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ABSTRACT

This report documents a series of bench- and intermediate-scale fire experiments that were conducted on flooring materials and floor assemblies. The primary objective was to provide fire test data for subfloor materials used in Canadian houses. The particular emphasis was on oriented strandboard (OSB) panels used for subfloors to provide data for selecting an OSB subfloor material for use in the full-scale experiments. The emphasis was on OSB as it is representative of subfloor materials typically used in single-family residential applications. In addition, a limited number of experiments were conducted with other materials including a plywood subfloor panel, plywood underlay, residential carpet and carpet underpad.

ACKNOWLEDGMENTS

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- Canada Mortgage and Housing Corporation
- Canadian Automatic Sprinkler Association
- Canadian Wood Council
- City of Calgary
- Cement Association of Canada
- FPInovations Forintek Division
- North American Insulation Manufacturers Association
- Ontario Ministry of Community Safety and Correctional Services/Office of the Fire Marshal
- Ontario Ministry of Municipal Affairs and Housing
- Wood I-Joist Manufacturers Association

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1 INTRODUCTION

This report documents a series of bench- and intermediate-scale fire experiments that were conducted on flooring materials and floor assemblies. The primary objective of the experiments was to provide fire test data for subfloor materials used in Canadian houses. The particular emphasis was on oriented strandboard (OSB) panels used for subfloors to provide data for selecting an OSB subfloor material for use in the full-scale experiments with unprotected floor assemblies. The emphasis was on OSB as it is representative of subfloor materials typically used in single-family residential applications. In addition, a limited number of experiments were conducted with other materials including a plywood subfloor panel, plywood underlay, residential carpet and carpet underpad.

Bench-scale tests were conducted using a cone calorimeter to provide flammability data for the flooring materials. In addition, intermediate-scale furnace tests were conducted on floor assemblies to provide data on flame penetration through a floor assembly.

2 OSB SUBFLOOR REQUIREMENTS

The National Building Code of Canada (NBC) [1] references two standards for OSB materials. These are CAN/CSA-O325.0-92 [2] and O437.0-93 [3].

CSA-O325 is a performance-based document. There is no specified thickness for the panels. The nominal thickness is 15 mm but can be as much as 15.5 mm. The panels are labelled in terms of span rating. A panel rated 1F16 can be used to span 406 mm (16 in.) and a 1F20 panel can be used to span 508 mm (20 in.). The 1F20 panel can also be used to span 406 mm (16 in.).

CSA-O437 provides prescriptive requirements for OSB panels. The NBC requires that OSB subfloor panels be 15.5 mm thick (Grade O-2) to span 406 mm (16 in.) and 15.9 mm thick (Grade O-1) to span 508 mm (20 in.).

3 TEST SAMPLES

3.1 OSB Samples

Five samples of OSB panels were obtained from the manufacturer or purchased locally. Samples were obtained from four of the five major manufacturers of OSB: Louisiana-Pacific, Weyerhaeuser, Ainsworth and Grant Forest Products. In addition, samples were obtained from a local supplier, Norbord.

The thickness of each OSB sample is provided in Table 1. OSB-01 was labeled Grade O-1 in accordance with CSA-O437. The other four samples were labeled 1F20 in accordance with CSA-O325. All samples could be used for spans up to 508 mm (20 in.). (Note: Discussions with manufacturers and certification organizations indicated that the OSB panels can typically meet the requirements for the higher span and that panels limited to the 406 mm (16 in.) span are typically not produced.)

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Table 1. OSB samples.

Sample #	Average Thickness* (mm)
OSB-01	16.1
OSB-02	15.0
OSB-03	15.0
OSB-04	15.3
OSB-05	15.1

*Average thickness measured using calipers.

3.2 Flooring Materials

A limited number of intermediate-scale tests were conducted with other flooring materials. These included

1. 15.9 mm thick plywood panels, which are also used for subfloor applications;
2. 6 mm thick poplar plywood underlay;
3. residential carpet with 10 mm long beige tufts glued to a polyolefin backing;
4. multicolored 10 mm thick carpet underpad made using recycled polyurethane foam.

All these materials were purchased locally.

4 TEST FACILITIES

The bench-scale tests were conducted using a cone calorimeter. The tests were conducted in accordance with the ASTM E 1354 and ISO 5660-1 test methods [4, 5]. The cone calorimeter is instrumented to measure all the quantities (O_2, CO, CO_2, temperature and volumetric flow rate) in the exhaust stream that are needed to calculate the heat release rate using the oxygen-depletion technique [6]. In addition, measurements of mass loss, smoke production and ignition times were also collected.

The intermediate-scale fire experiments for floor assemblies were conducted using a 1.33 m by 1.94 m horizontal furnace. The furnace is oriented in the East-West direction with the exhaust stack located at the East end. A full description of the intermediate-scale furnace facility is provided by Sultan et al. [7].

Four dual element Chromel-Alumel K-type thermocouple probes are used to measure the temperature inside the furnace chamber. These furnace thermocouples are located approximately 150 mm below the underside of the test assembly at the locations shown in Figure 1. The average temperature measured using these four thermocouples was used to control the furnace. For the experiments discussed in this report, the temperature in the furnace initially followed the standard time-temperature curve given in CAN/ULC S101 [8]. Once the floor assembly ignited, the temperature in the furnace was not controlled.

5 FLOOR ASSEMBLIES

The floor assemblies used for the intermediate scale tests were all constructed using a 1260 mm x 1949 mm lightweight steel frame (Figure 1). This frame consisted of four 203 mm deep steel C-joists spaced 406 mm O.C. The steel joists were fastened together using two lengths of 203 mm x 1260 mm steel tracks.

The floor assemblies used in the intermediate-scale experiments are summarized in Table 2. Two experiments were conducted for each of the five OSB samples using the following floor assemblies:

1. Tests OSB-0xB were conducted using floor assemblies constructed using a 1206 mm x 1949 mm OSB panel. The construction details are shown in Figure 2.
2. Tests OSB-0xA were conducted using floor assemblies constructed with an unsupported tongue and groove joint, which ran across the width of the assembly perpendicular to the steel joists (North-South direction). The joint was located approximately 750 mm from the West end of the floor assembly. The construction details are shown in Figure 3.

Table 2. Intermediate-scale floor experiments.

Test	OSB Joint	Notes
OSB-01A	Yes	60 s scanning rate
OSB-01B	No	Only unexposed surface temperatures recorded
OSB-01BR	No	Repeat test OSB-01B
OSB-02A	Yes	DVD recorder off at 2 min
OSB-02B	No	
OSB-03A	Yes	
OSB-03B	No	
OSB-03C	Yes	OSB joint along length of assembly
OSB-03D	No	Loaded with two concrete blocks
OSB-03E	Yes	Plywood underlay
OSB-03F	Yes	Carpet and underpad on OSB
OSB-03G	No	Plywood underlay and loaded with 12 concrete blocks
OSB-03H	No	Loaded with 12 concrete blocks
OSB-04A	Yes	
OSB-04B	No	
OSB-05A	Yes	
OSB-05B	No	
PLY-01A	Yes	15.9 mm thick plywood subfloor
PLY-01B	No	15.9 mm thick plywood subfloor

Additional experiments were conducted using OSB-03 to investigate other floor arrangements and scenarios:

1. Test OSB-03C was conducted using a floor assembly with a tongue and groove joint, which ran along the length of the assembly (East-West direction) parallel to the steel joists. The joint was located along the East-West centreline of the assembly (Figure 4). (Note: this construction is not used in practice.) The construction details are shown in Figure 4.

2. Tests were conducted with floor assemblies constructed using the assembly with the tongue and groove joint that ran across the width of the assembly (Figure 3) as a base and with additional flooring materials. This included assemblies with the addition of a 6 mm thick poplar underlay (Tests OSB-03E). The butt joint between two underlay panels ran across the width of the floor assembly. This joint was offset from the OSB tongue and groove joint by approximately 450 mm. The construction details are shown in Figure 5. One experiment was also conducted using residential carpet and carpet underpad (Test OSB-03F).
3. Two loaded tests were conducted using the base floor assembly shown in Figure 2. In Test OSB-03D, two 16.2 kg concrete blocks were placed on the East-West centerline of the assembly. The blocks were located approximately 250 mm from the centre of the assembly. In Test OSB-03H, twelve concrete blocks were placed on the floor assembly. The blocks were in three rows of four blocks running in the East-West direction. The rows were centred between the steel joists. The blocks in each row were spaced 454 mm apart with the two centre blocks offset from the centre of the test assembly by 227 mm. This was the same load per unit area of floor assembly used in the full-scale tests for unprotected floor assemblies (0.95 kPa) [9].
4. Test OSB-03G was conducted with a base floor assembly, which included the 6 mm poplar plywood underlay (Figure 5). The assembly was loaded with twelve concrete blocks at the same locations used in Test OSB-03H.

In addition to the tests with OSB subfloors, two tests were conducted using plywood subfloor with and without a tongue and groove joint. The construction details were the same as those used for the OSB floor assemblies (see Figures 2 and 3).

Five thermocouples were installed on the unexposed side of the test assembly (Figure 1). One thermocouple was at the centre of the assembly. A thermocouple was located in each of the four quadrants of the assembly. These thermocouples were located 315 mm and 487 mm from the sides and ends of the assembly, respectively. For all assemblies except the test with the residential carpet, the thermocouples were mounted on the unexposed surface of the assembly and were covered with an insulating pad in accordance with CAN/ULC S101. For the test with the residential carpet, the thermocouples were located between the carpet underpad and the OSB subfloor. The insulated pads were not used.

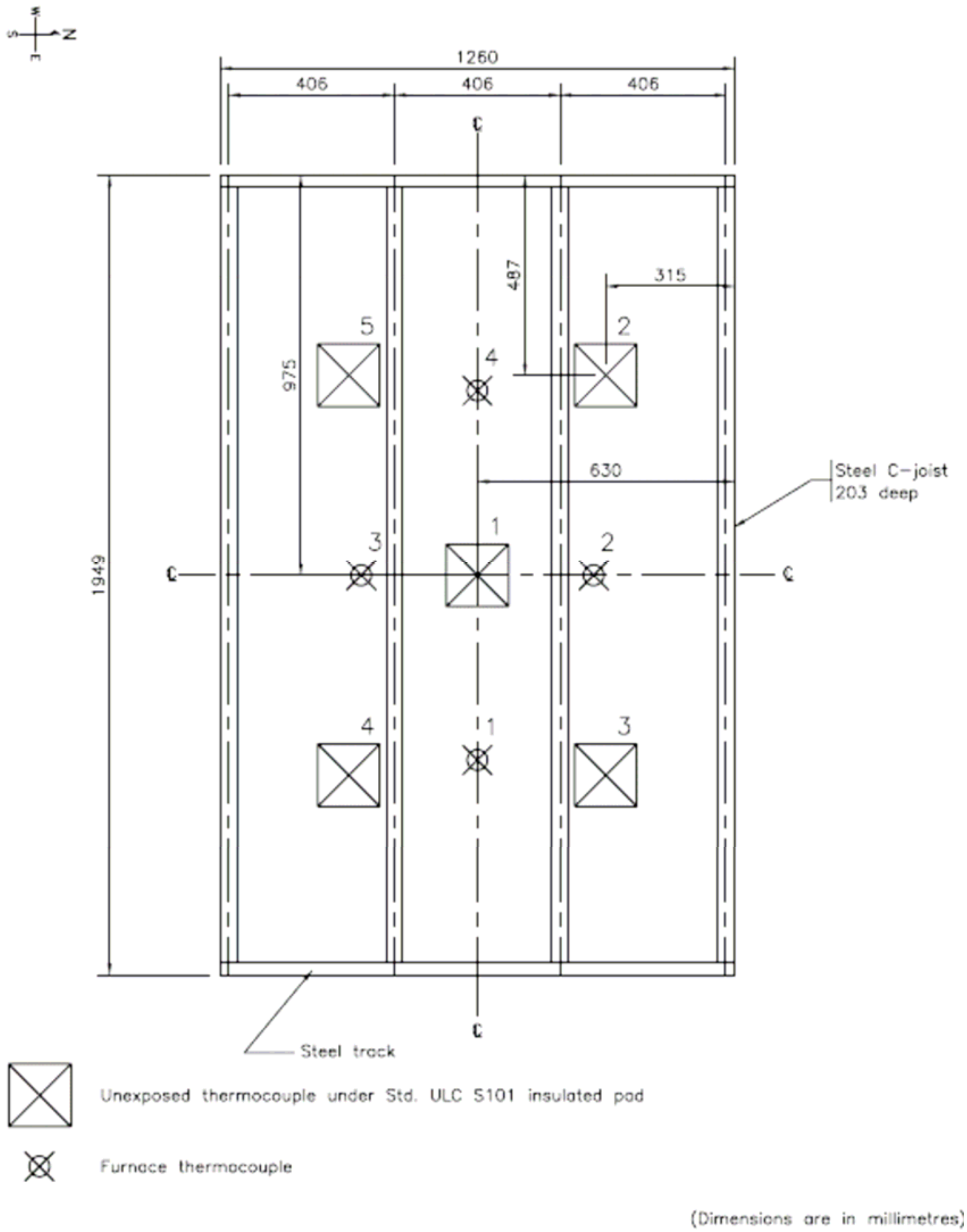

Figure 1. Joist and thermocouple layout for intermediate-scale tests.

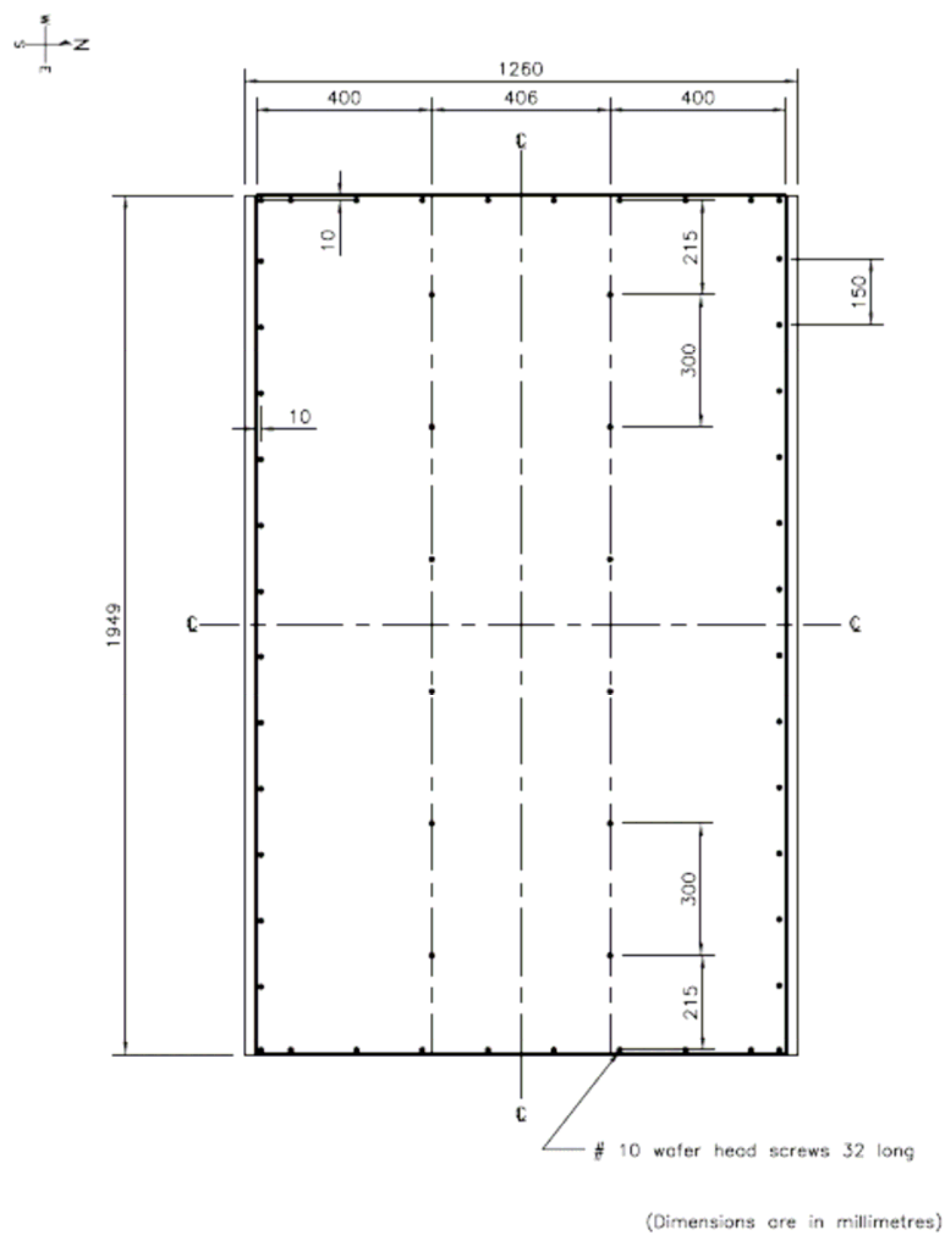

Figure 2. Test assembly layout with full wood structural panel.

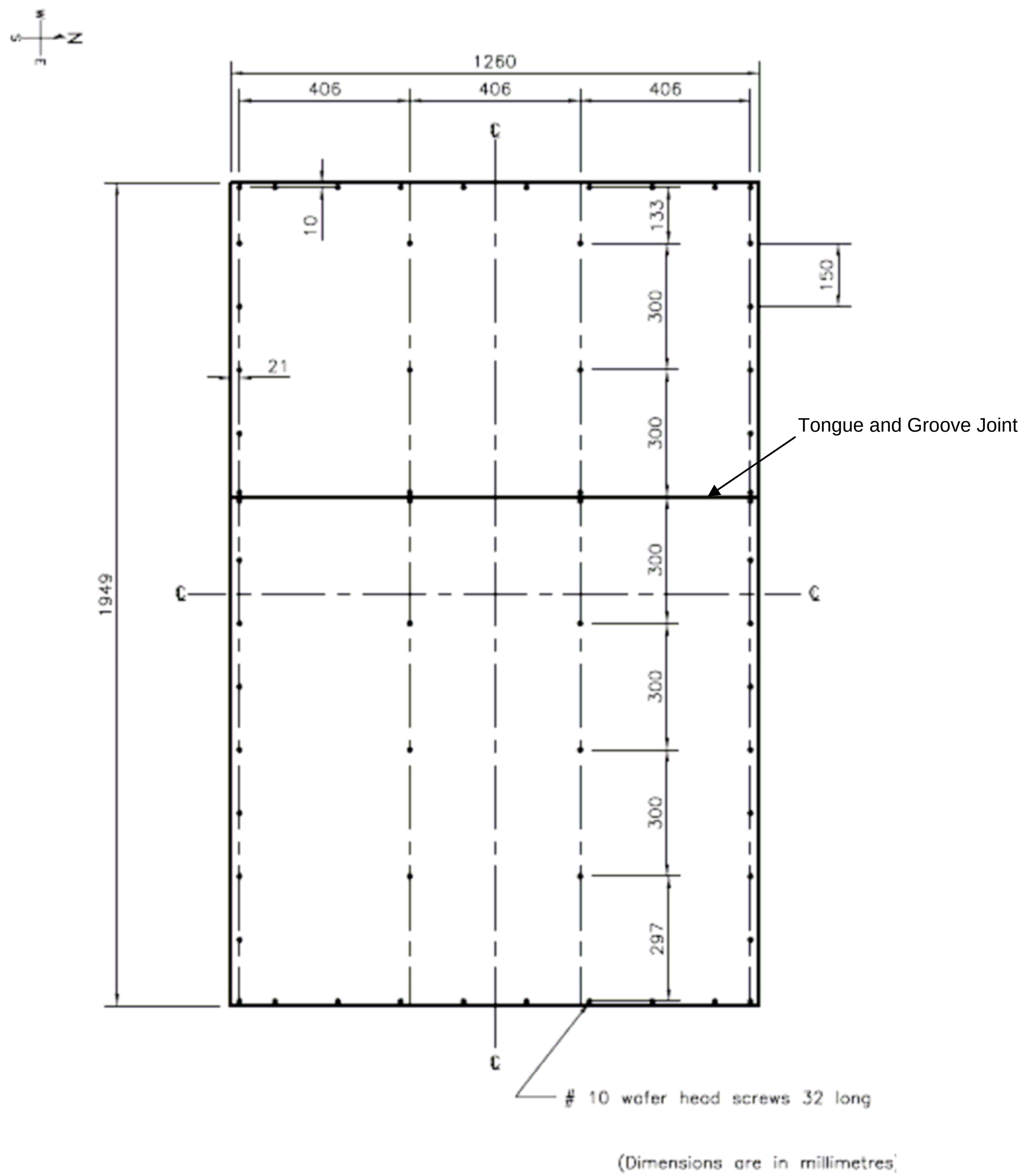

Figure 3. Test assembly layout with North-South tongue and groove joint.

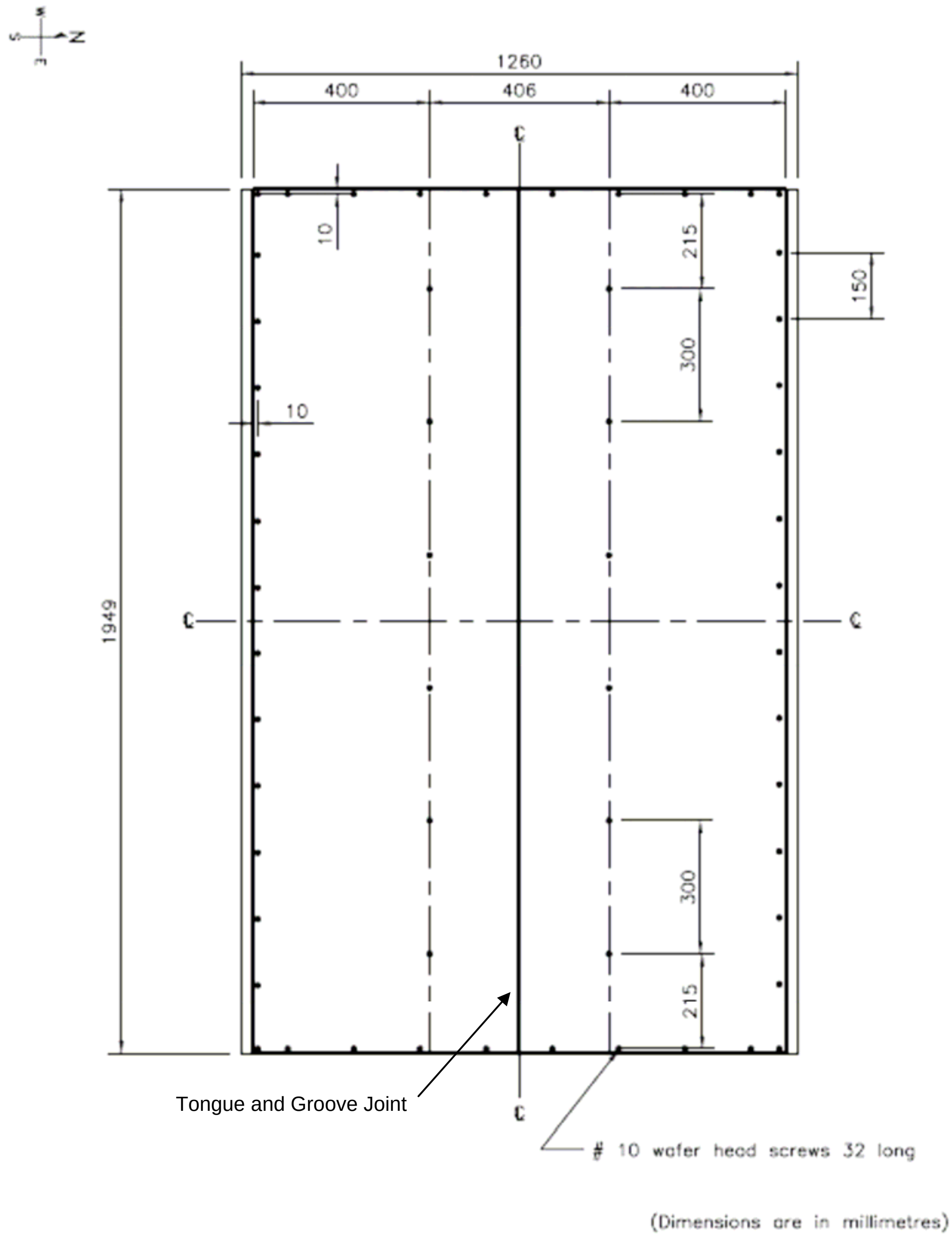

Figure 4. Test assembly layout with East-West tongue and groove joint.

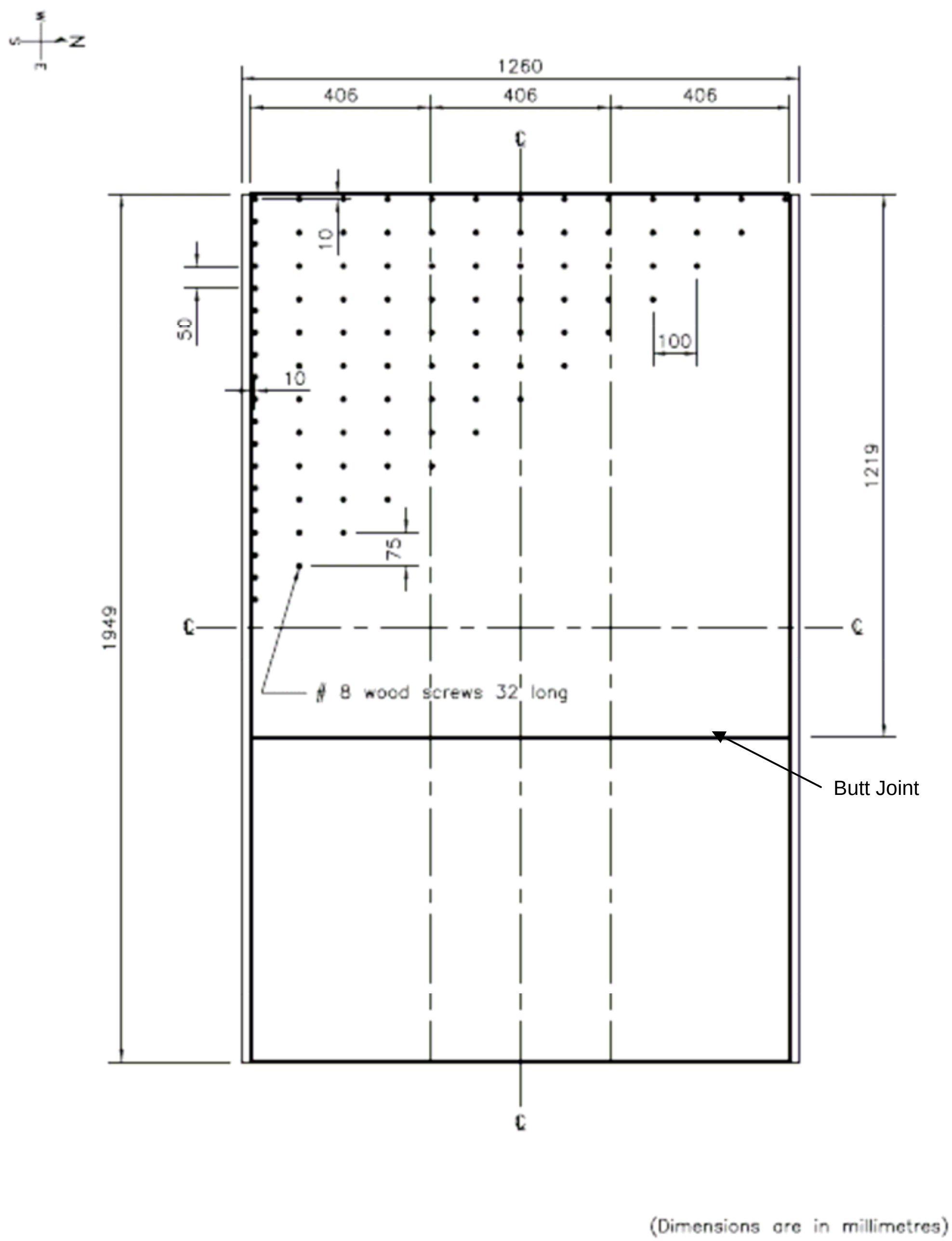

Figure 5. Test assembly layout with poplar plywood underlay over OSB subfloor.

