Developments in Windows, Doors and Hardware for Northern Conditions

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

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This publication is one of the many items of information published by CMHC with the assistance of federal funds.

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Introduction

This report is intended to stimulate discussion on ways in which improvements can be achieved in the performance of windows, doors and associated hardware for northern conditions. Comments will be reviewed and will result in a revised document which will be given wider distribution.

Nils Larsson was primarily responsible for gathering information and preparing the report. Michael Glover, of Edgetech Ltd., provided valuable information and prepared much of the material in Section 5. Michael Pine and Hai-toh Lim assisted in the gathering of information, provided critiques and made valuable suggestions for changes to the report.

1.0 Problem

There is a long history of problems with the performance of doors, windows and their related hardware in northern conditions. Not only are current windows and doors relatively poor in thermal resistance, but their short lifespan have a major detrimental effect on other major building systems, leading to shortened overall housing longevity.

Unsuitable doors and windows, as well as poorly insulated and leaky houses help to explain annual energy costs in the older NWT housing stock which could average up to $5000 per unit. With the introduction of well insulated and air-tight houses, annual oil heating cost now averages $1500. This figure should be further reduced when high performance doors and windows are widely installed.

In addition to poor functional performance, windows and doors used in the North are generally lacking in durability and this is coupled with difficulty and expense of maintenance in the North. Reviews of modernization and improvement expenditures in the North indicate that a large proportion of them are allocated to replacement of window and door hardware.

There are many specific failure conditions. The extremely cold conditions in the north causes window and door hardware and weatherstripping to become brittle and fail. During winter conditions, occupants often find it difficult to open windows because of the bond between weatherstripping and the frame caused by escaping moisture that has turned to ice; one colleague in Whitehorse keeps a small hatchet by the front door so he can chip away the ice each morning. If there is success in opening a window, the occupant will often find that it is difficult or impossible to close it until warmer weather arrives, because of ice and snow that has become packed around the opening. Differential humidity conditions cause wood exterior doors to bow and, while metal doors have the advantage of being easy to insulate, they tend to bow under conditions of extreme temperature differentials.

While the inability to open a window for cold-weather ventilation may be irritating, a window or door frozen shut can be a very serious matter where emergency fire egress is needed. According to Alaska Window, the U.S. Code applicable in Alaska requires an egress window in each sleeping room that is only served by one door and is located below the fourth floor. The National Building Code 9.7.1.3 has a similar requirement. Neither of these clauses will be very helpful if windows are frozen shut. It can be argued that the glazing can be broken, but this is likely to create injury amongst escaping occupants.

The environmental challenges will remain, but many other problems can be alleviated. The use of vestibules, for example, can reduce the temperature differentials that doors are exposed to, and the increasing reliability of mechanical ventilation systems is reducing the extent to which windows are needed for winter ventilation. There remains a major need, however, for an improvement in the design of windows, doors and hardware.

The causal factors of such problems can be summarized as follows:

1. The environment places severe demands on windows, doors and hardware, during installation and operation. Contributing factors include large indoor/outdoor temperature differentials, high winds and wind-driven snow. Differential settlement is a problem in some areas and the consequent racking forces are an additional problem.

2. Almost all of current window, door and hardware designs were developed to perform under less severe southern conditions. The lack of designs suited to northern conditions reflects the fact that the northern market is small and is not very lucrative for manufacturers.

3. Many occupants of northern houses are not responsible for energy costs and this reduces their incentive to operate houses in an energy-efficient mode. One consequence is that windows and doors tend to be left open for ventilation to cool down the house, which often makes them impossible to close properly for the rest of the heating season. As many northern houses are in remote areas, there also tends to be a greater wear and tear on such components than in urban areas.

4. The capital cost of high-quality components is high and the need to pre-purchase and to transport long distances add to the cost. This is a dis-incentive to buying durable or energy-efficient components, and has been a contributing factor to poor overall energy performance in the past. The use of life-cycle costing is making such an investment more attractive in the eyes of major agencies, such as NWTHC and YHC, but individual homebuilders or small delivery agencies find it more difficult to take the long view.

5. Many consumers are concerned with cost and style instead of quality, while some builders lack knowledge, motivation or a concern for quality. These human factors are not unique to the North, but their negative effects on the selection and installation of windows and doors are much more severe.

Recent generations of northern houses have shown a good deal of improvement in the approach to window, door and hardware design, but northern designers and builders are still limited by costs and by the prevalence of southern thinking in component manufacture. Almost all hardware used in Canadian windows, for example, is made by a single manufacturer and is clearly inadequate, even for southern conditions. Standards are also a problem: the primary existing standard, CAN3-A440-M84 "Windows", does not cover the longevity of windows or installation procedures, so other means must be found to encourage the development of such high-performance units. The most hopeful trend is that the recent upgrading of components to meet new energy performance requirements in the south is creating the market conditions that will make it possible to produce components that will also meet northern requirements.

2.0 Goals

This study is intended to result in the identification of existing types of windows, doors and hardware that are suited to northern conditions. It is also intended to suggest strategies for development where existing systems are inadequate.

The final goal may be expressed as the production of doors and windows that will achieve minimal air infiltration, a high thermal resistance, a twenty year lifespan under conditions of hard usage, low life-cycle costs and widespread consumer acceptance.

While these performance criteria are very loosely stated, they do cover a range that is important to recognize. Much effort in the past has been expended on developing purely technical criteria, such as thermal resistance or resistance to air infiltration, but it is clear that other factors are extremely important in assuring "on-the-ground" performance. These include durability (not covered in standards), better installation procedures, consumer acceptance of high quality, and an understanding by private and public developers that life-cycle cost is more important than initial capital cost.

If we are to ensure better performance in northern windows, doors and hardware, a broad attack on the problem is therefore required, involving close cooperation between manufacturers and major purchasers. In the meantime, we have identified a number of approaches and developments that point the way.

3.0 Window Issues

3.1 Failure Mechanisms

Although a clear identification of the frequency of failures by type would be very useful in pointing the way to required improvements, no such data tabulations are yet available. The comments in this paper are therefore based on anecdotal experience elicited in interviews with a sample of manufacturers, suppliers, designers and maintenance people across the country. Although this is less desirable, it should be noted that the comments were relatively consistent.

The NWTHC reports that the primary failure mechanism appears to be in the weatherstripping, which appears to have a lifespan of only one to two seasons. One mechanism of failure appears to be the aging of weatherstripping because of very low temperatures or rapid shifts in temperatures. In conditions of extreme cold, the nature of many plastics can change and they simply do not function in intended ways. Another is the "ice bonding" that results as warm humid air from the house interior condenses at the weatherstrip, forming ice that effectively bonds the sash to the frame weatherstrip. Under such conditions, the attempt to open a window will damage the weatherstripping, and this will allow an increase in the rate of ice build-up. Closing a window that is heavily frosted, or attempts to chip away frost will also destroy the effectiveness of the weatherstrip.

Another common problem that results from occupants attempting to operate a window that is reluctant to move because of ice or snow accumulation or because of ice bonding, is hardware failure. Rotary operators are the most susceptible, with lever/scissor types running a close second. The persons interviewed who stated a preference for sliding or double-hung windows did so because these types have a minimum of operating hardware.

A third failure type is breakage of glass, due to vandalism or, less frequently, due to stresses in glazing created by high temperature differentials. Breakage of glazing does not require replacement of the whole unit, but replacement units may only be available the following summer, or when brought in by air.

3.2 Window Types

There appears to be a consensus amongst northern designers that the infiltration rates of sliding windows compared to other types makes them less suited to northern applications from the point of view of energy conservation. Double-hung windows have a similar problem. Where such windows are located so that exfiltration occurs (on an upper floor and/or on the lee side of the house), the escaping warm and moist air will condense, causing them to become frozen shut. While this undoubtedly reduces the initial heat loss due to air leakage, it does call into question the usefulness of these units for winter ventilation or emergency egress purposes. The greater rate of air leakage of sliding window types appears to be due to the difficulty of providing a weatherstrip that will prevent air movement and consequent condensation without constraining the sliding motion (horizontal or vertical) of the unit.

Despite the disadvantages of sliding windows, some designers have gone back to using them after having tried out a variety of other window types. Their advantage lie in the fact that they do not rely on mechanical working parts to open or close and, as one northern designer has put it "even if frozen in their tracks, they can be opened with a bit of encouragement from a hammer and a wood block".

Although horizontal sliding windows are leaky, the new generation of horizontal sliding sash windows have improved their thermal resistance and air-tightness greatly, some approaching that of casement and awning windows.

Alcan makes a vinyl horizontal slider with an interesting sill section that may be suitable for northern conditions. This window does not run on tracks which is where dirt and ice normally accumulate but on a wide raised monorail with a rounded top which sheds condensation away from the operating parts. It is to be used in the Auyuittuq National Park Reserve at Pangnirtung, N.W.T., and we would suggest that the long term performance of this window should be followed up after a winter with the maintenance staff.

Other common types, including casement, awning, and hoppers, all share the inherent advantage of closing against the weatherstrip, with the reservation that the weatherstrip at the hinge point is subject to the greatest stress. The window frame, pane and hardware of such units are, however, under considerable stress during opening and closing.

The outward opening casement and awning types have an inherent energy-performance problem, in that the operating hardware must by-pass the internal fly-screen and penetrate the frame. The thin section reduces the thermal resistance of the section and the difficulty of providing good weatherstripping at this point tends to increase the possibility of air leakage. Given the fact that North American window hardware tends to be inferior (see Section 3.7), the opening mechanism of such window types will quickly fail if the window has to be forced open against the constraint of ice buildup.

