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Fire Performance of Interior Finishes, Room Linings and Structural Panel Products

by

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Abstract

This final report summarises progress in the fourth and final year of this multi-year project intended to characterise the fire performance of decorative wood room-linings and finishes. Forintek is often asked when decorative wood panelling is permitted in our export markets as a wall lining, a ceiling lining and as wainscoting. The question is challenging because both building code requirements and fire test methods for room linings vary from country to country.

A literature review was undertaken that demonstrated that different countries apply different test methods to regulate the use of combustible interior finish. The single-burning item test is used in Europe and is likely to be adopted in China; the cone calorimeter test is used in Japan, Australia and New Zealand; and the Steiner tunnel test is used in North America. Since Canadian wood products are sold in a variety of markets, it was decided that Forintek should document how they perform in each of these tests.

As globalisation intensifies, there is much interest internationally in comparing the performance of products as assessed by the different test methods used in various jurisdictions in order to facilitate trade. The room-corner test is proving useful in this regard. Although expensive and time-consuming to run, of all the test methods used to quantify the performance of lining materials, it is most representative of real-world fire scenarios. Consequently the room-corner test has become a reference scenario whereby the results generated in other tests can be understood. In fact, as countries move towards harmonisation of standards, there is a tendency to base product acceptance on performance in either the national fire test method or in the ISO room-corner fire test.

An agreement was made with Southwest Research Institute (SwRI) to conduct tunnel tests (ASTM E84), cone calorimeter tests (ISO 5660 / ASTM E1354), single-burning-item tests (SBI / EN 13823) and room-corner tests (ISO 9705) on several wood products. The wood products were white pine boards, white oak boards, OSB, Douglas fir plywood and FRT Douglas fir plywood. Due to equipment problems, the final report was not forwarded to Forintek until March 27. This has left little opportunity for analysis of the results. However, Forintek scientists have reviewed some of the raw data and have concluded that, in the reference scenario, the room-corner test, wainscoting performs very well.

A detailed analysis of the test data generated for Forintek by SwRI will be undertaken and an amendment to this final report will be made by the end of the First Quarter in 2006-2007.

The results of this study will allow Forintek scientists to respond appropriately to questions from members about when decorative wood panelling is permitted in our export markets. Because the project has involved testing in the internationally sanctioned reference scenario, the room-corner test, the results of the study also allow Forintek to recommend where it may be possible to recommend relaxations in requirements for room lings and wainscoting in our international markets.

Acknowledgements

Forintek Canada Corp. would like to thank its industry members, Natural Resources Canada (Canadian Forest Service), British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, New Brunswick, Newfoundland and Labrador, and the Yukon Territory, for their guidance and financial support for this research.

Forintek would like to acknowledge the assistance of Bodycote Materials Testing Canada Inc. and Southwest Research Institute for conducting the fire tests required for this project.

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1 Objectives

- To document the fire performance of wainscoting and identify markets where it can be used.
- To characterise the flammability of room linings and structural panels as assessed by international tests.

2 Introduction

Forintek is often asked whether wood panelling is permitted in specific applications in Canada's export markets. The question is challenging because both building code requirements and fire test methods for room linings vary from country to country. As countries move towards harmonisation of standards however, the situation is changing. Product acceptance is often based on performance in either a national fire test method or in the international room-corner fire test (ISO 9705).

Originally this project was intended to document the fire performance of wainscoting and to identify where it can be used in Canada's export markets. The project was to begin with a review of international requirements for fire performance of decorative wood room linings. Subsequently, room-corner tests were to be conducted on hardwood and softwood wainscoting. Based on the results of these tests, export markets were to be identified where wood panelling and wainscoting could be used.

Selection of the room-corner fire test for this study was quite appropriate. In the room-corner fire test, wood panelling lines the four walls and the ceiling. A small fire is set in a corner and one observes how long it takes for the entire surface to become involved in fire. A variant of the test involves lining the walls only, and under these com-corner test (ISO), the single-burning item test (Europe), the cone calorimeter test (Japan) and the tunnel test (Canada and the USA). It was also proposed that a correlation be developed inter-relating the performance of wood products in these internationally recognised flammability tests. Progress to these ends is summarised in this report.

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4 Proposed Approach

Originally this was to be a one-year Forintek research project with the following proposed work plan:

- By August 2002, international requirements for fire performance of decorative wood room linings were to be reviewed.
- By September 2002, performance of wood panelling products in the room-corner fire test was to be reviewed.
- By October 2002, a room-corner test for hardwood wainscoting was to be conducted.

- By November 2002, a room-corner test for softwood wainscoting was to be conducted.
- By March 2003, markets where wood panelling and wainscoting can be used were to be identified.

Early in 2002-2003, the Chair of the Fire Safety Engineering Program at Carleton University expressed interest in the research. Furthermore, the Carleton Chair was establishing collaborative agreements with the National Research Council Canada (NRC) which would permit his students to conduct room-corner tests on room lining materials using NRC's facilities. He was eager to combine his testing program with the one described above. Since this would enable Forintek to increase the number of materials investigated without increasing the costs, in October 2002, the schedule for completion of the various tasks was revised and the project completion date extended in order to take advantage of this opportunity. The revised work plan was as follows:

- By August 2003, international requirements for fire performance of decorative wood room linings were to be reviewed.
- By September 2003, performance of wood panelling products in the room-corner fire test was to be reviewed.
- By October 2003, a room-corner test for hardwood wainscoting was to be conducted.
- By November 2003, a room-corner test for softwood wainscoting was to be conducted.
- By March 2004, markets where wood panelling and wainscoting can be used were to be identified.

