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FULL-SCALE TESTS IN A FURNISHED LIVING ROOM TO EVALUATE THE FIRE PERFORMANCE OF PROTECTED CROSS-LAMINATED AND NAIL LAMINATED TIMBER CONSTRUCTION

FINAL REPORT
Consisting of 85 Pages

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INTRODUCTION

The objective of the two tests described in this report was to evaluate the performance of cross-laminated timber (CLT) and nail laminated timber (NLT) construction protected with two layers of ⅝-in. (16-mm) type X gypsum board when exposed to the thermal environment of a severe living room fire for the American Wood Council (Client), located in Leesburg, Virginia. The tests were conducted on September 3 and 15, 2015, at Southwest Research Institute's (SwRI's) Fire Technology Department, located in San Antonio, Texas.

This report describes the testing of the assemblies that were evaluated and the results that were obtained. The results presented in this report apply specifically to the materials and products tested and in the manner tested.

FIRST ROOM TEST

The first room test was conducted Thursday September 3, 2015. The data acquisition system was started at approximately 8:45 a.m., and the ignition source was applied at approximately 8:50 a.m. Temperature and relative humidity in the laboratory at the start of the test were 75 °F (24 °C) and 87%, respectively. The test was terminated at approximately 11:50 a.m. at the Client's direction.

1.1 Room Construction

1.1.1 Wood Structure

The walls of the test room were constructed from CLT panels (CrossLam™) made by StructurLam, located in Penticton, BC, Canada. The CLT panels consisted of five layers of spruce-pine-fir (SPF) lumber stacked at right angles and glued together into 7-in. (175-mm) thick panels. The front wall, back wall, and each side wall of the compartment consisted of a single continuous panel (see Figures A-1 through A-3). The panels were connected with 5/16 × 11¾-in. (8 × 300-mm) screws with a 7⅞-in. (200 mm) spacing, as shown in Figure B-1. A schematic and picture of the CLT wall assembly are shown in Figures 1 and B-2, respectively. The dimensions in Figure 1 are the interior dimensions of the compartment after attaching the two layers of gypsum board.

The ceiling consisted of 14-ft (4.27-m) long by 2 × 6-in. (38 × 140-mm) Southern pine floor joists nailed together one-by-one using 0.131 × 3½-in. (0.7 × 89-mm) nails as shown in Figure B-3. The nail schedule is shown in Figure 2 and a schematic of the finished NLT ceiling is shown in Figure 3. Small gaps around the perimeter at the wall-ceiling interface were sealed with 3M Fire Barrier Sealant (CP 25WB+ Red).

The moisture content of the CLT walls and NLT ceiling was measured with a Delmhorst RDM³ moisture meter in the vicinity of where the wall and ceiling thermocouples (TCs) were located, prior to attaching the base layer of gypsum board. The results are given in Table 1.

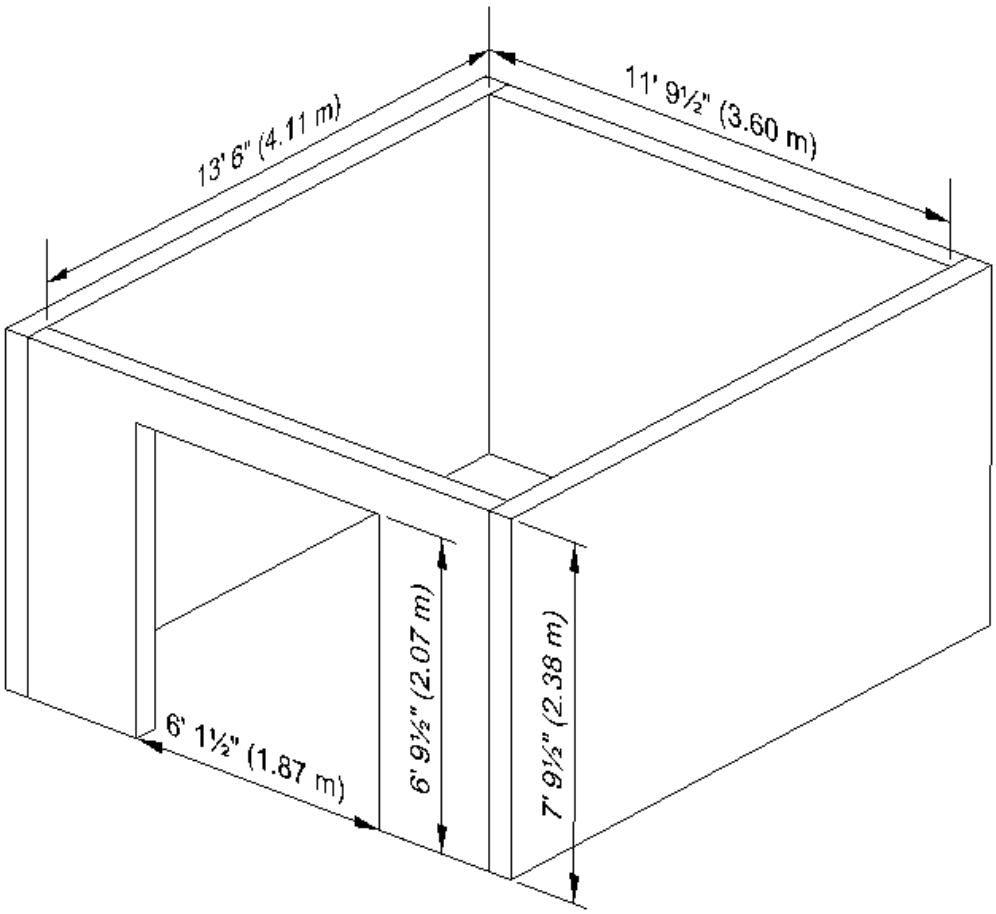


Figure 1. CLT Wall Panel Assembly for Test 1 Compartment.

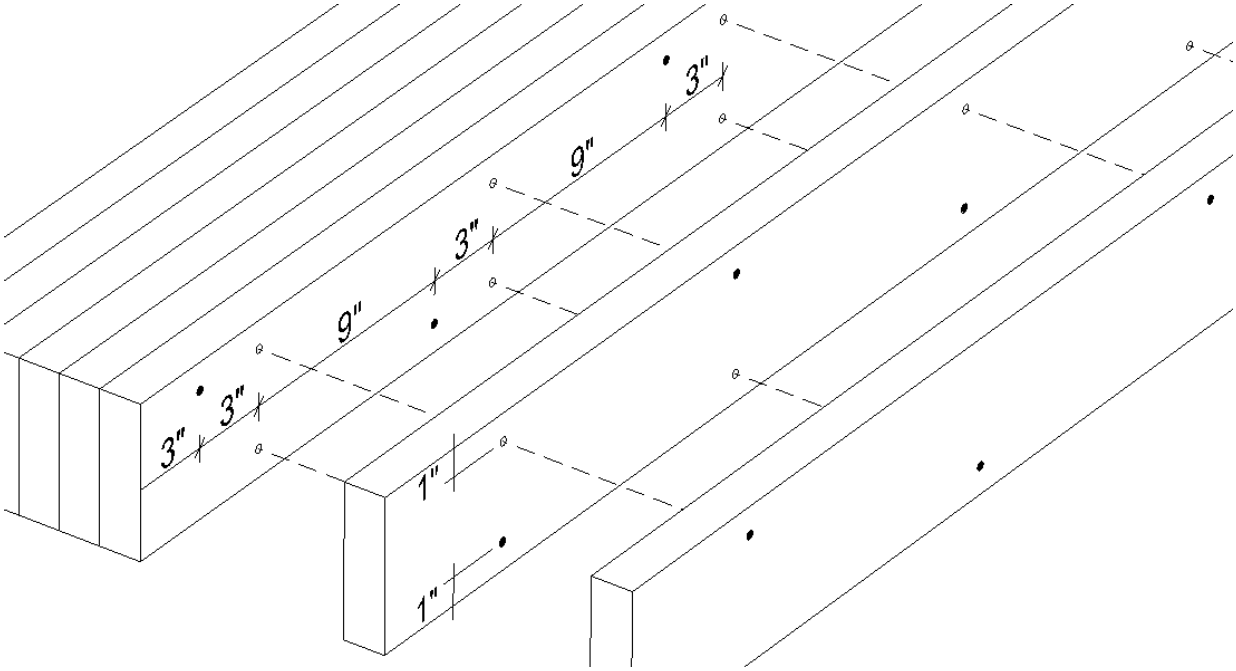


Figure 2. NLT Nail Schedule.

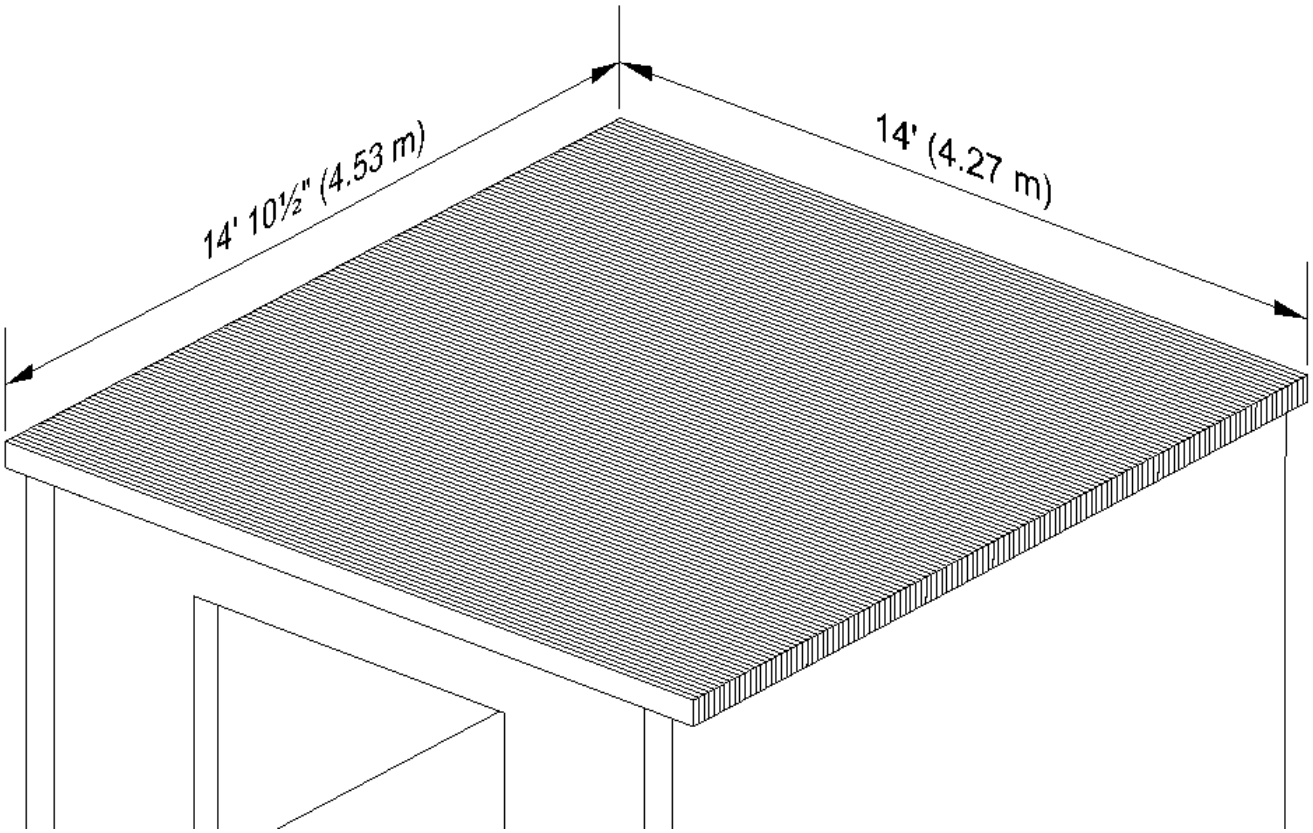


Figure 3. NLT Ceiling for Test 1 Compartment.

Table 1. CLT and NLT Moisture Content (Test 1).

Location Code	MC 1 (%)	MC 2 (%)	Mean MC (%)
SWF-T	11.7	10.4	11.1
SWB-T	11.9	11.8	11.9
SWF-M	10.9	11.2	11.1
SWB-M	12.2	12.2	12.2
SWF-B	11.1	11.3	11.2
SWB-B	12.4	12.1	12.3
BW-T	12.1	11.9	12.0
BW-M	10.9	12.1	11.5
BW-B	11.2	12.3	11.8
CF	15.0	13.4	14.2
CB	12.4	12.8	12.6

1.1.2 Gypsum Board

The walls and ceiling were covered with two layers of ⅝-in. (16-mm) type X gypsum board so that the joints were staggered (see Figures B-4 through B-7). The base layer of gypsum board was

attached to the CLT walls and NLT ceiling with #6 1⅝-in. (41-mm) type "S" (fine thread) screws, spaced 12 in. (0.305 m) apart in the field, and 1 in. (25 mm) from the edges around the perimeter. The face layer of gypsum board was attached with #6 2¼-in. (57-mm) type "S" (fine thread) screws, spaced 12 in. (0.305 m) apart in the field and 1 in. (25 mm) from the edges around the perimeter. The joints of the face layer were taped and floated using Durabond 90 joint compound (see Figure B-8). Two layers of off-white latex paint were applied to the walls and ceiling the day before the test (see Figure B-9). The floor of the laboratory was covered with two layers of ⅝-in. (16-mm) type X gypsum board.

1.1.3 Structural Load

19/32-in. (15-mm) thick plywood was fastened to the top of the NLT ceiling using #8 2¼-in. (57-mm) coarse thread wood screws (see Figure B-10). Concrete blocks were placed on the plywood to impose a distributed structural load of 40 psf (1.9 kN/m^2) as shown in Figure B-11.

1.2 Instrumentation

1.2.1 Heat Release Rate Calorimeter

The fire effluents were collected in the hood of an oxygen consumption calorimeter.

1.2.2 Wall and Ceiling Thermocouples

The room walls and ceiling were instrumented with 20 AWG (0.812 mm diameter) type K TC wire that was placed between the two sheets of gypsum board and between the gypsum and the interior wood surface. The locations of the TCs are shown in Figure 4. The hot junction of the TCs was stapled to the wood or gypsum board, as shown in Figure B-12.

1.2.3 Room Interior Thermocouples

Three TC trees were used to measure the vertical gas temperature profile in the doorway and at two locations inside the room. In addition, TCs were installed at 4 in. (102 mm) below the ceiling at the center and the four quadrants to measure the hot gas layer (HGL) temperature. The tree and HGL TCs were ⅛-in. (3.2-mm) diameter Inconel sheathed exposed junction type K made by Duro-Sense. Detailed information about the location of the individual TC locations is provided in Figure 5.

1.2.4 Plate Thermometers

ISO 834 plate thermometers (PTs) were installed with the Inconel plate facing the fire to measure incident heat fluxes to walls and ceiling. The locations of the PTs are shown in Figure 5.

1.2.5 Video and Photographic Documentation

Three video cameras were used to obtain footage of the fire compartment from three angles. One of the video cameras was directed at the ceiling to monitor gypsum board fall-off. Extensive photographic documentation was obtained prior to, during, and following the test.

TC #	Location Code	Wall or Ceiling	Distance from Center	Height above Floor	Depth Location
1	SWF-T-W	Side Wall	-34 in. (-0.86 m)	6 ft (1.83 m)	Between Wood and Gypsum
2	SWB-T-W	Side Wall	+34 in. (+0.86 m)	6 ft (1.83 m)	Between Wood and Gypsum
3	SWF-M-W	Side Wall	-34 in. (-0.86 m)	4 ft (1.22 m)	Between Wood and Gypsum
4	SWB-M-W	Side Wall	+34 in. (+0.86 m)	4 ft (1.22 m)	Between Wood and Gypsum
5	SWF-B-W	Side Wall	-34 in. (-0.86 m)	2 ft (0.61 m)	Between Wood and Gypsum
6	SWB-B-W	Side Wall	+34 in. (+0.86 m)	2 ft (0.61 m)	Between Wood and Gypsum
7	BW-T-W	Back Wall	NA	6 ft (1.83 m)	Between Wood and Gypsum
8	BW-M-W	Back Wall	NA	4 ft (1.22 m)	Between Wood and Gypsum
9	BW-B-W	Back Wall	NA	2 ft (0.61 m)	Between Wood and Gypsum
10	CF-W	Ceiling	-34 in. (-0.86 m)	NA	Between Wood and Gypsum
11	CB-W	Ceiling	+34 in. (+0.86 m)	NA	Between Wood and Gypsum
12	SWF-T-G	Side Wall	-34 in. (-0.86 m)	6 ft (1.83 m)	Between Gypsum Layers
13	SWB-T-G	Side Wall	+34 in. (+0.86 m)	6 ft (1.83 m)	Between Gypsum Layers
14	SWF-M-G	Side Wall	-34 in. (-0.86 m)	4 ft (1.22 m)	Between Gypsum Layers
15	SWB-M-G	Side Wall	+34 in. (+0.86 m)	4 ft (1.22 m)	Between Gypsum Layers
16	SWF-B-G	Side Wall	-34 in. (-0.86 m)	2 ft (0.61 m)	Between Gypsum Layers
17	SWB-B-G	Side Wall	+34 in. (+0.86 m)	2 ft (0.61 m)	Between Gypsum Layers
18	BW-T-G	Back Wall	NA	6 ft (1.83 m)	Between Gypsum Layers
19	BW-M-G	Back Wall	NA	4 ft (1.22 m)	Between Gypsum Layers
20	BW-B-G	Back Wall	NA	2 ft (0.61 m)	Between Gypsum Layers
21	CF-G	Ceiling	-34 in. (-0.86 m)	NA	Between Gypsum Layers
22	CB-G	Ceiling	+34 in. (+0.86 m)	NA	Between Gypsum Layers

* negative is toward front, positive is toward back

SWF = Side Wall Front
SWB = Side Wall Back
BW = Back Wall
CF = Ceiling Front
CB = Ceiling Back

T = Top
M = Middle
B = Bottom

W = Between Wood and Gypsum
G = Between Gypsum Layers

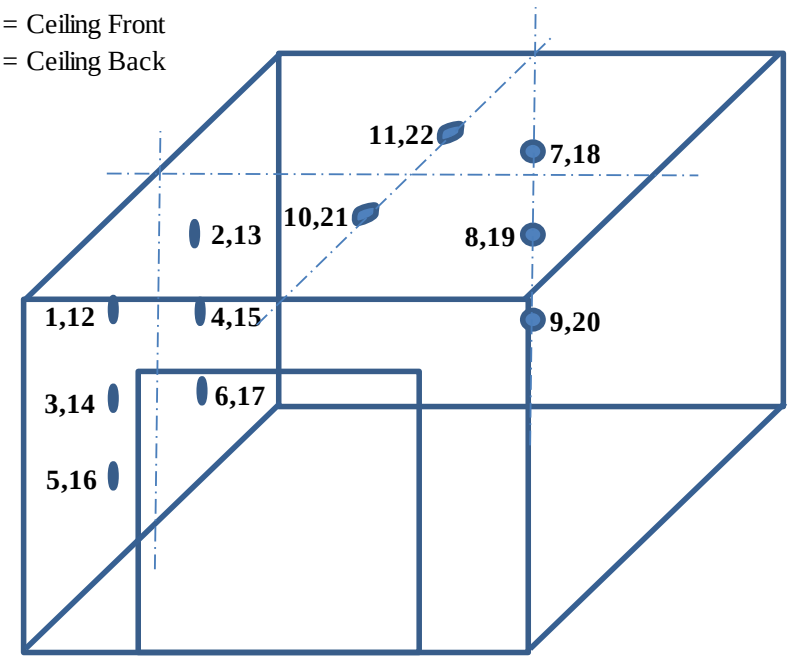


Figure 4. Wall and Ceiling Thermocouple Layout.

Doorway TC Tree			Front Interior TC Tree*			Back Interior TC Tree**		
TC #	ID	Distance from Header	TC #	ID	Distance from Ceiling	TC #	ID	Distance from Ceiling
23	DT-5	5 in. (0.13 m)	31	FT-6	6 in. (0.15 m)	39	BT-6	6 in. (0.15 m)
24	DT-15	15 in. (0.38 m)	32	FT-18	18 in. (0.46 m)	40	BT-18	18 in. (0.46 m)
25	DT-25	25 in. (0.64 m)	33	FT-30	30 in. (0.76 m)	41	BT-30	30 in. (0.76 m)
26	DT-35	35 in. (0.89 m)	34	FT-42	42 in. (1.07 m)	42	BT-42	42 in. (1.07 m)
27	DT-45	45 in. (1.14 m)	35	FT-54	54 in. (1.37 m)	43	BT-54	54 in. (1.37 m)
28	DT-55	55 in. (1.40 m)	36	FT-66	66 in. (1.68 m)	44	BT-66	66 in. (1.68 m)
29	DT-65	65 in. (1.65 m)	37	FT-78	78 in. (1.98 m)	45	BT-78	78 in. (1.98 m)
30	DT-75	75 in. (1.91 m)	38	FT-90	90 in. (2.29 m)	46	BT-90	90 in. (2.29 m)

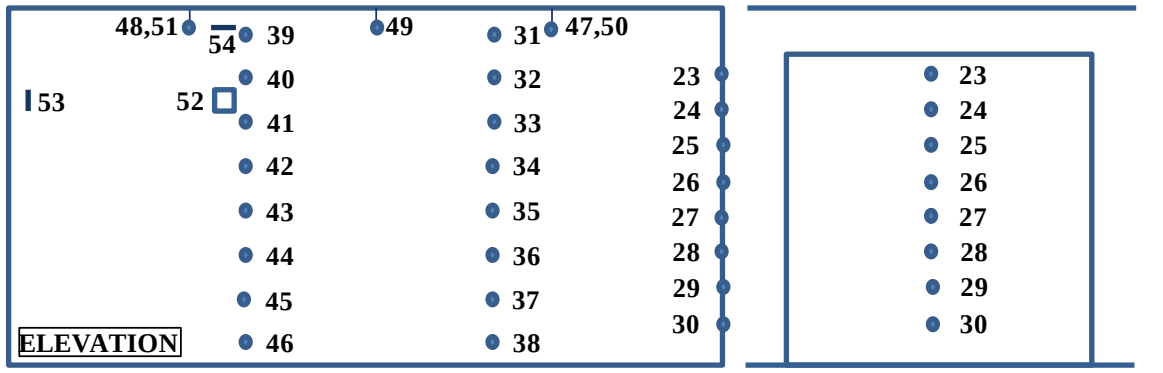
* located in the middle between the side walls and 34 in (0.86 m) from room center toward the front

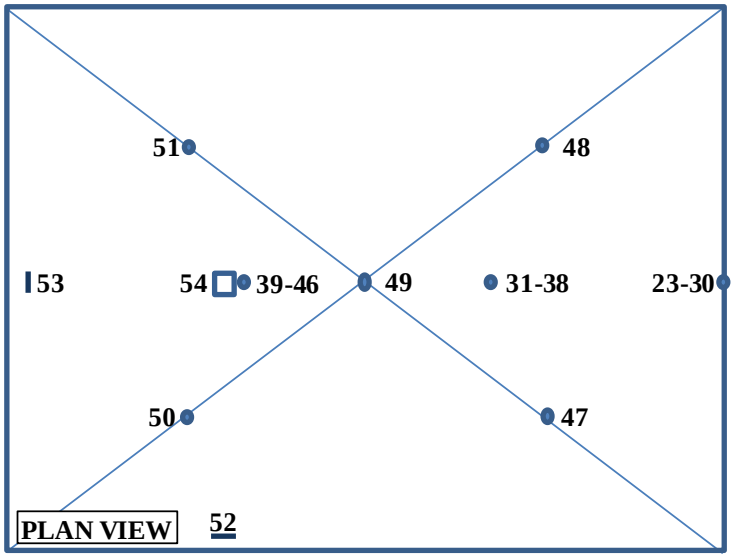
** located in the middle between the side walls and 34 in (0.86 m) from room center toward the back

Gas TCs 4 in. (0.10 m) below Ceiling		
TC #	ID	Location
47	C-FL	Front Left Quadrant
48	C-FR	Back Left Quadrant
49	C-C	Center
50	C-BL	Front Right Quadrant
51	C-BR	Back Right Quadrant

Plate Thermometers 4 in. (0.10 m) from Wall/Ceiling

TC #	ID	Distance from Center	Height above Floor
52	SW-PT	+34 in. (-0.86 m)	6 ft (1.83 m)
53	BW-PT	NA	6 ft (1.83 m)
54	C-PT	+34 in. (+0.86 m)	NA





Test 1 Interior Dimensions	
Height, H	7' 9½" (2.37 m)
Length, W	13' 6" (4.11 m)
Width,W	11' 9½" (3.59 m)

Test 2 Interior Dimensions	
Height, H	7' 9½" (2.37 m)
Length, W	14' 7¾" (4.11 m)
Width,W	10' 7¾" (3.59 m)

Vent Dimensions	
Height, H	6' 9½" (2.07 m)
Width, W	6' 1½" (1.87 m)

Figure 5. Room Interior Thermocouple Layout.

