info@fpinnovations.ca
www.fpinnovations.ca

FLAME SPREAD IN CONCEALED MASS TIMBER SPACES

REPORT TO FORESTRY INNOVATION INVESTMENT LTD.

Lindsay Ranger, P.Eng, M.A.Sc
Christian Dagenais, P. Eng., PhD.

March 31, 2020
PROJECT NO 301013624 – Floor Voids

Client: BC Forestry Innovation Investment
Suite 1200 – 1130 Pender Street West
Vancouver, B.C. V6E 4A4

Confidentiality Notice

FLAME SPREAD IN CONCEALED MASS TIMBER SPACES

PROJECT NO. 301013624 – FLOOR VOIDS

ACKNOWLEDGEMENTS

We would like to thank BC Forestry Innovation Investment Ltd. for funding this research. We would also like to thank GHL Consultants Ltd. for their valuable input and Underwriters Laboratories of Canada Inc. for conducting the tests.

AUTHORIZED BY:

Sylvain Gagnon, P.Eng.
Manager
Building Systems – Sustainable Construction
Sylvain.gagnon@fpinnovations.ca

REVIEWER

Christian Dagenais, P.Eng., PhD.
Senior Scientist
Building Systems – Sustainable Construction
Christian.dageanis@fpinnovations.ca

AUTHOR

Lindsay Ranger, P.Eng., M.A.Sc
Scientist
Building Systems – Sustainable Construction
343-292-6342
lindsay.ranger@fpinnovations.ca

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Urban densification and a desire for sustainability are helping to realize broader 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 occupancies. The success of the UBC Brock Commons tall wood building is further fueling a desire amongst developers to embrace the benefits of modern wood construction.

These timber buildings inherently contain significant concealed or void spaces to conceal services. A typical residential suite will have dropped ceilings to conceal the mechanical systems required to service bathrooms and kitchen equipment. Elsewhere in the building concealed spaces are required for mechanical systems and electrical systems, as well as to facilitate building geometry such as sloped roofs.

Further, in mid-rise buildings a new type of construction is evolving using mass timber floors with wood-frame walls with the mass timber exposed in the void spaces, as noted above, as well as elsewhere including over kitchens and bathrooms.

In many cases, wood elements cannot be left exposed in large and tall buildings; they are typically required to be protected with products such as gypsum board. A major factor driving these requirements relates to limiting flame spread and limiting the contribution of wood elements to fire growth and severity within a compartment. This unfortunately conceals the wood elements, preventing their natural aesthetic from being showcased.

These concealed or void space cases require installation of elements which represent additional material cost and labour. For wood buildings that rely heavily on prefabrication, these steps can have a significant impact on scheduling. Removing dependence on concrete and gypsum board in certain applications could make wood buildings more cost competitive to similar buildings of steel and concrete and could further enhance the benefits of prefabricated construction.

2. BACKGROUND

One advantage of mass timber construction is the reduction of concealed spaces within elements themselves, as compared to light frame construction. However, concealed spaces are still required to conceal unsightly building services (i.e. electrical, HVAC and plumbing services); one solution is to use a dropped ceiling which has the advantage of providing space for additional insulation to improve acoustic performance. The presence of insulation and a fire-rated dropped ceiling can improve the overall fire resistance of an assembly, if designed appropriately using fire-rated products. Another option is to design mass timber elements with intrinsic concealed spaces which can house building services, such as through hollow floor beams (hollow floor beams are used in Europe and will likely soon be used in North America, when supporting data become available).

Mass timber or encapsulated mass timber construction (EMTC) buildings will in many cases require sprinkler protection. The National Building Code of Canada (NBCC) [1] requires that sprinkler installation follow NFPA 13 [2]. NFPA 13 has certain exceptions where sprinklers are not required in wood assemblies, such as in concealed spaces not more than 150 mm (6 in.) deep (9.2.1.5 NFPA 13) or when surface protection is provided with a flame spread index (FSI) of 25 or less (9.2.1.11 NFPA 13). The details of these two clauses are provided below [2]. The

NBCC and NFPA 13 requirements for protection in concealed spaces are intended to limit flame spread and fire propagation.

9.2.1.5. *Concealed spaces formed by ceilings attached directly to or within 6 in. (150 mm) of wood joist or similar solid member construction shall not require sprinkler protection.*

9.2.1.11 *Concealed spaces where rigid materials are used and the exposed surfaces, in the form in which they are installed comply with one of the following shall not require sprinkler protection:*

1) The surface materials have a flame spread index (FSI) of 25 or less, and the materials have been demonstrated not to propagate fire more than 10.5 ft (3.2 m) when tested in accordance with ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials, extended for an additional 20 min.

2) The surface materials comply with the requirements of ASTM E2768, Standard Test Method for Extended Duration of Surface Burning Characteristics of Building Materials (30 min Tunnel Test).

FSI is determined in accordance with ASTM E84 [3]; the corresponding test method in Canada is CAN/ULC-S102 [4] to calculate flame rating (FSR). The two test methods are similar, but their results are not interchangeable. Generally, an FSI (ASTM E84) or an FSR (CAN/ULC-S102) of not more than 25 demonstrates that a product will propagate very limited flame, if any. The ASTM E84 and CAN/ULC-S102 tests run for 10 minutes; there is an additional ASTM E2768 [5] standard which specifies an ASTM E84 test that is extended for an additional 20 minutes.

A significant difference between these options is that 9.2.1.5 appears to be a function of the difficulty of installing sprinklers, notwithstanding this type of void space facilitates fire spread, whereas, 9.2.1.11 is a solution that inherently limits the spread of fire.

To sufficiently run services in buildings, 305-mm (12-in.) deep cavities are more practical than 150-mm cavities. In a mass timber building, cavities 305 mm deep would require sprinklers or the installation of protection (such as gypsum board) on the exposed wood surface, resulting in additional costs and additional labour.

FPInnovations has conducted some testing in the past to evaluate the FSR on different mass timber products, including CLT and NLT [6] [7], following CAN/ULC-S102. CLT and NLT both have FSRs between 30-55, which is less than many typical wood species (with FSRs around 150) [8]. FPInnovations has also done work in the past looking at flame spread in floor voids using light-frame construction and mass timber [9] [10]. The results from these tests, however, were somewhat inconclusive possibly due to experimental error and complex heat transfer processes within the cavities compared to standard FSR test procedures.

3. OBJECTIVES

The overall objective of this work is to expand options for designers of mass timber buildings by reducing the dependence on concrete and gypsum board though the demonstration of adequate fire performance of mass timber assemblies.

This work is intended to demonstrate that mass timber surfaces can be left exposed in concealed spaces, under certain conditions, while still performing well to control flame spread; this could result in significant savings in construction. Flame spread testing will be completed to compare the performance of mass timber assemblies and concealed space designs that are currently allowed by the NFPA 13 to be exempt from the installation of sprinklers.

Data is needed to support the use of exposed mass timber in concealed spaces by demonstrating limited flame spread in concealed mass timber void spaces. Flame spread testing has already shown that mass timber has lower flame spread ratings than typically found with thinner wood panels. This will lead the way in allowing unsprinklered 305 mm (12 in.) deep concealed spaces beneath mass timber assemblies or exposed mass timber in other concealed spaces such as hollow wood floor beams.

The goal is to generate data to support the use of exposed mass timber in concealed spaces. This data could be used in an Alternative Solution to gain approval for this type of design. Ultimately, this could lead to changing the NBCC to allow exposed mass timber in concealed spaces.

4. TECHNICAL TEAM

- Lindsay Ranger — Scientist, Building Systems, FPInnovations
- Christian Dagenais — Senior Scientist, Building Systems, FPInnovations
- Olivier Baes — Senior Technician, Building Systems, FPInnovations
- Pier-Luc Côté — Technician, Building Systems, FPInnovations
- Andrew Harmsworth — Principal, GHL Consultants Ltd.
- Matt Turco — GHL Consultants Ltd.

5. METHODOLOGY

The CAN/ULC-S102 test method evaluates flame spread under a very specific set of conditions. A series of six tests was conducted at Underwriters Laboratory of Canada (ULC) in Toronto (ON) using the CAN/ULC-S102 tunnel furnace and followed the test method as close as possible. The list of tests is presented in Table 1. The way the materials were tested did not strictly follow the CAN/ULC-S102 protocol. As an example, in tests where the additional material in the tunnel resulted in a smaller cross-sectional area, the pressure in the tunnel was reduced to try to recreate the same airflow as is used in CAN/ULC-S102.

The first three tests (Test 1-3) were intended to replicate wood-frame concealed space assemblies that would currently be permitted by NFPA 13 to be exempt from the installation of sprinklers. These served as establishing baseline allowable performance. Test 1 met the requirements of NFPA 13 – 9.2.1.11 with the surface materials having an FSI of 25 or less, and tests 2 and 3 met NFPA 13 – 9.2.1.5 having a cavity that was not more than 150 mm (6 in.) deep

Tests 4 and 5 were intended to replicate concealed spaces with exposed mass timber surfaces with a 305-mm (12-in.) deep cavity. 305-mm dropped ceilings typically are not sufficiently deep to install plumbing or heating systems. If the void space is greater than 305 mm, any wood surfaces would be required to be protected with a material having an FSI of not more than 25 (such as gypsum board), which represents extra material and installation cost.

Test 6 used an exposed mass timber surface but also included several building services that might be included in a concealed space. Test 6 was considered to be more explorative than tests 1 to 5 because of the introduction of several additional variables, which made it the least similar to the standard CAN/ULC-S102 of all the tests.

All the materials were conditioned to the CAN/ULC-S102 standard prior to the tests.

Table 1. Test Matrix

Test No.	Type	Cavity Depth	Description
1	Baseline test	290 mm	Light-frame construction meeting NFPA 13 – 9.2.1.11 All surfaces protected with FSR ≤ 25
2	Baseline test	130 mm	Light-frame construction meeting NFPA 13 – 9.2.1.5 Ceiling ≤ 150 mm from solid wood member construction
3	Baseline test	150 mm	Light-frame construction meeting NFPA 13 – 9.2.1.5 Ceiling ≤ 150 mm from wood joists
4	Targeted approval	290 mm	Exposed mass timber surface Type X gypsum on all other surfaces
5	Targeted approval	290 mm	Exposed mass timber surface Type X gypsum dropped ceiling
6	Targeted approval	305 mm	Exposed mass timber surface Type X gypsum ceiling Insulation and replicated building services within cavity

The following sections provide details on each of the assembly designs.

5.1 Test 1

For test 1, the 7,315-mm (24-ft) long tunnel had 12.7-mm (½-in.) plywood protected by 19-mm (¾-in.) acoustic ceiling tiles with a FSR and FSI of not more than 25 [11]. The ceiling tiles were T-bar type acoustic ceiling tiles that are common in most commercial buildings. The plywood pieces were 2,435 mm (8 ft) long, and the ceiling tiles were 1,219 mm (4 ft) long; both 500 mm (20 in.) wide. The other three surfaces of the tunnel, i.e. the two walls and the floor, were also lined with the same ceiling tiles. The tiles on the base of the tunnel were cut to 448 mm (17 5/8 in.), the tiles on the wall where there was no window were cut to 280 mm (11 in.), and the wall side with the windows pieces were 100 mm (4 in.). The flame spread test is a visual test that evaluates how quickly flames move down the tunnel under specific test conditions, so it was necessary to not block the windows. The setup is shown in Figure 1, and the tunnel during construction is shown in Figure 2. A side view of the ceiling tiles is shown in Figure 3.

This configuration was designed to be essentially compliant with NFPA 13 - 9.2.1.11, for which sprinklers would be exempt. The intent was to run the test for an additional 20 minutes. The ceiling tiles met the ASTM E84 and CAN/ULC-S102 requirements of having an FSI of not more than 25 [11], but there is no data on their performance in an extended 30-minute test. The goal was to create a 305-mm (12-in.) deep cavity. However, with the inclusion of the gypsum board on the floor of the tunnel, the maximum depth was 290 mm (11 ½ in.).

