RESEARCH REPORT

Drainage and Retention of Water by Cladding Systems

Part 6 – Air Flow Characteristics of Drainage Cavities

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DRAINAGE AND RETENTION OF WATER BY CLADDING SYSTEMS

Part 6 – Air Flow Characteristics of Drainage Cavities

Presented to

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SUMMARY

The primary purpose of these tests has been to obtain the air flow characteristics of drainage cavities of walls used for drainage and retention studies. This information will be used for attempts at correlating the drying rates that were found earlier.

All walls having a distinct drainage cavity (as opposed to walls that were applied directly against the WRB on base walls were tested to determine their air flow characteristics. These characteristics by themselves do not determine how a cladding system will perform in this regard. Each class of assemblies tested had their unique way of managing water, whether by intent or by default.

The test procedure involved channelling air to the drainage cavity and measuring both that flow, and the pressure difference across different sections of the flow path through the drainage cavity. The procedure and equipment used is described. Also described are suggestions for improving the procedure.

The results obtained were as expected – more open drainage cavities allowed more air to flow through at any given differential pressure. The relationship to drying of retained water was not examined in this report as that will be examined in the concluding report in this series. Of significance were measurements of the flow characteristics of the starter tracks which showed significant restriction. This merely highlights the importance that such details can have on the drainage/drying capability of walls.

RÉSUMÉ

Le but principal de ces essais était d'évaluer les caractéristiques d'écoulement d'air des cavités de drainage des murs utilisées dans le cadre des études de drainage et de rétention. Cette information permettra de faire des tentatives de corrélation avec les vitesses de séchage évaluées précédemment.

Tous les murs dotés d'une cavité de drainage distincte (par opposition aux bardages posés directement sur la MRI des murs) ont été mis à l'essai afin de déterminer les caractéristiques d'écoulement d'air. Les caractéristiques en elles-mêmes ne déterminent pas la performance d'un système de parement à cet égard. Chaque catégorie de murs mis à l'essai possède sa façon propre, voulue ou implicite, de gérer l'eau.

La méthode d'essai prévoyait la canalisation d'air dans la cavité de drainage et la mesure de cet écoulement, et la différence de pression entre les diverses sections de voie d'écoulement par la cavité de drainage. La méthode et l'équipement utilisés sont décrits. Sont aussi décrites des suggestions pour améliorer la méthode.

Les résultats obtenus ont été comme prévus : un plus grand nombre de cavités de drainage ouvertes admettait un volume d'écoulement d'air plus grand, peu importe la pression différentielle. La corrélation avec le séchage de l'eau retenue n'a pas été examinée ici étant donné qu'elle fera l'objet d'examen dans le rapport final de cette série. Les mesures des caractéristiques d'écoulement étaient significatives pour les rails de départ qui posaient des limites significatives. Cela ne fait que souligner l'importance que de tels détails peuvent avoir sur l'aptitude des murs au drainage/séchage.

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PREFACE

CMHC proposed that a series of drainage tests of exterior cladding assemblies be undertaken to produce data to quantify the ability of several types of cladding and methods of application on wall systems to manage and evacuate water that has intruded behind them. The test program has concentrated on the drainage characteristics of the tested systems, the amount of water that is retained and the drying ability of the cladding tested. The present report provides the results of air flow testing of the walls with drainage cavities to characterize the air flow resistance of those cavities both in the main portion as well as at the exit.

The reports are organized by the wall types tested and with additional supplementary tests done in support of the work. In summary, the different “Parts” of reporting in this project are:

Part 1 - Experimental Approach and Plan
Part 2 - Testing and Measurement Methodologies.
Part 3 – Drainage Testing of EIFS Wall Systems
Part 4 - Drainage Testing of Walls with Vinyl Siding
Part 5 - Drainage Testing of Walls with Wood-based and Fibrous Cement Siding
Part 6 - Air Flow Characteristics of Wall Systems Having Drainage Cavities
Part 7 - Air Leakage and Vapour Permeance of Joints in Some Siding Systems
Part 8 - Summary Report

Reporting has been compartmentalized into this series of “Parts” because of the extensive detail involved in reporting on the many wall variants that have been included. Comparisons were considered more manageable for the reader to face by providing the details separately in each segment of the work.

DRAINAGE AND RETENTION OF WATER BY CLADDING SYSTEMS

PART 6 - Air Flow Characteristics of Drainage Cavities

1 INTRODUCTION

This portion of the project report concentrates on results of air flow tests of walls having drainage cavities. The flow characteristics of these drainage spaces affects the rate at which air can flow in the cavity by buoyancy related to the moisture in the air and/or as a result of thermal gradients and driving air pressure differences. In turn, those flow rates govern the rate of moisture exchange that can take place between wetted surfaces and the air in those cavities. Depending on the construction of the cladding system and the materials used for providing drainage cavities, these tests provide mean flow characteristics. The film coefficients associated with surface roughness, when they are different on different faces of the cavity, can only be evaluated through specially built test samples that would allow that information to be obtained. At the present time, only the approximate overall flow characteristics can be evaluated using the wall samples tested for drainage.

Air and vapour exchange can occur between the space behind cladding through drainage cavities as well as through joints between siding courses. Each mode of transport has been explored in this project, but not all materials used for the drainage tests will have been evaluated.

In the present report we will refer to the product designations defined in earlier reports rather than by their trade names. It should not be construed that there is or is not acceptance of the performance of these materials in the applications employed. These materials were chosen for this project to provide a range of performance for the drainage tests mainly because of their type. Furthermore, the information provided herein is unique to the test samples built for the purpose. This work will provide order-of-magnitude information that may be useful in a more general way even though there are considerable differences between systems.

2 TEST WALLS STUDIED

2.1 Construction Details of Test Walls Studied

The measurement of flow characteristics was restricted to walls that had definite drainage cavities, top to bottom. This excluded all walls that were built with the siding applied directly to the base wall. The walls included were two walls with wood siding, two walls with hardboard siding, and six EIFS walls for a total of 10 test walls.

Since the construction of all walls has already been described in the earlier reports in the series, we will restrict the description of these walls to the relevant differences and factors that will influence air flow measurements.

Walls H2- Mat 1& 2:

The hardboard siding chosen for these walls was the same. It can be described as a 12-inch lap siding that, on the exposed surface was profiled to simulate 5-inch wood siding. In the previous report it was designated as H2. The back of the siding was not profiled in any way. Mat 1 consisted of a formed mesh intended for rainscreen wall construction. Mat 2 was a three dimensional nylon matrix which also provided a spacing capability but which is marketed as a spacer under wood shingles. The approximate standoff spacing provided by Mat 1 was 6.7 mm and for Mat 2 it was 6.9 mm. In both cases the mats were trimmed flush with the top and bottom of the siding. No starter tracks or proprietary flashing were involved. A depiction of the profile is provided in Figure 1.

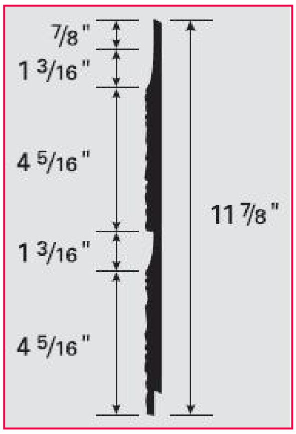


Figure 1   Profile for H2 hardboard siding.

Walls W1-Mat 3 and W2-battens

Wood siding designated as W1 can be described as a rabbetted bevel while W2 had a shiplap profile. Mat 3 was a solid sheet of polystyrene dimpled in one direction which provided a standoff spacing of 6.3 mm. The battens used were nominal 1 x 4 wood straps that provided a drainage space of 19 mm. Depictions of the wood siding used are provided in Figure 2 below. In both cases no special entry or exit provisions were made to the drainage space, such as insect screens or flashing.

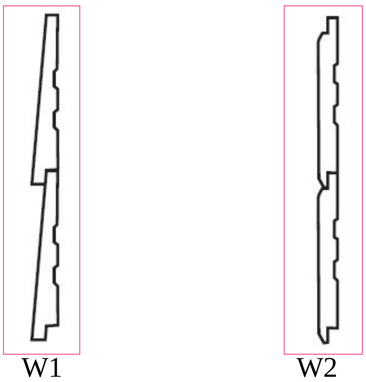


Figure 2   Profiles for wood siding used

EIFS Walls:

Six EIFS walls selected for this study out of 10 walls that were built for commercial drainage testing. These walls are designated below. They were selected on the basis of the magnitude of water retention in earlier drainage testing.

The walls that retained the least water in initial commercial tests were:

Wall 1; A-4
Wall 2; B-1
Wall 3; C-1

The walls that retained the most water in initial commercial tests were:

Wall 4; A-1
Wall 5; B-4
Wall 6: C-3

All EIFS walls had a liquid applied water penetration barrier (LA-WPB) applied to the OSB sheathing that was proprietary to the individual manufacturer. The 50 mm EPS panels were attached to that coating by adhesive beads that were applied to the back the panels by means of a notched trowel. As the panels were pressed against the wall, the beads were flattened and are referred to as adhesive ribbons in their finished cured form. The thickness of the space provided for drainage varied from approximately 2-3 mm. There were differences in the width of spaces provided for drainage in each wall. Measurements made to locate the edges of the ribbons at the top of the walls where these measurements were possible to make are provided in Table 1. Because the application of the adhesive beads was a field operation, the actual spacing of ribbons and their location from one panel to another up and down each wall was not likely to be the same nor were they likely to fully line up. The air flow characteristics obtained by the tests reported here will provide order-of-magnitude results that can be expected for these systems.

Other construction features that affect the airflow characteristics of EIFS walls are the starter tracks used at their base. Walls designated A had a formed starter track that acted as flashing and contained a shallow trough for collection of water below the bottom edge of the EPS. However, the drainage holes provided in that starter track allow drainage to take place close to the face of the base wall. In this case the gutter installed to collect drain water acted as the flashing. Walls designated B had a starter EPS panel (150 mm high) to which a corrugated mesh material was bonded over part of its height. The gutter acted as the flashing. This detail does not provide a specific flashing function. Walls designated C had a starter track that acted as both flashing and as a collector of drainage with the drip holes located on the leading edge of the shape at the front face of the EIFS wall. It was expected that each type of starter track system would possess different air flow characteristics.

Table 1 Spacing of adhesive ribbons for each EIFS wall tested.

Number of Spaces from One Edge	Least Initial Retention Walls			Highest Initial Retention Wall		
	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
1	40	27	40	30	25	45
2	35	27	42	24	26	46
3	35	27	45	37	24	43
4	40	27	45	41	54	46
5	40	32	40	48	27	42
6	35	27	42	37	24	42
7	45	30	41	31	27	40
8	45	30	43	45	65	44
9	40	47	45	44	25	43
10	35	32	38	24	26	42
11	45	33	37	38	24	42
12	45	31	33	43	19	46
13	35	34	33	20	33	40
14	40	35	37	43	35	41
15	40	25	40	48	26	45
16	45	42	54	42	68	47
17	35	28	45	25	29	42
18	40	29	50	43	25	45
19	35	33		35	21	28
20	25	33		38	22	
21		28				
22		31				
23		32				
~N	**21**	**33**	**19**	**21**	**21**	**20**
Sum	**796**	**753**	**769**	**757**	**646**	**829**
SDEV	**5.10**	**5.02**	**5.34**	**8.48**	**14.07**	**4.11**
Avg	**38.8**	**31.3**	**41.7**	**36.8**	**31.3**	**42.6**
COV	**0.13**	**0.16**	**0.13**	**0.23**	**0.45**	**0.10**
Estimated Ribbon Width (mm)	**20**	**14**	**24**	**22**	**27**	**20**

3 EVALUATING AIR FLOW CHARACTERISTICS OF DRAINAGE CAVITIES

The rate at which test walls in the experimental design can dry to the outside (to the chamber conditions) is largely controlled by the rate at which moisture can diffuse out of the outer ventilation cavity and be dissipated to the outside by air exchange with the outside air. This exchange is normally controlled by diffusion through the siding system and ventilation introduced by thermal and moisture buoyancy and by imposed airflow in that cavity. The flow rate is also affected by restrictions to flow provided by the flashing details that may be used at the top and bottom of the cavity.

The flow characteristics of the drainage cavities in the test walls included in this study were evaluated by directing air into the top of the drainage cavity. Some types of air gaps and cracks have different properties depending on the flow direction. These are generally tortuous and are affected by the flexibility of materials defining the boundaries. Or, they involve different inlet and out flow resistance coefficients, again depending on their tortuosity. For larger gaps, the flow resistance is similar no matter what the direction of flow, except for the entrance and exit resistance. The straight in/out characteristics of the top edge of the cladding, and the generally open details at the bottom of the drainage cavity where the gutter normally was located, suggested that there was no need to test both positive and negative pressure flows.

The EIFS test walls each had a steel gutter installed. The gutter was relatively open and distant enough that we assumed the flow would not be restricted compared with a straight exit. The wood and hardboard siding test walls had steel gutters installed for the drainage tests only and they were removed for the air flow tests.

3.1 Test Arrangement and Instrumentation

The following description of the arrangement of equipment is supplemented by photographs provided in Appendix I.

Air supply was provided by a regenerative air pump which directed flow through a 7 m long 50 mm diameter heavy duty vacuum cleaner hose to the air flow sensors. Air flow from the pump was controlled by a large ball valve between the pump and the hose. Two in-line Datametrics type 810L-M mass flow sensors were used to measure flow. The set-up allowed for either sensor to be used depending on the capacity required. The rated capacities were 1-100 standard litres per minute (SLPM) (type 1205) and 10-1000 SLPM (type 1202). The standard conditions of pressure and temperature used by the manufacturer were 70ºF (21.2ºC) and 14.7 psia (101.3 kPa). Ball valves were used to control flow to either sensor and each was installed with sufficient straight piping in advance of the sensor to act as a flow straightener in accordance with the manufacturer's specifications. The output from each sensor was conditioned by its own companion meter which provided a calibrated full scale output of 10v.