During 2003-2004, due to delays in establishing an agreement between Carleton University and NRC, testing had still not commenced. This delayed progress in this project, and as a consequence, the project was extended for another year, but with an expanded scope of work as follows:

- By August 2004, international requirements for fire performance of decorative wood room linings were to be reviewed.
- By September 2004, literature on the performance of wood panelling products in room-corner fire test was to be reviewed.
- By March 2005, a room-corner test for hardwood wainscoting was to be conducted.
- By March 2005, a room-corner test for softwood wainscoting was to be conducted.
- By March 2005, a series of international fire tests on wood products was to be conducted.
- By March 2005, markets where wood panelling and wainscoting could be used were to be identified.
- By March 2005, an assessment of the flammability of room linings and structural panels using international tests was to be completed.

At the end of 2004-2005, the work plan was extended for one more year. It had become evident that an agreement between Carleton University and NRC to run the required tests was not forthcoming. Consequently, it was decided to have the tests conducted under contract by Southwest Research Institute (SwRI) during 2005-2006.

5 Results and Discussion

5.1 Progress in 2002-2003

A review of international requirements for the fire performance of room linings was initiated. The test methods and building code requirements employed in Canada, the U.S.A. and Japan are summarised in this section. The global practice, as typified by the ISO room-corner test, is also discussed.

5.1.1 Canadian practice

5.1.1.1 The tunnel test

The Canadian method for assessing the fire performance (flammability) of interior finish is CAN/ULC-S102, the tunnel test. The test equipment consists of a horizontal tunnel 7.6 m long, 450 mm wide and 300 mm deep. During testing, flames impinge on one end of the test specimen which, for wood products, is mounted on the ceiling of the tunnel. The advance of flames along the specimen is recorded for 10 minutes. The flame-spread rating (FSR) is computed from a plot of the flame-front position versus time. A solid wood product typically has a FSR less than 150 and gypsum board less than 25. FSRs that have been reported in the literature for some wood products are shown in Table 1 (Richardson, 1996).

Table 1 Flame-spread ratings of typical wood products

Wood Product	Flame-spread Rating
Western red cedar	65 – 73
Douglas fir	67 – 117
Red oak	82 – 102
Eastern white pine	85
Douglas fir plywood 6 mm 9 mm 15 mm	117 - 145 94 - 119 84 – 95

5.1.1.2 Canadian building code requirements

The National Building Code of Canada (NBCC, 1995) restricts the usage of wall linings in buildings on the basis of their flame-spread ratings. NBCC requirements for walls in an apartment building follow.

- **Within Apartments:** Whether the building is low-rise or high-rise; sprinklered or not; and of combustible or non-combustible construction, walls within an apartment can be lined with a product with a flame-spread rating of 150 or less. Consequently, wood panelling is permitted.
- **Within Public Corridors:** In an unsprinklered building, walls in a public corridor can be lined with a product with a flame-spread rating of 150 or less on the lower half and 25 or less on the upper half. Consequently wood wainscoting is permitted on the lower half and gypsum board on the upper half.
- **Within Public Corridors:** In a sprinklered building, walls within a public corridor can be lined with a product with a flame-spread rating of 150 or less. Consequently wood panelling is permitted on the entire wall surface.
- **Within Exit Stairways:** Whether the building is low-rise or high-rise; sprinklered or not; and of combustible or non-combustible construction, walls in exit stairways can be lined with a product with a flame-spread rating of 25 or less. Consequently gypsum board is permitted.
- **Fire Retardant Treated Wood:** The NBCC defines fire retardant treated wood (FRTW) as wood that has been pressure impregnated with fire retardant chemicals such that its flame-spread rating is reduced to 25 or less. FRTW can be used most places that gypsum board can be used.
- **Other Requirements Governing Combustible Linings:** Additional requirements limit the thickness and, in high-rise buildings, the smoke producing propensity of combustible wall linings.

5.1.2 American practice

The American practice is similar to Canadian practice. Flame-spread ratings are assessed employing ASTM E 84 in a tunnel with only a few variations from the CAN/ULC tunnel. The method of assessing the flame-spread ratings from the performance in the test is moderately different so that E84 ratings for wood products are about 92% of the CAN/ULC values (Mehaffey, 1987).

American building codes also restrict the usage of wall linings on the basis of their FSRs. However, American codes often allow more flammable linings than the NBCC. For example, walls in an apartment can be lined with a product with a FSR of 200 or less in the U.S.A. as opposed to 150 or less in Canada.

5.1.3 Canadian and American fire loss records

Fire loss statistics (Rohr, 1998 and Richardson, 2001) suggest that the American requirements for interior finish are adequate. As the requirements in Canada are moderately more stringent than in the U.S.A. and as building practices and lifestyles are rather similar in the two countries, one can assume that the Canadian requirements are also adequate. As shown in Table 2, in the U.S.A., a fire in which a wall covering (finish) is the first item ignited is much less likely to cause deaths and injuries than a fire in which upholstered furniture or a mattress is the first item ignited. These statistics hold for wood-frame houses, apartment buildings with 1 to 4 storeys, or a reinforced concrete or structural steel apartment building with 5 or more storeys.

