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ABSTRACT

This two-part report explores the efforts of businesses and individuals to improve the thermal performance of windows. Part I discusses the basics of what makes a window product insulate or save energy. Topic areas addressed include saving energy lost through windows, key components of window insulation, three basic types of window insulation, amount of energy window insulation can save, and ways to improve the performance of existing window treatments. Part II discusses whether or not to put insulation inside or outside a window, which sealing systems are available and make the most sense to use, and how to operate products used on heat-gaining windows. In addition, choices for new construction and retrofit are explained. Information on how to calculate heat losses through windows, a reading and resource list, and descriptions of Department of Energy appropriate technology grants (reviewed in researching and preparing this document) are included in appendices. (ML)

WINDOW INSULATION

How to Sort Through the Options

Prepared for:
U.S. Department of Energy
Assistant Secretary, Conservation and Renewable Energy
Small Scale Technology Branch
Appropriate Technology Program
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March 1984

WINDOW INSULATION
How To Sort Through the Options

PREFACE

From 1978 to 1981, the U.S. Department of Energy (DOE) awarded more than 2,000 small grants to individuals, organizations and small businesses across the nation to research and demonstrate appropriate technologies. Grants were given in the general areas of conservation, solar, biomass, wind, geothermal and hydro power.

This booklet is part of a series of publications that focuses on appropriate technologies and their application in the home and the work place. These publications combine a qualitative assessment of the DOE grant projects with the results of current research for the particular technology highlighted in this document. A list of pertinent projects reviewed in preparation of this document appears in Appendix C.

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INTRODUCTION

Each year, Americans spend several billions of dollars covering their windows with drapes, shades and blinds. Yet, only a small fraction of these expenditures are on products that can conserve the substantial amount of energy that is routinely lost through windows.

Window coverings are already expected to play many roles. They are used to control light and glare, provide privacy, serve as decoration, protect windows and sometimes improve home security. Yet, devices that serve these same functions can also insulate, as well as provide a return on the investment and improve comfort in the home. More important, perhaps, is the fact that in many instances a device that saves energy will cost no more than many consumers had planned to spend on non-insulating window coverings anyway.

However, several obstacles remain in the path of the consumer who wishes to achieve the benefits that stem from window insulation. Additional information on available products and assistance in using these products is needed. Few businesses offer a truly comprehensive approach to helping consumers sort through the options, and a lack of information and training has stopped many existing window treatment businesses from adopting the goal of insulating, as well as decorating, windows. The result has been that the consumer, in many cases, must attempt to solve problems without professional advice or service help.

The work of the many grantees who researched and demonstrated window insulation options in the course of the Department of Energy's Appropriate Technology Small Grants Program gives further indication that many people want to improve the thermal performance of their windows, and that a potentially large market is awaiting businesses who can offer quality assistance with this work.

Grantees took on the challenge of reducing window energy losses in many ways. Projects fell in a wide variety of areas, ranging from materials testing and research to studies of how well homeowners adapt to using window insulation devices.

Some grantees concentrated their efforts on providing consumer information and training, while others developed and tested low-cost, do-it-yourself devices. Some organizations designed and manufactured several types of window insulation, to learn which was the easiest to make and had the most user appeal.

Window insulating devices, both homemade and commercial, were employed in a number of passive solar and conservation projects. Several new small business ventures grew from work with window insulation, and existing small businesses developed products that are now commercialized. Still other grantees developed and patented products that have yet to hit the market.

Just as grantees explored a seemingly endless number of ways to reduce energy losses due to windows, consumers currently face a confusingly large array of options. Although the window insulation industry has grown during the last five years, many consumers remain baffled by the choices.

By reviewing the grantees' work, consumers can learn how to sort through the options available for residential settings, including:

- how to identify window insulating devices that can save a significant amount of energy, including a discussion of components and types;
- how operating window insulating devices compares with using conventional, non-insulating window coverings;
- how to choose a product that can serve all the functions traditionally required of window coverings;
- how to avoid problems with do-it-yourself projects; and
- how to estimate costs and savings with window insulation.

In addition, this publication provides information on window choices for new construction, and an overview of current research in window insulation. The appendices provide summaries of selected grant projects, and a reading list is presented for those who want more information on window insulation.

Part I:

What Is "Window Insulation," and How Does It Compare With Non-Insulating Window Coverings?

With the many choices currently facing consumers, it is often difficult to chart a path through the many product claims and offerings. This section explores the basics of what makes a window product insulate or save energy. An overview of costs and energy savings also is presented.

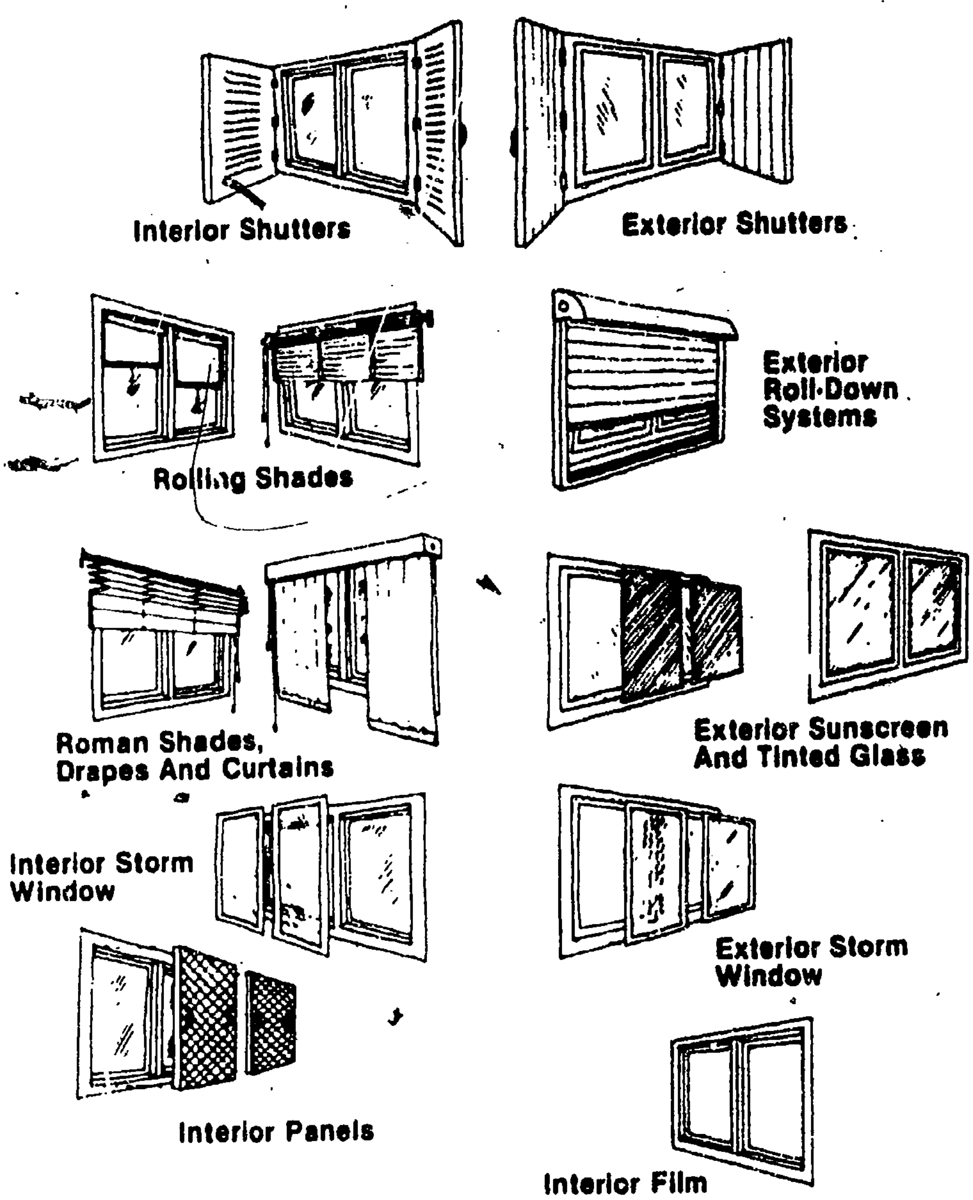

FIGURE 1: *Products that can save energy are available in many different styles, many of which resemble non-insulating window coverings. The major difference is that insulating products usually feature a* sealing system, *which stops air movement behind the window insulation.*

Saving Energy Lost Through Windows

Because window insulation is new, the window treatment industry still has not adopted a working name for insulating products. Often referred to as "movable insulation," "window energy treatments," "solar window treatments," or "night insulation," the concept of window insulation can be difficult to pin down. Also, devices and products that can save energy come in many styles (Figure 1).

To define a product that reduces energy consumption, one first should note how energy is lost through windows. In colder weather, loose-fitting windows can lead to heat losses through *infiltration*, which describes air passing into and out of the house through cracks and leaks around the window. Infiltration is mainly a function of temperature differences between the indoors and outdoors and of wind speed. It is often experienced as cold drafts of air.

In a process described as *convection*, a cold window pane sets air in motion downward, with warm air being pulled from above to the window, where it is cooled. Thus, a loop of air is constantly passing over the window.

Heat also passes directly through the glass and the window frame to the cold outdoors through *conduction*. Conduction and convection go hand-in-hand.

Finally, warmer objects naturally radiate energy toward colder objects, and the cold window pane is often the coolest surface in most houses. Heat losses through *radiation* losses typically make for discomfort; people feel chilled when body heat is being radiated toward a cold surface.

On the other hand, windows can contribute to cooling costs when, in hot weather, unwanted solar radiation passes into the house through the windows.

Some window devices will reduce heat losses or heat gains in one way, but not others. For example, glass is probably the most common "window insulation." An extra layer of "glazing" (another term for glass or plastic films that act like glass) provides an insulating layer of air between the layers of glass, which helps reduce losses through conduction. Yet, ordinary glass does little to prevent heat losses through convection and radiation.

A thin layer of inexpensive polyethylene plastic taped to the window frame may reduce infiltration, but it will do little to conserve energy lost in other ways. Other devices that shade windows, such as reflective or tinted glass, films, screens or fabrics can reduce cooling costs that stem from unwanted heat gains from sunshine, but, alone, they won't do much to stop heat losses.

The most effective type of window insulation will save energy year round. It will reduce heat losses in winter and prevent unwanted heat gains in the summer. In this publication, the term "window insulation" refers to devices and products that can save a significant amount of energy—generally 40 percent or more of the energy lost through windows, whether it be due to unwanted heat losses or heat gains.

The Key Components

Highly effective window insulation has several components that distinguish it from its ineffective counterpart. The most important component in effective window insulation is usually the *sealing system*. This system, which tightly seals the window covering to the window on all sides, is the key to reducing heat loss through infiltration, convection, and conduction.

A sealing system is critical in stopping the convective loop of air that naturally occurs when the cold window pane chills room air, and this convective loop helps cause heat losses through both infiltration and conduction.

Research in the 1970's has illustrated the importance of stopping air movement around any type of insulation. If air can freely pass around or through insulation, whether it is in the attic, walls or over the windows, the insulating power is diminished, sometimes dramatically. If insulation is to perform as expected, air movement around it must be reduced, and this is one of the reasons why sealing systems are critical to the performance of many window insulating products.

The effect of air movement around window treatments is the major reason why conventional window treatments do little to insulate (Figure 2). In studies of the thermal performance of conventional blinds, drapes and shades, the material the window treatment was made of had less effect on the product's insulating ability than the tightness of the fit and seal around the window. Thick but loose-fitting products provided well under 10 percent savings over

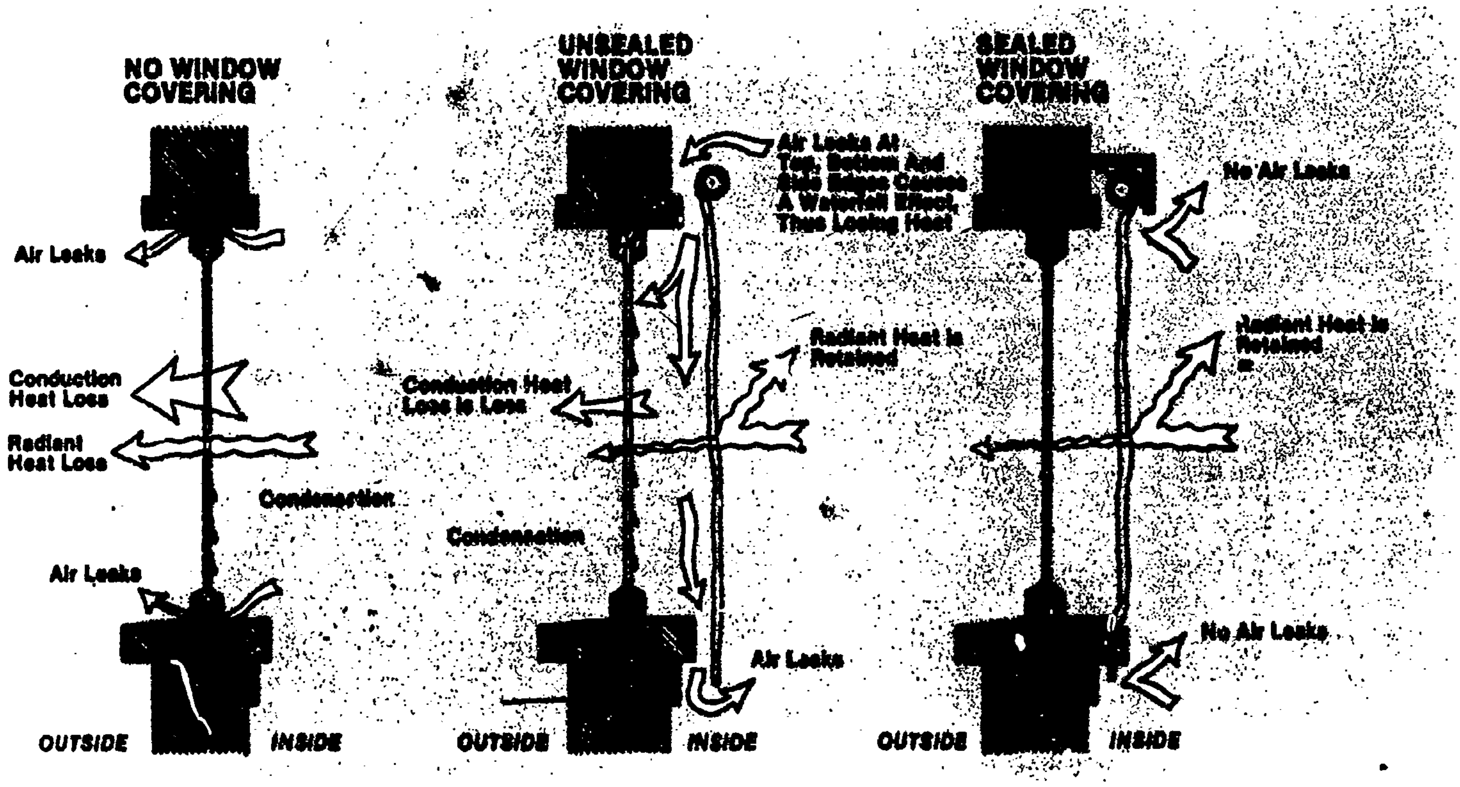

FIGURE 2: *An uninsulated window loses valuable energy through radiation, convection, and conduction. Infiltration is another way in which heat is lost through windows. An unsealed window covering does virtually nothing to stop these heat losses, while a sealed window-insulating device can reduce all types of heat loss.*

one pane of glass, while conventional roman shades (shades that fold up vertically in an accordion-like fashion) that formed a sort of seal around a window casing provided as much as 30 percent savings, mainly because of the reduction of air movement. A number of grantees saw the potential of retrofitting standard window treatments with sealing systems to enhance thermal performance. (See: IMPROVING THE PERFORMANCE OF EXISTING WINDOW TREATMENTS.) Sealing systems are covered in detail in Part II.

Insulating materials slow conductive heat losses, usually by trapping air between layers or within the material itself. Materials used in window insulation are diverse, ranging from a single layer of highly reflective, aluminized plastic and layered batts of air-trapping insulating fabrics to a variety of rigid insulating boards.

Highly reflective materials, like opaque aluminized films, are very effective at reducing heat losses through radiation, if there is an air space (at least 1/8-inch) that separates the reflective material from the window pane or from other insulating materials.

Although research is continuing on the issue, it is generally thought that heat losses through radiation alone are as great as losses through the combination of convection and conduction. Radiant heat loss can be somewhat reduced by any tightly woven material that covers the cold window pane, but opaque reflective materials are much more effective. In fact, a single layer of reflective material may be more effective at stopping heat loss than a one inch thick layer of some types of insulating board.

Insulation is typically described in terms of "R-value," which is a measure of how resistant a material is to heat transfer. The higher the R-value, the greater the insulating power of the material. The R-value of a single layer of glass is slightly under 1, while 3½ inches of standard fiberglass batt has an R-value of about 11. Generally, products that have R-values of under 1 are not considered to be window insulators, except, perhaps, in the case of sun rejection devices, whose performance is not measured in terms of R-value.

Window insulation specialists have generally agreed that window insulation should cut heat loss (or unwanted gain) by at least 50 percent to be considered a "good" window insulation choice. Such reductions can usually be accomplished with relatively low R-values, and most of the window insulation products on the market have R-values in the R-2 to R-5 range.

As with other insulation investments, the "law of diminishing returns" sets in after about R-5 in many cases, making greater levels of insulation less economic. In addition, some researchers report that it is difficult to get materials with high R-values to perform as expected on windows; the R-value of the material has been proven to be high when tested alone, yet when it is used over windows, its R-value is less than expected. The reasons for this problem are still unclear.

While R-value is one measure of the insulating power of a device, effectiveness is often more dependent on the performance of the sealing system than how powerful an insulator the material is. For example, a product may have a tested R-value of 3, but if edge seals are lacking, the actual R-value of the product would probably be much lower.

Another common feature in many window insulation products is an integral *vapor barrier*. Unlike the sealing system or the insulating material, the lack of a vapor barrier usually doesn't significantly affect the product's ability to save energy. A vapor barrier prevents moisture from passing through the insulation. In extremely cold weather, this moisture can be cooled to the point where it condenses on the window or within the window insulation itself. Vapor barriers are usually made of plastics or aluminized films that are highly impervious to moisture transfer. Some insulating boards are quite impervious to moisture, without the addition of a separate vapor-stopping layer.

Window Insulation Comes in Three Basic Types

Window insulation products can generally be grouped into three basic types: *movable, seasonal* and *fixed* (Figure 3). They can be transparent, translucent or opaque. Each type may be used on the inside or the outside of the window.

One of the first tasks facing the consumer [illegible] designer is to correctly choo[illegible]ng movable, seasonal o[illegible]ons to window insula[illegible]s to achieve the most energy savings and the greatest degree of overall benefits from other features of the window insulation.

Movable insulation describes devices that can be easily opened and closed over the window. In this category are roll-up or fold-up (Roman) shades, sealed drapery or curtains, folding or movable shutters, and movable sun-screen shades. A standard component of passive solar heating systems, movable insulation is opened or removed to admit daytime solar radiation, and closed at night or during cloudy, cold weather to conserve heat gains from the sun. Because it is operable, movable insulation is often more expensive than seasonal or fixed devices. Thus, movable insulation tends to make the most sense economically when used on windows that receive a significant amount of sunshine.

Movable insulation is the closest insulating counterpart to traditional non-insulating window treatments, because it often can serve the same functions. Yet, unlike conventional window coverings, movable insulating devices usually demand some management by the occupants to achieve maximum energy savings and to prevent potential damage to the window.

