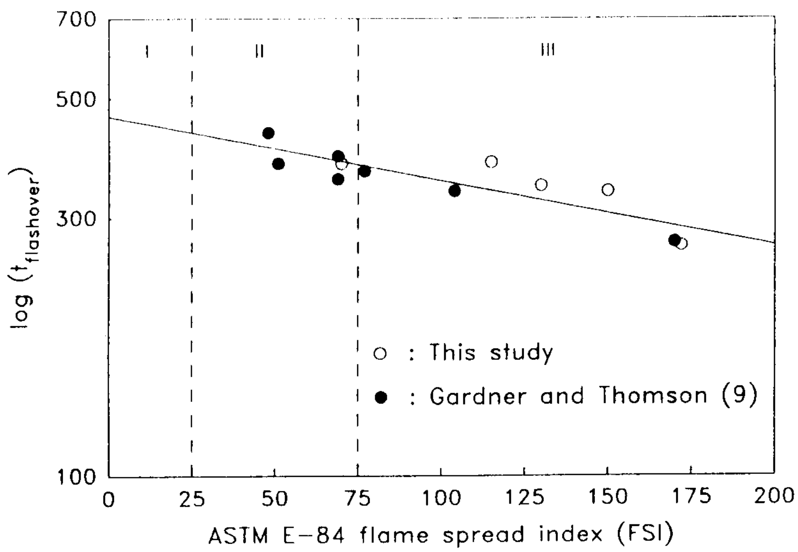

Figure 7. Correlation between flashover time and the ASTM E-84 flame spread index.

proposed. For example, Östman and Nussbaum [10] suggested a correlation between time to flashover and a combination of time to ignition in a bench-scale test at an irradiance of 25 kW/m^2, density of the lining material, and bench-scale HRR over the peak burning period at an irradiance of 50 kW/m^2. Their full-scale tests used a room of the same dimensions as the ASTM standard room. However, the burner and its output were set according to the ISO DP 9705 draft standard (100 kW for 10 min, and raised to 300 kW if fiashover did not occur). The back wall, two side walls, and ceiling were lined with the test material. Most materials caused flashover during the 100 kW exposure, except for gypsum board.

As mentioned, simple correlations may only be applicable to a narrow range of products and test configurations. For instance, in the full-scale tests used for correlation by Östman and Nussbaum, the ceiling was also lined with the test material. In such cases, fire growth is driven by wind-aided flame spread over the ceiling. In our corner tests, however, the ceiling was noncombustible and visual observations showed that downward (i.e., wind-opposed) flame spread was the main mechanism, resulting in increased burning area prior to flashover. Consequently, it is no surprise that different variable combinations seem to yield the best correlation in both studies. As straightforward correlations lack flexibility, it is advantageous to develop high-level correlations, namely, mathematical models that use bench-scale data to predict fire growth in a variety of real fire scenarios.

Much has been said about model validation. However, which criteria are needed for validation? In this research program, efforts were made to satisfy two main criteria: 1) range of scenarios and 2) comparison of model predictions with experimental data that are suitable and compatible with the model output. With respect to criterion 1, a database is now available of more than 30 full-scale tests covering a range of different major factors such as burner position, power output programs, and lining materials (both combustible and noncombustible). With respect to criterion 2, special attention was paid to the instrumentation of the full-scale tests so that data reduction can be performed to produce data comparable to the model output. The model being developed will be tested rigorously against this database, keeping these criteria in mind prior to its release.

CONCLUSIONS

Large amounts of data were generated in these wall and corner test series. The general findings agreed with results from the previous sensitivity study [61]: 1) T'he ceramic fiber lining of the ceiling and remaining walls increases the severity of the test, may significantly shorten flashover time, and makes it difficult to distinguish between various flame spread classes of wood products; 2) the corner burner is a more servere ignition source than the wall burner; and 3) the three flashover criteria agree well, at least for the corner tests.

The problem of not knowing the true moisture content of the materials at the time of the test may be significant and may obscure the apparent differences in file behavior of the untreated products. However, it is expected that the preheat period may help eliminate this effect by drying out the materials to equalize moisture content.

For the wood materials tested, the white-light and laser smoke systems showed excellent agreement. This agreement increases the confidence level assigned to smoke data obtained so far for wood products using white-light systems.

The range of selected wood products confirmed a previous finding that the optimum burner program is 40 kW for 5 min followed by 160 kW for 5 min. The two settings present two “challenge” levels. As demonstrated in the corner tests, the two-step burner program was able to distinguish between materials. Materials having a high FSI caused

Flashover within 5 min at 40 kW exposure. The FRT materials did not cause flashover during the total 10 min of exposure. In this study, most wood materials required 160 kW for flashover to occur.

The complexity of fire growth in an enclosure cannot be accounted for by simple correlations that are only applicable for a narrow range of products and set of test variables. High-level correlations with the flexibility to account for the effects of the main variables such as position oft he ignition source, its output, and the thermal properties of the lining materials are needed. The data presented in this paper were developed to help in the validation of mathematical models that theoretically have the capacity to account for all the significant variables.

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