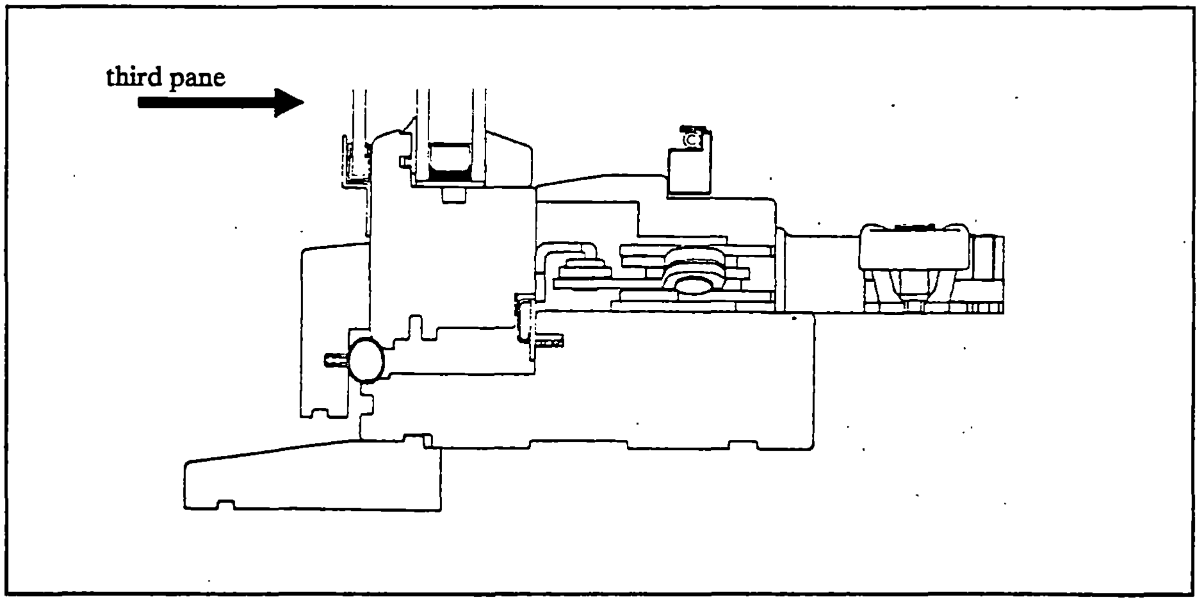
Inward opening hopper windows do have the disadvantage of requiring a mechanical lever arm to open, and they also allow the occupant to push the sash closed against the weatherstripping, which in this case is on the warm side of the window. Even so, if such units are used for winter ventilation, the build-up of frost at the head of the window as air moves across it from the hot, humid interiors frequently makes it difficult to close the hopper. In some houses at Rankin Inlet, we have seen the open hopper stuffed with cushions.

A fairly recent introduction into the market is the European designed Tilt-and-Turn windows which can be opened in a hopper position for ventilation, or be opened inward as a casement for summer ventilation, emergency egress or easy cleaning. This type is explained more fully in Section 5.5.

Fixed windows are of course the least susceptible to deterioration. The combination of fixed windows and special ventilators have been tried in the past and new variants (see Section 3.8 below) still offer potential for effective solutions. Our interviews and previous northern experience, however, lead us to believe that a realistic approach must allow for some operable windows as fixed windows are thoroughly disliked - they are claustrophobic, and the fear of fire makes opening windows desirable as a means of escape.

Types of glazing that are claimed to be 'unbreakable', such as Lexan, have been tried to help solve the vandalism problem that exists in some northern communities, but most officials and occupants favour having windows that can be easily broken from either the inside or from outside to provide an emergency escape route in case of fire.

New approaches to window design have been suggested that bear investigation in a northern context. The Northern Measures Committee, for example, suggested that the use of the combination of a single, removable outer glazing combined with an inner thermopane unit would allow the outer glazing to be quickly replaced if broken, while the inner glazing would tend to remain intact. This approach is used by the NWTHC as a standard design (see Fig. 1). Such a feature, which appears of little consequence in southern urban areas, can be of vital importance in remote settlements where replacement is difficult.



1: Window produced by Loewen for NWTHC with a third pane

A consideration of the factors outlined in this section should make it clear that the choice of a window configuration type should be related to the type of house ventilation system used. If a ventilation system can be installed that is extremely reliable and that satisfies psychological requirements for occasional high-volume supply as well as the steady-state air exchange called for in standards, then it may be possible to reduce the number of operable windows and the problems that are associated with them in cold weather operations.

3.3 Window Materials

The type of material used is of considerable importance, since the characteristics and production requirements of each material largely determine the configuration and performance of the finished components.

Aluminum

In a northern context, aluminum is not a contender (and is not sold into this market) because of its relatively low thermal resistance and the high cost of providing effective thermal breaks.

Wood

Wood is a traditional, easily available and standard window material. It is specified for most NWTHC housing, the largest housing developer in the North, and by most private-sector designers and builders. All-wood windows are relatively inexpensive, have a relatively high thermal resistance. It can absorb considerable physical abuse, both in transit and when installed, without impairment of function.

One of the disadvantages of wood is its susceptibility to dramatic changes in humidity, leading to a lack of dimensional stability. The very cold, dry arctic atmosphere "freeze dries" wood causing excessive shrinkage. It is also difficult to produce a section with enough internal air spaces to improve thermal resistance. Wood windows also require regular maintenance to ensure that the material remains sealed by sealer and/or paint. In this regard it should be noted that pressure-treated wood windows are available in Europe and could prove useful here. However, our experience suggests that investigation would be required to ensure that their appearance would be accepted by the northern occupants.

Metal or vinyl-clad wood windows are also available. They do not require regular maintenance but cost more than all-wood windows.

PVC

A growing contender is the "vinyl" or PVC (poly-vinyl chloride) window. This type of window is taking an increasing share of the southern rehabilitation market, primarily on the basis of its low maintenance requirement and the ease with which custom sizes can be fabricated. Assembly is simple, making northern assembly plants economically feasible. Another advantage in a northern context is that the extrusion process used to manufacture PVC frames makes it easy to provide air spaces within the frame, adding to their thermal resistance.

The Yukon Housing Corporation has been installing vinyl windows on all its housing units during the last two years and has found them to function as well as wood windows, with reduced maintenance problems.

Despite these apparent advantages, there is some controversy as to the suitability of PVC windows for northern applications. Several informants expressed an unwillingness to use PVC windows on the basis of their low production quality, mediocre thermal performance and a problem with brittleness in cold conditions, leading to breakage. This issue may be somewhat overstated, since there are indications that quality has improved and that the brittleness problem may be more relevant during installation in cold weather, rather than use during cold weather.

Alaska Window, manufacturer of PVC windows in Fairbanks, points out that properly compounded PVC should not suffer from problems such as brittle fracture, ultraviolet bleaching or poor weldability. However, they do suggest that the relatively low Modulus of Elasticity of PVC (2500 N/m^2, compared to 10,000 for wood) does require a careful approach to design, centering on the use of metal reinforcing within the PVC frame at all pressure points. Load-bearing screws should be attached to the metal reinforcement and non load-bearing screws should be of the hi/low thread design that is specially produced for the PVC industry. The metal reinforcement is expensive, invisible and its function is not understood by many building designers, and it is frequently the first cost cutting step taken by some manufacturers. We recommend that all PVC windows made for northern conditions should have this reinforcement.

PVC also has a relatively high coefficient of expansion, leading to significant dimensional changes under temperature differentials. Loewen reports that a recent test with temperature differentials of -40 to +70F resulted in a vinyl window sash separating away from the weatherstripping.

One explanation for the divergence in views on PVC may be that there are two grades of PVC window - "cheap" and "expensive" - and it is the former that appears to have given vinyl its poor reputation. Most PVC window manufacturers are producing low-cost units for the residential rehab market, which is not known for its high standards. Designers and builders who use such products in northern conditions are likely to find high infiltration rates, poor thermal performance and inadequate hardware. The only test currently applicable is the CSA A440, and the relatively few tests outlined in this standard certainly makes life easier for the manufacturers.

Quality can have marked effect on prices: one source quoted a range of from $12 to $48 per square foot for PVC windows. They will probably make further market gains in the North if funds can be found for the higher-quality range which are about 20% more expensive than the market wood windows.

Fibreglass

Fibreglass has been sporadically used as a window material for over 20 years, but production has been intermittent and low in volume. The main problem has been the susceptibility of the material to ultraviolet radiation, and the difficulty of developing protective coatings that are durable and attractive.

Nevertheless, fibreglass has inherent advantages over other materials. It has high tensile and compressive strength, high thermal resistance and is light in weight. Its coefficient of expansion is low; more importantly, it is the same as that of glass.

These factors would appear to make fibreglass an ideal material for window frames and sashes.

The limited acceptance of fibreglass to date may be about to change. The use of "pultrusion" production technologies (similar to extrusion, but pulling the profile instead of pushing it) will, according to one manufacturer (In-Line Ltd. of Toronto), result in costs that are lower than thermally-broken windows and competitive with PVC and wood windows. The same manufacturer claims to have developed a stable two-component polyurethane coating, and is backing this with a ten-year guarantee. the In-Line window is now available in awning, hopper and casement configurations.

3.4 Weatherstripping

Compression weatherstripping offers the best opportunity to reduce air infiltration or exfiltration. Although low infiltration rates are important in reducing energy losses, low exfiltration rates (depending on the relative pressures at the window) are important in reducing the outward flow of moist air that will create icing and hence physical damage to the weatherstripping during operation of the window.

Spring-loaded compression weatherstripping is being used, but field reports indicate that the mechanical action is susceptible to failure during winter conditions. A variety of composition materials are available that provide compression weatherstripping through a combination of profile and material characteristics.

The gasketing that appears to function best at extremely low temperature is in a triple row configuration, made of high quality thermoplastic elastomer (e.g. Santoprene) or thinly extruded EPDM. Silicone-based neoprene rubber weatherstrip is available and will function at extremely low temperatures. All gaskets should be silicone base or treated to limit their moisture absorption, freeze up and friction against contact surfaces.

