FENESTRATION AIR LEAKAGE – A COMPARISON OF FIELD MEASUREMENTS WITH LABORATORY TESTED VALUES

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ABSTRACT

Field testing based on a statistical approach was carried out on a newly installed fenestration product to study the nature of distribution of air leakage measurements. A total of 32 fenestration units were tested. The measured values from these tests were also compared to the laboratory tested value of the same product and to the values as suggested in field testing guidelines as provided in AAMA 502. The results as presented in this paper indicate that field measured values follow a normal distribution with a mean and a variance. The results also show that while a number of test results fall within a certain range of the laboratory value and also the AAMA 502 stipulated value there are number of values that are higher than them. The results indicate that consideration needs to be given to such expected distribution of measured values in stipulating the use and interpretation of the values obtained from testing.

MAIN THRUST OF THE REPORTED WORK

The main thrust of this paper is understanding the nature of variability between air leakage as measured in the field to that measured in the laboratory for the same type of fenestration product. The air leakage value of a fenestration product as measured under controlled condition in the laboratory, in most instances, forms the basis for the selection of the fenestration product to meet stipulated requirements. The purpose of this paper is not to argue against such an approach. Performance of products under controlled conditions is necessary to compare products and their relative performance at the time of design decisions.

However, the question as to how the laboratory measurement compares to the installed product is an important one to ask. It is not unreasonable for designers and specifiers to expect that the installed performance will be, within reason, close to the performance predicted by laboratory performance.

It is understood that there are many reasons for the installed performance to be different from the laboratory performance. This paper does not purport to suggest that they should be the same. However, the magnitude of difference between the two is important for the design community to take into account whether they are considering the contribution of air leakage to the HVAC, thermal comfort or energy considerations.

An issue that often arises particularly with condominium projects is the determination of whether the performance of the installed fenestration product is similar to the specified product. While it is true that certification and labelling process provides a level of assurance in this regard it does not take into account the impact of installation. After all what good is a certified product if it does not work as specified?

Finally any performance metric of a fenestration product will have some inherent statistical variation. Specifying products based on one value, as is done in selecting fenestration products, has no room to account for such statistical variation. In more established areas of structural design the values of resistance of structural products are based on some statistical measure. Limit state design incorporates variations in both loads and resistances based on some statistical measures.

As will be shown in one of the following sections there is very little information about the statistical variation of air leakage rates of a fenestration product. Furthermore, there is very little information about the differences between the laboratory measured air leakage rate and the installed air leakage rate of the same product.

This paper reports on installed air leakage of the fenestration product using a statistical approach. It compares it against the air leakage rate upon which the tested product was certified. While it is possible to begin to hypothesize the reasons for the differences, the purpose of this paper is to:

- Layout a framework for carrying out similar studies on other products
- Begin to highlight the magnitude of variation and its potential impacts

A REVIEW OF AIR LEAKAGE ISSUES RELEVANT TO THIS WORK

Field Testing to Verify Laboratory Tested Performance of Fenestration

The widely used Fenestration Standard, NAFS, AAMA (2011), clearly stipulates in section 0.1.1-Applicability that provisions in the standard apply to laboratory testing only. For field testing in the US the NAFS makes reference to AAMA 502 (2012). The AAMA 502 provides guidance in terms of the manner in which the field testing might be carried out and also guidance in terms of the interpretation of results with respect to performance values that are stipulated in the AAMA. For Canada the NAFS makes no reference in terms of using AAMA 502. Some reference to the similar guidance in Canada can be found in CSA A440.4. In the Annex D (informative) to A440.4 it provides information on the field testing of window and door installations.

AAMA 502 (AAMA, ND) addresses the need to carry out field testing that is often necessary to verify the performance against the values that are used for certification. It clearly stipulates the parameters for the time in which testing can be done after installation. The standard is limited to the field testing of newly installed fenestration products. It is intended for testing prior to issuance of the occupancy permit and for a period not to exceed 6 months after installation of the fenestration product. The CSA A440.4 stipulates that the standard "does not require routine field testing". There are no time limit stipulations in CSA A440.4.

For air leakage testing AAMA 502 allows for the testing to be carried out at the same pressure differences as required for NAFS but allows the air leakage to be 1.5 times the value that is used for certifying the product as per the NAFS. The CSA A440.4 indicates the air leakage testing to be carried out at a pressure of 75 Pa. With respect to the air-leakage testing, the annex recognizes the difficulty in doing the test for air exfiltration and suggests that air infiltration may be acceptable way of determining the air leakage characteristics. It provides a detailed list of allowable rates of air leakage for field testing based on the original window rating

and the size. CSA A440.4, also has a separate section for doors in which it stipulates the maximum air-leakage rates for doors based on the original rating. The maximum values stipulated for sliding doors are as follows: Rating A1 – 2.79 m^3/h, Rating A2 – 1.65 m^3/h, rating A3 – 1.00 m^3/h.