Seasonal window insulation describes insulation that is installed during the heating (or cooling) season, and is not regularly opened or moved. In this catagory might be translucent or opaque panels that cover windows that don't receive sun in winter, or perhaps a sun-reflecting exterior

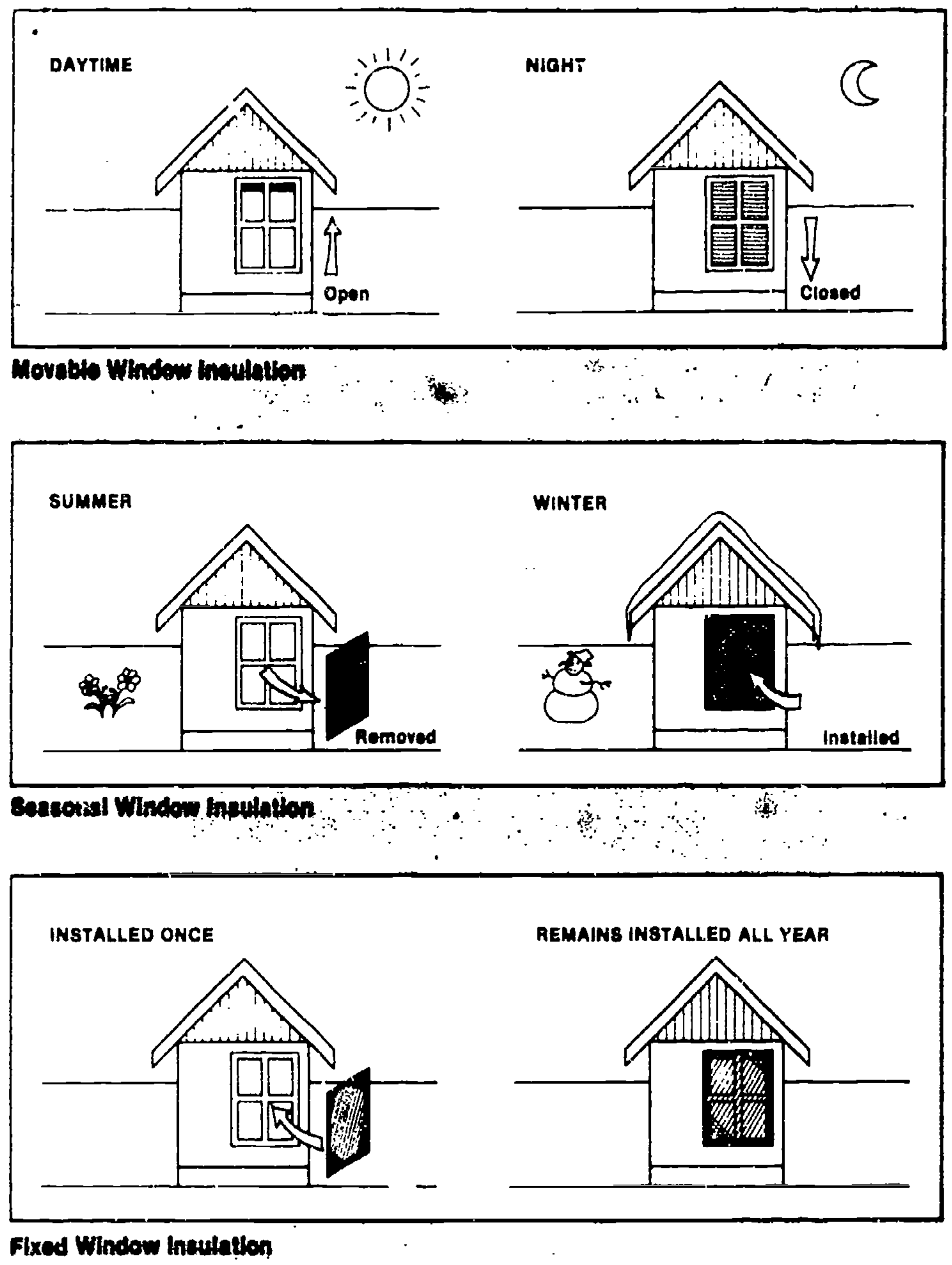

FIGURE 3: *Improved consumer satisfaction and cost savings can be achieved by choosing the right type—movable, seasonal, or fixed—window insulation for each window in the house.*

screen in hot climates to prevent unwanted heat gain. In many households, storm windows are seasonal window insulation, installed for the colder season and removed in the summer to allow ventilation.

Because they have no mechanical or moving parts, seasonal insulation devices can be quite inexpensive, and they often work well with existing window coverings. In addition, they demand little attention.

Fixed window insulation describes products that are installed permanently. Extra glazings might fall into this category, as do many types of solar control film, which are permanently attached to glass to rejec solar heat gains. Most fixed products are transparent so that the view is not obstructed.

The permanent nature of fixed insulation can be an advantage; insulation that is always in place demands virtually no attention from the occupants. But, permanence also can be a disadvantage. The device may not be able to maximize savings related to seasonal changes. And, some types of fixed window insulation can make windows difficult or impossible to open for ventilation purposes.

How Much Energy Can Window Insulation Products Save?

Window heat loss and solar gain depend on the climate, the orientation of the house, the current condition of the windows, and the amount of solar energy the windows receive.

Whether your climate demands heating, cooling or substantial amounts of both, windows can be a major energy expense in your household budget. Generally, the colder the climate, the greater the energy loss through the windows. For most households, heat loss through windows during cold weather has been estimated to range from about 15 to 35 percent of the total annual cost of heating. In passive solar houses, this heat loss can be as much as 40 percent, because of the large expanses of glass that are often employed in passive designs.

Wintertime heat losses are the main concern in most climates, but cooling costs that stem from unwanted solar radiation also can be a major expense in some households. Cooling is most often powered by electricity, and in some regions, peak pricing can make electricity very expensive during the warmest times in the summer.

Products aimed at stopping both winter and summertime energy losses can save from 60 to 80 percent of the total energy lost due to the windows. How this translates to dollar savings depends on the amount of window space, the climate and the cost of fuel.

For example, in a climate like that of Chicago, a double-glazed window may lose more than $1 worth of energy per square foot of glass per year, assuming that electricity is used for heat and costs 7¢ per kilowatt-hour. If the house has 200 square feet of glass, this adds up to a cost of $200 per year of heat loss through the windows. In 1979, trade and industry groups estimated the dollar value of heat loss through single-pane glass to be anywhere from 40¢ to $1.50 per square foot per year, and energy prices have risen substantially since then. (For details on how to roughly calculate heat losses for your climate and window conditions, see Appendix A.) If the Chicago homeowner installs window insulation that reduces heat loss by 80 percent, as much as $160 a year could be saved.

Another important point to note is that, on an annual basis, unobstructed, south-facing double-glazed windows can be net heat gainers in all climates, if the windows receive regular sunlight. In other words, south-facing windows have the potential to gain more heat in the daytime than they lose at night or during cloudy weather over the course of the year. But, in many climates these heat-gaining windows will be net losers during the coldest two or three months of the year.

East- and west-facing windows also have the potential to gain heat, although in much smaller quantities than south-facing windows. East- and west-facing windows often cause overheating during warm, sunny weather, however, because roof overhangs rarely can provide the needed shading during summer because they would have to be so large.

Except for heat rejection devices and extra glazing, window insulation on heat-gaining windows should be easily movable to control heat gain effectively. If managed properly, movable window insulation can turn all windows that get some sunlight into net gainers, and make south-facing windows a more permanent "free" heat source, especially during very cold weather.

Does Window Insulation Make Economic Sense In Your Situation?

With the recent growth of the window insulation industry and the new developments with glazings and low-emittance films (heat mirrors), it is probably possible for many consumers to purchase windows or window coverings that insulate for no more money than they were planning to spend in any case. Window insulation that provides light control, privacy and decoration can be substituted for conventional window treatments, sometimes even at a savings over what the consumer planned to spend.

The decision to invest in energy conservation for windows is usually quite different from most other types of conservation improvements. Unlike wall or ceiling insulation, window insulation can play many roles. Also, wall insulation demands no management from the occupant, while some types of window insulation require that the buyer make a commitment to operate the devices properly to achieve the expected energy savings and avoid problems. Another major difference with window insulation is that no other insulating or energy-saving device in the home is so subject to the occupants' tastes and preferences.

At present, a broad range of product types, styles, colors and designs are available in non-insulating window coverings to meet the many different tastes of consumers. With this broad range of product offerings, costs for non-insulating window treatments range from as low as 30¢ per square foot to well over $30 per square foot of window covered.

Yet, consumers do not expect non-insulating window treatments to provide a return on investment. Instead, these products are accepted as an integral component of most houses, providing shading, privacy and other functions.

Consumers fall into many categories, as far as conventional window treatment goes, based on income, tastes and preferences and the needs of the house in question. To some people, the appearance of the window treatments is much more important than that of the other furnishings, while other people don't want their windows covered at all.

For example, if the homeowner was planning to spend $800 on new drapery anyway, it is possible to spend a similar amount on aesthetically similar window insulation and get "instant" returns on the investment. If the homeowner planned to spend under $100 on a number of simple, vinyl roll-down shades, it is now possible to purchase vinyl roll-down shades in this same price range that have integral edge seals. Again, this would be an instant return on the investment.

For homeowners who like their existing, non-insulating window treatments and don't plan to replace them in the near future, the economics of the situation are somewhat different. Lower-cost window insulation products that work with existing window treatments may be a good choice that can enhance comfort and provide substantial economic return. Or, in some cases, an effective sealing system can be added to existing window coverings that will turn them into energy savers.

For those who don't need or want any conventional window treatments, the benefits of window insulation lie mainly in how much energy the products can save and the potential for improved comfort. In some households, privacy and shading are taken care of by exterior vegetation or by where the house is sited. For some people, an unobstructed view is the most important consideration, and these consumers may demand that any window insulation purchased does not interfere with this view in the slightest. For those consumers who have no need or desire for window covering of any kind, the economics of window insulation should explored more completely.

Movable Insulation May Require Attention to Avoid Problems

Consumers should be aware that movable types of window insulation may need special attention to avoid problems, such as overheating from sunshine, thermal shock during cold weather in colder climate regions and damage from excessive moisture condensation.

Overheating can occur when an insulating device is left in place, sealed over the window when the sun is shining on the window. The insulation can turn the window into a type of solar collector, but the heat has no way to escape. The window panes can expand and crack.

Thermal shock is a similar phenomenon to pouring hot water into a chilled glass. When a cold window is suddenly exposed to heat, it may crack. Thermal shock appears to be an unlikely occurrence in most cases, but it can be a problem in colder climate regions. Specialists in Idaho have reported that it may be a particular problem in homes heated with wood stoves. For example, on extremely cold mornings, the occupant first fires the wood stove, which usually increases the indoor temperature to a high level. Then, when window insulation on windows near the wood stove is removed, very hot air rushes to the windows, causing them to crack. If the window insulation was opened before the wood stove was fired, the problem could be easily avoided.

Moisture condensation problems can occur when the sealing system isn't tight enough or when the window doesn't have storm windows. Moisture problems are most likely to occur in households where indoor relative humidity is constantly high.

Minor changes in daily habits can overcome most of these potential problems, and simple management strategies are discussed in Part II of this publication.

IMPROVING THE PERFORMANCE OF EXISTING WINDOW TREATMENTS

At least one grantee explored the possibility of improving the performance of existing window treatments in the course of work with new, movable insulation products.

John Pierre Stephens and Barbara Wezelman, working in the moderate climate of Davis, California, designed and fabricated nine interior movable insultion options, which were installed in a demonstration house managed by the Solar Community Housing Association of Davis, a non-profit cooperative.

The nine types of products ranged from traditional-looking draperies and simple, roll-down shades to heavy, wood-framed fiberglass board shutters and wood-sheathed pop-in panels. Stephens and Wezelman then produced a booklet that describes each of their designs, which are aimed at do-it-yourselfers. (See Appendix B for details on how to get this booklet.)

Material costs for the products range from 95¢ to $4.90 per square foot (1981 prices), and R-values ranged from R-2 to R-8. The pair concluded that in Davis (a 2,800 heating degree day climate), consumers could get a positive economic benefit from spending an extra $2 to $4 a square foot on window insulation, over and above the cost they would be willing to spend on conventional window coverings.

The first design described in their booklet (Figures 4 and 5) shows that traditional draperies can be retrofitted at a low cost by adding a reflective drapery liner that employs a tight sealing system. The sealing system entails adding a tightly woven fabric "loop" for a top seal, sand-weighted bottom hem and a low-cost wooden clamp for a side seal on one side and a permanent, tacked-down seal on the other side. The materials cost of this insulating drape option is listed as $1.60 per square foot, while the decorative-front

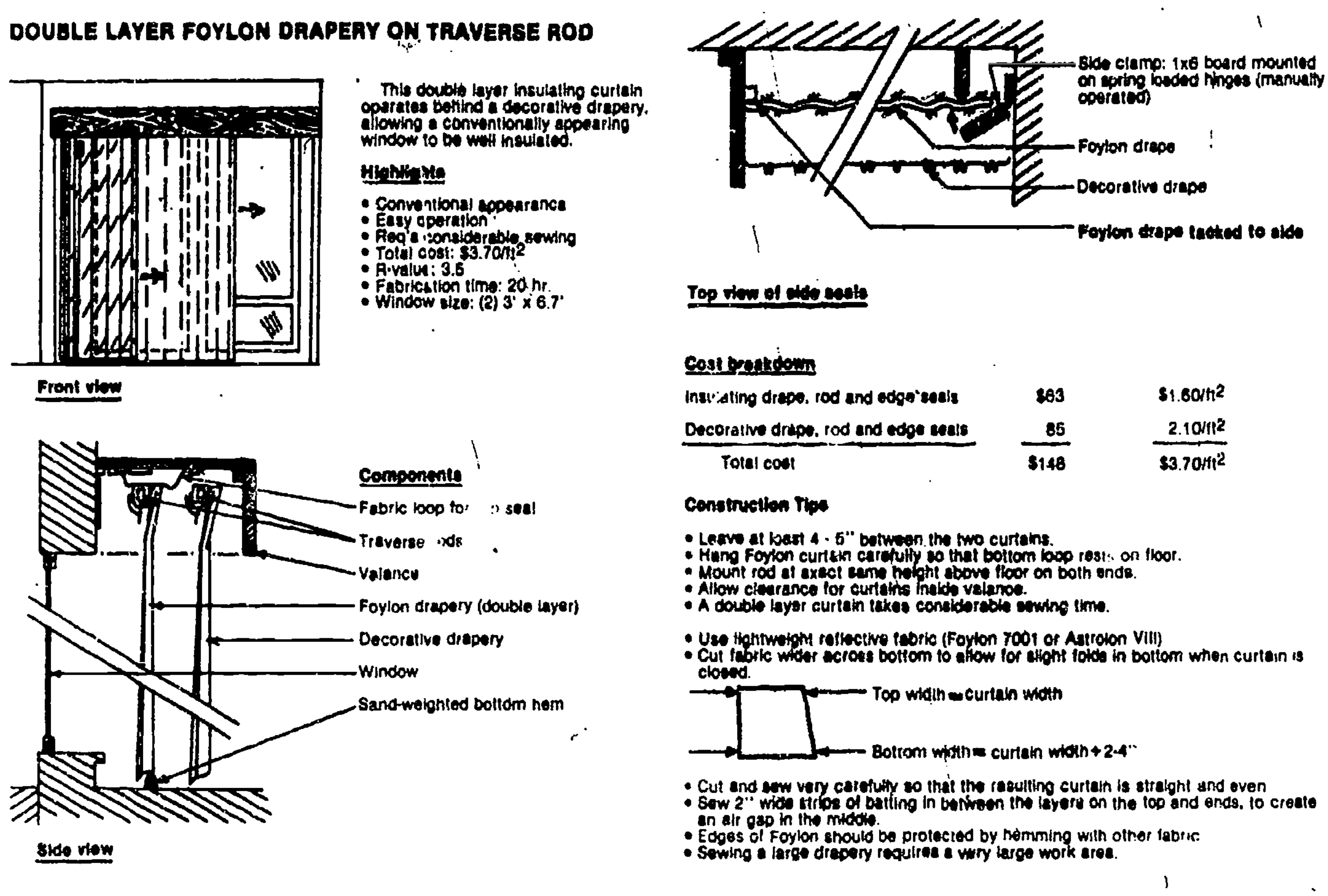

FIGURE 4: *This design, taken from the publication developed by Stephens and Wezelman, illustrates one way to improve the thermal performance of existing drapery. The key components in this design are highly reflective material and a sealing system.*

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drape cost an additional $2.10 per square foot. The R-value is listed as R-3.5.

If the liner ' 'as tacked to existing drapery, this design could be adapted for an even lower cost (about 95¢ per square foot), by saving the cost of buying an extra curtain rod. (The hardware and rods can sometimes be more expensive than the draperies themselves.) For best results, this liner material should be quite impermeable to moisture transfer, as well as durable.

The grantees reported that making this type of window insulation yourself requires a very large work area and plenty of time. However, because it is similar to drapery products that are currently being produced in custom shops across the country, it may be possible to get this work professionally done at an affordable cost.

As for the other movable insulation designs, Stephens noted that some insulation boards may be too heavy for use in shutters. In particular, he said, the fiberglass board shutters are so heavy that operation can be difficult.

Looking back on the project, Stephens reported that the conventional-looking curtains were well received by those who toured the demonstration house and by the current occupants of the house. He warned, however, that consumers should look for a very durable lining material; some materials he and his partner tried delaminated after being installed.

This project illustrates that existing conventional-looking products can be transformed into window insulators, and that this work can be low-cost and extremely cost-effective.

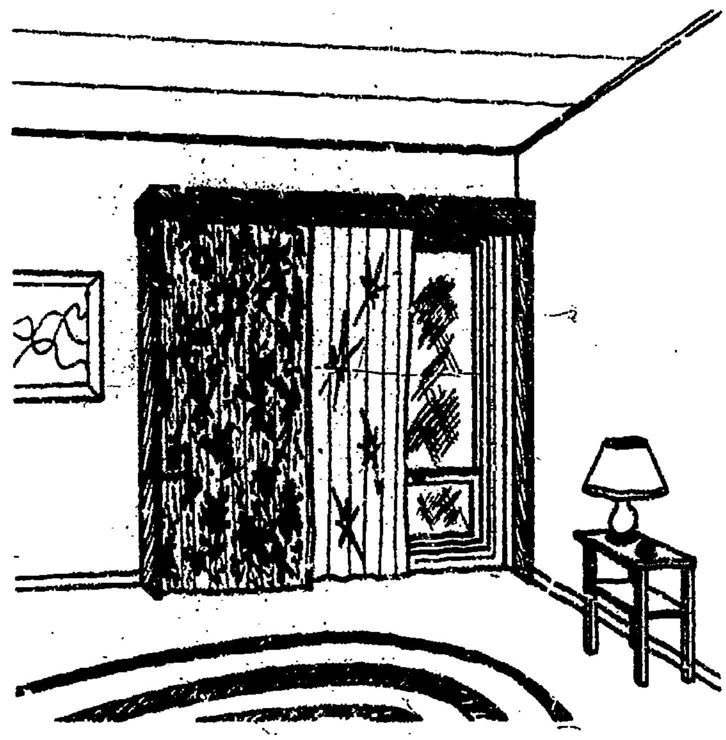


FIGURE 5: *This drawing shows the finished insulating drapery system as it looks in the demonstration house in Davis, California. When open, the reflective liner can be completely hidden behind the decorative drapery.*

Part II: Sorting Through the Options

Movable or seasonal? More glazing or other types of window insulation? Do it yourself or hire a contractor? These and many other questions confront the consumer who is trying to sort through the options available in today's window insulation market.

This section provides guidance on these issues as well as a discussion of whether to put insulation on the inside or the outside of the window, which sealing systems are available and make the most sense in your application, and how to operate products used on heat-gaining windows. In addition, choices for new construction and retrofit are explained.