Table 2 Canadian and American fire loss record

Item First Ignited	Percentage of Fires[1]	Deaths per 100 Fires[2]	Injuries per 100 Fires[2]
Single-family house			
Upholstered furniture	3.0 %	5.1	9.2
Mattress or bedding	5.9 %	1.9	7.5
Interior wall covering	4.7 %	1.2	3.0
Two-family house			
Upholstered furniture	5.7 %	5.3	12.8
Mattress or bedding	11.4 %	1.7	9.2
Interior wall covering	3.3 %	1.5	5.2
1-4 Storey apartment building			
Upholstered furniture	5.5 %	4.2	15.7
Mattress or bedding	10.1 %	2.2	12.2
Interior wall covering	2.7 %	1.7	6.5
5+ Storey apartment building			
Upholstered furniture	5.2 %	5.6	24.4
Mattress or bedding	9.3 %	2.4	12.5
Interior wall covering	~ 0 %	-	-

1. The percentage of all fires for which this item is the first item ignited.
2. The number or deaths (or injuries) per 100 fires that start on this item.

5.1.4 Japanese practice

5.1.4.1 The cone calorimeter test

The Japanese method for classifying the combustibility of interior wall finish (Notification 1433) entails testing small specimens in a cone calorimeter (ISO 5660). As summarised in Table 3, a material is classified as noncombustible, quasi-noncombustible or fire retardant based on its performance in a cone calorimeter test at an exposure of 50 kW m^{-2}.

Table 3 Classification of room linings in Japan

Classification	Duration of Exposure	Total Heat Released	Peak Rate of Heat Release
Noncombustible	20 min[1]	≤ 8 MJ m^{-2}	≤ 200 kW m^{-2}
Quasi-noncombustible	10 min[1]	≤ 8 MJ m^{-2}	≤ 200 kW m^{-2}
Fire retardant	5 min[1]	≤ 8 MJ m^{-2}	≤ 200 kW m^{-2}

1. The specimen must not develop cracks on the back surface or distort excessively during exposure.
2. This rate may be exceeded for a period of time not exceeding 10 seconds.

If a material meets the specifications of the Cabinet Orders listed below, it is not necessary to run tests in order to determine the classification of a room lining material.

- By Cabinet Order 1400, some interior finishes are deemed to be noncombustible including concrete, brick and gypsum board with thickness ≥ 12 mm and paper face thickness ≤ 0.6 mm.
- By Cabinet Order 1401, some interior finishes are deemed to be quasi-noncombustible including fibre cement board with thickness ≥ 15 mm and gypsum board with thickness ≥ 9 mm and paper face thickness ≤ 0.6 mm.
- By Cabinet Order 1402, some interior finishes are deemed to be fire retardant including fire-retardant treated plywood with thickness ≥ 5.5 mm and gypsum board with thickness ≥ 7 mm and paper face thickness ≤ 0.6 mm.

5.1.4.2 Japanese building code requirements

Requirements in the Japanese Building Standard Law (BSL) for the flammability (combustibility) of interior finish tend to be more stringent than those in the NBCC. For many occupancies, the interior finish must be noncombustible or quasi-noncombustible for the entire wall, although sometimes only for the portion above 1.2 m (so wainscoting may be permitted). There are exceptions. For example, the interior finish of walls is not regulated for apartment buildings with height ≤ 10 storeys or with single-storey area ≤ 200 m^2, so wood panelling is permitted. Also, for most sprinklered office buildings, even if they are tall, fire-retardant materials are permitted for the walls.

5.1.5 Global practices

5.1.5.1 The room-corner test

Building code requirements and fire test methods for room linings vary from country to country. As countries move towards harmonisation of standards, however, there is a tendency to base product acceptance on performance in either a national fire test method or in the international room-corner fire test (ISO 9705). The European Union, Japan, Australia and New Zealand all accept ISO 9705 data as one way of demonstrating compliance with building regulations.

In ISO 9705, the test specimen lines the walls and the ceiling of a room with floor dimensions 2.4 m by 3.6 m and height of 2.4 m. A burner in a back corner, opposite an open door (0.8 m by 2.0 m), burns at 100 kW for 10 minutes, then at 300 kW for another 10 minutes. The primary purpose of the test is to observe how long it takes for the entire interior finish to be involved in fire. This time is referred to as the time to flashover. A variant of the test involves lining the walls only, and under these conditions the fire grows more slowly. Sample data for room fire tests is summarised in Table 4 below (Mehaffey, 1987).

Table 4 Time to flashover in the room-corner test

Wall Lining	Ceiling Lining	Time to Flashover (min:sec)
Gypsum board	Gypsum board	∞
Douglas fir plywood	Gypsum board	~ 7:30
Douglas fir plywood	Douglas fir plywood	~ 3:00
Polyurethane foam	Polyurethane foam	~0:13

The results in Table 4 are old and the tests may not have been compliant with the standard. The results are, however, encouraging. When Douglas fir plywood lines both the walls and ceiling of the room, the time to flashover is about 3 minutes. On the other hand, when Douglas fir plywood lines the walls and gypsum board lines the ceiling of the room, the time to flashover increases dramatically. It is evident that if wainscoting were to be tested in the room, the time to flashover would be longer yet. Unfortunately no data could be found in the literature on room-corner tests conducted on wainscoting.

5.1.6 Status of fire testing

The Chair of the Fire Safety Engineering Program at Carleton University expressed interest in this project. He was establishing an agreement with NRC to permit his students to conduct room-corner tests using NRC's facilities. He was eager to combine his testing program with the one described here. Since this would enable Forintek to increase the number of materials investigated without increasing the costs, the schedule for completion of the various tasks was revised and the project completion date extended.