The air flow was directed to a distribution chamber clamped and sealed to the top of the test wall. The test wall was laid horizontally with the cladding facing upward. The distribution chamber was itself divided into an inner distribution chamber in which the RH and T were measured. The inner distribution chamber was evenly perforated with 6.5 mm holes to direct air flow evenly across the full width of the test wall. These jets of air swirled air into the main portion of the distribution chamber. Prior to entering the drainage cavity, the air passed through flow straighteners that consisted of short 1-inch segments of drinking straws attached to masking tape to hold them in line. Several layers of these flow straighteners were employed for the full width of the wall depending on the depth of the opening to the drainage cavity. The intent of these flow straighteners was to take the flow in the chamber where flow would be turbulent and to provide relatively laminar flow for entry to the drainage cavity. All joints in the siding were taped to prevent leakage from the drainage cavity during each test.

An alternate test arrangement would have involved deploying the air pump to draw air through the drainage cavity from the top of the wall. This would have obviated the need for air flow straightners at these locations.

A Datametrics model 590D-1KPa-2P1-V1X4D barocell was used to measure differential pressures between different sections of the flow path. For each wall, three separate air flow tests were performed using the one barocell. This was done to measure the pressure drop between the entrance to the drainage cavity and the main cavity, the pressure drop along the drainage cavity, and the pressure drop across the bottom of the drainage cavity where, in some cases, starter tracks were installed. As a general rule it can be expected that the flow/pressure characteristics of entry and exit details will be different from those for the main drainage cavity. These depend on the construction details employed. Whether the instrumentation and technique of measurement is sufficiently accurate to allow this information to be obtained is another matter. In this case, the intent was to undertake these measurements to determine if the test protocol was sufficiently robust to make this measurement.

The measurement of pressure differences across different sections of the flow path are described next. One pressure tap was located in the main distribution chamber. This pressure tap was connected to the middle of a 19 mm tube with closed ends located in the distribution chamber to both shield the tap from turbulence and to average the pressure in that space. The tube was perforated with small holes to allow pressure in the tube to reflect the average pressure in the distribution chamber. All pressure taps were connected to their respective averaging chambers using 6.45 mm OD plastic tubing.

The pressure measurements in the drainage cavity were concentrated at both ends of the drainage cavity. The average pressure at each end was obtained by installing 6 pressure taps across the width of the wall in each line near each end of the drainage cavity. Each pressure tap consisted of a fitting that was inserted and sealed into a hole drilled through the OSB sheathing and through the WRB into the drainage cavity. To each fitting, connectors for the tubing was attached as required. Each set of 6 pressure taps was directed to a plastic bucket chamber for pressure averaging. If there was more or less resistance at any one or several tap locations, there would be a differential pressure and some flow would result between them. This arrangement allowed such unavoidable flow to take place, but provided mixing and a single pressure pick up point to be used to represent the average pressure across the wall in the drainage cavity at that line. The distance from the top of the wall to the first line of pressure taps was 152 mm, and the distance from the bottom of the wall to the bottom line of pressure taps was the 229 mm and this was the same for all walls tested. The projected height and location of cladding relative to the basic wall frame was different for each system tested. Hence, while the top and bottom distances varied, the flow path length to the main drainage cavity was similar for all walls tested. These dimensions are all summarized in Table 2 and are based on those depicted in Figure 3 following.

Table 2 Dimensions detailing the flow path lengths D1, D2, and D3

Wall Type	Top of Cladding to top line of Pressure Taps [D1] (mm)	Top of Wall to top of Cladding (mm)	Bottom of wall to bottom of Cladding (mm)	Height of Cladding (mm)	Distance between lines of Pressure Taps [D2] (mm)	Distance from Bottom Pressure Taps to Bottom of Cladding [D3] (mm)	Distance from Bottom of Wall to Pressure Taps (mm)
EIFS	152	152	152	2134	1905	77	229
H2-Mat1	152	380	75	1983	1677	154	229
H2-Mat2	152	380	75	1983	1677	154	229
W1-Mat3	152	292	83	2063	1765	146	229
W2-Battens	152	248	83	2107	1809	146	229

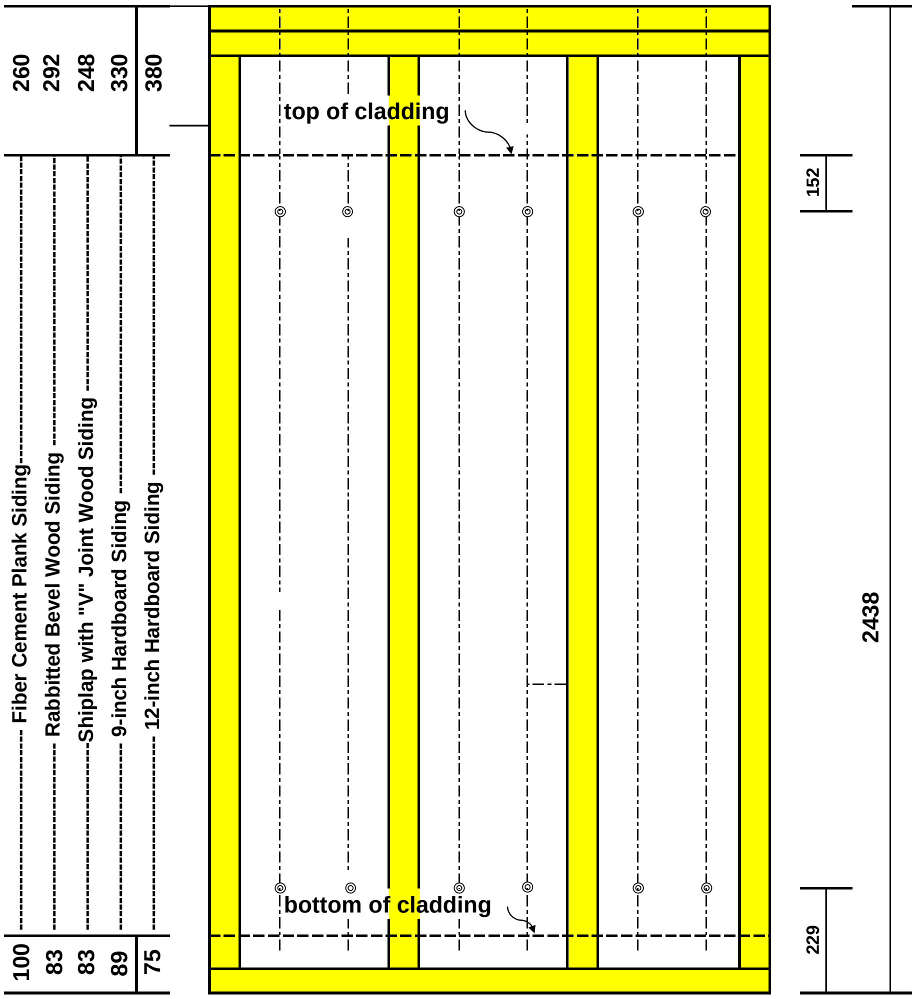


Figure 3 Dimensions of cladding position and locations of pressure taps

In summary, the pressure differences were measured a) between the distribution box and the top line of pressure taps, b) between the two lines of pressure taps in the drainage cavity, and c) between the bottom line of pressure taps and the air outside of the wall. These pressure difference pathways are identified as D1, D2, and D3 respectively in the remainder of this report and on all of the Pressure/Flow plots provided in the Appendices. During the analysis it was determined that the pressure in the distribution box had been measured in the inner compartment and that it did not reflect the pressure just prior to entry to the drainage cavities. Pressure differentials were measured appropriately for only the D2 and D3 pathways.

Additional measurements made during these tests included the relative humidity and temperature of the air in the distribution chamber at the top of the wall. All measurements were sampled at 20 readings per second for 15 seconds and the averages were recorded together with the date and time of the measurement by a Sciemetrics data acquisition system and computer controller.

3.2 Test Procedure

As noted earlier, individual tests were conducted to evaluate the pressure/flow characteristics of each section of the flow path from the top to the bottom of each test wall. In each case the following protocol was employed.

With the regenerative air pump on but with the control valve closed, zero flow to all instruments was recorded for at least 5 minutes. The control valve was then opened slightly to a targeted flow rate and held for 5 minutes before continuing to open the control valve further to attain the next higher targeted flow rate. The targeted flow rates were 0.5, 1.0, 1.5, 2.0, 6.0, 12.0, 15.0, and 17 SLPM and measurements were held for approximately 5 to 6 minutes each time. The corresponding pressures depended on the resistance to the flow imposed. These flow levels are relatively low and, particularly at the initial levels, are more subject to variability associated with turbulent air flow. The low target air flows chosen did not require use of the in-line 10-1000 SLPM meter. Most of the pressure/flow plots proved to be sufficiently suitable for analysis. However, and this was not determined until the analysis was undertaken, for drainage cavities that had significantly lower resistance, particularly the wall involving 19 mm batten strips, much higher flow rates should have been employed because pressure drops were very low and variable. One particular D3 pathway could not be evaluated for this reason.

3.3 Analysis of Flow Characteristics

The general technique used for this analysis follows.

- The data was scanned for each flow transition. Several records, based on the flow values recorded, were deleted where it was obvious that steady state flow had not yet been attained. Preliminary trend lines were examined to determine additional outlier points for deletion, and whether the characteristic was linear or non linear.
- The flow rate measurements and pressure measurements were then corrected for the instrument zeros, and the temperature and RH of the gas mixture. The gas constant is dependent on the gas measured; each meter was factory calibrated for dry air.
- The corrected pressure (P) and flow (Q) data were then curve fitted by linear regression to either a linear relationship passing through zero or to the power relationship $Q = c\,P^{\,n}$ where n generally falls between 0.5 and 1.0. When n=1.0 the relationship is linear and flow is laminar. When n=0.5 the relationship is representative of turbulent flow for a square-edged orifice.
- The range of data used for each regression varied. In general as much of the flow range was selected as possible to attain a squared regression coefficient (R^2) of at least 0.99. The zero corrected flow and several of the low flow levels below the range of the flow meter were omitted, but generally data sets from 1.5 SLPM and higher were kept for regression analysis. When larger flows should have been entertained for very open drainage cavities, it was necessary to accept poorer R^2 than 0.99.

4 Results

All data plots, regression plots, and equations for each air flow test are provided in Appendix II. Those plots and equations relate flow in L/min with pressure difference in Pa. The usual convention for representing flow is L/s and that convention will be followed in the body of this report. In presenting this information in a comparative way, we will draw upon the equations derived in that appendix.

The fitting of test data was made to the expression

$$Q = c\,P^{\,n}$$

In keeping with convention, the units for the flow Q will be L/s and the coefficient "c" will be adjusted from that shown in the Appendix.

The value of the coefficient (c) derived in Appendix II will be normalized for path width and path length. Thus,

$$c_n = c\,/60 \bullet P_L \,/\, P_W$$

where P_w = path width (m)
and P_L = path length. (m)

Thus for a given pressure difference, the value of "c" to use in the equation for obtaining flow under other circumstances and dimensions is

$$c_n \,.\, P_w \,/\, P_L$$

In the case of concentrated flow resistances, such as that offered by starter tracks or starter panels, it will be more appropriate to treat the path length as unity.

4.1 Air Flow Characteristics of Drainage Cavities in EIFS Walls

A summary of the flow coefficients for Paths D2 and D3 for paired walls (by manufacturer) 1-4, 2-5, and 3-6 are summarized in Table 3. For all of the D2 pathways, i.e., the main drainage cavities, the exponent was near or slightly above unity. The regressions for those air flow paths were then repeated as linear regressions with zero intercepts. This signifies that despite the potentially obstructed narrow pathways offered by adhesive ribbons, the flow was essentially laminar. The exponents for the D3 pathways ranged from 0.53 to 0.65 signifying that the measured flow was predominantly turbulent.

Table 3 Summary of flow coefficients for pathways D2 and D3 for EIFS walls.

EIFS Wall No.	Manufacturer	Initially Best/Worst Retention	Path Designation	Length of Path (m)	Measured Flow Coefficients c (min.Pa^n/L)	n	Regression Coefficient R^2	Normalized Flow Coefficient c_n (s.Pa^n/L)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	A	Best	D2	1.9050	0.3251	1.0000	0.9998	0.00847
1	A	Best	D3	1.0000	0.8972	0.5865	0.9994	0.01227
4	A	Worst	D2	1.9050	0.1737	1.0000	0.9974	0.00452
4	A	Worst	D3	1.0000	0.7215	0.5640	0.9987	0.00986
2	B	Best	D2	1.9050	0.0988	1.0000	0.9994	0.00257
2	B	Best	D3	1.0000	1.4490	0.6516	0.9991	0.01981
5	B	Worst	D2	1.9050	0.0988	1.0000	0.9994	0.00257
5	B	Worst	D3	1.0000	5.9834	0.6456	0.9983	0.08181
3	C	Best	D2	1.9050	0.2120	1.0000	0.9997	0.00552
3	C	Best	D3	1.0000	0.6999	0.5434	0.9984	0.00957
6	C	Worst	D2	1.9050	0.2082	1.0000	0.9973	0.00542
6	C	Worst	D3	1.0000	0.6998	0.5332	0.9991	0.00957

Note 1 The width of all pathways in EIFS walls was assumed to be 1219 mm (4 feet)

Note 2 The normalized flow coefficient was the value in column (6) in SLPS divided by the wall width and multiplied by the cladding height as tested, except for D3 pathways (see note 3).

Note 3 The path length for D3 was 0.077 m for all EIFS walls. Since the flow resistance is largely attributed to the starter track or panel, it will be assigned a concentrated rather than distributed resistance, and the path length will be taken as unity.

The coefficients for the D3 pathways, i.e., some small portion of D2-like cavity plus the concentrated resistance to flow provided by the starter track or starter panel, were considered as lumped resistances. This was because the concentrated effect of that resistance dominated the measurement. The one exception was the starter panel used by Manufacturer B which offered the least resistance. In both cases, the lumped resistance includes the exit flow characteristics.

