Performance of partition walls between attached residential units: airtightness, fire and acoustical testing

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Performance of Partition Walls between Attached Residential Units: Airtightness, Fire and Acoustical Testing

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Executive Summary

In phase 1 of this study, six (6) party-wall specimens were tested on the airtight of partitions between adjacent residential units' project. The selected six specimens were defined to reflect current industry practices of party-walls construction among Canadian homebuilders.

Following up on project phase 1 outcomes, the present report summarizes phase 2 results of the project. For the phase 2, future code requirements, it was determined to continue with several other alternatives for airtightness testing using a spun-bonded polyolefin (SBPO) membrane as an air barrier (AB) within double wood stud partition wall specimens. As the use of the SBPO represents a novel approach in partition wall construction, it was desired by the project collaborators, Canadian Home Builders Association (CHBA), to evaluate fire performance as well as acoustical performance of such assemblies. The following double wood stud wall specimens were examined:

Airtightness test

1. with 2 unsealed spun-bonded polyolefin (SBPO) membranes (AB) behind drywall
2. with 2 sealed SBPO membranes (AB) behind drywall.
3. with 2 sealed SBPO membranes (AB) behind drywall with penetrations from nails and screws.
4. with airtight drywall AB.
5. with airtight drywall AB with penetrations from nails and screws.
6. with 2 sealed Polyethylene (PE) membranes (AB) behind drywall.
7. with 2 sealed PE membranes (AB) behind drywalls with penetrations from nails and screws.

Fire resistance test

- F1. with 2 unsealed SBPO membranes (AB) behind drywall.
- F2. with 2 sealed SBPO membranes (AB) behind drywall.

Acoustic test

- A1. with 2 unsealed SBPO membranes (AB) behind drywall,
- A2. with 2 sealed SBPO membranes (AB) behind drywall.

The airtightness test results show that the use of membrane AB systems (both, SBPO and PE) increases airtightness very effectively (air flow rates as low as 0.005 L/(m^2·s)) and screw and nail penetrations do not affect the airtightness significantly. The air flow rate of the specimen with airtight drywall approach was higher: 0.116 L/(m^2·s) and the effect of fastener penetrations was considerable: the value increased to 0.136 L/(m^2·s).

Fire resistance test results show a slight difference in the time till failure: 75 minutes and 72 minutes for sealed and unsealed SBPO membrane respectively, both with identical structural failure.

Similarly, acoustic test results show a slight difference between the two specimens: Sound Transmission Class STC51 and STC49 for sealed and unsealed SBPO membrane respectively.

1 Introduction, Project Description

Across Canada, construction of attached homes is becoming the major form of new residential construction. According to the Canada Mortgage and Housing Corporation (CMHC) report (CMHC 2021), only 48,387 residential units out of 186,766 built in 2020 were single detached houses. While details for constructing air-tight exterior walls are well understood, best practice details for partitions (walls/floors/ceilings) between residential units are less understood. Lack of air leakage requirements through these partitions to limit the transfer of pollutants between adjacent units, e.g., kitchen fumes, tobacco smoke, etc., is resulting in compliance issues for builders to meet future Canadian tiered building codes. Current designs often result in complex interfaces between adjoining units making achieving an air-tight finish challenging. In addition, current practices often leave the finishing of partition walls until the end of the construction process (to enable easy movement between units by trades during construction). There is therefore a need to identify solutions and test their efficacy.

To further the knowledge generated from studies of in-situ airtightness measurements (Lozinsky. (2021), Rosen (2020), Ueno (2015)), the aim of this study was to generate laboratory-based test data for input to future energy and building code requirements for partition wall airtightness. Since a novel approach in using non-traditional materials to build partition walls was applied, it was deemed important to evaluate fire performance as well as acoustical performance of such assemblies.

2 Project Background

In phase 1 of this study, six (6) party-wall specimens were tested on the airtight of partitions between adjacent residential units' project. The selected six specimens were defined to reflect current industry practices of party-walls construction among Canadian homebuilders.
Following up on project phase 1 outcomes (Bartko et. al 2022), the present report summarizes phase 2 results of the project. For the phase 2, future code requirements, it was determined to test several alternatives of partition wall specimens for airtightness testing, mainly consisting of using a spun-bonded polyolefin (SBPO) membrane as an air barrier (AB) within double wood stud partition wall specimens. As the use of the SBPO represents a novel approach in partition wall construction, it was desired by the project collaborators, Canadian Home Builders Association (CHBA) members and staff, to evaluate fire performance as well as acoustical performance of such assemblies.
Seven specimens of partition walls were identified, constructed, and tested to determine their airtightness performance. These specimens are described in detail in Section 4.

Two specimens of partition walls were identified constructed, and tested to determine their fire resistance performance. These specimens are described in detail Section 6.2.

Two specimens of partition walls were identified, constructed, and tested to determine their acoustical performance. These specimens are described in detail Section 7.2

3 Airtightness Test Methodology

A specific test method for the evaluation of party-wall airtightness does not exist. Therefore, for the purpose of this research, the test method for building envelope assemblies was adopted, defined in the ASTM E2357 – 18 “Standard Test Method for Determining Air Leakage Rate of Air Barrier Assemblies”. The test facility is described in Section 3.1 and the test procedure is described in Section 3.2.

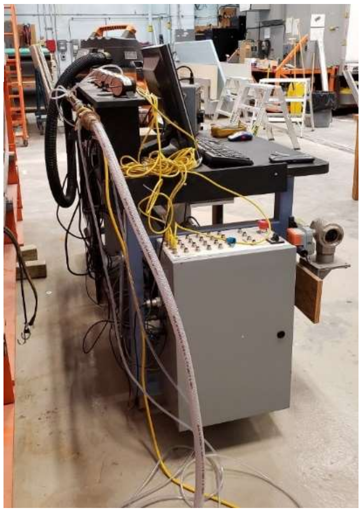
3.1 Airtightness Test Facility

Preparation and testing of specimens were undertaken at the NRC Airtightness Laboratory located at the NRC Construction Research Centre campus on Montreal Road in Ottawa. The test facility is pictured in Figure 1. The chamber size is 8 ft x 8 ft (2.438 m x 2.438 m). It is a 6 in (15 cm) deep steel chamber with an air inlet located at the back side. The chamber has a steel L-shaped flange on all four sides of its perimeter. The flanges are covered with rubber gaskets to ensure an airtight connection between the chamber and the specimen. An air pipe connects the chamber inlet with calibrated pressure transducers and the pressure pump apparatus. The pump system can be configured to deliver either positive or negative pressures. A connected data acquisition unit (DAQ) measures the air flow rate at predetermined constant pressure levels in the chamber.

a)

b)

c)



d)

Figure 1. NRC Airtightness Test Facility; a) 8 ft by 8 ft chamber, b) chamber back side with air inlet and air pipe, c) air pipe connected to pressure transducers and pressure generating vacuum pump, d) installed specimen (left) and pressure vacuum apparatus with DAQ computer (bottom right)

3.2 Airtightness Test Procedure

The test procedure followed Section 9 of ASTM Standard E2357-18. The air leakage value at a given pressure difference is determined from an average of three independent tests using positive pressures, and an average value of three independent tests using negative pressures. Each test contains of a minimum seven (7) pressure points between 25 Pa and 300 Pa, collected for a minimum 10 seconds at each pressure point. The data points are then fit to the power law regression in Equation 1:

$$Q = C \cdot \Delta p^{n} \qquad (1)$$

Where:

Q flow rate, $L/(m^2 \cdot s)$

C flow coefficient, $L/(m^2 \cdot s \cdot Pa^n)$

Δp pressure difference across the specimen, Pa

n flow exponent, -

Equation 1 is then used to determine leakage at Δp=75 Pa per the reporting requirements of ASTM E2357-18 to characterize the air leakage performance of the specimen.

The authors realize that typically, partition walls are exposed to lower pressure differences than building enclosures, and air leakage rates at lower pressures (i.e. Δp at 50 Pa) could be more representative, however, this is left for future discussion.

To eliminate extraneous leakage at the perimeter of the specimen, two sets of tests under positive pressure and two sets under negative pressure are performed for each specimen:

1. “covered” specimen, to determine a perimeter extraneous leakage;
2. “uncovered” specimen, to determine a gross specimen leakage

The “covered” and “uncovered” tests are described in the following subsections.

3.2.1 Test with impermeable cover

For the first test, the specimens are covered with an air-impermeable polycarbonate sheet with dimensions identical to the specimen size. If there is leakage detected, the measured value (average of three tests for positive pressure and three tests for a negative pressure) is assumed to be due to the extraneous perimeter leakage, and is therefore subtracted from the overall leakage determined without the impermeable cover.

3.2.2 Test without impermeable cover

In the second test, the polycarbonate sheet is removed and the tests are repeated. A flow rate value obtained from this test is the gross flow rate @ ΔP=75 Pa, Q_{gross}, including perimeter air leakage. The total air leakage rate of the specimen, $Q_{t,}$ is calculated as follows:

$$Q_t = Q_{gross} - Q_{ext} \qquad (2)$$

Where:

Q_{gross} gross flow rate, L/(m^2*s) @ Δp=75 Pa
Q_{ext} extraneous perimeter flow rate, L/(m^2*s) @ Δp=75 Pa.

4 Airtightness Test Specimens

Seven (7) test specimens were defined in Phase 2 of the project, and were constructed and tested. The specimens represent progressive party-wall building practices as recommended by the joint CHBA and NRC staff project committee.

The list of specimens consists of the following double wood stud wall sections:

1) with 2 unsealed spun-bonded polyolefin (SBPO) membranes AB behind drywall
2) with 2 sealed SBPO membranes AB behind drywall.
3) with 2 sealed SBPO membranes AB behind drywall with penetrations from nails and screws.
4) with airtight drywall AB.
5) with airtight drywall AB with penetrations from nails and screws.
6) with 2 sealed Polyethylene (PE) membranes AB behind drywall.
7) with 2 sealed PE membranes AB behind drywall with penetrations from nails and screws.

Each of these specimens is described in the following sections. Photos taken during construction of the specimens are shown inAppendix A - Appendix A - Photo Documentation on Airtightness Specimens Construction.

4.1 Specimen 1: Double wood stud wall fragment with two unsealed spun-bonded polyolefin (SBPO) membranes AB behind drywall

The exploded diagram of Specimen 1 is shown in Figure 2. The assembly consists of the two 2” x 4” @ 16” o. c. wood stud walls with fibre-glass acoustical insulation and 2.54 cm (1 in.) air cavity in between. Both wall faces were covered with regular 1.27cm (1/2 in.) thick drywall (gypsum boards) and 1.59 cm (5/8 in.) thick, X-type- fire resistant gypsum boards. For the air barrier (AB), spun bonded polyolefin (SBPO) membranes were stapled approximately 30 cm (12 in) along the stud wall frames on both sides of the specimen. Similarly, the periphery of the air barrier was stapled approximately 30 cm (12 in) along the stud wall frames. An exhaust fan and electric box penetration in the drywall and AB sheets were included in this test specimen, shown in Figure 2.

4.2 Specimen 2: Double wood stud wall fragment with two sealed SBPO membranes AB behind drywall

The exploded diagram of Specimen 2 is shown in Figure 3. The assembly consists of the two 2” x 4” @ 16” O. C. wood stud walls with fibre-glass acoustical insulation and 2.54 cm (1 in.) air cavity in between. Both wall faces were covered with regular 1.27cm (1/2 in.) thick drywall (gypsum boards) and 1.59 cm (5/8 in.) thick, X-type- fire resistant gypsum boards. The air barrier consisted of two SBPO membranes were stapled approximately 30 cm (12 in) along the stud wall frames on both sides of the specimen. The periphery of the air barrier was sealed to the stud frame using an acoustical sealant. An exhaust fan and electric box penetration in the drywall and AB sheets were included in this test specimen.

4.3 Specimen 3: Double wood stud wall fragment with two sealed SBPO membranes AB behind drywall with penetrations from nails and screws

The exploded diagram of Specimen 3 is shown in Figure 4. It is constructed identically to Specimen 2 except the effect of air barrier penetrations by nails and screws installed by a homeowner were investigated. Five (5) gauge 6D nails (50 mm long, 1.5 mm in diameter) were installed at the wood stud rows location (into each stud) and five (5) gauge #8 nylon plugs (40 mm long, load bearing capacity: 35 kg) with screws were installed between the wood studs. All five nails, as well as all five screws were removed from the specimen; the nylon plugs remained installed in the drywall during testing.

4.4 Specimen 4: Double wood stud wall fragment with airtight drywall AB

The exploded diagram of Specimen 4 is shown in Figure 5. The assembly consists of the two 2” x 4” @ 16” O. C. wood stud walls with fibre-glass acoustical insulation and 2.54 cm (1 in.) air cavity in between. Both wall faces were covered with regular 1.27cm (1/2 in.) thick drywall (gypsum boards) and 1.59 cm (5/8 in.) thick, X-type- fire resistant gypsum boards. The drywall system served as an air barrier in this specimen. An exhaust fan and electric box penetration in the drywall and AB sheets were included in this test specimen.

4.5 Specimen 5: Double wood stud wall fragment with airtight drywall AB with penetrations from nails and screws

The exploded diagram of Specimen 5 is shown in Figure 6. It is constructed identically to specimen 4 except the effect of air barrier penetrations by nails and screws installed by a homeowner were investigated. Five (5) gauge 6D nails (50 mm long, 1.5 mm in diameter) were installed at the wood stud rows location (into each stud) and five (5) gauge #8 nylon plugs (40 mm long, load bearing capacity: 35 kg) with screws were installed between the wood studs. All five nails, as well as all five screws were removed from the specimen and the nylon plugs remained installed in the drywall before testing.

4.6 Specimen 6: Double wood stud wall fragment with two sealed Polyethylene (PE) membranes AB behind drywall

The exploded diagram of Specimen 6 is shown in Figure 7. The assembly consists of the two 2" x 4" @ 16" O. C. wood stud walls with fibre-glass acoustical insulation and 2.54 cm (1 in.) air cavity in between. Both wall faces were covered with regular 1.27cm (1/2 in.) thick drywall (gypsum boards) and 1.59 cm (5/8 in.) thick, X-type- fire resistant gypsum boards. The air barrier consisted of polyethylene sheets (6-mil poly) were stapled approximately 30 cm (12 in) along the stud wall frames on both sides of the specimen. The periphery of the air barrier was sealed to the stud frame using an acoustical sealant. An exhaust fan and electric box penetration in the drywall and AB sheets were included in this test specimen, shown in Figure 7Figure 2.

4.7 Specimen 7: Double wood stud wall fragment with 2 sealed PE membranes AB behind drywall with penetrations from nails and screws

The exploded diagram of Specimen 7 is shown in Figure 8. It is constructed identically to Specimen 6 except the effect of air barrier penetrations by nails and screws installed by a homeowner were investigated. Five (5) gauge 6D nails (50 mm long, 1.5 mm in diameter) were installed at the wood stud rows location (into each stud) and five (5) gauge #8 nylon plugs (40 mm long, load bearing capacity: 35 kg) with screws were installed between the wood studs. All five nails, as well as all five screws were removed from the specimen and the nylon plugs remained installed in the drywall before testing.

