

## NRC Publications Archive Archives des publications du CNRC

### Full-scale standard fire resistance test of a wall assembly for use in lower storeys of mid-rise buildings: report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings

Lafrance, P-S; Berzins, R.; Leroux, P.; Su, J.Z.; Loughheed, G.D.

For the publisher's version, please access the DOI link below. / Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

#### **Publisher's version / Version de l'éditeur:**

<https://doi.org/10.4224/21274560>

*Client Report (National Research Council of Canada. Construction), 2014-12*

#### **NRC Publications Archive Record / Notice des Archives des publications du CNRC :**

<https://nrc-publications.canada.ca/eng/view/object/?id=1898139a-15da-4e3c-8242-bad41bbc85fd>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=1898139a-15da-4e3c-8242-bad41bbc85fd>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

**Questions?** Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

**Vous avez des questions?** Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.



NATIONAL RESEARCH COUNCIL CANADA

# **FULL-SCALE STANDARD FIRE RESISTANCE TEST OF A WALL ASSEMBLY FOR USE IN LOWER STOREYS OF MID-RISE BUILDINGS**

CLIENT REPORT: A1-004691.1

December 31, 2014



National Research  
Council Canada

Conseil national  
de recherches Canada

Canada

# Full-Scale Standard Fire Resistance Test of a Wall Assembly for Use in Lower Storeys of Mid-Rise Buildings

**P-S. Lafrance, R. Berzins, P. Leroux, J.Z. Su, and G.D. Lougheed**

Report No. A1-004691.1  
Report date: December 31, 2014  
Contract No. A1-004691  
Prepared for Canadian Wood Council

28 pages

This report may not be reproduced in whole or in part without the written consent of both the client and the National Research Council of Canada.

# **Full-Scale Standard Fire Resistance Test of a Wall Assembly for Use in Lower Storeys of Mid-Rise Buildings**

P-S. Lafrance, R. Berzins, P. Leroux, J.Z. Su and G.D. Lougheed

## **INTRODUCTION**

The acceptable solutions provided in the 2010 National Building Code of Canada (NBC) Division B [1] limits the use of combustible (wood) construction based on building height and area requirements. For buildings that exceed the height and area requirements for combustible construction, the prescriptive requirements in the 2010 NBC require that noncombustible construction be used for the primary structural elements.

A research project, Wood and Wood-Hybrid Midrise Buildings, was undertaken to develop information to be used as the basis for alternative/acceptable solutions for mid-rise construction using wood structural elements. As one approach, encapsulation materials could be used to protect the combustible (wood) structural materials for a period of time in order to delay the effects of the fire on the combustible structural elements, including delay of ignition. In delaying ignition, any effects of the combustion of the combustible structural elements on the fire severity can be delayed. In some cases, and depending upon the amount of encapsulating material used (e.g. number of layers), ignition of the elements might be avoided completely. This scenario would primarily depend upon the fire event and the actual fire performance of the encapsulating materials used. The effectiveness of the encapsulation approach in limiting the involvement of wood structural materials in fires was demonstrated in the research project through bench-, intermediate- and full-scale fire experiments.

In addition to developing the encapsulation approach for protecting the wood structural materials to meet the code intent, research was undertaken to examine standard fire resistance of encapsulated wood structural assemblies for use in mid-rise wood/timber buildings. One of the major differences between structural lightweight wood frame (LWF) assemblies used in mid-rise wood buildings (5-6 storeys) and low-rise wood buildings ( $\leq 4$  stories) is the wall assemblies for the lower storeys. For mid-rise wood buildings, loadbearing wall assemblies on the lower storeys have to be designed to resist higher axial loads due to the self-weight of the upper storeys, which often result in the need for larger-size stud members and/or a greater number of studs, and higher lateral loads in case of seismic events or wind loads, which often requires the use of wood shear panels within the wall assembly. These wall assemblies very often will need to meet standard fire resistance requirements, and therefore, information regarding their standard fire-resistance ratings should be developed.

Five full-scale furnace tests were conducted in conformance with CAN/ULC-S101 [2] to determine the standard fire resistance of encapsulated lightweight wood frame wall assemblies for use in mid-rise applications. The test assemblies and the results of the five tests are provided in Reference [3].

One of the wall assemblies used in the previous tests [3], Wall Assembly #5, was constructed using 2x6 (38 mm x 140 mm) staggered studs spaced at 400 mm o.c., a 2x8 (38 mm x 190 mm) double top plate, 2x8 single bottom plate and 2x8 single end studs. At the structural failure of this wall assembly at 81 min, many of the studs, particularly those on the exposed side of the assembly, deformed within the plane of the wall rather than perpendicular to the wall plane. It was decided that a repeat test would be conducted for this assembly with blocking added at

mid-height to determine if the deformation of the studs within the plane of the wall assembly could be reduced and the fire endurance period for the assembly increased. This report provides the results of the test with the modified wall assembly (Wall Assembly #6).

## **FULL-SCALE EXPERIMENT**

### **Test Method and Setup**

A full-scale furnace test was conducted to determine the fire endurance period for a generic encapsulated LWF assembly. The test was conducted in conformance with CAN/ULC-S101 [2], with additional instrumentation installed for research data collection. Figure 1 shows the wall furnace used for the fire resistance test.



**Figure 1. Full-scale wall furnace used for fire resistance test.**

### **Description of Test Assembly and Instrumentation**

Figure 2 to Figure 7 show construction details of the wall assembly (Wall Assembly #6).

The basic framing for Wall Assembly #6 was the same as that used for Wall Assembly #5 in Reference [3]. Both assemblies were constructed using 2x6 (38 mm x 140 mm) staggered studs spaced at 400 mm o.c., a 2x8 (38 mm x 190 mm) double top plate, 2x8 single bottom plate and 2x8 single end studs. However, for the assembly used in this test, horizontal blocking, using

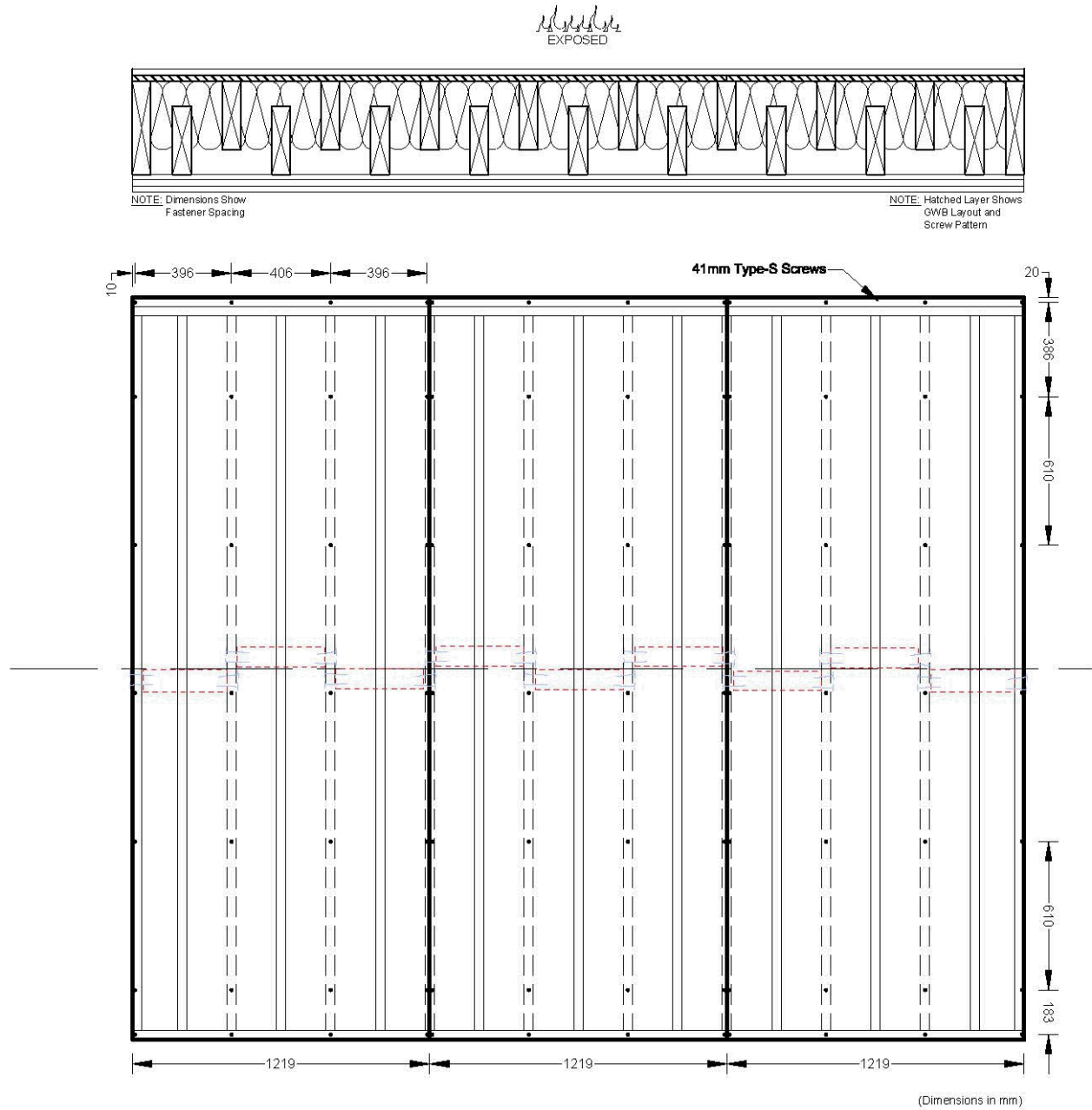
2x4 (38 mm x 89 mm) wood material, was added at the mid-height of the wall assembly (see Figure 3 and Figure 5).

For both assemblies, a shear membrane layer of 11.1 mm thick OSB was attached to one side of the framing. Two layers of 12.7 mm thick Type X gypsum board were applied to both sides of the framing. 140 mm thick glass fibre insulation was installed in the wall cavities. The insulation was installed with its back side (side facing the studs) partially scored (leaving approximately 70 mm not scored) so that it wrapped around the center staggered stud and that the gypsum board was not put under excessive stress.

Figure 8 and Figure 9 show nine deflection gauges and nine padded thermocouples installed on the unexposed surface of the wall assembly. In addition, a set of 80 thermocouples were embedded at various interfaces across the wall assembly as shown in Figure 10, including gypsum board-gypsum board, gypsum board-stud, gypsum board-cavity, stud-cavity, cavity-OSB, stud-OSB and gypsum board-OSB interfaces.

A total superimposed load of 506 kN was applied along the width of the assembly, satisfying a full specified load condition as per CAN/ULC-S101. The side without the shear membrane layer was exposed to the fire.

