

RESEARCH REPORT



Measured Pressure Equalized Performance of an Exterior Insulation Finish System (EIFS) Specimen. Performance of Pressure Equalized Rainscreen Walls: A Collaborative Research and Development Project

Progress Report #6



CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) has been Canada's national housing agency for more than 60 years.

Together with other housing stakeholders, we help ensure that Canada maintains one of the best housing systems in the world. We are committed to helping Canadians access a wide choice of quality, affordable homes, while making vibrant, healthy communities and cities a reality across the country.

For more information, visit our website at **www.cmhc.ca**

You can also reach us by phone at 1-800-668-2642
or by fax at 1-800-245-9274.

Outside Canada call 613-748-2003 or fax to 613-748-2016.

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1-800-668-2642.



NRC-CNRC

Client Report

A-3028.7

Measured Pressure Equalized Performance of an
Exterior Insulation Finish System (EIFS) Specimen

Performance of Pressure Equalized Rainscreen Walls
A Collaborative Research and Development Project

for


Canada Mortgage and Housing Corporation
700 Montréal Road
Ottawa, Ontario
K1A 0P7

26 June 1996

Progress Report #6
Measured Pressure Equalized Performance of an
Exterior Insulation Finish System (EIFS) Specimen

Performance of Pressure Equalized Rainscreen Walls
A Collaborative Research and Development Project

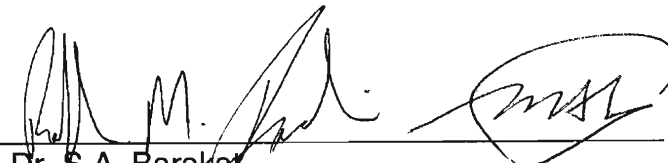
Author


for James M. Ullett, P.Eng.

Author


William C. Brown
Project Manager

Approved


Dr. S.A. Barakat
Head, Building Performance Laboratory

Report No: A3028.7
Report Date: June 26, 1996
Contract No: A3028
Reference: Agreement Dated March 24, 1992
Laboratory: Building Performance

22 pages
Copy No. 4 of 4 copies

EXECUTIVE SUMMARY

The National Research Council (NRC) has initiated a research project to generate design guidelines for pressure equalized rainscreen (PER) walls. This project has three tasks, namely computer modeling, experimental evaluation and development of design guidelines. In support of the research project, NRC and Canada Mortgage and Housing Corporation (CMHC) entered into a cooperative agreement on the first two tasks. Sto Industries Canada, the Canadian Prestressed Concrete Institute and Antamex Inc. have agreed to participate in the agreement by supplying test specimens and providing technical and practical information.

This report presents data from the experimental evaluation of two Exterior Insulated Finish System (EIFS) test specimens as supplied by Sto Industries Canada Inc. The two test specimens were 2.43 m high by 1.12 m wide. The two specimens differed in the cavities only. Each specimen was structurally supported by 89 mm steel studs located at 406 mm on center and was finished with 13 mm gypsum sheathing (see Figure 1 of this report). The air barrier system consisted of Sto Flexyl adhesive applied to the gypsum sheathing. Exterior Wall Lamella by Roxul were adhered to the gypsum sheathing using the adhesive. One of the specimens had 13 mm grooves in the lamella spaces 100 mm on center while the second specimen had 6 mm grooves, also at 100 mm on center. The Lamella were covered with a mesh and StoSilco Lit Finish (see Figures 2 and 3 of this report).

The two specimens incorporated an open vent with a total vent area of 0.0294 m². The only difference between the two specimens was the dimensions of the vertical grooves.

Each test specimen was subjected to three sinusoidal loading conditions, with each condition containing nine frequencies, as follows:

1. a mean pressure of 0 Pa and an amplitude of 500 Pa
2. a mean pressure of 0 Pa and an amplitude of 1000 Pa
3. a mean pressure of 1000 Pa and an amplitude of 1000 Pa.

Pressure difference was measured across the specimen, and across the air barrier system at five locations over the height of the specimen and at 4 locations across the width of the specimen. The pressure difference across the rainscreen was determined by subtracting the pressure difference measured across the air barrier system at each location from the pressure difference measured across the specimen. The following observations were found true for both specimens:

- Adequate pressure equalization was obtained at frequencies below 1 Hz but deteriorated as the frequency increased.
- The pressure difference across the rainscreen increased as the distance from the vent increased.
- The pressure difference across the rainscreen was the same at the centre and at the edge of the cavity for measurements at the same distance from the vent.
- The specimen with the 12 mm vertical channels exhibited resonance behavior above 2 Hz. The data in Appendix A shows this as an amplitude ratio of the driving to measured response greater than unity.
- The amount of water which entered the specimen in a face seal specimen was much greater than that which entered as a pressure equalizing system.
- The artificial horizontal defect introduced into the test specimen had a small effect on the amount of water that entered into the system.
- All of the water that entered into the wall system was drained out through the vent. No water appeared in any of the stud cavities and there was no indication of any moisture in the gypsum sheathing.

INTRODUCTION

The pressure equalized rainscreen (PER) principle is considered the most effective design approach to control rain penetration in walls. However, a literature review conducted by the National Research Council (NRC) to determine design guidelines for such walls (IRC Internal Report No. 629) concluded that current guidelines are not at all comprehensive. As a consequence, NRC initiated a research project to develop design guidelines for PER walls. The project has three tasks, namely experimental evaluation, numerical modeling and development of design guidelines. In support of the research project, NRC and Canada Mortgage and Housing Corporation (CMHC) entered into a cooperative agreement on the first two tasks. In addition, Sto Industries Canada Inc., the Canadian Prestressed Concrete Institute and Dryvit Canada Inc. have agreed to participate in the agreement by supplying test specimens and providing technical and practical information.

This report presents results from the experimental evaluation task. It documents the air leakage performance, pressure equalization response, and water penetration results of two EIFS specimens which were supplied by Sto Industries Canada.

TEST SPECIMENS

Each test specimen measured 2.43 m high by 1.12 m wide. The specimens were constructed by Sto Canada representatives at NRC under the supervision of IRC personnel. Following is a summary of the procedure used to construct each specimen. It is based on observations by IRC staff and information from Sto Industries publications.

The structural support for the EIFS specimens was provided by 16 ga and 18 ga, 89 mm steel studs (Figure 1). Lateral support was provided by 18 ga, 19 mm strapping that connected opposite corners on the test specimen. All of the steel work was welded together.

The steel stud frame was covered with 13 mm gypsum sheathing faced with glass fibre reinforcing. One coat of Sto Flexyl was applied by trowel to the exterior side of the sheathing. This material is used as a combination air barrier and adhesive for the Roxul Exterior Wall Lamella which were applied vertically to the sheathing. The Lamella measured 63 mm by 152 mm by 2440 mm and has a density of approximately 120 kg/m³. (Note that the thickness of Lamella samples obtained by NRC from the same lot used to produce the test specimens varied by as much as 12 mm in 63 mm.). The Lamella was adhered such that there was either a 12 mm (Specimen 5) or 6 mm (Specimen 6) gap running the full height of the wall (see Figure 2). Small pieces of Lamella, approximately 12 mm deep were cut and carefully placed in the vertical air spaces. They were placed such that the exterior surface of the assembly consisted of Lamella and there were no air spaces. This was performed in order to provide continuous support for the base coat and finish materials.

One coat of BTS-NC Base Coat was applied directly onto the Lamella. Standard Sto reinforcing mesh was embedded into the wet BTS-NC Base Coat and an additional coat was applied to ensure that the mesh was fully embedded. The assembly was then allowed to dry. One coat of StoSilco primer was applied with a roller and was left to dry thoroughly. StoSilco Lit Finish was applied directly over the primer using a trowel.

The specimens cured a minimum of 30 days before testing commenced.

The test specimens had identical vent details but different cross sections. The pressure equalizing cavity was 1.178 m wide by 2.274 m high. Vents in both specimens were located at the same vertical height and had a vent area of 0.0294 m².