Other than the two standards indicated above there is some mention in Woods et. al. (1995) about determining the rationale for field testing. They suggest that field air leakage testing on existing buildings, for values of greater than 15% of the design values for windows and doors would call for intervention.

Both the AAMA 502 and the CSA A440.4 indicate that the field testing for air leakage is to be done in accordance with ASTM E783-02 (2010). However it is evident that the acceptable values for field testing are not similar. It would seem that AAMA 502 appears to be more widely used compared to similar requirements in CSA A440.4.

There has been discussion in popular media about the field testing with respect to water leakage in accordance with AAMA 502. An example of it is a BSC Experts Session in 2014, Baker (2014) talks in much detail about windows and water leakage testing in relationship to field performance. In it the question of "how much testing?" has been raised. Baker suggests that for punched windows and door a total of 1% to 2% of the total number of units installed to be tested. AAMA 502 suggests a minimum of three units to be tested in the field.

Neither the suggestion made by Baker (2014) nor suggestions made in AAMA 502 are indicative of any statistical basis for determining the sample sizes for testing in the field. It would seem they are more reflective of the practicality and the cost of field testing which in itself may be reason enough to determine the extent of field testing to be done. On the other hand, Section 9 of ASTM E783-02 (2010) provides some guidance in terms of sampling based on statistical considerations.

Practical considerations related to field testing are well addressed by Goncalves et al (2007). They provide some guidelines to decide on the choice of sample selection for testing. They recommend at least three tests, one each at the beginning, the middle and end of the installation.

Variations Between Field Measured Air Leakage and Laboratory Tested Air Leakage

ASTM E783-02 (2010) raises caution in terms of comparing field results to laboratory results. Section 5.3 indicates that correlation between actual performance of in-service products and the response to these tests has not been established because of insufficient data.

A review of published and publicly available information provides very little guidance in terms of the correlation between air leakage stated as part of the product labelling and the field performance of the same products. A few experts that we contacted were unaware of any recent studies in this regard. One expert suggested that, if such information is available, it would not readily be made public.

To find any study coming close to providing any correlation one has to go back to 1979, Weidt et al (1979) and Weidt et al (1980). These two studies are based on the same piece of work which was undertaken for the Lawrence Berkeley Laboratory and where the air-leakage characteristics of 192 newly installed windows in residential buildings were compared to the industry and government standards and manufacturer's reports. The main result of the study was that the air leakage of newly installed windows can be significantly higher

that might be expected from laboratory tests. The report indicates that the main determinant of the difference between field results and the specified results were the type of window operation (i.e. casement) had the least variation, sliders had moderate variation and hung windows had the most variation.

It appears that the concern about the variations between the laboratory tested values and field performance drove the study in 1979. According to Weidt et al (1980) "designers and builders who specify and purchase windows frequently assume that these laboratory test results are indicative of these laboratory test results are indicative of the window's field performance capabilities and make their selections accordingly". This is similar to concerns today which have driven the refinements of AAMA 502. Yet there are no modern studies providing similar comparisons as this study done in 1979.

The findings of the Weidt study are startling. They reported that 40% of all windows tested possessed air leakage higher than industry and government standards and 60% of the windows tested exceeded the specification of the manufacturers. Further breaking down by window operation the study found that the proportion by which the field tested values were higher than the manufacturers values were as follows: casement – 33%, double slider – 70%, double hung – 79%, single slider – 84% and single hung – 100%.

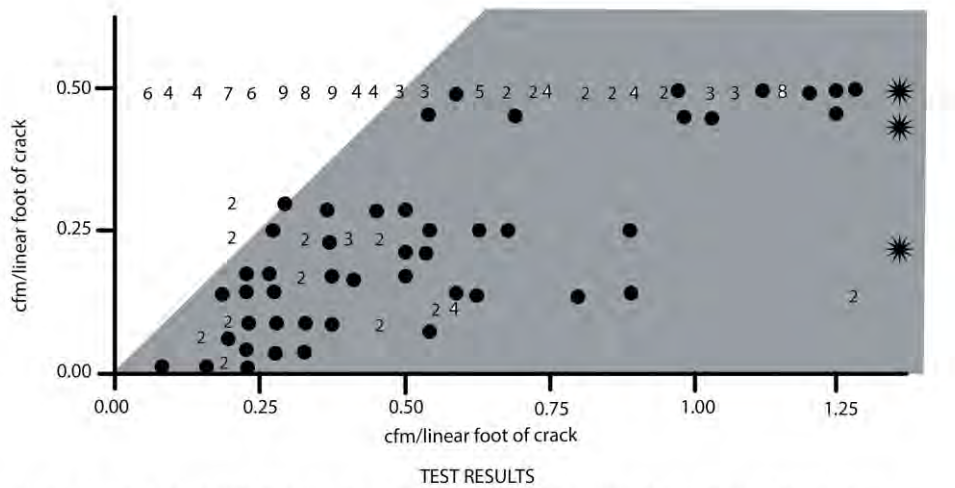
The study also compared air leakage characteristics of 25 windows from the time they were manufactured to the time they were installed in the field. The decline in performance was noted to be 29%.