6 CONE CALORIMETER RESULTS

6.1 OSB Samples

The OSB test specimens were 100 mm x 100 mm by the thickness of the OSB sample. The specimens were conditioned at a temperature of 23°C and 50% relative humidity prior to the tests.

Triplicate tests were conducted using a radiant flux of 50 kW/m^2 using specimens from the five OSB samples. Additional tests were conducted with OSB-03 using radiant exposures of 25 and 35 kW/m^2 to provide data for use in numerical modeling. The results for all the cone calorimeter tests are provided in Appendix A.

Table 3 shows average results for the OSB samples for tests with a radiant exposure of 50 kW/m^2. The tests using Specimen 1 for each OSB sample were conducted with a specimen holder without a grid. In these tests, there was visible swelling of the OSB specimen, which resulted in a higher and earlier initial peak heat release rate than was found in the tests for Specimens 2 and 3 with a grid installed. The results for all specimens are provided in Appendix A. The average results provided in this section are based on Specimens 2 and 3.

The average heat release rates per unit area for the five OSB samples for the tests with a radiant exposure of 50 kW/m^2 are shown in Figure 6. The double peaks in the heat release rate plots for the OSB samples are typical of those found for thermally thick cellulosic materials. The second peak occurs near the end of the test when there is additional from pyrolysis from both the bottom and top of the specimen. The time at which the second peak in the heat release rate occurs is noted in Table 3. It may be possible to use this time to evaluate the flame penetration time for subfloor materials using the cone calorimeter.

The heat release rate in the initial 350 s for the five OSB samples was comparable (Figure 6). However, parameters such as the time to ignition, initial peak heat release rate and time to initial peak heat release rate do show that there is a small variation between the samples. The fire growth rate (FIGRA) index (the peak heat release rate/time to peak heat release rate), which is used to determine the relative combustibility of building materials [10], varied from 2.24 to 3.00. This range of values is comparable to the expected variation in this parameter. This indicates that the potential contribution of the OSB samples to fire spread would be similar based on the cone calorimeter results.

Table 3. Average cone calorimeter results using a radiant flux of 50 kW/m^2.

Sample #	Thickness	Mass Loss	Ignition Time	First PHRR	Time 1st PHRR	FIGRA	Total HR	Time 2nd PHRR
	(mm)	(g)	(s)	(kW/m^2)	(s)	(kW/m^{2}s)	(MJ/m^2)	(s)
OSB-01	16.12	92.7	29	214.9	78	2.76	137.6	640
OSB-02	15.02	80.4	33	209.2	80	2.61	137.1	658
OSB-03	15.00	76.6	31	218.9	73	3.00	131.8	560
OSB-04	15.32	88.5	25	216.3	93	2.32	148.5	603
OSB-05	15.09	80.3	31	201.7	90	2.24	132.7	545

PHRR – Peak Heat Release Rate per Unit Area   Total HR – Total Heat Release per Unit Area

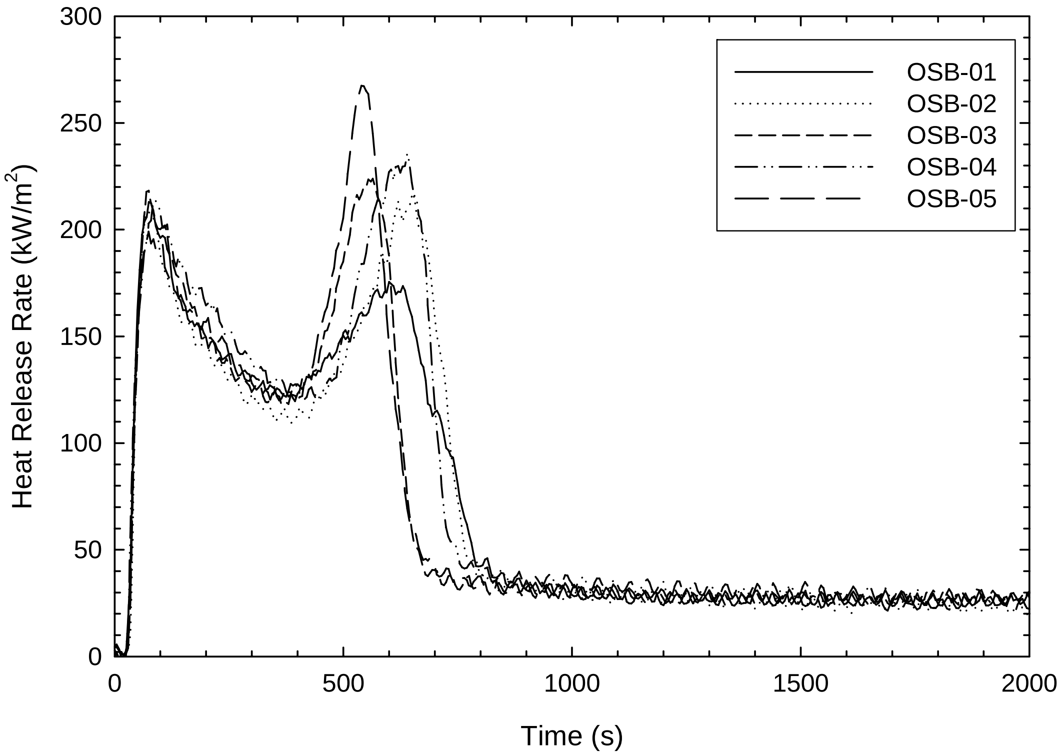

Figure 6. Average heat release rate per unit area for OSB samples with an exposure of 50 kW/m^2.

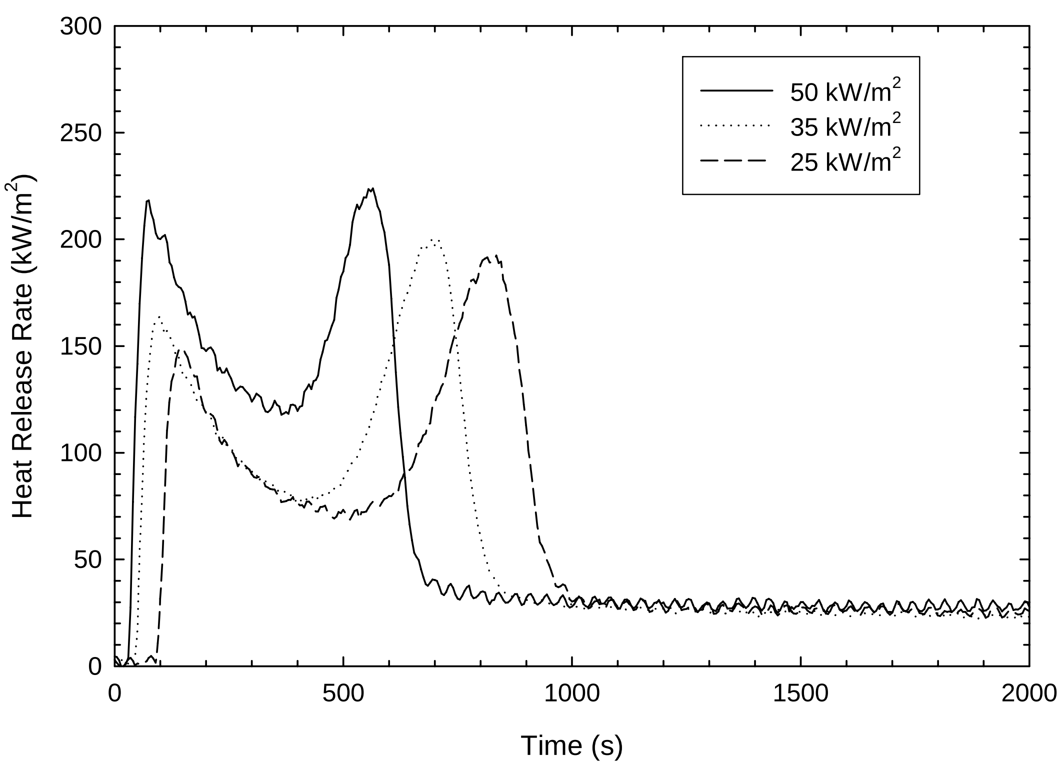

Figure 7. Average heat release rate per unit area for OSB-03 with radiant exposures of 25, 35 and 50 kW/m^2.

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Tests were also conducted with the OSB-03 specimens with lower radiant exposures to provide data for numerical modeling. Results for all the test specimens are provided in Appendix A. The average results for selected parameters are shown in Table 4. The average heat release rates are shown in Figure 7. The average results in Table 4 and Figure 7 excludes the results for Test OSB-03-01, which was conducted without a grid, but includes all the other tests with a grid.

Table 4. Average cone calorimeter results for OSB-03.

Radiant Exposure	Mass Lost	Ignition Time	First PHRR	Time 1st PHRR	FIGRA	Total HR	Time 2nd PHRR
(kW/m^2)	(g)	(s)	(kW/m^2)	(s)	(kW/m^2s)	(MJ/m^2)	(s)
50	76.6	31	218.9	73	3.00	131.8	560
35	72.4	45	165.9	93	1.78	119.0	688
25	73.0	96	150.6	145	1.04	118.2	823

PHRR – Peak Heat Release Rate per Unit Area Total HR – Total Heat Release per Unit Area

6.2 Flooring Materials

Cone calorimeter tests were conducted with flooring materials sometimes used in conjunction with the floor assemblies with OSB subfloors. The materials included a 6 mm thick poplar plywood underlay, residential carpet and carpet underpad. Cone calorimeter tests were conducted using a radiant exposure of 50 kW/m^2 to provide data on the fire characteristics for these materials. A holder with a grid was used for all tests. Triplicate tests were conducted for the plywood underlay and the carpet. A fourth test was conducted for the carpet underpad because of uncertainty in ignition time for Test CARUP-1. The results for all the cone calorimeter tests for the flooring materials are provided in Appendix B.

The test specimens were 100 mm x 100 mm by the thickness of the flooring material. The specimens were conditioned at a temperature of 23°C and 50% relative humidity prior to the tests.

Table 5. Average cone calorimeter results for flooring material with a 50 kW/m^2 exposure.

Material	Mass Lost	Ignition Time	PHRR	Time PHRR	FIGRA	Total HR	PSPR	Total Smoke
	(g)	(s)	(kW/m^2)	(s)	(kW/m^2s)	(MJ/m^2)	(m^2/s)	(m^2)
PLYUL	30.0	21	313.9	169	1.86	53.3	0.028	2.2
CARUP	14.2	10	699.4	60	11.66	40.9	0.101	6.2
CARPT	20.3	19	520.6	100	5.20	46.5	0.120	9.7

PHRR – Peak Heat Release Rate per Unit Area Total HR – Total Heat Release per Unit Area
PSPR – Peak Smoke Production Rate PLYUN – Poplar Plywood Underlay
CARUP – Carpet Underpad CARPT – Carpet

Average results for selected parameters are shown in Table 5. The average heat release rate per unit area and smoke production rate for the three flooring materials are shown in Figures 8 and 9.

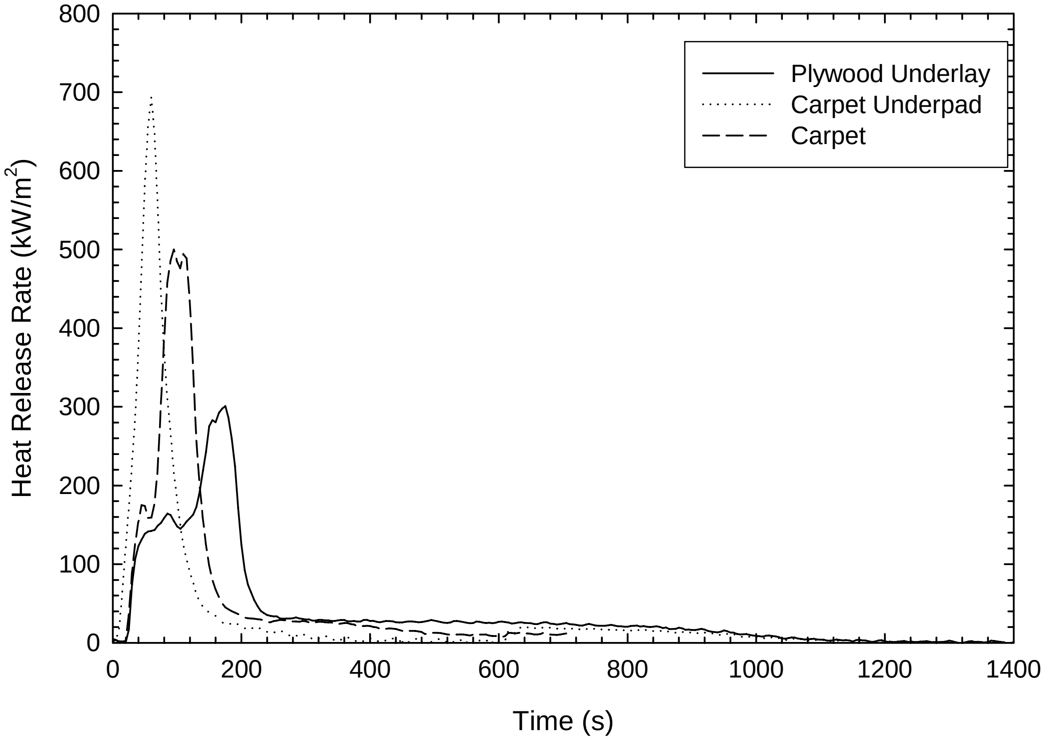


Figure 8. Heat release rate for flooring materials.

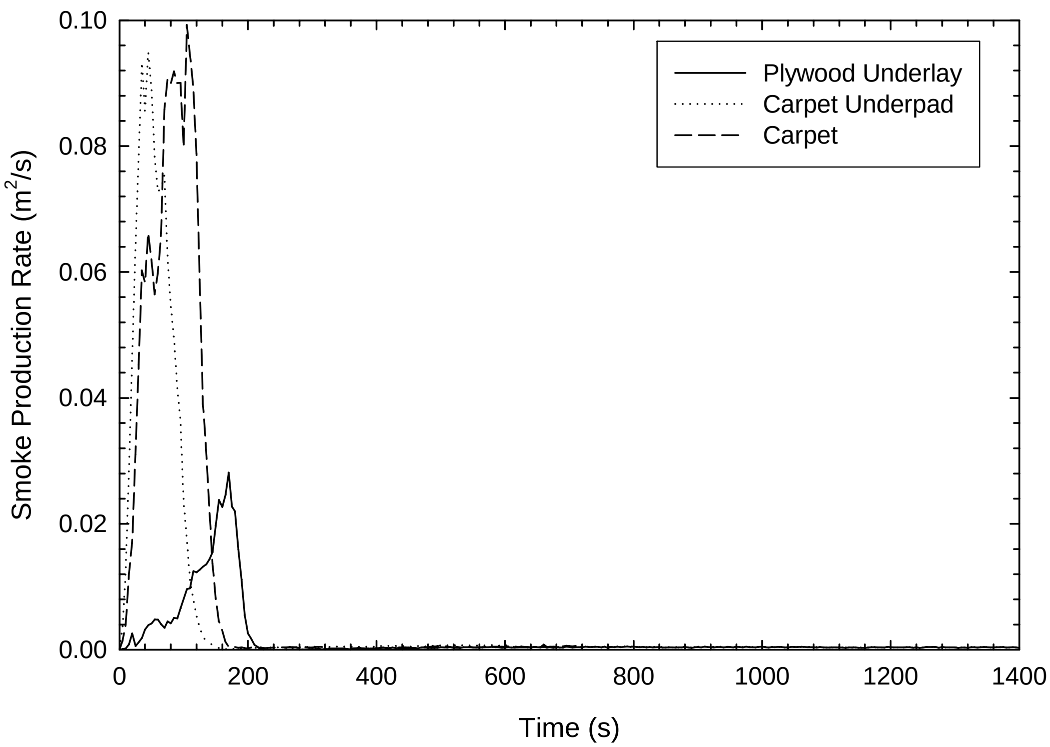


Figure 9. Smoke production rate for flooring materials.

7 INTERMEDIATE-SCALE FIRE TEST RESULTS

7.1 OSB Floor Assemblies

Intermediate-scale fire tests were conducted for floor assemblies constructed using the five OSB samples. Two assemblies were constructed for each of the five OSB materials: 1) a floor assembly using a single OSB panel (Figure 2), and 2) a floor assembly with two panels butted together at a tongue and groove joint across the width of the assembly (Figure 3). A second specimen (OSB-01BR) without the tongue and groove joint was tested for the OSB-01 material, as the ignition time could not be determined due to failure of the furnace thermocouples in the test with specimen OSB-01B.

For each test, the temperatures were measured at four locations in the furnace. The temperatures inside the furnace for a typical test are shown in Figure 10. The average temperature was used to control the furnace prior to the ignition of the OSB such that the temperature followed the standard time-temperature curve provided in CAN/ULC S101 [8].

The time at which the temperatures diverged from the standard time-temperature relationship is taken as an indication of the ignition time for the subfloor. The ignition times for the tests are shown in Table 6. There was limited variation in the ignition time for the 10 tests. The mean, minimum and maximum times were 242, 233 and 249 s, respectively.

From the time that ignition of the OSB was assumed to have occurred, the temperature quickly increased to approximately 800°C. Subsequently, the temperature increased slowly throughout the remainder of the test. The propane flow rate was minimal and the temperature increase was due to the burning of the OSB subfloor.

The temperatures were measured at five locations (Figure 1) on the unexposed side of the test assembly. Temperatures measured on the unexposed side for Tests OSB-03B and OSB-01BR are shown in Figures 11 and 12, respectively. In both tests, the temperature on the unexposed surface of the OSB began to increase at approximately 3 min. For Test OSB-03B, there was a continuous increase in the temperature throughout the remainder of the test with maximum temperatures > 300°C at the end of the test (Figure 11). In addition, the rate of temperature rise increased as the test progressed.

For Test OSB-01BR, the temperature on the unexposed side reached 100°C at approximately 6 min and subsequently remained constant until approximately 10 min. These results would suggest that there was sufficient moisture in the OSB to affect the heat transfer through the assembly. (Note: the moisture content in the OSB was not measured prior to testing.)

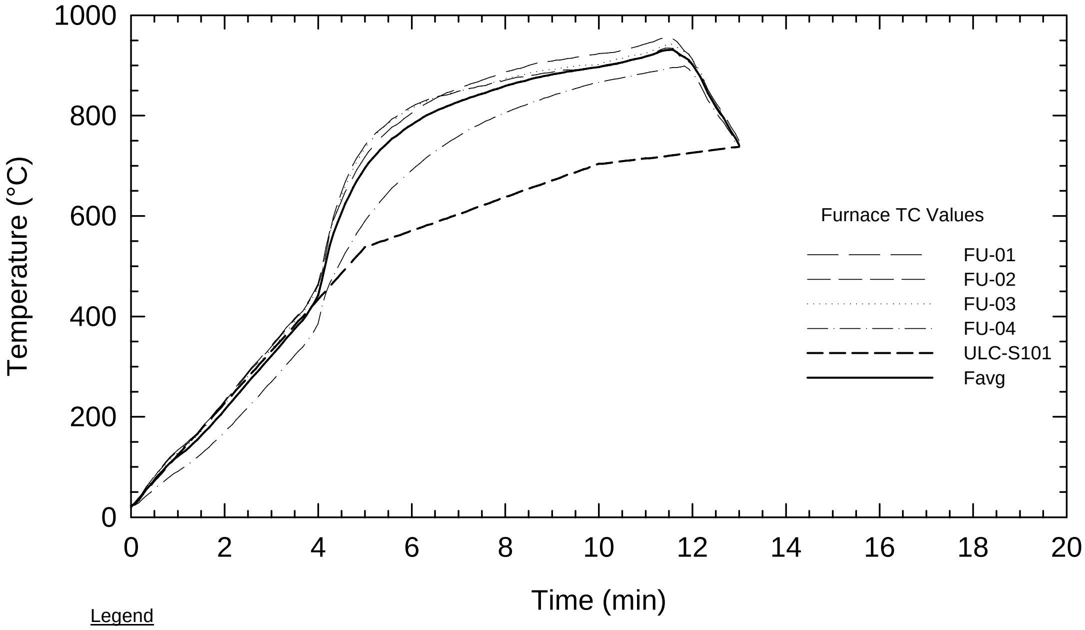
The OSB samples were conditioned at a temperature of 23°C and 50% relative humidity prior to the construction of the floor assemblies. However, the floor assemblies were constructed in the laboratory space and were stored in this space prior to the tests.

The temperatures measured for the 11 tests with the five OSB subfloor samples are provided in Appendix C. Photographs showing typical test assemblies, flame penetration and fire damage are also shown in the Appendix C.

The primary parameter that was measured in the intermediate-scale tests was the time for flames to penetrate through the subfloor material. These times were based on video records and are summarized in Table 6.

For the assemblies with a tongue and groove joint, the flame penetrated the subfloor at the tongue and groove joint. The mean, minimum and maximum times were 446, 408 and 478 s, respectively.

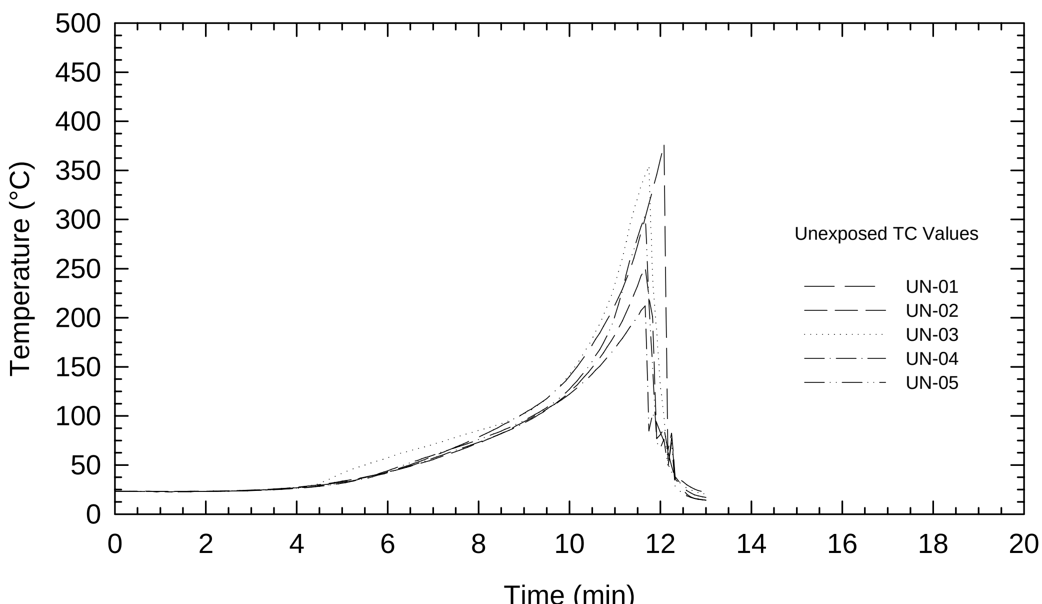
For the assemblies using a single OSB panel, there was flame penetration through a large section of the OSB subfloor. The mean, minimum and maximum times for flame penetration were 670, 608 and 741 s, respectively.



Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple,

Figure 10. Furnace temperatures for typical test (Test OSB-03B).



Legend

UN-01 to 05 - Unexposed Surface Thermocouple

Figure 11. Temperatures on unexposed surface for Test OSB-03B.

The difference between the minimum and maximum time required for the flame to penetration through the subfloor was 70 s and 133 s for the floor assemblies with a tongue and groove joint and the floor assemblies with a single OSB panel, respectively. The flame penetration results for the floor assemblies using OSB-03, which was used for the full-scale fire tests, were comparable to the results for all the OSB samples.

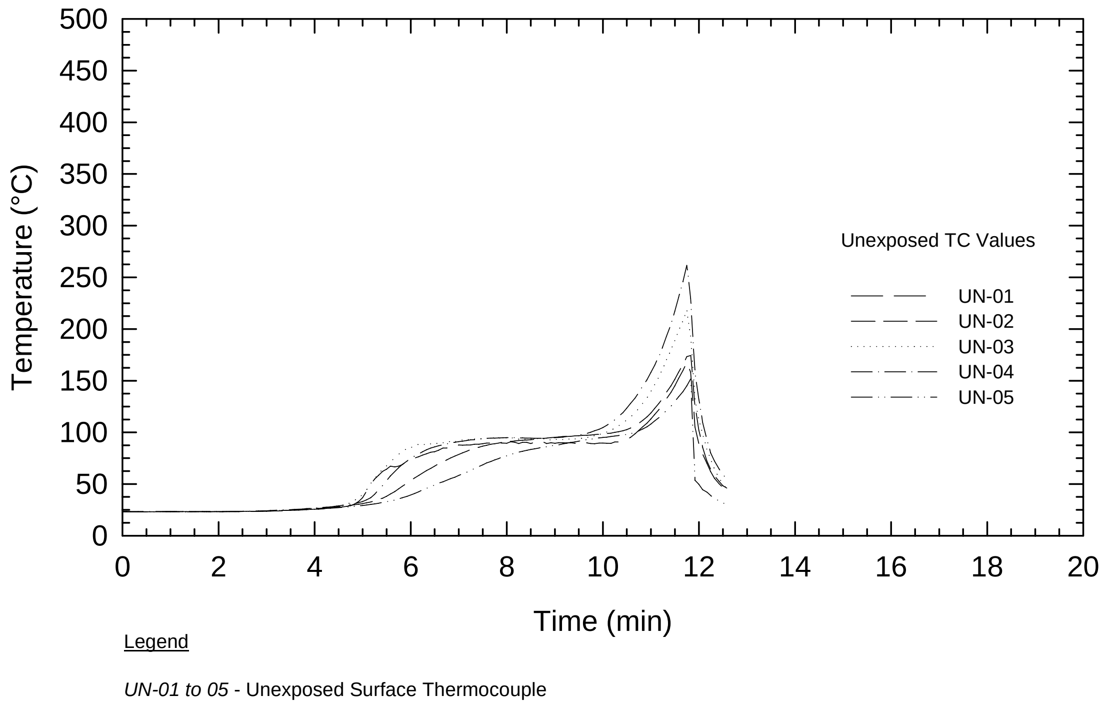


Figure 12. Temperatures on unexposed surface for Test OSB-01BR.