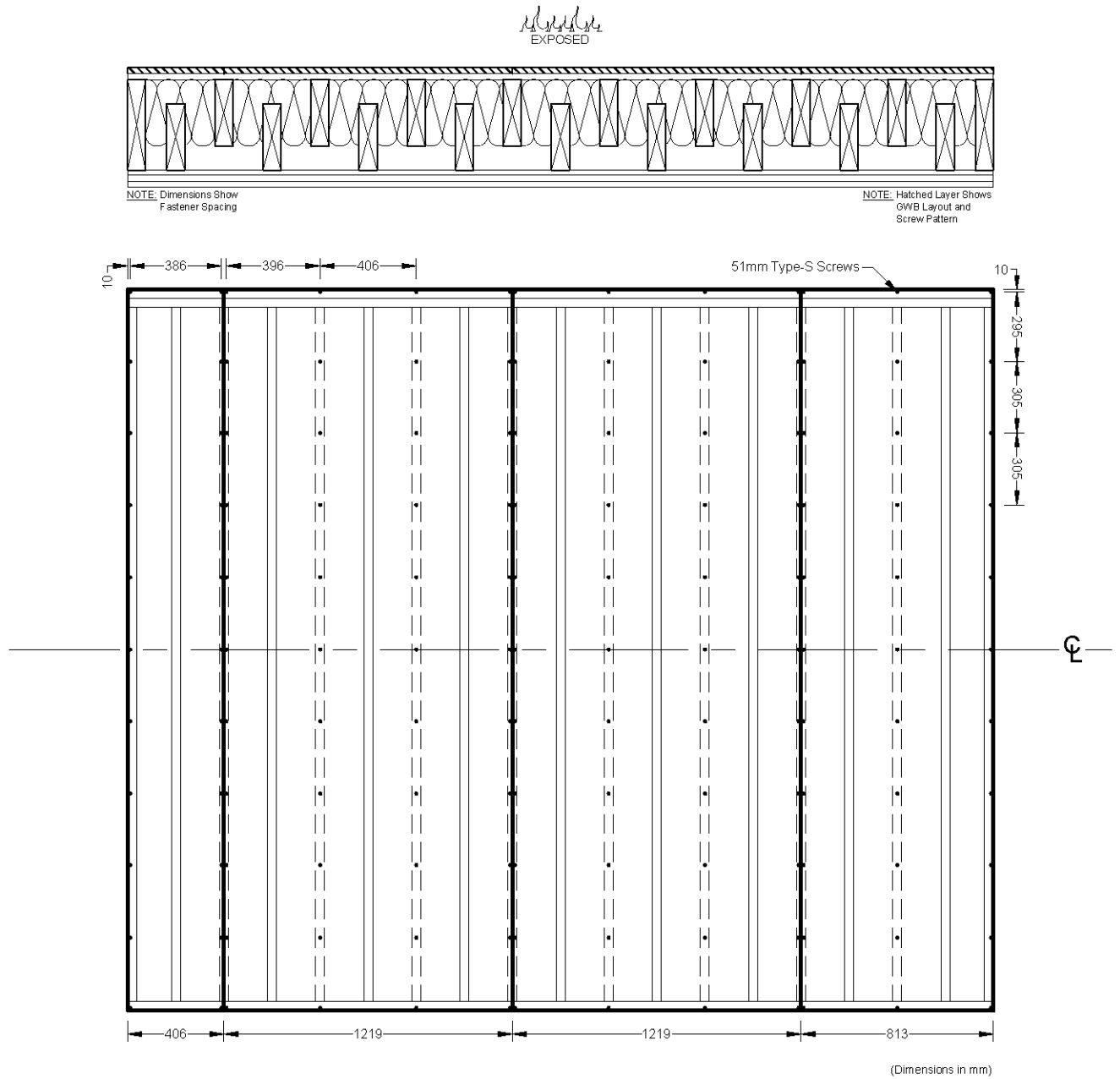




Exposed Base Layer - Gypsum Board Layout and Screw Pattern

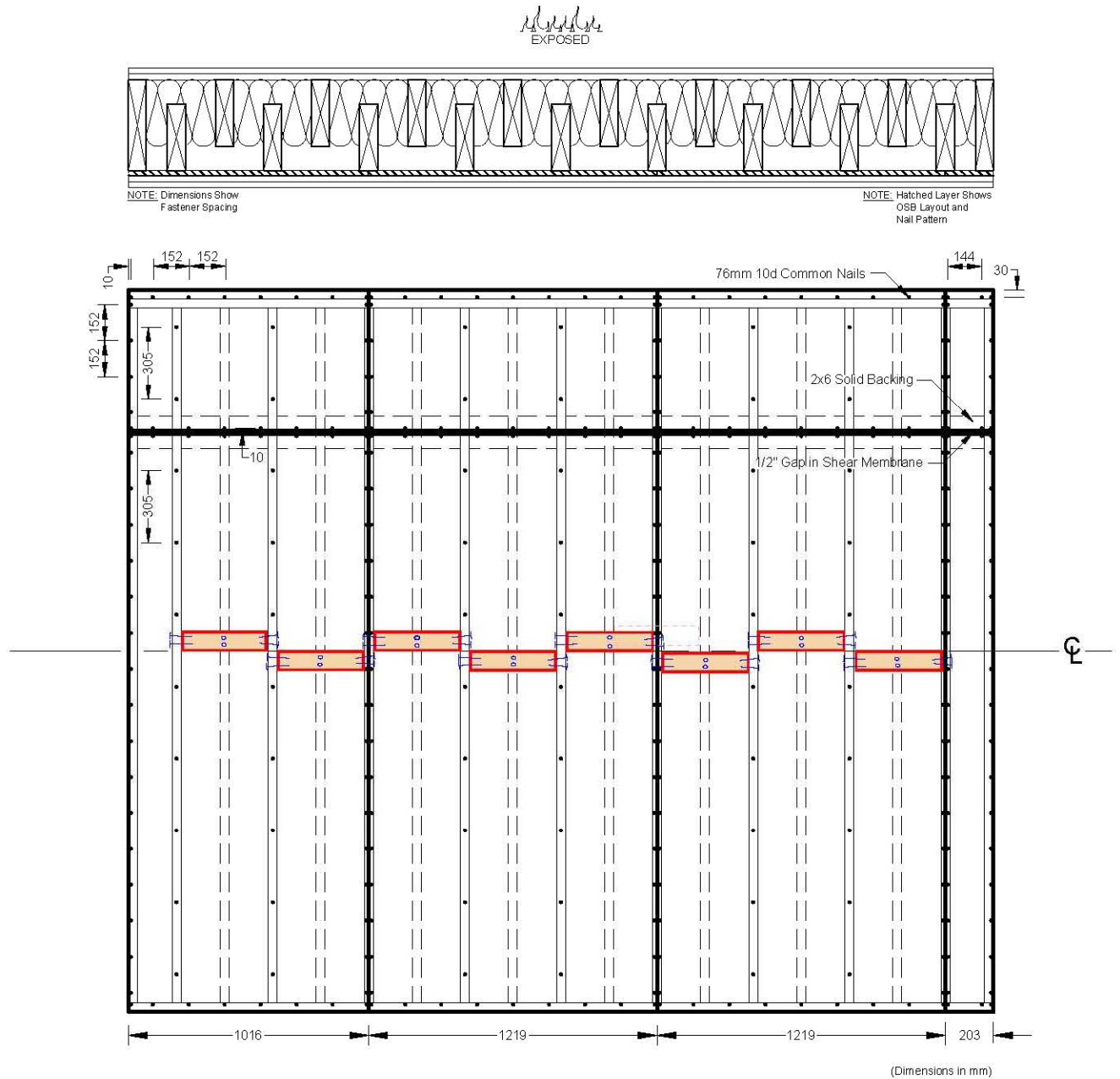
**Figure 3. Base layer of gypsum board on exposed side of wall assembly with horizontal blocking at mid-height.**





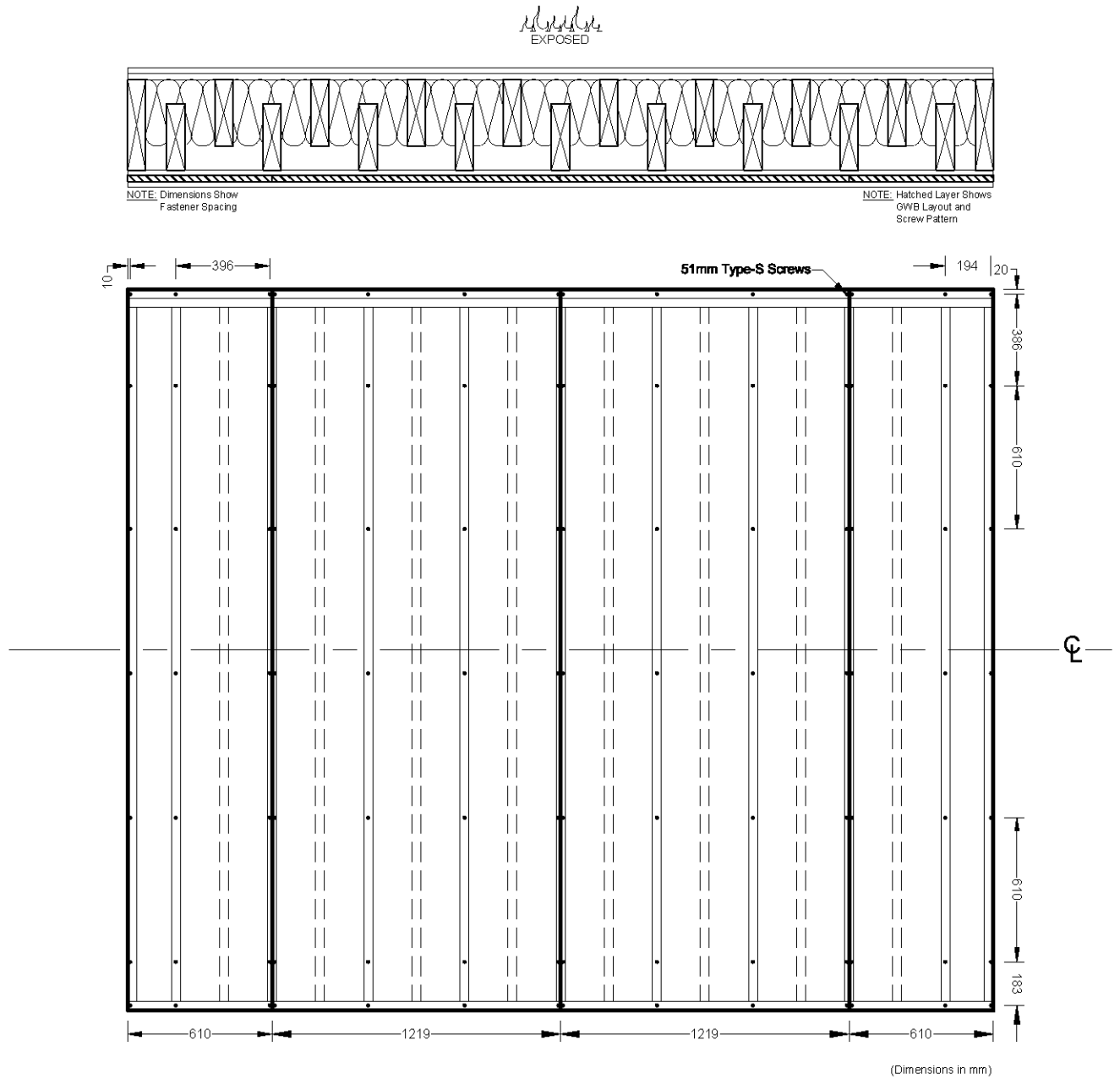
Exposed Face Layer - Gypsum Board Layout and Screw Pattern

**Figure 4. Face layer of gypsum board on exposed side of wall assembly.**



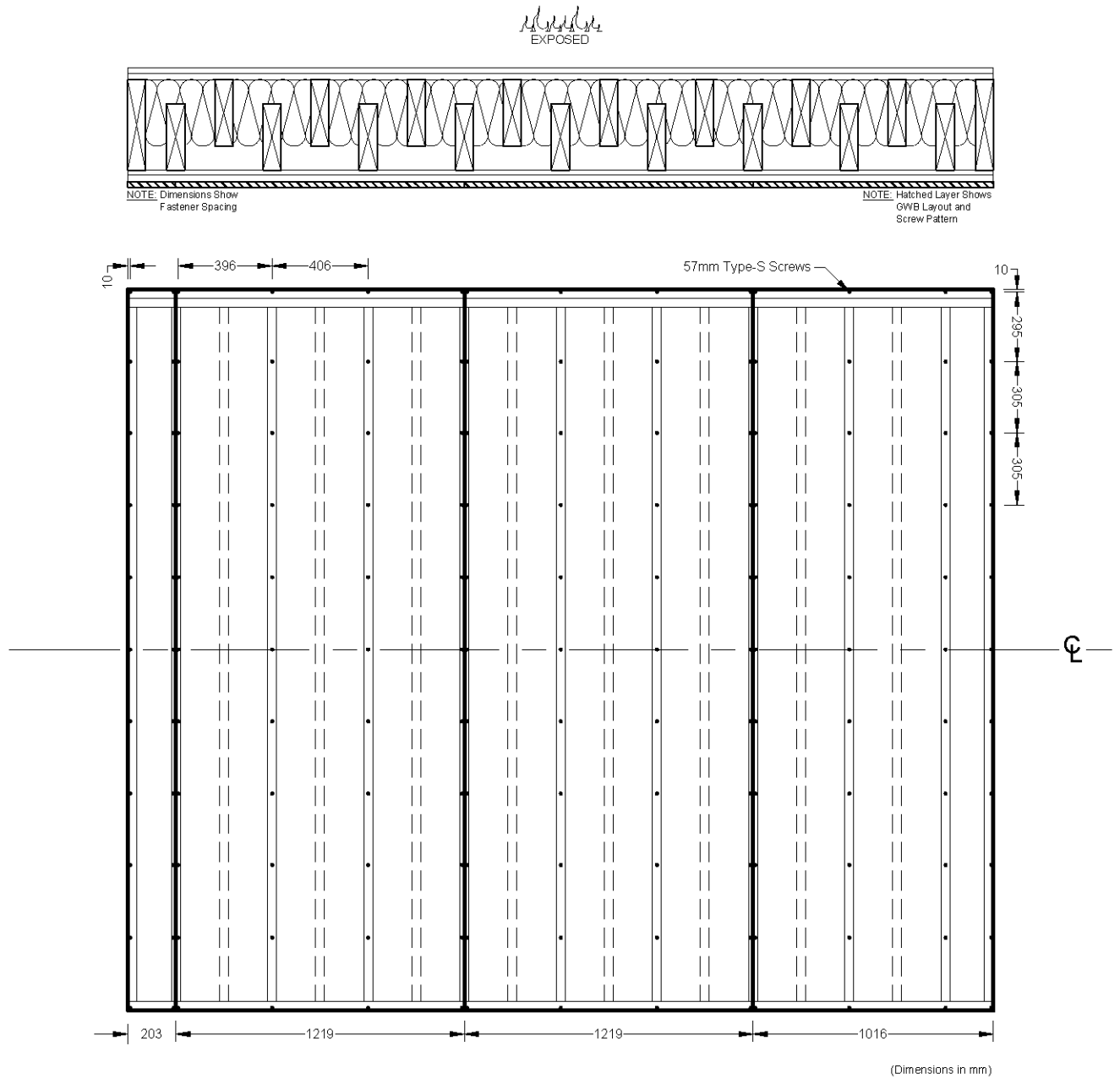
OSB Shear Layer Layout, Nail Pattern and 2x4 Bracing on Unexposed Side

