BUILDING IN ALASKA

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WINDOWS

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INTRODUCTION

The importance of windows can be traced back to dark wintry days in Scandinavian fjords where the word originated. Window ("Vindu" in Norwegian) comes from the old Norse words, "vindr auga" that literally mean "wind eye." One can imagine a small round portal of glass on the windward side of coastal farmsteads that allowed these seafaring people to keep an "eye to the wind." Thus a wind eye became the name for our modern window, because it was a direct view of the weather.

Windows are the most unique element of buildings. They ideally provide opportune lighting, security, protection from weather and prevent air leakage. At the same time they are often operable and may be relied upon for ventilation. In Alaskan conditions, they must function as transparent insulation. Their sizing and orientation is a crucial element of thermal design in our climate zone. Windows are very important to obtaining a quality, durable energy-efficient home. They also have marketing importance; they are an important aesthetic feature for homes. Who wants a home with inadequate natural lighting and poorly planned windows? Windows have developed into modern, high-tech building elements that continue to move to higher energy efficiency and durability.

1 HEAT LOSSES AND SOLAR GAIN THROUGH WINDOWS

The use of a glossary of new window terms and technologies is helpful. A full glossary is available in Appendix 3 and includes definitions of many of the new technologies and concepts needed to understand modern windows. A few terms that will help understand how energy flows through windows are described below; these are the basic heat flow mechanisms for windows that also apply to all building elements. Familiarity with these terms and concepts will also help you to read labels and talk to building contractors and building supply merchants.

Conduction is the flow of heat through a material. One molecule transfers heat to the molecules next to it. Direct conduction occurs through glass, the window frame and the edge seals.

Convection is the flow of heat within a fluid. The misunderstanding of convection has led to the phrase "heat rises." Actually, hot air convects upwards because it is lighter (less dense) than cold air. This is relevant to windows because convection occurs as downdrafts–the familiar "drafts" below windows–from cold window surfaces. Convection currents in the inner pane airspace, transfer heat from the inner light of glass to the outer light.

R-value is a measure of the resistance of a material or an assembly of materials to heat flow. It is expressed in English units as hr-ft^2-F/BTU. Window manufacturers and engineers commonly use the R-value to describe the rate of non-solar heat loss or gain through the window. The higher a window's R-value, the greater the resistance to heat flow and the greater the insulating value.

Radiation is the transfer of electromagnetic waves (infrared, ultra-violet, visible), from one separate body to another. Heat energy is transferred in the infrared band. This is how the sun heats the earth. Radiant heat transfer makes you feel cold standing in front of a cold window even if the inside air is warm. Your body radiates heat to the cold window surface. Windows are the primary areas in buildings where radiative heat loss (and gain from the sun) are dominant.

Solar Heat Gain Coefficient (SHGC) is the fraction of solar radiation admitted through a window, both directly transmitted, and absorbed and subsequently released inward. The solar heat gain coefficient has replaced the shading coefficient as the standard indicator of a window's shading ability. It is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits, and the greater its shading ability. SHGC can be expressed in terms of the glass alone or can refer to the entire window assembly.

2 REDUCING HEAT LOSSES FROM WINDOWS

By understanding the mechanisms for heat loss from windows, technologies can be developed to minimize these heat losses. Some examples include:

1. Increasing the air space between the sheets of glass or plastic to at least ½-inch. (See Figures 1, 2.1a, 2.1b).
2. Increase the number of still air spaces. By going from double or triple pane, to quadruple glazing, the R-value increases by about R1 for every ½-inch air space that you add. (See Figures 2.1a and 2.1b)
3. Reflect heat radiation back into the house. Radiant heat losses, which account for a large component of heat loss through window glass, can be reduced with heat reflective coatings. Heat reflective coatings are also known as low emittance– "low e"–coatings. Heat reflective coatings are placed on glass or plastic sheets which are then built into double or triple glazed windows. A heat reflective coating on one sheet of glass in a double glazed window will give that window an R-value of approximately equal to that of a typical triple glazed window. The solar transmission of these windows also is affected. The solar heat gain coefficient is decreased as less solar radiation is allowed to pass through these windows. (See Figure 2.1b)
4. Using a gas fill between the panes of glass, which is a better insulator than air, will decrease heat loss and will typically not substantially reduce the shading coefficient of the glazing.

Table 1 (see Appendix 1 on page 18) shows the R-values of various windows. Included in Table 1 is the description of the effects of the frame of the window. The edge of a single window is worth discussing, because the edge effects were not of great concern before multiple pane, low-e, and gas filled windows were widely used. As the glass became more insulative, the effect of including frame in the performance of the

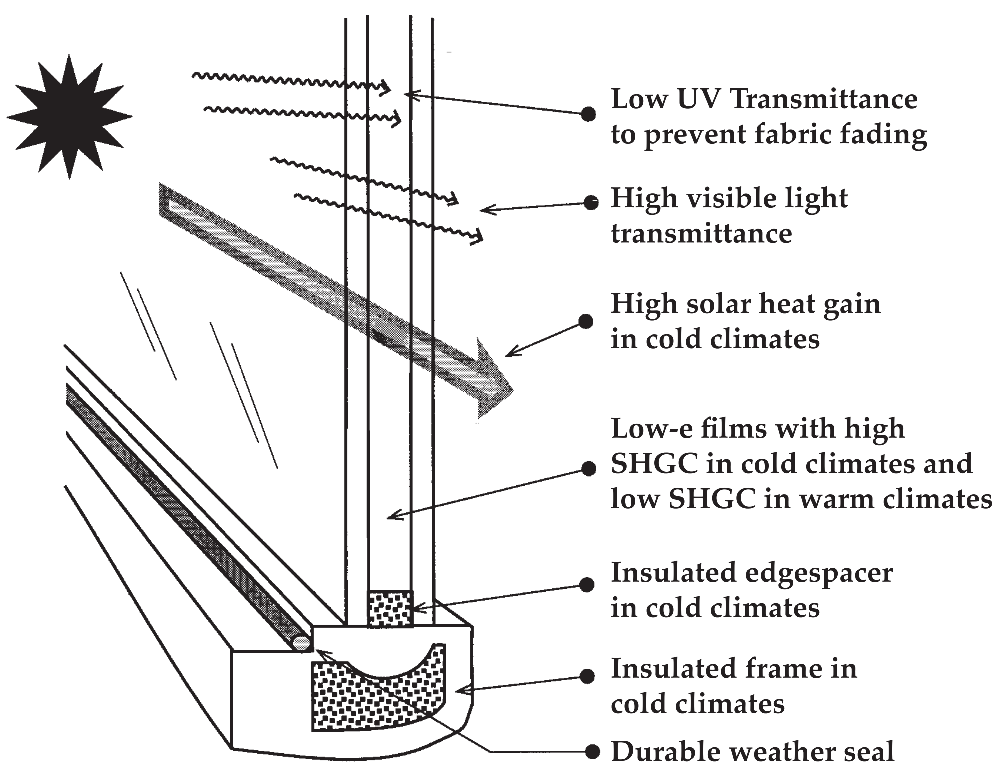

Figure 1. Energy Efficient Window

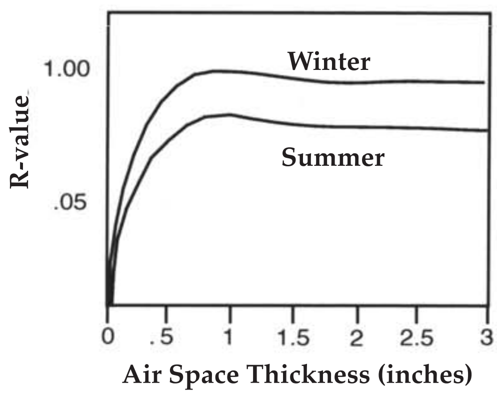

Figure 2.1a. Thermal Resistance of Air Space

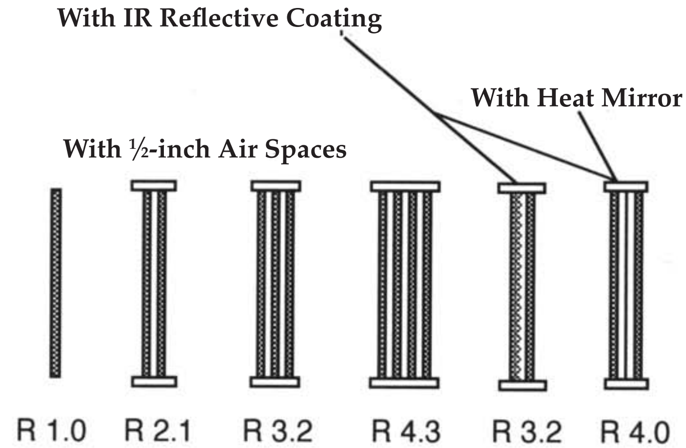

Figure 2.1b. Insulation Values of Glazings

window became radically more important. Today, the window frame and glass edge effects play a critical role in determining overall insulating R-values of windows. One factor to consider related to the edge effect is that a larger window is less impacted by these edge effects, simply because the perimeter is smaller portion of the whole system.