Figure 1 Specimen Structure

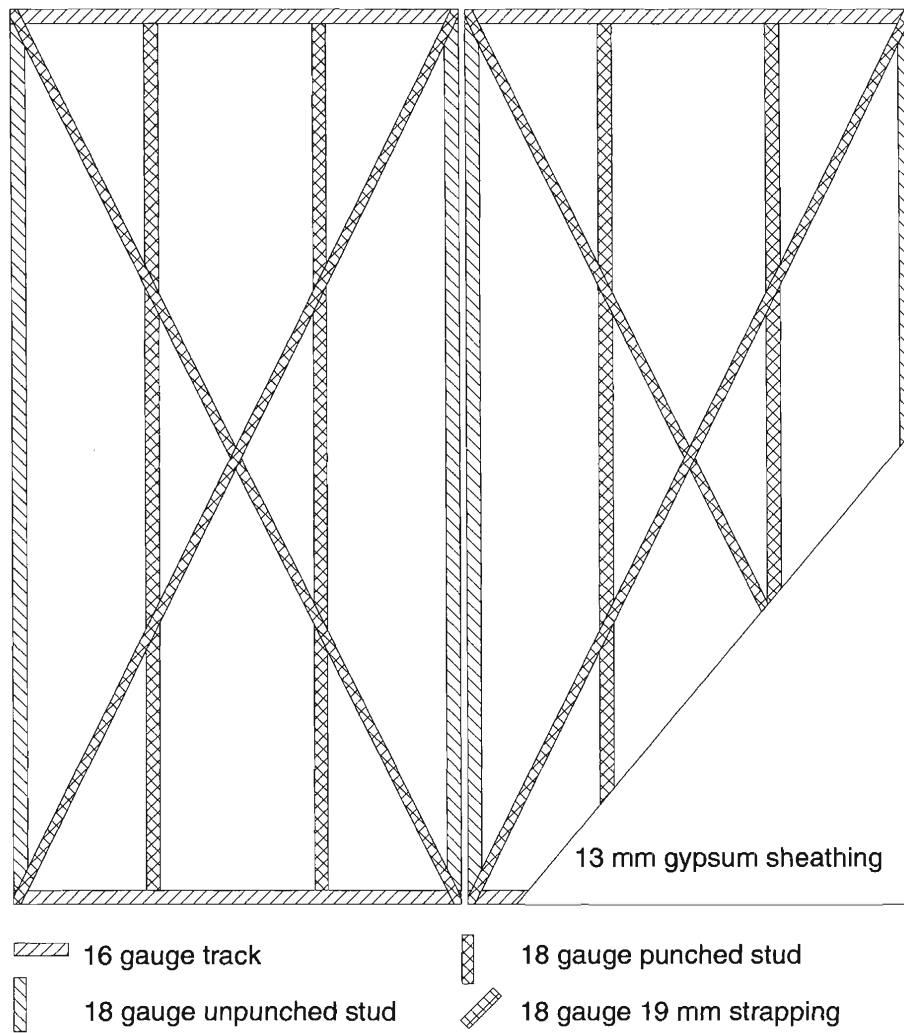


Figure 2: Test Specimen horizontal and vertical section details.

TEST PROGRAM

Air leakage, pressure equalization and water penetration performance were measured in the DWTF. The sub-tasks are summarized as follows:

1. Air leakage characteristics of the specimen were measured for static pressure differences.
2. Pressure equalization response was measured at a range of frequencies for different sinusoidal loading (i.e., mean value and amplitude) scenarios.
3. Water penetration was measured under both static and dynamic pressures with and without a defect in the rainscreen. The artificial horizontal defect measured 500 mm long and 1 mm wide and approximately 3 mm deep.

Air Leakage

Air leakage was measured with Miriam Laminar Flow Elements (LFE) and Air Limited's Micromanometers (± 0.5 Pa) at static pressure differences across the specimen ranging up to approximately 1000 Pa. The measurements were performed for the following conditions:

- *Base Leakage.* Polyethylene was tightly sealed to the steel frame on the laboratory side of the DWTF, covering both specimens and their seals to the frame. The only leakage would be through the seals around the door and piston.
- *Specimen Perimeter Leakage.* All leakage holes in the air barrier system were closed. The polyethylene was removed so that leakage could occur through the specimen perimeter seal.

The *Base Leakage* and *Specimen Perimeter Leakage* measured for the experimental setup are shown in Figure 2. To determine the air flow characteristics, air flow (L/s) is correlated to pressure difference across the air barrier system (Pa) by a least squares fit to the following equation:

$$Q = C \bullet \Delta P^n \quad (1)$$

where Q is the air flow through the air barrier system and ΔP is the pressure difference across the air barrier system. Values for C and n determined for each of the *Air Barrier System Leakage* test conditions are also shown in Figure 3.

Observations: Air leakage through the air barrier system can be minimized by careful design and construction, but it is unwise to ignore the likelihood that some level of leakage will be present. According to a recently prepared guide¹ for the evaluation of air barrier systems, a properly functioning air barrier system should have a flow rate of not more than 0.1 L/s/m² at a pressure difference of 75 Pa, or approximately 0.3 L/s for a specimen area of 2.88 m².

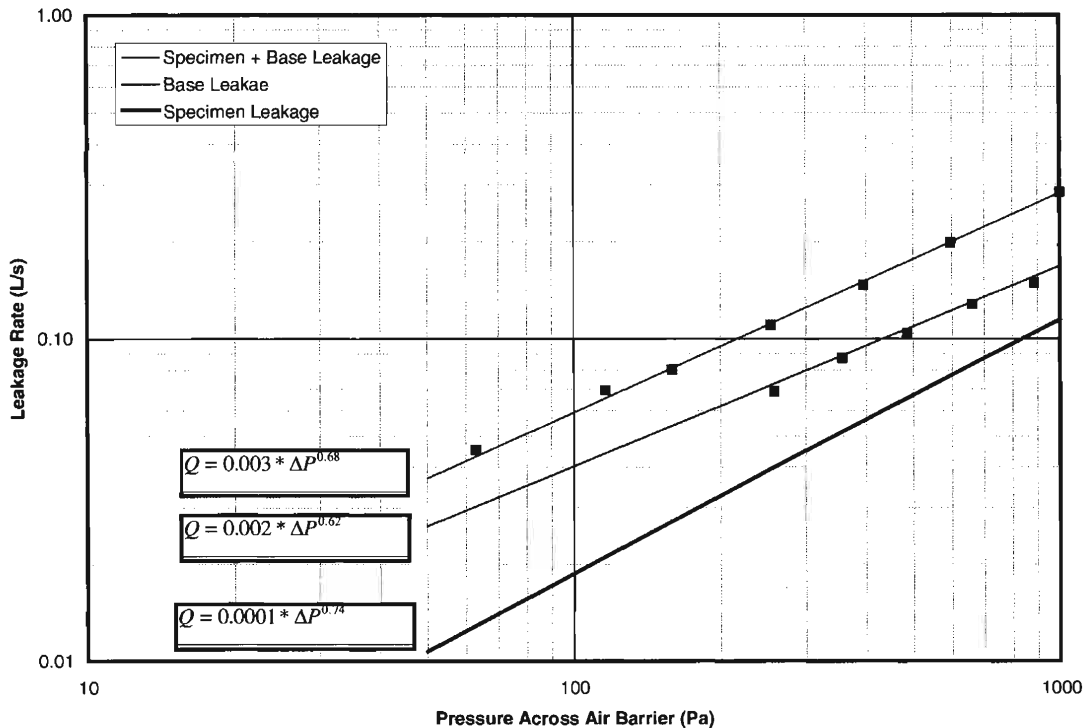
Pressure equalization

The dynamic component of wind approaching a building over open terrain can be represented by adding together sinusoidal components of suitable amplitude, phase, and frequency, selected from a limited range of frequencies. The higher the frequency, the more difficulty a given PER wall system will have in transmitting the fluctuation into the cavity in time to keep the pressure difference across the rainscreen within desirable limits. An important design issue is the upper bound for frequency content. The main energy content of wind flowing over open terrain is at relatively low frequencies in the range of 0.01 Hz to 0.1 Hz. The amount of energy contained at frequencies of 0.1 Hz and higher is normally negligible, but designers should be aware that some areas of the building envelope may experience energy at higher frequencies through interaction of the flow with parts of the building or with upwind structures. In the absence of special considerations, it is suggested that results at two frequencies, 0.5 Hz and 5 Hz, be used to evaluate the performance of test specimens.

The response of the cavity of the test specimen was measured for sinusoidal loading at seven frequencies for seven leakage rates and three sinusoidal loading (i.e., amplitude) scenarios (see following table). Since both of the specimens were identical, only one specimen was instrumented and monitored for the pressure equalizing performance.

¹ Technical Guide for Air Barrier Systems, Canadian Construction Materials Centre, National Research Council Canada, Ottawa Canada.

Figure 3: Air leakage measurement results.



Leakage Type	Leakage Holes (Ø 6 mm)	Loading Scenarios ¹	Frequencies ² f
A	0	3	7
B	3	3	7

Notes: 1. The three loading scenarios were $0+500 \cdot \sin(2\pi f t)$ Pa, $0+1000 \cdot \sin(2\pi f t)$ Pa, and $1000+1000 \cdot \sin(2\pi f t)$ Pa

2. The seven frequencies, f , were 0.05, 0.1, 0.2, 0.5, 1, 2 and 5 Hz.

Pressure difference across the air barrier was measured along the height of the specimen (Figure 6) with Setra differential pressure transducers, all with similar frequency response characteristics. These were installed using the same length of vinyl tubing and attached to the same length of copper pressure tap. Channel 2 measures the pressure difference across the entire specimen (i.e., the driving potential). The pressure taps located in the vertical channels of the Lamella (channels 3 through 7) extended flush with the Densglas Gold[®] gypsum board. The pressure taps located in the centre of the Lamella (channels 8 to 11) extended through the air barrier system to the centre of the Lamella. All pressure taps were epoxied in place to ensure a high strength, airtight seal.

Figure 4 provides a graphical representation of data obtained from a typical pressure equalization test. The top half of the figure presents data collected with a loading scenario of $0+500 \cdot \sin(2\pi f t)$ Pa with f equal to 1.0 Hz. The bottom half presents the pressure difference calculated across the rainscreen by subtracting the pressure measured across the air barrier from the measured excitation pressure. Figure 5 also demonstrates that degradation of the response of the specimen is caused by both a reduction in amplitude ratio and an increase in phase lag for cavity pressure. It is important to note that the maximum pressure difference across the rainscreen is a consequence of both factors, and that a substantial pressure difference can result even though the amplitude of the pressure difference across the air barrier may be close to that across the specimen.

All of the pressure data measured for each test condition were fitted to sine/cosine functions using a least squares fit. From this analysis, an amplitude and phase angle were determined and the pressure

equalization characteristics (in terms of amplitude ratio across the air barrier system, the phase shift of the response, and the resultant amplitude ratio across the rainscreen) of the specimen were determined. Figure 5 provides a summary of the results obtained from the specimen. Plotted are the percentage load across the rainscreen for channel 3 (bottom of the specimen inside the vertical channels), channel 5 (mid-height of the specimen inside the vertical channels) and channel 7 (top of the specimen inside the vertical channels) versus the number of leakage holes and the loading condition for both 0.5 Hz and 5.0 Hz for the two test specimens. The pressure equalization response measured for all test conditions are presented in Appendix A.