1.3 Fire Load

The room contents consisted of an upholstered sofa, two upholstered chairs, accent tables, two bookcases with books, an armoire, a TV stand with a CRT TV, and an area rug (see Figures B-13 through B-15). The corresponding fire load was calculated based on the measured weight of each item and the corresponding heat of combustion reported by Bwalya et al.[1] The fire load calculations are shown in Table 2 below. The resulting fire load density, i.e., the fire load per unit floor area, is 570 MJ/m^2. This corresponds to the 90th percentile of the fire load density frequency distribution for living rooms in Canada reported by Bwalya et al. as shown in Figures 6 and 7. Note that the pre-2013 California Technical Bulletin 117 compliant polyurethane foam padding in the upholstered furniture was replaced with untreated foam of the same density (2 pcf or 32 kg/m^3) to increase the growth rate and severity of the fire.

Table 2. Fire Load (Test 1).

Based on Actual Weight Test 1				
Furniture Item	**Weight (kg)**	**HOC (MJ/kg)**	**Quantity**	**FL Contribution MJ**
Loveseat	50.9	20	1	1019
Chair	29.3	20	2	1171
Coffee Table	18.6	18	1	335
End Table	12.2	18	1	220
Area Rug	8.9	20	1	179
Armoire	64.2	18	1	1155
TV stand	35.4	18	1	638
TV	29.8	25	1	745
Book Case	76.4	18	1	1376
Book Case	42.9	18	1	772
Books	45.5	18	1	819
Floor Width (m)	3.59		**Total**	8427
Floor Length (m)	4.11		**Low Target (Mean)**	6092
Floor Area (m²)	14.79		**High Target (95%)**	9019

1.4 Test Results

After a 5-minute baseline, a small butane flame (BS 5852 Source 2) was applied for 40 seconds in the center of the sofa seat cushion closest to doorway (see Figure B-16). The fire quickly developed (see Figures B-17 through B-19) and reached flashover in about four minutes (see Figure B-20). The fire reached peak intensity between five and six minutes (see Figures B-21 and B-22).

[1] Bwalya, A., Lougheed, G., Kashef, A., and Saber, H., "Survey Results of Combustible Contents and Floor Areas in Canadian Multi-Family Dwellings," *Fire Technology*, Vol. 47, pp. 1121-1140, 2011.

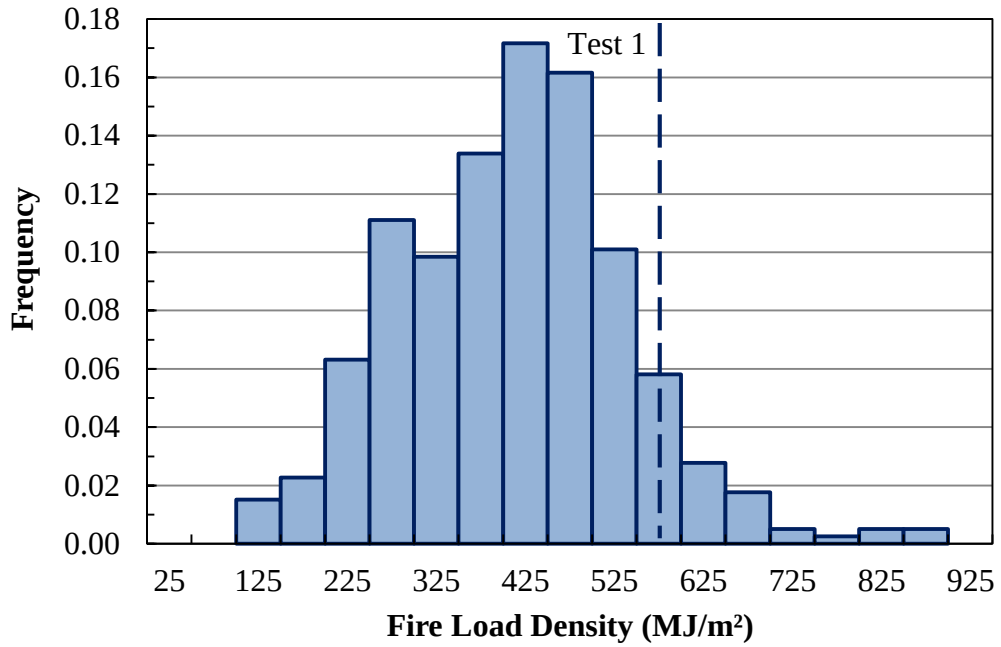


Figure 6. Test 1 vs. Fire Load Density Frequency Distribution from Canadian Survey.

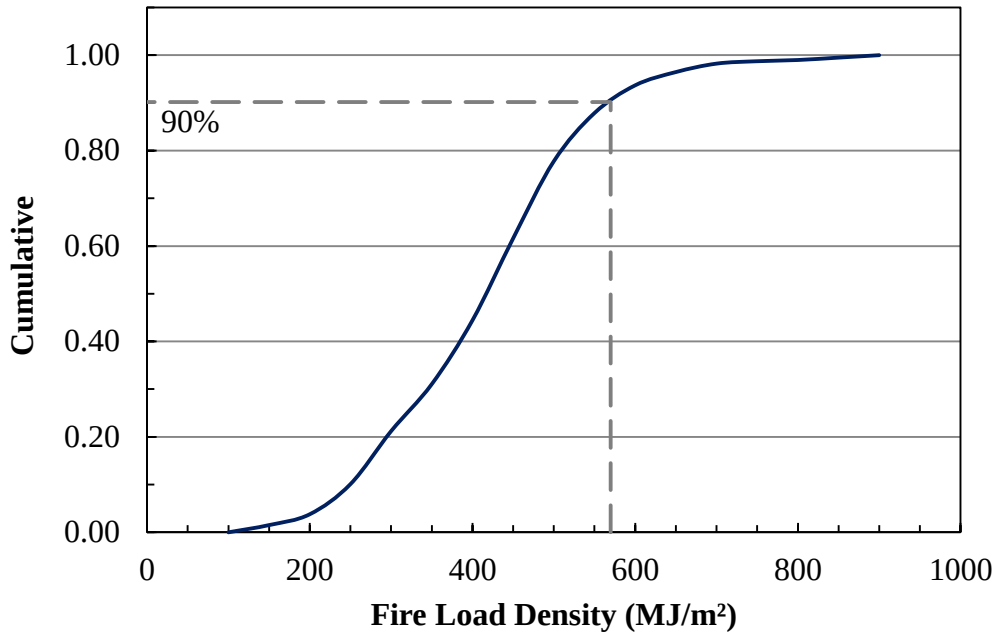


Figure 7. Test 1 vs. Cumulative Fire Load Density Distribution from Canadian Survey.

Shortly thereafter, smoke started spilling from the exhaust hood and filled the laboratory (see Figures B-23 and B-24). At approximately 27, 67, 73, and 90 minutes several small pieces of the gypsum board face layer fell from the ceiling (see Figures B-26 and B-29). Approximately 30 minutes into the test the smoke had largely cleared, and most of the contents had been consumed except for the remains of the armoire and the two bookcases, which continued to burn (see Figures B-

25 through B-30). Finally, after about three hours, the compartment had completely burnt out (see Figure B-31), and the test was terminated.

1.4.1 Heat Release Rate

The heat release rate as a function of time is shown in Figures C-1 (first 30 minutes) and C-2. The peak measured heat release rate was approximately 5.5 MW, although the actual peak heat release rate may have been somewhat higher since smoke spilling started to occur when the peak heat release rate was recorded

The wall and ceiling TC temperatures are shown in Figures C-3 through C-10. The highest temperature was recorded at TC 18 (516 °F or 269 °C), which was between the two layers of gypsum board. The TC temperatures between the base layer gypsum board and the CLT or NLT never exceeded 212 °F (100 °C).

1.4.2 Gas Temperatures

The tree TC temperatures are shown in Figures C-11 through C-16. The front interior TC tree was lost between 12 and 13 minutes into the test. The HGL temperatures are shown in Figures C-17 and C-18, and compared with the standard ASTM E119 time-temperature curve. These figures clearly show that the room fire was more severe than the standard fire, but also shorter in duration. The maximum HGL temperature recorded was 2273 °F (1245 °C).

1.4.3 Heat Fluxes

The plate thermometer temperatures are shown in Figures C-19 and C-20. The corresponding heat fluxes in Figures C-21 and C-22 were calculated from

$$\dot{q}_e^{"} \approx \varepsilon\sigma(T_s^4 - T_\infty^4)$$

where

$\dot{q}_e^{"}$ = Incident heat flux (kW/m^2);

ε = Surface emissivity of the Inconel plate ($\approx$ 0.8);

σ = Boltzmann constant ($5.67 \cdot 10^{-11}$ kW/m^2·K^4);

T_s = Plate temperature (K); and

T_∞ = Ambient temperature (K).

This equation assumes that the conduction heat losses through the ceramic fiber board Inconel plate backing are negligible. The highest heat flux reading of 253 kW/m^2 was recorded at TC 53.

1.5 Post-Test Observations

The gypsum board face layer sustained limited damage, except for the pieces that fell from the ceiling during the test and some additional pieces that fell down during cool-down (see Figure B-32). The base layer remained largely intact although there was some noticeable damage in the three corners where solid furniture items burned for a long time (see Figures B-33 and B-34). The wood structure was also intact except for the same three corners (see Figure B-35). Some superficial charring was observed in the back corners (see Figures B-36 and B-37), while a maximum char depth of ¼ in. (6 mm) was measured in the front corner where the heavier bookcase was located (see Figure B-36).

SECOND ROOM TEST

The second room test was conducted Tuesday September 15, 2015. The data acquisition system was started at approximately 8:50 a.m., and the ignition source was applied at approximately 8:55 a.m. Temperature and relative humidity in the laboratory at the start of the test were 71 °F (22 °C) and 90%, respectively. The test was terminated at approximately 11:10 a.m. at the Client's direction.

1.6 Room Construction

1.6.1 Wood Structure

The walls of the compartment were constructed from a second set of CLT panels that were identical to those used in the construction of the compartment for the first test (see Figure D-1). However, the sidewalls in this case were inside the front and back panels as shown in Figure 8. The ceiling consisted of two CLT panels (see Figures A-4 and A-5) that were connected to the walls with 5/16 × 11-in. (8 × 280-mm) partial thread screws with a 5⅞-in. (150-mm) spacing. Figure D-2 shows placement of the first ceiling panel on the walls of the compartment. A spline was attached with #8 2¼-in. (57-mm) coarse thread wood screws to connect the two ceiling halves (see Figure D-3). The assembled CLT compartment is shown in Figure D-4. The joint around the perimeter at the wall-ceiling interface was sealed with 3M Fire Barrier Sealant (CP 25WB+ Red) as shown in Figure D-5.

The moisture content was measured with a Delmhorst RDM³ moisture meter in the vicinity of where the wall and ceiling thermocouples (TCs) were located prior to attaching the base layer of gypsum board. The results are given in Table 3.

1.6.2 Gypsum Board

The walls, ceiling, and floor of the compartment were covered with two layers of ⅝-in. (16-mm) type X gypsum board as in the first test (see Figures D-6 through D-9). The walls and ceiling were subsequently finished the same as the first test (see Figures D-10 and D-11).

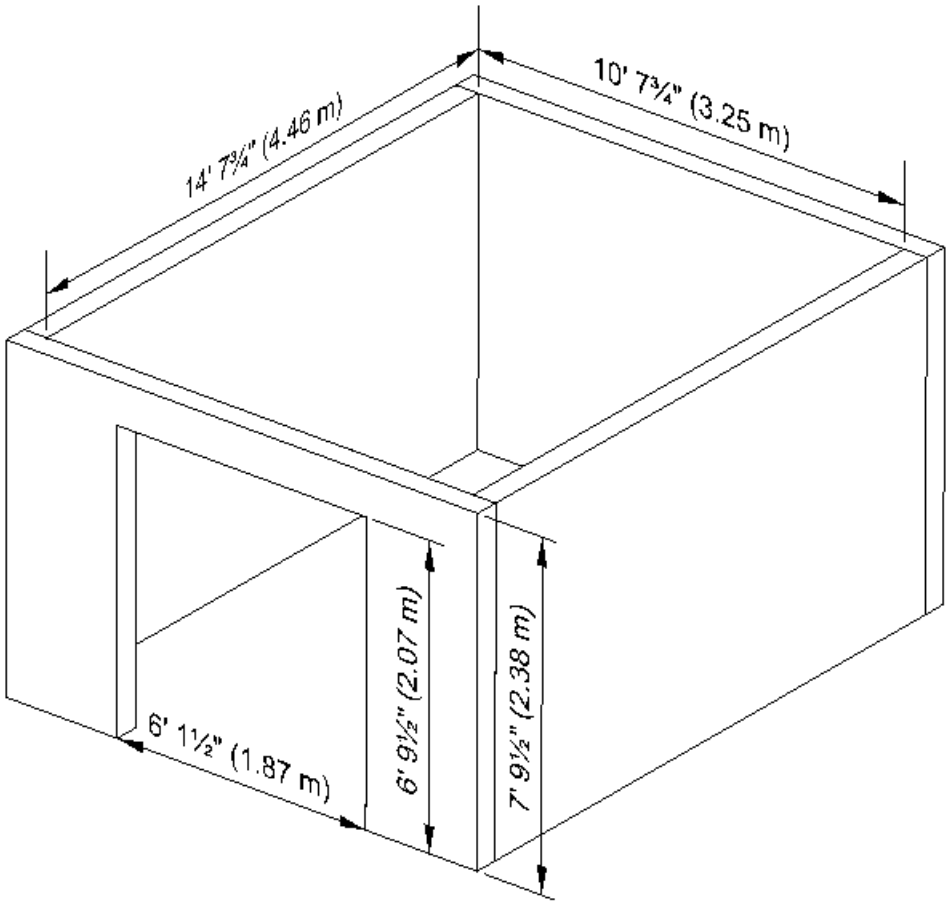


Figure 8. CLT Wall Panel Assembly for Test 2 Compartment.

Table 3. CLT Moisture Content (Test 2).

Location Code	MC 1 (%)	MC 2 (%)	Mean MC (%)
SWF-T	11.3	10.8	11.1
SWB-T	11.6	10.1	10.9
SWF-M	12.5	11.9	12.2
SWB-M	10.1	11.4	10.8
SWF-B	10.5	11.2	10.9
SWB-B	10.4	11.5	11.0
BW-T	11.1	11.4	11.3
BW-M	10.4	11.2	10.8
BW-B	10.9	10.4	10.7
CF	11.2	11.5	11.4
CB	11.4	11.4	11.4

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1.6.3 Structural Load

19/32-in. (15-mm) thick plywood was fastened to the top of the CLT ceiling using #8 2¼-in. (57-mm) coarse thread wood screws (see Figure D-12). Concrete blocks were placed on the plywood to impose a distributed structural load of 40 psf (1.9 kN/m2) as shown in Figure D-13.

1.7 Instrumentation

The instrumentation was identical to that used in the first test.

1.8 Fire Load

As in the first test, the room contents consisted of an upholstered sofa, two upholstered chairs, accent tables, two bookcases with books, an armoire, a TV stand with a CRT TV, and an area rug (see Figures D-14 and D-15). The corresponding fire load was again calculated based on the measured weight of each item and the corresponding heat of combustion reported by Bwalya et al. The fire load calculations are shown in Table 4 below. The resulting fire load density is 601 MJ/m^2, which is slightly higher than the fire load density in the first test because a heavier TV set was used. This corresponds to the 94th percentile of the fire load density frequency distribution for living rooms in Canada reported by Bwalya et al. as shown in Figures 9 and 10. As in the first test, the pre-2013 California Technical Bulletin 117 compliant polyurethane foam padding in the upholstered furniture was replaced with untreated foam of the same density (2 pcf or 32 kg/m^3) to increase the growth rate and severity of the fire.

Table 4. Fire Load (Test 2).

Based on Actual Weight Test 2				
Furniture Item	**Weight (kg)**	**HOC (MJ/kg)**	**Quantity**	**FL Contribution MJ**
Loveseat	50.9	20	1	1019
Chair	29.3	20	2	1171
Coffee Table	18.6	18	1	335
End Table	12.2	18	1	220
Area Rug	8.9	20	1	179
Armoire	64.2	18	1	1155
TV stand	35.4	18	1	638
TV	40.9	25	1	1023
Book Case	76.4	18	1	1376
Book Case	42.9	18	1	772
Books	45.5	18	1	819
Floor Width (m)	3.24		**Total**	8705
Floor Length (m)	4.46		**Low Target (Mean)**	5967
Floor Area (m²)	14.48		**High Target (95%)**	8834

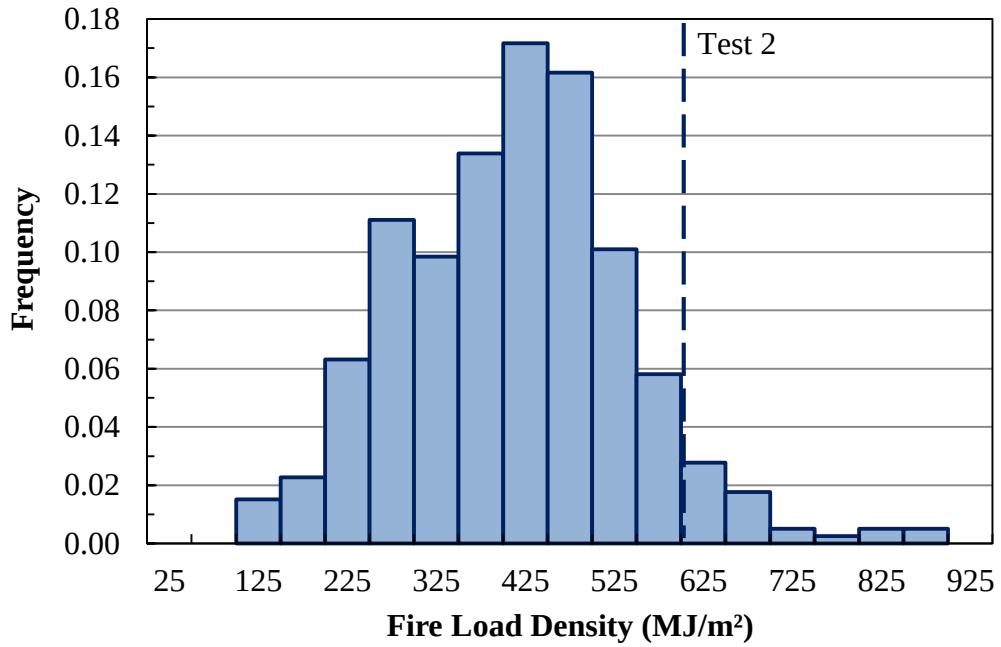

Figure 9. Test 2 vs. Fire Load Density Frequency Distribution from Canadian Survey.

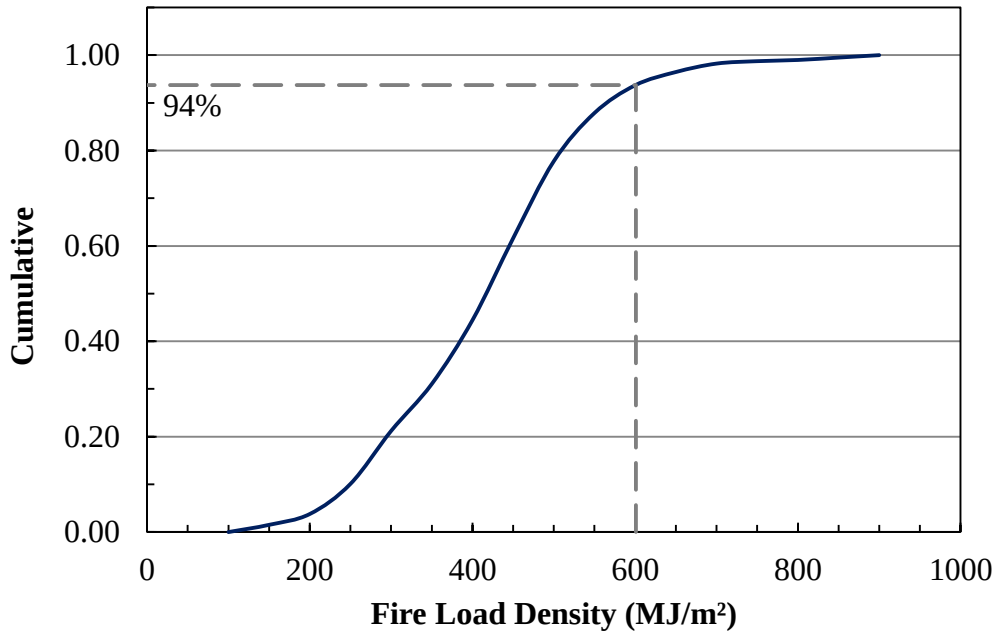

Figure 10. Test 2 vs. Cumulative Fire Load Density Distribution from Canadian Survey.

1.9 Test Results

As in the first test, after a 5-minute baseline, a small butane flame (BS 5852 Source 2) was applied for 40 seconds in the center of the sofa seat cushion closest to doorway. The fire quickly developed (see Figures D-16 through D-18), reached flashover in about four minutes (see Figure D-19), continued to grow (see Figure D-20), and reached peak intensity between the sixth and seventh

minute (see Figures D-21 and D-22). Shortly thereafter smoke started spilling from the exhaust hood and filled the laboratory (see Figures D-23 and D-24). After approximately 31 minutes a small piece of the gypsum board face layer fell from the ceiling (see Figure D-25). At that time the smoke had largely cleared, and most of the contents had been consumed except for the remains of the armoire and the two bookcases, which continued to burn (see Figures D-25 through D-27). Finally, after about two hours and fifteen minutes, the compartment had largely burnt out (see Figure D-28), and the test was terminated.

1.9.1 Heat Release Rate

The heat release rate as a function of time is shown in Figures E-1 (first 30 minutes) and E-2. The peak measured heat release rate was slightly lower than in the first test (4.9 MW versus 5.5 MW), but the fire continued to burn at a high rate for a longer period.

1.9.2 Wall and Ceiling Temperatures

The wall and ceiling TC temperatures are shown in Figures E-3 through E-10. The highest temperature was recorded at TC 21 (448 °F or 231 °C), which was between the two layers of gypsum board. The TC temperatures between the base layer gypsum board and the CLT again never exceeded 212 °F (100 °C).

1.9.3 Gas Temperatures

The tree TC temperatures are shown in Figures E-11 through E-16. The HGL temperatures are shown in Figures E-17 and E-18, and compared with the standard ASTM E119 time-temperatures curve. These figures clearly show that the second room fire was also more severe than the standard fire, but again shorter in duration. The maximum HGL temperature recorded was 2232 °F (1222 °C).

1.9.4 Heat Fluxes

The plate thermometer temperatures are shown in Figures E-19 and E-20. The corresponding heat fluxes are shown in Figures E-21 and E-22. A highest heat flux reading of 241 kW/m² was recorded at TC53.

1.10 Post-Test Observations

The gypsum board face layer sustained limited damage, except for the piece that fell from the ceiling during the test (see Figure D-29). The base layer remained largely intact (see Figure D-30). The wood structure was also intact except for some superficial charring in the back corners (see Figure D-31). There were no penetrations through the compartment walls or ceiling, except for the ½-in. (13-mm) pipes supporting the plate thermometers. Figure D-32 shows some slight charring at these penetrations.