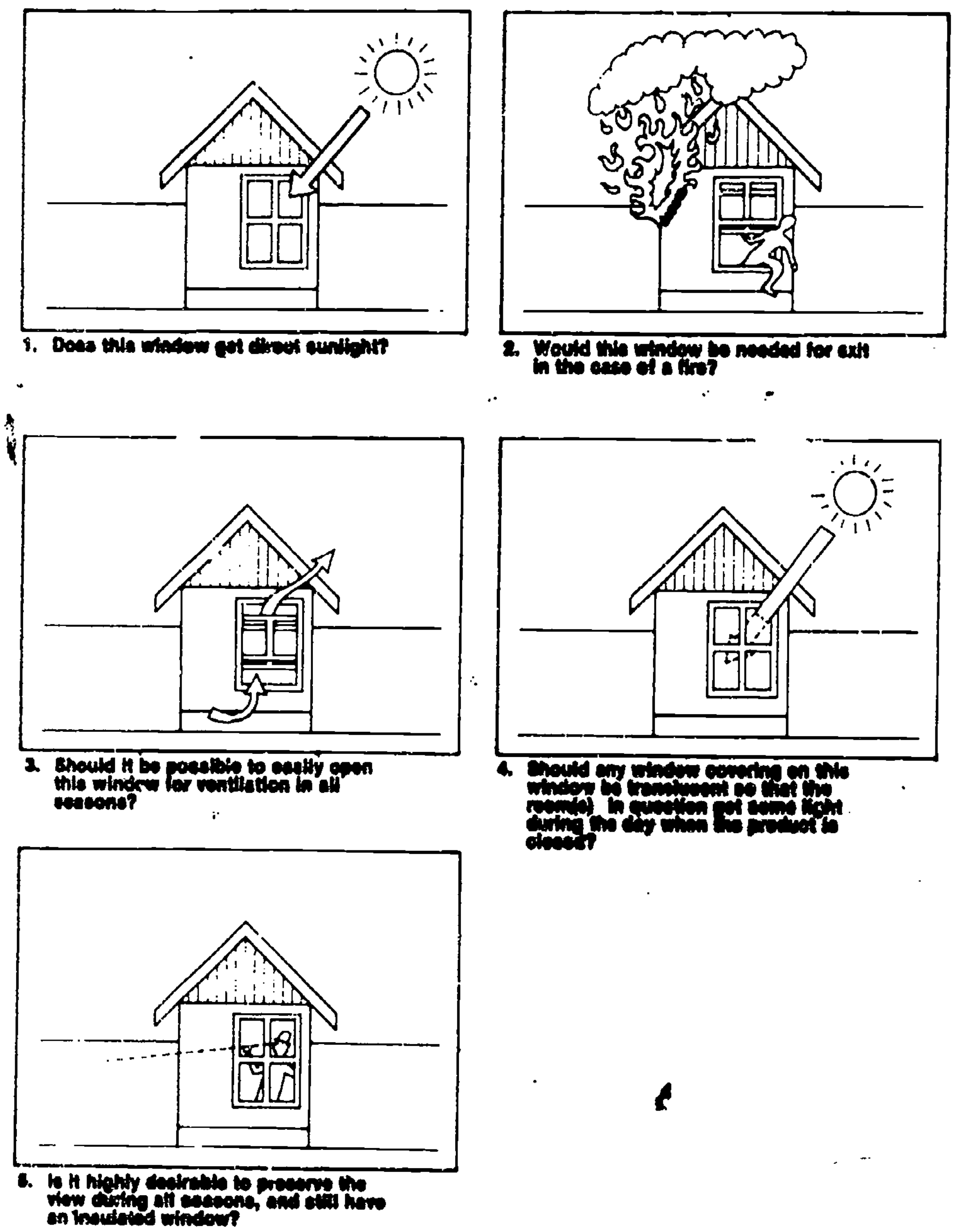


FIGURE 6: *To choose among the options requires that the occupant review all the uses of the windows.*

Movable, Seasonal or Fixed Window Insulation?

Much expense and many problems can be avoided by choosing the right product for your window in the first place. The first step in making the right decision is to determine the uses of each of the windows (Figure 6). The following questions should be answered in all climate regions:

1. Does this window receive direct sunshine?
2. Would this window be needed for exit in case of a fire?
3. Should this window be easy to open for ventilation in all seasons?
4. Should any window covering on this window be translucent so that the room gets some light during the day when the product is in place?
5. Is it highly desirable to preserve the view during all seasons, and still have an insulated window?

By reviewing the answers to these questions, the homeowner can decide which windows are candidates for the various types of window insulation. Let's go through each question separately.

1. Does this window get direct sunlight?

IF YES: This window should in most cases have movable insulation or a fixed insulation that either admits or rejects solar energy, depending on climate. Movable insulation will demand operation, while fixed insulation requires no attention.

Movable insulation should be *truly easy* to operate. It may be wise to avoid opaque, one-piece pop-in panels that may be bulky or inconvenient to store or cause any other type of difficulty in operation. *Effective operation is critical because sun-gaining windows can overheat when window insulation isn't removed when the sun is shining.* The heat can build up, and, in severe cases, this can result in breakage of glass and warpage of window casings.

Seals on movable insulation on heat-gaining windows should allow ease of summer operation to ensure proper escape of heat buildup. Also, sealing mechanisms should be able to withstand high temperatures without problems.

If the occupants cannot or do not want to operate the window insulation, movable insulation may not be the best choice. More glazing might be the answer in this case, or else automated control of the window treatment. (Automated controls are discussed later in this publication.)

IF NO: If the window receives no sunlight and isn't important for ventilation or fire egress, movable insulation may be an unnecessary expense. Low-cost, pop-in panels are perfect choices for windows that get no sunshine. Window insulation for this purpos may be translucent or opaque. It may be installed during the winter and left in place all season, making for 24-hour heat savings. Panels demand no attention and tend to have high returns on investment when used throughout the heating season. (See: AVOID INSULATING PRODUCTS THAT ARE DIFFICULT TO OPERATE.)

2. *Would this window be needed for exit in the case of a fire?*

IF YES: This window must have window insulation that is very easy to open (even in the dark), which speaks for movable insulation. Seasonal window insulation, such as non-operable storm windows or pop-in panels, can block easy exit from a window. Note that codes often require operable windows in sleeping areas.

IF NO: Any sort of fixed or seasonal window insulation will work in this case.

3. *Should this window be easy to open for ventilation in all seasons?*

IF YES: Movable insulation would be the best choice. Windows are the main source of needed ventilation in most households, although not every window need be operable. It makes sense to find the windows that provide the best cross-ventilation, and designate them to be fully operable, no matter what the season. Ventilation needs are not seasonal.

IF NO: Any type of fixed or seasonal window insulation will work in this case.

4. *Should any window covering on this window be translucent so that the room in question gets some light during the day when the product is closed?*

IF YES: Don't settle for window insulation that is of the black-out type if you want to retain some light. Translucent window insulation products are available, for both seasonal and movable modes. If the product allows enough light to come through to avoid turning on room lights, energy can be saved.

IF NO: The lower-cost products tend to be "black-out" types. If you don't need translucent window coverings, you might be in for some savings. In bedrooms, black-out products may be desirable.

5. *Is it highly desirable to preserve the view during all seasons, and still have an insulated window?*

IF YES: More glazings may be the best approach in this case, or a combination of another glazing layer and movable insulation that won't obscure view when it is opened. Seasonal insulation, whether opaque or translucent, is out of the question here. Extra work may be needed to ensure that the movable insulation fully exposes the window when it is open, if you want to fully preserve the view. This aspect also may rule out some movable insulation designs. Note mounting details carefully as you explore the various options.

IF NO: Any type of window insulation will be suitable, and this window may be a candidate for a low-cost product.

Examining Other Options

With the answers to these first questions concerning the use of the windows will come a preliminary assessment of what types of products might work best in each situation. Next, you'll need to determine whether more glazings or other types of window insulation would suit the need, and whether you want interior or exterior products. But, before a discussion of these decision points, let's first explore some more unusual, but low-cost, options for windows in all climate regions.

Some energy specialists start out a window insulation consulting job by noting whether any windows can be insulated by being boarded up permanently. This usually entails removing the window sashes and adding exterior grade board, regular insulation, and an interior surface. If a house has too many windows, this course may be an excellent option.

However, this course should be avoided in the case of historic buildings or buildings located in federally designated historic landmark districts. In this case, windows should be carefully retrofitted to retain the architectural features as well as improve thermal performance. (For guidelines on this job, see Appendix B.)

Another low-cost option often suggested by researchers is to retrofit inexpensive vinyl roller shades with a thin exterior layer of highly reflective aluminized material. For ease of operation, the aluminized layer should be attached to the shade only at the top of the roller, and left free at the bottom. This option works well when it is difficult or impossible to retrofit existing drapery or curtains, yet you want to retain these curtains and improve the thermal performance of the windows at a low cost.

More Glazings or Other Types of Window Insulation?

The answer to whether you should attempt substituting other types of window insulation for extra glazing layers depends on your

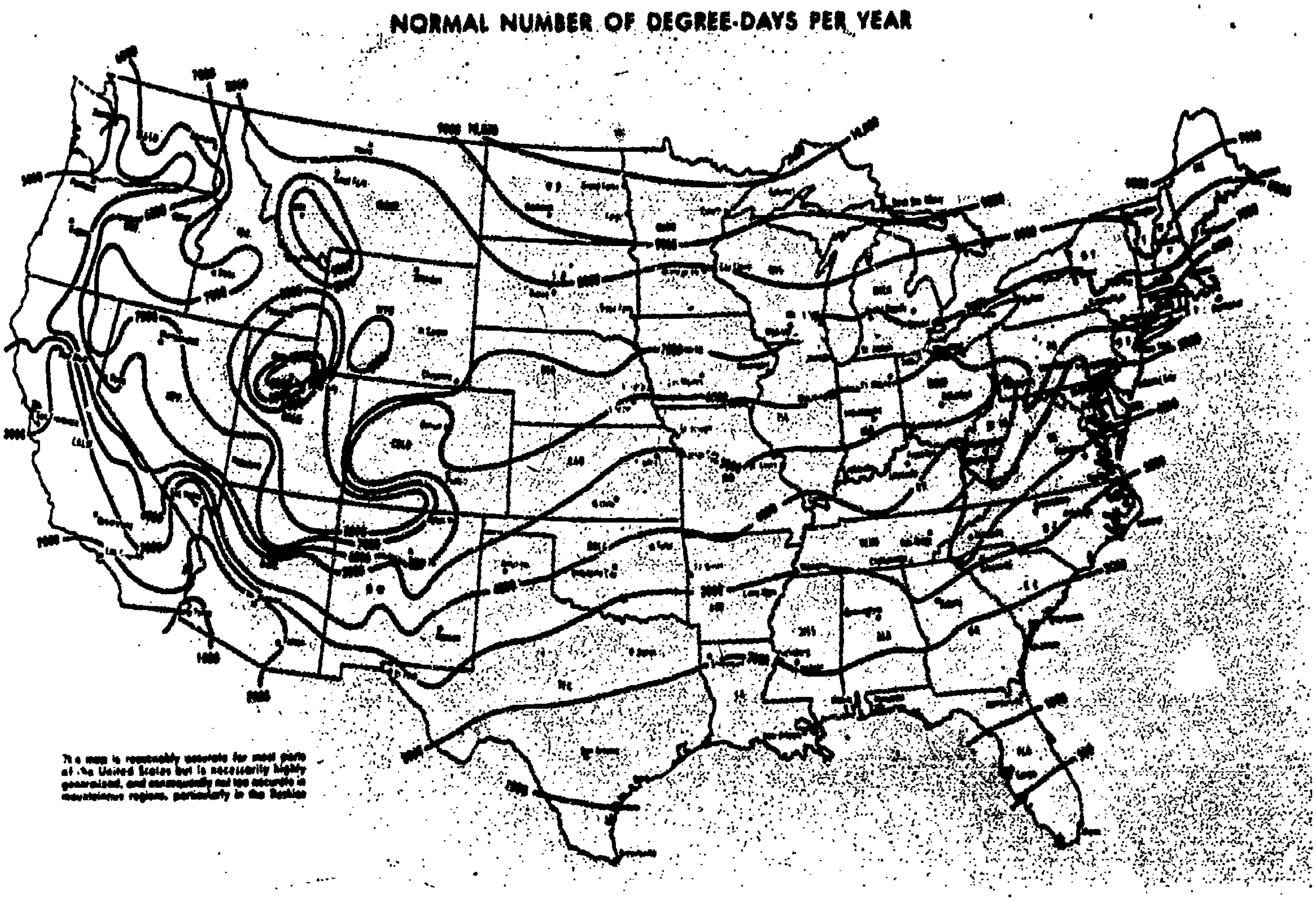


FIGURE 7: *The first map illustrates "heating degree days," while the second map shows "cooling degree days." The maps help indicate how cold or how hot a particular region is, on the average. Degree days represent the difference between the average outdoor temperature for a particular day and the base reference temperature for the indoors. (These degree-day averages use an indoor reference temperature of 65°F to calculate heating degree days, and 75°F for cooling degree days.) The more degree days in your location, the greater your energy usage for heating or cooling is likely to be.*

climate (Figure 7) and your pocketbook. You may be able to get more insulating power for your money if you avoid extra glazings, but you also may be asking for trouble in some cases.

Storm windows are a standard part of most weatherization efforts, in all but the warmest parts of the nation. Extra layers of glass serve as extra insulation mainly through the creation of a "dead" air space between the layers of glass. These extra glazings also help tighten up windows, thus reducing infiltration.

Other measures to reduce infiltration through the existing windows ought to be accomplished as a first course in any energy-saving program concerning the windows: weatherstripping and caulking the windows, replacing any cracked glass, and resetting the glazing compound around the glass, if needed.

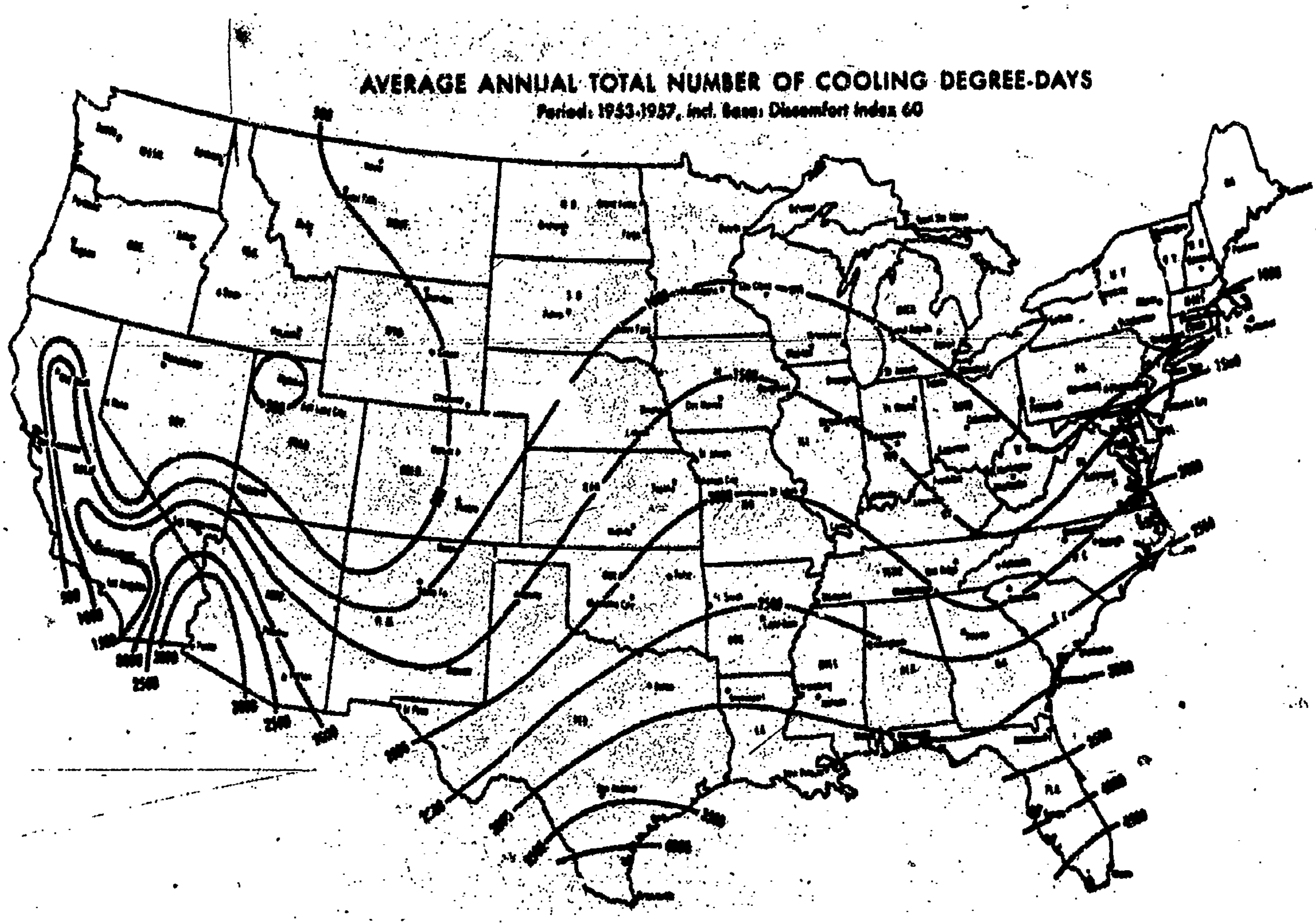
Most energy conservation specialists recommend these energy-saving steps and adding storm windows before making any further investment in window insulation. However, some grantees explored the possibilities of foregoing storm windows and using sealed window treatments instead. (See: SUBSTITUTING SEALED WINDOW TREATMENTS FOR WINDOWS IN MODERATE CLIMATES.)

The decision to add more substantial insulation or to go with an extra layer of glazing depends on the current condition of the window, tastes and preferences, and the climate.

A minimum of two layers of glazing is recommended for climates with 4,000 heating degree days or more. In colder climates, it often makes sense from an economic standpoint to add extra glazing over single-pane windows *as well as* other types of window insulation.

In more moderate climates, (under 4,000 heating degree days) skipping the storm windows in favor of a movable insulation may seem to make economic sense. But, in this case the product must seal very tightly to avoid potential moisture condensation, and movable insulation must be operated on a regular basis if the window receives sunlight.

One of the main differences between the two courses of action is that storm windows or extra glazing layers are usually *fixed* or *seasonal*. These devices save energy on a 24-hour basis, while a movable window insulation product may be in place only 14 hours a day. However, if a window gets significant sunshine, the overall savings can be greater with the movable insulation that has a



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higher R-value than an extra single layer of glazing.

Another important difference is that the glazing or storm window might have a longer lifespan and require less maintenance than the movable insulation. Movable insulation may need periodic cleaning or laundering, and it will need management.

The most important point to note about adding storm windows or more glazings is that in climates where heating is predominant, the room-side window should be tightest to avoid unwanted moisture condensation between the layers of glass. In climates where winter temperatures fall to 35° F or below, window surfaces can get cold enough that warm, moist room air will condense on the window pane (Figure 8). The warmer the window surface is, the less likely it is that moisture will condense.

Thus, if your inside layer of glazing is looser than the outer glazing layer, warm, moist inside air will move around the inner sash and condense on the outer pane, which can obscure the view and cause significant damage to window sills and other components. This same problem can occur with loose-fitting drapes or ill-fitting interior window insulation products. The rule of thumb then becomes: *Any interior window insulation in colder climates must fit tightly to avoid excess moisture condensation.*

Products in a wide price range are available for use as interior windows. Interior storm windows can be operable, fixed or seasonal. When adding an interior storm, make sure the fit and seal are excellent. With an exterior storm, the fit and seal are still important, but if the exterior storm is tighter than the primary window, condensation might become a problem.