Observations: The following observations on the pressure equalization response of the specimen derive from the summary of results given in Figure 6 and Appendix A.

- Pressure equalization response improved as the air leakage decreased.
- The pressure difference across the rainscreen varies along the height of the specimen. In general, the further from the vent location, the greater the pressure difference across the rainscreen. This is probably due to the resistance to air flow in the channels. The effect becomes amplified as both the air leakage and test frequency increases. The test specimen with the 12 mm vertical channels performed better than the test specimen with the 6 mm vertical channels.
- The pressure equalization response became worse as the frequency increased. Comparison of the response at 0.5 Hz to that at 5.0 Hz demonstrates that, without adequate dynamic pressure equalization response, a significant pressure difference can be imposed on the rainscreen as the frequency increases.
- The pressure across the rainscreen did not vary significantly across the width of the specimens.
- The specimen with the 12 mm vertical channels exhibited resonance behavior above 2 Hz. The data in Appendix A shows this as an amplitude ratio of the driving to measured response greater than unity.

Water Penetration

Water penetration results were recorded for the test specimen. A catch was built and installed such that any water which penetrated into the system and drained through the vent was drained out to be measured. The catch was installed such that it would not interfere with pressure equalizing performance of the specimen. In addition, a series of moisture pins were installed into the Lamella that extended through the air barrier system to approximately the mid-depth of the Lamella. The length of the pins limited the depth to 50 mm into the Lamella and therefore, pins were not able to extend to the lamina. A horizontal defect, measuring 500 mm long, 1 mm high and 3 mm deep, was cut into one of the test specimens 300 mm from the top. The water supply rate was the same for all tests, 4.2 L/min/m².

For the first series of tests, the vent area for the specimen with the 12 mm vertical channels was sealed and static pressure differences were applied across the specimens. The results are shown in Figure 7. This test indicates the static water penetration performance of a face sealed system. For the second series of tests, the vents were opened and a drip edge was placed over the catch basin. This was done in order to eliminate the possibility of any water entering the basin as a result of direct spray. The specimen was then subjected to a dynamic pressure of $300+200\sin(2\pi ft)$ Pa at a frequency of 0.5 Hz. The tests were performed both with and without an effective air barrier system (i.e., 0 leakage holes versus 3 leakage holes). All water penetrations tests had a duration of 60 minutes.

Figure 4: Typical test data. Measured for Specimen 5 with a loading condition of a mean pressure difference of 0 Pa, an amplitude of 500 Pa, and at a Frequency of 1.00 Hz.
(See Figure 4 for location of Channels)

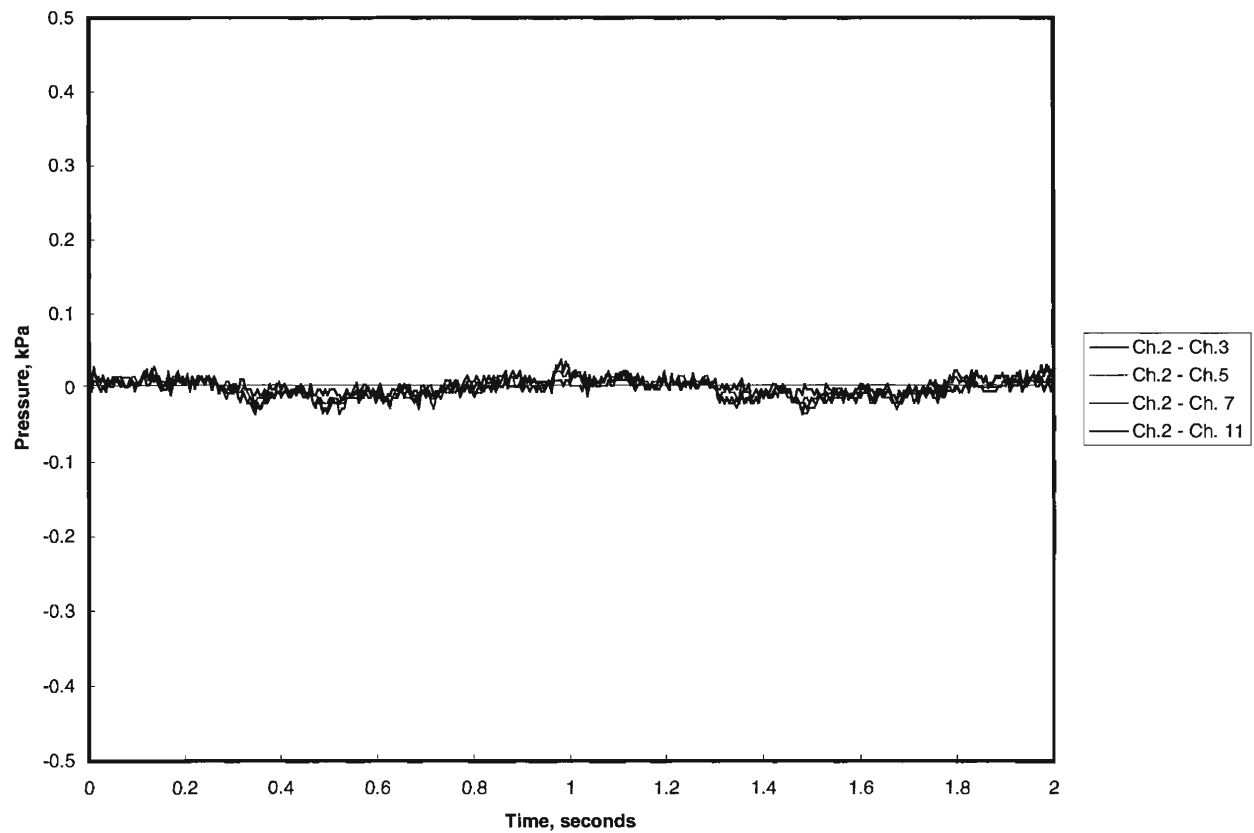
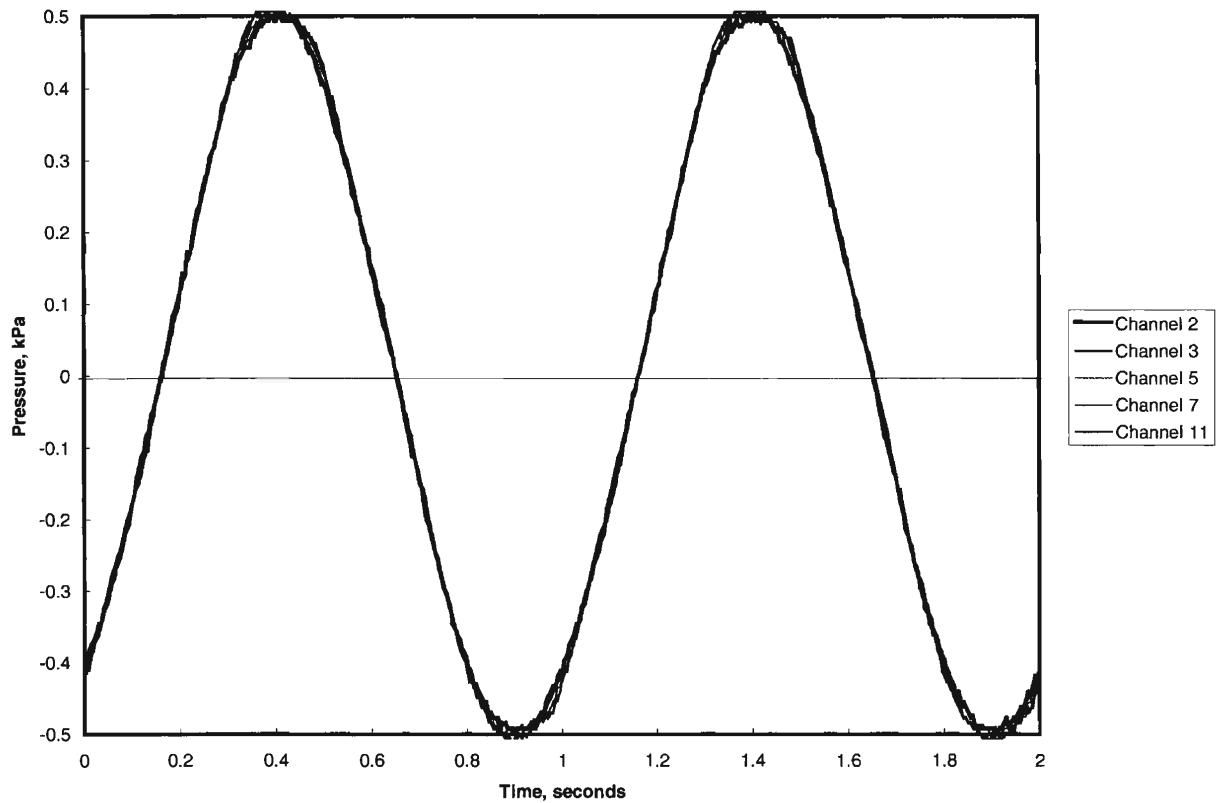


Figure 5: *Percentage load across the rainscreen for the EIFS Test Specimens under the various test conditions.*