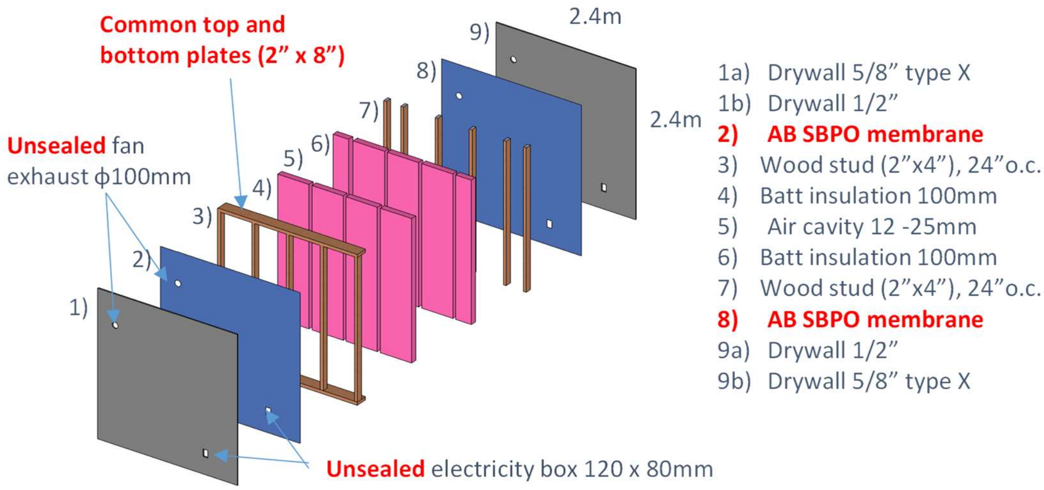


Figure 2. Specimen 1 diagram

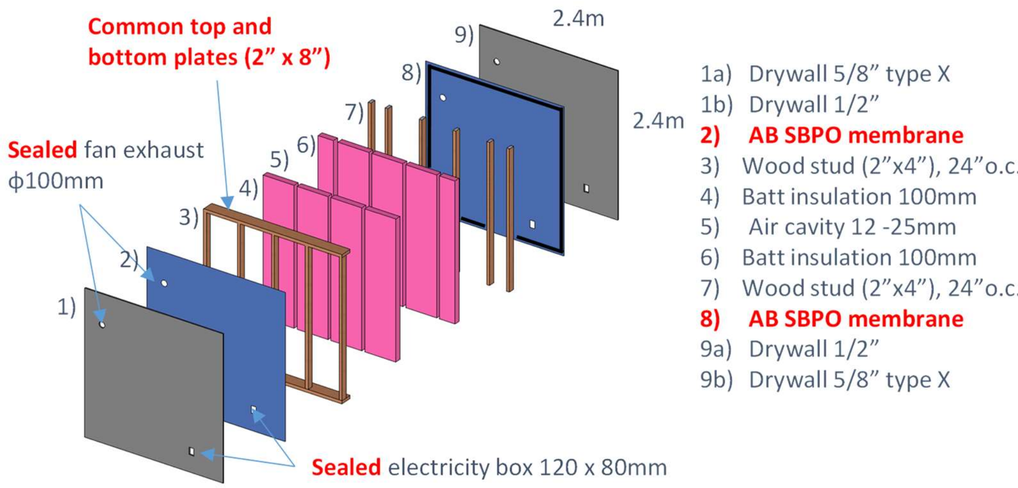


Figure 3. Specimen 2 diagram

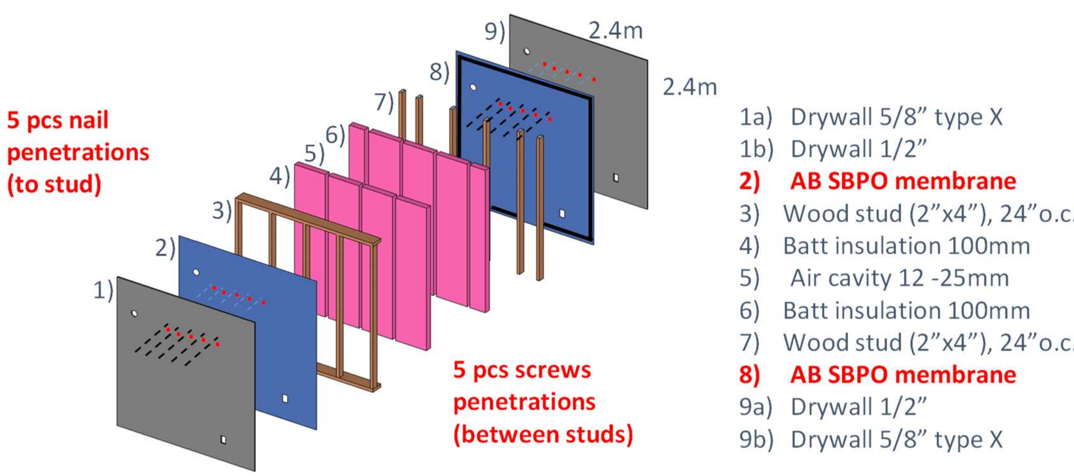


Figure 4. Specimen 3 diagram

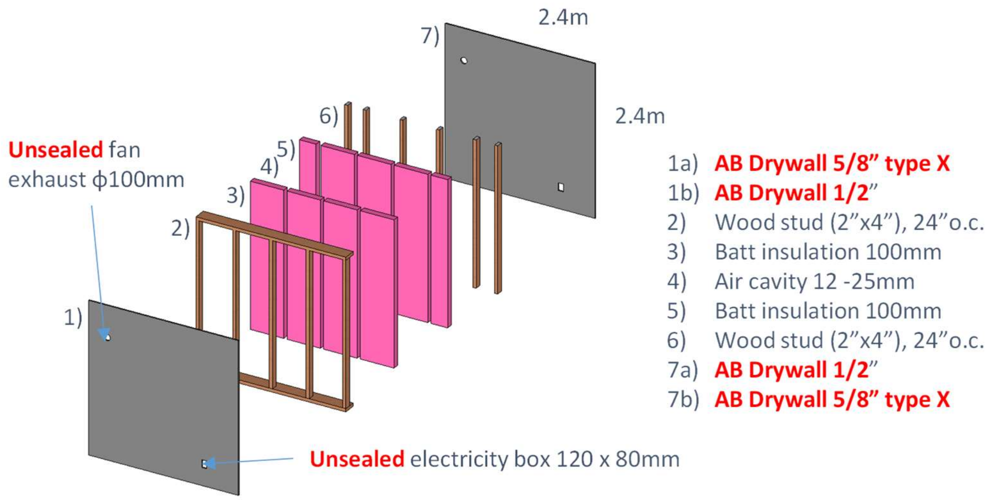


Figure 5. Specimen 4 diagram

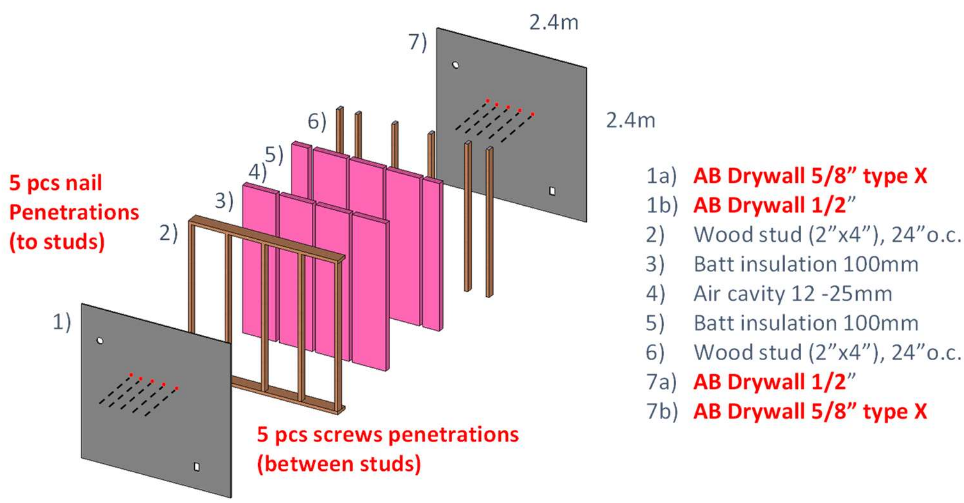


Figure 6. Specimen 5 diagram

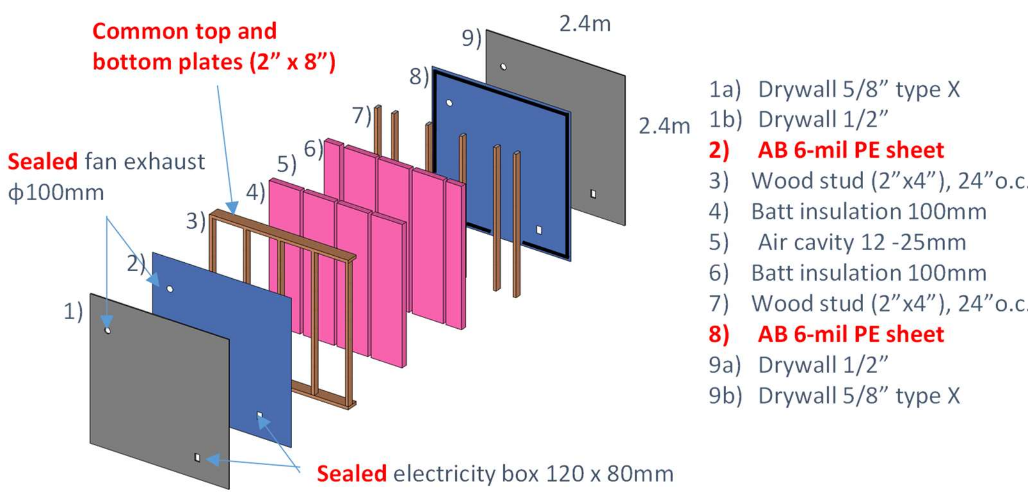


Figure 7. Specimen 6 diagram

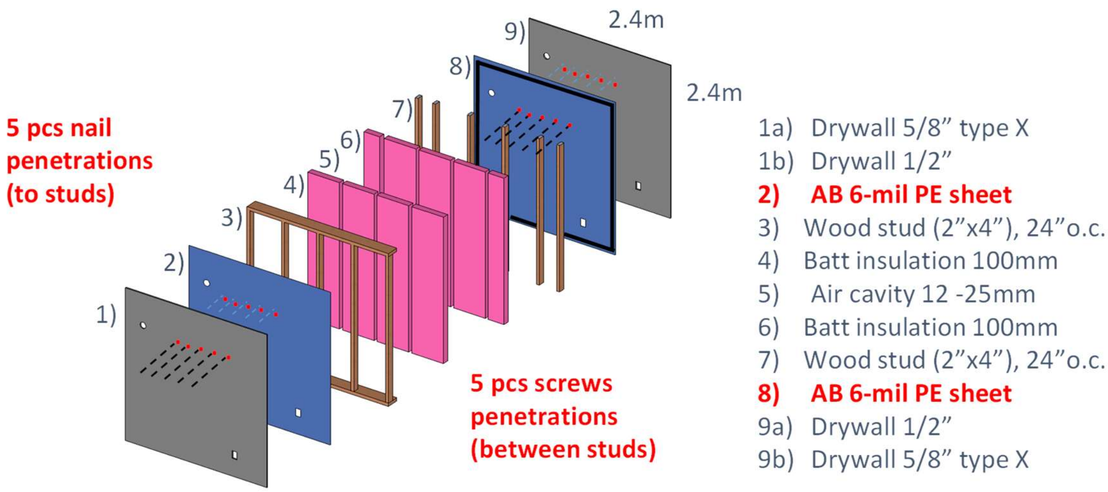


Figure 8. Specimen 7 diagram

5 Airtightness Test Results and Discussion

The air flow rate test results @ Δp=75 Pa, L/(m^2·s) were calculated using the equations (1) and (2). The positive and negative chamber pressure results are presented in Tables 1 and 2, respectively. The graphical interpretation of both the positive and negative pressure test results are presented in Figure 9. The values shown in the tables and the diagram are the average values of the three independent tests.

Given today's construction practices, the partition wall specimen with airtight drywall air barrier system (Specimen 4) can be considered as a benchmark value. For this specimen, at a 75 Pa pressure difference, the air leakage rate was 0.115 L/(m^2·s) and 0.116 L/(m^2·s) for negative and positive pressure differences respectively. The air leakage rates in the airtight drywall system with nail and screw penetrations (Specimen 5) increased to 0.137 L/(m^2·s) and 0.134 L/(m^2·s) for negative and positive pressures differences respectively, which represents a 17% increase.

Table 1. Air flow rate results for positive pressure tests

	Air flow rates at positive pressure difference of 75Pa L/(m^2·s)		
	Total	Gross	Perimeter Extraneous
Specimen 1, unsealed SBPO	**0.054**	0.069	0.015
Specimen 2, sealed SBPO	**0.000**	0.003	0.003
Specimen 3, sealed SBPO, penetrations	**0.003**	0.006	0.003
Specimen 4, airtight drywall	**0.116**	0.123	0.007
Specimen 5, airtight drywall, penetrations	**0.134**	0.137	0.003
Specimen 6, sealed PE	**0.005**	0.009	0.004
Specimen 7, sealed PE, penetrations	**0.001**	0.009	0.008

Table 2. Air flow rate results for negative pressure tests

	Air flow rates at negative pressure difference of 75 Pa L/(m²·s)		
	Total	Gross	Perimeter Extraneous
Specimen 1, unsealed SBPO	**0.097**	0.113	0.016
Specimen 2, sealed SBPO	**0.000**	0.006	0.011
Specimen 3, sealed SBPO, penetrations	**0.004**	0.006	0.002
Specimen 4, airtight drywall	**0.115**	0.123	0.008
Specimen 5, airtight drywall, penetrations	**0.137**	0.141	0.003
Specimen 6, sealed PE	**0.001**	0.006	0.004
Specimen 7, sealed PE, penetrations	**0.002**	0.008	0.006

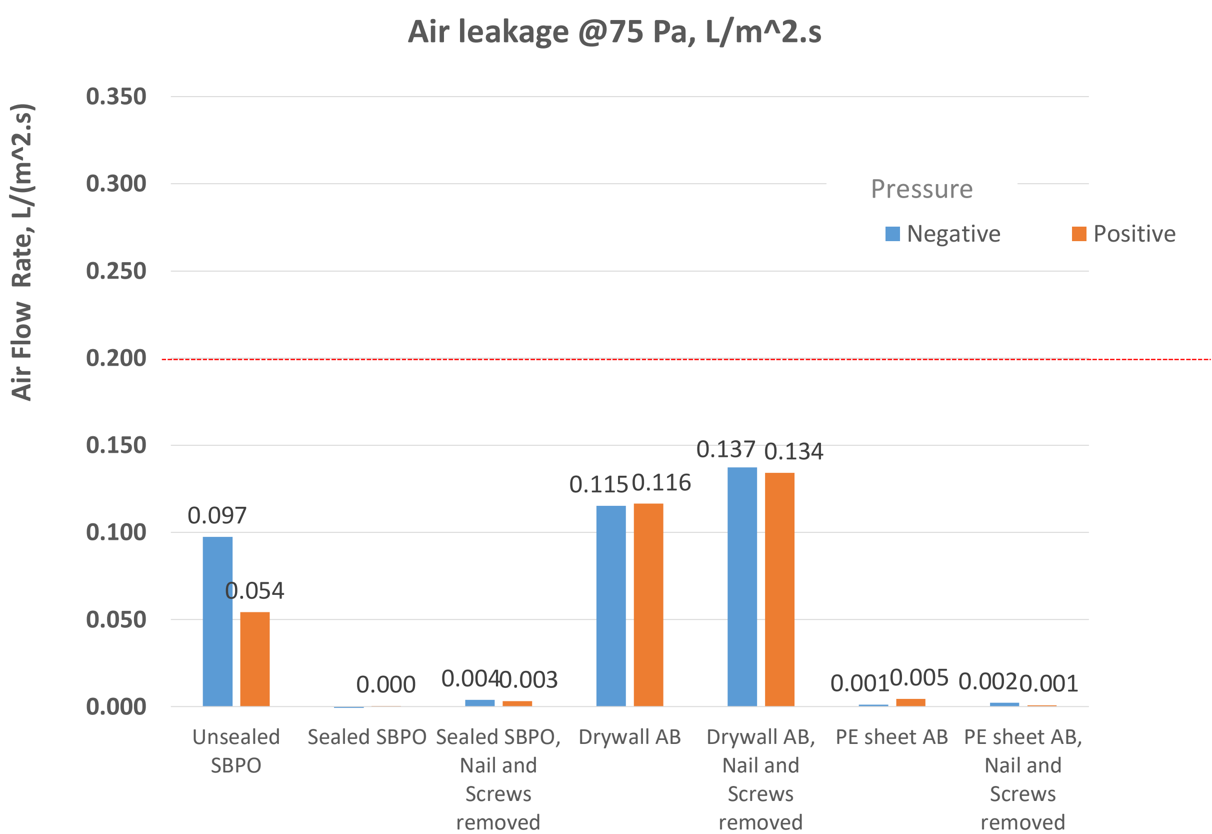


Figure 9. Air leakage test results at pressure difference 75 Pa

The air flow rates at pressure 75 Pa for an unsealed SBPO sheet specimen (Specimen 1) were 0.097 L/(m^2·s) and 0.054 L/(m^2·s) for negative and positive pressure differences respectively.

The air leakage for both sealed specimens (SBPO- Specimen 2, and PE membranes- Specimen 6) were essentially non-existent; the flow rates values were 0 L/(m^2·s). For both membrane air barrier systems, the effect of penetrations (Specimen 3 and Specimen 7) was negligible. The air flow rates of both specimens remained close to 0 L/(m^2·s).

The red line at the value of 0.2 L/(m^2·s) represents the limit value for airtightness of building envelope assemblies in NBC 2020 and serves for comparison purposes only. The detailed air leakage test results are presented in Appendix B - Air Leakage Test Results.

6 Fire Resistance Test Methodology

The fire resistance testing was done in accordance with the test protocol of the standard CAN ULC-S101-14 “Standard methods of fire endurance tests of building construction and materials”.

6.1 Fire Test Facility

Preparation and testing of specimens were undertaken at the NRC Construction Research Centre campus on Montreal Road in Ottawa. The Wall Furnace Test Facility shown in Figure 10 was used for this purpose. The chamber size is 12 ft x 10 ft (3.658 m x 3.048 m).

Figure 10. NRC Wall Furnace Test Facility

6.2 Fire Test Specimens

Two specimens were examined. The wall assembly was identical for both. The exploded diagram of the fire test specimens is shown in Figure 11. The assembly consists of the two 2” x 4” @ 24” O. C. wood stud walls with fibre-glass acoustical insulation and up to 1 cm (1/2 in.) air cavity in between the wood frames. Both wall faces were covered with regular 1.27 cm (1/2 in.) thick drywall (gypsum boards) and 1.59 cm (5/8 in.) thick, X-type- fire resistant gypsum boards. The air barrier (AB) consisted of two spun bonded polyolefin sheets and were stapled approximately 30 cm (12in) along the stud wall frames on both sides of the specimen.

The difference between the two specimens was the attachment method for the AB. The Specimen F1 had the AB sheet **sealed** to the stud frame at the perimeter using an acoustical sealant. An electric box penetration in the drywall included in this test specimen, was also sealed to the AB sheet. The Specimen F2 had its AB sheet **unsealed**, it was attached to the wood frame with staples only.

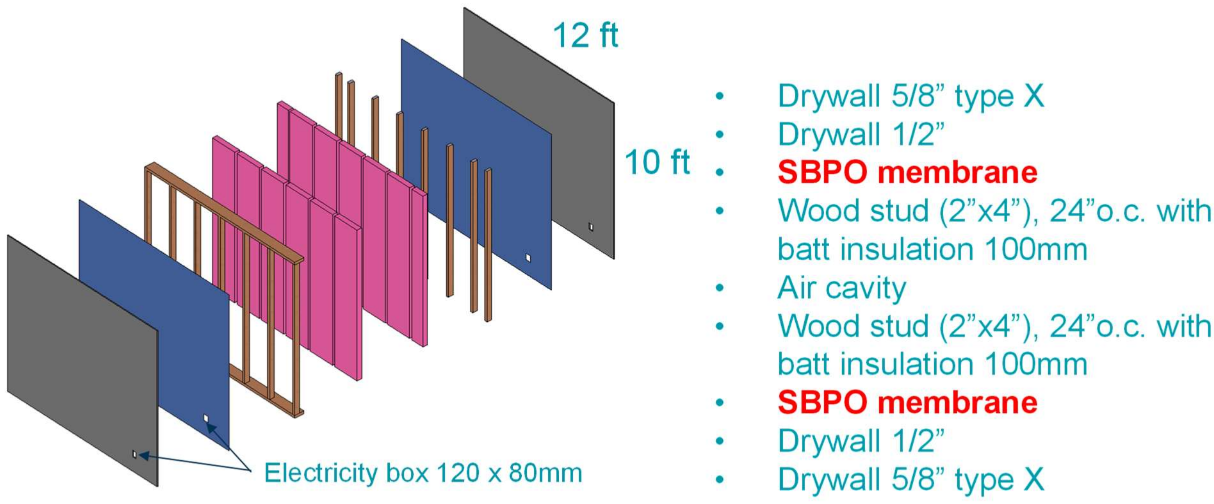


Figure 11. Diagram of Fire test specimens

Photos taken during specimen construction are shown in Appendix C - Photo Documentation on Fire Specimens Construction.

6.3 Superimposed Load Calculation

The load calculation was identical for both tested specimens. The NRC carried out the detailed load calculations for the partition wall assembly and it is given in Appendix E - Superimposed Load Calculation.

6.4 Failure Criteria

The failure criteria as per CAN/ULC-S101-14 standard in Section 7.4 "Determination of Fire Endurance Period" are as follows:

1. Transmission of heat through the test specimen throughout the fire endurance test shall not raise the average temperature measured by the stationary thermocouples on its unexposed surface more than 140°C above its initial average temperature; nor shall the temperature rise at any individual point exceed 180°C including a temperature measured by the roving thermocouple.

2. The test specimen shall have sustained the applied load throughout the fire endurance test without passage of flame or passage of gasses.

6.5 Video Recordings

Two video cameras were used to record the observations of the fire-exposed side of the wall assembly, viewed through two ports (east and west sides) in the furnace. A third video camera was also used to record observations on the unexposed side of the wall. Copies of these video recordings can be provided upon request and constitute part of the report.

6.6 Fire Test Results

The summary of the fire test results for each specimen is shown in Figure 12 and summarized in Table 3. The detailed results are presented in Appendix D - Fire Test Results.

Figure 12. Fire test specimens' failure

Table 3. Fire rating of the test specimens

Specimen	Time to failure (min)	Mode of failure
F1, Sealed AB	75	Structural
F2, Unsealed AB	72	Structural

7 Acoustic Test Methodology

The acoustic testing was done in accordance with the test protocol of the standard ASTM E90-09 (2016) “Standard method for laboratory measurement of airborne sound transmission loss of building partitions and elements”. Airborne sound transmission loss tests were performed in the forward (receiving room is the large room) and reverse (receiving room is the small room) directions. Results presented in this report are the average of the tests in these two directions. In each case, sound transmission loss values were calculated from the average sound pressure levels of both the source and receiving rooms and the average reverberation times of the receiving room. One-third octave band sound pressure levels were measured for 32 seconds at eight microphone positions in each room and then averaged to get the average sound pressure level in each room. Five sound decays were averaged to get the reverberation time at each microphone position in the receiving room; these reverberation times were averaged to get the average reverberation times for each room. Information on the flanking limit of the facility and reference specimen test results are available on request.

7.1 Acoustic Test Facility and Equipment

Preparation and testing of specimens were undertaken at the NRC Construction Research Centre campus on Montreal Road in Ottawa. The schematic representing a wall sound transmission facility used for this purpose is shown in Figure 13.

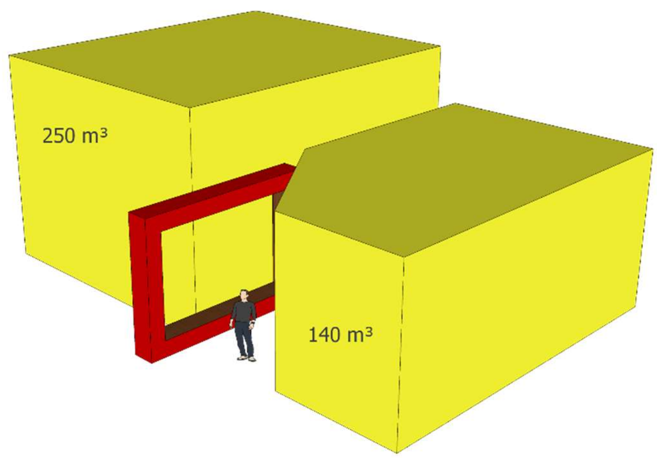


Figure 13. NRC Wall Sound Transmission Facility

The NRC Construction Wall Sound Transmission Facility accommodates the specimen size of 12 ft x 8 ft (3.658 m x 2.438 m, specimen area: 8.92 m^2). It is comprised of two reverberation rooms (referred to in this report as the large and small rooms) with a moveable test frame between the two rooms. The large room has an approximate volume of 256 m^3 while the small room has an approximate volume of 141 m^3. In each room, there are 8 pre-polarized diffuse-field ½" microphones, Brüel & Kjær Type 4942. Measurements are made in both rooms simultaneously using a NI PXI 4499 DAQ system with LabVIEW measurement software. Each room has four loudspeakers driven by separate amplifiers and noise sources. To increase diffusivity of the sound field, there are fixed diffusing panels in each room.

7.2 Acoustic Test Specimens

Four specimens were examined. The wall assembly was identical for all four. The exploded diagram of the acoustic test specimens is shown in Figure 14. The assembly consists of two 2 in. x 4 in. @ 24 in. O. C. wood stud walls with fibre-glass acoustical insulation and up to 1 cm (1/2 in.) air cavity in between. Both wall faces were covered with regular 1.27cm (1/2 in.) thick drywall (gypsum boards) and 1.59 cm (5/8 in.) thick, X-type- fire resistant gypsum boards. The air barrier (AB) consisted of a spun bonded polyolefin sheet and was stapled approximately 30 cm (12in) along the stud wall frames on both sides of the specimen.

There were two variations of two specimens:

- Specimen with vs. without exhaust and electrical box penetrations
- Specimens with sealed vs. unsealed AB sheet and penetrations.

The specimen No 1 and 2 had the AB sheet **sealed** to the stud frame at the perimeter using an acoustical sealant. An electric box, and an exhaust penetration in the drywall of specimen 2 were also sealed to the AB sheet. The specimens No 3 and 4 had its AB sheet **unsealed**; it was attached to the wood frame with staples only.

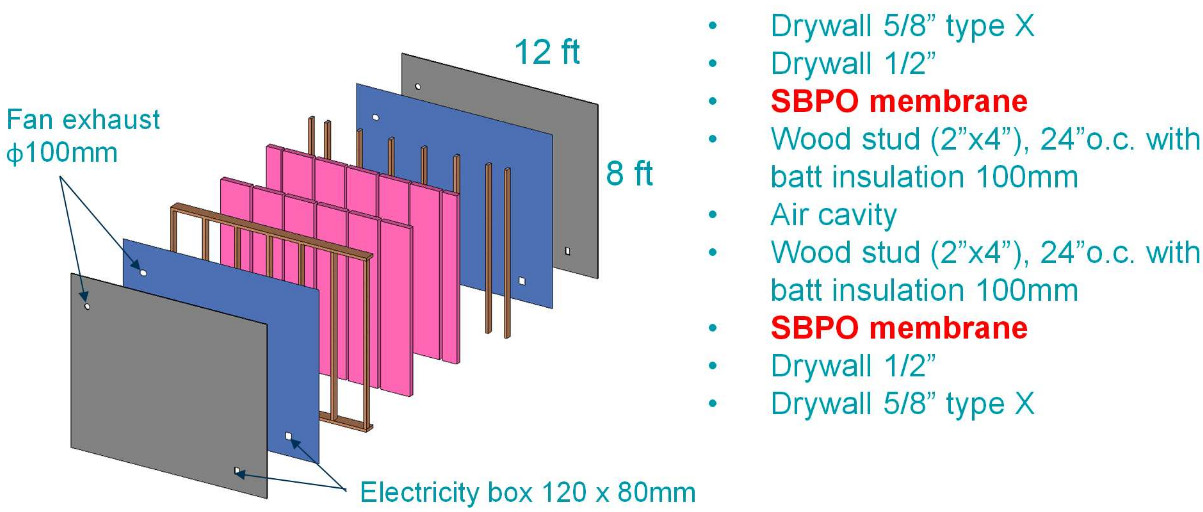


Figure 14. Diagram of Acoustic test specimens

Photos taken during specimen construction are shown in Appendix F - Photo Documentation on Acoustic Specimen Construction.

