ENERGY EFFICIENT DOORS AND WINDOWS

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For years people concerned with energy conservation have been trying to find a solution to the disproportionate amount of heat lost through windows and doors. That is, because of their lower resistance to heat flow, or R value, doors and windows lose much more heat than other parts of the house. In some extreme cases, as much as 50% of the total heat loss goes out through windows. Just how great the difference is depends on the actual house construction, but, for comparative purposes, the average R value of a standard 2 X 4 wall filled with insulation is about R12. An ordinary single pane window has an R value slightly less than R1, while a typical 1-3/4 inch solid wood exterior door has an R value of about R2. It is easy to see that one square foot of window will lose about twelve times as much heat as one square foot of adjacent wall. The windows only have to make up about 8% of the total wall area and they lose as much heat as all the rest of the solid wall area combined. Fortunately, the situation is slightly better for doors because they have a slightly higher R value and generally do not make up very much of the exterior surface of a building. Still, this conductive loss is only part of the story. Perhaps a much more important part of heat loss through windows and doors is caused by the infiltration of cold outside air into the home through gaps and cracks in the doors, windows, and framing around them. Usually this can be corrected easily by caulking cracks in surfaces that do not move and applying weatherstripping to surfaces where one or both members do move. This is covered in much greater detail in the WEES factsheet "Caulking and Weatherstripping", but suffice it to say this is usually a very inexpensive conservation investment that pays back quickly. The intention of this fact sheet is to discuss tactics and products available for improving the energy efficiency of doors and windows that go beyond the level of caulking and weatherstripping, such as insulated doors, insulated glass, options for storm windows, and the newer, technologically improved "reflective" film windows.

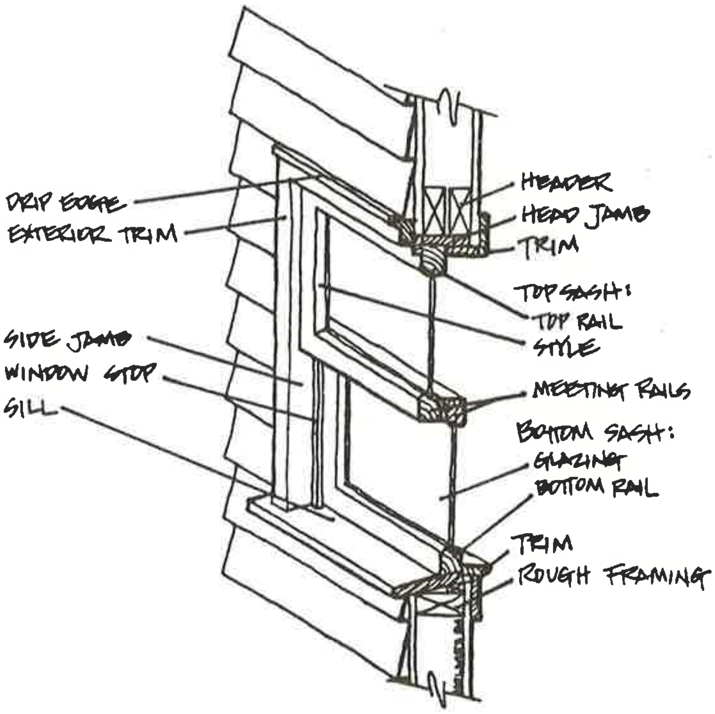

Figure 1. Anatomy of a Sash Window

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DOORS

The question of energy efficiency in doors is a somewhat limited one because there are only a few instances which justify replacing an old door with a better quality one. Storm doors are often suggested as a solution to the poor insulation doors provide. A storm door will reduce the flow of heat by creating a dead air space between the two doors, if both are well sealed with weatherstripping. In addition, it will protect the surface of the primary door from the effects of weather. Still, the installation of a storm door becomes questionable from a cost effectiveness point of view when compared to the cost and benefits of other conservation measures. This is because the actual heat lost is small and the cost relatively high, by comparison. If the primary door needs replacement, however, purchasing one of the newer, insulated, metal-clad doors can be a smart investment. These doors are built so that the core of the door is filled with a high R value foam insulation, then covered with metal for the exterior surface. The foam will raise the R value of the door to R7 through R14 depending on the type and thickness of foam used. The metal clad exterior improves the door by requiring less maintenance and resisting warping. In addition, many metal clad doors use a magnetic strip as well as a compression weatherstripping to insure a good tight seal. The one disadvantage is that the surface will dent. These doors are now available with various designs, raised panels, or windows and compare in price to similarly designed wood doors.

The door type can also make a difference. Despite their convenience, sliding glass doors are notorious heat losers,largely because of the expanse of glass and poor quality weatherstripping that is used on less expensive models. As energy consciousness has been raised over the last few years, some manufacturers have made great efforts to improve the weatherstripping on these units. This is an important point to examine in order to avoid drafts. Metal-framed units will experience more condensation, and even icing in some climates, than will wood framed units, unless the metal frame has what is called a "thermal break". (This is also true of some metal-clad doors.) A thermal break is a piece of non-conducting material, like vinyl or neoprene, that is sandwiched between the two <u>separate</u> pieces of metal making up the inside and outside surfaces of the frame. The vinyl interrupts the direct, low R value metal path from the inside surface to the outside surface. If there is a window in the door, the conduction through the glass will be similarly interrupted if an insulated, or double glazed, unit is used instead of single glass. The air space between the panes breaks the thermal conductivity through the glass area. Using a french door is an option many builders have chosen to avoid the leakiness of sliders. These doors typically seal better because of the weatherstripping used and the ability to get a compression seal. Regardless of door type, the importance of quality weatherstripping and good installation is clear.