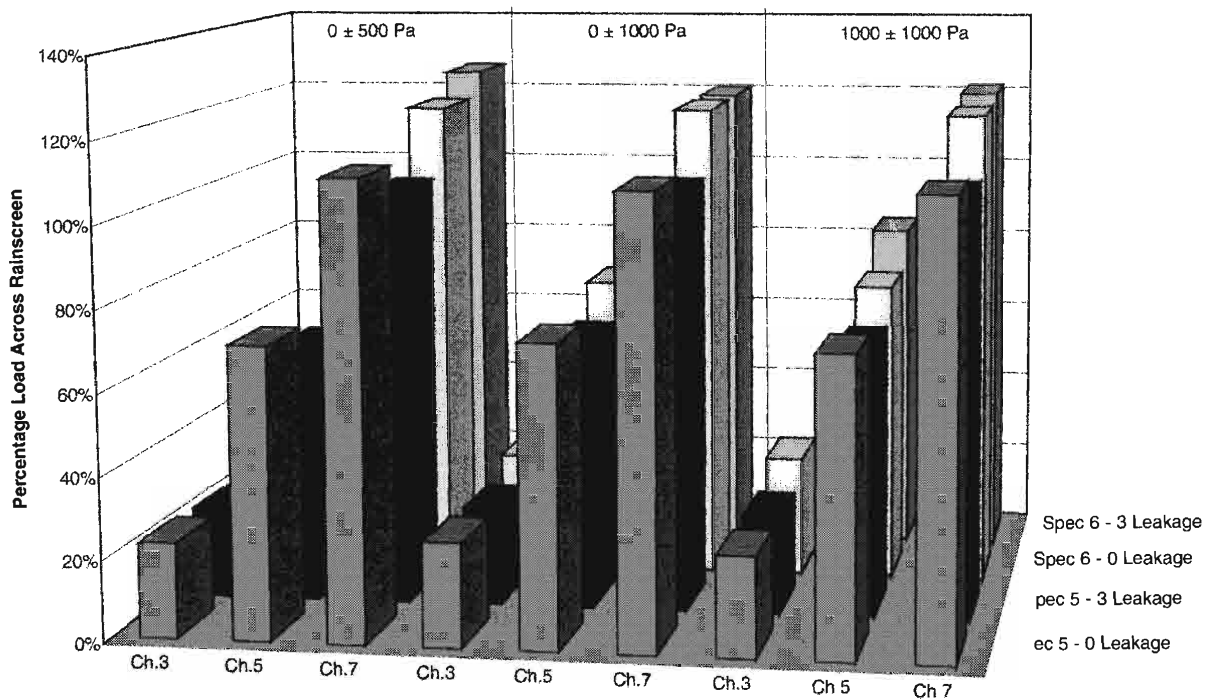
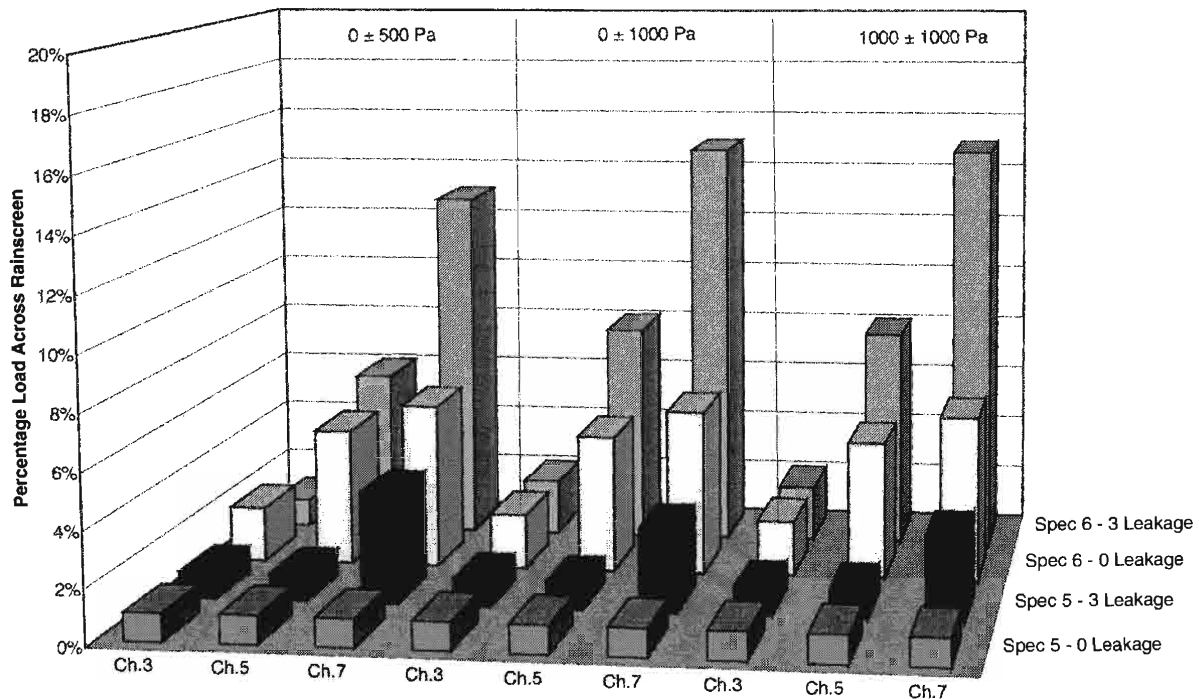
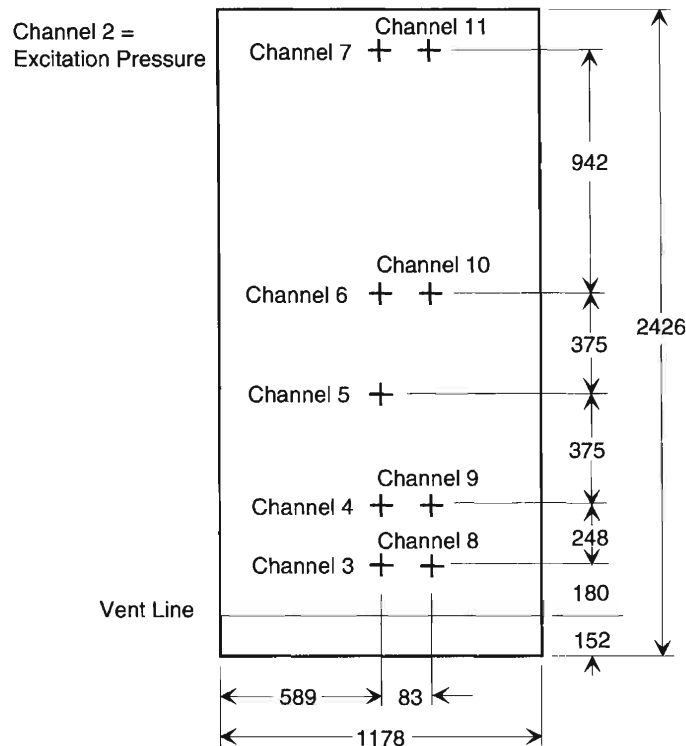


Figure 6: Location of Pressure Taps and Moisture Pins.



Observations: The results of the water penetration tests for both the defective and non-defective test specimens are graphically shown in Figure 7. Under static conditions, the amount of water that passed through the system increased as the pressure across the specimen increased. With no pressure difference across either specimen, the amount of water through the system was slightly greater for the defective than the non-defective specimen. At higher pressures, the rate of water penetration increased for both the defective and the non-defective specimens. At 500 Pa, the water penetration rate was approximately 0.1 L/min greater for the defective specimen than the non-defective specimen. This leads one to conclude that the majority of the water collected during the water penetration tests came through the lamina. The dynamic tests were performed at a mean pressure of 300 Pa with an amplitude of 200 Pa at a frequency of 0.5 Hz. The amount of water that entered both specimens was significantly lower when the wall system performed as a pressure equalizing one (i.e., the vent area was open). The rate at which water was collected from the system increased noticeably when the air barrier system was compromised. During all of the tests, none of the moisture pins indicated any moisture. It should also be noted that the pins were unable to extend beyond the mid-depth of the lamella and that moisture pins are a point method of measurement. Water which passes the rainscreen will follow the path of least resistance until it finds its way into one of the channels where it will drain out through the vent due to gravity. If the pins are not located along one of the paths of least resistance, moisture will not be detected. It should also be noted that at no time did any water appear in any of the stud cavities.

Figure 7: Measured water penetration rates for the test specimen with 12 mm vertical channels for the defective and non-defective specimens under both static and dynamic pressure loadings.