7.3 Acoustic Test Results

ASTM E90-09 (2016) requires measurements in one-third octave bands in the frequency range between 100 Hz and 5000 Hz. Within this range, reproducibility has been assessed by inter-laboratory round robin studies. The standard recommends making measurements and reporting results over a larger frequency range, and this report presents such results, which may be useful for expert evaluation of the specimen performance. The precision of results outside the

100 Hz to 5000 Hz range has not been established, and is expected to depend on laboratory-specific factors.

The Sound Transmission Class (STC) was determined in accordance with ASTM E413-22, “Classification for Rating Sound Insulation.” It is a single-number rating scheme intended to rate the acoustical performance of a partition element separating offices or dwellings. The higher the value of the STC rating, the better the performance of the building element is expected to be. The rating is intended to correlate with subjective impressions of the sound insulation provided against the sounds of speech, radio, television, music, and similar sources of noise characteristic of offices and dwellings. The STC is of limited use in applications involving noise spectra that differ markedly from those referred to above (for example, heavy machinery, power transformers, aircraft noise, motor vehicle noise). Generally, in such applications it is preferable to consider the source levels and insulation requirements for each frequency band.

The results of the acoustic tests for each specimen are summarized in Table 4. The detailed results are presented in Appendix G - Acoustic Test Results.

Table 4. Acoustic rating of the test specimens

Specimen	STC
A1, Unsealed, no penetrations	49
A2, Unsealed, with penetrations	49
A3, Sealed, no penetrations	51
A4, Sealed, with penetrations	51

Note: **In-Situ Performance:** The ratings obtained by this standard test method tend to represent an upper limit of what might be measured in a field test, due to structure-borne sound transmission (“flanking”) and construction deficiencies in actual buildings.

8 Summary and Conclusions

Seven (7) party-wall specimens were tested in the phase 2 study on the airtight of partition walls between adjacent residential units project. The selected seven specimens were defined to reflect current and novel industry practices of party-walls construction among Canadian homebuilders. The assemblies of specimens were vetted and approved by a committee consisting of NRC staff and CHBA membership.

Several conclusions can be drawn from the phase 2 airtightness test results:

- The airtightness of a partition wall assembly with no membrane type air barrier, using an airtight drywall approach, while being the poorest performing of all specimens is still initially acceptable; however, due to unpredictability of the number of fastener penetrations increasing over time (occupant behaviour) this solution is unlikely to maintain performance over the long term.
- The airtightness of partition wall assemblies with two membranes of both types: polyethylene (PE) sheets and spun-bonded polyolefin (SBPO) membranes, is considerably higher than the airtight drywall system; the air flow rates are well within the test facility uncertainty specifications: practically zero air leakage occurs.

- Penetrations to the assemblies with membrane air barriers decrease airtightness (increase air flow rate) only slightly, allowing for an assumption of continued long-term performance.
- To assure required airtightness, construction openings (cuts in air barrier to simplify between unit communication) should ideally be avoided. In case they are applied, care must be taken to ensure they are properly sealed at the end of the construction, which increases on-site quality assurance requirements for crews and crew chiefs.

Two SBPO partition wall specimens were also tested for fire and acoustical resistance. The fire resistance test results show a slight difference in the time till fracture: 75 minutes and 72 minutes, for sealed and unsealed SBPO membrane respectively, both with identical structural failure.

Similarly, acoustic test results show a slight difference between the two specimens: STC51 and STC49 for sealed and unsealed SBPO membrane respectively.

Acknowledgments

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Authors express thanks to the NRC Fire Safety department colleagues: Mohamed Sultan, Masoud Adelzadeh, Eric Gibbs, Karl Gratton, Pier-Simon Lafrance and Mark Weinfurter as well as Acoustic department colleague Ryan Moloughney.

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Appendix A - Photo Documentation on Airtightness Specimens Construction

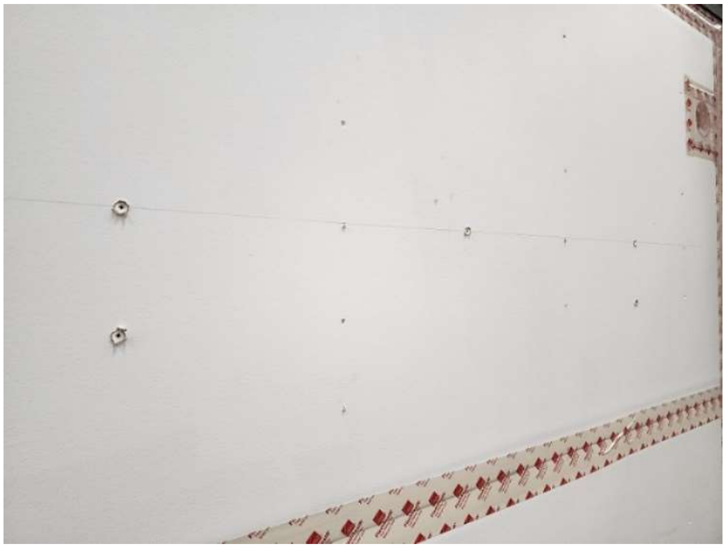
A.1 Specimen 1: Double wood stud wall fragment with two unsealed SBPO membranes AB behind drywall

Figure 15. Specimen 1 construction photos

A.2 Specimen 2: Double wood stud wall fragment with two sealed SBPO membranes AB behind drywall

Figure 16. Specimen 2 construction photos

A.3 Specimen 3: Double wood stud wall fragment with two sealed SBPO membranes AB behind drywall with penetrations from nails and screws



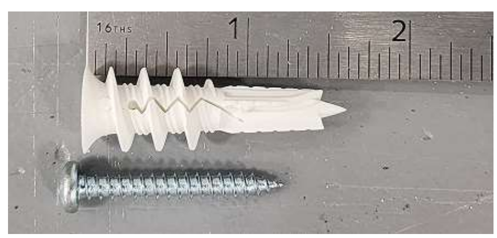


Figure 17. Specimen 3 construction photos

Note: Specimen 2 was used to prepare Specimen 3 by making the fasteners penetrations

A.4 Specimen 4: Double wood stud wall fragment with airtight drywall AB

Figure 18. Specimen 4 construction photos

A.5 Specimen 5: Double wood stud wall fragment with airtight drywall AB with penetrations from nails and screws

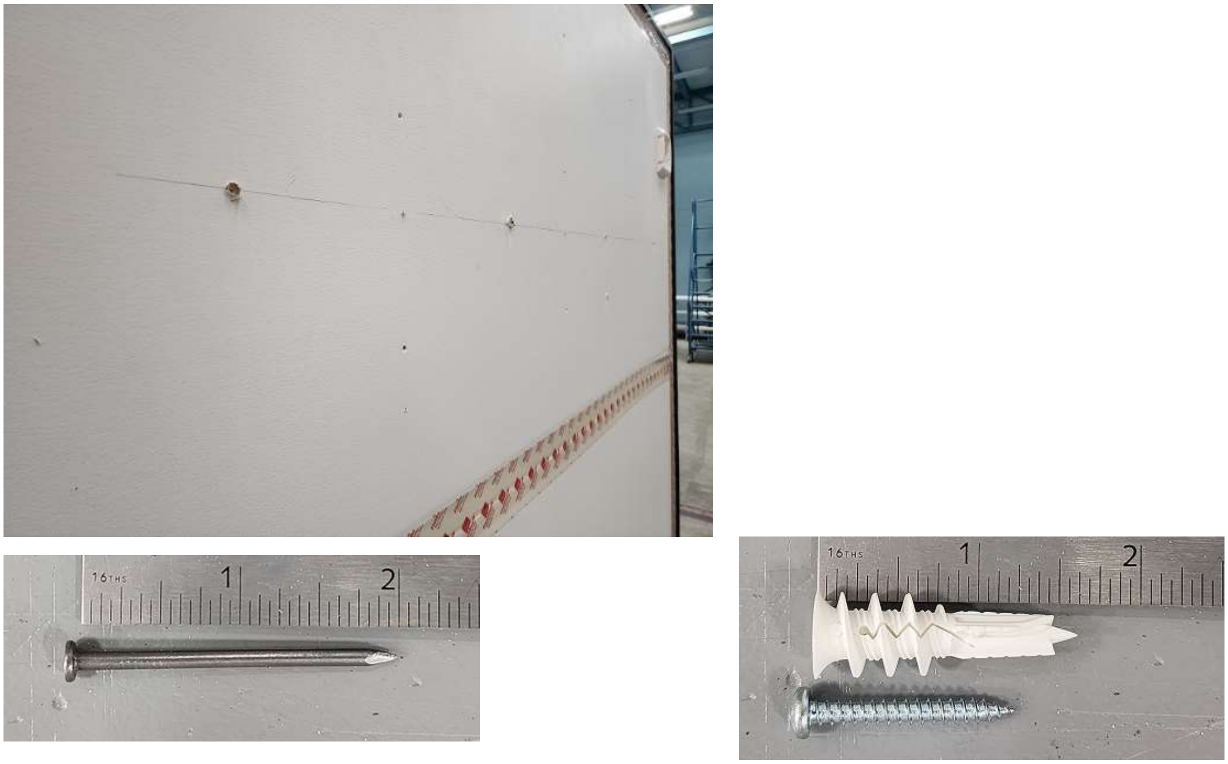


Figure 19. Specimen 5 construction photos

Note: Specimen 4 was used to prepare Specimen 5 by making the fasteners penetrations

A.6 Specimen 6: Double wood stud wall fragment with two sealed PE membranes AB behind drywall

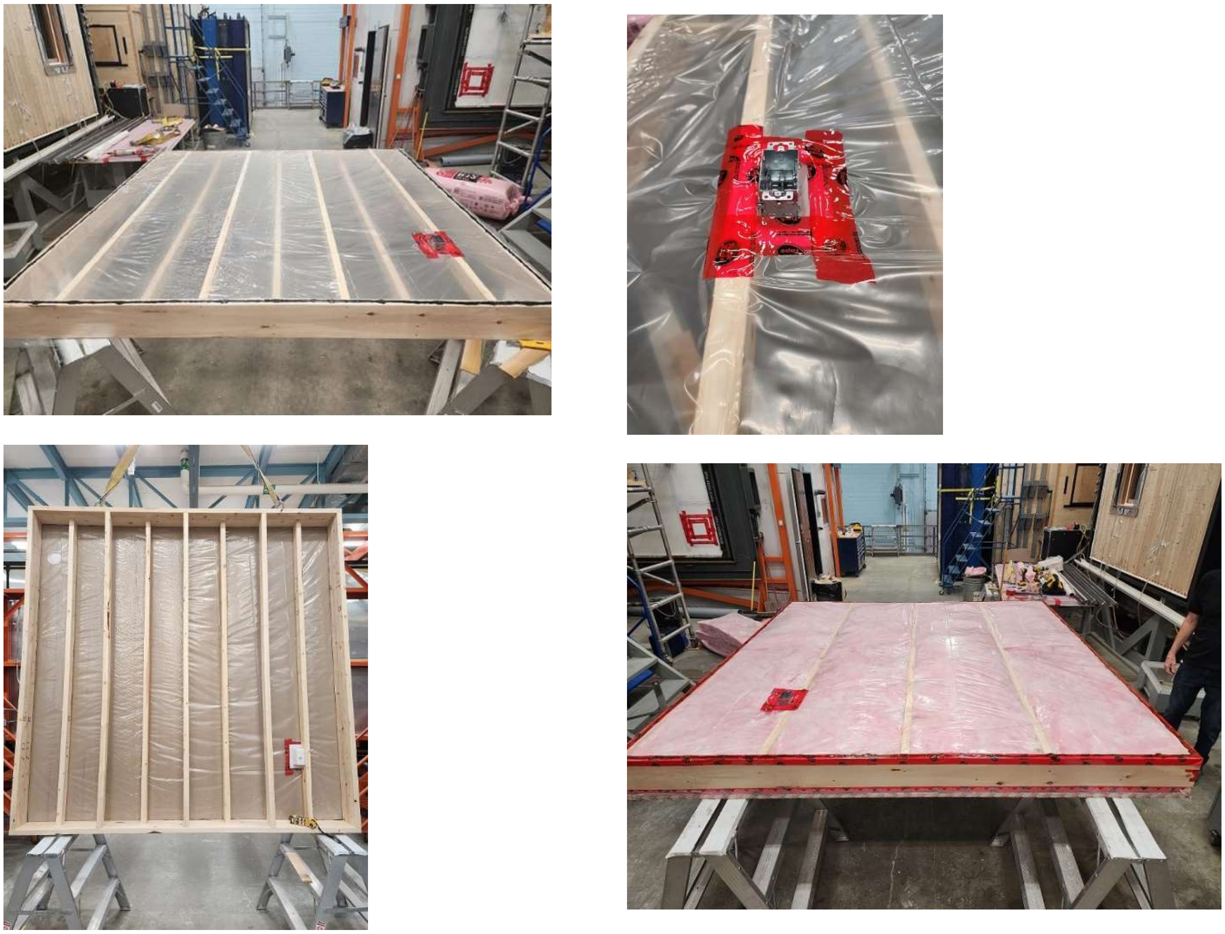


Figure 20. Specimen 6 construction photos

A.7 Double wood stud wall fragment with two sealed PE membranes AB behind drywall with penetrations from nails and screws

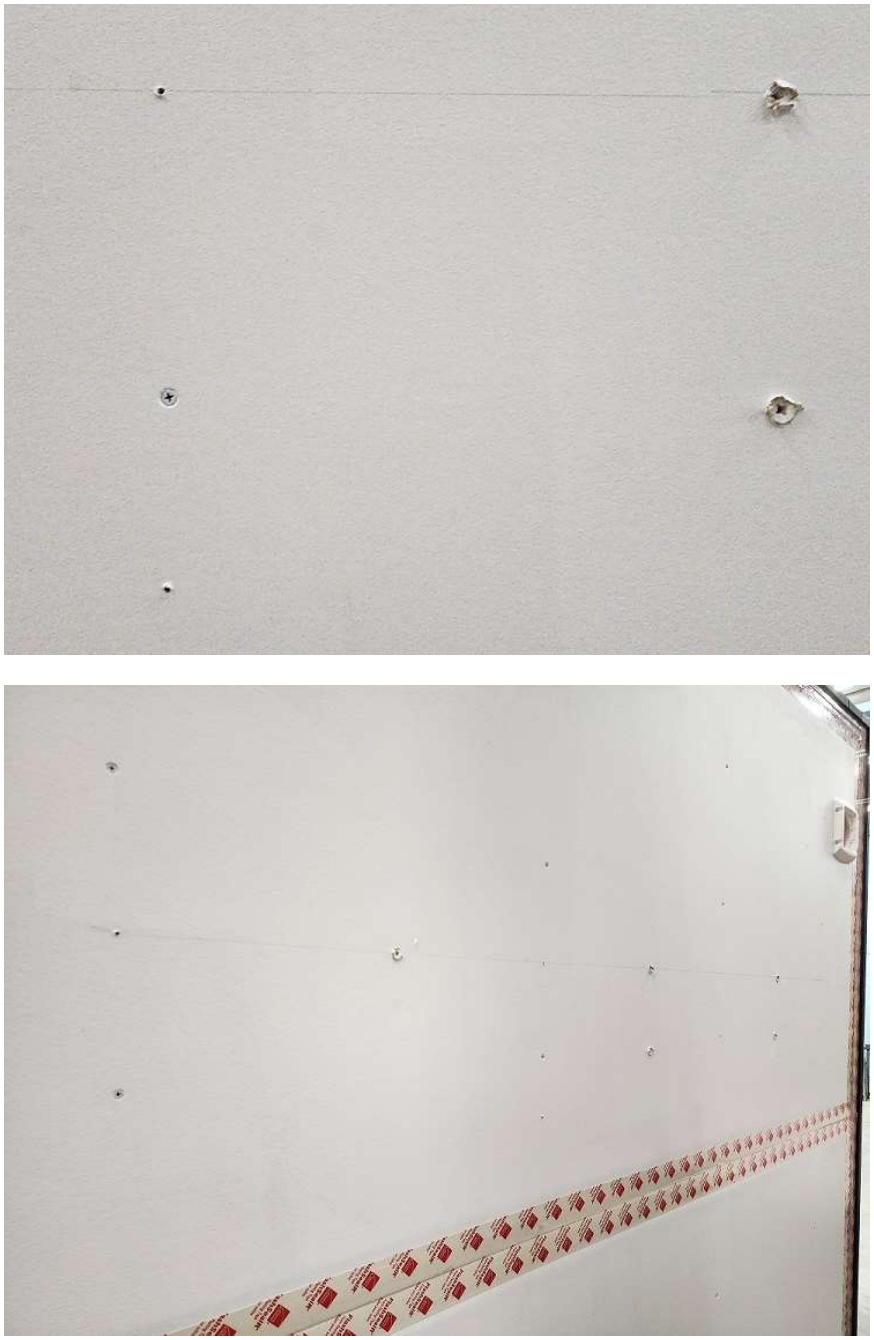


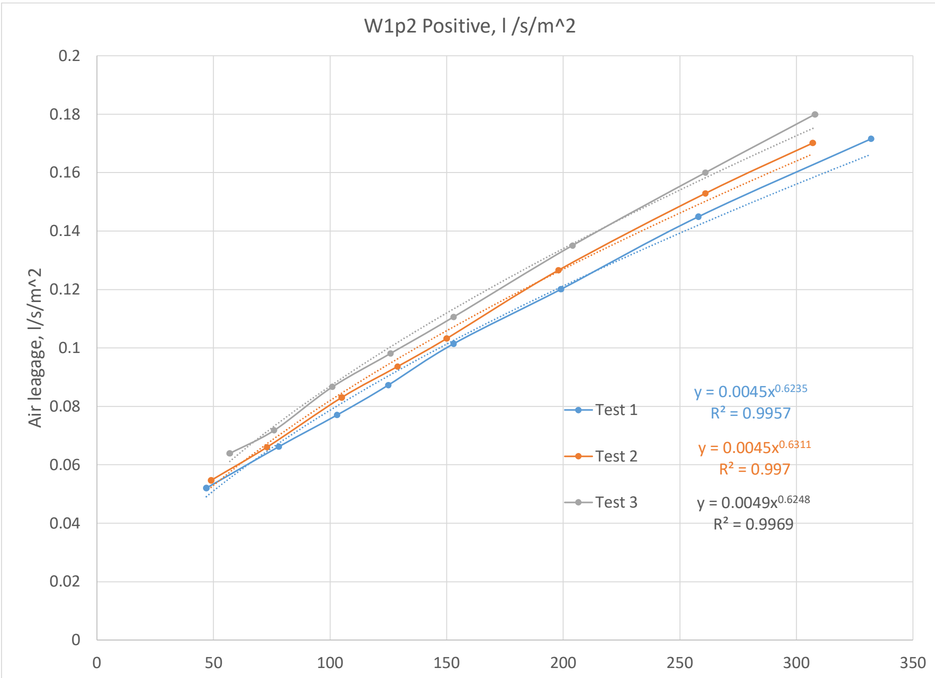
Figure 21. Specimen 7 construction photos

Note: Specimen 6 was used to prepare Specimen 7 by making the fasteners penetrations

Appendix B - Air Leakage Test Results

B.1 Specimen 1: Double wood stud wall fragment with two unsealed SBPO membranes AB behind drywall