5.2 Progress in 2003-2004

A review of international requirements for the fire performance of decorative wood room linings was continued. In 2002-2003, the test methods and code requirements employed in Canada, the U.S.A. and Japan were reviewed. In this section, a discussion of the test method in use in Europe was added. A first attempt at comparing the results of the various test methods was also presented.

5.2.1.1 European practice

In the European Union the principal method for classifying the fire performance of wall and ceiling linings is the "Single Burning Item Test" (SBI) designated as EN 13823. The SBI is an intermediate-scale test in which two panels of a product are mounted in a corner configuration and subjected to thermal attack by a 30 kW sand-box burner. The performance of a material is expressed in terms of an index called the FIGRA (FIre Growth RAte). FIGRA is defined as the maximum size (maximum heat release rate) divided by the time at which this maximum occurs. A smoke parameter called SMOGRA (SMOke Growth RAte) is defined in a similar way.

5.2.1.2 Comparison of performance in room-corner test and other tests

Room-corner tests are expensive and time-consuming to run, but, of the test methods used to quantify the performance of lining materials, are the most representative of real-world fires. Consequently the room-corner test is a reference scenario whereby the results generated in other tests can be understood.

This comparison between the results of the room-corner test and the SBI test was crucial in establishing Euroclasses. A product is classified into a Euroclass depending on its performance in four tests:

- The noncombustibilty test, EN ISO 11182
- The heat of combustion test, EN ISO 1716
- The ignitability test, EN ISO 11925
- The single-burning item (SBI) test, EN 13823.

As far as wood products are considered, it is the FIGRA determined in the SBI that is most important. A comparison of the performance in the room-corner test (assessed by the time to flashover) and performance in the SBI test (assessed by the FIGRA) is provided for the various Euroclasses in Table 5 (Sundstrom, 1999). Typical building products that fall into the Euroclasses are also listed in Table 5.

Table 5 Comparison of performance in the room-corner test and the SBI

• Euroclass	• SBI	• ISO 9705	• Example Materials
• A1	FIGRA ~ 0	No flashover	non-combustibles (brick)
• A2	FIGRA ≤ 120 W s^{-1}	No flashover	gypsum board
• B	FIGRA ≤ 120 W s^{-1}	No flashover	painted gypsum board
• C	FIGRA ≤ 250 W s^{-1}	Flashover: 10 to 20 min	most fire retardant MDF
• D	FIGRA ≤ 750 W s^{-1}	Flashover: 2 to 10 min	most wood products
• E	FIGRA > 750 W s^{-1}	Flashover: before 2 min	polyurethane foam
• F	FIGRA > 750 W s^{-1}	Flashover: before 2 min	polystyrene foam

Research has also shed light on the relative performance of building products in the room-corner test and in the tunnel test (flame-spread rating, FSR) (Mehaffey, 1987). Table 6 provides a comparison of the performance of three products in the two tests.

Table 6 Comparison of performance in the room-corner test and the tunnel test

Material	ISO 9705 Mounting	ISO 9705	CAN/ULC S102
Gypsum board	Walls & ceiling	No Flashover	FSR < 25
Douglas fir plywood	Walls & ceiling	Flashover ~ 3 minutes	FSR ~ 135
Polyurethane foam	Walls & ceiling	Flashover ~ 13 seconds	FSR ~ 500

A more recent study compared the performance of products in the American tunnel test (ASTM E84) and in a room-corner test (White, 1999). The room-corner tests were conducted with a non-standard fire exposure however, so the results are not of immediate application to regulatory acceptance of products.

Finally, a method had been proposed to predict performance in the room-corner test using an ignitability index, I_{ig}, and a rate of heat release index, I_Q, measured in cone calorimeter tests (Kokkala, 1993). Using these indices, one can predict that, if the material was tested in the room-corner test, whether flashover occurs before 2 minutes, between 2 and 10 minutes, or between 10 and 20 minutes.

5.2.1.3 Selection of materials for testing

Several years ago, NAWPFRC (the North American Wood Products Fire Research Consortium) sought to characterise the fire performance of wood products. A large supply of panel products was assembled at the U.S. Forest Products Laboratory. These panel products were subjected to room-fire tests, cone calorimeter tests and LIFT (lateral ignition and flame travel) tests so that their flammability properties were well documented. As much of this material was still warehoused at US-FPL, it was decided that it would be useful to employ these panel products as wainscoting in the tests planned for this study.

5.2.1.4 Status of testing

Due to delays in establishing an agreement between the Chair and NRC, testing did not commence in 2003-2004. This once again delayed progress in this project.

5.3 Progress in 2004-2005

5.3.1 Chinese practice

The review of international requirements for the fire performance of decorative wood room linings was continued. In 2002-2003, the test methods and code requirements employed in Canada, the U.S.A. and Japan were reviewed. In 2003-2004, a discussion of the test method in use in Europe was considered and in 2004-2005, the requirements in China were reviewed.

5.3.1.1 The flammability / combustibility classification system

As market access in China for interior finish was of interest to the wood industry, Chinese flammability (combustibility) test methods were reviewed. This proved difficult as the test methods were not available in English. Nonetheless, with the assistance of Canada Wood employees in China, the following tentative conclusions were drawn. In China, building materials are classified according to GB 8624 “Classification of Burning Behaviour for Building Materials” into four classes:

- Class A: non-combustible.
- Class B1: difficult-combustible.
- Class B2: combustible.
- Class B3: easy-combustible.