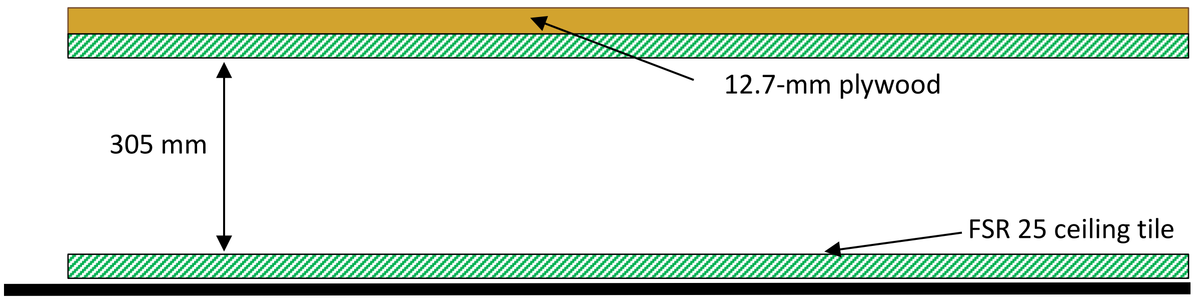


Figure 1. Test 1 setup. NFPA 13 - 9.2.1.11 compliant. Ceiling tiles line three sides of tunnel.

Figure 2. Test 1 during construction

Figure 3. Ceiling tiles with FSR of not more than 25

5.2 Test 2

Test 2 was designed to be compliant with NFPA 13 - 9.2.1.5, for which sprinklers would be exempt. A concealed space of 130 mm (5 1/8 in.) was formed between 12.7-mm (½-in.) plywood and 19-mm (¾-in.) acoustic ceiling tiles with an FSI/FSR of not more than 25. The ceiling tiles on the floor of the tunnel were supported by mineral wool insulation. Ceiling tiles were also placed along the wall with no windows (a total of two surfaces were covered); the windows were partially blocked by the assembly, leaving no room for ceiling tiles on that side. Once all the materials were in place the depth of the cavity was 127 mm (5 in.). The test setup is shown in Figure 4, and the tunnel under construction is shown in Figure 5.

To ensure that flames did not propagate beneath the ceiling tiles, two pieces of Type C gypsum board (305 mm and 610 mm in length) were used to transition from the base of the tunnel to the height of the ceiling tiles above the mineral wool insulation (placed on an angle).

The pressure in the tunnel was reduced to attempt to recreate the same airflow as is used in CAN/ULC-S102 since the additional material in the tunnel resulted in a smaller cross-sectional area. The standard requires that the control damper be adjusted so that the average air velocity is 1.2 m/s +/- 0.025 m/s (a range of 231 to 241 ft/min) as recorded by a velocity transducer at seven points [4].

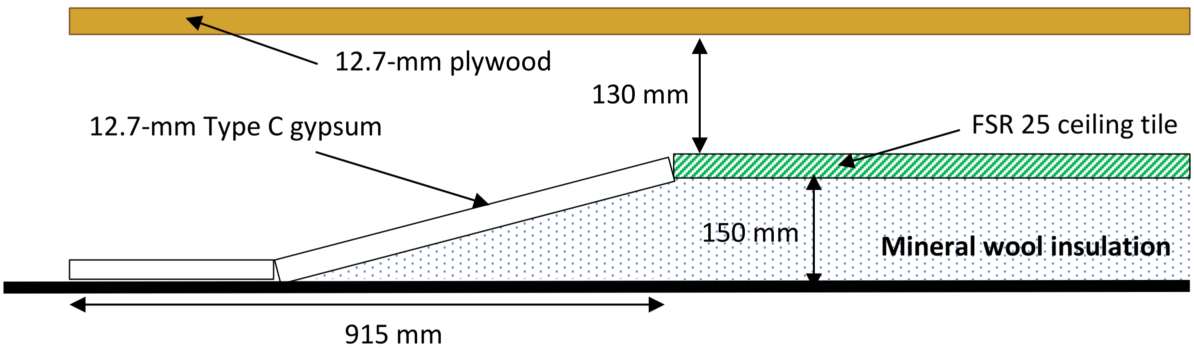


Figure 4. Test 2 setup. NFPA 13 - 9.2.1.5 compliant. Ceiling tiles line one wall and floor.

Figure 5. Test 2 during construction

5.3 Test 3

Test 3 was designed to also be compliant with NFPA 13 9.2.1.5 where a ceiling is within 150 mm (6 in.) of wood joists. 2 x 6 lumber, to replicate joists, were cut into 430-mm (17-in.) pieces and screwed into 500 mm wide 12.7-mm (½-in.) plywood; this way the plywood rested on top of the tunnel, and the joists fit inside the cavity. Boards were spaced at 405-mm (16-in.) intervals. The first joist started 405 mm down the tunnel. 19-mm (¾-in.) acoustic ceiling tiles lined the floor of the tunnel and the two walls (the height of the boards under the windows on one side was 120 mm and up to the height of the joists on the other, 150 mm). The test setup is shown in

Figure 6, construction of the wood components is shown in Figure 7, and construction in the tunnel is shown in Figure 8.

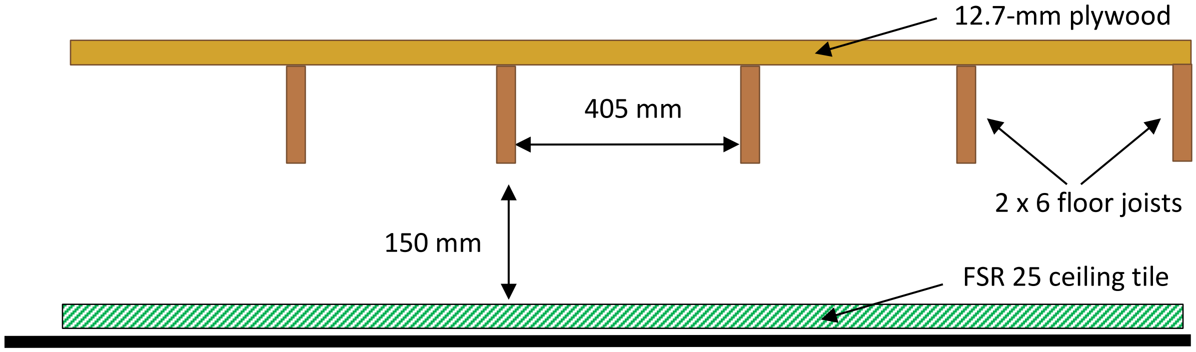


Figure 6. Test 3 setup. NFPA 13 - 9.2.1.5 compliant. Ceiling tiles line two sides of tunnel.

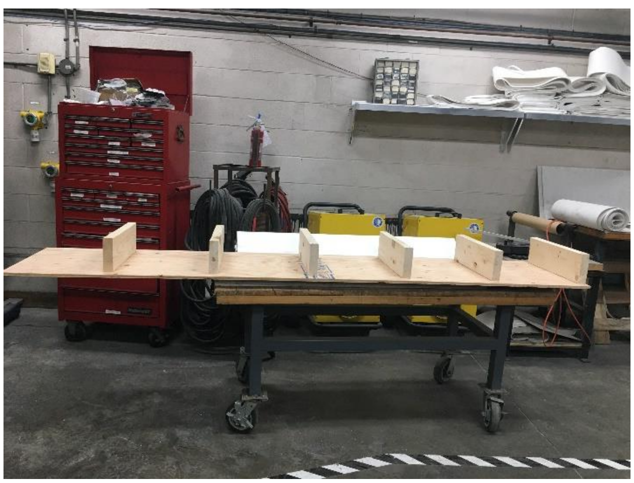


Figure 7. Test 3 wood assembly

Figure 8. Test 3 preparations in the tunnel

5.4 Test 4

Tests 4 to 6 were designed to represent a concealed space with an exposed mass timber surface. In all three tests a replicated mass timber component was constructed. The FSR of mass timber products, such as CLT, has previously been established [6]. In all the laboratories with flame spread tunnels in Canada, there is limited capability to lift heavy materials into the tunnel itself. Therefore, the panels were designed to reduce their overall weight, while still providing an exposed surface with an FSR consistent with mass timber elements.

The mass timber panels were built using 2 x 12 and 2 x 10 lumber on flat. The 2 x 12s were cut into 500-mm (19 ½-in.) wide pieces to be laid perpendicular to the tunnel to create the exposed surface. Two 2 x 10s were screwed perpendicular to the back of the 2 x 12s to hold the boards in place using 57-mm (2-¼ in.) wood screws in two rows every 305 mm (12 in.). These panels were constructed in 1,430 mm (56 in.) and 1,600 mm (63 in.) lengths; Figure 9 illustrates the panel design. To reach the 7,315-mm (24-ft.) length, four panels of 1,430 mm and one 1,600 mm were used. The mass timber panels are shown in Figure 10. Some gaps up to 3 mm developed between some of the lumber boards on the exposed surface, shown in Figure 11.

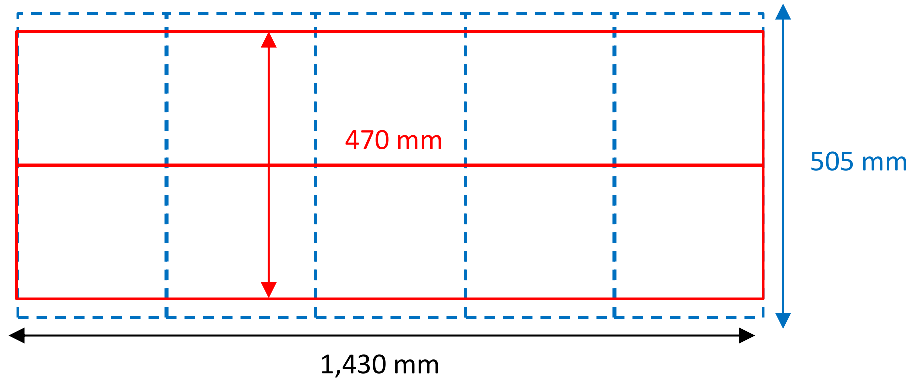


Figure 9. Construction details of replicated mass timber panels

Figure 10. Ends of mass timber panels

Figure 11. Edges of mass timber panels

Test 4 had an exposed mass timber surface along the top of the tunnel and 12.7-mm (½-in.) Type C gypsum boards along the floor of the tunnel and the two walls (with heights of 120 mm and 300 mm). The intent was to create a 305-mm (12-in.) deep cavity. However, with the inclusion of the gypsum board on the floor of the tunnel, the maximum depth was 290 mm (11 ½ in.). The setup is shown in Figure 12; the installation of the gypsum board is shown in Figure 13 and the mass timber on the tunnel in Figure 14.

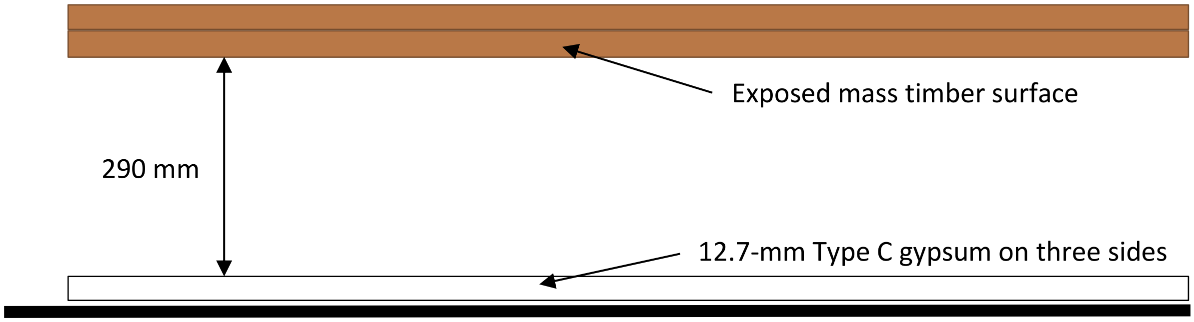


Figure 12. Test 4 setup. Mass timber surface with 12.7-mm Type C gypsum lining three sides of tunnel.

Figure 13. Construction of test 4

Figure 14. Mass timber installed test 4

5.5 Test 5

Test 5 was like test 4, except gypsum only lined the floor of the tunnel (not on the walls). This potentially represents more closely to what a construction of a concealed space might look like. The test setup is shown in Figure 15, and the test under construction is shown in Figure 16.

