RETROFIT AND REMEDIAL WORK ON EXISTING SLIDING DOORS AND WINDOWS

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ABSTRACT

Aluminum sliding windows and doors help clad a significant proportion of the residential building stock in Canada. Since their appearance on the market in the 1950's, they gained in popularity and use due to their relative low cost, simple installation, and ease of maintenance. Deterioration of the original weatherstripping results in assemblies with poor air leakage performance and other incidental anomalies. Nationwide replacement of these windows and doors with more energy efficient models is a difficult and expensive undertaking.

It is the purpose of this study to analyse the alternatives which can be used to upgrade these windows rather than to completely replace them. By simply changing or replacing certain components, it was found that significant improvements could be achieved to the air leakage resistance of these units. Most of these upgrades, such as changing deteriorated weatherstripping gaskets with more efficient models, are relatively simple tasks which could be carried out by a building superintendent with some special training. The modified or upgraded doors and windows could thus obtain air leakage performance comparable to new windows on the market today. The costs associated with the implementation of such modifications are considerably less than those expected for complete replacement.

EXECUTIVE SUMMARY

Introduction

In the course of numerous years of building evaluations and testing, our team has identified air and water infiltration through the exterior envelope of buildings as a serious problem affecting a large proportion of the country's building stock. The situation is even more evident if one considers the slider type windows and doors, which attained the height of their popularity in the 1960's and 1970's. Today, due primarily to the deterioration of certain components, these units do not respond to the performance requirements related to air infiltration contained in the 1995 National Building Code. Replacement of these windows and doors would represent an onerous cost to the home and building owners affected. It is the goal of this study to suggest retrofit solutions which could be used to improve the performance of existing sliding window and door units at a reduced cost when compared to the costs of total replacement.

Case Study Buildings

Five subject buildings constructed between 1964 and 1975 were chosen, and tests were conducted to evaluate the window performance both before and after the suggested retrofitting. The test subjects chosen are typical of a large number of residential buildings built in Canada during that time period. In all cases testing was carried out in accordance to the standard test procedure ASTM E 783 "Field measurement of air leakage through installed exterior windows and doors".

Test Methodology

Typically tests were conducted on windows of the double slider type. These are composed of two pairs of single-pane glass units held in a gasketed aluminum frame. The sashes typically ride on an aluminum track and have weatherstripping gaskets on all sides as well as on the meeting rails. In some cases the upper track is of the "floating" type and is held snug to the top of the slider unit by means of a foam gasket. The aluminum tracks are in turn fastened to a wooden frame which is trimmed out on the inside and either painted or clad in aluminum on the outside. Test results without modifications indicated an infiltration rate of between 0.58 cfm/ft and 0.85 cfm/ft.

The following modifications were carried out to each of the test windows:

1. All the weatherstripping located on the rails, top and bottom of the **inside sashes**, as well as the meeting rails and jamb tracks were replaced with high efficiency flanged weatherstripping models permitting a more efficient seal.
2. Where applicable, the foam gasket compressing the top track was replaced with a plastic-jacketed model permitting a more efficient seal at the top of each window as well as long term durability, something that was lacking in the original gasket.
3. A caulking seal was applied to the exterior side of the interior tracks. This was done to reduce any infiltration between the wooden frame and the aluminum tracks and jamb. The exterior sashes were not caulked nor was the weatherstripping modified so as to take advantage of the rain-screen principle and have a beneficial impact on the problem of condensation formation on the outer sashes.

The time required to modify each window was between 45 and 60 minutes. In some cases this time could be further reduced with efficiencies of scale.

The infiltration rates obtained from tests after the modifications were carried out varied between 0.12 and 0.27 cfm/ft. This represents a decrease in air leakage of between 54% to 83%. The results obtained after the modifications indicate that the test windows could qualify as A-2 rated windows based on CSA standard A-440.

Cost comparison

A simple cost analysis was carried out to compare the costs of complete window replacement versus simple retrofitting. It was found that the retrofit would cost approximately $ 110.00 to $ 130.00 for an average-sized window. Total replacement of the same unit would run between $ 900.00 to $ 1,000.00.

In a typical scenario where an apartment building has 500 windows, the cost of replacement would be $ 475,000.00. Retrofitting these same windows using the methods described in this report would cost less than $ 76,000.00. This retrofit would not only include weatherstripping replacement, but also the replacement, as needed, of plastic flashing, glazing splines, broken glass, sill tracks, and pressure head foam on the outside slider. As such retrofitting can be accomplished for less than 20% of the cost of complete replacement.

Conclusions

The results of the testing described above demonstrate that the proposed retrofit method can not only modify the performance of existing windows and doors at a fraction of the cost of replacing them with new units, but that the results obtained for air leakage are equivalent to the performance of new slider units on the market today. The relative ease with which these modifications can be carried out, as well as the savings in energy costs which can be realized, leads to the conclusion that this retrofit procedure is a valid and viable alternative to complete replacement.

RÉSUMÉ

Introduction

À l'issue de nombreuses années d'évaluation et de mise à l'essai de bâtiments, notre équipe a déterminé que l'infiltration d'air et d'eau par l'enveloppe extérieure est un problème qui touche à une grande proportion du parc de bâtiments au pays. Ceci est encore plus vrai quand il s'agit des portes et fenêtres coulissantes, qui ont été surtout populaires au cours des années soixante et soixante-dix. En raison principalement de la détérioration de certains composants, ces unités ne répondent pas aux normes actuelles de rendement en matière d'infiltration d'air décrites dans le *Code national du bâtiment 1995*. Le remplacement de ces portes et fenêtres représenterait un coût très élevé pour les propriétaires des habitations et immeubles touchés. Cette étude vise à suggérer des solutions afin d'améliorer le rendement des fenêtres et portes coulissantes à un coût moindre que le coût total de remplacement.

Étude de cas

Des essais en vue d'évaluer le rendement des fenêtres avant et après amélioration ont été effectués sur cinq bâtiments construits entre 1964 et 1975. Ces bâtiments ont été choisis parce qu'ils sont caractéristiques d'un grand nombre d'immeubles résidentiels construits au Canada au cours de cette période. Tous les essais ont été effectués conformément à la procédure d'essai normalisé décrite dans la norme ASTM E 783 *"Field measurement of air leakage through installed exterior windows and doors"*.