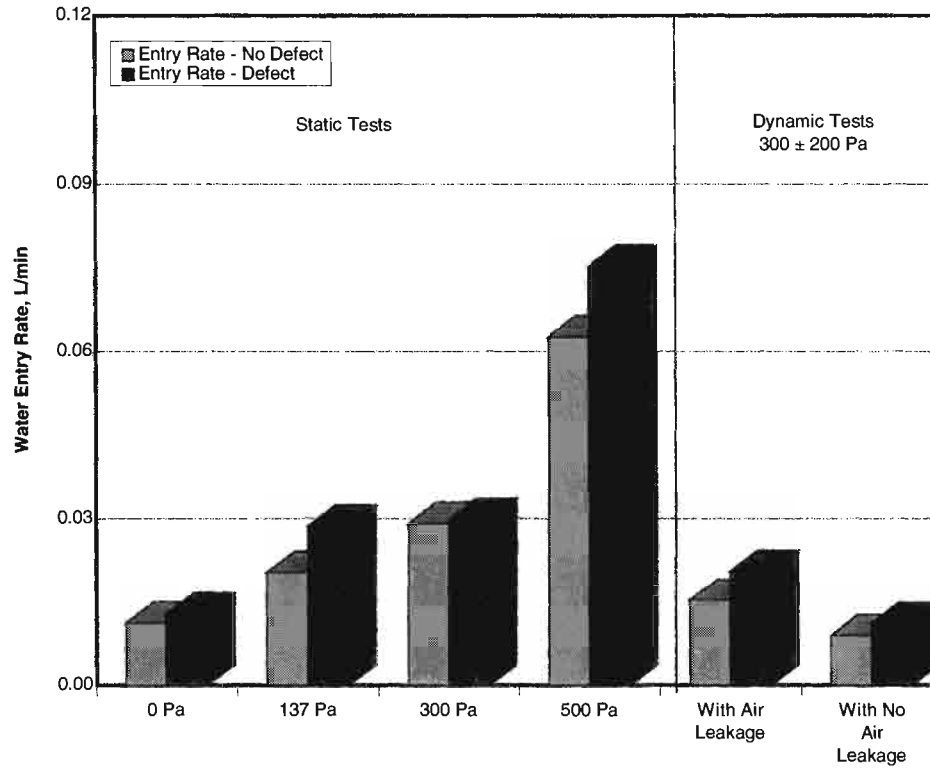


Figure A1: Specimen 5 (12 mm spacing). Test A 0 ± 0.50 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 3	Amp. ABS	1.00	1.00	1.00	1.00	1.00	1.02	1.00
	Phase ABS	0.0	-0.1	-0.1	-0.3	-0.7	-2.0	-13.4
	Amp RS	0.00	0.00	0.00	0.01	0.01	0.04	0.23
Channel 4	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.03	1.05
	Phase ABS	0.0	-0.1	-0.2	-0.4	-1.2	-3.4	-26.2
	Amp RS	0.00	0.00	0.00	0.01	0.02	0.07	0.47
Channel 5	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.06	1.18
	Phase ABS	0.0	-0.1	-0.2	-0.7	-1.6	-4.6	-36.5
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.10	0.71
Channel 6	Amp. ABS	1.00	1.00	1.00	1.01	1.02	1.08	1.32
	Phase ABS	0.0	-0.1	-0.1	-0.4	-1.1	-3.9	-39.0
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.11	0.83
Channel 7	Amp. ABS	1.00	1.00	1.00	1.01	1.03	1.11	1.54
	Phase ABS	0.0	-0.1	-0.1	-0.4	-1.3	-4.6	-45.9
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.14	1.11

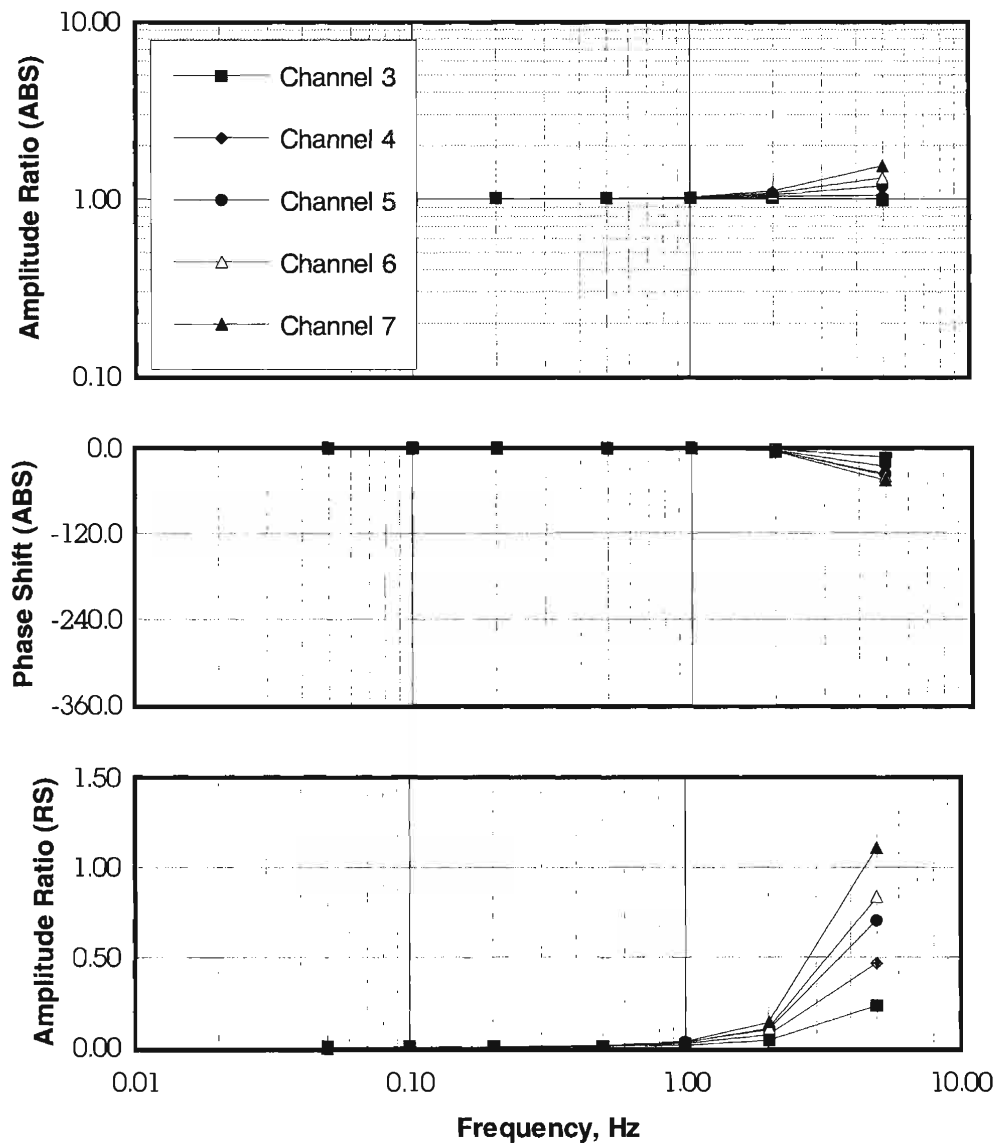


Figure A1: Specimen 5 (12 mm spacing). Test A 0 ± 0.50 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 8	Amp. ABS	1.00	1.00	1.00	1.00	1.00	1.01	1.00
	Phase ABS	0.0	0.0	0.1	0.1	0.0	-0.5	-9.0
	Amp RS	0.00	0.00	0.00	0.00	0.00	0.01	0.16
Channel 9	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.04	1.06
	Phase ABS	0.0	0.0	0.1	0.0	-0.3	-1.7	-24.6
	Amp RS	0.00	0.00	0.00	0.00	0.01	0.05	0.44
Channel 10	Amp. ABS	1.00	1.00	1.00	1.00	1.02	1.08	1.33
	Phase ABS	0.0	0.0	0.0	0.0	-0.5	-2.5	-34.7
	Amp RS	0.00	0.00	0.00	0.00	0.02	0.09	0.76
Channel 11	Amp. ABS	1.00	1.00	1.00	1.01	1.03	1.11	1.56
	Phase ABS	0.0	0.0	0.0	-0.1	-0.7	-3.2	-42.4
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.12	1.06

Figure A2: Specimen 5 (12 mm spacing). Test B 0±1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 3	Amp. ABS	1.00	1.00	1.00	1.00	1.00	1.01	0.93
	Phase ABS	0.0	-0.1	-0.1	-0.4	-0.9	-2.9	-14.2
	Amp RS	0.00	0.00	0.00	0.01	0.02	0.05	0.25
Channel 4	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.03	0.93
	Phase ABS	0.0	-0.1	-0.2	-0.5	-1.5	-5.1	-29.6
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.09	0.50
Channel 5	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.05	1.01
	Phase ABS	-0.1	-0.1	-0.3	-0.7	-2.0	-6.9	-42.5
	Amp RS	0.00	0.00	0.00	0.01	0.04	0.13	0.73
Channel 6	Amp. ABS	1.00	1.00	1.00	1.01	1.02	1.07	1.11
	Phase ABS	0.0	-0.1	-0.2	-0.5	-1.7	-6.6	-46.6
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.14	0.84
Channel 7	Amp. ABS	1.00	1.00	1.00	1.01	1.02	1.09	1.28
	Phase ABS	0.0	-0.1	-0.2	-0.5	-1.9	-7.7	-55.7
	Amp RS	0.00	0.00	0.00	0.01	0.04	0.17	1.09