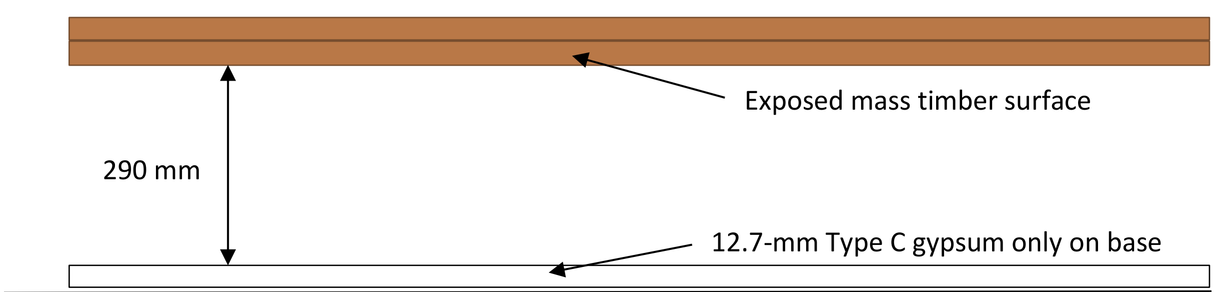


Figure 15. Test 5 setup. Mass timber surface with 12.7-mm Type C gypsum lining three sides of tunnel.

Figure 16. Test 5 construction

5.6 Test 6

Test 6 was intended to recreate how a fire might spread in a concealed space that was filled with typical materials and services. The setup was the same as Test 5 with the addition of two 125-mm (5-in.) aluminum air ducts, three 38-mm (1-½ in.) PVC pipes (grey), three 12.7-mm (½-in.) PEX pipes (blue) and 90 mm (3 ½ in.) of noncombustible fiberglass insulation. Both the PVC and PEX pipes had FSRs of not more than 25 [12] [13]. The pipes were placed on the side of the tunnel away from the windows to allow for a clear view into the space. The ends of the pipes were stuffed with mineral wool insulation and then covered with foil tape to prevent flaes from entering the pipes. The setup and configuration of the materials are shown in Figure 17 and Figure 18. The tunnel during installation is shown in Figure 19.

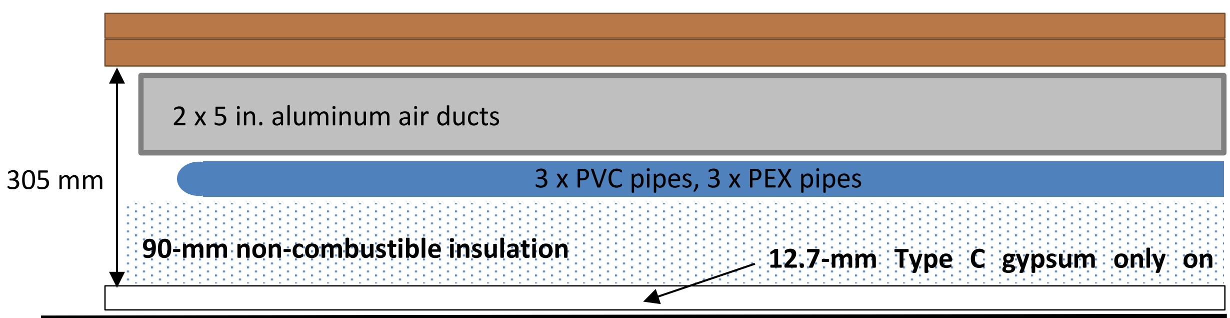


Figure 17. Test 6 setup. Mass timber surface with replicated services and gypsum on base.

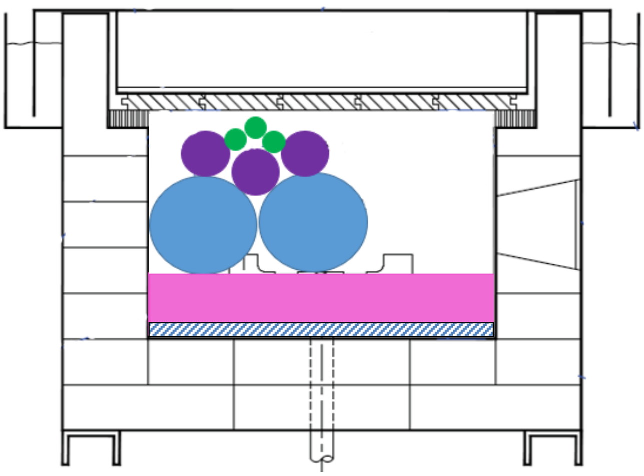


Figure 18. Test 6 layout of material in tunnel

Figure 19. Test 6 test construction

The pressure in the tunnel was reduced to try to recreate the same airflow as is used in CAN/ULC-S102, since the additional material in the tunnel resulted in a smaller cross-sectional area.

5.7 Additional Instrumentation

Additional thermocouples were added to the ceiling surface to evaluate temperatures along the length of the tunnel. Three thermocouples were installed at 3,200 mm (10 ½ ft.), 4,570 mm (15 ft.) and 5,940 mm (19 ½ ft.). The locations are shown in Figure 20. In Test 1 the thermocouples were on the ceiling tile surface; in the other tests the thermocouples were on the exposed wood surface. In test 3 thermocouples were installed on the bottom of joists closest to the measurement locations, which were closer to 3,200 mm (10 ½ ft.), 4,480 mm (14.7 ft.) and 6,096 mm (20 ft.).

The thermocouple wires ran along the tunnel along the unexposed side of the wood surface. The wires came out the end of the tunnel through the last window that was replaced with the metal plate that is used for anemometer readings. Any openings were covered with foil tape.

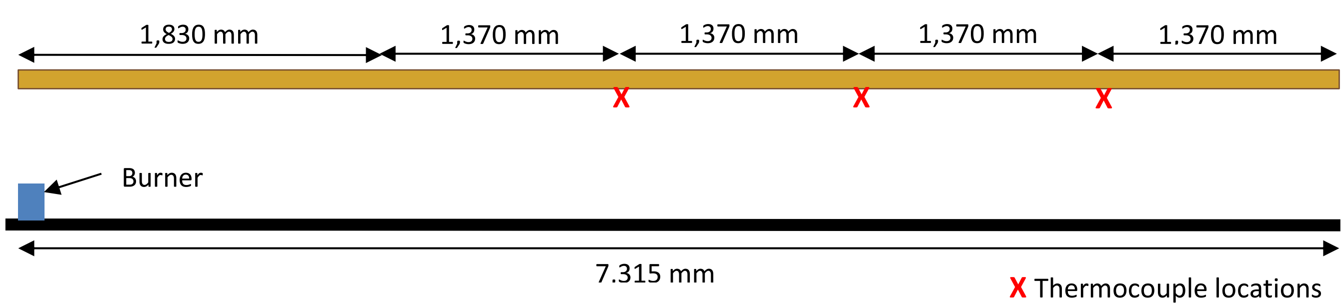


Figure 20. Test 6 layout of material in tunnel

6. RESULTS

Testing was completed at the ULC Laboratory in Toronto (ON) and witnessed by FPInnovations staff. The tests generally followed the CAN/ULC-S102 [4] procedure except only one replicate of each assembly was conducted (vs. a minimum of three) as CAN/ULC-S102 is designed only for a single surface in a flat orientation. In most cases the installation did not meet the mounting procedures, and additional material was provided in the tunnel. Further velocities were adjusted for the unique configuration based on cross sectional area.

Smoke obscuration was measured, and smoke developed values (SDV) calculated, but the focus of this research was mainly on the flame spread aspect. The flame spread value (FSV) for each test was measured based on the first 10 minutes of the test.

A summary of the results can be found in Section 6.8.

6.1 Test 1

Test 1 was conducted on January 27, 2020. Before the test the average air flow in the tunnel was measured with an anemometer across three points to be 239 ft/min. Flames quickly moved down the tunnel within 2 minutes. Flames in the void at the beginning of the test are shown in Figure 21. It appeared as though the surface paper on the ceiling tiles burned quickly. The ceiling tiles along the walls and floor were cut, exposing their edges. During the test some ceiling tile paper delaminated. After 7 minutes the flames began to subside, receding to 4,875 mm (16 ft.) down the tunnel, then at about 9 minutes the flames were confined to the burner location for the remainder of the test. The test was run for an additional 20 minutes, for a total of 30 minutes. The calculated FSV was 192.

After the first test it was difficult to cool down the tunnel to perform the other tests. There was also an issue with extinguishment after the test, which led to activation of the facility smoke alarm. Several of the subsequent tests were ended early, before the full 10-minute duration, so as not to permit any continued burning after the tests because of difficulties in extinguishment, as well as some other complications.

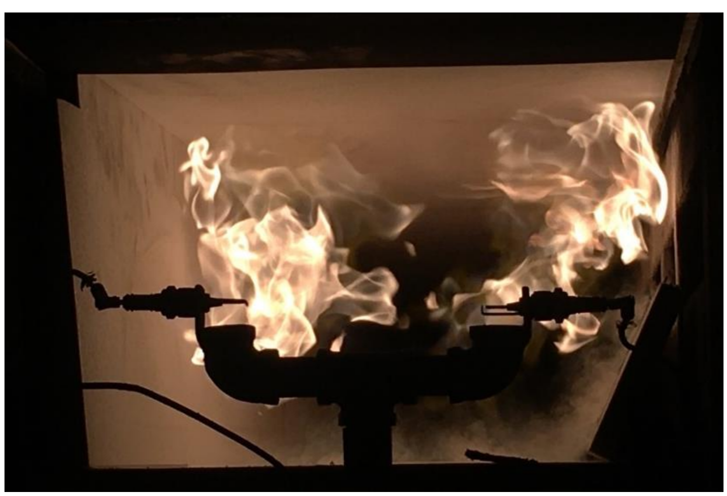


Figure 21. Test 1 at beginning of test

6.2 Test 2

Test 2 was conducted on January 28, 2020. Additional materials in the tunnel reduced cross-sectional area; the depth of the cavity was reduced to 130 mm. The average air flow rate through the cavity measured at three points was 255 ft/min, higher than standard requirement. The insulation and ceiling tiles slightly blocked the observation windows, but the ceiling surface was still visible, so the location of the flames could accurately be measured.

Once the test started, additional turbulence was noted near the burner. There was intense burning for 1 minute, then flaming became less intense and was primarily concentrated on the wood surface. Flames quickly progressed to the end of the tunnel within 2 minutes. The test was stopped after 5 minutes to ensure complete extinguishment, after challenges arose in the first test. The flaming was more severe than test 1, and it did not appear as though the flames would subside as in the test 1. An FSV of 244 was calculated.

The top of the insulation, which was placed on the floor of the tunnel and was protected with ceiling tiles, charred, shown in Figure 22; the plywood surface can also be seen on the left of the figure.

Figure 22. Test 2 insulation and plywood after the test

6.3 Test 3

Test 3 was conducted on January 28, 2020. The inclusion of the dropped wood joists reduced the cross-section in the void space. The average airflow through the tunnel was measured to be 258 ft/min, higher than the standard requirements.

Prior to the start of this test, the humidity level in the room was at 41%, which is lower than the standard requirement of 45%. The standard also requires that the tunnel be within a certain temperature range before the test. Because these assemblies are more intricate than is typically tested in the tunnel, installation took longer. The decision was made to ensure the tunnel was at the correct temperature, as opposed to waiting for the humidity level to rise. Waiting for the humidity to rise may have resulted in the tunnel cooling down too much.

At the beginning of the test, the first joist (at 450 mm (1.5 ft.) down the tunnel) caused additional turbulence in the flames. Once the plywood surface ignited, fire moved down the tunnel. The flames advanced more slowly than in tests 1 and 2. The final reading for the test was at 5,638 mm (18.5 ft.) because that was the location of the last visible joist; flames did not progress from the base of the joist to the plywood surface at the end of the tunnel, it was only the base of the joists that was burning. The charred wood assemblies after the test are shown in Figure 23.

The elevation of the wood joists in the tunnel was lower than the typical ceiling surface. This resulted in burning closer to the windows. Three-glass observation windows broke because of intense heat from joists burning; this, along with the additional turbulence in the tunnel, led to ending the test prematurely. An FSV of 101 was calculated.