Window frames are not at a higher stage of technical development however. Frames are only at the initial stages of improvement, and much potential still remains to develop better window frames. A close inspection of Table 1 will show this to be the case. Compare the frame R-values between aluminum and wood framing, for instance. Aluminum frames with or without a thermal break are not recommended for Alaskan applications. (See Table 1 on page 18).

2.1 IMPROVING WINDOW THERMAL PERFORMANCE

Heat losses through the window frame can be reduced in the following ways:

- Use an airtight seal between the glazed unit and the sash. This is accomplished with durable, flexible gaskets and glazing boots.
- Use fixed (non-operable) units. It is generally easier to ensure an airtight seal.
- Provide an airtight seal between opening sashes and the window frame. The airtightness of this joint depends on the type of weather stripping used and the amount of pressure that can be placed on the window frame and opening sash joint. Sliding windows, whether horizontal or vertical, tend to have the highest air leakage rate because positive closure and compression is more difficult. Turn/tilt, casement, awning, and hopper windows tend to be more airtight, since more pressure can be placed on the weather-stripped joint. Any warping of the opening sash will also affect the airtightness of an openable window. Compressible weather-strip made of E.P.D.M.* or EPDM compounds, are desirable for cold climates. A standard test procedure rates windows on the basis of the volume of air leaking through the window at a standard pressure difference. Air leakage test results can be used to compare one window with another, but certain factors must be considered when studying test results. 1. windows that are tested are new; 2. test windows are built to be tested; and 3. during structural testing, the windows are the same temperature on both sides.
- The space between the panes of glass can be filled with gases that insulate better than air. Argon, sulfur hexafluoride, and krypton are among the gases that have been used for this purpose. Gas fills add little to the cost of most windows, and have proven most effective when used in conjunction with low-E coatings. For these reasons, some manufacturers have made gas fills standard

*E.P.D.M. is the acronymic name for ethylene propylene diene monomer, a synthetic rubber product with a wide applicability in gasket uses.

in their low-e windows. Table 1 (page 18) provides R-values for some low-E and gas-filled window configurations. Table 2 (on page 5) (Gas R-values) shows the different insulative values for different gas fills of windows. Note also that in the second column of Table 1, the R-Values are for the center of the glass only and do not account for the edge effects.

- Minimize heat conduction through the window frame by:
    1. Using a low conductivity material such as wood, fiberglass, or vinyl for the window frame.
    2. Using a window frame with air chambers or thermal breaks.

Recently a vacuum technology window glazing system has been introduced in Japan. This is the world's first commercialized vacuum glazing. Figures 2.1c and 2.1d show how this glazing system is configured. Although this is a wonderful option it is not available in the North American market. Plans for making it available are not imminent. However, if and when this should happen, UAF Cooperative Extension Service will alert the public. The vacuum glazing made by Nippon Sheet Glass Co. claims to achieve an R-value of 3.85 (u = .26 in English units), achieved in a glazing system lighter than a single pane of North American window glass, and only 8 mm thick (~.31 inches).

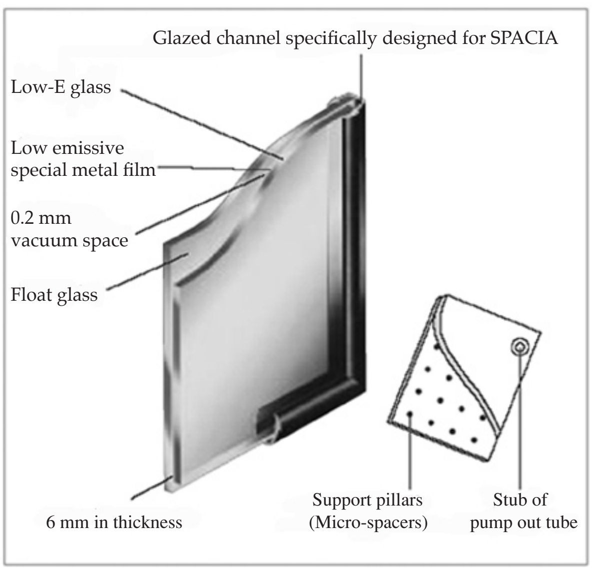

Figure 2.1c. Structure of the vacuum glazing unit.

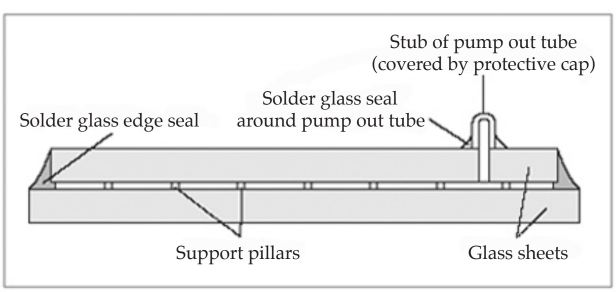

Figure 2.1d. Cross section of the vacuum glazing unit.

2.2 CENTER-OF-GLASS INSULATION

In the past, many window manufacturers advertised the thermal performance of their windows as if they were of infinite size without any edge effect or heat loss through the frame. Increased customer awareness and the formulation of the National Fenestration Rating Council (NFRC) in 1989 have caused a change to this practice in Alaska, and many of the colder regions of the U.S. Windows tested under the NFRC procedure are tested for the overall window of a specific size. The center of glass R-value can be very impressive but is of little use when calculating heat loss from a building. The actual thermal performance of a window is dependent on the framing materials used, the edge spacers, the degree of glass inset into the frame, and other design characteristics. The thermal performance in the center of the glass is better than the "whole unit" performance. This means that, in general, larger windows will have a better overall thermal performance than small ones. A picture (or fixed) window will be better than an opener. When comparing windows, the consumer must be aware of the type of information they are being given.

2.2.1 AIR SPACE

The higher the number of air spaces, the higher the R-value and the lower the heat loss through the window. The number and thickness of the air spaces between glazing is the most important factor. Windows with a ¼-inch air space between glazing (even with low-E glazing) have a lower R-value than windows with ½-inch or more air space. In most cases, however, air spaces of more than 1-inch will be less effective than ¾-inch space, due to convective air movement between the panes of glass. Air spaces over ¾-inch allow the convection flow air films to be unrestricted and the convection transfers heat from the inner pane of glass to the outer pane at a faster rate. The difference in temperature and the height of the window also effect the amount of heat transferred by convection.

Air Space	R-value
¼″	R-1.5
½″	R-1.8
1″	R-1.96

2.2.2 LOW-E

Low-e glazing systems are now widely accepted for all energy efficient buildings. The low emittance (low-e) surface blocks radiant heat loss and warms up the inner surface of the glazing. The low-e surface is either vacuum "sputtered" onto finished glass or a .002″ polyester membrane (the so-called soft coat), or applied hot during glass manufacture (hard coat). In the case where the film is applied to the polyester membrane, the membrane is suspended between the lights of glass, establishing two air spaces, as well as the radiant heat reflection. This configuration is trademarked "Heat Mirror".

The soft coat surfaces deteriorate when exposed to moisture, so can only be used in sealed units. Hard coat is more durable and can be used for window surfaces exposed to the air. While this durability difference is used to market hard coat low-e windows, it has no significance in sealed unit windows. A second generation hard coat process has been recently developed to reduce the emissivity (increase R-value) and control the solar heat gain coefficient (the ability to transmit solar energy).

2.3 ARGON AND OTHER GAS FILLING FOR WINDOWS

Argon is an inert gas that is denser than air. An air space properly filled with argon can result in an R-value increase of 1.0. In general, the theoretical R-value of an insulated low-e window will go from R-3.0 to R-4.0 with the addition of the gas. Krypton gas is also now being used for window fills. Table 2 shows the various R-values and respective gas layer thickness presently used in windows. Care must be taken to optimize spacer thickness for gas filling because heavy gases convect more readily than air.

TABLE 2. GAS R-VALUES

INCHES	AIR	ARGON	KRYPTON
0.250	2.21	2.50	3.68
0.375	2.79	3.31	3.81
0.500	2.90	3.59	3.72
0.625	2.90	3.40	3.61
0.750	2.90	3.40	3.61
1.000	2.90	3.31	3.42

Extrapolated from Energy Design Update, November 1991.