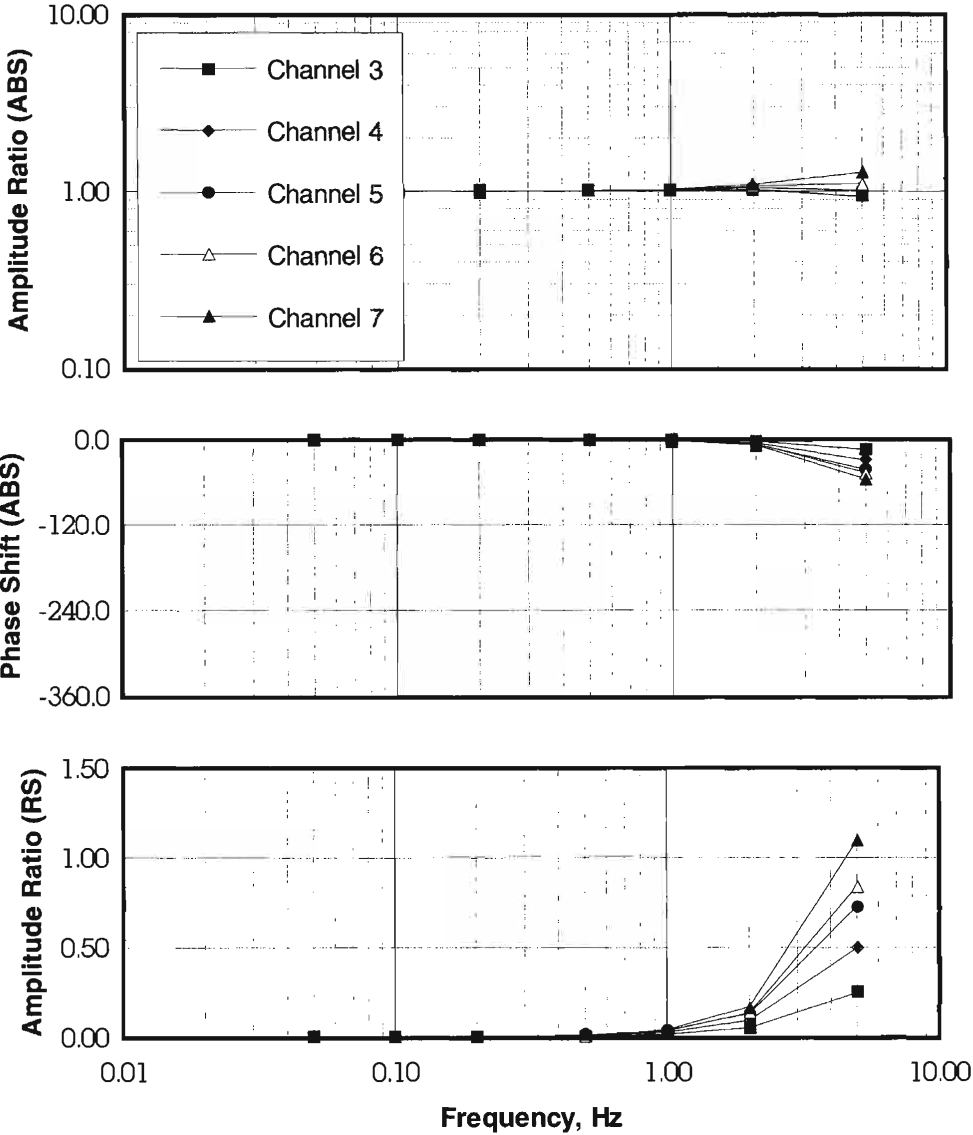


Figure A2: Specimen 5 (12 mm spacing). Test B 0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 8	Amp. ABS	1.00	1.00	1.00	1.00	1.00	1.01	0.95
	Phase ABS	0.0	0.0	0.0	0.0	-0.2	-1.2	-9.8
	Amp RS	0.00	0.00	0.00	0.00	0.00	0.02	0.17
Channel 9	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.03	0.92
	Phase ABS	0.0	0.0	0.0	-0.1	-0.7	-3.6	-28.8
	Amp RS	0.00	0.00	0.00	0.00	0.02	0.07	0.48
Channel 10	Amp. ABS	1.00	1.00	1.00	1.01	1.02	1.06	1.12
	Phase ABS	0.0	0.0	0.0	-0.2	-1.0	-5.0	-42.1
	Amp RS	0.00	0.00	0.00	0.01	0.02	0.11	0.77
Channel 11	Amp. ABS	1.00	1.00	1.00	1.01	1.02	1.09	1.29
	Phase ABS	0.0	0.0	-0.1	-0.2	-1.3	-6.3	-52.5
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.15	1.05

Figure A3: Specimen 5 (12 mm spacing). Test C 1.0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 3	Amp. ABS	1.00	1.00	1.00	1.00	1.00	1.01	0.94
	Phase ABS	0.0	-0.1	-0.1	-0.4	-0.9	-2.8	-14.0
	Amp RS	0.00	0.00	0.00	0.01	0.02	0.05	0.24
Channel 4	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.02	0.93
	Phase ABS	0.0	-0.1	-0.2	-0.5	-1.4	-4.8	-29.1
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.09	0.49
Channel 5	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.05	1.02
	Phase ABS	0.0	-0.1	-0.2	-0.7	-1.9	-6.5	-41.9
	Amp RS	0.00	0.00	0.00	0.01	0.04	0.12	0.72
Channel 6	Amp. ABS	1.00	1.00	1.00	1.00	1.02	1.06	1.12
	Phase ABS	0.0	-0.1	-0.1	-0.5	-1.6	-6.1	-45.9
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.13	0.84
Channel 7	Amp. ABS	1.00	1.00	1.00	1.00	1.02	1.09	1.29
	Phase ABS	-0.1	-0.1	-0.1	-0.6	-1.8	-7.2	-55.1
	Amp RS	0.00	0.00	0.00	0.01	0.04	0.16	1.09

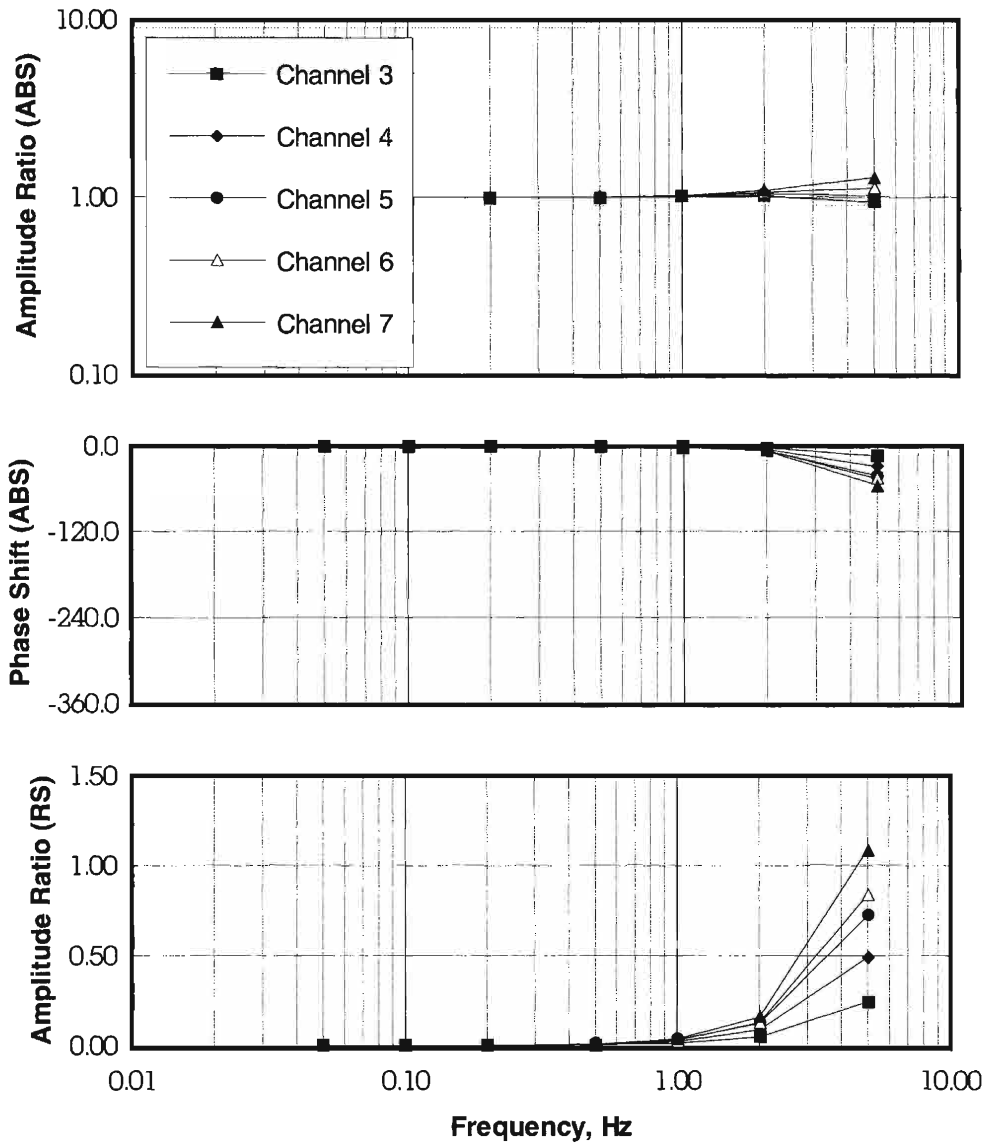


Figure A3: Specimen 5 (12 mm spacing). Test C 1.0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 8	Amp. ABS	1.00	1.00	1.00	1.00	1.00	1.01	0.95
	Phase ABS	0.0	0.0	0.1	0.0	-0.1	-1.2	-9.6
	Amp RS	0.00	0.00	0.00	0.00	0.00	0.02	0.17
Channel 9	Amp. ABS	1.00	1.00	1.00	1.00	1.01	1.03	0.93
	Phase ABS	0.0	0.0	0.0	-0.1	-0.6	-3.3	-28.0
	Amp RS	0.00	0.00	0.00	0.00	0.01	0.06	0.47
Channel 10	Amp. ABS	1.00	1.00	1.00	1.00	1.02	1.06	1.13
	Phase ABS	0.0	0.0	0.0	-0.2	-0.9	-4.6	-41.4
	Amp RS	0.00	0.00	0.00	0.00	0.02	0.10	0.76
Channel 11	Amp. ABS	1.00	1.00	1.00	1.00	1.02	1.09	1.31
	Phase ABS	0.0	0.0	0.0	-0.3	-1.2	-5.8	-51.8
	Amp RS	0.00	0.00	0.00	0.01	0.03	0.14	1.04

