UL Solutions

WHITE PAPER

The Importance of Field Performance Testing for Fenestration Products

Mitigating air leakages and water penetration

LET'S GO

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Introduction

The most common and costly problems associated with the in-service performance of the vertical building envelope can be attributed to excessive air leakage and water intrusion through fenestration systems. It is, therefore, imperative to properly evaluate the fenestration products' performance as installed. Standards and design principles have contributed to significant overall improvements in the performance of fenestration systems, including resistance to water penetration and air leakage. However, the reality is that many recently constructed buildings still experience problems with the in-service performance of installed fenestration. Typically, these problems are often the result of poor fabrication or installation, or lack of adequate quality control.

This document discusses evaluating the field performance of fenestration during the early stages of construction to validate as-built designs, and during later construction stages as a quality control measure. The objective of this document is to increase awareness among members of the building community of the benefits of field testing in evaluating the performance of fenestration systems.

Performance Requirements

Fenestration systems constitute a large percent of the exterior cladding of most construction projects. As an important architectural feature, they do represent a significant portion of the overall cost of a construction or renovation project and play an essential role in the overall performance. Fenestration systems must be air and watertight; therefore, the evaluation of their performance during both the pre-construction and construction phase is essential to minimize the risk of undesirable and costly problems during a building's expected service life.

Any form of water infiltration or excessive air leakage to the interior of a building would be unacceptable to any building owner or occupant. Accordingly, having an appropriate level of resistance to water penetration and air leakage are two of the primary performance criteria for any fenestration system.

With regards to those criteria, one needs to consider the following issues:

- Resistance to water penetration – Performance requirements for resistance to water penetration vary depending on the building's height, geographic location, and exposure classification. In the U.S., ratings for resistance to water penetration are typically established as a function of the design wind pressure. However, in Canada, requirements for resistance to water penetration are determined by the driven rain wind pressure (DRWP) metric, a unique measure of climatic condition that has been established for each of over 640 Canadian cities, based on their geographic location and a building's installation height.
- Air leakage resistance – Air leakage resistance performance requirements are often established by local building and energy codes, and will vary for fixed and operable sections.

Ultimately, performance requirements need to be established for each project on a case-by-case basis, depending on building height and geographic location, exterior and interior design parameters, as well as the type of building occupancy.

Figure 1: Example of water infiltration within a curtain wall assembly

Figure 2: Example of water infiltration at a punch window assembly

Industry standards

Both the U.S. and Canada have industry standards that establish stringent performance requirements and testing methods for fenestration products. In North America the referenced performance standard for manufactured fenestration products by a harmonization process between the Fenestration and Glazing Industry Alliance (FGIA) formerly the American Architectural Manufacturers Association (AAMA), the Window and Door Manufacturer Association (WDMA)and the Canadian Standards Association (CSA). In both the U.S. and Canada, testing methods to evaluate both laboratory and field performance are established by the American Society for Testing and Materials (ASTM).

Here is a list of the principal industry standards that are commonly used to establish the laboratory performance criteria for fenestration products throughout North America:

AAMA/WDMA/CSA 101/I.S.2/A440

NAFS – North American Fenestration Standard/ Specification for windows, doors, and skylights. Outlines laboratory performance requirements applicable in the U.S. and Canada regarding resistance to water penetration, air leakage and wind load for windows, doors and skylights.

CSA A440S1

Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/ A440, NAFS - North American Fenestration Standard/ Specification for windows, doors, and skylights. Outlines simplified methods for calculating minimum performance levels for resistance to water penetration, wind loads and snow loads for fenestration products on buildings in Canada, and has to be used in conjunction with the NASF. However, it is important to note that this Standard does not apply to storefronts, window walls, curtain walls and other glazed structures. For those products, Section 5.9.3 of the 2015 Canadian Building Code specifies the use of calculations detailed in CSA A440S1 to determine the minimum performance requirements for resistance to water penetration.

The following is a list of the principal industry standards which are commonly used to establish the field performance criteria for installed fenestration systems in North America:

- AAMA 502 – Voluntary Specification for Field Testing of Newly Installed Fenestration Products. Outlines field performance requirements applicable in the U.S. for assessing resistance to water penetration and air leakage for windows and glass doors.
- AAMA 503 – Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems. Outlines field performance requirements applicable in the U.S. for assessing resistance to water penetration and air leakage for storefronts, curtain walls and sloped glazing Systems.
- CAN/CSA-A440.4 (Annex E) – Field Testing of Window and Door Installations. Outlines field performance requirements applicable in Canada for assessing resistance to water penetration and air leakage for assembled windows, exterior doors, and skylights that are intended for installation in low-rise buildings and buildings used primarily for, but not limited to, residential occupancy where the windows, doors, and skylights (including window wall) are R, LC, or CW class within the application of AAMA/WDMA/CSA 101/I.S.2/A440.
- CAN/CSA-A440.6 (Appendix E) – High exposure fenestration installation. Outlines Field testing during construction sequence for fenestration products within the scope of AAMA/WDMA/CSA 101/I.S.2/A440 that are intended for installation in buildings of all occupancies to which NBC Parts 3, 4, 5, and 6 of Division B apply, in both new and existing buildings.