In comparing the results from windows of different manufacturers and also results of windows installed by different installers the study noted some impact of these variables but not as great as the operation type.

Three defects that appeared to be contributing to the higher leakage rates were: weather-stripping discontinuity, fitting of the sashes and hardware seal.

Interestingly enough the study found that the method of report air leakage (as crack length, as area of window and as area of room) made a difference between the type of window which performed better between the double and the single operating windows.

The most important aspect of this study is that the results provide statistics in terms of means and standard deviations. There are two graphs from the study that are worth sharing in this paper. Figure 1 shows a scatter plot indicating for each of the window tested the extent to which the field measurements were different than the manufacturer's specifications. The results that fall on the right side of the line at 45 degree from the origin indicate tests where the measured values were more than manufacturer's specifications. Figure 2 provides the mean, range and the standard deviation of the measured values by different window operation types.



TEST RESULTS

Results of each test are plotted relating their field test performance to manufacturer's specifications. Each number indicated that more than one result occurred at a given point. As an example, a point occurring at X=.75, Y=.25 means that the window's manufacturer reported a lab test at .25, the field-measured leakage of the unit was .75. points within the grey area related to windows whose field air leakage were greater than reference. The ✷ designate outliers.

Figure 1: Weidt (1979) – Variation between field test performance and manufacturer's specification

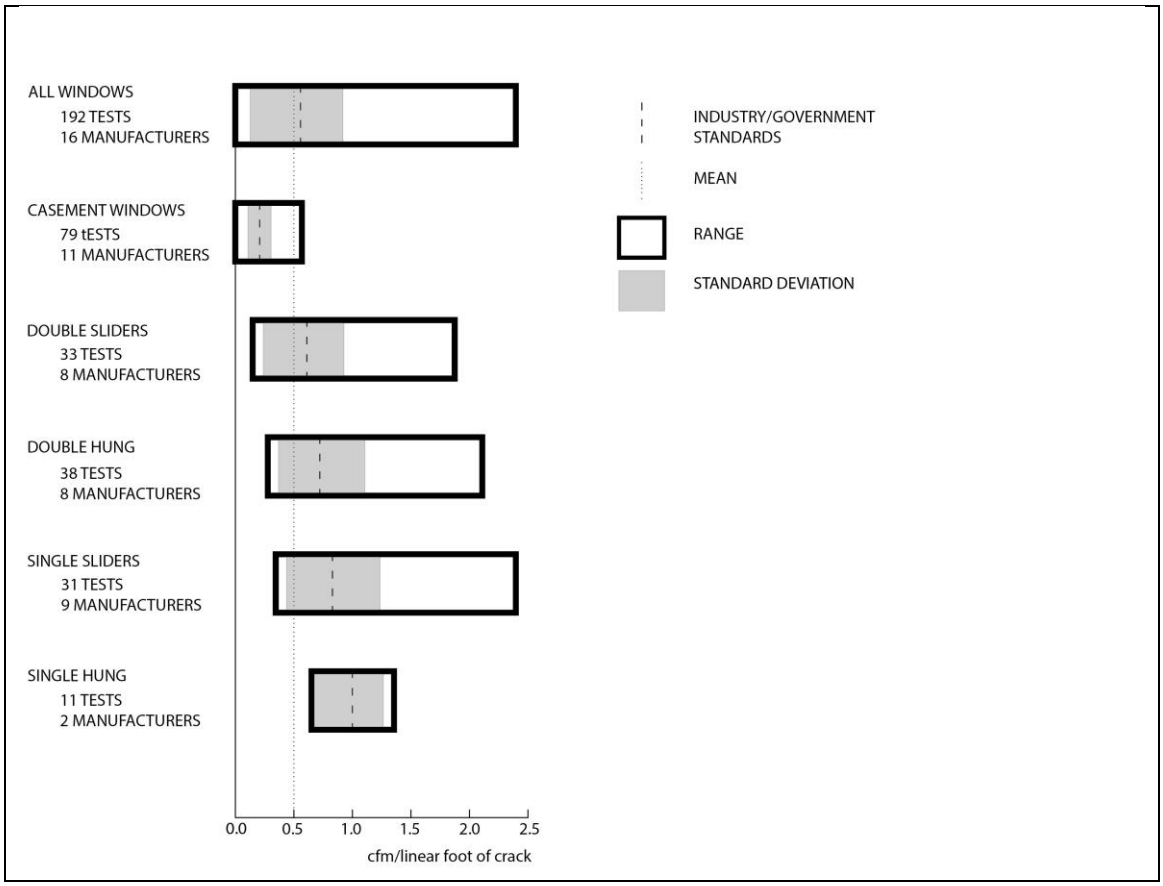


Figure 2: Weidt (1979) – Distribution of variations in field air leakage by window type