The field of weatherstripping and sealing is extremely complex because of the great number of materials, configurations and conditions under which they are installed. A recent study[1] states that .... *the study of weatherstrip products revealed hardly any standards relating directly to weatherstrip performance, though some of the manufacturers were applying their own performance tests ..... It was clear that, with one or two exceptions, the existing range of standards constituted a poor basis for quality control....*

3.5 Glazing

It is in the area of improved sealed units that immediate progress can be made; the technology and the products are available now. Standard sealed double glazing is

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1 D. Jennings, D. Eyre and M. Small, *The Development of a Knowledge Base Relating to Indoor use of Caulks, Sealants and Weatherstrip Products*, by the Saskatchewan Research Council for Energy, Mines and Resources Canada, August 1988.

still used in many northern areas, but is rapidly giving way to triple glazing or double glazing with gas-fill and/or low-emissivity (Low-E) coatings.

Recent improvements in centre glazing (the area of a window not affected by edge conditions) are permitting thermal performance levels of R4 to R10, depending on the number of layers, gas fillings, coatings etc. For example, a double glazed window with a soft low-e coating and gas fill and with a separate outer pane with hard low E coating can reach R6 to R7.

The field is complicated, and only a brief reference can be given here. A report prepared by EMR and presented at the recent EEBA conference[2] provides a good summary:

1. Although low-E coatings and gas fills can offer significant improvement to centre glazing U-values, their full potential is not realized due to the increased losses through the spacer and the frame.
2. The benefit of the insulating spacer increases as the performance of the centre glazing increases.
3. Low-E coatings provide a thermal benefit, but at the cost of reduced solar transmission which for most buildings is not a particularly important factor. Both gas fills and non-conductive spacers, however, improve the overall thermal performance of windows without affecting the solar transmittance.
4. As the thermal resistance of the glazing units is increased, the warmer the inner glazing becomes and thus higher indoor relative humidity can be maintained without causing condensation on the glass.
5. The higher inner-glazing temperatures of high-performance windows tend to reduce swings in room air temperatures.
6. Space heating energy savings from 9 to 18 percent can be achieved by upgrading from standard to high-performance glazings. Savings in energy are greater in locations having colder heating seasons, but cost savings depend on climate as well as energy costs.
7. Compared to a standard double-glazed window, a low-E coated window provides a minimum energy saving of 9 percent for all locations. For a low-E plus argon fill unit, the energy saving ranges from 14% to 17%.
8. A "super-double" with low-E and argon out-performs a standard triple-glazed window, which in turn always performs slightly better than a double-glazed, low-E, air-filled window.

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2 Anil Parekh and Timothy Mayo, *Thermal Analysis and Energy Savings with High-Performance Windows*, Energy, Mines & Resources, March, 1989

3.6 Glazing Spacers

Aluminum has been the traditional material used for glazing edge spacers. The high conductance of aluminum, however, has become an increasing liability in the context of higher-performance glazing systems. Not only is the overall performance of the window greatly reduced, but there may be a higher temperature differential between the centre glazing and the edges, leading to a greater potential for stress fractures in the glazing. The poor thermal resistance of aluminum can be mitigated by burying the glazing edge deeper into the frame.

Butyl-metal or "swiggle-strip" spacers have become more popular and are now, for example, used as a standard component by a small window manufacturer in Whitehorse. The system consists of a butyl sealant strip containing desiccant fill and a zig-zag shaped metal reinforcing strip. Laboratory testing has shown that, despite the metal strip, the system provides a reasonable thermal performance although its low-temperature performance is not proven.

Various efforts have been made over the past twenty years to substitute plastic for metal in edge spacers. The fibreglass spacer is dimensionally stable, but the material is somewhat hydroscopic, and sealed units manufactured with these units have not consistently passed the Canadian durability tests.

Further types are under development. One is made from silicone foam material, incorporating a high percentage of molecular-sieve dessicant-fill material. The product has the highest insulating performance of all commercially produced spacers. It is backed with a low-permeable vapour barrier film, with pressure-sensitive adhesive pre-applied on two sides. To achieve twenty-year durability for gas-filled glazing units, it is recommended that the spacer be backed by hot-melt butyl sealants.

The choice of spacers can have a marked effect on the overall performance of windows, especially when high-performance glazings are used. Putting it another way, it is not rational to pay the extra cost for higher-performance glazings unless the spacers with higher performance are also selected. A similar argument applies to frame materials. The point is underlined in a comparison of the total performance of windows with different spacer types.

Table 1 Performance Effects of Spacers [3]

	Glazing Type (all in wood frames)	Glazing RSI-value (centre)	Total window RSI by spacer type Aluminum	Insulated
1.	Standard double (1/2")	0.36	0.35	0.37
2.	Low-E double	0.70	0.47	0.53
3.	Standard triple	0.56	0.47	0.54
4.	Triple - middle PET fill	0.79	0.56	0.70
5.	As (4) with Krypton fill	N.A.	0.66	0.80

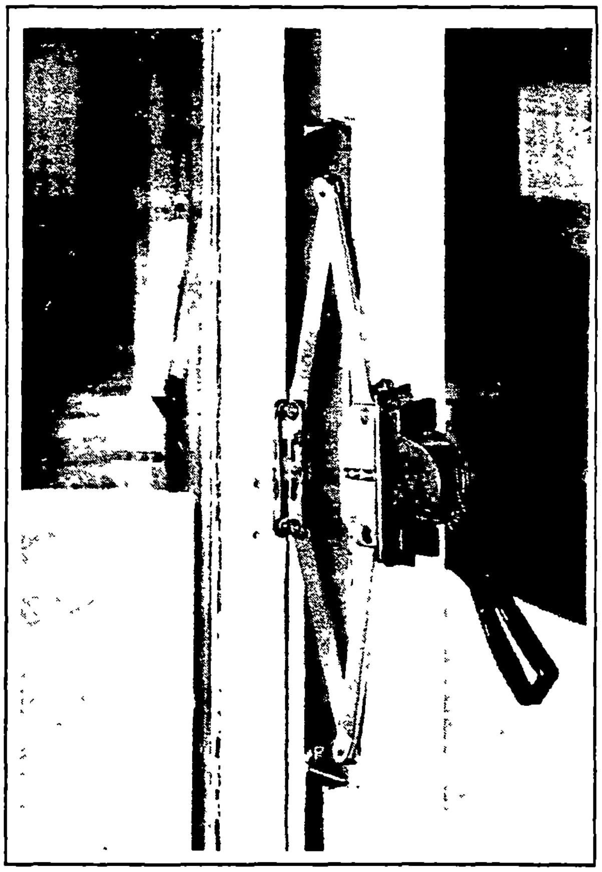
(note: 1.0 RSI = 5.678 R)

3.7 Window Hardware

Hardware is one of the weakest points in northern windows. Many users have switched from using casement to awning types solely because the lever hardware used in awning types is more reliable than the rotary types used in casement windows. A hotel in Whitehorse (see Fig. 2) has replaced all rotary operators on its casement windows with jury-rigged lever hardware.

As a result of the problems that are encountered with all hardware, some users therefore specify sliding windows because of their hardware-related simplicity. These facts indicate a lack of confidence in window hardware, at least the type that is produced in North America.

There is a lack of demand for high quality hardware for the southern market. Better quality European hardware is available in Canada, though



2: Modified window in Whitehorse

3 Source: Adapted from Table 5 in *The Effect of Frame Design on Window Heat Loss*, by Enermodal Engineering Limited for Energy Mines & resources, Sept., 1987

its use in the south has only recently increased, mainly in higher-priced developments.

Conventional North American hardware systems appear inappropriate for arctic conditions. Most persons interviewed expressed more confidence in the quality, functionality and durability of European hardware. The Whitehorse manufacturer of PVC windows uses a French-made scissor-type component for inclusion in a normal lever-operated awning opener.

Of the mass-produced European hardware systems that are available, Tilt-and-Turn hardware potentially offers the most advantages for the arctic market. This type of hardware was developed and is being used in Europe and is successfully used in Alaskan houses. The hardware is now being given a wider introduction into the North American market, mainly in higher-priced urban projects

The potential advantages of the Tilt-and-Turn hardware for arctic windows are as follows:

- multiple locking points for tight air sealing,
- on-site adjustable clearances for fine-tuning clearances between the frame and the weatherstripping.
- no structural loads on the screws holding the hardware in position.
- structural loads absorbed by the metal reinforcement of the frame.
- capability to support heavy triple glazed sealed units
- capability of supporting large sizes of sealed units (maximum size of about 4 feet by 8 feet) so that perimeter heat loss is reduced.
- glazing is dry mounted and units can be reglazed by homeowner without special tools, materials or training.
- cold-weather operation is good, with no reports of freezing shut.

The incremental cost of the hardware system is about $15 to $20 per window and the tilt-and-turn profiles are available at an increased cost of 50 per cent. However, because the profile allows opening windows to be larger, it is typically found that a combination of a fixed and opening window can be replaced by a single opening window. As a result, the higher cost of the turn-and-tilt profiles are off-set against the reduced cost of a single opening unit so that, depending on the complexity of the window design, the incremental cost may not be that significant. In addition, the larger window eliminates intermediate mullions that are not energy efficient, Against these advantages must be weighed the higher replacement cost of larger units of glass.

3.8 Ventilation

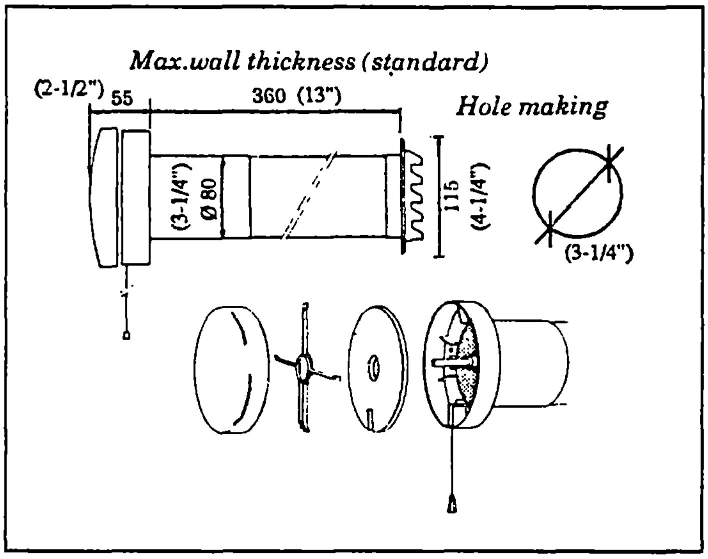
Operational problems for windows are mainly related to operating windows; fixed units tend to be a concern only with respect to thermal resistance. The question of ventilation is therefore very important since, if ventilation systems were to be improved, the reliance on opening windows for ventilation could be reduced. We are not taking the standpoint that a good central ventilation system could totally do away with the need for operable windows, since it is clear that an open window can provide safety and comfort functions that are very hard to match in such a system.

