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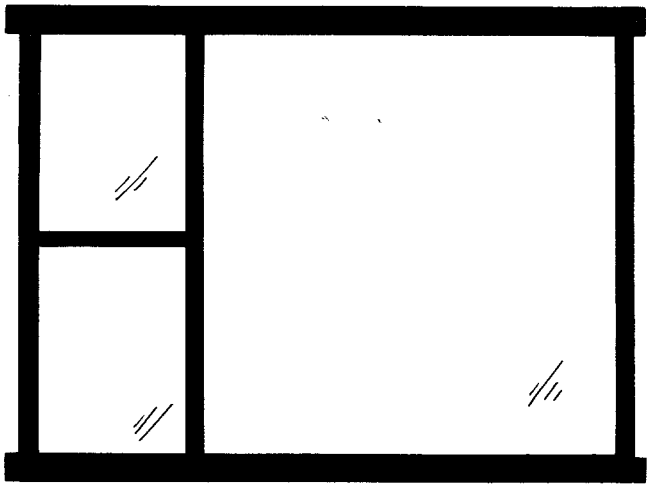

ENERGY CONSERVING WINDOWS

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Windows have often been compared to a hole in the wall when it comes to energy conservation. The best window available with all of the potential energy conserving features possible (except for shutters and shutter type coverings) will have an R-value of less than 6. Even without insulation, a wall will usually have an R-value in excess of 6. Some of the walls in newer homes will have an R-value around 45 and ceilings may be as high as 70. Since R-value is a measure of resistance to heat flow, it is easy to see why a window is commonly considered to be an energy waster.

Over the years there have been a number of attempts at improving the R-value of windows. The first attempts were made by adding various coverings to the windows. Research at NDSU showed that most window coverings only provided modest improvement in R-value (Table 1 shows how some common materials reduced the heat lost through a 26" x 41" window. The Roman shades and extruded polystyrene were most effective in reducing heat loss). Edge sealing did reduce the heat loss of the windows; however, unless special efforts were made to prevent moisture from passing through the window treatment, all treatments increased condensation problems on the window.

Heat loss through the window system occurs in three ways: conduction, convection and radiation. Conduction and radiation losses are commonly grouped together and a R-value is assigned to the window to account for these losses. Convection losses occur as air leaks through the window framing and around poorly fitting glazings.

The total heat lost through a window system is determined by the R-value, air infiltration rate, solar radiation, temperature difference between the inside and outside, wind speed and direction and the low temperature radiation exchange between the window surfaces and the surroundings.

If all the other items are held constant, the higher the R-value, the less the heat loss through the window. Table 2. shows how the number of glazings and glass spacing affect the R-value. Generally, the

Table 1. Total heat lost through a 26 inch by 41 inch window. Losses include heat lost through the frame. The smaller the number, the less total heat lost.

THERMAL CONDUCTANCE BTU/HR/DEGREE F			
Treatment	**No Modifications**	**With Cornice**	**Edge Sealed**
Bare Window	3.16		
A. Draperies			
Antique Satin	2.86	2.84	
Coated Back	2.98	3.02	
Open Weave	3.02	3.04	
Rocion Insulated	3.02	3.12	
Sheer	3.04	2.90	
B. Roller Shades			
Mylar Backing	2.96		
Room Darkening	2.88		2.46
"Home Energy"			1.96
C. Roman Shades			
Mylar/Polyester	2.62		1.84
Thinsulate	2.40		1.74
Polarguard fill	2.50		1.74
Window Quilt			2.04
D. Films			
4 mil plastic	2.60		
6 mil plastic	2.42		
E. Other			
Shutter	2.52		
Moveable Blind	2.90		
1" extruded polystyrene	1.32		

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Table 2. Overall R-value of windows, sliding patio doors and skylights. Vertical mounting. No storm sash, no shade.

	Winter	Summer
Single glass clear	0.91	0.96
Single glass Low Emittance coating		
e = 0.60	0.98	1.00
e = 0.40	1.10	1.11
e = 0.20	1.27	1.33
Insulating glass Double panes		
3/16 in air space	1.16	1.54
¼ in air space	1.72	1.64
½ in air space	2.04	1.79
Low Emittance coating ½ in air space		
e = 0.60	2.33	2.63
e = 0.40	2.63	2.13
e = 0.20	3.13	2.56
Insulating glass Triple		
¼ in air space	2.56	2.27
½ in air space	3.23	2.56

Values based upon the ASHRAE handbook of Fundamentals.