WINDOWS

In order to discuss windows, it's helpful to identify the parts. A typical window is shown in Figure 1 on page 1. As with doors, the type of window can make a big difference in the heat lost through the unit (see Figure 2). Here the difference

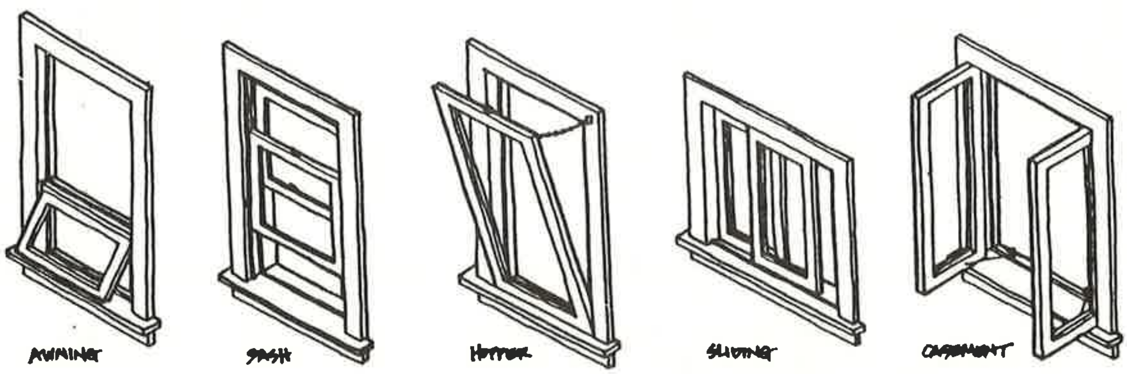

Figure 2. Styles of Windows

is due to the difference in leakiness. As Chart 1 shows, casement or awning windows rank best, generally speaking. Again, the reason is because of the weatherstripping used and the ability to get a compresion seal.

The frame material, as well as the style, is important too. Wood or vinyl framed windows will lose less heat than metal-framed windows, even when the frame is a thermally-broken metal frame. For comparative purposes, examine the chart converted from the BPA Heat Loss Methodology (Chart 2).

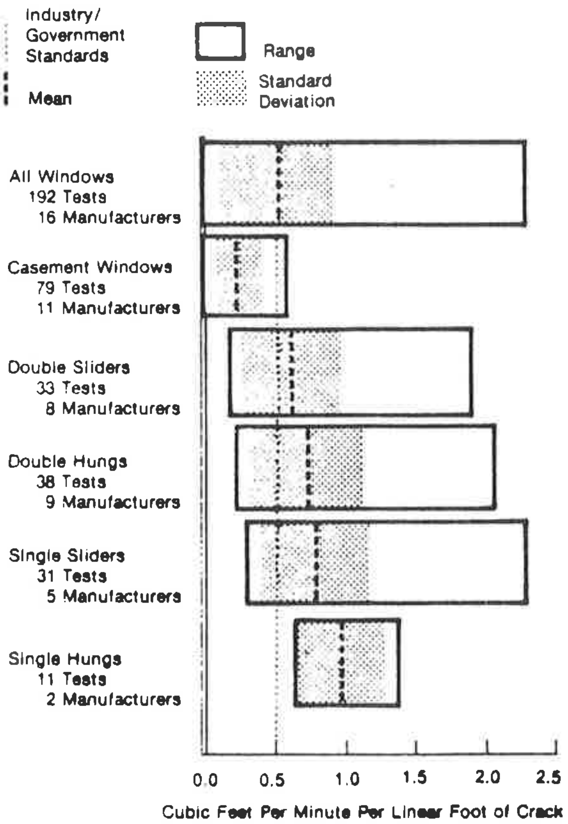

Chart 1. Leakage Through Windows

WINDOW TYPE	FRAME TYPE: WOOD	METAL	THERMALLY IMPROVED METAL
SINGLE GLASS	1.04 (0.96)	0.91 (1.10)	0.99 (1.01)
SINGLE GLASS PLUS STORM WINDOW*	2.08 (0.48)	1.56 (0.66)	1.75 (0.57)
INSULATING GLASS:			
DOUBLE: 1/4" air space	1.82 (0.55)	1.41 (0.71)	1.52 (0.66)
1/2" air space	2.13 (0.47)	1.64 (0.61)	1.85 (0.54)
TRIPLE: 1/4" air space	2.70 (0.37)	1.75 (0.57)	2.13 (0.47)
1/2" air space	3.33 (0.30)	2.22 (0.45)	2.70 (0.37)

*Applies to outdoor storm windows, indoor acrylic storm windows, or sash mounted storm windows. July 1983

Chart 2. R Values for Windows and Sliding Glass Doors

A brief note about terminology is in order here. In describing the efficiency of insulations, designers usually discuss the resistance of R values. With windows, however, a reciprocal term is used, the U value or thermal transmission. The larger the U value number, the more easily heat flows, hence the poorer an insulation it is describing. The terms are easily convertible in that U = 1/R and R = 1/U. For example the double glazed, wood-framed, one-half inch air space window in Chart 2 has a U = 0.47 or an R = 1/0.47 or 2.13. For the sake of consistency, the thermal resistance values or R values will be used here, with U values in parenthesis.