**Figure 5. Shear membrane layer of OSB panel on unexposed side of wall assembly with horizontal blocking at mid-height.**



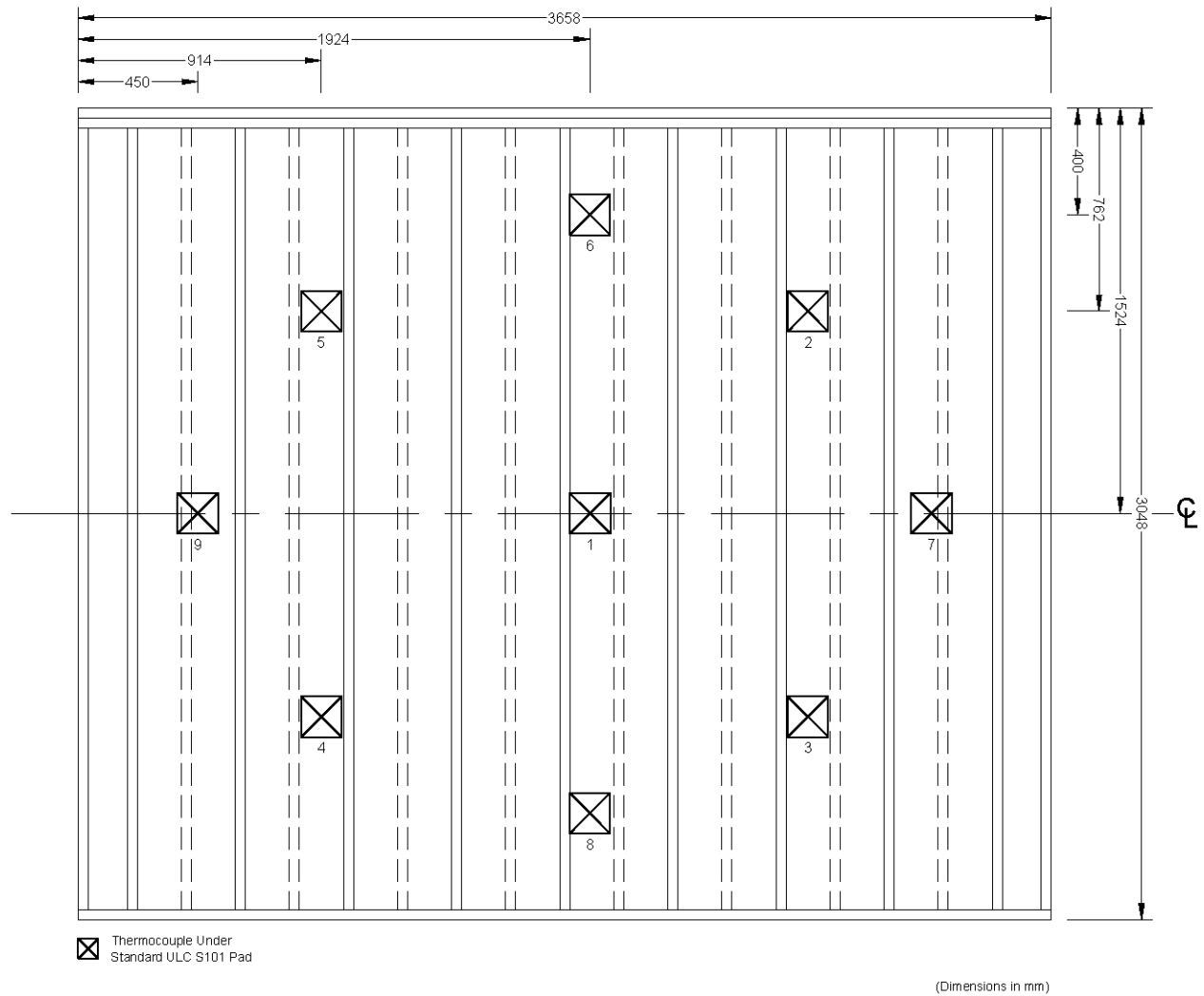
Unexposed Base Layer - Gypsum Board Layout and Screw Pattern

**Figure 6. Base layer of gypsum board on unexposed side of wall assembly.**

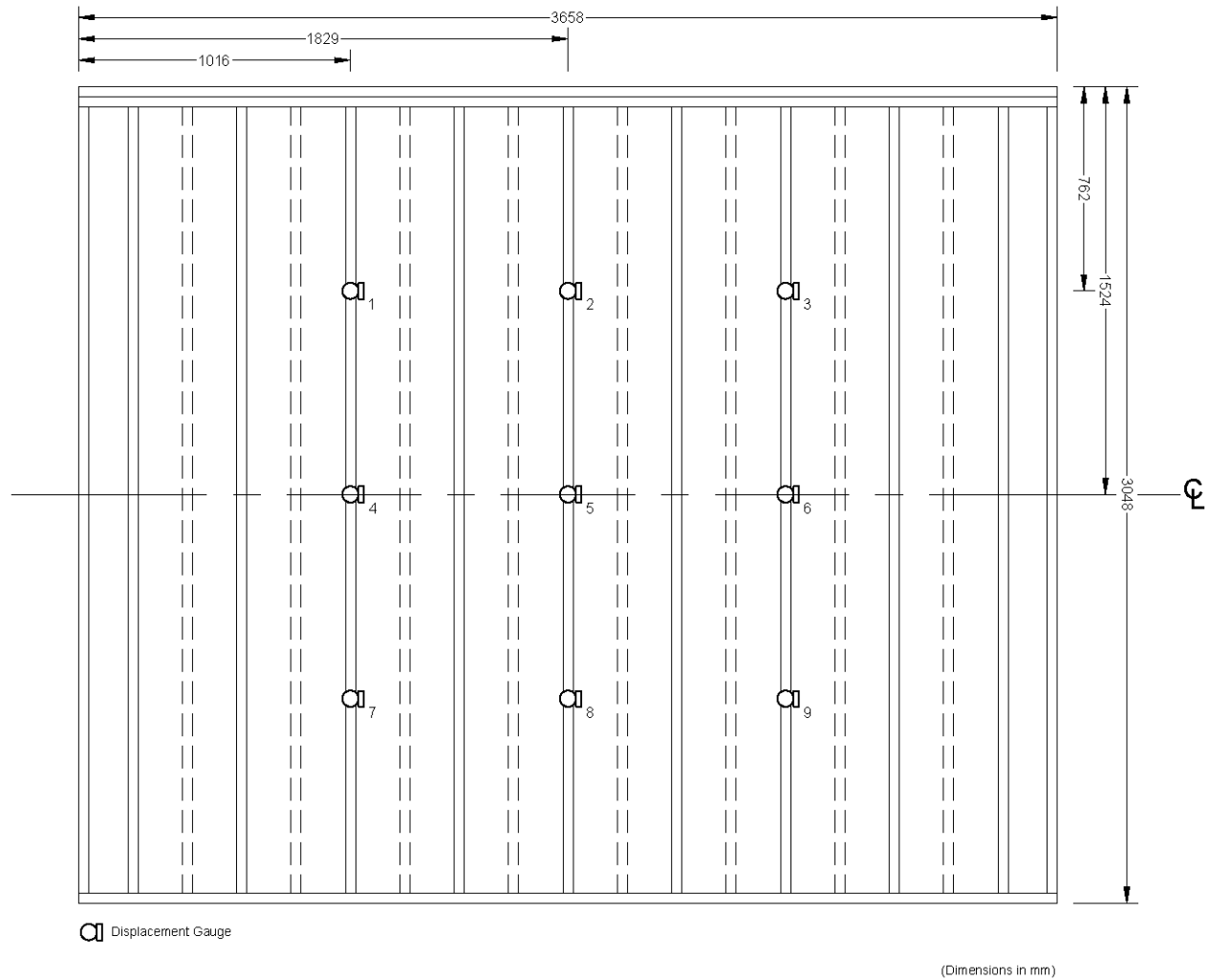


Unexposed Face Layer - Gypsum Board Layout and Screw Pattern

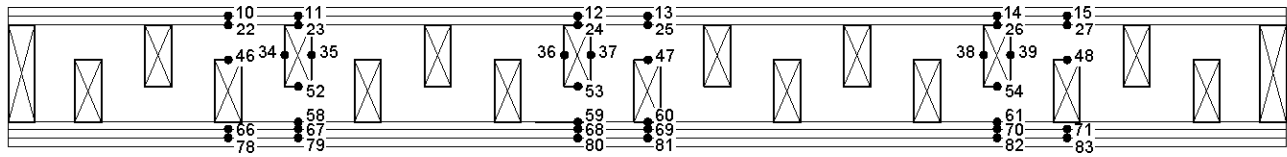
**Figure 7. Face layer of gypsum board on unexposed side of wall assembly.**



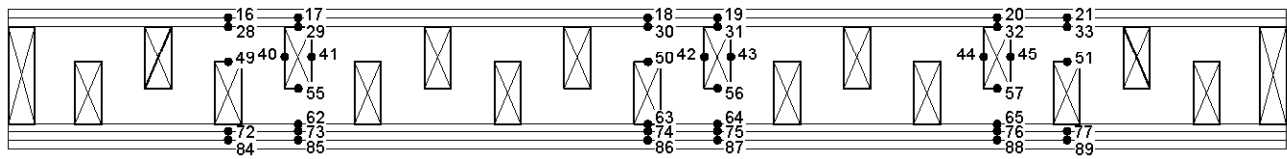
**Figure 8. Thermocouples on unexposed face of wall assembly.**



**Figure 9. Deflection gauges on unexposed face of wall assembly.**



Cross Section at 1/4 Height From Top



Cross Section at 3/4 Height From Top

**Figure 10. Thermocouples inside wall assembly.**

## RESULTS

Plots showing the data for all the measurements for the wall assembly (Wall Assembly #6) are provided in Appendix A.

Figure 11 shows the average furnace temperature ( $F_{ur_{avg}}$ ) measured during the test. There is a good comparison between the measured temperature and the temperature specified in CAN/ULC-S101 [2].

Also shown in Figure 11 are the average temperatures measured at the interface between the face and base layers of gypsum board (GB/GB), the interface between the base gypsum board layer and the wall cavity (GB/Cavity), and the interface between the base gypsum board layer and the studs (GB/stud), on the exposed side of the wall assembly.

The average temperature at the interface between the face and base gypsum board layers was  $< 100^{\circ}\text{C}$  for 11.5 min and was  $> 300^{\circ}\text{C}$  after 23.5 min. After 11.5 min, there was a continuous increase in temperature until 85 min. After 85 min, the temperature was comparable to the temperature in the furnace. This suggests some of the face layer of gypsum board remained in place until near the end of the test.

Initially, there was a slow temperature increase at the interface between the base layer of gypsum board and the cavity and between the base layer and the studs, with the temperatures  $< 150^{\circ}\text{C}$  for 43.3 min. Subsequently, there was a more rapid temperature increase at both interfaces, with the fastest increase at the gypsum board-cavity interface. The average temperatures exceeded  $300^{\circ}\text{C}$  at the gypsum board-cavity and the gypsum board-stud interfaces at 49.7 min and 55.5 min, respectively. The temperatures were  $< 600^{\circ}\text{C}$  for 68.5 min. The average temperature measured at gypsum board-cavity and gypsum board-stud interfaces increased more rapidly after approximately 88 min indicating the base layer of gypsum board was falling off.