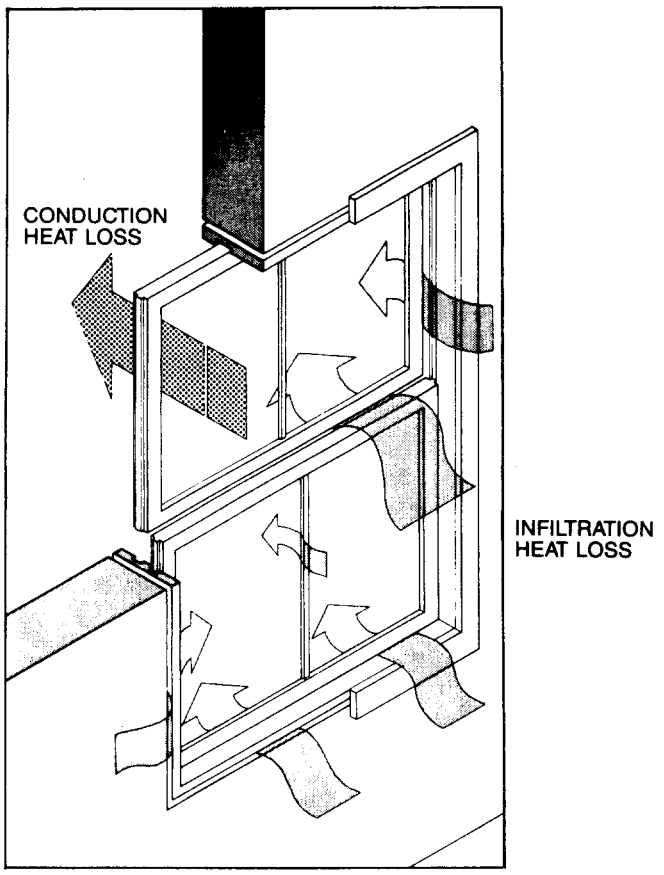

Figure 1. Windows are the weak spot in the house thermal envelope.

greater the spacing (up to ¾ inch) between the glazing, the greater the R-value. Recent advances in the use of selective coatings (low E) have also increased the R-value. Other efforts to increase the R-value of the window have included using Argon gas in the space between the glazings and using a vacuum in this space. The use of a vacuum has not worked very well since the glazings will bend inward until they touch.

The greater the air velocity across the glass surface, the greater the heat loss. The R-value for the inside of a window (assuming no fans or heat ducts adjacent to the window) is 0.68. With a wind of 7.5 miles per hour, the R-value is 0.25. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals has a detailed discussion of these effects including the use of the reflective coatings and temperature effects.

On a still, cold winter night with a coated low E glass, the total R-value can vary from 2.4 to 2.2. On a windy, cool winter night for uncoated single glass, the R-value can vary from .97 to .85. On a hot summer day with no wind, the R-value may be 0.5 changing to .076 with 20 mile per hour winds to 0.04 with 40 mile per hour winds.

AIR INFILTRATION

The amount of heat lost by air leakage is based upon total air leakage and the temperature dif-

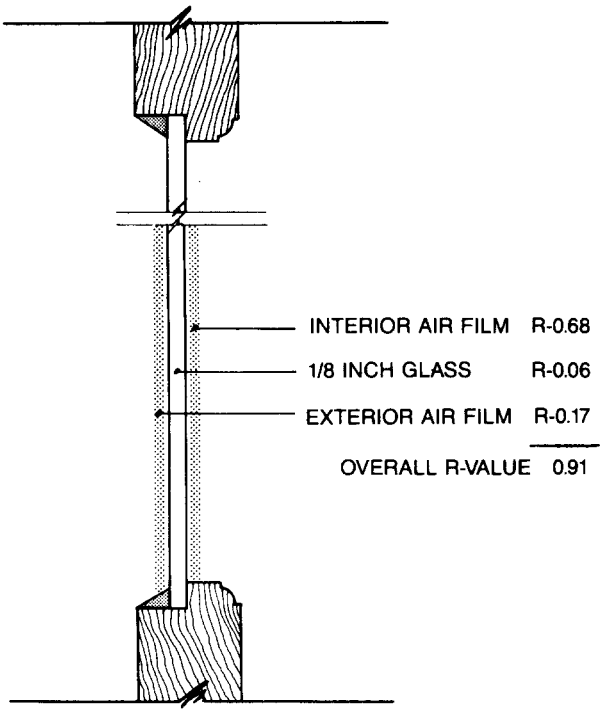

Figure 2. The thermal resistance of a single glazed window is due mostly to air films on glass.

ference between the inside and the outside. Typically, windows are rated in terms of cubic feet per minute (cfm) of air leakage per lineal foot of crack area. Figure 3 shows how several window types compare in terms of air leakage. The window industry suggests that an air leakage of 0.5 cfm per foot of crack or less is a good window. Check with the manufacturer or dealer for the particular window you are considering. Generally speaking, casement windows have the lowest air leakage rates, while the double hung or horizontal sliders have higher leakage rates.