Figure 3: Field testing for resistance to water penetration

Figure 4: Field testing for resistance to water penetration

Field performance evaluation

The previous section of this white paper summarizes the primary performance requirements and industry standards related to fenestration systems and intended to provide the reader with some basic background information on the subject. However, our main focus is the field evaluation of the performance of installed fenestration systems. Given the ever-growing complexity and variety of modern building envelopes, the evaluation of the performance of installed fenestration in the pre-construction and construction phase is essential in order to avoid undesirable and costly problems during the service life of the building.

In most projects of any significance, the performance of fenestration systems intended to form part of the building envelope is evaluated in an accredited testing laboratory prior to construction. However, it is equally important that the field performance of the installed products be evaluated during different phases of construction as a quality control measure. Site conditions, variations in the manufacturing process and the quality and experience of the field installation team are all factors that can impact the performance of the installed products or systems.

When considering field testing, the first step is to identify test areas which are representative of the most common elements of the building envelope. Typically, field testing is usually limited to three to six test areas due to budgetary and scheduling constraints. Therefore, obtaining the most representative sampling depends on the careful selection of the areas to be tested.

Test areas should be selected based on the complexity of any given detail or condition, as well as the frequency with which a given detail or condition is repeated throughout the project. Further, in order for field testing to provide results that are representative of the entire installation, it should always include the interface between the window and/or curtain wall and the adjacent wall assembly. This interface is often the most critical element of any installation and may not have been validated by any form of laboratory testing conducted prior to construction.

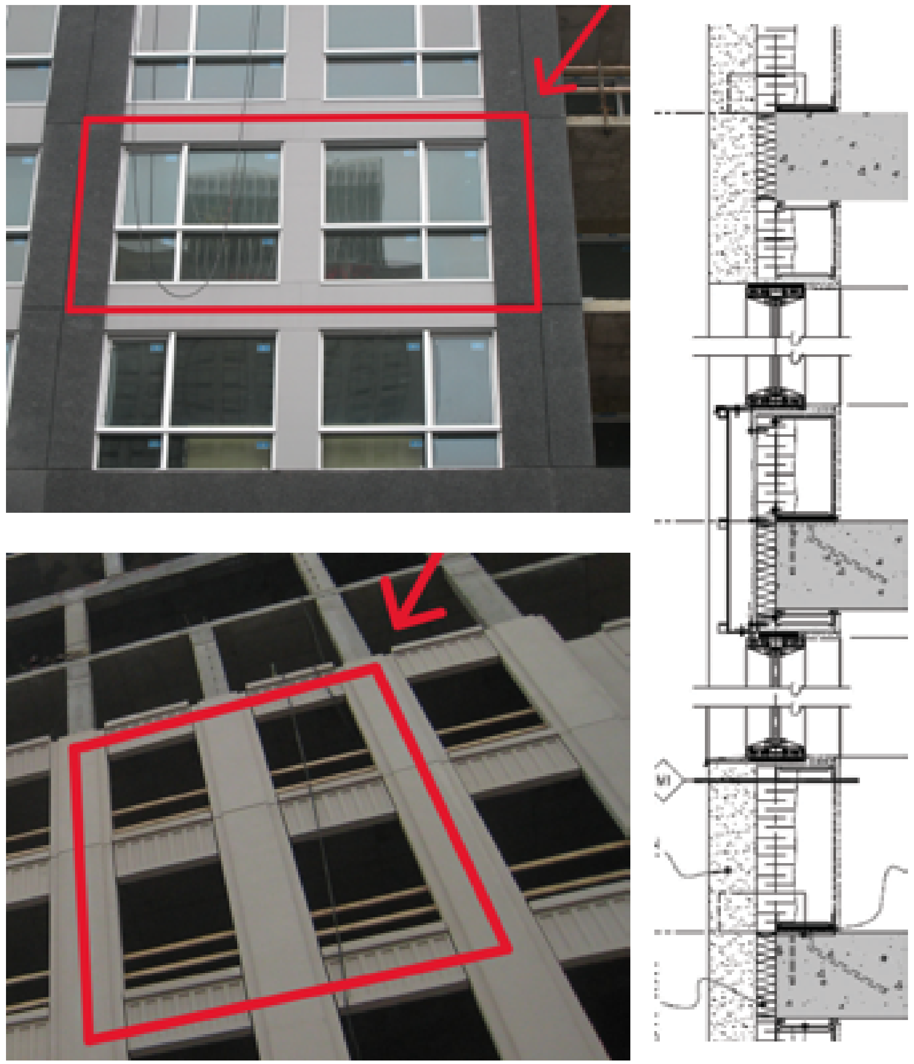


Figure 5, 6 and 7: Identification of representative areas for field testing (precast concrete/punch window wall assembly)

The specified test area for metal and glass curtain walls must incorporate all the essential components in order to thoroughly represent anticipated conditions. This means that a given test area should include least three glass bays in width in order to incorporate a central bay as well as all of the junction details. In the case of a unitized curtain wall system, a vertical module joint should also be included within the test area. The height of the test area should include at least one expansion or stack joint, at least one spandrel section, and one vision section. Typically, the height of the test area should be at least one full floor story high. Finally, if the curtain wall is installed adjacent to another type of wall assembly, the interface detail between the two types of assemblies should also be included within the test area.