Table 6. Ignition and flame penetration times for OSB floor assemblies.

Test	Thickness	OSB Joint	Ignition Time	Surface Flaming
	(mm)		(s)	(s)
OSB-01A	16.12	Yes	243	408
OSB-01B	16.12	No	NA	741
OSB-01BR	16.12	No	248	694
OSB-02A	15.02	Yes	249	455
OSB-02B	15.02	No	238	662
OSB-03A	15.00	Yes	238	473
OSB-03B	15.00	No	233	683
OSB-04A	15.32	Yes	243	417
OSB-04B	15.32	No	244	633
OSB-05A	15.06	Yes	243	478
OSB-05B	15.02	No	242	608

7.2 Additional Floor Assemblies

Additional tests were conducted to investigate the effect of factors such as additional floor materials and loads on the flame penetration time. All of these tests were conducted using OSB-03 for the subfloor. The ignition and flame penetration times for these tests are summarized in Table 7. The temperatures measured for each test are provided in Appendix D. Photographs showing typical test assemblies, flame penetration and fire damage are also shown in the Appendix D.

7.2.1 Joint Orientation

The typical test assembly with a tongue and groove joint was constructed with the joint running across the width of the floor assembly (Figure 3). It was observed during the tests that there was separation of the two OSB panels producing an open area in the assembly through which the flames eventually penetrated the subfloor (Test OSB-03A). One possible reason for the separation of the OSB panels was the elongation of the steel joists due to thermal effects.

Test OSB-03C was conducted with the tongue and groove joint along the length of the assembly (Figure 4). The flame time penetration time for this test was comparable to the time for the test with the normal joint orientation. This would suggest that the elongation of the steel joist may not be the primary reason for the separation between the panels at the tongue and groove joint.

During the cone calorimeter tests, it was noted that the OSB specimens shrank with thermal exposure. This phenomenon may partly help to explain the reason for the separation between the panels in the intermediate-scale tests.

Table 7. Ignition and flame penetration times for OSB floor assemblies.

Test	Thickness	OSB Joint	Ignition Time	Surface Flaming
	(mm)		(s)	(s)
OSB-03A	15.00	Yes	238	473
OSB-03B	15.00	No	233	683
OSB-03C	15.00	Yes	234	470
OSB-03D	15.00	No	242	731
OSB-03E	15.00	Yes	241	772
OSB-03F	15.00	Yes	242	763
OSB-03G	15.00	Yes	238	768
OSB-03H	15.00	No	235	616
PLY-01A	15.90	Yes	251	603
PLY-01B	15.90	No	248	819

7.2.2 Ignition of Combustible Flooring Materials

Tests OSB-03E and OSB-03F were conducted using assemblies with a tongue and groove joint running across the width of the assembly. Typical flooring materials were added to the top of the assembly to determine their effect on the time to flame penetration.

For Test OSB-03F, a typical residential carpet and carpet underpad were added to the test assembly. This test was conducted to investigate the potential for early ignition of the carpet and carpet underpad to produce flame spread on the finished surface of a carpeted floor assembly.

Flames were observed on the surface of the carpet at 763 s. This was longer than the time required for flame penetration through the bare OSB panel (Test OSB-03B) and considerably longer than the time for flame penetration at the tongue and groove joint (Test OSB-03A). These results suggest that there was not sufficient flame penetration at the tongue and groove joint to ignite the carpet underpad.

During the latter stages of the test, there was an increase in the smoke production from the top of the floor assembly. Although there were no visible flames, this is believed to have occurred because the carpet underpad was pyrolyzing, producing the additional smoke. (There was minimal damage to the carpet other than in the region directly above the tongue and groove joint at the end of the test. However, almost the entire carpet underpad was consumed during the test indicating that most of the smoke was from the carpet underpad.)

For the specific test conditions, there was no indication that the flame spread through the tongue and groove joint to the carpet underpad or carpet. However, two important factors regarding the intermediate-scale test series were:

1. The furnace pressure was negative relative to the surrounding laboratory space.
2. Tests were not undertaken to determine the relative combustibility of residential carpets and carpet underpads.

Further research is required to fully investigate the potential for flame spread to combustible flooring materials due to flame penetration through the tongue and groove joint.

The temperature at the interface between the unexposed surface of the OSB subfloor and the carpet underpad exceeded 100°C at approximately 600 s and 200°C at approximately 690 s. For the latter case, the temperature rise criteria [8] used to determine assembly failure in fire resistance tests due to potential flame spread to combustible materials was exceeded.

For Test OSB-03E, a 6 mm thick poplar plywood underlay was added to the top of the floor assembly. The underlay panels were screwed to the OSB using the recommended screws and screw pattern for this application (Figure 5). The butt joint between the two underlay panels was offset from the tongue and groove joint in the OSB subfloor.

Flames were observed on the unexposed side of the assembly at 772 s. This time was longer than the time required for flame penetration through the solid OSB panel (Test OSB-03B). The initial flame penetration for assembly OSB-03E was at the butt joint between the two plywood underlay panels. It was observed after the test that the primary damage to the underlay was in this area compared to the extent of damage noted at the location of the joint in the OSB subfloor. This would suggest that there is more pyrolysis and eventually ignition at this location. This may be due to more availability of oxygen for pyrolysis at the butt joint between the plywood underlay panels.

The results of this test indicate that the plywood underlay would delay the flame spread through the tongue and groove joint between OSB panels.

7.2.3 Loaded Assemblies

For Tests OSB-03D, OSB-03G and OSB-03H, the floor assembly was loaded using concrete blocks.

Two concrete blocks were located on the centerline of the floor assembly for Test OSB-03D. The blocks were centered between two joists. The OSB subfloor was able to support the blocks until after the flames penetrated the OSB subfloor. However, a block did fall through shortly after flames were observed.

Twelve concrete blocks were used for Tests OSB-03G and OSB-03H. The load per unit floor area was the same as used in the full-scale fire tests with unprotected floor assemblies. However, for the intermediate tests, the blocks were all centered between the joists.

For Test OSB-03G, the floor assembly included a plywood underlay. The flame penetration time for this test was comparable to that for Test OSB-03E (Table 7), which used the same assembly without a load.

For Test OSB-03H, the flames penetrated through the OSB at 616 s compared with 683 s for Test OSB-03B with the same floor assembly without a load. This indicates that the load may have some effect on flame penetration through the OSB subfloor. The OSB subfloor supported the concrete blocks until after the flames penetrated the subfloor. However, blocks did fall through shortly after the flames were observed.

7.3 Plywood Floor Assemblies

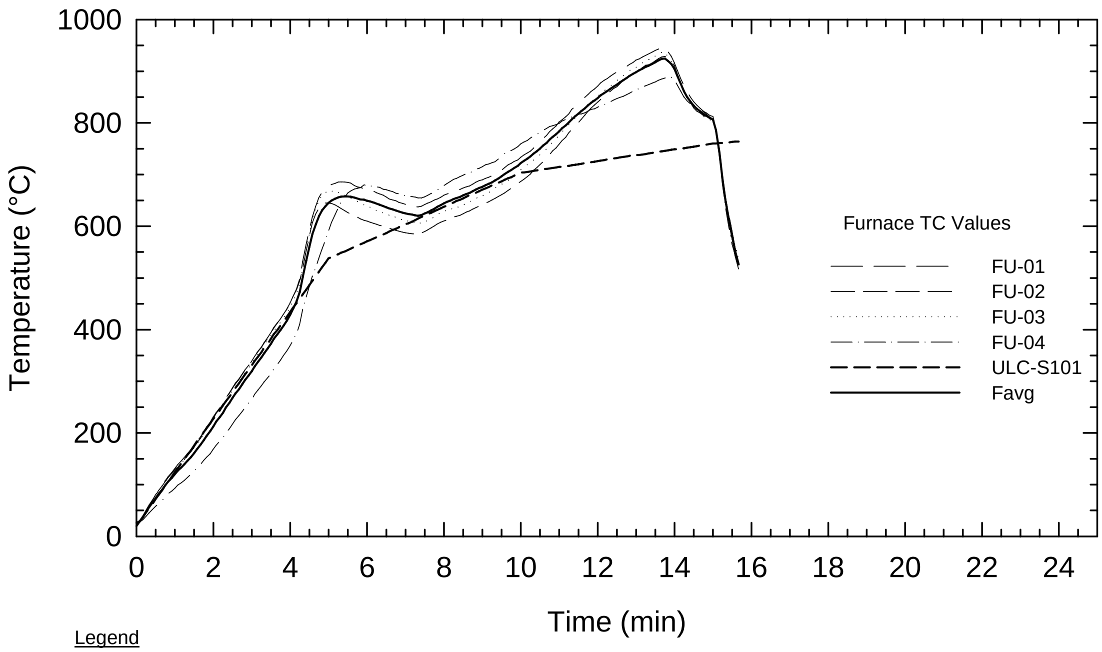
Two tests were conducted for floor assemblies constructed using a plywood subfloor. One plywood floor assembly had a tongue and groove joint running across the test assembly. The construction details for this assembly were identical to the OSB floor assembly shown in Figure 3. The second floor assembly was constructed using a single plywood panel and the construction details were identical to the OSB floor assembly shown in Figure 2.

The temperatures measured for each test are provided in Appendix E. Photographs showing typical test assemblies, flame penetration and fire damage are also shown in the Appendix E.

The temperatures in the furnace for Test PLY-01B are shown in Figure 13. As with the OSB specimens (Figure 10), there was a temperature increase above the standard time-temperature curve with the ignition of the plywood subfloor. However, the temperature subsequently decreased to the standard temperature until the latter part of the test (approximately 10 min).

The ignition time and flame penetration times for the floor assemblies are shown in Table 7. The ignition times are comparable to those determined for the floor assemblies with OSB subfloors. The flame penetration times through the plywood subfloors were longer than the times for the assemblies using OSB subfloors. However, the plywood subfloor was thicker than all the OSB subfoor panels except OSB-01. In addition, after the plywood subfloor was ignited, the temperature increase in the furnace was less than for the OSB subfloors.

Tests were conducted for only one plywood sample and no tests were conducted to determine the variation in the flame penetration time for other plywood subfloors.



Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple,

Figure 13. Furnace temperatures for Test PLY-01B.

8 SUMMARY AND CONCLUSION

This report documents a series of bench- and intermediate-scale fire experiments that were conducted on flooring materials and floor assemblies. The primary objective of the experiments was to provide fire test data for subfloor materials used in Canadian houses. The particular emphasis was on orientedstrand board (OSB) panels used for subfloors.

Cone calorimeter tests were conducted for five OSB samples using a radiant exposure of 50 kW/m^2. The heat release rate in the initial 350 s for the five OSB samples was comparable. However, parameters such as the time to ignition, initial peak heat release rate and time to initial peak heat release rate did vary indicating that there was a difference in the flammability of the OSB samples. The FIGRA index varied from 2.24 to 3.00 for the five OSB samples. This range of values is comparable to the expected variation in this parameter. This indicates that the potential contribution of the OSB samples to fire spread would be similar.

Cone calorimeter tests were conducted with flooring materials used in conjunction with the floor assemblies with OSB subfloors. The materials included a 6 mm thick poplar plywood underlay, residential carpet and carpet underpad. Cone calorimeter tests were conducted using a radiant exposure of 50 kW/m^2 to provide data on the fire characteristics for these materials.

Intermediate-scale fire tests were conducted for floor assemblies constructed using five OSB subfloor samples. Two assemblies were constructed for each of the five OSB subfloor materials: 1) a floor assembly using a single OSB panel, and 2) a floor assembly with a tongue and groove joint across the width of the assembly.

In every case for the assemblies with a tongue and groove joint, the flame penetrated the subfloor at the tongue and groove joint. The average time for flame penetration was 446 s. For the assemblies using a single OSB panel, there was flame penetration through a large section of the OSB subfloor. The average time for flame penetration was 670 s. The difference between the minimum and maximum time required for the flame to spread through the subfloor was 70 s and 133 s for the floor assemblies with a tongue and groove joint and the floor assemblies with a single OSB panel, respectively. The flame penetration results for the floor assemblies using OSB-03, which was used for the full-scale fire tests, were comparable to the results for all the OSB subfloor samples.

Additional tests were conducted with floor assemblies to investigate the effect of joint orientation, additional flooring material and load on the time required for the flames to penetrate the subfloor. The results showed:

1. The flame penetration time was comparable for the two assemblies with different orientation of the tongue and groove joint. This suggests that the elongation of the steel framing used to construct the test assemblies did not affect the time required for the flames to penetrate the OSB subfloor.
2. The flame penetration time for the assembly with the residential carpet and carpet underpad was longer than that for the floor assembly with a full panel. The flame penetration through the tongue and groove joint was not sufficient to ignite the combustible flooring material. However, there was significant production of smoke from the carpet underpad as the temperature increased at the interface between the OSB subfloor and underpad. It is recommended that further research be conducted to investigate the potential for ignition of combustible materials on the unexposed side of the floor assembly.
3. The addition of the poplar plywood underlay to the floor assembly increased the time required for flames to penetrate through the floor assemblies with a tongue and groove joint. The time for flame penetration for these assemblies was slightly longer than that for assemblies using full OSB panels.
4. The OSB subfloor was able to support the concrete blocks used to load the floor assemblies until after the flames spread through the OSB subfloor. However, blocks did fall through the floor shortly after flames were observed on the unexposed side of the assembly.
5. Tests were conducted with one plywood subfloor sample. The time for flame penetration was longer than for the comparable floor assembly with an OSB subfloor.

The bench- and intermediate-scale tests provide data on the fire behavior of flooring materials and the time for flames to penetrate a subfloor. These test methods could form the basis for evaluating the fire performance of alternative subfloor materials. However, further research is required to develop the test requirements.

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Appendix A – Cone Calorimeter Results for OSB Samples

The results of the cone calorimeter tests for the five OSB sample are summarized in this Appendix. Triplicate tests were conducted using specimens from each OSB sample with a radiant exposure of 50 kW/m^2. One test for each specimen was conducted using a specimen holder without a grid. There was some swelling of the OSB with the radiant exposure. All other tests were conducted using a specimen holder with a grid. Additional tests were conducted with OSB-03 with radiant exposures of 25 and 35 kW/m^2. Results for selected parameters for all tests are summarized in Table A1. The heat release rate and smoke production rate for the test specimens are provided in Figures A1 – A12. The average results shown in the plots are for the two tests conducted with a grid.

ASTM 1354 [4] has three criteria for the duration of cone calorimeter tests: the time at which flaming or other signs of combustion cease (flameout), the average mass loss over 1-min period drops below 150 g/m^2 or until 60 min have elapsed. For the OSB specimens, most of the heat release occurred within 800 s. However, sustained flaming occurred over a longer time with burning of small pieces of the material remaining in the holder. As a result, the time for flameout varied from specimen-to-specimen (Table A1).

ISO 5660 [5] provides alternative criteria for the test duration: 32 minutes after sustained flaming is observed (30 minutes if no ignition), oxygen levels return to the initial levels to within 100 ppm or all the mass is lost. These criteria were applied to the OSB tests to determine an end of test time and results are shown in Table A1. The ISO criteria provide an estimate for the end of test time, which had less variability than the flameout time. The ISO end of test time was used for the calculation of parameters such as total heat release rate and total smoke shown in Table A1, which are dependent on the end of test time. This approach leads to less variability in the results.

Figures A1 – A10 show the heat release rate and smoke production rate for all the tests with each OSB sample using a radiant exposure of 50 kW/m^2. There were differences between the tests conducted with and without a grid. In particular, there was a higher initial peak heat release rate at an earlier time for the tests without the grid. The average heat release rate and smoke production rate for each sample shown in the figures was based on the two tests with a specimen holder with a grid. In addition, the average data used in Section 6.1 was based on the tests with Specimens 2 and 3 from each OSB sample.

No smoke data was obtained for Test OSB-01-2. Only the results for the tests with Specimens 1 and 3 are shown in Figure A2.

Table A1. Cone calorimeter test results for OSB specimens.

OSB specimen	Radiant flux	Initial mass	Mass lost	Ign. time	Time flame -out	Time end test	Peak HRR1	Time peak HRR1	Peak HRR2	Time peak HRR2	Total HR	Avg. HRR (360 s)	Effect. heat comb.	Peak SPR	Total smoke
	(kW/m^2)	(g)	(g)	(s)	(s)	(s)	(kW/m^2)	(s)	(kW/m^2)	(s)	(MJ/m^2)	(kW/m^2)	(MJ/kg)	(m^2/s)	(m^2)
OSB-01-1	50	97.4	97.4	14	1426	1810	261.7	45	172.6	665	150.2	138.2	13.6	0.015	3.8
OSB-01-2	50	101.0	95.9	34	1330	1834	217.8	80	181.4	680	133.2	144.6	12.3	NA	NA
OSB-01-3	50	93.9	89.5	23	3016	1823	211.9	75	202.2	600	142.0	154.6	14.0	0.018	5.9
OSB-02-1	50	96.4	90.8	9	1441	1809	245.6	40	246.8	660	151.2	125.5	14.7	0.022	4.4
OSB-02-2	50	100.0	76.6	34	1748	1834	207.6	85	232.8	655	139.4	140.5	16.1	0.022	4.9
OSB-02-3	50	95.9	84.2	31	3500	1831	210.9	75	202.8	660	134.8	144.2	14.2	0.021	6.8
OSB-03-1	50	87.2	84.1	24	2000	1824	268.0	45	240.3	610	137.4	139.4	14.5	0.024	5.0
OSB-03-2	50	84.2	75.2	29	3118	1829	211.6	75	218.2	565	130.4	149.3	15.4	0.024	5.6
OSB-03-3	50	87.3	77.9	33	3307	1833	225.9	70	232.2	555	133.1	149.5	15.1	0.019	4.0
OSB-03-4	35	86.1	76.3	40	900	1840	155.7	100	203.7	695	NA	NA	NA	0.015	2.8
OSB-03-5	35	83.4	74.1	49	915	1849	166.7	85	197.8	680	116.3	108.8	13.9	0.017	3.0
OSB-03-6	35	88.4	66.8	46	1005	1846	175.2	95	209.7	690	121.6	113.7	16.07	0.015	2.9
OSB-03-7	25	82.8	76.2	91	997	1891	149.1	140	198.7	830	118.8	97.5	13.8	0.016	1.9
OSB-03-8	25	86.9	69.7	100	1016	1900	152.3	150	191.8	815	117.6	100.13	14.9	0.013	2.3
OSB-04-1	50	103.9	93.7	19	2828	1819	244.0	50	275.9	645	158.4	156.7	15.0	0.028	6.2
OSB-04-2	50	101.3	89.4	27	4028	1827	207.9	95	298.0	640	152.9	157.4	15.1	0.031	5.8
OSB-04-3	50	97.8	87.5	23	3500	1823	224.6	90	222.4	565	144.0	156.5	14.6	0.020	4.7
OSB-05-1	50	87.5	81.3	17	1400	1817	227.9	35	302.1	525	138.7	144.8	15.1	0.036	7.3
OSB-05-2	50	93.0	82.4	32	2080	1832	201.0	105	238.7	550	133.8	152.1	14.4	0.023	5.7
OSB-05-3	50	88.9	78.1	30	1828	1830	202.3	75	297.0	540	131.5	145.9	14.9	0.034	5.4

HRR – Heat Release Rate per Unit Area   Total HR – Total Heat Release per Unit Area   SPR – Smoke Production Rate   NA – Data not available

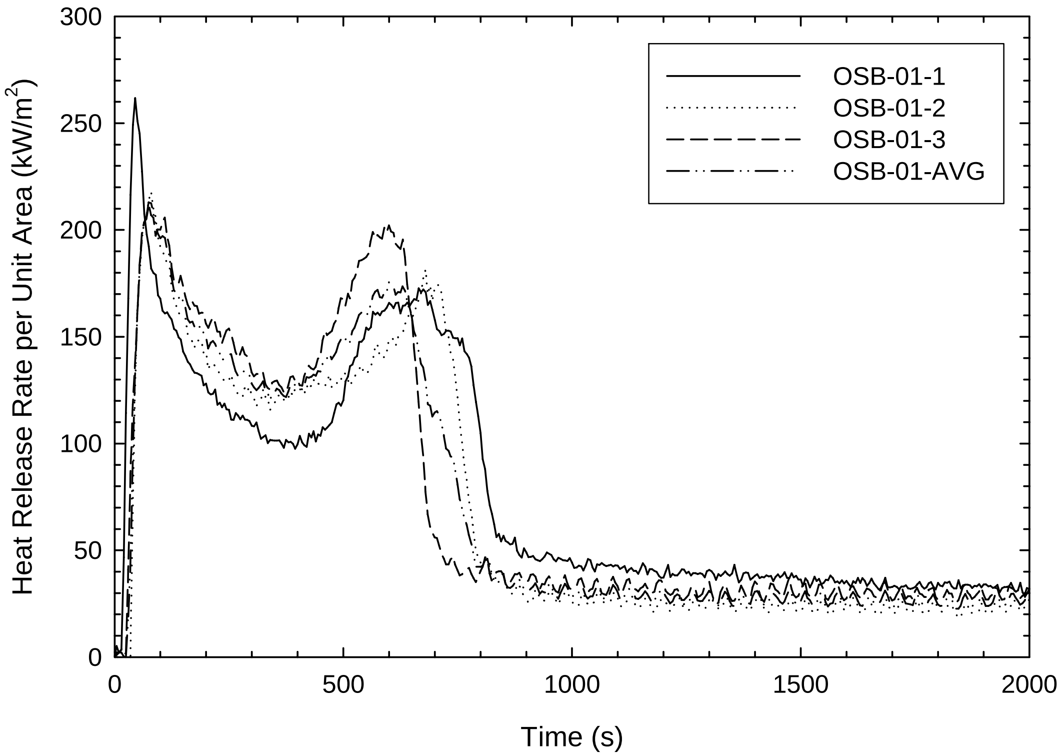


Figure A1. Heat release rate for OSB-01.

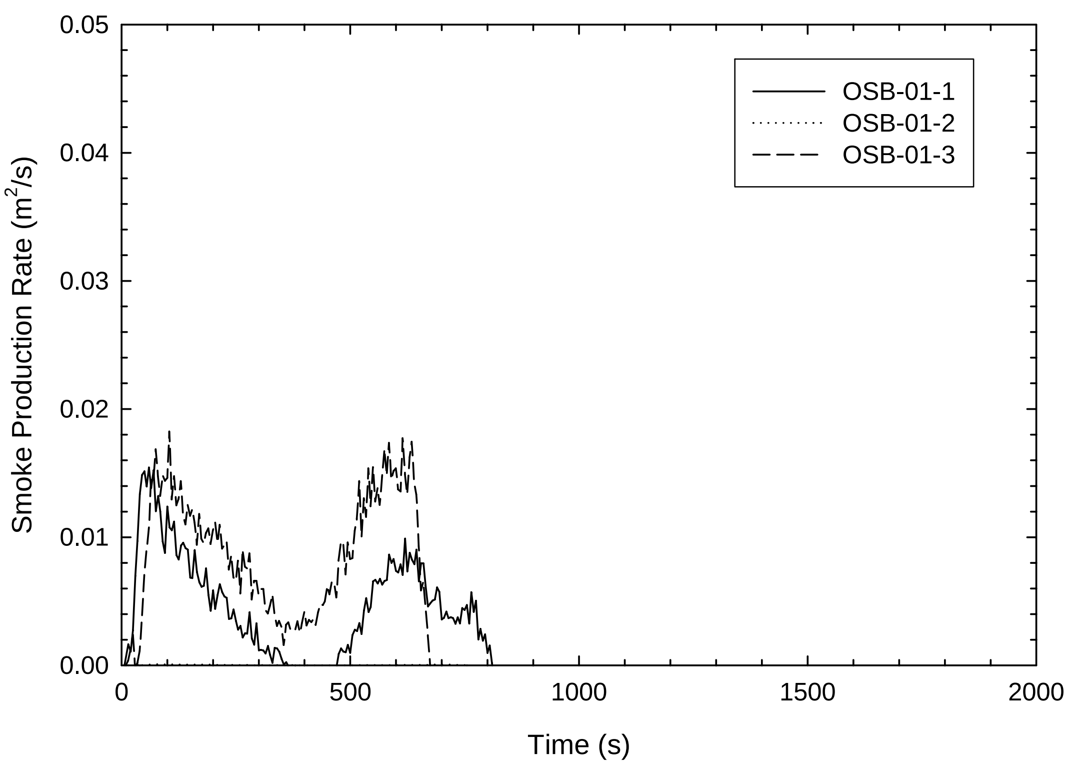


Figure A2. Smoke production rate for OSB-01.

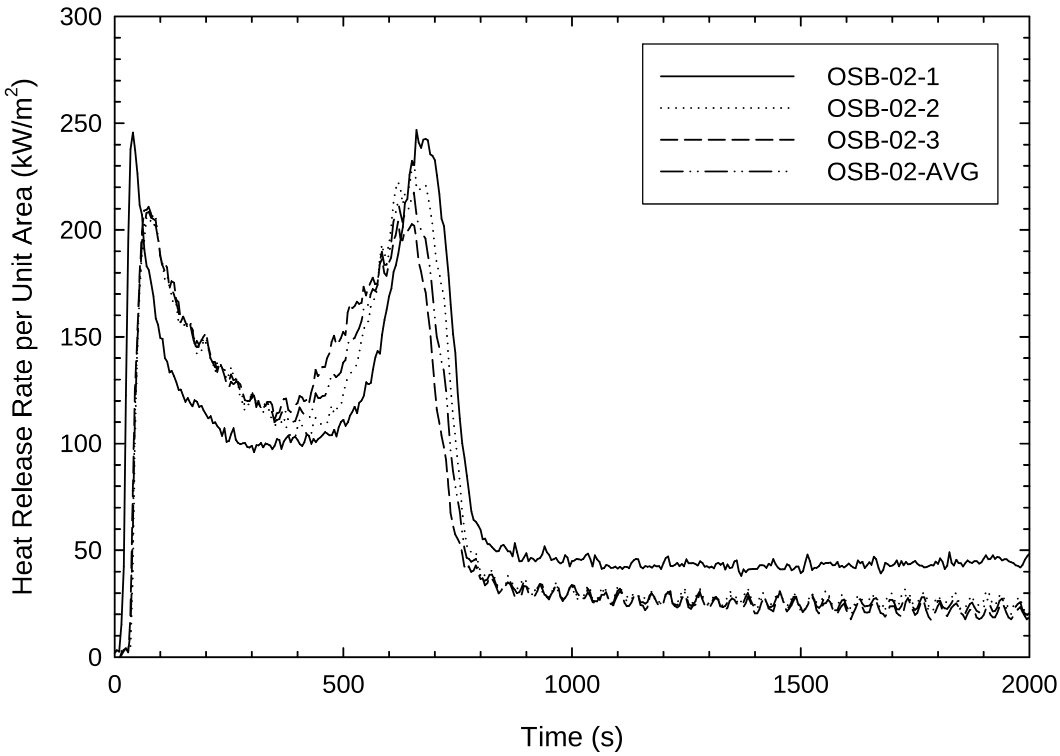


Figure A3. Heat release rate for OSB-02.