There is a somewhat "hidden" issue, which needs to be understood when shopping for windows that use a gas other than air between the panes. Both the commonly used inert gas options, argon and krypton, diffuse slowly out of the space between the panes through the edge-spacer sealing compound. This diffusion is very slow however. It typically takes ten years for the concentration of inert filler gas to become effectively air.

So is argon or krypton gas fill a worthy option? The answer is yes. Even though it slowly is lost, the gas fill is much better at insulating the window than is air. Argon fill for a ½-inch air space (see table 2 above) is .69 R-value better than air. This is a 27% improvement in a simple double pane glazing with a ½-inch space, over an air-filled space. With a triple glazed, or "heat mirror"™ type window the advantage is nearly doubled, since there are two argon filled spaces.

Although the precise energy savings are difficult to determine, these advantages of argon (or krypton fill) are significant enough and add very little incremental cost to the window. In fact one retailer of windows in Fairbanks doesn't charge anything extra for the argon, at least when they're selling the top quality (triple glazed, double argon space, double low-e) grades of windows. Homeowners are well advised to purchase argon fill windows.

2.4 WINDOW EDGE INSULATION

Most windows use aluminum spacers to separate the panes, an unfortunate choice from a heat loss point-of-view. For windows used in cold climates, some manufacturers have substituted foam spacers and thin metal spacers standing on edge encapsulated in sealant to help reduce the edge effect. Southwall's Heat Mirror™ units must utilize steel spacers to withstand the drumhead effect of the polyester membrane when it's suspended between the panes. These steel spaces are frequently separated by a foam thermal break. Another approach is to simply recess the spacer deeper in the frame and thereby reduce the conduction of the edges by "sheathing" them in framing and glazing gaskets. This is a common practice in European designed PVC window systems.

The edge spacer is clearly a weak spot in the thermal performance of windows. To counteract the edge losses of heat, research into suitable material substitutions for edge spacers has been ongoing for more than a decade.

Some materials tested include a corrugated metal spacer, a metal spacer with a polyurethane thermal "break" (an insulated spacer), silicone foam spacers, and vinylm butyl-rubber edge spacers.

Particularly good performance has been achieved with the "warm edge"® technologies, both the vinylm butyl-rubber, and silicone foam materials. They do cost more than standard metal edges, but the better performance makes this technology suitable for all window systems. It should be considered mandatory when low-e coatings and inert gas fills are used. If warm-edge technology is not used with these technologies, much of the benefit of these technologies is lost by the poor performance of normal metal edge spacers.

2.5 ADDITIONAL GLAZING OPTIONS

There are some interesting materials other than glass which are now available for architectural and home applications. Some of the more diverse options are available from Kalwall Corporation (www.kalwall.com). Kalwall's products are translucent glazings, panels, and flexible fiberglass of a patented type. A series of products made for applications as either windows or translucent wall sections are available. They are in panel form, typically either in 4 or 5 ft. wide choices, and lengths in one foot increments from 3 to 20 feet.

Figure 2.5. An example of a Kalwall glazing used in an elementary school in Rochester, New Hampshire. This is the R-10 translucent glazing material, a double surface fiberglass with insulation between the fiberglass sheets. The view is from the inside of the building, so that actual light levels are shown. (Photo from www.kalwall.com)

Even more of interest is that some of Kalwall's products have substantial insulation value while still maintaining translucence. While the light transmittance decreases as the insulating value of the panel increases, panels with an R-value of 10 (U = .10) are rated at .18 solar heat gain coefficient, and 18% of the light transmission of full sun. This may be the closest option available to translucent insulation. An option with 5% light transmission and an R-value of 20 is also available. This is a product designed for use as a skylight, so light transmission is not its highest positive feature. The R-10 option material is perhaps the most interesting because it could find wide application as a translucent *shutter!* R-10 is more than twice the R-value of "heat-mirror" type glazings, so this material still has some daylight transmission capability, but is effectively an insulating shutter. It also weighs less than 2 pounds per square foot, much less than glass, or wooden-framed shutters with insulation.

2.6 WINDOW FRAMING MATERIALS

Choosing the frame material for windows is a major consideration. There are three materials that are recommended for northern window framing material: wood, fiberglass, and PVC (an abbreviation of polyvinyl chloride, the plastic material from which this type of frame is made). Although aluminum frame windows are still manufactured they are not recommended for northern climates, as their thermal performance is poor compared to the three materials listed above.

Wood Frames: Wood is listed first in the choice framing materials because it is an excellent workable material, can be finished in many ways, and has good thermal and physical properties for window framing. It is also cost competitive and is recommended as the best choice for framing non-opening windows. Wood's disadvantages are its biodegradability (mold) and it can warp, so is a high maintenance material.

Fiberglass Frames: Fiberglass frames have only become available in Alaska in the past 4-5 years. It is an ideal framing material for windows, can be painted, has virtually the same coefficient of thermal expansion as glass (meaning it expands or contracts at the same rate as glass with a change in temperature), and doesn't warp, rot, or mold. Fiberglass should last the life of a building. It is the most expensive choice of framing materials, but has all the advantages of PVC windows and none of the disadvantages. It has higher strength and can be used with fastenable hardware better than can PVC.

Vinyl (PVC) Frames: Although by far the most popular material in the marketplace for window frames, PVC is not an ideal choice. This is particularly so for the colder climates of the far north, where greater temperature differences are a concern. PVC expands (or contracts) four times faster with temperature changes than does either wood or fiberglass. This stresses the external caulk/weather seal (see figure 7.2e) during times of extreme cold, as the window literally shrinks away from the wood "rough opening." Caulks that can handle this condition are described on page 17 in the section on the plywood window installation method.

3 INFILTRATION AND AIR LEAKAGE

Air infiltration is another area of a window's energy performance that warrants some attention. Window manufacturers list air leakage

Figures 2.6a & b. Two views of fiberglass window frames taken at the Fairbanks Home Show. Photos by author.

rates for their windows in terms of cubic feet per minute per square foot of window opening (CFM/ft). Typical figures range from .02 to .22 CFM/ft; the lower number indicates a tighter window. Turn/tilt and casement windows are less leaky than double hung, side slider windows or patio sliders. The type of weather stripping affects air leakage. Weather stripping made of low temperature synthetic rubber like EPDM and

Figures 2.6c, d, e. Several views of PVC (vinyl) plastic window frames from commercial website images.

TPE[*] perform much better at low temperature than plastic. Consider the material used in the window assembly to choose the tightest window. When considering the published air leakage data provided by a manufacturer, remember the window that was tested was, 1. new, 2. made to be tested, and 3. the same temperature on both sides.

4 WINDOWS AS SOLAR COLLECTORS

An often asked question regarding the selection of high performance windows is whether or not they should be used on south facing windows? The answer is complex. About 86% of the solar radiation striking a single pane of glass is transmitted through the glass. Double glass allows about 70-75% of solar radiation through, triple glazing about 60%. Low-e double glazing will transmit about 50-60%. So, there is about a 15%-20% higher loss in solar gain with high performance glass (or triple glazing) than with standard double glaze. If solar gain is important, low-e may not be the best choice. Low emittance coatings are customized too by some producers like Southwall Corp's Heat Mirror™ products so the SHGC on south and west walls may be lower than the north and east walls. This practice of allowing solar heat gain where you want it and blocking it where you don't, is known as "tuning the building".

5 ENERGY CONSERVATION AND THE VALUE OF HIGH PERFORMANCE WINDOWS

How does the heat gain verses heat loss pan out for various window options? This question has long irked designers. Should you put large energy efficient windows in the south wall of a home, or minimize windows and insulate the walls better?

Fairbanks building scientist Ron Smith used the HOT-2000 computer program to do an analysis of these trade-offs to determine where an astute homeowner or builder should put his money: in high efficiency modern windows, or thicker walls? He analyzed a "test" home with 88 square feet of double glazed, average windows facing south, and four square feet north-facing, 40 square feet west-facing, and 28 square feet east-facing, a total amount of window area equal to 20% of the floor area of the home (160 square feet). With these windows, the home's heating energy use was calculated with R-55 ceiling, and R-45 wall insulation. The wall heat loss in this calculation was 16.2% of the annual total, while the windows were responsible for 54% of the annual heat loss.

The same size house tested with R-4.3 modern energy efficient windows, and R-42 ceiling and R-30 walls, resulted in an annual heat loss distribution where 30% of the total heat was lost by the walls, and about 32% lost by the better windows. The latter option (windows which are R-4.3, walls R-30 and ceiling R-value reduced to R-42) saves 18.2 million BTUs of energy. With slightly adjusted ventilation rates (from .40 ACH to .35 ACH in the second case), the total energy use of the second case, with the high efficiency window, saves 25% of the annual heating fuel consumption.