Figure 8: Identification of representative area for field testing (metal and glass curtain wall

Figure 9: Identification of representative area for field testing (metal and glass curtain wall and adjacent masonry assembly)

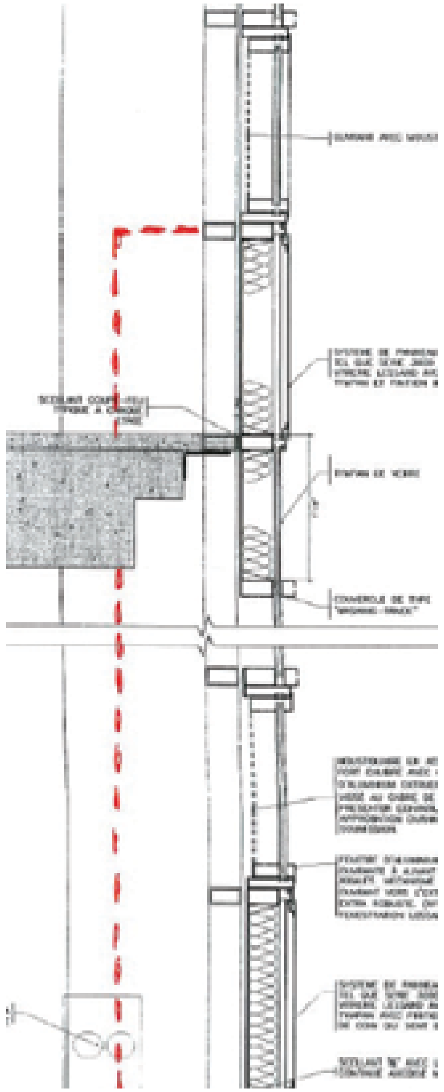


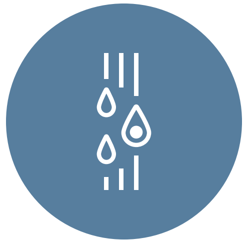
Figure 10: Vertical section illustrating location of test chamber and elements included in typical curtain field test

Test methods

The two primary criteria evaluated in the field are air leakage resistance and resistance to water penetration. The following are the commonly used standardized test methods used to evaluate these criteria in the field.

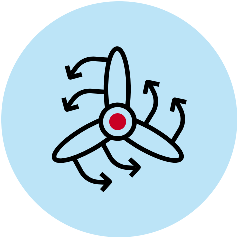
ASTM E783

Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors. Outlines the test method for field measuring air leakage through installed exterior windows and doors. This test method is also used for measuring air leakage through curtain wall systems (quantitative test method).



ASTM E1105

Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference. Outlines the test method for the field determination of water penetration of installed exterior windows, curtain walls and doors



AAMA 501.1

Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure. Outlines the equipment, procedures and requirements for laboratory and field testing of exterior windows, curtain walls and doors for water penetration using dynamic pressure.

In utilizing each of these four test methods, a pressure differential must be created across the test specimen in order to simulate wind pressure. There are two different methods for creating the required pressure differential. The procedure specified in the ASTM test methods requires the use of a test chamber erected on the interior side of the test specimen and a vacuum blower. The procedure specified in the AAMA test method uses a wind generator installed on the exterior surface.

In cases where the use of a test chamber is required but interior access is problematic (such as in the case of skylights), a test chamber can be erected on the exterior side of the test specimen. In certain cases, it may also be possible to use high-power blower doors installed within a confined space. However, this method is typically only used for forensic testing in occupied buildings.

For new construction or major renovation projects, a minimum of three tests sequences should be anticipated as a quality control measure, with the first sequence to be conducted at the very beginning of the project, the second midway through the project, and the third near the end of the project. The dynamic method can be used for both quality control and forensic evaluation.

Figure 11: Interior test chamber used to test a portion of curtain wall section

Figure 13: Exterior test chamber used to test a skylight section

Figure 12: Interior test chamber used to test a punch window assembly

Figure 14: Dynamic water penetration field test as per AAMA 501.1

Test pressures are typically specified by the project architect and differ depending on the specific test to be conducted. The air infiltration/exfiltration test is typically undertaken at a pressure differential of 75 Pa (1.57 psf) or 300 Pa (6.27 psf). The water penetration test is undertaken at pressure differentials varying between 140 Pa (2.93 psf) and 720 Pa (15.0 psf). Table 1 is referenced in several publications and provides the wind speed equivalences for various pressure differentials.

Pa	kph	psf	in.H2O	mph
75 Pa	40 kph	1.57 psf	0.30''H20	25 mph
137 Pa	54 kph	2.86 psf	0.55''H20	34 mph
144 Pa	56 kph	3.00 psf	0.58''H20	35 mph
150 Pa	57 kph	3.13 psf	0.60''H20	35 mph
180 Pa	62 kph	3.75 psf	0.72''H20	39 mph
200 Pa	66 kph	4.17 psf	0.80''H20	41 mph
216 Pa	68 kph	4.50 psf	0.87''H20	42 mph
252 Pa	74 kph	5.25 psf	1.01''H20	46 mph
288 Pa	79 kph	6.00 psf	1.15''H20	49 mph
299 Pa	80 kph	6.24 psf	1.20''H20	50 mph
300 Pa	80 kph	6.26 psf	1.20''H20	50 mph
324 Pa	83 kph	6.75 psf	1.30''H20	52 mph
360 Pa	88 kph	7.50 psf	1.44''H20	55 mph