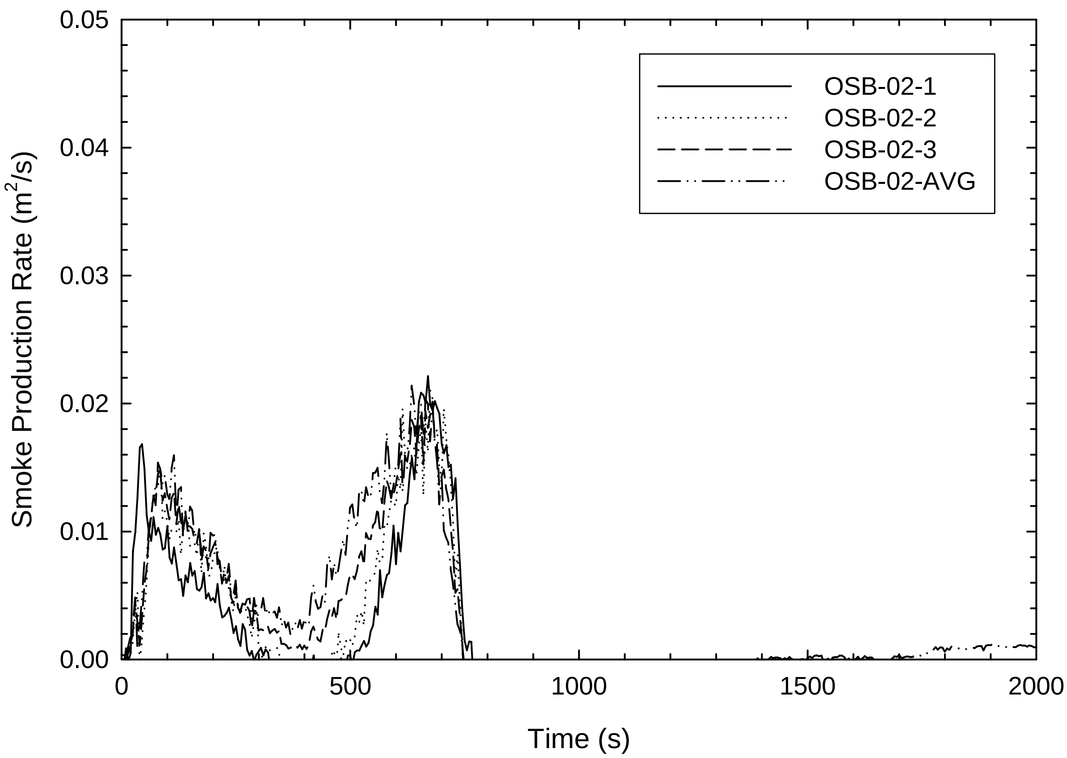


Figure A4. Smoke production rate for OSB-02.

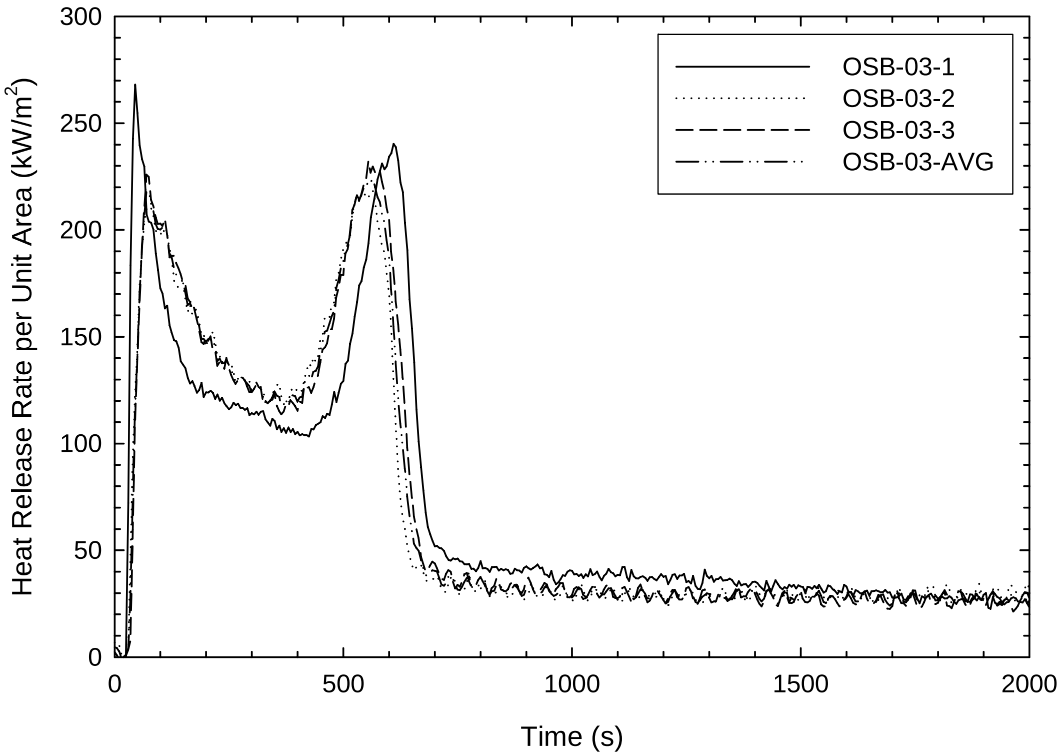


Figure A5. Heat release rate for OSB-03.

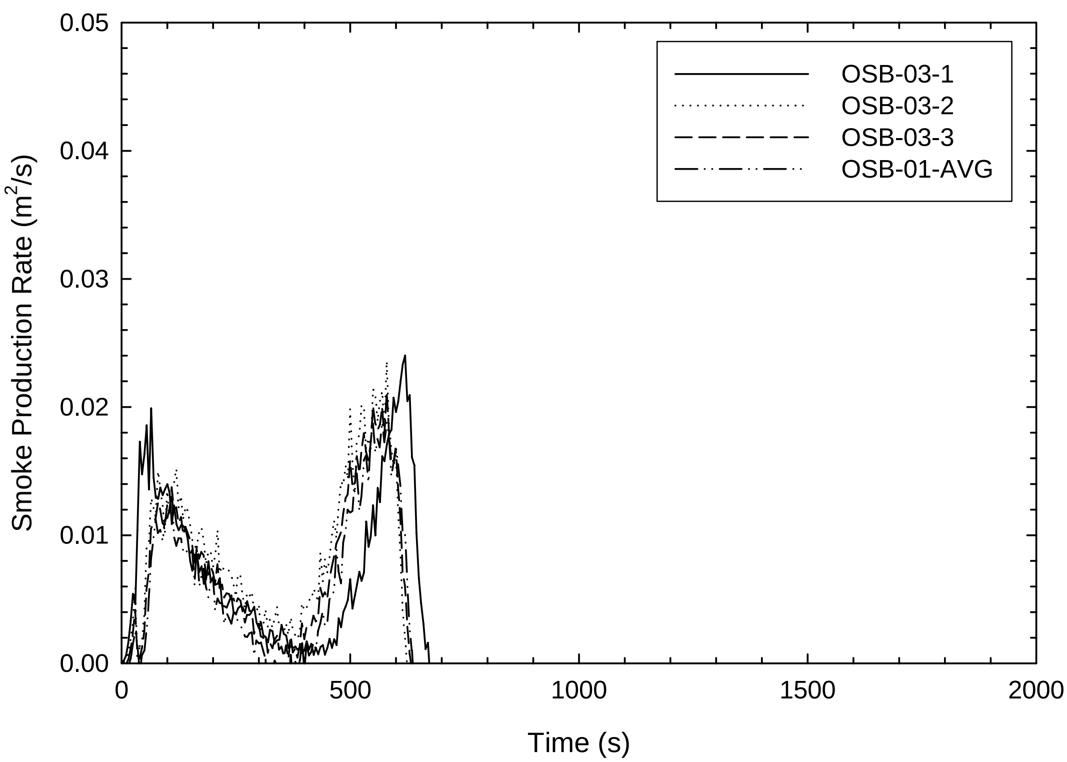


Figure A6. Smoke production rate for OSB-03.

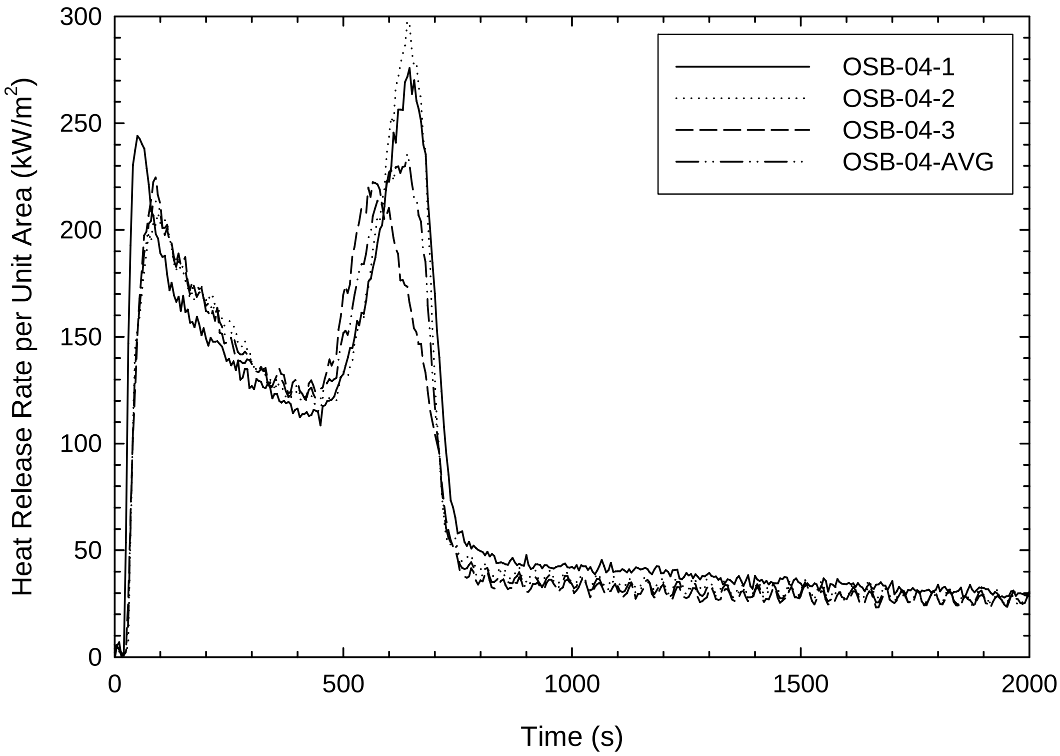


Figure A7. Heat release rate for OSB-04.

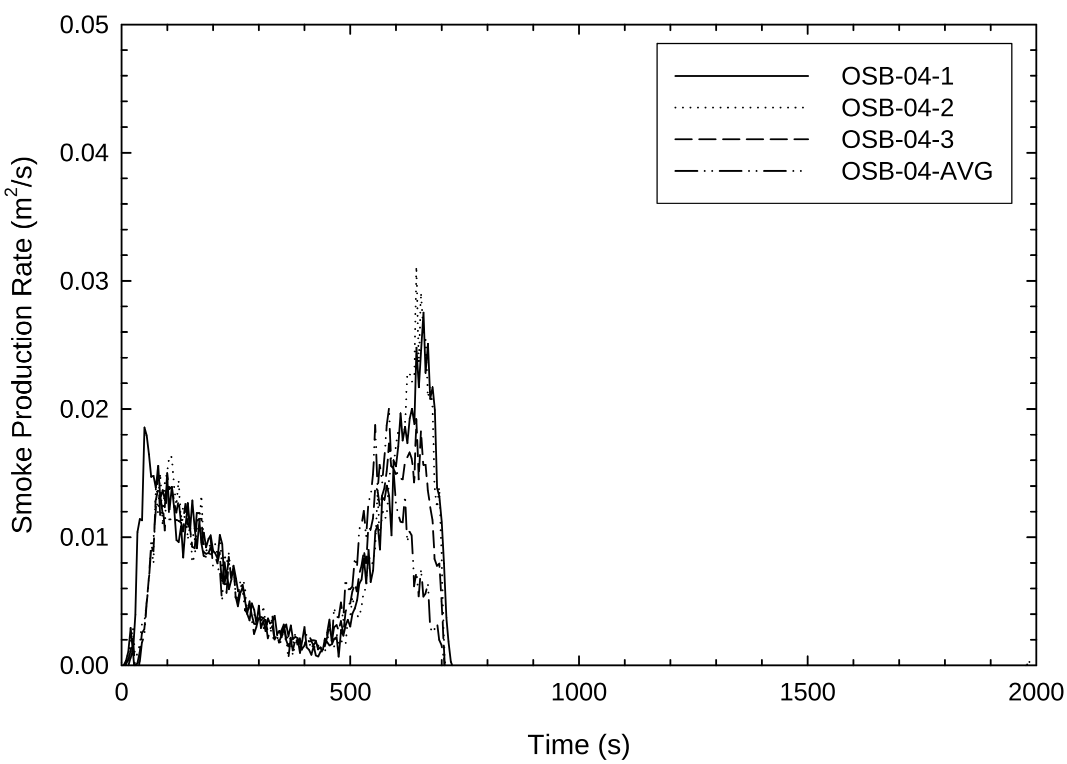


Figure A8. Smoke production rate for OSB-04.

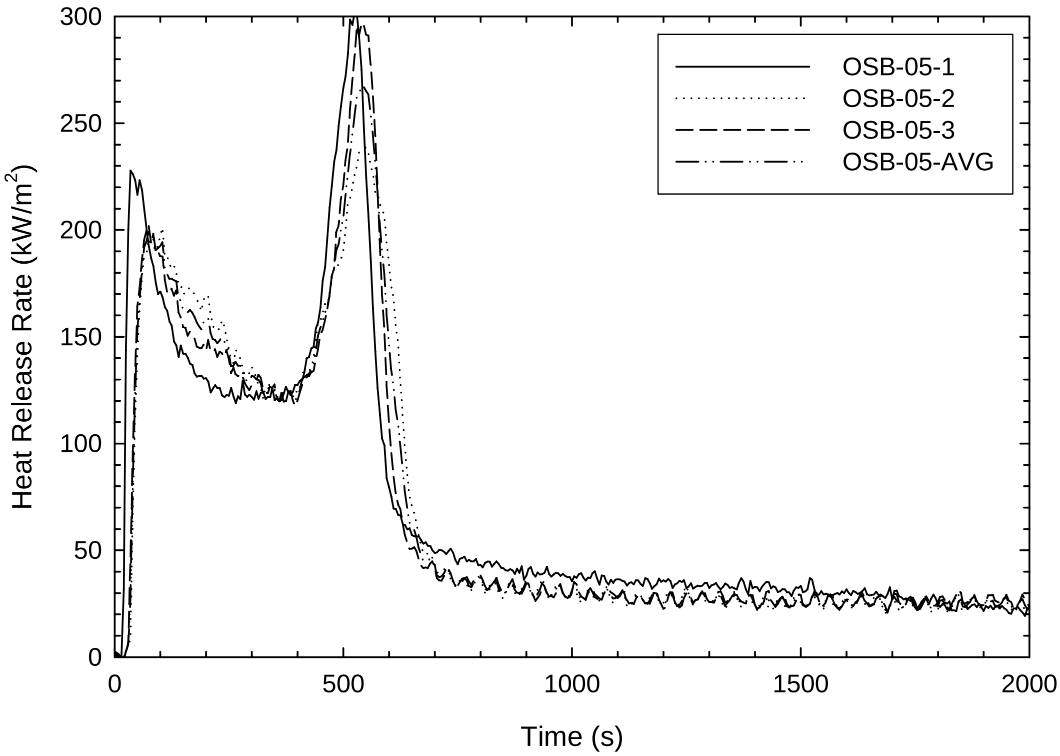


Figure A9. Heat release rate for OSB-05.

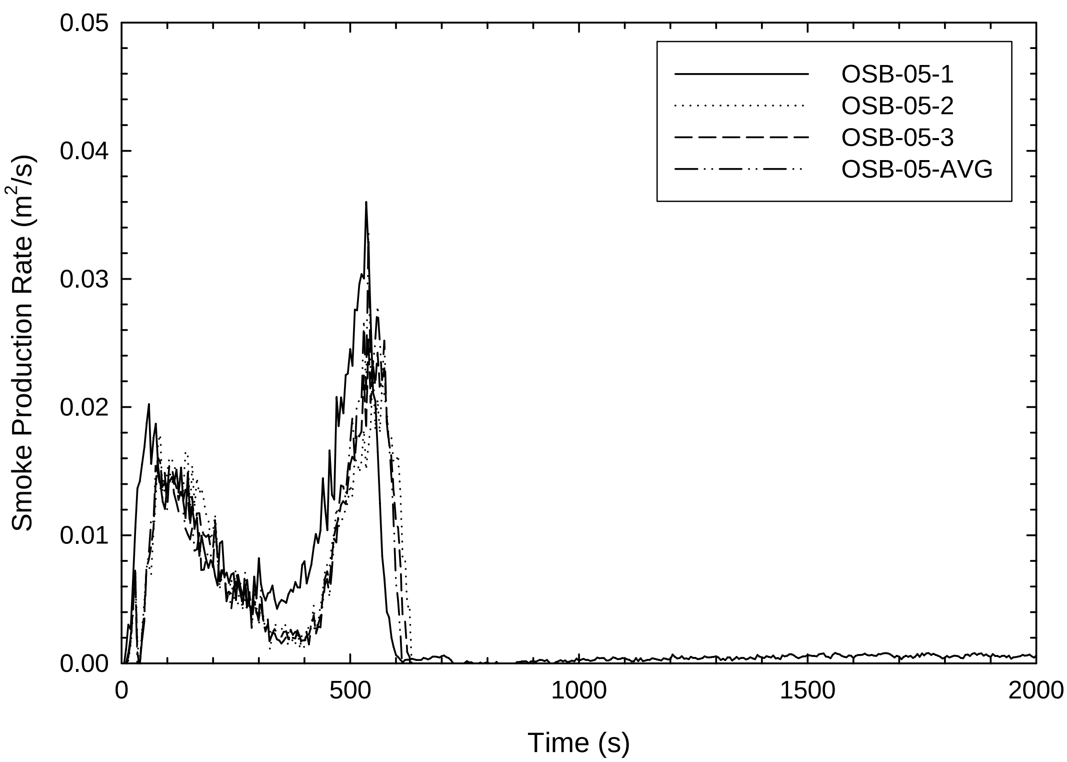


Figure A10. Smoke production rate for OSB-05.

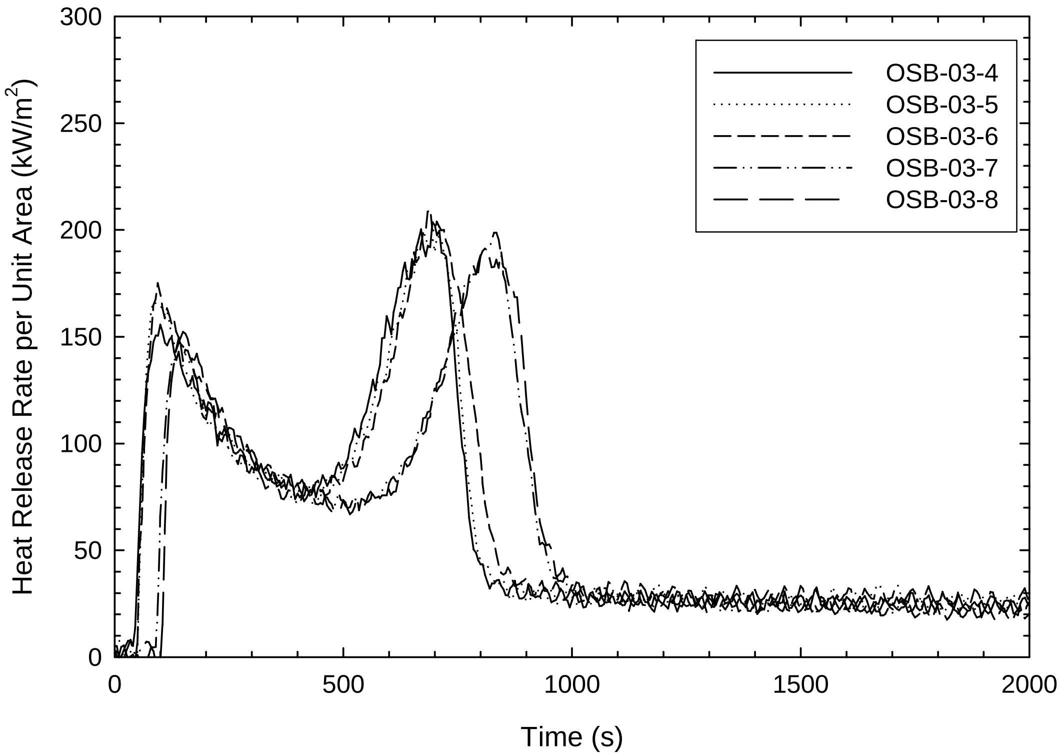


Figure A11. Heat release rate OSB-03 with 25 and 35 kW/m^2 radiant flux.

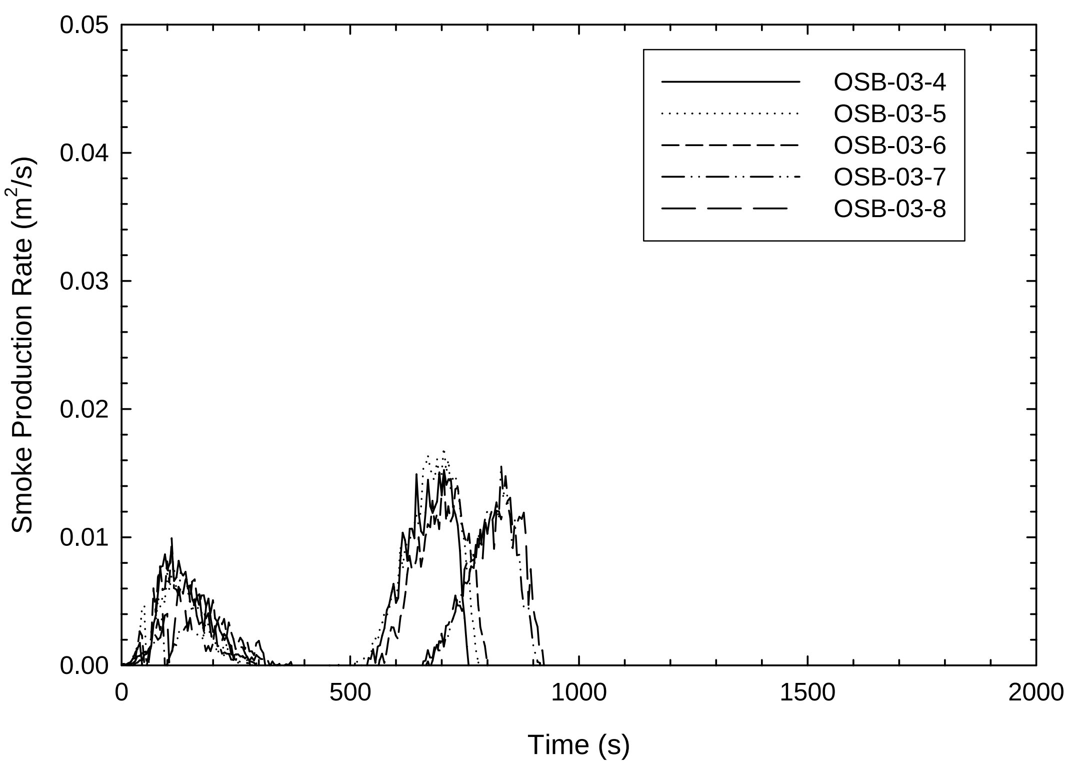


Figure A12. Smoke production rate OSB-03 with 25 and 35 kW/m^2 radiant flux.

Appendix B – Cone Calorimeter Results for Flooring Materials

Some intermediate-scale tests were conducted with flooring materials used in conjunction with the OSB floor assemblies. The materials included a 6 mm thick poplar plywood underlay, carpet underpad and carpet. Cone calorimeter tests were conducted for these materials using a radiant exposure of 50 kW/m^2 to provide flammability data for these materials. A grid was used for all tests. Results for selected parameters for all tests are summarized in Table B1. The heat release rate and smoke production rate for the test specimens are provided in Figures B1 – B6. The averaged results shown in the table and the plots are for all the tests conducted for each material.

Table B1. Cone calorimeter test results for flooring materials.

Flooring material specimen	Radiant flux	Initial mass	Mass lost	Ignition time	Time to flameout	Time to end of test	Peak HRR	Time peak HRR	Total HR	Avg. HRR (360 s)	Effect. heat of comb.	Peak SPR	Total smoke
	(kW/m^2)	(g)	(g)	(s)	(s)	(s)	(kW/m^2)	(s)	(MJ/m^2)	(kW/m^2)	(MJ/kg)	(m^2/s)	(m^2)
PLYUN-1	50	31.1	31.2	22	1094	1045	320.8	155	54.0	110.1	15.4	0.029	2.5
PLYUN-2	50	30.4	30.1	19	1037	1180	310.9	175	54.5	108.2	16.0	0.025	2.2
PLYUN-3	50	29.5	28.7	22	1002	1095	310.1	175	51.4	105.7	15.9	0.030	1.9
CARUP-1	50	14.9	14.5	16	195	610	735.0	60	41.4	112.2	25.3	0.098	6.8
CARUP -2	50	14.8	14.4	10	340	610	547.2	65	40.7	111.0	24.9	0.099	5.2
CARUP -3	50	14.6	14.5	9	154	525	706.3	60	40.8	112.6	24.7	0.100	6.8
CARUP -4	50	14.0	13.2	4	138	480	809.0	55	40.5	111.6	27.11	0.106	6.1
CARPT-1	50	27.4	19.5	17	282	610	509.4	95	46.0	118.6	20.9	0.140	9.3
CARPT-2	50	27.6	22.0	21	306	710	501.9	90	47.1	120.0	19.0		9.9
CARPT -3	50	29.3	19.5	20	247	705	550.5	115	46.5	120.7	21.1	0.100	9.5

HRR – Heat Release Rate   Total HR – Total Heat Release   SPR – Smoke Production Rate   NA – Data not available

PLYUN – Poplar Plywood Underlay   CARUP – Carpet Underpad   CARPT – Carpet

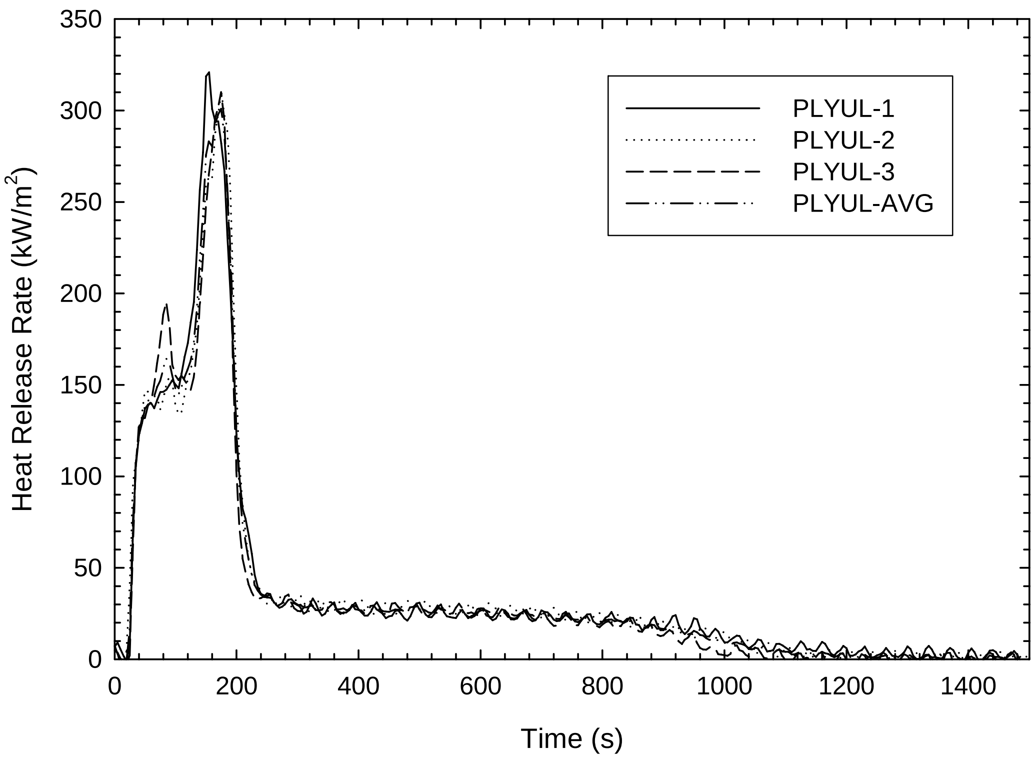


Figure B1. Heat release rate for poplar plywood underlay.