APPENDIX A

CLT DRAWINGS

(CONSISTING OF 5 PAGES)

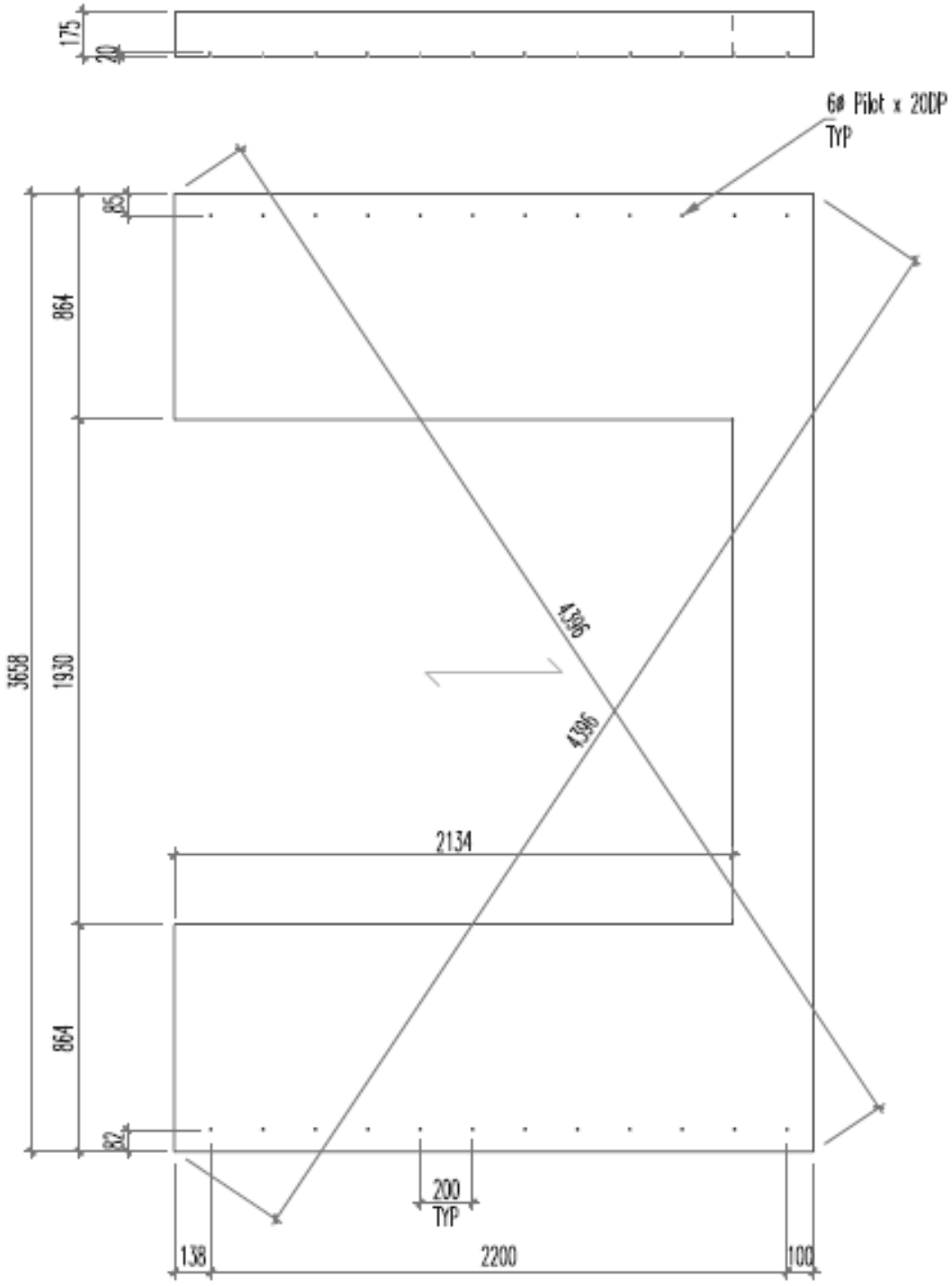

Figure A-1. Front Wall (Tests 1 and 2).

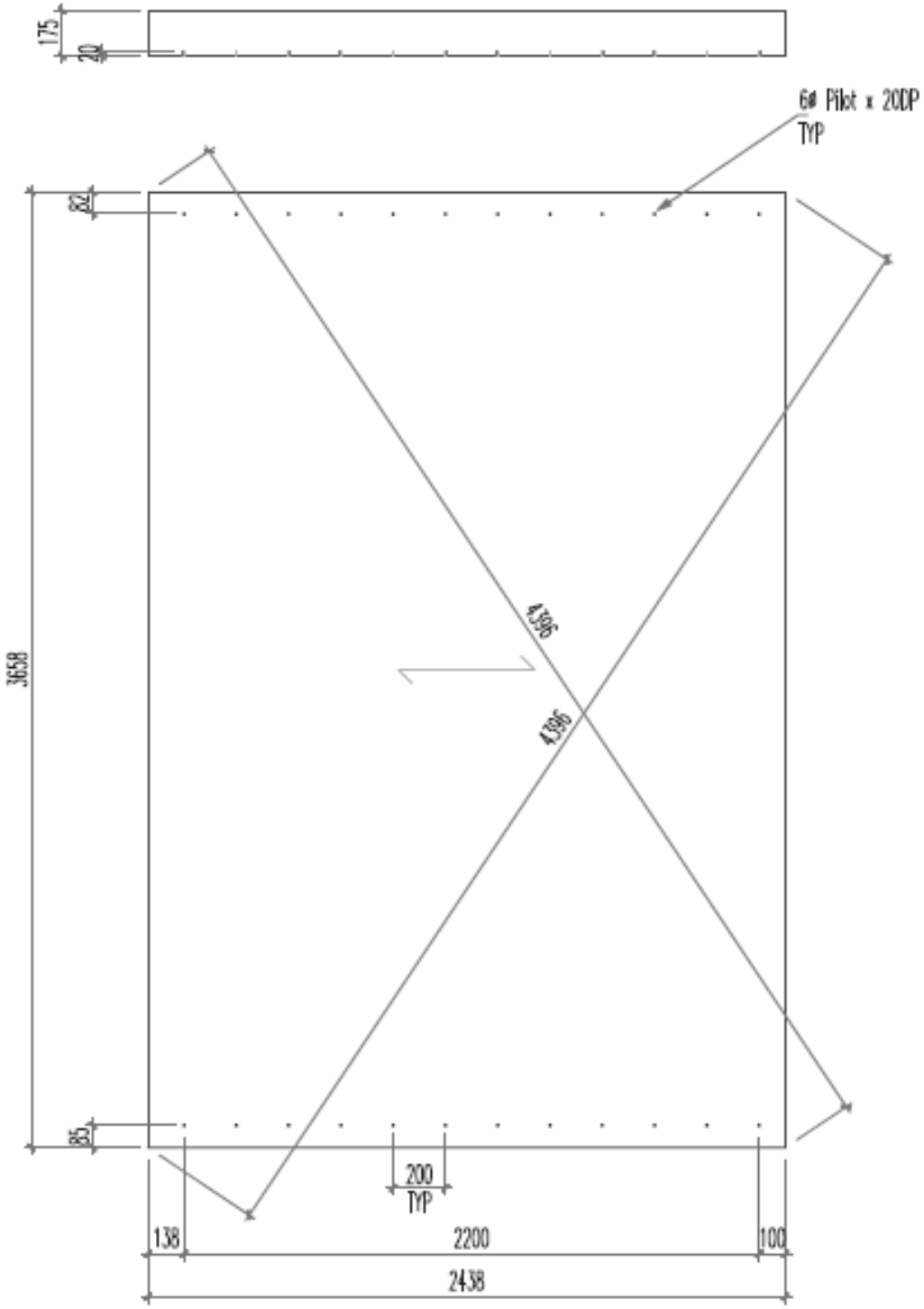

Figure A-2. Back Wall (Tests 1 and 2).

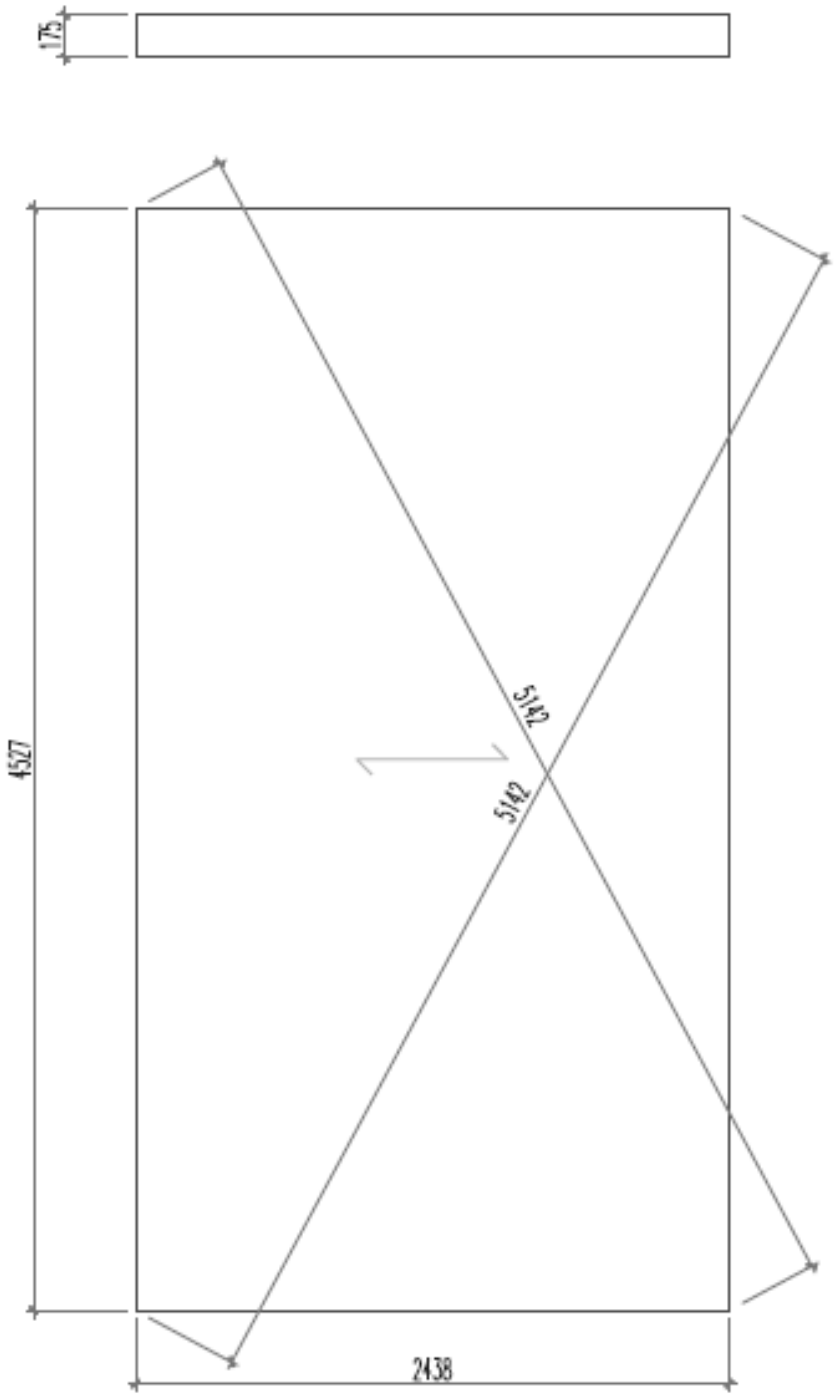

Figure A-3. Side Walls (Tests 1 and 2).

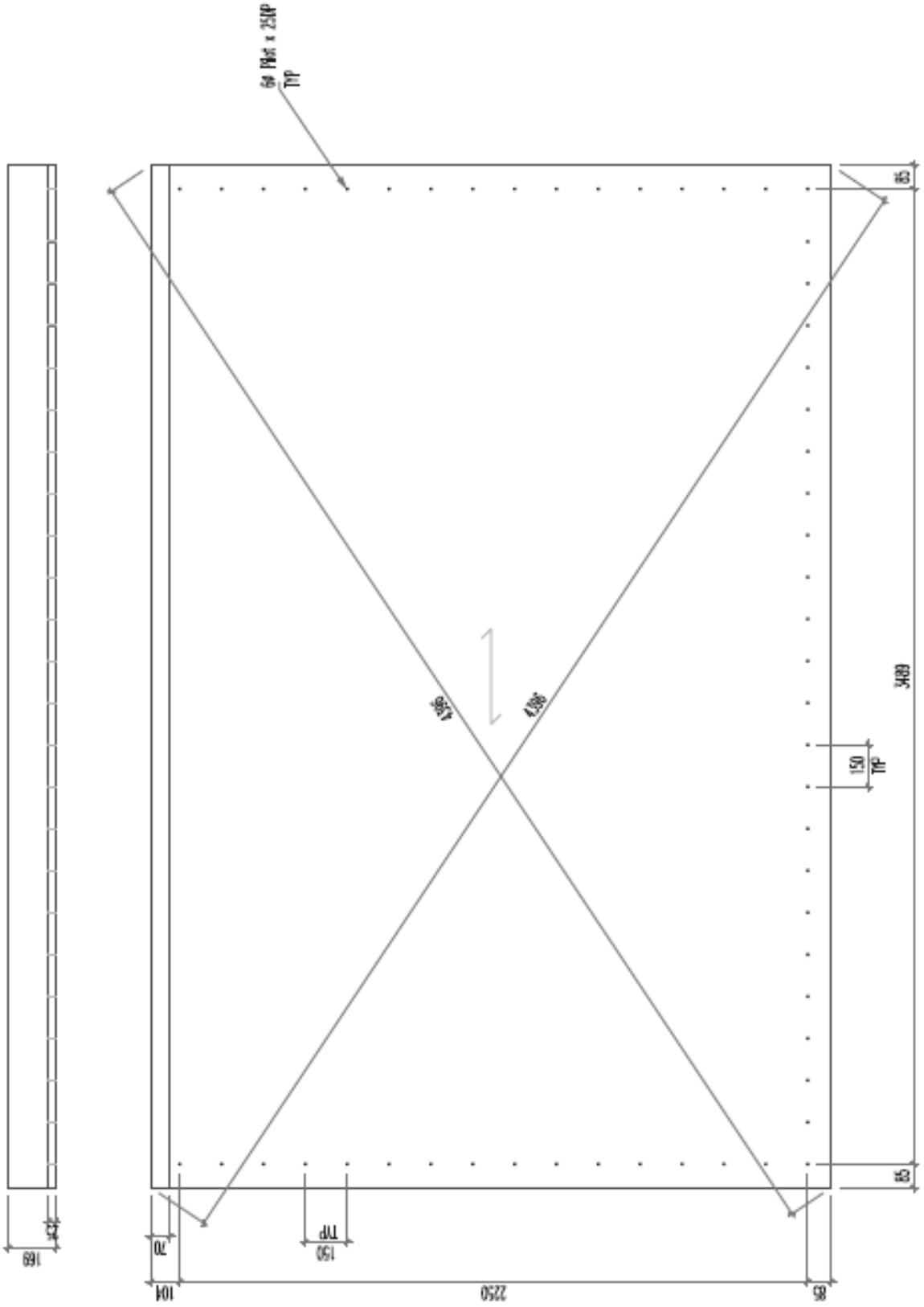

Figure A-4. Front Ceiling Panel (Test 2).

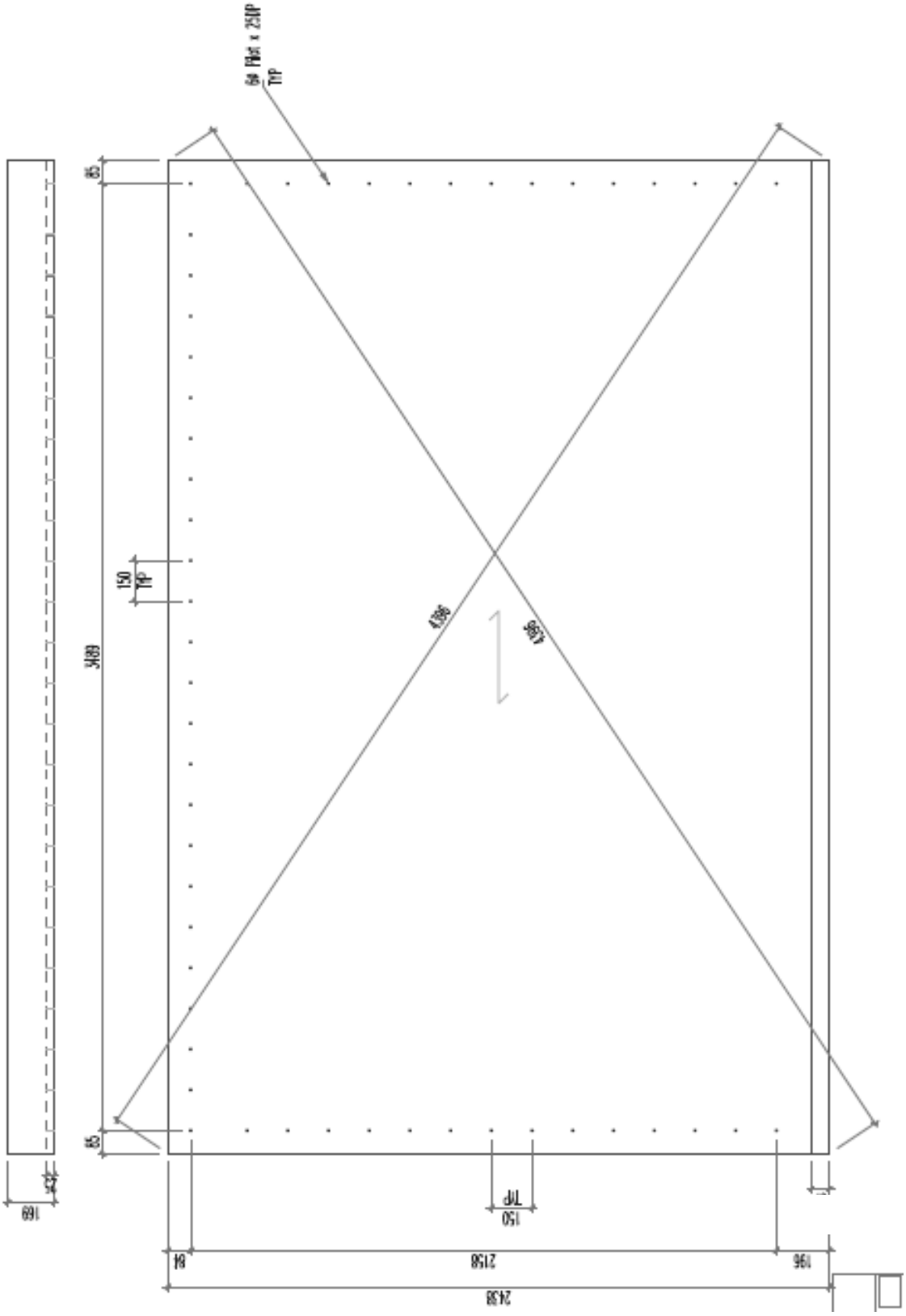

Figure A-5. Back Ceiling Panel (Test 2).

APPENDIX B

TEST 1 PHOTOGRAPHS

(CONSISTING OF 19 PAGES)

Figure B-1. CLT Connection.

Figure B-2. Assembled CLT Walls.

Figure B-3. NLT Ceiling under Construction.

Figure B-4. Base Layer of Gypsum Board on Ceiling.

Figure B-5. Base Layer of Gypsum Board on Walls.

Figure B-6. Face Layer of Gypsum Board on Ceiling.

Figure B-7. Face Layer of Gypsum Board on Walls.

Figure B-8. Gypsum Board Joints Taped and Floated.

Figure B-9. Room Painted.

Figure B-10. Plywood on NLT Ceiling.

Figure B-11. Load Applied.

Figure B-12. Thermocouple on Floor Joist.

Figure B-13. Furnished Room (Right Sidewall).

Figure B-14. Furnished Room (Back Wall).

Figure B-15. Furnished Room (Left Sidewall).

Figure B-16. Start of Test (Application of BS5852 Ignition Source 2).

Figure B-17. Approximately 1 min into the Test.

Figure B-18. Approximately 2 min into the Test.

Figure B-19. Approximately 3 min into the Test.

Figure B-20. Approximately 4 min into the Test.

Figure B-21. Approximately 5 min into the Test.

Figure B-22. Approximately 6 min into the Test.

Figure B-23. Approximately 7 min into the Test.

Figure B-24. Approximately 8 min into the Test.

Figure B-25. Approximately 30 min into the Test.

Figure B-26. Approximately 45 min into the Test.

Figure B-27. Approximately 60 min into the Test.

Figure B-28. Front Left Corner approximately 60 min into the Test.

Figure B-29. Approximately 120 min into the Test.

Figure B-30. Front Left Corner approximately 120 min into the Test.

Figure B-31. Approximately 180 min into the Test.

Figure B-32. Room Post-Test.

Figure B-33. Base Layer Post-Test.

Figure B-34. Base Layer Front Left Corner Post-Test.

Figure B-35. Wood Structure Post-Test.

Figure B-36. Charring in Back Right Corner Post-Test.

Figure B-35. Charring in Back Left Corner Post-Test.

Figure B-36. Charring in Front Left Corner Post-Test.

APPENDIX C

RESULTS FOR TEST 1

(CONSISTING OF 11 PAGES)

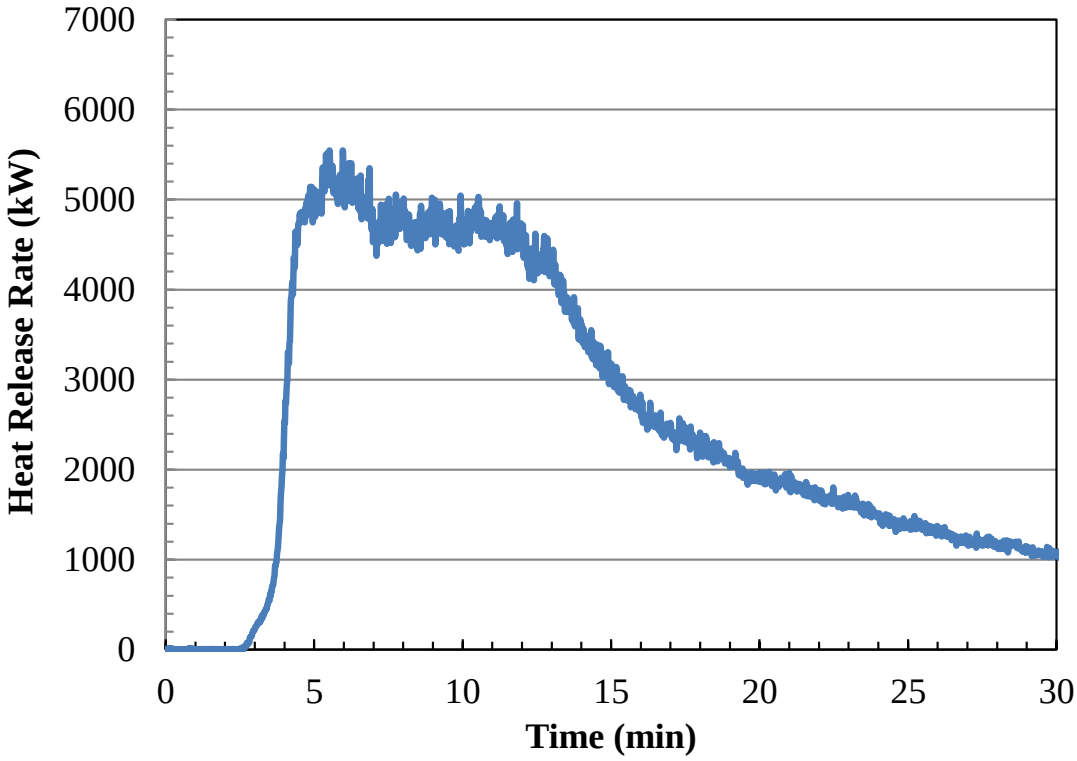

Figure C-1. Test 1 Heat Release Rate (First 30 min).

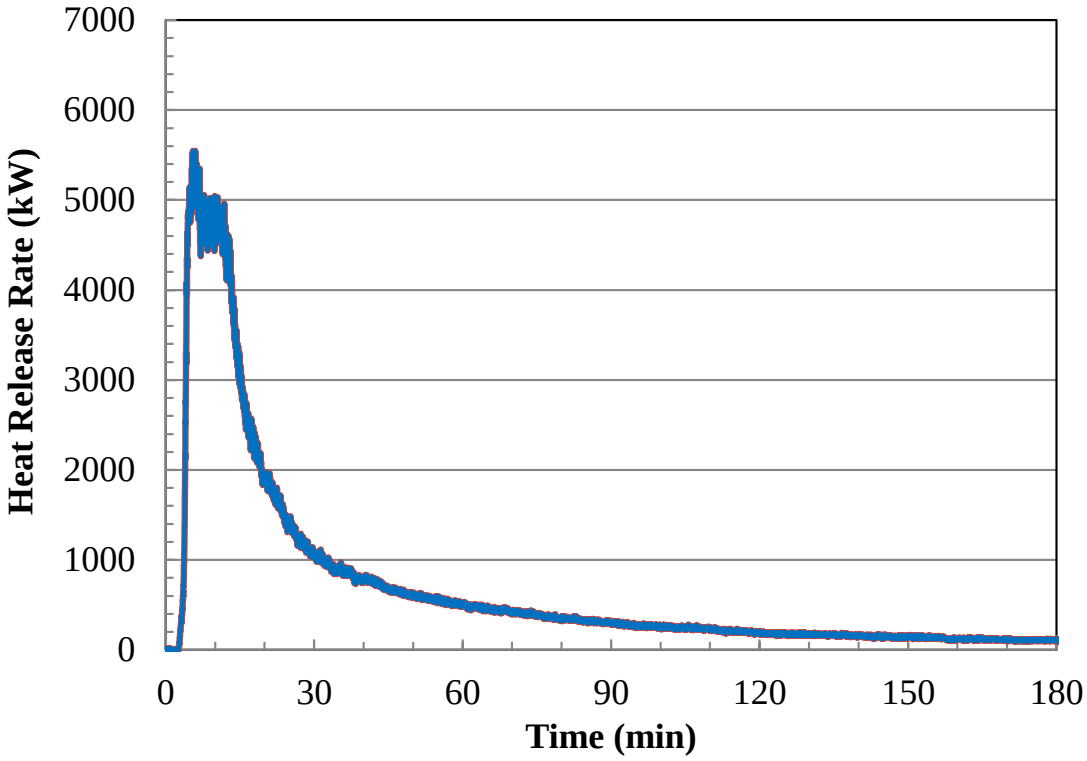

Figure C-2. Test 1 Heat Release Rate.