The answer as to whether it is a good invest-ment to put money into high efficiency windows is

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*A thermoplastic elastomer (TPE) is a material that combines the processability of a thermo-plastic with the functional performance and properties of a conventional thermoset rubber. See Modern Plastics Mid-October 1991.

clearly YES! With modern window technologies available, the insulation in the walls and ceiling can be reduced in R-values by 20-30% with little or no sacrifice in overall performance when windows with a real performance of R-4 or better are used.

Alaskan studies evaluating the cost effectiveness of various window choices, also come to similar conclusions (Colt, 1991). In an economic investment analysis, Colt looked at the incremental costs and benefits of R-3.1 windows versus cheaper double-paned, R-1.7 window. Evaluating the windows for gas heated homes in Anchorage, oil heated homes in Fairbanks, and oil heated homes outside Anchorage in Southcentral Alaska, Colt's analysis showed that under a broad range of assumptions about future fuel prices and the actual cost of R-3.1 windows, these windows are cost-effective relative to baseline double pane R-1.7 windows. Even if Anchorage's cheap gas prices stay absolutely constant the efficient windows pay off in Anchorage. In Fairbanks and Southcentral, with vastly higher fuel prices, the investment makes overwhelming economic sense.

A frequently overlooked consideration for high performance windows is the comfort factor. Uncomfortable cold drafts created by infiltration and cold air convecting off low quality insulated glass, cause some rooms and portions of room not to be used during really cold weather. A quality window can increase the usable area of a house.

6 DURABILITY, QUALITY AND HARDWARE ISSUES

Windows are critical to the real-life performance of energy efficient housing. They are also the most expensive building element (per square foot of area) in the house. Selection should command great attention, and requires the window specifier to be technically competent and aware of window technologies. This is especially important considering Alaskan climates. An excellent review of window developments for Northern application (a Canadian perspective) was accomplished by Larsson Consulting of Ottawa, Ontario, in a report entitled, "Development in Windows, Door and Hardware for Northern Conditions" (January 1990, see references for full citation). Considerations from the Larsson report make clear the pitfalls and areas of concern in selecting modern windows for the north:

1. The environment places severe demands on windows, doors and hard-ware during installation and operation. Contributing factors including 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 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 cost of high-quality components is high and the need to pre-purchase and transport long distances add to the cost. This discourages purchase of 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 investment more attractive in the eyes of major government agencies. However individual home builders 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. The most hopeful trend is that the recent upgrading of components to meet new energy performance requirements in the south is creating market conditions that will make it possible to produce components that will also meet northern requirements (Larsson, 1990).

6.1 DESIGN AND PLACEMENT OF WINDOWS

The design and placement of windows can have a significant impact on both the comfort level and energy efficiency of a house. The highlights to consider in placement and sizing windows include:

- The majority of windows should face within 30 degrees east or west of due south.
- Avoid large areas of west-facing windows that can lead to overheating late in the day.
- Keep south-facing glass to within 8 to 10 per cent of the floor area for a conventional frame house. Do not use more glazing than this on a south exposure unless shuttering is considered.
- Provide for summer shading using overhangs (which are not effective for east, west- or north-facing windows), using deciduous shade trees, where possible, or providing for shades or shutters.

Some important comparative and evaluative points to consider in specifying windows are:

1. Although low-e coatings and gas fills can offer significant improvement to center glazing U-values, the full potential is not realized because of the increased losses through the spacer and the frame. They have a more significant effect on large windows where the edge effects are minimized. Use the "warm-edge" technologies when available.
2. The benefit of the insulating spacer increases as the performance of the center glazing increases.
3. Most 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. Heat Mirror™ 88 however will effectively block the long wave infrared from leaving the building while allowing 88% of the solar heat gain to enter. Both gas fills and nonconductive 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 a higher indoor relative humidity can be maintained without causing condensation on the glass (see Table 1 on page 18).
5. The higher inner-glazing temperatures of high-performance windows tend to reduce swings in room air temperatures.

Figure 6.1. Two views of the very well designed architectural shading devices used on the home of the University of Alaska president. The top one is a view from the front, and the lower one is a view looking upward from below the shades. These devices have many advantages: they are in a fixed position, so they don't need to be moved seasonally; they are not solid so they easily allow shedding of snow, and because they are not solid, they allow indirect light to pass through them even when the direct light is shaded.

6. Space heating energy savings can be achieved by upgrading from standard to high performance glass. Savings in energy are greater in locations having colder heating seasons, but cost savings depend on climate as well as energy costs. Additional material and performance features to consider include:
   - Fixed windows are generally the tightest.
   - Turn/tilt, casement or awning windows are tighter than sliding windows.
   - Window framing materials should be made of wood, PVC or fiberglass. If windows are non-openable, wood framing is recommended.

6.2 WINDOW HARDWARE

The demands on window hardware in Alaska are legend. Windows are opened all year round, must be openable for fire egress. Of the mass-produced European hardware systems that are available, Tilt and Turn hardware potentially offers the most advantages for the Arctic market. This hardware was developed and is being used in Europe and is successfully used in Alaskan Windows. 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:

- multiple locking points for tight air sealing
- on-site adjustable clearances for fine-tuning clearances between the frame and the weather stripping
- no structural loads on the screws holding the hardware in position
- structural loads absorbed by the metal reinforcement of the frame
- capability of supporting 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
- glass 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 $30 to $45 per window and the tilt-and-turn profiles are available at an added cost of 50 percent. However, because the profile allows opening windows to be larger, typically a combination fixed and opening window can be replaced by a single opening window. The higher cost of the turn-and-tilt profiles is offset by 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 (structural framing that separates windows) that are not energy efficient. These advantages must be weighed against the higher replacement cost of larger units of glass. Window hardware should be a primary concern for Alaskan demands. The advantages of superior hardware are numerous, durability is much greater, and judging from the small incremental cost ($30-$45 per window) the selection of "best available" window hardware is encouraged.

7 WINDOW INSTALLATION

The walls of an energy efficient house are generally thicker than those of a conventional house. This presents choices of installing the window on the inside or outside face (see Figure 7). Mounting on the inside theoretically is more effective from an energy conservation perspective because recessed windows are protected from heat stealing winds. In addition, the inside pane has fewer condensation problems because the interior air flow over the window surface is improved.

However, inside mounting requires extra care and detailing to construct the deep weatherproof sill. In colder areas, thermal bridging may cause interior condensation. It is much easier to have the window recess on the inside and faced with drywall than have a deep exterior sill with the resultant flashing requirements. For this reason, the majority of builders install windows on the outside face. The details required for outside window installation are the same as used in conventional building.

To make the window as energy-efficient as possible, it must be correctly installed. This requires two separate jobs.

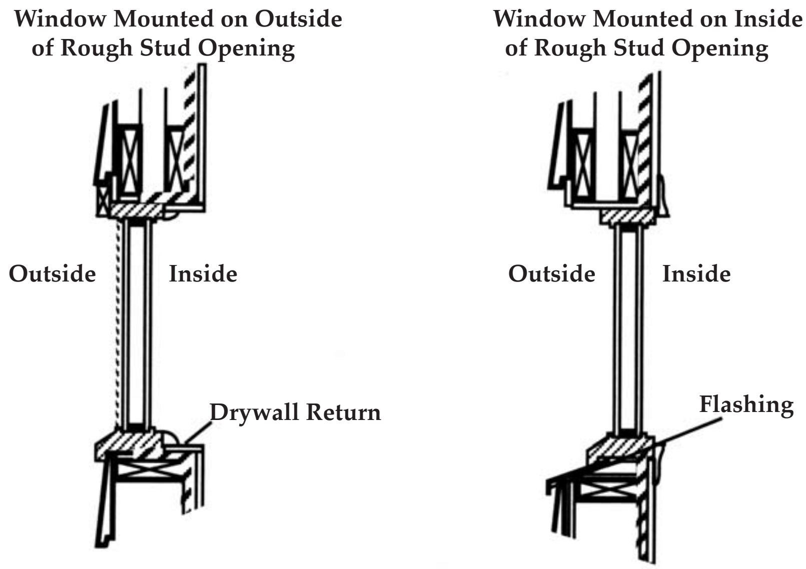


Figure 7. Window Mounting Options

- Insulate the space between the window frame and rough opening.
- Ensure that the air-vapor barrier is continuous and sealed directly to the window frame.

Two methods have been developed for sealing the air-vapor barrier to the window frame:

- Polyethylene wrap – a 6-mil polyethylene flap is attached to the window frame. This method is most commonly applied to wood windows.
- Plywood or drywall wrap – the rough opening is lined with exterior plywood and the window frame is sealed to the plywood.