Figure 23. Test 3 wood assembly after the test

6.4 Test 4

Test 4 was conducted on January 28, 2020. It was similar to a flame spread test on a mass timber surface (such as CLT), with the inclusion of an enclosed gypsum board cavity beneath. The average air flow in the tunnel measured at three locations was 234 ft/min, within the standard range. The FSV was calculated to be 35.8.

When the test started, before ignition of the surface, the wood began to char. The ignition of the wood surface started at a similar time as test 3, but close to 1 minute later than tests 1 and 2. The flames then progressed down the tunnel more slowly than the first three tests. The flame front reached 2,590 mm (8.5 ft.) after 4 minutes and then receded back down to 760 mm (2.5 ft.) over the next 3 minutes. The flames then increased to 3,200 mm (10.5 ft.) over the course of 2 minutes, then reduced again to 2,590 mm (8.5 ft.) at the end of 10 minutes. A typical FSV test is ended after 10 minutes. The test continued for an additional 11 minutes until flames reached the end of the tunnel. The flames reduced to 457 mm (1.5 ft.) after 14 minutes, then progressed to the end of the tunnel after 21 minutes 30 seconds.

As the wood surface charred early in the test, it protected wood underneath, making it more difficult to ignite and ultimately reducing the FSV. It is likely that the gypsum board lining the tunnel absorbed heat being given off by the flames which also delayed the progression of the flame front down the tunnel. When exposed to high temperatures, gypsum board absorbs heat as intrinsic water within the boards is heated to evaporation.

6.5 Test 5

Test 5 was conducted on January 29, 2020. The average air flow in the tunnel measured at three locations was 234 ft/min, within the standard range. The construction of test 5 was similar to test 4, except there was no Type X gypsum board included along the walls. This assembly performed better than test 4, with a lower maximum flame distance of 2,285 mm (7.5 ft.); flames did not reach the end of the tunnel. The flames slowly increased to a maximum distance of 2,285 mm (7.5 ft.), but then decreased back down to 457 mm (1.5 ft.), then increasing again to 1,065 mm (3.5 ft.) 10 minutes into the test. The flame front then stayed in the 760-mm (2.5-ft.) to 1,370-mm (4.5-ft.) range for the remainder of the test. The calculated FSV was calculated to be 29. The condition of the mass timber board after the test at different locations along the tunnel are shown in Figure 24 and Figure 25. The wood charred close to the burners but only lightly charred or had smoke staining near the end of the tunnel. The gypsum board paper also appeared lightly charred up to 915 mm (3 ft.) down the tunnel.

An FSV of 29 is on the low end of what has previously been observed for other mass timber assemblies. It is likely that the gypsum board on the floor of the tunnel absorbed some of the heat from the flames and slowed the progression of the flame front.

Figure 24. Test 5 wood panels after the test (near burner)

Figure 25. Test 5 wood panels after test (from end of tunnel)

6.6 Test 6

Test 6 was conducted on January 29, 2020. The cross-sectional area of the tunnel was reduced due to the inclusion of the insulation and pipes. Only one anemometer reading was taken to confirm the flow rate because the presence of the materials in the tunnel prevented any additional measurements. The air flow was taken at 270 ft/min with the damper at the beginning of the tunnel nearly fully closed. This is higher than the standard requirements.

Ignition was the fastest in test 6 out of all the tests, at 28 seconds, and flames quickly reached the end of the tunnel within 2 minutes. It appeared as though the PVC and PEX pipes began burning first, but it was difficult to discern what was actually burning. Once the pipes ignited, they began to melt. The pipes burning and melting near the beginning of the tunnel are shown in Figure 26. The PEX can PVC pipes were placed above the aluminum air duct, although orientation in the field could be either way.

PVC is combustible in accordance with CAN/ULC-S135 [14] and has a low flame spread rating but a high SDC; the products used had a rating of not more than 25. PEX piping is also combustible. Having the combustible material placed so close to the mass timber surface likely resulted in reradiation between the two surfaces leading to faster flame spread down the tunnel.

Figure 26. Test 6 combustible piping material burning in the tunnel

6.7 Thermocouple Temperatures

The data acquisition system did not record the exact time of the start of measurements, it only provided the time up to the minute, not to the second. This could result in error up to 60 seconds for some tests. This was identified after completion of test 1. Following the first test, the data acquisition system was started in synchronization with the start of the test to reduce this error. There may still be error up to 4 seconds for the remainder of the tests because measurements were taken at 4-second intervals or due to human delay in starting the system.

The time that the thermocouples reached 300 °C are presented in Table 2. 300 °C is a commonly accepted value used to evaluate when wood has begun to char. The tests where 300 °C was reached at the first thermocouple in less than 100 seconds correlate to tests with higher FSVs of over 100. The tests involving the exposed mass timber with the tunnel lined with gypsum board, tests 4 and 5, had the longest time to reach this value. Test 6, using mass timber, insulation and pipes, had the fastest times to reach this temperature.

Table 2. Time to reach 300 °C at additional thermocouple locations

Test No.	3,200 mm	4,570 mm	5,940 mm
1	72 s	128 s	136 s
2	28 s	80 s	72 s
3	108 s	116 s	116 s
4	168 s	228 s	1,160 s
5	236 s	732 s	1,420 s
6	12 s	68 s	48 s

6.8 Summary and Discussion

A summary of the results from the tests is presented in Table 3. A graph of the flame spread distance for the tests is shown in Figure 27. The FSV is calculated using the total area under the flame spread time-distance curve, as per CAN/ULC-S012 for 10 minutes [4]. Any flame front recession is ignored, so the maximum point that the flame front reached is used for the remainder of the test. FSR is calculated as the average of three FSV values, rounded to the nearest multiple of 5. Each assembly design was unique, having different exposed surfaces, material configurations and varying degrees of protection along the walls and/or floor. It is difficult to determine what the quantitative effect of these different paraments had on the calculated FSV values.

Tests 1 to 3 were intended to be indicative of combustible construction designs that are currently allowed to be exempt from the inclusion of sprinklers in void spaces according to NFPA 13. Tests 4 to 6 were designed to demonstrate what fire spread might look in concealed spaces with exposed mass timber surfaces. Test 6 was considered to be exploratory because the inclusion of additional materials in the tunnel deviated for the other test designs. The comparison between tests 1 to 3 and tests 4 and 5 indicates that the mass timber assemblies performed better, with respect to FSV and SDC.

The FSV for tests 1 to 3 were all over 100, whereas the FSV for tests 4 and 5 were less than 36. Plywood, which was used as the ceiling material in tests 1 and 2 (protected with ceiling tiles in test 1), has an assigned FSR of 150 in the NBCC so long as the minimum thickness is 11 mm [1]. The FSV in both tests was higher than this value; indicating that the introduction of additional variables resulted in worse performance. This may be related to a reduction in the cross-sectional area or the additional ceiling tile surfaces on the floor and wall. In test 3, the FSV was 101, which is consistent with assigned values for wood products [1]. The flame spread performance of the ceiling tiles should be verified; if the tiles do not meet the extended ASTM E84 or ASTM E2768 then these assemblies would not fully meet the NFPA 13 sprinkler exemption requirement.

Typical FSR mass timber values fall between 30-55 [6] [7], with values for CLT at 35-40 [15]. In one series of CLT tests, the FSV values were very stable at 36, 37 and 37; having a final FSR of 35 [6]. If the FSV values for tests 4 and 5 are rounded up, they would become 40 and 30, respectively, indicating these are in line with what would be expected for mass timber and lower than the results for tests 1 to 3. A direct comparison between the FSV calculated in these tests with existing FSR data is difficult due to modifications during tests.

Although mass timber was the exposed surface in test 6, this assembly generally performed the worst. The inclusion of the combustible pipes in a narrow space near the mass timber surface likely resulted in reradiation effects between the pipes and the wood surface, leading to faster flame spread in the narrow space between the two. Having these combustible pipes located close to the wood surface was a severe test scenario. None of the other tests included combustible pipes in this manner, so it is difficult to make a performance comparison. Based on this result, it would be good practice to avoid installing combustible materials close to exposed mass timber surfaces in concealed spaces.

The ignition time in tests 1 and 2 was between 30 seconds to 1 minute faster than in tests 4 and 5, indicating that it took longer for the mass timber assemblies to ignite. Ignition in test 3 was similar to tests 4 and 5; the additional distance to the first 2 x 6 joist, and the thickness of the joists likely had an impact.

Over the first 10 minutes of the tests, which is the standard time for a CAN/ULC-S102 flame spread test, the maximum flame distance for tests 1 and 2 was 19.5 ft and 18.5 ft in test 3; in tests 5 and 6 the maximum distance was 8.5 ft or less. During these 10 minutes, the flames in tests 4 and 5 did not reach the end of the tunnel. The time to reach the end of the tunnel was also much slower in tests 5 and 6 compared to tests 1 to 3. If you just consider the 10-minute exposure, the flames did not reach the end of the tunnel in either test. Flames reached the end of the tunnel in tests 1 to 3 all within 4 minutes of the test.

Table 3. Flame spread test results

TEST No.	SAMPLE DESCRIPTION	CALCULATED VALUES		IGNITION TIME (min:sec)	MAX FLAME DISTANCE (ft)	RELATIVE HUMIDITY IN THE ROOM (%)	TIME TO REACH END OF TUNNEL (min:sec)
		FLAME SPREAD VALUE (FSV)	SMOKE DEVELOPED VALUE (SDV)				
1	Floor void assembly 1	192.0	59.7	0:46	19.5	52	1:42
2*	Floor void assembly 2	243.7	285.4	0.32	19.5	51	1:26
3*	Floor void assembly 3	101.0	443.7	1:28	18.5	43	4:00
4	Floor void assembly 4	35.8	22.6	1:25	19.5	51	21:30
5	Floor void assembly 4 (without gypsum board along the walls)	28.8	11.1	1:03	7.5	51	-
6*	Floor void assembly 5 with services	251.4	486.9	0:28	19.5	46	1:52

* The test was terminated prematurely, before 10 minutes

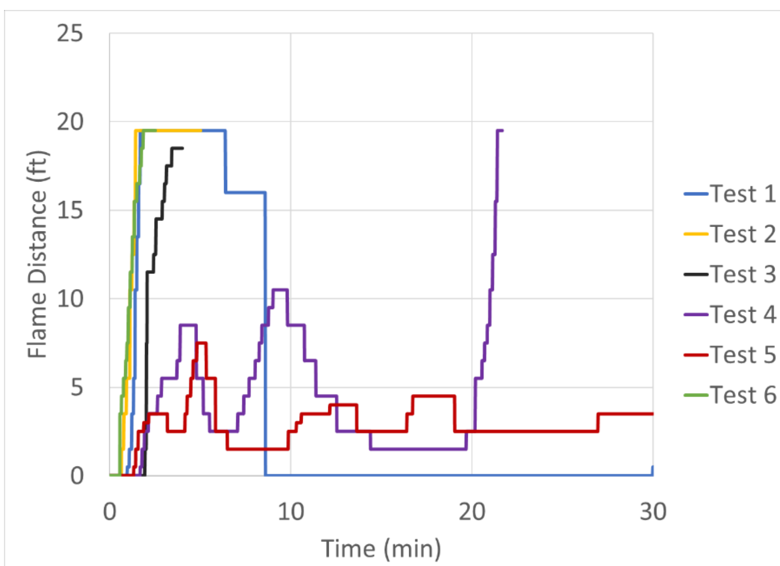


Figure 27. Flame distance along tunnel

7. CONCLUSION

With the increased use of mass timber in midrise buildings and the anticipated release of the 2020 NBCC to include provisions for encapsulated mass timber construction, it is expected that the interest in mass timber buildings is going to increase. That interest is high can be seen in the implementation of EMTC construction in BC and Alberta before release of the NBC 2020. In order to help reduce barriers to mass timber construction, this project examined a potential mean to reduce costs for these buildings by leaving mass timber surfaces within concealed spaces exposed. Currently, within concealed spaces, combustible mass timber surfaces are required to be protected (e.g., with gypsum board), or the space must be sprinklered. The installation of gypsum board or sprinklers represents additional costs for materials, labour and slows project timelines.

