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ADVANCING KNOWLEDGE OF MID-PLY SHEAR WALLS

MID-PLY SHEAR WALL FIRE RESISTANCE TESTING

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Mid-Ply Shear Wall Fire Resistance Testing

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1. INTRODUCTION

Urban densification and a desire for increased sustainability are helping to realize greater construction of higher occupancy wood buildings. In British Columbia, mid-rise construction has been proven to be a viable and economical solution for responding to the needs of consumers and governments. Many completed projects are showcasing the positive aspects of using wood for larger and taller buildings as well as mixed-use occupancy. British Columbia continues to be a leader in wood construction, with the early adoption of Encapsulated Mass Timber Construction (EMTC) in some areas ahead of the release of the 2020 National Building Code of Canada (NBCC) [1].

Modern applications of wood construction often feature large floor spans, concrete toppings and heavy tiles on the roof. As a result, the overall lateral loads acting on the building become greater, which is an especially critical issue for wood buildings in regions susceptible to severe earthquakes. Furthermore, in recent years, there has been growing interest in residential designs that favour an open-space concept and large glass façades; this results in fewer structural shear walls. This trend places additional demands on the standard lateral load-resisting system, thereby compounding the need for wood-frame shear walls to be designed for increased lateral resistance. Midply shear walls, that were jointly developed by FPInnovations (Forintek) and the University of British Columbia, have approximately twice the load-carrying capacity of comparable standard shear walls; therefore, they can meet the high structural demands for residential and non-residential multi-storey construction. A significant amount of structural research has gone into the development of the midply wall systems [2, 3, 4]. Midply shear walls can also be used in post-and-beam construction and retrofitting, where they can be inserted into a building.

Midply shear walls help make multi-storey non-residential wood buildings more attractive to designers, providing better design options to meet high lateral load requirements; this is a market that is typically dominated by steel or concrete buildings. The 2015 edition of the NBCC introduced increased seismic load requirements which present challenges for designing mid-rise buildings in high seismic zones. Midply shear walls are a solution to address this problem and will ensure the success of mid-rise buildings in these areas.

To ensure increased resiliency of mid-rise wood-frame buildings (both residential and non-residential), shear wall performance needs to be improved to meet the demands of modern building design. There is a demand for this BC technology in Canadian and US markets, as well as internationally (midply shear walls have been used in Japan). The Canada Wood Group has been working in Japan on the development of a design manual that addresses midply shear walls.

A structural design methodology for midply shear walls was introduced into CSA O86 [5] in 2014, and a proposal was submitted for the implementation into the 2021 AWC Special Design Provisions for Wind and Seismic (SDPWS) [6]. In addition, design guides including detailing for midply shear walls are being jointly developed in collaboration with APA – The Engineered Wood Association.

To ensure broad acceptance and use of midply shear walls, comprehensive design information needs to be available. This gives confidence to designers to ensure a robust design. Currently, there is significant structural research available but no known fire test data specifically for midply shear walls. Fire research of midply walls would help to support code implementation of these shear walls; adoption of this technology will support broader acceptance of mid-rise residential and non-residential buildings.

2. OBJECTIVES

The objective of this research is to address a knowledge gap related to fire performance of midply shear walls. Testing has already been done to establish the structural performance of these assemblies. To ensure their safe implementation and their broad acceptance, this project will establish fire resistance ratings for midply shear walls. Fire tests will provide information for the development of design considerations for midply shear walls and confirm that they can achieve at least 1-hour fire-resistance ratings that are required for use in mid-rise buildings.

This research will support greater adoption of mid-rise residential and non-residential wood-frame construction and improve competition with similar buildings of noncombustible construction. This work will also support the development of the APA system report for midply walls, which will be a design guideline for using midply walls in North America.

3. TECHNICAL TEAM

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4. BACKGROUND

The midply shear wall was first developed in the 1990s by researchers from FPInnovations and the University of British Columbia. Testing has shown that midply walls possess approximately twice the lateral capacity of conventional wood shear walls. The midply wall was not formally recognized in the Canadian timber design standard, CSA O86 [5], until 2014 when design provisions first appeared in the standard.

These walls have already successfully been used in limited mid-rise projects in Canada and overseas. Some critiques of the original configuration were that the walls did not have sufficient vertical load capacity and were not able to accommodate services well. To address this, a new configuration has been developed which provides higher vertical load carrying capacity and is able to allow services to be installed in and pass through the assemblies. The new midply shear wall includes asymmetrical components, which are not commonly used in wood-frame construction. FPInnovations has already completed structural tests of the original and the new midply shear walls [3].

There is existing test data on the fire performance of light-frame wood walls, but there has not been any testing completed specifically on midply shear walls to date (on neither the original nor new configuration).

In fire testing, assemblies are always evaluated for fire resistance from their 'weaker' side, so for the new configuration it is unclear which side is the 'weaker' side.

4.1 Acoustic Testing

Acoustic testing was conducted by National Research Council Canada (NRC) on the original midply shear wall configuration during the mid-rise research consortium in 2014 [7]. Mid-rise residential buildings typically require an STC rating of at least 50. Four midply walls were tested, with and without cavity insulation to study the effects of the narrow cavities. Insulation was pulled apart to fit within the 38 mm deep cavities. A summary of the results is presented in Table 1.

Table 1. Results from NRC original midply acoustic tests [7]

	Original Midply Wall Details	STC
32W	• 2 x 12.7 mm thick Type X gypsum directly attached to both sides • 38 mm thick glass fibre insulation in cavities on both sides of the shear membrane	48
33W	Same as 32W but • Use resilient channel at 610 mm o.c. on one side of the frame to attach the two layers of the gypsum board	55
34W	Same as 33W but • Use resilient channels at 610 mm o.c. on both sides to attach the two layers of the gypsum board	57
35W	Same as 34W but without insulation	46

Their tests demonstrated that an STC rating of 50 is achieved when gypsum board is attached with resilient channels on at least one side of the wall and all cavities are filled with insulation (on both sides of the shear membrane). However, the inclusion of resilient channels can reduce fire-resistance rating and potentially shear capacity if the gypsum board is considered to provide shear resistance in the design.

5. METHODOLOGY

A series of four full-scale fire-resistance tests were completed on midply walls in accordance with CAN/ULC-S101 [8], this included the original and new midply wall configurations. One test was completed on the original configuration, and three full-scale fire tests were conducted on the new configuration. For the new configuration, two tests were completed to expose each side (A and B) to fire, since the design is not symmetrical (fire-resistance ratings are determined from the performance of the weakest side). The fourth test was a hose stream test on the new configuration. A follow-up intermediate scale test was conducted on the original configuration with internal thermocouples installed.

The tests included:

- Full-scale fire test: original midply configuration, unloaded.
- Full-scale fire test: new midply wall configuration, flatwise side exposed (Side A), loaded.
- Full-scale fire test: new midply wall configuration, edgewise studs exposed (Side B), loaded.

- Full-scale fire test: new midply wall configuration, hose stream test, perpendicular studs exposed (Side B), loaded.
- Intermediate-scale fire test: original midply wall configuration, unloaded.

The assemblies were constructed and tested at QAI Laboratories in Burnaby, BC.

5.1 Original Midply Wall Configuration

The original configuration of midply shear walls uses two rows of wood studs oriented flatwise (i.e., with the larger dimension of the cross-section parallel to the wall), with a layer of structural sheathing sandwiched in between.

Detailed design drawings can be found in Appendix A. In these tests 2x4 No. 2 & better SPF wood studs were used for the wall studs, and top and bottom plates. Studs were spaced 610 mm (24”) o.c. The sheathing was 12.7 mm (½”) OSB, with a 3 mm (1/8”) gap between each OSB board. A 12.7 mm (½”) gap was left between the OSB and the end studs and the top and bottom plates. The studs were nailed through the OSB with 89 mm (3.5”) nails every 100 mm (4”) along the studs.

One layer of 15.9 mm (5/8”) Type X gypsum board was installed vertically on both sides of the wall. Research has shown that gypsum board orientation (vertical or horizontal) has little impact on the fire resistance of wall assemblies [9]. One side of the gypsum board was attached directly to the studs using No. 6 (32 mm (1.25”) in length) Type W drywall screws vertically spaced 305 mm (12”) o.c. The other side, which was the exposed side during the test, was hung on 12.7 mm (½”) 24-gauge resilient metal channels spaced 610 mm (24”) o.c. The gypsum board on the exposed side was attached to No. 6 (25 mm (1”) in length) Type S drywall screws spaced 305 mm (12”) o.c. All gypsum joints were taped and mudded, and gypsum screw heads were mudded as well.

Based on previous acoustic tests, it was deemed necessary to include resilient channels in the tests. However, resilient channels are known to reduce the fire resistance of an assembly [10]. The reduction in fire resistance is attributed to creating unprotected vertical joints in the gypsum board on the fire exposed side; whereas when gypsum is directly applied to studs the gypsum board joints can be backed by the studs [11]. The gap created by the resilient channels also allows fire to move freely between cavities [11].

In the Component Additive Method (CAM) in the NBCC, the inclusion of a resilient channel beneath a single layer of gypsum board on load-bearing walls reduces the fire-resistance rating by 10 minutes (D-2.3.4. [1]). Resilient channels were therefore installed on the exposed side of the assembly.

R12 insulation was installed in the stud cavities on both sides. The insulation was pulled in half so that it would fit within the 38 mm (1 ½”) stud space. The intent was to fill the cavity 90% full of insulation so that it was not overfilled. The full dimensions of the wall were 3568 mm (144”) wide x 2743 mm (108”) tall. This wall was designed to be non-load bearing.

A cross-section of the assembly is shown in Figure 1; insulation is shown in pink and gypsum board in blue. The wall under construction, from the exposed side, before the installation of the gypsum board is shown in Figure 2.

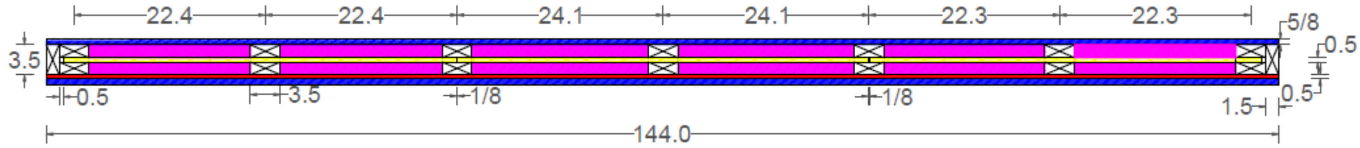

Figure 1. Cross-section of the original midply wall

Figure 2. Exposed side of original midply wall during construction

5.1.1 Intermediate-Scale Design

An intermediate-scale test was also conducted on the original midply wall configuration. This test included internal thermocouples throughout the assembly to assess temperatures within the wall. This wall measured 2032 mm wide (80”) x 1828 (72”) tall. Design drawings are provided in Appendix B.

Thermocouples were installed in a horizontal line at the centre of the assembly. They were placed at the centre of the wood studs beneath the gypsum board, on either side of the studs within the cavities, on the OSB face (on both the exposed and unexposed side), and in locations of the OSB joints, as demonstrated in Figure 3.

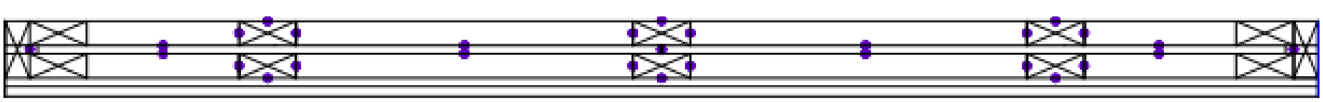

Figure 3. Thermocouple locations in midply tests

5.2 New Midply Wall Configuration

The new midply configuration consisted of flatwise studs on one side of sheathing and edgewise studs (same as a standard shear wall) on the other side of the sheathing, shown in Figure 4. The use of standard shear wall framing provides space to run services in the cavity as well as increases the overall load-bearing capacity of the wall.