If your home has consistently high indoor relative humidity, the seals on your interior storm windows or other window insulation will have to be extremely tight to prevent moist air from reaching the window pane. On sunny south-facing windows, this condensation may still harm the sills. You will be less likely to suffer from moisture damage if you first install tight storm windows, and do the needed weatherization work on the existing windows.

It should be noted that when movable insulation products are used, a minor level of moisture condensation is common and shouldn't cause concern. Thus, don't worry if your windows are slightly fogged when you open movable products in the morning after a cold night. However, if the windows become heavily iced and water runs down the glass when the ice melts, corrective action is in order. This problem indicates that either indoor relative humidity is too high or that there is a problem with the storm windows or the lack of them. Excess moisture condensation is more likely when the

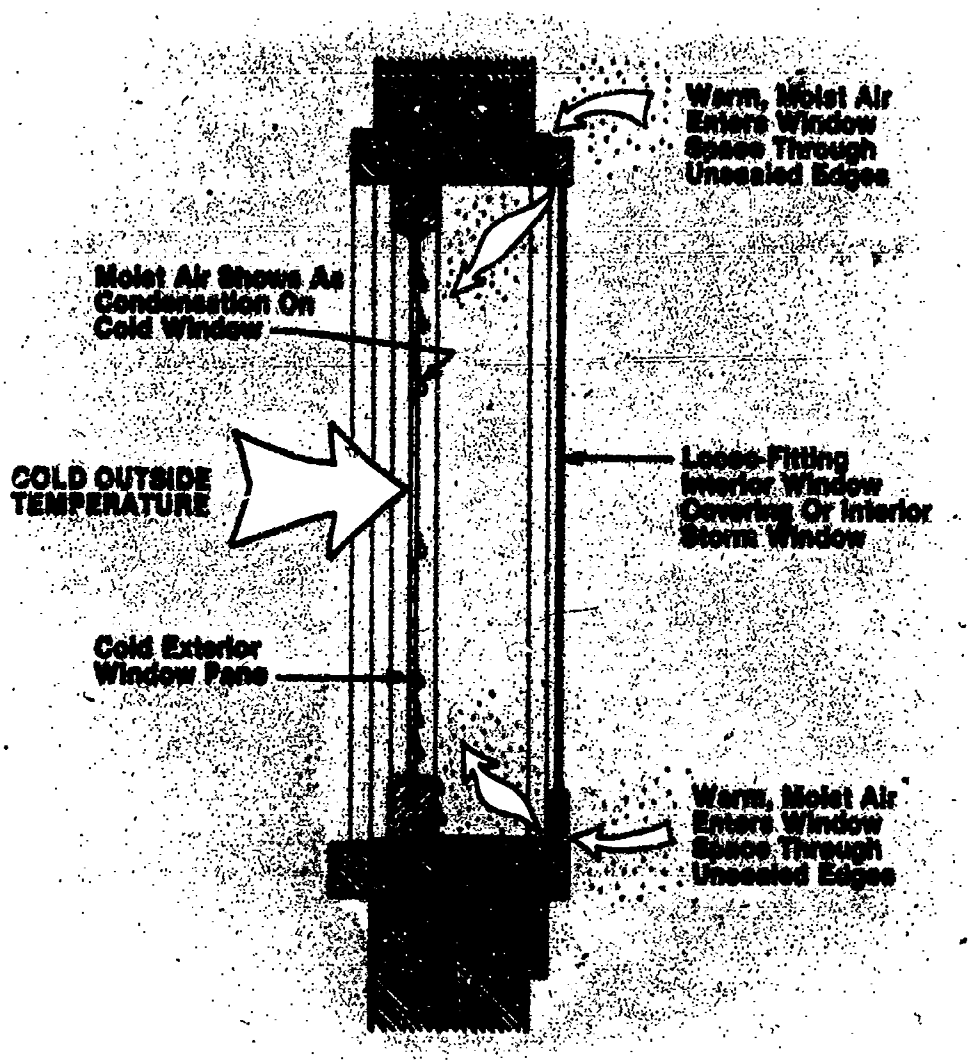


FIGURE 8: *To avoid excess moisture condensation during cold weather, all interior window insulating devices, including storm windows or extra glazings, must be tightly sealed.*

movable insulation has a high R-value because the window becomes much colder.

Any type of additional window insulation will appear to be more cost-effective over single-glazed windows than over double- or triple-pane windows. The reason is simple: single-glazed windows lose the most heat. In warmer climates, where condensation may be less likely to a problem, it may be acceptable to avoid going to double glazing and instead opt for some other type of insulating window treatment. But, remember that the single-glazed window is more likely to fog or ice up than a double-paned window (Figure 9).

Going from double to triple glazing can be a cost-effective move, even in moderate climates when fuel costs are high. Yet, the cost of going to triple glazing may mean that you cannot afford to add any additional window insulation, which might be desirable strictly from a comfort standpoint in winter.

Triple-glazing can cut solar gains somewhat, as well (Figure 10). At present, most experts recommend triple glazing on all but south-facing windows where heating degree days exceed 6,000 and above, and triple glazing now commands more than 20 percent of the total sales of new windows.

Again, money can be saved by going to some other type of window insulation with more insulating power than glass, especially if new window coverings are needed or desired for other reasons. In cold climates, you may wish to add both glazing and additional window insulation. If you must decide between the options, however, you can roughly figure out the difference in savings by consulting Appendix A.

Interior or Exterior Window Insulation?

Climate affects the choice between interior and exterior insulation, as well as concerns over the appearance of the outside of the house. The majority of window insulation products are for interior use, with many meant to replace conventional window treatments.

Exterior products have both advantages and disadvantages (Figure 11). In hot climates where the reduction of solar gain is important, it makes sense to install heat-rejecting devices on the outside. This way the unwanted solar energy is rejected before it can warm up the window and, eventually, the house. In cold climates, exterior treatments can help avoid moisture condensation problems, by keeping the window panes or glazing warm. In all climates, some types of exterior treatments can help make the house more secure; it is more difficult to break into a house with a locking exterior window treatment.

But exterior products must be able to stand up to the elements; wind, rain and snow can damage them, as several grantees discovered. In northern climates, movable exterior products may be difficult to open and close in winter, yet overheating won't be a problem with them because the sun can't reach the window. Movable exterior products are inappropriate on hard-to-reach windows, unless they are mechanically operated.

Many of the available exterior products and do-it-yourself window insulation schemes will rather dramatically affect the exterior appearance of the home, which some consumers don't like. Interior products with reflective appearance can strike a bad chord with some consumers, as well.

The main features to look for in an exterior product are: ability to withstand high winds without damage or noise from vibration, effectiveness of the sealing system (for cold-climate products) and ease of operation and maintenance. Other questions to ask yourself include: Will I like the looks of the product when it's in

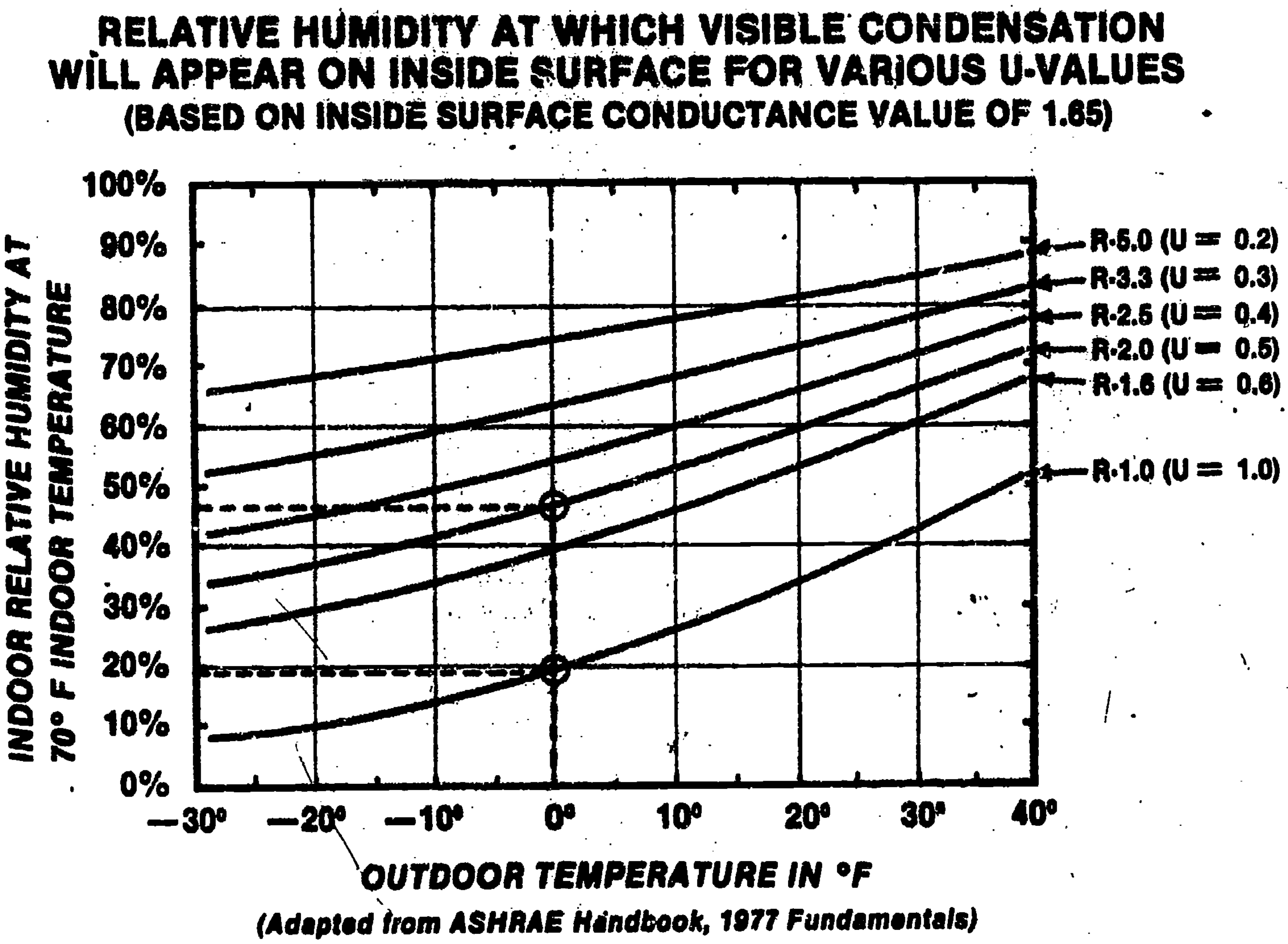


FIGURE 9: *The level of insulation on the window will determine the probability of moisture condensing on the glass during cold weather. With a single-glazed window, moisture will condense at lower indoor relative humidity than if the window has double glazing. The higher your indoor relative humidity, the more insulation will be needed to avoid visible condensation. Note from the chart above that when the temperature outdoors is 0°F, condensation will occur on a single-glazed window (R-1) when indoor humidity is only 19 percent. If the window's R-value was increased to R-2, however, condensation wouldn't occur until relative humidity reaches 47 percent. This chart can be helpful in making the decision on whether more glazings would be desirable to avoid moisture condensation.*

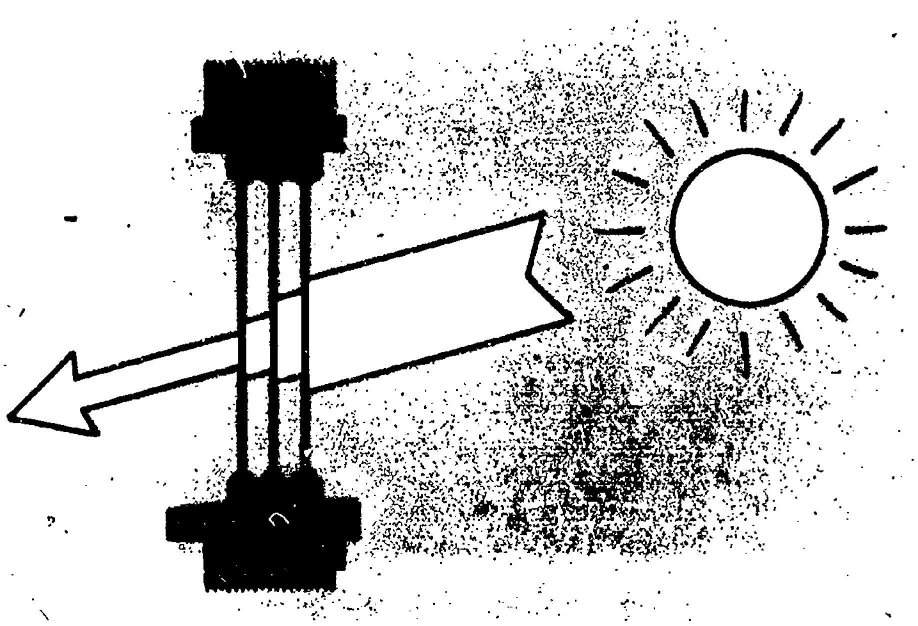


FIGURE 10: *Triple glazing can cut heat gains from solar radiation. For this reason, triple glazing is often avoided on south-facing windows that receive regular sunlight. However, triple glazing makes economic sense on windows that face north, east, or west in cold climates or in locations where fuel costs are high.*

place, both from the interior and the exterior? Can this product replace traditional window treatments or is it meant to be used in conjunction with them?

In general, exterior products probably make the most sense in warm climates. Transparent sun screens that are clamped to the exterior (so they shouldn't be affected by winds) can make for an excellent solar-rejection strategy, particulary when used seasonally.

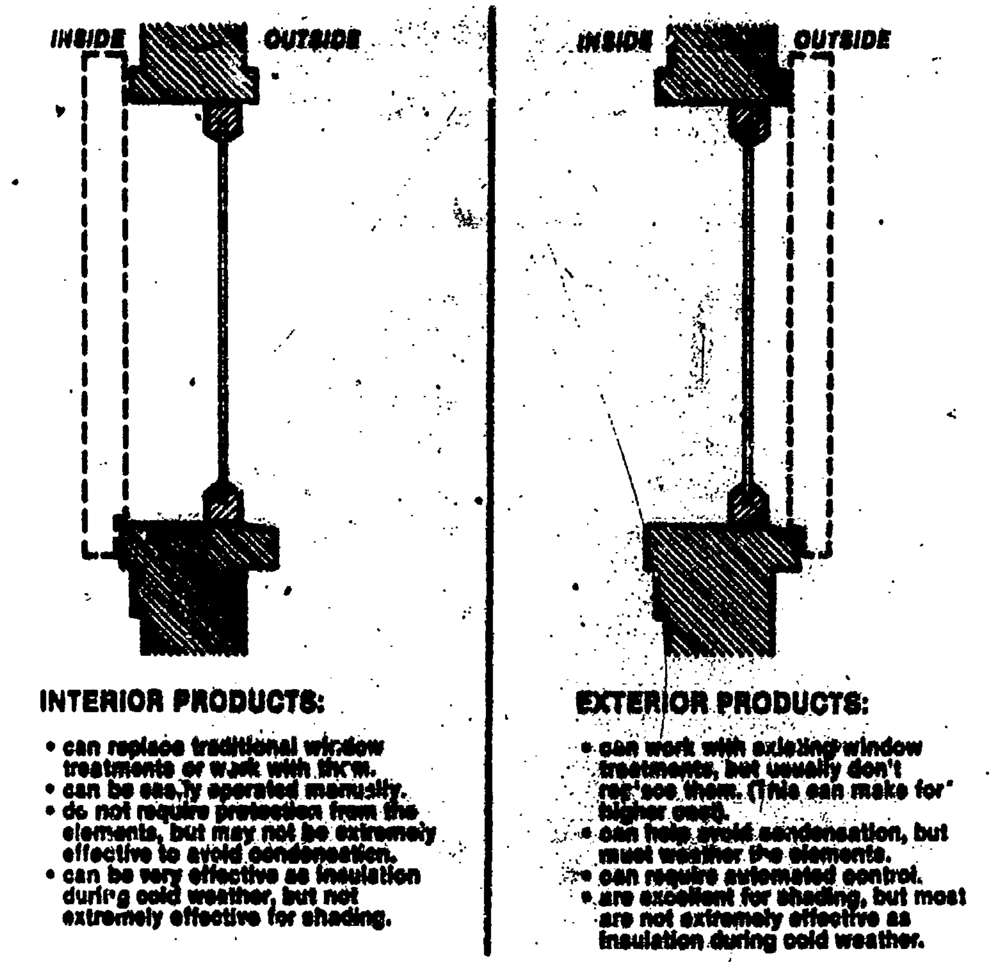


FIGURE 11: *Interior and exterior products both have advantages and disadvantages.*

Exterior products can be reasonable choices in cold climates if they are used seasonally. For example, north-facing windows in a moisture-prone area of the home may be treated with a tight-fitting exterior product that would prevent moisture condensation on the glass. The product can be employed for the winter season and forgotten, and then removed in the spring. Most available strategies and products for exterior use in colder climates are opaque products, however, so this should be noted if some light is desirable.

On east- and west-facing windows that receive some sunlight, an exterior product can work well and won't demand operation to avoid overheating. Some exterior products allow for interior operation, of course, but these products will be more expensive because of their operable nature.

Because of the drawbacks with some (but not all) of the exterior products, most people in climates requiring some winter heating tend to choose insulation that is installed inside the house. Interior insulation can replace a traditional window treatment, it is handy and can be easy to operate, and it needn't be strong enough to withstand rain, wind and snow.

Sealing System Options

Grantees used a wide variety of products and components to achieve tight seals around window-insulating devices (Figure 12). Work done during these projects reveals that the design of the window insulation can make a big difference on how well the product can be sealed, and that each sealing system has its drawbacks and advantages.

How tight the sealing system must be depends on what condition the primary window is in and where the insulating device is to be mounted. Products mounted over single-glazing should be extremely tight to avoid moisture condensation problems, while windows with double or triple glazing may be somewhat more forgiving.

If the product is to be mounted by pressing it directly against the glass, seals around the edges are unnecessary. The seal in this case is achieved by the fact that no significant air movement can occur behind a plate that is within ¼-inch of the window surface. An on-the-glass seal is fairly easy with either exterior or interior seasonal panels, which can be wedged into position and held tight against the glass by putting shims around the edges.

However, the majority of window insulation products are not mounted in this manner. Flexible products are often sealed around the window casing or the surrounding wall. Some designs employ side tracks of various types, while others use seals achieved with hook-and-loop tape, flexible magnetic tape or wooden side clamps operated on spring-load hinges. Shutters and rigid panels are fit between the jambs, with seals of soft foam, "v-strip" weatherstripping or other similar methods.

When the product is more than ¼-inch away from the window pane, seals around the edges of the product become imperative. Further, most specialists note that gaps greater than 1/8-inch in these edge seals can significantly reduce the effectiveness of the product. Also, if the window itself allows much infiltration the seal on the window insulation must be extremely tight and strong.

How Do the Sealing Systems Compare?

In most retrofit situations, it is usually easier to achieve an effective seal with a soft, flexible product than with a rigid panel or shutter. The reason for this is that the fit with rigid products often must be exacting, because many are designed to fit between the jambs of the window. The problem is that many older windows are not perfectly in square. (At least two manufacturers of do-it-yourself panel kits have overcome this fitting problem by providing sealing systems that can make up for an inexact fit of the rigid panel itself.

Some sealing systems may be affected by heat or moisture. For instance, one grantee found that some varieties of hook-and-loop tape will stretch out if exposed to moisture. This grantee concluded that these tapes should probably be washed and dried once before being installed to avoid this potential problem. Some plastic tracking systems will warp and expand if exposed to heat or sunlight, and some varieties of magnetic tape can lose their magnetic power when exposed to heat or direct sunlight.