A series of custom flame spread tests was conducted to compare performance of concealed space assemblies that are currently permitted by NFPA 13 to have exposed combustible materials and do not require sprinkler protection to void spaces with exposed mass timber.

The tests were performed as close as practical to the CAN/ULC-S102 standard method, but there were several differences, including only one test that was completed for each assembly (as opposed to three replicates to be able to calculate an FSR) and in some tests additional material lined the sides and/or floor of the tunnel which resulted in a reduced cross-section of the tunnel. Because of these deviations and complex heat transfer processes within the cavities compared to standard FSR test procedures, it is difficult to directly compare the results of these tests with existing FSR data. When it was safe to do so, the test ran for an additional 20 minutes, bringing the total test length to 30 minutes.

Three tests were conducted on combustible assemblies that are exempt from the sprinkler requirements, two tests included an exposed mass timber surface, and one final explorative test was conducted using a mass timber surface but also had the void filled with typical services that might be installed in a building. The final test included insulation, combustible pipes and metallic air ducts within the space. One of the exemptions allows exposed wood surfaces so long as the cavity is less than 150 mm (6 in.) deep. However, 305-mm (12-in.) deep cavities are more practical. Therefore, the mass timber assemblies used 305-mm deep cavities.

In general, the exposed mass timber concealed spaces performed better than the NFPA 13 sprinkler exempt assemblies. For the mass timber assemblies, FSVs were lower, ignition time was longer, and temperatures along the length of the tunnel were slower to reach 300 °C; flames spread down the tunnel more slowly and in both tests the flame front did not reach the end of the tunnel during the 10-minute test. The FSV values were 40 and 30 for the two mass timber tests, which are consistent with FSR values for other mass timber products. This was not true for the explorative mass timber test where the inclusion of the combustible pipes (with a FSR or not more than 25) close to the mass timber surface likely resulted in reradiation effects between the pipes and the wood surface, leading to faster flame spread in the space between the two. This would suggest that within a concealed space, the distance between an exposed mass timber surface and any combustible materials should be maximized. More research is needed into flame spread behaviour in concealed spaces with exposed mass timber on a larger scale with realistic construction designs. This may also suggest that the current practice in NFPA 13 of lining the concealed space with materials with an FSV of 25 or less but allowing services with an FSV of 25 or less may result in high flame spread in these spaces.

The mass timber surface began to char early in the test, then protected wood underneath, resulting in longer ignition times and ultimately reducing the FSV. It is likely that the gypsum board lining the tunnel absorbed heat being given off by the flames which also delayed the progression of the flame front down the tunnel.

If the exposed mass timber assemblies performed better than the NFPA 13 sprinkler exempt wood assemblies, then this demonstrates that the exposed mass timber assemblies represent an increase in the minimum performance level that is currently accepted by the code and should therefore be allowed. This information could be used to develop an alternative solution to allow exposed mass timber surfaces within concealed spaces. The knowledge should be transferred to other designers to provide them with more options for the design of mass timber ceilings and void spaces. Guidance documents could be developed for the design community detailing the important aspects of this research, and other similar research, to aid in the development and approval of alternative solutions.

This research could also support changes to NFPA 13 to explicitly include exposed mass timber concealed spaces to be exempt from sprinkler requirements given that the mass timber assemblies performed better than what is currently allowed. This research should be shared with NFPA also to consider revising the current sprinkler exemptions for spaces with combustible surfaces, since flame spread was very high for these assemblies. The research did however indicate that NFPA 13 rules for concealed spaces may be over simplistic where plastic services that meet FSR 25 are present. However, further research is needed on this issue.

8. REFERENCES

[1] National Building Code of Canada, Ottawa, ON: National Research Council Canada, 2015.

[2] NFPA 13: Standard for the Installation of Sprinkler Systems, Quincy, MD: National Fire Protection Association, 2016.

[3] "ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials," ASTM International, West Conshohocken, PA, 2019.

[4] CAN/ULC-S102. Standard Method of Test for Surface Burning Characteristics of building Materials and Assemblies, Toronto: Underwriters' Laboraties of Canada (ULC), 2018.

[5] "ASTM E2768 - Standard Test Method for Extended Duration Surface Burning Characteristics of Building Materials (30 min Tunnel Test)," ASTM International, West Conshohocken, PA, 2018.

[6] C. Dagenais, "Surface Burning Characteristics of Massive Timber Assemblies," FPInnovations, Quebec, QC, 2013.

[7] L. Ranger and C. Dagenais, "Evaluating Fire Performance of Nail-Laminated Timber. Surface Flammability," FPInnovations, Ottawa, ON, 2019.

[8] "Flame Spread," Canadian Wood Council, Ottawa, ON, 2014.

[9] L. Osborne, "Alternative Solutions: 3.2.6 Assess Fire Spread in Floor Voids. Phase 1 – Literature and Code Review," FPInnovations, Ottawa, ON, 2013.

[10] L. Osborne, "Alternative Solutions: 3.2.6 Assess Fire Spread in Floor Voids. Phase 2 – Test Report," FPInnovations, Ottawa, ON, 2013.

[11] "Symphony M 75. Smooth Mineral Fiber. Square Edge. Data Sheet," Certainteed.

[12] "System 15 PVC. Data Sheet.," System 15, 2016.

[13] "Plumbing Products Listing Program. Reliance Worldwide Corporation DBA Cash Acme. Cash Acme/SharkBite Type PEX," QAI Laboratories, 2018.

[14] ULC, "CAN/ULC-S135. Standard Test Method for the Determination of Combustibility Parameters of Building Materials Using and Oxygen Consumption Calorimeter," Underwriter's Laboratories of Canada, Toronto, ON, 2004.

[15] E. Karacebeyli and S. Gagnon, "Canadian CLT Handbook. 2019 Edition," FPInnovations, Quebec, QC, 2020.

[16] J. Mehaffey and C. Dagenais, "Assessing the Flammability of Mass Timber Components: A Review," FPInnovations, Quebec, QC, 2014.

APPENDIX I – TEST REPORT

Summary of Investigation
For
FP Innovations, Ottawa ON

Subject: Surface Burning Characteristics of Floor Void Assemblies
Reference: SV19007 / 4789229710

February 24th, 2020
(Revised: April 8th, 2020)

The following is a summary of the test results obtained on floor void assemblies under Project 4789229710. The tests were conducted at ULC's test facility in Toronto, Ontario on January 27th to 29th, 2020 in general accordance with CAN/ULC-S102:2018-REV1, *Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies*, 8th Edition (Including Revision 1) (Exception, less than three tests were conducted as indicated under "Results", some or all tests were terminated early as indicated under "Results" and some or all test assemblies were not mounted following the uniform procedures specified in the standard as indicated under "Sample Description and Preparation").

The issuance of this Report does not imply Listing, Classification, or Recognition by ULC and does not authorize the use of ULC Listing, Classification, or Recognition Marks or any other reference to Underwriters Laboratories of Canada on or in connection with the product or assembly. Underwriters Laboratories of Canada did not witness the production of the samples nor were we provided with information relative to the formulation or identification of component materials used in the samples.

The sole purpose of this investigation was to provide fire test data for the lumber submitted and tested in general accordance with the requirements of CAN/ULC-S102. The test results relate only to the items tested and may not apply to subsequently produced samples or assemblies. This data should not be considered representative of test results for other lumber in the absence of testing the lumber in accordance with CAN/ULC-S102.

Underwriters Laboratories of Canada, its employees, and its agents shall not be responsible to anyone for the use or nonuse of the information contained in this Report, and shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use of, or inability to use, the information contained in this Report.

Underwriters Laboratories of Canada authorizes the above-named company to reproduce this Report provided it is reproduced in its entirety.

Sincerely,

Stanis Yu
Project Handler
Building Science Technologies

Reviewed by:

Beny Spensieri, Jr.
Project Handler
Building Science Technologies

SAMPLE DESCRIPTION AND PREPARATION

Six unique floor void assemblies were submitted for testing. Details of the materials used in the construction of the floor void assemblies were not provided nor investigated.

All materials were conditioned at a temperature of 23 ± 3°C and a relative humidity of 50 ± 5% prior to the tests.

Floor void assembly 1 consisted of nominal 19 mm thick ceiling tiles lining both walls, floor and ceiling of the 7,315 mm long furnace. Additionally, a layer of plywood was laid on top of the ceiling tiles on the ceiling of the furnace.

Floor void assembly 2 consisted of nominal 19 mm thick ceiling tiles lining both walls and the ceiling of the 7,315 mm long furnace. Similar to floor void assembly 1, a layer of plywood was laid on top of the ceiling tiles on the ceiling of the furnace. Mineral wool insulation was laid on the floor of the furnace underneath nominal 19 mm thick ceiling tiles to create a nominal 150 mm tall channel in the furnace. 12.7 mm thick Type C gypsum board was used to create a ramp at the burner end to transition to the 130 mm tall channel.

Floor void assembly 3 consisted of nominal 19 mm thick ceiling tiles lining both walls and floor of the 7,315 mm long furnace. Plywood with 2' x 6' joists were mounted on the ceiling of the tunnel furnace.

Floor void assembly 4 consisted of 12.7 mm thick gypsum board lining both walls and floor of the 7,315 mm long furnace. Pre-assembled lumber assemblies were mounted on the ceiling of the tunnel furnace.

Floor void assembly 5 consisted of 12.7 mm thick gypsum board lining the floor of the 7,315 mm long furnace. Pre-assembled lumber assemblies were mounted on the ceiling of the tunnel furnace.

Floor void assembly 6 consisted of 12.7 mm thick gypsum board lining the floor of the 7,315 mm long furnace. A layer of fibreglass insulation was laid on top of the gypsum boards. Nominal 38 mm diameter PVC pipes, nominal 12 mm diameter PEX pipes and nominal 125 mm diameter aluminum duct piping were placed on top of the fibreglass insulation and secured with aluminum tape. Pre-assembled lumber assemblies were mounted on the ceiling of the tunnel furnace.

Due to the rigidity of the test assemblies, supplementary means of support was not required. The test assemblies were installed on the ceiling of the tunnel furnace. A 350 mm long by 560 mm wide by 1.6 mm thick, uncoated, steel plate was placed on the specimen mounting ledge in front of and under the specimen at the fire end of the tunnel furnace “upstream” from the gas burners to complete the 7620 mm chamber length. An airtight water seal was maintained around the furnace lid during the test.

TEST METHOD

The tests were conducted in general accordance with CAN/ULC-S102:2018-REV1, *Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies*, 8th Edition (Including Revision 1) (Exception, less than three tests were conducted as indicated under “Results”, some or all tests were terminated early as indicated under “Results” and some or all test assemblies were not mounted following the uniform procedures specified in the standard as indicated under “Sample Description and Preparation”).

This method defines the relative surface burning characteristics under specific test conditions. Although the procedure is applicable to materials, products and assemblies used in building construction for development of comparative surface spread of flame data, test results may not reflect the relative surface burning characteristics of tested materials under all building fire conditions. Test results relate only to the items tested.