Figure A4: Specimen 6 (6 mm spacing). Test A 0 ± 0.50 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 3	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.94	0.81
	Phase ABS	-0.1	-0.2	-0.3	-1.4	-4.2	-10.2	-14.2
	Amp RS	0.00	0.00	0.01	0.02	0.07	0.18	0.29
Channel 4	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.91	0.67
	Phase ABS	-0.1	-0.2	-0.5	-2.0	-6.5	-17.7	-26.7
	Amp RS	0.00	0.00	0.01	0.03	0.11	0.31	0.50
Channel 5	Amp. ABS	1.00	1.00	1.00	1.00	1.00	0.90	0.57
	Phase ABS	-0.1	-0.3	-0.7	-2.8	-9.2	-26.2	-48.0
	Amp RS	0.00	0.01	0.01	0.05	0.16	0.44	0.75
Channel 6	Amp. ABS	1.00	1.00	1.00	1.01	1.00	0.91	0.52
	Phase ABS	-0.1	-0.3	-0.7	-3.0	-10.7	-32.6	-69.7
	Amp RS	0.00	0.01	0.01	0.05	0.19	0.54	0.95
Channel 7	Amp. ABS	1.00	1.00	1.00	1.01	1.01	0.93	0.58
	Phase ABS	-0.2	-0.4	-0.9	-3.6	-12.7	-39.1	-94.6
	Amp RS	0.00	0.01	0.02	0.06	0.22	0.65	1.20

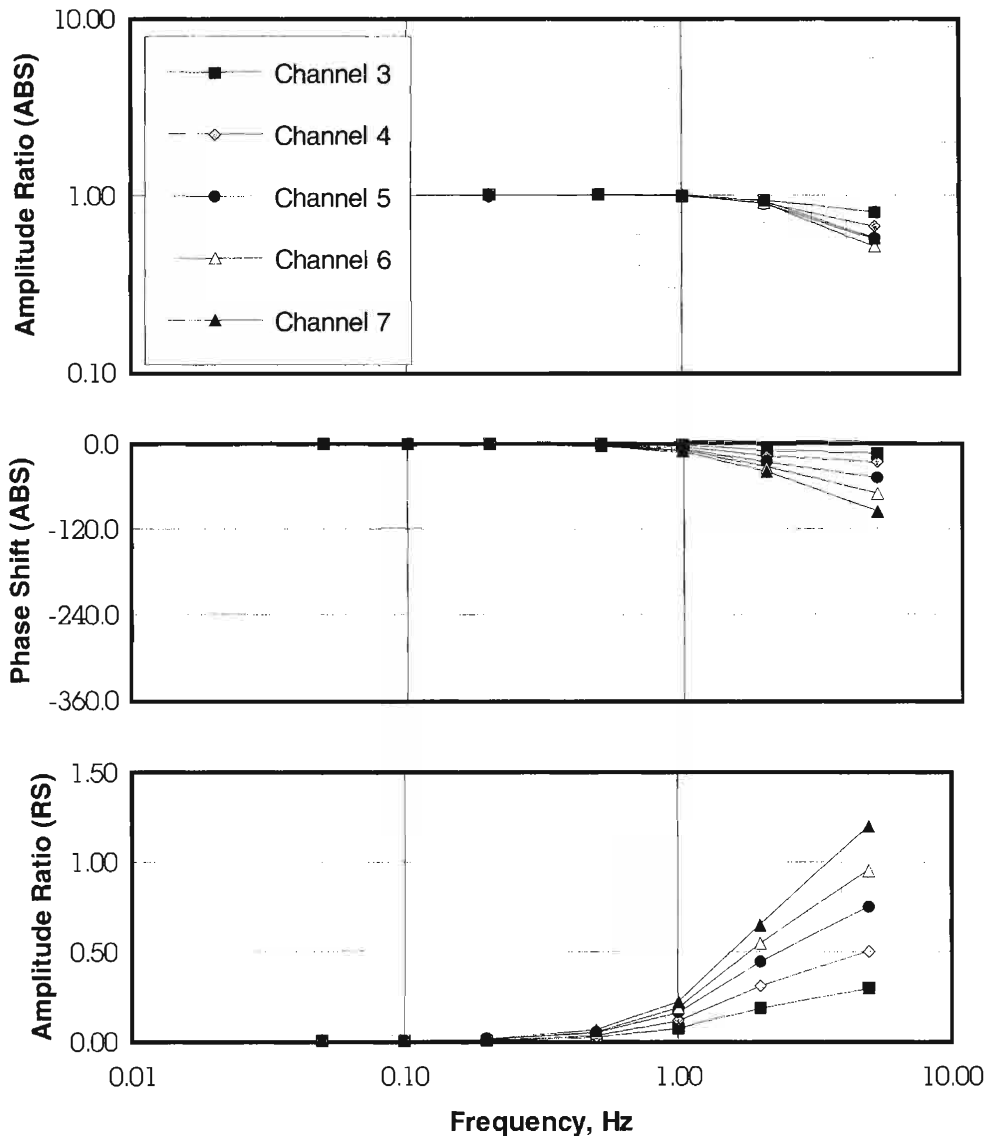


Figure A4: Specimen 6 (6 mm spacing). Test A 0 ± 0.50 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 8	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.94	0.82
	Phase ABS	-0.1	-0.1	-0.3	-1.2	-3.6	-9.0	-12.4
	Amp RS	0.00	0.00	0.01	0.02	0.06	0.16	0.26
Channel 9	Amp. ABS	1.00	1.00	1.00	1.00	1.00	0.92	0.68
	Phase ABS	-0.1	-0.2	-0.4	-1.9	-6.3	-17.1	-25.5
	Amp RS	0.00	0.00	0.01	0.03	0.11	0.30	0.48
Channel 10	Amp. ABS	1.00	1.00	1.00	1.01	1.00	0.90	0.49
	Phase ABS	-0.1	-0.3	-0.7	-3.1	-11.1	-33.6	-71.2
	Amp RS	0.00	0.01	0.01	0.05	0.19	0.56	0.96
Channel 11	Amp. ABS	1.01	1.01	1.01	1.01	1.02	0.93	0.57
	Phase ABS	-0.2	-0.4	-0.8	-3.6	-12.7	-39.3	265.9
	Amp RS	0.01	0.01	0.02	0.07	0.22	0.65	1.19

Figure A5: Specimen 6 (6 mm spacing). Test B 0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 3	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.94	0.81
	Phase ABS	-0.1	-0.2	-0.3	-1.4	-4.2	-10.2	-14.2
	Amp RS	0.00	0.00	0.01	0.02	0.07	0.18	0.29
Channel 4	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.91	0.67
	Phase ABS	-0.1	-0.2	-0.5	-2.0	-6.5	-17.7	-26.7
	Amp RS	0.00	0.00	0.01	0.03	0.11	0.31	0.50
Channel 5	Amp. ABS	1.00	1.00	1.00	1.00	1.00	0.90	0.57
	Phase ABS	-0.1	-0.3	-0.7	-2.8	-9.2	-26.2	-48.0
	Amp RS	0.00	0.01	0.01	0.05	0.16	0.44	0.75
Channel 6	Amp. ABS	1.00	1.00	1.00	1.01	1.00	0.91	0.52
	Phase ABS	-0.1	-0.3	-0.7	-3.0	-10.7	-32.6	-69.7
	Amp RS	0.00	0.01	0.01	0.05	0.19	0.54	0.95
Channel 7	Amp. ABS	1.00	1.00	1.00	1.01	1.01	0.93	0.58
	Phase ABS	-0.2	-0.4	-0.9	-3.6	-12.7	-39.1	-94.6
	Amp RS	0.00	0.01	0.02	0.06	0.22	0.65	1.20