To establish the Class of a building material it must be subjected to one or more of the following 3 tests:

- GB/T 8625 “Test method for non-combustible building materials”.
- GB/T 8626 “Test method for combustible building materials”.
- GB/T 8627 “Test method for density of smoke from the burning or decomposition of building materials”.

According to GBJ 16 (the Fire Code), a non-combustible material must not ignite or char when exposed to fire. Materials classified as non-combustible (Class A) must pass the acceptance criteria of GB/T 8625. GB/T 8625 is likely similar to the non-combustibility test ISO 1182 “Reaction to fire tests for building products - Non-combustibility test”. In any case, concrete, steel, bricks, stone, etc. are Class A.

According to GBJ 16, a difficult-combustible material does not ignite easily, and burns or chars weakly when exposed to fire. Materials classified as difficult-combustible (Class B1) must be subjected to all three tests and satisfy the following criteria:

- When tested to GB/T 8625, it must meet the combustible requirements and filter paper must not be ignited by flaming drippings.

- When tested to GB /T 8626, the average length of remaining sample must be greater than 15cm and the smoke temperature peak value must be less than 200°C.
- When tested by GB/T 8627, smoke density rating must be less than 75.

Fire-retardant treated wood and gypsum board appear to be Class B1.

According to GBJ 16, a combustible material ignites when exposed to fire but supports weak combustion when the fire source is removed. Materials classified as combustible (Class B2) must be subjected to all three tests. Wood is classified as Class B2.

Materials classified as easy-combustible (Class B3) must be subjected to all three tests. Although a definitive statement has not been found, presumably many plastics fall into this Class.

J.R. Mehaffey and L.R. Richardson participated in a Mission of Canadian Fire Experts to China which gave Forintek scientists an opportunity to hold technical exchanges with fire scientists from the Tianjin Fire Research Institutes (TFRI) and Sichuan Fire Research Institute (SFRI). The following findings of the Mission relate to this project

- Both TFRI and SFRI were having brand new laboratory facilities constructed in 2005. They were to be equipped with a cone calorimeter, SBI apparatus and a room-corner facility.
- China planned to abandon its combustibility classification system GB 8624. The system was based on old German tests no longer used in Germany. China was considering adopting a newer, international system perhaps based on the European SBI test.
- Much as was planned for this project, SFRI intended to compare the performance of room lining materials in a variety of international tests.

5.3.1.2 Chinese building and fire code requirements

In the Timber Code, GB 50005, published in 2003, the following combustibility requirements are found:

- Roof coverings must be Class A, non-combustible. (Clause 10.2.1, Note a).
- Interior finish of walls and ceilings can be Class B1, difficult-combustible. (Clause 10.5.2).
- Insulation in wood-frame cavities can be Class B1, difficult-combustible. (Clause 10.5.4).

Clearly then, wood paneling is not permitted in buildings governed by GB 50005. Furthermore, the author has not been able to locate requirements in GBJ 16 which would permit wood paneling. Nonetheless, there are numerous examples of buildings in China in which it is used!

5.3.2 Status of fire testing

As it became apparent in 2004-2005, that an agreement between Carleton University and NRC to conduct fire tests for this project would not be forthcoming, Forintek approached the laboratories listed in Table 7 to conduct the tests.

When Southwest Research Institute (SwRI) was contacted to run single-burning item (SBI) tests for Forintek, it was learned that SwRI had initiated an internal research program to generate fire test data to validate models that could be used to predict performance in the tunnel, SBI and room/corner tests based on the basis of cone calorimeter data. Their plan was to test eight different materials in the cone calorimeter, the tunnel (following ASTM E84), SBI apparatus and ISO 9705 room/corner test with material on the walls and ceiling. Only two of the eight materials in the SwRI program were wood products. The objective of the SwRI program was similar to that of this Project, except that the focus of Forintek's Project was on wood products. SwRI suggested that there may be a way to combine the two projects so that Forintek would get a lot more for its money.

Table 7 Test laboratories contacted to run fire tests

Test Method	Jurisdiction	Test Laboratory
Room-corner test: ISO 9705	International	National Research Council Canada
Tunnel test: CAN/ULC-S102	North America	Bodycote, Mississauga
Cone calorimeter: ISO 5660	Japan	Bodycote, Mississauga
Single-burning item: EN 13823	Europe	Southwest Research Institute

In the fall, negotiations commenced with SwRI to run all fire tests required in this Project. A contract between SwRI and Forintek was signed in January and testing at SwRI commenced in March. A summary of the tests to be conducted by SwRI is provided in Table 8.