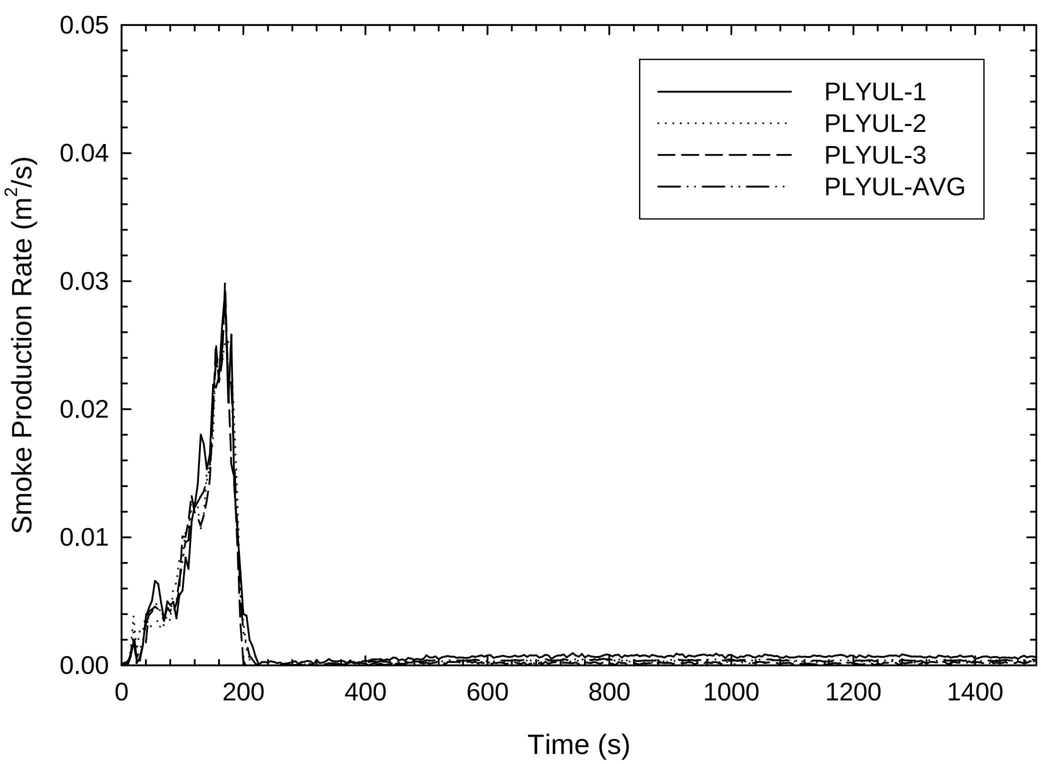


Figure B2. Smoke production rate for poplar plywood underlay.

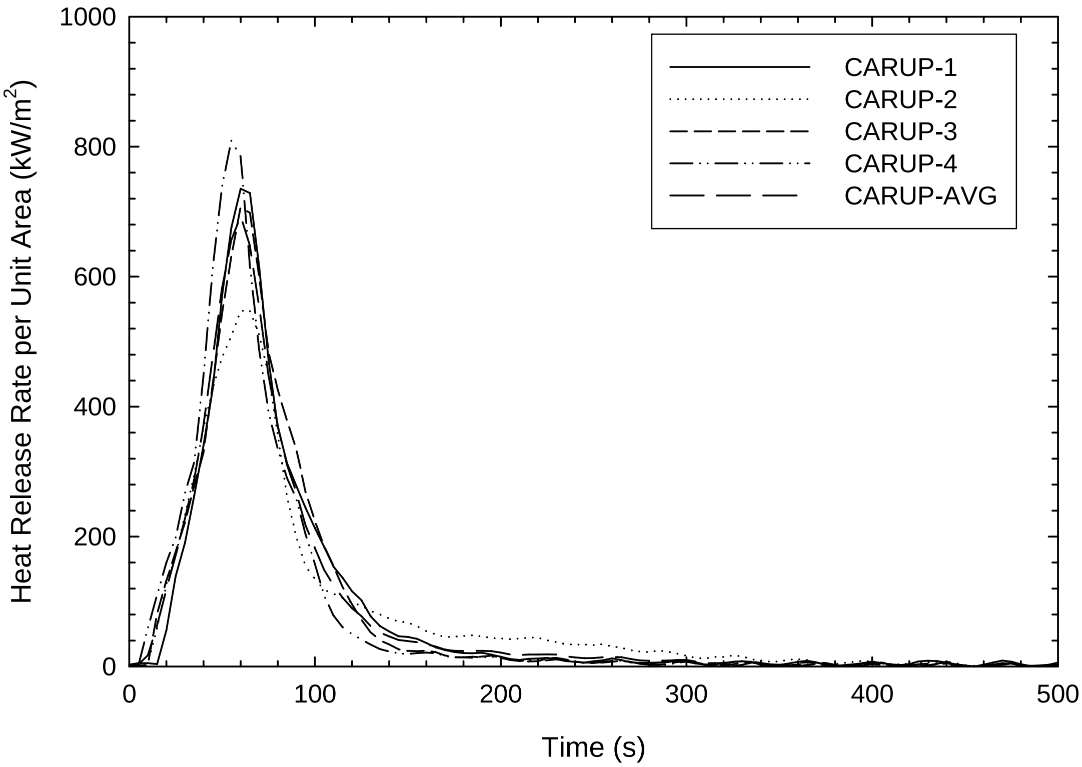


Figure B3. Heat release rate for carpet polyurethane foam underpad.

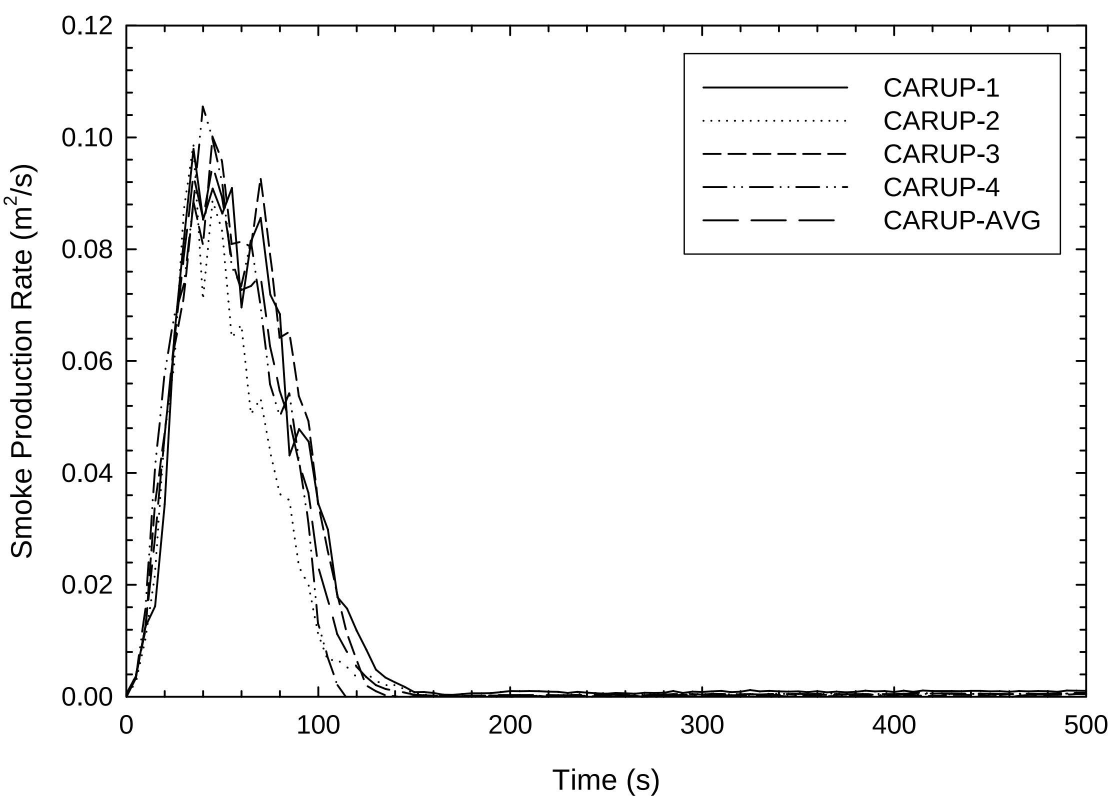


Figure B4. Smoke production rate for carpet polyurethane foam underpad.

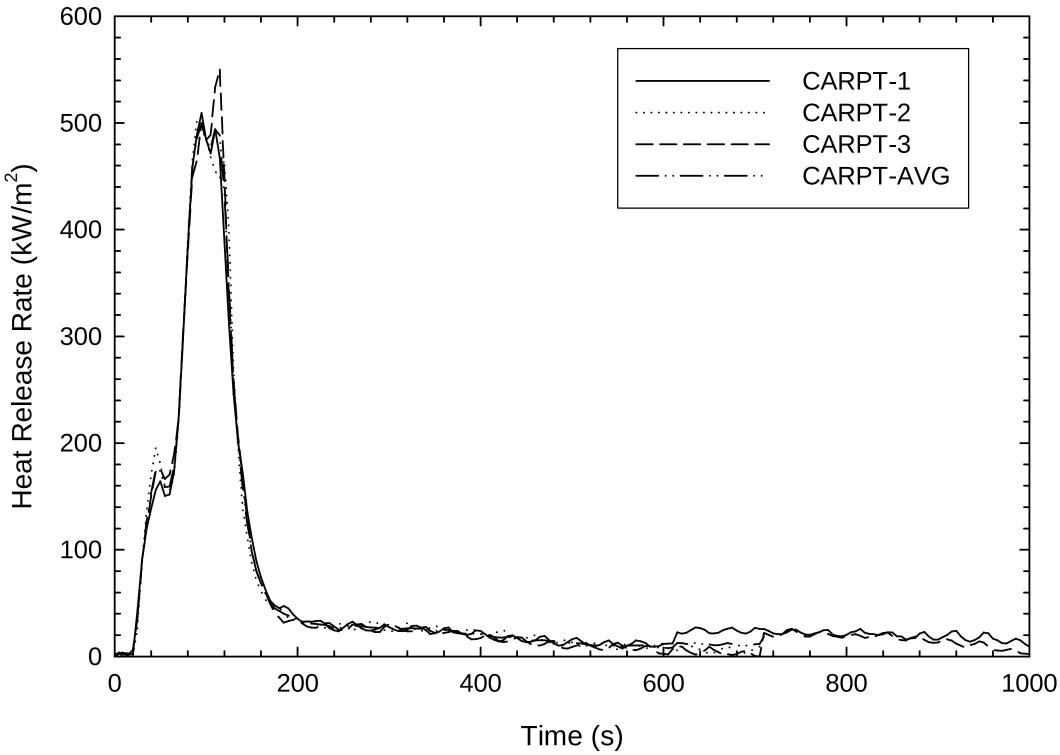


Figure B5. Heat release rate for carpet.

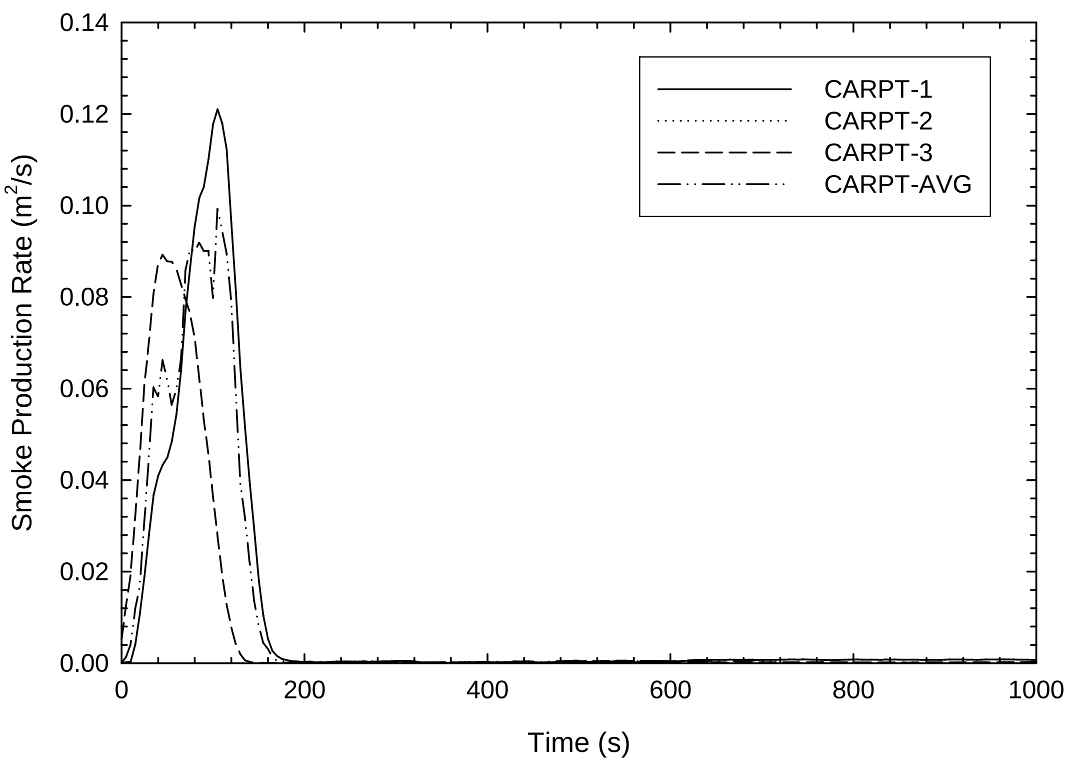


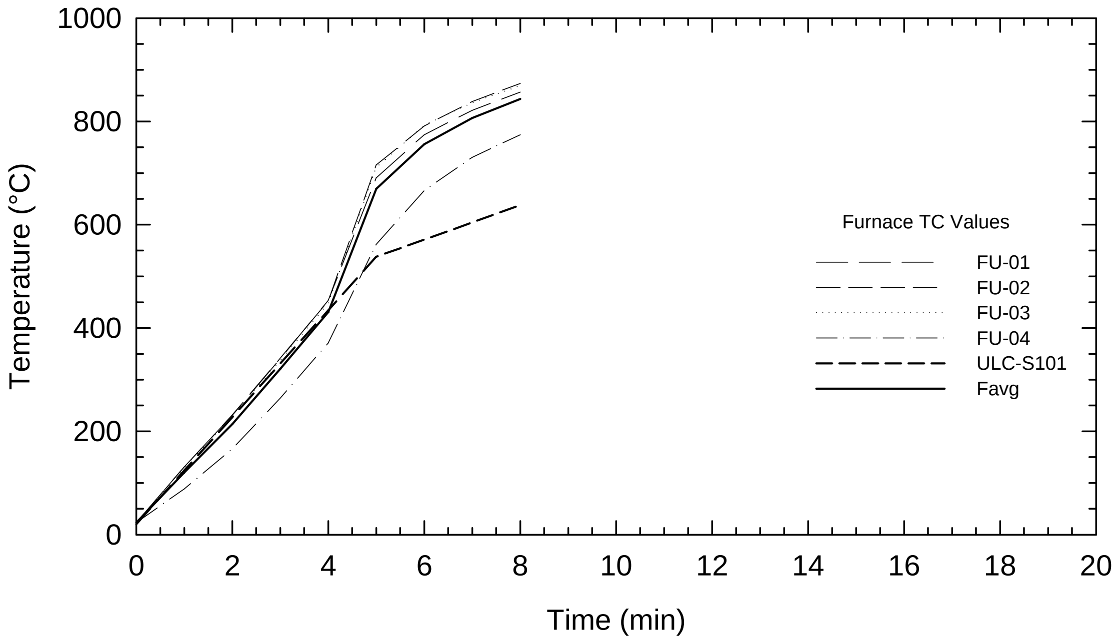
Figure B6. Smoke production rate for carpet.

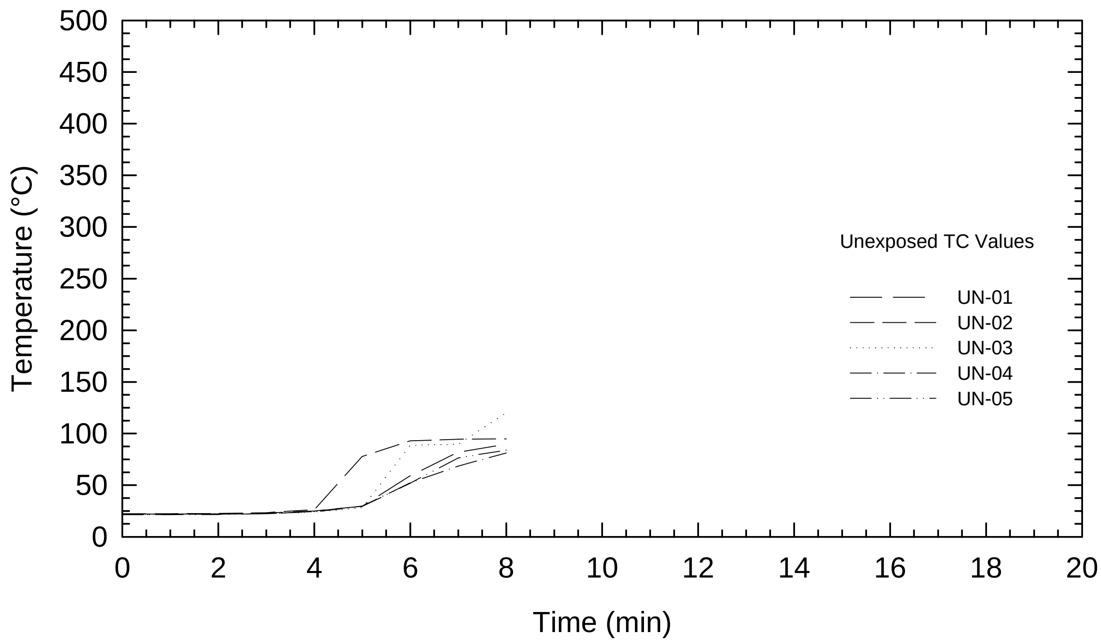
Appendix C – Temperature Data and Photographs for OSB Floor Assemblies

Intermediate-scale fire tests were conducted using floor assemblies constructed using the five OSB samples. Two assemblies were constructed for each of the five OSB materials: 1) a floor assembly using a single OSB panel (Figure 2), and 2) a floor assembly with a tongue and groove joint across the width of the assembly (Figure 3). A second specimen (OSB-01BR) without the tongue and groove joint was tested for the OSB-01 material, as the ignition time could not be determined due to failure of the furnace thermocouples in the test with specimen OSB-01B.

In each test, the temperatures were measured at four locations in the furnace. The average of these temperatures was used to control the furnace during the initial stages such that the temperature followed the standard time-temperature curve provided in CAN/ULC S101 [8]. The temperatures were measured at five locations on the unexposed side of the test assembly. The location of the thermocouples is shown in Figure 1. The temperatures measured on the exposed and unexposed side of the test assembly for each test are shown in Figures C1 – C11.

Photographs for a typical test for a floor assembly with a tongue and groove joint between two OSB panels are shown in Figures C12 – C15. Photographs for a floor assembly with a single OSB panel are shown in Figures C16 – C19.

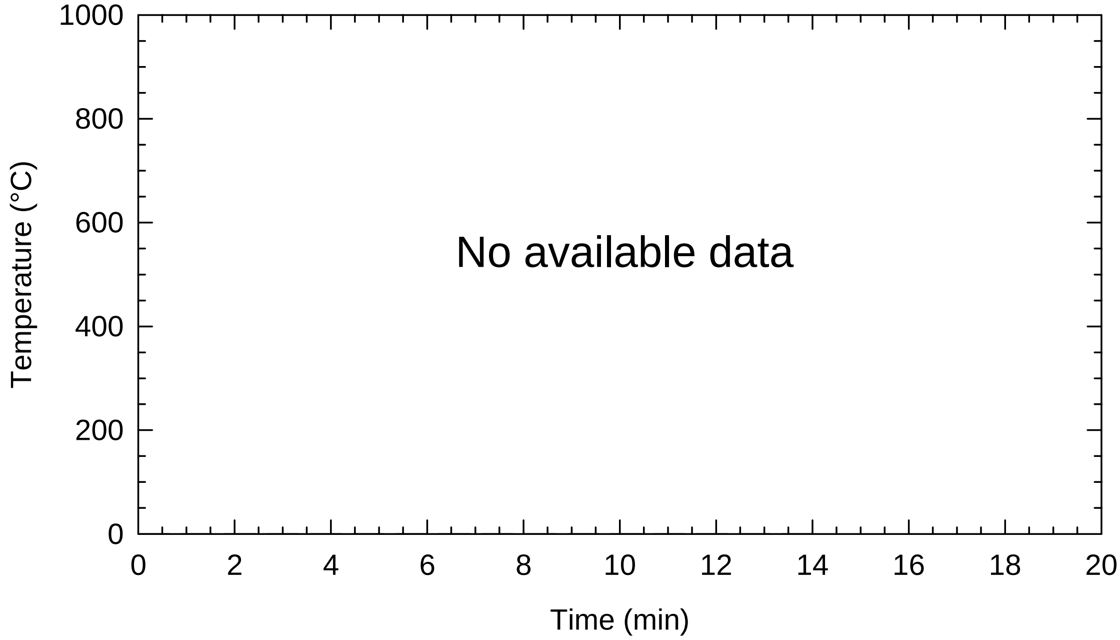


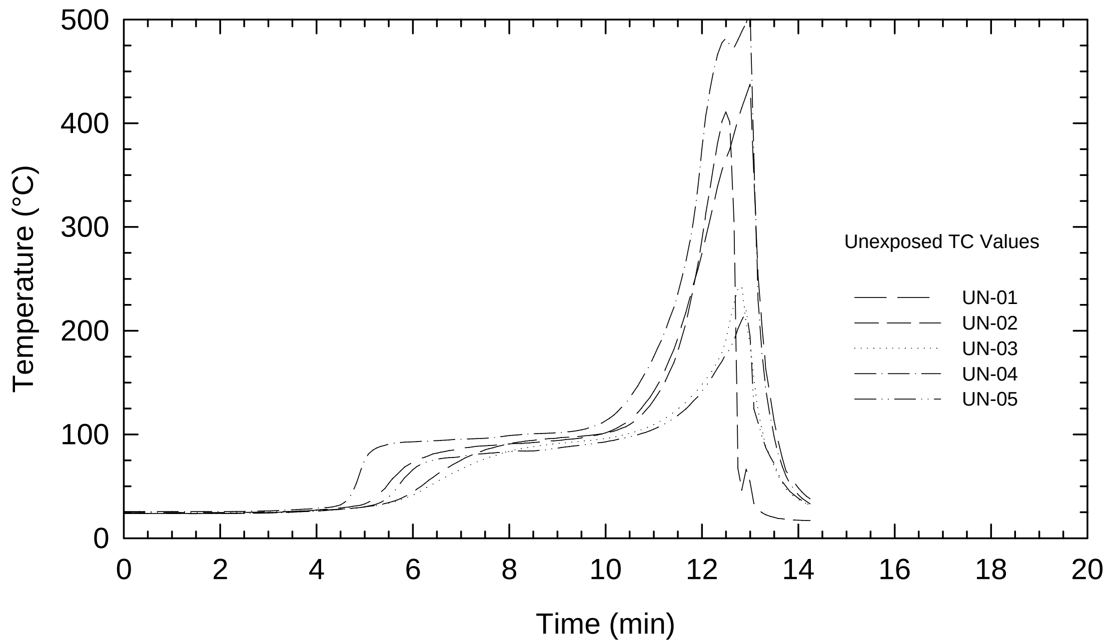


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C1. Temperatures for Test OSB-01A.