The Importance of Air Leakage on Building Performance

There exists a significant body of work related to air leakage characteristics of whole buildings. In particular the energy loss through infiltration has shown to be excessive. Orme (2001) developed a methodology to determine a high-level impact of air change related energy used for buildings in 13 countries. The paper estimates that air change is estimated to amount to 53% of delivered space conditioning energy use. Air changes occurs through intended ventilation and unintended ventilation. The 53% accounts for intentional and unintentional air changes. But the study provides a level of magnitude saving that may be possible through controlling air changes in buildings.

Woods et. al (1995) report savings of 12% on cost basis following measures which include improvements of air tightness of windows and doors in two high rise apartment buildings.

Alfano et al (2016) report on the results of window retrofit on air-tightness on older building. This recent paper provides a good overview of the various issues involved with air leakage and energy in buildings. They indicate that at EU policy level improving building air-tightness is crucial issue. Yet there are major differences in the way the issue is taken into account. They also point to the importance of air-tightness on the Indoor Environmental Quality and the design of mechanical ventilation system.

Waite et al. (2009) did a review of literature to determine the extent of whole-building air infiltration. They determined that for energy modelling purposes a high value of 7.9 L/s·m^2 was appropriate with a similar low value of 0.76 L/s m^2. They then used the range of values and modelled the impact of the different air leakage rates on a building located in Miami, Las Vegas and Chicago. They also compared the reduction in air leakage strategy to improvements in SHGC, improvements in R value of roof and improvements in R value of the wall. Their results indicate that improvements in air leakage rate from 7.9 L/s m2 had a greater impact on energy reduction than other measures. In heating dominated climate of Chicago the reduction in air leakage provide a benefit of 5.3% for moderately tight condition to 9.4% for very tight condition.

Most studies that focus on the benefits of improving the air-tightness of buildings examine it from a whole-building perspective. In high-rise apartment buildings where operable fenestration is a norm, the air leakage characteristics of the fenestration can form a substantial portion of the whole-building air leakage. It is therefore important that designers particularly in such buildings are aware about the differences between the specified air leakage values and the field tested air leakage values.

Some Thoughts from the Literature Review

The energy implications of air leakage from the point of view of whole building have been of interest. As one of the studies indicated, the implications if reducing air leakage can be as significant as improving R values in roofs or walls or improving SHGC. As we improve the air tightness of buildings and with energy recovery from ventilated air, the air leakage characteristics of operable fenestration products will become relatively more important. The values of air leakage specified in the certification process need to reflect in some form the air leakage values achieved after installation. Recent changes to field testing standards such as AAMA 502 appear to deal with this issue. However we still do not know the level of variation, statistically speaking, in the field-installed window. Although the Weidt (1979) study is decades old it did show that variations can be significant. Some of these variations may be reduced by better quality control during manufacturing and more care during installation. However, without undertaking a study on such variations

it may be viewed as mere speculation.

DESCRIPTION OF THE METHOD

Selection of Building for Field Testing[1]

A building under construction was selected for the field testing of air leakage of the fenestration product. The building is located in a built-up-area of Toronto, Ontario, Canada. The exterior envelope of the building had been constructed and the interior finishes were constructed to varying degrees. The building HVAC system was not operational. The building is over 60 storeys and is typical of condominium buildings being constructed in Toronto at the time of this study – its exterior envelope uses window-wall construction, and the structure is cast-in-place concrete with unenclosed cantilevered balconies.

The choice of the building was predominantly dictated by the need to study fenestration that would not have been subjected to extended use, and the ability to get a sample size adequate for statistical purposes. The chosen building provided that opportunity.

Selection of Type of Fenestration for Testing

This building provided an opportunity to choose fixed windows, operable windows and sliding patio doors for testing. In this study sliding patio doors were chosen for testing predominantly because of the ease of access to the exterior side through the balcony. Such access would be necessary as part of the testing. The laboratory test results that formed the basis of the certification of the patio door and the details of the patio door were made available by the manufacturer.