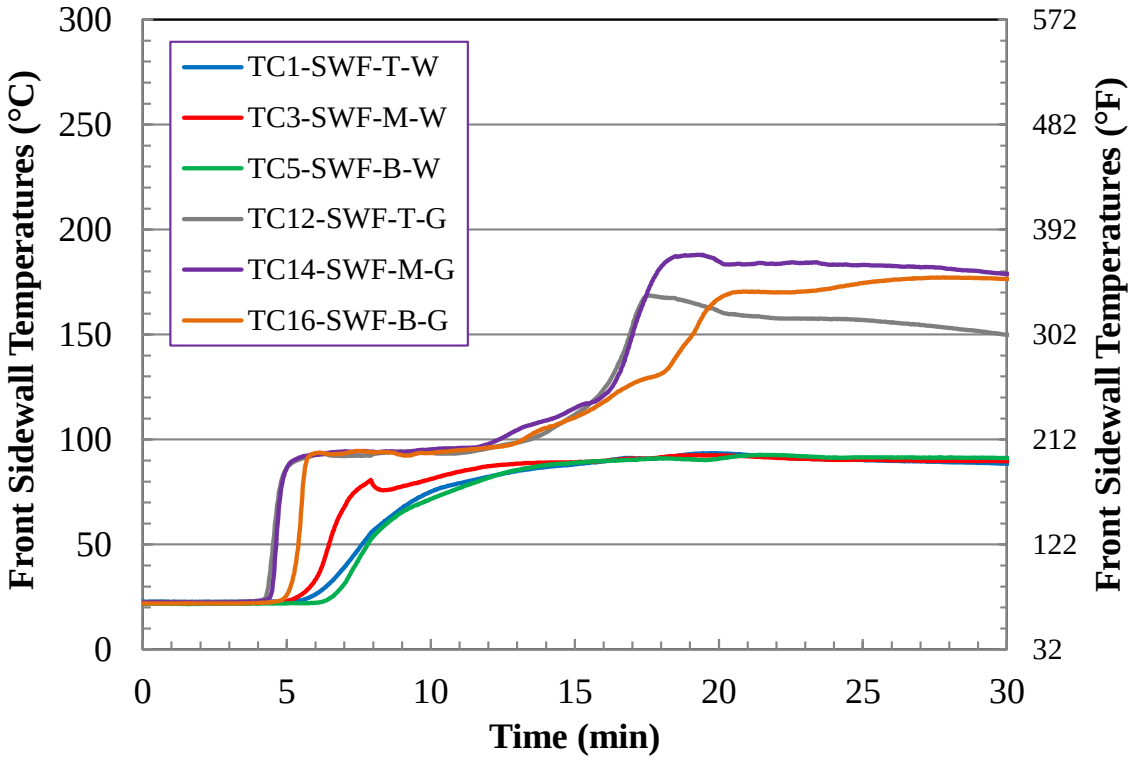

Figure C-3. Test 1 Front Sidewall Temperatures (First 30 min).

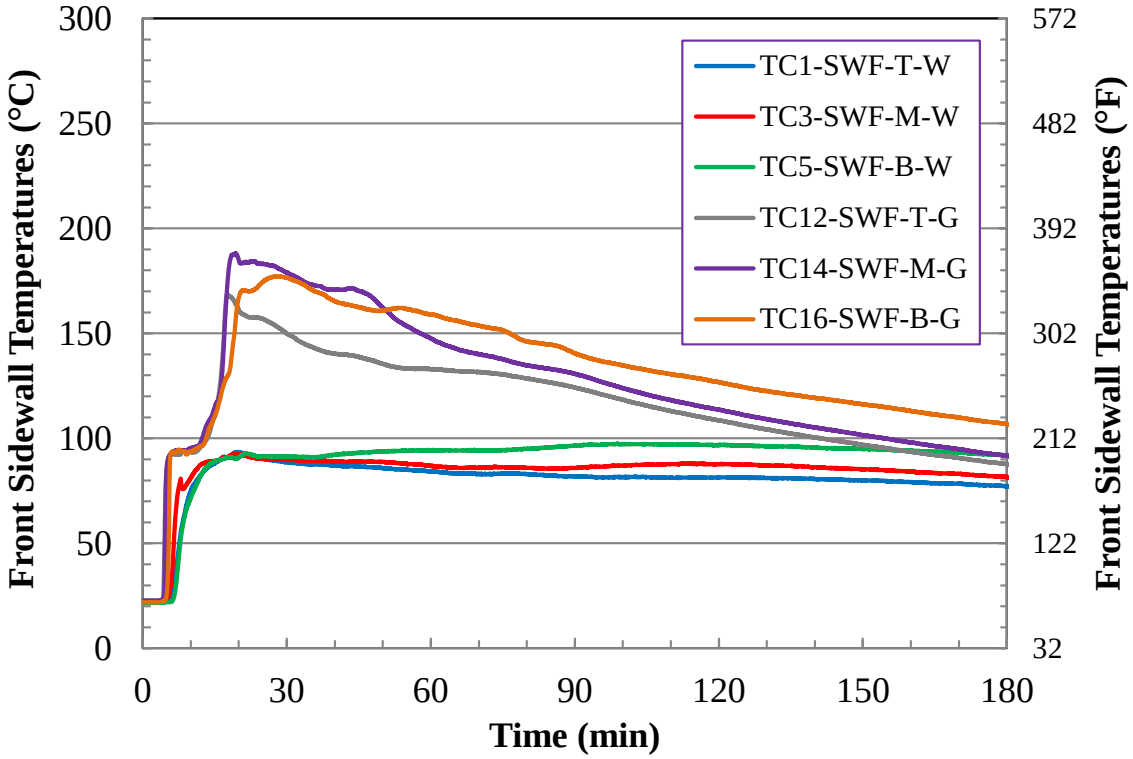

Figure C-4. Test 1 Front Sidewall Temperatures.

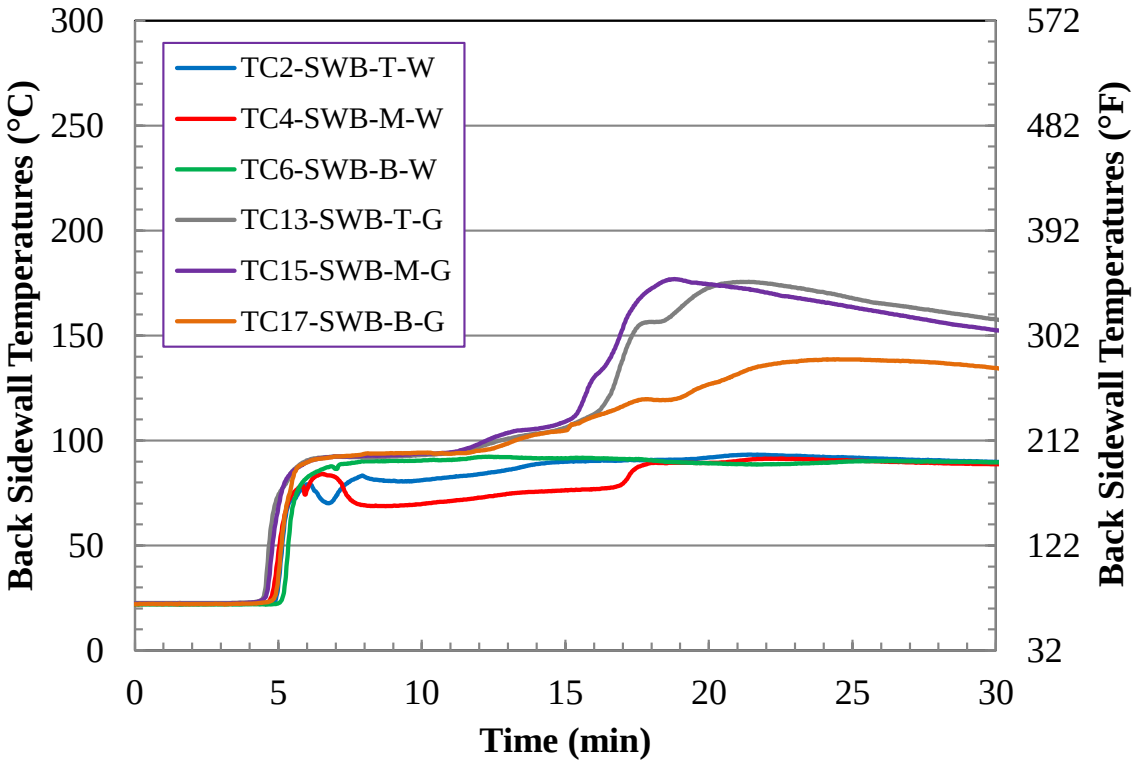

Figure C-5. Test 1 Back Sidewall Temperatures (First 30 min).

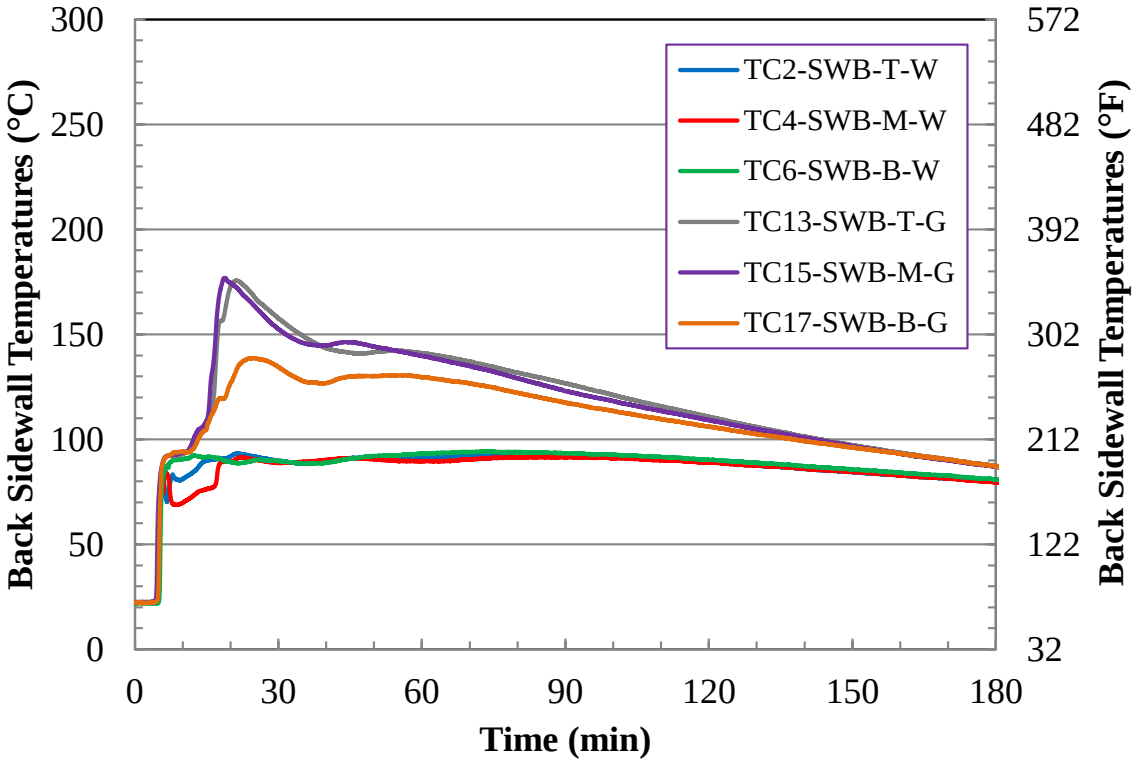

Figure C-6. Test 1 Back Sidewall Temperatures.

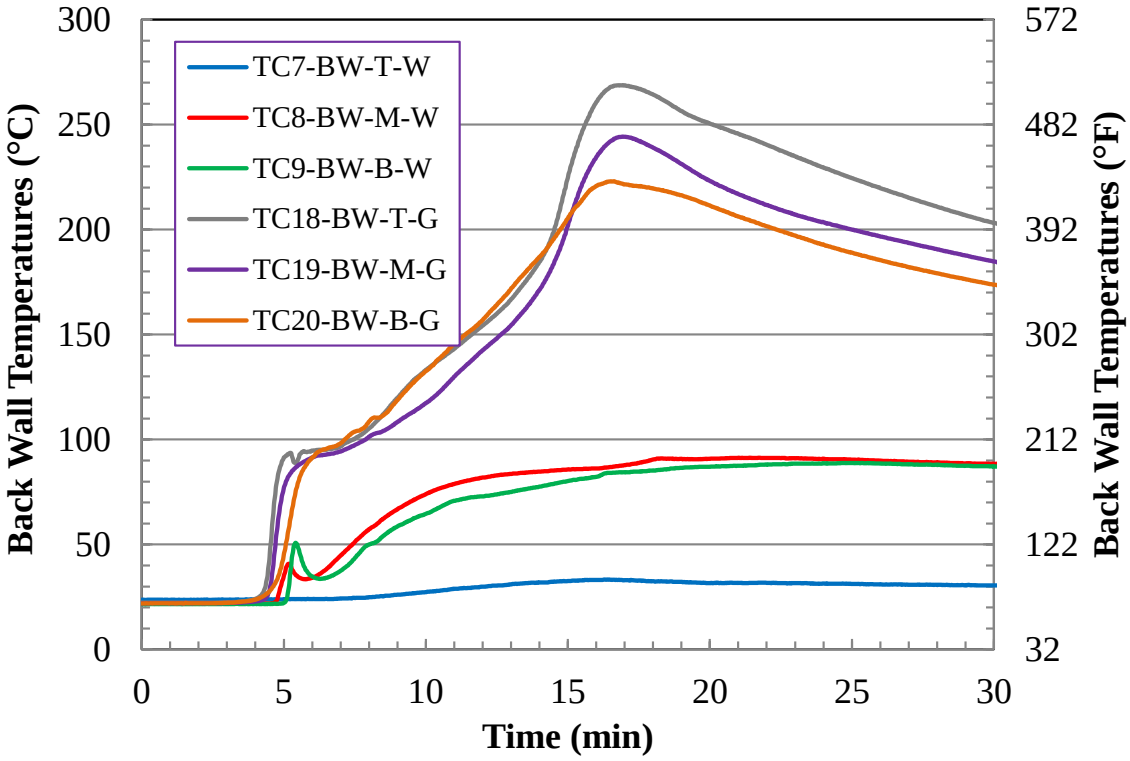

Figure C-7. Test 1 Back Wall Temperatures (First 30 min).

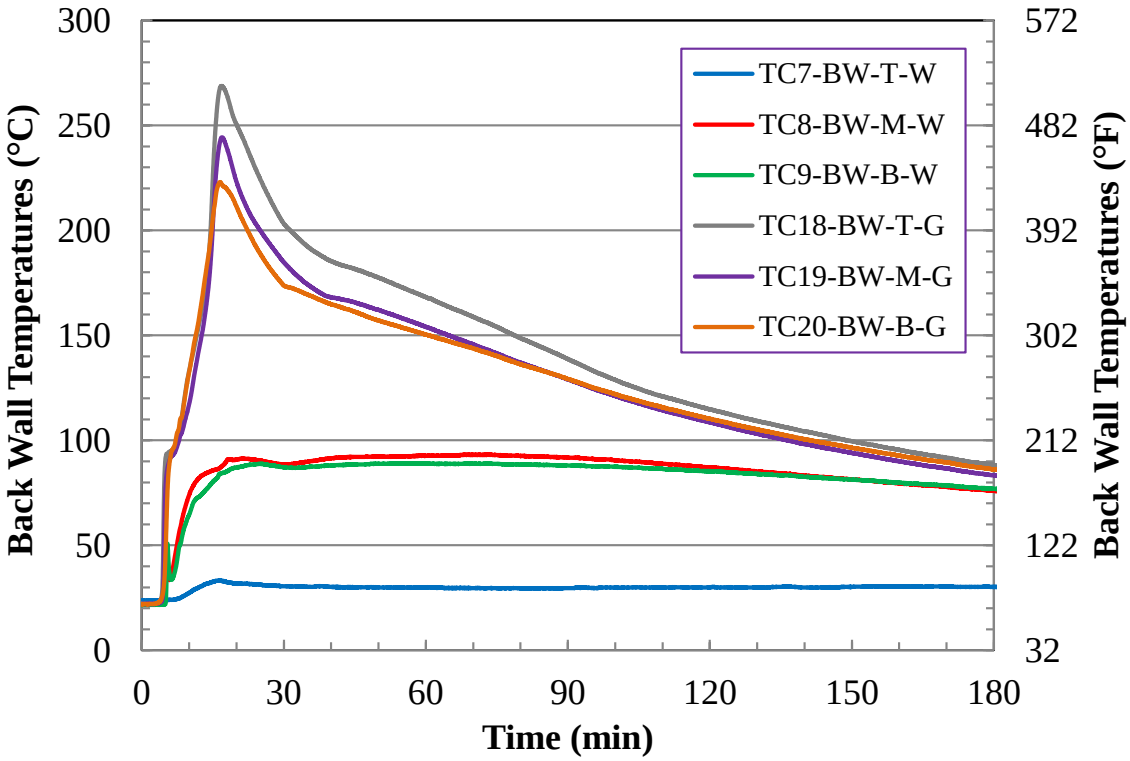

Figure C-8. Test 1 Back Wall Temperatures.

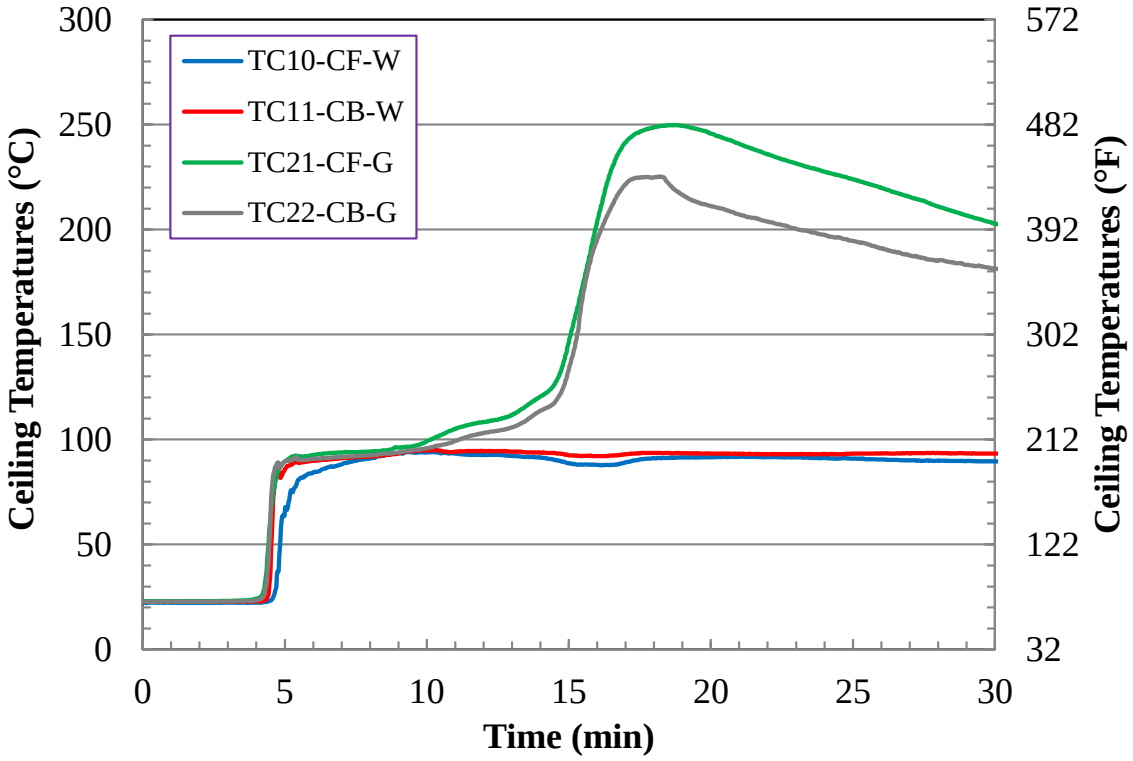

Figure C-9. Test 1 Ceiling Temperatures (First 30 min).

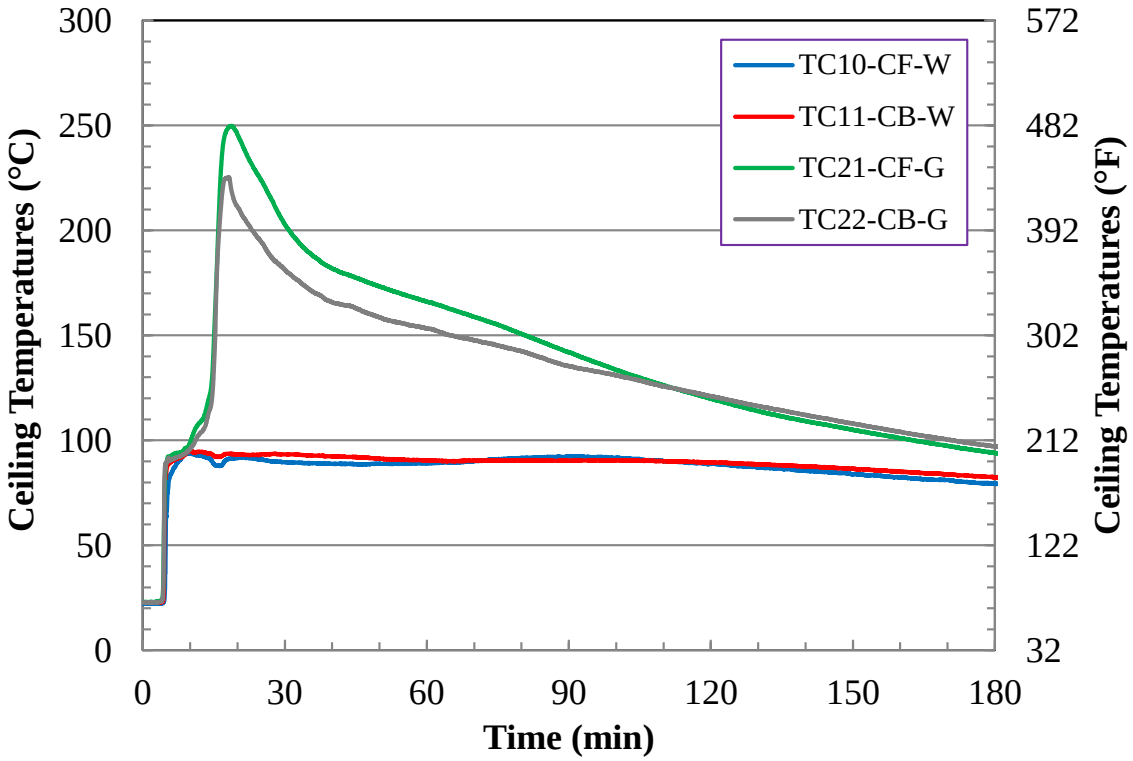

Figure C-10. Test 1 Ceiling Temperatures.

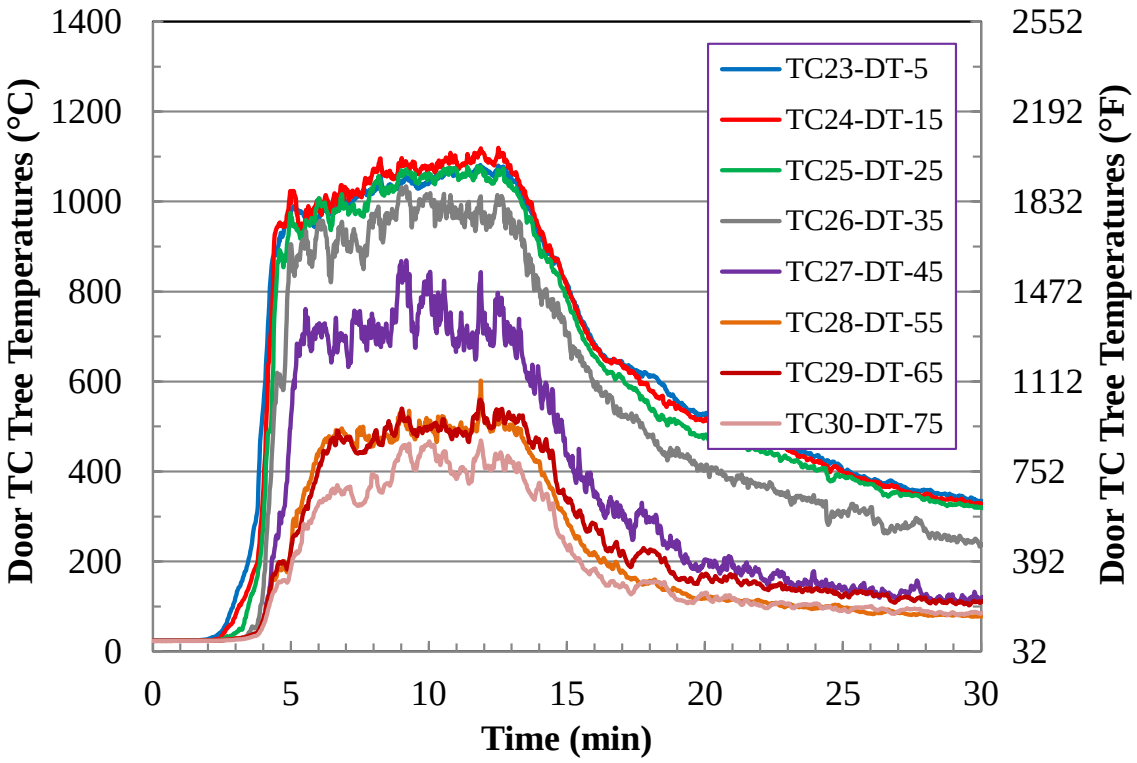

Figure C-11. Test 1 Door TC Tree Temperatures (First 30 min).