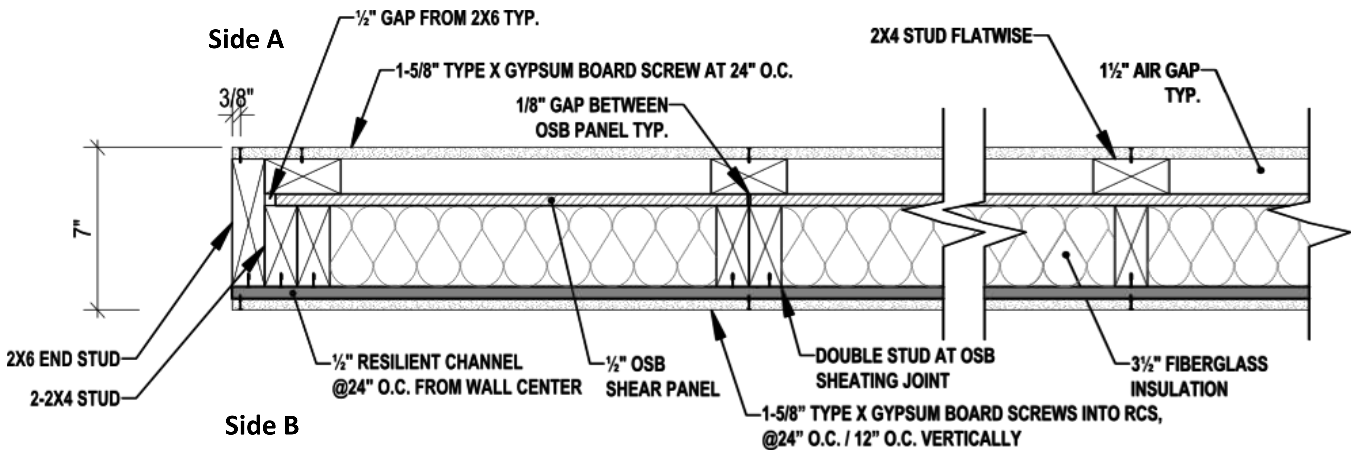

Figure 4. Cross-section of the new midply wall design

The intent of the tests was to achieve a 1-hour fire-resistance rating for the midply assemblies. Because there was limited existing data on the fire performance of midply walls, the design was modelled after an existing standard wood stud wall assembly, W3b in the Fire and Sound Tables in the NBCC [1], which is known to achieve a 45-minute rating in load-bearing applications and has an STC rating of 48. The W3b design uses nominal 2x4 (38 mm x 89 mm) studs spaced 600 mm o.c., with 89 mm insulation, resilient channels on one side spaced 600 mm o.c., and 15.9 mm Type X gypsum board.

Several aspects were considered in the design of the new midply wall for fire testing, including the intention to ensure the assemblies provided adequate fire resistance and acoustic performance. Mid-rise buildings typically require an STC of 50 for walls. Based on the existing acoustic testing from NRC [7], the new midply wall design is expected to perform acoustically better since it incorporates larger cavities on one side. Resilient channels were also included to improve the performance but are known to reduce fire performance.

For the midply wall, the addition of a wood sheathing layer and an additional row of studs was assessed to likely provide the additional 15 minutes to achieve the required fire-resistance rating. The second cavity was thought to likely increase the STC rating above 50. The addition of a shear membrane to regular wall assemblies has been shown to increase the fire resistance of assemblies; this may be due to additional stiffness, a reduction in deflection, or from the shear membrane providing protection to the studs (on the exposed side) [11].

Detailed design drawings can be found in the report in Appendix C. Nominal 2x4 No. 2 & better SPF wood studs were used for the interior vertical studs and top and bottom plate. The top plate, bottom plate, and end studs were nominal 2x6 No. 2 SPF was used for the capping plate and end stud to facilitate load transfer of lateral loads. Studs were spaced 610 mm (24”) o.c. The sheathing was 12.7 mm (½”) OSB, with a 3 mm (1/8”) gap between each board. A 12.7 mm (½”) gap was left between the OSB and the end studs as well as the top and bottom plates. The framing members were connected with power-driven common nails (89 mm (3.5”) in length and 3.33 mm (0.131”) in diameter).

One layer of 15.9 mm (5/8”) Type X gypsum board was vertically installed on both sides of the wall. One side of the gypsum board was attached directly to the studs using No. 6 (32 mm (1.25”) in length) Type W drywall screws vertically spaced 305 mm (12”) o.c. The other side, which was the exposed side during the test, was hung on 12.7 mm (1/2”) 24-gauge resilient metal channels spaced 610 mm (24”) o.c. The gypsum board on the exposed side was attached to No. 6 (25 mm (1”) in length) Type S drywall screws spaced 305 mm (12”) o.c. All gypsum joints were taped, and mudded and gypsum screw heads were mudded as well.

89 mm (3.5”) of R12 insulation was installed in the deeper stud cavity. The full dimensions of the wall were 3759 mm (148”) wide x 2540 mm (100”) tall. This wall was designed to be load-bearing (gravity loads). During the tests, a vertical load of 7.3 kN/m was applied (this equates to a total applied load of 14,695 lb). This load was conservatively calculated based on the structural capacity of edgewise studs (standard shear wall studs) alone, the flatwise studs were assumed to provide no capacity.

The unexposed side of the wall under construction (with the flatwise studs) is shown in Figure 5. The exposed side, before the installation of the gypsum board during construction is shown in Figure 6.

Figure 5. Unexposed side (flatwise studs) of new midply wall during construction

Figure 6. Exposed Side B of new midply wall during construction

Two tests were conducted. One with Side A exposed (flatwise studs) and the other with Side B exposed (as in the figure above, edgewise studs). Given that the edgewise studs are providing the load-bearing resistance of the new midply shear wall, it is deemed that Side A would provide a greater fire resistance since the studs will be shielded from fire exposure for a longer time when compared to Side B. Since the location of the resilient channels does not impact the STC rating, the resilient channel could be placed on either side of the assembly. Since resilient channels are known to reduce fire performance when they are on the exposed side of an assembly, the resilient channels were installed on the fire-exposed side in both tests.

6. RESULTS

6.1 Original Midply Wall

The full-scale original midply wall was tested on October 23rd, 2020. A test report was drafted by QAI Laboratories [12]. The test was virtually attended by FPInnovations staff. This specimen was not instrumented with internal thermocouples.

The test lasted for 1 hour 20 minutes. The test ended due to insulation failure; thermocouple TC6 (located near the top centre of the wall) on the unexposed side exceeded the CAN/ULC-S101 limit of an increase of 180 ^oC. The other nine thermocouples did not exceed 120 ^oC.

Around 1 hour into the test a dark spot started to form on the unexposed side of the assembly, shown in Figure 7. As the test progressed, the spot grew larger and other spots started to appear. These indicated increasing temperatures behind the gypsum board within the cavity and signalled that insulation failure was likely to occur. The exposed side of the assembly at the end of the test, before a hose stream was applied, is shown in Figure 8.

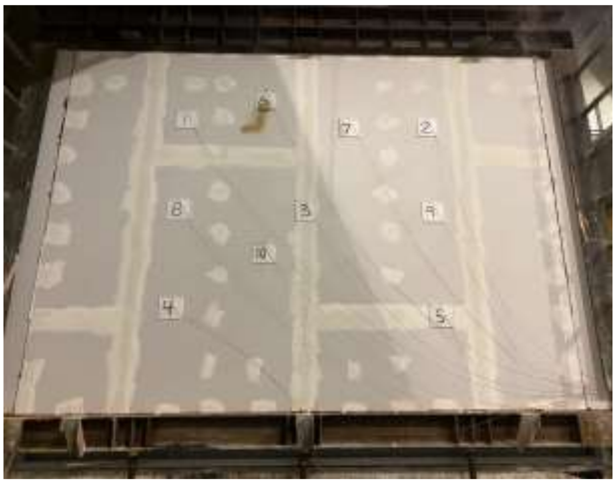

Figure 7. Unexposed side of the original midply wall after the test [12]

Figure 8. Exposed side of the original midply wall after the test [12]

6.1.1 Intermediate-Scale Test

A follow-up intermediate-scale test was completed on the original midply wall which included the installation of internal thermocouples. This test was completed on January 25th, 2021. The test ran for 1 hour 20 minutes, and it did not fail within this timeframe. The maximum temperature reached on the unexposed side was 120 ^oC, similar to the full-scale test.

A plot of the temperatures is shown in Figure 9. Thermocouples that were installed on the exposed side are depicted by a solid line, and thermocouples that were located on the unexposed side are depicted by dashed lines.

The data indicates that the studs on the exposed side began to char between 22 to 35 minutes, which is slightly faster than the expected encapsulation time for a single layer of 15.9 mm Type X gypsum board protection. The temperatures behind the gypsum, although some of the highest temperatures for the first 40 minutes of the test, did not rise past 700 ^oC. These thermocouples may have fallen off with gypsum board. In the full-scale test the gypsum was noted to start falling off around 40 minutes, which is consistent. The studs on the unexposed side began to char between 43 to 55 minutes, and the OSB face on the unexposed side began to char after 48 minutes. A summary of the average time that each type of thermocouple location began to char (based on a criterion on 300 ^oC) is presented in

Table 2.

A successful hose stream test, to be conducted after 30 minutes of fire exposure, is required on this assembly to achieve an official 1-hour fire-resistance rating.

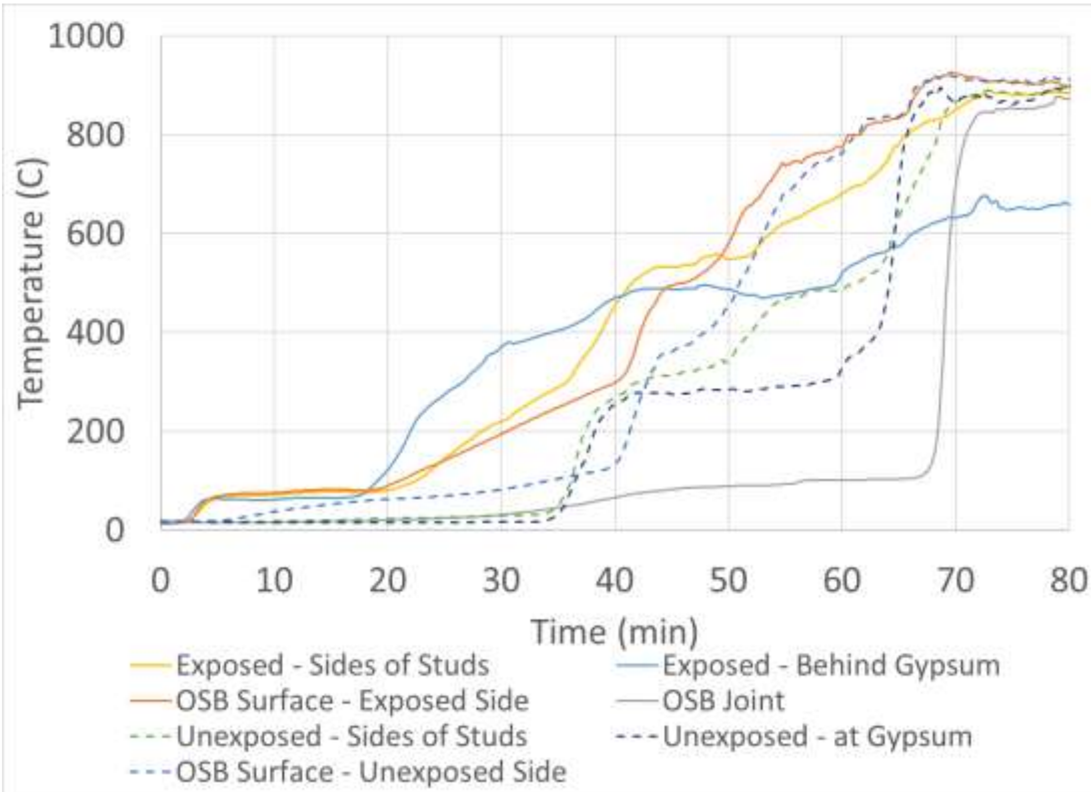

Figure 9. Internal thermocouple temperatures in original midply intermediate scale test

6.2 New Midply Wall

6.2.1 Side-A Exposed

The new midply wall, with the A side exposed, was tested on December 16th, 2020. The A side had flatwise studs as well as resilient channels on the fire exposed side. A test report was drafted by QAI Laboratories [13]. The test was attended by FPInnovations staff remotely.

The test ran for 1 hour 12 minutes, but insulation failure was detected using a roving thermocouple at 55 minutes (single point temperature rise exceeded 180 °C). All of the fixed unexposed thermocouples stayed below 100 °C, except for TC1 (located in the top left corner) which reached 160 °C at 1 hour 10 minutes. Around 54 minutes a dark spot started to develop on the gypsum board in the bottom left corner, as shown in Figure 10. Shortly after a second hot spot started to form near the bottom centre of the wall. The assembly after the test is shown in Figure 11.

Figure 10. New midply wall. Side A exposed. Locations of insulation failure [13]

Figure 11. New midply wall. Side A exposed. Assembly after the test [13]

A plot of the internal temperatures is presented in Figure 12. Thermocouples that were installed on the exposed side are depicted by solid lines and thermocouples that were located on the unexposed side are depicted by dashed lines.

The data indicates that the studs on the exposed side started to char between 27 to 30 minutes on the exposed side, again within the expected encapsulation time for a single layer of 15.9 mm Type X gypsum board protection. Gypsum began to fall off around 40 minutes, similar to the old midply wall test. The studs on the unexposed side began to char between 54 and 57 minutes. However, not all thermocouples reached 300 °C. The OSB surface on the unexposed side began to char after 42 minutes.