Table 8 Fire tests to be conducted at SwRI

Materials to be tested at SwRI	ISO 9705 Walls & ceiling	ISO 9705 Walls only	ISO 9705 Wain-scoting	ASTM E1354 Cone	ASTM E84 Tunnel	EN 13823 SBI
Supplied by SwRI Douglas fir plywood	3*	1	1	m*	3*	3*
Supplied by SwRI FRT Douglas fir plywood	3*	0	0	m*	3*	3*
From FPL Material Bank Weyerhaeuser OSB	1	0	0	m	2	1
Purchased by FCC in TX White pine boards	0	0	1	m	2	1
Purchased by FCC in TX White oak boards	0	0	1	m	2	1
From FCC Material Bank LP OSB	0	0	0	m	2	1

The asterisk (*) in the table indicates that SwRI would purchase the materials (Douglas fir plywood and fire retardant treated (FRT) Douglas fir plywood) and run the tests at no cost to Forintek. Sufficient southern yellow pine, FRT southern yellow pine and OSB was forwarded to SwRI from the materials bank at FPL and sufficient white oak and white pine boards was ordered locally by SwRI but paid for by Forintek. Although not part of the SwRI Project, the wainscoting tests were to be conducted for Forintek. The results of all of these tests were to be shared with Forintek, but SwRI would also use the data for its own analysis. The "m" in the table indicates that cone calorimeter tests were to be run in duplicate at heat fluxes of 25, 50 and 75 kW m^{-2} and additional ignition tests would be run to determine the minimum heat flux for ignition. The cone calorimeter tests would be run in compliance with ASTM E1354 which is essentially identically to ISO 5660. The tunnel tests were to be run to the American standard ASTM E84, but Forintek was to make the necessary adjustments to predict the flame-spread ratings had the products been tested to CAN/ULC S101.

Forintek also planned to run an additional set of tests at the new Fire Research Facility under construction for Carleton University as Summarised in Table 9. It was anticipated that the new Facility would be up and running in the fall of 2005 and these tests would be the first to be run.

Table 9 Fire tests to be conducted at Carleton University

Materials to be tested at Carleton University	ISO 9705 Walls & ceiling	ISO 9705 Walls only	ASTM E1354 Cone
From FCC Material Bank LP OSB	1	1	m
From FPL Material Bank Hardboard	1	1	m
From FPL Material Bank Douglas fir plywood	1	1	m

5.3.3 Related developments

5.3.3.1 Western red cedar

During a meeting in early 2004, a Working Group of CEN TC 175 (round and sawn timber) had considered a recommendation of the EU Fire Regulator's Group that wood finish with minimum density of 390 kg m^{-3} and of minimum thicknesses (depending on the application) be classified without further testing (CWFT). As Europe considers western red cedar (WRC) to have density 350 kg m^{-3}, WRC would not be CWFT. This was not good news for the Western Red Cedar Export Association (WRCEA). After all, in North America, where the tunnel test is used to regulate the flammability of interior finish, WRC exhibits better fire performance than most other wood products (see Table 1).

The Fire Regulator's recommendation was based on SBI tests conducted in Denmark on WRC and other wood products together with the assumption that the less dense a product, the poorer the performance in the SBI. Having recently studied European standards, Forintek scientists reviewed the Danish tests and the Fire Regulator's recommendation. Forintek noted that decisions based on the Danish tests were, for some applications, questionable. It was recommended that WRCEA approach SwRI to undertake a more extensive set of SBI tests on WRC products than had been run in Denmark. It was likely that the minimum density of 390 kg m^{-3} for many applications (and thicknesses) could be challenged if sufficient test data were available. WRCEA entered into a contractual agreement with SwRI for such testing.

5.3.3.2 Harmonisation of ULC S102 with ASTM E84

In 2001, Underwriter's Laboratories Inc. (ULI) in the USA bought Underwriter's Laboratories of Canada (ULC). This made it easier for ULI's American clients to access the Canadian marketplace by having fire tests conducted in accordance with Canadian standards in Canada and to access the Japanese marketplace because ULC is accredited to run several Japanese fire tests. As far as fire testing had been concerned, the arrangement had worked well. Most Canadian and American fire tests are similar. However, there are differences between the Canadian tunnel test (CAN/ULC-S102) and the American tunnel test (ASTM E84). These differences result in the flame-spread rating (FSR) for products assessed by the Canadian method to differ from the FSR assessed by the American method. In an attempt to save its American clients from having to run tests in both the USA and Canada, ULI was pressuring ULC to harmonise ULC S101 with ASTM E84. A ULC Task Group was established to consider this proposal. J.R. Mehaffey was asked to join the Task Group as, when he was at the National Research Council in the early 1980s, he had access to much of the original data demonstrating the proficiency of the Canadian method.

5.3.3.3 Publication

The 3rd Edition of the Plastics Flammability Handbook: Principles, Regulations, Testing, and Approval, edited by J. Troitzsch, was published by Hanser, Munich. J.R. Mehaffey wrote Chapter 10.3 Canada (pp. 258-265) which addressed Canadian fire safety regulations and test procedures pertinent for combustible building products.

5.4 Progress in 2005-2006

5.4.1 Australian and new Zealand practice

The review of international requirements for the fire performance of decorative wood room linings was continued. In 2002-2003, the test methods and code requirements employed in Canada, the U.S.A. and Japan were reviewed. In 2003-2004, a discussion of the test method in use in Europe was considered and in 2004-2005, the requirements in China were reviewed. In 2005-2006, the test procedures in use in Australia and New Zealand have been added to the mix.

May 23-24, J.R. Mehaffey participated in *Building Confidence in Timber: A Seminar on Fire Safe Use of Timber in Construction* in New Zealand. During the meeting it was reported that the provisions related to controlling the flammability of room lining materials in the Building Code of Australia were revised in 2003. It was also reported that New Zealand is likely to adopt the same provisions. Wall and ceiling lining materials are now classified into four groups based on their "time to flashover". The "time to flashover" can either be measured by tests conducted in compliance with ISO 9705 (the room-corner test) or predicted using data obtained by testing the material at an irradiance of 50 kW m^{-2} in the cone calorimeter (AS/NZS 3837 or ISO 5660). The groups (based on the results of ISO 9705 tests) are as follows:

- Group 1: Materials for which flashover is not observed; e.g. gypsum board.
- Group 2: Materials for which flashover occurs between 10 and 20 minutes; e.g. many fire-retardant treated wood products.
- Group 3: Materials for which flashover occurs between 2 and 10 minutes; e.g. wood products.
- Group 4: Materials for which flashover occurs before 2 minutes; e.g. most untreated foamed plastic insulations. (Group 4 materials cannot be used as wall or ceiling materials anywhere in a building.)