Figure 12 shows the average temperatures at the interfaces between the studs and the wall cavity. The measurement locations were: the side of the studs on the exposed side of the wall (Stud Side), the face of the studs on the unexposed side of the wall assembly (Stud Face Unexposed Side), and the face of the studs on the exposed side of the wall assembly (Stud Face Exposed Side). Also shown is the average temperature at the interface between the cavity and the OSB shear membrane layer on the unexposed side of the wall assembly (Cavity/OSB).

There was a slow temperature increase on the sides of the studs on the exposed side of the wall assembly. The average temperature was  $< 100^{\circ}\text{C}$  for 68.5 min and  $< 300^{\circ}\text{C}$  for 95.0 min. The average temperature measured on the face of the studs on the unexposed side had a slow temperature increase with the average temperature  $< 100^{\circ}\text{C}$  for 55.7 min and  $< 300^{\circ}\text{C}$  for 80.5 min.

Comparable temperatures were measured on the face of the studs on the exposed side of the wall assembly and at the interface between the cavity and the OSB shear membrane layer on the unexposed side of the wall assembly.

The average temperatures measured on the unexposed side of the wall assembly are shown in Figure 13. This includes the average temperatures at the interface between the studs and the OSB shear membrane layer (Stud/OSB), at the interface between the OSB and the base

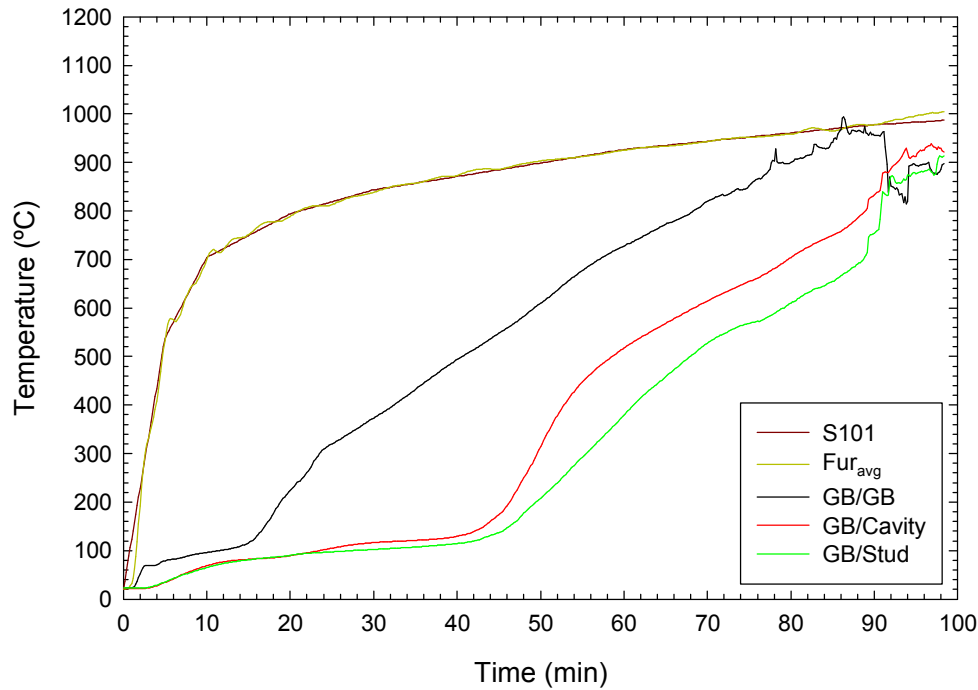


gypsum board layer (OSB/GB), at the interface between the base and face layers of gypsum on the unexposed side (GB/GB (unexposed)), and on the unexposed surface (Unexposed).

There was a gradual temperature increase at all locations beginning at approximately 15 min. The temperatures at all locations were 112.1°C or less at the end of the test. The highest temperatures were measured at the interface between OSB shear membrane and the gypsum board base layer.

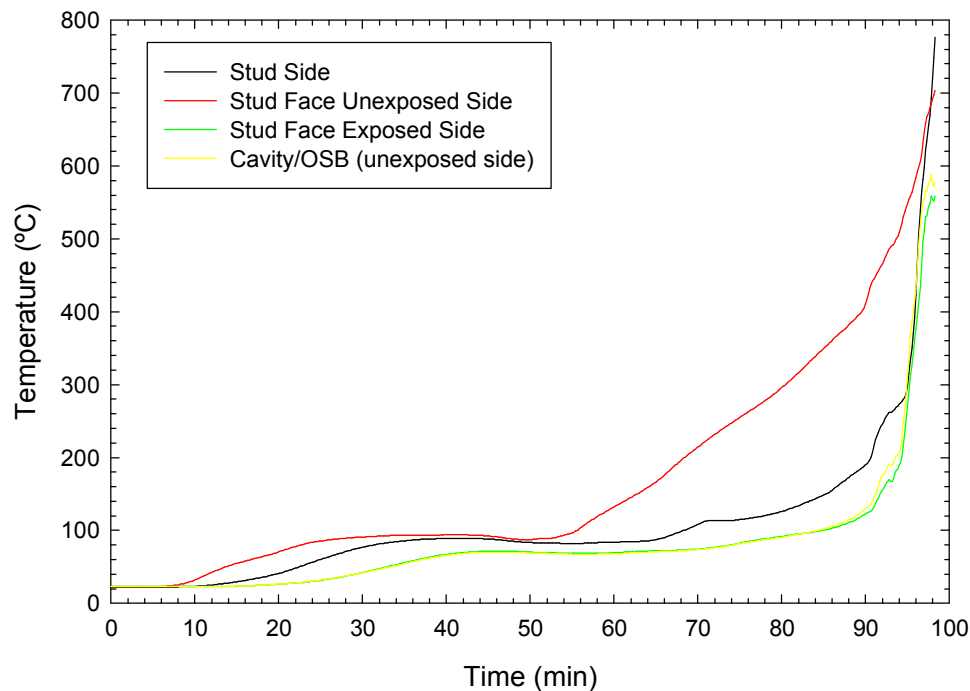
Figure 14 shows the average and maximum deflections measured during the test. The maximum deflection was measured by Deflection Gauge 5 located at the center of the wall assembly. There was minimal deflection for the initial 60 min. Subsequently, there was a continuous increase in the rate at which the assembly deflected until structural failure.

The wall assembly failed structurally at 98 min with the studs deforming perpendicular to the plane of the wall. The addition of the horizontal blocking limited the in-plane deformation of the studs. This resulted in a 17 min increase in the fire endurance period compared with the wall assembly without the blocking (Wall Assembly #5 in Reference [3]).



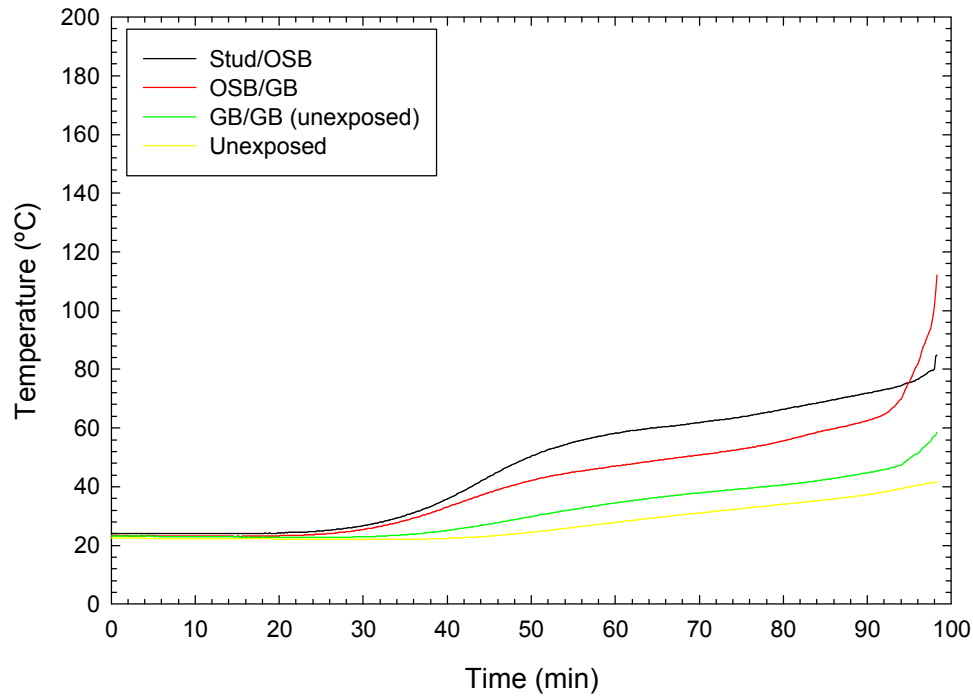
**Notes:** GB/GB is the average of TCs #10-21; GB/Cavity is the average of TCs #22, 25, 27, 28, 30 and 33; GB/Stud is the average of TCs #23, 24, 26, 29, 31 and 32.

**Figure 11. Furnace temperatures and average temperatures at interfaces on exposed side of the wall assembly.**



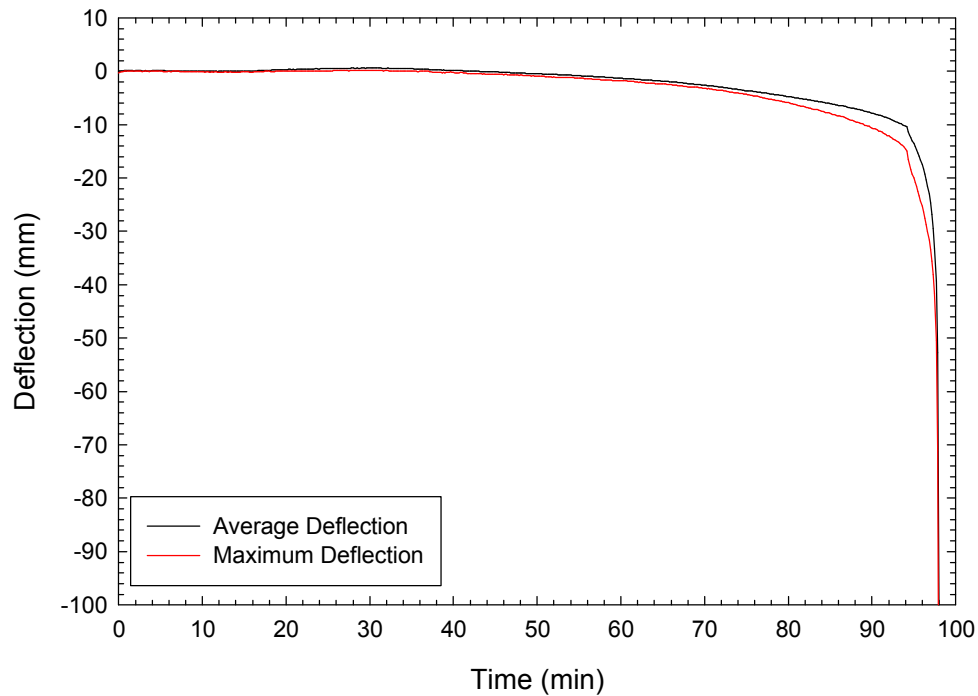
**Notes:** Stud Side is the average of TCs #34-45; Stud Face Unexposed is the average of TCs #46-51; Stud Face Exposed is the average of TCs #52-57; Cavity/OSB is the average of TCs #58, 59, 61, 62, 64 and 65.

**Figure 12. Average temperatures at stud-cavity and cavity-OSB interfaces for the wall assembly.**



**Notes:** Stud/OSB is the average of TCs #60 and 63; OSB/GB is the average of TCs #66-77; GB/GB (unexposed) is the average of TCs #78-89; Unexposed is the average of TCs #1-9.

**Figure 13. Average temperatures on unexposed side of the wall assembly.**



**Figure 14. Deflections the wall assembly.**

## SUMMARY

This report documents the results of a full-scale furnace test conducted to investigate the standard fire resistance performance of a generic wall assembly (Wall Assembly #6). Staggered studs were used for the wall assembly, a shear membrane layer of 11.1 mm thick OSB was attached to the unexposed side of the framing, and both sides of the assembly were protected using two layers of 12.7 mm thick Type X gypsum board.