The resistance to heat flow provided by windows does not, for the most part, come from the window material itself. A single pane window, for example, might have an R value of about 0.91 (U = 1.1). Of the 0.91, 0.85, or 93% comes from air films that cling to both sides of the window glass. Any surface, including a vertical one like a window, has a thin, dead air film that clings to it. On the inside of the window, this air film is given an R value of 0.68 (U = 1.47). On the outside the air film is interrupted more frequently by window blowing across the surface of the building, so its R value is rated at 0.17 (U = 5.88). The reason multiple glazings or panes are more resistant to heat loss is that these air films are multiplied. This is pointed out in Chart 2, as is the fact that the space between the two panes makes a difference.

The interaction of frame type with the number and spacing of glazings can also make a significant difference, as comparing the R value of a double-glazed, wood-framed unit with a one-half inch air space, with that of a triple-glazed, metal-framed unit with only one-quarter inch air space shows. Generally speaking, however, the R value of a window unit will increase with the number of glazings. Typically, the quoted nominal R value matches the number of glazings, though this is not strictly true.

SIZE OF AIRSPACE

The effect of air space is a little more complicated, in that the R value increases with the air space up to about 5/8 of a inch. From that point the R value slowly drops as the air space is increased to four inches, then drops rapidly thereafter. The change is due to the action of a convective current between the panes. At less than one-quarter of an inch, air movement is not a concern, but there is little resistance to heat transfer by conduction or radiation. Yet, as Chart 3 shows, the heat lost by the action of air movement up along the interior pane, then out and down along the exterior pane, surpasses the ability of the dead air space to resist heat flow by conduction from air spaces of 5/8 of an inch and up.

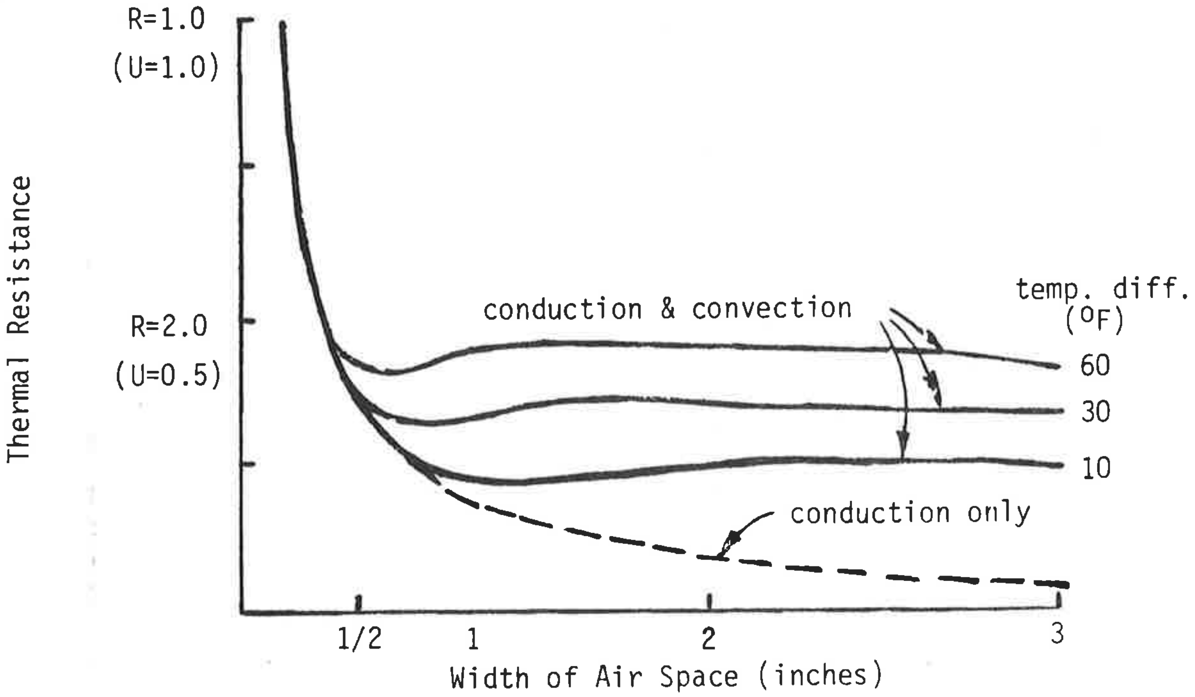

Chart 3. R-Valued Insulation Glass vs. Separation

WINDOW GLAZING MATERIALS

The actual material used for the glazing matters much less than the number of glazings and space between them. Some manufacturers fill the air space with a gas like carbon dioxide or nitrogen which has greater resistance to heat flow than air. With this design, a smaller dimension between the glazings is possible with little loss in efficiency. That is, a quarter inch space filled with carbon dioxide yields approximately the same resistance as a half inch of air space.

For commercially produced windows, the most common materials are ordinary float glass and the impact resistant plastics, like acrylic and polycarbonates. The opposite end of the spectrum, do-it-yourself units, usually employ the less expensive and durable plastic films, like polyethylene or polyvinylchloride (PVC). The properties of these and other materials are presented in Chart 4. There are exceptions, of course. In some passive solar heating applications, designers will specify "solar" glass--sometimes called "water white" because the edge of the glass is clear due to lower iron content, instead of having the greenish color that ordinary float glass has. Such "solar" glass transmits more solar energy (91% instead of 87%) than float glass does. Another special case to be explored later, is the application of "heat reflective" films between glazings to achieve higher resistance to heat flow.

IMPROVING EXISTING WINDOWS

The homeowner who wants to improve the thermal integrity of the existing windows has a number of tough decisions to make. The first is whether the existing window is sound enough to support some modification like adding a storm window or converting to insulated glass. In some cases, the right approach will be to scrap the old unit and replace it with something new, preferably an insulated glass unit. If the existing window is sound, the question becomes "should I install a storm window or convert to insulated glass?". The issues here are primarily: 1) how much is the homeowner willing to spend, and 2) which of these units can be installed most easily and effectively.