The flow characteristics based on the flow coefficients in Table 3 for the D2 and D3 pathways are shown over a 20 Pa pressure range in Figurer 4 and 5 for the EIFS walls tested. As far as the D2 pathways are concerned, both walls in the pair experienced nearly identical resistance to air flow (Manufacturers B and C). There were some differences between wall 1 and 4 for Manufacturer A.

In the case of the D3 pathway, the resistance to flow for the starter tracks used by Manufacturer C was identical in the two walls tested. Some difference was seen for the starter track used by Manufacturer A. The starter panel used by Manufacturer B was quite open and offered little resistance.

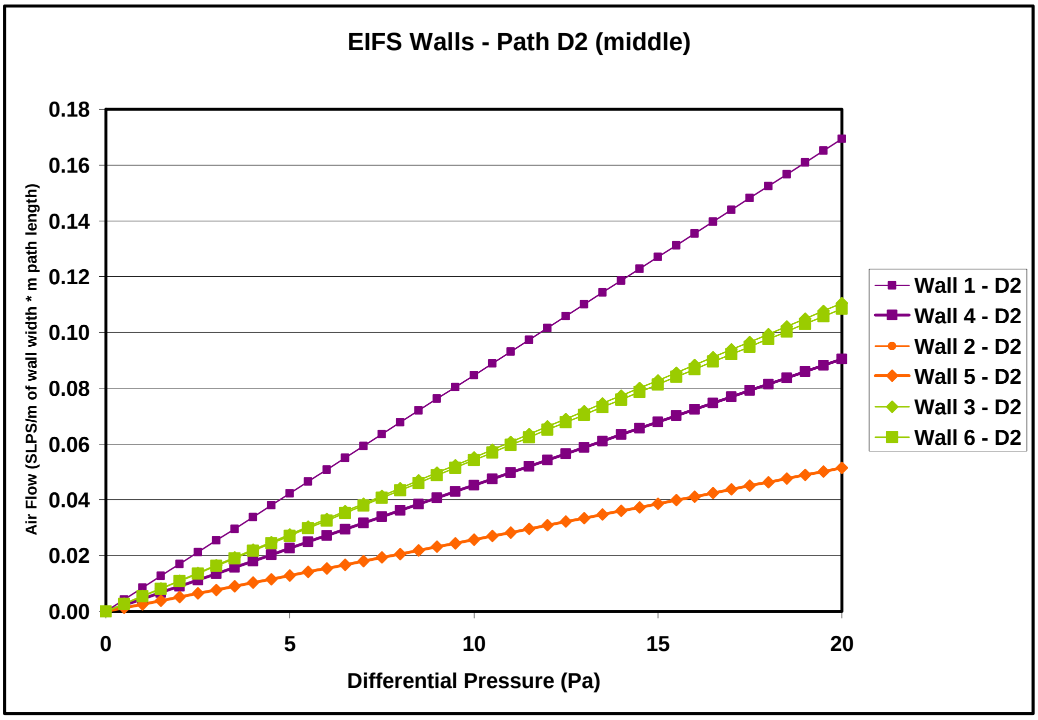


Figure 4   Normalized flow characteristics for EIFS drainage cavities (the D2 pathway).

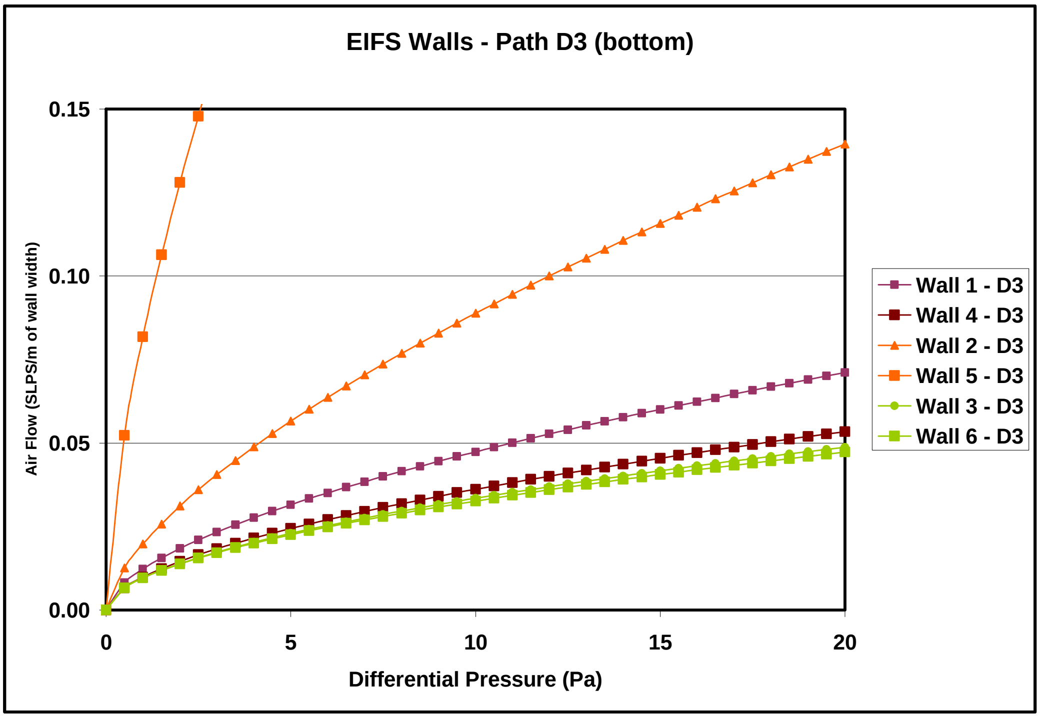


Figure 5   Lumped flow characteristics for EIFS starter tracks and starter panel (the D3 pathway).

4.2 Air Flow Characteristics of Drainage Cavities Involving Wood and Hardboard Siding

In a similar manner tests were conducted on all the remaining walls having distinct drainage cavities. A summary of those results are provided in Table 4, and the plots of all D2 and D3 flow paths are provided in Appendix II. As for the EIFS walls, the D1 pathway results are omitted because of the error in location of the pressure taps on the driving side of the flow stream. One D3 pathway (W2 siding on batten strips) could not be measured reliably because of the very low pressure drop over the short distance involved and by the presence of significant turbulence in the relatively large drainage cavity (19 mm).

Table 4 Summary of flow coefficients for paths D2 and D3 for hardboard and wood siding.

Wall No.	Manufacturer	Path Designation	Length of Path (m)	Measured Flow Coefficients c (min.Pa^n/L)	n	Regression Coefficient R^2	Normallized Flow Coefficient c_N (s.Pa^n/L)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
H2-Mat1	D	D2	1.6770	1.9858	1.0000	0.9926	0.0460
H2-Mat1	D	D3	0.1540	13.2770	0.7953	0.9965	0.0283
H2-Mat2	D	D2	1.6770	1.7592	1.0000	0.9918	0.0408
H2-Mat2	D	D3	0.1540	11.4930	0.7583	0.9680	0.0245
W1-Mat3	E	D2	1.7650	2.1625	0.6237	0.9986	0.0527
W1-Mat3	E	D3	0.1460	12.0240	0.5310	0.9920	0.0243
W2-Battens	E	D2	1.8090	34.4980	0.5001	0.9460	0.8625
W2-Battens	E	D3	0.1460	*	*	*	*

Note 1 The width of all pathways in the H2 and W1 walls was assumed to be 1206 mm (4 feet minus 0.5 inches for the foamed sealant). For W2 the width was 1029 mm (4 feet minus the width of 3 batten strips).

Note 2 The normalized flow coefficient was the value in column (5) in SLPS divided by the wall width and multiplied by the path length as tested.

Note 3 The path lengths for D3 measurements are noted in the table. Since no special starter tracks were used the flow resistance should be similar to the distributed resistance found for the D2 measurement.

As noted in the table, the D3 pathway length was applied, as for the D2 pathway, since there were no special starter tracks or gutters used (unlike the tests on the EIFS walls reported in previous Section).

The D2 pathway exhibited laminar flow (n=1) for the mats that were formed with a matrix of fibrous elements (Mats 1 & 2). On the other hand, Mat 3 which was a dimpled solid sheet of polystyrene plastic offered some obstruction to the flow of air in the cavity which caused turbulence (n = 0.6237). The large drainage cavities formed by batten strips experienced a high degree of turbulence which suggests that the flow straighteners, as applied in this case, were not successful in producing laminar flow to the top of the cavity. It would normally be expected that flow within that cavity size would be laminar except for some turbulence associated with surface roughness of the back of the wood siding, or of the WRB used. The plots of the equations described by the coefficients in Table 4 are shown in Figures 6 and 7 for pathways D2 and D3.

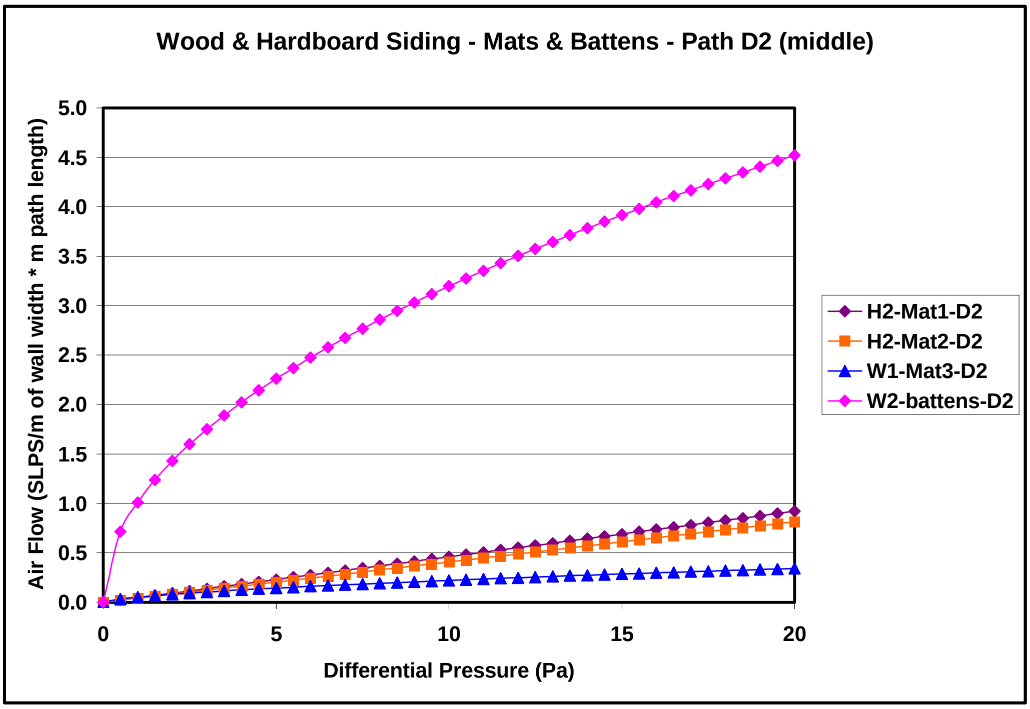


Figure 6 Air flow characteristics of drainage cavities formed by mats and battens, the D2 pathway.

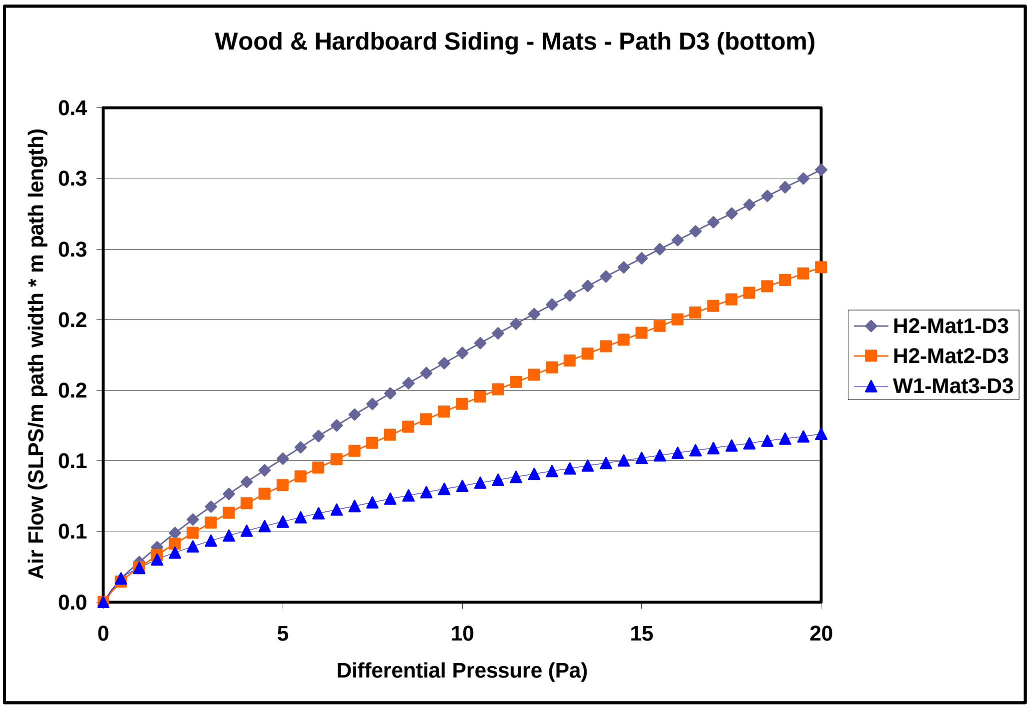


Figure 7 Air flow characteristics of drainage cavities formed by mats, the D3 pathway.

5 DISCUSSION OF RESULTS

For comparison, all D2 results have been plotted in Figure 8. These show the relative ease with which air can flow through the drainage cavity for any given differential pressure. This is not necessarily related to the drying capability of the walls tested; they are different systems and hold retained water in different ways.