We do believe, however, that an improvement in central and through-the-wall ventilation systems can lead to a reduction in the use of operable windows.

We will not deal with central ventilation systems in this paper, but some new approaches to through-the-wall ventilation are worth mentioning.

One is a Swedish "Fresh Air Ventilator" (see Figure 3), which is a simple device for providing through-the-wall ventilation into individual rooms. Units similar to this are widely used in Europe and are of interest here because of the new National Building Code requirements for fresh air supply to all rooms.

The unit is designed to provide for the fresh-air needs of a room of max. 25 sq.m (270 sq.ft.). Larger rooms will require several ventilators to maintain draft free operation. The ventilator is easy to open and shut by pulling the operating cord, resulting in fully adjustable air flow. Extra insulation is provided at the ventilation disc to minimize condensation and to reduce sound transmission. One concern for northern applications is that the air intake might be blocked by fine blowing snow.

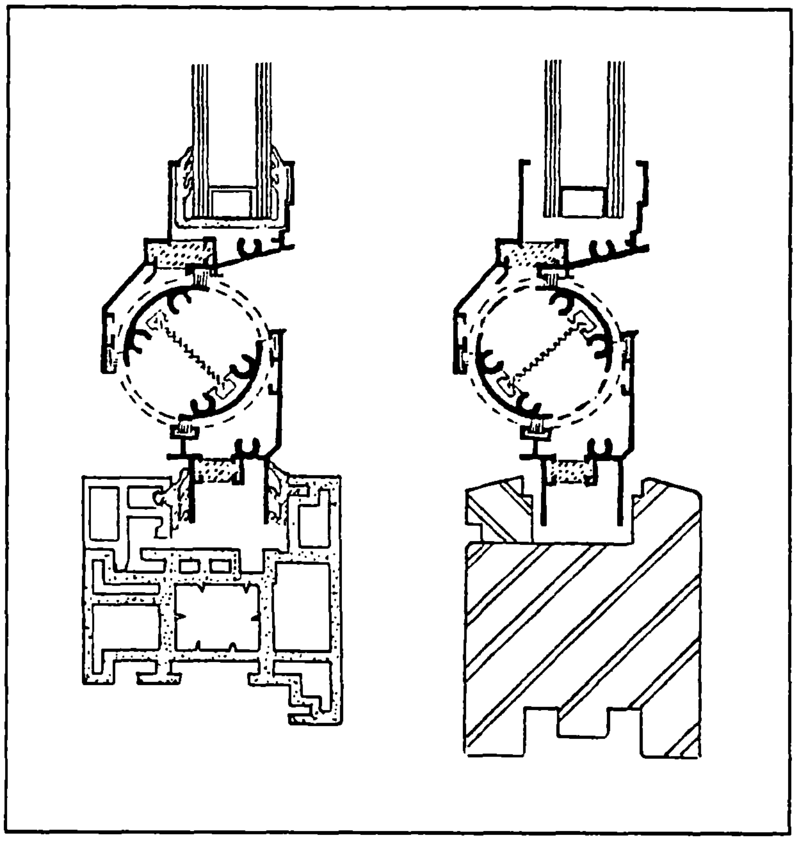


3: "Fresh 80" Through-the-wall Ventilator

Another ventilation device consists of a non-glazed ventilator containing a cylinder that can be rotated to provide a ventilation slit. When closed, the unit presents two solid surfaces and two weather seals. One variant of the system (see Figure 4) is produced by a German manufacturer as a separate unit that can be incorporated into the window glazing unit by a window manufacturer. Another variant will be incorporated into a fibreglass window assembly by a Canadian manufacturer, and is expected to hit the market in 1989. The NWTHC will be testing the German unit in some housing units this winter.

3.9 Some Design Considerations

Despite recent advances, windows are still the weak link in envelope performance, due to their low thermal resistance and high infiltration rate, relative to other elements of the building envelope. A Canadian researcher has recently suggested that windows with a thermal resistance exceeding R-10 will enjoy a net heat gain, even



4: Aralco adjustable airvents

from diffuse daylight, but we suggest that there would still be a net loss of energy north of 60 due to the large number of relatively or completely dark days. Other sources agree that little economic benefit is to be gained by the adoption of overall thermal performance in excess of R10[4]. Despite these limitations, there is clear benefit from using windows with considerably higher thermal performance than those currently sold in the North.

Even with windows that have a lower performance level, there are several well-known design techniques that can reduce heat loss.

The build-up of snow and ice on exterior sills can be avoided if they provide a generous clearance from the bottom of the window and have a sufficient slope to shed loose snow. Designers should continue to avoid north-facing windows and all windows should be kept as small as possible, consistent with the needs of the occupants. This last caveat is, of course, less critical if a very high-performance window is selected. Insulating shutters can increase the effective thermal resistance at window openings, but we know of no shutter that works effectively in practice : leaky interior insulating shutters cause heavy condensation on the glass, and may cause breakage of glazing due to thermal stress; exterior insulating shutters are troublesome to operate and tend to become inoperable in winter conditions. An interesting new idea in shutters is an "Arctic Window Box", under development by Ortech International[5]. This unit will consist of an insulated shutter with a reflective surface that slides horizontally between an outer single pane and an inner double pane.

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4 Enermodal Engineering Limited, *Summary Report on Window Research Priorities Meeting*, prepared for Energy, Mines and Resources Canada, August 1988.

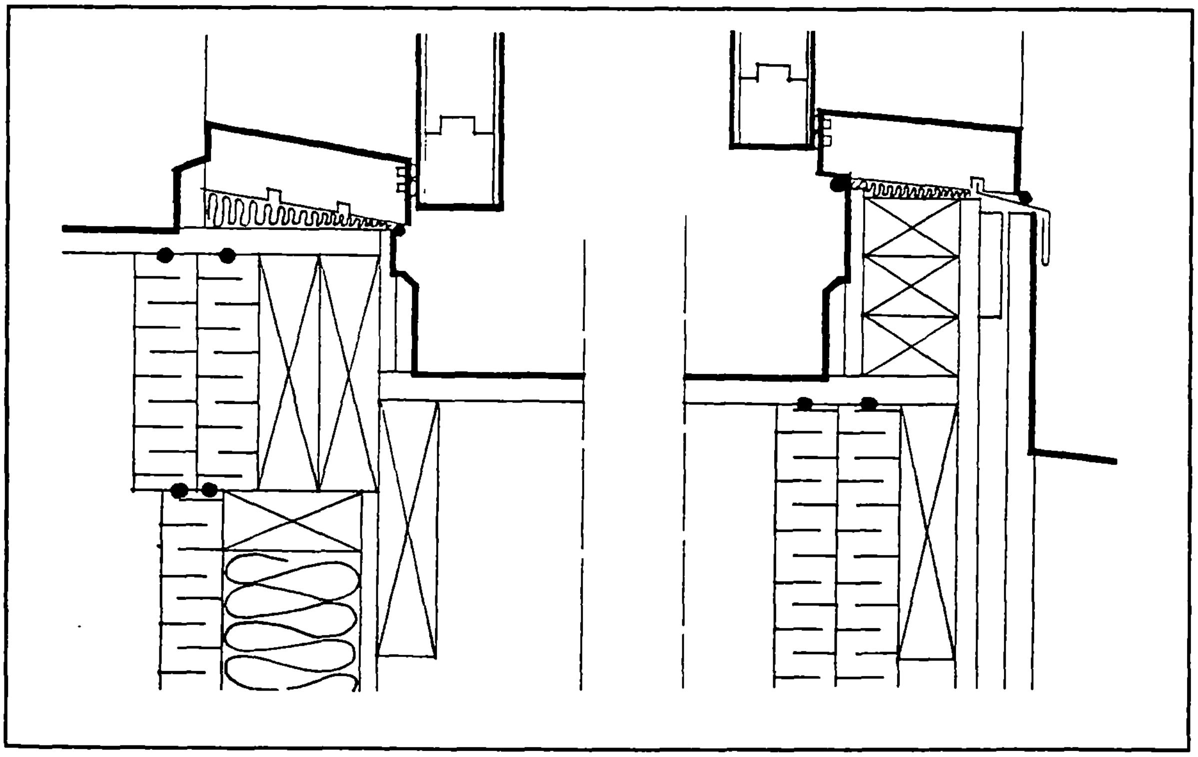
5 Source: Communication from R. Veerasammy and D. Bailey of Ortech to T. Mayo of Energy, Mines and Resources, September 1988.

4.0 Exterior Doors

Exterior doors in the north are exposed to severe environmental conditions and heavy usage. Steel insulated doors tend to bow due to temperature differentials, and wood doors bow due to humidity differentials. Doors refuse to close because of ice and snow packing in between the weatherstripping and the door; weatherstripping deteriorates because of the combination of hard usage and the action of the ice on the weatherstripping, and hardware that breaks or refuses to work in very cold conditions.

Much of the trouble with doors however appears to stem from bad practice rather than a poor product. In order to form a tight fit and to exclude cold air, the main door must be protected by a vestibule that keeps the snow from packing between the door and frame, particularly at the sill and up the hinge side. The outer door of the vestibule should, wherever possible be oriented in a way to avoid snow blowing into it, and the bottom of the door must be well off the floor to reduce blockage by snow, and the subsequent force needed to push it open or shut.

The Société d'Habitation du Québec (SHQ) has developed several approaches to the issues of door and vestibule detailing that help to deal with some of these problems. As a first step, they and most northern designers, use unheated vestibules which exposes doors to less severe temperature differentials. To deal with



5: SHQ Door Details

the problem of ice and snow packing between jamb and the door, and of damage to the door itself, doors are designed to close against the sill instead of sliding over it.