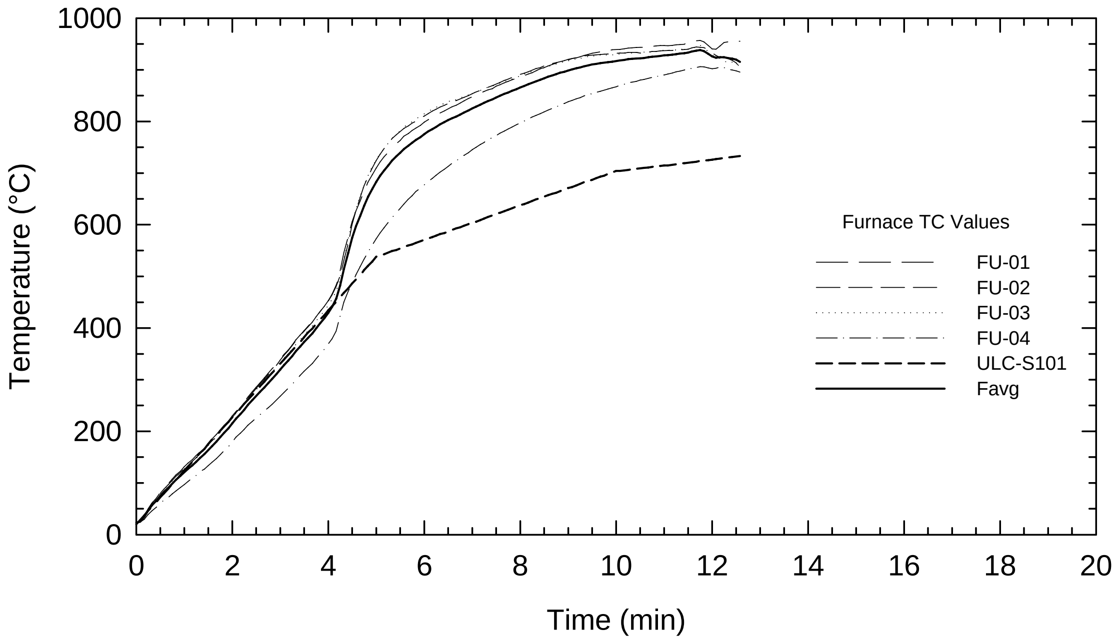


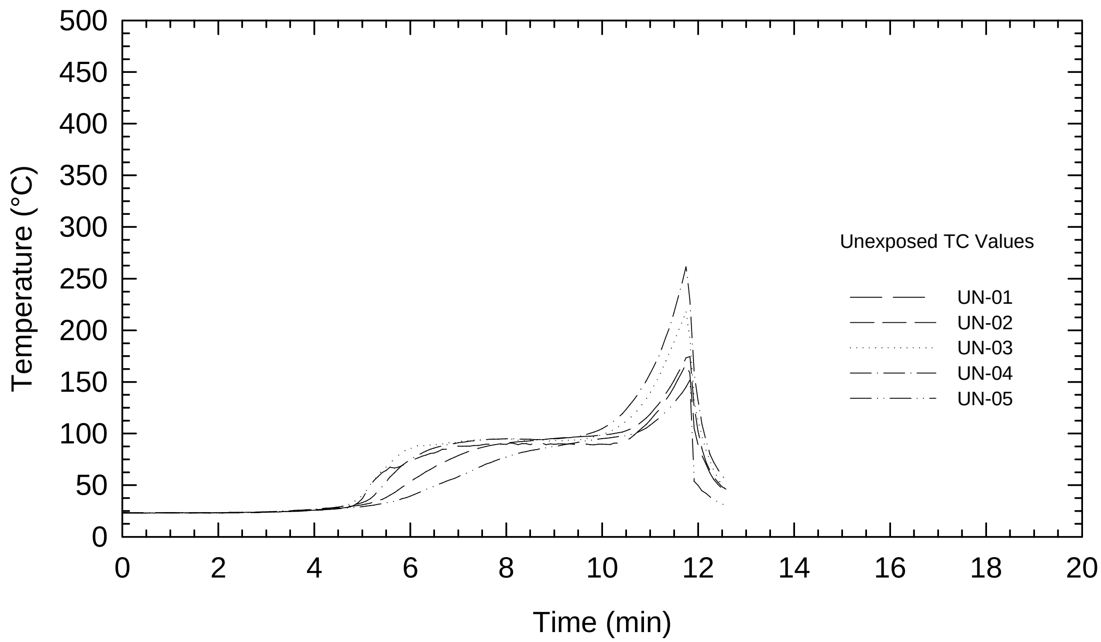


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C2. Temperatures for Test OSB-01B

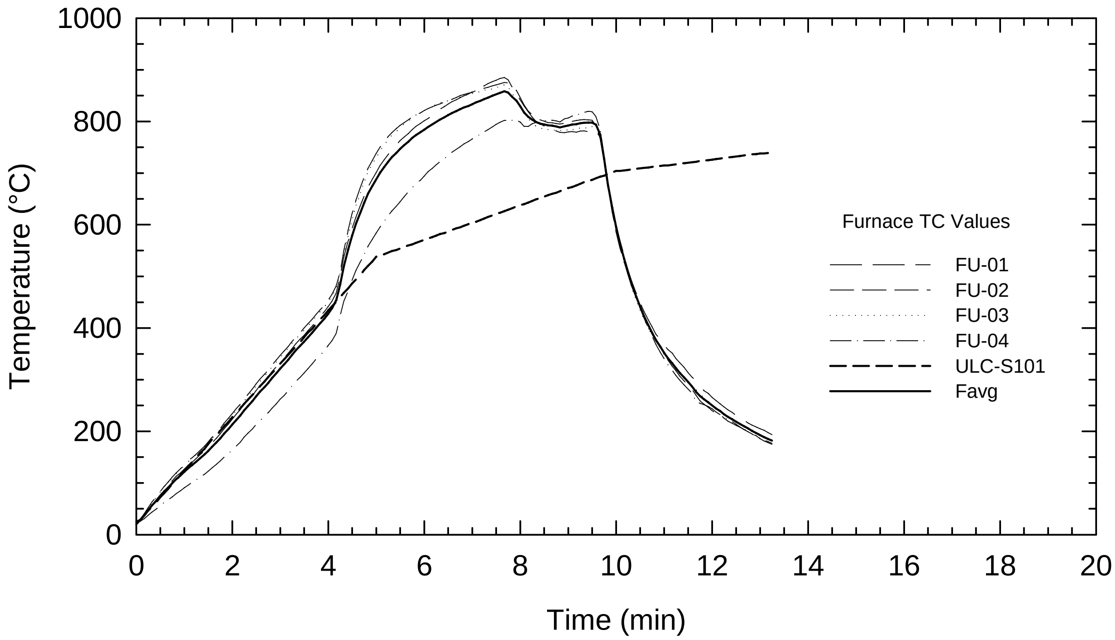


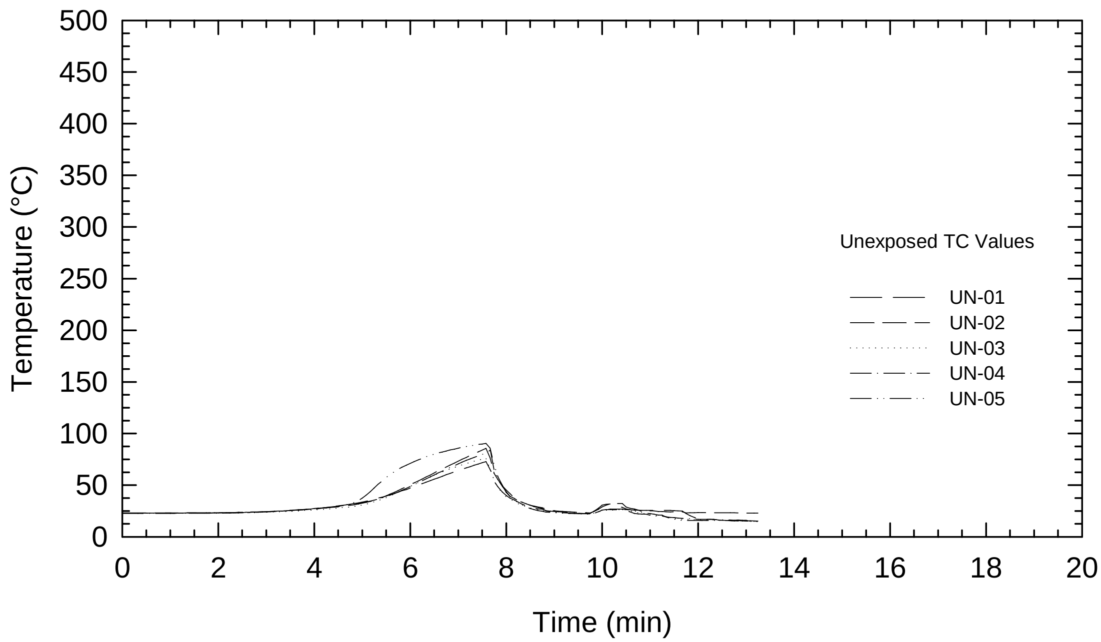


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C3. Temperatures for Test OSB-01BR

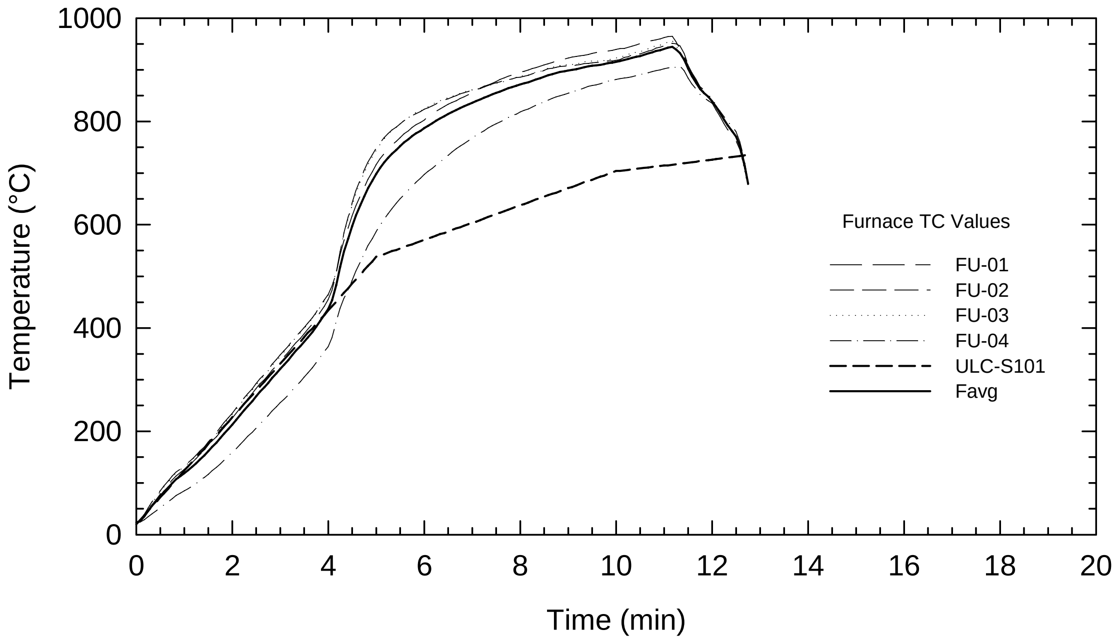


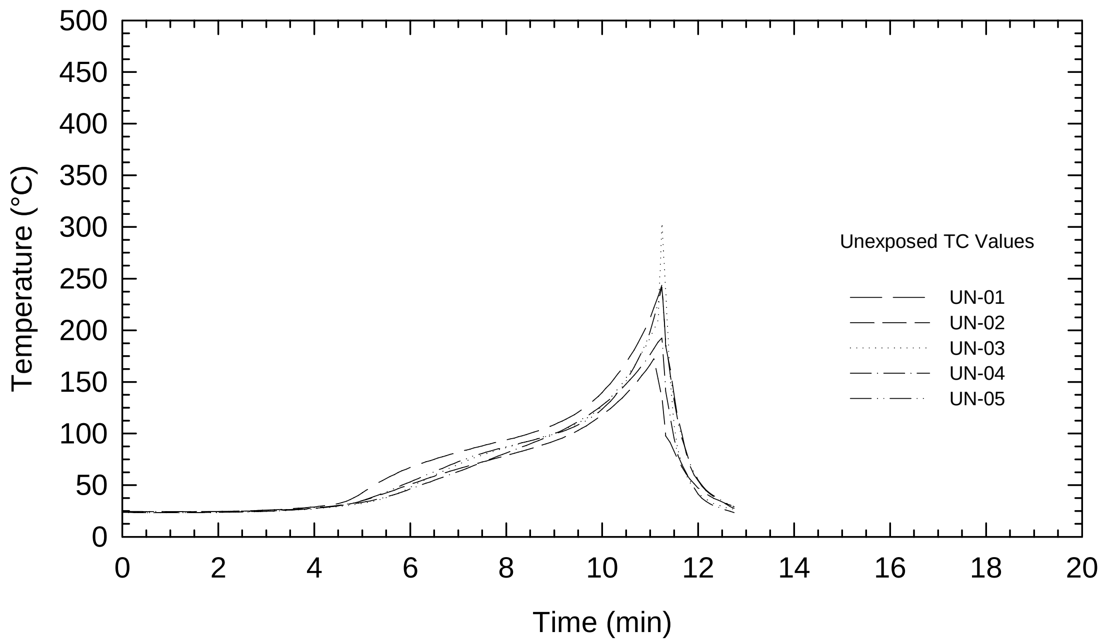


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C4. Temperatures for Test OSB-02A

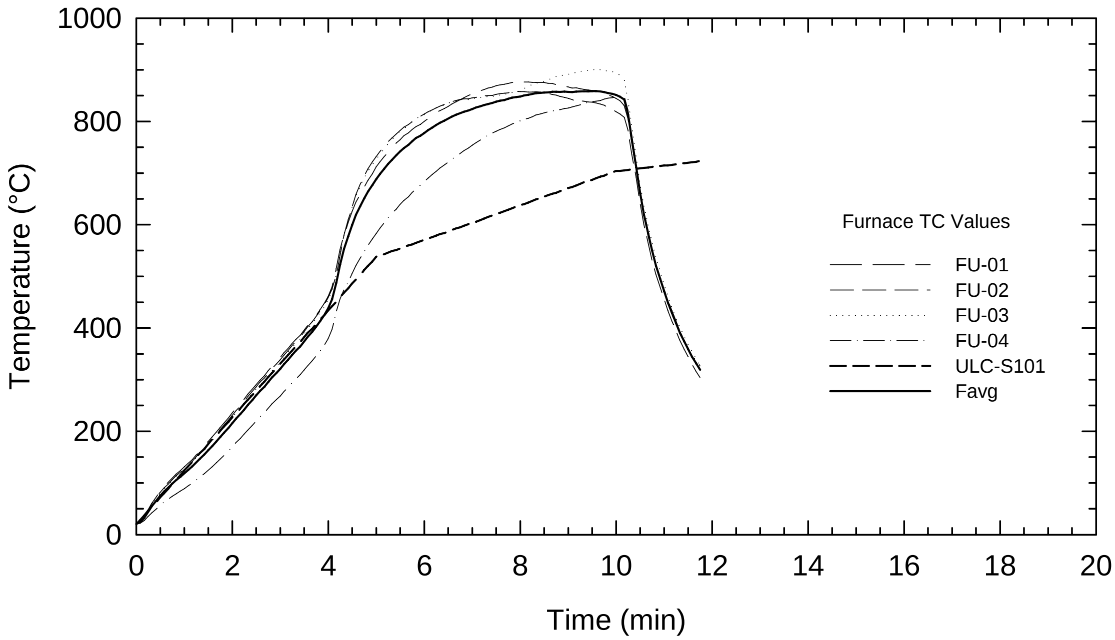


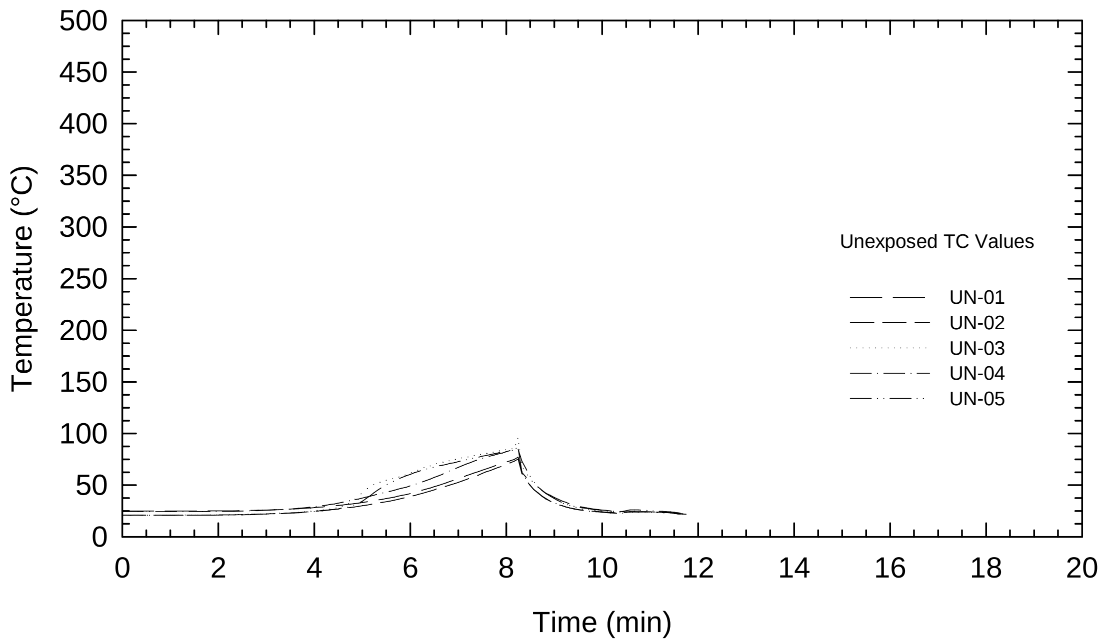


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C5. Temperatures for Test OSB-02B.

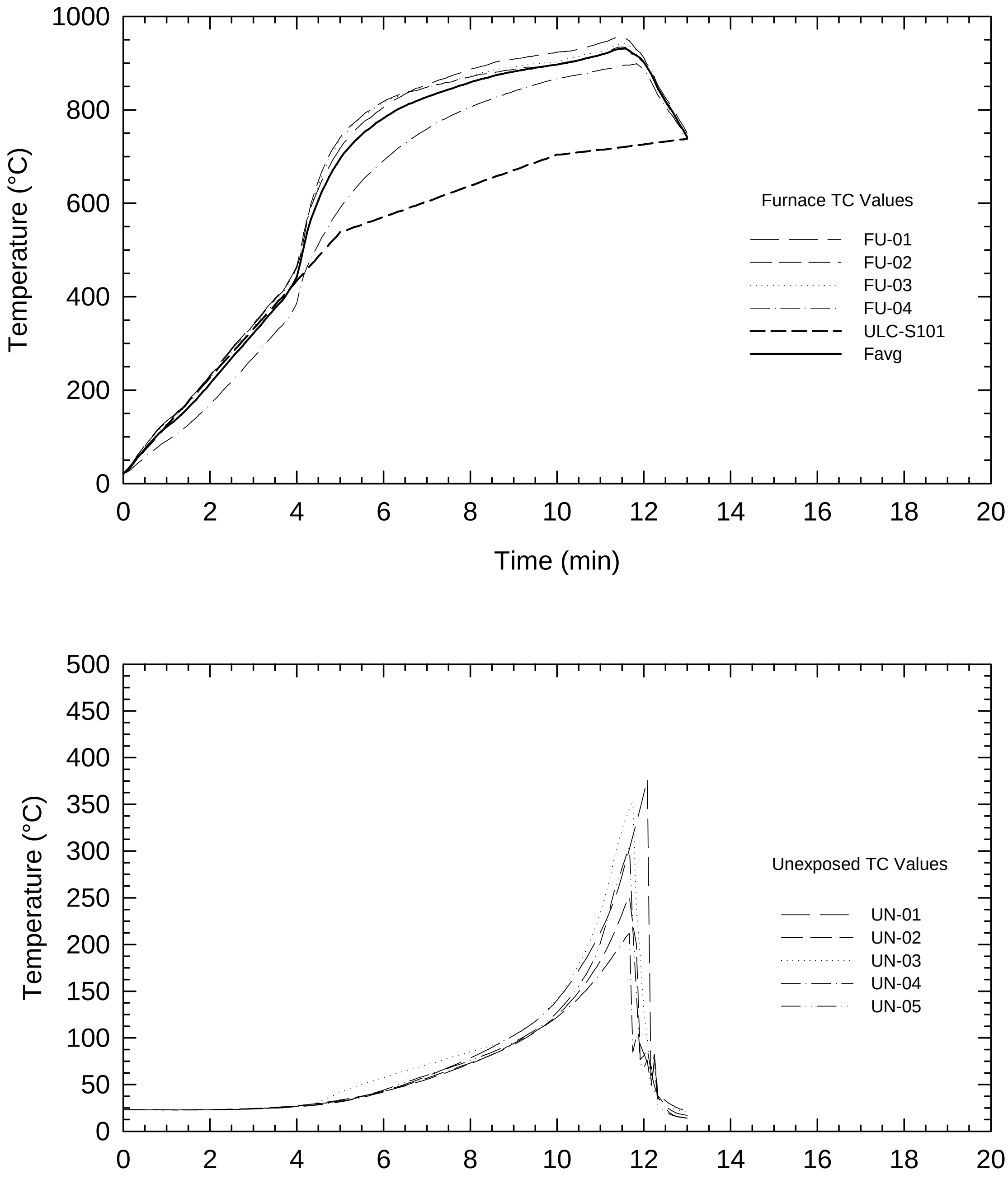




Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

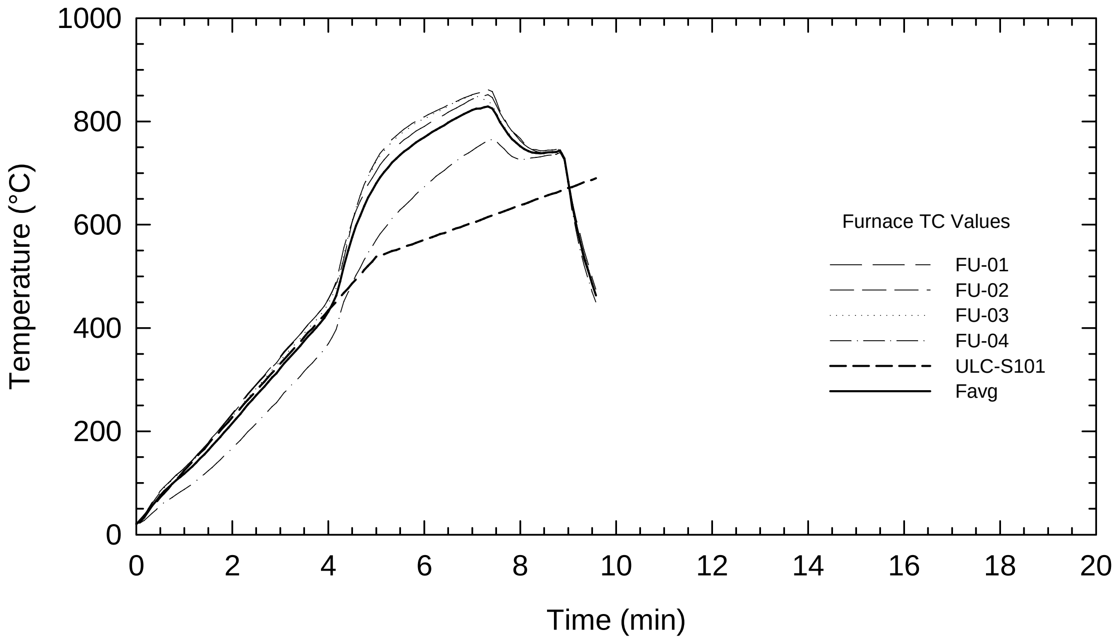
Figure C6. Temperature for Test OSB-03A.

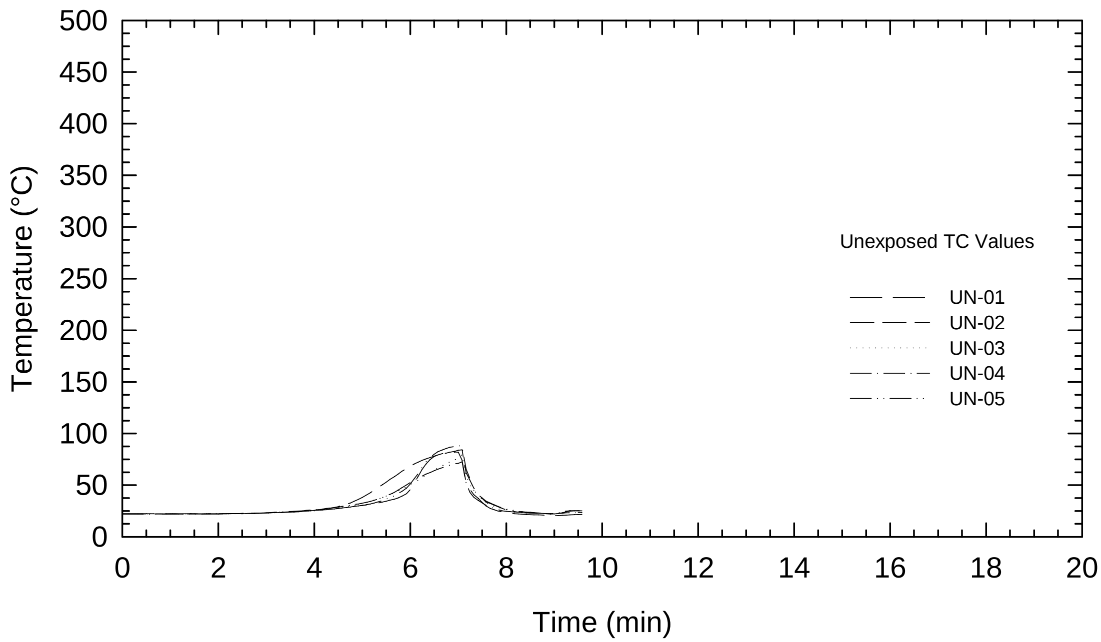


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C7. Temperatures for Test OSB-03B.

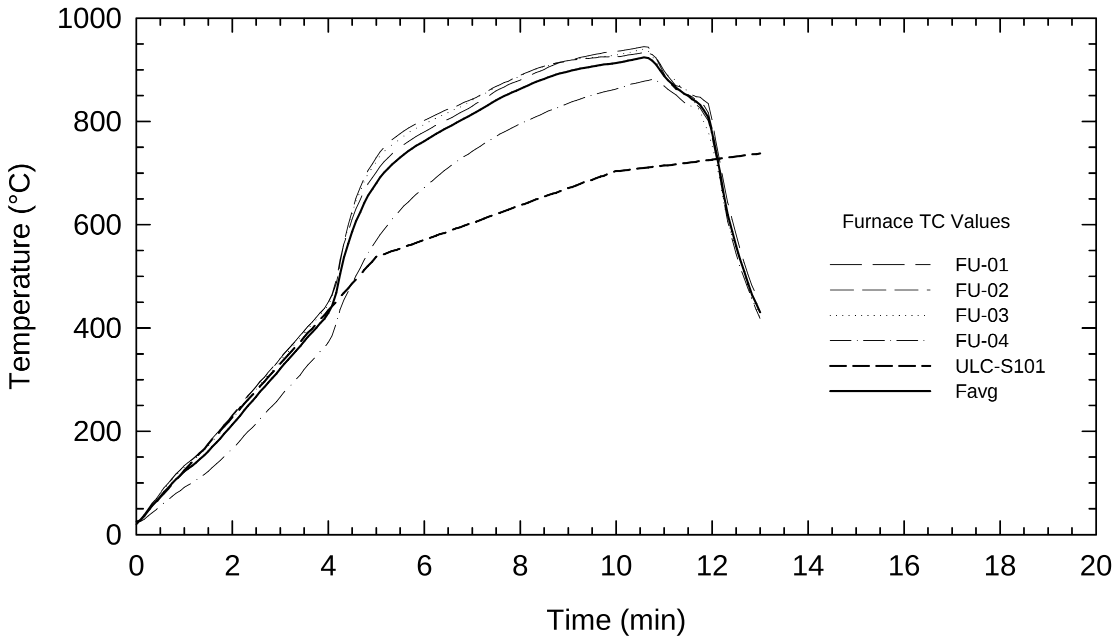


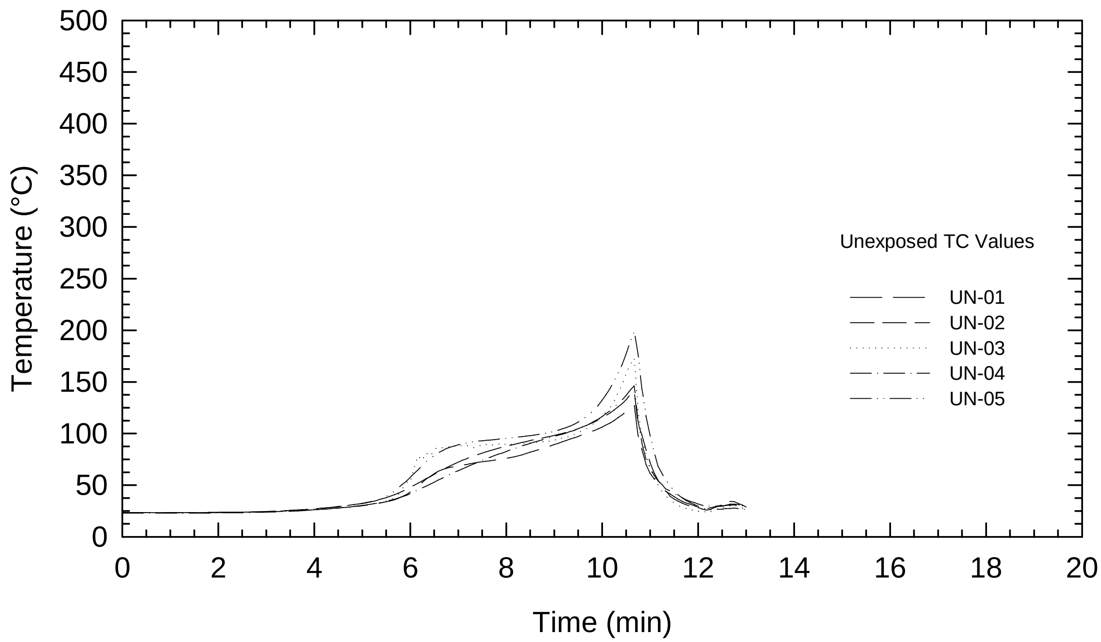


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C8. Temperatures for Test OSB-04A.