B.1.1 Positive pressure tests



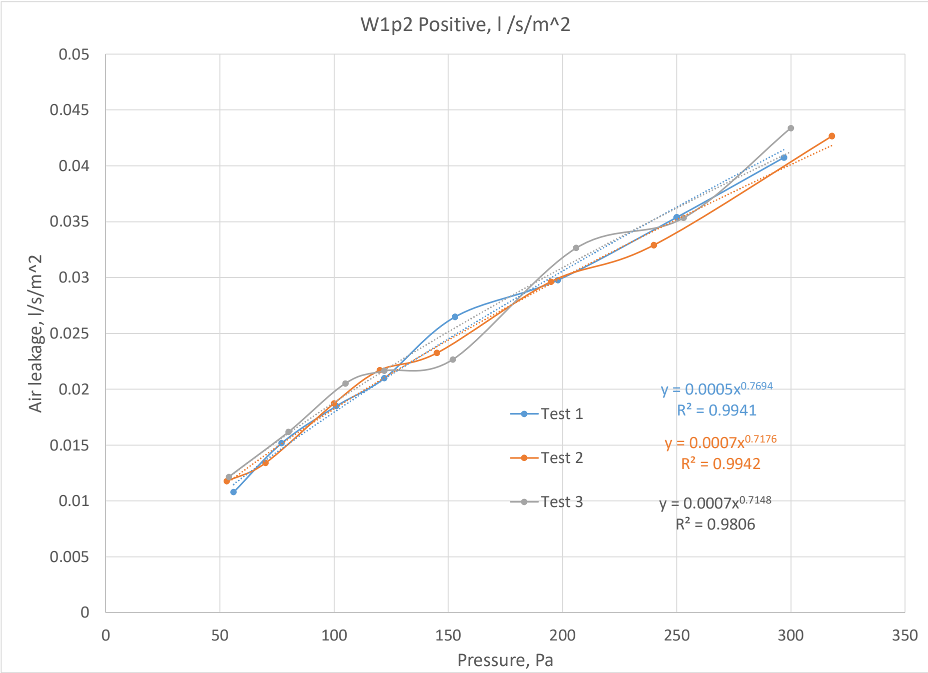
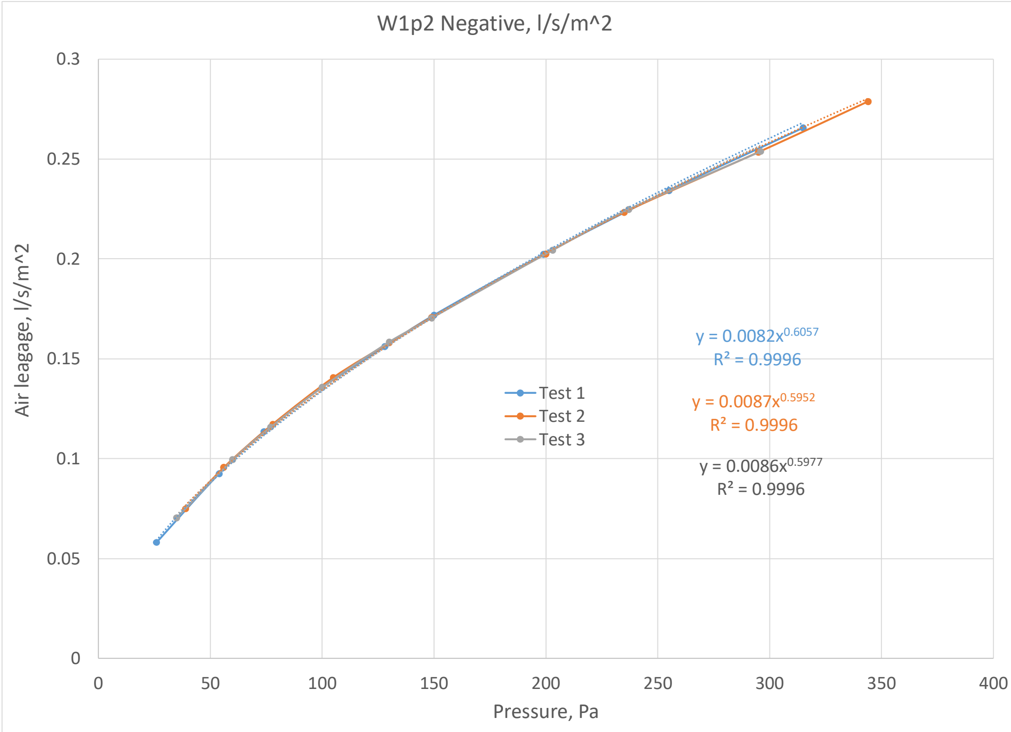


Figure 22. Specimen 1 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.1.2 Negative pressure tests



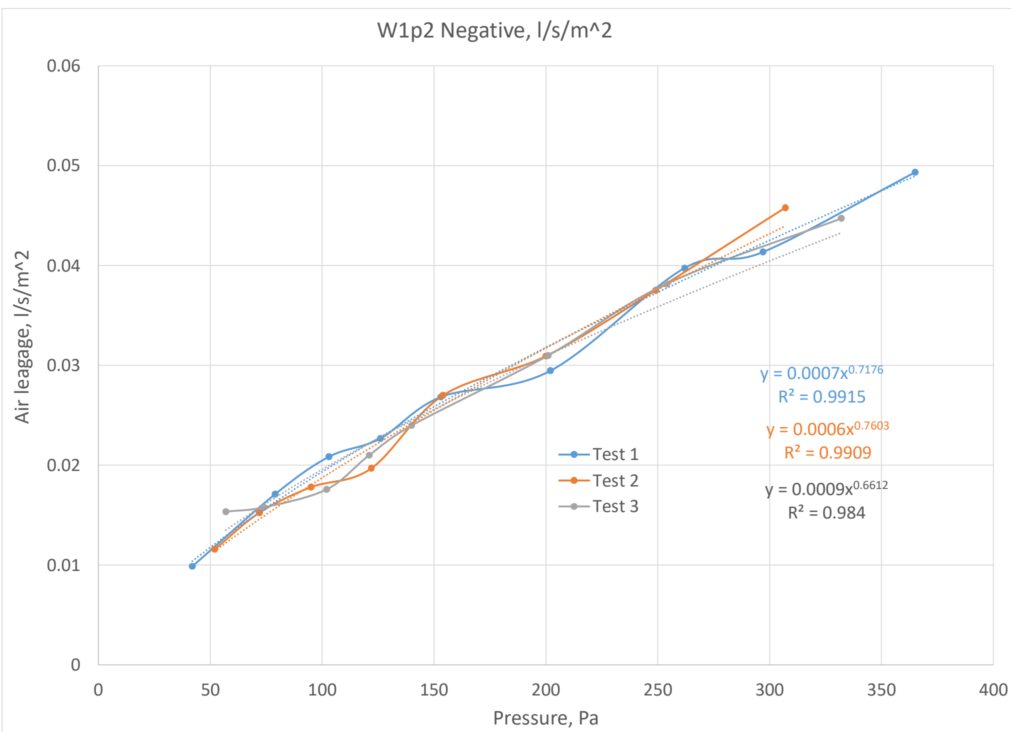
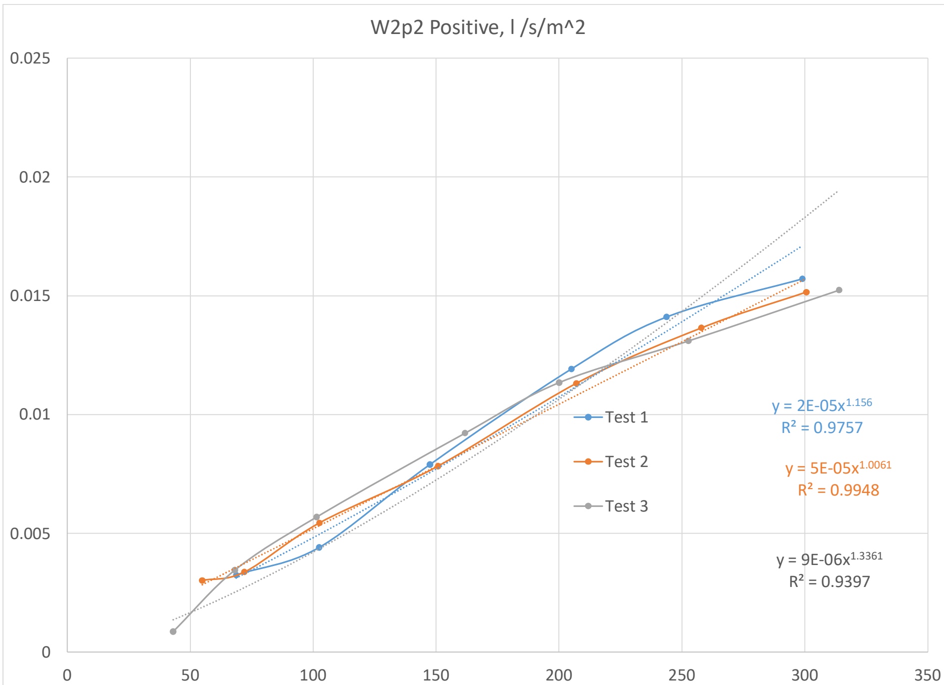


Figure 23. Specimen 1 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.2 Specimen 2: Double wood stud wall fragment with two sealed SBPO membranes AB behind drywall

B.2.1 Positive pressure tests



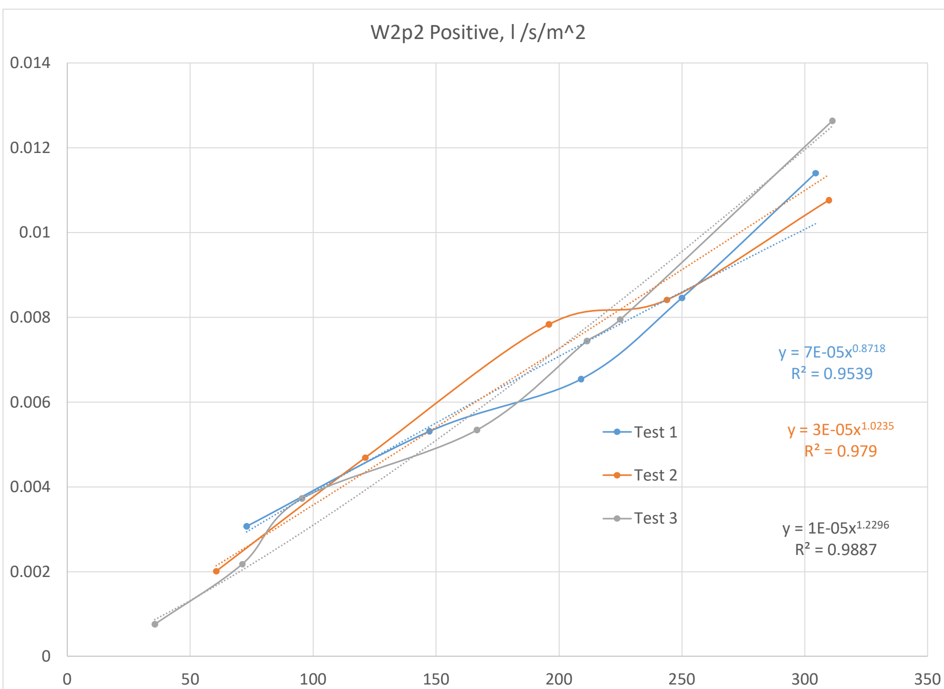
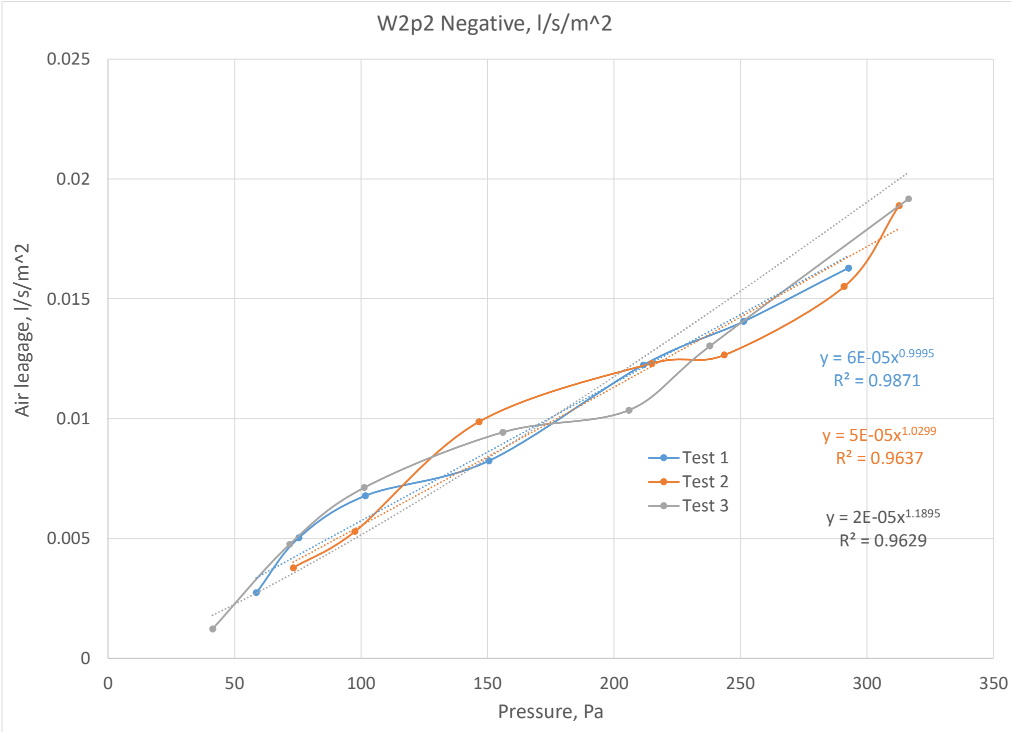


Figure 24. Specimen 2 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.2.2 Negative pressure tests



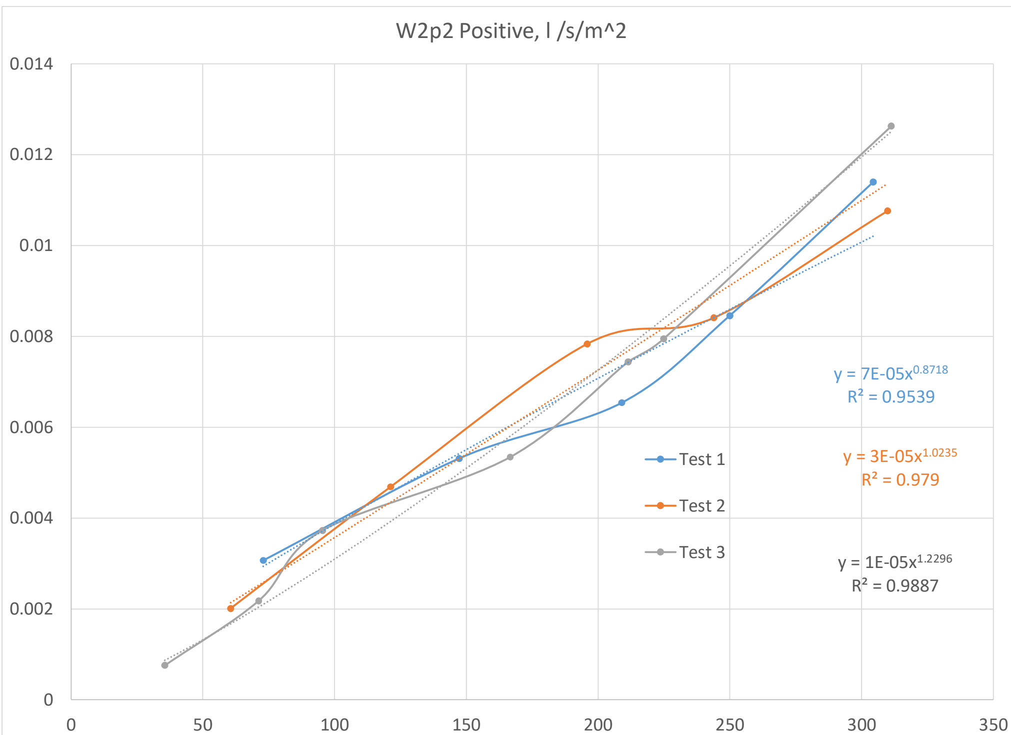
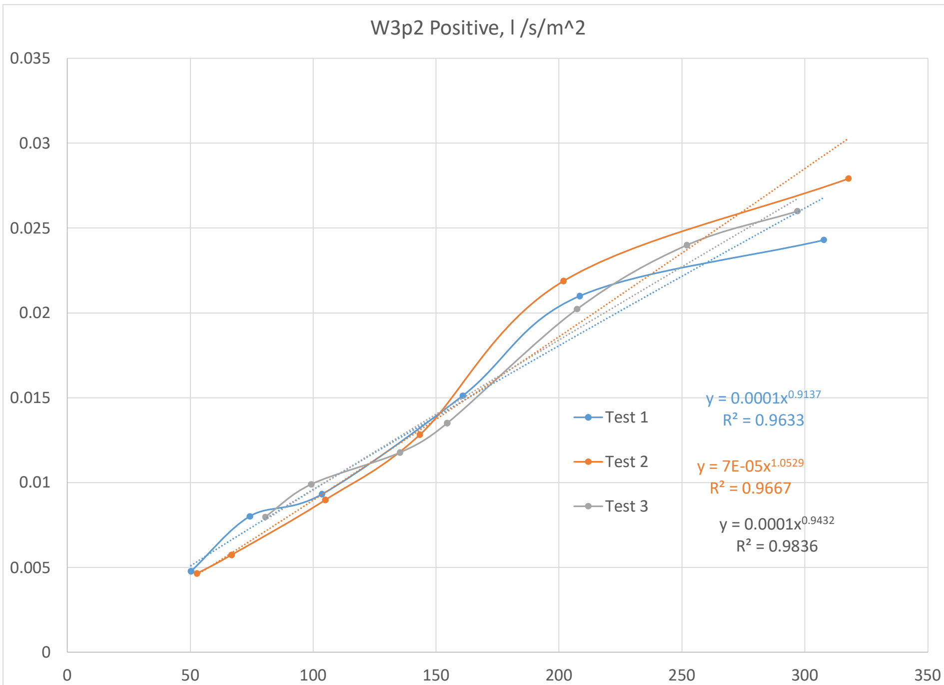


Figure 25. Specimen 2 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.3 Specimen 3: Double wood stud wall fragment with two sealed SBPO membranes AB behind drywall with penetrations from nails and screws

B.3.1 Positive pressure tests



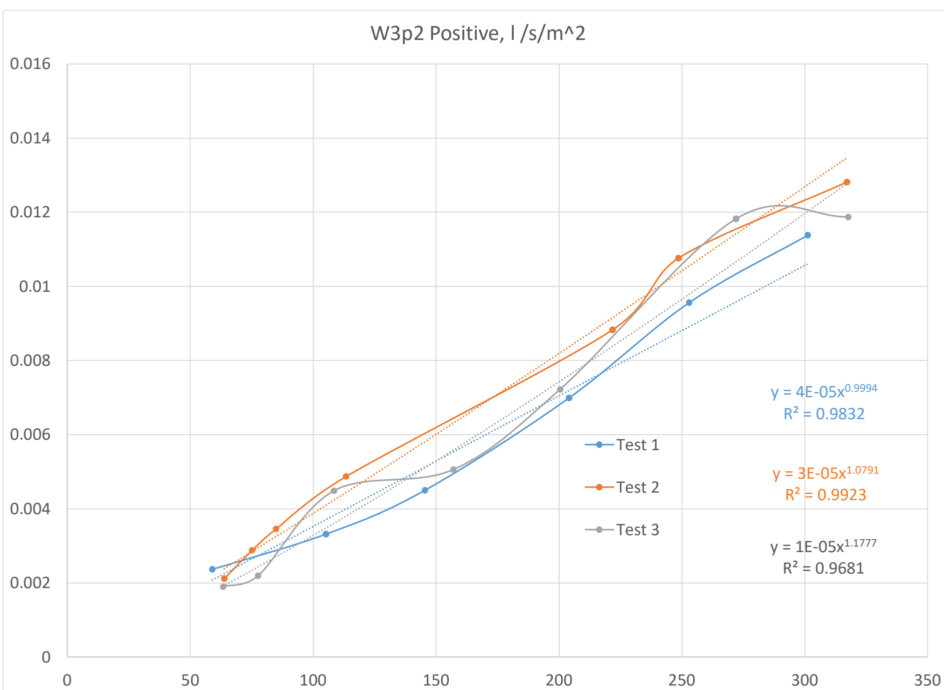
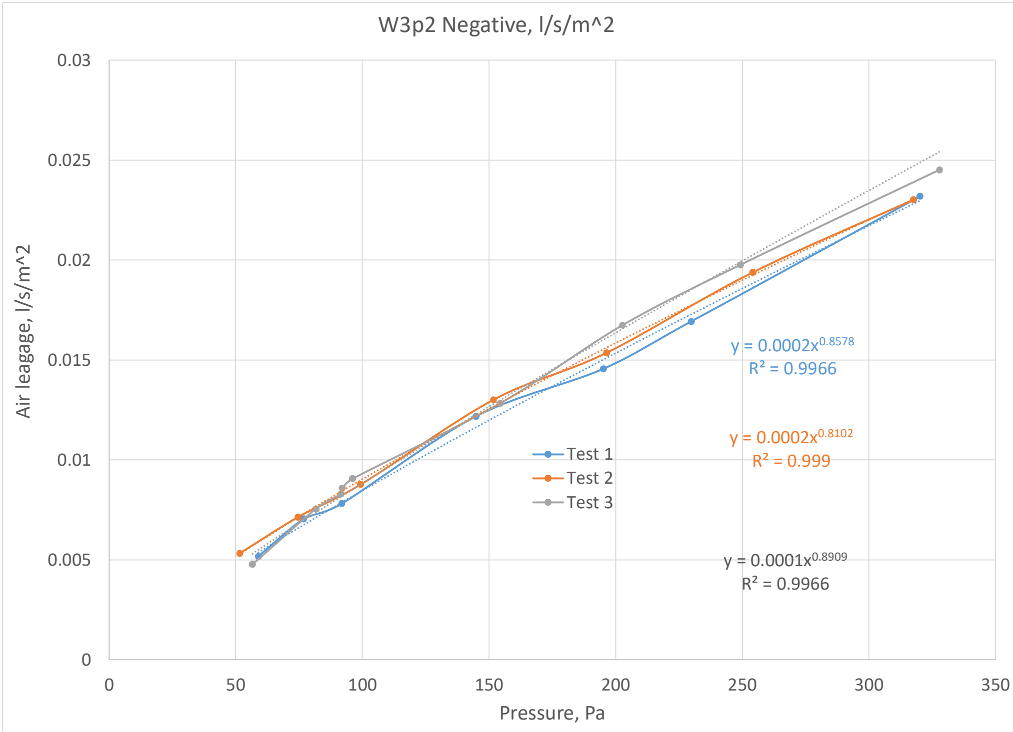