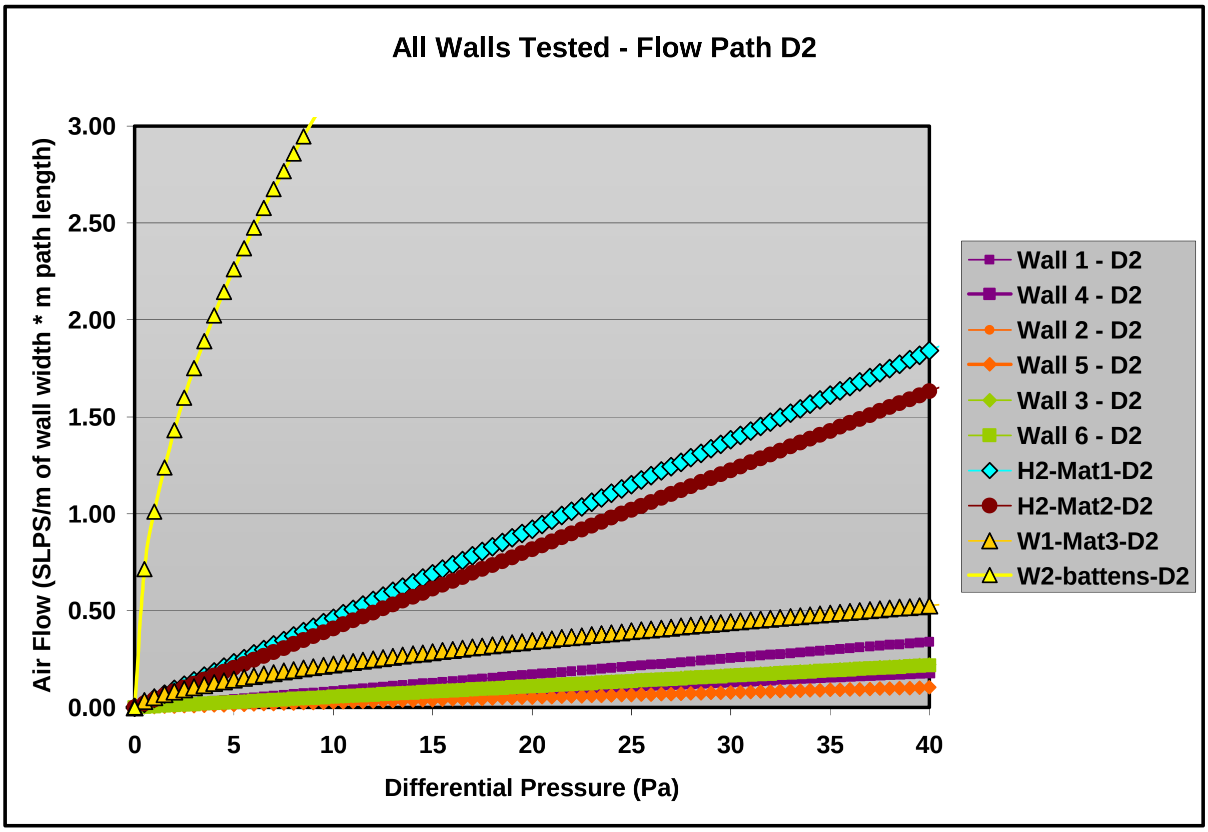


Figure 8 Comparison of all measured main drainage cavity flow characteristics (D2)

In this report, it was seen that the drainage cavities of all EIFS test walls exhibited somewhat similar air flow characteristics. Also, for two manufacturers the pairs of test walls exhibited nearly identical performance. All D2 pathways possessed laminar flow despite the potential obstructions provided by the adhesive ribbons. On the other hand, the flow characteristics of the D3 pathways (involving starter tracks) were relatively restrictive. The starter panels used by Manufacturer B were relatively open as expected. Unexpectedly, the results for one wall (W2) were relatively restrictive yet still more open than those with specific starter tracks (Figure 5). Close examination of the raw data files and the experimental technique used, could not resolve why this unexpected result was obtained. The D2 plots for EIFS walls are shown as Walls 1 to 6 in Figure 8 above.

With respect to the flow characteristics of drainage mats, mesh-type mats also resulted in apparent laminar flow overall. The drainage material involving a dimpled plastic sheet offered multiple obstructions to flow and the flow was characteristic of more turbulent flow and was closer to that of the

EIFS walls. However, as shown in Figure 8, the mesh type mats were considerably more permissive as they provided a drainage space (approximately 6 mm) compared with the EIFS walls (2-3 mm).

Measuring flow characteristics of the drainage cavity formed by use of batten strips proved to be somewhat problematic. More turbulence seemed to have been introduced in the space and greater fluctuations were measured. Only the main cavity flow path (D2) could be measured reliably. Clearly, at 19 mm thickness, this drainage space allows relatively uninhibited flow. As a curiosity, one might again remark that the measured flow exhibited turbulence which suggests that the experimental technique did not supply sufficiently laminar flow to the entrance of this drainage cavity.

From the point of view of the experimental procedures used, this experience suggests several improvements be made. The air should be drawn from rather than supplied to the drainage cavities. This requires a reversal in the connection at the regenerative pump, and reversal of the flow sensors. The distribution box needs to be made more open to the space at one end of the cavity. The negative pressure at the mass flow sensors should be kept as low as possible and be measured together with its temperature in the vicinity of the flow sensors to allow proper correction for the density of the air passing through them. Preferably, pressure taps should be installed at the time walls are being built in order that they are properly located with respect to the layers at which those measurements are of interest. In this instance, all pressure taps were installed after the drainage tests were completed with less certainty as to their penetration.

6 SUMMARY AND CONCLUSIONS

The primary purpose of these tests has been to obtain the air flow characteristics of drainage cavities of walls used for drainage and retention studies. This information will be used for attempts at correlating the drying rates that were found earlier.

The results obtained were as expected – more open drainage cavities allowed more air to flow through at any given differential pressure. The relationship to drying of retained water was not examined in this report as that will be examined in the concluding report in this series. Of significance were measurements of the flow characteristics of the starter tracks which showed significant restriction. This merely highlights the importance that such details can have on the drainage/drying capability of walls.

APPENDIX I

Photos of Air Flow Test Set-up

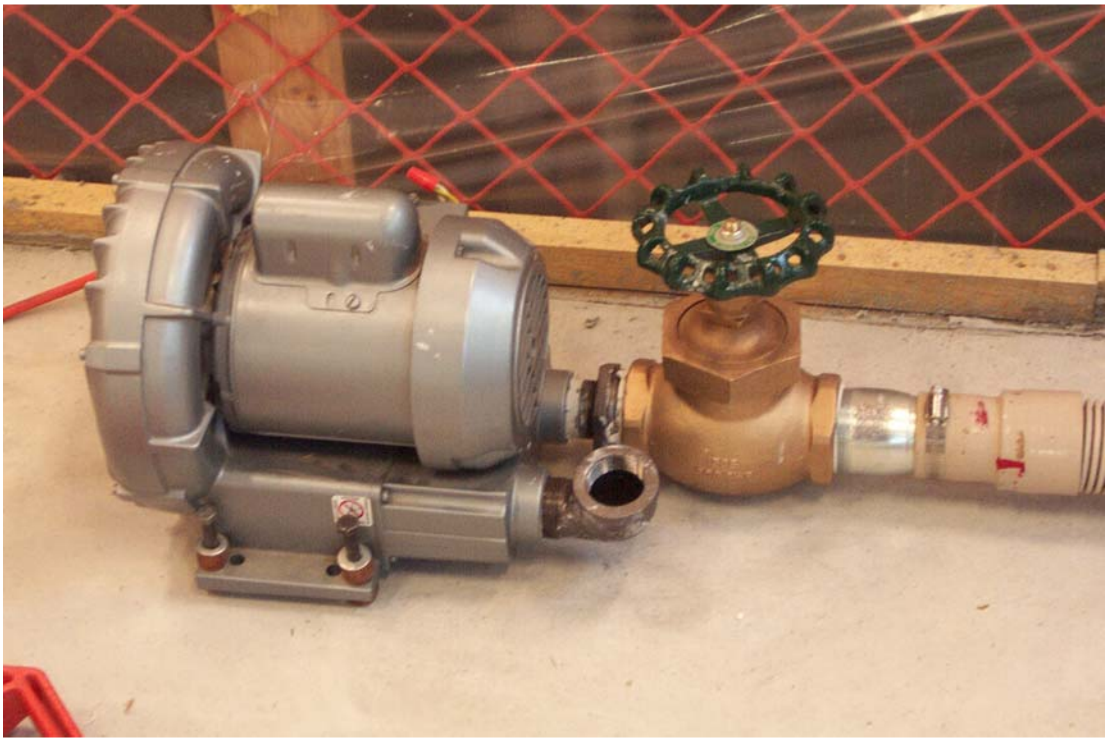


Figure II-1: Regenerative air pump supply with manual control valve to measurement set-up.

Figure II-2: Two flow measurement sensors set up with ball flow control valves and flow straighteners.

Figure II-3: Instrumentation and data acquisition equipment set-up

Figure II-4: Overall view of set up for a test on an EIFS wall

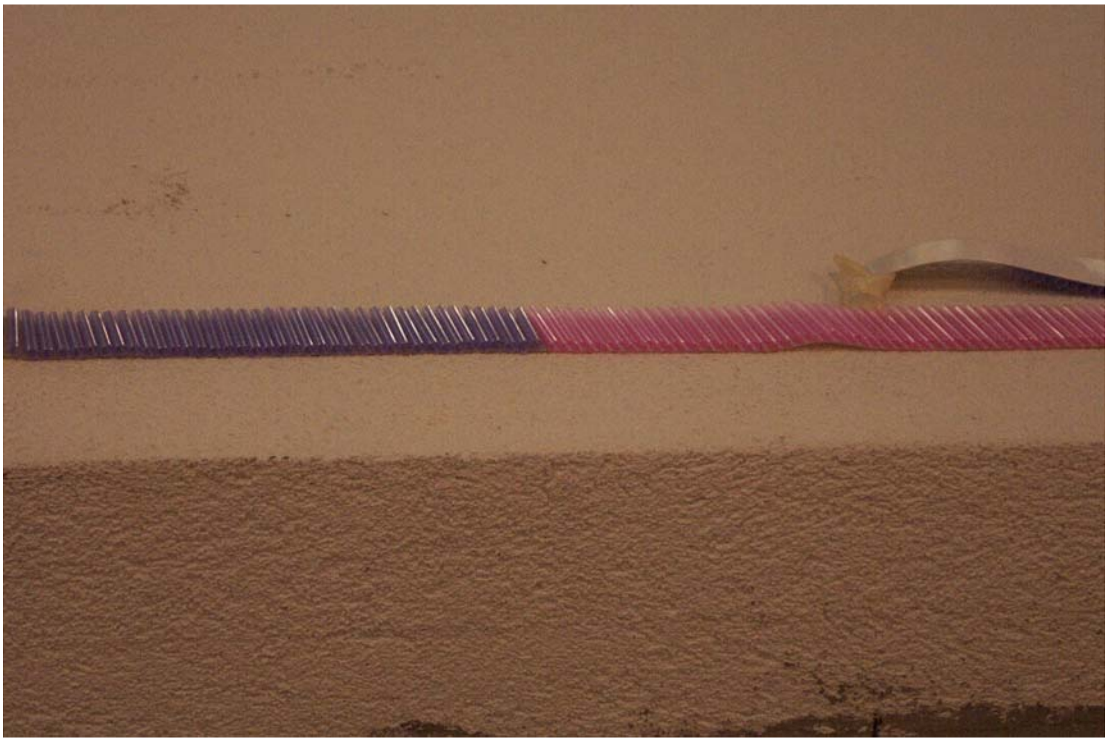


Figure II-5: Drinking straw flow straighteners positioned on a tape and used at the entry to the drainage cavity.

Figure II-6: Underside of wall undergoing test showing connection of 6 pressure taps at a cross section of the wall. The tubing was led to a pressure averaging manifold (pail).

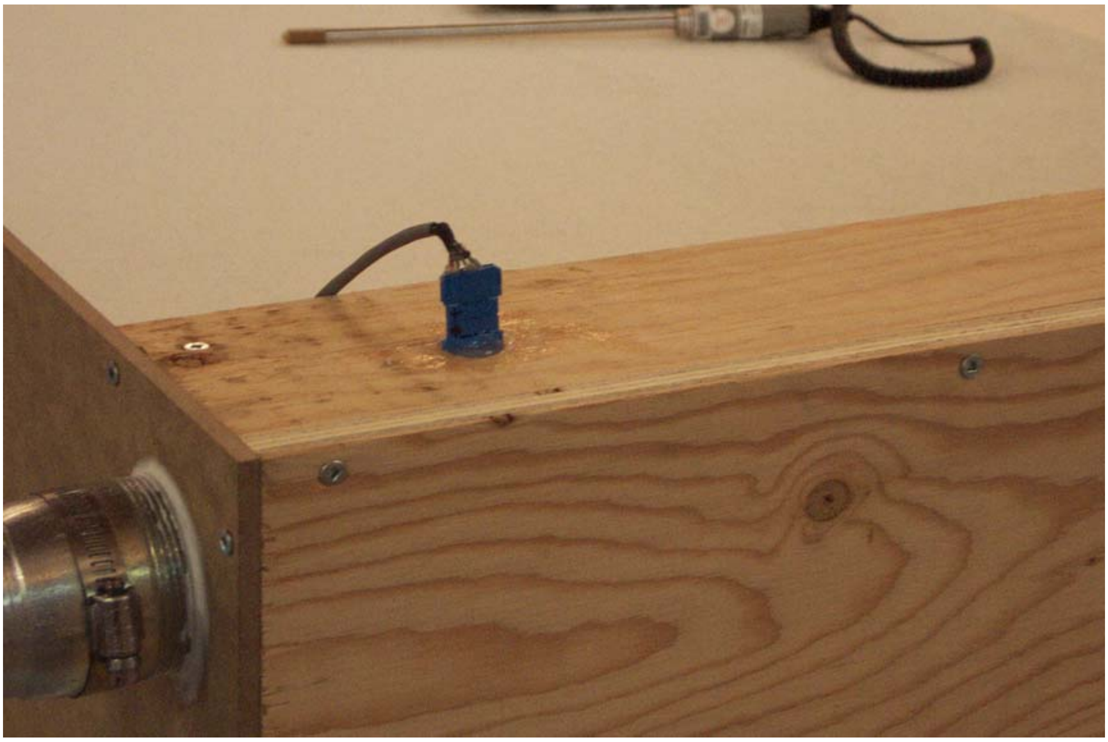


Figure II-7: RH and T measurement sensor positioned to measure conditions of supply air at the flow supply distribution box.