5.4.2 Status of fire testing

5.4.2.1 Test results for two OSB products

Bodycote Materials Testing Canada Inc. conducted tunnel tests on two OSB products for Forintek employing the procedures outlined in CAN/ULC-S102. The two products are exterior sheathing recently manufactured by two different Canadian companies. Three tests were conducted on samples of each of these OSB products and the resultant flame-spread ratings (FSR) and smoke-developed classifications (SD) are listed in the Table 10.

Table 10 Flame-spread ratings of two OSB products

Product	Thickness	Test	Flame-spread rating	Smoke-developed
OSB(1)	11 mm (7/16”)	1	178	60
OSB(1)	11 mm (7/16”)	2	159	55
OSB(1)	11 mm (7/16”)	3	189	93
		Average	175	69
OSB(2)	11 mm (7/16”)	1	219	79
OSB(2)	11 mm (7/16”)	2	210	59
OSB(2)	11 mm (7/16”)	3	195	58
		Average	208	65

The average FSR, as assessed in the Canadian version of the tunnel test, for OSB(1) is 175 and for OSB(2) 208. Both products are acceptable for use as exterior sheathing in Canada and the U.S.A. However, neither product can be used as interior finish in Canada where the maximum permitted FSR is 150. If these products were tested according to the American version of the tunnel test (ASTM E84), their FSRs would likely be about 160 for OSB(1) and 190 for OSB(2). Consequently it is likely that both products could be used as interior finish in the U.S.A. where the maximum permitted FSR is 200.

5.4.2.2 Test results generated by Southwest Research Institute

In 2004-2005, contracts were signed whereby Southwest Research Institute (SwRI) would conduct tunnel tests (ASTM E84), cone calorimeter tests (ISO 5660 / ASTM E1354), single-burning-item tests (SBI / EN 13823) and room-corner tests (ISO 9705) on several wood products for Forintek. By late April, Forintek had arranged to have white pine boards, white oak boards, and two OSB products shipped to SwRI. SwRI also purchased Douglas fir plywood and FRT Douglas fir plywood locally (in Texas) for the project. In addition to providing Forintek with test reports, SwRI was to video the intermediate-scale SBI tests and the full-scale room-corner tests for Forintek’s viewing.

All testing was completed in the tunnel (ASTM E84), cone calorimeter (ISO 5660 / ASTM E1354) and room-corner configuration (ISO 9705) by the fall. However SwRI had problems with the calibration of the single-burning-item apparatus (SBI / EN 13823). This caused significant delay so that the final report was forwarded to Forintek on March 27. This has left little opportunity for analysis of the results.

However, Forintek scientists asked for and received an advanced copy of the raw data for the room-corner tests (ISO 9705) so some preliminary analysis of these data is presented here. In the ISO 9705 test, the interior finish of interest lines the four walls and ceiling of a room 2.4 m by 3.6 m with height of 2.4 m. A burner in a back corner, opposite an open door (0.8 m by 2.0 m), is programmed to burn at 100 kW for 10 minutes and then at 300 kW for another 10 minutes. The purpose of the test is to observe how long it takes for the entire interior finish surface to be involved in fire. This time is referred to as the time to flashover.

The raw data includes the following time-dependent quantities: rate of heat release; rates of generation of smoke, CO_2 and CO; temperature at various locations in the room; and radiant heat flux measured at the centre of the floor. Forintek has analysed the data to determine the time to flashover (should it occur) in each room-corner test. Since videos of the tests have not been forwarded to Forintek yet, it was assumed that flashover occurred when the radiant heat flux at the centre of the floor reached 20 kW m^{-2}. This is one of the criteria recommended in ISO 9705. The results of Forintek's assessment are summarised in the following Table 11.

Table 11 Time to flashover in the room-corner test

Wood Product	Run	Location	Flashover (min:s)
OSB	1	Walls & Ceiling	2:15
Plywood	1	Walls & Ceiling	3:10
Plywood	2	Walls & Ceiling	2:45
FRT Plywood	1	Walls & Ceiling	10:40
FRT Plywood	2	Walls & Ceiling	10:20
Plywood	1	Walls	8:10
Plywood	1	Wainscoting	No flashover
White Oak Boards	1	Wainscoting	No flashover
White Pine Boards	1	Wainscoting	No flashover

Tests conducted with OSB and plywood lining the walls and ceiling proceed to flashover within the first 3 minutes of the test. However, if the walls are lined with plywood and the ceiling with gypsum board, flashover is delayed until 8 minutes. Nonetheless with these products, flashover occurs within the first ten minutes of the test when the burner is set at 100 kW.

At the 10 minute mark in the test, the burner's rate of heat release is increased to 300 kW. When FRT plywood lines the walls and ceiling, flashover occurs shortly after this increase to 300 kW. However, flashover did not occur in any of the tests involving wainscoting. As a benchmark, it has been known for some time that when the walls and ceiling are lined with gypsum board, flashover also does not occur.