Figure 26. Specimen 3 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.3.2 Negative pressure tests



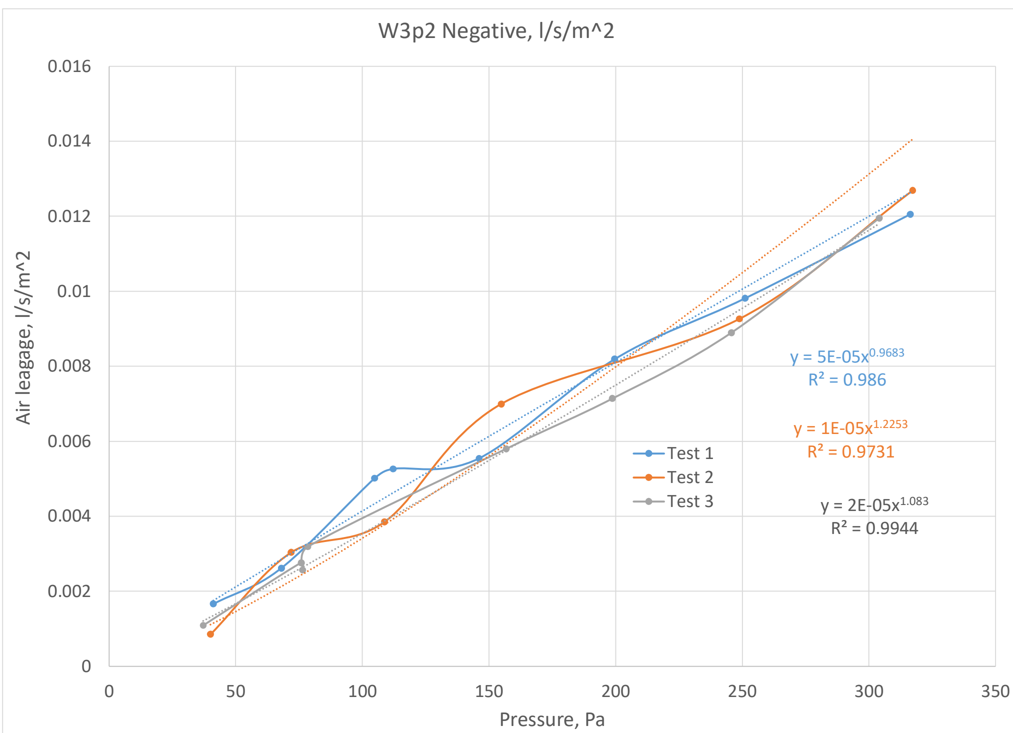
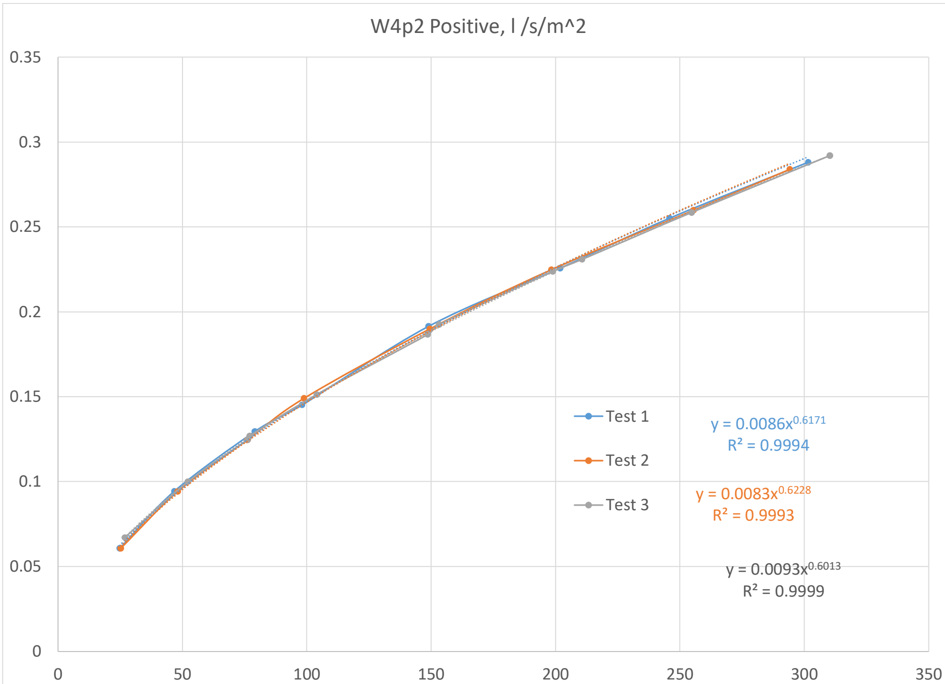


Figure 27. Specimen 3 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.4 Specimen 4: Double wood stud wall fragment with airtight drywall AB

B.4.1 Positive pressure tests



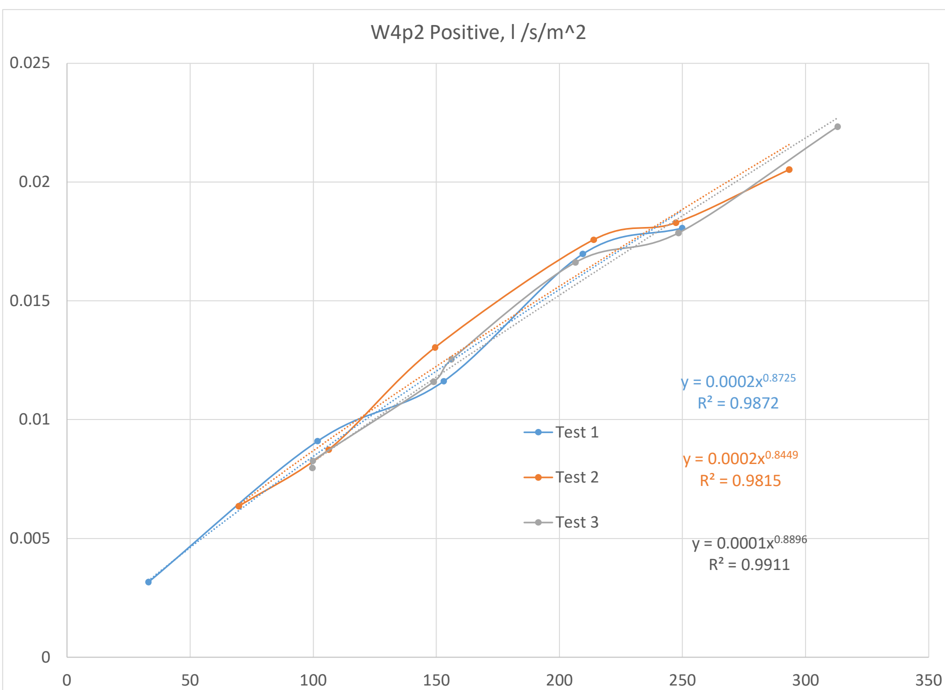
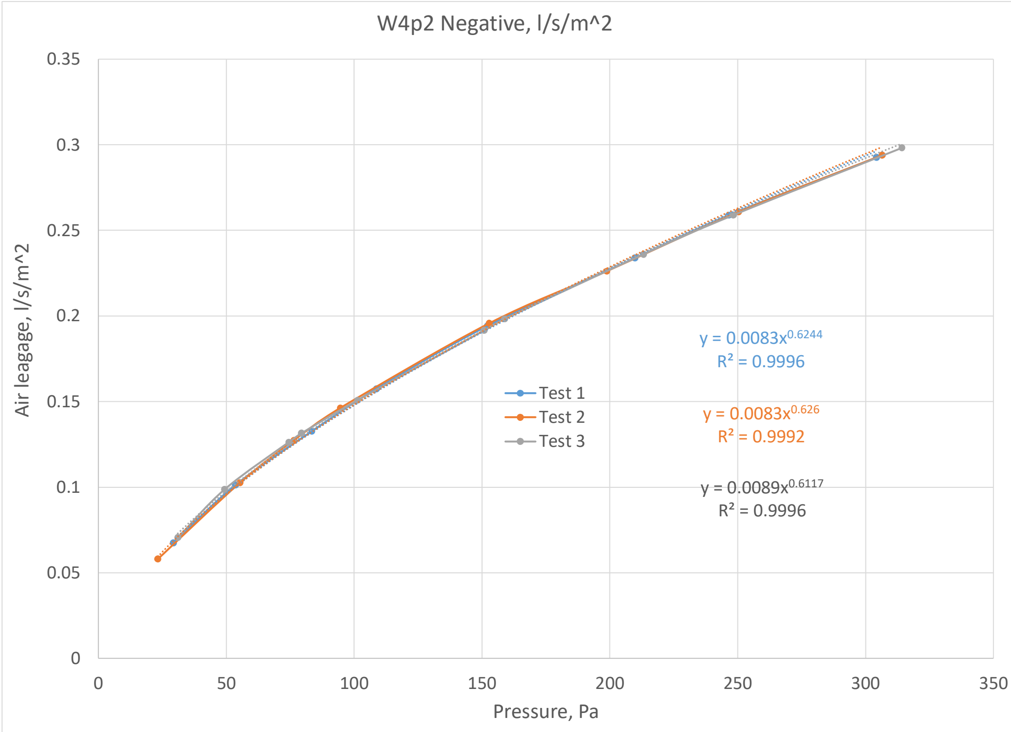


Figure 28. Specimen 4 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.4.2 Negative pressure tests



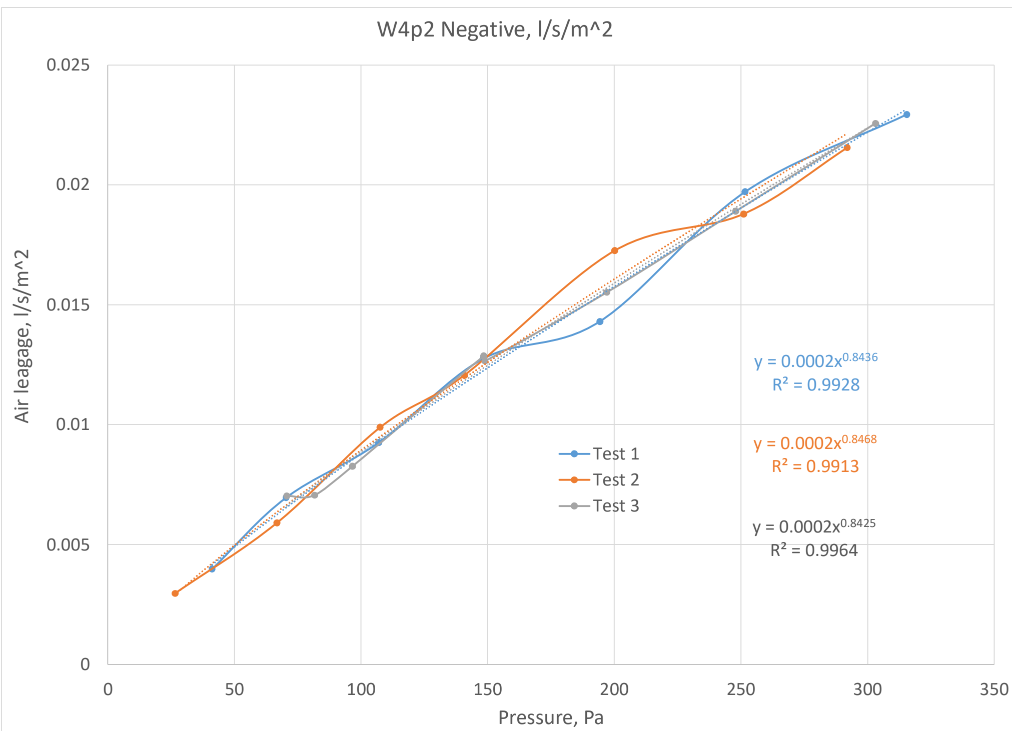
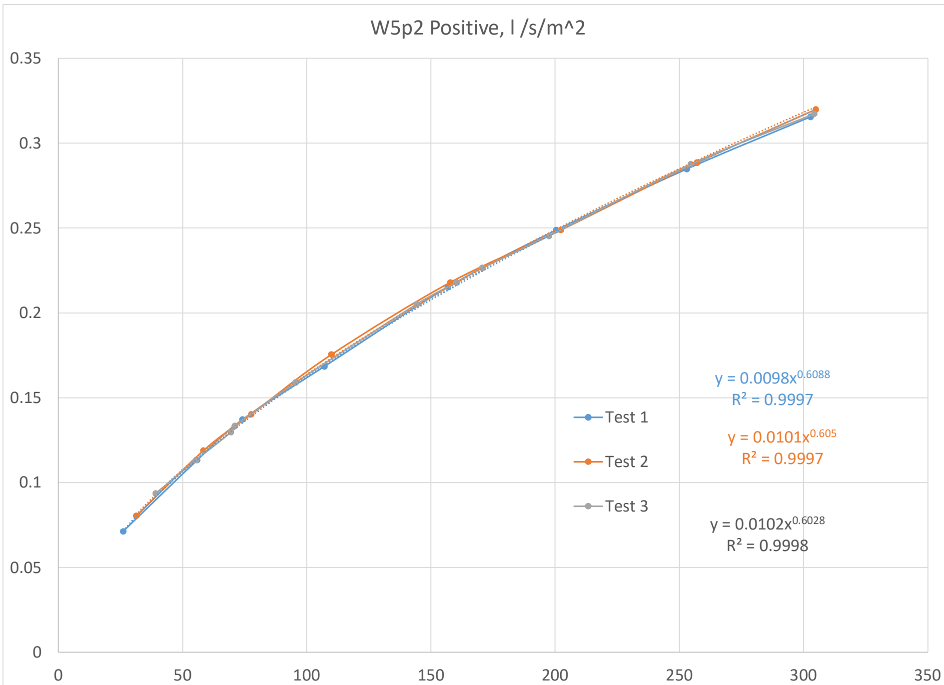


Figure 29. Specimen 4 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.5 Specimen 5: Double wood stud wall fragment with airtight drywall AB with penetrations from nails and screws

B.5.1 Positive pressure tests



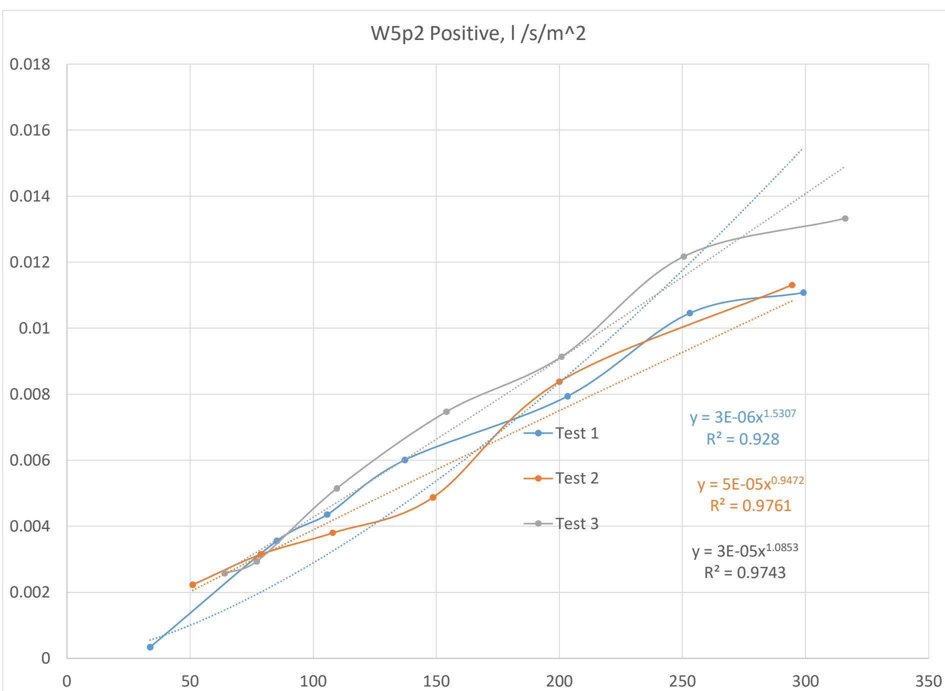
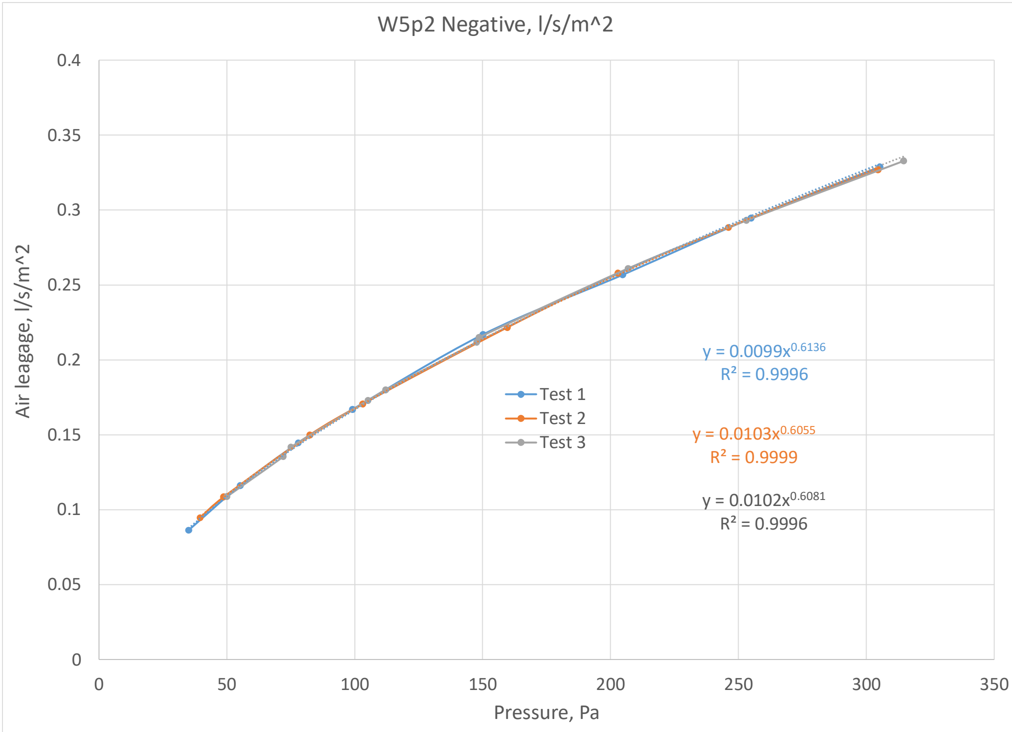


Figure 30. Specimen 5 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.5.2 Negative pressure tests



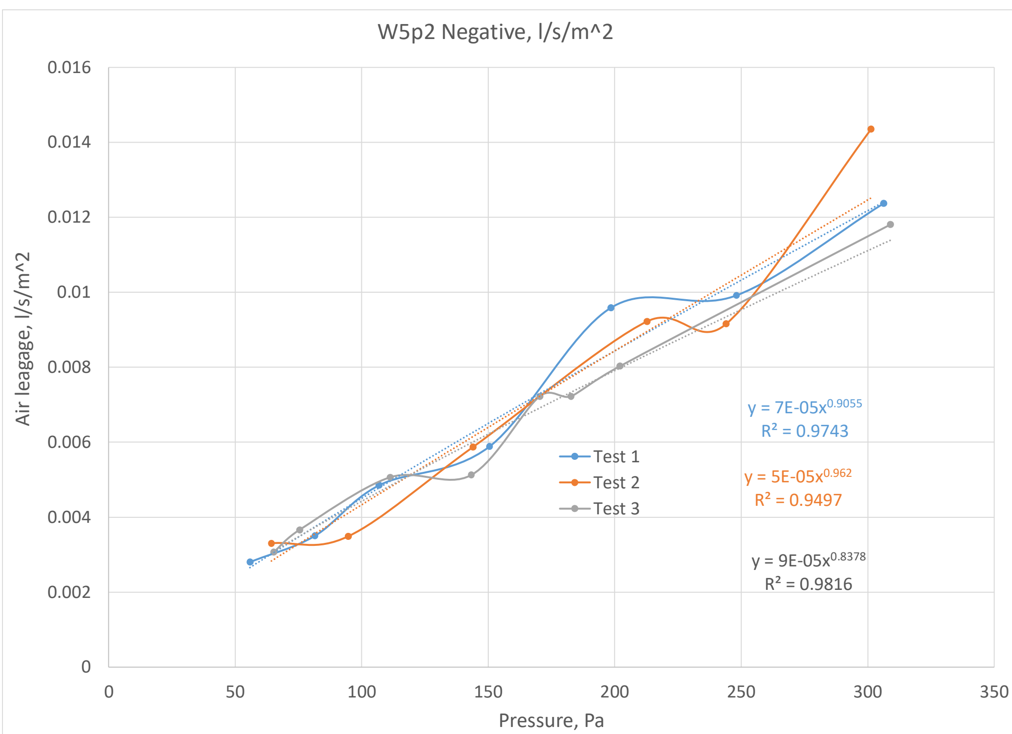
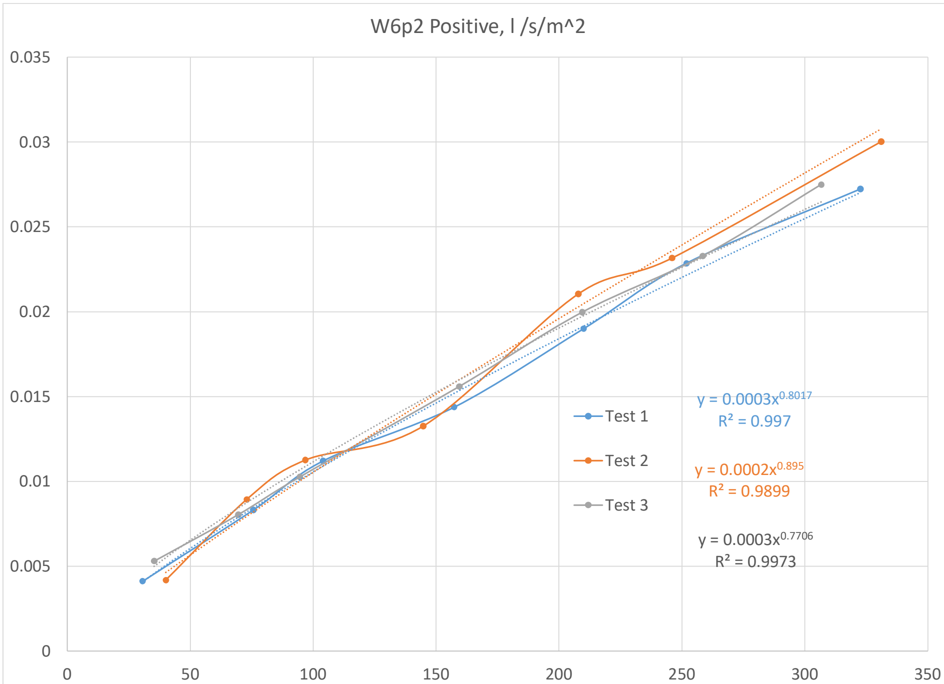