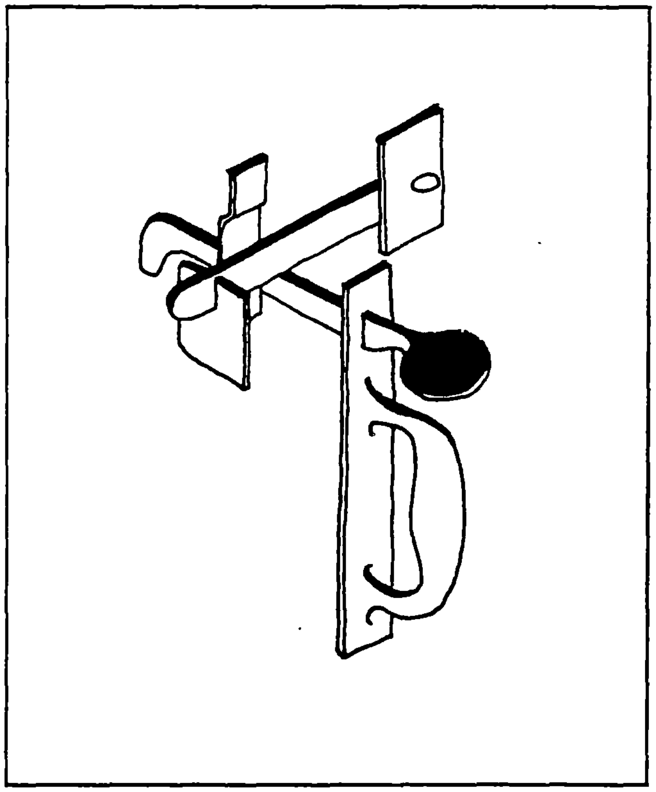
As Figure 5 shows, the door closes against the front face of the sill, which has a weatherstrip placed on it. The door drops down over the face of the sill, ensuring that no snow or ice will accumulate and providing a weatherstripping that is out of harm's way. This technique involves the use of a raised sill, which will make it difficult to bring a skidoo into the vestibule, both this may have to be accepted if the integrity of the vestibule is to be maintained.

After having experimented with insulated wood and steel doors, SHQ has gone back to using 44 mm solid core wood doors for the exterior door, and 57 mm insulated wood doors for the inner door. This has not solved the problems of bowed doors, but is one that gives a minimum of trouble.

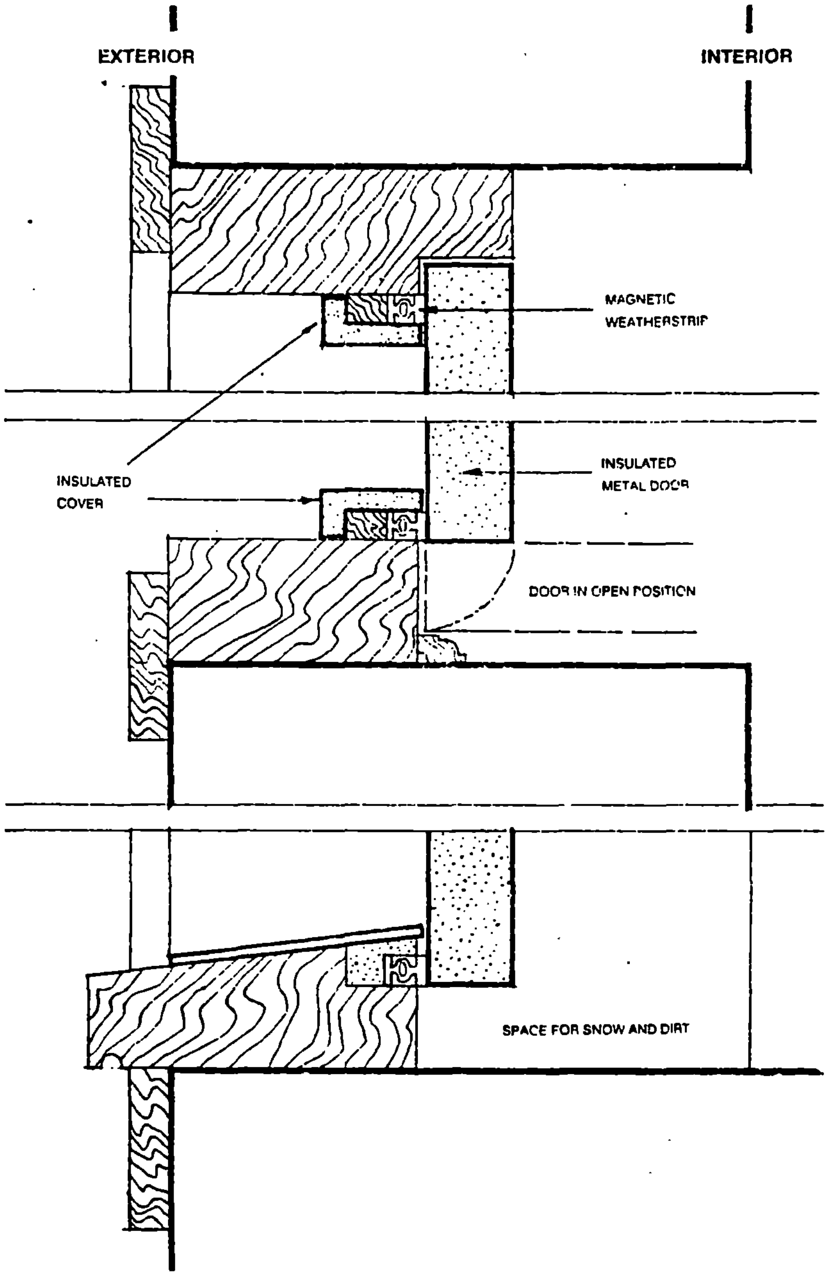
Door knobs are difficult to use when wearing heavy arctic mitts, and lever handles are preferable. The NWTHC has found some lever door handles in its units with fractures that may be due to temperature stresses or a combination of temperature conditions and design defects.

The SHQ has gone through much experimentation in this area as well, but has come back to a simple solution: an outer door latch instead of a lockset. Figure 6 shows the unit being used: it is very cheap, and it has a simple handle for pulling on. The absence of a lock is not a serious defect in many small northern communities, but the owner can always install a bolt and a padlock. This solution is probably not applicable in larger communities with problems of vandalism or crime.

A method to improve the performance of the door leading from the vestibule to the inside of the house has been designed by Bob Chill, formerly of DIAND. The design is similar to that of SHQ, but provides a metal insulated door with magnetic gaskets protected from damage and the weather by metal clad insulated covers. This insures the gaskets are kept warm and free of snow and frost. There is no protruding sill under the door and no protruding frame at the hinged side of the door which greatly reduces the common problem of packed snow collecting at these two places (see Figure 7).



6: SHQ door latch



7: Bob Chill's Door Details

5.0 Strategy for Improvement

5.1 Improved Window Technology

For many years it has been recognized that conventional off-the-shelf "southern" window technology does not adequately function in the extreme cold arctic climate. It is possible to dream up special exotic window technology for the arctic housing market which might overcome the deficiencies of the existing technology. This is not a realistic course of action, however, because the arctic window market is very small and fragmented and, almost regardless of what efforts are made to consolidate the market, the market will never be large enough to justify developing special northern window technology. In order to overcome the present problems with the existing technology, the only practical and feasible solution is to develop improved designs using the best of available "southern" technology. One may hope that manufacturers will find it worthwhile to develop windows with good performance in northern conditions, on the grounds that this will help their marketing efforts in southern areas.

Although we initially looked at the feasibility of pursuing the improved windows based on a performance specification, this course was rejected as unrealistic because the size of the arctic window market does not justify the high cost of product development, testing and evaluation. We therefore recommend that a more prescriptive specification be applied. To ensure that a cost competitive price is obtained and that there is competition between the window manufacturers, the improved designs must be capable of being manufactured by several different manufacturers in each of the major supply points for the arctic market (Montreal, Winnipeg, Edmonton, etc.).

The proposed improvements are grouped under two headings: (a) high thermal performance sealed glazing units and (b) window frame profiles, hardware and weatherstripping.

5.2 High Thermal Performance Sealed Glazing Units

Within the past few years, substantial technical improvements have been made to sealed glazing technology through the introduction of the following three main components: low-e coatings, low-conductive gas fill, and insulating edge seals. Using these components and depending on the number of glazing layers and low-e coatings, sealed glazing units can now be produced with a thermal performance ranging from R-4 to R-9, and are available in virtually all parts of the country.

For the arctic market, it is proposed that the standard sealed glazing unit should be a triple glazed unit with two high performance low-e coatings, argon gas fill and insulating foam spacer. Compared to conventional R-2 double glazing, the recommended design is rated about R-8 which means that glazing heat loss is reduced by about 75 per cent.

Smaller window manufacturers typically purchase their sealed units from comparatively large insulating glass manufacturers and it is projected that in the near future that these high-performance sealed units will be available at a competitive price.

The incremental cost of these additional features without mark-up are approximately as follows:

(i) $1.00 x 2 per sq. ft. for two low-e coatings

(ii) $0.50 per sq. ft. for the inner glazing layer

(iii) $0.10 x 2 per sq. ft. for argon gas fill

(iv) $0.15 x 2 per lin. ft. for insulating spacer

Depending on quantity, the selling price of the "improved" high thermal performance sealed units with profit and overhead would be about $8 per sq ft with the potential for the price to be reduced further in the future to about $5, compared to current costs for conventional double glazing of about $2.50. All these prices are ex-factory and are, of course, considerably marked up for retail applications (current standard replacement 1/2" sealed glazing in Ottawa costs over $8 per sq. ft.).

5.3 Window Frame Profiles, Hardware and Weatherstripping

With the radical improvement in the thermal performance of the sealed glazing unit, the window frame becomes the weak link in the window systems.