The framing for the wall assembly was the same as that used for Wall Assembly #5 in Reference 2. However, horizontal blocking was added at the mid-height of the assembly to limit the deformation of the studs in the plane of the wall assembly. The fire endurance period for the wall assembly was 98 min compared with 81 min for the wall assembly without horizontal blocking.

## ACKNOWLEDGMENTS

Financial and in-kind support for the project provided by the Canadian Wood Council is gratefully acknowledged. Extensive technical input by Ineke Van Zeeland and Peggy Lepper is also gratefully acknowledged.

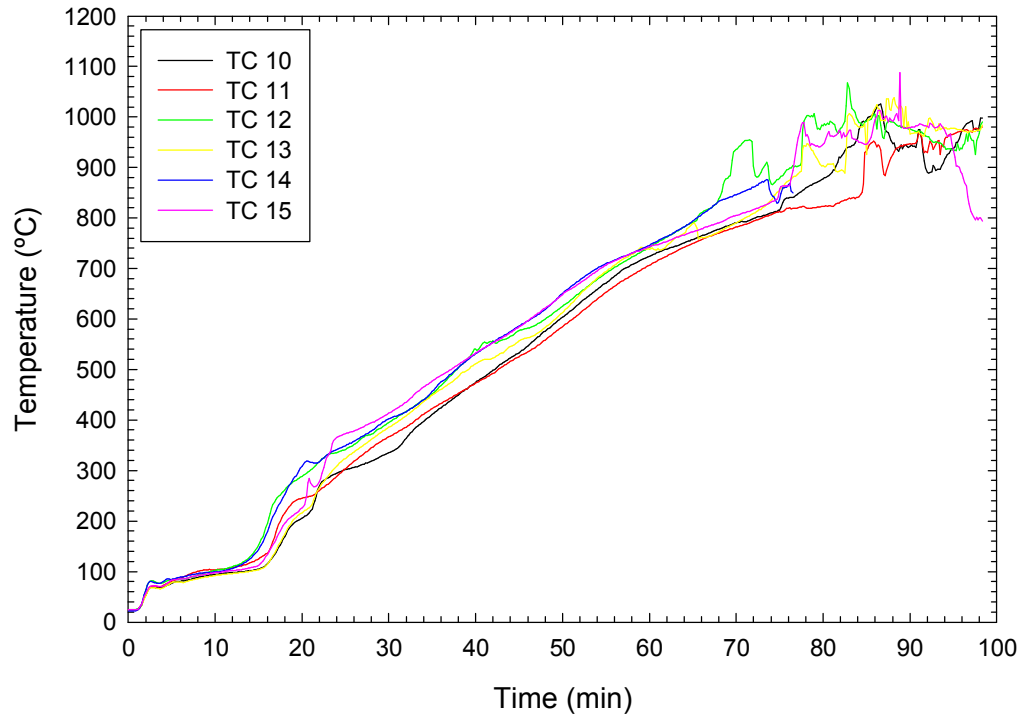
## REFERENCES

1. 2010 NBC, National Building Code of Canada, National Research Council, Ottawa, Ontario, 2010.
2. CAN/ULC-S101, Standard Methods of Fire Endurance Tests of Building Construction and Materials Underwriters Laboratories of Canada, Ottawa, Ontario, 2007.
3. Lafrance, P-S, Berzins, R., Leroux, P., Su, J.Z., Loughheed, G.D. and Bénichou, N., Alternative Solution for Mid-Rise Wood Construction: Full-Scale Standard Fire Resistance Tests of Wall Assemblies for Use in Lower Storeys of Mid-Rise Buildings, CLIENT REPORT A1-100035-01.8, National Research Council, Ottawa, Ontario, 2013.

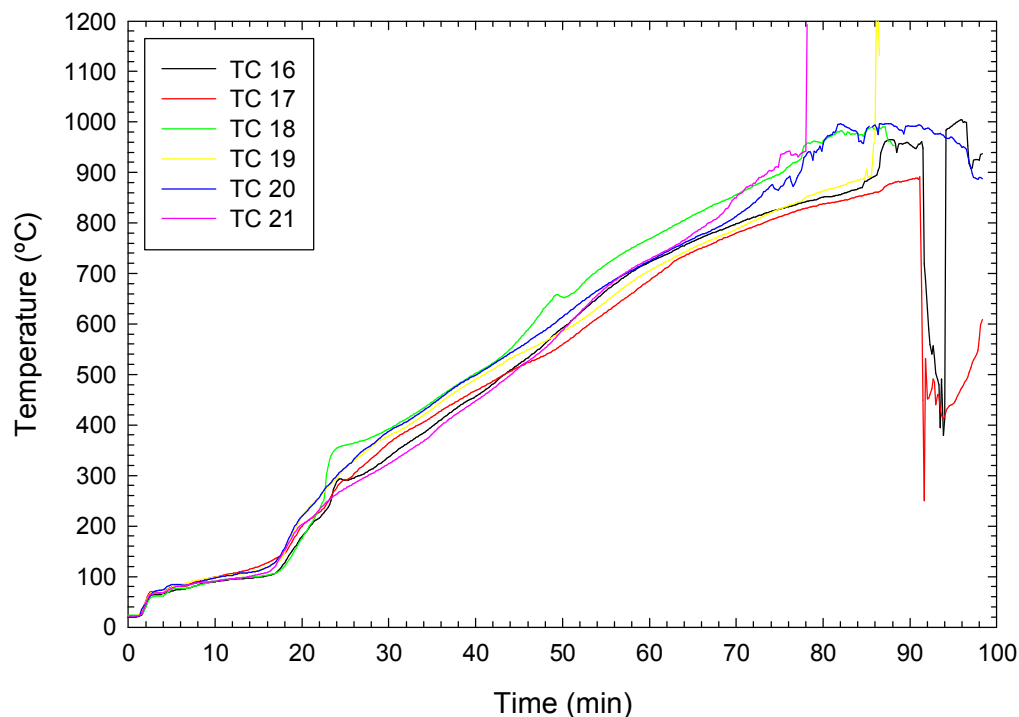
## APPENDIX A- DATA FOR WALL ASSEMBLY #6

A series of plots showing the results of the measurements for Wall Assembly #6 are provided. The plots are:

1. Figures A-1 and A-2 show the temperatures measured at the interface between the face and base layers of gypsum board on the exposed side of the wall assembly at the  $\frac{1}{4}$  and  $\frac{3}{4}$  heights from the top of assembly, respectively.
2. Figure A-3 shows the temperatures measured at the interface between the base layer of gypsum board and the studs on the exposed side of the wall assembly.
3. Figure A-4 shows the temperatures measured at the interface between the base layer of gypsum board and the wall cavity on the exposed side of the wall assembly.
4. Figures A-5 and A-6 show the temperatures measured on the sides of the studs on the exposed side of the wall assembly at the  $\frac{1}{4}$  and  $\frac{3}{4}$  heights from the top of assembly, respectively.
5. Figures A-7 and A-8 show the temperatures measured on the face of the studs on the unexposed and exposed side of the wall assembly, respectively.
6. Figures A-9 and A-10 show the temperatures measured at the interface between the wall cavity and the OSB shear membrane layer and between the stud and the OSB shear membrane layer, respectively.
7. Figures A-11 and A-12 show the temperatures measured at the interface between the OSB shear membrane layer and the base gypsum board layer on the unexposed side of the wall assembly at the  $\frac{1}{4}$  and  $\frac{3}{4}$  heights from the top of assembly, respectively.
8. Figures A-13 and A-14 show the temperatures measured at the interface between the base and face gypsum board layers on the unexposed side of the wall assembly at the  $\frac{1}{4}$  and  $\frac{3}{4}$  heights from the top of assembly, respectively.
9. Figure A-15 shows the temperatures measured on the unexposed side of the wall assembly.
10. Figure A-16 shows the average furnace temperature measured during the test.
11. Figures A-17, A-18 and A-19 show the deflections measured at the  $\frac{1}{4}$ , mid- and  $\frac{3}{4}$  heights of the test assembly, respectively.

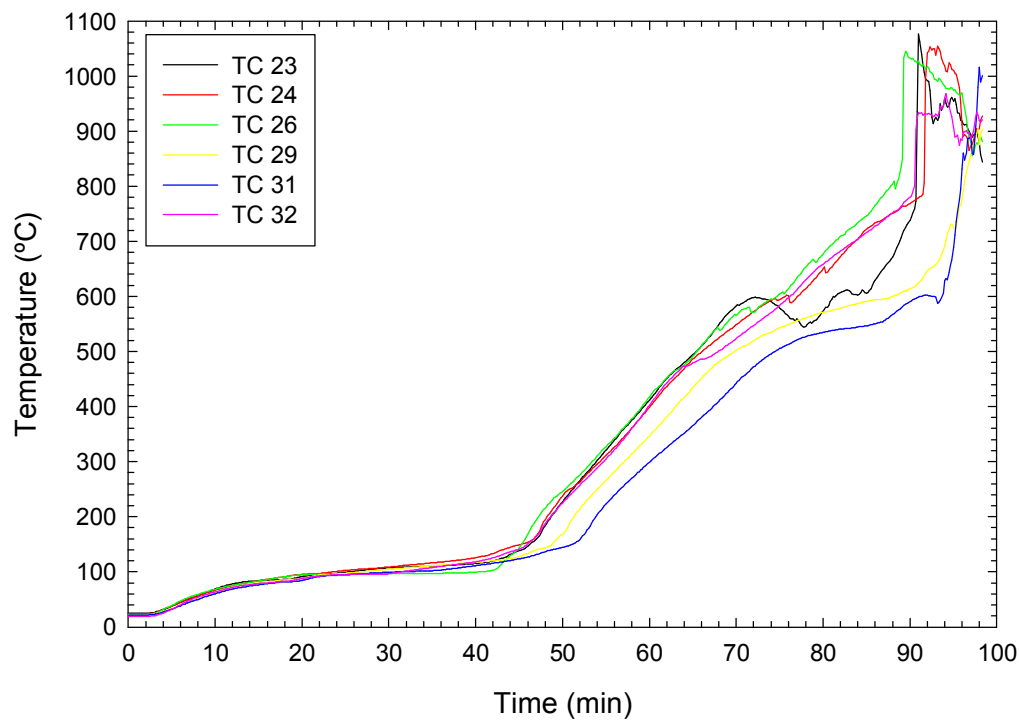


**Figure A-1. Temperatures measured at interface between face and base gypsum board layers at  $\frac{1}{4}$  height from top on exposed side of wall assembly.**

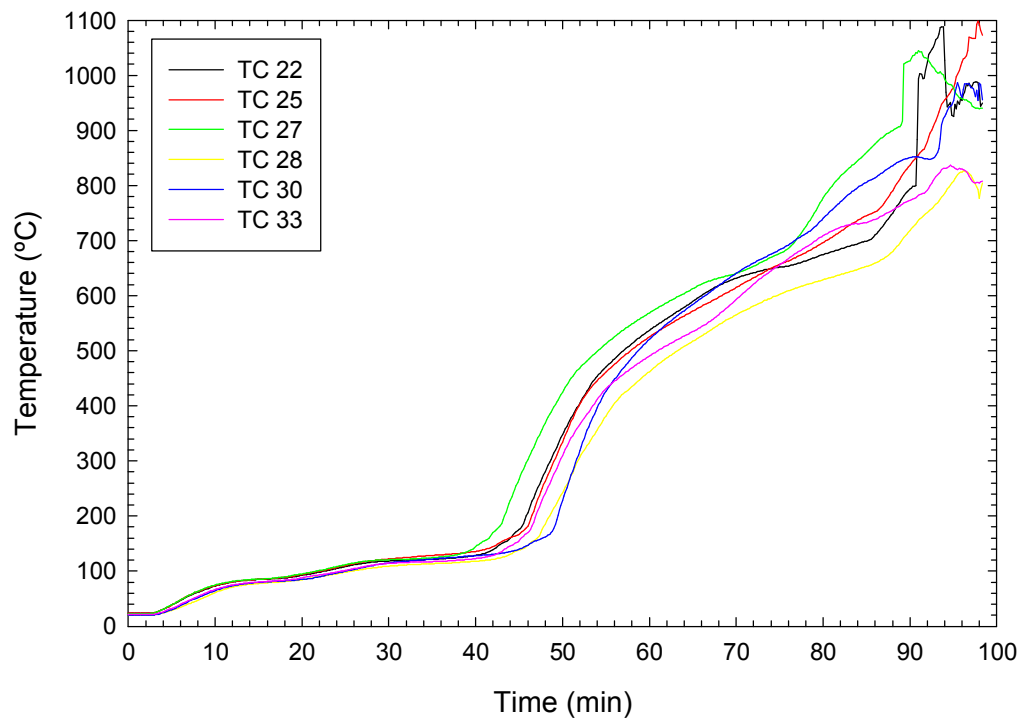


**Notes:** TCs#16 and 17 measured extreme temperature decreases towards the end of the test, which could be resulted from shielding by the base layer gypsum board falling from above.