7.1 POLYETHYLENE WRAP

To install polyethylene wrap:

- Cut a 24-inch wide strip of 6-mil polyethylene. It should be long enough to go around the window with about 20 inches extra.
- Apply a bead of acoustical sealant to one side of the wood window frame. The bead must be located toward the outside of the window frame to ensure that joints between the window frame and jamb extensions are sealed.
- Lay the polyethylene strip over the caulking bead and staple it to the frame through the caulking bead.
- At the corners place a pleat 1-inch wide in the polyethylene on both sides of the corner (see Figure 7.1a). Staple the pleats to the wood frame and inject acoustical sealant to seal the pleats (see Figure 7.1b). The pleats allow the polyethylene flap to fold back at the corners and seal against the wall air vapor barrier (see Figure 7.1c). Continue this process around the frame and join the polyethylene strip to itself with a bead of acoustical sealant.
- Place a continuous piece of fiber-reinforced tape on the polyethylene above the bead of the acoustical sealant and staple through the tape, polyethylene, and acoustical sealant into the window frame at intervals not greater than three inches. This ensures that the polyethylene will stay in place, as staples by themselves do not always have the holding power to keep the polyethylene in place.
- Insert the window frame in the rough opening and shim in place if necessary. When installing wedges, ensure that they go between the polyethylene flap and the rough opening and not between the polyethylene and the window frame.
- Insulate between the window frame and rough opening with non-expanding polyurethane foam, or stuff the space with batt insulation.
- Staple the polyethylene flap to the rough opening.
- After the wall air vapor barrier is applied, cut out around the window opening. A bead of acoustical sealant is applied between the

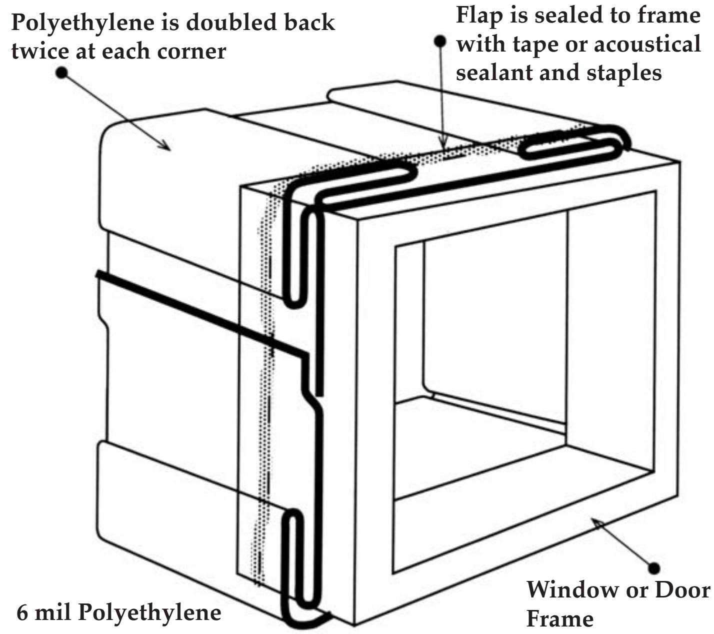


Figure 7.1a. Wrapping The Window Frame

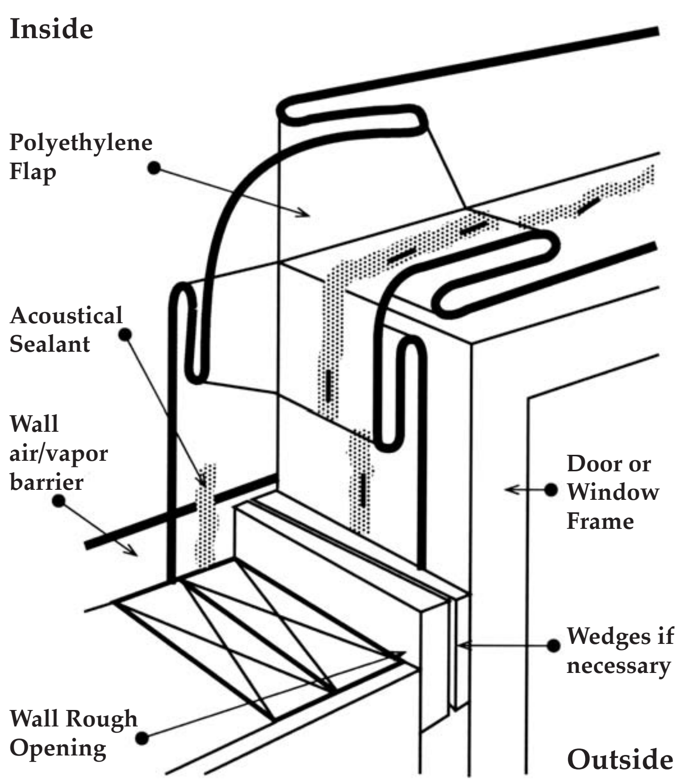


Figure 7.1b. Corner Pleating

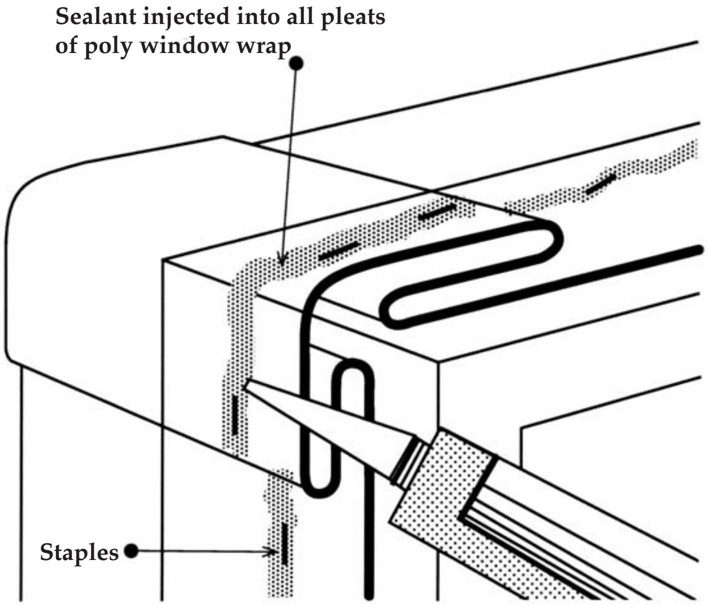


Figure 7.1c. Sealing The Pleats

window flap and wall air-vapor barrier and then staple them together.

7.2 PLYWOOD METHOD

- The rough stud opening is framed to accommodate a ½-inch plywood liner covering the width of the opening. This will mean an increase in both height and width of 1-inch.
- Seal the air-vapor barrier from the house wall to the plywood liner, with either polyethylene or drywall. In both cases, the seal can be to the edge of the plywood facing the room (see Figures 7.2a,b,c,d).
- Nail the plywood liner into place flush with the interior finish and the exterior sheathing. The liner should be caulked to the rough stud on the interior.
- Install the window into the liner from the inside or the outside, depending on the intended location. If the window is to be located toward the interior of the assembly, install proper flashing on the sill before window installation.
- Insulate and seal the gap between the window and the plywood frame. This gap should be approximately ½-inch to allow for proper sealing and insulation.
- Backer rod is a closed cell polyethylene rope and is not a seal or an insulation. Its sole purpose is to be a bond breaker between the caulking and the foam, and it gives the caulking an hour glass shape.
- The caulking should be single part polyurethane or neutral cure silicone. Caulks for use with PVC ("vinyl") windows include these highly recommended products: Bostik Chem-caulk 900, Tremco 830, (both these are single-part urethane caulks) or Tremco Spectrum 11 or Tremco 600, both neutral cure silicone caulks. Use these caulks at joints on PVC windows as shown in 7.2e. Do not use acid cure silicone caulk for sealing the window to the rough opening, as it will not stick to bare wood.
- Allow ½-inch between the window and the plywood wrap in the rough opening to facilitate caulking and insulating.
- Minimum expanding, single part, urethane foam insulation of a type that does not become brittle with age is recommended.

7.3 DRYWALL METHOD

- After sealing, install drywall over the liner and install the finished sill (see Figure 7.3).
- The rough stud framing and window installation follow conventional practice.
- The drywall interior finish is butted and sealed to the window frame to provide a continuous air barrier.