Selection of Samples for Testing

From the architectural floor plans, the elevations, and the information provided in the fenestration shop drawings, it was determined that there were many different types of patio doors that had been used in the building. The samples to be tested were selected on a randomized basis. However, before a random selection could be made, it was necessary to identify all patio doors into their type categories. The shop drawings indicated the location of each window-wall type throughout the building. Each window-wall consisted of a combination of a fixed portion, an operable window portion and in balcony locations a patio door. One type of patio door – which will be called Type I in this study – was chosen to be studied. The drawings indicated that there were 460 Type I sliding doors on this project. All these Type I doors were categorized under the same classification in terms of their air-leakage characteristics. A further examination revealed that Type I doors that were installed had two different heights. For the purpose of this study the population of the doors to be studied was based on them being the same height. There were 310 doors with the same height and same air-leakage characteristics that formed the final population for this study. The distribution of the doors by

[1] To maintain anonymity of the building and the fenestration product this paper uses generic information so as not to disclose the specific types while at the same time providing all the information that pertains to the technical aspects of the issues discussed

floors is shown in Table 1.

Table 1: Distribution of Type I Patio Doors by Floors – Total and Tested

Floor	Nos of Type I Patio Doors	
	Total	Tested
Podium	None	None
To 10th	24	0
11th – 15th	11	4
16th -20th	18	2
21st – 25th	26	3
26th – 30th	33	2
31st – 35th	27	2
36th – 40th	41	3
41st – 45th	22	1
46th – 50th	54	7
51st – 55th	33	5
55th and more	21	3
Total	**310**	**32**

For the purpose of this study a random sample from the total population 310 doors was taken. Each of the 310 doors was assigned a number and a random number generator was used to select the required numbered of doors to form the study sample.

Typically the size of the sample in such a study needs to be determined based on the level of confidence and the confidence interval desired from the expected results. It is assumed for this study that the air leakage of the doors would follow a normal distribution. In this particular instance, the variables that impact the air-leakage characteristics are the variations in the manufacturing process and the variations in the installation process. Variations related to degradation from use and environmental factors is minimal, as the doors are tested before they have been substantially used.

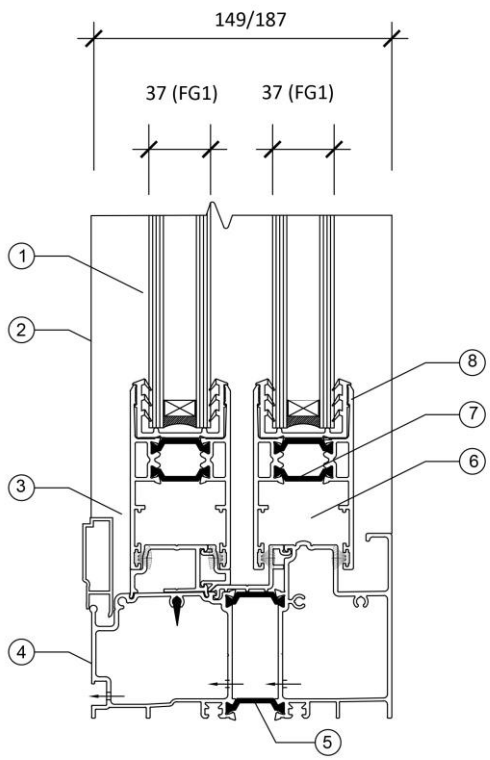
As was indicated earlier, there are no previous studies that provide an estimate of the variance to be expected in air leakage rates related to manufacturing and installation considerations. In order to get a reasonable sample size to allow use of normal probability distribution, a sample size of more than 30 was selected. For this sample size a 95% confidence interval would allow the use a z-value of 1.96. The air-leakage rate for this door based on laboratory testing is 0.5 $l/s/m^2$. It would be reasonable to expect low variability and therefore the standard deviation can be expected to be small. A sample size of 30 would be statistically adequate for a study to determine the mean that would be representative of the population with a confidence level of 95% with a standard deviation of 25% of the mean and the margin of error of 10%.

For this study, air leakage was measured for 32 patio doors. To allow for situations such as problems with access or other factors that would preclude a specific randomly selected door from being tested, a total of 40 doors were randomly chosen, of which 32 were tested.

Description of the Sliding Door

The description of the sliding door as stated in the laboratory test results is stated here. The installed door was the same as the laboratory door but with different dimensions.

The door is described as a thermally broken aluminum exterior sliding door set on a frame with a width from the inside to the outside of 149 mm (Figure 1). It has one fixed panel and one operable panel. It has a fiberglass fly screen in aluminum frame on rollers. The frame finish is anodized aluminum. The handle and locking hardware consists of a pull-handle on each side of the operable door, a single-point hook lock, and an interior lock. The overall door frame size of the laboratory-tested sample was 1830mm wide x 2260mm high. The operable and fixed panel were each 1716mm wide x 890mm high. The weatherstripping of polyester pile was used at all fixed and operable rails, at the operable-panel lock stile, and at the fixed and operable interlocks. Composite dust plugs were used at the end of interlock stile. All corners in the frame were square-cut and butted aluminum sealed with butyl tape and secured with long pan-head screws. All corners in the panels were mitered and sealed with sealant and secured with two aluminum corners and one plastic corner bracket.