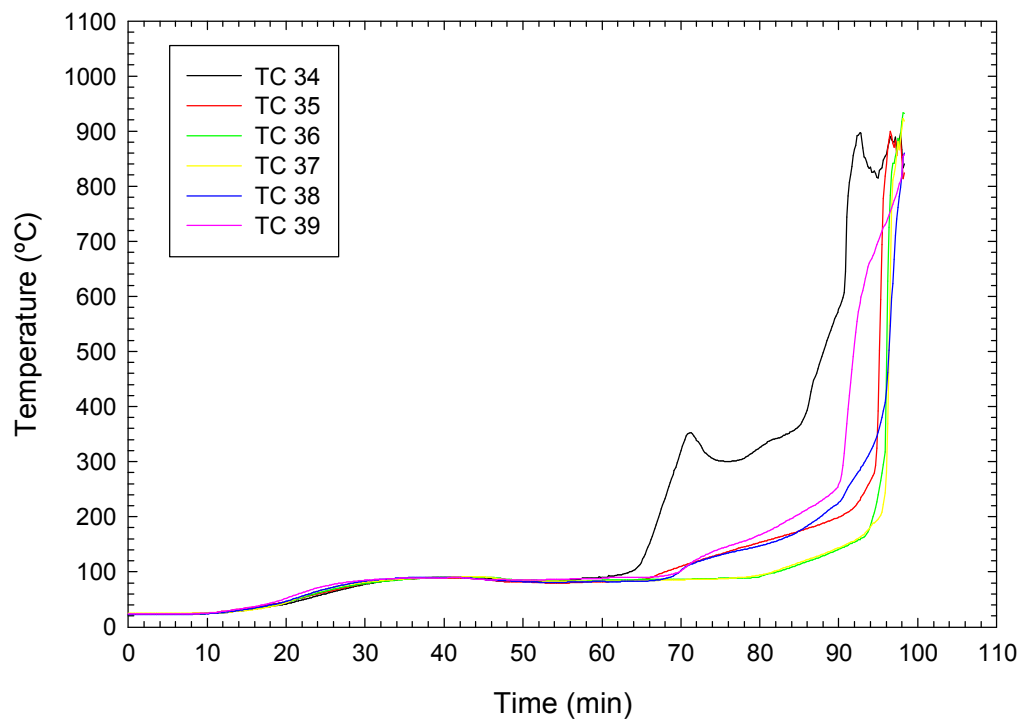
**Figure A-2. Temperatures measured at interface between face and base gypsum board layers at  $\frac{3}{4}$  height from top on exposed side of wall assembly.**



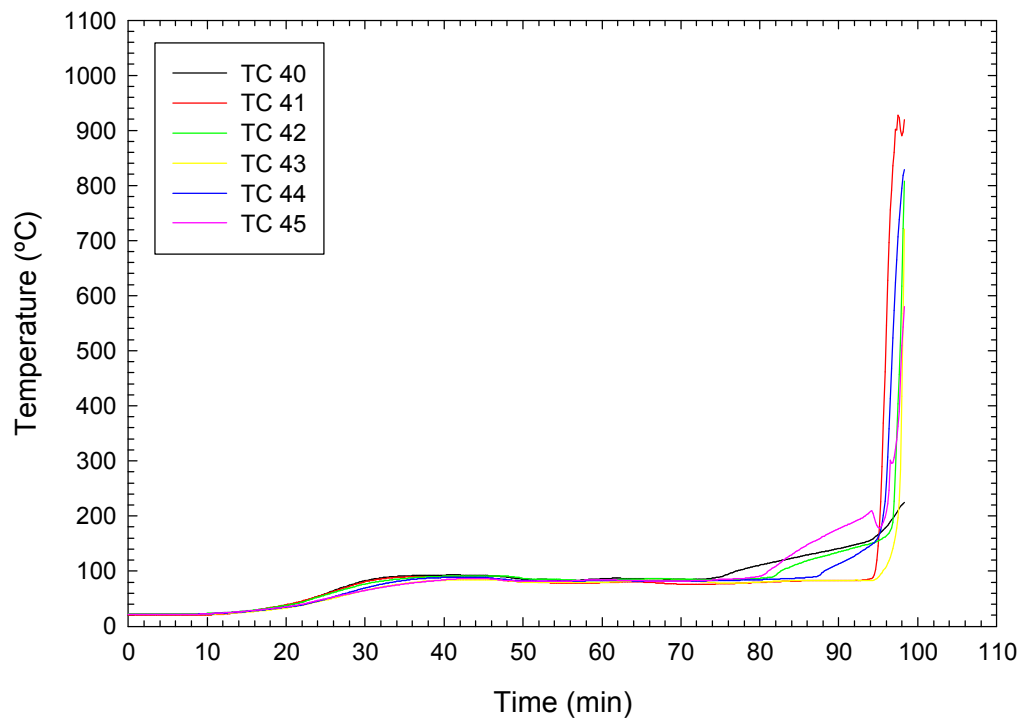
**Figure A-3. Temperatures measured at interface between base gypsum board layer and studs on exposed side of wall assembly.**



**Figure A-4. Temperatures measured at interface between base gypsum board layer and the wall cavity on exposed side of wall assembly.**