Pa	kph	psf	in.H2O	mph
383 Pa	90 kph	8.00 psf	1.53''H20	56 mph
384 Pa	91 kph	8.00 psf	1.54''H20	56 mph
396 Pa	92 kph	8.25 psf	1.59''H20	57 mph
400 Pa	93 kph	8.34 psf	1.61''H20	58 mph
431 Pa	96 kph	9.00 psf	1.73''H20	60 mph
467 Pa	100 kph	9.75 psf	1.88''H20	62 mph
500 Pa	104 kph	10.43 psf	2.01''H20	64 mph
503 Pa	104 kph	10.50 psf	2.02''H20	65 mph
539 Pa	108 kph	11.25 psf	2.17''H20	67 mph
575 Pa	111 kph	12.00 psf	2.31''H20	69 mph
600 Pa	114 kph	12.51 psf	2.41''H20	71 mph
700 Pa	123 kph	14.60 psf	2.81''H20	76 mph
750 Pa	127 kph	15.64 psf	3.01''H20	79 mph

Table 1: Table of wind speed equivalences

However, these equivalences are valid only in cases where the wind speed is known at the exact surface location where the differential pressure will be applied. Wind speeds will be greater at various building elevations than the wind speed recorded near ground level. Typically, the reference wind speed for a given locality is usually based on measurements taken at about 10 m (33 ft) above ground level. Thus, the resulting differential pressure at a higher elevation will be greater than the equivalent differential pressure where the wind speed was recorded. In meters, this relationship can be expressed as Differential Pressure $_{\text{at elevation H in meters}}$ = Differential Pressure $_{\text{at 10 m}}$ * $(H/10)^{0.28}$. In imperial / English units, it is expressed as: Differential Pressure $_{\text{at elevation H in ft}}$ = Differential Pressure $_{\text{at 33 ft}}$ * $(H/33)^{0.28}$. Tables 2 and 3 provide the relation between differential pressure and wind speed equivalences as a function of height above ground.

m	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph	Pa	kph
10	40	29	60	36	80	41	100	46	120	51	140	55	160	58	180	62	200	65	220	68	240	71	260	74	280	77	300	80	350	86	400	92	450	98	500	103	550	108	600	113	650	118	700	122	720	124
15	45	31	67	38	90	44	112	49	134	53	157	58	179	62	202	66	224	69	246	72	269	76	291	79	314	82	336	85	392	91	448	98	504	104	560	109	616	115	672	120	728	124	784	129	807	131
20	49	32	83	42	97	45	121	51	146	56	170	60	194	64	219	68	243	72	267	75	291	79	316	82	340	85	364	88	425	95	486	102	546	108	607	114	668	119	729	125						
25	52	33	84	42	103	47	129	52	155	57	181	62	207	66	233	70	258	74	284	78	310	81	336	85	362	88	388	91	452	98	517	105	582	111	646	117	711	123								
30	54	34	85	42	109	48	136	54	163	59	190	64	218	68	245	72	272	76	299	80	326	83	354	87	381	90	408	93	476	101	544	108	612	114	680	120	748	126								
35	57	35	85	43	114	49	142	55	170	60	199	65	227	70	256	74	284	78	312	82	341	85	369	89	398	92	426	95	497	103	568	110	639	117	710	123										
40	59	35	86	43	118	50	147	56	177	61	206	66	236	71	265	75	295	79	324	83	354	87	383	90	413	94	442	97	516	105	590	112	663	119	737	125										
45	61	36	86	43	122	51	152	57	183	62	213	67	244	72	274	76	305	81	335	84	366	88	396	92	427	95	457	99	533	107	609	114	686	121	762	127										
50	63	37	86	43	126	52	157	58	188	63	220	68	251	73	282	78	314	82	345	86	377	90	408	93	439	97	471	100	549	108	628	116	706	123												
55	64	37	87	43	129	52	161	59	193	64	226	69	258	74	290	79	322	83	355	87	387	91	419	94	451	98	484	101	564	110	645	117	725	124												
60	66	37	87	43	132	53	165	59	198	65	231	70	264	75	297	80	330	84	363	88	396	92	429	96	462	99	495	103	578	111	661	119	743	126												
65	68	38	87	43	135	54	169	60	203	66	236	71	270	76	304	80	338	85	372	89	405	93	439	97	473	100	507	104	591	112	676	120														
70	69	38	87	43	138	54	172	61	207	66	241	72	276	77	310	81	345	86	379	90	414	94	448	98	483	101	517	105	604	113	690	121														
75	70	39	88	43	141	55	176	61	211	67	246	72	281	77	316	82	352	87	387	91	422	95	457	99	492	102	527	106	615	114	703	122														
80	72	39	88	43	143	55	179	62	215	68	251	73	286	78	322	83	358	87	394	92	430	96	465	100	501	103	537	107	627	115	716	123														
85	73	39	88	43	146	56	182	62	218	68	255	74	291	79	328	84	364	88	401	92	437	96	473	100	510	104	546	108	637	116	728	125														
90	74	40	88	43	148	56	185	63	222	69	259	74	296	79	333	84	370	89	407	93	444	97	481	101	518	105	555	109	648	117	740	126														
95	75	40	88	43	150	57	188	63	225	69	263	75	301	80	338	85	376	89	413	94	451	98	488	102	526	106	563	110	657	118	751	126														
100	76	40	89	43	152	57	191	64	229	70	267	75	305	81	343	85	381	90	419	94	457	99	495	103	534	107	572	110	667	119																