(i) Hardware

Conventional hardware systems are clearly inappropriate for arctic conditions. Two systems appear to offer advantages for the northern market: Tilt-and-Turn hardware or the In-Line system. We suggest that both systems should be evaluated further and installed in arctic housing conditions for testing.

(ii) Window Frame Profiles

Various technical improvements in window frame technology are under development although compared to sealed glazing technology, it is not as easy to identify the improvements that can be immediately specified for arctic housing. For the windows to be cost-competitive, it is necessary that the windows are made from mass-produced profiles and that generally any substantial improvement in performance must be obtained through add-on components.

For the Eastern Arctic market, where there are extreme cold temperature conditions, none of the traditional framing materials such as wood or PVC are really ideal. Pultruded fibreglass reinforced plastic profiles may prove to be an improvement, but to date only one manufacturer is producing this type of window profile for the residential market and so unlike PVC profiles, pultruded profiles are not widely available.

For Tilt-and-Turn PVC windows, suitable profiles are available from several manufacturers. Because the window opens inward, one option for the future is to overlap the window frame by an outer rigid laminated built-in panel so that the window frame is partially buried within the wall assembly and not exposed to the cold arctic environment. A variety of "clip-on" edge sections are available that can address this issue for PVC windows.

(iii) Higher Performance Weatherstripping Material

For arctic windows, weatherstripping profiles made from more durable materials with improved low-temperature flexibility can be substituted. The preferred materials are either EPDM or possibly silicone. Assuming that the higher performance weatherstripping can be made in relatively large production runs, the incremental cost can be less than 10 cents per ft.

5.4 Cost of Improved Window Technology

Although the total cost of a window suited to arctic conditions is about $10 to $20 per sq ft more than a conventional window, the increased cost can be justified for several reasons.

- the substitution of high-thermal performance windows reduces overall heat loss from a typical well-built energy efficient northern house by about 20 per cent. Assuming that the typical oil heating cost is about $1500 per year, the energy savings are $200 per year.
- replacement costs are substantially reduced because of the more robust hardware and window frame construction.
- maintenance costs are reduced because of integral frame finishes and simple method of glass replacement.
- windows that operate under all weather conditions insure a safe means of alternate egress for the occupants in case of fire.

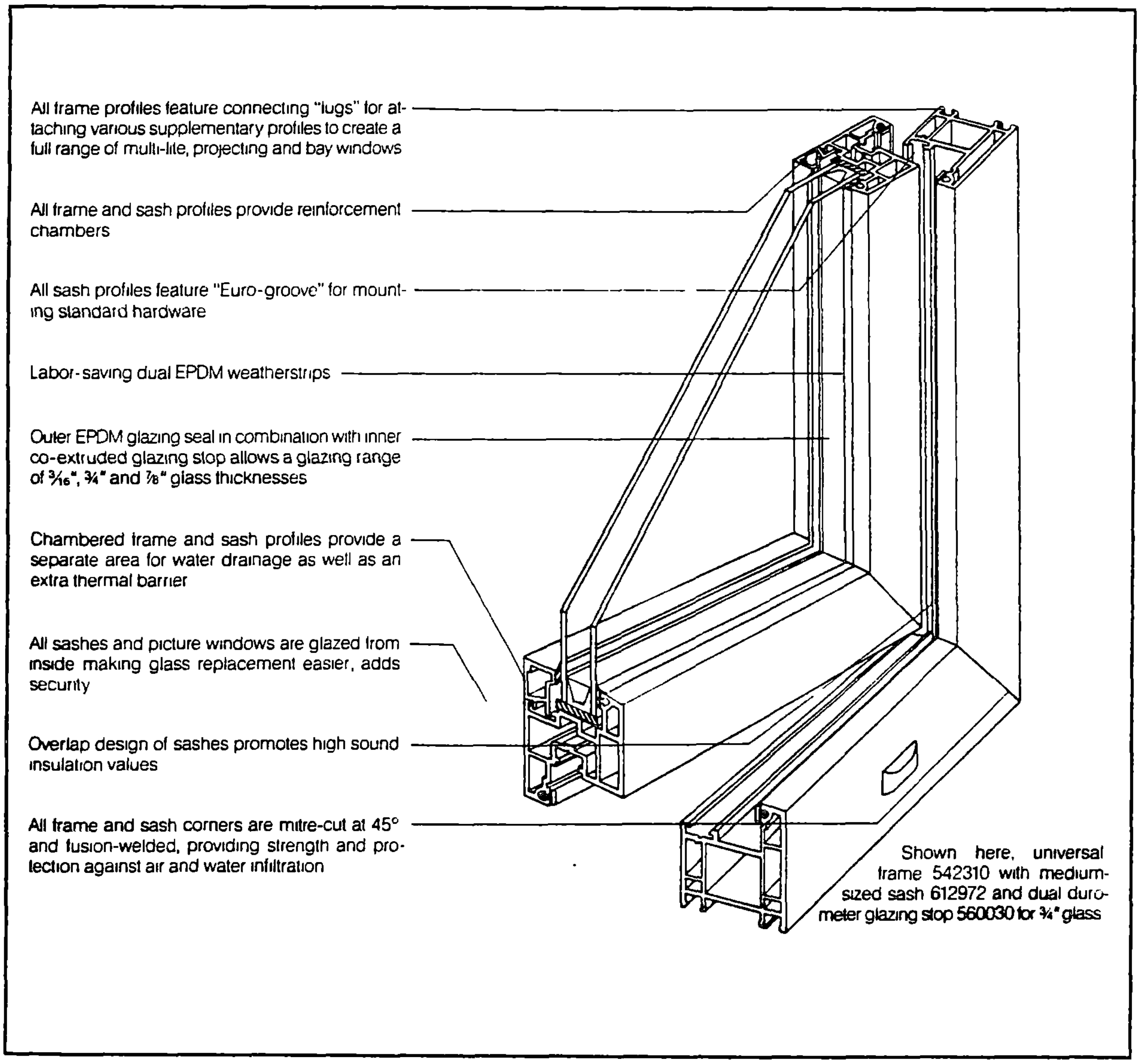
5.5 Emerging Designs Suitable for the North

New and promising window and window component designs are being developed and should be monitored. We suggest, however, that no new product should be used before it is confirmed that it meets specifications and has been laboratory and field tested. R. S. Dumont suggests that a laboratory with a minus forty degree cold room could be used. Units should be sprayed with water, subjected to high room-side relative humidity values and the closure mechanism tested for durability under accelerated wear tests. They should then be subjected to field tests, preferably in an occupied house with teenage children, for at least one arctic winter. Some of the most promising types include the following:

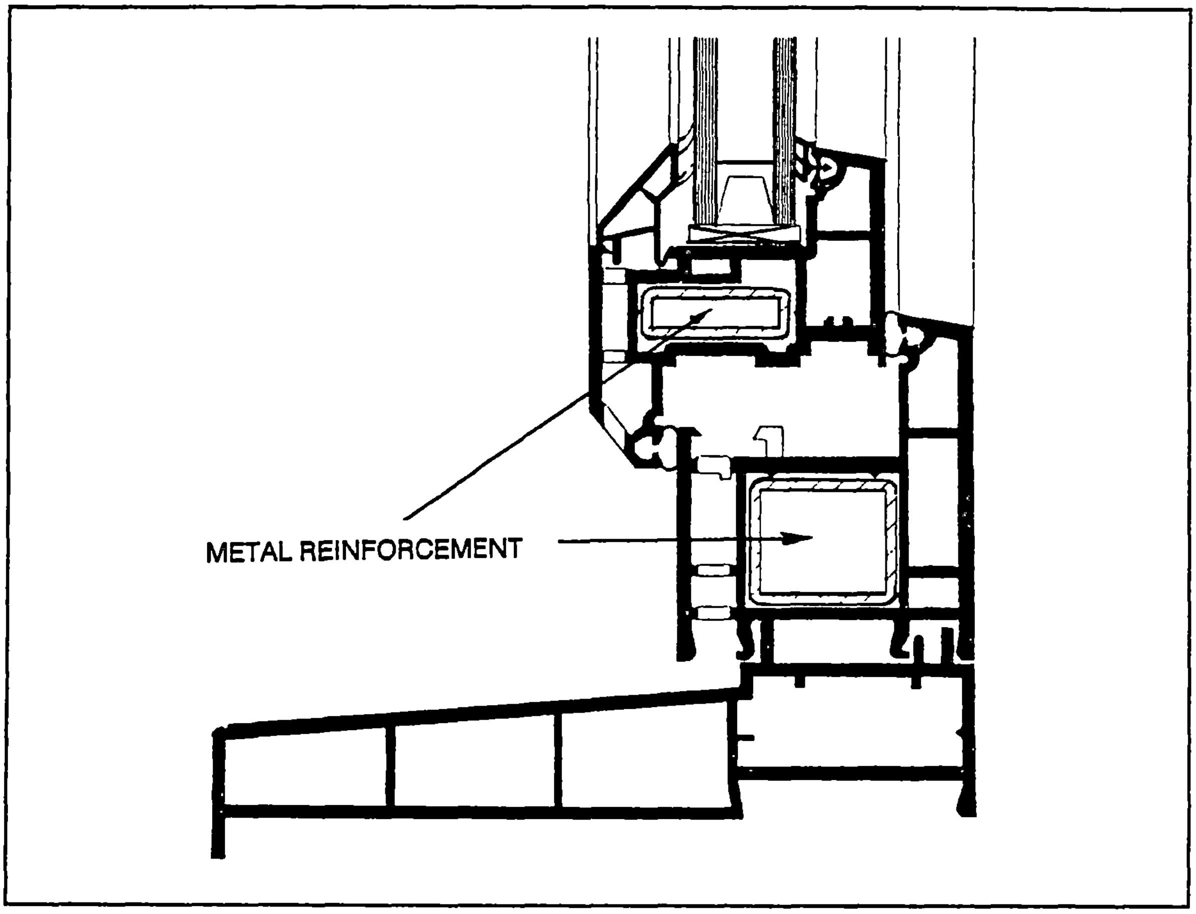
European designed PVC windows

European manufacturers routinely produce PVC sections to high standards and North American manufacturers produce a window suited to northern conditions using profiles manufactured in Europe. A Canadian distributor, K Windows of Ottawa, supplied a high quality European PVC casement windows to the NWTHC in 1987/88. The company also produces a Tilt-and-Turn window, Rehau (see Figure 8), using PVC profile from Germany. Similar PVC profile is expected to be manufactured in Canada in two years time. The Rehau unit is similar in many respects to the Danish profile used by Alaska Windows (Fairbanks, Alaska). Both are Tilt-and-Turn windows. Both windows feature dual EPDM glazing seals, extruded glazing stops that can be snapped out for maintenance and hardware with multiple locking points.