Méthode d'essai

Typiquement, les essais ont été effectués sur des fenêtres à double coulisse. Ces fenêtres se composent de deux paires de volets à vitrage simple retenus dans un cadre en aluminium avec joint d'étanchéité. Les châssis coulissent habituellement sur un rail en aluminium; les quatre côtés et la traverse sont munis d'un coupe-froid. Dans certains cas, le rail supérieur est « flottant » et est ajusté dans la coulisse supérieure à l'aide d'une garniture de mousse. Les rails en aluminium sont fixés à un cadre en bois; la face intérieure est dégrossie et la face extérieure est peinte ou plaquée d'aluminium. Les résultats des essais (sans modifications) révèlent une infiltration d'air variant de 0,58 pi^3/mn/pi. à 0,85 pi^3/mn/pi.

Les modifications suivantes ont été apportées à chacune des fenêtres au banc d'essai :

1. Tous les coupe-froid apposés sur les rails, sur les parties supérieure et inférieure des châssis intérieurs, ainsi que sur les traverses et les montants, ont été remplacés par des modèles ailés à haut rendement qui assurent une meilleure étanchéité.

2. Dans certains cas, la garniture de mousse comprimant le rail supérieur a été remplacée par un modèle revêtu d'une gaine plastifiée. Ce modèle est plus étanche et aussi plus durable à long terme, ce qui n'était pas le cas du joint original.

3. Du mastic de calfeutrage a été appliqué le long de la face extérieure des rails intérieurs afin de réduire les fuites d'air entre le cadre de bois et les rails et montants d'aluminium. Nous n'avons pas calfeutré les châssis extérieurs ni remplacé les coupe-froid afin de tirer avantage du principe de l'écran pare-pluie et de résoudre en partie le problème de la formation de condensation sur les châssis extérieurs.

Pour chaque fenêtre, il a fallu entre 45 et 60 minutes pour apporter les modifications. Dans certains cas, on pourrait réduire ce temps davantage grâce à une efficacité d'échelle.

Le taux d'infiltration mesuré lors des essais effectués sur les fenêtres modifiées variait entre 0,12 et 0,27 pi^3/mn/pi, soit une réduction de 54 % à 83 % des fuites d'air. Les résultats obtenus après modification démontrent que les fenêtres au banc d'essai répondraient aux exigences des fenêtres de type A-2 selon la norme A-440 de la CSA.

Comparaison des coûts

Nous avons comparé le coût de revient du remplacement complet de fenêtres et de leur amélioration par la méthode à l'essai. Nous avons découvert que l'amélioration d'une fenêtre de taille moyenne selon la méthode à l'essai coûterait entre 110,00 $ et 130,00 $. Le remplacement complet de la même unité varierait de 900,00 $ à 1 000,00 $.

Pour un immeuble typique comportant 500 fenêtres, le coût de remplacement s'élèverait à 475 000,00 $. L'amélioration de ces mêmes fenêtres par la méthode décrite dans le présent rapport coûterait moins de 76 000,00 $. Cette amélioration comprendrait non seulement le remplacement des coupe-froid mais aussi le remplacement, au besoin, des solins en plastique, languettes de vinyle, vitres brisées, allèges et garnitures de mousse sur les rails extérieurs. Ces améliorations peuvent être apportées pour moins de 20 % du coût du prix du remplacement complet de la fenêtre.

Conclusion

Les résultats des tests décrits auparavant démontrent que la méthode proposée permet d'améliorer le rendement énergétique de portes et fenêtres existantes à une fraction de ce qu'il en coûterait pour les remplacer par des unités neuves. De plus, le volume d'air infiltré mesuré sur les fenêtres améliorées équivaut à celui de nouvelles fenêtres coulissantes que l'on retrouve sur le marché aujourd'hui. Étant donné que ces fenêtres peuvent être améliorées assez facilement et que ces améliorations peuvent réduire substantiellement les coûts d'énergie, nous en concluons que cette méthode d'amélioration est valable et constitue une solution viable au remplacement complet de fenêtres.

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1. INTRODUCTION

In the past 25 years an overwhelming majority of the housing stock built in Canada has made use of sliding doors and windows. Their popularity can be attributed to a number of factors not the least of which is their low initial cost. Since they did not require specialized manpower for their installation, construction labour rates were also lower with these types of units in that they were installed by carpenters working for general contractors.

Added to the economic savings are some practical reasons for their success. They are relatively easy to clean, requiring no outside access. In addition, maintenance is comparatively simple, as aluminum is extremely stable and very resistant to the elements. Glass breakage repair is also easily dealt with usually requiring nothing more than a trip to a local hardware store. Aluminum sliders do not infringe on either outdoor or indoor space during operation, and large areas of their surface can be devoted to ventilation or egress. Finally, given the high strength characteristics of aluminum, relatively large areas of the window opening can allow unobstructed light passage.

Despite these benefits, aluminum slider doors and windows installed during the 1950's, 60's, and 70's are energy inefficient when compared to the requirements of current Canadian standards and the 1995 edition of the National Building Code. A large component of this inefficiency derives from the poor performance of aluminum sliders in terms of air leakage and deterioration of weatherstripping. Our experience has also shown that this leakage is one of the most common problems affecting building envelopes and their long term durability. In addition, deterioration of other components combined with some awkward geometric proportions have caused problems with ease of operation of these systems.

Faced with these problems, many owners have opted for replacement of the older units with newer, more efficient models. The systematic replacement of deficient units throughout the nationwide housing stock represents capital expenditures which are economically unfeasible and not justified in terms of energy savings alone. However, an increase in performance as a result of retrofit measures constitutes a highly effective means to correct these deficiencies. This report focuses on the development, testing, analysis, and evaluation of such measures.

2. OBJECTIVES AND SCOPE OF WORK

The research project described in this report is aimed at the development of practical solutions to the problems associated with the typically reduced performance of existing sliding windows and doors in terms of weather tightness, due mainly to the wearing of components and materials. Performance data on existing assemblies was accumulated in order to quantify the impact of the observed deficiencies as well as to determine the anticipated benefit of upgrading the air and water tightness of the window units.

The study concentrates on the technical feasibility of the suggested upgrades and the development of techniques capable of achieving the desired results. The market was reviewed in search of products which could be used in the development of strategies as well.