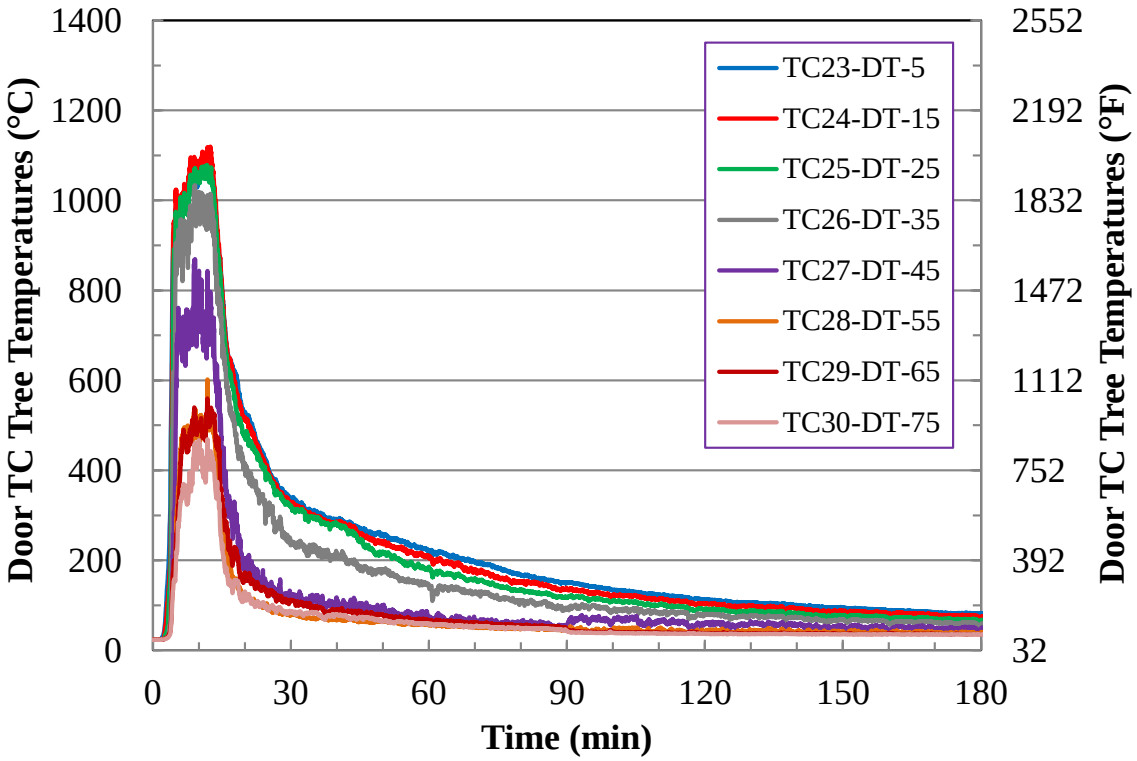

Figure C-12. Test 1 Door TC Tree Temperatures.

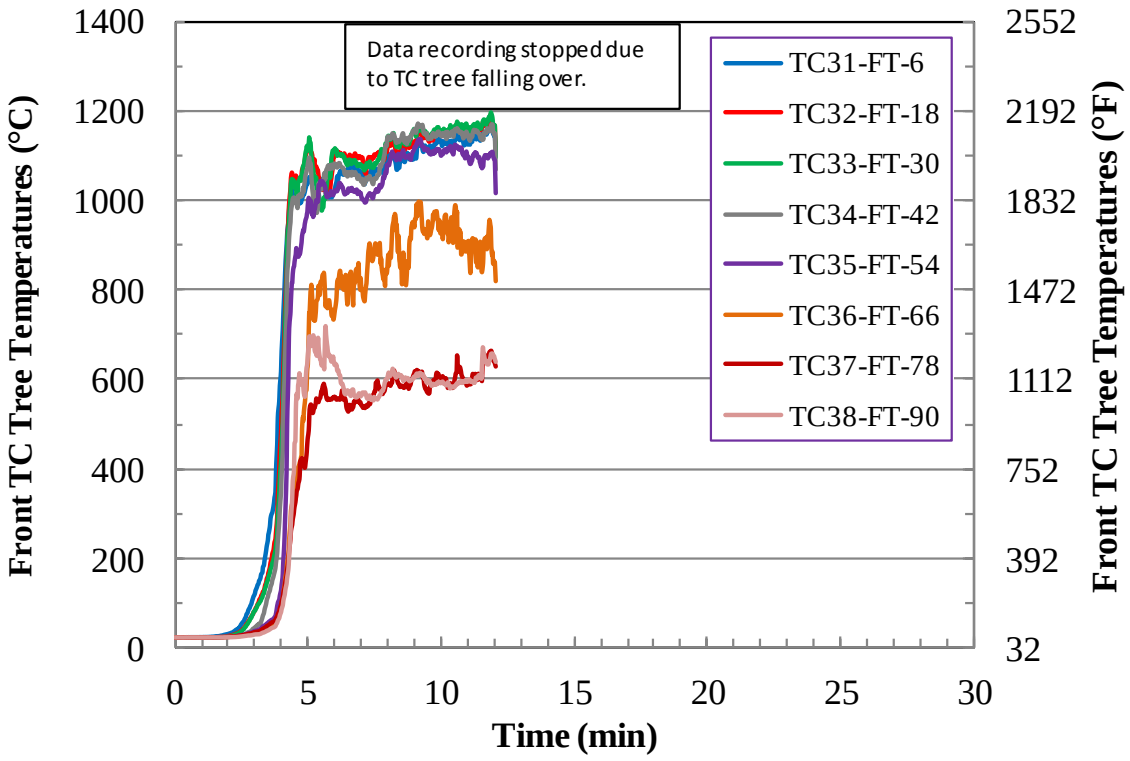

Figure C-13. Test 1 Front Interior TC Tree Temperatures (First 30 min).

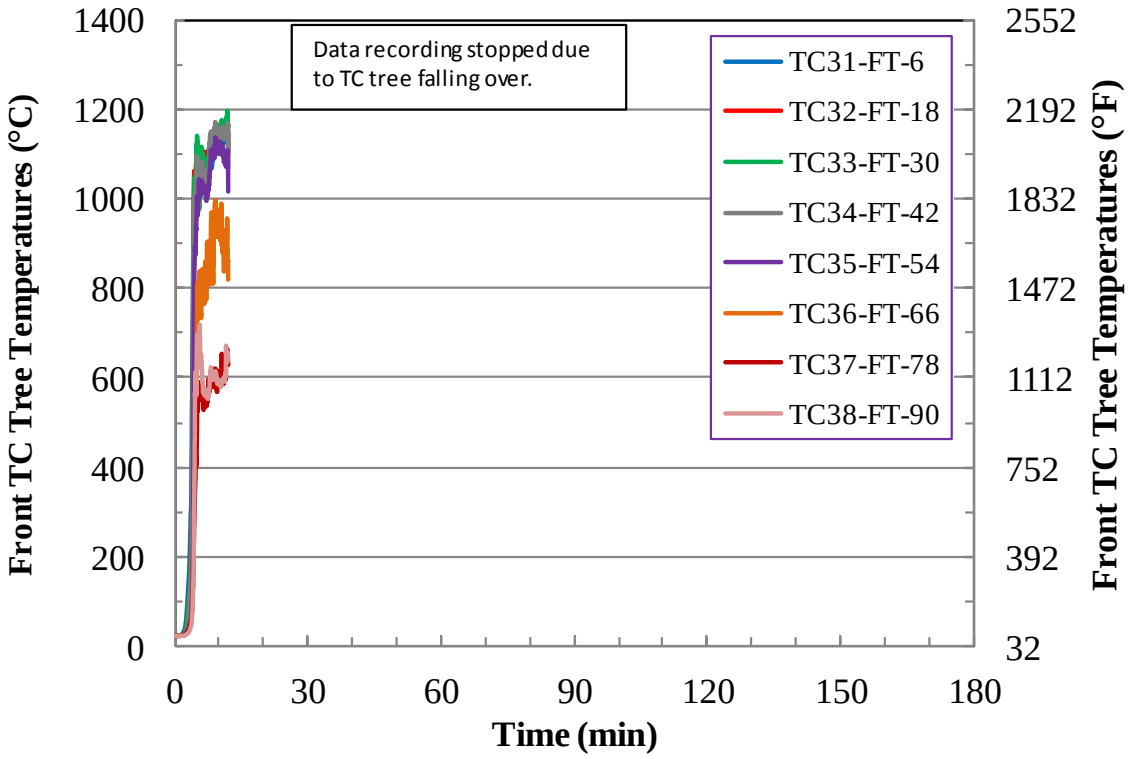

Figure C-14. Test 1 Front Interior TC Tree Temperatures.

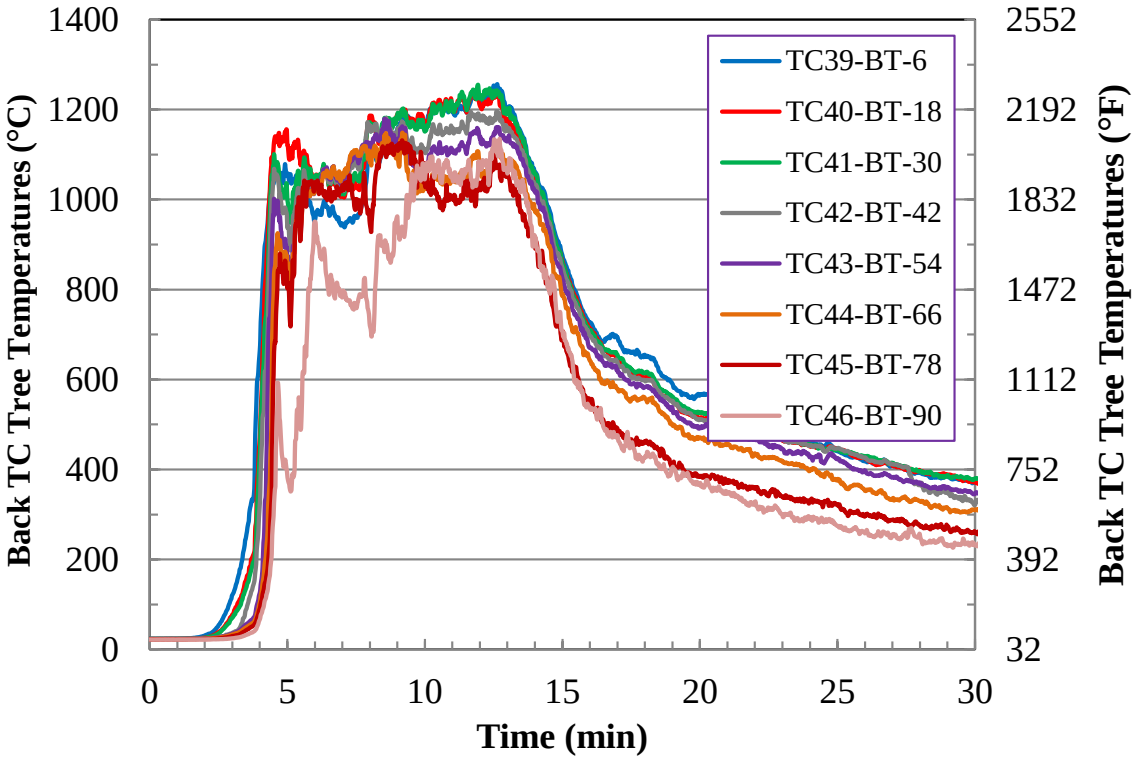

Figure C-15. Test 1 Back Interior TC Tree Temperatures (First 30 min).

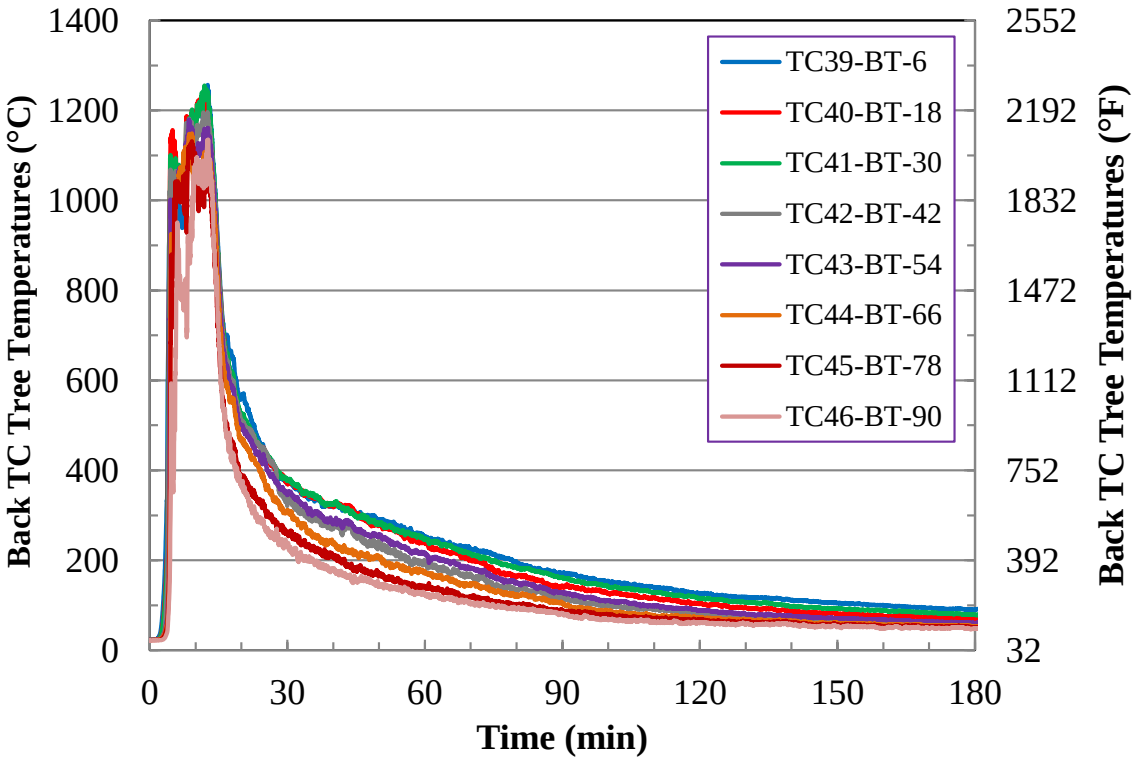

Figure C-16. Test 1 Back Interior TC Tree Temperatures.

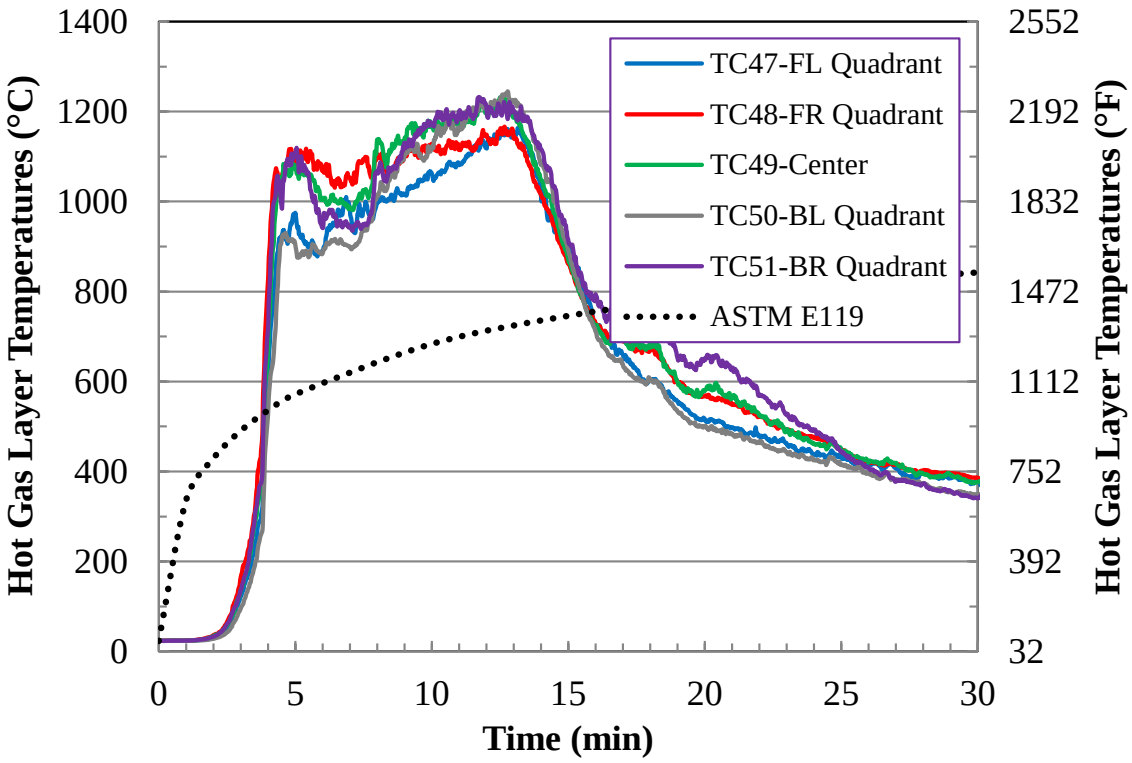

Figure C-17. Test 1 Hot Gas Layer Temperatures (First 30 min).

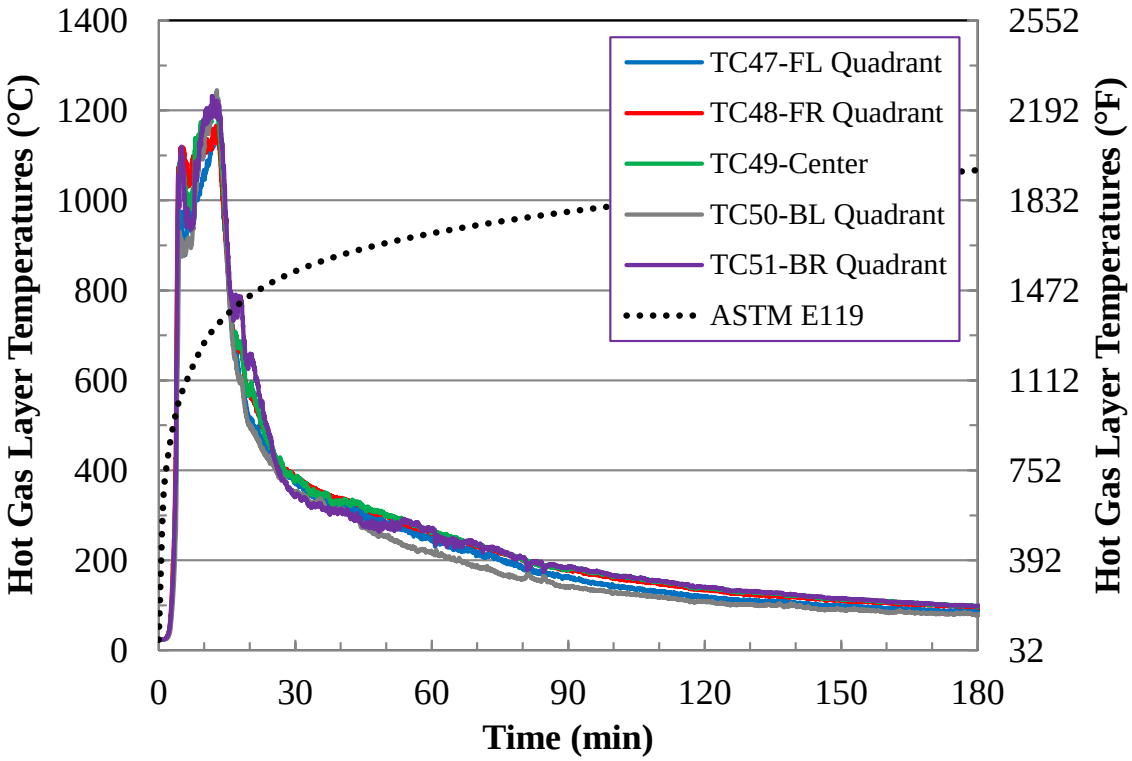

Figure C-18. Test 1 Hot Gas Layer Temperatures.

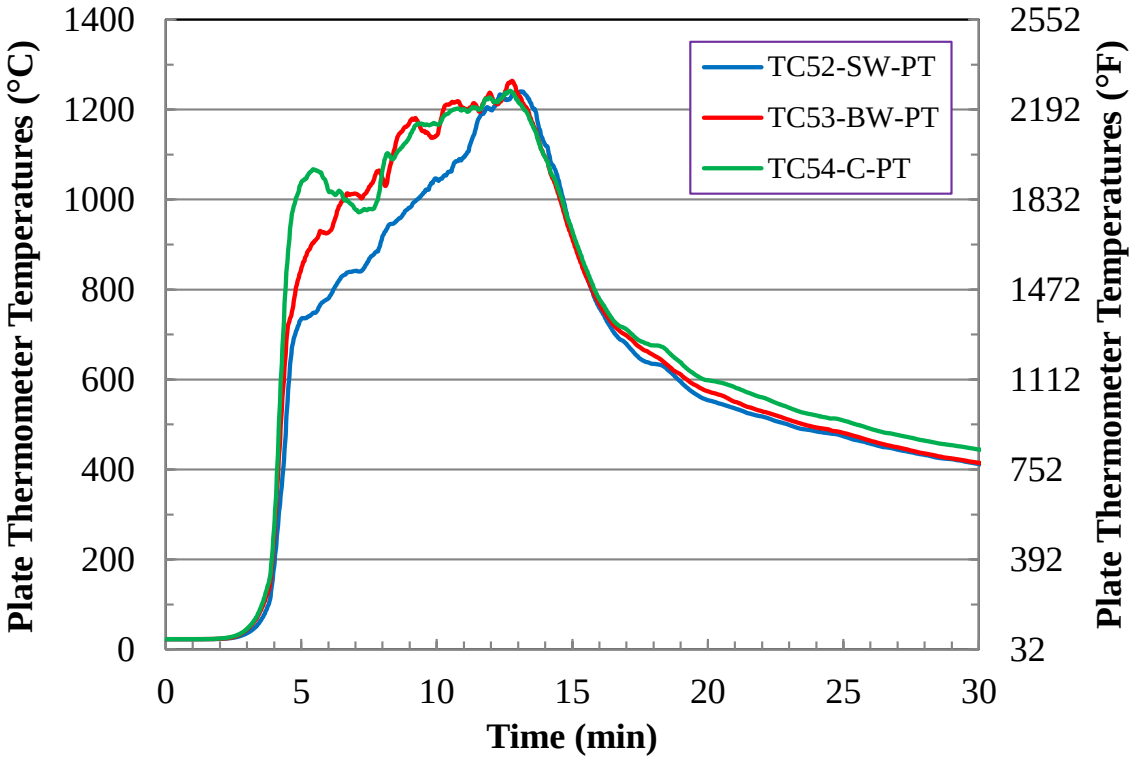

Figure C-19. Test 1 Plate Thermometer Temperatures (First 30 min).