The general rule is: Don't try to cut costs too much with sealing system components. Higher quality products may cost quite a bit more, but the performance will easily be worth the money. A seal that doesn't work can ruin your project and reduce the insulating value of your product to the point where it is nearly worthless as window insulation.

Adhesives used to apply sealing components also must be of high quality, able to withstand heat and moisture. "Self-adhesive" tapes have sometimes given way (during washing or dry cleaning or during regular use), and quite a number of these products demand an extra layer of additional adhesive to be truly effective. Trying a

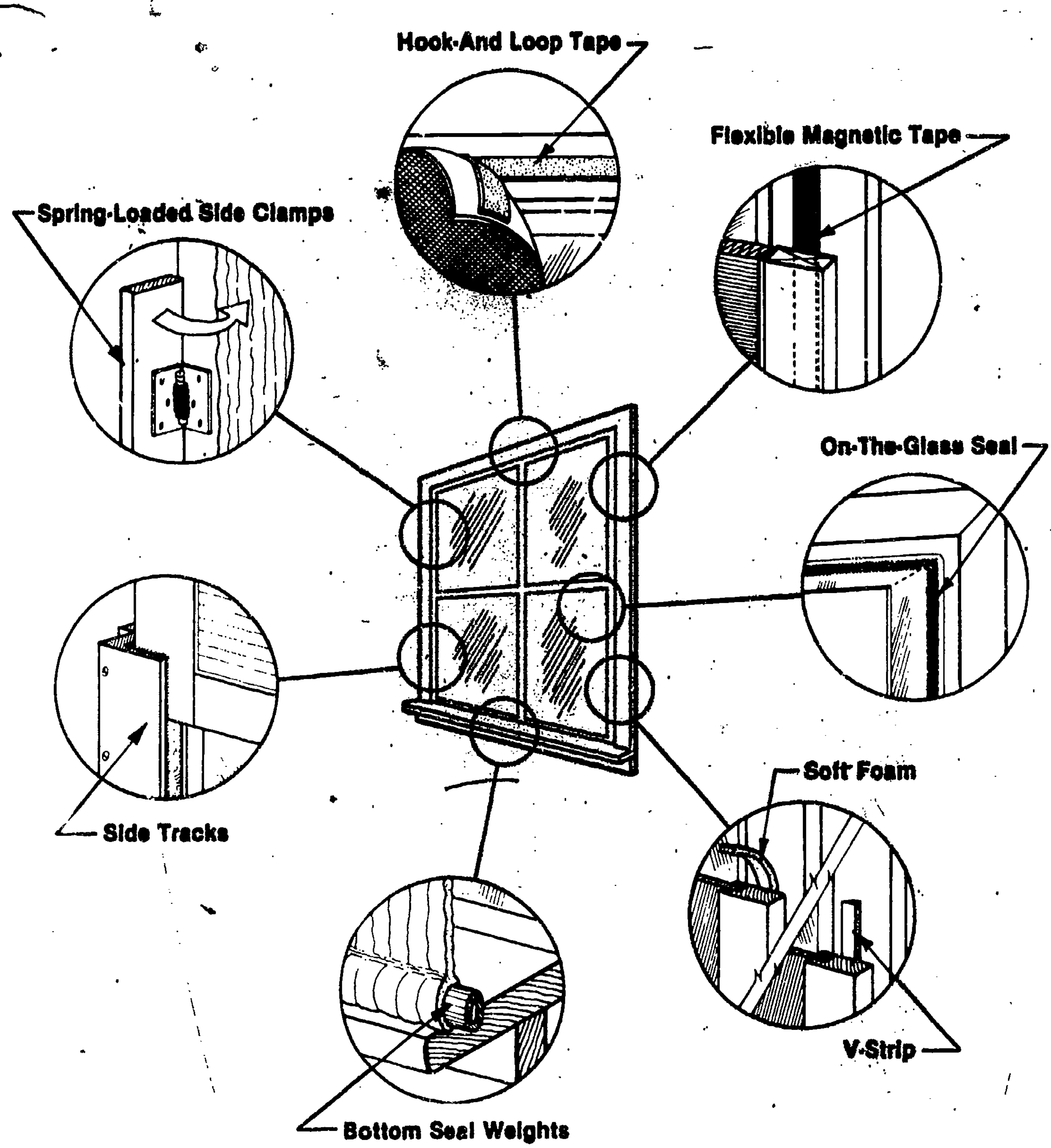


FIGURE 12: *These sealing systems are among the many options available for window insulating devices.*

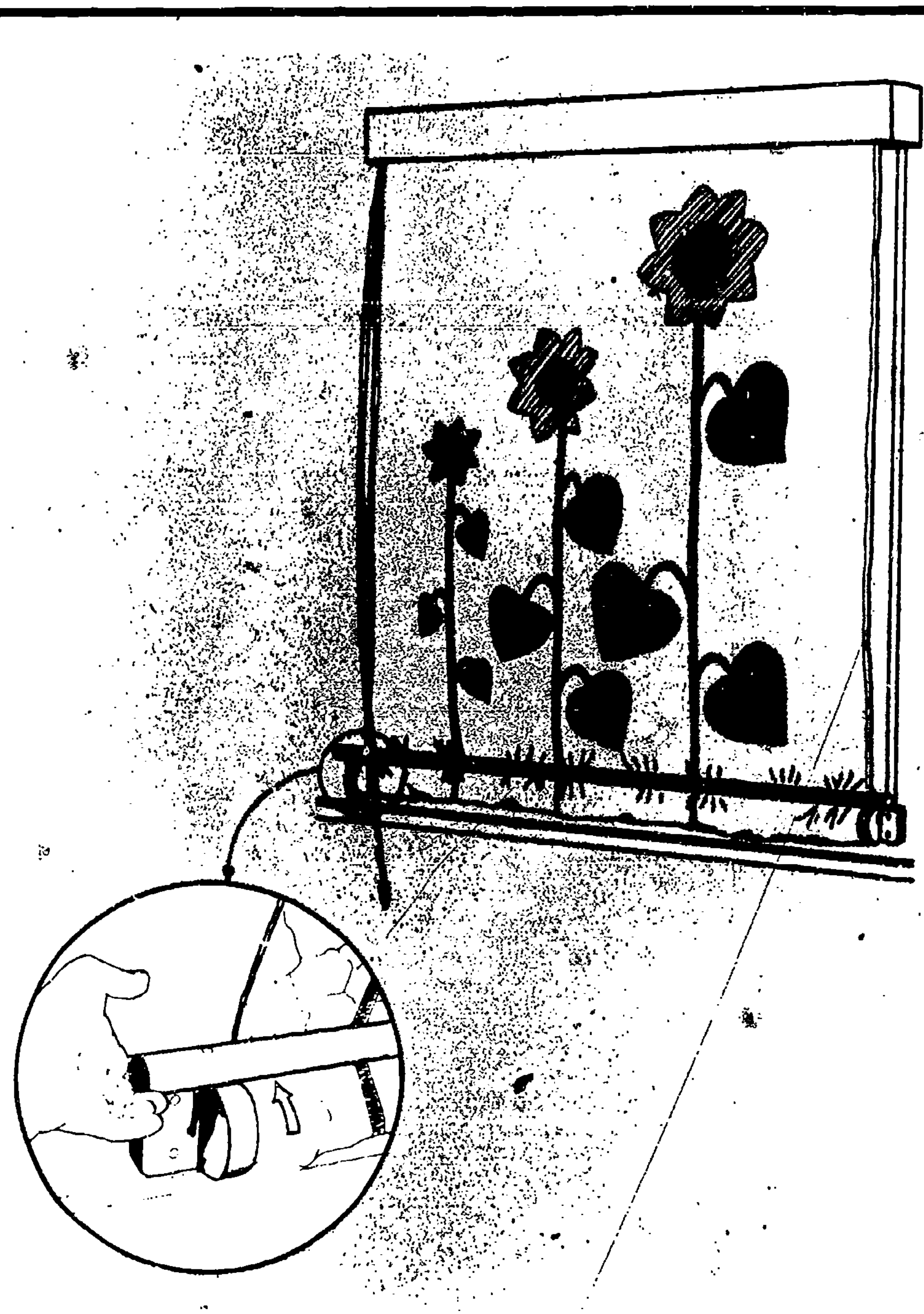


FIGURE 13: *Grantees in the Shades of West Virginia Sewing Cooperative designed this drapery shade, which seals at the bottom with a wooden rod that is held securely in place by side brackets. The rod is attached with a spring, to ensure easy operation and hold it in place when not in use.*

test section with this type of product is a good idea before doing the entire job. Try the self-adhesive product in an inconspicuous place, and test the hold of the adhesive by tugging the strip repeatedly.

Perhaps the simplest and most trouble-free sealing system used by grantees was the wooden side clamp system. This system is useful with all types of soft, flexible insulation materials for interior use, and it is an excellent sealing option for existing drapery.

One aspect of this type of seal is that it must be manually operated; the insulating product is closed over the window, and the side clamps are snapped into place over the edges of the insulation. Unlike other types of sealing systems that are somewhat "automatic," this manually operated seal may prevent inadvertent sealing of the product at an inappropriate time. This type of seal allows the product to be in place for shading or light control on a heat-gaining window without employing the seals, which can help avoid overheating.

Sealing folding shutter products proved difficult for several grantees. Foam tapes and vinyl weather-stripping may break down due to friction caused during operation. Also, there are more edges to seal than with a one-piece product. Shutters may need some additional hardware to keep them snugly in place; if the fit is less-than-exact, the shutters may have a tendency to pop away from their seals.

Seals for the bottoms of flexible products usually rely on adding weight to the bottom of the window insulation. Grantees used metal weight bars of steel, sand, standard weight chains (which are often used in conventional, non-insulating drapery), small marbles and rods that are clamped over the bottom of the window insulation. (Figure 13). Magnetic tapes also can work well for bottom seals.

The top seal can be achieved in a number of ways, depending on the design of the product. For conventional-looking draperies and curtains, grantees used valances and soft, flexible materials to bridge the gap between the wall and the drapery rod. Shades that operate vertically are often permanently tacked to the top of the window, or lightweight shades can be mounted with hook-and-loop tape. At least one manufacturer offers top and bottom seals for horizontally operated shades that employ tracking devices.

Just as the grantees used a variety of sealing systems with their projects, consumers have a number of choices to make when it comes to achieving an adequate seal with window insulation. Manufacturers and small businesses continue to work on sealing systems, and innovations in this area will continue in the future.

Perhaps no other part of the window insulation field baffles consumers as much as sealing systems do, yet no other component is as essential to the performance of these products. Newcomers to window insulation manufacturing and sales sometimes overlook the importance of the sealing system, and unwary consumers can be left to fend for themselves.

Do It Yourself or Hire a Contractor?

The most popular products in today's window insulation market are do-it-yourself products. Considerable savings await the occupant who wants to use skills in either sewing or carpentry (or both) to make and install window insulation. But, as one grantee discovered in the course of a survey of potential users of window insulation, many people don't have the ability to complete a do-it-yourself project successfully.

If the device is a shade or curtain, sewing skills and a sewing machine will be needed, while if the product is a shutter that folds open, considerable carpentry skills will be necessary to ensure a tight fit.

Yet, some do-it-yourself products demand few skills or tools. Probably the most popular in this regard are simple, pop-in panels that fit between the jambs of the window (Figure 14). In the simplest of cases, the occupant purchases standard insulation board from the lumber yard and a kit from another firm that supplies the instructions and sealing system. In the more difficult circumstance, the occupant buys the insulation board and fends for himself when it comes to the sealing system.

As with any do-it-yourself project, your chances of success are much greater if you follow an established, proven plan and avoid improvising when it comes to the details, especially with the sealing system.

For several years, consumers have demanded window insulation at a faster rate than firms have been able to supply it. In the meantime, passive solar advocates and practitioners tried to get information to consumers on do-it-yourself schemes and products. Yet, many consumers were starting out without the basic information they needed to ensure success. This has led to numerous complaints about the "difficult" features of window insulation: the products blocked light, were difficult to open, allowed excess moisture condensation due to poor sealing systems and, in many cases, were unsatisfactory simply because they were so different from the conventional window treatments that are familiar to most people.

FIGURE 14: *A pop-in panel is one of the easiest options for the do-it-yourselfer. Kits that include a flexible edge sealing system can help overcome the problem of out-of-square windows*

A number of do-it-yourself products were introduced that had little chance of success because consumers didn't have the skills to overcome such obstacles as out-of-square windows. Billed as "simple to make and install," these products sometimes produced a massive headache for the consumer, who was expecting an easy-to-tackle project. In addition, some products advertised as "insulating" products made little or no provision for effective sealing systems.

The greatest difference between making standard window treatments and insulating products is that the insulators usually must fit well; there is little margin for error if a good seal is to be achieved.

If you are contemplating a do-it-yourself project with window insulation, first determine what skills and tools will be needed to do the job and be realistic about your ability to handle the task. Try to estimate how many hours it will take to do the job and whether you are willing to put in the time. If you feel confident that you:

- understand the design of the product and how it will work and seal on your window;
- have the tools and skills to do the tasks, or can hire out the parts that you can't do;
- have the time to devote to the project;
- trust the instructions and design to do a good job;
- and understand how you will manage and maintain the product when the job is finished,

then you're probably ready to undertake the job of making your own window insulation. Otherwise, try to find a local dealer or contractor who has these same skills, has a thorough understanding of the product(s) and can guarantee the work.

In many parts of the country, "energy conservation" businesses handle the bulk of the window insulation work in their areas. Sometimes products and services are available at major department stores or at interior furnishings or decoration businesses. Also, architects who specialize in passive solar work are likely to have knowledge of window insulation strategies and products.

A reputable contractor generally will need to visit the house to look at the windows and help the customer choose the best products to meet the demands of the situation. Because window insulation often demands a good fit, hiring a contractor usually means a custom job. Measurements often must be exact to make sure the seal is located in a place where it won't be hampered by the design of the window or the casings. Also the contractor should be able to discuss and explain management and maintenance of the products.

Many contractors handle only one type or design of window insulation, and this design might not meet your needs. Don't hesitate to shop around and compare different designs and operational features. For example, because of decorative trim on your window, one type of window insulation may not be able to be tightly sealed at the bottom of the window, while another would work fine.

Another level of do-it-yourself activity may come in buying a finished product and installing it yourself. In this case, you usually supply the measurements, and the finished product is delivered with a sealing system for your installation. If you go this route, be sure, again, that you fully understand how the product will be sealed and will operate before you buy. Carefully think through how the product will be mounted and whether you will be able to successfully mount the product.

Installing insulating products can be extremely simple or very difficult. For example, mounting a basic, vinyl roll-down shade with magnetic sealing system can be simple, while installing bi-folding shutters can sometimes try the patience of a seasoned carpenter.

Many of the problems associated with do-it-yourself projects can be avoided if you first think through the sealing system and the mount. Many a disappointed homeowner has learned this painful lesson when trying to install a finished product in a situation that is really impossible, because of window design or other unforeseen "hitches."

Sorting Through Product Claims

A frequent complaint about window insulation relates to inflated or inconsistent claims as to how much energy the product will save. Some manufacturers have labeled conventional window treatments as "energy savers," when there is little to indicate that the products are capable of any energy savings because of inadequate or missing sealing systems.

Manufacturers of products with an R-value (based on accepted engineering practice) of less than R-2 may claim the product works at an R-10 level. Many products are described in terms of what the "total" R-value will be over single or double glazing, which is a difficult thing to bank on, because the thermal effectiveness of windows varies, depending on how tight the window is and how great the air space is between the layers of glazing.

At least one trade association is pushing for an acceptable industry-wide standard of testing that will overcome these inconsistencies and help clear up false or misleading claims. Until this happens, however, the consumer should beware

Reputable contractors or dealers should be able to give a reasonable estimate of the R-value of their products, discounting the existing insulating power of the windows. Some manufacturers have had their products tested at reputable laboratories, and they are usually willing to show you a copy of the lab's report or a summary.

If you have any doubt about the truth of claims made by a manufacturer or dealer, keep shopping.

Managing the Windows Through All the Seasons

When managing movable insulation, the main goals are to produce the greatest energy savings, and avoid overheating, thermal shock, and excessive moisture condensation. Obviously, movable insulation will produce the best benefit on south-facing windows if it is faithfully opened when the sun is shining and closed during cloudy weather and at night. Such operation is easily possible if someone is home to open and close the products, but in many households, everyone is away from home during part of each day. Yet, simple habits can be adopted to allow for near-optimal use of interior window insulation. Some rules of thumb include:

1) If you are routinely away from the house during the daytime, open any interior movable insulation on all heat-gaining windows before you leave for the day. It's not necessary to open the products completely if you wish to obscure view into your windows for security reasons, but you should open them sufficiently to avoid heat buildup behind the insulation. (The same holds true if you are leaving the house for several days or for a long period of time.)

2) During the coldest weather, open movable insulation slowly to avoid thermal shock. Just break the seal a bit at first, and let the window temperature change slowly. If you heat with a wood stove, open movable products *before* firing your stove in the morning.

3) In wintertime, the effectiveness of the seal at the bottom of the window is the most important; in summertime, the top seal is the most effective (Figure 15). In the summer, an alternative to leaving an insulating device unsealed at the bottom (to allow some escape of heat into the room) is to open the window sufficiently to encour-

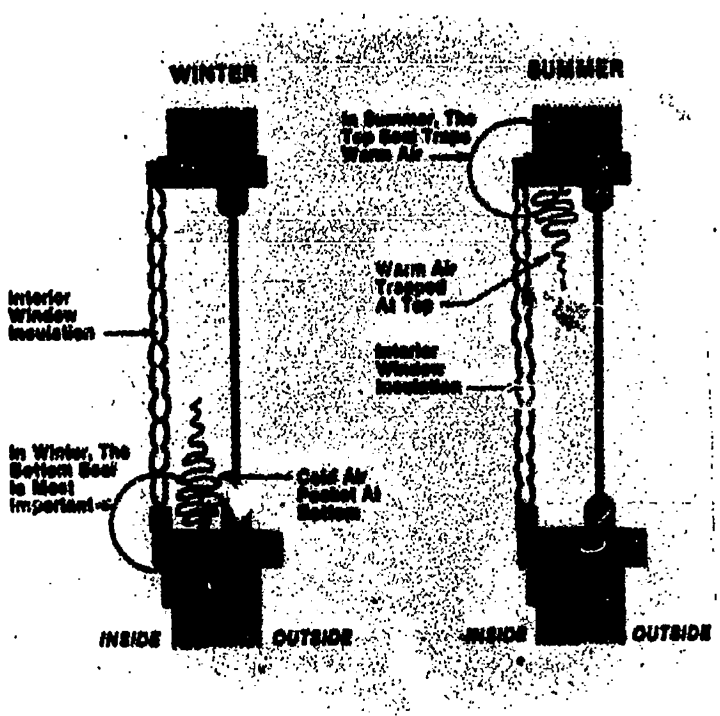


FIGURE 15: *In winter, the bottom seal is critical, while in summer, the seal at the top of the window is the most important.*

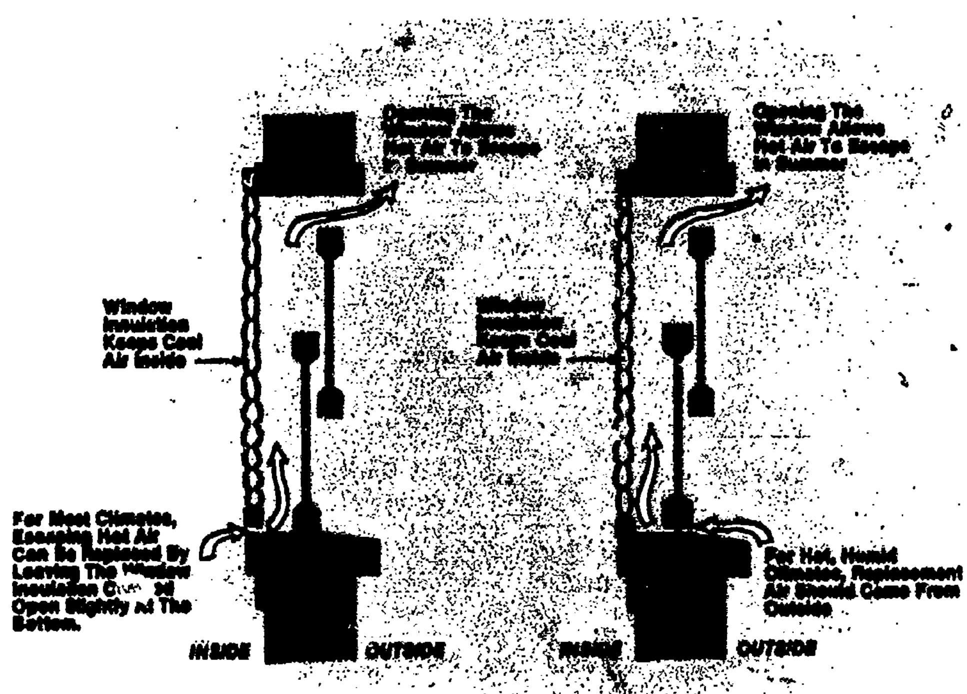


FIGURE 16: *When using sealed window insulation products to prevent unwanted heat gains, it is important to either open the window covering or the window to avoid damaging heat buildup.*

age heat to return to the outdoors (Figure 16).