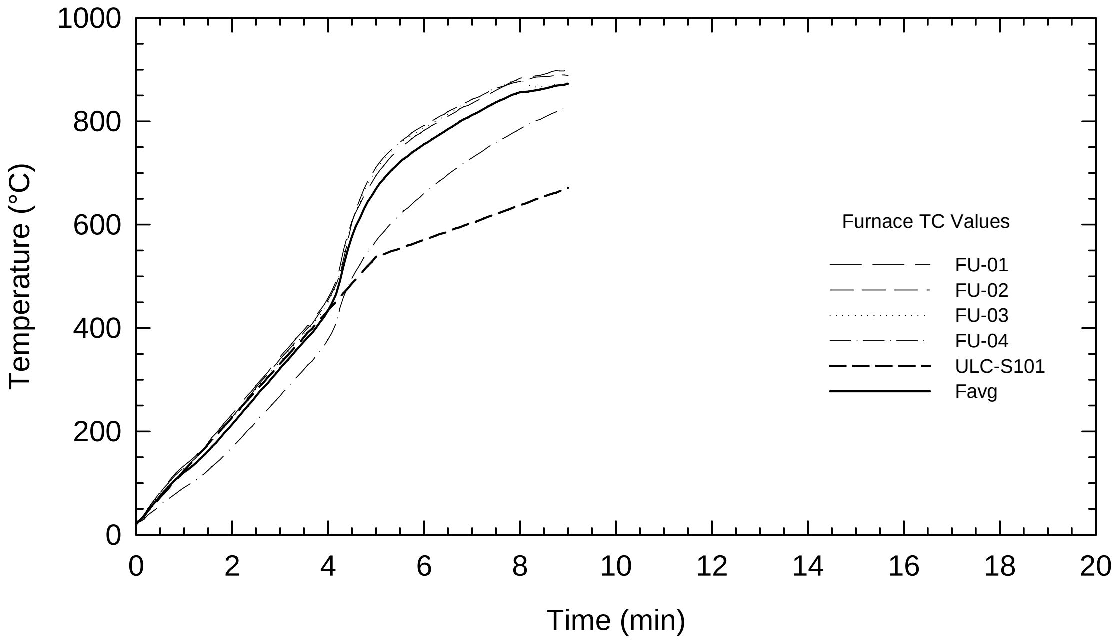


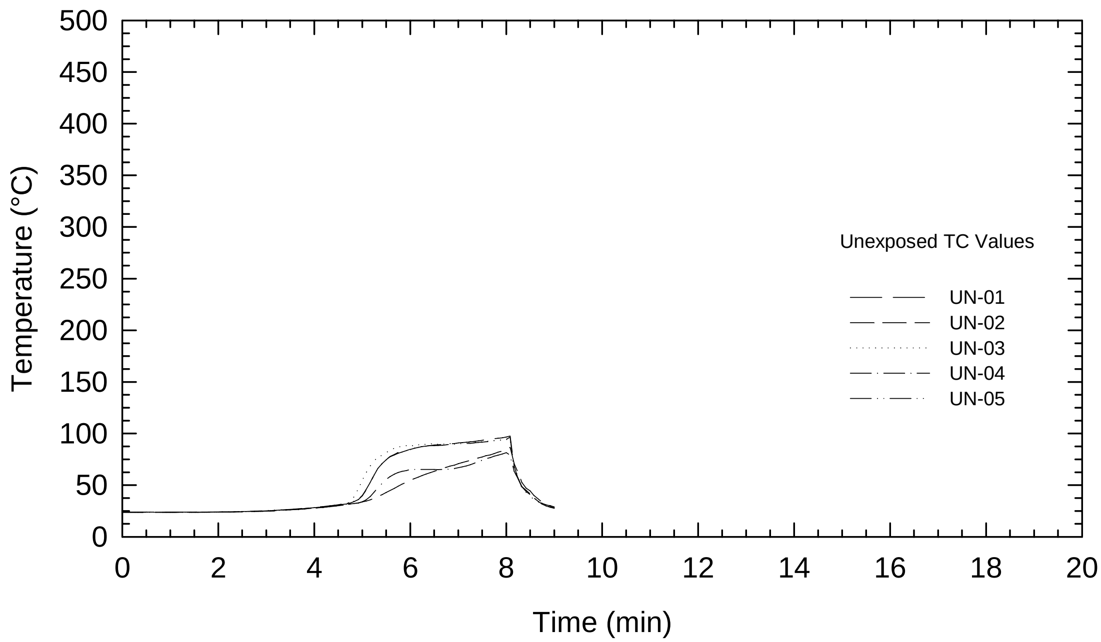


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C9. Temperatures for Test OSB-04B.

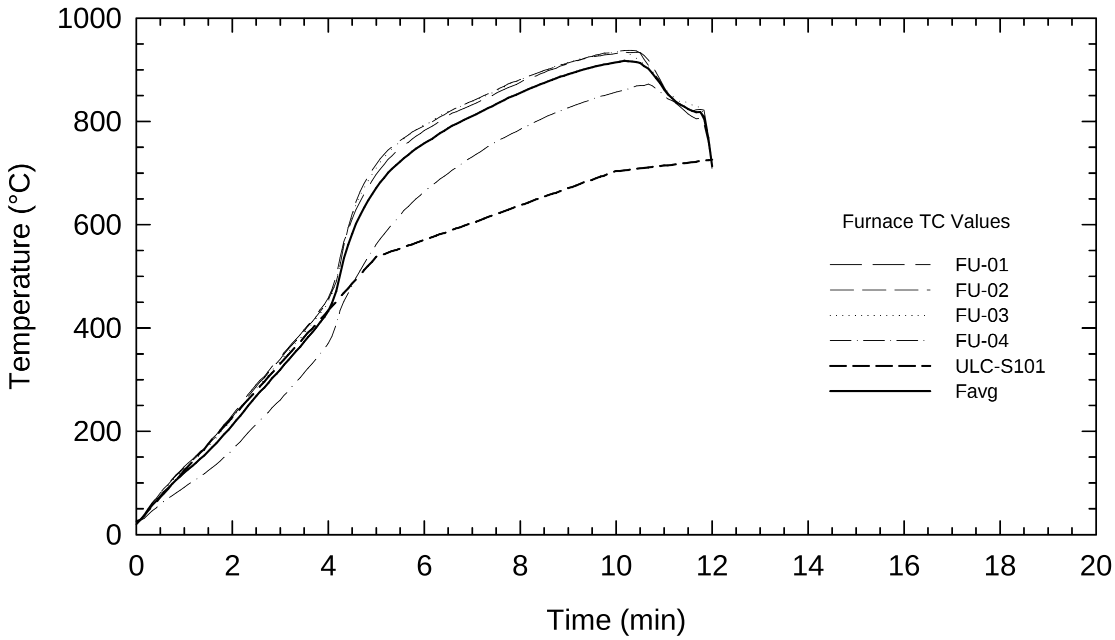


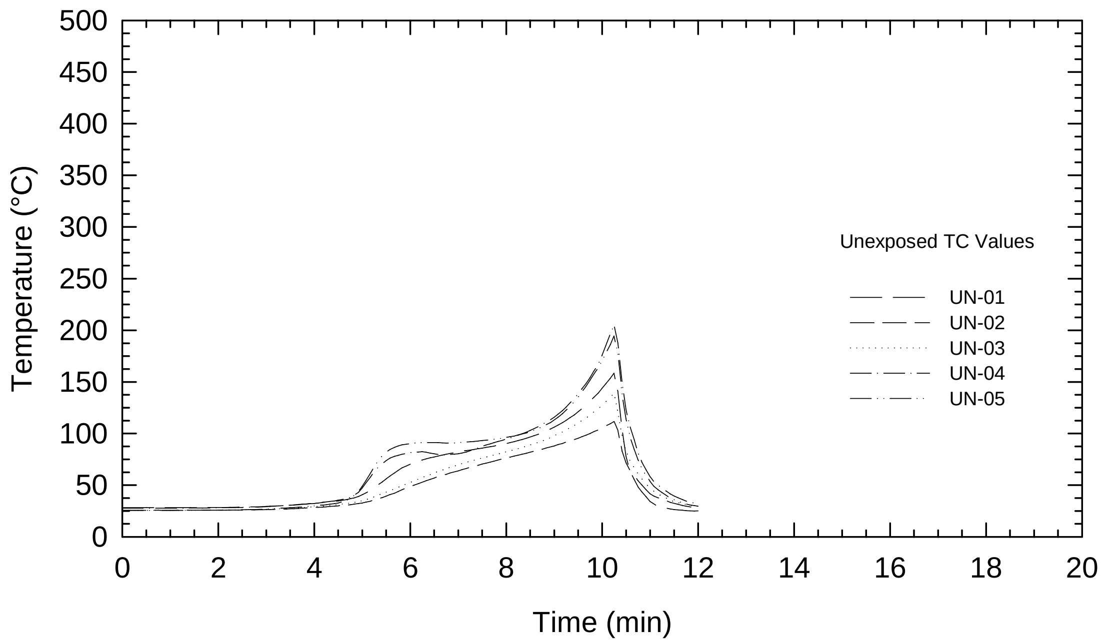


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C10. Temperatures for Test OSB-05A.





Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure C11. Temperatures for Test OSB-05B.

Figure C12. Typical floor assembly with tongue and groove joint (Test OSB-01A).

Figure C13. Flame penetration through tongue and groove joint (Test OSB-03A).

Figure C14. Damage to unexposed side of floor assembly (Test OSB-03A).

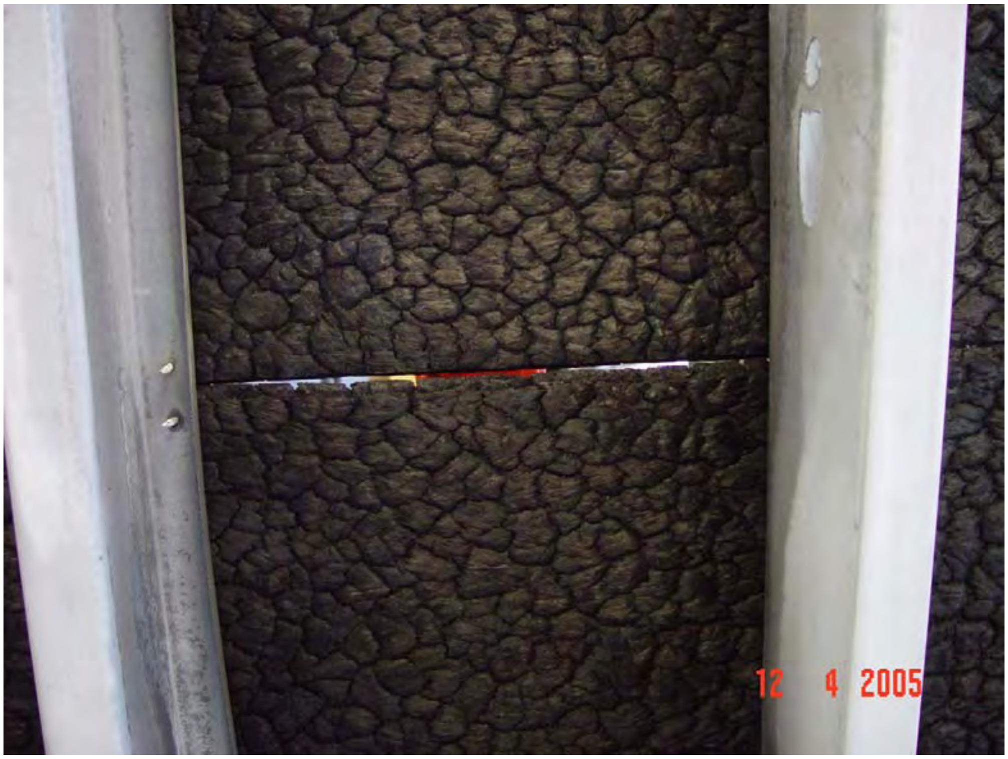


Figure C15. Damage to exposed side of floor assembly (Test OSB-03A).

Figure C16. Typical floor assembly with full OSB panel (Test (OSB-02B).

Figure C17. Flame penetration through test assembly (Test OSB-02B).

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Figure C18. Damage to unexposed side of test assembly (Test OSB-02B).

Figure C19. Damage to exposed side of test assembly (Test OSB-02B).

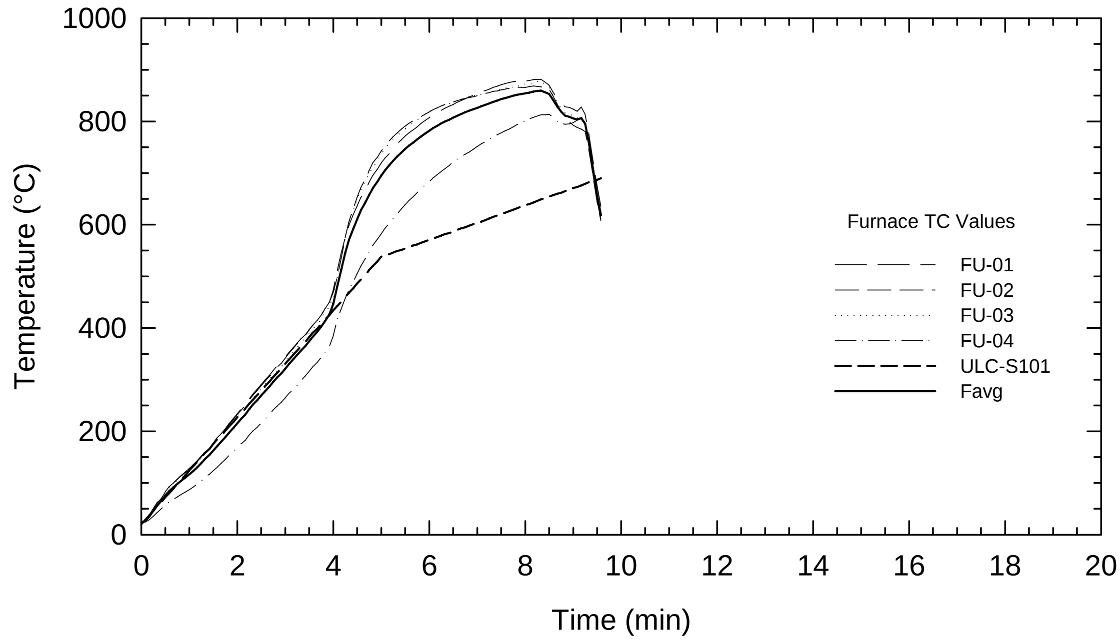
Appendix D – Temperature Data and Photographs for Additional Floor Assemblies

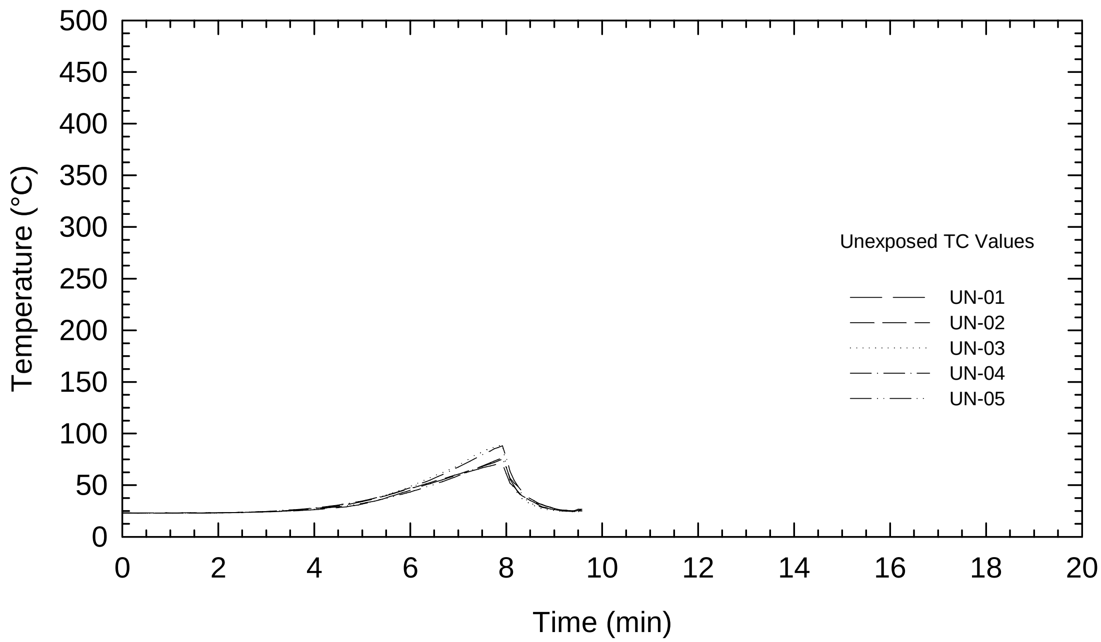
Additional intermediate-scale tests were conducted to investigate the effect of factors such as additional floor materials and loads on the flame penetration time. All of these tests were conducted using OSB-03 for the subfloor. The floor assemblies used for the additional tests were:

1. A floor assembly with an unsupported tongue and groove joint, which ran along the length of the assembly (Test OSB-03C).
2. A floor assembly with 6 mm thick poplar plywood underlay added to the floor assembly. There was a butt joint between the plywood panels that was offset from the tongue and groove joint in the OSB subfloor (Test OSB-03E).
3. A floor assembly with residential carpet and carpet underpad added to the floor assembly (Test OSB-03F). There was a tongue and groove joint between the OSB panels in the OSB subfloor.
4. A floor assembly design with a single OSB panel as the subfloor for which two specimens were tested: one loaded with two concrete blocks and one with 12 concrete blocks (Tests OSB-03D & OSB-03H).
5. A floor assembly with 6 mm thick poplar plywood underlay added to the floor assembly and loaded with 12 concrete blocks. There was a butt joint between the plywood panels that was offset from the tongue and groove joint in the OSB subfloor (Test OSB-03G).

In each test, the temperatures were measured at four locations in the furnace. The average of these temperatures was used to control the furnace during the initial stages such that the temperature followed the standard time-temperature curve provided in CAN/ULC S101 [8]. The temperatures were measured at five locations on the unexposed side of the test assembly (for the test with the carpet and underpad the temperature was measured on the OSB subfloor beneath the underpad). The location of the thermocouples is shown in Figure 1. The temperatures measured on the exposed and unexposed side of the test assembly for each test are shown in Figures D1 – D6.

Photographs for the floor assemblies are shown in Figures D7 – D30.

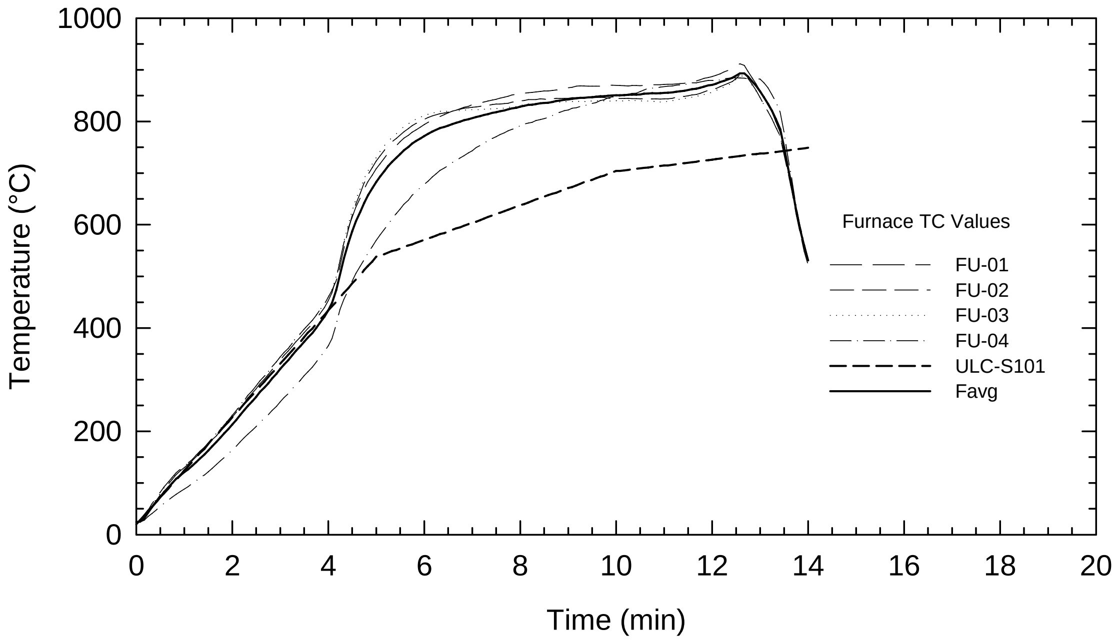


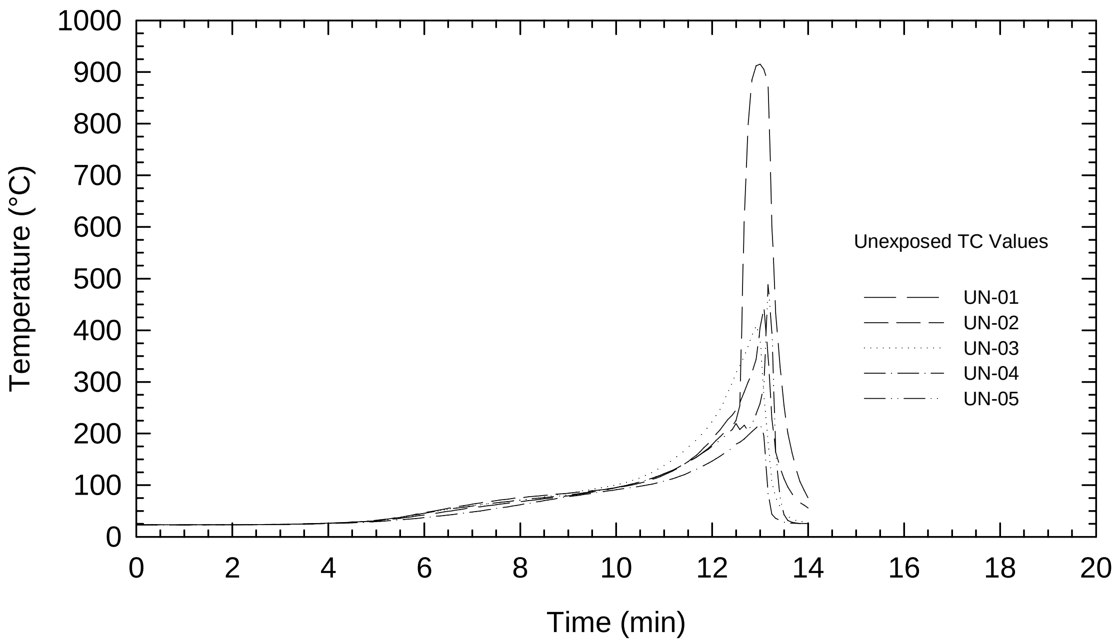


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure D1. Temperatures for Test OSB-03C.

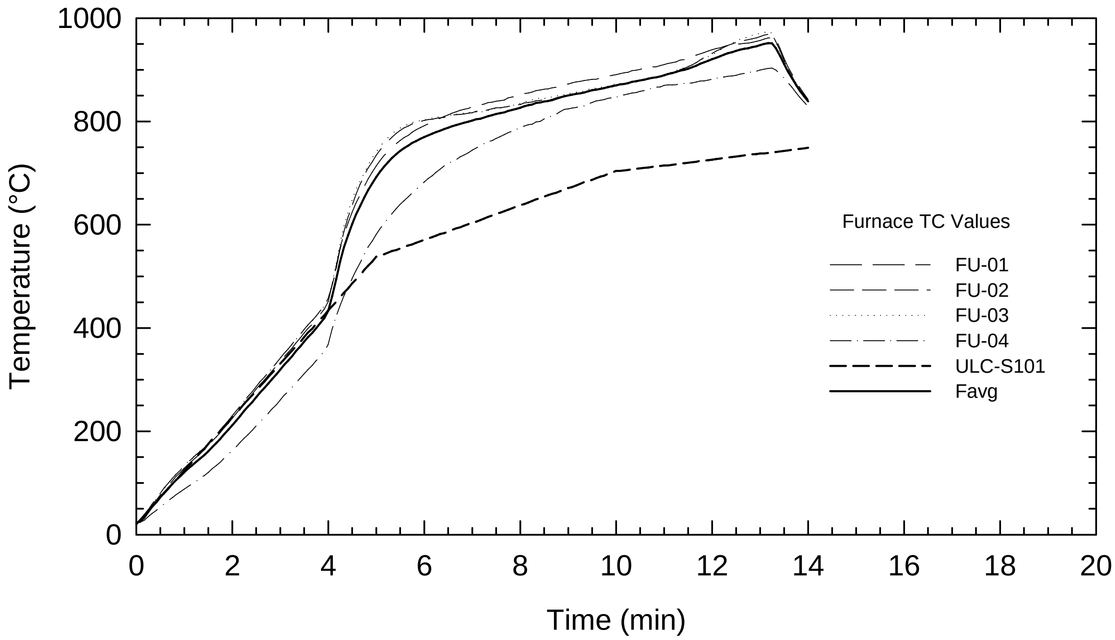


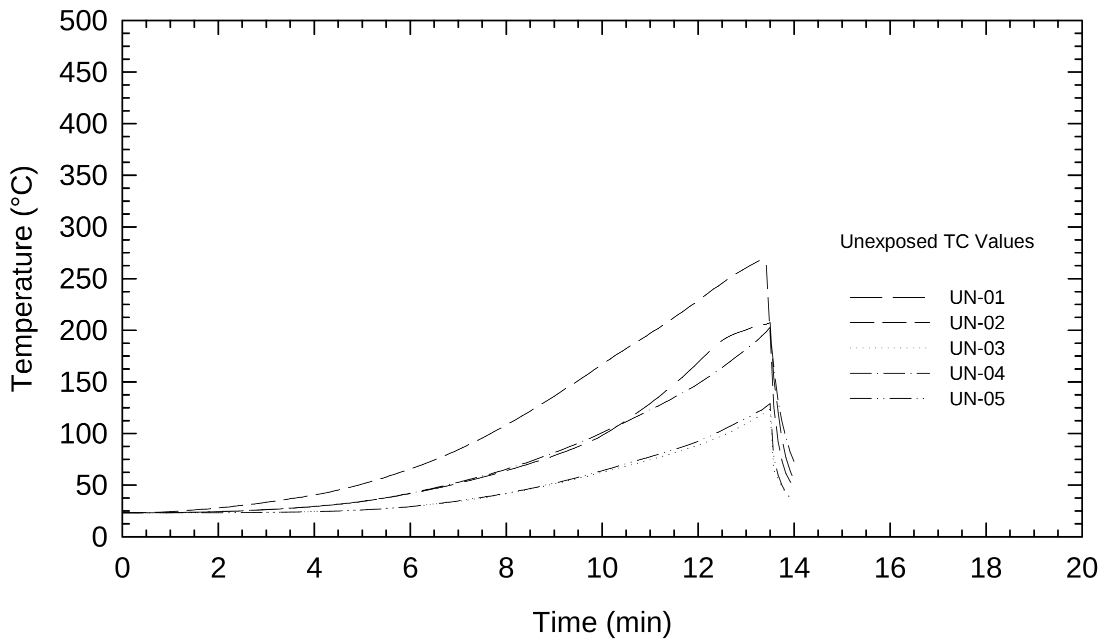


<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure D2. Temperatures for Test OSB-03D.