1 – IGU, 2- Fly screen, 3 – Fixed panel, 4-Threshold, 5-Thernal break, 6- Roller, 7- Thermal break, 8-Sliding panel

Figure 3: Cross-section at the sill of the door assembly

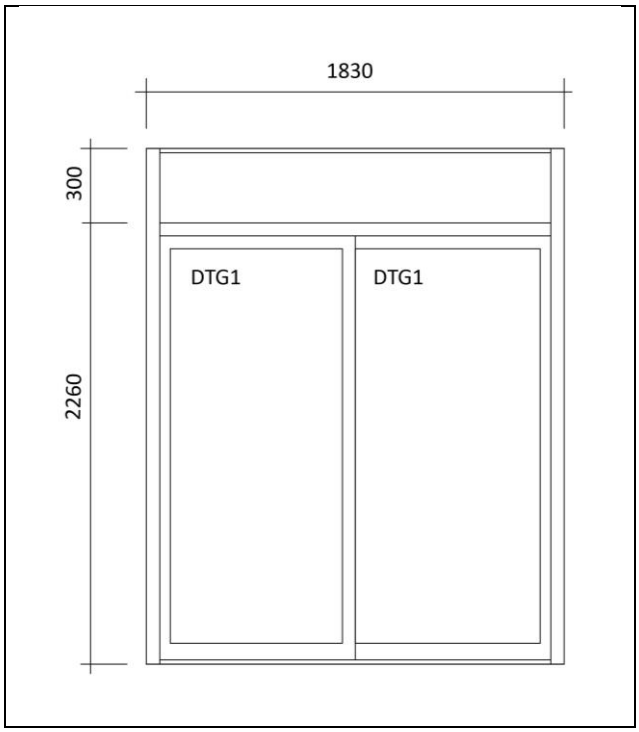


Figure 4: Elevation view of the door assembly

The air leakage reported in the laboratory test report was 0.5 l/s/m2 at 75Pa pressure difference in infiltration and exfiltration as tested in accordance with ASTM E283.

Field Air Leakage Testing

All the sliding doors that were tested for this study were done in accordance with ASTM E783. A calibrated Wind Maker Plus test kit was used to conduct the testing. Figures 1 to 3 show the test apparatus and a typical test assembly.

Figure 5: Typical test assembly

Figure 6: Wind Maker test equipment

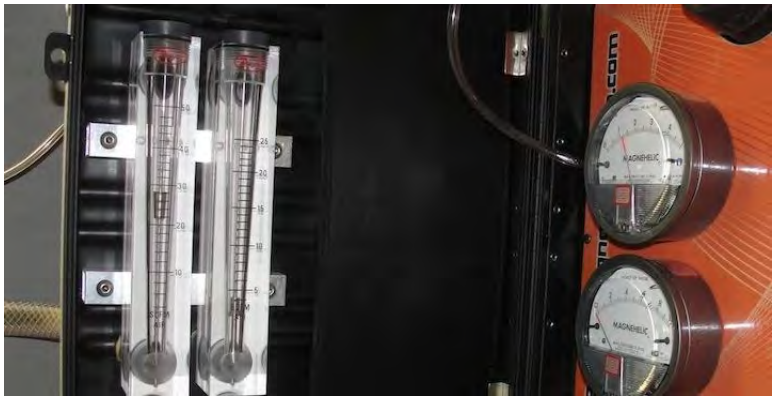


Figure 7: Air flow and Pressure measuring devices

In general the test procedure consisted of the following steps:

1) The patio door was examined from the inside and outside for signs of conditions that may impact air leakage measurements.

2) Ambient conditions of temperature and relative humidity were measured. Wind speeds were noted based on local weather reports.

3) A chamber was created on the interior using polyethylene sheets. The fan apparatus was connected to the chamber.

4) The exterior was isolated with polyethylene sheets taped to the frame.

5) The chamber was depressurized and infiltration was measured at 4 different pressure differences: 25, 50, 75 and 100 Pa. Visual observations using smoke pencils and infra-red thermographic camera were made to study paths of air leakage.

6) The exterior polyethylene sheet was removed and Step 5 was repeated.

The 32 tests were done over a period of 5 days. The weather conditions on these days varied widely. The results obtained from field tests were tabulated and corrections applied to bring the air-leakage measurements to 20º C.