COMMERCIALLY BUILT STORM WINDOWS

The following points should be carefully considered when choosing a pre-manufactured storm window:

1. Most commercially built storm windows are aluminum-framed units. Metals conduct heat much more rapidly than plastic, wood, or even glass. If your present window is metal-framed, make sure the storm frame is separated from it by an air space or a piece of non-conducting material like plastic or rubber. Most installers will use a closed-cell foam or neoprene gasket between the mounting surface and the storm. This can act as a thermal break.
2. An "anodized" aluminum frame will guard against corrosion better than "mill finish". Anodizing may also impart a more suitable color.
3. Wood or plastic frames will cost slightly more than aluminum, but also lose less heat. Unless the frame makes up a substantial part of the unit, the difference is unlikely to show up dramatically on the heating bill.
4. The hardware must be compatible with the frame material if aluminum is used. At any rate, non-rusting hardware is preferable.
5. Storm windows function best when installed with an airtight seal. This could be the gasket mentioned above. Good weatherstripping or caulking reduces air leakage and, thus, reduces heat loss. When condensation between the glazings can't be prevented, this air tight seal will have to be broken by weep holes at the bottom of the window.
6. Some storm windows have a sliding portion which can be opened for ventilation. In some cases, this means the storm is only put up on the house once, because the storm and screens slide past each other in tracks. This is especially convenient for second or third floor windows since the storm and screen can be put in place from the inside of the house. Good weatherstripping is important here. These units tend to be the most expensive, however.
7. Good signs are quality weatherstripping where the unit is attached to the home and where any sashes move; glass that is tightly sealed in the frame, as with "marine glazing"; good tight joints at corners; and structural reinforcements like tie bars and anti-bow clips on metal-framed units.

DO-IT-YOURSELF STORM WINDOWS

While someone skilled with tools can make glass storm windows, most people prefer to deal with something more forgiving. Glass is an excellent glazing material because it provides good visibility and long life, but it is heavy and fragile. The fact that different glazing materials conduct heat at different rates does not profoundly affect the insulative ability of the storm window. This is because most of the resistance comes from thin dead air films which cling to both sides of the glass. For this reason, the do-it-yourselfer can choose from a variety of rigid or flexible plastic glazing materials that may be easier to work with than glass, and still make a satisfactory storm window. These various materials are described in Chart 4.

FRAMING MATERIALS

The choice of framing materials should be made at the same time as the glazing is chosen to insure that the two will work well together. Plastic framing materials are easily obtained at hardware stores or department stores which carry weatherstripping materials. Usually the framing material will consist of two pieces: 1) a grooved piece that is affixed to the house with adhesive, nails or screws, and 2) a second piece with a spline that snaps into the groove of the first piece to secure the glazing material snugly in place. Sometimes these two pieces are hinged together on one edge (see Figure 3). Usually, framing materials suitable for use with flexible plastics (i.e. films) will not work with rigid plastics. Also, rigid plastics come in different thicknesses, so the framing material must be chosen for the dimension of the the plastic involved. Some additional considerations include:

1. Is this an aesthetically acceptable material?
2. Are there flat surfaces to mount it on? Decorative moldings can present problems.
3. Can it be painted to match the trim?
4. Is there something else less expensive that will do the job? If many windows are planned, it pays to look up "Plastics--Rods, Sheets and Tubes" in the Yellow Pages for a bulk supplier. This can provide considerable savings over buying many kits from a neighborhood hardware store.
5. Are the materials best applied on the inside or the outside? Plastics exposed to the sun, whether the framing or the glazing, will last much longer if they are "UV treated", that is treated to resist decay due to ultraviolet light. UV degradation is the main cause of the short life for polyethylene glazing materials.

A less expensive storm window is made with a one-by-two wood frame and polyethylene or clear vinyl (PVC) glazing. If the dimensions are cut one-quarter inch smaller than