Figure II-8: Flow distribution chamber clamped and taped to the test wall for supply of air to the drainage cavity.

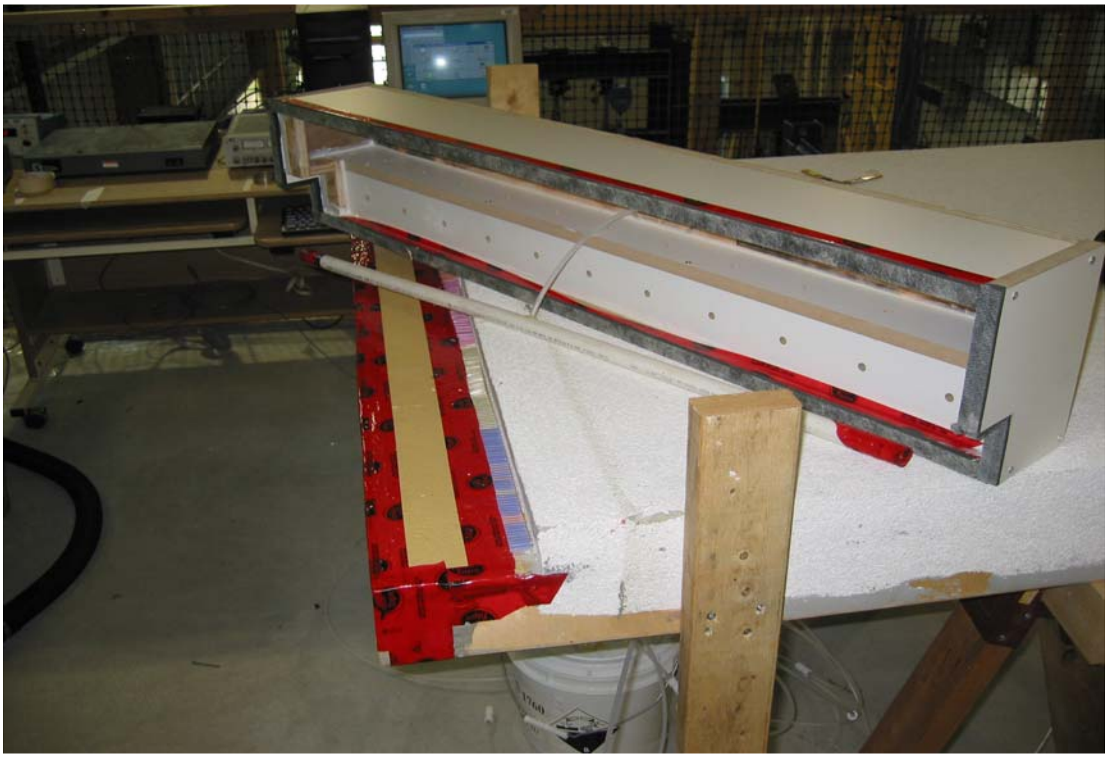
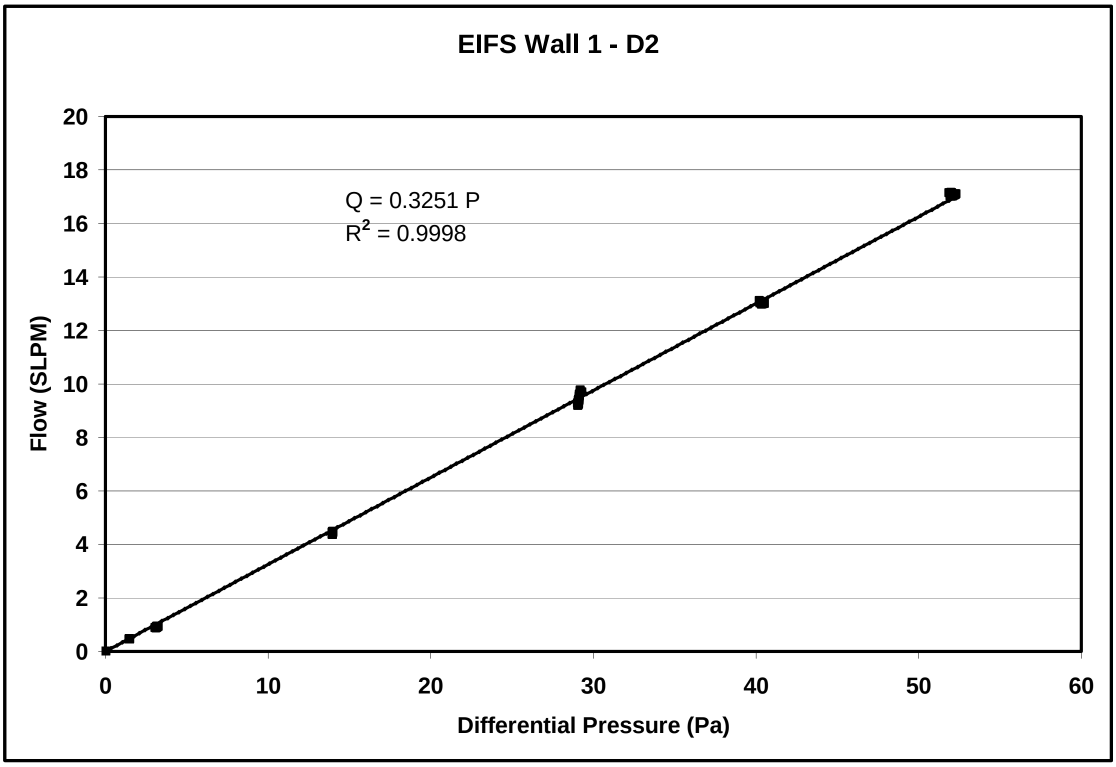


Figure II-9: Construction of typical flow distribution chamber used for tests on EIFS walls. Other test walls had different fitting requirements and a chamber was built to accommodate those needs.

APPENDIX II

Plots of Air Flow Tests

Note: All plots in this appendix show the relationship between air flow and pressure differentials based on the measured data adjusted for gas constants with **TOTAL** flow through the described flow paths expressed as standard litres per minute (SLPM).



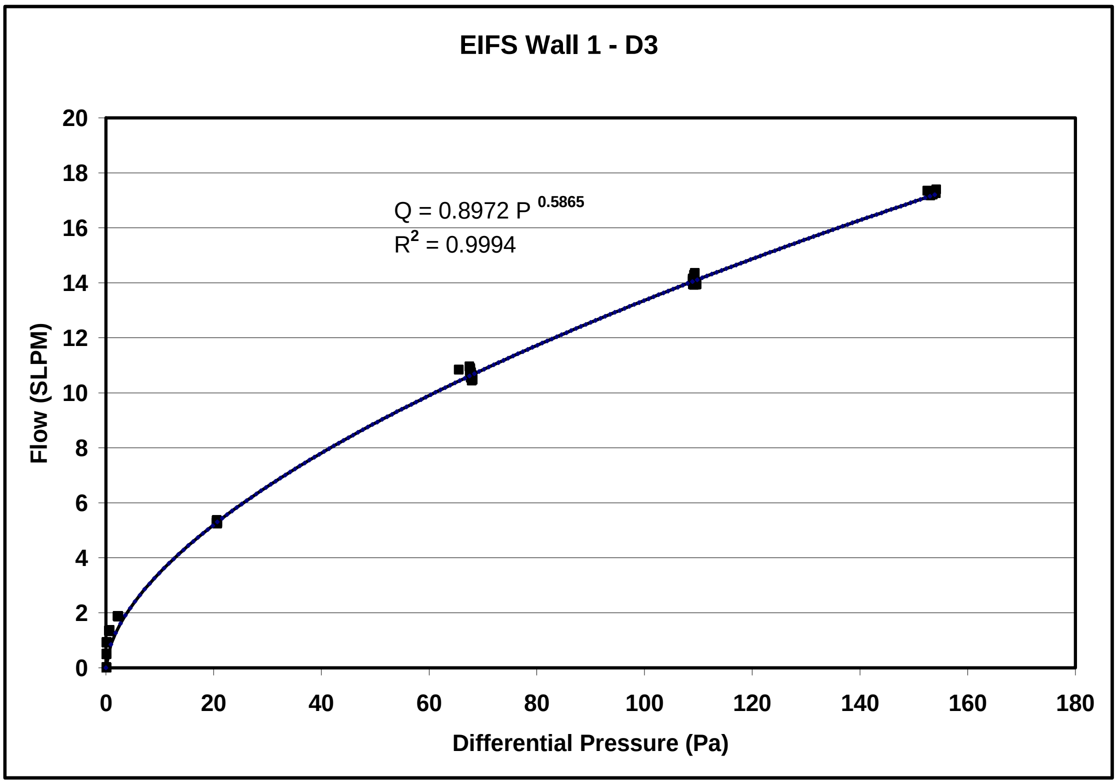
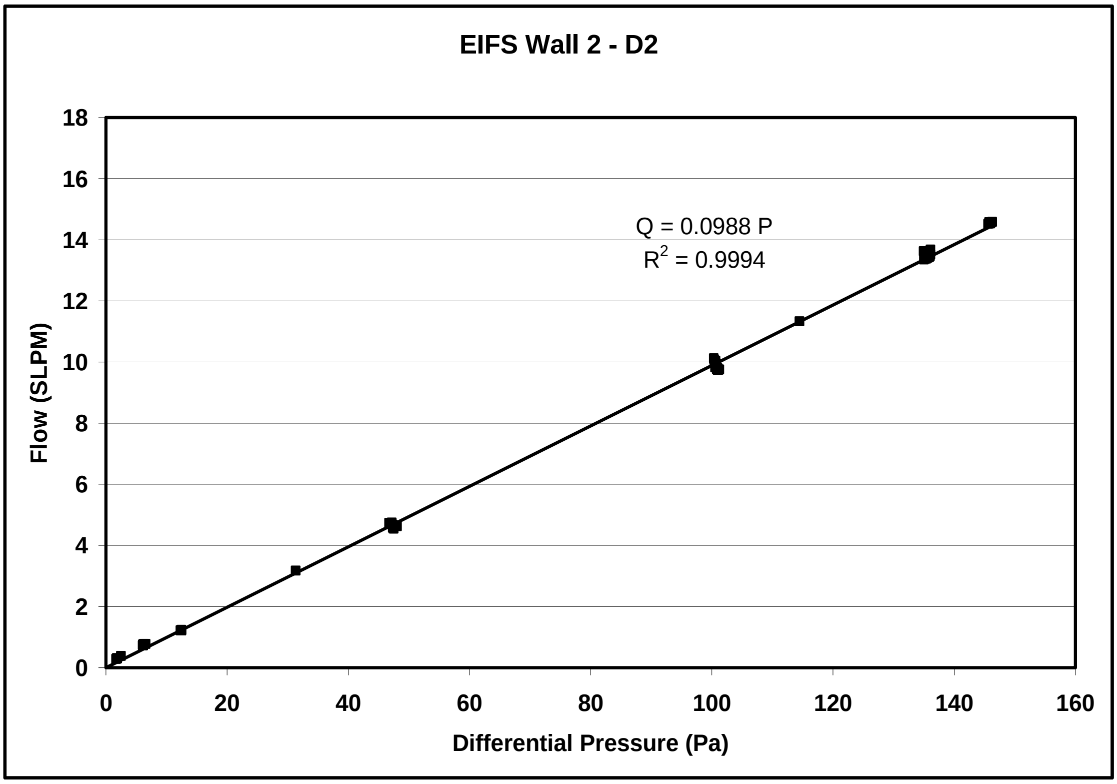


Figure II-1   Power fitting plots and correlations for D2, and D3 pathways for EIFS Wall 1