Height above ground Reference data at 10m Differential pressure Equivalent wind speed

Table 2: Table of differential pressure and wind speed equivalences with relation to height above ground in metric

ft	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph	psf	mph
33	0.84	18	1.25	22	167	26	209	29	251	32	2.93	34	334	36	376	39	4,18	41	460	43	5 02	45	5,43	46	5,85	48	6.27	50	7,32	54	8,36	58	9,41	61	10,45	64	11,50	68	12,54	71	13,59	74	14,63	76
49	0.94	19	1.4	24	187	27	234	31	281	33	328	36	375	39	421	41	4,68	43	515	45	5,62	47	6,09	49	6,56	51	702	53	8,19	57	9,37	61	10,54	65	11,71	68	12,88	72	14,05	75	15,22	78	16,39	81
66	1.02	20	1.74	26	203	28	254	32	305	35	355	38	406	40	457	43	5,08	45	558	47	6,09	49	6,60	51	7,11	53	761	55	8,88	59	10,15	64	11,42	67	12,69	71	13,96	75	15,23	78				
82	1.08	21	1.75	26	216	29	270	33	324	36	378	39	432	41	486	44	5,40	46	594	49	6,48	51	7,02	53	7,56	55	810	57	9,45	61	10,81	66	12,16	70	13,51	73	14,86	77						
98	114	21	1.77	27	227	30	284	34	341	37	398	40	455	43	512	45	5,69	48	625	50	6,82	52	7,39	54	7,96	56	853	58	9,95	63	11,37	67	12,79	71	14,21	75	15,64	79						
115	119	22	178	27	237	31	297	34	356	38	416	41	475	43	534	46	5,94	49	653	51	7,12	53	7,72	55	8,31	58	890	60	10,39	64	11,87	69	13,36	73	14,84	77								
131	123	22	179	27	246	31	308	35	370	38	431	41	493	44	555	47	6,16	50	678	52	7,39	54	8,01	56	8,63	59	924	61	10,78	66	12,32	70	13,87	74	15,41	78								
148	127	23	180	27	255	32	318	36	382	39	446	42	510	45	573	48	6,37	50	701	53	7,64	55	8,28	57	8,92	60	955	62	11,15	67	12,74	71	14,33	76	15,92	80								
164	131	23	180	27	262	32	328	36	394	40	459	43	525	46	590	48	6,56	51	722	54	7,87	56	8,53	58	9,18	60	984	63	11,48	68	13,12	72	14,76	77										
180	1.35	23	181	27	269	33	337	37	404	40	472	43	539	46	606	49	6,74	52	741	54	8,08	57	8,76	59	9,43	61	1011	63	11,79	68	13,47	73	15,16	78										
197	1.38	23	182	27	276	33	345	37	414	41	483	44	552	47	621	50	6,90	52	759	55	8,28	57	8,97	60	9,66	62	1035	64	12,08	69	13,81	74	15,53	79										
213	1.41	24	182	27	282	34	353	37	424	41	494	44	565	47	635	50	7,06	53	777	56	8,47	58	9,18	60	9,88	63	1059	65	12,35	70	14,12	75												
230	1.44	24	183	27	288	34	360	38	432	41	505	45	577	48	649	51	7,21	54	793	56	8,65	59	9,37	61	10,09	63	1081	66	12,61	71	14,42	76												
246	1.47	24	183	27	294	34	367	38	441	42	514	45	588	48	661	51	7,35	54	808	57	8,82	59	9,55	62	10,29	64	1102	66	12,86	72	14,70	76												
262	1.5	24	184	27	299	35	374	39	449	42	524	46	599	49	673	52	7,48	55	823	57	8,98	60	9,73	62	10,48	65	1122	67	13,09	72	14,96	77												
279	1.52	25	184	27	304	35	381	39	457	43	533	46	609	49	685	52	7,61	55	837	58	9,13	60	9,89	63	10,65	65	1142	67	13,32	73	15,22	78												
295	1.55	25	184	27	309	35	387	39	464	43	541	46	619	50	696	53	7,73	55	851	58	9,28	61	10,05	63	10,83	66	1160	68	13,53	73	15,47	78												
312	1.57	25	185	27	314	35	393	40	471	43	550	47	628	50	707	53	7,85	56	864	59	9,42	61	10,21	64	10,99	66	1178	68	13,74	74	15,70	79												
328	1.59	25	185	27	319	36	398	40	478	44	558	47	637	50	717	53	7,96	56	876	59	9,56	62	10,35	64	11,15	67	1195	69	13,94	74														

Height above ground Reference data at 10m Differential pressure Equivalent wind speed

Table 3: Table of differential pressure and wind speed equivalences with relation to height above ground in IP

Applying the information from these tables to a building of 30 floors (about 90 m or 295 ft), with a reference wind speed at ground level of 65 kph (41 mph), the differential pressure at the full height of the building would be equal to 370 Pa (7,73 psf), equivalent at that elevation to 89 kph (55 mph). Therefore, in evaluating the relationship between differential pressure and wind speed, it is important to account for the building's total elevation, given that the available wind speed data is usually measured near ground level. This concept is also the basis for the method used to calculate the minimum performance levels for resistance to water penetration found in CSA A440S1: Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/A440, NAFS - North American Fenestration Standard/ Specification for windows, doors, and skylights.