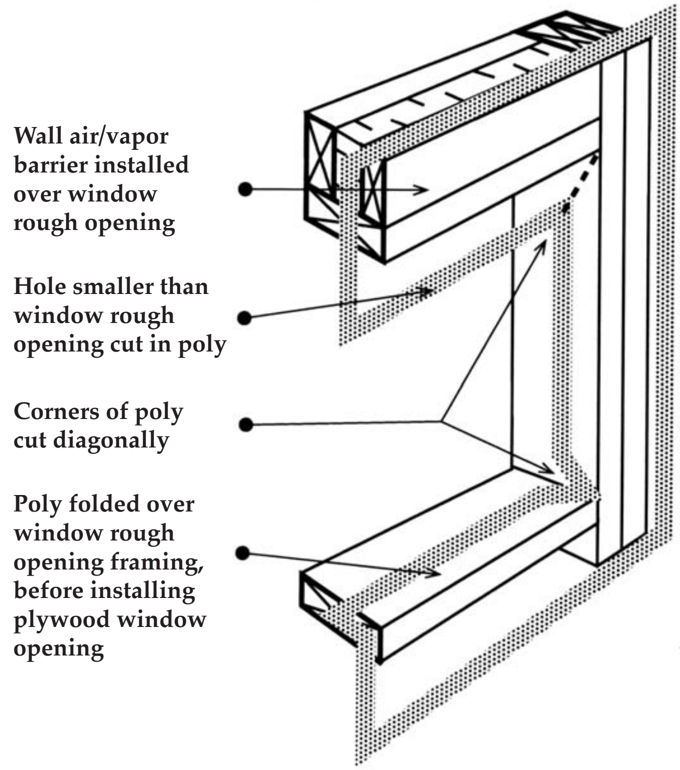


Figure 7.2a. Plywood Wrap: Prior Window Penetration

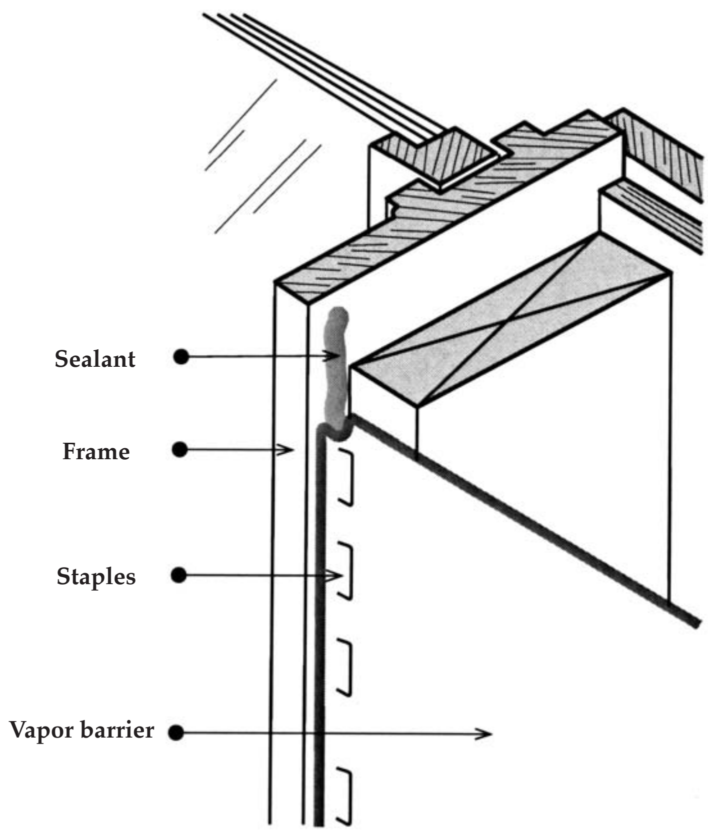


Figure 7.2b. Vapor Barrier Sealed To Window Frame At Edge

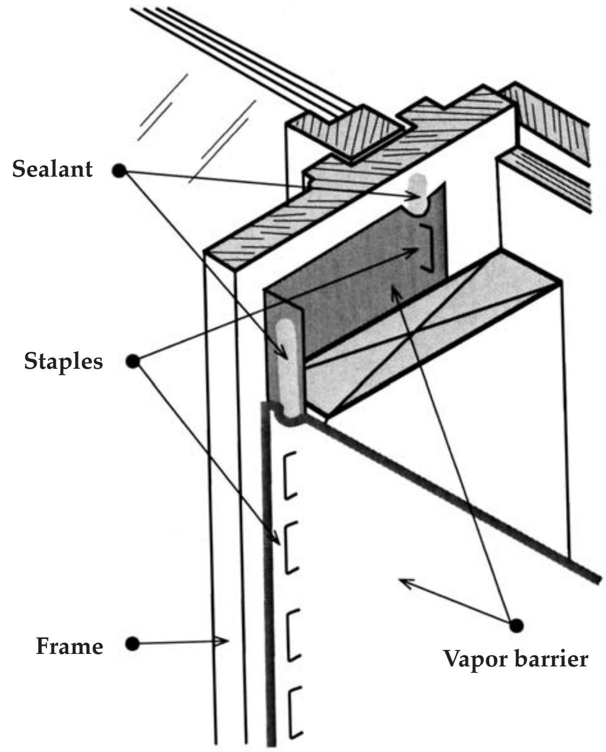


Figure 7.2c. Vapor Barrier Sealed In Single Frame Wall

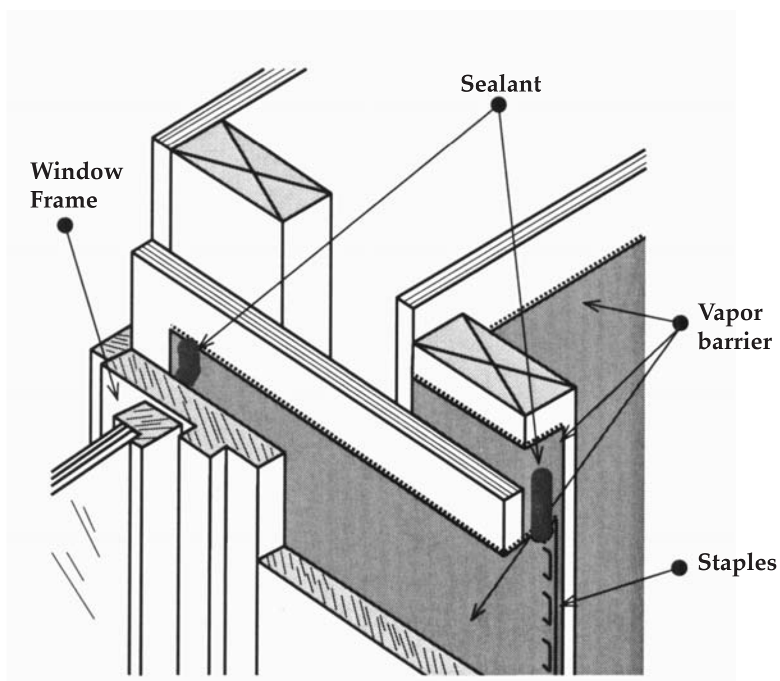


Figure 7.2d. Vapor Barrier Sealed In "Saskatchewan" Type Double Wall

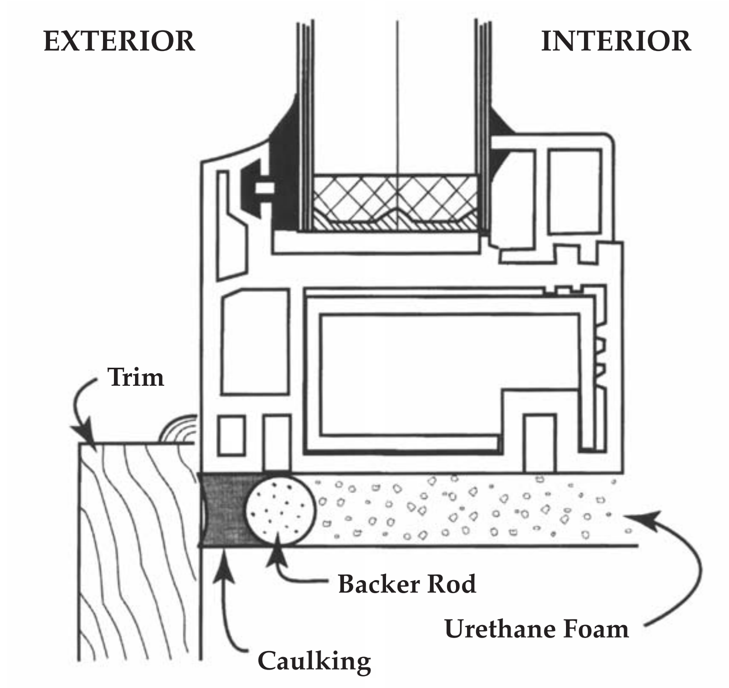


Figure 7.2e. Sealing and Framing Details for PVC Window Frame

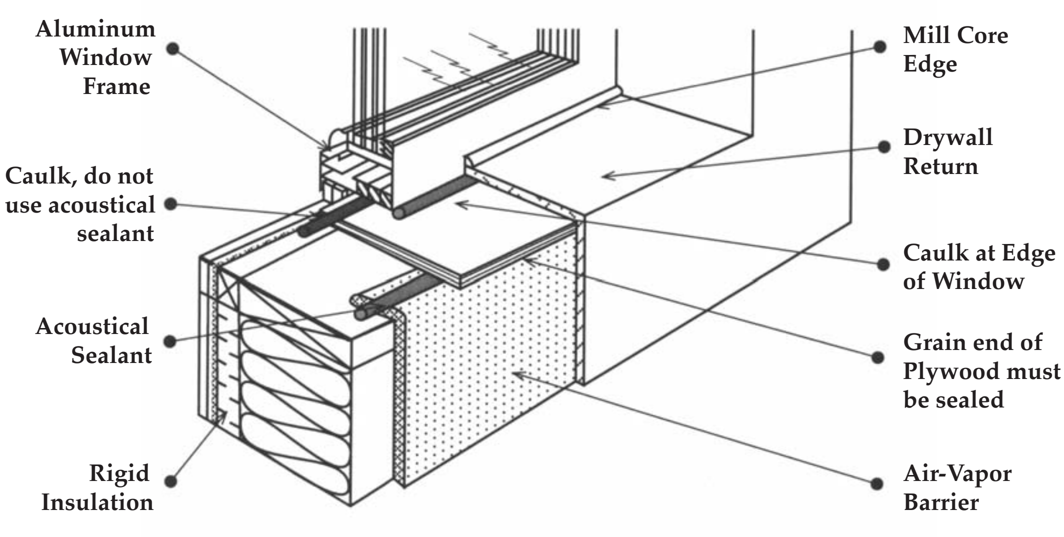


Figure 7.3. Vapor Barrier Sealed In Single Frame Wall

- Where the window is installed on the outside face of the wall, a drywall return will be required in the rough opening and it should butt onto the face edge of the window frame. Caulk this joint. Using a U-shaped drywall cap called a “mill core edge” to cover the cut edge of the drywall makes caulking this joint a simple matter (see Figure 7.3).
- When the window is installed on the inside face of the wall it may be located so that the face edge of the frame is flush with the face of the drywall. This butt joint may be sealed with tape and covered with trim.

Appendix I, Table 1.1

WINDOW DEW POINT CONDITIONS

Type Glazing	Insl. R-val	To, F	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50
		Outside Temperature (To, F), Temperature Gradient (Tg, F), Relative Humidity (Rhi, Pct)												
SINGLE GLAZING	0.85	Tg, F	-34	-26	-18	-10	-2	6	14	22	30	38	46	54
		Rhi, Pct	1	1	2	3	5	7	10	15	22	31	42	57
DOUBLE GLAZING														
center of glazing 1/2” airspace														
	1.70	Tg, F	18	22	26	30	34	38	42	46	50	54	58	62
		Rhi, Pct	13	15	19	22	26	31	36	42	49	57	66	76
1/2” air space filled with argon														
	2.10	Tg, F	28	31	34	38	41	44	47	51	54	57	60	64
		Rhi, Pct	20	24	27	31	35	39	44	50	56	63	71	80
1/2” airspace, hard-coat low-emissivity coating														
	2.66	Tg, F	37	39	42	44	47	50	52	55	57	60	62	65
		Rhi, Pct	30	33	36	40	44	48	53	58	64	70	77	84