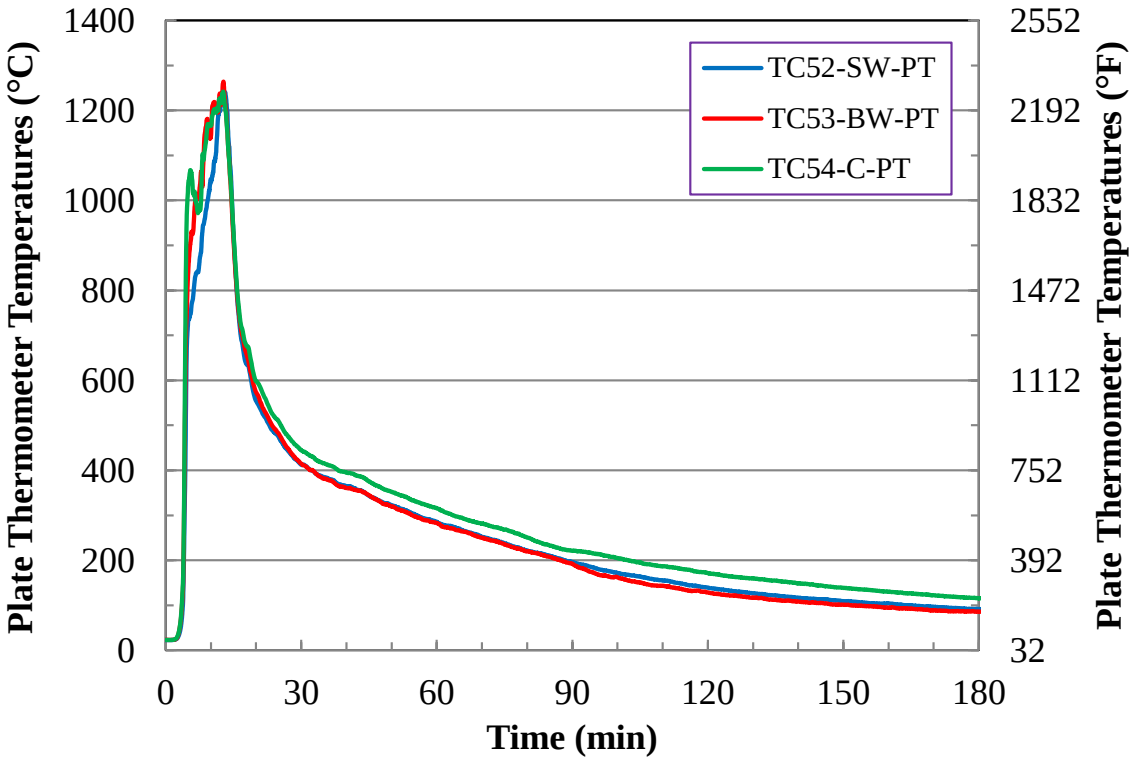

Figure C-20. Test 1 Plate Thermometer Temperatures.

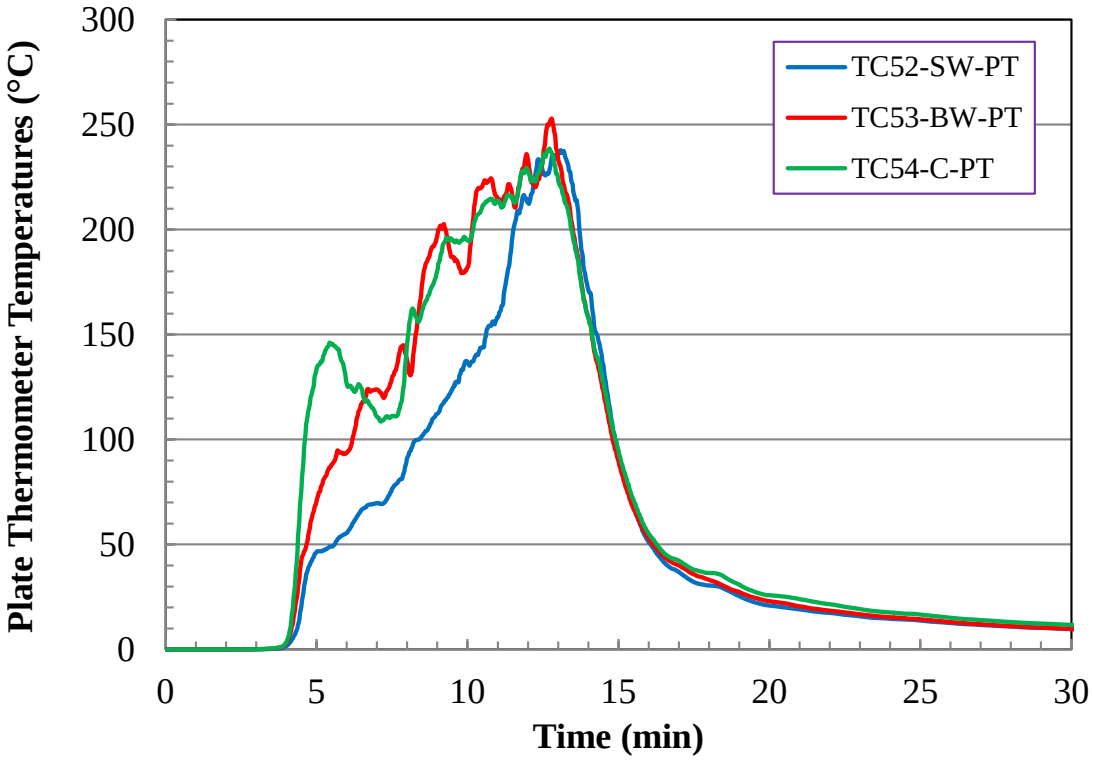

Figure C-21. Test 1 Plate Thermometer Heat Fluxes (First 30 min).

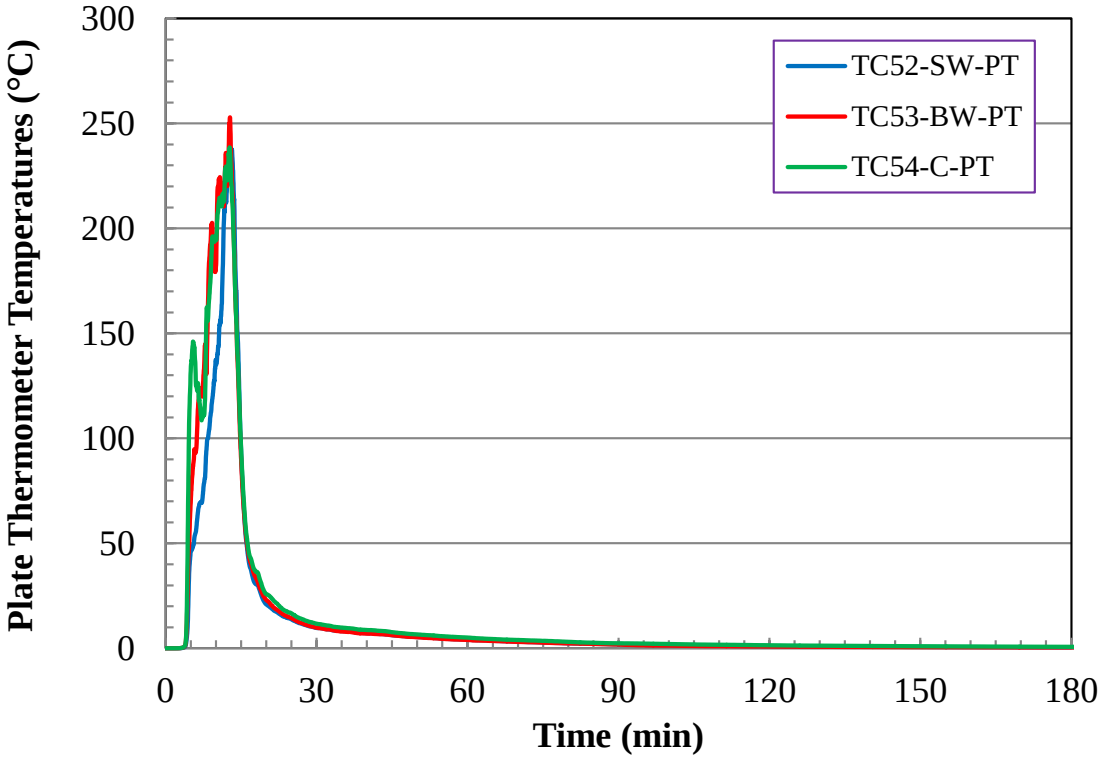

Figure C-22. Test 1 Plate Thermometer Heat Fluxes.

APPENDIX D

TEST 2 PHOTOGRAPHS

(CONSISTING OF 16 PAGES)

Figure D-1. Connection of CLT Back Wall and Left Sidewall.

Figure D-2. CLT Ceiling under Construction.

Figure D-3. Spline Covering Joint between CLT Ceiling Panels.

Figure D-4. Assembled CLT Compartment for Test 2.

Figure D-5. Fire Sealant around Room Perimeter at Wall-Ceiling Interface.

Figure D-6. Base Layer of Gypsum Board on Ceiling.

Figure D-7. Base Layer of Gypsum Board on Walls.

Figure D-8. Face Layer of Gypsum Board on Ceiling.

Figure D-9. Room with Face Layer of Gypsum Board on Walls.

Figure D-10. Gypsum Board Joints Taped and Floated.

Figure D-11. Room Painted.

Figure D-12. Plywood on CLT Ceiling.

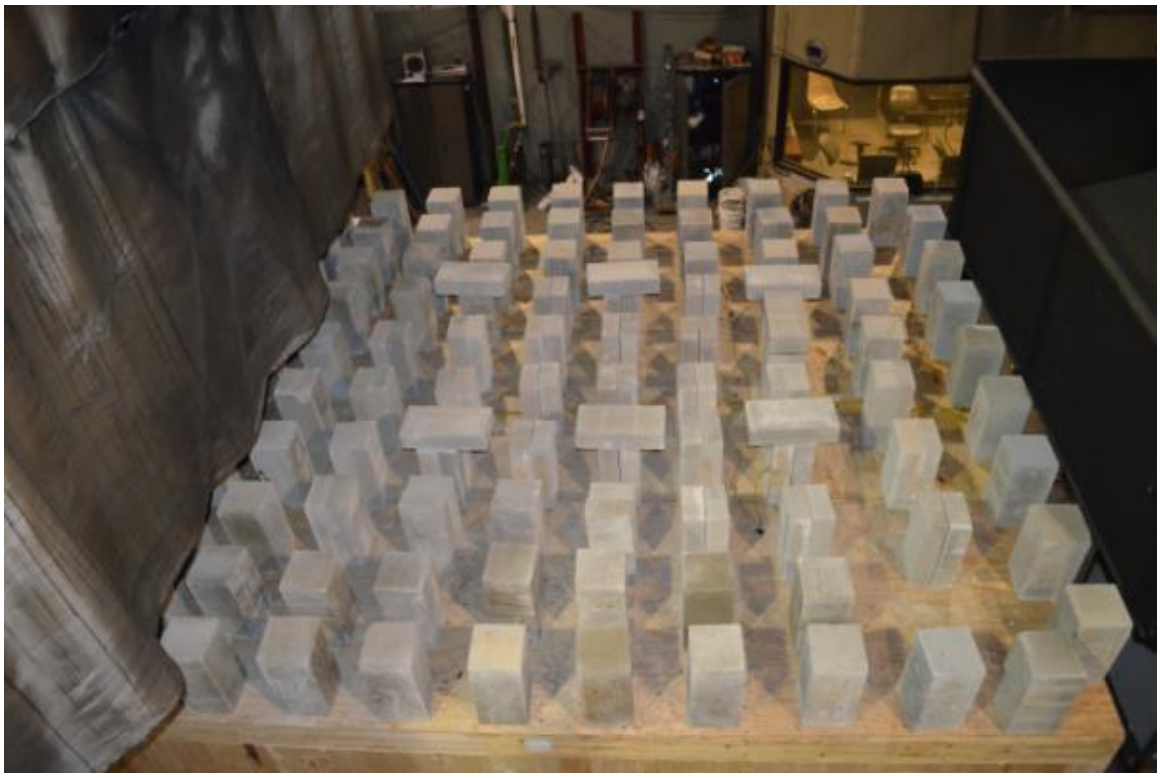

Figure D-13. Load Applied.

Figure D-14. View of Furnished Room through Doorway.

Figure D-15. View of Furnished Room toward Front Wall.

Figure D-16. Approximately 1 min into the Test.

Figure D-17. Approximately 2 min into the Test.

Figure D-18. Approximately 3 min into the Test.

Figure D-19. Approximately 4 min into the Test.

Figure D-20. Approximately 5 min into the Test.

Figure D-21. Approximately 6 min into the Test.

Figure D-22. Approximately 7 min into the Test.

Figure D-23. Approximately 8 min into the Test.

Figure D-24. Approximately 20 min into the Test.

Figure D-25. Approximately 45 min into the Test.

Figure D-26. Approximately 60 min into the Test.

Figure D-27. Approximately 120 min into the Test.

Figure D-28. Approximately 135 min into the Test.

Figure D-29. Room Post-Test.

Figure D-30. Base Layer Post-Test.

Figure D-31. CLT Structure Post-Test.

Figure D-32. Charring around Plate Thermometer Conduit.

APPENDIX E

RESULTS FOR TEST 2

(CONSISTING OF 11 PAGES)

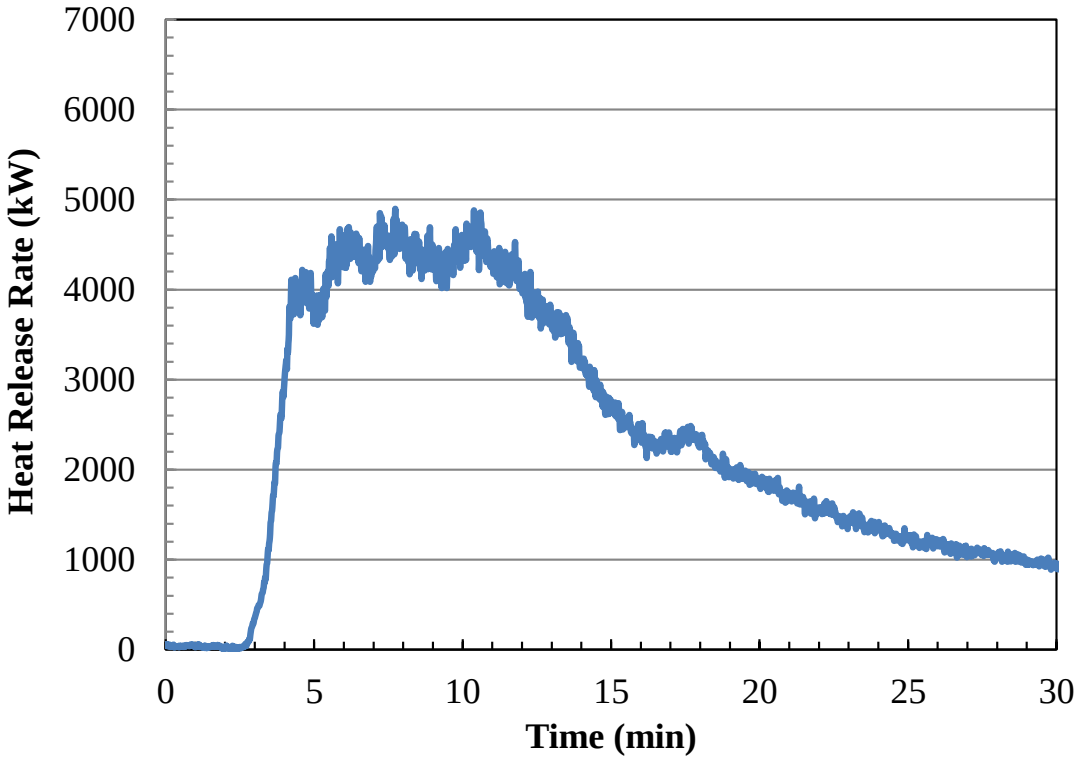

Figure E-1. Test 2 Heat Release Rate (First 30 min).

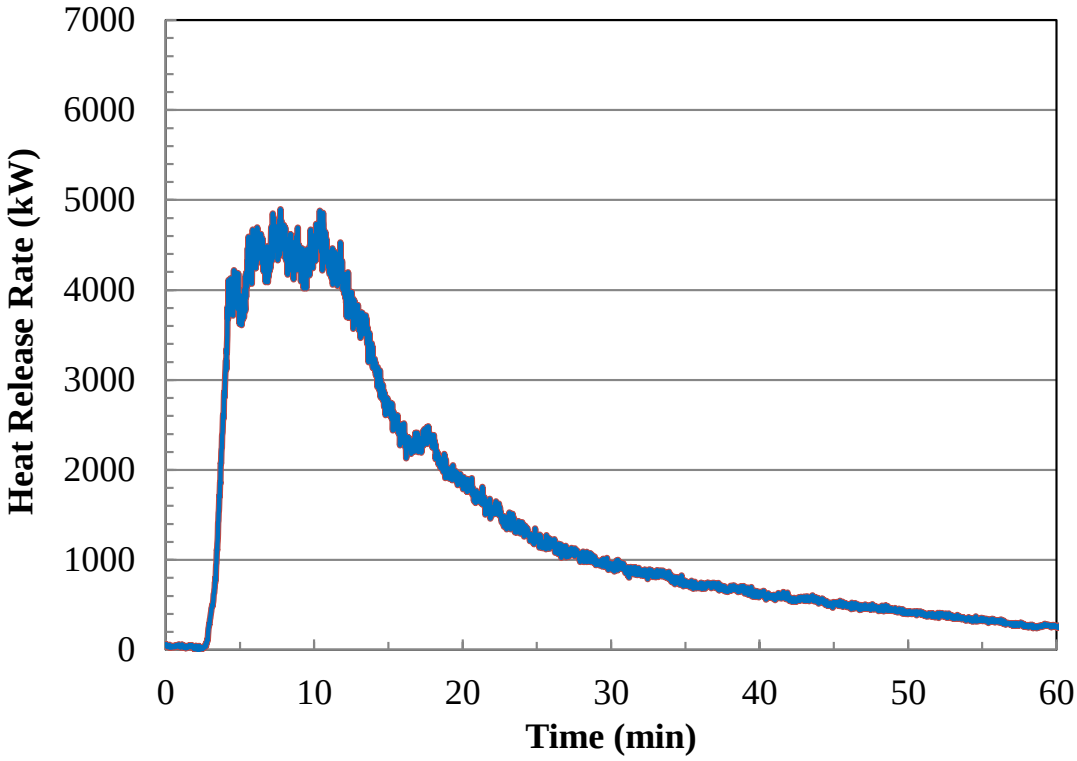

Figure E-2. Test 2 Heat Release Rate (First 30 min).

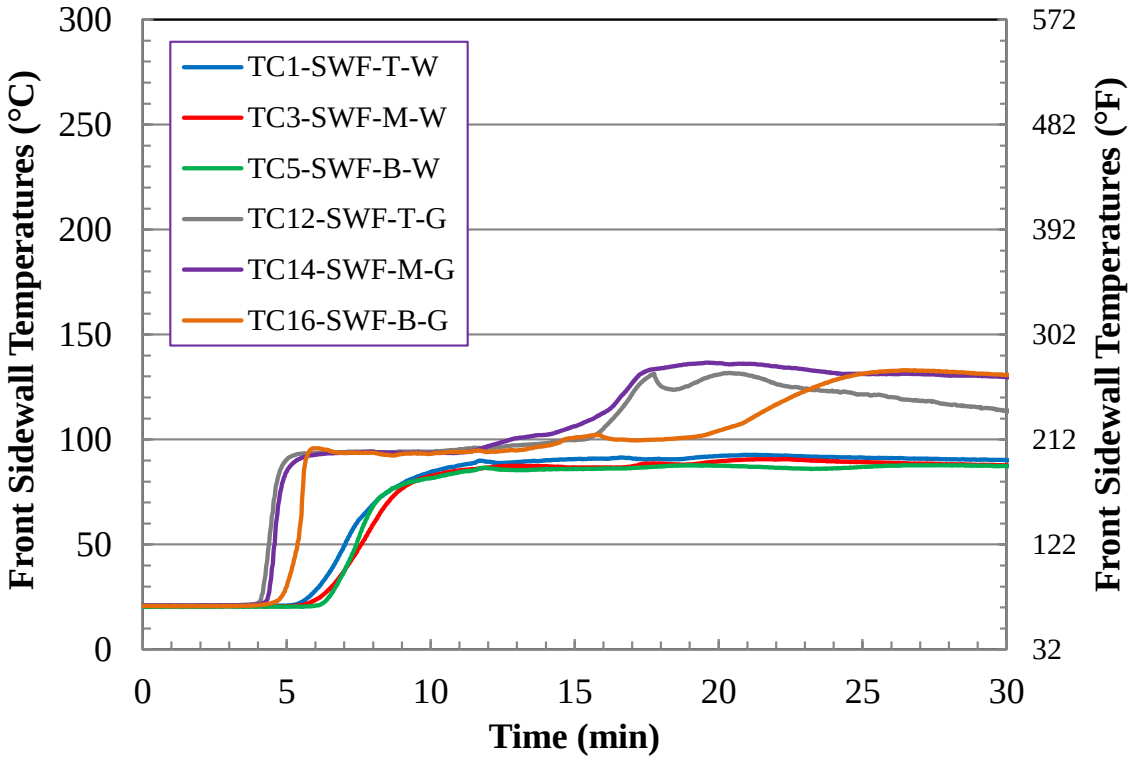

Figure E-3. Test 2 Front Sidewall Temperatures (First 30 min).

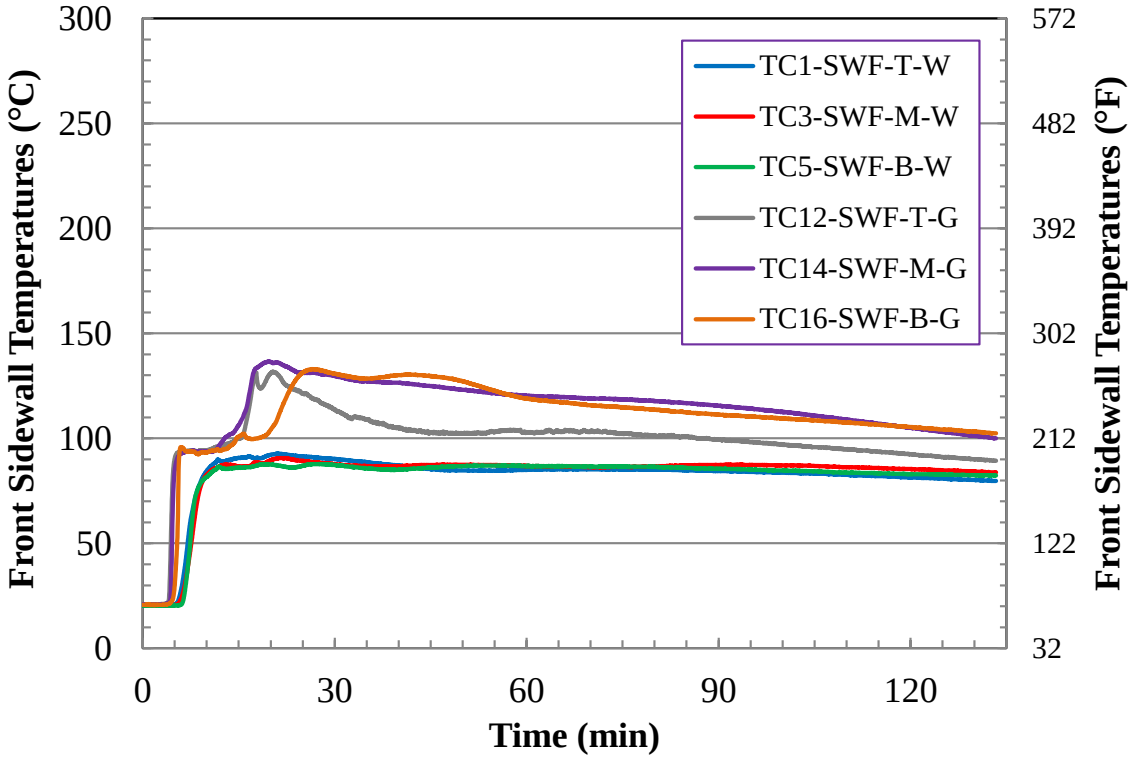

Figure E-4. Test 2 Front Sidewall Temperatures.

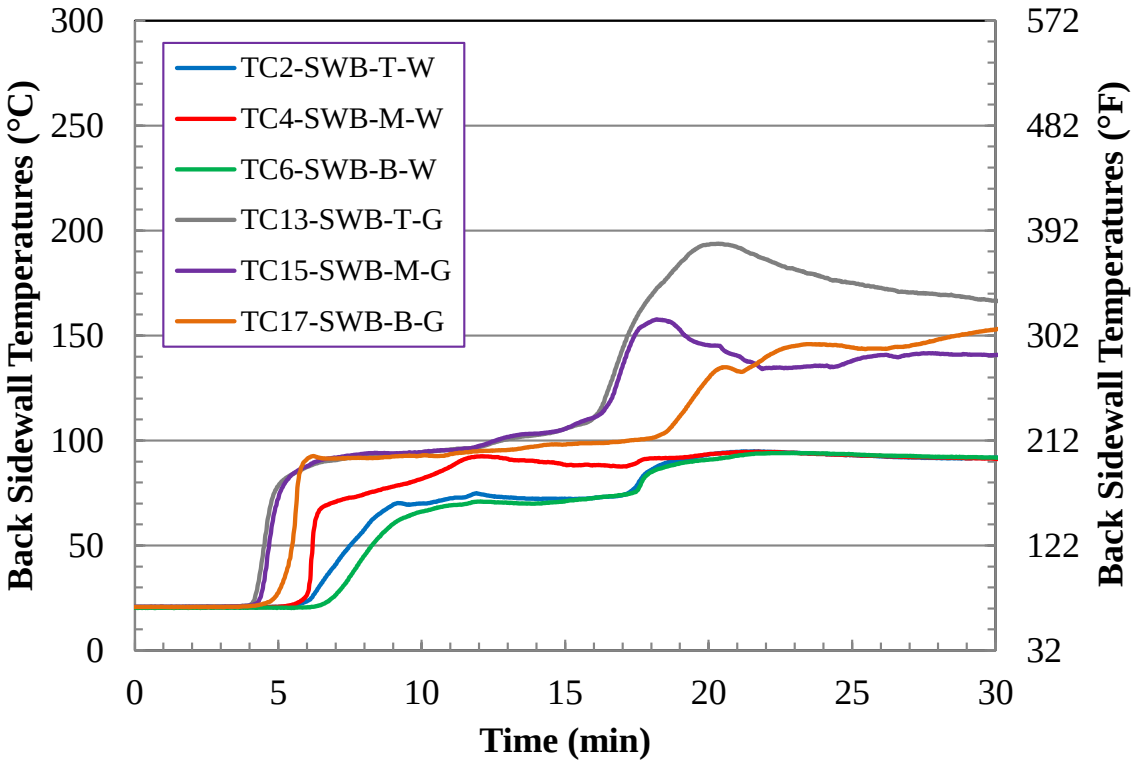

Figure E-5. Test 2 Back Sidewall Temperatures (First 30 min).