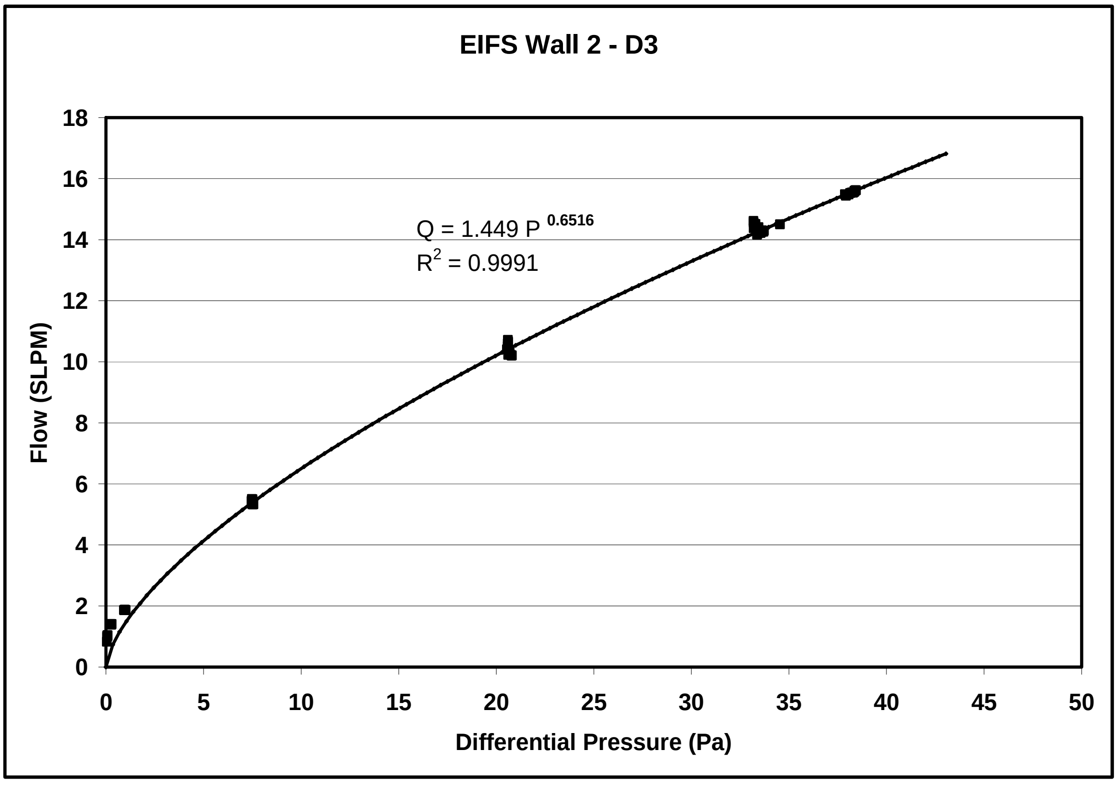
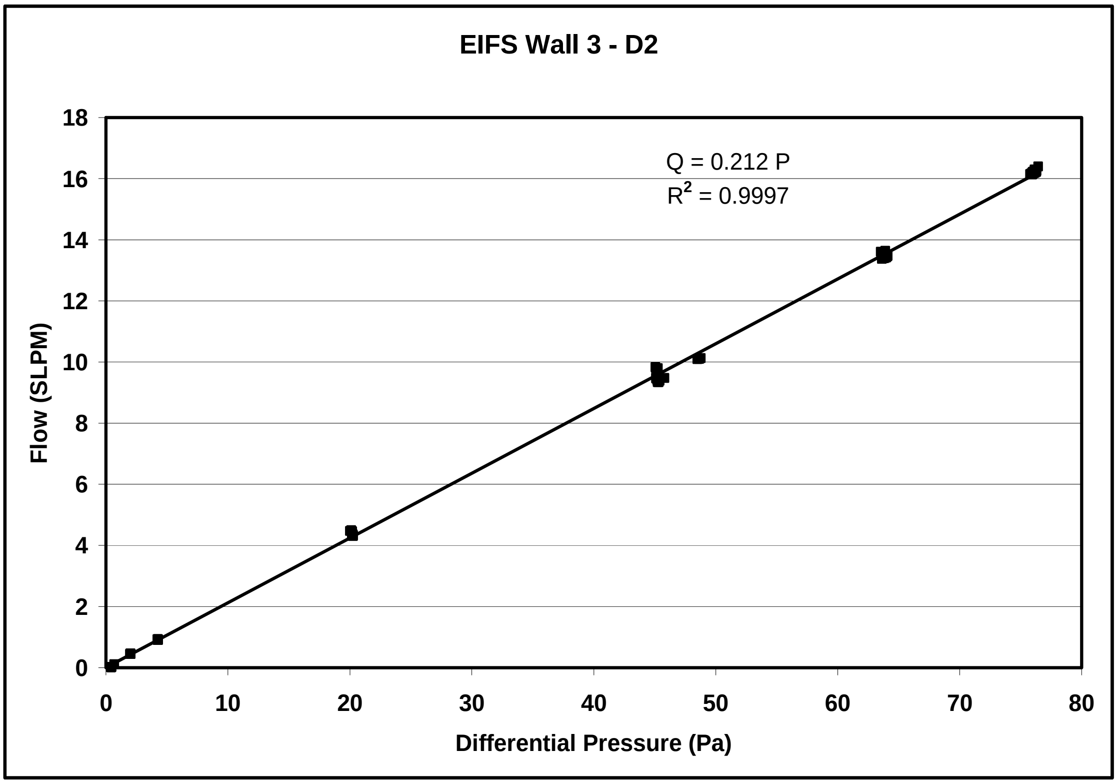


Figure II-2 Power fitting plots and correlations for D2, and D3 pathways for EIFS Wall 2



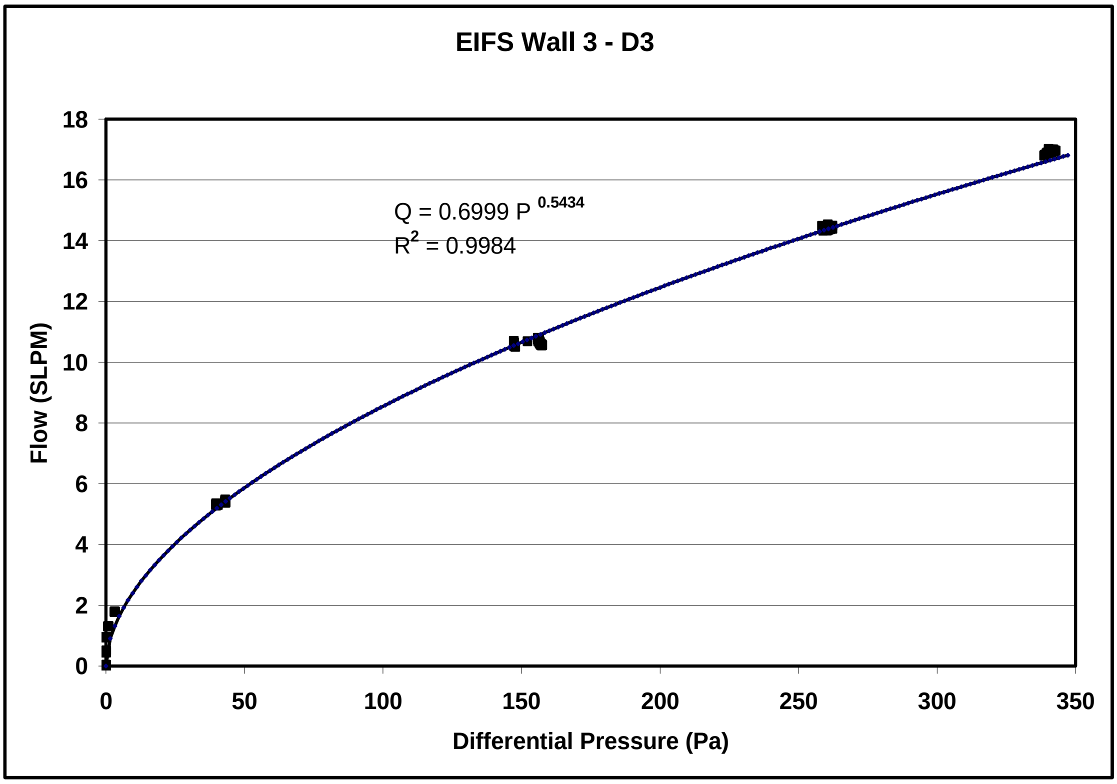
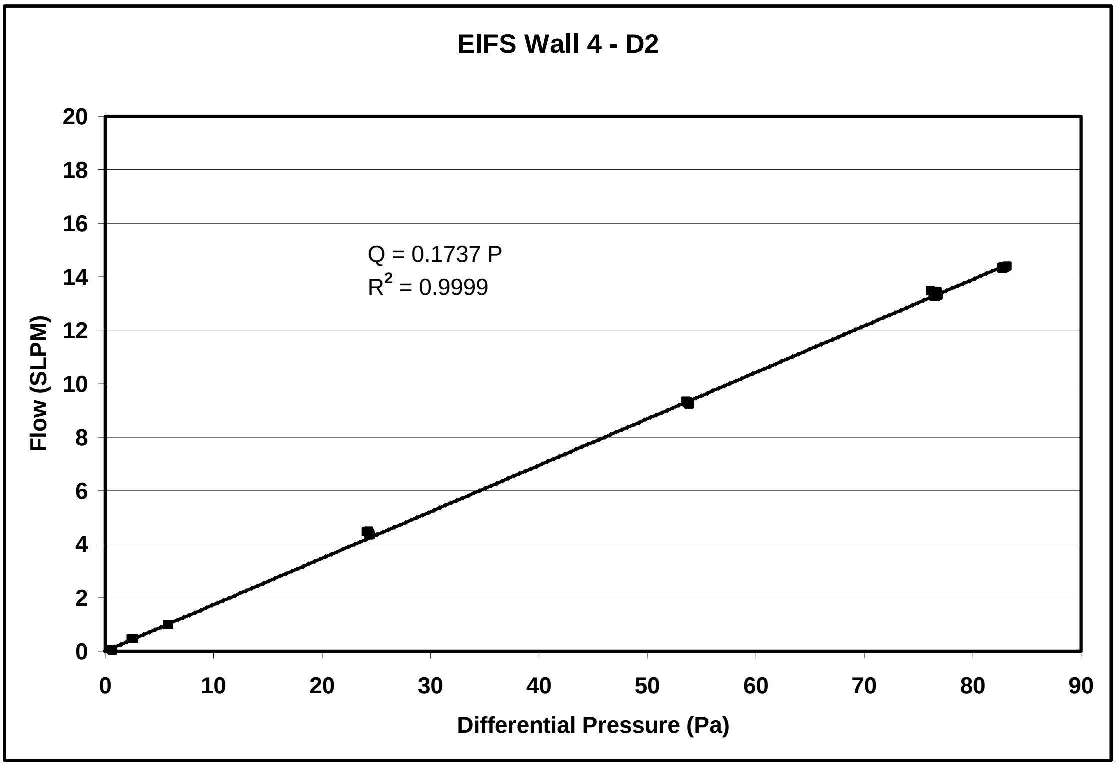


Figure II-3 Power fitting plots and correlations for D2, and D3 pathways for EIFS Wall 3.



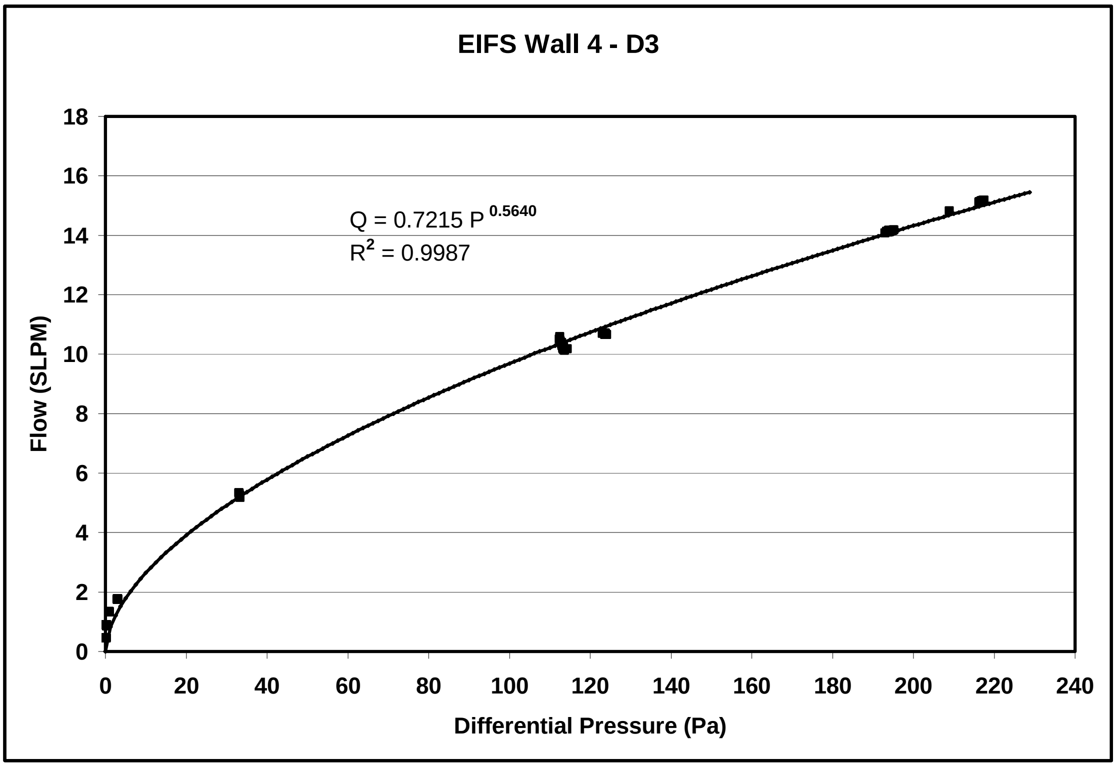
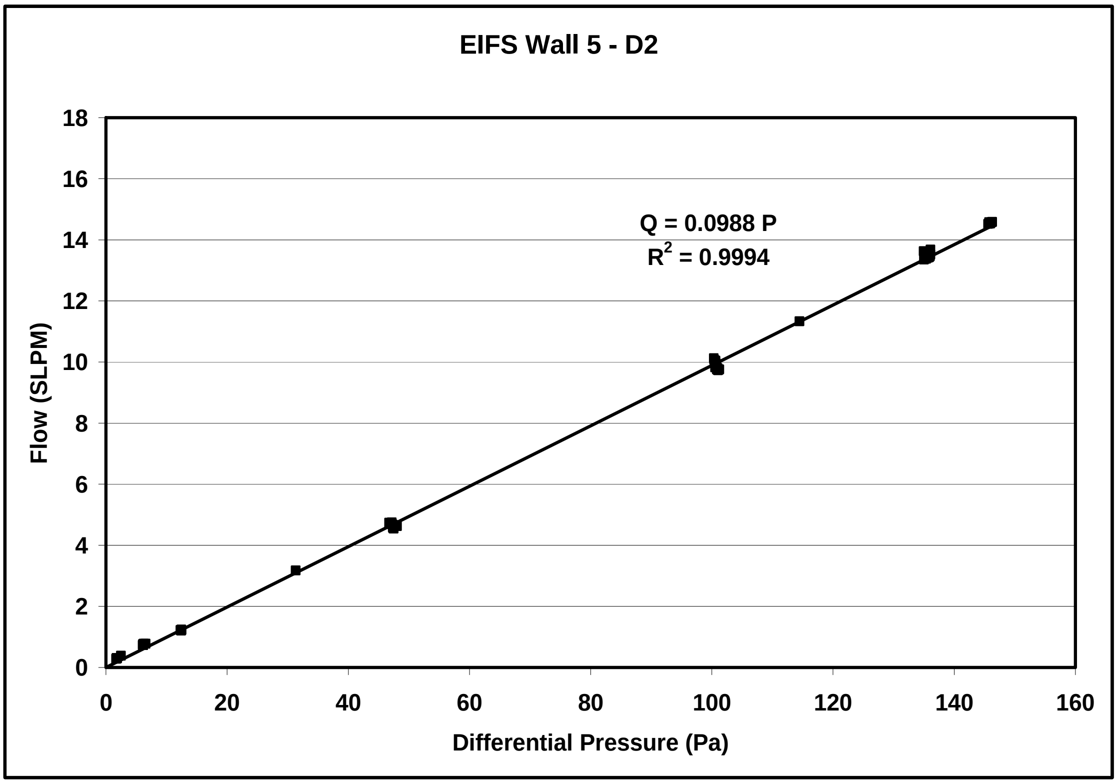


Figure II-4 Power fitting plots and correlations for D2, and D3 pathways for EIFS Wall 4.