In general, building owners and professionals have little practical information available to aid them in the selection of products and strategies that can be used in retrofitting housing or high-rise buildings. Information on the performance and durability of these products is also lacking. This research project includes an analysis of the field test results of existing conditions and selected strategies. These are presented in a form which designers, owners, and contractors can use to assist them in evaluating the performance of these products.

3. PROJECT METHODOLOGY

The research plan consisted of the following elements:

3.1 Documentation Search:

A documentation search for pertinent references, technologies, and products was carried out and we reviewed research papers, reference literature, the Internet, as well as construction industry databases.

Very little information relating to aluminum door and window energy retrofitting was found. A search through the Internet using a variety of search engines and key words also turned up little of value. Window manufacturers who were contacted were able to offer little help for the problems associated with older units. However, specialized repair contractors revealed possible opportunities for the retrofit of sliding windows.

3.2 Case Study Selection:

In order to gain an overview of the typical conditions and products found in existing structures, a study group of buildings was identified and examined in order to establish the most relevant detailed terms of reference for the ensuing research. Medium to high-rise applications in buildings of 8 or more storeys in height, built between the late 1950's and the mid 1970's were targeted. All buildings were located in the Montreal area for ease of testing, however they represent units typical of stock found throughout the country.

The buildings chosen include:

a) L'Emminence Apartment Building
Year of Construction: 1972
Test date: October 3, 1997

b) La Cité Apartments
Year of Construction: 1975
Test date: August 5, 1997

c) 5150 McDonald Ave. Apartment Building
Year of Construction: 1972
Test date: July 22, 1997

d) St-Georges Convalescent Home
Year of Construction: 1964
Test date: July 29, 1997

e) Le Riviera Apartment Building
Year of Construction: 1967
Test date: June 12, 1997

The windows studied in each of these buildings were chosen randomly. See Appendix B for photographs of test windows.

3.3 Review of Existing Products and Design:

Manufacturers and specialized repair contractors were consulted to determine which existing products could be used in the retrofit of the sliding doors and windows.

At the Design stage, based on the objectives established, a process was undertaken to devise pragmatic remedial strategies that involved the use of currently available products as well as implementation methods and site procedures.

Since all the windows studied were of the double slider type, and in order to take advantage of the pressure equalization principle, most efforts were concentrated on the inner pair of sliders, the goal being to ensure that the inner pair of sashes were more airtight than their outer equivalents. In this way water penetration resistance could be enhanced. Similarly, the typical problem of condensation formation on the inside face of the outer pane would be reduced as well.

The following modifications were implemented in order to increase air tightness and not compromise the window's resistance to water infiltration (i.e. maintain pressure equalization). In general, these modifications consisted of the following:

Weatherstripping: The existing weatherstripping at the window jamb tracks and sash sill, head and meeting rails (interior side) were removed and replaced by a High-Fin weatherstripping.
Pressure head: The existing foam at the pressure head (interior side) was removed and replaced by a new foam wrapped in a polyethylene film.
Miscellaneous: A sealant joint was applied around the outside perimeter of the interior tracks. Pieces of foam tape were installed at the top and bottom of the interior jamb tracks, and dust plugs installed at the meeting rail locations on the interior head and sill tracks .

For more information regarding the actual products used in the retrofitting process as well as sections across a typical window unit, please refer to Appendices A and C respectively.

3.4 Other Improvement Considerations and Testing

Other considerations such as ease of operation and maintenance items should also be reviewed when upgrading the windows' performance to air leakage. The following is a summary list of some of the types of considerations:

- Replacement of the foam in the pressure heads on the exterior side where deteriorated. This will prevent the sashes from falling off the track, reduce rattling noises due to wind and improve the ease of operation.

- Replacement of worn plastic gliders at the top and bottom of the sashes improving ease of operation.
- Replacement of broken, cracked and deteriorated plastic flashing at the window sill.
- Where water infiltration has been reported and it is observed that inverted slopes exist at the window sill, the wood sill could be planed or replaced to provide proper slope to the exterior.
- Where deteriorated, the existing vinyl glazing splines around the sashes could be replaced. As required, broken glass should be replaced.
- The tracks should be cleaned of debris, adjusted, and lubricated to ensure proper operation.
- Where deteriorated, the aluminium sill tracks could be replaced.

3.5 In-situ Testing of Typical Specimens

In order to quantify and qualify the problems of air tightness and rain penetration in typical doors and windows under actual exposure conditions, a specimen in each of the buildings was selected for in-situ testing. The testing method is described in further detail in the Analysis and Test results section of this report. The specimens were retrofitted and tests were then repeated in order to quantify the performance upgrade. The feasibility of their implementation was also evaluated. Samples of the materials used to retrofit the test units are included in Volume 2.

4. ANALYSIS AND TEST RESULTS

The air infiltration tests were conducted in accordance with the ASTM E-783 test method entitled "Standard Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors". The tests were conducted using a portable Air Leakage Test Apparatus. The apparatus is composed of an exhaust blower, a control valve, flow meters, a differential manometer and a test chamber composed of polyethylene film and retaining bars attached to the interior side of the window frame. The results of these tests record the amount of air leakage across the window specimen at a test pressure differential of 75 Pa representing a wind speed of 40 kph (25 mph).

Following these tests, the windows were modified and repaired in an attempt to improve their performance and reduce the amount of air leakage. Once the repairs were completed, the windows were retested in order to determine the improvement in air leakage performance and to compare the results with those for the windows in their original state.

The test results are summarized in table 1.0 which follows. The complete test results are included in data sheets for each case building in Appendix A.

Table 1.0 - Comparison of Air infiltration Rates

Test Specimen location	Air infiltration before modification	Air infiltration after modification	% Reduction of air infiltration
L'Emminence	0.58 cfm/ft. *	0.27 cfm/ft.	54 %
La Cité	0.73 cfm/ft.	0.22 cfm/ft.	70 %
5150 McDonald Av.	0.73 cfm/ft.	0.23 cfm/ft.	68 %
St-Georges Hospital	0.73 cfm/ft.	0.12 cfm/ft.	83 %
Le Riviera	0.85 cfm/ft.	0.26 cfm/ft.	69 %
AVERAGE	**0.72 cfm/ft.**	**0.22 cfm/ft.**	**69 %**

* : Note that the foam at the window head of this specimen had been recently replaced. This may account for the relatively lower air infiltration reading observed prior to the modifications.