What Options Are Available for Remodeling or New Construction?

Consumers now have more options in new windows for remodeling or new construction. For example, one manufacturer makes a window unit that includes a built-in, high-R shutter that slides into a pocket in the wall. Another makes a triple-pane window with a shade that slides down between the layers of glazing.

Many effective products and devices have been developed in the last ten years to help consumers save the energy lost through windows. Yet, there is still the need for significant innovation in this industry, and research is continuing in a number of promising areas. (See: THE WINDOW OF THE FUTURE.)

Heat Mirrors

Recent research has led to one striking development in window insulation: low-emittance films (also called "heat mirrors") that dramatically enhance the performance of windows. Heat mirrors spent more than a decade in the laboratory before entering the new-window market in the early 1980s.

Heat mirrors consist of an extremely fine layer of metal, so fine that it is not visible to the naked eye. The metal is embedded in a layer of clear synthetic material, that is sealed between two layers of glass.

Heat mirrors allow a double-glazed window to perform more like a window with four panes of glass, yet they do not cut heat gains from sunlight as much as a quadruple-paned window (Figure 17). Thus, solar radiation is transmitted by day, but the window is insulated at night or during cloudy weather.

On the other hand, heat mirrors can also be designed to reduce solar radiation, in a manner similar to conventional reflective films, but they insulate much more effectively than a clear, reflective film or a tinted glass. Thus, heat mirrors make sense in all climate regions.

The breakthrough in heat mirrors allows the occupant to forego additional window insulation, if desired. This can be especially helpful in passive solar applications, such as greenhouses, which have traditionally posed many problems with window insulation. For example, it has been difficult to find a movable insulation product that works well on slanted glass. In addition, when the insulation is pulled up during the daytime, it can sometimes obstruct desirable sunlight from overhead glazing.

Because the new windows which incorporate the heat mirrors

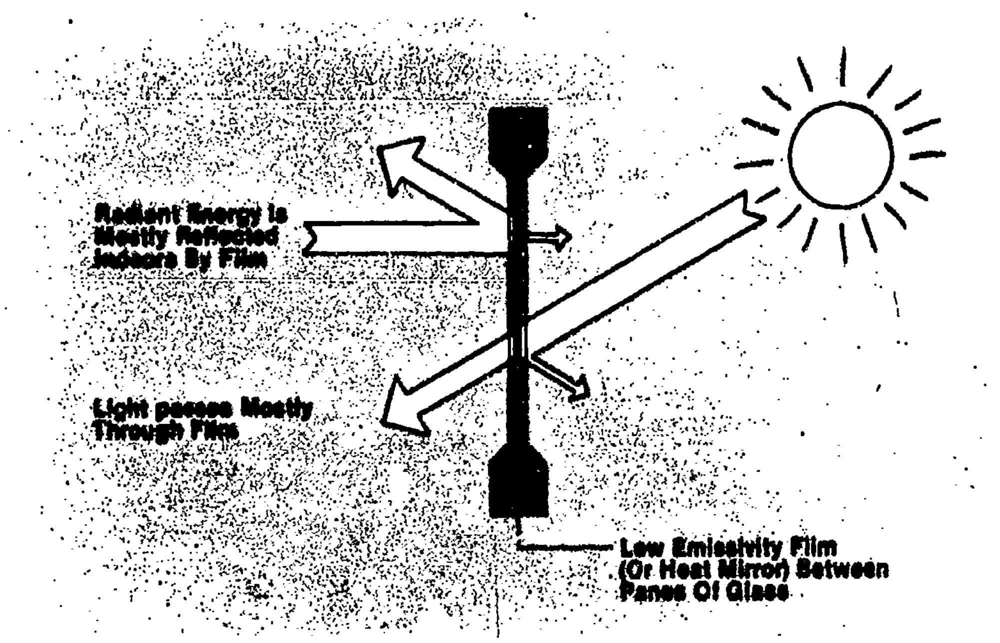


FIGURE 17: *Low-emittance films, or "heat mirrors," can allow solar radiation to pass through the glass to enhance solar heating, yet heat mirrors insulate a double-glazed window so that it performs better than a window with four panes of glass. For climates where heat gain is a problem, heat mirrors have been developed that cut solar gains, while still insulating the glass to a level of about R-5. The film is sealed between two panes of glass.*

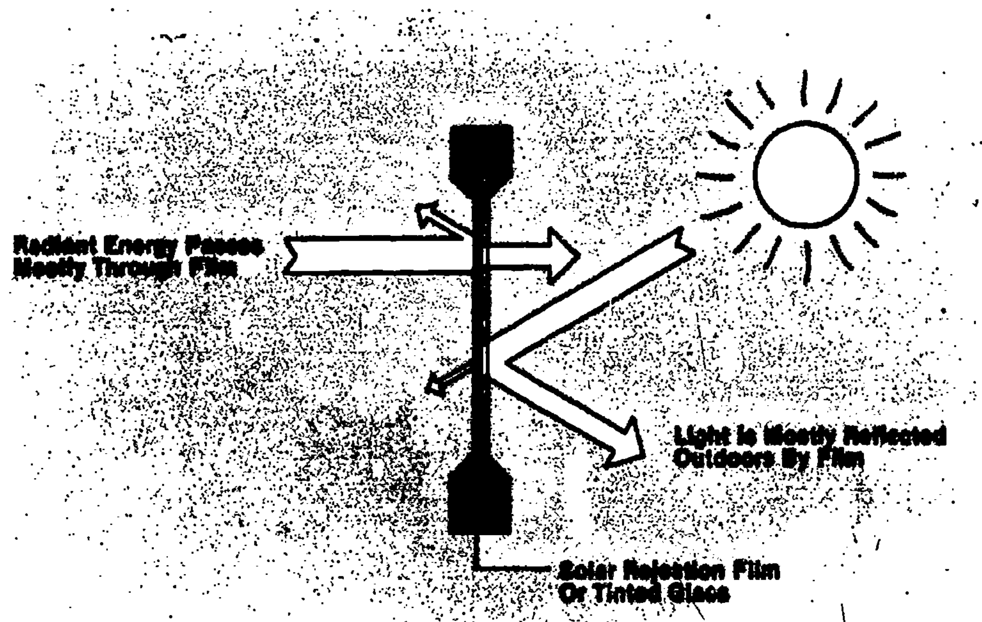


FIGURE 18: *Solar rejection films or tinted glass are for use only where heat gains are the major problem. Unless solar rejection devices are movable or seasonal, they will also cut solar gains that may be desirable in the winter.*

are in place 24 hours a day, and because they don't substantially reduce solar gains, they can be economically competitive with double-glazing combined with movable insulation. They have the extra advantage of saving the occupant time and trouble, because no window management is necessary.

Some observers have noted that these new windows may make movable insulation and other types of window insulation obsolete. However, this observation ignores the fact that some consumers will still want interior window treatments of some kind for other reasons. The overall cost of new windows plus additional window treatments could be much higher than if the homeowner had chosen basic double-glazing and an interior, movable window insulation.

Reflective Films and Tinted Glass

In contrast to heat mirrors, reflective films and tinted glass are suitable only when excess solar gains are the primary concern (Figure 18). Because solar gains may be desirable in most households during the winter (even in warmer climates), these options are more commonly recommended for commercial rather than residential applications.

Reflective films should not be added to existing windows if the windows are sealed double-paned units. Temperature difference can make the two panes expand and contract at different rates, causing the glass to break.

Some reflective films are removable, allowing for seasonal operation, while others are permanent. A reflective film or "sun screen" shade that is operable may be more practical than purchasing permanent reflective film or tinted glass.

Replace the Windows or Retrofit Them?

A choice confronts the homeowner who is considering replacing existing windows with new windows in order to save energy. The cost of new windows may make further investments in window insulation difficult, and the overall energy savings could be lower than retrofitting the existing windows.

For example, the homeowner who wants to replace single-glazed windows with new double-glazed windows may be able to save both money and energy by choosing instead to spend a similar amount on weatherizing the windows, adding storm windows and opting for further window insulation (Figure 19).

As with all types of window insulation, the tastes and preferences of the consumer will have more impact on the economic effectiveness of the various options than any other single factor. Thus, the decision to purchase new windows or some other window insulation option should be made after taking all the factors that influence the use of the windows and window treatment into account.

What About Automated Control of Window Insulation?

Automated controls for conventional, non-insulating window treatments have been available for years, though they tend to be too expensive for many households. High costs have also deterred the use of automatic controls for residential window insulation. At 1983 prices, the cost of completely automatic systems can run $450 or more per window.

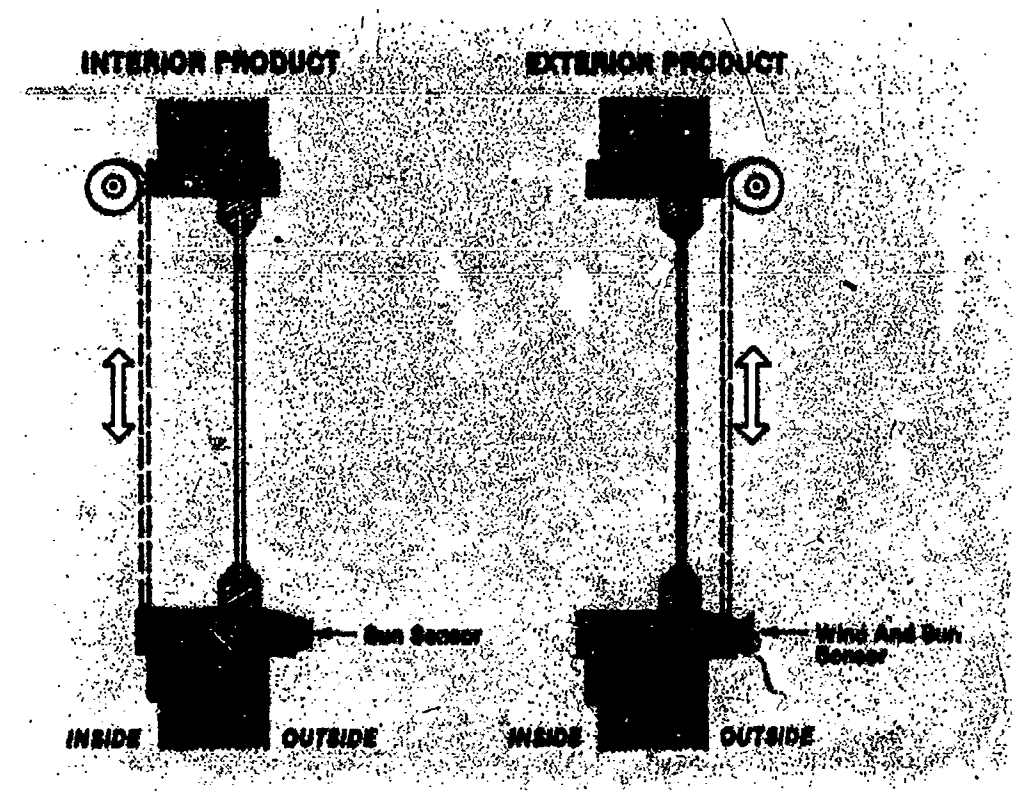


FIGURE 20: *Automated window insulation controls can work with either interior and exterior devices. With interior products, a sun sensor is used, while exterior products usually demand both a sun and wind sensor, to protect the product from wind damage.*

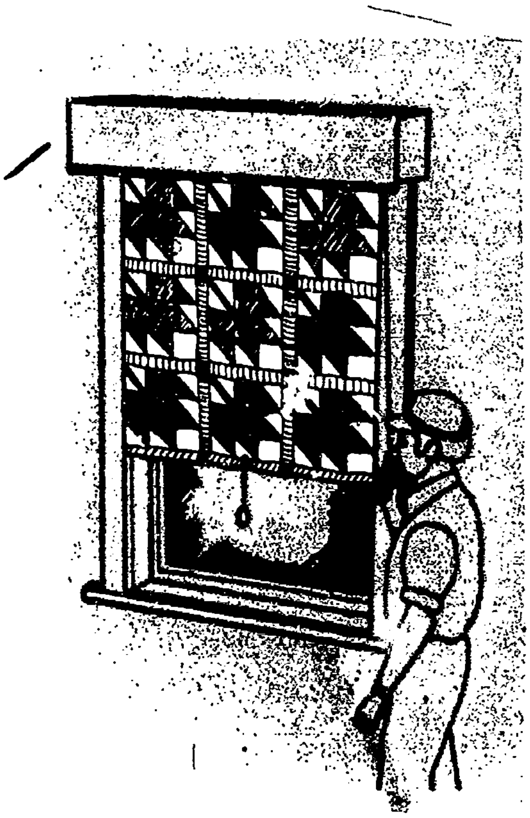


FIGURE 19: *Although movable insulation demands attention, many consumers will still prefer a window covering to a bare, well-glazed window. This design was fabricated for a public building by grantees in West Virginia. This project resulted in a small business, Shades of West Virginia Sewing Cooperative, which offers hand-quilted shade covers. The group plans to switch its emphasis to educational workshops on window insulation.*

Yet, automated control can make economic sense even at these prices. If the house has large expanses of south-facing glass, for instance, it may be worth it to automate the system.

Most completely automated systems employ a sun sensor which activates a motor that opens the window insulation when the sun is shining. Exterior automated systems often feature both a wind and sun sensor. If wind speeds are too great, the wind sensor will open the window insulation to prevent damage (Figure 20).

It takes an expensive mechanism to sense sunlight, mechanically open a product and then close it, while somehow ensuring that the sealing system is fully employed. In order to make sealing a reasonably good prospect, these automated systems generally work best on devices that employ tracking side seals.

At least one controls manufacturer is conducting research into some simpler controls, including a day-night control and a winter-summer control that would alter the operation of the window insulation to prevent heat gains in summer and maximize solar gains in winter. If prices are reasonable, these types of controls would eliminate the problems associated with the need to operate movable insulation devices.

One grantee explored the possibility of manufacturing a low-cost automated system for window insulation. This grantee attempted to design a mechanical roller system for exterior sun-rejection shades for large passive solar systems. The grantee reported that exterior products suffered from damage.

Yet, this grantee reasoned that a device that could simply drop the window insulation without concern for sealing the product would still be useful and possibly affordable in cooling applications.

AVOID INSULATING PRODUCTS THAT ARE DIFFICULT TO OPERATE

Several grantees discovered that not all "movable insulation" devices are easy to operate. Some developed exterior products that had to be opened from the outside, which was sometimes difficult or impossible. Others noted that heavy insulating materials caused operational difficulties.

One grantee developed a sliding glazing product and tested it in several homes. The device consisted of a roll-up, twin-layered shade, made of low-cost, clear plastic. Problems arose over the sealing system; it was difficult to get the flexible plastic to track up and down, despite the use of velvet-covered side tracks. Users reported that simply pushing on the plastic would disengage the side seals. Users also found the plastic virtually impossible to clean, a problem common with many plastic glazings.

Other grantees pointed out that some of the rigid boards used for insulating panels may pose fire hazards. Some suggested the use of flame-retardant papers or fabrics with these boards, while others simply opted for insulating boards that were already treated with flame retardant or were non-flammable.

In another project, two grantees in Iowa field tested insulating board panels in ten households. Kenneth Lillemo and Scott Holcomb of Huxley, Iowa, used an opaque, closed-cell insulating board. The sealing system consisted of a simple friction fit between the window jambs.

Although most of the participants in the ten households said they enjoyed the benefits of window insulation (greater comfort and potential energy savings), they noted a wide range of problems.

Because the panels were not covered with fabric or any other protective material, they tended to shed small particles. Some people noted that these opaque panels actually increased the need for extra lighting, since all natural light was blocked when the panels were in place.

Because the panels were quite difficult to remove (as are many friction-fit products), some participants tended not to remove them when appropriate. Heat built up behind the panels on windows that received sunlight, and the heat was intense enough to warp the panels in some cases.

When the panels were off the windows, other problems arose. Storing the panels was the major problem, and in one case, the panels were virtually destroyed by one participant's small children.

This project identified almost every potential problem associated with the use of low-cost, homemade, pop-in panels as "movable" insulation. The only difficulty not experienced was thermal shock. If these panels had been used as seasonal devices, rather than movable insulation, many of these problems would not have occurred.

Kits are available for the do-it-yourselfer that can help solve some operational troubles with rigid, pop-in panels. For example, one manufacturer has developed a soft-foam, sealing system for rigid panels that makes them much easier to remove.

The lesson many of the grantees learned is that if the movable insulation product isn't very easy to operate, it probably won't be used properly, may not last very long and won't give much user satisfaction.

SUBSTITUTING SEALED WINDOW TREATMENTS FOR STORM WINDOWS IN MODERATE CLIMATES

One grantee experimented with the concept of substituting sealed window treatments for storm windows in the moderate climate of Potomac, Maryland, a location with 3,800 heating degree days.

Robert Wehrli, an architect and former staffer at the National Bureau of Standards, explored the possibilities and economics of sealing conventional window treatments to allow these treatments to function in lieu of storm windows, and sometimes at significant cost savings over storm windows.

Wehrli noted that by employing a sealing system with tightly woven draperies, a total R-value of R-1.77 could be achieved, while adding an extra layer of glazing would yield about R-1.8. Thus, the grantee reported that his window treatments would cut his heat losses nearly in half. Wehrli produced a number of prototypes that employed zippers, hook-and-loop tape, weighted hems, and other strategies. He chose standard drapery lining fabrics that can be resistant to moisture, although they probably would not serve as a vapor barrier.