An inspection of the profile shows clearly that the section, while expensive, is carefully designed and manufactured. There is, for example, a steel insert that stiffens wider units and allows a more secure attachment of the hardware to the frame and of the frame to the building (see Figure 9). We recommend the use of this metal reinforcement in all PVC Tilt-and-Turn windows. The Tilt-and-Turn window opens in two ways; hinged at the side as an inward-opening casement, which allows



8: The Rehau PVC window with Tilt-and-Turn hardware



9: Metal reinforcement in Rehau Window

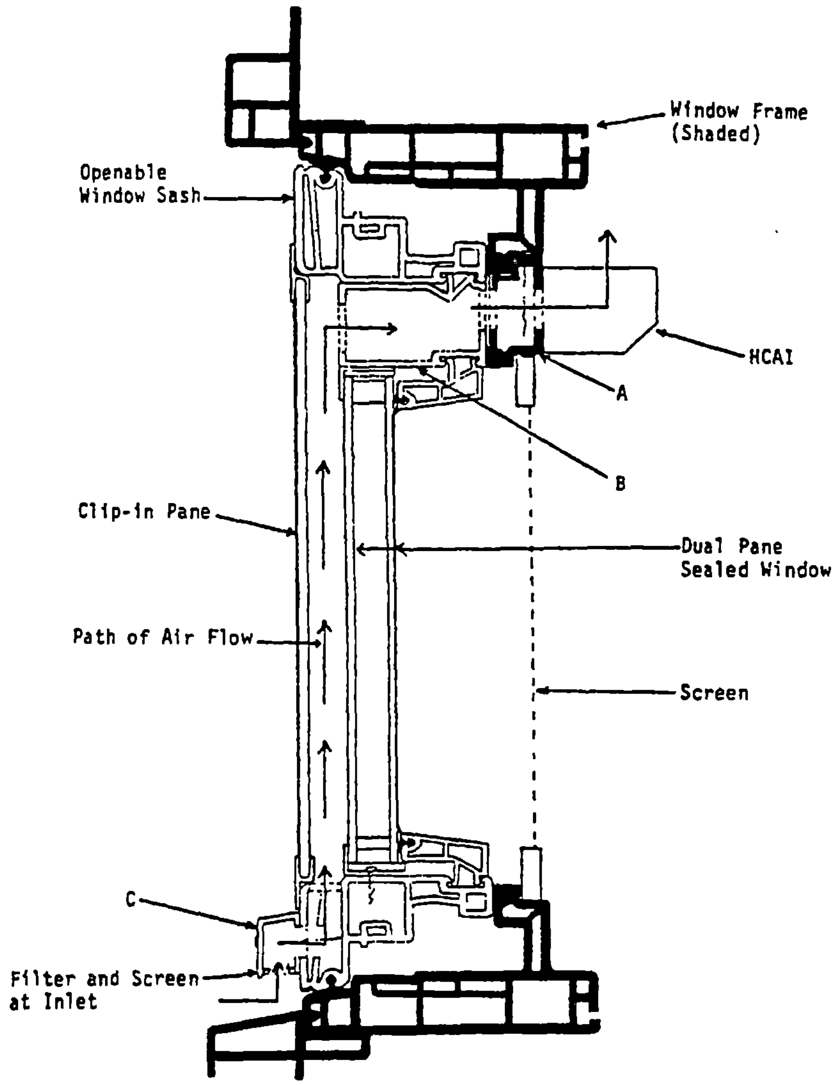
summer ventilation or emergency egress; or hinged at the bottom as a hopper, for winter ventilation.

One of the great advantages of the hollow PVC sash is that most of the operating hardware can fit inside the section. The windows have a robust lever handle that operates the hopper when turned upwards, operates the casement when turned horizontal, and firmly closes the window when pointing down.

Laminar-Flow Window

Another window design of interest is the ventilating, or "Laminar-Flow" window, which was developed by G.K. Yuill and Associates Ltd. of Winnipeg with a research grant from EMR. A prototype test window was manufactured by Willmar Windows Industries in Winnipeg.

The window (see Figure 10) consists of an inner double-glazed sealed window, plus a single outer pane. Fresh outside air is brought into the space between the outer and middle panes of the window through a slot at the bottom and exits at a slot at the top into the building. The incoming air is warmed by heat which radiates out through the double-glazed pane, heat which would otherwise be lost to the out-



A, B and C are new extrusion molded components.

10: Laminar-Flow Window

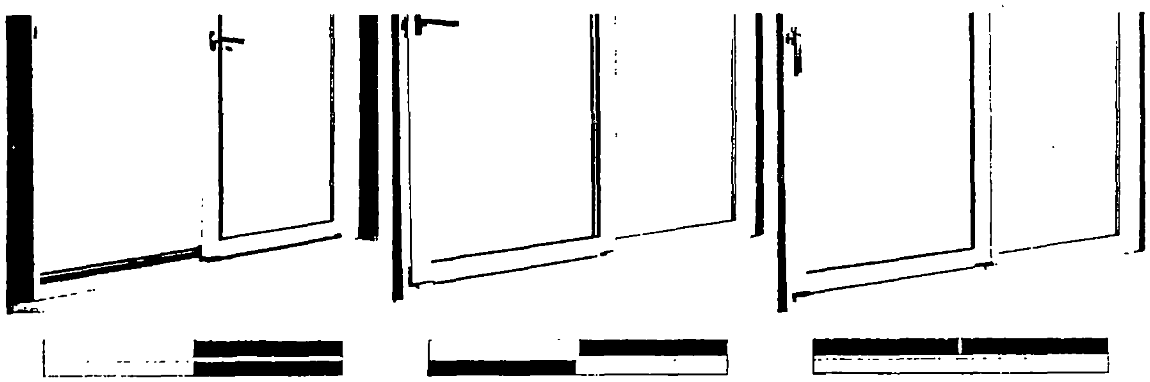
side. Filter and screen are provided at air inlet slot. The air flow can be adjusted manually by damper or the air outlet can be paired with a ventilation system.

The prototype was installed in a house and is being monitored by G.K. Yuill. EMR further contracted Willmar in June 1988 to develop and evaluate a ventilation window prototype incorporating a humidity-controlled air inlet ventilation (HCAI) system and a baseboard heating system. A demonstration house was built in Winnipeg and is being monitored. A computer simulation program was developed by G.K. Yuill and testing was done concurrently by NRC. Testing was to be complete in March 1989 and a final report will discuss the commercial viability and energy savings of the new window.

The inflow of warmed air in this type of window requires that a house exhaust system be provided to provide a balanced system, and it would not be sensible to pay the premium for the window unless an effective heat recovery system - such as a heat pump - is available to recapture the heat from the air being exhausted.

Fibreglass In-Line Windows

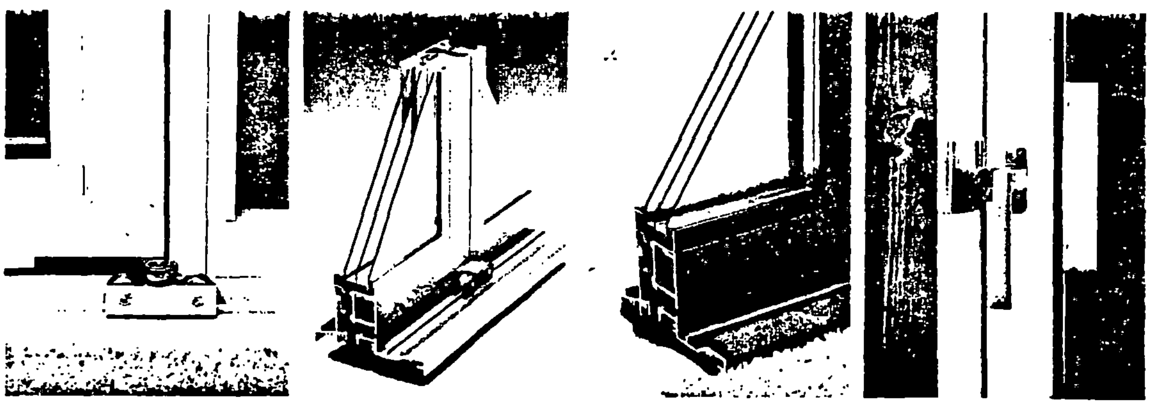
As mentioned in Section 3.3, fibreglass is beginning to look as if it will be a strong contender for the northern window market in the near future. The In-Line



A fully-opened INLINE patio door. Note its clean, functional lines

An INLINE patio door opened just enough to permit air to move indirectly in and out

Fully-closed, the INLINE patio door's air-tight, noise-reducing in-line feature is apparent.



Close-up of the double ball bearing housing on which INLINE patio doors and windows roll rather than slide, a feature that accentuates another desirable difference

Cut-away views illustrating the built-in ruggedness of INLINE patio doors and windows. Shown is a triple tempered sealed unit. Note the 9/16 inch air space. A double unit is available too. Tinted, heat-absorbing glass for additional protection winter and summer is optional.

Available in distinctive solid brass or white bronze, the handles on INLINE patio doors and windows favourably complement any home decor.