In general, the results demonstrate an average reduction in air leakage in the order of 54% to 83%. For an indication of the window rating, the CAN/CSA-A440 window standard for new windows provides the following classification:

Table 2.0 - Window Rating and Air Leakage

Window Rating (Air Tightness)	Maximum air leakage rate cfm/ft.
A1	0.5
A2	0.3
A3	0.1

If we compare the test results to this table, the existing windows, when tested without modification, have an average air leakage rate of 46% to 70% in excess of the minimum A1 rating. These same windows, when modified and repaired, met not only the A1 rating, but the stricter A2 rating as well. In terms of air leakage, the retrofitted windows are equivalent to many new units on the market today presently. It is important to note that the results and the improvement potential may vary depending on the quality of the original installation and the present state of deterioration.

4.1 Cost Estimates

From an energy savings and performance point of view, replacement of the existing weatherstripping with a new high performance weatherstripping is a very cost effective alternative to complete window replacement. A relatively short payback period in energy savings, an improvement in occupant comfort and a reduction in the formation of condensation on the exterior sashes are all attainable with a weatherstripping replacement and window retrofit option. However, as the windows continue to age, in the long term, window replacement may still be required. Also, aesthetical, functional and increased property value considerations are not taken into account with the weatherstripping replacement option. However, with regards to energy savings and the performance aspect, a much longer payback period can be expected with window replacement if these criterion are used as primary issues for evaluation purposes.

These other aspects all need to be taken into consideration prior to making an informed decision as to whether to proceed with a retrofit or a complete window replacement programme.

A cost estimate for both window retrofit and complete window replacement was prepared for discussion purposes. In order to compare the different options, we recommend that the costs associated with each approach be weighed against the different advantages and disadvantages. Furthermore, specific needs and objectives may need to be clearly identified and further evaluated.

4.1.1 Window Retrofit

The window retrofit option would normally include the following:

- Replacement of the existing weatherstripping at the window jamb tracks, bottom, top and meeting rails (interior side).
- Replacement of the existing foam at the pressure head (interior side) with a new foam wrapped in polyethylene film.
- Installation of dust plugs at the head and sill tracks (interior side), foam tape at the jamb corners (interior side) and a sealant joint around the outside perimeter of the interior track.
- Replacement of the plastic gliders at the top and bottom of the interior sashes, adjustment and verification of operation.
- Cleaning, adjusting and lubricating sill tracks.

In addition, it is recommend the following be considered where required:

- Replacement of the foam in the pressure heads on the exterior side where deteriorated. This will prevent the sashes from falling off the track, reduce rattling noises due to wind and improve the ease of operation.
- Replacement of broken, cracked and deteriorated plastic flashing at the window sill.
- Replacement of existing glazing spline around the sashes where deteriorated.
- Replacement of broken glass.
- Replacement of sill tracks where required.
- Replacement of the plastic gliders, adjustment, and verification of operation for exterior sashes where required.
- Application of caulking between the frame and trim, as well as the trim and the interior wall. This would be an attempt to emulate the improvements derived by the use of sprayed foam insulation in the window replacement option.

The estimated cost associated with the different items, for budget and discussion purposes, can be summarized as follows:

1.	All work associated with weatherstripping replacement and adjustments.	\$ 110.^{00} - \$ 130.^{00}/wdw.
2.	Replacement of plastic flashing at window sill	\$ 18.^{00} - \$ 20.^{00}/wdw.
3.	Replacement of glazing spline	\$ 9.^{00} - \$ 12.^{00}/sash
4.	Replacement of pressure-head foam (exterior side)	\$ 10.^{00} - \$ 13.^{00}/wdw
5.	Replacement of broken glass	\$ 30.^{00} - \$ 45.^{00}/sash
6.	Replacement of sill track	\$ 25.^{00} - \$ 35.^{00}/track

4.1.2 Window Replacement

The window replacement option would normally include the following:

- Removal of existing windows, wood frame and interior mouldings ("brick to brick").
- Removal and cleaning of existing sealant from brick.
- Installation and adjustment of new windows.
- Installation of a polyurethane based sealant joint around the exterior perimeter of the windows.
- Installation of sprayed in-place polyurethane insulation around the interior perimeter of the windows.

The total estimated cost for this option would be as follows:

- 7 1/2" thermally broken aluminium framed slider type window with 4 single glazed sashes and fly screen between two sashes $ 900.^{00} - $ 1,000.^{00}/wdw.

Overall, the anticipated total costs associated with each approach can be estimated as follows. These figures are presented as general estimates and for discussion purposes we have assumed a total of 500 windows with specific assumptions or allowance for other work.

4.1.3 Window retrofit Cost

Weatherstripping replacement and adjustments	500 wdws. @ \$ 120.00/wdw. = \$60,000.00
Replacement of plastic flashing at window sill (estimate 25% of the windows).	125 wdws. @ \$ 19.00/wdw. = \$2,375.00
Replacement of glazing spline (estimate 25% of the windows for four sashes)	625 sashes @ \$ 11.00/sash = \$ 6,875.00
Replacement of broken glass (estimate 15% of the windows for one sash)	75 sashes @ \$ 40.00/sash = \$ 3,000.00
Replacement of sill track (estimate 15% of the windows)	75 tracks @ \$ 30.00/track = \$ 2,250.00
Replacement of pressure-head foam on the exterior side (estimate 25% of the windows)	125 wdws. @ \$ 11.00/wdw = \$ 1,375.00
	Estimated total cost \$75,875.00

It should be pointed out that the percentage estimates for various repairs have been arbitrarily assigned based on observations of the case study buildings. Nevertheless, the cost associated with such repairs represents less than 25% of the total repair cost.

4.1.4. Window Replacement Cost

Complete window replacement 500 wdws. @ $ 950.^{00}/wdw. = $475,000.^{00}

When comparing these estimates, window replacement is expected to cost approximately six times as much as window retrofit. It is important to keep in mind however that these costs do not take into account other considerations which can not be evaluated from a monetary point of view alone such as aesthetic and functional issues, as well as increased property value.

5. DISCUSSION

In the course of the field work and the identification of case study projects we were informed that the major complaints regarding the windows were air infiltration, condensation and ice build-up on exterior sashes, and water penetration. All three of these are inter-related and are further discussed below.