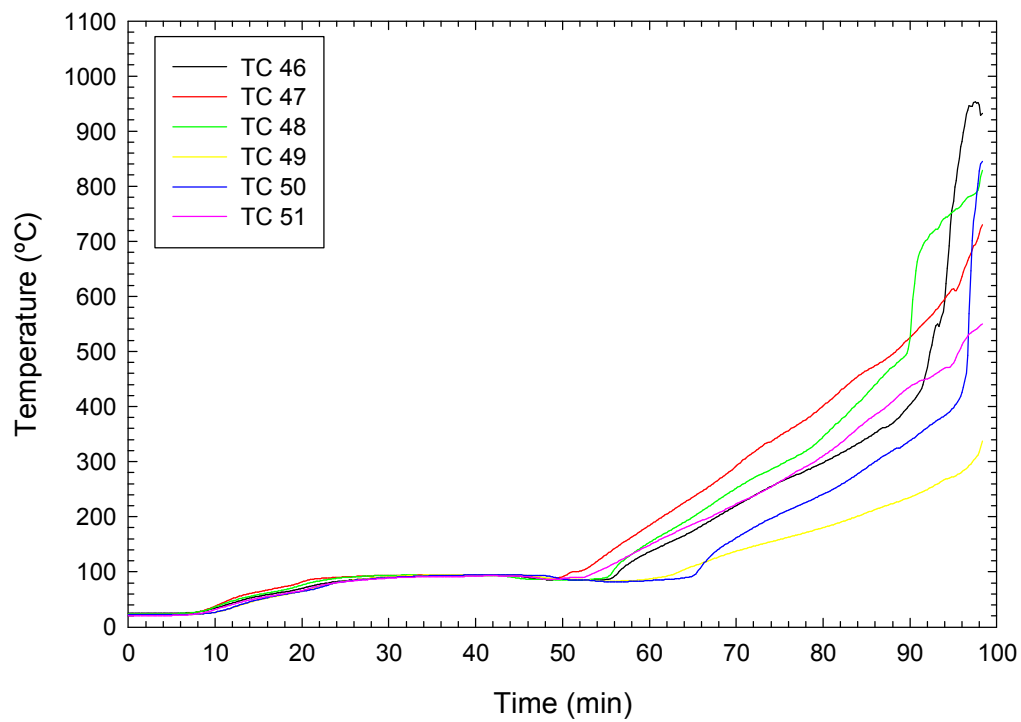


**Figure A-5. Temperatures measured on sides of studs on exposed side at 1/4 height from top of wall assembly.**

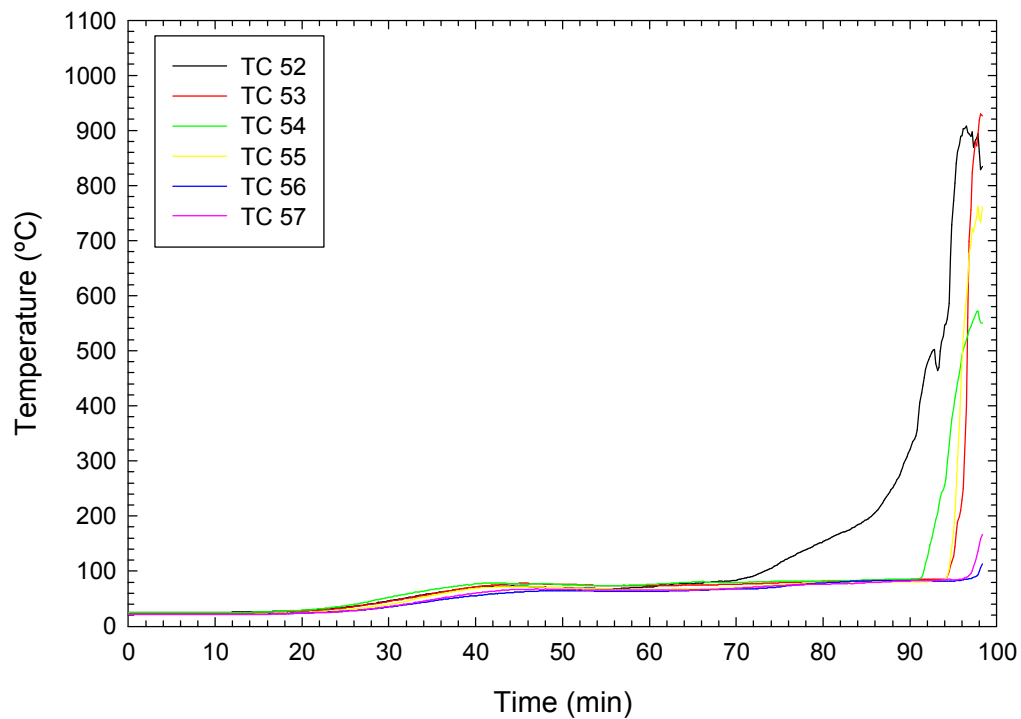


**Figure A-6. Temperatures measured on sides of studs on exposed side at 3/4 height from top of wall assembly.**

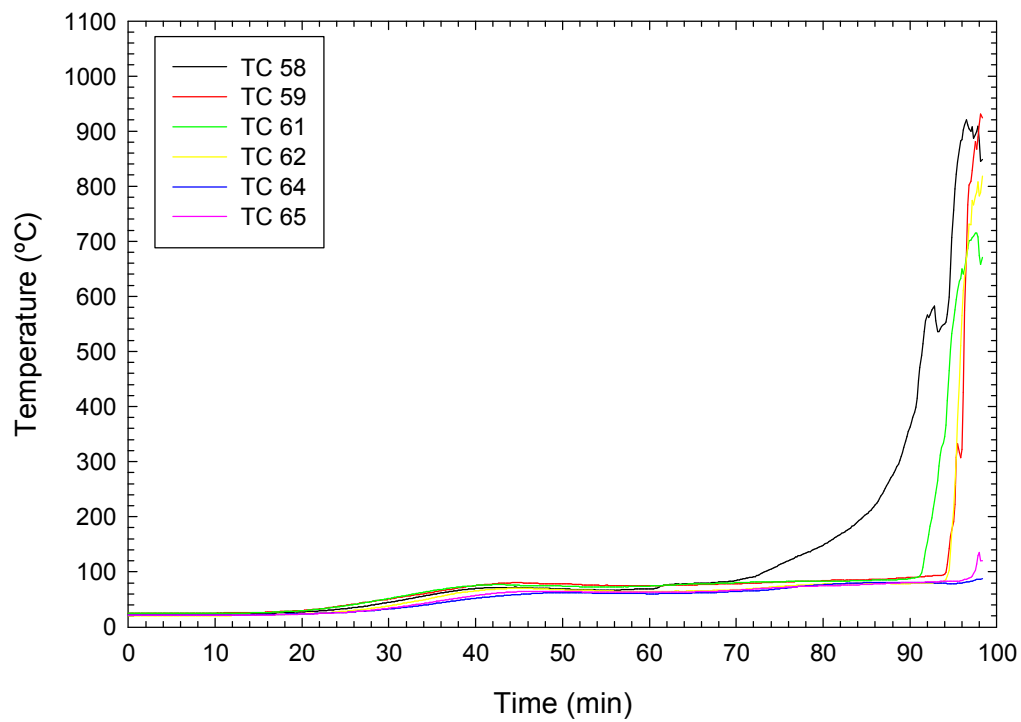




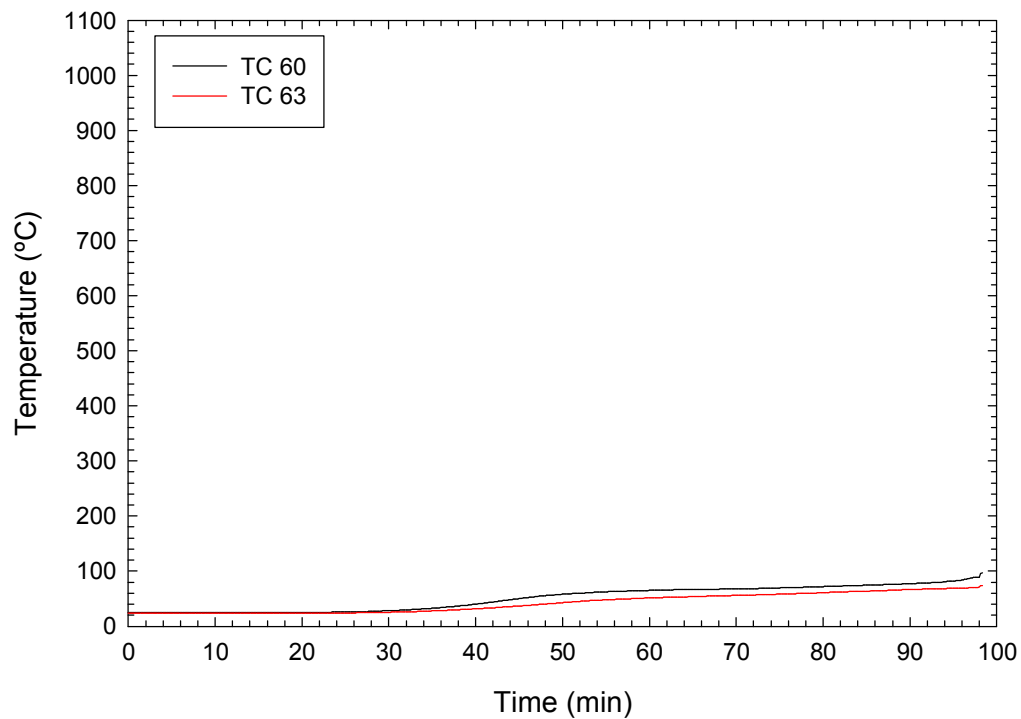
**Figure A-7. Temperatures measured on face of studs on unexposed side of wall assembly.**



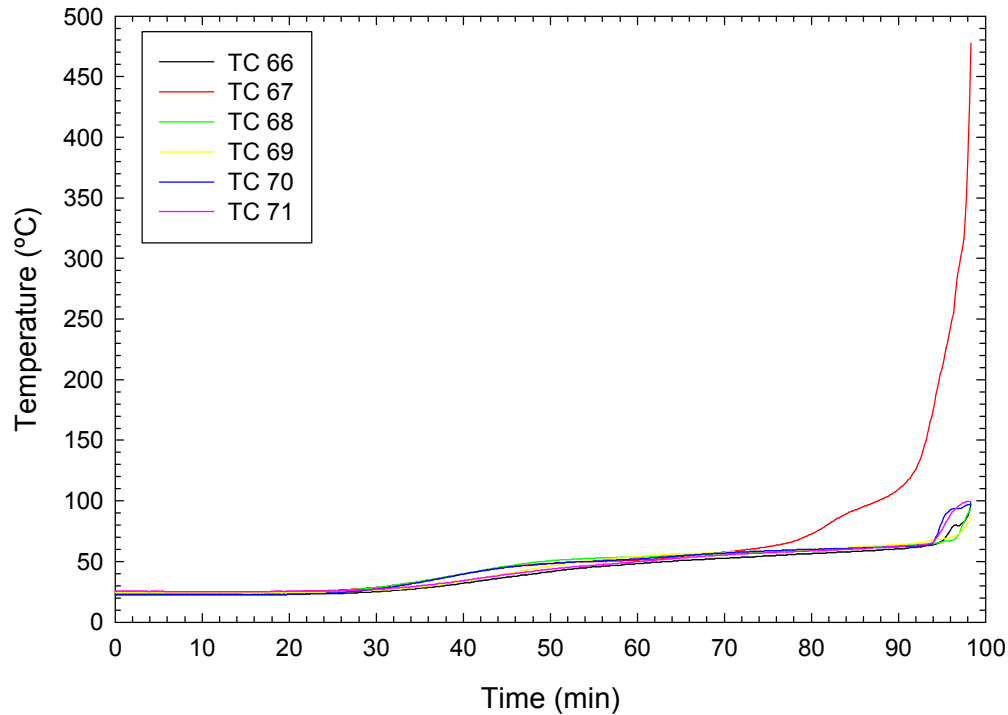
**Figure A-8. Temperatures measured on face of studs on exposed side of wall assembly.**



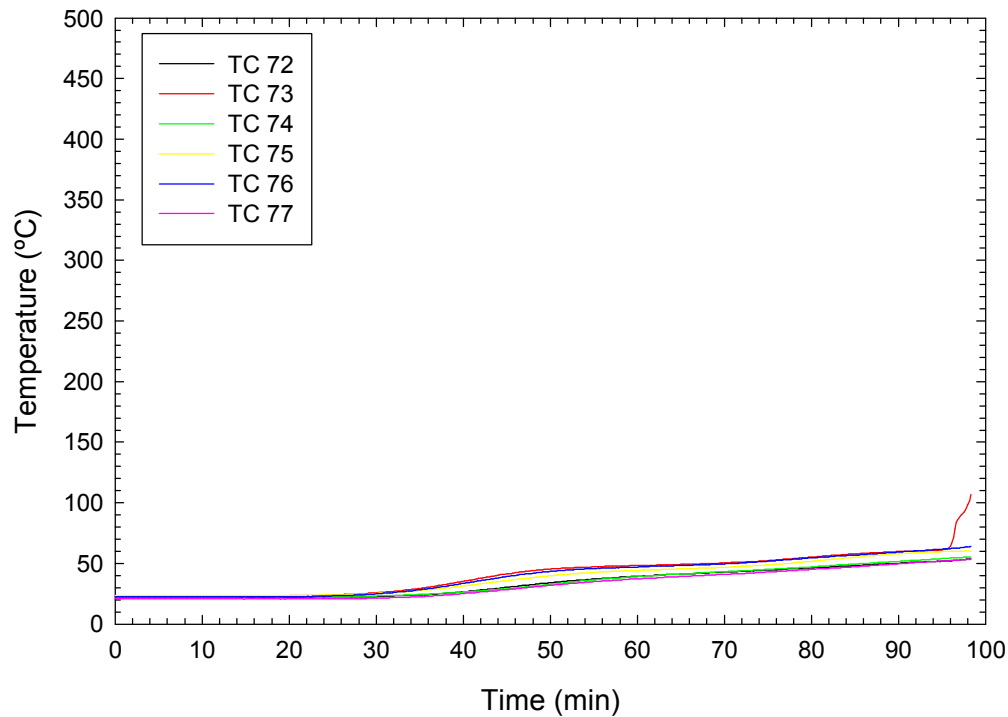
**Figure A-9. Temperatures measured at interface between wall cavity and OSB shear membrane layer on unexposed side of wall assembly.**



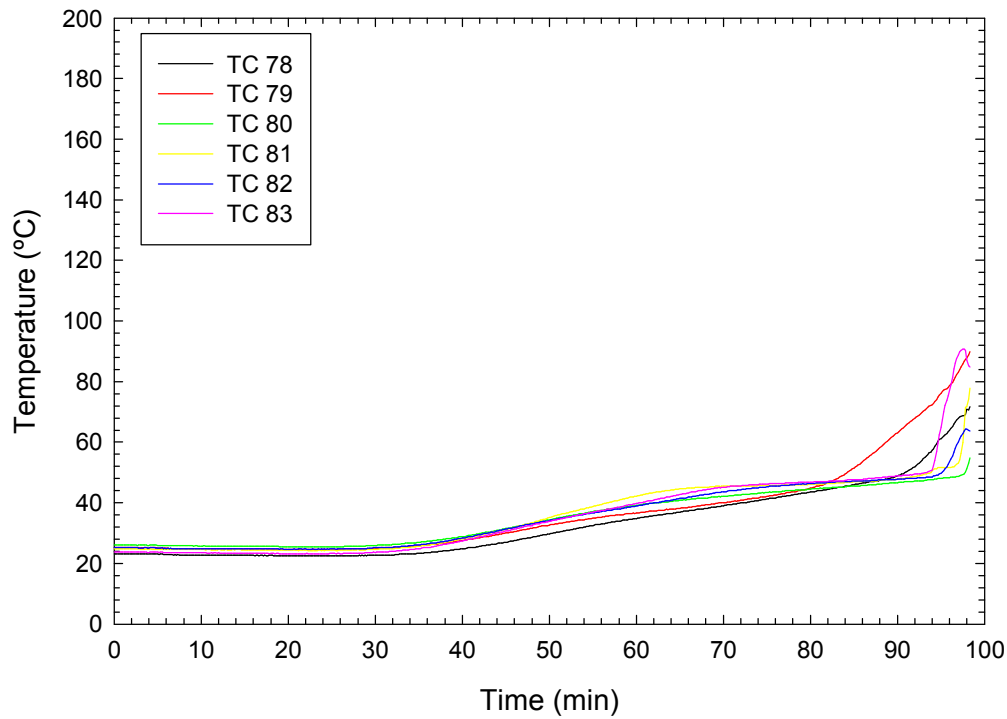
**Figure A-10. Temperatures measured at interface between stud and OSB shear membrane layer on unexposed side of wall assembly.**



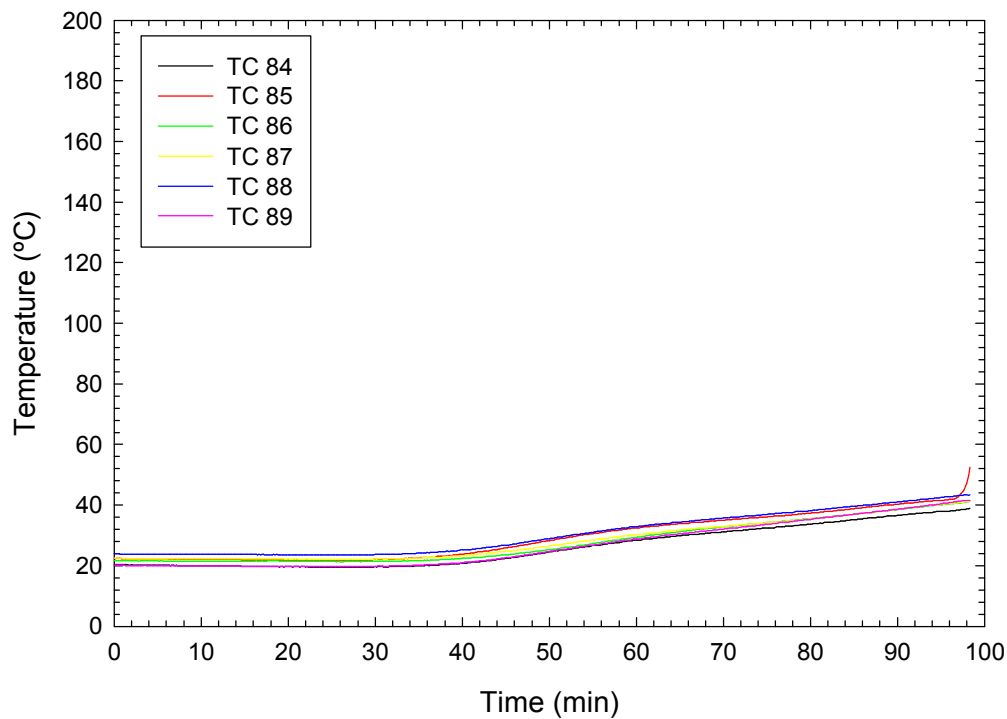
**Figure A-11. Temperatures measured at interface between OSB shear membrane layer and gypsum board base layer at  $\frac{1}{4}$  height from top on unexposed side of wall assembly.**