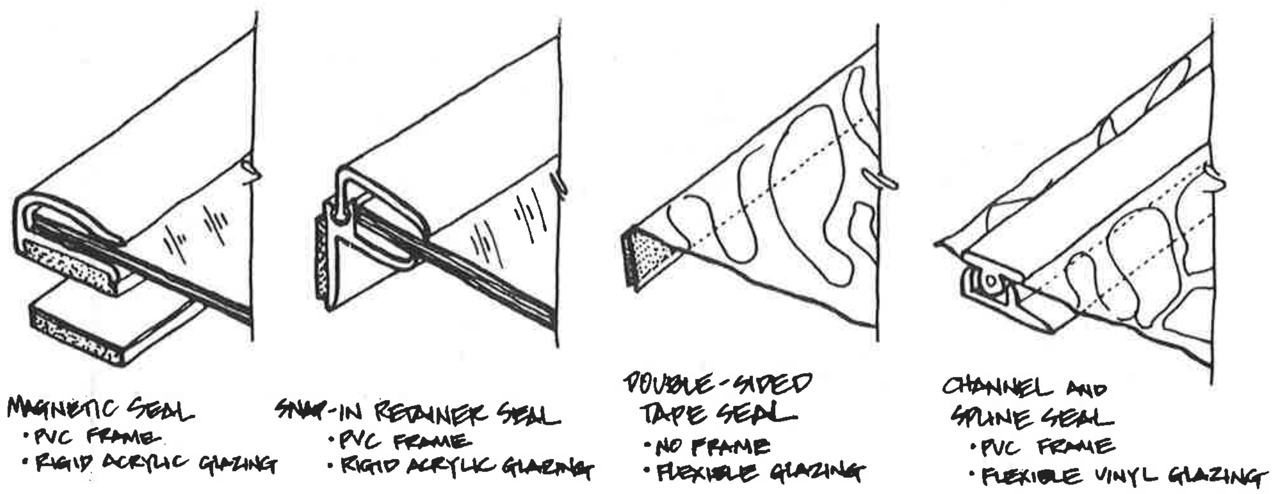

Figure 3. Types of Framing Materials

Chart 4. Glazing Materials

GLAZING MATERIAL	~~COMMON~~ TRADE NAMES[1]	VISIBLE LIGHT TRANSMISSION(%)[2]	INFRARED TRANSMISSION(%)[3]	OPTICAL CHARACTERISTICS	ULTRAVIOLET RESISTANCE[4] (Years until noticeable degradation)	ABRASION RESISTANCE[5]	IMPACT RESISTANCE	SERVICE TEMPERATURE (°F)[6]	THERMAL EXPANSION[7] (in/in/°F)	FLAMMABILITY	CLEANING	MACHINING/ CUTTING, etc/	WEIGHT (per square foot)	OTHER THICKNESSES AVAILABLE[8]	WIDTH x LENGTH AVAILABLE	COST/per square foot[9]	AVAILABILITY	AVAILABLE IN DOUBLE GLAZED UNITS?[10]	COATINGS AVAILABLE[11]
SHEETS																			
GLASS-- DOUBLE STRENGTH (1/8")	———	84-92	3	Clear Low distortion.	20+	High	Low	400°	.0000050	Non-flammable	Strong chemical cleaners okay	Cut with glass cutter only	25.5 oz.	80 mils-500 mils	Unlimited	$1.50-3.50	Yellow pages under "Glass--Auto, plate, window, etc." Also hardware/home improvement/greenhouse supply stores	Yes	Tinted, Reflective, Smoked
GLASS-- TEMPERED (1/8")	———	84-92	3	Clear Low distortion.	20+	High	Medium	575°	.0000050	Non-flammable	Strong chemical cleaners okay	Cannot be cut. Must be ordered to size.	25.5 oz.	125 mils-500 mils	Unlimited	$3.00-4.00	Yellow pages under "Glass-Auto, plate, window, etc."	Yes	Tinted, Reflective
ACRYLIC (1/8")	Acrylite, Exolite, K-Lux, Lucite, Plexiglass	92	5	Clear. Low distortion.	20+	Low, unless coated	High	180°	.0000410	Flammable	No strong chemicals unless coated. Mild, soapy water or plastic cleaner	Can be scored and broken, or cut with fine-tooth saw. Can be drilled.	12 oz.	30 mils-500 mils	up to 10' x 12'	$1.00-8.00 depending on thickness & coatings	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc." Also some hardware/home improvement stores	Yes	Tinted, Abrasion resistant, Chemical resistant
POLYCARBONATE (1/8")	Cyrolon, Exolite, Lexan, Merlon, Tuffak	85	6	Clear. Low distortion	6-10	Low, unless coated	High	250°	.0000380	Self-extinguishing	No strong chemicals. Mild soapy water or plastic cleaner	Can be scored and broken or cut with fine-tooth saw. Can be drilled or nailed	12.5 oz.	30 mils-500 mils	up to 6' x 8'	$5.00-15.00 depending on thickness & coatings	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc."	Yes	Abrasion resistant, Chemical resistant
STYRENE (1/10")	K-Lux	Info Not Available	Info Not Available	Clear. Slight distortion.	2-5	Low	High	200°	.0000390	Flammable	No strong chemicals. Mild, soapy water or plastic cleaner.	Can be scored and broken, or cut with fine-tooth saw. Can be drilled.	9 oz.	30 mils-100 mils	up to 4' x 8'	$1.00-4.00 depending on thickness	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc." Also some hardware/home improvement stores	No	None
FIBERGLASS[12] (30-40 mils)	Filon, Glasteel, Lascolite, Sun-lite	85-95	10	Significant light diffusion. Significant distortion.	1-5 untreated 3-10 if UV treated	Varies	High	200°-250°	.0000136-.0000179	Varies	Varies	Varies	4-8 oz.	Varies	Varies	$.60-1.50	Yellow pages under "Fiberglass Products" & "Plastics--Rods, Tubes, Sheets, etc." Also hardware/home improvement/greenhouse supply stores	Yes	U-V resistant, tints
FILMS																			
POLYETHYLENE (8 mils)	Dynafilm, Visqueen, Polyfilm, Monsanto 602	85-87	85	Some light diffusion. Significant distortion.	1-4 untreated. 4-10 if UV treated.	Medium	Medium	175°	.00011	Slow-burning	No strong chemicals	Cut with scissors or knife	.45 oz.	2 mils-10 mils	up to 40' x 200'	2-10¢ depending on thickness & UV coating	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc." Also hardware/home improvement/garden supply stores	No	Ultraviolet resistant
POLYESTER (5 mils)	Celanar, Llumar, Mylar	80-90	50	Clear Some distortion.	2-5 untreated. 5-10 if UV treated.	Medium	Medium	350°	Info Not Available	Flammable	Mild, soapy water or plastic cleaner	Cut with scissors or knife	.5 oz.	1 mil-20 mils	48" x unlimited length	5-50¢ depending thickness & coating	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc." Also hardware/home improvement stores	No	Tints, Reflective, UV resistant
POLYVINYLCHLORIDE (Clear vinyl) (8 mils)	Resinite, Reynolun, Velon, Vitafilm	90-94	Info Not Available	Clear Some distortion	3-5 untreated. 6-10 if UV treated.	Medium	Medium	175°	.00014	Self-extinguishing	Mild, soapy water or plastic cleaner	Cut with scissors or knife	8 mil-.7 oz.	4 mils-20 mils	up to 72" x unlimited length	10-40¢ depending on thickness & coating	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc." Also hardware/home improvement/green-house/canvas supply stores	No	UV resistant
POLYVINYLFLUORIDE ("PVF")[12] (4 mils)	Tedlar	90	50	Some light diffusion Some distortion.	UV resistant Life in years not available	Medium	Info Not Available	300°	.000040	Non-flammable	Information Not Available	Cut with scissors or knife	4 mil-.5 oz.	4 mils only	up to 100" x unlimited length	30-50¢	Yellow pages under "Plastics--Rods, Tubes, Sheets, etc."	No	None
FLUORINATED ETHYLENE PROPYLENE[12] ("FEP") (1 mil)	Teflon	96	50	Clear Some distortion.	11-20	Medium	Low	400°	.000058	Non-flammable	Information Not Available	Cut with scissors or knife	1 mil-.15 oz.	1 mil only	up to 58" x unlimited length	25-50¢ depending on thickness	Yellow pages under "Fiberglass Products" and "Plastics--Rods, Tubes, Sheets, etc." Also hardware/home improvement/greenhouse supply stores	No	None