Figure 31. Specimen 5 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.6 Specimen 6: Double wood stud wall fragment with two sealed PE membranes AB behind drywall

B.6.1 Positive pressure tests



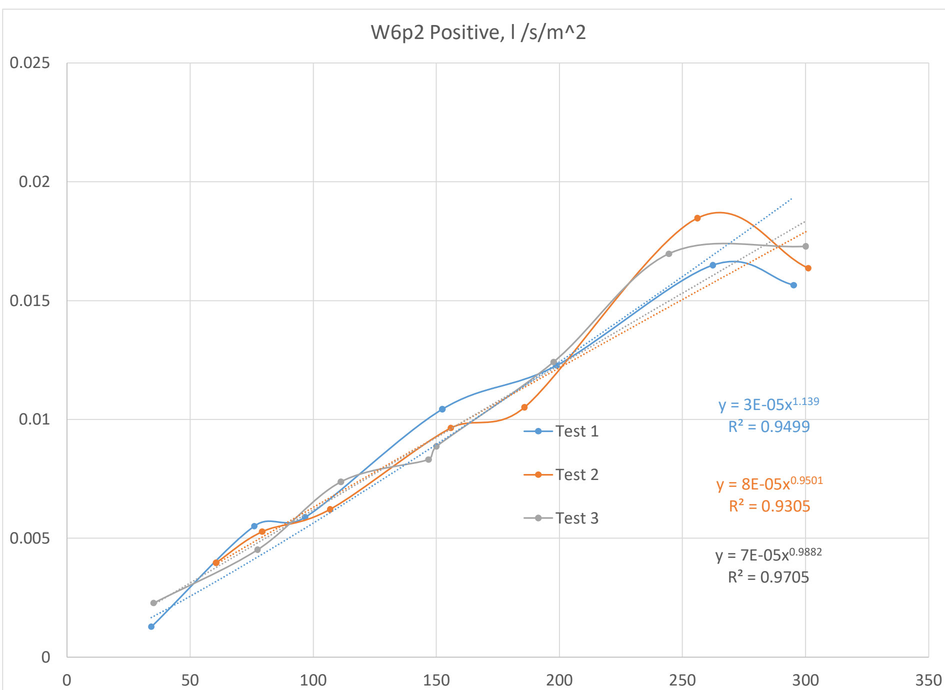
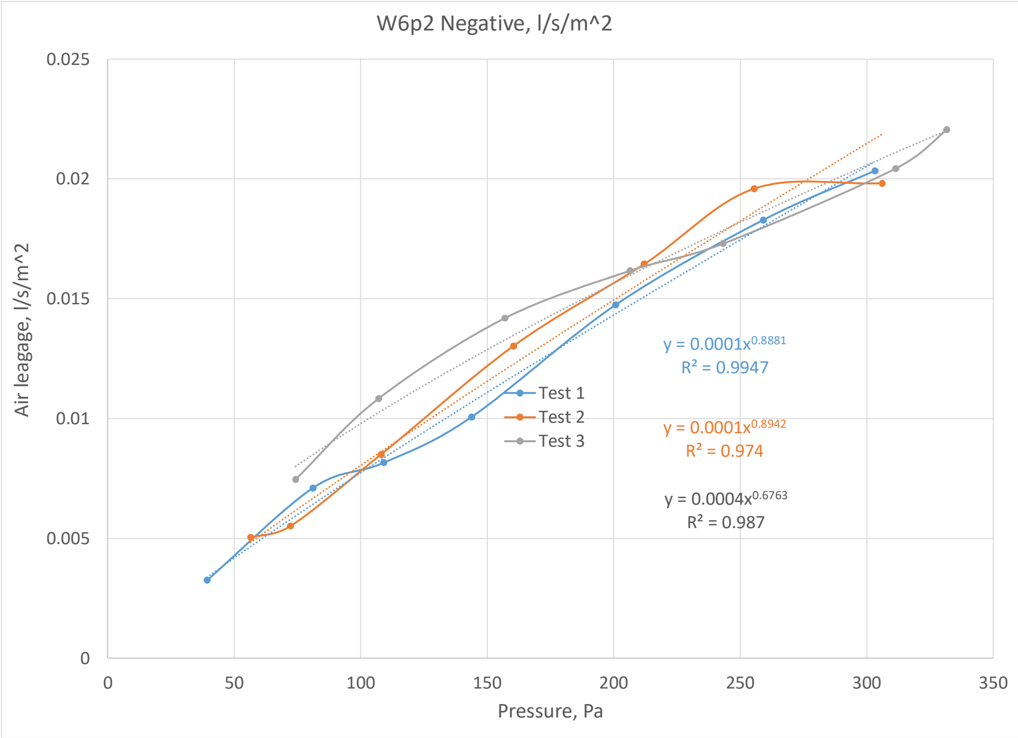


Figure 32. Specimen 6 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.6.2 Negative pressure tests



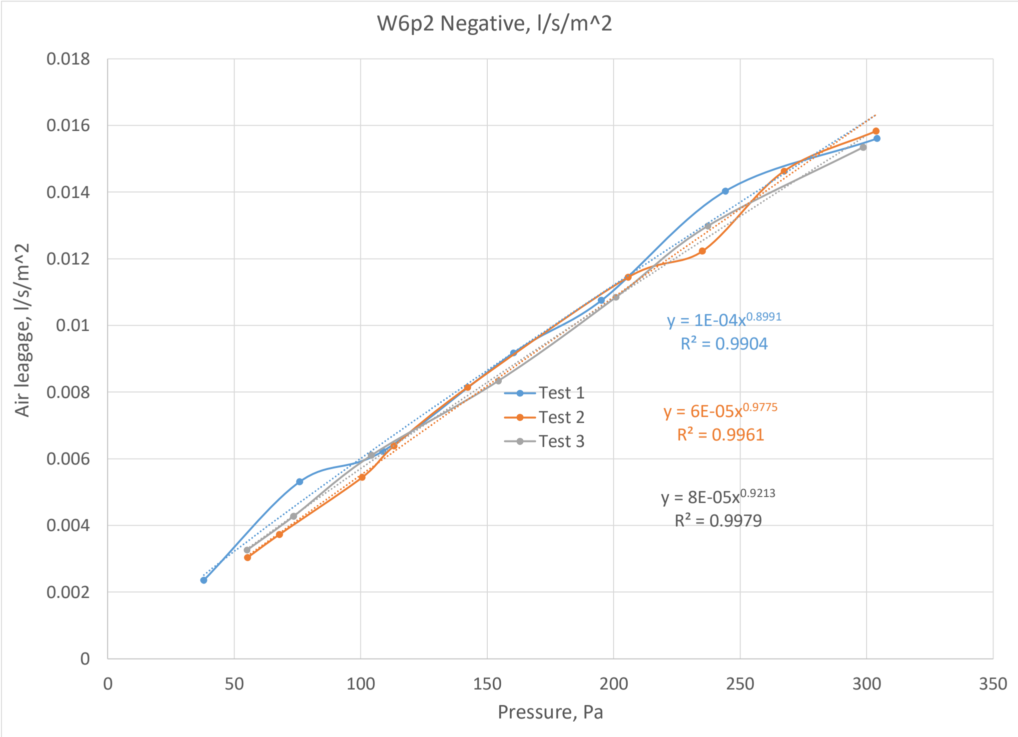
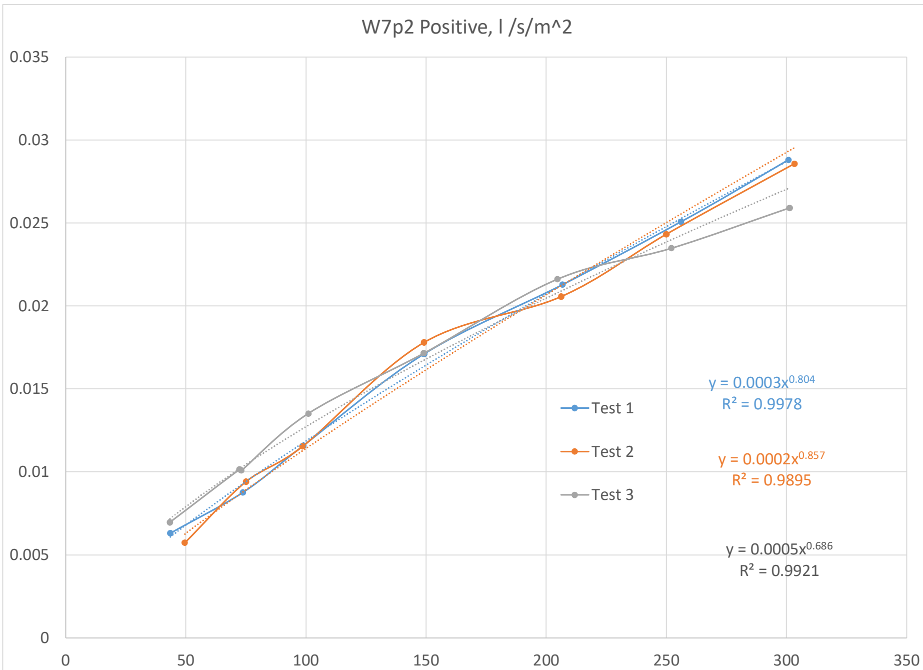


Figure 33. Specimen 6 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.7 Double wood stud wall fragment with two sealed PE membranes AB behind drywall with penetrations from nails and screws

B.7.1 Positive pressure tests



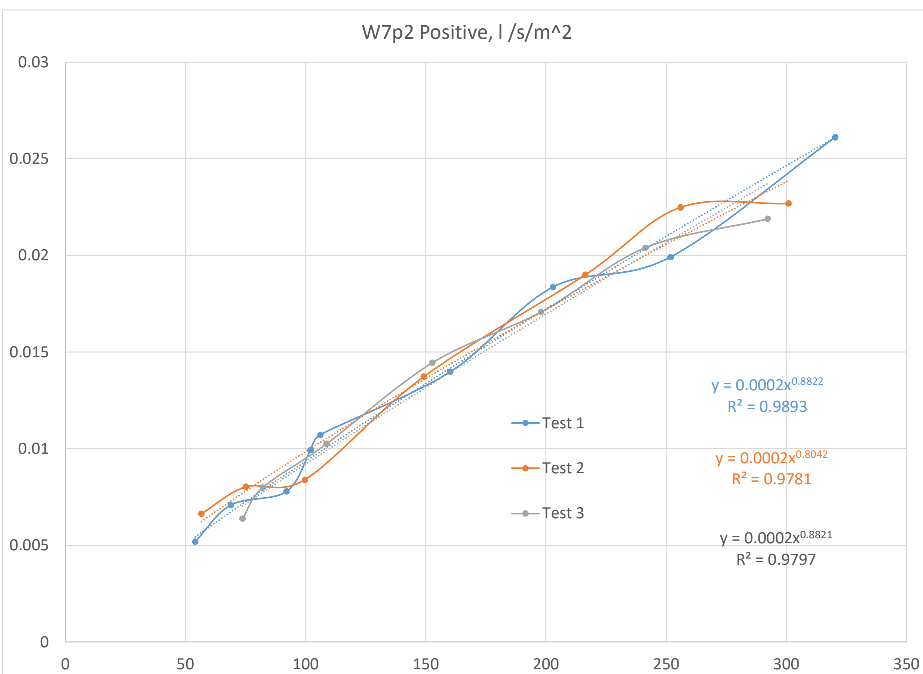
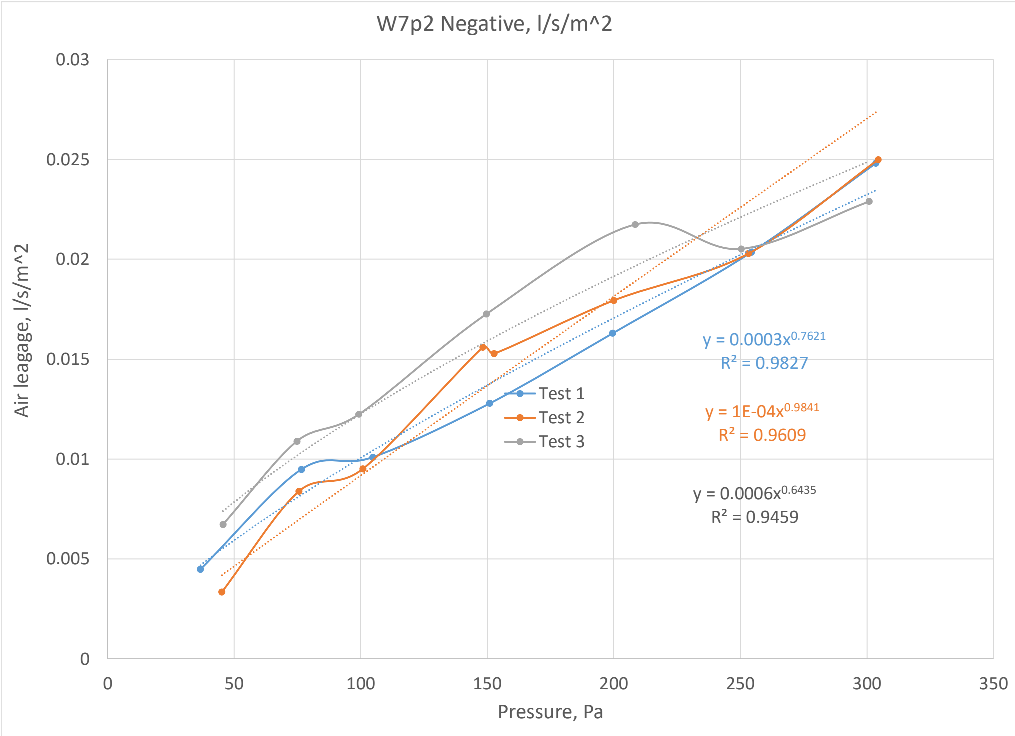


Figure 34. Specimen 6 Positive pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

B.7.2 Negative pressure tests



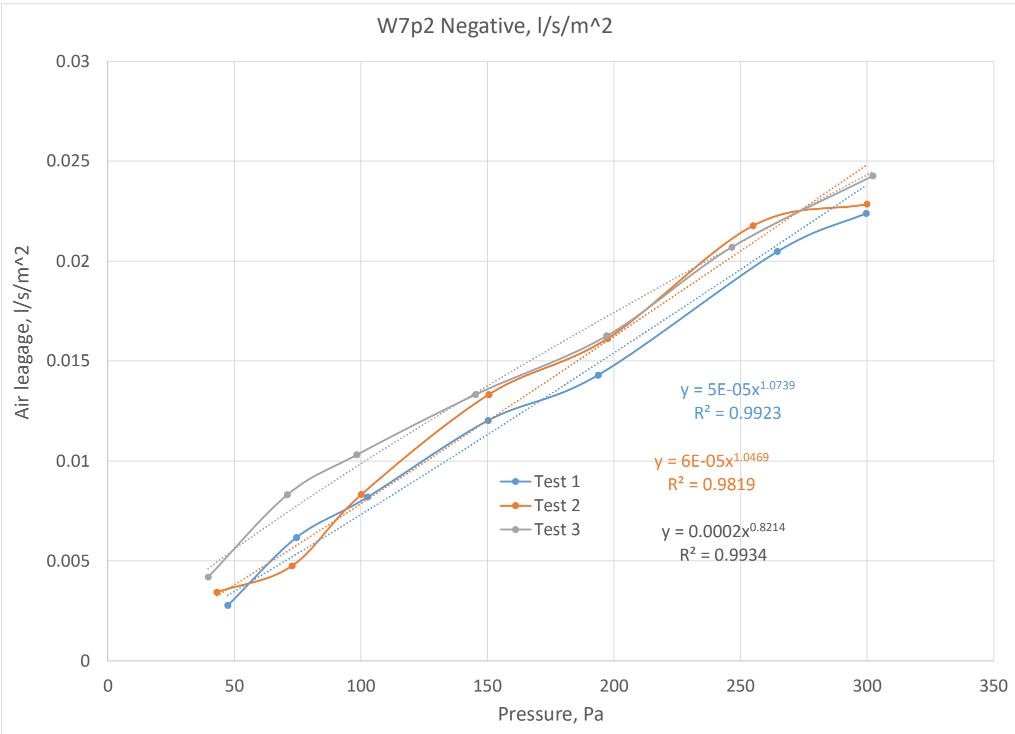


Figure 35. Specimen 6 Negative pressure test results. Top: gross leakage; Bottom: perimeter extraneous leakage