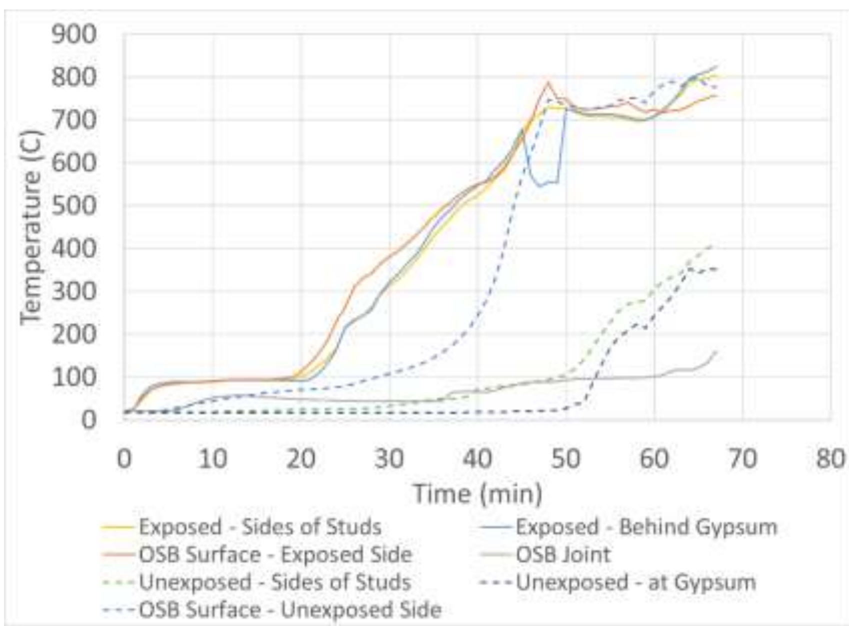

Figure 12. Internal thermocouple temperatures in new midply wall full-scale test. Side A exposed

6.2.2 Side B Exposed

The new midply wall, with Side B exposed, was tested on November 12th, 2020. Side B had the double studs and resilient channels on the fire exposed side. A test report was drafted by QAI Laboratories [14]. FPInnovations staff attended in person and remotely.

The test lasted for 1 hour 6 minutes. The test ended due to insulation failure; thermocouple TC2 (located near the top right corner of the wall) on the unexposed side exceeded the CAN/ULC-S101 limit of an increase of 180 °C. Just after 1 hour into the test a dark spot started to form on the unexposed side close to TC2. TC5 reached approximately 130 °C, and the other eight thermocouples did not exceed 100 °C. The wall after the test is shown in Figure 13 and after the hose stream test in Figure 14.

Figure 13. New midply wall. Side B exposed. After the test [14]

Figure 14. New midply wall. Side B exposed. After hose stream [14]

A plot of the internal temperatures is shown in Figure 15. The data indicates that the studs on the exposed side began to char between 24 to 46 minutes, which is faster than the expected encapsulation time for a single layer of 15.9 mm Type X gypsum board protection. The OSB surface beginning to char around 37 minutes. The studs on the unexposed side began to char around 60 minutes, but the face of the studs did not exceed 50 °C at any location. The OSB on the unexposed side began to char after 56 minutes. There was a lot of variability with the thermocouples on the OSB surface and the sides of studs on the exposed side, this was attributed to errors with the equipment.

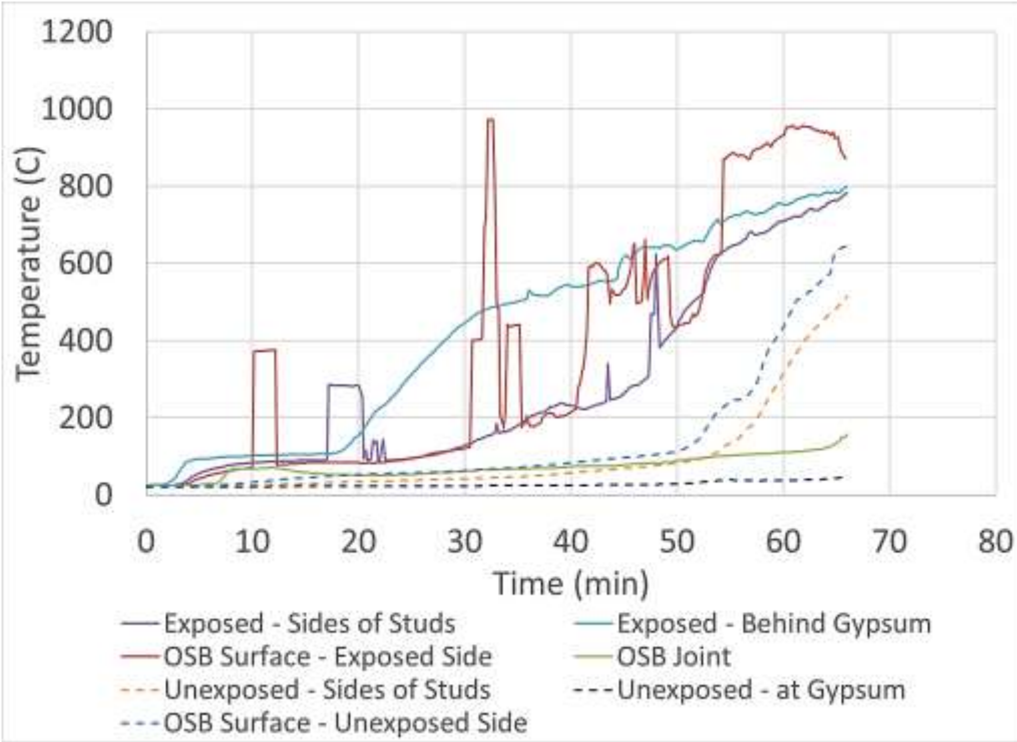

Figure 15. Internal thermocouple temperatures in new midply wall full-scale test. Side B exposed

6.2.3 Side B Exposed – Hose Stream

A hose stream test was conducted on January 15th, 2021. The new design assembly was built with Side B exposed to the fire. The assembly was exposed for 30 minutes and then subjected to a hose stream for 61 seconds. The wall passed the test with no through openings developing.

6.3 Onset of Charring

Table 2 summarizes the times at which different locations within the midply assemblies started to char. It should be noted that temperatures within the intermediate scale furnace can sometimes be higher than inside the full-scale furnace [15]. It is also possible that there may have been some size effects which impacted the results in the intermediate-scale test.

The thermocouples on the exposed side, located on the face of the studs, beneath the gypsum board, were generally the first to reach 300 ^{o}C in all three tests. In the new midply wall – Side A test temperatures within the cavity, on the sides of studs and on the OSB surface, began to char within 3 minutes of this. The new midply wall – Side A wall had no insulation within the exposed side cavity, whereas the other two tests did. For the original midply wall and new midply wall – Side B, the thermocouples in the cavities began charring between 12 to 22 minutes after the initial onset of charring on the face of the studs.

Table 2. Average Time to reach onset of charring (300 °C)

		Exposed Side (min)			Unexposed Side (min)			Average Final Temp. OSB Joints
		Stud Side	Stud Face	OSB Face	Stud Side	Stud Face	OSB Face	
Original	**Int. Scale**	35.6	22.6	41.0	53.4	55.1	48.2	879 °C
New – A	**Full Scale**	30.0	30.0	27.3	57.3[1]	54.0[2]	42.0	161 °C
New – B	**Full Scale**	46.4	24.8	36.9	60[1]	N/A	56.8	157 °C

[1] 1 TC did not reach 300 °C   [2] 2 TCs did not reach 300 °C

7. DISCUSSION

The failure times of each of the assemblies are summarized in Table 3. The original midply wall and the new midply wall (with Side B exposed) both achieved a 1-hour of fire resistance. The new midply wall (with Side B exposed) also passed a hose stream test. For the original wall to be assigned a fire-resistance rating, it must also undergo a hose stream test. For the new configuration, with the resilient channels on Side B, the Side A of the wall needs to be tested without resilient channels for a fire-resistance rating to be assigned.

Table 3. Failure times of midply wall assemblies

Configuration	Size	Applied Load	Failure Time	Type of Failure
Original midply wall	Full-scale	unloaded	1 hr 20 min	Insulation
Original midply wall	Intermediate-scale	unloaded	-[1]	-
New midply wall – Side A	Full-scale	7.3 kN/m	55 min	Insulation
New midply wall – Side B	Full-scale	7.3 kN/m	1 hr 6 min	Insulation

[1] 1 hour 20 minutes test duration, without failure

It is likely that the inclusion of insulation on the exposed side in the new midply wall – Side A test, may have prolonged the time to insulation failure so that the assembly would achieve a 1-hour rating. The insulation delayed the temperature increase in the cavity when compared to the original midply wall test; on the exposed side, the OSB face began to char 13 minutes later, and the sides of the studs began charring 5 minutes later.

Even though Side A failed in less than 1 hour, it was determined that Side B should be exposed to the hose stream since it is assumed that Side B is the weakest side due to the position of the perpendicular studs within the assembly. In practice, the wall would only require resilient channels on one side of the assembly. However, each assembly was tested with the resilient channels on the exposed side to represent a worst-case scenario and to allow flexibility for designers. Because Side A experienced insulation failed just shy of

1 hour, it is suggested that the cavity on the flatwise side be filled with insulation. This would improve the performance of Side A, likely to achieve a 1-hour rating. A subsequent test of Side A exposed to fire with cavity insulation and the resilient channels installed on the unexposed side (Side B) is recommended.

The resilient channels also negatively impacted the performance of the wall. Gypsum board was observed to start warping and pulling away from the studs early in the test. Reducing the spacing between resilient channels might improve this performance. However, it may negatively impact the sound insulation. Alternatively, more gypsum board layers could be added to improve fire performance.

8. CONCLUSION

The objective of this research was to address a knowledge gap related to fire performance of midply shear walls. Four full-scale and one intermediate-scale fire-resistance tests were completed on midply shear walls in BC. The assemblies were exposed to the CAN/ULC-S101 standard fire. The walls were instrumented with additional internal thermocouples to study the temperatures within the wall cavities.

The original midply wall configuration achieved 1 hour 20 minutes of fire resistance. This assembly requires a hose stream test be performed for an official rating.

The new midply wall configuration achieved 1 hour 6 minutes of fire resistance when exposed on Side B and successfully passed a hose stream test. When the assembly was exposed on Side A (with the resilient channel also placed on the exposed side) the assembly failure after 55 minutes. To improve the performance of this assembly insulation should be installed in all cavities to delay heat transfer. Additionally, the spacing between the resilient channels could be reduced to improve the gypsum board connection, or additional layers of gypsum board could be added. Acoustic testing is recommended to confirm that an STC of 50 can be reached with these assemblies.

This research should be shared with APA to support the development of the APA system report for midply walls.

9. REFERENCES

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[8] CAN/ULC-S101. Standard Methods of Fire Endurance Tests of Building Construction and Materials, Toronto, ON: Underwriters' Laboratories of Canada, 2014.

[9] A. Bwalya, M. Sultan and J. Thomas, "Impact of Board Orientation on the Fire Performance of Regular Gypsum Board Walls," National Research Council Canada, Ottawa, ON, 2007.

[10] M. A. Sultan and G. D. Lougheed, "Fire resistance of gypsum board wall assemblies," *Construction Technology Update. National Research Council Canada,* 1997.

[11] N. Bénichou, M. A. Sultan and V. K. R. Kodur, "Fire resistance performance of lightweight framed wall assemblies: effects of various parameters, key design considerations and numerical modelling," in *Fire and Materials. 8th International Conference*, 2003.

[12] Test Report No: T895-10A. FPInnovations wood mid-ply sheer wall identified as “Old mid-ply (A)”, Burnaby, BC: QAI Laboratories, 2020.

[13] Test Report No: T895-10C. FPInnovations Wood Mid-ply Shear Wall Identified as New Mid-ply (B), Side A Exposed., Burnaby, BC: QAI Laboratories, 2021.

[14] Test Report No: T895-10B. FPInnovations wood mid-ply shear wall identified as new mid-ply (B), Side B exposed., Burnaby, BC: QAI Laboratories, 2021.

[15] M. A. Sultan, Y. P. Séguin, J. C. Latour, P. Leroux and J. P. Henrie, "Intermediate-Scale Furnace: A New Fire Resistance Test Facility at the National Research Council Canada," National Research Council Canada, Ottawa, ON, 2006.