The formation of condensation and frost on the exterior sashes result from moist air exfiltration. In this regard, the moist air exfiltrates through the interior sashes and condenses (or freezes during colder exterior temperatures) on the inside face of the exterior sashes before it has the opportunity to exfiltrate or escape to the exterior. The phenomena occurs as a result of a net positive pressure across the envelope with respect to the exterior. Making the interior sashes more air tight will reduce the formation of condensation on the inside face of the exterior sashes. However, should the windows be improperly operated during the winter (i.e. occupants leave sashes open or improperly closed), condensation will continue to occur. Depending on a number of variables this normally occurs more frequently towards the top of the buildings during the winter due to stack effect.

It is important to note that the replacement of the weatherstripping will help reduce the formation of condensation, however, this also depends on a number of variables including the relative humidity maintained in the apartment, the proper operation of the windows, the exterior temperature, and the pressure difference across the envelope. These variables should be further reviewed on a case by case basis. For the new weatherstripping to perform as intended, the sashes with the new weatherstripping must remain on the inside and properly closed or engaged. In order to avoid interchanging of the sashes during window washing operations, identification markings or tags can be made to clearly identify the interior and exterior sashes.

Given the original geometric proportions and in some cases the deterioration of specific components, a problem of ease of operation could be present. From an ease of operation point of view, the existing sashes in the case of the study buildings are, in general, rather difficult to open, especially for elderly tenants. In order to improve the ease of operation, the window tracks were cleaned and treated with a silicone spray. However, in certain cases the tracks may have to be repaired or replaced as required. In addition, the interior jamb tracks could be pried apart slightly with a wood block wedge and the sashes adjusted, as required, with the plastic gliders on the bottom and top rail sashes replaced as necessary. It is important to note however, that the corrective work to the windows rendering them more air tight will by design tend to reduce the ease of operation to a certain degree. As such, for specific occupancies it may be necessary to purposely compromise, whereby some increased air leakage is tolerated in exchange for slightly improved ease of operation.

Given that the retrofit weatherstripping measures follow the intended original design for sliding window products, it is expected that deterioration due to exposure and repeated use (cycling) will cause increased air leakage requiring repeat retrofit at some point. Unfortunately, a review of available standards, testing procedures and information for weatherstripping products reveal a general absence of durability and life-cycle related data. Therefore, additional research and testing will be required in order to predict the expected durability of the retrofit products and measures.

In order to isolate the expected energy savings impact and evaluate the pay-back of the retrofit measures, it would be useful to review actual energy consumption records for a similar case study building (i.e. high-rise residential apartment) before and after implementation. This could be undertaken on a building which has had its windows retrofitted in the manner presented in this report, without having implemented any other energy sensitive repairs.

6. CONCLUSIONS AND RECOMMENDATIONS

This research has demonstrated that the retrofitting of aluminum sliding windows and doors using the described techniques is a viable alternative to window replacement in terms of air leakage control. The modification of existing units can be accomplished with less difficulty and may not necessarily require specialized labour. The work may be within the capabilities of some building managers, provided that some special training program is followed. Similarly, this type of modification also implies less inconvenience to the building's occupants.

A cost comparison between the retrofitting and complete replacement options reveals that total replacement costs approximately 6 times more. The implied savings when one considers the large stock of these types of doors and windows nationwide are considerable. It can be assumed that more owners and managers would opt for the modification option if reliable data was available to inform them. Presently, these decisions are being taken based primarily on factors such as aesthetics and resale value. Many owners simply do not know to what level window performance can be improved by retrofitting. It should be noted that air leakage rates were reduced by an average rate of 69% for the test windows modified in this study. It is also important to note that the results and improvement for other units will vary depending on the quality of the original installation and the state of deterioration.

While costs associated with replacement or modification of sliding doors and windows are relatively easy to determine, a comparison of energy cost savings possible through each option is more difficult. In the present case, air leakage performance was evaluated and factors affecting conductive and radiative heat loss, pressurization of the building, as well as the relative air leakage of the remaining assemblies have not been considered. Local climate, building geometry, window orientation, prevailing wind direction, as well as the energy costs in each region will impact the energy consumption. Further research is required before a detailed comparison can be undertaken. One method has already been discussed, whereby actual data from existing buildings could be analysed. Another element which would require further research concerns the durability of weatherstripping products. This is valid for both the retrofit and the replacement options. Furthermore, in some special circumstances, other considerations such as ease of operation may warrant a compromise in improvement.

It can however be stated that the relative ease and low cost with which retrofitting can be carried out, as well as the potential for savings in energy costs due to lower air leakage rates, leads to the conclusion that the procedure is a valid alternative to complete replacement.

APPENDIX A

TEST RESULT DATA SHEETS

Date: 1997-10-3

Project #: R-D-0102 A

Project name: L'EMMINENCE APARTMENT BUILDING

Apartment: 1403 Orientation: North-Est

Sample description:

Type of window: Slider

Dimension (lengh of crack):

Height: 49" Width: 72 1/2"

Type of weatherstripping:

Frame: sill: N/A Sash sill: Standard Pile

head: N/A Head: Standard Pile

jamb: Standard Pile Meeting rail: Standard Pile

Dust plug: Nylon block Jamb: N/A

Special notes: Foam at the window head was recently replaced.

Reading without modification: 0.58 CFM/ft (note reading with foam in-place)

Modifications:

Type of weatherstripping:

Frame: sill: N/A Sash sill: HF 7624 187

head: N/A Head: HF 7624 187

jamb: HF 7613 187 Meeting rail: HF 7624 187

Dust plug: ____ Jamb: N/A

Special notes: Sealant bead at the exterior perimeter of the interior frame was applied.

Reading with modification: 0.27 CFM/ft

Remarks:

Name: Gilbert Riopel

Date: 1997-08-05

Project #: RD-0102-A

Project name: LA CITÉ APARTMENTS

Apartment: 808, E Block   Orientation: East

Sample description:

Type of window: Slider

Dimension (lengh of crack):

Height: 62"   Width: 61"

Type of weatherstripping:

Frame: sill: N/A   Sash sill: Standard pile

head: N/A   Head: Standard pile

jamb: Rubber   Meeting rail: Standard pile

Dust plug: N/A   Jamb: N/A

Special notes:

Reading without modification: 0.73 CFM/F

Modifications:

Type of weatherstripping:

Frame: sill: N/A   Sash sill: HF 7612-187

head: N/A   Head: HF 7612-187

jamb: HF 7612-187   Meeting rail: HF 7612-187

Dust plug: DPAB-1062-2090FIN   Jamb: N/A

Special notes: Exterior sealant at the perimeter of the window was applied and the foam at the floating head was replaced.