TERMINOLOGY USED IN GLAZING CHART

1) Common brand names are listed because many of these materials are better known by proprietary names than chemical or generic names. No endorsement of any product or brand is intended or implied, nor is there any implication that brand names not listed are in any way inferior to those listed.
2) Light transmission refers to the percentage of visible light which passes through the glazing.
3) Infrared transmission refers to the percentage to radiant heat which passes through the glazing.
4) Ultraviolet resistance refers to the ability of glazing to resist degradation caused by sunlight. Ultraviolet degradation can cause discoloration, reduced light transmission, and embrittlement. If the vendor you're thinking of buying material from does not know whether it is U-V resistant, assume it is not.
5) Abrasion resistance refers to the ability of the glazing to resist scratching. This is primarily of concern when washing the glazing. The lower the abrasion resistance, the more care required when washing the glazing.
6) Service temperature is the maximum temperature to which the glazing can be subjected without damage.
7) Thermal expansion refers to the expansion of the glazing as temperature increases. It is expressed as inches of expansion, per inch of dimension, per degree Fahrenheit that the temperature is raised. For example, if you are installing a 60" wide piece of acrylic at 60°F and you expect a maximum temperature of 110°F, you want to know how much the acrylic will expand. To find the answer, multiply the dimension by the increase in temperature by the coefficient of expansion listed on the chart: 60" x 50° x .0000410 = .123". In this case, you'll need to allow for nearly 1/8" expansion.
8) Thickness of plastic glazings is commonly given in mils. One mil is 1/1000 inch. Ten mils is equivalent to 1/100 inch, 125 mils = 1/8 inch, 250 mils = 1/4 inch.
9) Costs are as of early 1983 and subject to change due to seasonal and geographic differences.
10) Double glazed units are generally more expensive, heavier, have lower light transmission than single glazed.
11) Coatings are available which can increase abrasion resistance and resistance to strong chemicals. Coatings can also provide coloration, decrease light transmission, resist ultraviolet degradation, and increase reflectivity. Some coatings can increase the cost of the glazing dramatically.
12) Polyvinylfluoride (PVF), Fluorinated Ethylene Propylene (FEP), and Fiberglass are unlikely candidates for storm window glazings, but their characteristics are listed here because they are of interest to builders of solar collectors and solar greenhouses.

the opening, there is plenty of room for good weatherstripping to seal the storm in. Mitering the corners (i.e. cutting the ends of the pieces at a 45^{o} angle) will make this slight frame a little more sturdy. Using fasteners on the front and back side of each corner helps the job go easily and simply. (Figure 4) Before attaching the glazing, the frame should be tested for fit in its opening and painted, if that is desirable. A heavyweight (8 mil vinyl or better) is then stretched and stapled across the frame, working from opposite sides and corners. Figure 4 also shows how the window can be held in place.

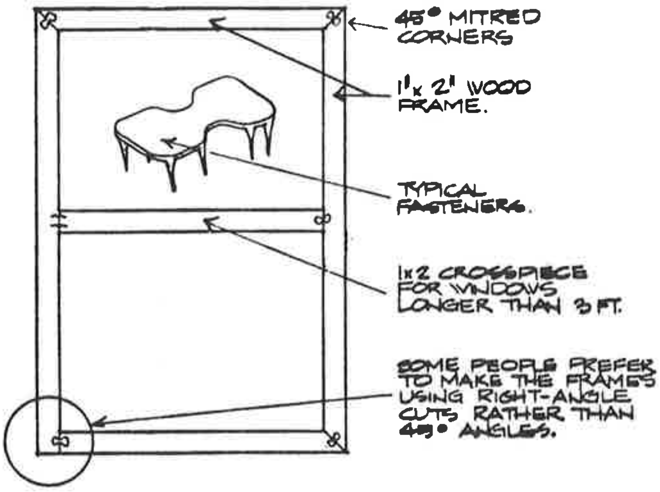

Figure 4. Wood Frame Storm Window

Probably the least expensive storm window is made from a sheet of plastic and tape (see Figure 3). The plastic is sealed to the window frame or to a wall surface with the tape. Ideally, the lightweight plastic film will be one to four inches from the original window glass. Because the films and tapes cannot stand a lot of weathering, this type of window is really only suitable for inside applications. Some people prefer to use a clear, two-sided sticky tape so the tape will be less obvious. One problem can be that the tape may remove the paint or finish from the surface when it is pulled down. Heating it with a blow dryer may make it easier to remove.