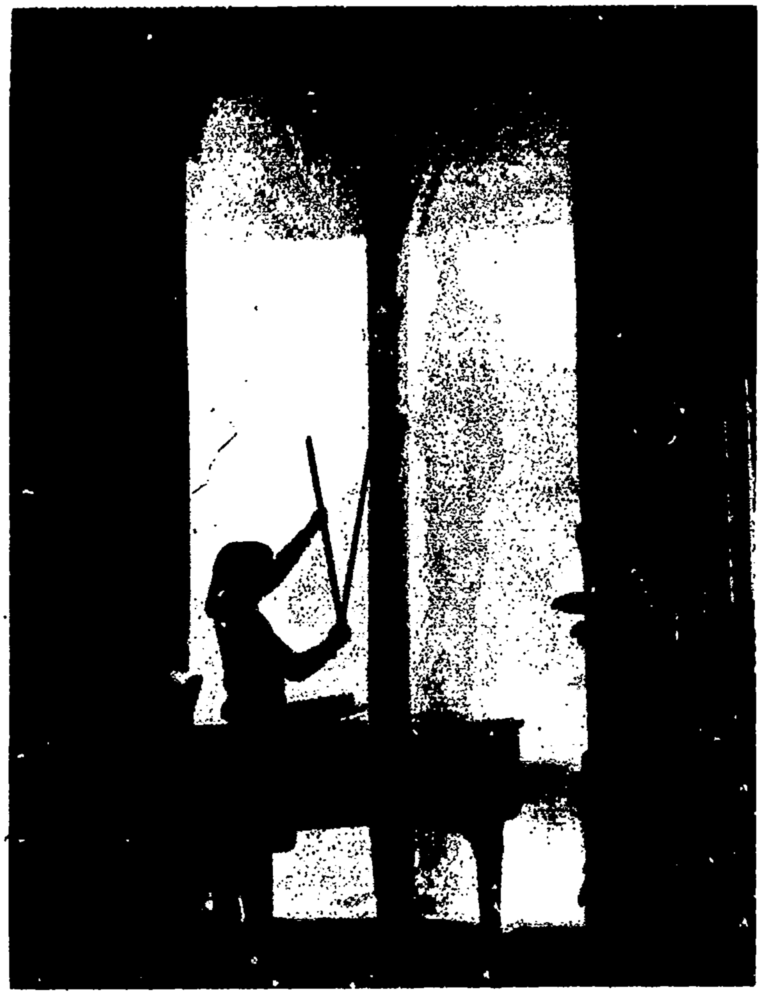
Wehrli employed the prototypes over 2,000 square feet of single glazing (see photos) This amount of glazing greatly exceeds the amount found in most homes, but Wehrli's house was designed to take advantage of solar gains through a large amount of south-facing windows. His main goal was to stop "the waterfall effect," which describes the way cold air moves down a window pane, as part of the convection process. Wehrli's windows were so tall that this waterfall effect caused chilling drafts that made it uncomfortable to be near the windows. Adding storm windows seemed less desirable in this case than covering the windows with a tightly woven fabric that could contain the cold air at the bottom of the window with the help of a sealing system.

The grantee carefully monitored his prototypes and found that they performed as expected. He reported that the window coverings stop drafts from the convective loop and that operating the devices isn't difficult despite their large size. Although moisture tends to condense on the windows in colder weather, he noted that no damage has resulted because the moisture quickly evaporates when warm room air moves to the window when the curtains are opened. However, Wehrli acknowledged that excess moisture condensation could be a problem in colder climates with his design.

In a cost analysis, he noted that the materials cost for his prototypes could be as low as 55¢ per square foot, and finished products with labor could run from 81¢ to $5.83 per square foot. Based on a comparison with storm windows, he noted that his prototypes would cost roughly one-third the cost of storm windows, with a similar final R-value.

Finally, he produced a manual for professional drapers, upholsterers and interior designers that explains the process of producing products similar to his prototypes (Appendix B). Wehrli noted that drapery production shops are already in existence across the country, and if these businesses could learn how to turn their products into insulating devices, these products may be able to compete favorably with other window insulation options.

Wehrli's sealed drapery is designed to stop the "waterfall" effects of air moving down these tall windows, which can cause chilling drafts. These sealed drapery liners effectively halt these convection currents.



On the inside, the tall drapes are closed with the help of a long rod. The drapes are translucent, and they can be left closed on a cold winter day without reducing light levels. (Photos by Robert Wehrli)

THE WINDOWS OF THE FUTURE

Research is continuing in many directions toward reducing energy lost due to windows. Although heat mirrors have entered the marketplace at last, research into this new technology will continue, to find ways to improve manufacturing techniques and to discover whether the concept can be adapted to the retrofit market.

Further from commercialization is the idea of one grantee, who explored the possibility of constructing a window unit that automatically adjusts to weather conditions: when the sun shines, the window rejects solar radiation to reduce cooling costs, and when the sun is gone, the window is insulated against the cold.

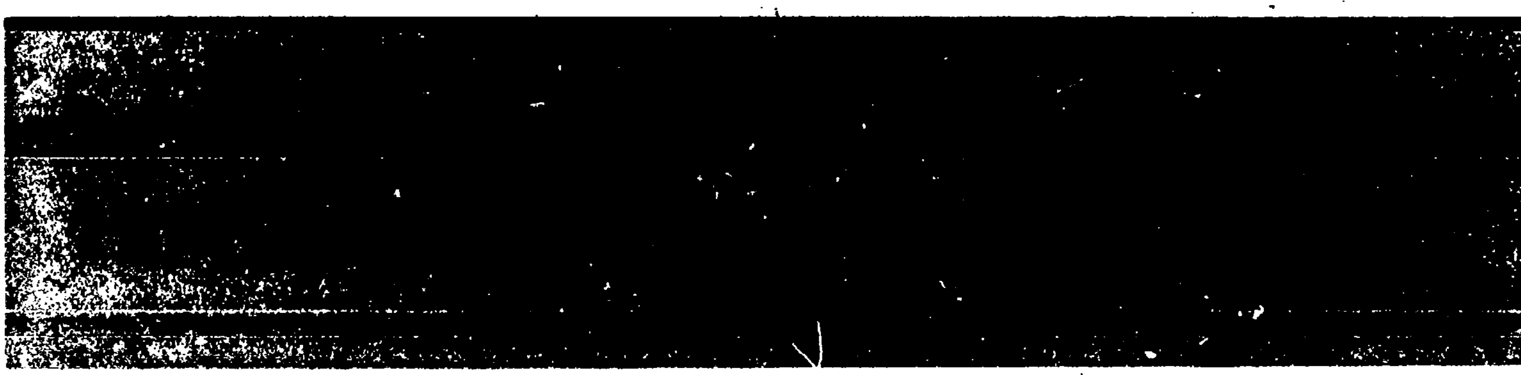
While this may seem to be a nearly impossible ideal, the concept of the "thermal shutter," which is being developed under the management of national laboratories with funding from the U.S. Department of Energy, comes close to it. The thermal shutter employs a gel-like substance between two layers of glass. When solar radiation is absent, the gel is transparent, but when the sun shines, the gel becomes translucent and reflective to reject solar radiation.

Like the early stages of the development of heat mirrors, which also was a research and development project funded by DOE, the thermal shutter heat mirrors overcame cost problems, and it is thus possible that the thermal shutter concept may be available in window units some time in the not-too-distant future.

One of the more promising concepts in window insulation is the notion of "microporous" transparent material for windows, a material that offers excellent thermal performance while maintaining its transparency. These materials consist of a rigid matrix of transparent silica with a pore size that is considerably shorter than the wavelength of light. Like foamed plastic or rubber, this material would consist of tiny pores, yet unlike these foams, which tend to diffuse light and hardly approach transparency, the microporous material's pores are so minute that light is transmitted directly, and the view isn't impeded.

This concept has been under development for about 50 years, with the greatest interest coming during the last ten years. Referred to as "aerogel," the material would work best sandwiched between two layers of regular glass, to protect it from moisture and compression, which will damage it. Lawrence Berkeley Laboratory (LBL) notes that the R-value of a 3-inch thick window made with this material would be R-15. This outstanding thermal potential has led to considerable interest in further development of this concept, yet much work remains. An aerogel preparation facility is in the works at LBL, and bench-scale testing is anticipated during the 1980's.

Another unusual concept was researched by one grantee, who explored the possibility of using highly polished half-cylinders of rock salt to both reject and transmit heat. The "heat-shield" of rock salt transmits radiant heat from its concave side, while the convex side rejects solar radiation, and thus cools. This concept is in the early development phase, and, while it may have applicability to window heat loss, no major research efforts have been directed toward using this technology.



The following method provides a way to roughly calculate heat lost through your windows. The answer you get will likely *underestimate* your heat losses, because it only takes into account heat lost through conduction, which is only one of several ways in which heat is lost through windows.

For example, if your windows are very leaky, heat losses from infiltration may easily exceed conductive heat losses. Also, many experts note that heat lost through radiation may be the most significant single source of heat loss through windows. However, it is not possible in a simple analysis to calculate heat losses through these methods. Nor does this method factor in heat savings from solar gains. Consult reference books listed in Appendix B if you wish to add this information to your economic analysis.

Yet, this method can give you a conservative idea of how much window heat loss is costing you annually. You can also use this method to compare savings from different window insulation options, and to calculate savings from other energy conservation work, such as wall or ceiling insulation.

In many cases, tax credits offered by states and the Federal Government could further reduce the cost of some window insulation items. Check with your state or local energy office, your state and federal revenue offices or your tax preparer for information about these tax incentives. In addition, remember that unlike many other types of investment, investments in energy conservation provide "tax free" returns.

To do the calculations, you will need a calculator, a tape measure, and a few utility or fuel bills to find out how much energy costs per unit. Follow the chart that follows for a step-by-step approach.

1. MEASURE YOUR WINDOWS
Measure width and height of all windows to calculate the number of square feet of window space. [Example: Window A: 40 inches times 50 inches = 2,000 inches, divide by 144 (inches in a square foot) = 14 square feet(SF)]

2. DETERMINE R-VALUE OF WINDOWS
Note, for each window, whether the window has single, double or triple glazing. For simplicity, use the following R-values:
Single glazing = R – 0.9
Double glazing = R – 1.8
Triple glazing = R – 2.7

3. CHOOSE A HEATING DEGREE DAY NUMBER
Consult the heating degree day map in Part II and select a heating degree day figure that is closest to your location. If your location is missing from the map or you wish to further refine your calculation, consult your local or state energy office or utility for an appropriate heating degree day estimate.

4. CALCULATE HEAT LOSS IN MILLIONS OF BTU'S (MBTU'S)
Plug your numbers from steps 1 through 3 into this formula, which will tell you roughly how many millions of British Thermal Units (Btu's are one way in which heating energy is measured) are lost through your windows on an annual basis:

$$\frac{\text{Window Area (SF)} \times \text{Heating Degree Days} \times \text{24 (Hours in a Day)}}{\text{Existing R-Value of Window Area}}$$

Example:

$$\frac{200\text{ (SF)} \times 6{,}000\text{ Degree Days} \times 24}{\text{(R)} - 0.9}$$

$$= \frac{28{,}800{,}000}{0.9} = 32\text{ MBtu's Lost Through Windows Annually}$$

5. CALCULATE THE DOLLAR VALUE OF ONE MBTU'S

A. Go to your utility or fuel bill, and note what type of fuel you use for heating, and what type of units your fuel is measured in. Use Chart A: CONVERTING YOUR UNIT OF ENERGY TO BTU'S to determine the number of Btu's per unit of fuel.

B. Take your number of Btu's per unit and divide it into 1,000,000 (Btu's). Example: You heat with natural gas, and the utility sells it in *therms*. From CHART A, you note that one therm delivers 100,000 Btu's. 1,000,000 divided by 100,000 = 10 therms in one million Btu's (MBtu's).

C. Note from your fuel bills the cost of one unit. Example: Your fuel bill tells you one therm costs $0.50.

D. Multiply your unit cost by the number of units in one MBtu's. Example: From Step 5.B you found that there are 10 therms in one MBtu's. Thus, 10 times the unit cost of $0.50 = $5.00 per MBtu's. Thus, your raw cost per MBtu's is $5.00.

E. Your raw cost per MBtu's probably doesn't reflect the cost of actually heating your home, because most heating systems are not 100 percent efficient. Thus, you need to make a rough estimate of how efficient your system is, and *divide* your raw cost per MBtu's by this efficiency factor to determine the *actual* cost of heat. Consult

CHART B: ESTIMATE OF HEATING PLANT EFFICIENCY LEVELS to determine what your efficiency divisor should be. Example: You heat with an older natural gas furnace. From CHART B you find that an older furnace may be 65 percent efficient. Thus, your $5.00 per MBtu's should be divided by the efficiency divisor from Chart B of 0.65: $5.00 divided by 0.65 = $8.00. Thus, $8.00 per MBtu's is your real cost.

6. DETERMINE THE DOLLAR VALUE OF HEAT LOST THROUGH YOUR WINDOWS

Return to Step 4 and note the number of MBtu's that are lost through your windows annually. In our example in this step, we found that 200 square feet of single-glazd windows loses 32 MBtu's per year in a climate with 6,000 heating degree days. Take the real cost per MBtu's from Step 5.E and multiply this cost by the number of MBtu's lost per year: Example 32 (MBtu's) × $8.00 (cost per MBtu's) = $256.00 per year. Remember that this estimate represents only a part of the heat losses through your windows; it can be considered to be the minimum your windows are losing, considering only losses through conduction.

Comparing Savings After Adding Window Insulation

After you have roughly determined how much heat is being lost through your windows and how much this heat costs, you are ready to estimate how much you could save by adding window insulation. There are two methods: one for fixed or seasonal devices and one for movable insulation. Again, use the step-by-step approach to estimate savings.

Estimating Savings from Fixed or Seasonal Insulation

1. CALCULATE HEAT LOSS AFTER ADDING INSULATION

First, estimate the R-value of the fixed or seasonal movable insulation. Use square-foot area measurements and degree day number from your initial calculations that estimated heat loss in our first step-by-step method. Plug your numbers into the following formula:

$$\frac{\text{Area (Square Feet)} \times \text{Degree Days} \times \text{24 (Hours in a Day)}}{\text{New R-Value with Window Insulation}} = \text{Heat Loss in MBtu's After Adding Window Insulation}$$

Example: Assume the homeowner in the 6,000-degree-day climate with 200 square feet of single-glazed windows wants to add storm windows. The R-value after adding the second layer of glazing would be R-1.8. The calculation looks like this:

CHART A: Convert Your Unit of Energy to BTU's

One gallon of oil	= 138,700 Btu's
One [illegible]	= 135,000 Btu's
One [illegible]	= 3,413 Btu's
One ton of coal	= 20,000,000 Btu's
One gallon of propane	= 91,000 Btu's
One [illegible] cubic foot of propane	= 252,100 Btu's
One [illegible]	= 100,000 Btu's
100 cubic [illegible]	= 100,000 Btu's
One Mcf ([illegible] cubic [illegible]) of [illegible]	= 1,000,000 Btu's
One [illegible] cubic [illegible] of [illegible]	= 1,000 Btu's
Cord of [illegible]	= 24,000,000 Btu's
Cord of [illegible]	= 16,000,000 Btu's
Cord of dried [illegible]	= 16,000,000 Btu's
Cord of unseasoned softwood	= 11,000,000 Btu's

*If your type of fuel or unit isn't listed, consult your utility or fuel supplier for Btu content per unit.

CHART B: Estimates of Heating Plant Efficiency Levels*

Fuel Type	Efficiency Divisor
Electric	
[illegible] or space heaters	[illegible] ([illegible] percent efficient)
Heat pump	[illegible] ([illegible] percent efficient)
Natural Gas	
Older furnace	[illegible] ([illegible] percent efficient)
New, high-efficiency furnace	[illegible] ([illegible] percent efficient)
Kerosene	[illegible] ([illegible] percent efficient)
Fuel Oil	
Older furnace	[illegible] ([illegible] percent efficient)
New, high-efficiency furnace	[illegible] ([illegible] percent efficient)
Propane	
Older furnace	[illegible] ([illegible] percent efficient)
New, high-efficiency furnace	[illegible] ([illegible] percent efficient)
Coal, older furnace	[illegible] ([illegible] percent efficient)
Wood	
Fireplace with [illegible]	[illegible] ([illegible] percent efficient)
Fireplace with [illegible]	[illegible] ([illegible] percent efficient)
Non-airtight stove**	[illegible] ([illegible] percent efficient)
Airtight stove**	[illegible] ([illegible] percent efficient)
Airtight furnace**	[illegible] ([illegible] percent efficient)

*Efficiency levels listed in this table are meant only to be estimates, for simplified use in your calculations.

**Add .05 extra efficiency for radiant-type stoves (rather than fan powered stoves), add .05 for heat exchangers and add .20 for stoves with effective catalytic afterburners.

$$\frac{200 \times 6000 \times 24}{\text{(R-) } 1.8} = 16 \text{ MBtu's Lost Annually After Adding Storm Windows.}$$

2. CALCULATE DOLLAR VALUE OF HEAT LOST AFTER ADDING INSULATION

Using the cost per MBtu's determined in our heat loss example, multiply the number of MBtu's by the cost of heat per MBtu's. [Example: 16×$8.00 (cost per MBtu's)=$128. Thus, $128 is the value of heat lost after adding storm windows.

3. COMPARE VALUE OF HEAT LOST BEFORE AND AFTER ADDING INSULATION

Compare before and after costs, using answers calculated in the heat loss method, to determine estimated annual savings. [Example: Using our heat loss estimates from earlier examples, note that the homeowner in our example was losing roughly $256 annually through 200 SF of single-glazing in a 6,000-degree-day climate. After adding storm windows, the loss is reduced to $128 (from Step 2 above):

$256 minus $128=$128 annual savings after adding storm windows.

4. DETERMINE COST OF ADDING INSULATION AND SIMPLE PAYBACK (OPTIONAL)

If you wish to determine simple payback times on your window insulation investments, first you must get estimates on how much the window insulation will cost. Once you have these costs, you can divide costs by the annual savings to determine simple payback. Example: Say 200 square feet of storm windows costs $3 per square foot, for a total cost of $600 of doing this storm window job. If annual savings are $128, then the calculation would look like this:

$600 divided by $128=4.69 years simple payback time.

Note that with many window insulation jobs, a simple payback approach, as defined here, may overestimate the actual payback time because only one type of heat loss is being considered. Your simple payback estimate could well be the absolute longest time such an investment may take to pay for itself.

Estimating Savings with Movable Insulation

1. ESTIMATE R-VALUES AND U-VALUES FOR THE MOVABLE INSULATION

Because movable insulation is not in place 24 hours a day, a slightly different approach is needed to calculate savings. First estimate R-values for the existing window and for the movable insulation. Then convert these values to U, which is the reciprocal of R, in order to do this calculation. U describes the rate at which heat is transferred, while R describes the resistance to heat transfer. Example: Assume window is double-glazed (R-1.8) and that a movable insulation device with an R-value of 5 will be used over the window. Because U=1/R, divide your R-values into 1:

1 divided by 1.8=U−0.55

1 divided by 5.0=U−0.20

2. ESTIMATE NUMBER OF HOURS PER DAY THAT MOVABLE INSULATION WILL BE USED

Decide, for your calculation, how many hours per day your movable insulation will be in place over the window. Example: The window insulation will be in place 14 hours a day, while the single-glazed window will be the only insulation for 10 hours a day. Thus, for 14 hours a day, the R-value will be 0.25, while for 10 hours a day it will be 1.1.

3. CALCULATE HEAT LOSSES WITH MOVABLE INSULATION

Using your degree day number and your window area in square feet, use the following formula:

Area × Degree Days
× (Hours with Insulation × U1)
+ (Hours without × U2) =
Heat Losses in MBtu's Annually
with Movable Insulation.

(Instead of simply multiplying by 24 hours, we break 24 hours down into the time with movable insulation and time without.)

Example.

50 SF × 6000 DD × [(10 hours) × U - .55)
+ (14 hours) × (U - .20)] =
2.49 MBtu's lost per year.

4. CALCULATE SAVINGS, COST OF JOB AND PAYBACK

Go to Steps 3 and 4 in the previous example to calculate savings, and if desired, simple payback.