Reading with modification: 0.22 CFM/F

Remarks:

Name: Gilbert Riopel

Date: 1997-07-22 Project #: RD-0102-A

Project name: 5150 McDonald Ave

Apartment: 1502 Orientation: East

Sample description:

Type of window: Slider

Dimension (lengh of crack):

Height: 47" Width: 39 1/2"

Type of weatherstripping:

Frame: sill: N/A Sash sill: Worn pile

head: N/A Head: Worn pile

jamb: Worn pile Meeting rail: Worn pile

Dust plug: N/A Jamb: N/A

Special notes: Worn pile without fin.

Reading without modification: 0.73 CFM/F

Modifications:

Type of weatherstripping:

Frame: sill: N/A Sash sill: HF 7624-187

head: N/A Head: HF 7624-187

jamb: HF 7613-187 Meeting rail: HF 7618-187

Dust plug: DPAB-1062-200FIN Jamb: N/A

Special notes: Neoprene blocks were placed at 4 corners sealant bead at the exterior perimeter of the interior frame was applied and the foam at floating head was replaced.

Reading with modification: 0.23 CFM/F

Remarks:

Name: Gilbert Riopel

Date: 1997-07-29 Project #: RD-0102-A

Project name: St-Georges Hospital

Apartment: 814 Orientation: West

Sample description:

Type of window: Slider

Dimension (lengh of crack):

Height: 48 1/4" Width: 64"

Type of weatherstripping:

Frame: sill: N/A Sash sill: Worn pile

head: N/A Head: Worn pile

jamb: Worn pile Meeting rail: Worn pile

Dust plug: N/A Jamb: N/A

Special notes: Worn pile without fin.

Reading without modification: 0.73 CFM/F

Modifications:

Type of weatherstripping:

Frame: sill: N/A Sash sill: HF 7620-187

head: N/A Head: HF 7620-187

jamb: HF 7611-187 Meeting rail: HF 7611-187

Dust plug: DPAB-1062-2090FIN Jamb: N/A

Special notes: Neoprene blocks were placed at 4 corners sealant bead at the exterior perimeter of the interior frame was applied and the foam at floating head was replaced.

Reading with modification: 0.12 CFM/F

Remarks:

Name: Gilbert Riopel

Date: 12-06-97 Project #: RD-0102-A

Project name: Le Rivièra

Apartment: 907 Orientation: South

Sample description:

Type of window: Slider

Dimension (lengh of crack):

Height: 46 1/2" Width: 48"

Type of weatherstripping:

Frame: sill: N/A Sash sill: Worn Pile

head: N/A Head: Worn Pile

jamb: Worn Pile Meeting rail: Worn Pile

Dust plug: N/A Jamb: N/A

Special notes:

Reading without modification: 0.85 CFM/ft

Modifications:

Type of weatherstripping:

Frame: sill: N/A Sash sill: HF-7615-187

head: N/A Head: HF-7615-187

jamb: HF-7615-187 Meeting rail: HF-7615-187

Dust plug: N/A Jamb: N/A

Special notes: Sealant bead at the exterior perimeter of the interior frame was applied, the foam urethane at floating head was replaced and neoprene blocks were placed at 4 coners.

Reading with modification: 0.26 CFM/ft

Remarks:

Name: Gilbert Riopel

APPENDIX B

PHOTOGRAPHS

Photo # 1: Exterior view of aluminum sliding window at the L'Emminence apartment building. The unit is typical of the size and construction of the units studied.

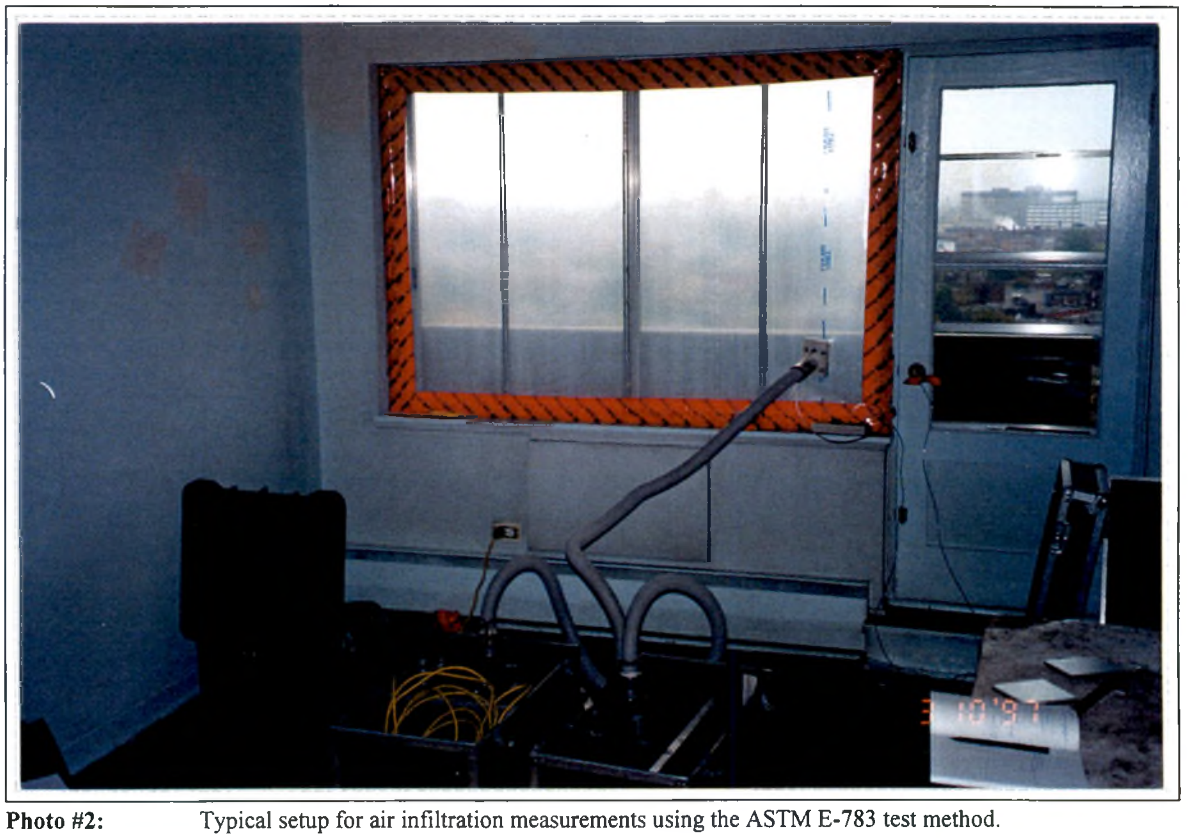


Photo #2: Typical setup for air infiltration measurements using the ASTM E-783 test method.