In the U.S., however, this concept does not exist, as the minimum performance levels for resistance to water penetration is established as a function of the design wind pressure, with values generally between 15% and 20% of design pressure. It is therefore quite important to differentiate between actual wind speed and the differential pressure at which the test is to be performed.

Air infiltration/exfiltration test

As previously noted, air leakage testing is typically undertaken at a pressure differential of 75 Pa (1.57 psf) or 300 Pa (6.27 psf). In the U.S., the AAMA 502 standard provides guidelines for allowable air leakage rates of newly installed windows and sliding glass doors. In accordance with AAMA 502, allowable rates of air leakage for field testing shall be 1.5 times the applicable laboratory test rating, unless otherwise specified (see Table 4).

Product Designation	AAMA/WDMA/CSA 101/I.S.2/A440		AAMA 502	
	Allowable Air Leakage		Allowable Air Leakage	
	Test Pressure	Maximum Rate	Test Pressure	Maximum Rate
Class R-PG15-H	75 pa (~1.57 psf)	1.5 L/s•m² (~0.30 cfm/ft²)	75 pa (~1.57 psf)	2.3 L/s•m² (~0.45 cfm/ft²)
Class LC-PG25-SD	75 pa (~1.57 psf)	1.5 L/s•m² (~0.30 cfm/ft²)	75 pa (~1.57 psf)	2.3 L/s•m² (~0.45 cfm/ft²)
Class CW-PG30-C	75 pa (~1.57 psf)	1.5 L/s•m² (~0.30 cfm/ft²)	75 pa (~1.57 psf)	2.3 L/s•m² (~0.45 cfm/ft²)
Class AW-PG40-FW	300 pa (~6.27 psf)	0.5 L/s•m² (~0.10 cfm/ft²)	300 pa (~6.27 psf)	0.8 L/s•m² (~0.15 cfm/ft²)

Table 4: Example of allowable air leakage rates depending on window classification (Source: Table 1, AAMA 502-21, Voluntary Specification for Field Testing of Newly Installed Fenestration Products. ©FGIA)

Allowable rates of air leakage for field testing (see clause E.42.)

Window type and class	Column A	Maximum air leakage for surfaces smaller than the value in column A			Rate of air leakage for surfaces larger or equal to the value in column A		
	Surface in m^2	A2	A3	Fixed	A2	A3	Fixed
		L/s	L/s	L/s	L/s-m2	L/s-m2	L/s-m2
Awning, hopper, projected window							
Class R	0.48	0.72	0.24		1.5	0.5	
Class LC	0.96	1.44	0.48		1.5	0.5	
Class CW	0.96	1.44	0.48		1.5	0.5	
Fixed window							
Class R	1.44			0.29			0.2
Class LC	1.96			0.39			0.2
Class CW	2.25			0.45			0.2
Sliding door							
Class R	3.6	5.4	1.8		1.5	0.5	
Class LC	4.62	6.93	2.31		1.5	0.5	
Class CW	5.04	7.56	2.52		1.5	0.5	

Table 5: Allowable air leakage rates depending on window classification (Source: Table E.1, CSA A440.4:19 (R2024), Window, door, and skylight installation. © 2019 Canadian Standards Association)

When it comes to metal and glass curtain walls, the allowable air leakage rates are typically indicated in the architectural specifications and will vary depending on local building and energy codes as well as for fixed and operable wall sections. Namely Section 5.9.3. Other Fenestration Assemblies of the Canadian Building Code 2020, more specifically subsections 5.9.3.4. Air Leakage and 5.9.3.5. Water Penetration specify the following requirements.

- For air leakage when measured at an air pressure difference of 75 Pa and tested in accordance with ASTM E283, "Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen," that is not greater than:
  - 0.2 L/(s×m2) for fixed portions, including any opaque portions
  - 1.5 L/(s×m2) for operable portions.
- For resistance to water penetration when tested in accordance with
  - ASTM E331, "Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference"
  - ASTM E547, "Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference.

The tests shall be carried out at the driving rain wind pressure as calculated in accordance with CSA A440S1, "Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/A440-17, North American Fenestration Standard/Specification for windows, doors, and skylights."

The field air leakage resistance test consists of installing and sealing a chamber to cover the interior or exterior face of the specimen to be tested. Air is then supplied to or exhausted from the chamber at the rate required to maintain the specified test pressure difference across the specimen. The resulting air flow through the test specimen is then measured.