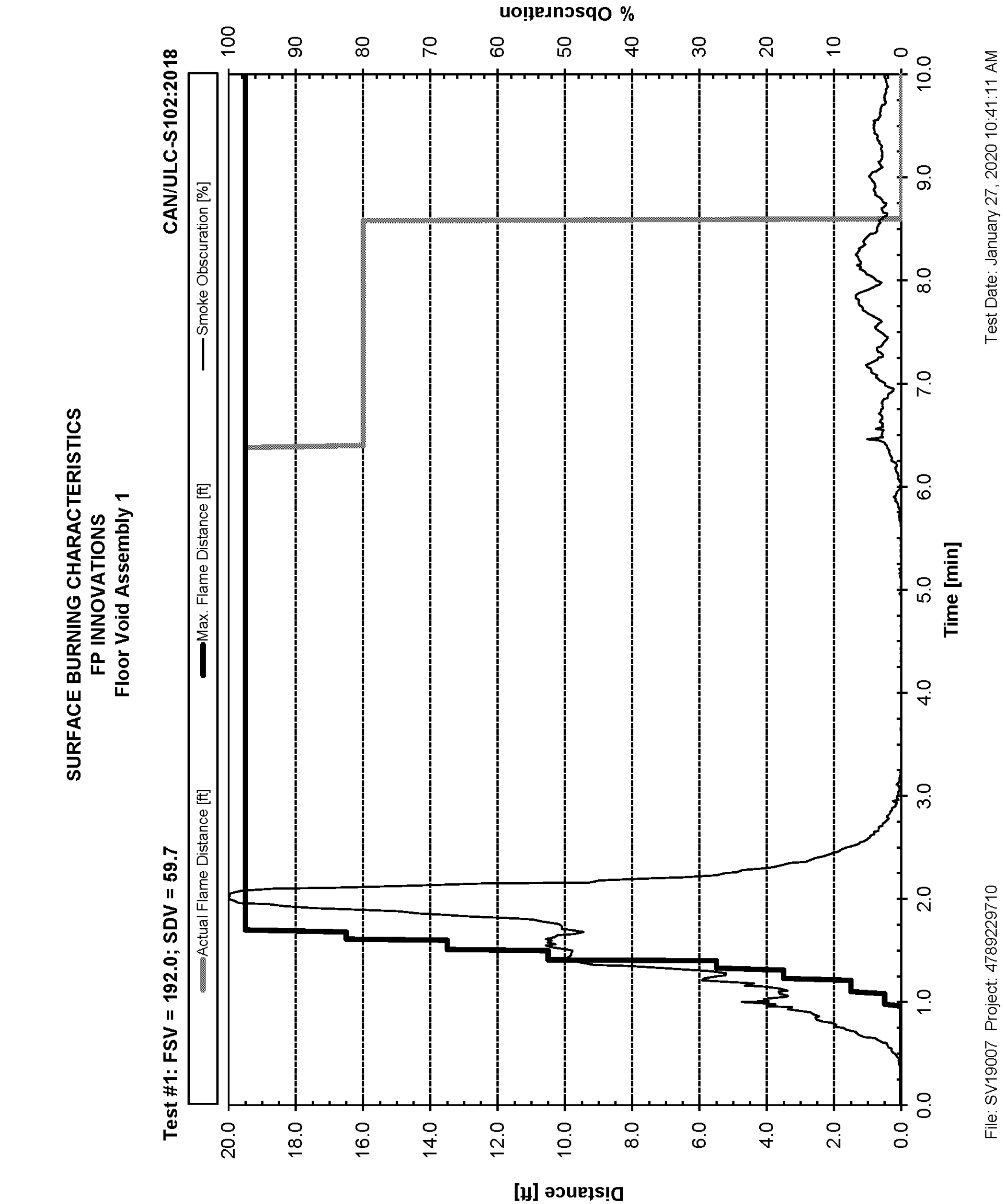
SURFACE BURNING CHARACTERISTICS

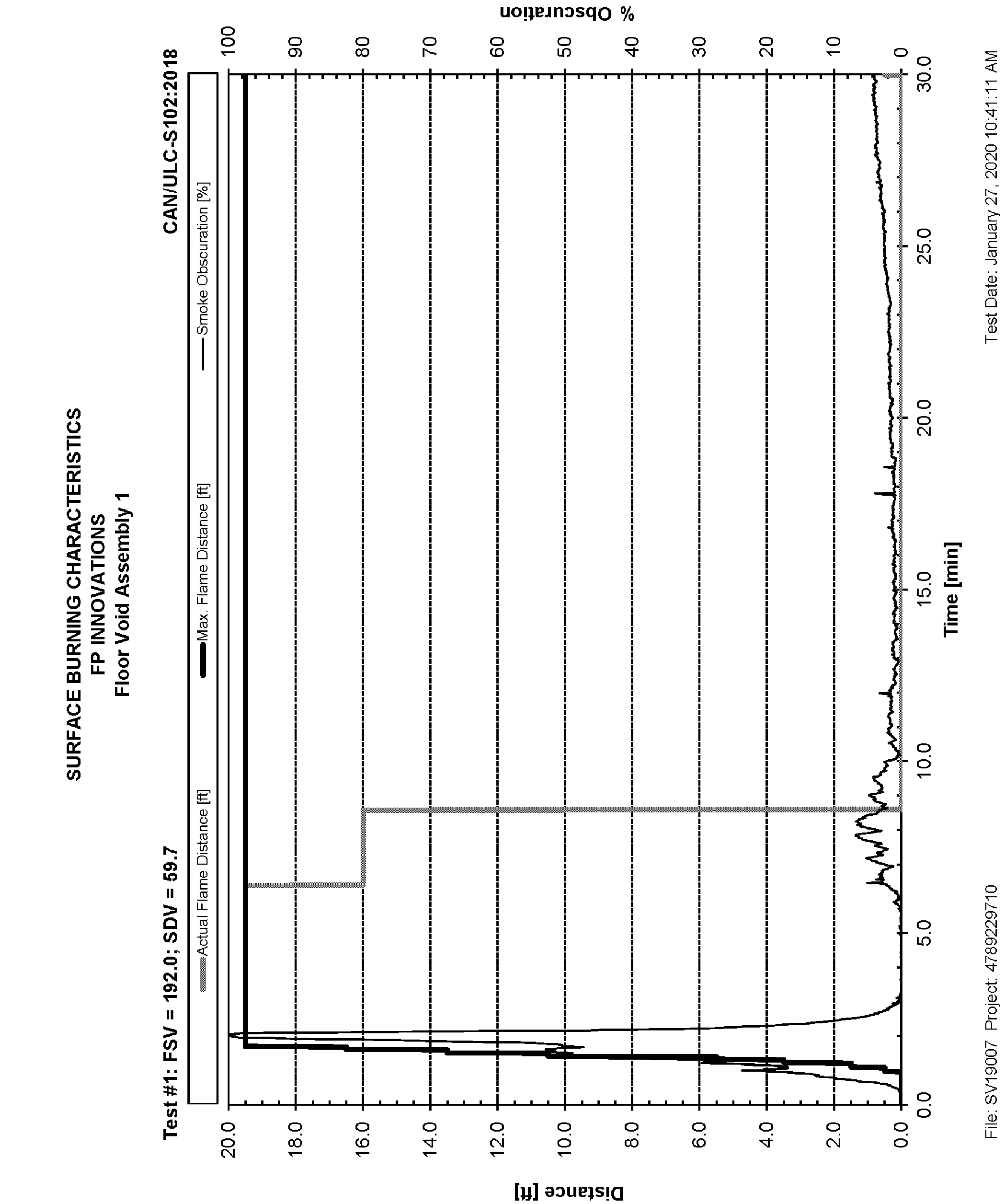
A summary of the individual test results is tabulated below. Graphical plots of flame spread and light transmission data are attached. The test results relate only to the actual samples tested.

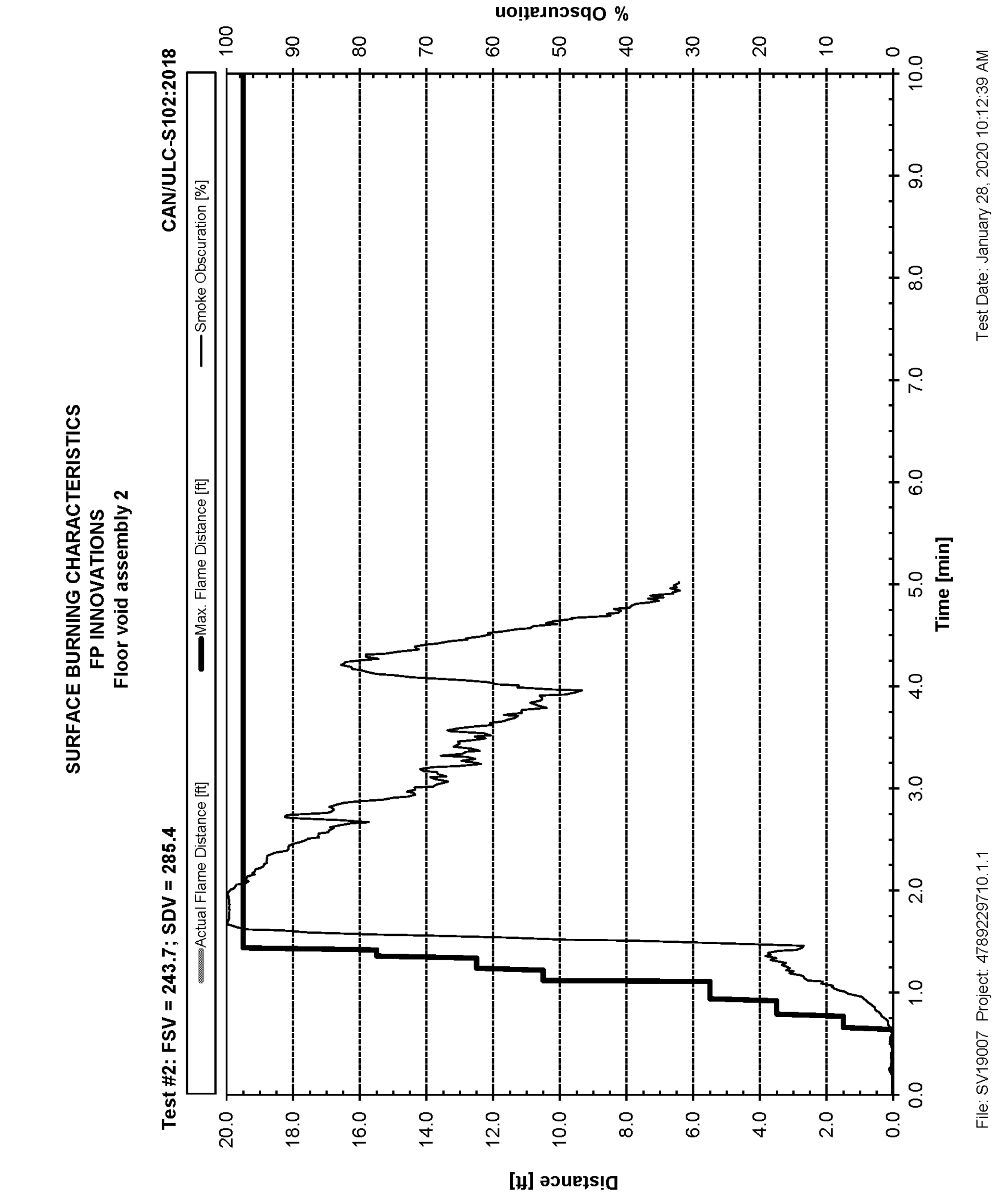
TEST No.	SAMPLE DESCRIPTION	CALCULATED VALUES	
		FLAME SPREAD VALUE (FSV)	SMOKE DEVELOPED VALUE (SDV)
1	Floor void assembly 1	192.0	59.7
2*	Floor void assembly 2	243.7	285.4
3*	Floor void assembly 3	101.0	443.7
4	Floor void assembly 4	35.8	22.6
5	Floor void assembly 5	28.8	11.1
6*	Floor void assembly 6	251.4	486.9

**NOTE: The test was terminated prematurely at the request of the submitter. Prior to termination, the flame front had reached the end of the furnace, therefore, the extrapolated FSV was judged not to be affected by the premature termination of the pilot burners. The SDV was extrapolated under the assumption that the smoke obscuration would remain at the last recorded reading for the remainder of the 10-minute test to yield a conservative determination for the extrapolated SDV.*

Section 9.4 of CAN/ULC-S102:2018-REV1, stipulates that the Flame Spread Rating (FSR) and Smoke Developed Classification (SDC) of a product or assembly shall be determined from the results of not less than three identical test specimens. Since only one test was conducted on each unique test assembly the assemblies do not warrant the assignment of a rating or classification.