INSIDE OR OUTSIDE?

Many people wonder whether the storm window is better installed on the inside or on the outside. Actually, if the primary window is in good shape and seals well, and the storm window is installed tightly, there should be no difference in the energy efficiency of the applications. This means the choice is based on some other set of considerations, like the following:

1. Convenience. Most storm windows need to be removed periodically for cleaning or summer ventilation. In some cases, an interior storm window may be more convenient--especially on second and third story windows.
2. Appearance. Some interior storm windows may be difficult to make inconspicuous. They may also interfere with your interior decorating plans--especially venetian blinds, Roman shades, roll shades and curtains--many of which may be energy savers in their own right.
3. Protection. Storm windows can act to protect your existing windows from breakage if they are made from impact resistant plastic. If yours have this high impact resistance, you may wish to put them on the side of your windows where impact is most likely to occur.
4. Moisture condensation. To minimize the possibility of condensation of moisture between the two layers of glazing material, you will want the window with the most airtight seal on the inside.
5. Noise. Some plastics (primarily polyester films) make flapping noises in the wind unless the plastic is stretched very tightly. If used inside, this flapping will be minimized or eliminated.

INSULATED GLASS

Insulated glass refers to a manufactured double or triple pane unit in which two or more sheets of glazing are sealed in the same frame with a dead air space between them. (Figure 5) Sometimes the air space is filled with another gas as mentioned previously. Typically, the edge of the glass is sealed around a metal spacer with any of a number of chemical sealants.

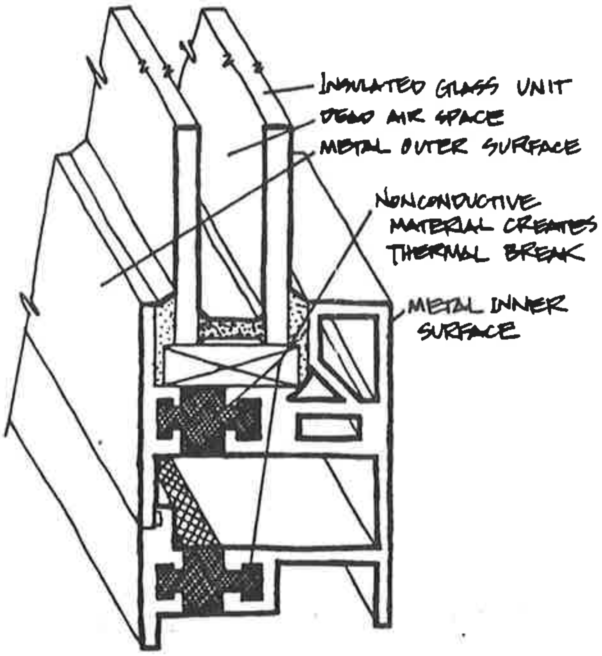

Figure 5. Thermally Broken Insulated Glass Unit

The cost effectiveness of insulated glass in new construction is well known. Whether it makes good sense for the replacement of an existing window can be a tougher question. To begin with, there are two choices: 1)replacing the whole window, frame and all, or 2)replacing just the glass in the existing frame. The first case makes good sense when the existing frame is deteriorated or very leaky. An insulated glass conversion (that is, replacing single glass with an insulated unit in the old frame) may not be as smart as putting up a storm window in some cases. If the dimensions of the existing frame are such that only insulated glass with a three-sixteenths or one-quarter inch air space can fit, and the existing frames are metal, a storm window has better potential. This is because the storm can be installed with a better sized air space and in such a way that there is a break between the existing metal frame and the storm frame. Conversions make the most sense when the frames are large and wood, because the optimum air air space (five-eighths inch) can be used in the glass panel and the frame is easier and less expensive to adapt to the new glass size. For an optimum insulated glass purchase, consider the following:

1. Don't install insulated glass in leaky frames. If the existing frame can't be made air tight before installing insulated glass, install a storm window instead. If that is not satisfactory or if the window is deteriorated, replace the whole unit.

2. Metal-framed units with a thermal break in the frame are 8-20% better than metal frames without the thermal break. (Figure 5)

3. Look for at least a five year guarantee against failure of the seal. Some manufacturers offer even more. If the seal fails, dust and moisture will enter between the panes and cannot be removed.

4. The optimum air space between the glazings is five-eighths of an inch. Some manufacturers reduce this considerably. Unless the manufacturer has compensated for this space reduction by replacing the air with a high molecular weight gas which has greater resistance to heat flow than does air, the efficiency of the unit will suffer.