RESULTS AND ANALYSIS

The measurements were made at 4 different pressure differences but this paper focuses on the measurements made at 75Pa, to allow direct comparison to the air-leakage rate as reported in the laboratory test. Further details about the procedures and results can be found in Pakzadianmoghaddam, N. (2017). A preliminary review of the 32 test results indicated that there were 2 outliers on the higher end and 4 outliers on the lower end of the air leakage test results. These were further removed from the analysis. The data collected on each date reflects environmental conditions similar for those dates and are shown in Table 2. The air leakage results of the remaining 26 tests organized by the dates on which they were done are shown in tables 3 to 6.

Table 2: Temperature and Wind Conditions During Testing

Date	Inside Temp. (°C)	Outside Temp. (°C)	Wind Dir - Speed Km/h
Nov. 19, 2016	12 to 15	**0.585**	**W – 20 to 26**
Dec. 1, 2016	7 to 8	**0.503**	**W – 24 to 38**
Dec. 3, 2016	5 to 13	**0.199**	**NW – 11 to 25**
Dec. 16, 2016	13	**0.714**	**W – 24 to 31**
Dec. 28, 2016	20	**0.293**	**W - 25**

Table 3: Air Leakage at 75 Pa – Nov. 19, 2016

Test Number	Level	Air leakage (L/s)/m²
1	47	**0.585**
2	46	**0.503**
3	43	**0.199**
4	20	**0.714**
5	17	**0.293**
6	14	**0.515**
7	14	**0.749**

Table 4: Air Leakage at 75 Pa – Dec. 1, 2016

Test Number	Level	Air leakage (L/s)/m²
8	**64**	0.775
9	**64**	0.521
10	**58**	0.407
11	**54**	0.604
12	**11**	0.654

Table 5: Air Leakage at 75 Pa – Dec. 3, 2016

Test Number	Level	Air leakage (L/s)/m²
14	**53**	0.483
15	**53**	0.894
17	**50**	1.112
18	**50**	0.592
20	**35**	0.423
21	**35**	0.604
22	**26**	0.785
23	**26**	0.846

Table 6: Air Leakage at 75 Pa – Dec. 16, 2016

Test Number	Level	Air leakage (L/s)/m²

25	**36**	0.130
26	**22**	0.526
27	**22**	0.886
28	**22**	1.155

Table 7: Air Leakage at 75 Pa – Dec. 28, 2016

Test Number	Level	Air leakage (L/s)/m²
31	**48**	0.904
32	**54**	0.628

Based on the 26 test results various statistical measures have been determined. A box plot showing the minimum value, the maximum value, the median and the interquartile ranges are shown in Figure 8. The frequency distribution of the air-leakage measurements using a bin interval of 0.25 L/s m^2 are shown in Figure 9. The median value is 0.604 L/s m2 with an interquartile range of 0.5 to 0.8 and the maximum and minimum values of 0.13 L/s m2 and 1.155 L/s m2 respectively.

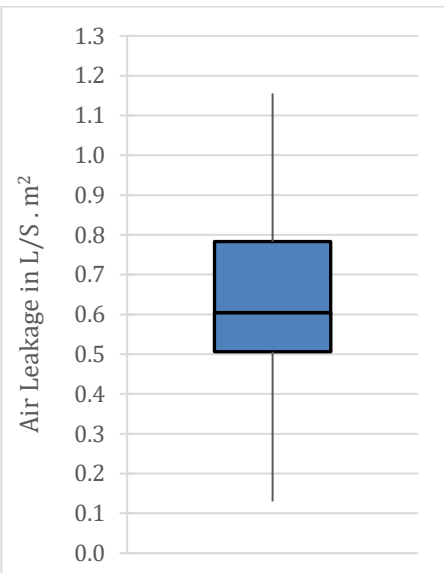


Figure 8: Box plot of Sample Air Leakage Rate

The air-leakage frequency based on a bin interval of 0.25 L/s m2 is shown in Figure 9. The mean air-leakage rate of the sample is 0.634 L/s m^2, and the standard deviation of the sample is 0.249 L/s m^2 based on 26 measurements. The distribution follows a normal Gaussian distribution.