LOW E GLASS

Estimates are that as much as 50 percent of the heat transfer across the air gap is by radiation. Limiting the emissivity (a measure of the amount of radiation given off by a surface at some temperature as compared to a perfect black body) should reduce the total heat lost through the window. Emissivity values range from 0 to 1 with 1 being a perfect black body and 0 being a perfect reflector. Most building materials will have an emissivity around 0.9 while shiny aluminum foil will be around 0.1. To reduce heat lost through the glass, you want a low emissivity (number close to 0).

Regular float glass has an emissivity of 0.84. Applying a special coating to the outside of the inner layer of glass of a double paned window may increase the overall R-value from 2 to 2.9.

One disadvantage of low E glass is that it also cuts down on the solar transmittance, limiting its use in areas where solar energy is desired.

Another way to use low E coatings is to place the coating on a thin plastic film suspended in the air space between the panes of glass on a double glazed window. Since there are now two air spaces plus the two layers of glass and the low E coating, R-values of up to 4 are possible.

CONDENSATION CONTROL

Because windows are not as well insulated as the rest of the wall, condensation usually occurs on the windows first. The rate of condensation is related to the glass surface temperature and the relative humidity in the home. Figure 5 shows how the maximum inside humidity level changes with different

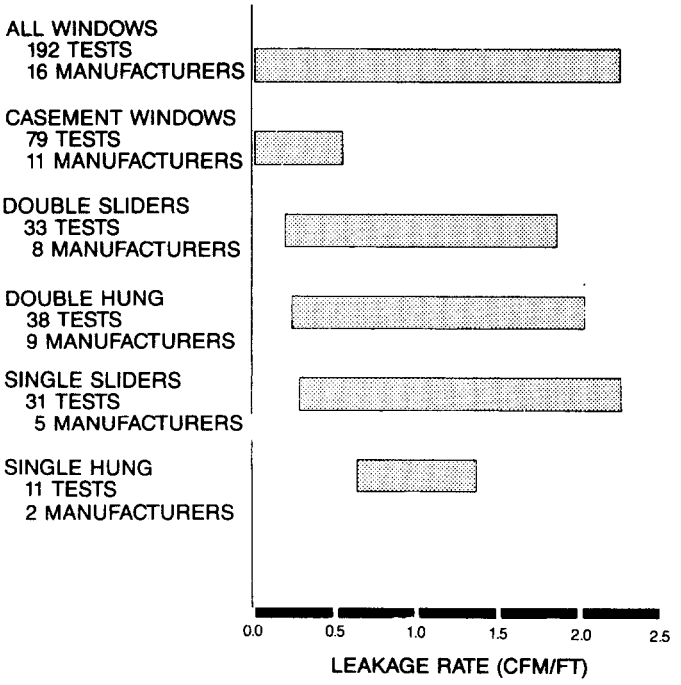

Figure 3. Comparative leakage rates of several common window types.