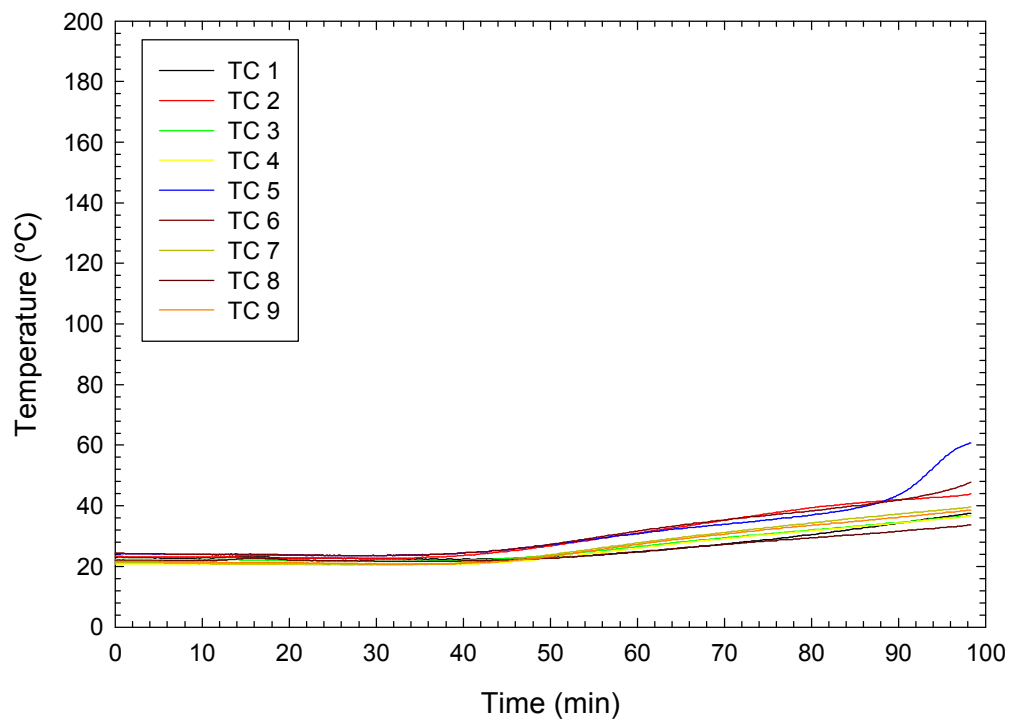
**Figure A-12. Temperatures measured at interface between OSB shear membrane layer and gypsum board base layer at  $\frac{3}{4}$  height from top on unexposed side of wall assembly.**



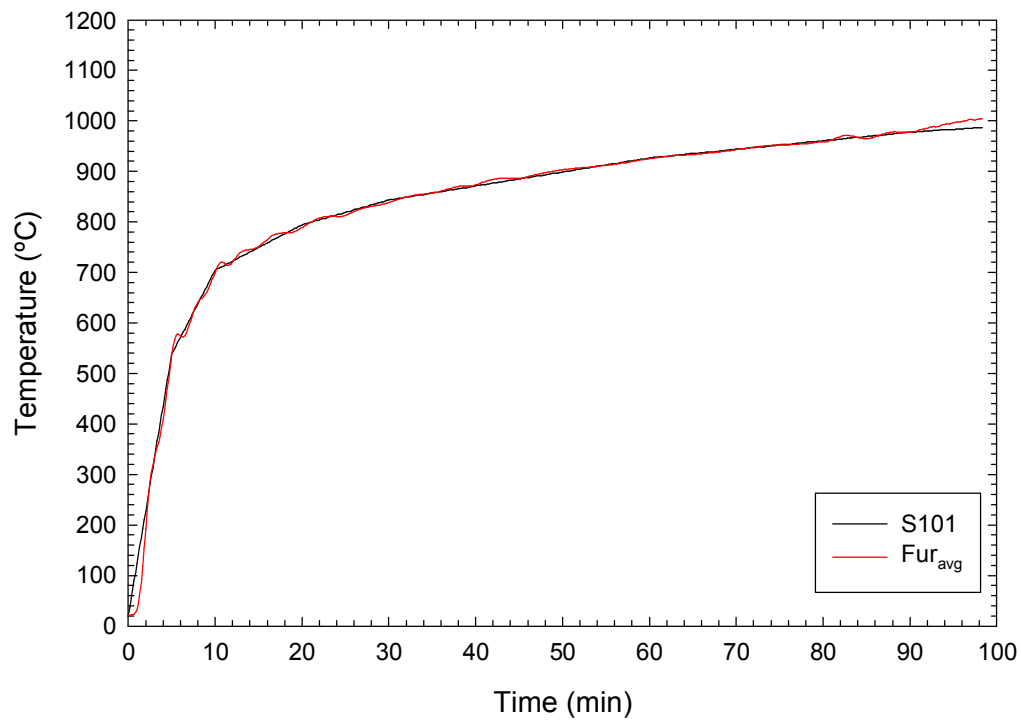
**Figure A-13. Temperatures measured at interface between base and face gypsum board layers at  $\frac{1}{4}$  height from top on unexposed side of wall assembly.**



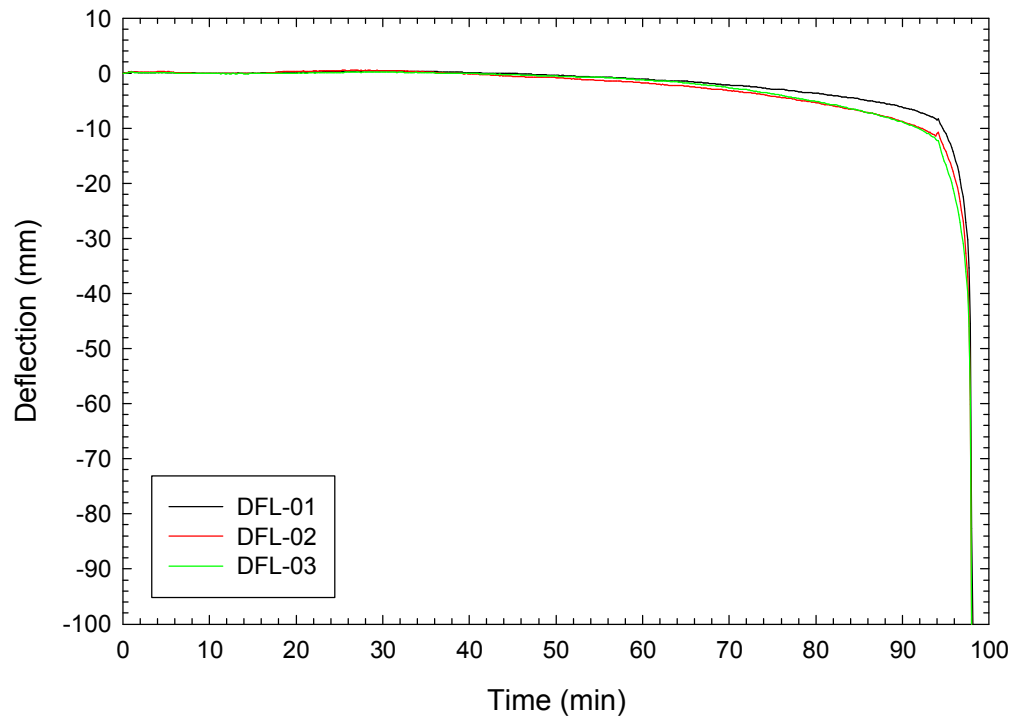
**Figure A-14. Temperatures measured at interface between base and face gypsum board layers at  $\frac{3}{4}$  height from top on unexposed side of wall assembly.**



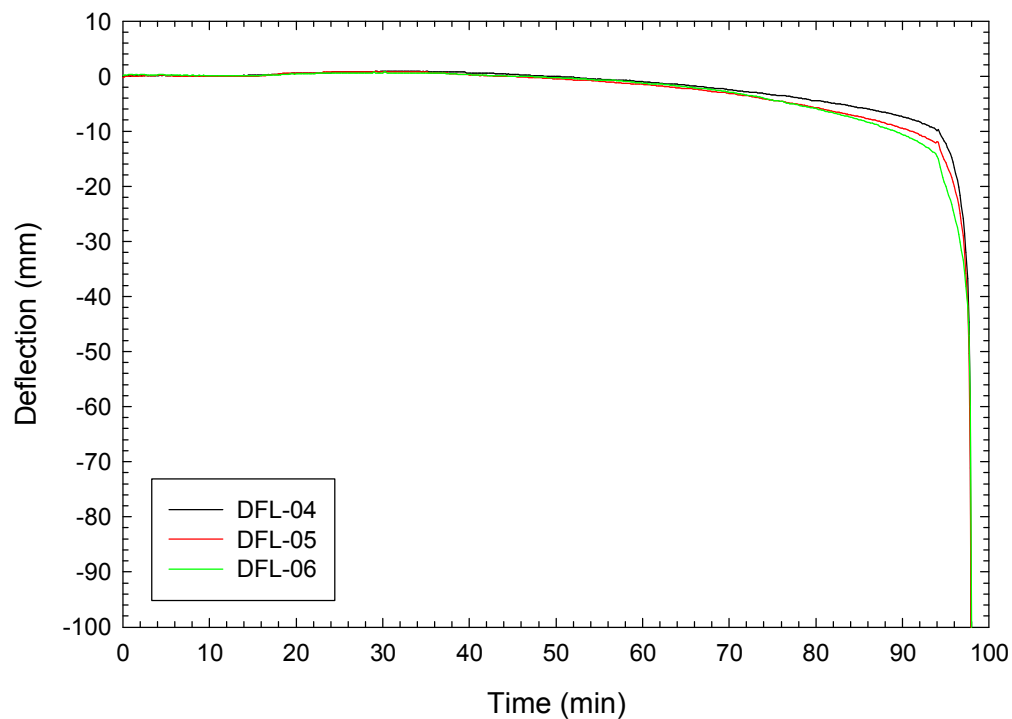
**Figure A-15. Temperatures measured on unexposed side of wall assembly.**



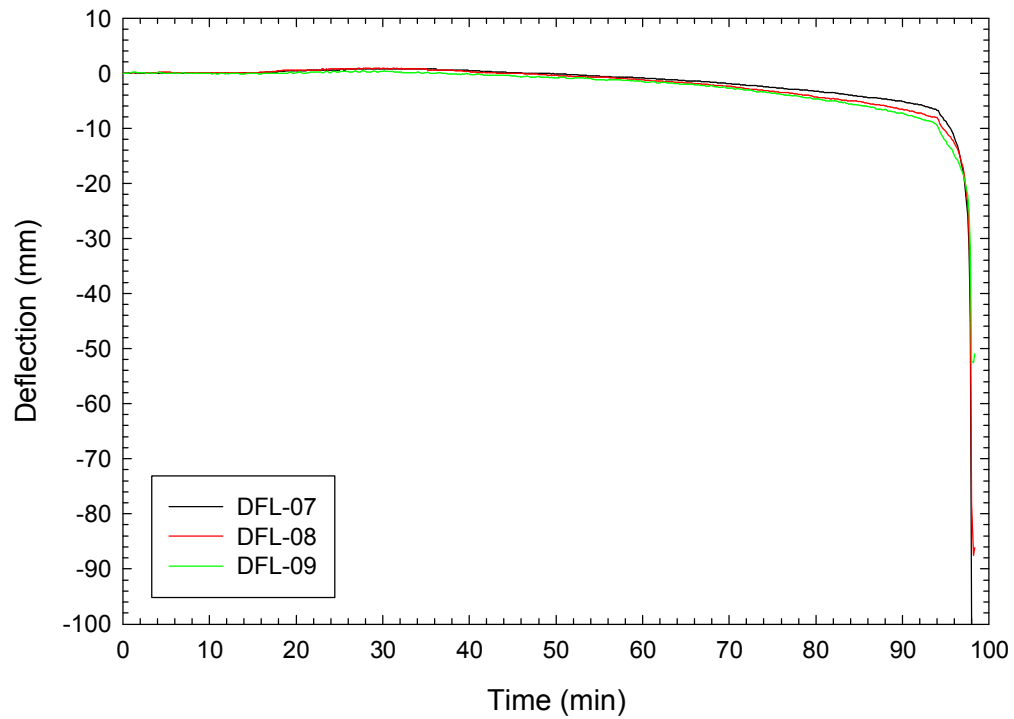
**Figure A-16. Average temperature measured by furnace thermocouples.**



**Figure A-17. Deflections measured at ¼ height from top of wall assembly.**



**Figure A-18. Deflections measured at mid-height of wall assembly.**



**Figure A-19. Deflections measured at  $\frac{3}{4}$  height from top of wall assembly.**