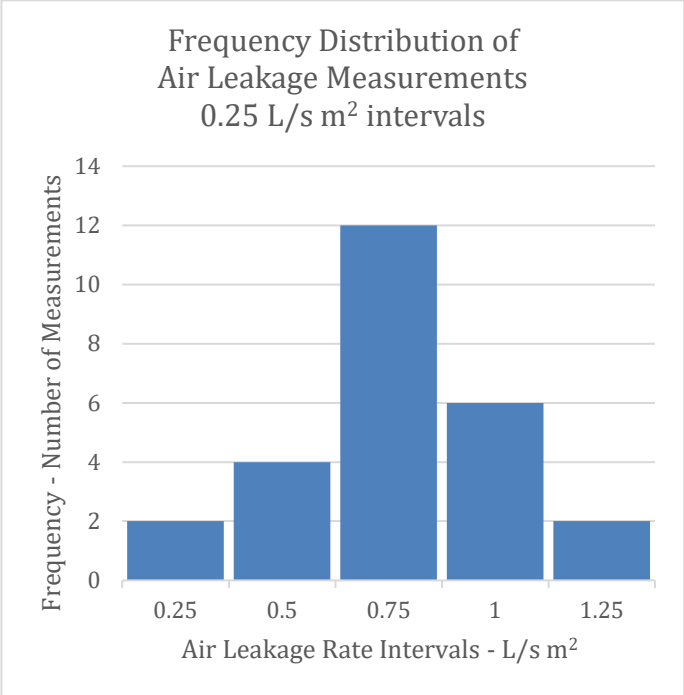


Figure 9: Frequency Distribution of Air Leakage Measurements

A summary of the various air leakage rates that can be used for comparison are listed in Table 8. The air-leakage rates stipulated in A440.4-07, Table D3 for sliding doors have been used. The values in A440.4-07 are not provided in a manner that are consistent with present standards and the rates shown in Table 8 had to be normalized to the area of the door from the crack length.

Table 8: Air Leakage Rates for Comparative Analysis

Source	Air leakage (L/s)/m²
Laboratory Tested Value Used for Certification1	**0.500**
Mean of Field Tested Value	**0.634**
Median of Field Tested Value	**0.604**
Minimum of Field Tested Value	**0.130**
Maximum of Field Tested Value	**1.155**
1.5 x Laboratory Value (AAMA 502 Allowable)	**0.750**
A440.4-07 Allowable – A1	**0.977**
A440.4-07 Allowable – A2	**0.577**
A440.4-07 Allowable – A3	**0.350**

In comparing the field-measured air-leakage rates with different benchmarks, it becomes evident that the comparison is not straightforward. For instance, in order to compare the field-measured values to the criteria set out by AAMA 502 or by A440.4-07, it is not clear if the average values should be used or that no field-measured value should be greater than the criteria stated in those standards. If the latter is the case then it will be seen that 20 out of 26 or approximately 77% of the tested product will not meet the laboratory measured result, and 8 out the 26, or about 31%, will not meet the AAMA 502 criteria based on the laboratory field result. Similar conclusions can be drawn about the allowable values for A2 and A3 rated doors in A440.4-07. Only with the A1 rated doors in A440.4-7 the results show that over 90% of the tested product will meet

the requirements. These results are similar to the results that reported in Weidt et al (1979) particularly for the products that were sliders. Another way to examine the data is the amount by which the measured values have exceeded the benchmarks. Comparing the field values of the product with the AAMA 502 benchmark it is noted that the highest value of 1.155 exceeds the AAMA 502 benchmark by 54%. The rationale for the benchmarks is not evident in any of the publicly available documents.

The dilemma that the scenario presents from a practical standpoint becomes evident in looking at the above discussion. However this is only one aspect of the issue. The bigger issue is that the measured values should follow a certain distribution. This should be expected in any measurement of such performance values. In this particular instance the measured values are distributed normally. In such a scenario the method of sampling becomes a very important aspect of choosing to do the field tests. AAMA 502 indicates that three tests are to be performed. It is possible that the samples selected for the 3 tests could be from the 79% that would have met the AAMA 502 benchmark. What would that result tell us about the acceptability of the fenestration product relative to the field testing? ASTM E783 provides some guidance in terms of sampling for field testing in this regard. It is recognized that practical and cost considerations often far outweigh the decisions regarding sample selection much more than the statistical nature of variation to be expected.

The bigger work upon (Pakzadianmoghaddam 2017) which the reported work is based examined the installation of the sliding doors and carried out additional testing using infra-red camera and smoke-pencil tests. From the testing conducted there, additional information is available about the reasons for the different air-leakage rates of the tested assembly. It was not the intention to report such reasons in this work. Such variations are considered as part of the random variations that are to be expected in any product and they have been treated as such in this paper.

CONCLUSION

The purpose of this paper was to examine the nature of differences between the air leakage determined in a laboratory condition to that measured in the field for the same product that is newly installed. The results indicate that in conducting tests based on random sampling the measured values will follow a distribution with a mean and a variance. In this particular case measurements made on sliding door indicate that the measurements follow a normal distribution. The mean value of the field measurements is higher than the laboratory measurements but are within the range of the AAMA 502 allowable values. However there are values that are greater than the allowable values. Based on this work it can be said that it is important to base the comparison of field and laboratory tested values on the recognition that these measurements will be based on some variations. The nature of such variations need to be further studied and taken into account when comparing field and laboratory values.

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