APPENDIX A

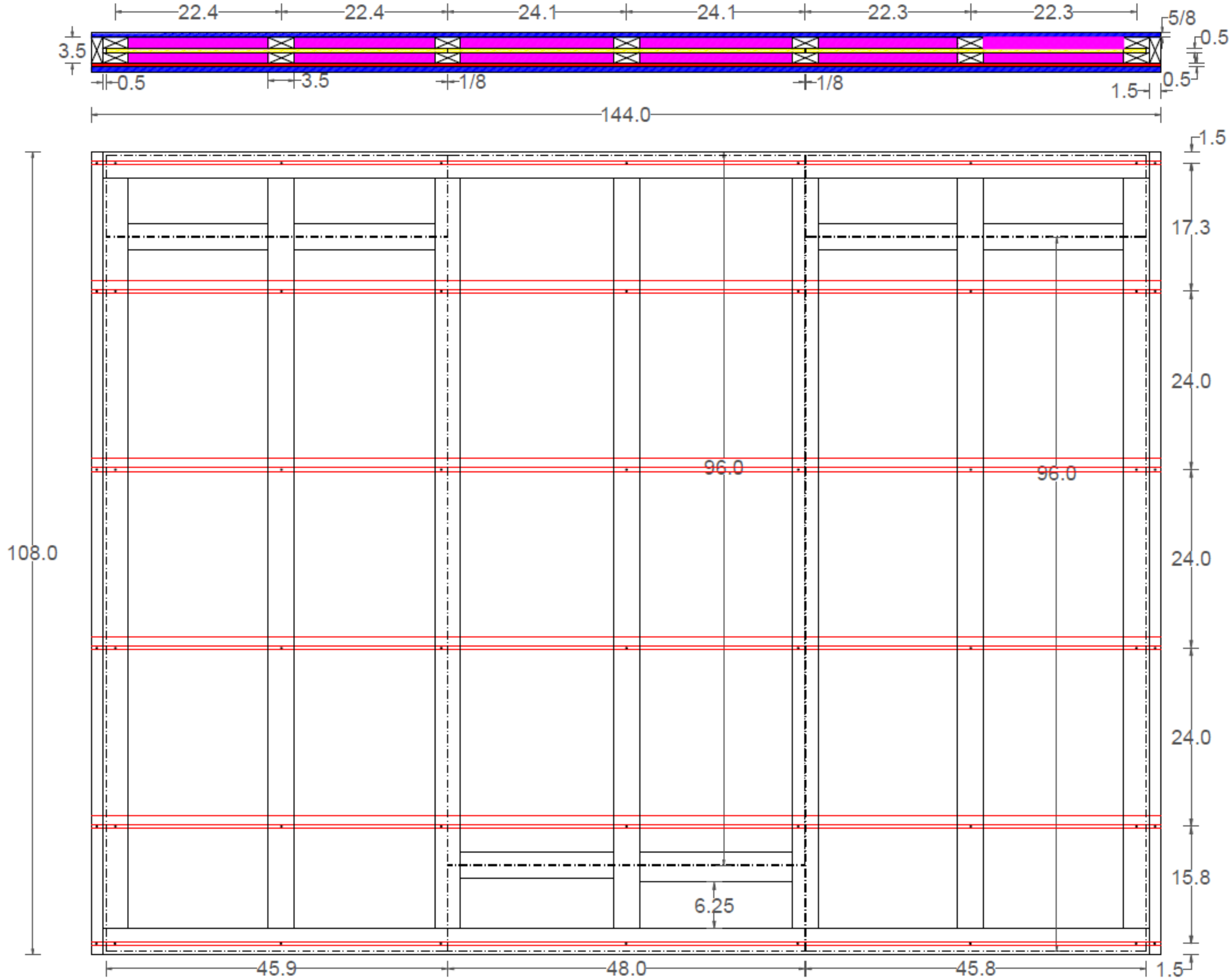
ORIGINAL MIDPLY WALL DRAWINGS

Original Midply Wall Fire Test Details

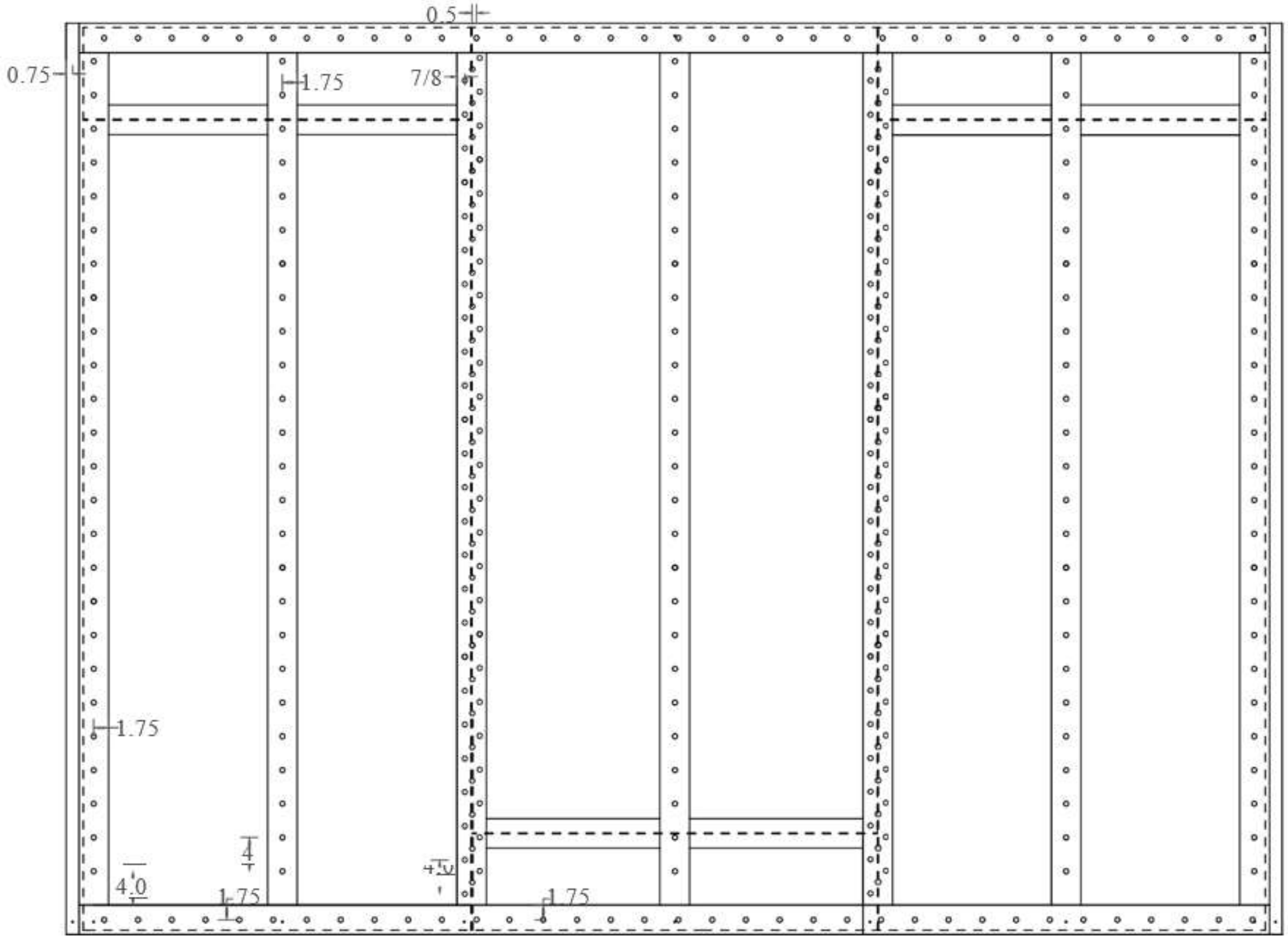
- Use 2x4 (No. 2 & Btr SPF) studs spaced roughly 24” o.c. flatwise
- Use 3 ½” 8d common nails to assembly studs
- ½” OSB sheathing sandwiched between framing
    - Provide a **½” gap** to outside edge of top plate and bottom plate, and end studs
    - **⅛” gap** between OSB shear panels
    - 4x8’ vertical OSB sheets, with a strip of 1’ high sheathing at the top. Stagger sheathing. 2x4 blocks where sheathing butts together.
- ½” resilient channels installed on exposed side. Spaced 24” o.c.
    - Use 1 ¼” Type W screws to install RCs to studs, spaced 24” o.c. into studs
    - Lowermost channel inverted
- 38 mm glass fibre insulation installed in cavities on both sides. Pull apart to match 1.5” depth
- One-layer 5/8” Type X gypsum board both sides
    - Use 1” Type S screws on exposed side, through gypsum into channel (do not screw into framing), 12” o.c.
    - Use 1 ¼” Type W screws to attach on unexposed side into studs, 24” o.c. in studs, 12” o.c. vertically
    - Screws 3/8” from the edge of gypsum boards
    - Mud and tape all gypsum board joints.
- This assembly will be unloaded
- All dimensions in inches

<u>Nailing Patterns</u>

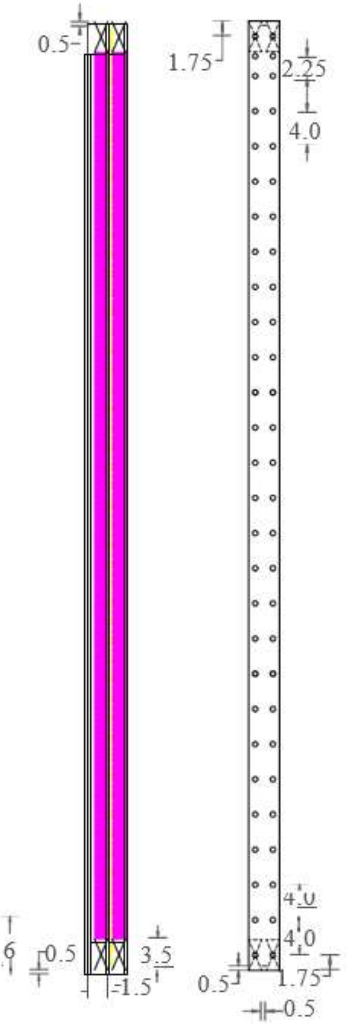
- End studs:
    - 3 ½” nails 4” o.c. in one line (through both studs and shear membrane)
- Flatwise 2x4 studs:
    - One row of 3 ½” nails (0.131” diameter) down centre, spaced 4” o.c. (through both studs and shear membrane)
- Studs above 1/8” OSB joints:
    - Three lines of 3 ½” nails (0.131” diameter) down centre, spaced 4” o.c.
    - Two lines offset from centre (penetrating studs and shear membrane), centre line within the 1/8” gap (between shear membrane panels, only penetrating studs)
- Keep nails a minimum of ½” away from OSB edges
- End Cap: Two rows of 3 ½” nails (0.131” diameter), 4” o.c.



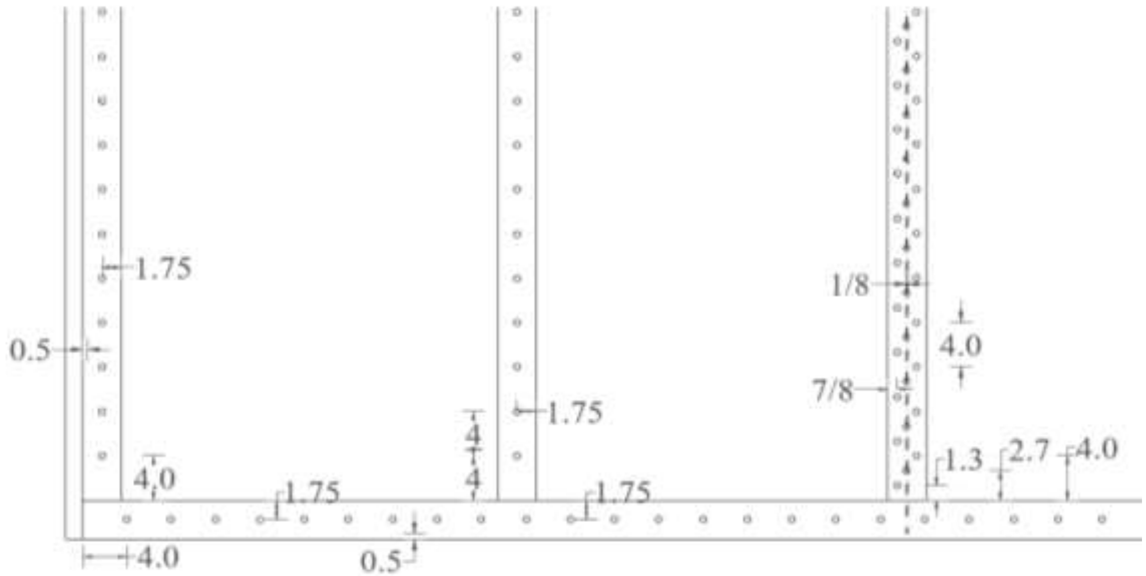
Original Midply Wall – Exposed Side Layout