1/2” airspace, soft- coat low-emissivity coating														
	2.90	Tg, F	40	42	44	47	49	51	54	56	58	61	63	65
		Rhi, Pct	33	36	39	43	47	51	56	61	66	72	78	85
3/4” airspace with low-emissivity coating between i.e., (two spaces of 3/8”)														
	3.29	Tg, F	43	45	47	49	51	53	56	58	60	62	64	66
		Rhi, Pct	38	41	44	48	52	56	60	65	70	75	81	87
3/4” argon-filled space with low-emissivity coating between (two spaces of 3/8”)														
	4.03	Tg, F	48	50	51	53	55	57	58	60	62	63	65	67
		Rhi, Pct	46	49	52	55	59	62	66	70	75	79	84	89
1/4 “ air space														
wood frame	1.79	Tg, F	21	24	28	32	36	40	43	47	51	55	59	62
		Rhi, Pct	14	17	21	24	28	33	38	44	51	59	67	77
metal frame	1.41	Tg, F	7	12	17	22	27	31	36	41	46	51	56	60
		Rhi, Pct	7	10	12	15	19	24	29	35	42	50	60	71
thermally broken	1.69	Tg, F	18	22	26	30	34	38	42	46	50	54	58	62
metal frame		Rhi, Pct	13	15	18	22	26	31	36	42	49	57	66	76
1/2” air space														
wood frame	2.16	Tg, F	29	32	35	39	42	45	48	51	54	57	61	64
		Rhi, Pct	21	25	28	32	36	40	45	51	57	64	72	80
metal frame	1.69	Tg, F	18	22	26	30	34	38	42	46	50	54	58	62
		Rhi, Pct	13	15	18	22	26	31	36	42	49	57	66	76
thermally broken	2.04	Tg, F	27	30	33	37	40	43	47	50	53	57	60	63
metal frame		Rhi, Pct	19	22	26	29	34	38	43	49	55	63	71	79
1/2” air space, low emissivity coating														
wood frame	2.78	Rhi, Pct	38	41	43	46	48	50	53	55	58	60	63	65
		Rh, %	31	34	38	41	45	50	55	60	65	71	78	84
metal frame	2.10	Tg, F	28	31	34	38	41	44	47	51	54	57	60	64
		Rhi, Pct	20	24	27	31	35	39	44	50	56	63	71	80
thermally broken	2.53	Tg, F	35	38	40	43	46	48	51	54	57	59	62	65
metal frame		Rhi, Pct	28	31	34	38	42	46	51	57	62	69	76	83

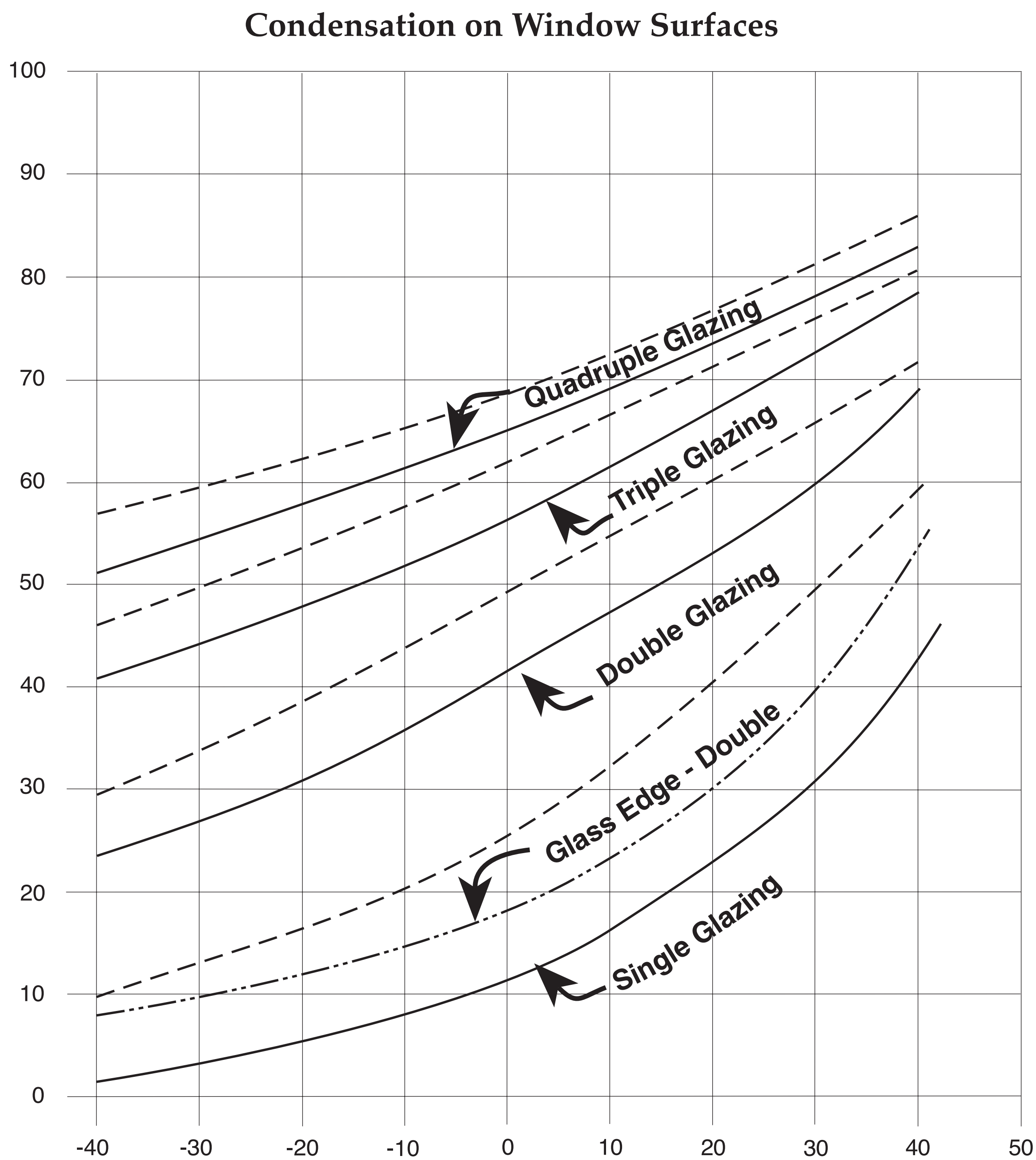
1. Window R-Values taken from Canadian Home Builders Association Builders Manual.
2. Temperature gradient, (Tg, F), Allowable relative humidity, (Rh, %). Temperature gradient and dew point temperature are equal.
3. Developed by Axel R. Carlson, Professor Emeritus, Extension Engineer, Cooperative Extension Service,University of Alaska Fairbanks, Fairbanks, AK 99775-6180.