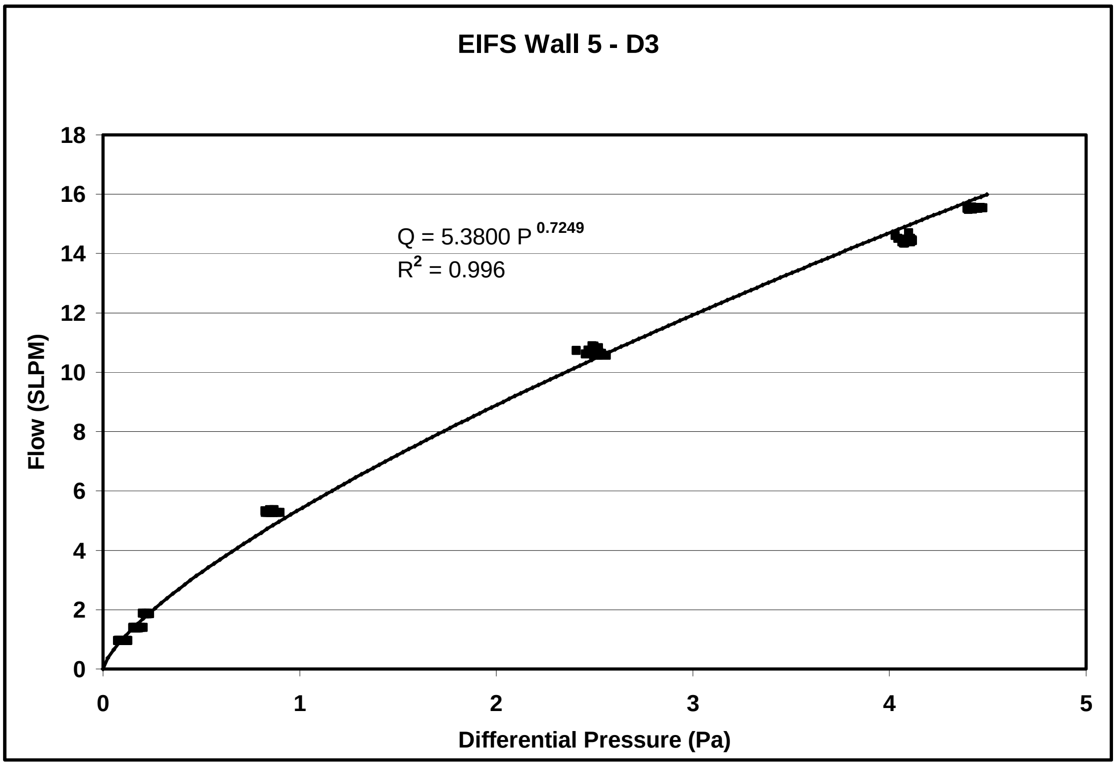
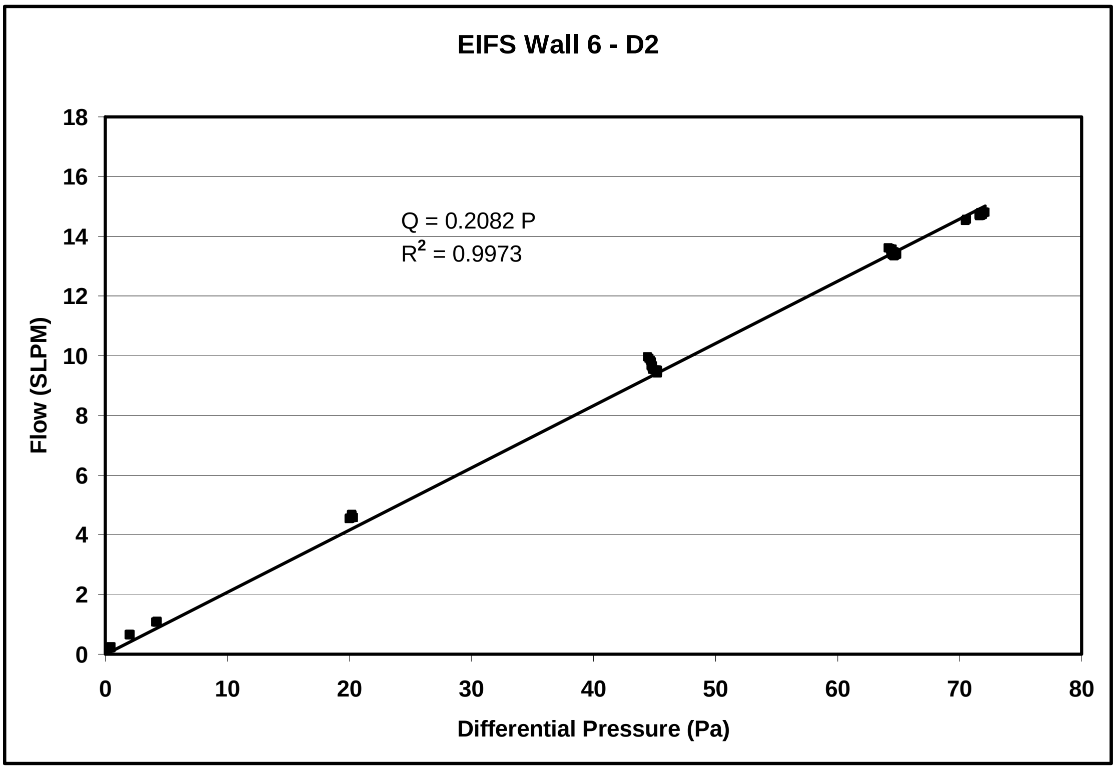


Figure II-5 Power fitting plots and correlations for D2, and D3 pathways for EIFS Wall 5.



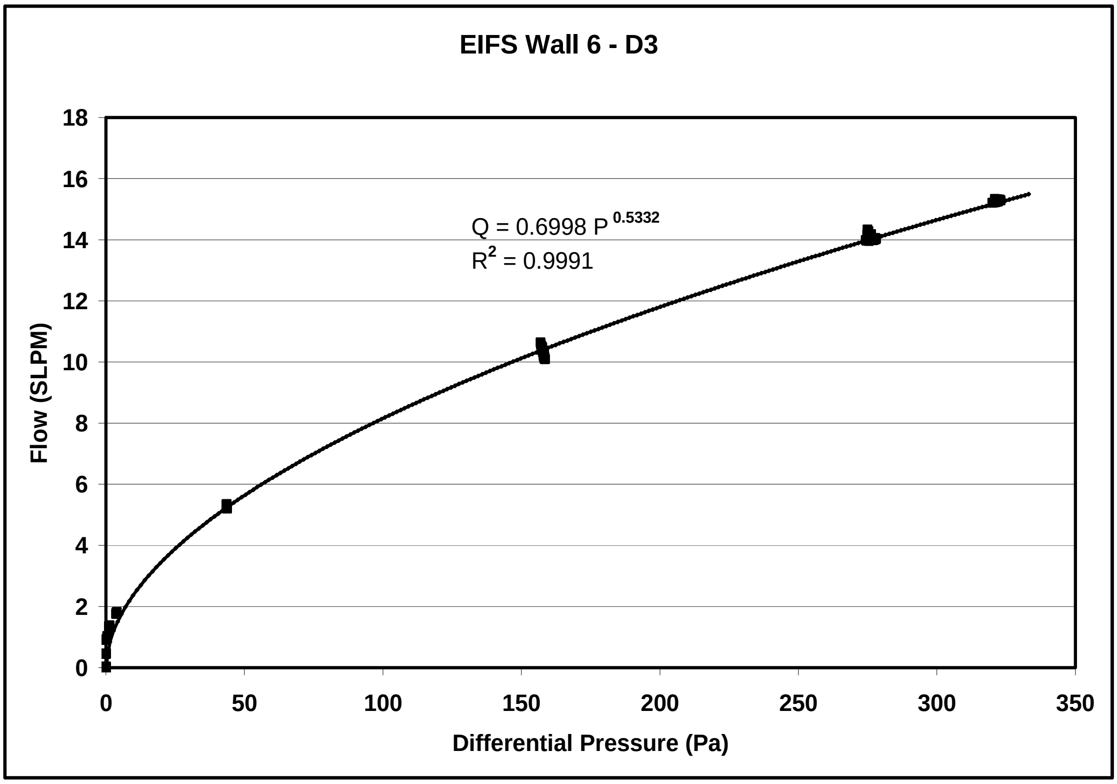


Figure II-6 Power fitting plots and correlations for D2, and D3 pathways for EIFS Wall 6

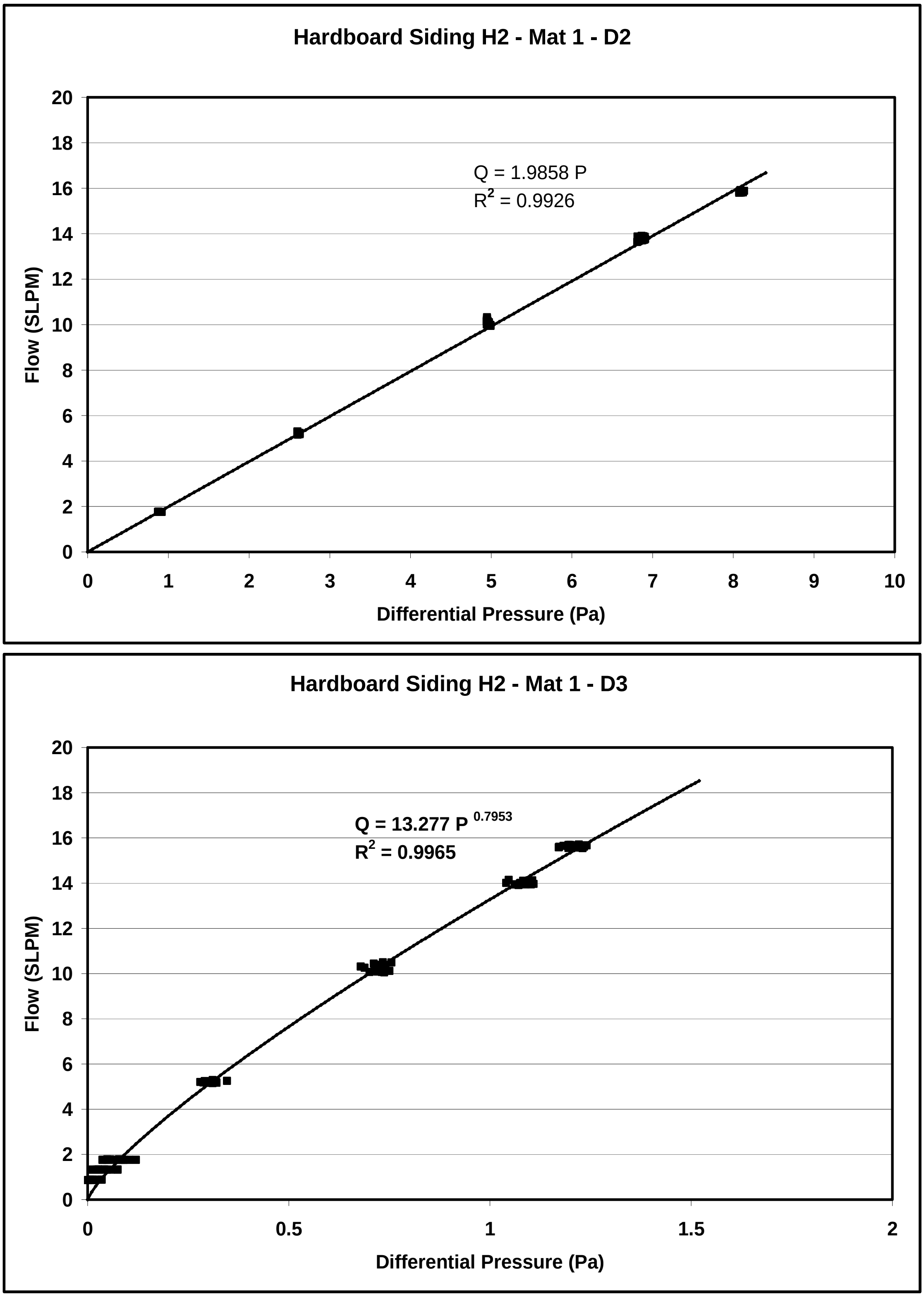
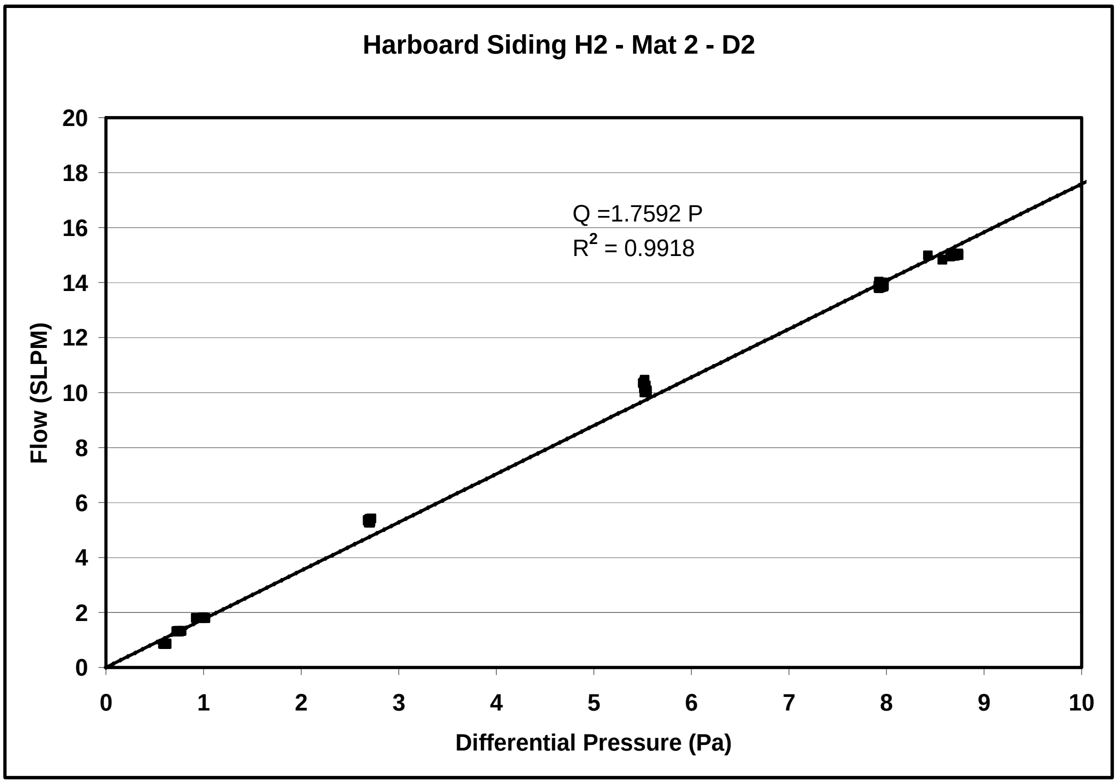