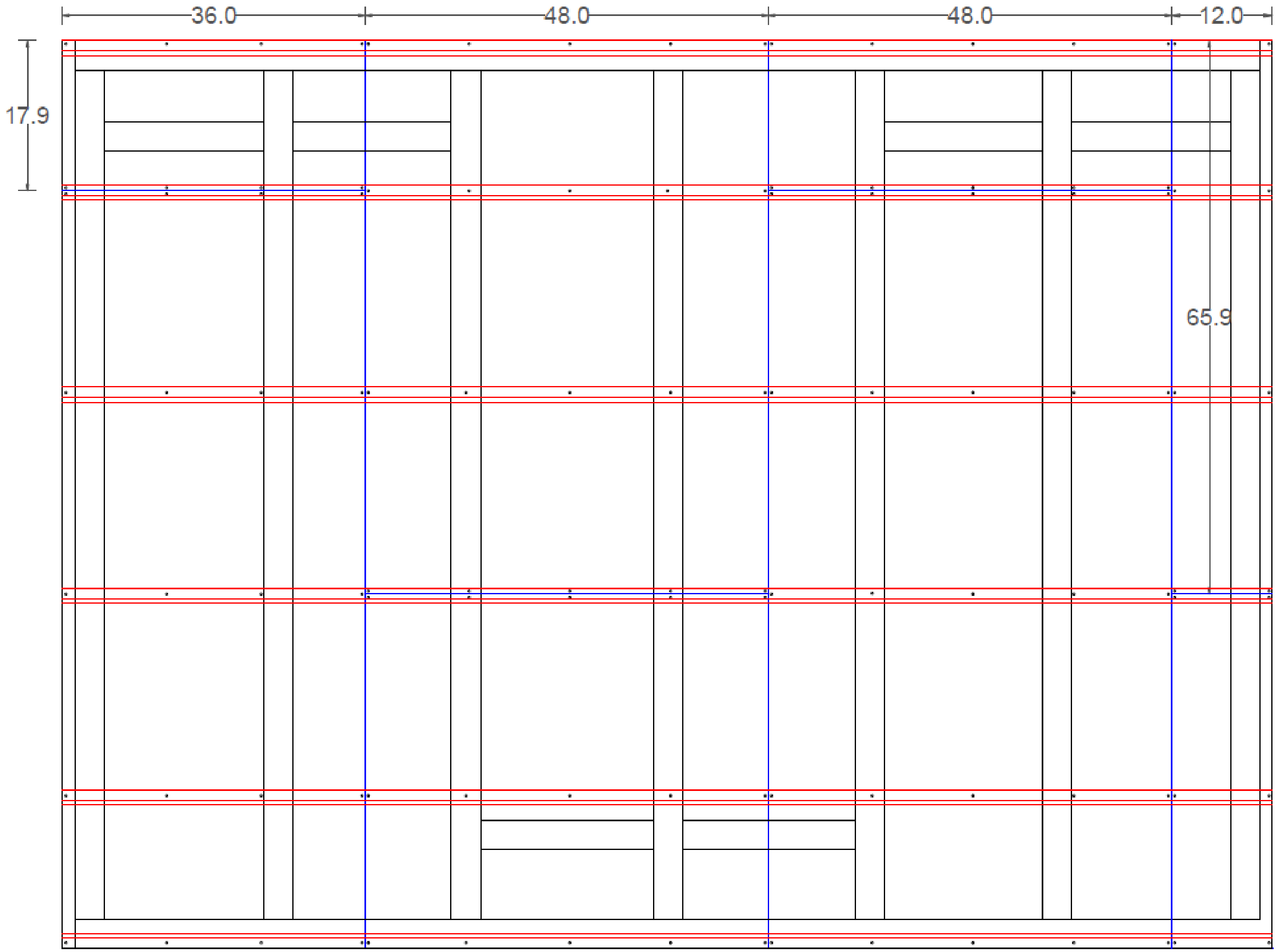
Stud Nailing Layout



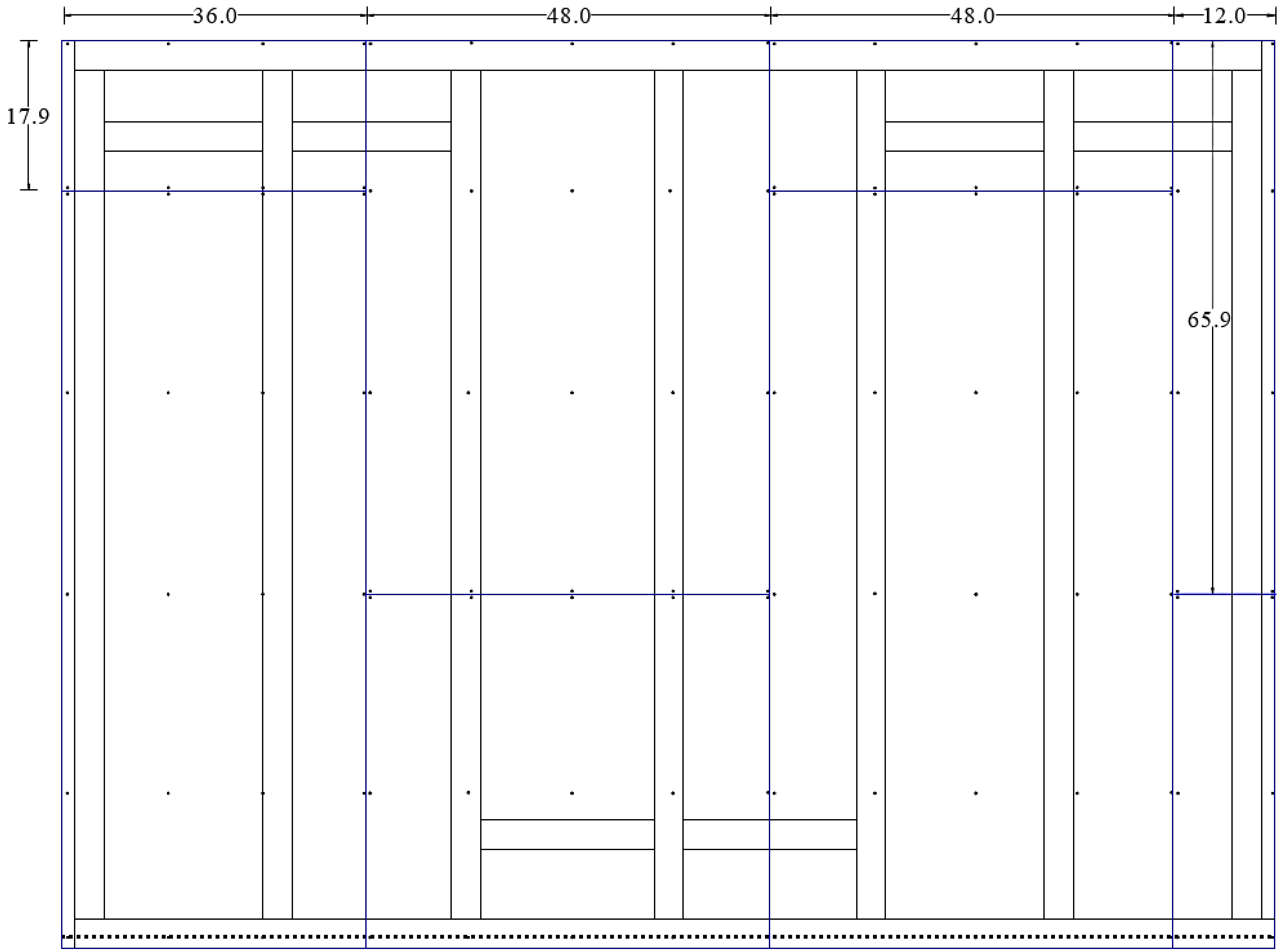
End Cap Cross-Section



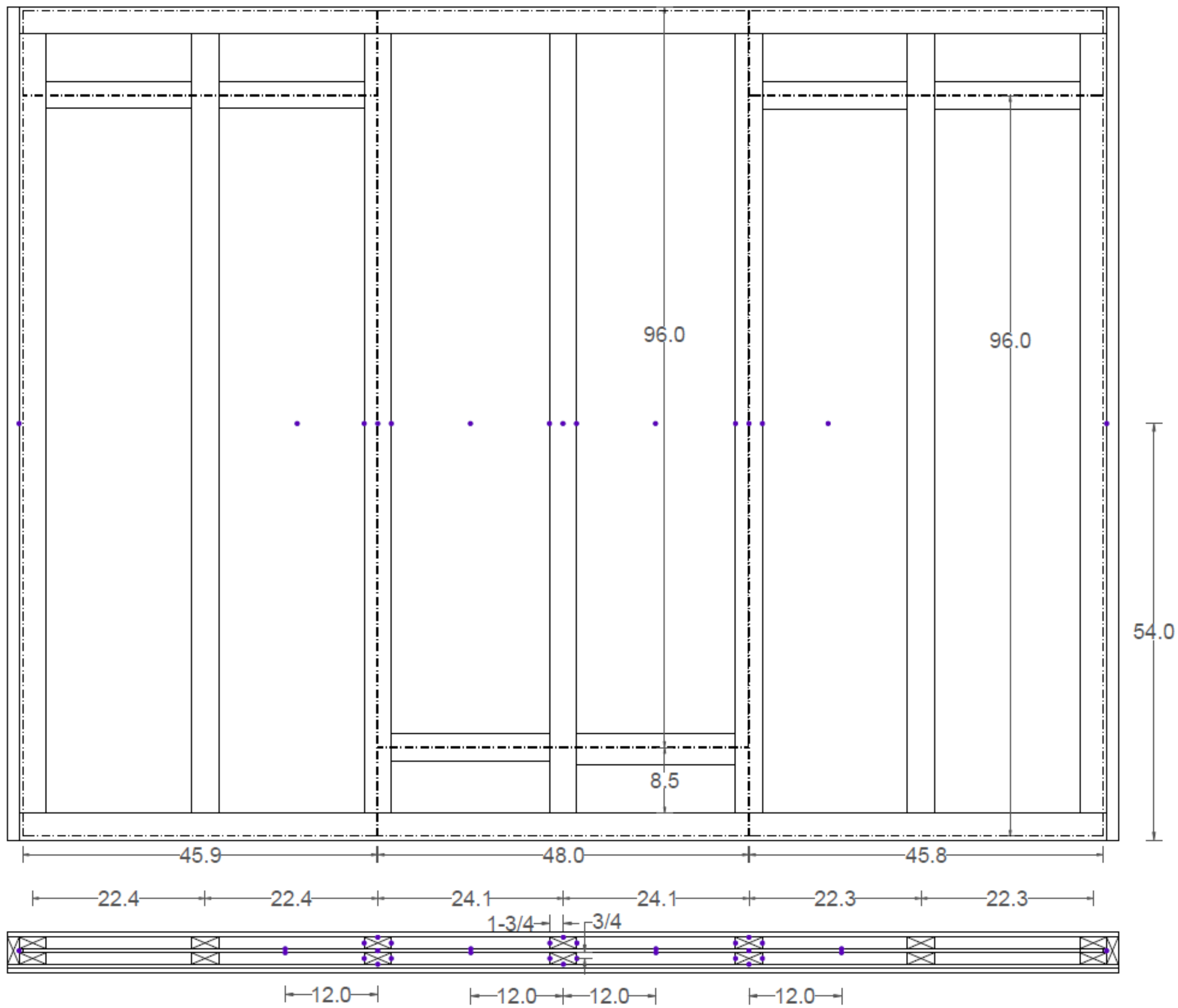
Original Midply Wall – Stud Nail Spacing