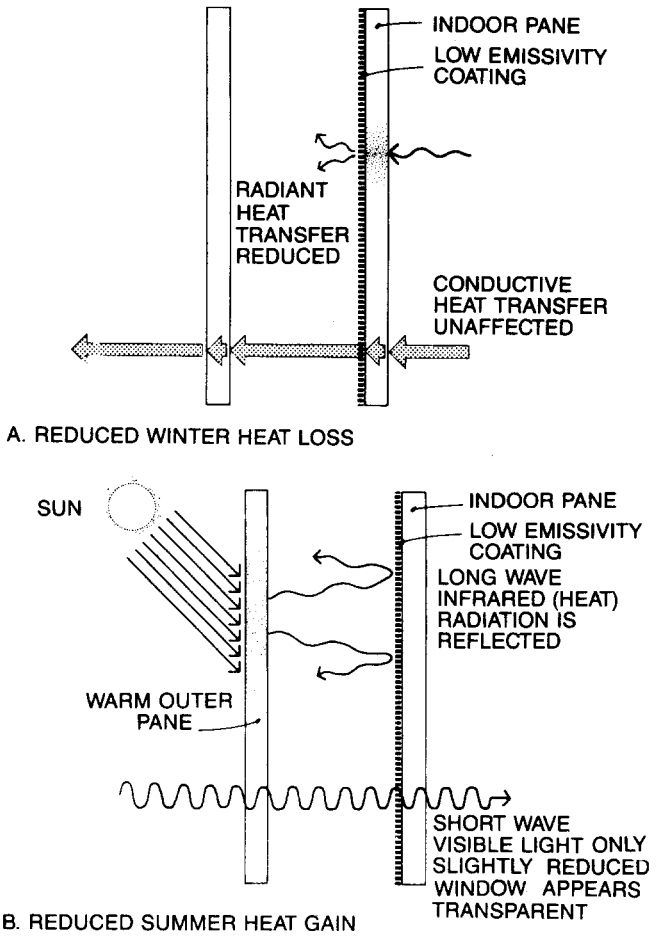

Figure 4. Coated "low-E" glass increases thermal resistance by reducing radiation heat transfer.

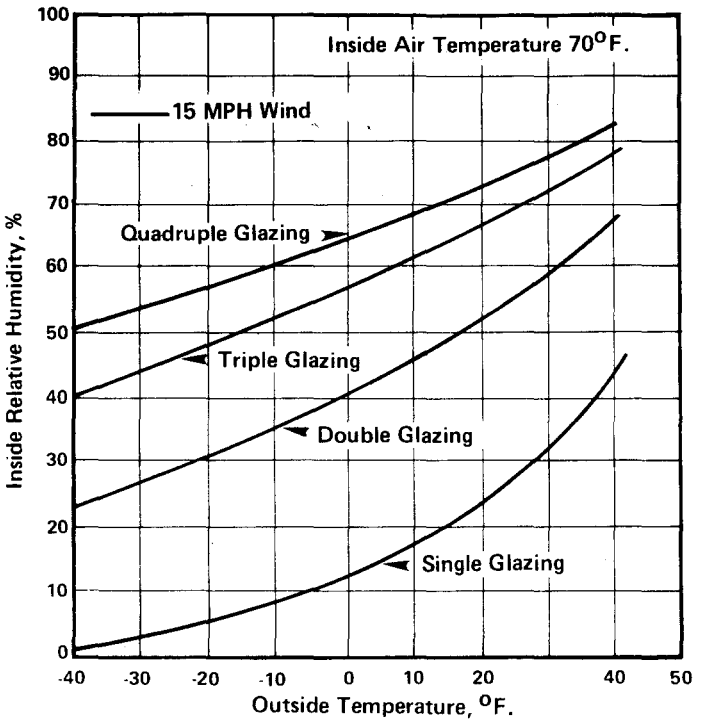

Figure 5. Condensation on window surfaces.

amounts of glazing. A double glazed window with a low E coating will perform about as well as a triple glazed window in controlling condensation, while a "heat mirror" double glazed window will perform about as well as a quadruple glazed window. Adding a window covering such as a tightly woven fabric drapery will increase the overall window R-value; however, it may make the condensation problems worse since the inside glass temperature will be lower than it would be without the drapery.

MOVABLE INSULATION

One effort to improve the R-value of windows is the use of movable insulation. This can take the form of specially made window inserts that are placed over the window at night or the use of special windows with a blower to move styrofoam beads into the space between the layers of glass at night and remove them in the morning.

The window inserts can increase the R-value from around 2 to 10 depending upon the thickness of the insulating material and its R-value. Performance is only as good as the operator's diligence in putting the material into place every evening and removing it in the morning. Condensation problems will be increased during the night time hours unless the insert fits very snugly into the window frame.

The blower and bead system can increase the R-value from about 2 to 10 or more depending upon the space between the layers of glass. The system can be automated with time clocks or photo switches. A major disadvantage of this system has been static electricity causing the beads to cling to the glazings. The use of an antistatic treatment has helped to reduce the problem.

External shutters do an excellent job of reducing heat loss through the windows and also provide increased security. They can be used to reduce glass breakage during a hailstorm. The major disadvantage of external shutters is that there are no reliable systems for operating them from the inside during different weather conditions.

EXCLUDING SUMMER HEAT

Excluding summer heat can be accomplished by shading the windows or by placing a reflective film on the glazing. Movable shades and canopies have been used very successfully to keep solar energy from getting into the living space. The best location for shading devices is on the exterior side of the window since any heat absorbed by the shade is dissipated to the outside air rather than to the room air as happens with interior shades. Shade trees are effective and improve overall appearance.

Reflective films reduce solar gain by reflecting most of the solar energy back to the outside. Some care must be used in selecting reflective films and installing them to avoid cracking the glass. If the reflective film is placed on the inner pane of a double paned window, there is a danger of cracking one of the panes as the inner pane absorbs some of the solar energy and is heated. Check with the window manufacturer before placing a reflective film on double paned windows.

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