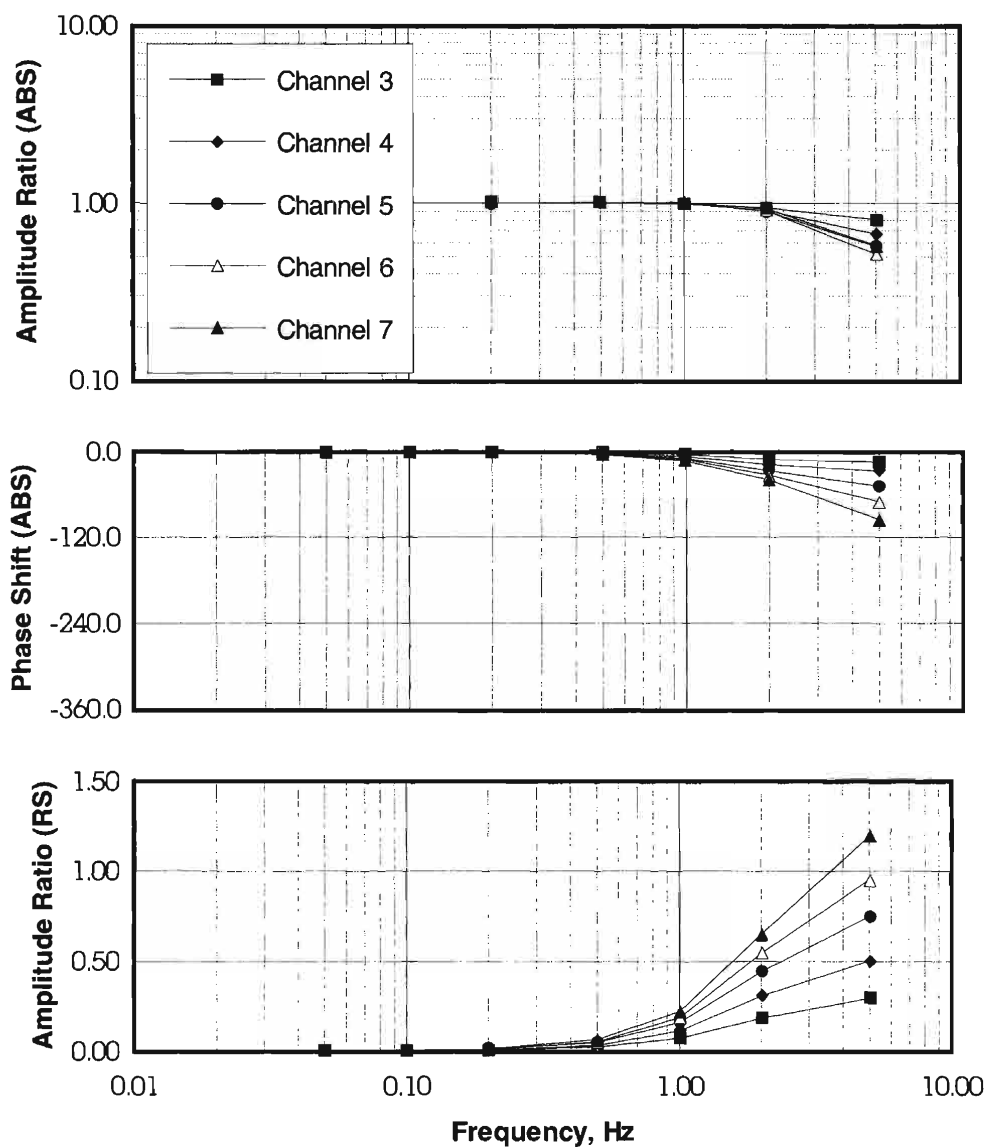


Figure A5: Specimen 6 (6 mm spacing). Test B 0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 8	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.94	0.82
	Phase ABS	-0.1	-0.1	-0.3	-1.2	-3.6	-9.0	-12.4
	Amp RS	0.00	0.00	0.01	0.02	0.06	0.16	0.26
Channel 9	Amp. ABS	1.00	1.00	1.00	1.00	1.00	0.92	0.68
	Phase ABS	-0.1	-0.2	-0.4	-1.9	-6.3	-17.1	-25.5
	Amp RS	0.00	0.00	0.01	0.03	0.11	0.30	0.48
Channel 10	Amp. ABS	1.00	1.00	1.00	1.01	1.00	0.90	0.49
	Phase ABS	-0.1	-0.3	-0.7	-3.1	-11.1	-33.6	-71.2
	Amp RS	0.00	0.01	0.01	0.05	0.19	0.56	0.96
Channel 11	Amp. ABS	1.01	1.01	1.01	1.01	1.02	0.93	0.57
	Phase ABS	-0.2	-0.4	-0.8	-3.6	-12.7	-39.3	265.9
	Amp RS	0.01	0.01	0.02	0.07	0.22	0.65	1.19

Figure A6: Specimen 6 (6 mm spacing). Test C 1.0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 3	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.94	0.80
	Phase ABS	-0.1	-0.2	-0.4	-1.4	-4.1	-10.2	-14.1
	Amp RS	0.00	0.00	0.01	0.02	0.07	0.18	0.30
Channel 4	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.91	0.67
	Phase ABS	-0.1	-0.2	-0.5	-1.9	-6.5	-17.7	-26.7
	Amp RS	0.00	0.00	0.01	0.03	0.11	0.31	0.50
Channel 5	Amp. ABS	1.00	1.00	1.00	1.00	1.00	0.90	0.57
	Phase ABS	-0.2	-0.3	-0.7	-2.7	-9.1	-26.3	-47.9
	Amp RS	0.00	0.01	0.01	0.05	0.16	0.44	0.75
Channel 6	Amp. ABS	1.00	1.00	1.00	1.01	1.00	0.90	0.51
	Phase ABS	-0.1	-0.3	-0.7	-3.0	-10.7	-32.7	-69.7
	Amp RS	0.00	0.01	0.01	0.05	0.19	0.54	0.95
Channel 7	Amp. ABS	1.00	1.00	1.00	1.01	1.01	0.93	0.58
	Phase ABS	-0.2	-0.4	-0.9	-3.6	-12.6	-39.3	-94.6
	Amp RS	0.00	0.01	0.01	0.06	0.22	0.65	1.19

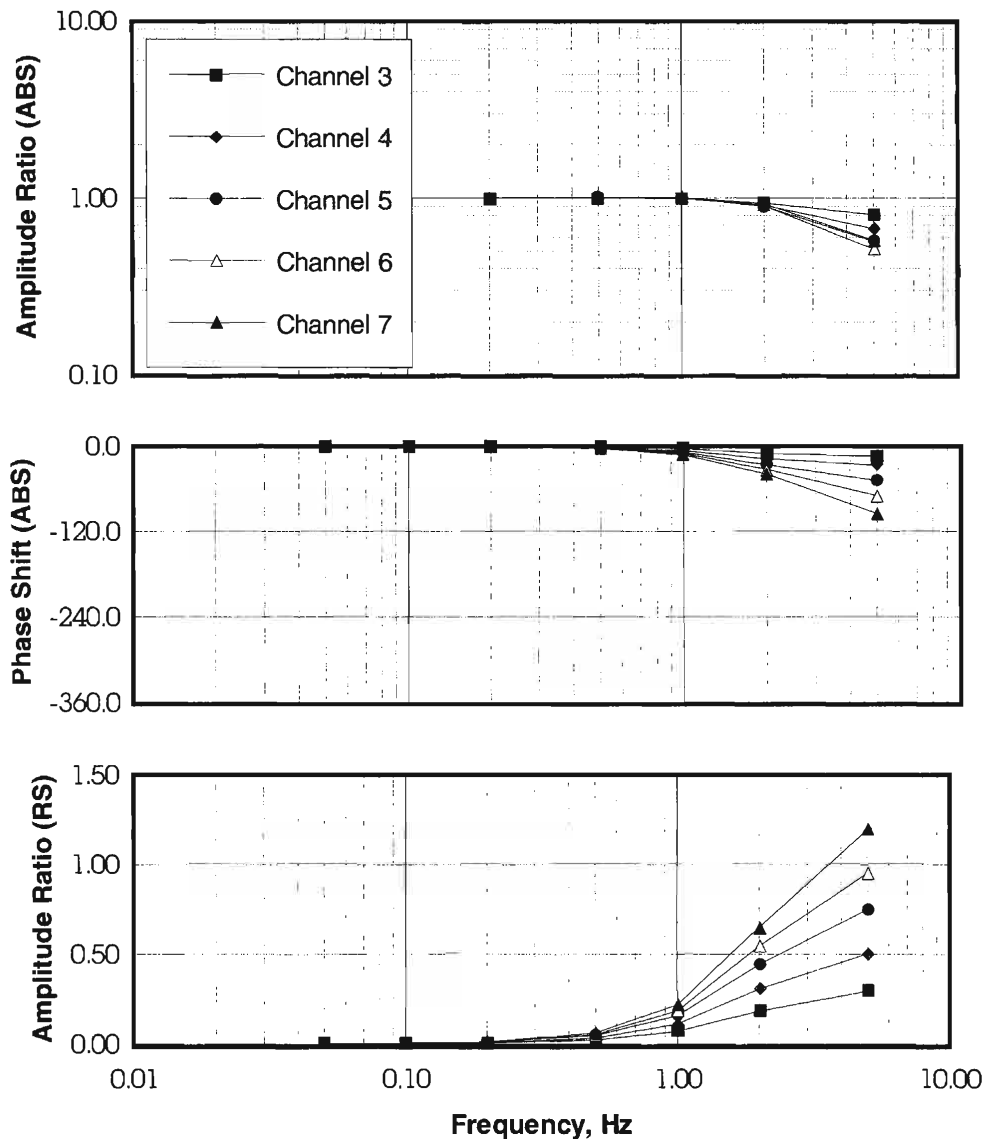


Figure A6: Specimen 6 (6 mm spacing). Test C 1.0 ± 1.0 kPa. No air leakage.

		Test Frequency						
		0.05	0.10	0.20	0.50	1.00	2.00	5.00
Channel 8	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.94	0.82
	Phase ABS	-0.1	-0.1	-0.3	-1.1	-3.6	-9.0	-12.4
	Amp RS	0.00	0.00	0.01	0.02	0.06	0.16	0.26
Channel 9	Amp. ABS	1.00	1.00	1.00	1.00	0.99	0.91	0.68
	Phase ABS	-0.1	-0.2	-0.4	-1.8	-6.2	-17.1	-25.4
	Amp RS	0.00	0.00	0.01	0.03	0.11	0.30	0.49
Channel 10	Amp. ABS	1.00	1.00	1.00	1.00	1.00	0.90	0.49
	Phase ABS	-0.1	-0.3	-0.7	-3.1	-11.0	-33.7	-71.2
	Amp RS	0.00	0.01	0.01	0.05	0.19	0.56	0.96
Channel 11	Amp. ABS	1.00	1.00	1.00	1.01	1.01	0.93	0.57
	Phase ABS	-0.2	-0.4	-0.8	-3.6	-12.7	-39.5	-94.1
	Amp RS	0.00	0.01	0.02	0.06	0.22	0.65	1.19