Original Midply Wall – Gypsum Layout Exposed Side



Original Midply Wall – Gypsum Layout Unexposed

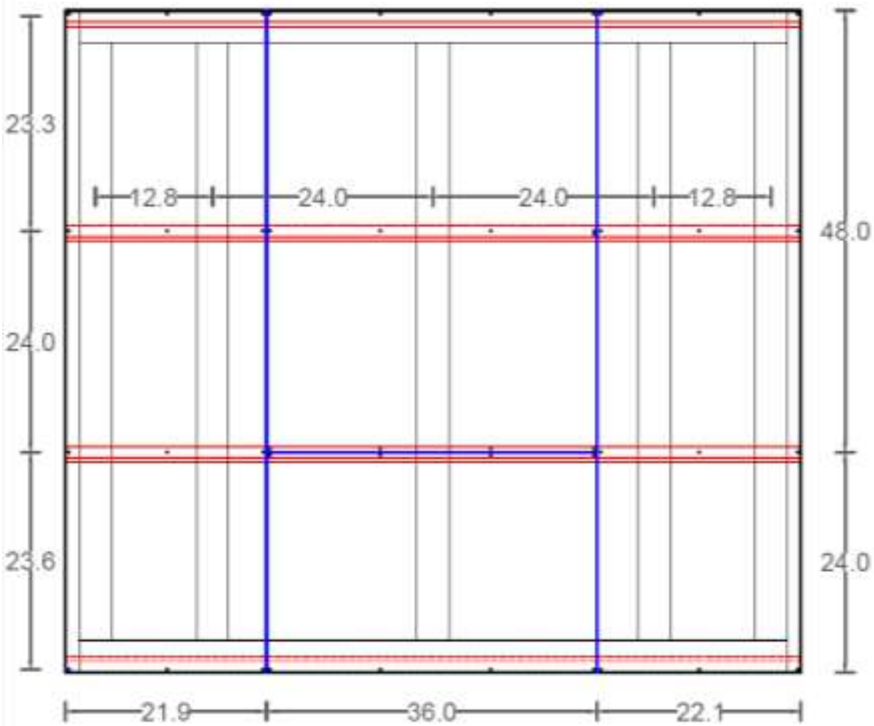


Original Midply Wall – Thermocouple Locations

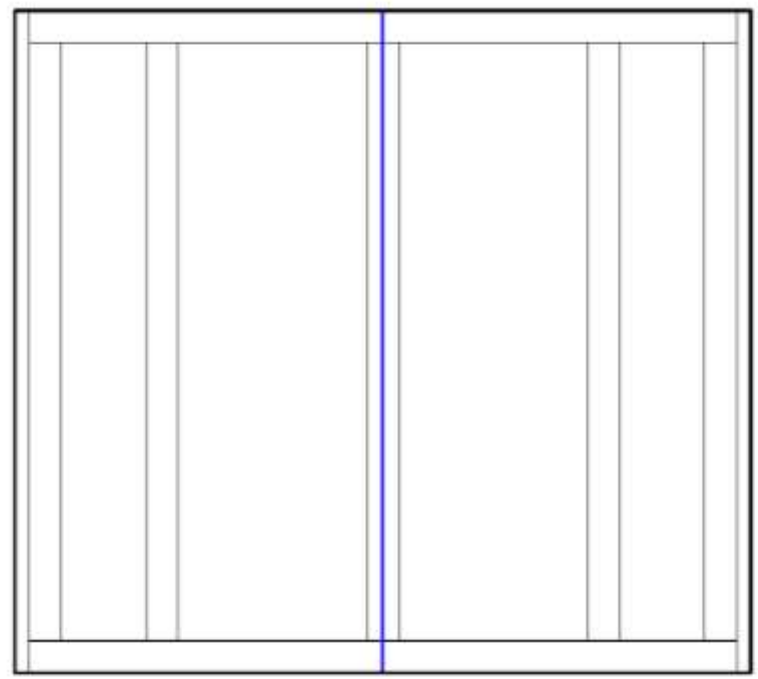
APPENDIX B

ORIGINAL MIDPLY WALL DRAWINGS

INTERMEDIATE SCALE TEST

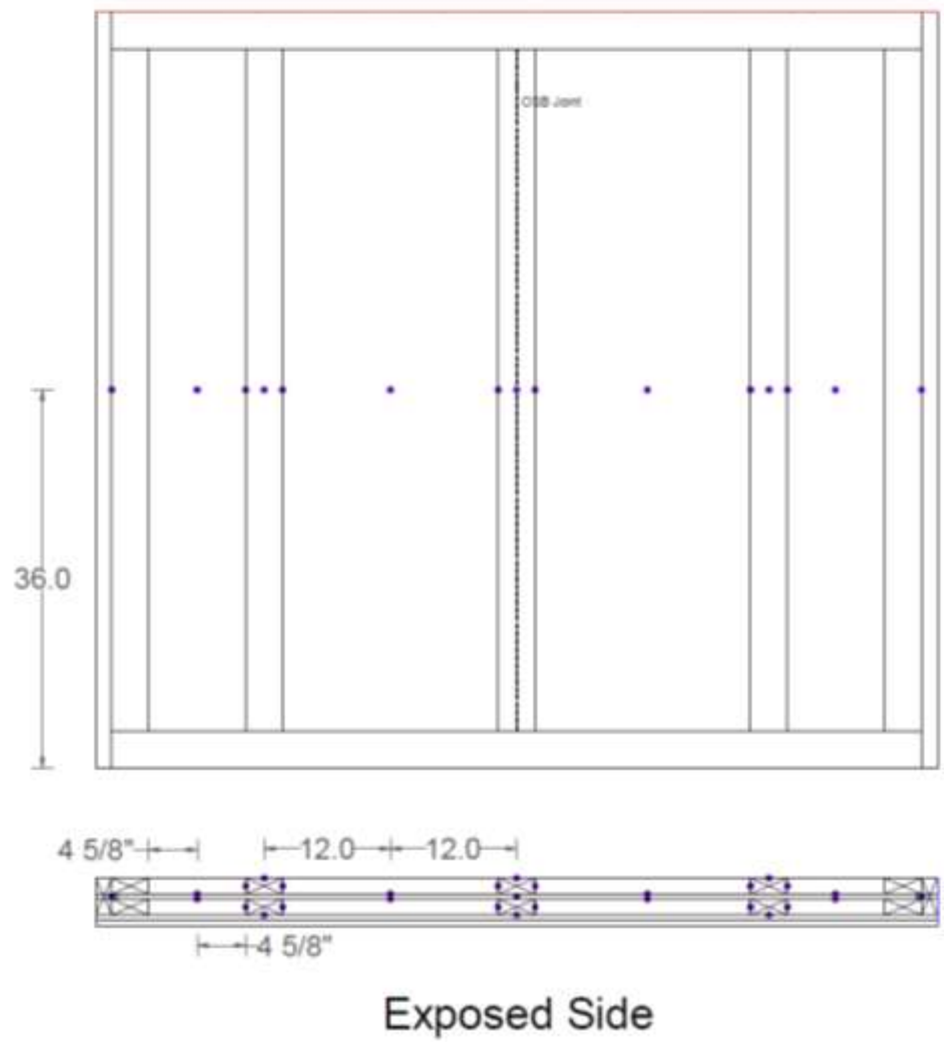


GB Layout Exposed Side



GB Layout Unexposed Side

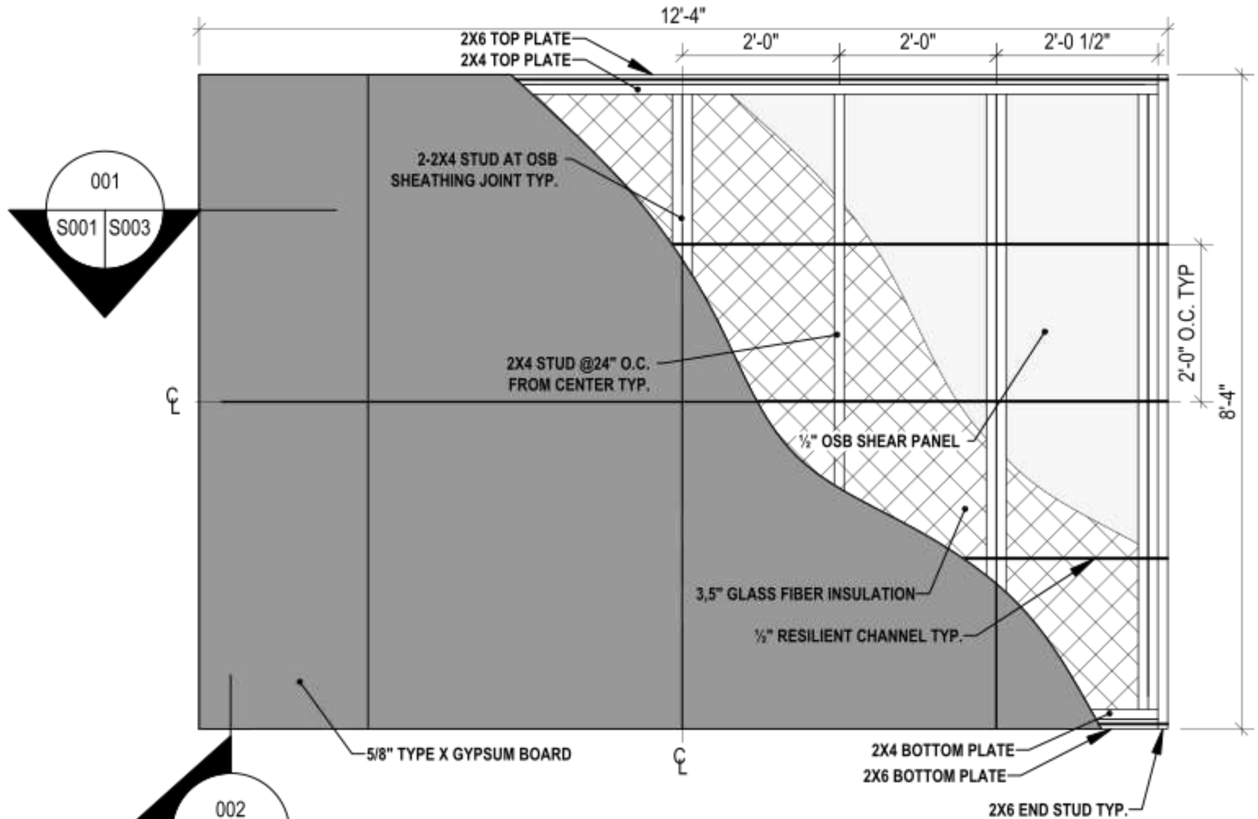
Intermediate-Scale Tests



Intermediate-Scale Thermocouple Layout

APPENDIX C

NEW MIDPLY WALL DRAWINGS



OVERALL WALL DESIGN - EXPOSED SIDE

SCALE ½"=1'-0"

NOTES:

- USE 10-2X4 (NO.2 & BTR SPF) STUDS SPACED ROUGHLY 24" O.C.
  - STUDS LENGTH : 94"
- USE POWER-DRIVEN 3 " COMMON NAILS 0.120"Ø TO ASSEMBLY STUDS
- ½" OSB SANDWICHED BETWEEN FRAMING (SHEATHING)
  - PROVIDE A ½" GAP TO OUTSIDE EDGE OF TOP PLATE AND BOTTOM PLATE, AND END STUDS
  - ⅛" GAP BETWEEN OSB SHEAR PANELS
  - 2-CENTER OSB BOARDS 48"X96"
  - 2-END OSB BOARDS 23 13/16"X96"
- USE 2X6 (NO.2 & BTR SPF) BOTTOM/TOP PLATE / END STUDS
  - 2-END STUDS LENGTH : 8'-4"
  - 2-TOP/BOTTOM PLATE LENGTH : 12'-1"
- USE 2X4 (NO.2 & BTR SPF) BOTTOM/TOP PLATE
  - 2-TOP/BOTTOM PLATE LENGTH : 12'-1"
- ½" RESILIENT CHANNELS(RCS) INSTALLED ON EXPOSED SIDE (STUDS IN STANDARD ORIENTATION)
  - SPACED 24" O.C.
  - LOWERMOST CHANNEL INVERTED
- 3.5" GLASS FIBER INSULATION INSTALLED ONLY ON DOUBLE STUD SIDE CAVITIES.
- SEE SKETCH S004/S005 FOR NAILING PATTERNS
- THIS ASSEMBLY WILL BE LOADED
- ALL DIMENSIONS IN INCHES

General notes

N°	Revision	By	App.	Date
01	ISSUED CONSTRUCTION	L.R.	C.N.	2020-10-26

		Date
Project no.	301014322	
Design by:	LINDSAY RANGER	2020-10-26
Revised by:	CHUN NI	2020-10-26
Approved by:	CHUN NI	2020-10-26
Drawn by:	PIER-LUC CÔTÉ	2020-10-26

Company name/address
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Project name/address
MIDPLY WALL
FIRE TEST DESIGN
OTTAWA

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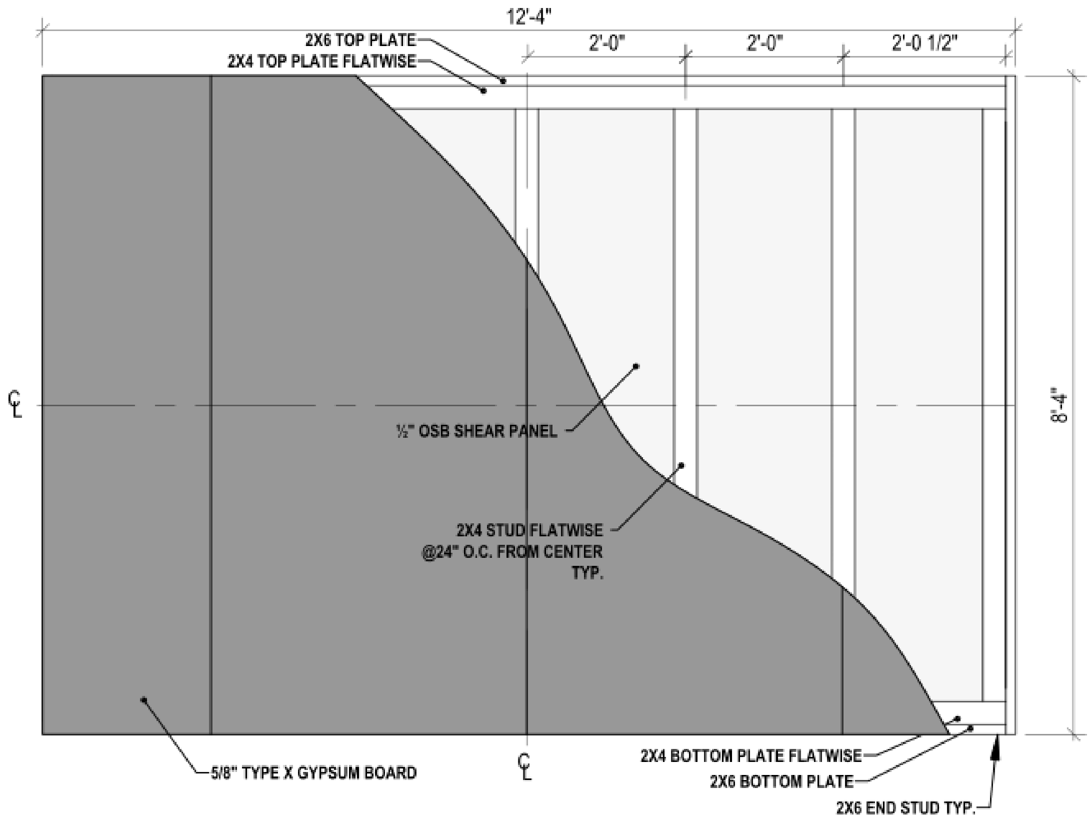
Sheet: S001	
Date: 2020-09-14	
Scale: AS DRAWN	