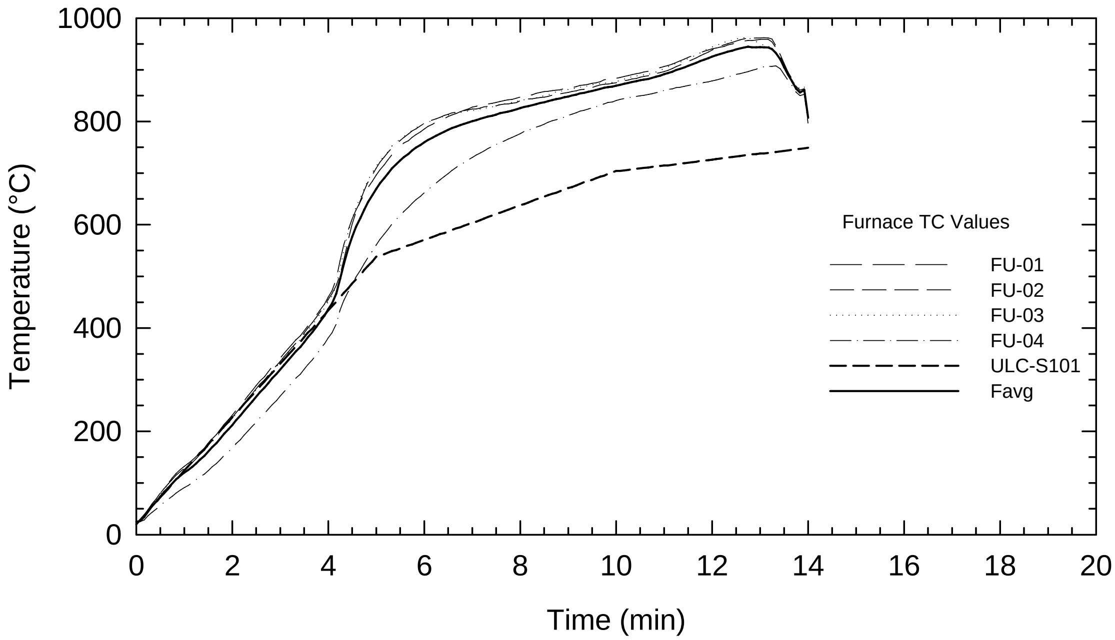


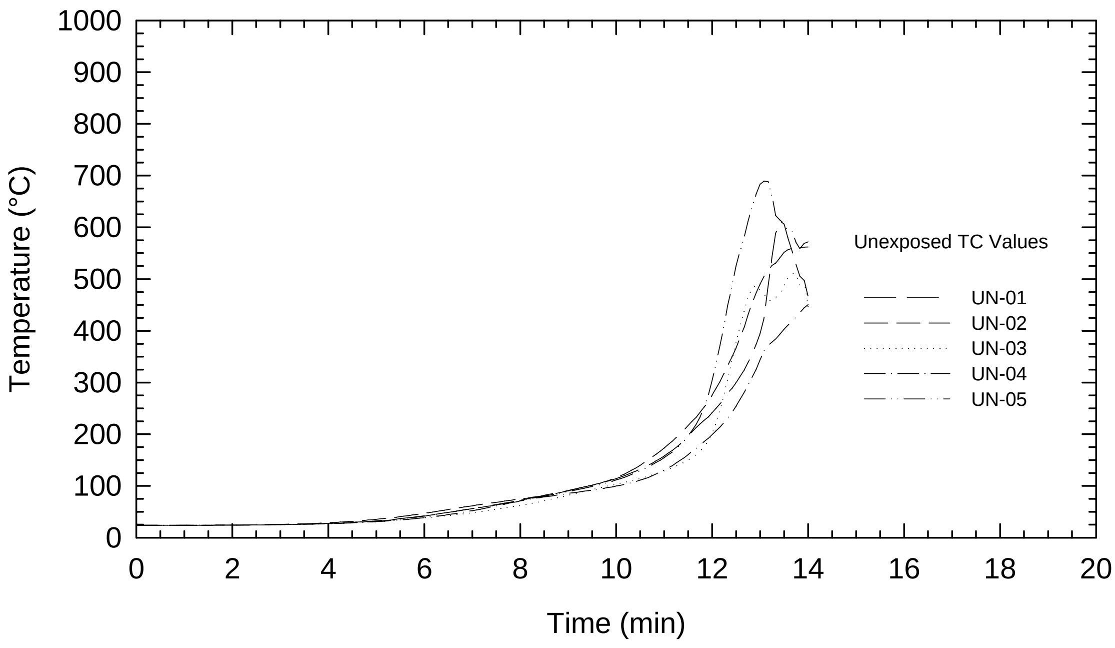


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure D3. Temperatures for Test OSB-03E.

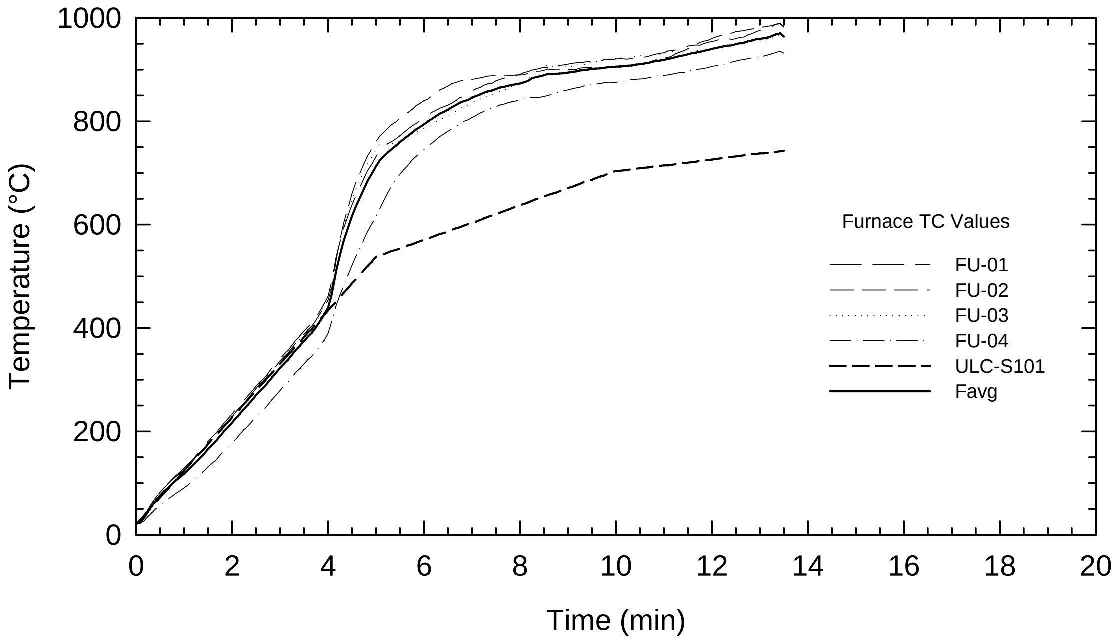


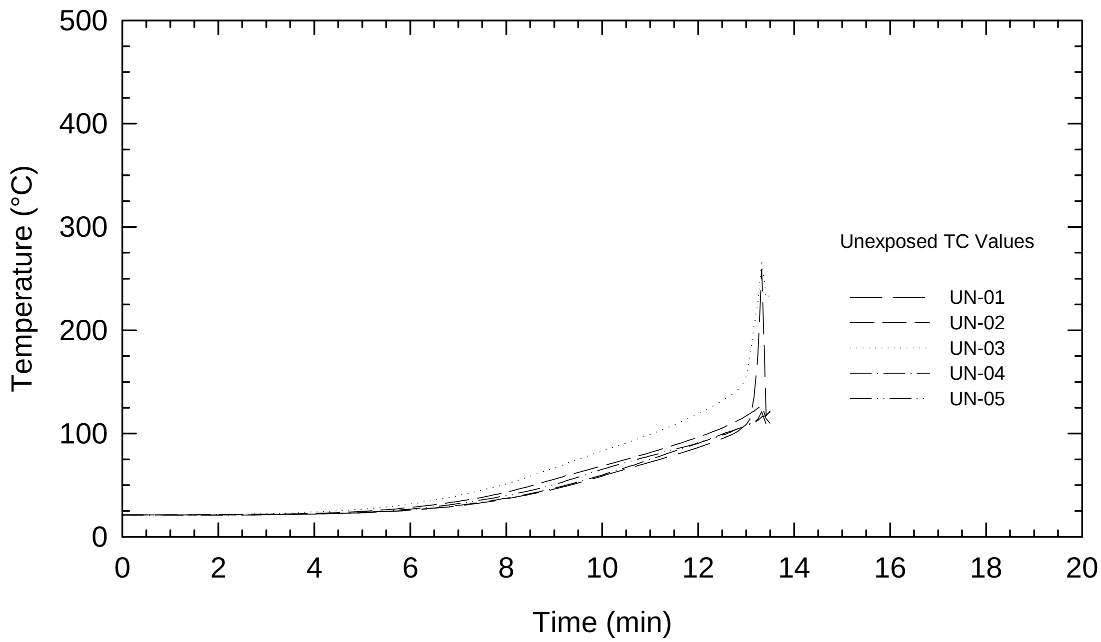


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure D4. Temperatures for Test OSB-03F.

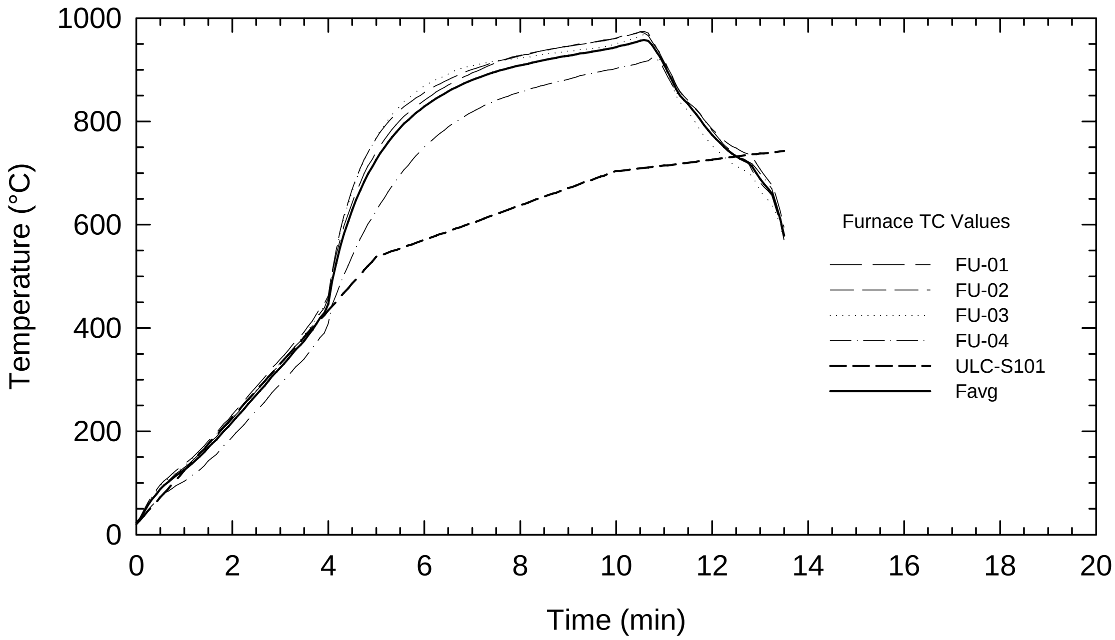


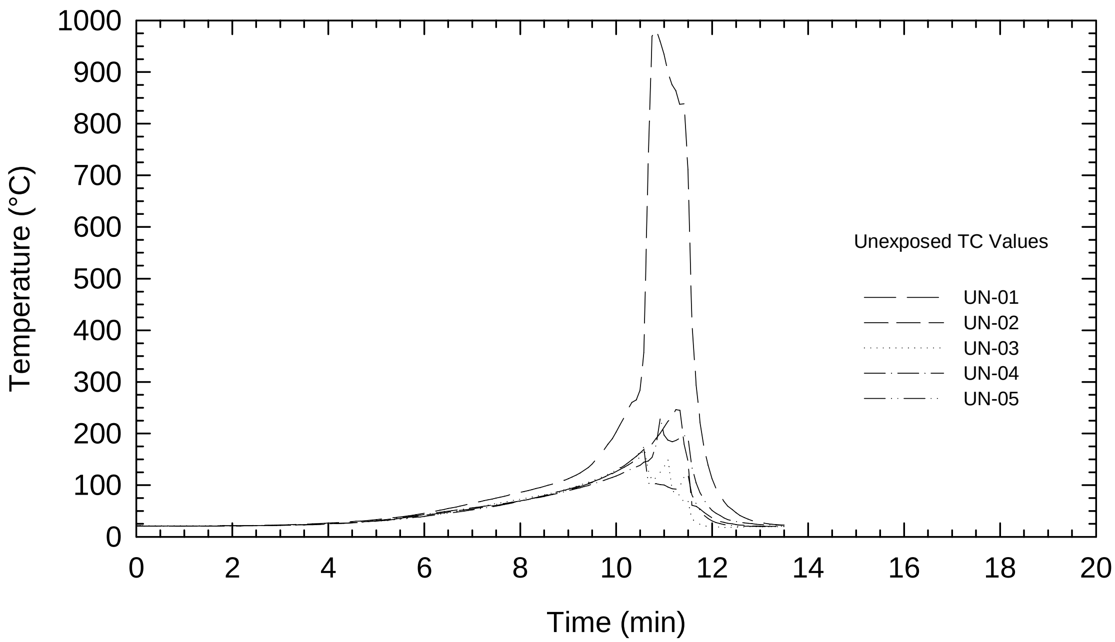


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure D5. Temperatures for Test OSB-03G.





Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure D6. Temperatures for Test OSB-03H.

Figure D7. Floor assembly Test OSB-03C.

Figure D8. Flame penetration Test OSB-03C.

Figure D9. Flame damage Test OSB-03C.

Figure D10. Damage joint Test OSB-03C.

Figure D11. Test assembly Test OSB-03D.

Figure D12. Flame penetration Test OSB-03D.

Figure D13. Damage Test OSB-03D.

Figure D14. Damage Test OSB-03D.

Figure D15. Test assembly Test OSB-03E.

Figure D16. Flame penetration Test OSB-03E.

Figure D17. Damage Test OSB-03E.

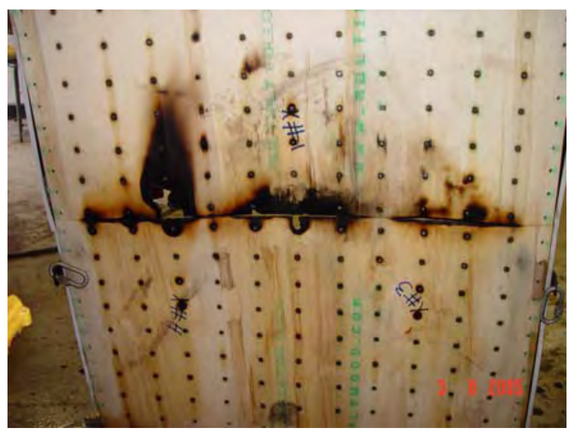


Figure D18. Damage Test OSB-03E.

Figure D19. Test assembly Test OSB-03F**.**

Figure D20. Smoke Test OSB-03F.

Figure D21. Damage Test OSB-03F.

Figure D22. Damage Test OSB-03F.

Figure D23. Test assembly Test OSB-03G.

Figure D24. Flame penetration Test OSB-03G.

Figure D5. Flame damage Test OSB-03G.

Figure D26. Damage Test OSB-03G.

Figure D27. Test assembly Test OSB-03H.

Figure D28. Flame penetration Test OSB-03H.

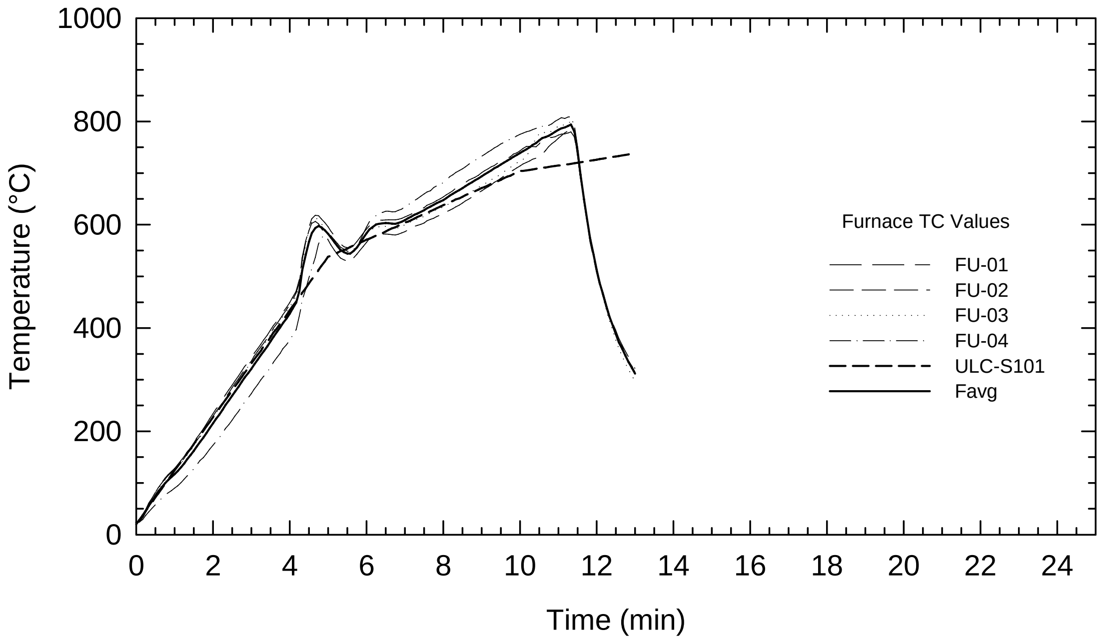
Figure D29. Damage Test OSB-03H.

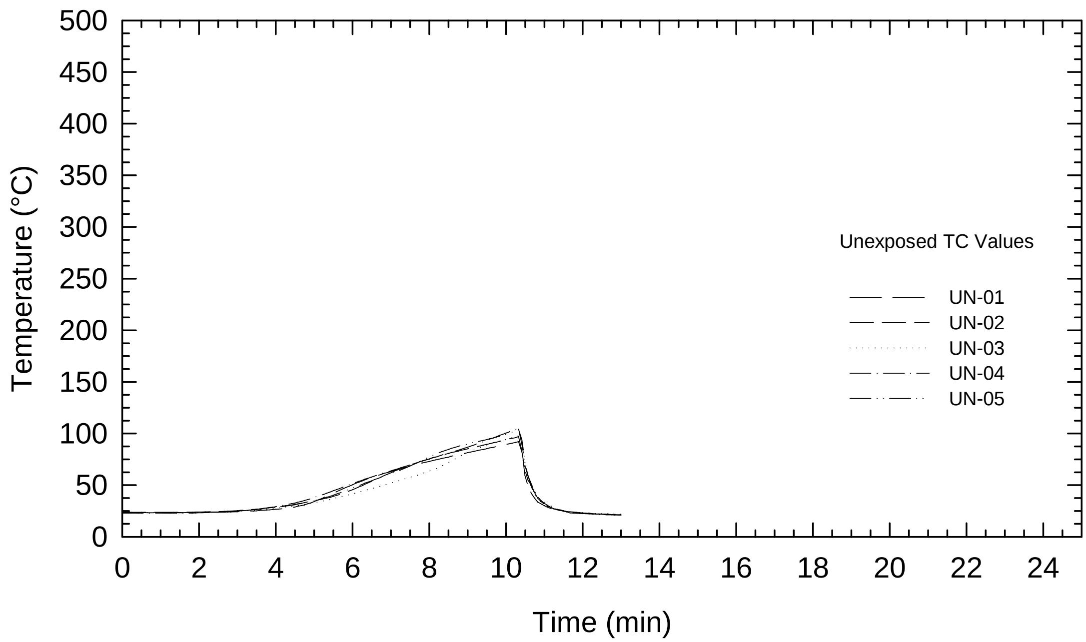
Figure D30. Damage Test OSB-03H.

Appendix E – Temperature Data and Photographs for Plywood Floor Assemblies

Two tests were conducted for floor assemblies constructed using a plywood subfloor. One plywood floor assembly had a tongue and groove joint running across the test assembly. The construction details for this assembly were identical to the OSB assembly shown in Figure 3. The second floor assembly was constructed using a single plywood panel and the construction details were identical to the OSB assembly shown in Figure 2.

The temperatures measured for the tests are shown in Figures E1 and E2. Photographs showing typical test assemblies, flame penetration and fire damage are also shown in Figures E3 – E10.

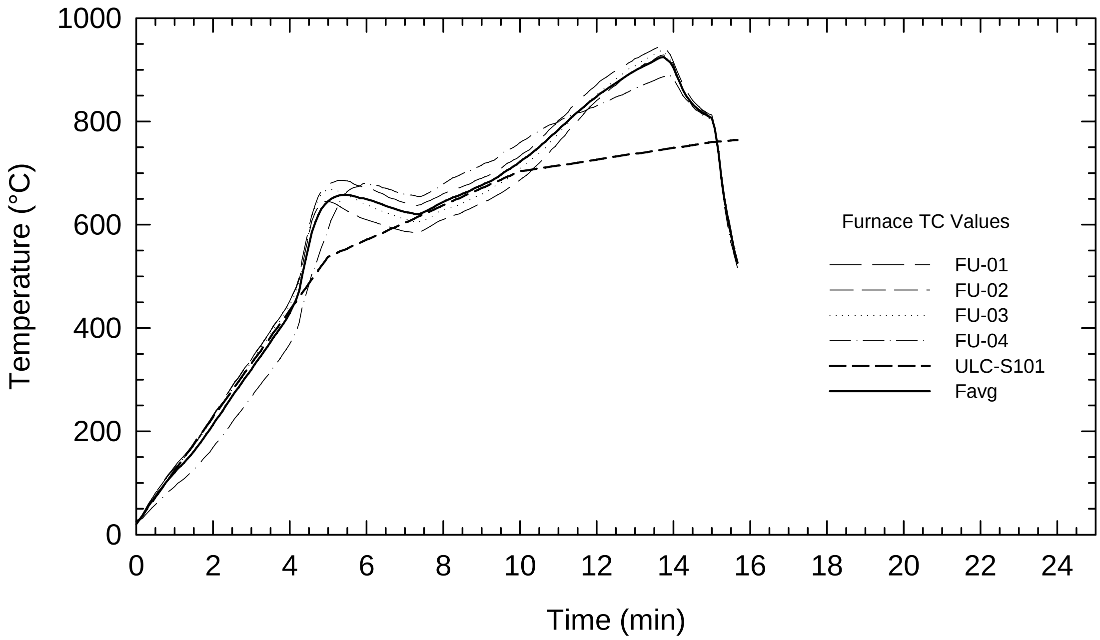


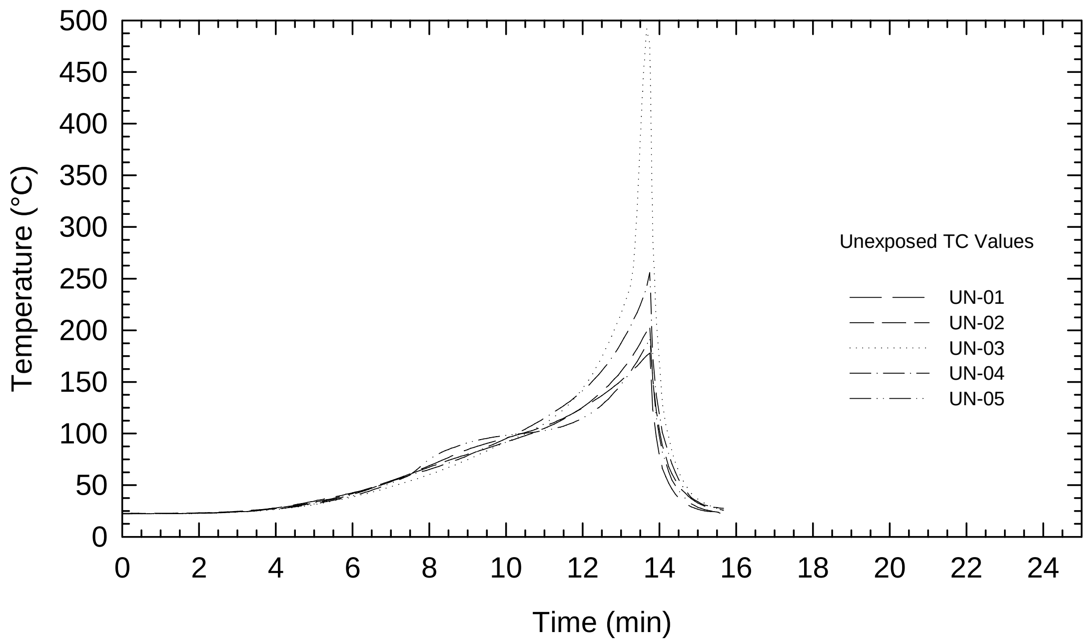


Legend

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure E1. Temperatures for Test PLY-01A.





<u>Legend</u>

ULC-S101 - Standard Temperature Curve, *Favg* - Average Furnace Temperature, *FU-01 to 04* - Furnace Thermocouple, *UN-01 to 05* - Unexposed Surface Thermocouple

Figure E2. Temperatures for Test PLY-01B.

Figure E3. Floor assembly Test PLY-01A**.**

Figure E4. Flame penetration Test PLY-01A.

Figure E5. Flame damage Test PLY-01A.

Figure E6. Damage Test PLY-01A.

Figure E7. Floor assembly Test PLY-01B**.**

Figure E8. Flame penetration Test PLY-01B.

Figure E9. Flame damage Test PLY-01B.

Figure E10. Damage Test PLY-01B.