Photos #3 & #4: Views of head and sill condition showing the floating head track above and the weepholes at the sill track. Note the jamb weatherstipping which has dropped about 30mm permitting free air movement across the assembly.

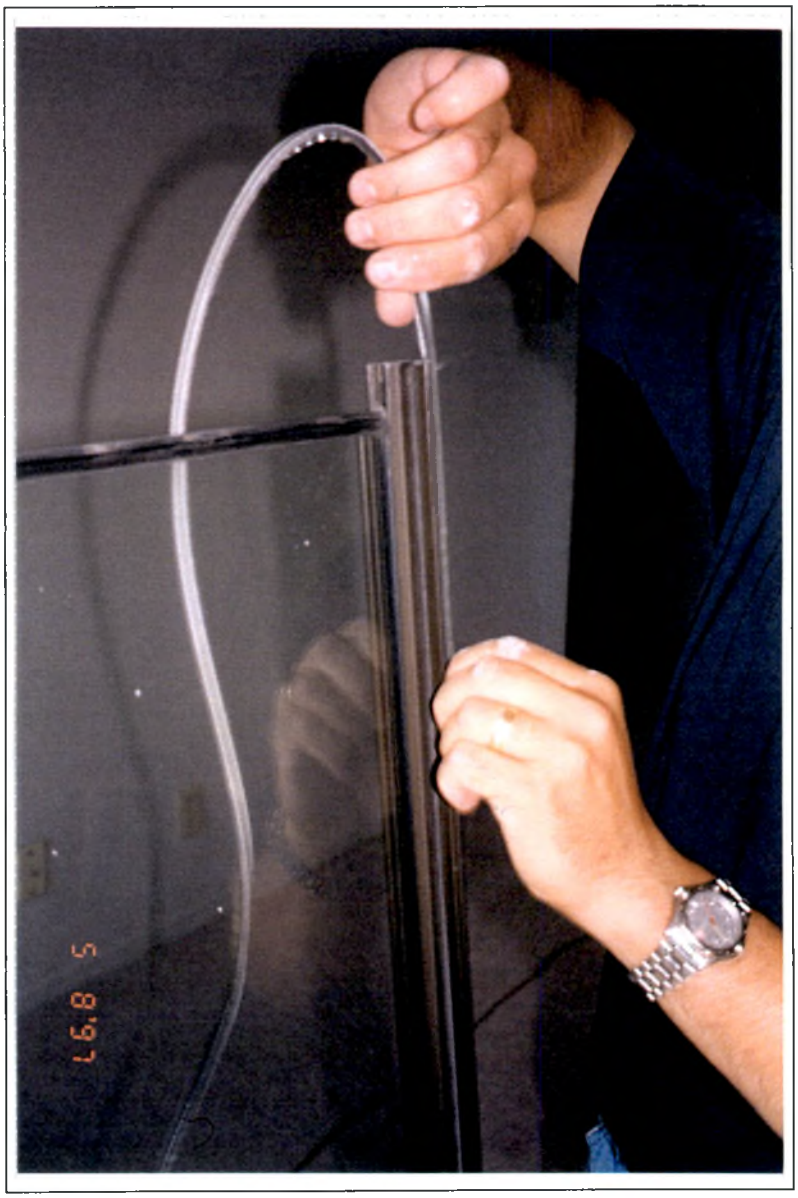
Photos #5: View of existing meeting rail weatherstripping at the La Cite Apartment test window.

Photos #6: Existing sill/jamb condition at the St.Georges convalescent home. Note the severe deterioration of the wooden window frame due to prolonged water infiltration problems.

Photos #7: Comparison between a new pressure head sponge on the left, and the existing sponge fron the MacDonald avenue apartments. The new foam provides for a much tighter seal at the window head and is wrapped to protect the foam from deterioration.

Photos #8: Maintenance worker from the La cite aprtment complex holding a sash sill with newly installed weatherstipping. Note the plastic glider at the end of the sash sill.

Photos #9: Application of caulking to seal the intersection of the jamb and the sill track at the L'Emminence apartments.