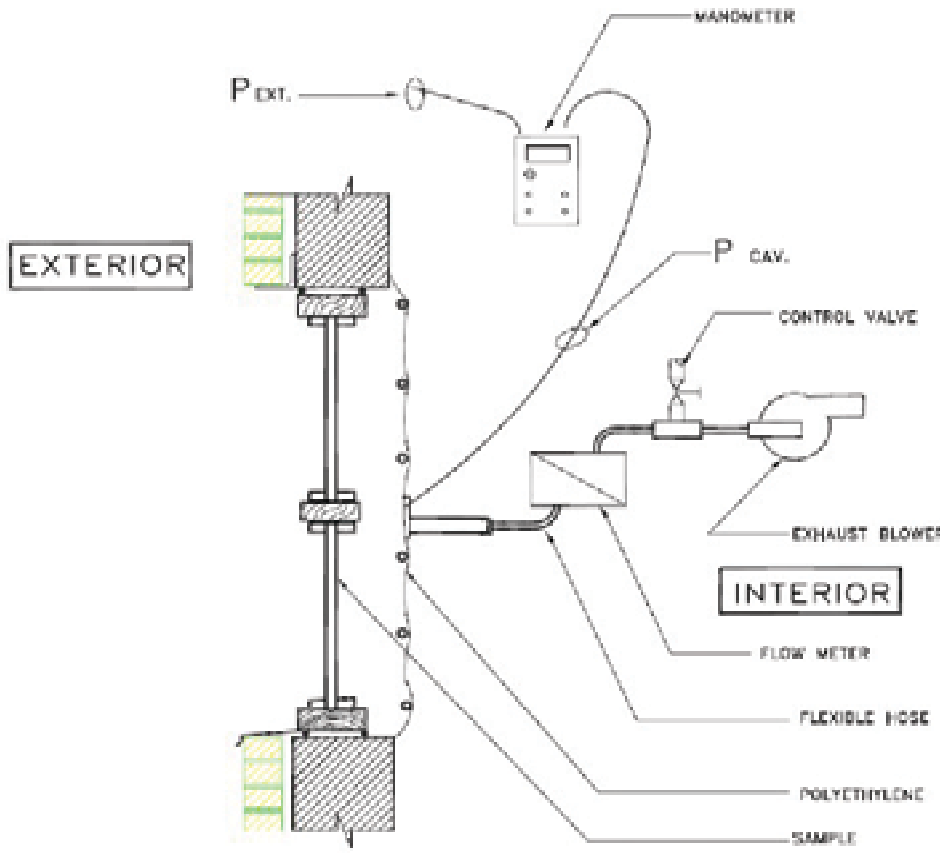


Figure 15: Typical set-up for field air leakage resistance test (Source: Figure E.2, CSA A440.4:19 (R2024), Window, door, and skylight installation. © 2019 Canadian Standards Association)

It is important to note that it is often difficult to obtain accurate air leakage results in the field, particularly with curtain wall assemblies. Therefore, test results should be questioned when extraneous air leakage from either the test chamber and/or the confines of the test specimen significantly exceeds the allowable air leakage for the test specimen.

In cases in which it is not practical or possible to quantify air leakage, smoke exfiltration testing can serve as an effective alternative method. The smoke exfiltration test is undertaken by applying a uniform positive static pressure differential of 75 Pa (1.57 psf) across the test specimen, and then filling the test chamber with white smoke generated by a portable smoke generator. It is then possible to check for any visible excessive smoke exfiltration from the exterior side of the test specimen.

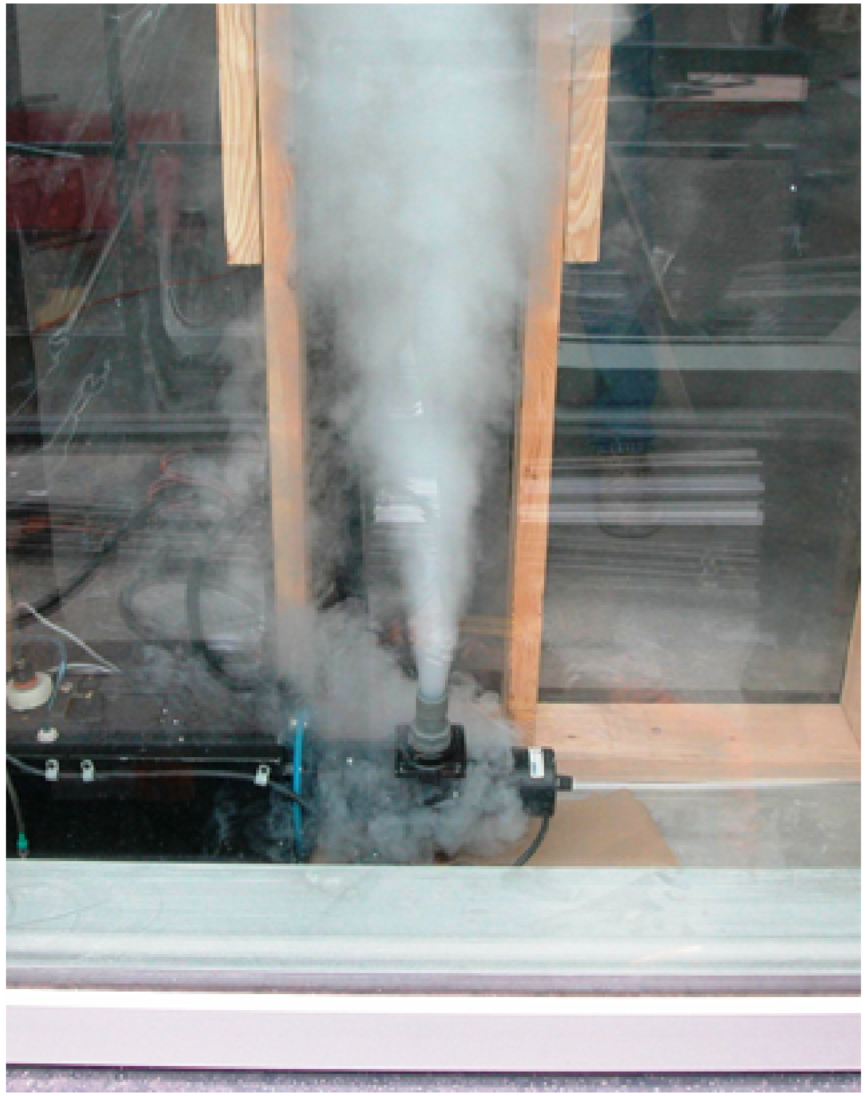


Figure 16: Portable smoke generator used to fill test chamber with white smoke

Figure 17: Excessive smoke exfiltration visible on exterior side of curtain wall test specimen