TABLE 1.2 WINDOW DEW POINT CONDITIONS (continued)

Type Glazing	Insl. R-val	To, F	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50
		Outside Temperature (To, F), Temperature Gradient (Tg, F), Relative Humidity (Rhi, Pct)												
TRIPLE GLAZING														
1/2” air space	2.79	Tg, F	38	41	43	46	48	51	53	55	58	60	63	65
		Rhi, Pct	31	35	38	42	46	50	55	60	65	71	78	85
TRIPLE GLAZING														
wood frame	3.30	Tg, F	43	45	47	49	51	54	56	58	60	62	64	66
		Rhi, Pct	38	41	44	48	52	56	60	65	70	75	81	87
metal frame	2.32	Tg, F	32	35	38	41	44	47	49	52	55	58	61	64
		Rhi, Pct	24	27	31	34	39	43	48	54	60	66	74	82
metal frame	2.90	Tg, F	40	42	44	47	49	51	54	56	58	61	63	65
		Rhi, Pct	33	36	39	43	47	51	56	61	66	72	78	85
thermally broken	4.34	Tg, F	50	51	53	54	56	57	59	61	62	64	65	67
metal frame		Rhi, Pct	48	51	54	58	61	64	68	72	76	81	85	90
low emissivity	4.34	Tg, F	50	51	53	54	56	57	59	61	62	64	65	67
coating		Rhi, Pct	48	51	54	58	61	64	68	72	76	81	85	90
WALL 2x6 STUDS														
6” fiberglass	19.97	Tg, F	66	66	66	67	67	67	68	68	68	69	69	69
		Rhi, Pct	86	87	88	89	90	91	92	93	94	95	97	98
Plate & Sole, 2x6	6.88	Tg, F	57	58	59	60	61	62	63	64	65	66	67	68
		Rhi, Pct	64	66	68	71	73	76	79	81	84	87	90	93
SUPER-INSULATED,														
DOUBLE STUDS	30.00	Tg, F	67	67	68	68	68	68	68	69	69	69	69	70
		Rhi, Pct	90	91	92	93	93	94	95	95	96	97	98	98
INSIDE CONDITIONS														
Interior film		Ri	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Temperature, Ti, F =		Ti, F	70	70	70	70	70	70	70	70	70	70	70	70
Saturated pressure, Psf		Psi, Psf	52.2	52	52	52	52	52	52	52	52	52	52	52

1. Window R-Values taken from Canadian Home Builders Association Builders Manual.
2. Temperature gradient (Tg, F), Allowable relative humidity (Rh, Pct) Temperature gradient (Tg, F) and dew point temperature (Tdw) are equal.
3. Developed by Axel R. Carlson, Professor Emeritus, Extension Engineer, Cooperative Extension Service, University of Alaska Fairbanks, Fairbanks, AK 99775-6180.

Appendix I, Table 1.3



In this chart, based on an indoor temperature of 70° F, the assumed window R-values, center of glass, are:

0.89 ....for single glazing
1.81 ....for double glazing
2.79 ....for triple glazing
3.74 ....for quadruple glazing

All assume air between the panes.

Appendix 2 PERFORMANCE CRITERIA

Key parameters for a high-performance northern window would include the following:

- an overall thermal performance of a least R-4 for an operating window and R-5 for a picture window
- openable windows with minimal air infiltration
- minimum twenty-year durability on all major components
- ability to withstand substantial abuse and vandalism
- be repairable in case of broken glass or hardware

Although these parameters may seem to be inclusive, there are many other parameters that should be considered in assessing window and doors. The following performance criteria provide a suitable framework for future assessments of specific systems:

Physical Performance

Dimensional stability
Warping/racking resistance
UV resistance
Air infiltration
Solar heat gain coefficient
Water/rain resistance
Durability/life span
Maintain performance levels

Function Performance

General operability
Winter operability
Ventilation effectiveness
Percent rough opening visible

Safety & Security

Fire egress
Resist freezing shut
Combustion product
Resist external breakage
Resist burglary

Construction & Maintenance

Transport & handling
Ease of installing correctly
Level of maintenance required
Ease of maintenance & repair
Glass replacement from the inside of building
Capital cost
Maintenance cost
Life-cycle cost

Other

Consumer acceptance

APPENDIX 3 GLOSSARY OF WINDOW TERMS

Argon

A colorless, odorless, inert gaseous element found in air and volcanic gases. Used as a filler in electric bulbs and electronic tubes, or in applications where pressure needs to be balanced. It has a low thermal conductivity.

Cladding

A material, aluminum, vinyl, or other plastic material that is applied as a covering to a wood window frame. The cladding reduces the need for painting and other maintenance usually associated with wood windows.

Emissivity

Unit of measure to measure a surface's emittance. A number between 0.00 and 1.00 that describes a surface's ability to transmit or receive radiation. A perfect black body (black valet) would have an emissivity of 1. The glass liner from a thermos bottle would have an emissivity of .003.

Expansion & Contraction

The physical property of a material's response to temperature changes. Metals have extreme dimensional changes in response to temperature, while porous material such as wood or insulation material change very little. Most rigid plastics have great dimensional changes and are difficult to use as glazing.

Heat Mirror™

A low emittance coating applied to a plastic film and suspended between the glazing. The low-E coating is applied by the sputtering technique.

Insulated Glass

Two or more lights of glass (layers) separated by a spacer, with the edges sealed. The spacer is usually aluminum, ¼-to 1-inch wide, which provides the separation between the lights. The space between the glass may be filled with plain air, argon or krypton, or the space may be a vacuum.

Low-Emittance (Low-E) Coating

Microscopically thin, virtually invisible, metal or metallic oxide layers deposited on glass or plastic film to reduce the radiative heat flow. A typical type of low-E coating is transparent to the solar spectrum (visible light and short wave infrared radiation) and reflective of long-wave infrared radiation.

Pyrolitic (hard coat)
Typically a metallic oxide usually tin with some additives applied to surface 1, 2, or 3, most commonly applied to the third surface. It is fire-fused to the glass.

Racking
A type of lateral deformation of a building or frame caused by inadequate shear resistance or by larger loads than a structure was designed for. A racking failure occurs when wind stress "accordions" a building, for instance.

Reflective Coating Low-E
Coating applied to glass to change the thermal characteristics. There are two types of coating commercially available.

Sputtered (soft coat)
Multilayered coating deposited on glass or plastic film in a vacuum chamber. Silver is often used. The film must be protected from humidity and contact. Emittance rating as low as .04 may be attained.

Surface Coating
In insulated glass units, the surfaces are numbered from the outside surface to the inside surface, the outside surface being the first surface. In a two-layered unit, there are 4 surfaces. When dealing with films on glass, it is important to which surface the film is applied. Not all films are applied to the same surface.

Thermal Break
In metal door and window frames, a vinyl strip, or other low conductivity material, that separates the inside from the outside. It is intended to break the conduction path from the inside surface to the outside surface. In extruded aluminum door and window frames, the inside surface is separated from the outside surface, and the hollow frame is filled with a foam insulation material.

Thermal Bridge
Conductance of heat through window framing material or glass edge seals.

U-Value
The inverse of R-value. In windows look for low U-value rating. $U = {}^{1}/_{R}$.

Vacuum Deposited
The most expensive coating process. The film is usually silver or silver oxide, and occasionally gold. The metal is usually placed on the third surface in cold climates. Stainless steel and chromium are used in combination as materials also.

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