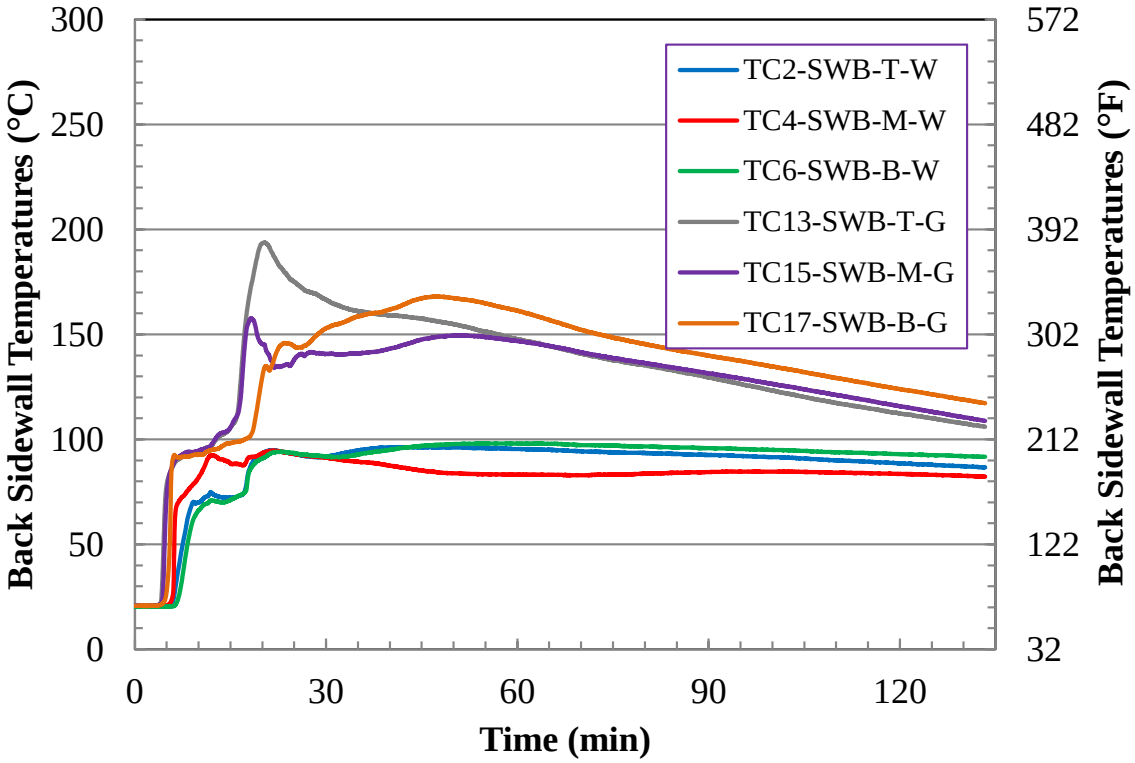

Figure E-6. Test 2 Back Sidewall Temperatures.

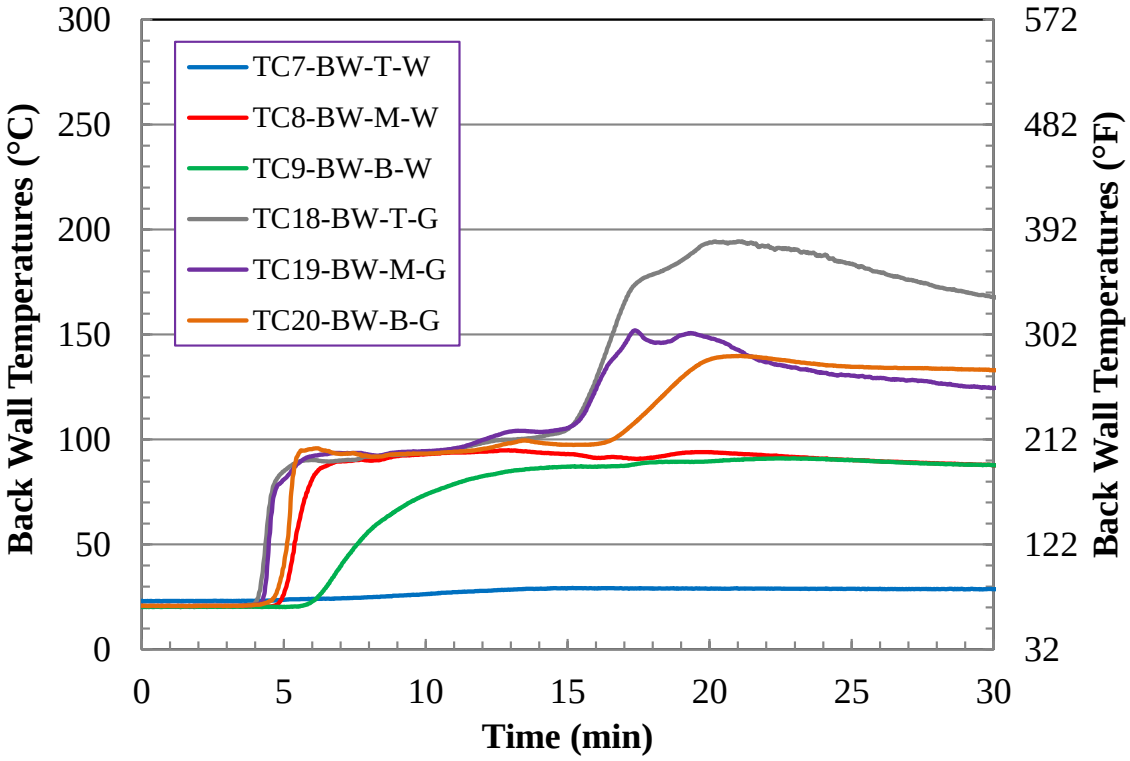

Figure E-7. Test 2 Back Wall Temperatures (First 30 min).

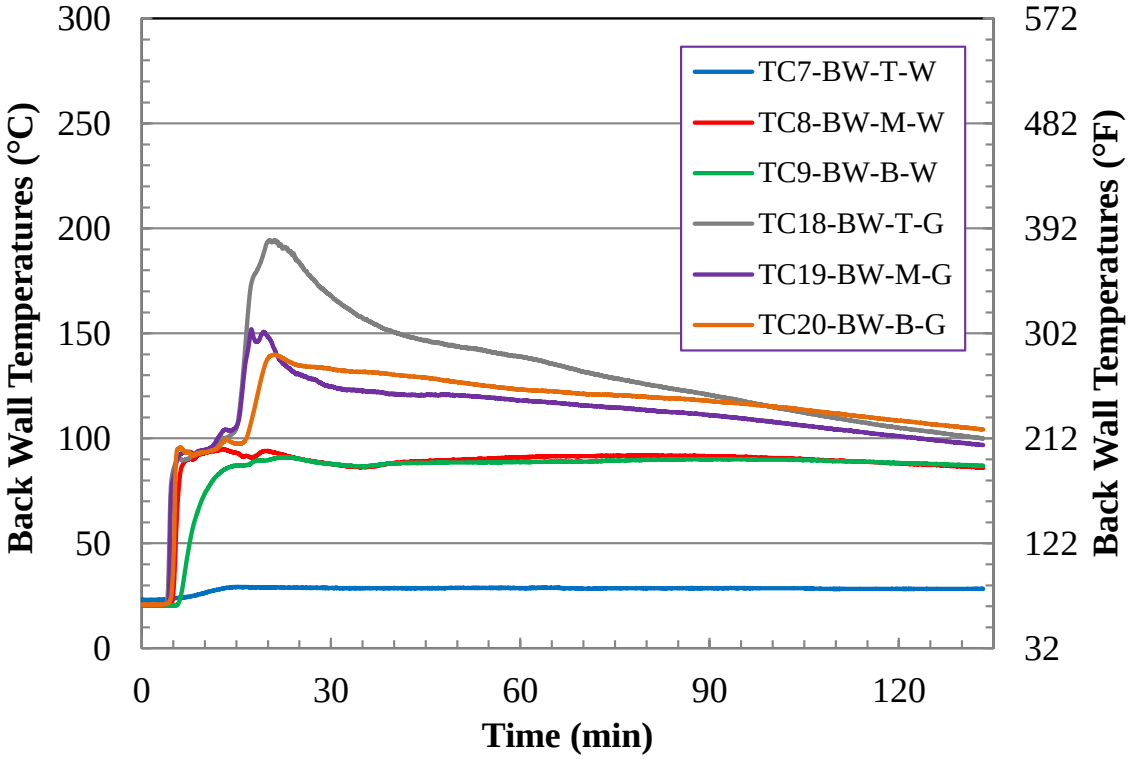

Figure E-8. Test 2 Back Wall Temperatures.

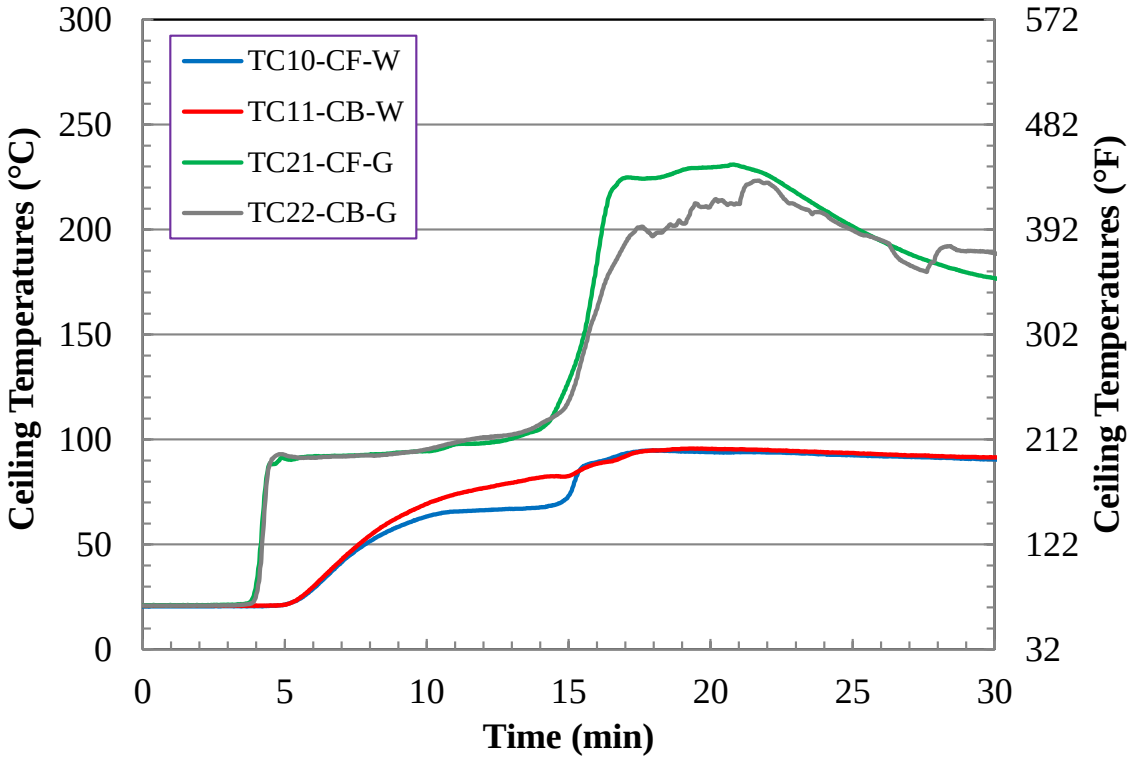

Figure E-9. Test 2 Ceiling Temperatures (First 30 min).

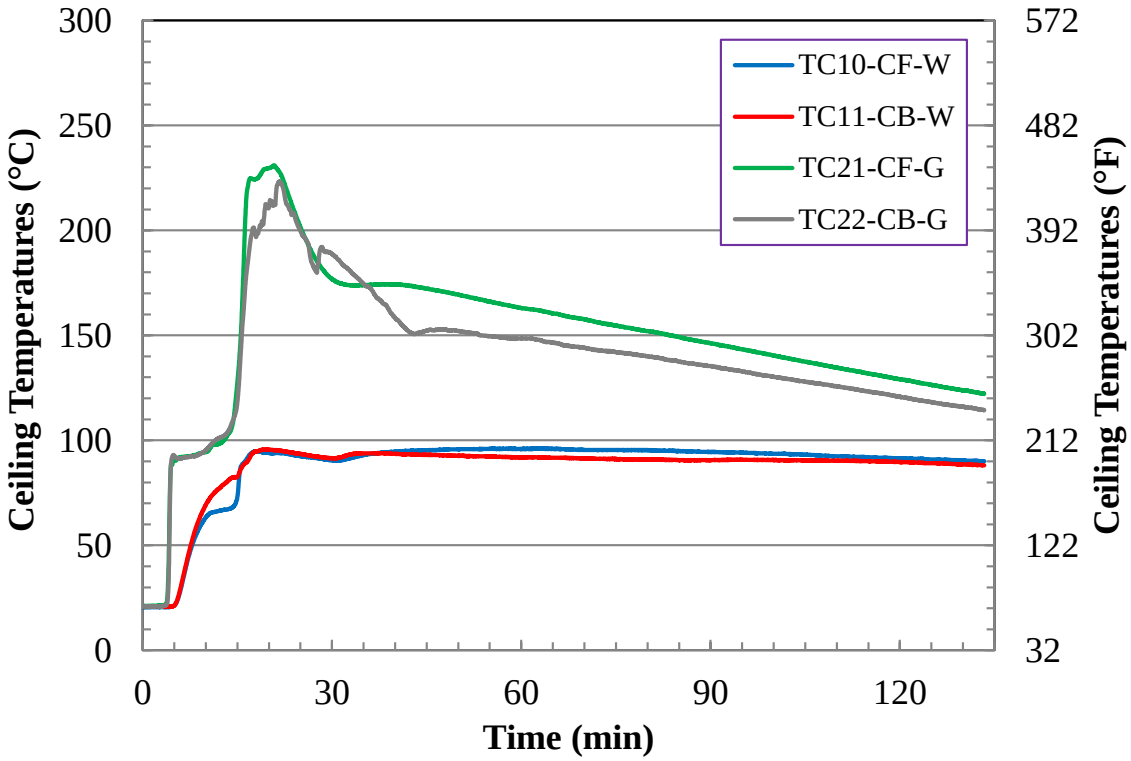

Figure E-10. Test 2 Ceiling Temperatures.

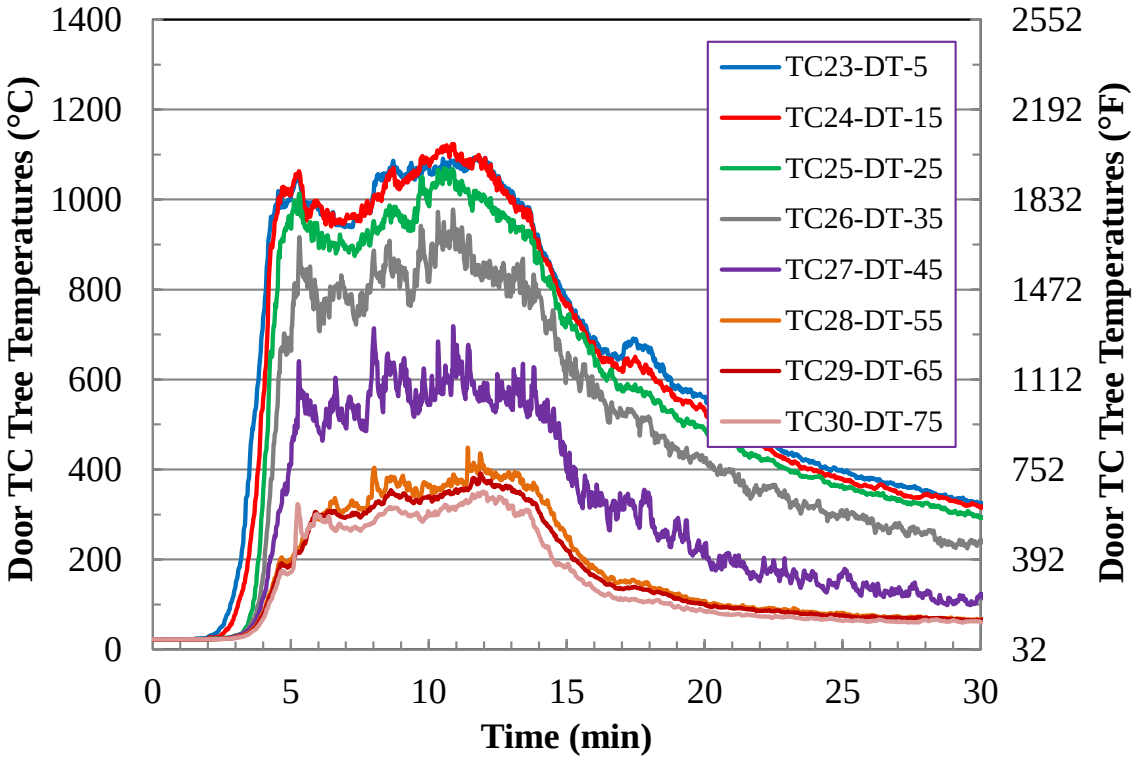

Figure E-11. Test 2 Door TC Tree Temperatures (First 30 min).

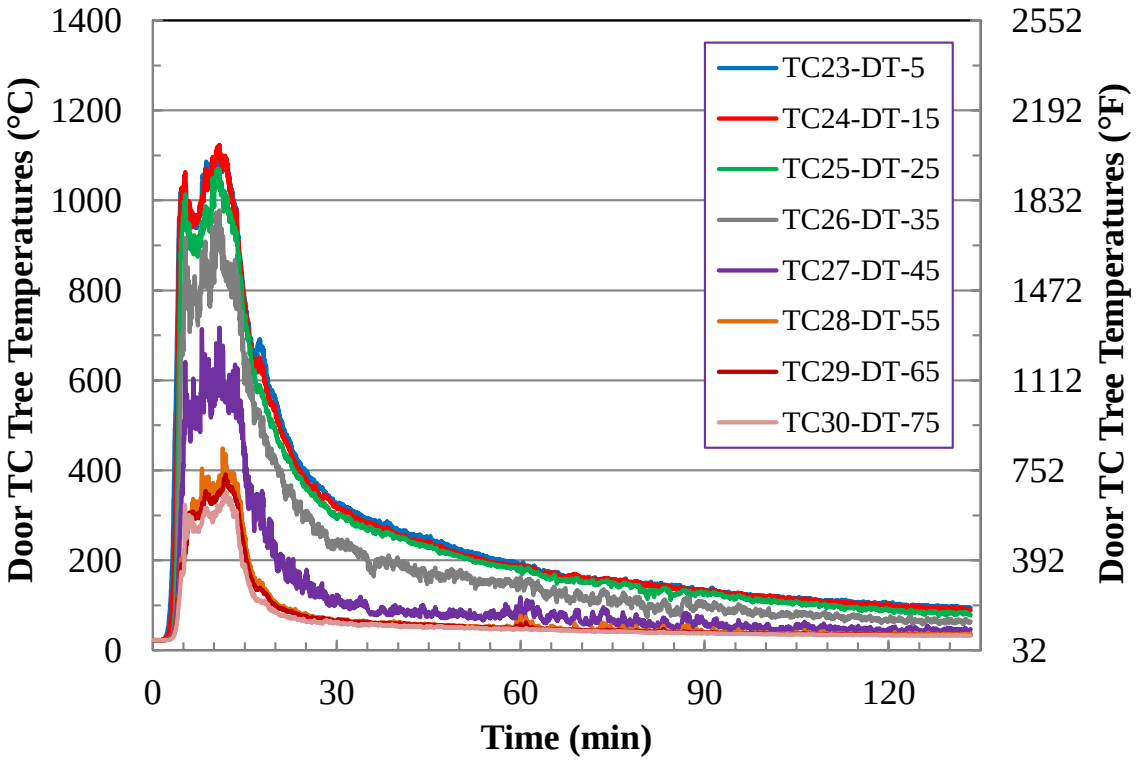

Figure E-12. Test 2 Door TC Tree Temperatures.

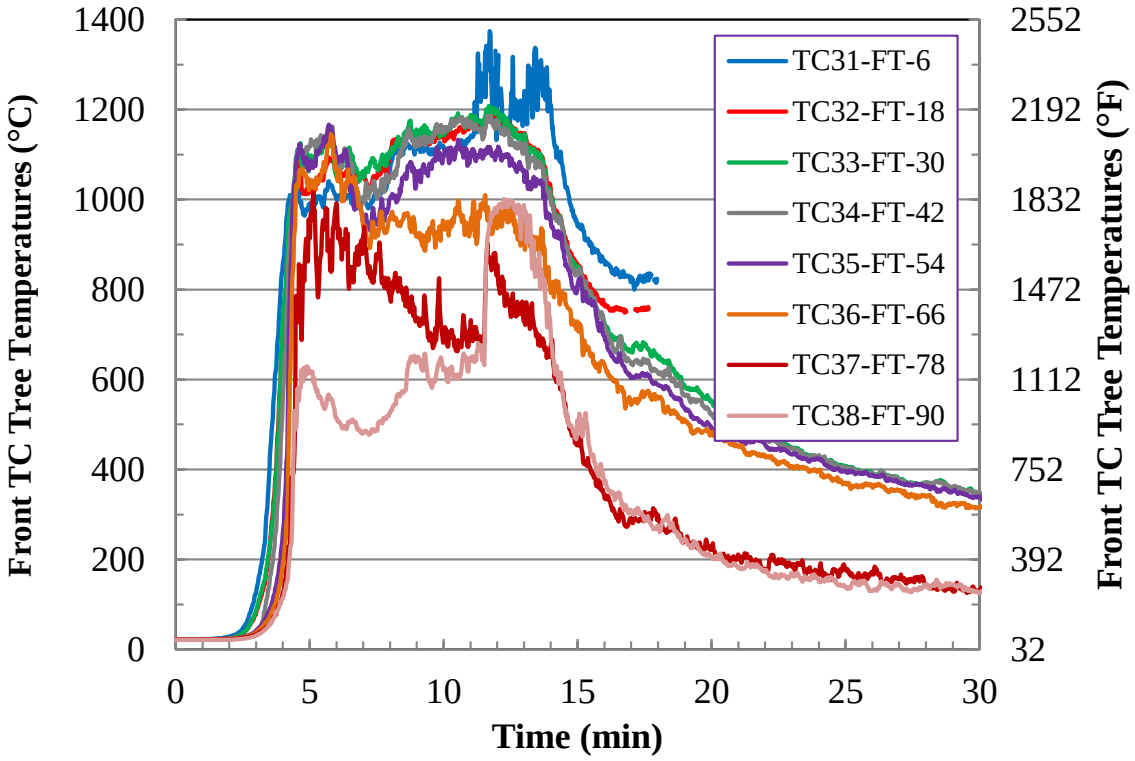

Figure E-13. Test 2 Front Interior TC Tree Temperatures (First 30 min).