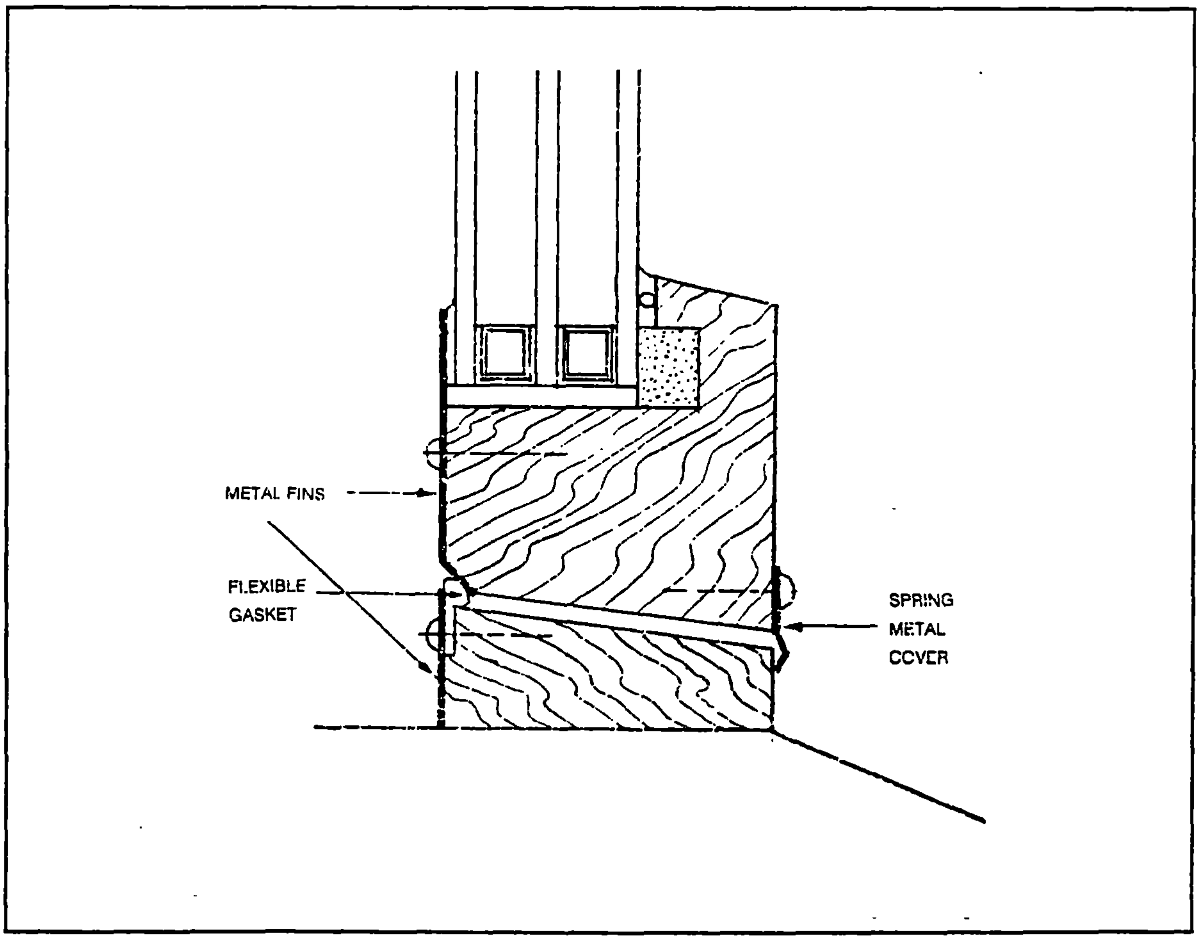
11: In-Line Window

company is currently producing patio doors and a line of windows with fibreglass sash sections and have introduced a window mechanism that works on the principle of a van door - it pulls out and then slides to one side (see Figure 11). This "in-line" type of unit needs to be tested in arctic conditions, but the fact that the weatherstrip at all edges of the window makes a clean compression contact should reduce weatherstrip damage commonly found at the hinge side of casement windows.

Weatherstripping

Problems with weatherstripping for the arctic market are not always due to their design, the material used or to their location in the window system. The most frequent cause of failure is damage caused by opening or closing of window when the weatherstrip is heavily frosted or coated with ice.

The answer appears to be keeping the weatherstrip warm, either by locating it on the warm side of the window or where this is not possible, by other devices. Two types that have been demonstrated are discussed below.



12: Bob Chill's Iqaluit Window

passive metal conducting fins

A passive metal fin that conducts heat from the warm side of the window to the weatherstrip may keep the weatherstripping warm, which should keep the window from freezing shut. Bob Chill has built and installed a window in a DIAND house in Iqaluit that operates on this principle (Figure 12). It is reported that the window has functioned well over a number of winters.

heating tapes and electronic lock

An interesting possible solution is to install heating tapes around the window and an electronic lock so that it the homeowner must switch on the tape heating system and thaw out the weatherstripping before the window can be opened. The electronic lock could incorporate several user-friendly features and with good design, this should ensure that the window is not vandalized by an impatient homeowner.

In terms of the increased cost, the electronic locking device could add about $3 or $4 per window. Assuming an off-the-shelf heating tape could be used, the additional cost would be a further $1 per square foot. In addition, there is additional cost of wiring up the system which could be relatively low, if low voltage, low amperage power could be used. Although some authorities suggest that this approach is over-complicated and therefore subject to frequent failure, the technical feasibility of this approach could be investigated in more detail and a prototype product developed and installed on an arctic housing project.

6.0 Summary

There appear to be two main schools of thought with respect to resolving door and window problems in the North.

Some designers and builders would follow a "low-tech" route, choosing robust, simple products that require minimum maintenance and repair. This attitude reflects their experience that high-tech products do not tend to survive the severe environmental conditions, hard usage, vandalism, and the infrequent or poor maintenance that is common in the North.

Another view is that recent technical advances have improved the performance of windows, doors and hardware (but especially windows) to such an extent that they can no longer be ignored.

We do not believe that either viewpoint can be neglected, and we suggest that modern technology can make a substantial contribution to the performance and livability of northern housing, as long as adequate field testing takes place before decisions are taken to implement.

Appendix 1: Performance Criteria

In outline, the key performance parameters for a high-performance northern window would include the following:

- an overall thermal performance of at least R-6
- openable windows with essentially no heat loss due to air infiltration
- minimum twenty-year durability on all major components
- ability to withstand substantial abuse and vandalism.

Although these parameters may seem at first sight to be inclusive, there are many other parameters that should be considered in assessing windows and doors. The following performance criteria may provide a suitable framework for future assessments of specific systems (some are applicable only to windows):

Physical Performance
Dimensional stability
Warping/racking resistance
UV resistance
Air infiltration
Thermal resistance
Shading coefficient
Water/rain resistance
Durability/lifespan
Maintain performance levels

Functional Performance
General operability
Winter operability
Ventilation effectiveness
Percent rough opening visible

Safety & Security
Fire egress
Combustion products
Resist external breakage
Resist burglary

Construction & Maintenance
Transport & handling
Ease of installing correctly
Level of maintenance required
Ease of maintenance & repair

Cost
Capital cost
Maintenance cost
Life-cycle cost

Other
Consumer acceptance

Some of these performance criteria are more critical than others. The following tables outline these, and can be used as the basis of a performance specification for manufacturers:

A. For Whole Window

1. Air infiltration
2. Thermal resistance
3. Water/rain resistance
4. Durability/lifespan
5. Transport & handling
6. Ease of installing correctly
7. Capital cost
8. Maintenance cost
9. Life-cycle cost
10. Consumer acceptance

B. For Frame and Fixed Sash

11. Dimensional stability
12. Warping/racking resistance
13. Thermal resistance
14. Water/rain resistance
15. Maintain performance levels
16. Percent rough opening visible
17. Combustion products
18. Resist external breakage
19. Ease of maintenance & repair

C. Operating Sash

20. Dimensional stability
21. Warping/racking resistance
22. Air infiltration
23. Thermal resistance
24. Water/rain resistance
25. Durability/lifespan
26. Maintain performance levels
27. General operability
28. Winter operability
29. Ventilation effectiveness
30. Percent rough opening visible
31. Fire egress
32. Combustion products
33. Resist external breakage
34. Resist burglary
35. Level of maintenance required
36. Ease of maintenance & repair
37. Consumer acceptance

D. Seals

38. Dimensional stability
39. UV resistance
40. Air infiltration
41. Thermal resistance
42. Water/rain resistance
43. Durability/lifespan
44. Maintain performance levels
45. Combustion products
46. Ease of maintenance & repair

E. Glazing

47. Thermal resistance
48. Shading coefficient
49. Durability/lifespan
50. Maintain performance levels
51. Resist external breakage
52. Ease of maintenance & repair

F. Glazing Edge

53. Dimensional stability
54. UV resistance
55. Thermal resistance
56. Durability/lifespan
57. Maintain performance levels

G. Hardware

58. Air infiltration
59. Durability/lifespan
60. Maintain performance levels
61. General operability
62. Winter operability
63. Resist burglary
64. Level of maintenance required
65. Ease of maintenance & repair
66. Consumer acceptance

Appendix 2: Interviews

Norm Ridgley, VP, NWTHC
Clarence Emberly, Chief of Maintenance Management, NWTHC
Mark Haines, NWT PWC, Cambridge Bay
Dick Bushell, NWTHC
Marshall Wilson, NWTHC
Bob Chill, Ottawa
Leon Derenoski, Saskatchewan Housing Corporation, Saskatoon
Ron Pasetka, CMHC Inspector, Winnipeg Branch
Bob Lucas, Yukon Housing Corporation Capital projects
Serge Pageau & Andre Drolet, SHQ
Dan Friesen, Willmar Windows, Winnipeg
John Hochman, Appin Associates, Winnipeg
John Butler, Yellowknife CREO
Jan Vincent Thue, University of Trondheim, Norway
Stanley Rockiki, In-Line Fibreglass Systems Ltd.
John Letkeman, Loewen Windows, Steinbach, Manitoba
Rob Mason, Architect, Whitehorse
Wayne Wilkinson, Designer, Energy Trainer, Whitehorse
Barry Stewart, Igloo Construction, Edmonton