Water penetration test

The field water penetration resistance test consists of attaching and sealing a chamber to the interior or exterior face of the test specimen to be tested, and then supplying or exhausting air to the chamber at the rate required to maintain the desired air pressure difference across the test specimen. At the same time, water is applied to the exterior face of the test specimen at the required rate (5 gal US/h/ft^2) while observing for any water penetration in the interior.

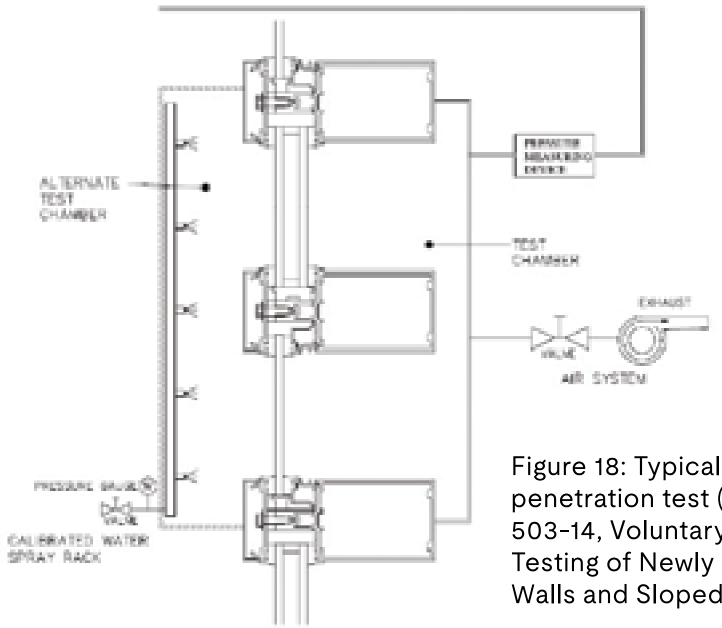


Figure 18: Typical set-up for field water penetration test (Source: Figure 3, AAMA 503-14, Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems. ©FGIA)

For the water penetration resistance field test, a calibrated sprinkler rack is hung on the exterior side of the test specimen so that a continuous and uniform water spray can be applied. Sufficient water pressure must be available on-site in order to ensure that the required amount of water is sprayed on the entire specimen. When available water pressure is not sufficient, the use of a portable water reservoir and pump system may be necessary.

It is also important that the exterior temperatures be above freezing in order to run a water test. When undertaking a water test in winter conditions, a temporary heated enclosure should be installed on the exterior side of the test specimen.

Figure 19: Calibrated sprinkler rack hung from suspended scaffolding

Figure 21: Portable water reservoir and pump system

Figure 20: Calibrated sprinkler rack hung from motorized man lift

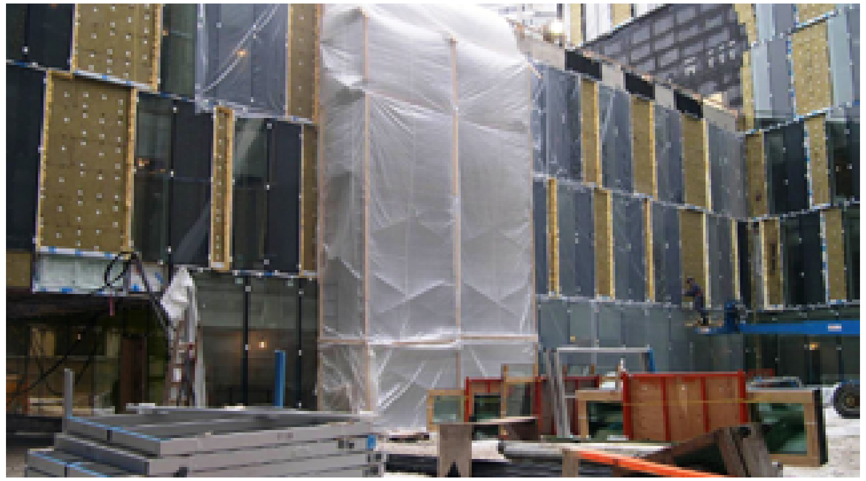


Figure 22: Temporary exterior heating via test specimen

Summary and conclusion

Today, major building projects require specialized attention to the quality and integrity of fenestration systems, both during and after construction. The testing of these critical building elements to evaluate their performance under the range of anticipated exposure scenarios is essential, not only to help increase the safety and comfort of building occupants, but also to reduce the potential for premature repairs and renovations that can adversely impact a building's return to investors and shareholders.

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