OVERALL WALL DESIGN -UNEXPOSED SIDE

SCALE ½"=1'-0"

NOTES:

- USE 7-2X4 (NO.2 & BTR SPF) STUDS SPACED ROUGHLY 24" O.C. FLAT WISE LENGTH 90"
- USE 2X4 FLATWISE (NO.2 & BTR SPF) BOTTOM/TOP PLATE
  - 2-TOP/BOTTOM PLATE LENGTH : 12'-1"
- USE POWER-DRIVEN 3 "COMMON NAILS 0.120"Ø TO ASSEMBLY STUDS
- (AS EXPOSED SIDE) ½" OSB SANDWICHED BETWEEN FRAMING (SHEATHING)
  - PROVIDE A ½" GAP TO OUTSIDE EDGE OF TOP PLATE AND BOTTOM PLATE, AND END STUDS
  - ⅛" GAP BETWEEN OSB SHEAR PANELS
- SEE SKETCH S004/S005 FOR NAILING PATTERNS
- THIS ASSEMBLY WILL BE LOADED
- ALL DIMENSIONS IN INCHES

General notes

N°	Révision	By	App.	Date
01	ISSUED CONSTRUCTION	L.R.	C.N.	2020-10-26

Project no.	301014322	Date
Design by:	LINDSAY RANGER	2020-10-26
Revised by:	CHUN NI	2020-10-26
Approuved by:	CHUN NI	2020-10-26
Drawn by:	PIER-LUC CÔTÉ	2020-10-26

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MIDPLY WALL
FIRE TEST DESIGN
OTTAWA

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Date: 2020-09-14	
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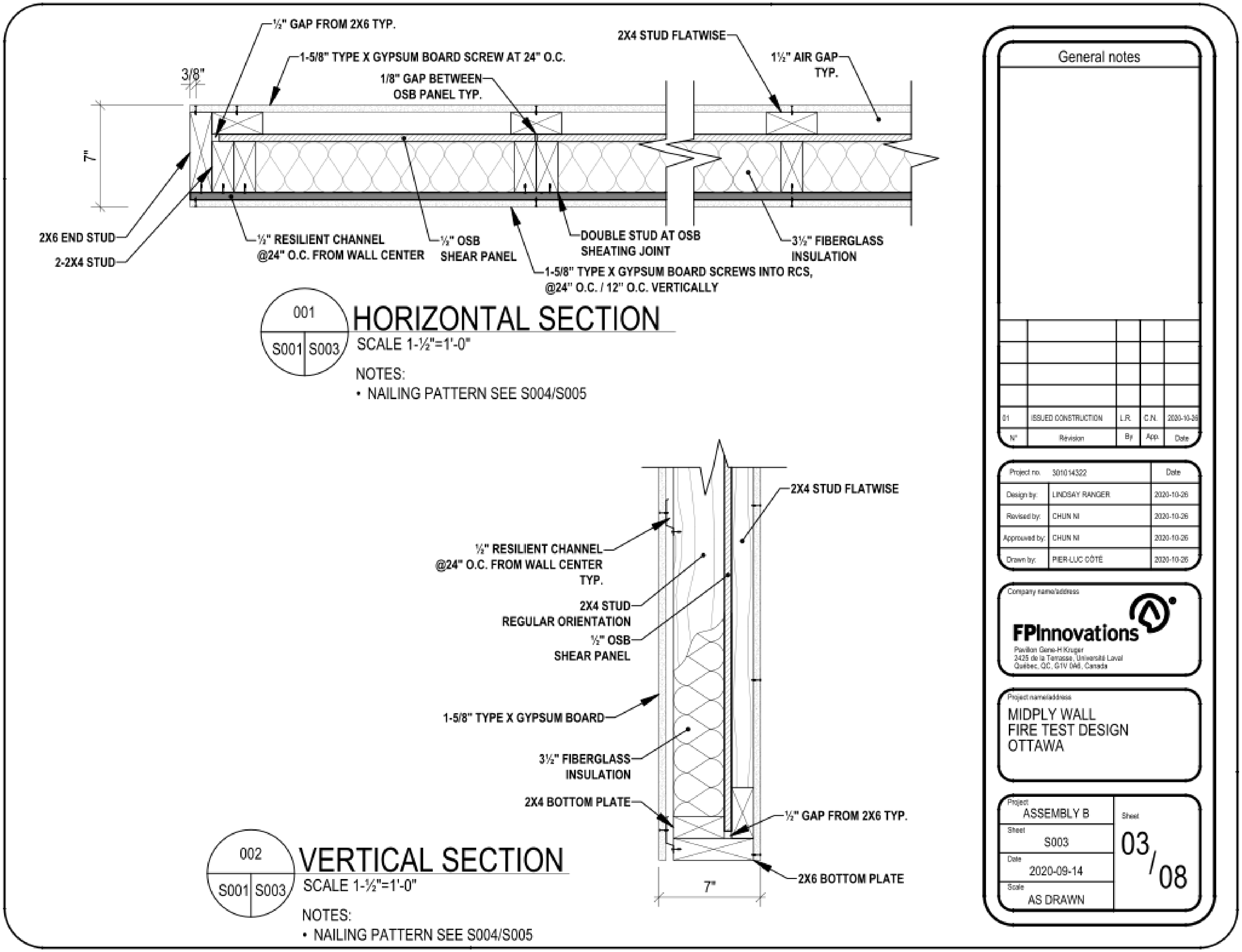

½" GAP FROM 2X6 TYP.
1-5/8" TYPE X GYPSUM BOARD SCREW AT 24" O.C.
3/8"
1/8" GAP BETWEEN OSB PANEL TYP.
2X4 STUD FLATWISE
1½" AIR GAP TYP.
7"
2X6 END STUD
2-2X4 STUD
½" RESILIENT CHANNEL @24" O.C. FROM WALL CENTER
½" OSB SHEAR PANEL
DOUBLE STUD AT OSB SHEATING JOINT
3½" FIBERGLASS INSULATION
1-5/8" TYPE X GYPSUM BOARD SCREWS INTO RCS, @24" O.C. / 12" O.C. VERTICALLY
001
S001 S003
HORIZONTAL SECTION
SCALE 1-½"=1'-0"
NOTES:
• NAILING PATTERN SEE S004/S005
2X4 STUD FLATWISE
½" RESILIENT CHANNEL @24" O.C. FROM WALL CENTER TYP.
2X4 STUD REGULAR ORIENTATION
½" OSB SHEAR PANEL
1-5/8" TYPE X GYPSUM BOARD
3½" FIBERGLASS INSULATION
2X4 BOTTOM PLATE
½" GAP FROM 2X6 TYP.
2X6 BOTTOM PLATE
7"
002
S001 S003
VERTICAL SECTION
SCALE 1-½"=1'-0"
NOTES:
• NAILING PATTERN SEE S004/S005
General notes
01 | ISSUED CONSTRUCTION | L.R. | C.N. | 2020-10-26
N° | Révision | By | App. | Date
Project no. 301014322 | Date
Design by: | LINDSAY RANGER | 2020-10-26
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OTTAWA
Project
ASSEMBLY B
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S003
Date
2020-09-14
Scale
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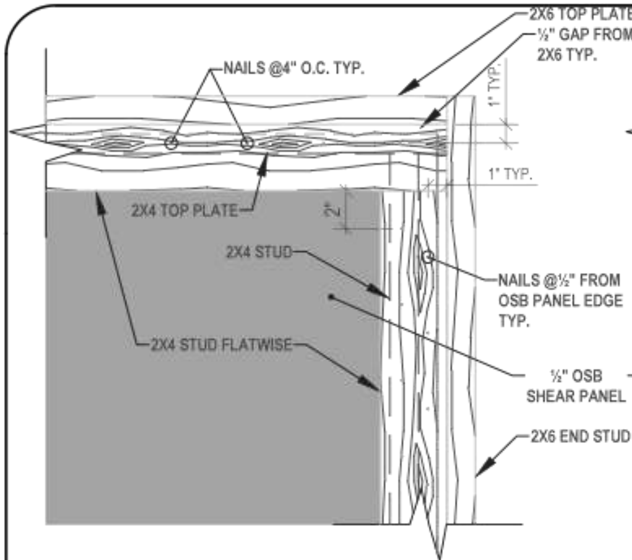
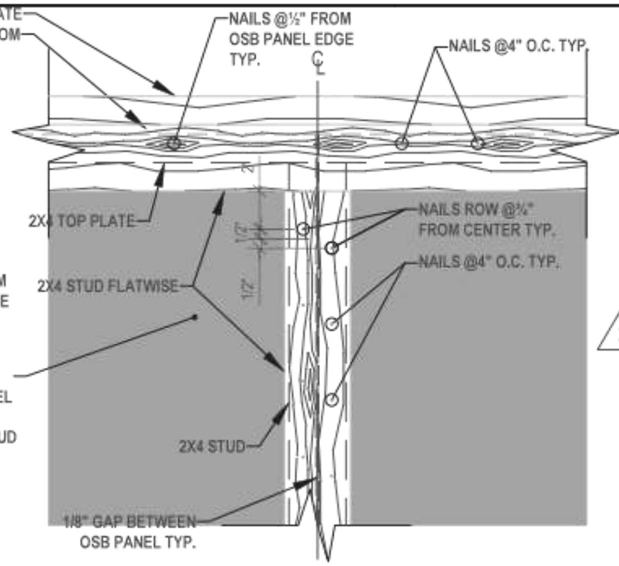
Sheet
03/08

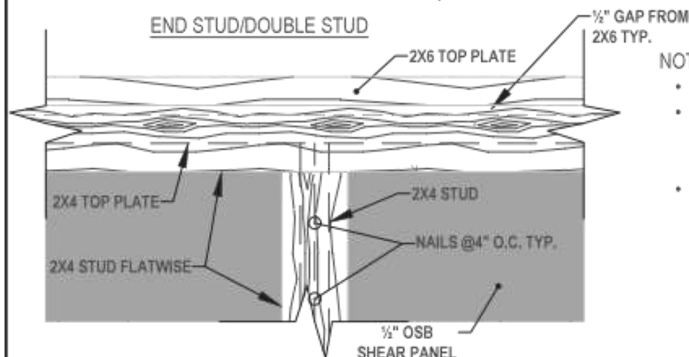


END STUD/DOUBLE STUD



OSB SHEATING JOINT

2



SINGLE STUD

NOTES:

- ENSURE ½" GAP FROM OSB TO EDGE OF FLATWISE STUDS
- END STUDS:
  - USE POWER-DRIVEN 3½"COMMON NAILS 0.131"Ø@ 4" O.C. IN ONE LINE (THROUGH BOTH STUDS AND SHEAR MEMBRANE)
- DOUBLE STUDS:
  - TWO ROWS OF POWER-DRIVEN 3½"COMMON NAILS 0.131"Ø@ 8" O.C. STAGGERED
  - TWO ROWS OF POWER-DRIVEN 3"COMMON NAILS 0.131"Ø@ 4" O.C. SPACED AT 1/3 THICKNESS OF STUD ALONG WIDE EDGE(3,5") OF DOUBLE STUDS TO HOLD DOUBLE STUDS TOGETHER 2
- FLATWISE 2X4 STUDS (SINGLE STUD):
  - ONE ROW OF POWER-DRIVEN 3½"COMMON NAILS 0.131"Ø DOWN CENTRE@ 4" O.C. (THROUGH BOTH STUDS AND SHEAR MEMBRANE)
- STUDS ABOVE OSB JOINTS:
  - THREE LINES OF POWER-DRIVEN 3½"COMMON NAILS 0.131"Ø DOWN CENTRE@ 4" O.C.
  - TWO LINES OFFSET FROM CENTRE (PENETRATING STUDS AND SHEAR MEMBRANE), CENTERLINE WITHIN THE 1/8" GAP (BETWEEN SHEAR MEMBRANE PANELS, ONLY PENETRATING STUDS)
- KEEP NAILS A MINIMUM OF ½" AWAY FROM OSB EDGES

BACKSIDE NAILING PATTERNS

SCALE 1-½"=1'-0"

General notes

N°	Revision	By	App.	Date
02	REVISION 1	L.R.	C.N.	2021-01-28
01	ISSUED CONSTRUCTION	L.R.	C.N.	2020-10-26

Project no.	301014322	Date
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Drawn by:	PIER-LUC CÔTÉ	2020-10-26

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MIDPLY WALL
FIRE TEST DESIGN
OTTAWA