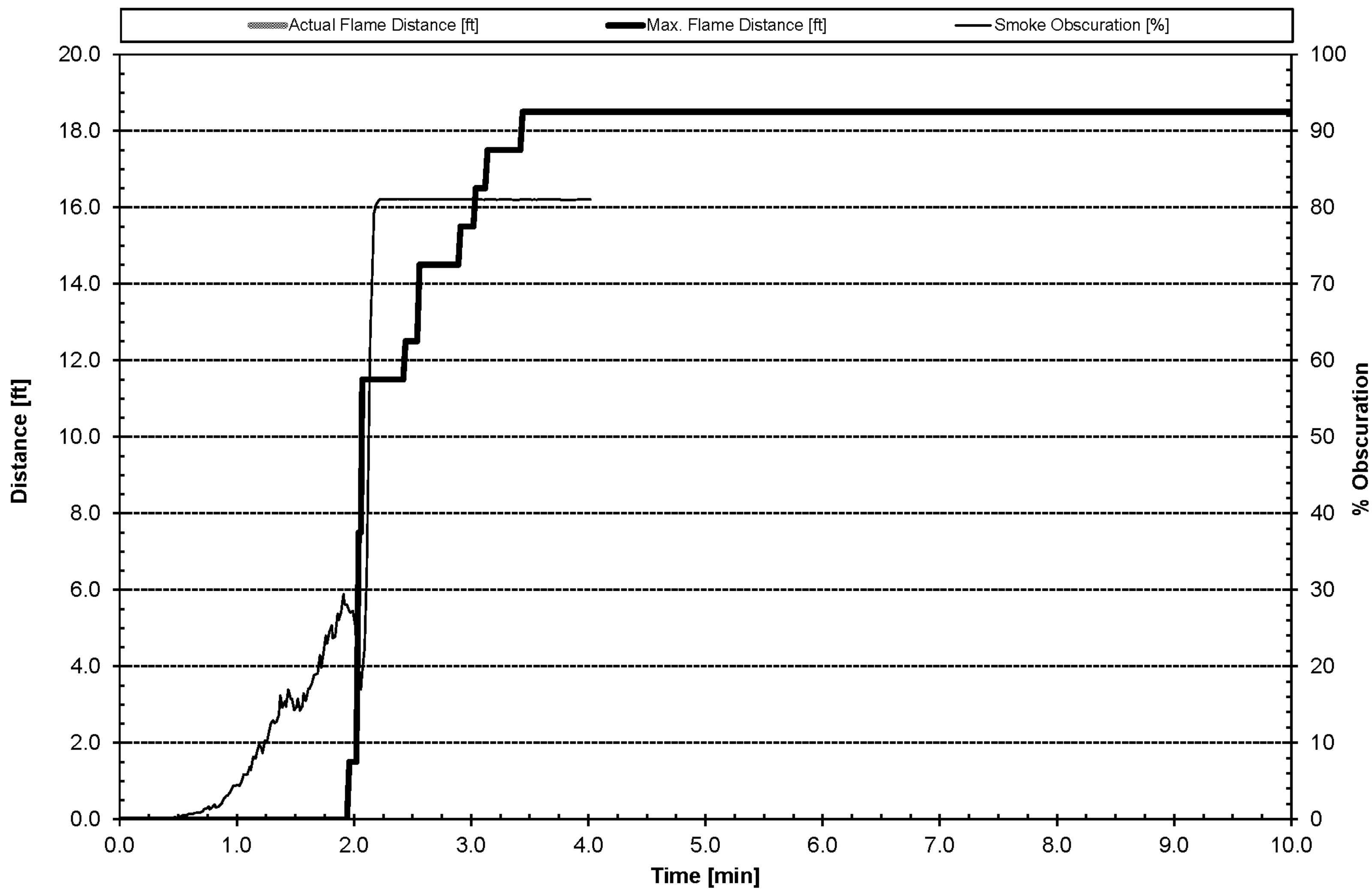

SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor Void Assembly 1
Test #1: FSV = 192.0; SDV = 59.7
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
File: SV19007 Project: 4789229710
Test Date: January 27, 2020 10:41:11 AM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor Void Assembly 1
Test #1: FSV = 192.0; SDV = 59.7
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
100
90
80
70
60
50
40
30
20
10
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
File: SV19007 Project: 4789229710
Test Date: January 27, 2020 10:41:11 AM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 2
Test #2: FSV = 243.7; SDV = 285.4
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
File: SV19007 Project: 4789229710.1.1
Test Date: January 28, 2020 10:12:39 AM

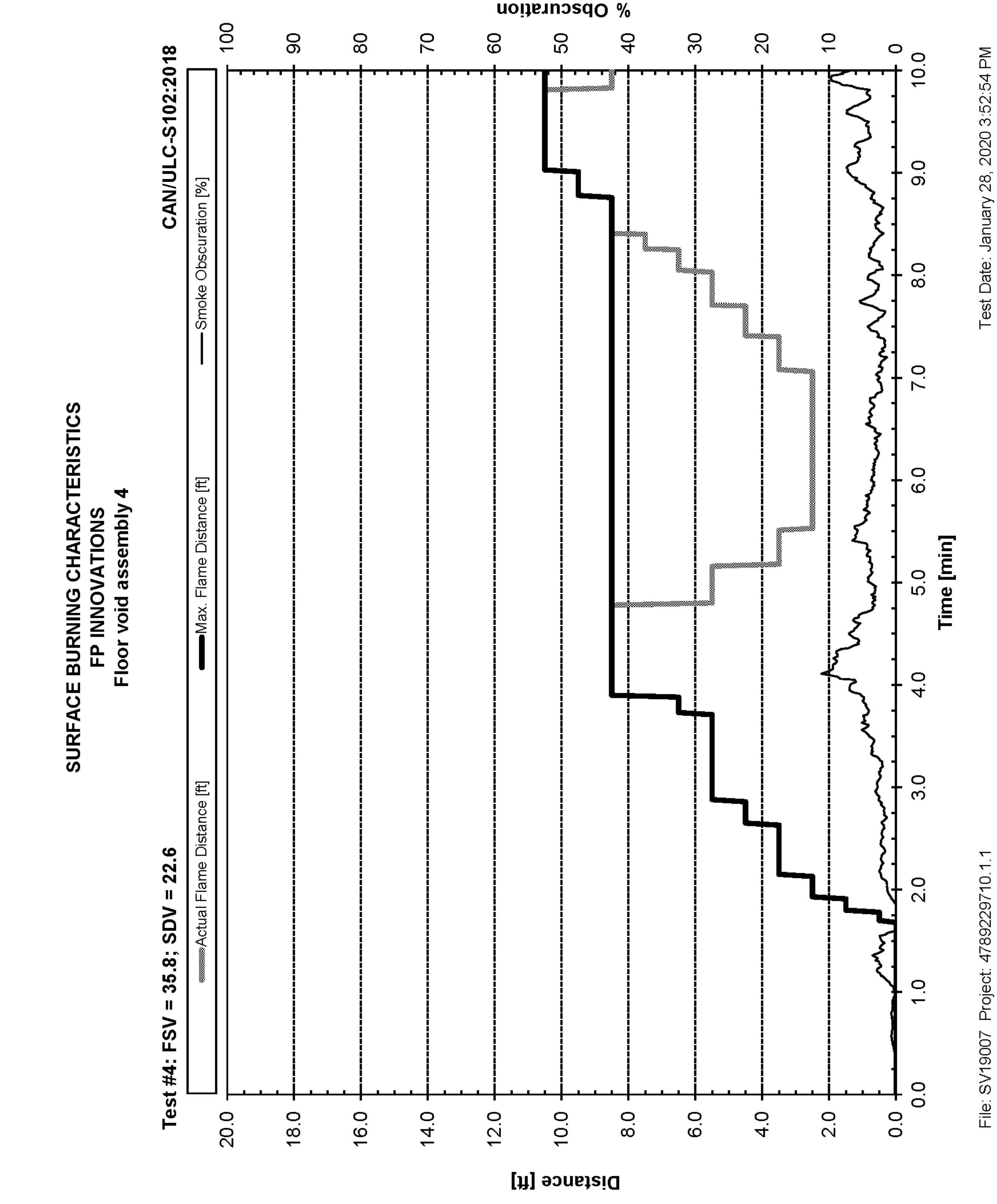
SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 3

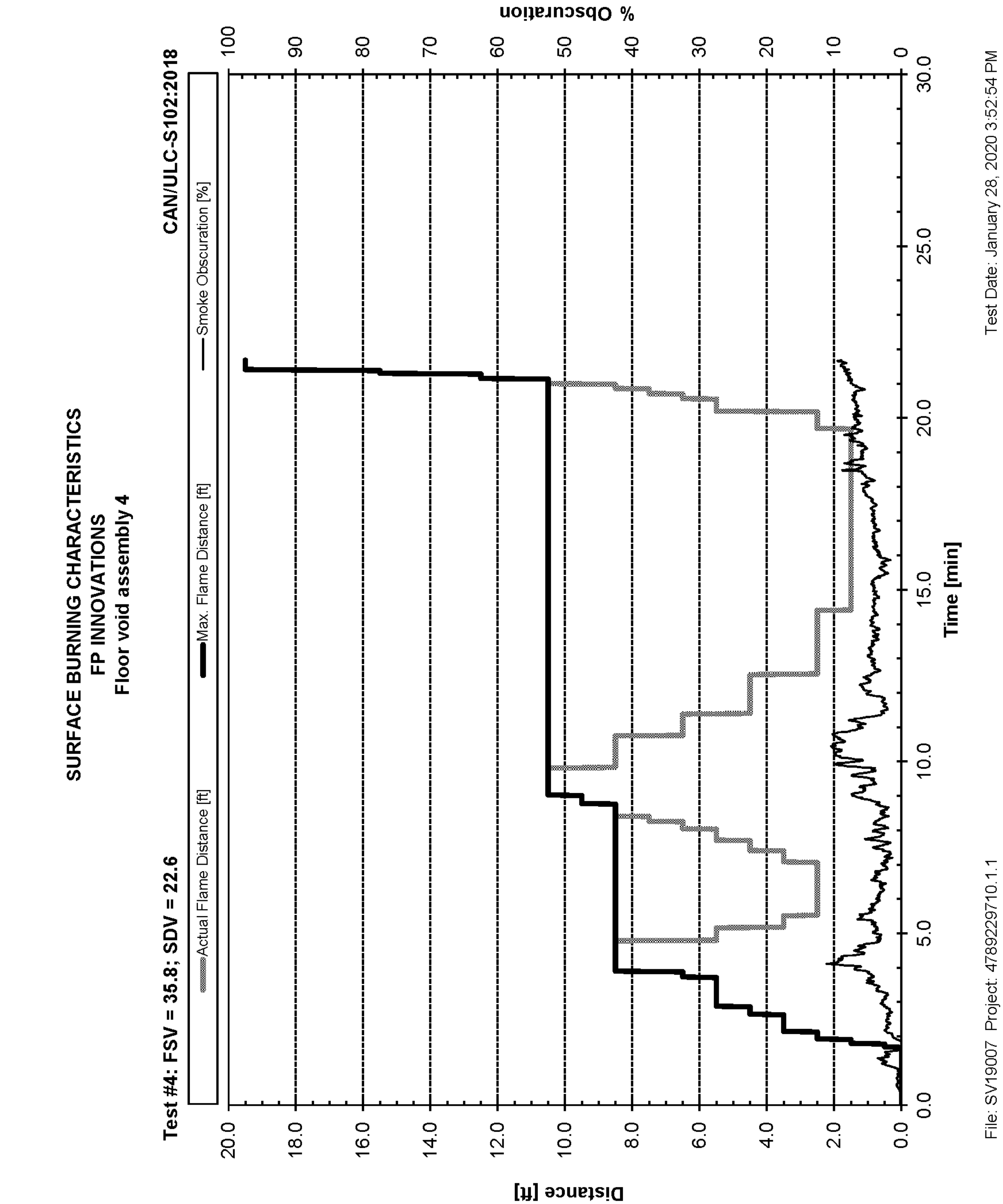
Test #3: FSV = 101.0; SDV = 443.7 **CAN/ULC-S102:2018**