Appendix C - Photo Documentation on Fire Specimens Construction

C.1 Specimen F1: Sealed SBPO membrane AB

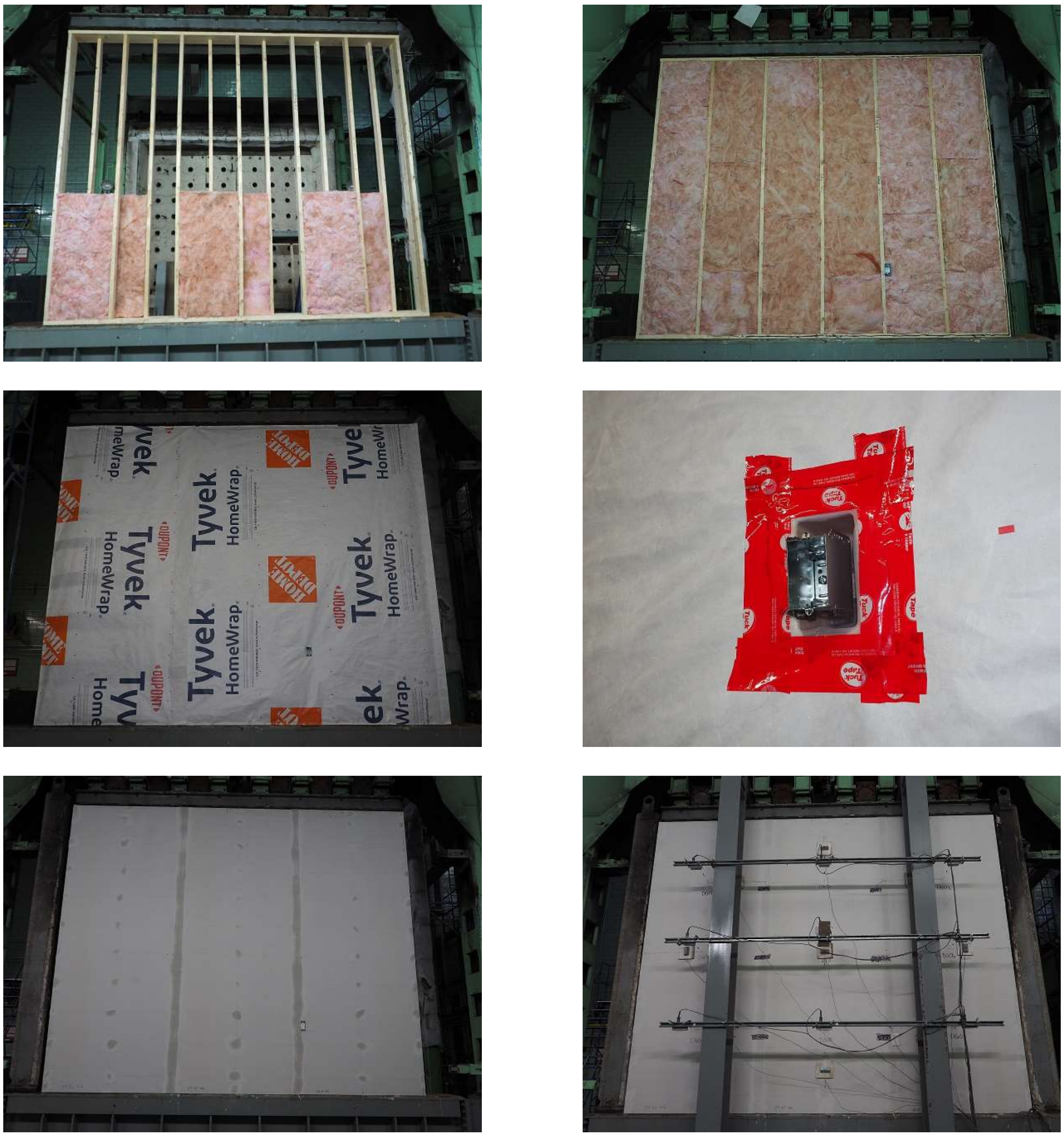


Figure 36. Specimen F1 construction photos

C.2 Specimen F2: Unsealed SBPO membrane AB

Figure 37. Specimen F2 construction photos

Appendix D - Fire Test Results

D.1 Specimen F1: Sealed SBPO membrane AB

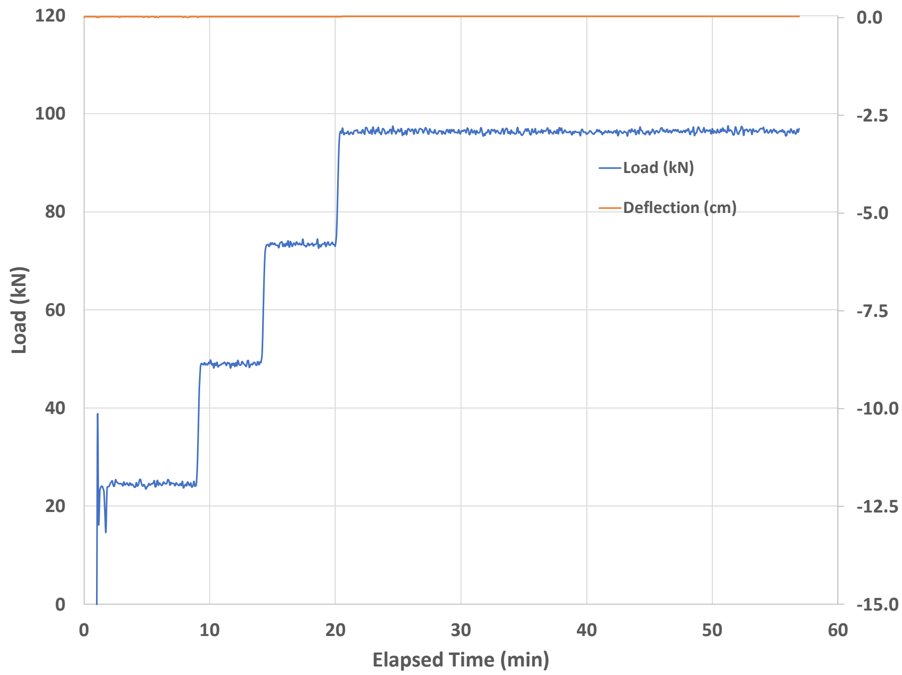


Figure 38. Specimen F1- Pre-load and deflection

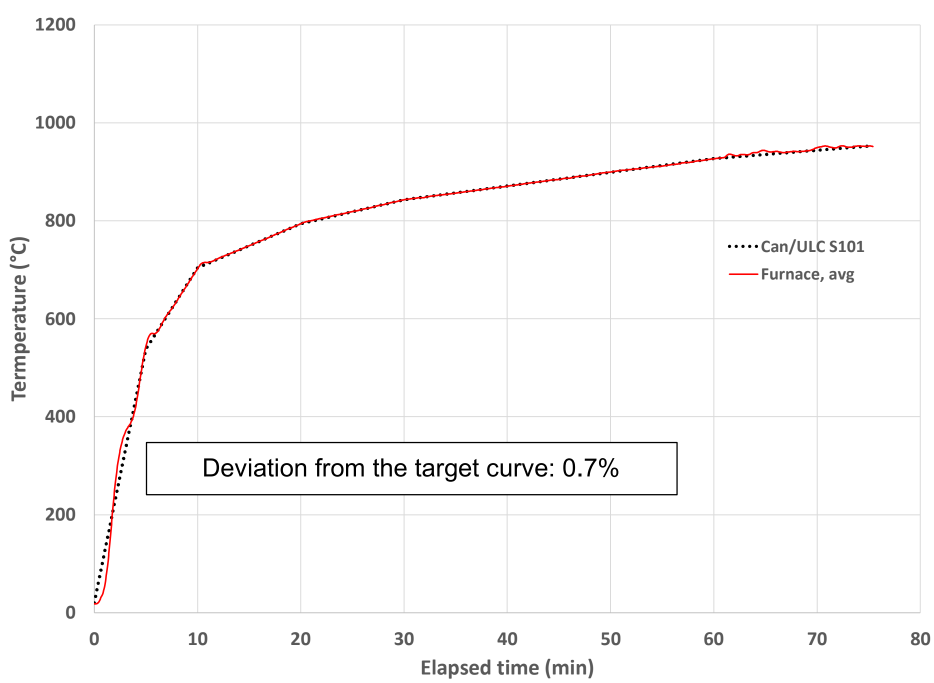


Figure 39. Specimen F1- Furnace temperature

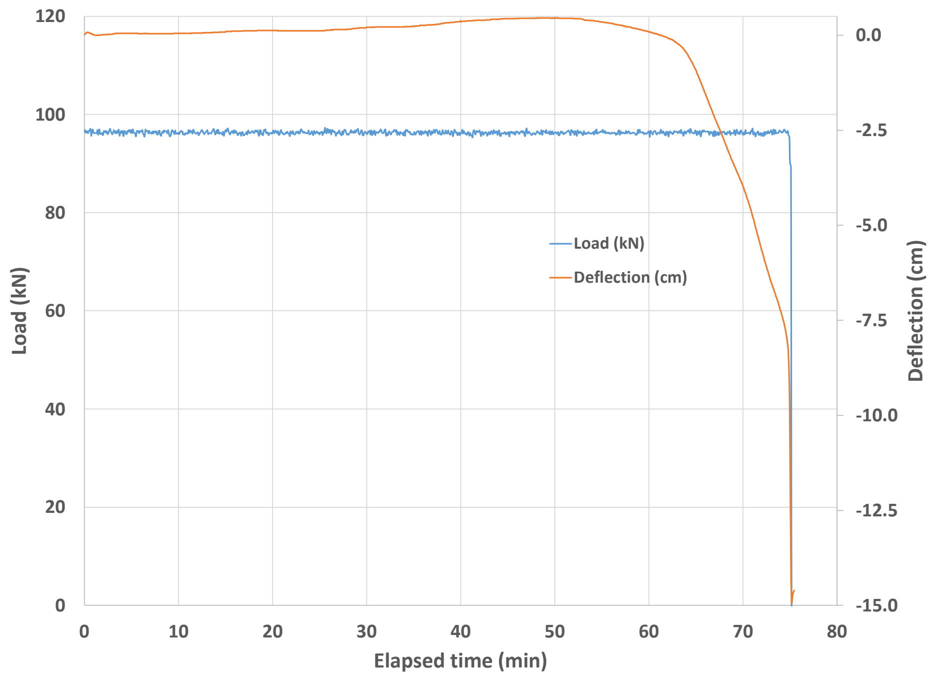


Figure 40. Specimen F1- Applied load and deflection during the test

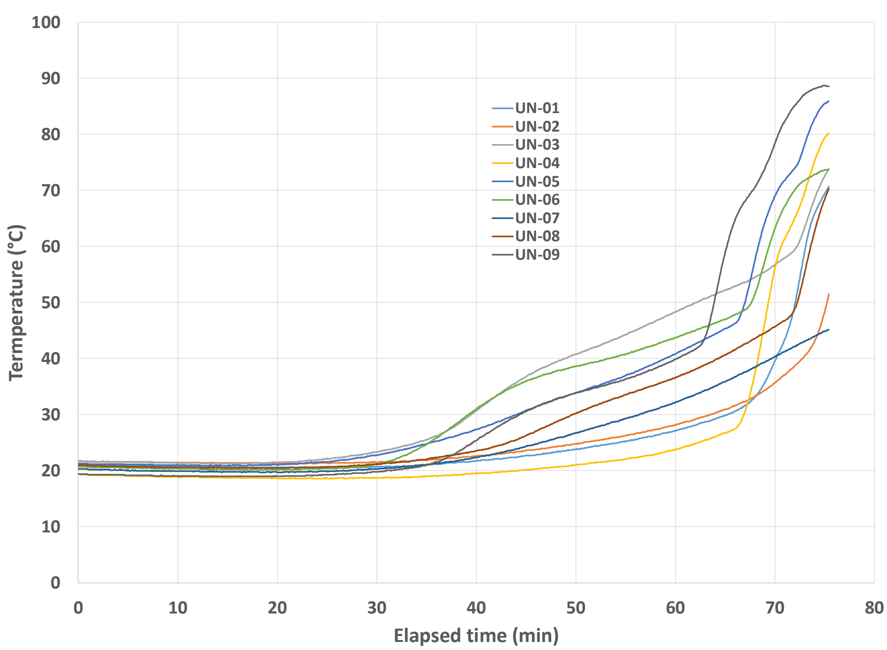


Figure 41. Specimen F1- Temperatures on unexposed side

D.2 Specimen F2: Unsealed SBPO membrane AB

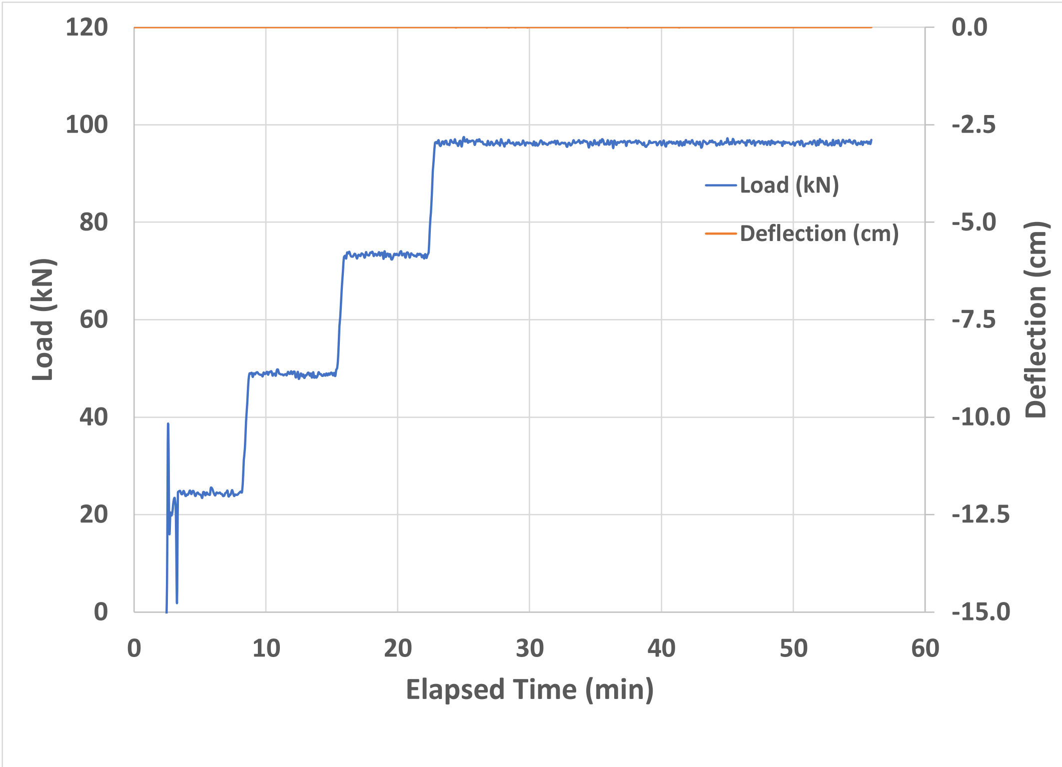


Figure 42. Specimen F2- Pre-load and deflection

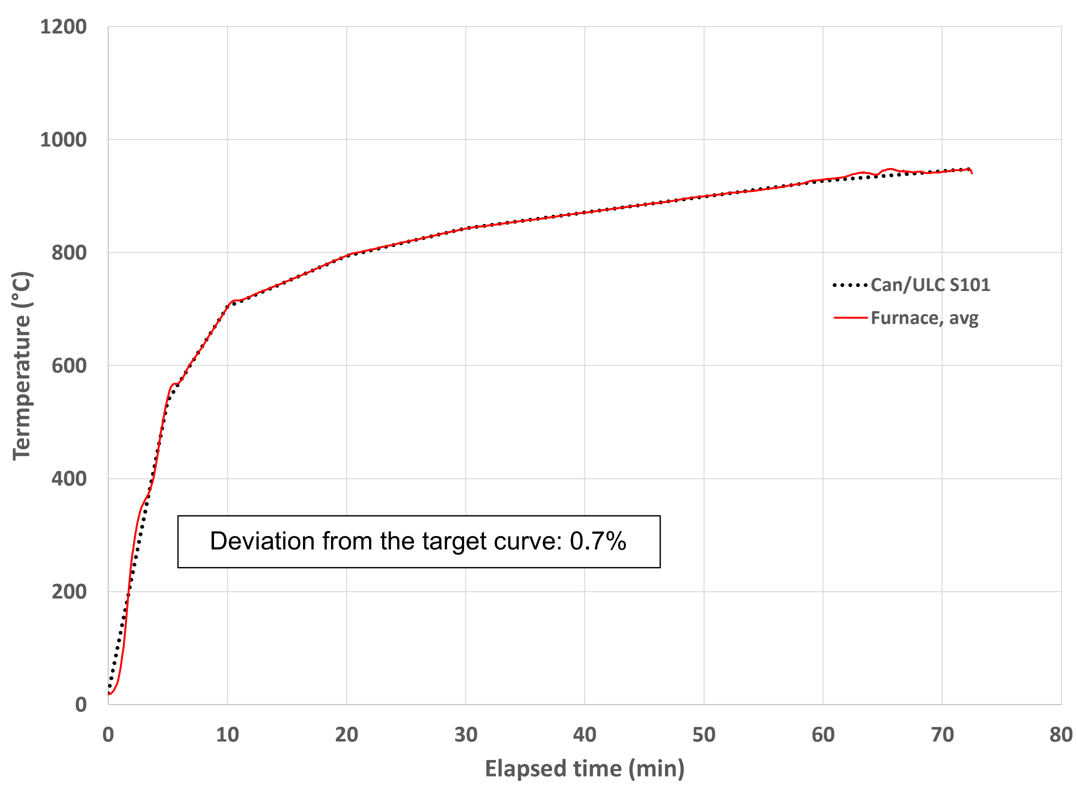


Figure 43. Specimen F2- Furnace temperature

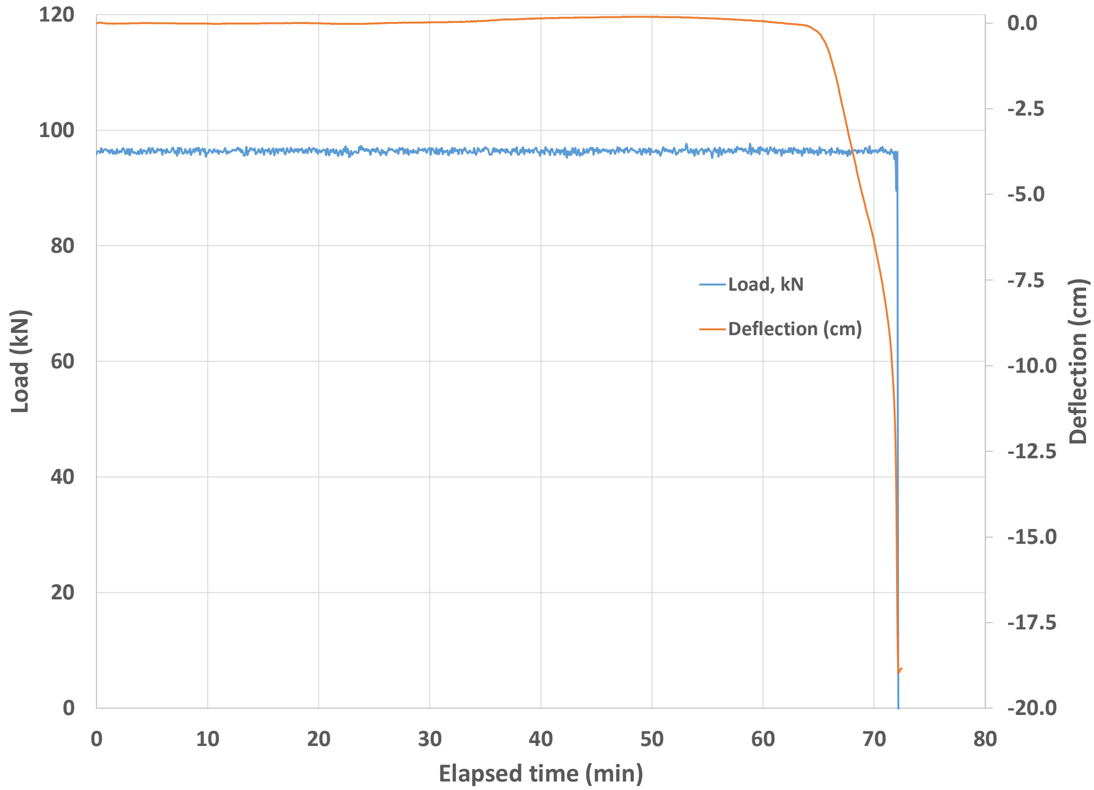


Figure 44. Specimen F2- Applied load and deflection during the test

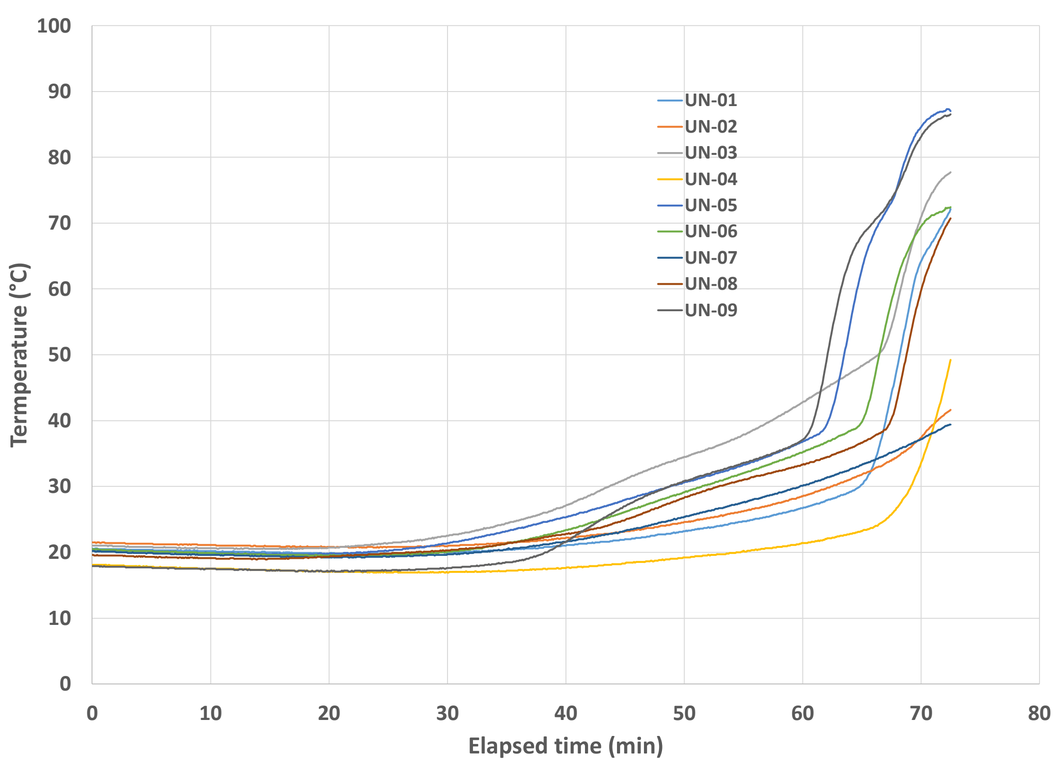


Figure 45. Specimen F2- Temperatures on unexposed side

Appendix E - Superimposed Load Calculation

Load Calculations wood stud wall

g= 9.806132 m/s^2

Wall Details:

	Wall Height:	120 *in*	3048 *mm*	10 *ft*	
	Wall width:	144 *in*	3658 *mm*	12 *ft*	
	Wood species:	SPF			
	Wood Grade:	No.1/No.2			6
	Stud Spacing:	24 *in*	610 *mm*		
	Stud size:				
L	stud Length:	115.5 *in*	2934 *mm*	9.6 *ft*	
w	width:	2 *in*	38 *mm*		
d	height:	4 *in*	89 *mm*		
	Area:	8 in^2	3382 mm^2		

Design Assumptions

K_e	Effective Length Factor	1.00		CSA O86-14 Table A.6.5.2
K_D	Load Duration	1.00		CSA O86-14 Table 5.3.2.2
K_H	System Factor	1.10		CSA O86-14 Table 6.4.4
K_SC ‖	Service Condition Factor: copression Parallel to grain	1.00		CSA O86-14 Table 6.4.2
K_SCP ⊥	Service Condition Factor: copression Prependicular to grain	1.00		CSA O86-14 Table 6.4.2
K_T	Treatment Factor	1.00		CSA O86-14 Table 6.4.3
K_SE	Service Condition Factor: Modulus of Elasticity	1.00		CSA O86-14 Table 6.4.3
K_B	Length of Bearing Factor	1.00		CSA O86-14 Table 6.5.7.6
K_Z_cp	size factor for bearing	1.15		CSA O86-14 Table 6.5.7.5
r	dead to live ratio	0.25		ULC S101-14 C1.4
alpha_Dead	Dead load factor	1.25		NBCC 2015 Table 4.1.3.2-A
alpha_Live	live load factor	1.50		NBCC 2015 Table 4.1.3.2-A
alpha	Load factor	1.45		ULC S101-14 C1.2
P_d	Dead load of wall	5031 *N*	1131 *lbf*	
w_d	Dead line load of wall	1.375 *kN/m*		