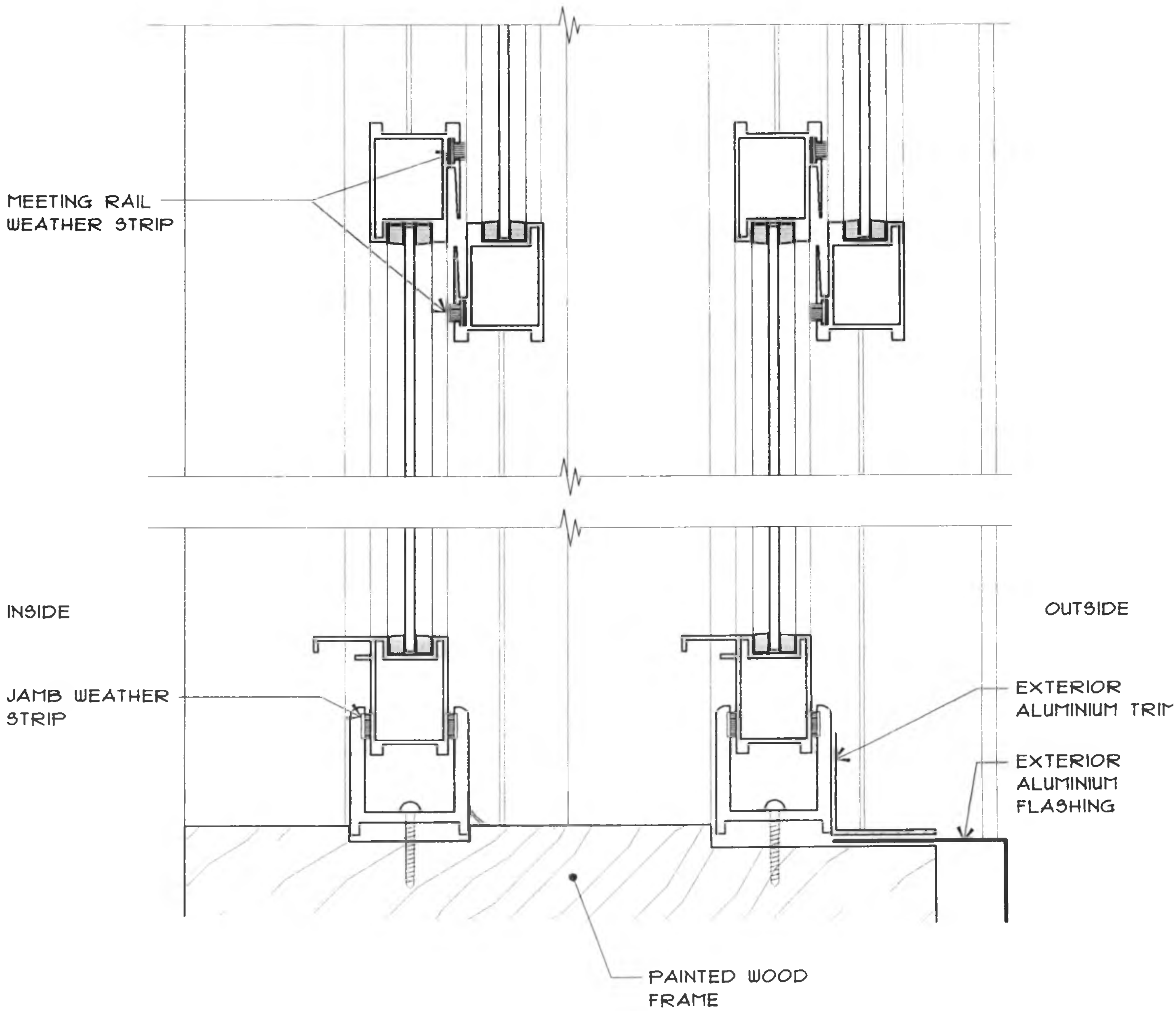


Photos #10: Insertion of new finned meeting rail weatherstripping at the La Cite apartments.

Photos #11: Application of caulking sealant at the perimeter of the interior window tracks and jambs.

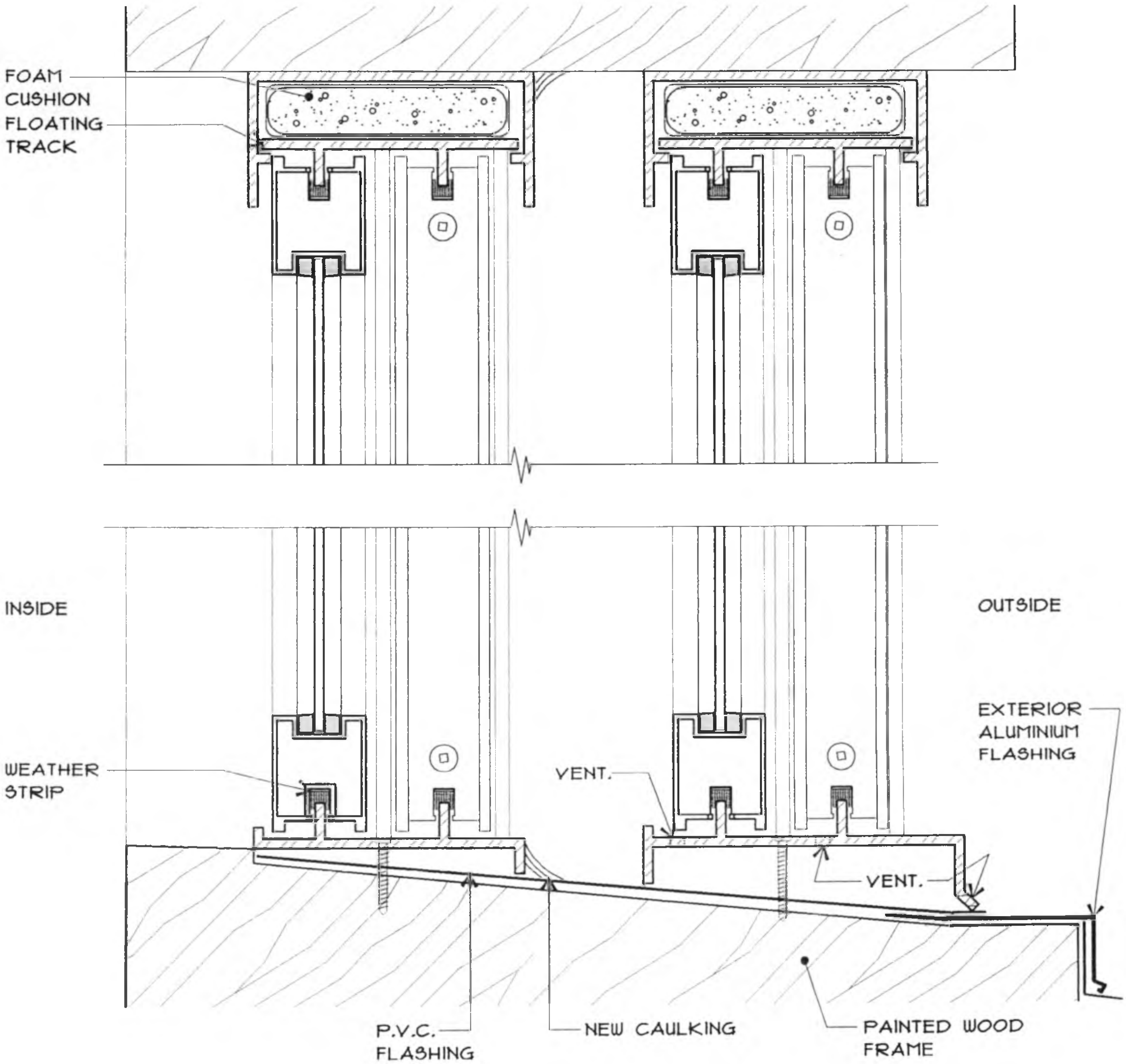
APPENDIX C

SECTIONS OF TYPICAL TEST WINDOW



1 WINDOW JAMB SECTION

FULL SCALE



2 WINDOW HEAD AND SILL SECTIONS

FULL SCALE