In the tests involving wainscoting, the maximum value of the radiant heat flux measured during the 20 minute test at the centre of the floor was 13.7 kW m^{-2} for plywood, 10.6 kW m^{-2} for white oak boards and 16.6 kW m^{-2} for white pine boards. Because, the critical radiant heat flux required for the ignition of wood is 12.5 kW m^{-2}, the data suggest that with white pine wainscoting a wooden floor would not be ignited. Simple models suggest that it would take more than 20 minutes at 13.7 kW m^{-2} (plywood wainscoting) and more than 15 minutes at 16.6 kW m^{-2} (white pine wainscoting) before a wooden floor could be ignited. The data suggest that in the reference scenario, the room-corner test, wainscoting performs very well.

A detailed analysis of the test data generated for Forintek by SwRI will be undertaken in early 2006-2007. As a consequence, an amendment to this final report will be made by the end of the First Quarter in 2006-2007.

5.4.3 Related developments

5.4.3.1 Harmonisation of ULC S103 with ASTM E84

On April 26, J.R. Mehaffey participated in a meeting of the Underwriter's Laboratories of Canada Fire Test Committee (ULC-S100A) during which a proposal to harmonise CAN/ULC S102 (the Canadian tunnel test) with ASTM E84 (the American tunnel test) was discussed. Interior finish (walls and ceilings) are regulated on the basis of flame-spread ratings (FSR) measured in CAN/ULC S102 (in Canada) and ASTM E84 (in the USA). A manufacturer must have his product tested to both standards if he wishes to sell his product in both Canada and the USA. To remedy this situation, ULI (USA) proposed that ULC S102 be amended to permit the use of ASTM E84 as an alternative. A comparison of FSRs measured by ULC S102 and ASTM E84 was submitted to support the proposal. Several concerns were expressed by ULC-S100A members. Firstly, there are differences between the Canadian and American tunnel tests; for example, the manner in which turbulence is generated and the requirements for the tunnel-roof construction. Furthermore, for most materials, the FSR assessed by ULC S102 is about 9% greater than the FSR assessed by ASTM E84, so for materials close the acceptance criteria of the National Building Code of Canada (namely FSR = 25, 75 or 150), some products judged acceptable by ASTM E84 would currently be judged unacceptable by ULC S102. Worse, however, is the fact that for foamed plastics the FSR (ULC S102) can be an order of magnitude larger than the FSR (ASTM E84). Task Group 41 (surface burning characteristics) was charged with reviewing the proposal and making recommendations to ULC-S100A. Due to his previous experience with the test, J.R. Mehaffey was appointed a member of Task Group 41 for the purpose of addressing this issue.

J.R. Mehaffey participated in a meeting of ULC Task Group 41 in Toronto on June 1. The Task Group reviewed in detail the ULI (USA) proposal that ULC S102 be amended to permit the use of ASTM E84 as an alternative. For the reasons discussed in the preceding paragraph, the Task Group decided to recommend that ULC-S100A not proceed any further with the proposal. ULC-S100A accepted this recommendation.

6 Conclusions

This final report summarises progress in the fourth and final year of this multi-year project intended to characterise the fire performance of decorative wood room-linings and finishes.

A literature review identifying the test methods that are used in Australia and New Zealand to regulate the use of combustible interior finish has been completed. This complements earlier analyses undertaken for other Canadian export markets including the U.S.A., the European Union, Japan and China. All of these jurisdictions employ different test methods, but Forintek can now identify how typical wood products are classified in each of these markets and where they are permitted for use as interior finish.

As globalisation intensifies, there is much interest internationally in comparing the performance of products as assessed by the different test methods used in various jurisdictions in order to facilitate trade. The room-corner test is proving useful in this regard. Although expensive and time-consuming to run, of all the test methods used to quantify the performance of lining materials, it is most representative of real-world fire scenarios. Consequently the room-corner test has become a reference scenario whereby the results generated in other tests can be understood. In fact, as countries move towards harmonisation of standards, there is a tendency to base product acceptance on performance in either one of these national fire test methods or in the ISO room-corner fire test. Already, the European Union, Japan, Australia and

New Zealand accept room-fire tests as one way of demonstrating compliance with building regulations. Interestingly, for products such as wainscoting, the room-corner test may be the only test method that can give a meaningful indication of fire performance in real life scenarios.

Because Forintek had been unable to locate a Canadian laboratory able to run all the tests required for this project, an contractual agreement was made with Southwest Research Institute (SwRI) to conduct tunnel tests (ASTM E84), cone calorimeter tests (ISO 5660 / ASTM E1354), single-burning-item tests (SBI / EN 13823) and room-corner tests (ISO 9705) on several wood products. The wood products were white pine boards, white oak boards, OSB, Douglas fir plywood and FRT Douglas fir plywood. All testing was completed in the tunnel (ASTM E84), cone calorimeter (ISO 5660 / ASTM E1354) and room-corner configuration (ISO 9705) by the fall. However SwRI had problems with the calibration of the single-burning-item apparatus (SBI / EN 13823). This caused significant delays so that the final report was forwarded to Forintek on March 27. This has left little opportunity for analysis of the results. However, Forintek scientists have reviewed some of the raw data and have concluded that, in the reference scenario, the room-corner test, wainscoting performs very well.

A detailed analysis of the test data generated for Forintek by SwRI will be undertaken in early 2006-2007. As a consequence, an amendment to this final report will be made by the end of the First Quarter in 2006-2007.

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