Material Properties

f_c	specific strength: comp parallel to grain	11.5 *MPa*	CSA O86-14 Table 6.3.1A
f_cp	specific strength: comp prependicular to grain	5.30 *MPa*	CSA O86-14 Table 6.3.1A
E_05	Modulus of elasticity	6500 *MPa*	CSA O86-14 Table 6.3.1A
L_e	Effective Length	2934 *mm*	CSA O86-14 Clause 6.5.6.1
C_cd	Slenderness ratio	32.96	CSA O86-14 Clause 6.5.6.2.2
C_cw	Slenderness ratio	77.2	CSA O86-14 Clause 6.5.6.2.2

Load Calculations

Pr			
phi	0.80		CSA O86-14 Clause 6.5.6.2.3
F_C=f_c(K_D*K_H*K_	12.65 *MPa*		CSA O86-14 Clause 6.5.6.2.3
K_Zc=6.3*(d*L)^-0.13	1.24		CSA O86-14 Clause 6.5.6.2.3
K_C=1/(1+(F_C*K_Zc*	0.287		CSA O86-14 Clause 6.5.6.2.4
P_r=phi*F_C*A*K_Zc	**12246** *N*	2,753 *lbf*	CSA O86-14 Clause 6.5.6.2.3
Qr			
phi	0.80		CSA O86-14 Clause 6.5.7.2
F_CP	5.30 *MPa*		CSA O86-14 Clause 6.5.7.2
K_Z_cp	1.15		CSA O86-14 Table 6.5.7.5
K_B	1.00		CSA O86-14 Table 6.5.7.6
Q_r	**16491** *N*	3,707 *lbf*	CSA O86-14 Clause 6.5.7.2
min(Pr,Qr)=	12246 *N*	2,753 *lbf*	
Ps	8446 *N*	1,899 *lbf*	
line load	13.9 *kN/m*		
Superimposed load ULC S101 method	**96.3** ***kN***	21,655 *lbf*	twice the load of one wall

Appendix F - Photo Documentation on Acoustic Specimen Construction

F.1 Specimen A1, A2: Unsealed SBPO membrane AB

Figure 46. Specimen A1 and A2 construction photos

F.2 Specimen A3, A4: Sealed SBPO membrane AB

Figure 47. Specimen A3 and A4 construction photos

Appendix G - Acoustic Test Results

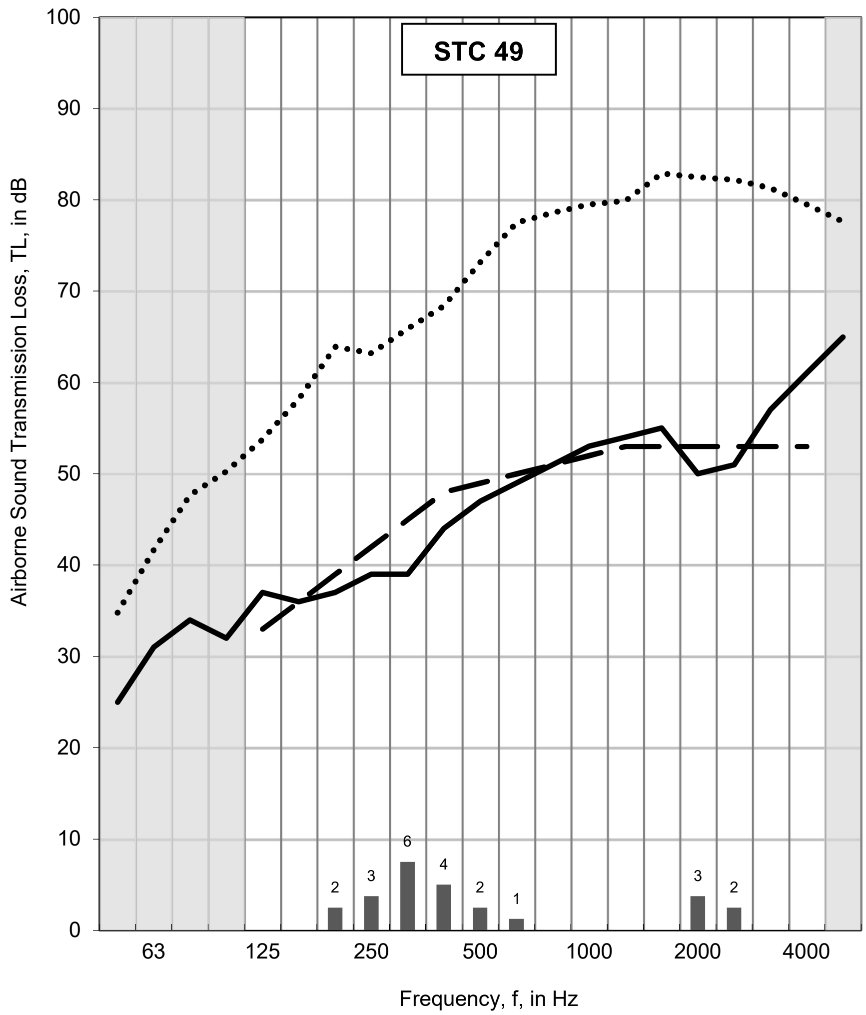
G.1 Specimen A1: Unsealed AB, no penetrations

Room	Volume (m³)	Air Temperature (°C)	Humidity (%)
Small	140.2	18.4 to 18.6	41.8 to 41.9
Large	256.1	22.7	40.7 to 41.0

Area of test specimen:	8.92 m^2

f (Hz)	Airborne TL (dB)
50	25
63	31
80	34
100	32
125	37
160	36
200	37
250	39
315	39
400	44
500	47
630	49
800	51
1000	53
1250	54
1600	55
2000	50
2500	51
3150	57
4000	61
5000	65
Sound Transmission Class (STC)	49

Sum of Deficiencies (dB)
23
Max. Deficiency (dB)
6 dB at 315 Hz



For a description of the test specimen and mounting conditions see text pages before. The results in this report apply only to the specific sample submitted for measurement. No responsibility is assumed for performance of any other specimen. **Airborne sound transmission loss measurements were conducted in accordance with the requirements of ASTM E90-09, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements".**

In the graph:
The solid line is the measured sound transmission loss for this specimen. The dashed line is the STC contour fitted to the measured values according to ASTM E413-22. The dotted line (may be above the displayed range) is the flanking limit established for this facility. For any frequency band where the measured transmission loss is less than 10 dB lower than the dotted line, the reported value is potentially limited by flanking transmission via laboratory surfaces, and the true value may be higher than that measured. Bars at the bottom of the graph show deficiencies where the measured data are less than the reference contour as described in the fitting procedure for the STC, defined in ASTM E413-22. The shaded cells in the table and areas in the graph are outside the STC contour range.
In the table:
Values marked "c" indicate that the measured background level was between 5 dB and 10 dB below the combined receiving room level and background level. The reported values have been corrected according to the procedure outlined in ASTM E90-09. Values marked "*" indicate that the measured background level was less than 5 dB below the combined receiving room level and background level, in which case, the corrected values provide an estimate of the lower limit of airborne sound transmission loss.

Figure 48. Specimen A1- Acoustic test results

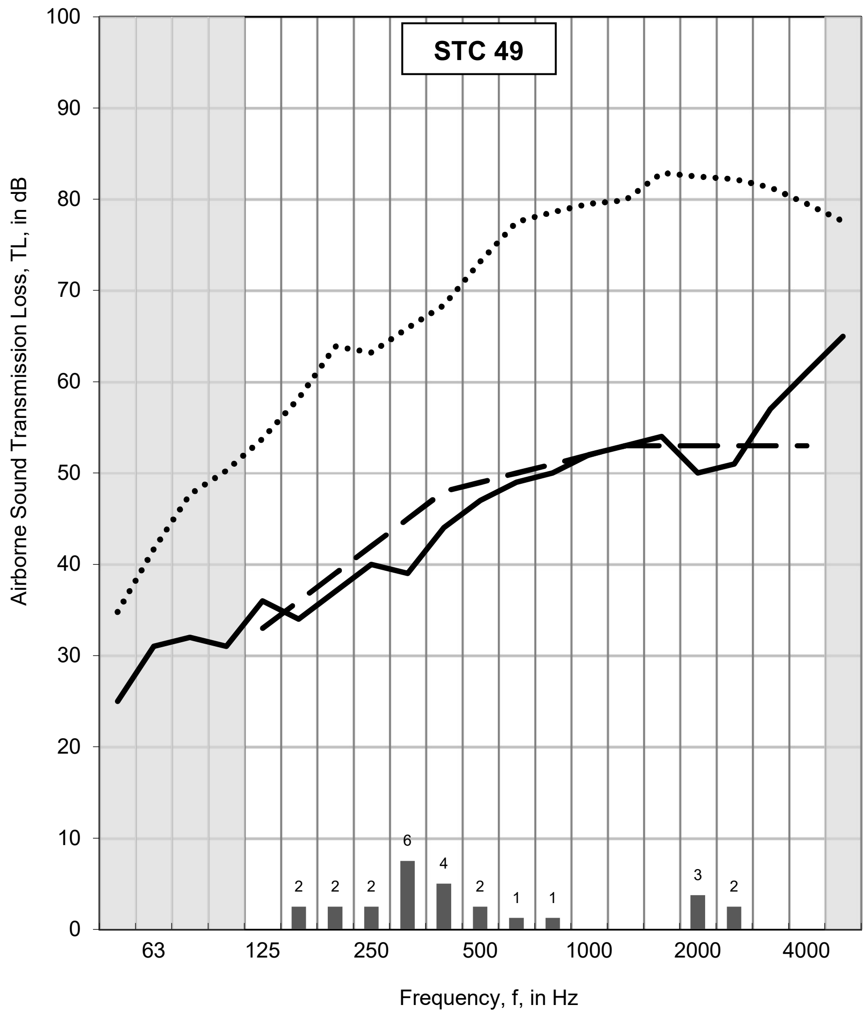
G.2 Specimen A2: Unsealed AB, with penetrations

Room	Volume (m³)	Air Temperature (°C)	Humidity (%)
Small	140.2	18.7 to 18.9	43.1 to 43.5
Large	256.1	22.5 to 22.6	34.8 to 35.0

Area of test specimen:	8.92 m^2

f (Hz)	Airborne TL (dB)
50	25
63	31
80	32
100	31
125	36
160	34
200	37
250	40
315	39
400	44
500	47
630	49
800	50
1000	52
1250	53
1600	54
2000	50
2500	51
3150	57
4000	61
5000	65
Sound Transmission Class (STC)	49

Sum of Deficiencies (dB)
25
Max. Deficiency (dB)
6 dB at 315 Hz



For a description of the test specimen and mounting conditions see text pages before. The results in this report apply only to the specific sample submitted for measurement. No responsibility is assumed for performance of any other specimen. **Airborne sound transmission loss measurements were conducted in accordance with the requirements of ASTM E90-09, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements".**

In the graph:
The solid line is the measured sound transmission loss for this specimen. The dashed line is the STC contour fitted to the measured values according to ASTM E413-22. The dotted line (may be above the displayed range) is the flanking limit established for this facility. For any frequency band where the measured transmission loss is less than 10 dB lower than the dotted line, the reported value is potentially limited by flanking transmission via laboratory surfaces, and the true value may be higher than that measured. Bars at the bottom of the graph show deficiencies where the measured data are less than the reference contour as described in the fitting procedure for the STC, defined in ASTM E413-22. The shaded cells in the table and areas in the graph are outside the STC contour range.

In the table:
Values marked "c" indicate that the measured background level was between 5 dB and 10 dB below the combined receiving room level and background level. The reported values have been corrected according to the procedure outlined in ASTM E90-09. Values marked "*" indicate that the measured background level was less than 5 dB below the combined receiving room level and background level, in which case, the corrected values provide an estimate of the lower limit of airborne sound transmission loss.

Figure 49. Specimen A2- Acoustic test results

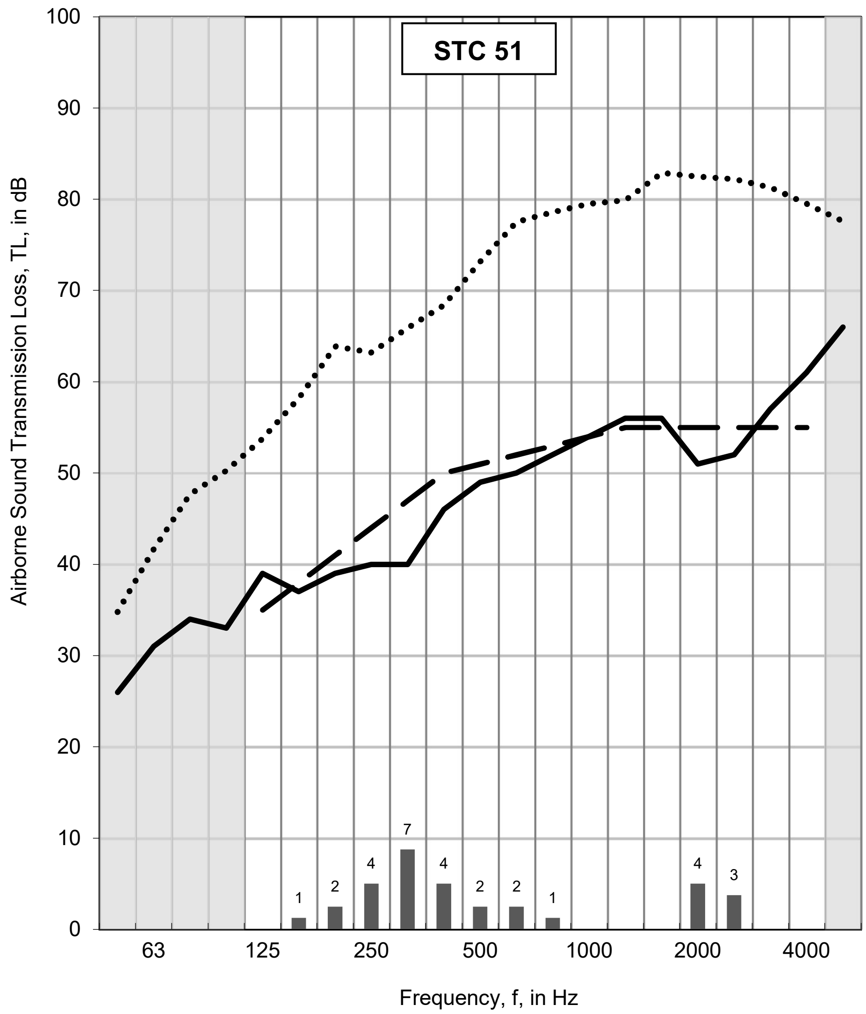
G.3 Specimen A3: Sealed AB, no penetrations

Room	Volume (m³)	Air Temperature (°C)	Humidity (%)
Small	140.2	19.0 to 19.1	39.7 to 40.0
Large	256.1	22.5 to 22.6	41.3 to 42.6

Area of test specimen:	8.92 m^2

f (Hz)	Airborne TL (dB)
50	26
63	31
80	34
100	33
125	39
160	37
200	39
250	40
315	40
400	46
500	49
630	50
800	52
1000	54
1250	56
1600	56
2000	51
2500	52
3150	57
4000	61
5000	66
Sound Transmission Class (STC)	51

Sum of Deficiencies (dB)
30
Max. Deficiency (dB)
7 dB at 315 Hz



For a description of the test specimen and mounting conditions see text pages before. The results in this report apply only to the specific sample submitted for measurement. No responsibility is assumed for performance of any other specimen. **Airborne sound transmission loss measurements were conducted in accordance with the requirements of ASTM E90-09, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements".**

In the graph:
The solid line is the measured sound transmission loss for this specimen. The dashed line is the STC contour fitted to the measured values according to ASTM E413-22. The dotted line (may be above the displayed range) is the flanking limit established for this facility. For any frequency band where the measured transmission loss is less than 10 dB lower than the dotted line, the reported value is potentially limited by flanking transmission via laboratory surfaces, and the true value may be higher than that measured. Bars at the bottom of the graph show deficiencies where the measured data are less than the reference contour as described in the fitting procedure for the STC, defined in ASTM E413-22. The shaded cells in the table and areas in the graph are outside the STC contour range.

In the table:
Values marked "c" indicate that the measured background level was between 5 dB and 10 dB below the combined receiving room level and background level. The reported values have been corrected according to the procedure outlined in ASTM E90-09. Values marked "*" indicate that the measured background level was less than 5 dB below the combined receiving room level and background level, in which case, the corrected values provide an estimate of the lower limit of airborne sound transmission loss.

Figure 50. Specimen A3- Acoustic test results

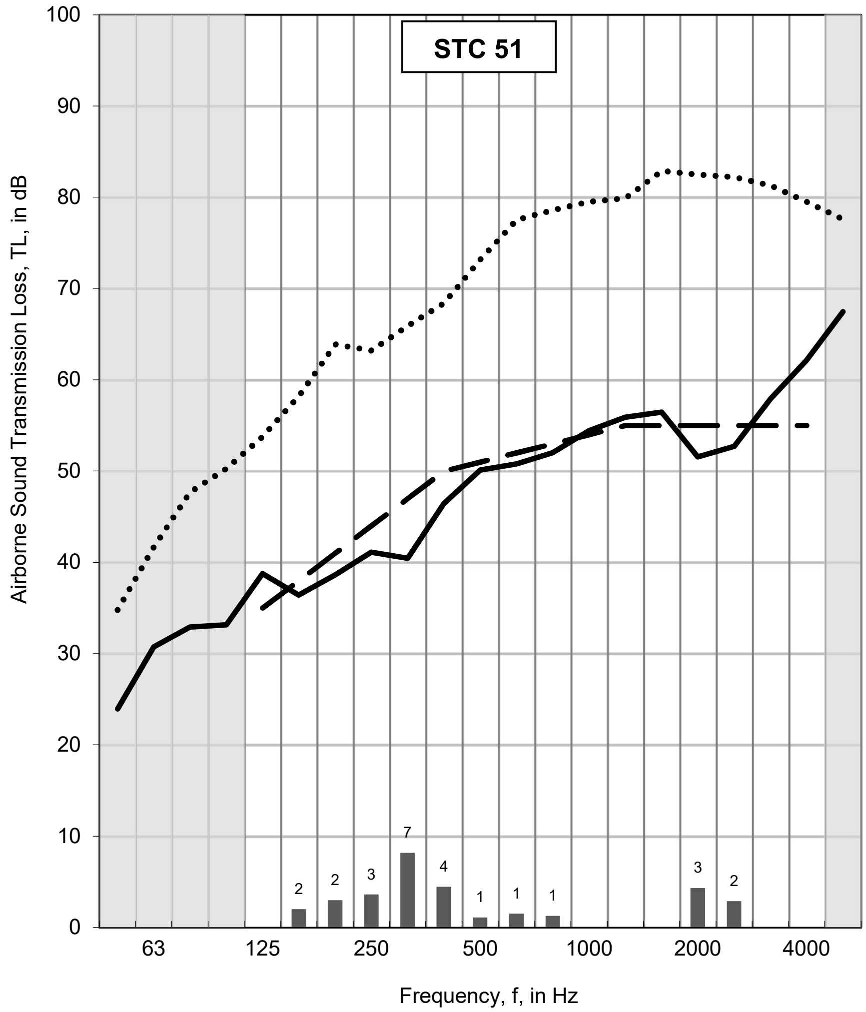
G.4 Specimen A4: Sealed AB, with penetrations

Room	Volume (m³)	Air Temperature (°C)	Humidity (%)
Small	140.2	17.8 to 17.9	42.4 to 42.5
Large	256.1	22.6	35.9 to 37.5

Area of test specimen:	8.92 m^2

f (Hz)	Airborne TL (dB)
50	24
63	31
80	33
100	33
125	39
160	36
200	39
250	41
315	40
400	46
500	50
630	51
800	52
1000	54
1250	56
1600	56
2000	52
2500	53
3150	58
4000	62
5000	67
Sound Transmission Class (STC)	51

Sum of Deficiencies (dB)
26
Max. Deficiency (dB)
7 dB at 315 Hz



For a description of the test specimen and mounting conditions see text pages before. The results in this report apply only to the specific sample submitted for measurement. No responsibility is assumed for performance of any other specimen. **Airborne sound transmission loss measurements were conducted in accordance with the requirements of ASTM E90-09, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements".**

In the graph:
The solid line is the measured sound transmission loss for this specimen. The dashed line is the STC contour fitted to the measured values according to ASTM E413-22. The dotted line (may be above the displayed range) is the flanking limit established for this facility. For any frequency band where the measured transmission loss is less than 10 dB lower than the dotted line, the reported value is potentially limited by flanking transmission via laboratory surfaces, and the true value may be higher than that measured. Bars at the bottom of the graph show deficiencies where the measured data are less than the reference contour as described in the fitting procedure for the STC, defined in ASTM E413-22. The shaded cells in the table and areas in the graph are outside the STC contour range.

In the table:
Values marked "c" indicate that the measured background level was between 5 dB and 10 dB below the combined receiving room level and background level. The reported values have been corrected according to the procedure outlined in ASTM E90-09. Values marked "*" indicate that the measured background level was less than 5 dB below the combined receiving room level and background level, in which case, the corrected values provide an estimate of the lower limit of airborne sound transmission loss.

Figure 51. Specimen A4- Acoustic test results