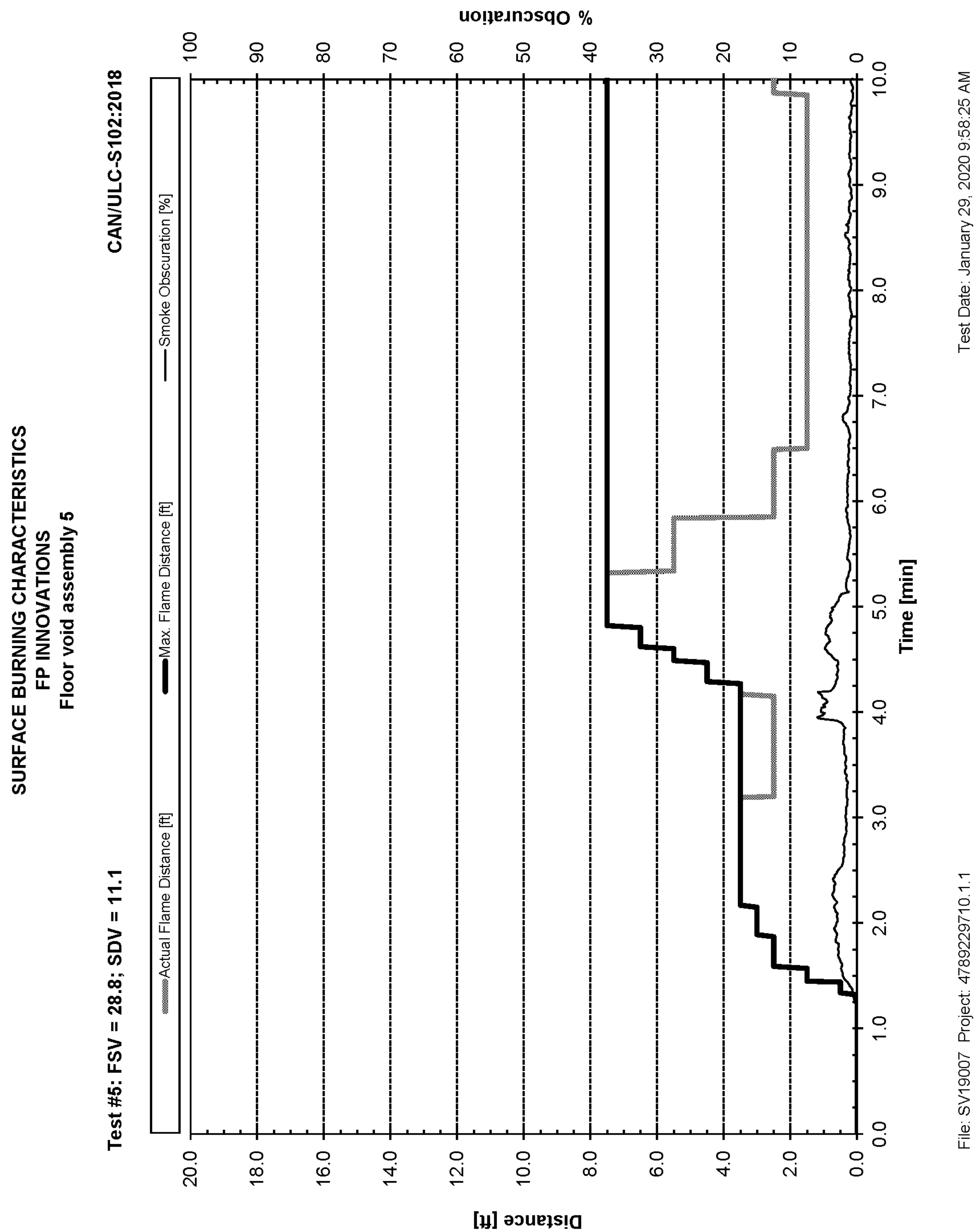


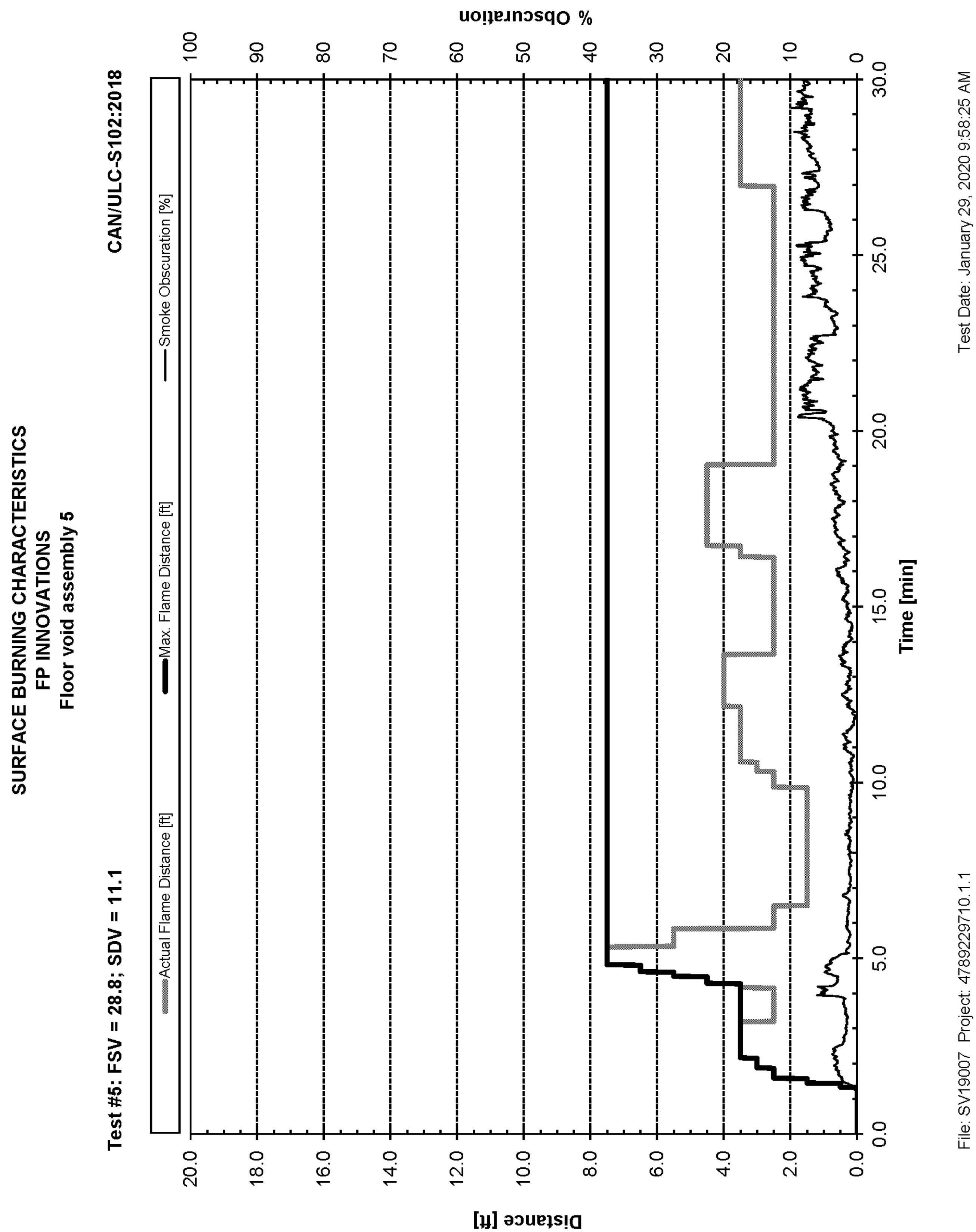
File: SV19007 Project: 4789229710.1.1

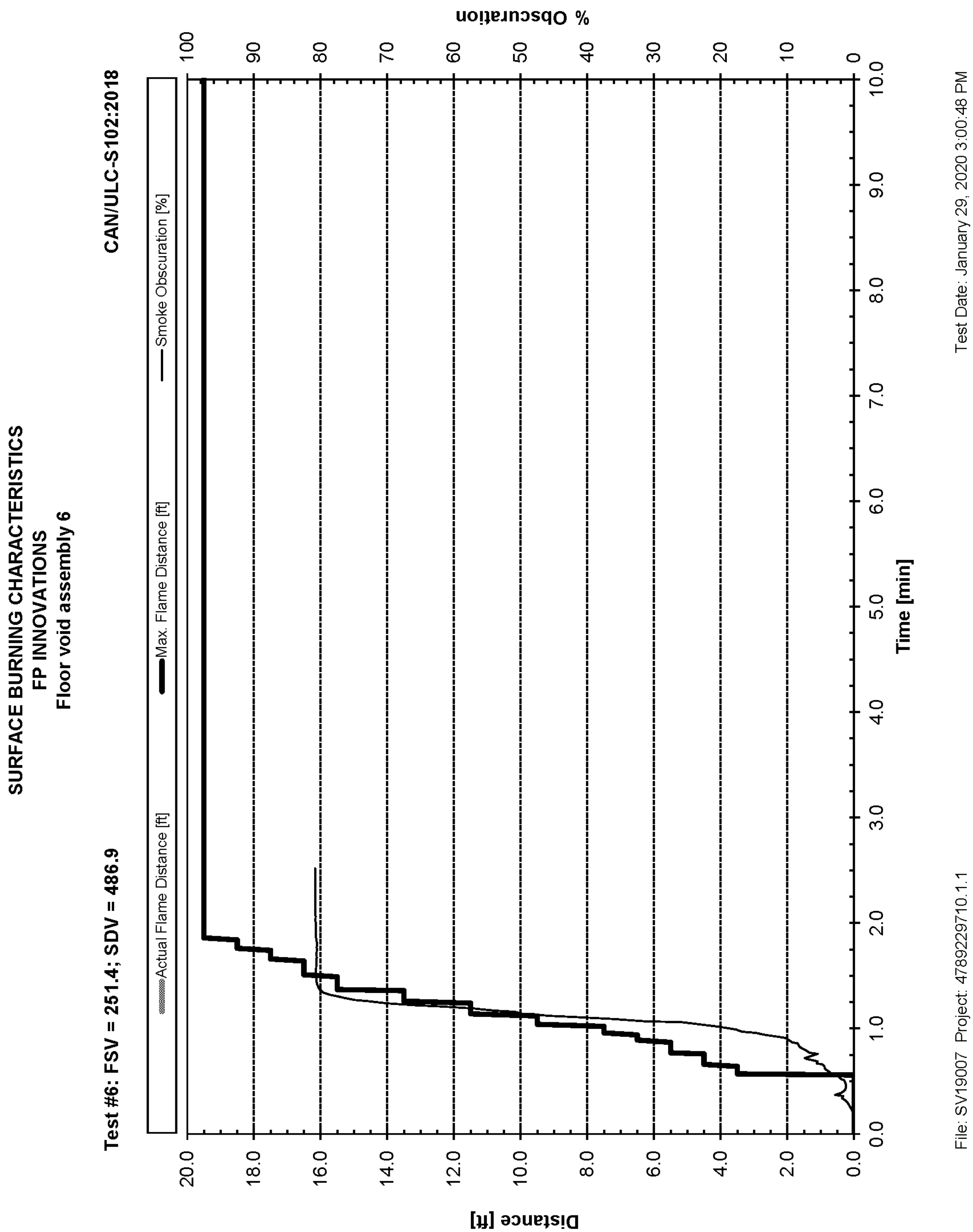
Test Date: January 28, 2020 12:24:32 PM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 4
Test #4: FSV = 35.8; SDV = 22.6
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
File: SV19007 Project: 4789229710.1.1
Test Date: January 28, 2020 3:52:54 PM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 4
Test #4: FSV = 35.8; SDV = 22.6
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
File: SV19007 Project: 4789229710.1.1
Test Date: January 28, 2020 3:52:54 PM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 5
Test #5: FSV = 28.8; SDV = 11.1
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
0
10
20
30
40
50
60
70
80
90
100
File: SV19007 Project: 4789229710.1.1
Test Date: January 29, 2020 9:58:25 AM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 5
Test #5: FSV = 28.8; SDV = 11.1
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
% Obscuration
Time [min]
File: SV19007 Project: 4789229710.1.1
Test Date: January 29, 2020 9:58:25 AM


SURFACE BURNING CHARACTERISTICS
FP INNOVATIONS
Floor void assembly 6
Test #6: FSV = 251.4; SDV = 486.9
CAN/ULC-S102:2018
Actual Flame Distance [ft]
Max. Flame Distance [ft]
Smoke Obscuration [%]
Distance [ft]
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
% Obscuration
100
90
80
70
60
50
40
30
20
10
0
Time [min]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
File: SV19007 Project: 4789229710.1.1
Test Date: January 29, 2020 3:00:48 PM

info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
514 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
604 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
418 659-2647