Figure II-7 Power fitting plots and correlations for Hardboard siding on Mat 1 for D2, and D3 pathways.



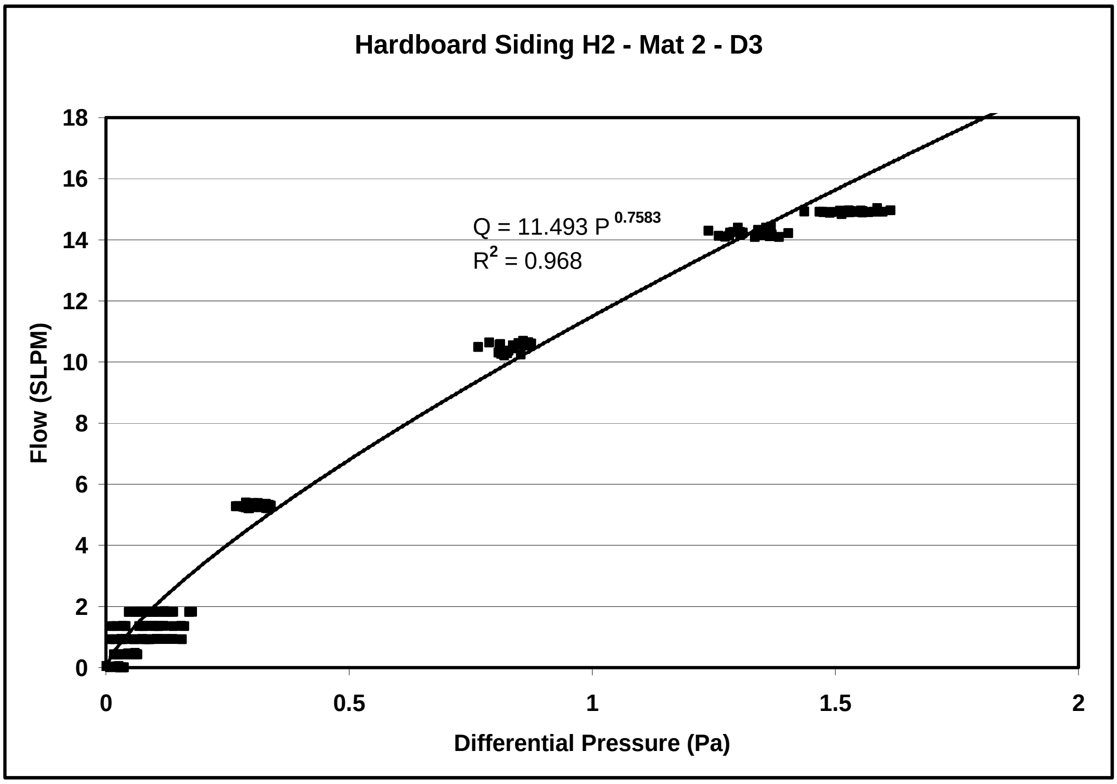
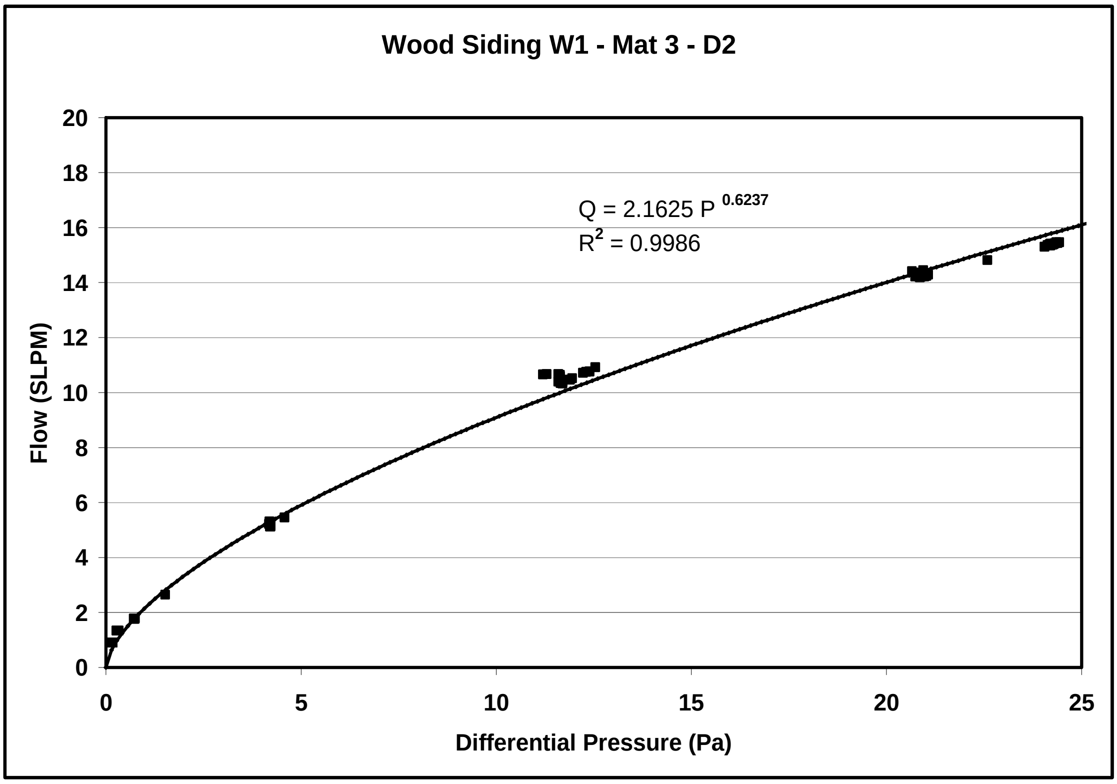


Figure II-8 Power fitting plots and correlations for Hardboard siding on Mat 2 for D2, and D3 pathways.



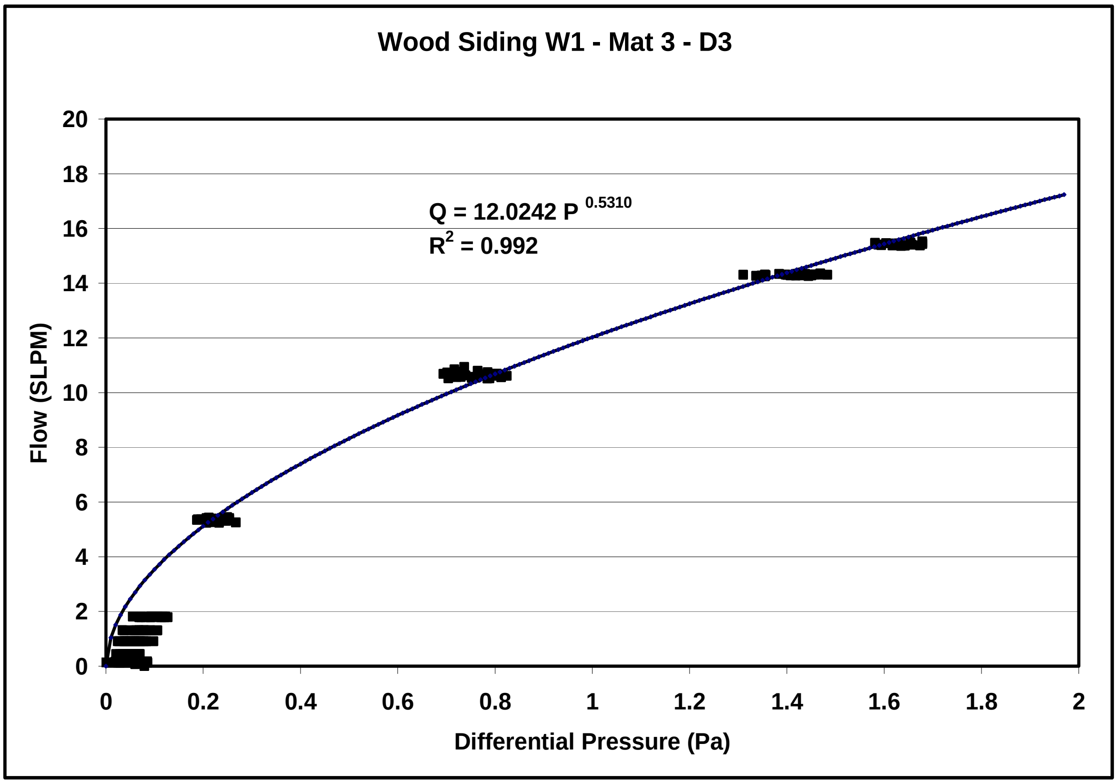


Figure II-9 Power fitting plots and correlations for Wood siding on Mat 3 for D2, and D3 pathways.

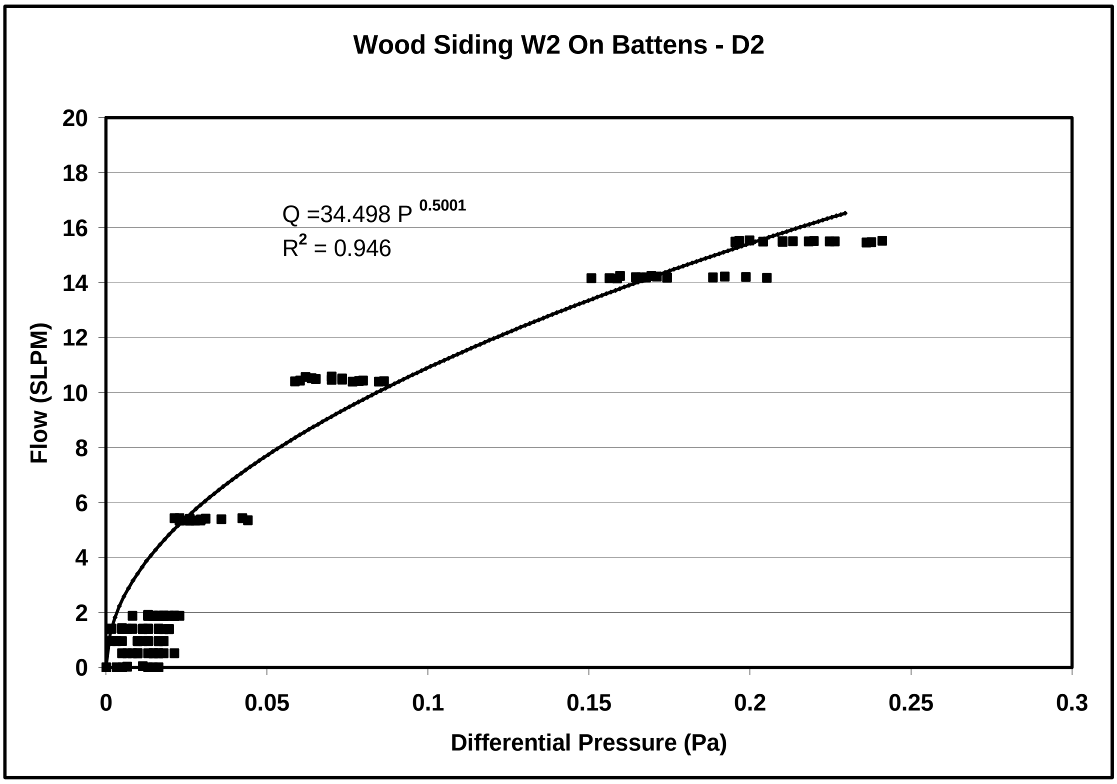


Figure II-10 Power fitting plot and correlation for Wood siding on batten strips for the D2 pathway. The flow rates and resulting pressure differentials were too low to secure a reliable result for the D3 pathway at the bottom of the cavity.