HIGH TECH WINDOWS

Attempts to achieve more resistance to heat flow than a double glass unit provides have involved extending the same concept--add another layer and triple glaze the unit. This drops the U value to about .33 (depending on the air space). In the last few years, however, a different approach has swept the glass industry. This is the use of "heat reflective" films in insulated glass units. These films actually do not reflect heat but part of the light spectrum called "far infrared radiation". When this far infrared light is absorbed by objects it is converted to a longer wave length of energy which is sensed as "heat". This technology has been common-place for years as solar control films on office building windows to prevent heat gain. Only recently has the idea been applied to residential windows. The reflective surface is made by depositing (or laminating, or "sputtering") microscopic sized metal particles on a plastic film. This film, (there are actually a couple different manufacturers), is either suspended as the middle glazing between two panes of glass in an insulated unit, or laminated to the inside of the outer pane of a double glazed insulated unit. The film is relatively fragile, so putting it inside the insulated unit protects it. In the triple glazed unit with one-half inch air spaces between the panes of glass and the middle sheet of film, an R value of 4.3 (U = 0.23) is achieved with overall dimensions less than a triple glass unit (U = .33; R = 3). When the film is laminated to the inner surface of the outer pane of a double glass unit an R of about 3.85 (U = 0.26) can be achieved. The one disadvantage to this technique is that it does reduce the solar radiation transmitted. In the examples mentioned, the triple glazed unit is reduced to 53% transmittance and the double glazed unit to 65%, while an ordinary double glazed unit would have about 71% transmittance of the solar spectrum. This does not mean that these units will make the house dark, since the solar spectrum is larger than the visible light spectrum. The same unit that reduces the solar spectrum to 53%, only reduces visible light to 88%. While the cost of these units is significantly higher than conventional insulated glass, they still make good economic sense in climates where preventing heat loss is more important than promoting heat gain, as is the case in a good part of Washington state. Furthermore, this technology is continually improving. Many major manufacturers are switching over to this technology instead of triple insulated glass. One manufacturer is meeting with success at applying the microscopic particles directly to the glass instead of using a film as the intermediary. It seems logical that the incremental cost will diminish as the industry "comes on line", just as it did when insulated glass first became popular.

CONDENSATION

A special section on condensation is in order since it is a common problem with windows in winter. Since warm air can hold more moisture in a vapor state than cold air, the cold glass surface provides an excellent surface on which condensation can form. Installing a second pane of glass to the window essentially raises the temperature of the inner most surface of the window unit. This means that condensation is less likely to occur, or may be entirely avoided.

The point at which condensation occurs is a good indication of the cause of the problem. With insulated glass units, if condensation occurs between the panes, the seal has failed and the unit will have to be replaced. If the unit is well sealed, but there is condensation on the glass, the humidity level in the home is too high. With storm windows there are a couple of different possibilities. If condensation is forming on the inside surface of the innermost window it may be that the humidity level is too high, but it could also be that the exterior window is not sealed well enough. In the latter case, providing better caulking or weatherstripping on the exterior window may prevent cold air from leaking in between the panes and chilling the innermost pane. This should, at least, reduce the problem. When the condensation forms on the inside surface of the outermost pane, it is an indication that the interior window is not well sealed and is leaking warm moist air into the cavity, where it is cooled when it hits the inner surface of the exterior window. If improving the seal does not relieve the problem, then weep holes should be provided at the bottom of the storm. These will allow the moisture to drain out and permit a slow exchange of air with the outside. Two holes (3/16") should be drilled to begin with, then more added if necessary. The hole should be stuffed with fiberglass or covered with some screen to keep out insects. The hole should be swabbed with a sealer, like varnish, to prevent moisture damage to the window frame or sill.

BENEFITS OF STORM WINDOWS OR INSULATED GLASS

INCREASED COMFORT:	There will be fewer drafts near windows and the inside of the window will be warmer so more of the house can be used comfortably.
REDUCED CONDENSATION:	Storm windows and insulated glass usually reduce condensation on windows. Mildew and dry rot are less likely on window sills.
REDUCED MAINTENANCE:	Exterior storm windows help protect wood frames from exposure to weather. Therefore, repainting, reputtying and replacing windows is needed less often. Plastic storm windows protect windows from breakage.
NOISE REDUCTION:	The dead air space between the windows reduces outside noise.
LOWER HEATING BILLS:	Storm windows or insulated glass will lower heating bills by 5-20%. (For expensive, commercially-built storm windows and insulated glass, it may take 10 to 20 years to recover the cost of your investment. If you make your own storm windows, you can expect a much faster payback. For example, clear vinyl glazing with one-by-two frames may pay for themselves in as little as two heating sessions.)

SUGGESTED READING

- Shurcliffe, William. Thermal Shades and Shutters. Brick House Publishing Co. 1980.

  A good chapter on how heat is lost through windows.

- Langdon, William. Movable Insulation. Rodale Press. 1980.

  First three chapters discuss basics of windows and heat transfer.

- Watson, Donald, ed. Energy Conservation Through Building Design. McGraw-Hill Co. 1979.

  John Yelliot's chapter on "Fenestration and Heat Flow Through Windows" will interest those desiring a more technical discussion of heat flow through windows.

- Hastings, S. Robert and Crenshaw, Richard W. Window Design Strategies to Conserve Energy. National Bureau of Standards. 1977.

  Good discussion of multiple glazings, but much has happened with reflective films since 1977.

MAGAZINES

- "Great Windows: A Computor's Choice", Solar Age. Feb. 1983.

  Compares various new types of windows, including some with "heat reflective" films.

- "Smart Skylights", Rodale's New Shelter. Dec. 1983.
  "Good News on Skylight Performance", Solar Age. Feb. 1983.

  For those who must have overhead glass.

- "South Facing Glass - What Type and How Much", Solar. Sept/Oct 1983.

  Good analysis from a Seattle designer. Advantage here is that he is aware of our climate.

- "More on Glazing Performance", Solar Age. Oct. 1984.

  Compares double, triple, and low emittance glazings for a specific locale, unfortunately not the NW, but useful anyway.

- "Engineers Guide to Plastic Glazings", Solar Age. Aug. 1983.

  Good, thorough discussion.

- "Storm Window Repair", Rodale's New Shelter. Sept. 1984.

  Good for replacing glass in a couple types of windows.

This factsheet was written by Chuck Eberdt.

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