Comparing Your Options

Let's work through some options with dollar values added in. This example concludes with a simple payback analysis. Our mythical family, the Smiths, live in a 7,000 degree-day climate, where heating costs them $9.50 per MBtu, after furnace efficiency is taken into account. The family wants to explore the minimum savings they could expect from a window insulation program that looks like this:

Option 1: Add storms to 50 square feet of south-facing, single-pane windows, with the lowest bid at $3 per square foot.

Option 2: Add R-8, non-movable seasonal panels with tight seals to 40 square feet of north-facing, single-paned windows, with the cost being $2.25 a square foot.

Option 3: Add an R-2 double storm window to the same 40 square feet of north-facing, single-pane glass for a total of R-.7, instead of the panels, with the cost being $5.50 a square foot.

Option 4: Add R-5 movable insulation to east- and west-facing windows that total 70 square feet of single glazing, at a cost of $7 a square foot, assuming the movable insulation is open ten hours a day.

With Option 1: Savings would look like this:

Before: 9.3 MBtu's a year lost, worth $88.35

After: 4.65 MBtu's a year lost, worth $44.17

Cost of job: $150.

Annual savings (at 1983 fuel costs) are $44.17.

Simple (longest) payback: 3.4 years.

(Note, in that these are south-facing windows, they would actually experience no heat loss, but a net gain on an annual basis if they are unobstructed, after the new storm windows are installed. This could significantly shorten payback time.)

With Option 2: Before: 7.4 MBtu's a year lost, worth $70.87.

After: .84 MBtu's a year lost, worth $7.90.

Cost of job: $90.

Annual savings (at 1983 fuel costs) are $62.97

Simple payback: 1.42 years.

With Option 3: Before: 7.4 MBtu's a year lost, worth $70.87.

After: 2.7 MBtu's a year lost, worth $25.65.

Cost of job: $220.

Annual savings (at 1983 fuel costs) are $45.22.

Simple payback: 4.8 years.

(Note the difference between the choices for the same windows. The low-cost high-R panels have an exceptionally short payback. Yet, if the occupants prefer the view from these north-facing windows, they still would get a good return on triple glazing.)

With Option 4: Before: 13 MBtu's a year lost, worth $123.50.

After: 8.5 MBtu's a year lost, worth $80.75.

Cost of Job: $490.

Annual savings (at 1983 fuel costs) are $44.75.

Simple payback: 10.9 years.

If the Smiths do Options 1, 2 and 4, the annual savings would work out to be $151. Overall cost of these three options would be $730, with a total payback for the package of 4.8 years.

Note that this analysis doesn't take into account the expected lifespan of the product or any maintenance costs that may be associated with them. Durability should be an important criterion for deciding between various options.

APPENDIX B
READING AND RESOURCE LIST

General

Movable Insulation, William Langdon, Rodale Press, Emmaus, PA, 1980.

Thermal Shutters and Shades, William A. Shurcliff, Brick House Publishing Co, Andover, MA, 1980.

Solarizing Your Present Home, Joe Carter, ed., Rodale Press, Emmaus, PA, 1980.

Insulating Window Shades, Ray Wolf, Rodale Press, Emmaus, PA, 1980.

Preservation Briefs: 9, The Repair of Historic Wooden Windows, Technical Preservation Services Division, U.S. Department of the Interior, Washington, DC. Usually available through state historic preservation offices.

Energy Conservation and Solar Energy for Historic Buildings: Guidelines for Appropriate Designs, Technical Preservation Services Division, U.S. Department of the Interior, Washington, DC. This publication is available for $6.95 a copy from the National Center for Architecture and Urbanism, 1927 S Street, NW, Suite 300, Washington, DC, 20009.

A comprehensive window insulation product directory can be found in the February 1982 and the June 1983 issues of *Solar Age*. The magazine can be contacted by writing to *Solar Age*, Harrisville, NH 03450 or by calling 603/827-3347.

The following two periodicals regularly feature articles on the latest developments in window insulation:

New Shelter, 33 E. Minor St., Emmaus, PA 18049.

Popular Science, 380 Madison Avenue, New York, NY, 10017.

Other References

Movable Window Insulation, John Pierre Stephens and Barbara Wezelman, Sunwise Co-op, 2535 Westernesse St., Davis, Ca 95616, 1982. Copies are available for $2 each by writing to the above address and including a self-addressed, stamped envelope.

How To Make Low-cost Energy-Saving Zip-Up Curtains for Professional Drapers, Upholsterers and Interior Designers, Robert Wehrli and Rita Molyneau, Potomac, MD, 1981.

Energy Efficient Interior Window Treatments, Leona Windley, Cooperative Extension Service, Utah State University, Logan, UT, 1982.

Proceedings of the American Section of the International Solar Energy Society; Annual Meetings 1978-82, Passive Solar Conference, 1979-82.

Optimal Weatherization of Low-Income Housing in the U.S.: A Research Demonstration Project, Richard Crenshaw and Roy E. Clark, National Bureau of Standards, U.S. Government Printing Office, NBS-BSS-144, Washington, DC, 1982.

Window Design Strategies to Conserve Energy, Robert Hastings and Richard Crenshaw, National Bureau of Standards, U.S. Government Printing Office, no. 003-003-01794-9, Washington, DC.

Moisture and Home Energy Conservation: How to Detect, Solve and Avoid Related Problems, prepared by the National Center for Appropriate Technology for the U.S. Department of Energy, Government Printing Office, Washington, DC, 1983. GPO 061-000-00615-0

Appendix C

DOE Appropriate Technology Grants Related to Window Insulation

The following grants were among those reviewed in the course of researching and preparing this document.

Benard Domning, Jr.
Mobile, AL
DOE Contract No. DE-FG44-81R410446
ATMIS ID: AL-81-006

The grantee designed, constructed and installed insulated, decorative shutters for a residence. The shutters had an R-value of 7.2 and cost $2.16 per square foot.

Environment Research
Tempe, AZ
DOE Contract No. DE-FG03-78R901990
ATMIS ID: AZ-78-003

The grantee tested glazings for the patented "Solar Heat Exchanger Window Wall." Heat-absorbing reflective glass was used for collection on the inside surface during the heating season with efficiencies comparable to those of active air collector systems. During the summer a pivotal sash is rotated 180 degrees to position the heat-absorbing reflective glass with the reflective surface to the exterior. Theoretical analysis and experimental tests have confirmed that 65 percent of the solar and thermal gain can be rejected in the summer mode. Venting is also provided to dissipate absorbed solar energy to the outside atmosphere.

John Pierre Stephens
Davis, CA
DOE Contract No. DE-FG03-80R950028
ATMIS ID: CA-80-001

The grantee performed a literature search on state-of-the-art movable window insulation. This research led to the consideration of a number of possible designs that were then fabricated and installed in a demonstration house. The results of this research were documented in an informational pamphlet for the public.

Nyle Robert Werthmann
San Francisco, CA
DOE Contract No. DE-FG03-78R901987
ATMIS ID: CA-78-025

The grantee reviewed natural lighting concepts and the use of insulating/reflecting shutters. The planning, assembly, installation, and control techniques for insulating shutters are addressed. Model studies of illumination distribution are also described in the final report.

Raymond Auger
Aspen, CO
DOE Contract No. DE-FG48-81R801070
ATMIS ID: CO-81-010

The grantee designed and tested a motorized roller system for exterior window insulation and sunscreens. The commercialization of the system was interrupted by several problems. An exterior system like this is subject to extremes in weather conditions (high winds) affecting the mechanical operation of the roller system. Fulfilling terms of the system warranty was expensive with the first installation, due to unknowns. The system needs refinement through continued field testing and the grantee needs additional financing to promote and sell the product.

Laurence Rasmussen
Boulder, CO
DOE Contract No. DE-FG48-79R800437
ATMIS ID: CO-79-008

The final report describes the benefits of using foam for insulating glazing systems; it provides testing methods and results, a list of materials tested, and problems encountered.

Stephen Andrews
Denver, CO
DOE Contract No. DE-FG48-80R801401
ATMIS ID: CO-80-001

The grantee proposed a passive solar retrofit of an existing house to include the installation of exterior window blinds (lowered shades) to reduce solar gain during the cooling season and movable exterior window insulation for the heating season.

Wilbert Minor
Newark, DE
DOE Contract No. DE-FG43-79R306053
ATMIS ID: DE-79-009

The grantee mounted two insulating window treatments between two roll-down shades and tested the thermal performance of each against conventional blinds. Also, an insulating drapery liner (R-3.8) was mounted on a standard traverse rod behind pinch-pleated drapery. Both were tested in an independent laboratory. Effects of details, materials and edge seals are discussed in the final report.

Frederick Tyrell
Port Richey, FL
DOE Contract No. DE-FG44-80R410301
ATMIS ID: FL-80-012

The grantee implemented a new technique for attaching storm windows to awning windows, while still allowing for their operation. The design was tested and demonstrated increased thermal efficiency while allowing for adequate ventilation.

Robert Henderson
Jerome Kaplan
Indianapolis, IN
DOE Contract No. DE-FG02-79R510116
ATMIS ID: IN-79-004

The grantee designed, built, installed, and evaluated a double-layer Mylar, inside storm window system. Fifty units were produced as an initial step toward commercializing the product. Thermal performance of the design has been reported successful, but installation and operational problems require some design changes prior to any serious commercialization effort.

Linda Nicholson
Des Moines, IA
DOE Contract No. DE-FG47-81R701204
ATMIS ID: IA-81-006

The Energy Research and Information Foundation collaborated with two other local and state energy groups to develop a model demonstration house that shows how the insulation of interior walls, application of vapor-barrier paint, contructior of a breadbox solar water heater, weatherstripping and caulking, and the installation of basement insulation can save energy in a conventional house.

Kenneth Lillemo
Huxley, IA
DOE Contract No. DE-FG47-80R701112
ATMIS ID: IA-80-013

A rigid foam product made from PVC resins was employed in a ten-household study of the use in movable nighttime insulation. The study focused on acceptance of the product and its use. The thermal effectiveness of the product was not determined; the study focused on a user evaluation of the product, which was made into "pop-in" panels.

Charles and D.L. Pariseau
Mt. Lake Pike, MD
DOE Contract No. DE-FG43-80R302406
ATMIS ID: MD-80-008

The grantee installed a mechanical down draft duct system in a south-facing, solar A-frame house. This work was coupled with the installation of window quilts and crawlspace insulation. These measures reportedly increased the comfort level in the house as well as reducing fuel consumption. A $180-200 reduction in electric bills and a 3-to-4 cord drop in wood consumption during the heating season was noted in the final report.

Robert Wehrli
Potomac, MD
DOE Contract No. DE-FG43-81R308083
ATMIS ID: MD-81-008

The grantee developed an instruction guide for professional drapers, upholsterers and interior designers on how to fabricate low-cost, energy-saving, sealed-edge, zip-up curtains. Performance data from the final report indicates that use of the sealed fabric curtains increased the R-value of single-glazed windows from 0.9 to 1.77, cutting energy losses from windows in half.

Barbara Allen
Bozeman, MT
DOE Contract No. DE-FG48-79R800445
ATMIS ID: FT-79-005

The grantee reseaiched the historic uses of daylighting for purposes of educating designers on how to use natural light to conserve electricity.

Richard Thompson
Charlestown, NH
DOE Contract No. DE-FG41-81R124257
ATMIS ID: NH-81-001

The grantee tested and monitored an insulated solar shutter in order to document actual energy savings during both the heating and cooling season. Testing identified several problems; the panels started to delaminate due to the temperature extremes within the shutter, and snow accumulating between the shutter and the window made operation difficult. The edge seal (3M Z-strip™) provided an effective seal around the edge of the laminated, rigid insulation shutter.

Todd Brown
Dover, NJ
DOE Contract No. DE-FG42-81R205263
ATMIS ID: NJ-81-002

The grantee constructed and tested the performance of a solar window/collector. The collector consists of three panes of glass; the inner pane is tinted and the space between the tinted layer and the next layer is vented to allow movement of heated air up and out of the collector into a series of ducts which distribute the heated air throughout the house. This passive/active system is designed to heat and cool an existing house. The grantee is still working to refine the system.

Ted Dunn and Tom Horan
Jersey City, NJ
DOE Contract No. DE-FG42-80R205174
ATMIS ID: NJ-80-006

The grantees retrofitted a wood frame house with thermal curtains and passive solar air collectors. Public outreach activities such as tours, newspaper articles, and slide shows were developed to help disseminate information to Hudson County residents.

Sunshine Insulation Consultants
Albuquerque, NM
DOE Contract No. DE-FG46-79R610970
ATMIS ID: NM-79-006

The grantee built and installed 12 insulating window shutters. The shutters cost $12 a square foot, too costly to compete with storm windows and draperies.

Peter Grande
Phoenixville, PA
DOE Contract No. DE-FG43-79R306074
ATMIS ID: PA-79-015

The grantee built a 64-square-foot window collector, with a V-groove, foam-glass and plastic glazing. At a materials cost of $258.27 the collector cut heating demands by about 7 percent and a 3.7-year payback is predicted, assuming that the labor is free.

Laura Duncan
Austin, TX
DOE Contract No. DE-FG46-79R610960
ATMIS ID: TX-79-016

The grantee constructed a one-way heat shield from highly polished, half-hollow cylinders of rock salt. The shield predominately transmits radiation in one direction. Most radiation attempting to pass through the shield in the other direction is reflected. The concave side that receives the transmitted and reflected radiation heats, while the convex side cools.

James Briggs
Kerrville, TX
DOE Contract No. DE-FG46-79R610956
ATMIS ID: TX-79-003

The grantee developed a device that will insulate a window, shade it or reflect light towards the window. It can be retrofitted to existing windows or used in new construction. Mechanical and structural problems encountered during the project are presented in the final report.

Leona Windley
Logan, UT
DOE Contract No. DE-FG48-81R807312
ATMIS ID: UT-81-004

The grantee produced and disseminated a booklet and four slide/tape presentations covering energy-conserving interior window treatments suitable for educating others to teach how to construct, mount and select interior window treatments. The report covers the process for development, evaluation, accomplishments and impact of the project.

William Briggs
Richmond, VA
DOE Contract No DE-FG43-80R302445
ATMIS ID: VA-80-010

The grantee produced and tested a passive solar device similar to a venetian blind for cooling and increasing interior lighting. The exterior-mounted device was monitored for temperature and lighting levels over a one-year period and the results were analyzed.

Ellen Starr
Bellingham, WA
DOE Contract No. DE-FG51-80R000480
ATMIS ID: WA-80-035

The grantee expects to start a small cottage industry by constructing and demonstrating a low-cost, easy-to-make, insulating curtain for greenhouses and sunspaces.

James Gaitor
Hinton, WV
DOE Contract No. DE-FG43-80R302446
ATMIS ID: WV-80-001

Seventeen roll-down, solid-core, roman and drapery-type window coverings were installed in seven public buildings. The quilts, which measured 760 square feet, were made in workshops attended by local craftsmen. The grantee expects the systems to be cost-effective over the lifetime of the quilts. The project helped promote community awareness, lowered fuel bills, refined window quilt movement mechanisms, and developed a co-op cottage industry according to the grantee.

Eugene Eccli
Washington, DC
DOE Contract No. DE-FG43-80R302391
ATMIS ID: DC-80-001

The grantee conducted a user survey, workshops, developed a training manual, and a slide show on how to construct insulating curtains. The cost of constructing curtains was approximately one-third that of factory-made insulated curtains.

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Highlights twenty of the many success stories that are found in the DOE grants program.
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WASTES TO RESOURCES: APPROPRIATE TECHNOLOGIES FOR SEWAGE TREATMENT AND CONVERSION

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GPO 061-000-00616-8

USING THE EARTH TO HEAT AND COOL HOMES

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Focuses on the experiences of hundreds of DOE grantees who designed and built greenhouses, and examines individual greenhouse components, including framing, glazing, storage, ventilation and control mechanisms.
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Teaches owner-builders, building trades people, and designers how to size ventilation systems for energy-efficient housing. Major emphasis is placed on the air-to-air heat exchanger.
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Introduces the use of wind, water, and the sun as electricity producers and, based on the experiences of grantees, helps the reader make a realistic appraisal of these systems.
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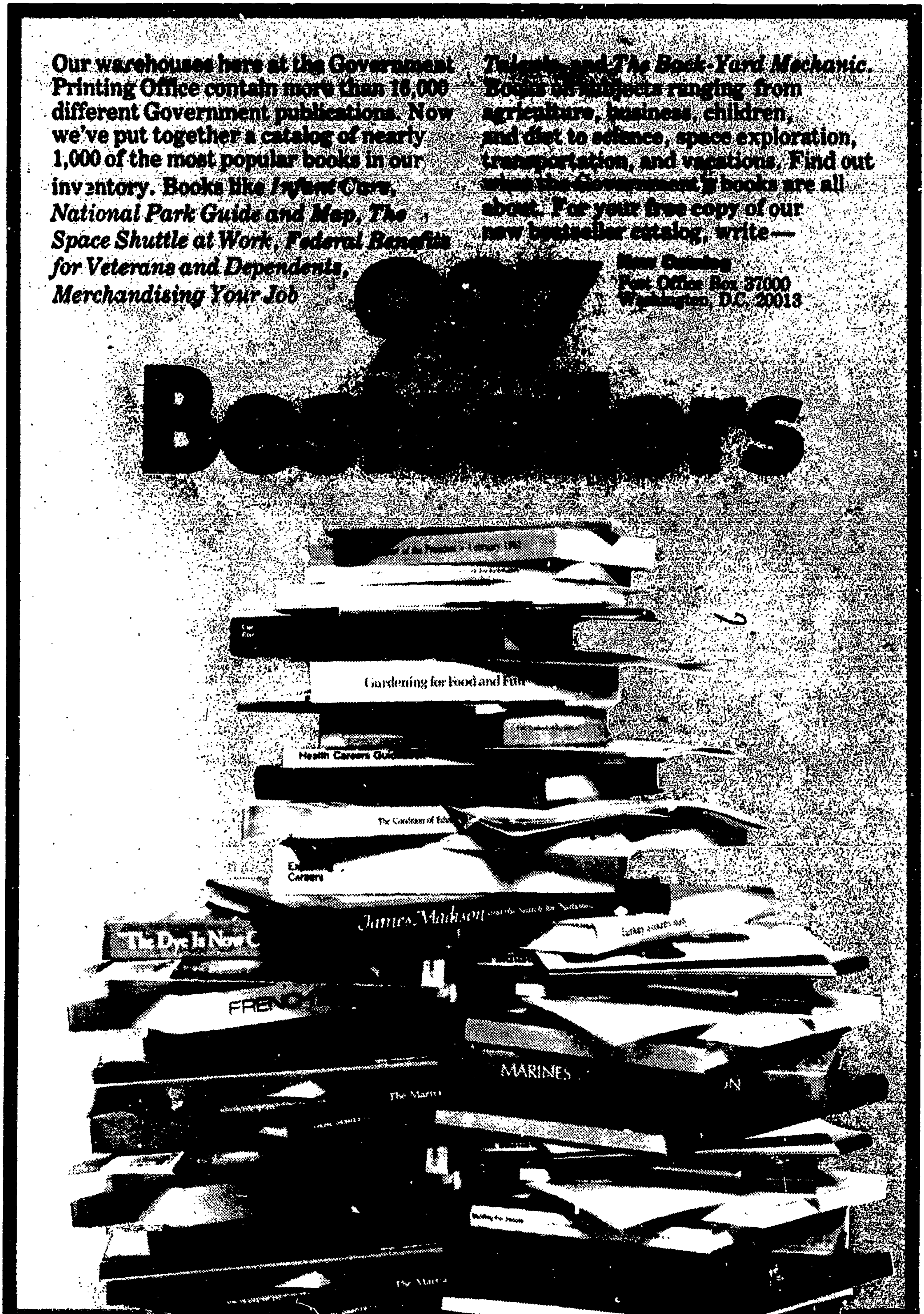

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