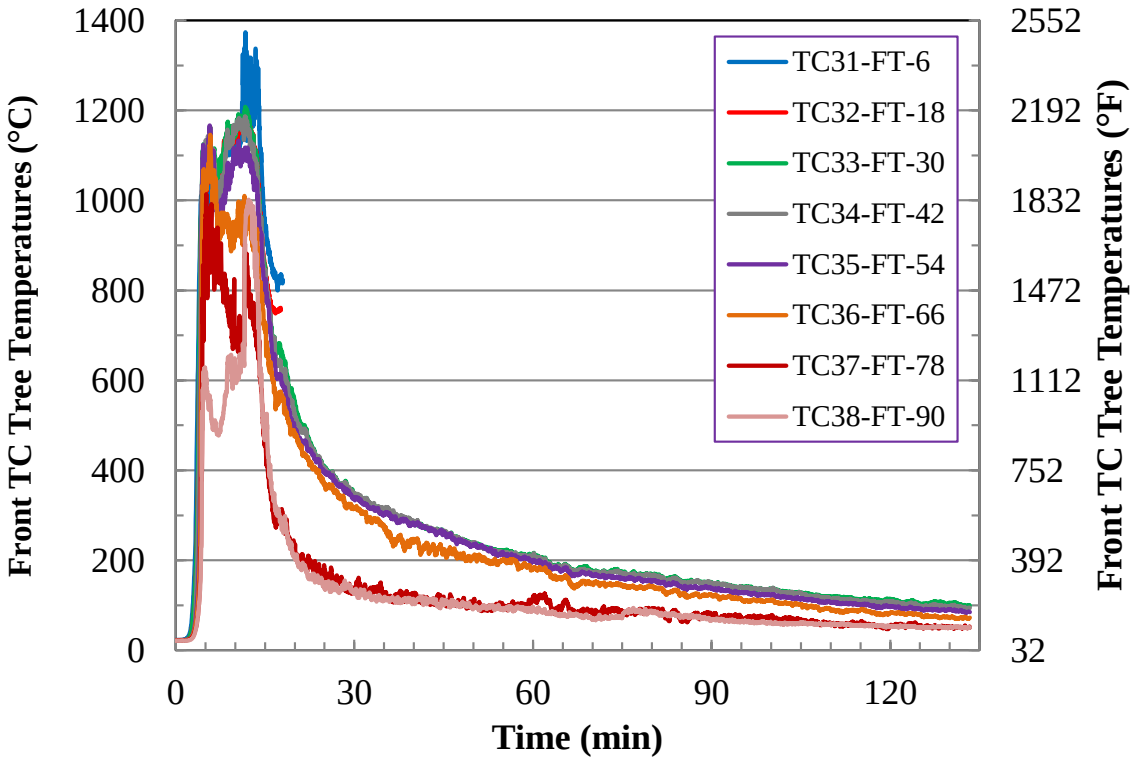

Figure E-14. Test 2 Front Interior TC Tree Temperatures.

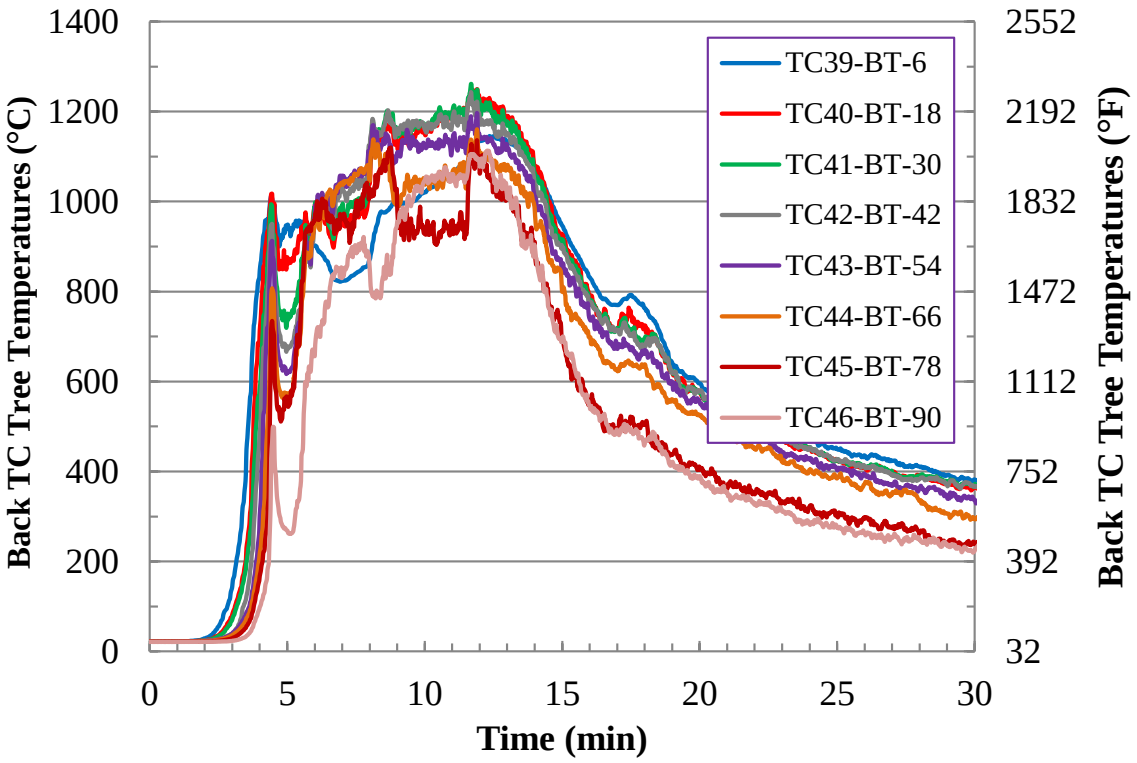

Figure E-15. Test 2 Back Interior TC Tree Temperatures (First 30 min).

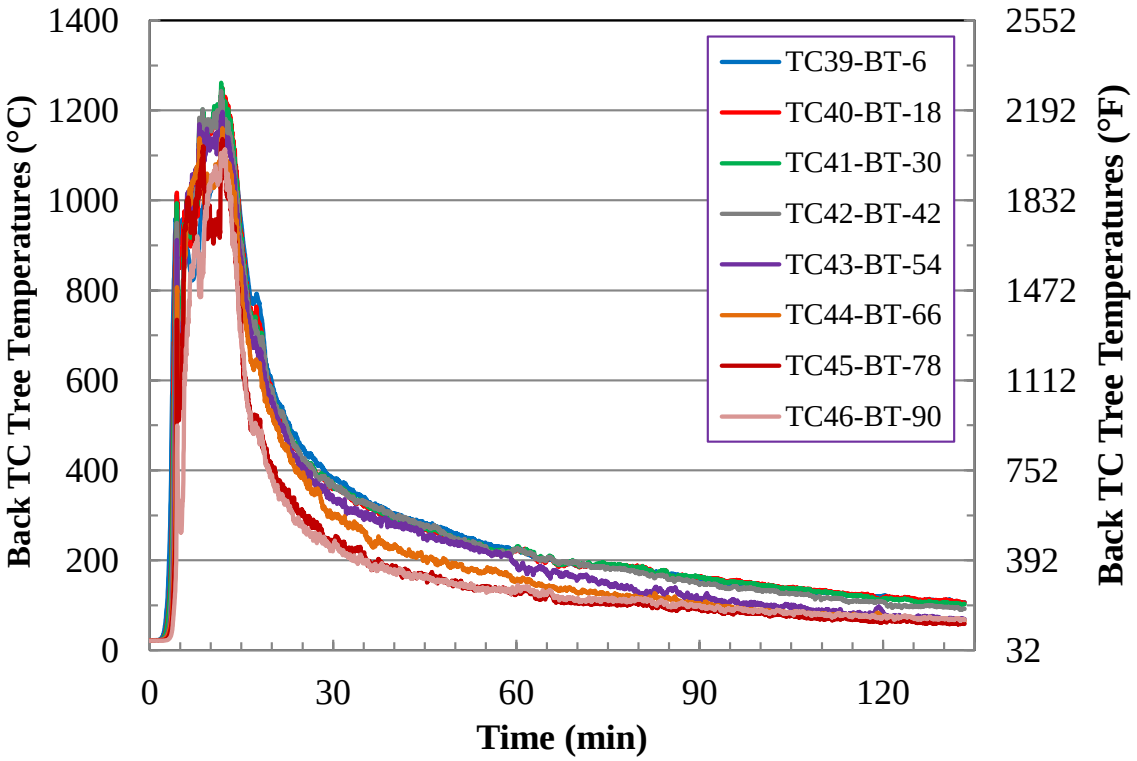

Figure E-16. Test 2 Back Interior TC Tree Temperatures.

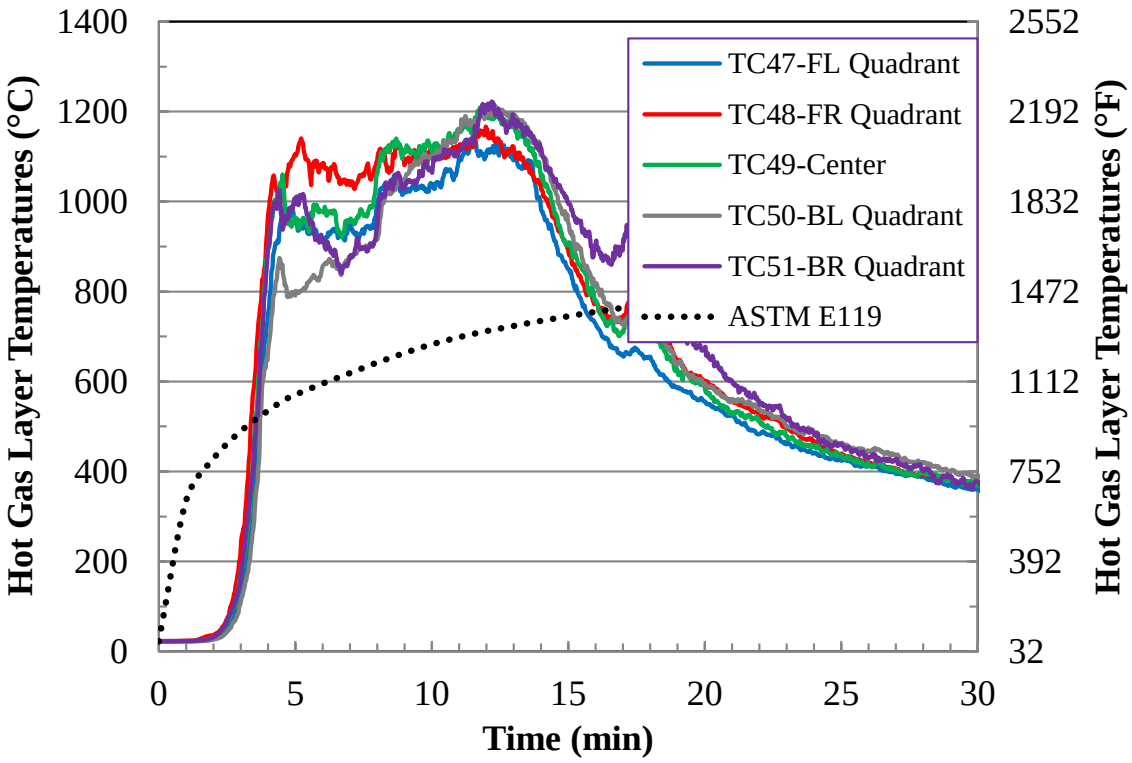

Figure E-17. Test 2 Hot Gas Layer Temperatures (First 30 min).

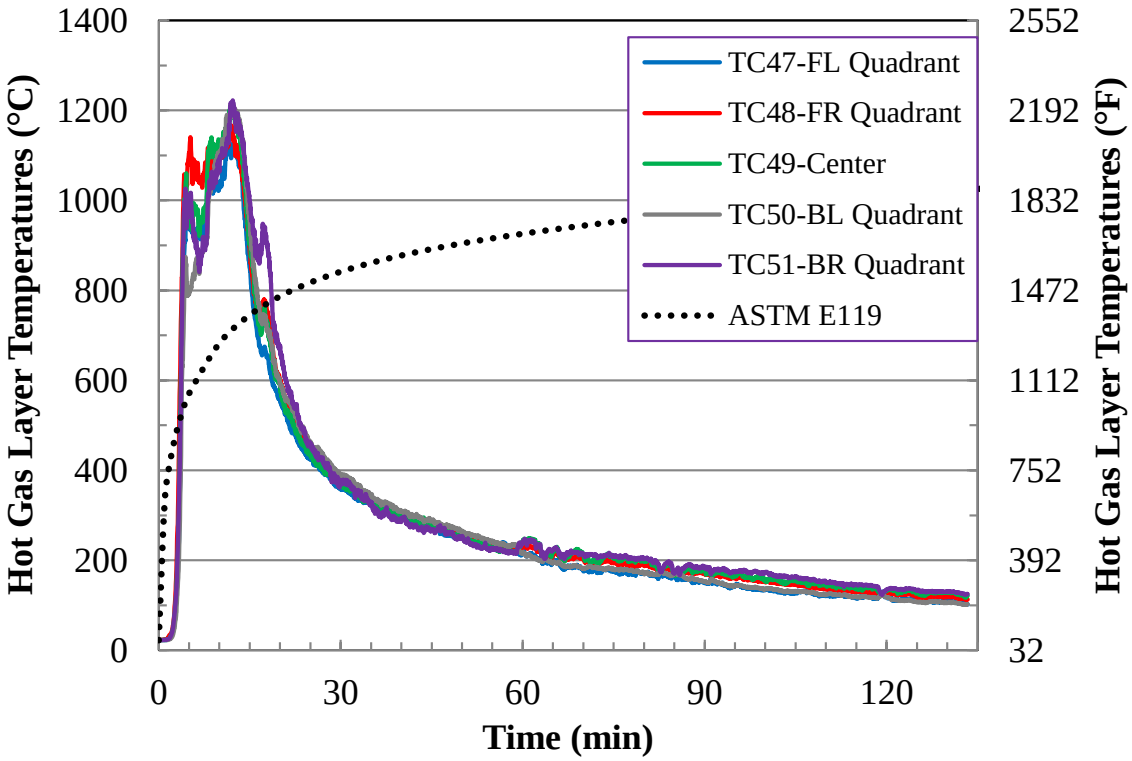

Figure E-18. Test 2 Hot Gas Layer Temperatures.

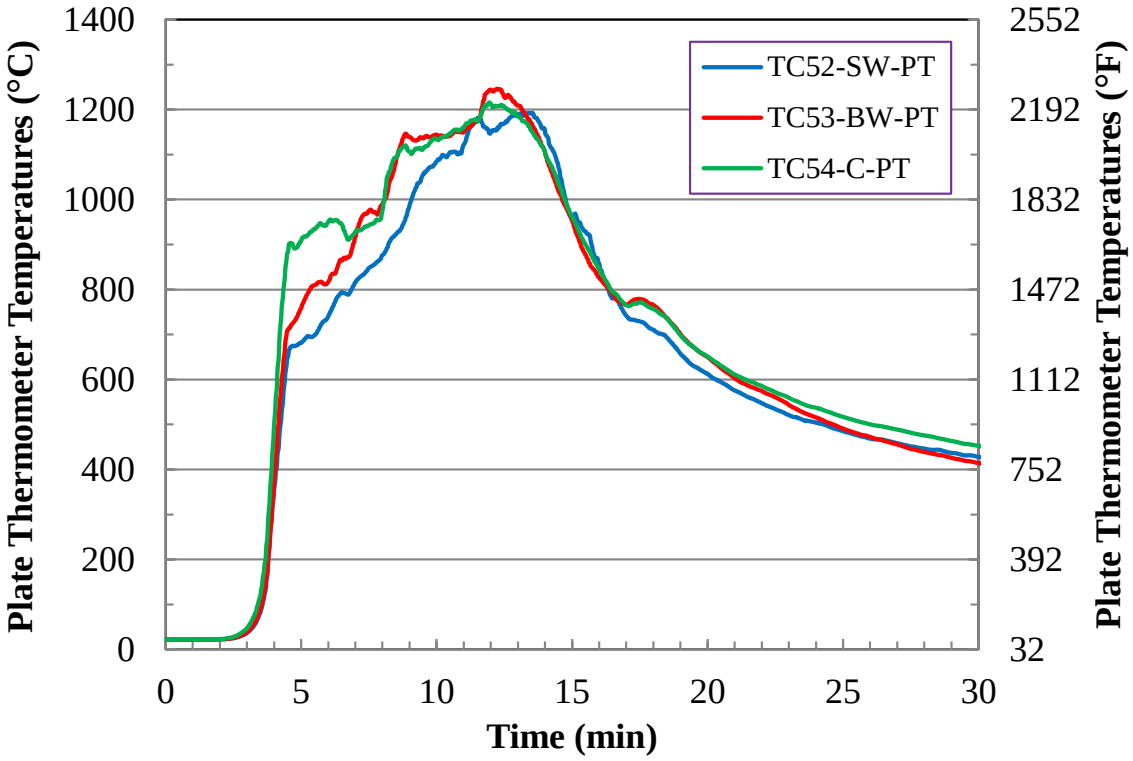

Figure E-19. Test 2 Plate Thermometer Temperatures (First 30 min).

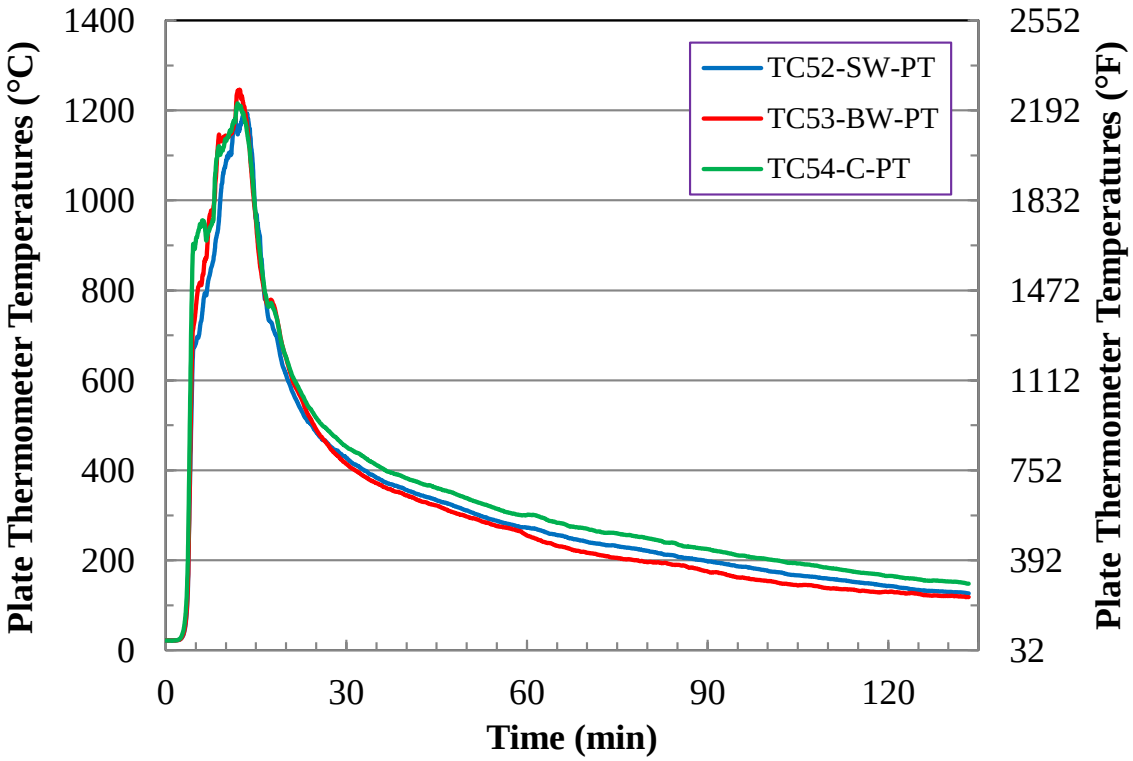

Figure E-20. Test 1 Plate Thermometer Temperatures.

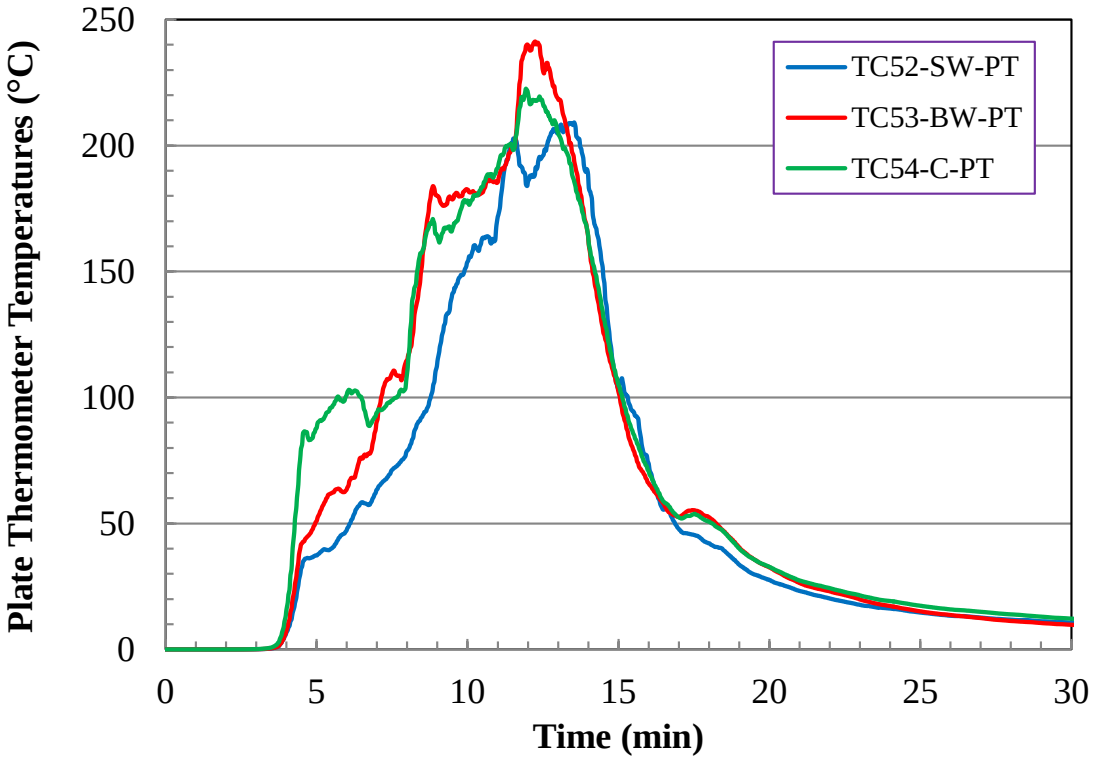

Figure E-21. Test 2 Plate Thermometer Heat Fluxes (First 30 min).

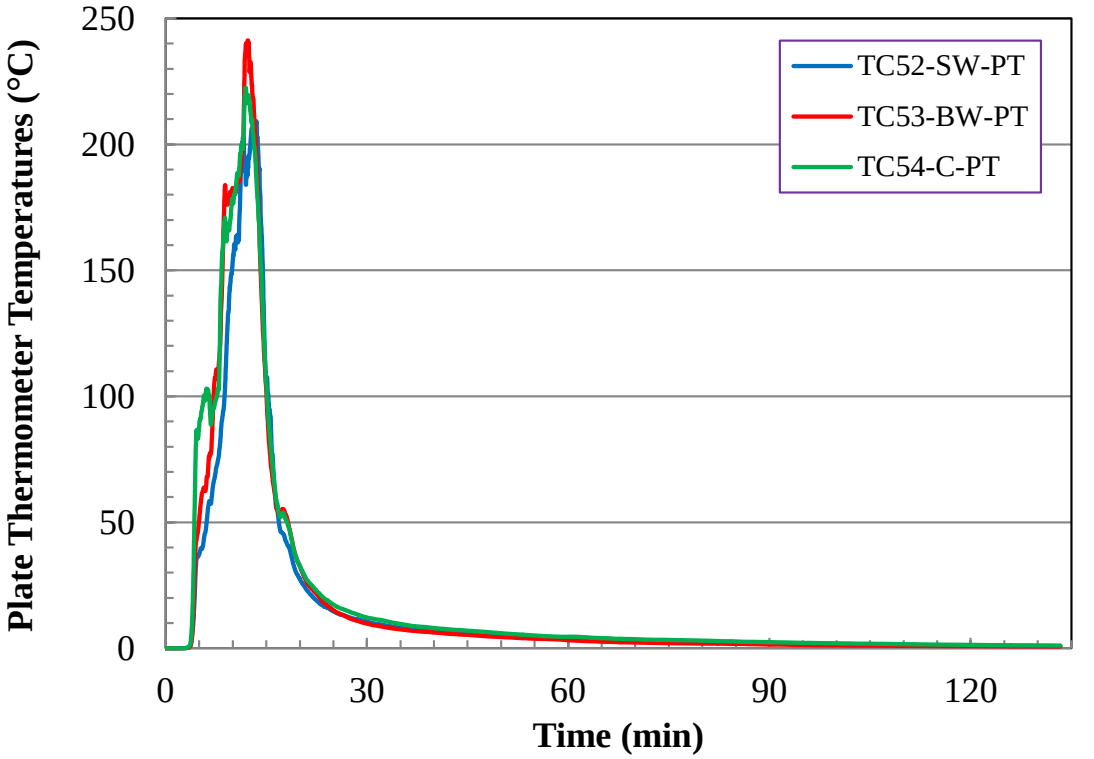

Figure E-22. Test 1 Plate Thermometer Heat Fluxes.