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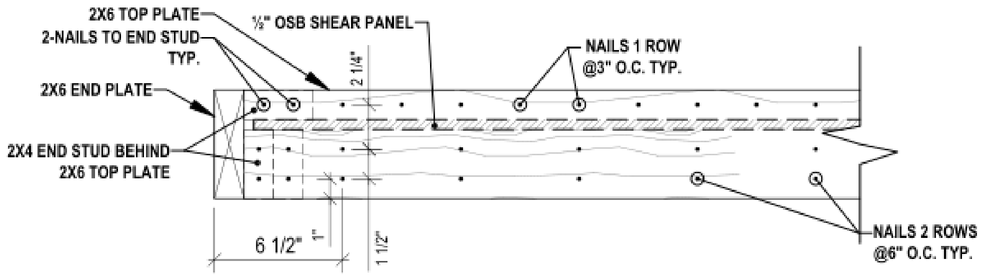
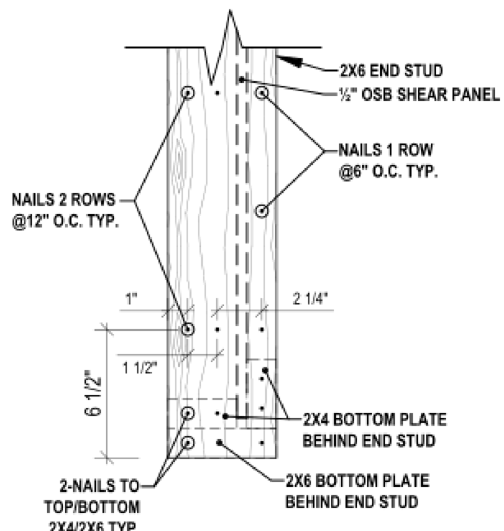
Sheet: S004	
Date: 2020-09-14	
Scale: AS DRAWN	



TOP/BELOW VIEW

NOTES:

- USE POWER-DRIVEN 3"COMMON NAILS 0.120"Ø
- 2X6 LUMBER END STUD
  - •• 3 ROWS OF NAILS
  - •• ONE ROW OF NAILS@ 6" O.C. CONNECTED TO THE SIDE OF FRAMING WHERE LUMBER WAS PLACED AT FLAT TO THE SHEATHING
  - •• TWO ROWS OF NAILS@ 12" O.C. CONNECTED TO THE OTHER SIDE OF FRAMING WHERE LUMBER WAS PLACED THE SAME AS WITH A REGULAR SHEAR WALL.
  - •• TWO NAILS CONNECTED TO TOP/BOTTOM PLATE AND END PLATE
- 2X6 LUMBER TOP AND BOTTOM PLATE
  - •• 3 ROWS OF NAILS
  - •• ONE ROW OF NAILS@ 3" O.C. CONNECTED TO THE FLATWISE 2X4 TOP/BOTTOM PLATE
  - •• TWO ROWS OF NAILS@ 6" O.C. CONNECTED TO THE 2X4 TOP/BOTTOM PLATE WHERE LUMBER WAS PLACED THE SAME AS WITH A REGULAR SHEAR WALL.
  - •• TWO NAILS TO 2X4 END STUD
- KEEP NAILS A MINIMUM OF ½" AWAY FROM OSB EDGES



SIDES VIEW

CAPPING PLATES NAILING PATTERNS

SCALE 1-½"=1'-0"

General notes

N°	Revision	By	App.	Date
01	ISSUED CONSTRUCTION	L.R.	C.N.	2020-10-26

Project no.	301014322	Date
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Drawn by:	PIER-LUC CÔTÉ	2020-10-26

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MIDPLY WALL
FIRE TEST DESIGN
OTTAWA

Project: ASSEMBLY B

Sheet: S005

Date: 2020-09-14

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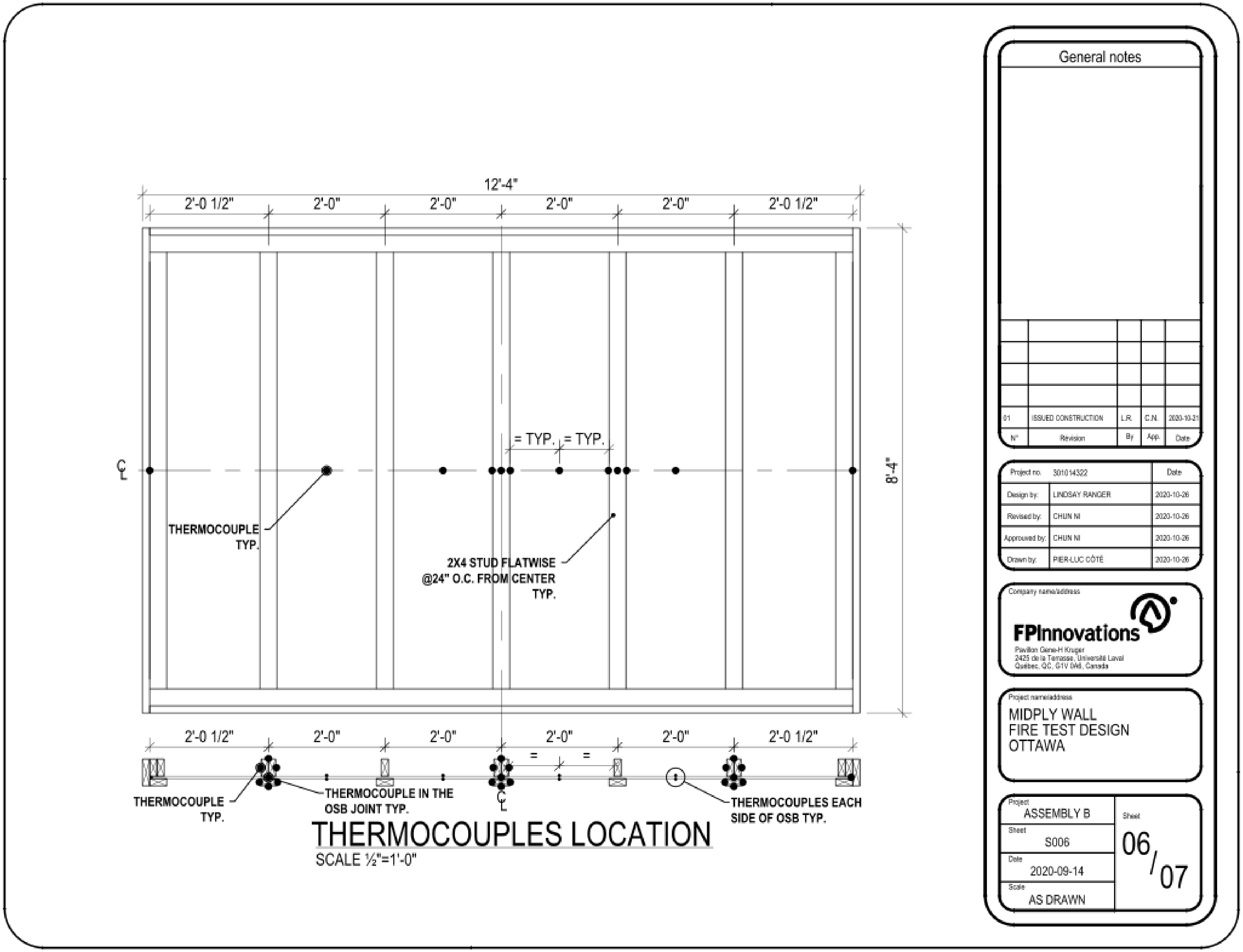
Sheet: 05/07


12'-4"
2'-0 1/2"
2'-0"
2'-0"
2'-0"
2'-0"
2'-0 1/2"
= TYP.
= TYP.
8'-4"
THERMOCOUPLE TYP.
2X4 STUD FLATWISE @24" O.C. FROM CENTER TYP.
THERMOCOUPLE TYP.
THERMOCOUPLE IN THE OSB JOINT TYP.
THERMOCOUPLES EACH SIDE OF OSB TYP.
THERMOCOUPLES LOCATION
SCALE ½"=1'-0"
General notes
01
ISSUED CONSTRUCTION
L.R.
C.N.
2020-10-31
N°
Revision
By
App.
Date
Project no.
301014322
Date
Design by:
LINDSAY RANGER
2020-10-26
Revised by:
CHUN NI
2020-10-26
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Project name/address
MIDPLY WALL
FIRE TEST DESIGN
OTTAWA
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2020-09-14
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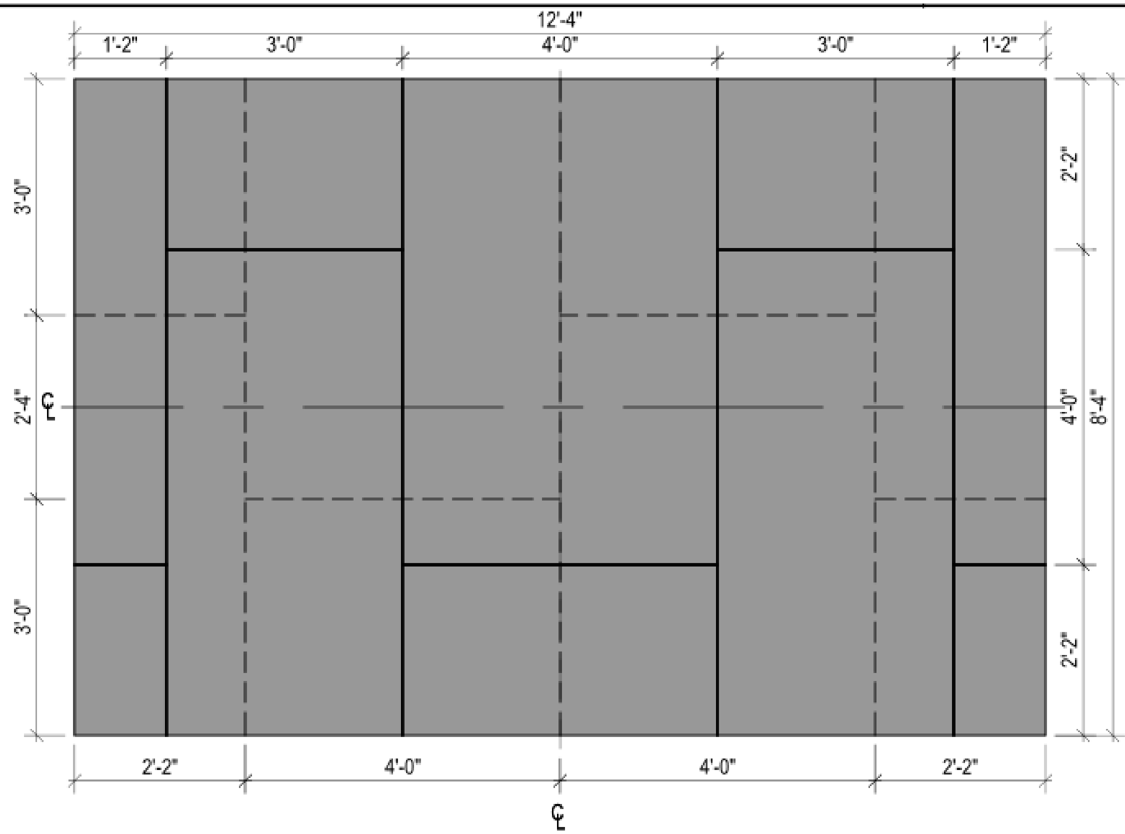

GYPSUM BOARD INSTALLATION

SCALE ½"=1'-0"

— — — UNEXPOSED SIDE GYPSUM BOARD HORIZONTAL AND VERTICAL JOINTS

——— EXPOSED SIDE GYPSUM BOARD HORIZONTAL AND VERTICAL JOINTS

NOTES:

- ONE-LAYER 5/8" TYPE X GYPSUM BOARD BOTH SIDES.
- UNEXPOSED SIDE
  - USE 1 ¼" TYPE W SCREWS TO ATTACH INTO STUDS, 24" O.C. IN STUDS, 12" O.C. VERTICALLY
  - SCREWS 3/8" FROM THE EDGE OF GYPSUM BOARDS
- EXPOSED SIDE
  - USE 1" TYPE S SCREWS, THROUGH GYPSUM INTO CHANNEL (DO NOT SCREW INTO FRAMING), @12" O.C.
  - USE 1 ¼" TYPE W SCREWS TO INSTALL RCS TO STUDS, SPACED 24" O.C. INTO STUDS
  - SCREWS 3/8" FROM THE EDGE OF GYPSUM BOARDS
- MUD AND TAPE ALL GYPSUM BOARD JOINT

General notes

N°	Revision	By	App.	Date
01	ISSUED CONSTRUCTION	L.R.	C.N.	2020-10-26

Project no.	301014322	Date
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Drawn by:	PIER-LUC CÔTÉ	2020-10-26

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Project name/address

MIDPLY WALL
FIRE TEST DESIGN
OTTAWA

Project: ASSEMBLY B

Sheet: S007

Date: 2020-09-14

Scale: AS DRAWN

Sheet: 07/07

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